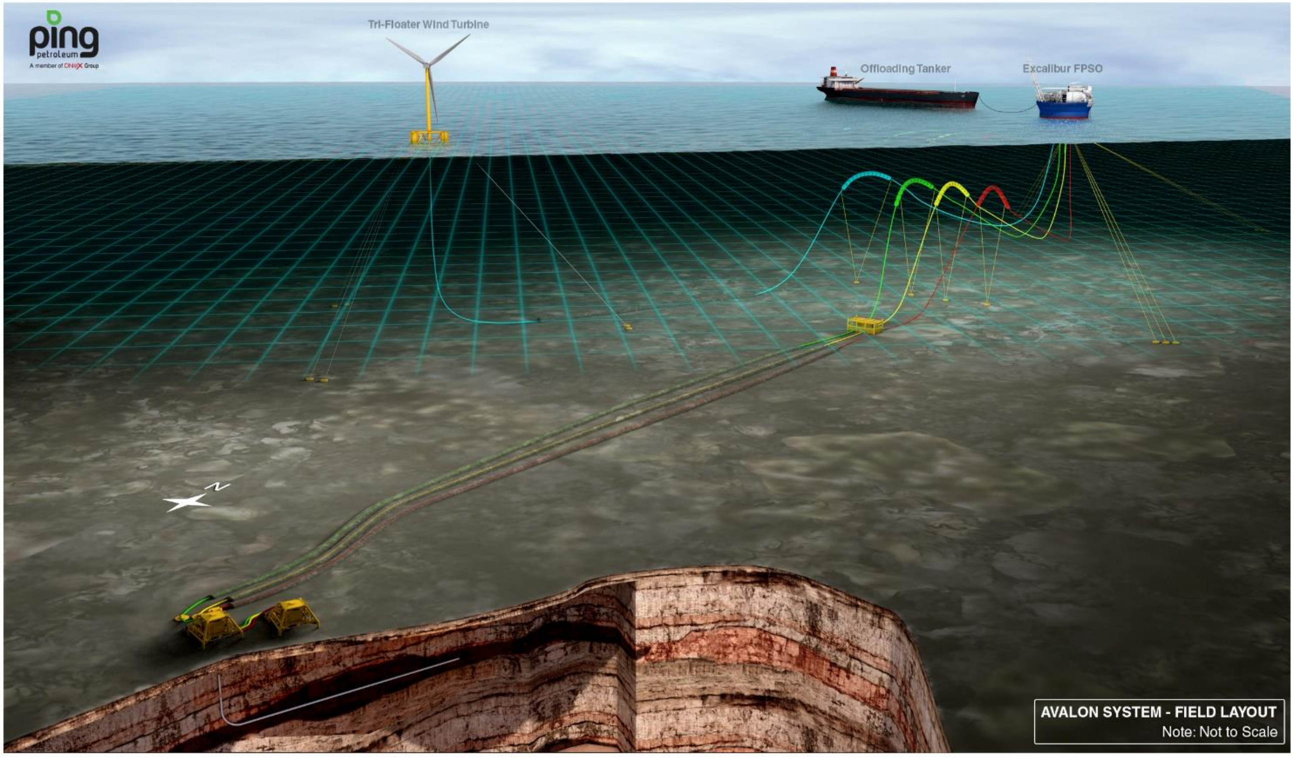
ping petroleum
A member of DNeX Group

Avalon Field Development

UKCS Block 21/6b

Environmental Impact Assessment (EIA)



ES/2022/005

Health, Safety and Environment (HSE) Policy

Our vision is to be a safe and environmentally responsible operator and partner while maximising economic recovery of hydrocarbon resources. We are committed to ensuring a safe and healthy working environment for our personnel and minimising the environmental impact of our activities.

Responsibility for achieving and maintaining high standards of HSE starts with the Board of Directors and carries through line management to every employee and contractor engaged in Ping Petroleum activities.

Ping Petroleum shall:

- Ensure our leaders promote a culture of health, safety and environmental care and awareness amongst our personnel.
- Comply with all health, safety and environmental laws and regulations.
- Accomplish our activities with competent and adequately trained personnel.
- Understand the risks associated with the assets we operate and reduce them to As Low As Reasonably Practicable.
- Maintain integrity of our assets over their life cycle.
- Provide a safe working environment that protects against injury and minimises work-related ill health.
- Commit to prevent pollution and minimise the impact to the environment from our operations.
- Ensure engagement with our operating partners, contractors and suppliers reflects the level of risk they bring to the business.
- Identify and manage change in our organisation.
- Develop and maintain robust systems and processes.
- Instigate timely investigation and reporting of incidents and near misses to prevent recurrence and share lessons learned.
- Actively engage with all relevant stakeholders.
- Ensure appropriate emergency response procedures are in place and regularly tested to minimise the impact of any such incidents or emergencies.
- Regularly review and audit HSE management and performance to achieve continuous improvement.

Employees, contractors and others engaged in work on our behalf will be expected to comply with this policy.

[redacted]

Chief Executive Officer
Ping Petroleum UK PLC

ENVIRONMENTAL STATEMENT - SUBMISSION SUMMARY

THE OFFSHORE PETROLEUM PRODUCTION AND PIPE-LINES (ASSESSMENT OF ENVIRONMENTAL EFFECTS) REGULATIONS 1999 (AS AMENDED)

SUBMISSION OF AN ENVIRONMENTAL STATEMENT IN SUPPORT OF AN APPLICATION FOR THE CONSENT OF A PROJECT UNDER THE PETROLEUM ACT 1998 OR THE ENERGY ACT 2008

Section A: Administrative Information

A1 – Project Reference Number

Number ES/2022/005

A2 - Applicant Contact Details

Company name: Ping Petroleum UK PLC
Contact name: [redacted]
Contact title: Wells Manager

A3 – ES Contact Details

Company name: Ping Petroleum UK PLC
Contact name: [redacted]
Contact title: Wells Manager

A4 – ES Preparation

Key expert staff involved in the preparation of the ES:

Name	Company	Title	Relevant Qualifications/Experience
[redacted]	Fugro GB Marine Limited	Environmental Consultancy Team Leader	Over twenty years in environmental consultancy role for the offshore oil and gas industry and other marine industries. MSc Marine Resource Development and Protection BEng Environmental Technology
[redacted]	Fugro GB Marine Limited	Senior Environmental Consultant	Eleven years in environmental consultancy role, in which main specialisms have been environmental impact assessment and permitting applications. MSc Ecology BSc (Hons) Zoology
[redacted]	Fugro GB Marine Limited	Environmental Consultant	One year in environmental consultancy role in which main specialisms have been environmental impact assessments and desktop studies. MSc Climate Change: Managing the marine environment BSc (Hons) Marine Science
[redacted]	Fugro GB Marine Limited	Assistant Environmental Consultant	Three years in environmental consultancy role in which main specialisms have been environmental impact assessments, desktop studies and GIS. MSc International Marine Science BSc (Hons) Applied Animal Science
[redacted]	Ping Petroleum UK PLC	HSE & A Manager	Over 34 years in the oil and gas sector. A Chartered Chemical Engineer and Chartered Environmentalist with extensive experience in HSE, Operations and Engineering leadership.
[redacted]	Ping Petroleum UK PLC	Wells Manager	Over twenty years in the oil and gas sector. Specialist in wells, production operations and project management of small developments. Experience in HSE, environmental permit, oil spill response and risk management. BSc (Hons) in Microbiology

A5 - Licence Details

a) **Licences covering proposed activities**

Licence numbers: P2006

b) **Licensees and current equity**

Company	Percentage Equity
Ping Petroleum UK PLC	100 %

Section B: Project Information

B1 - Nature of Project

a) Name of the project: Avalon Field Development

b) Name of the ES: As above

c) Brief description of the project:

Ping Petroleum UK PLC (PPUK) propose to develop the Avalon field which will comprise two production wells (Well 21/6b-J and Well 21/6b-K) and associated subsea infrastructure which will be tied-back to a Floating Production Storage and Offloading (FPSO) vessel, the Excalibur FPSO.

Export of the Avalon hydrocarbons will be via shuttle tanker which will transport the offloaded hydrocarbons from the Excalibur FPSO to shore.

The proposed development will use all Avalon produced gas for FPSO power generation. When the FPSO becomes gas deficient, the use of Floating Offshore Wind, as an alternative to additional diesel consumption, is currently being evaluated. As part of this evaluation, a Crown Estate Scotland INTOG application is presently underway to permit placement of a floating Offshore Wind Turbine (OWT) at the Avalon site. If the floating OWT is sanctioned, a power cable between the floating OWT and the FPSO will be installed and may be up to 25 km in length depending on the final location of the floating OWT.

PPUK proposes to commence drilling operations in Q3 of 2023 with first oil anticipated in Q3 2025. The Avalon Field Development is expected to produce hydrocarbons for 10 years.

B2 - Project Location

a) Offshore location of the main project elements

Location	Coordinates			
	Degrees Minutes Seconds (DMS)*		Decimal Degrees	
FPSO	57°49'38.218"N	0°10'46.251"E	57.827283	0.179514
P1 Well	57°49'8.14"N	0°10'46.552"E	57.818928	0.179598
P2 Well	57°49'19.6"N	0°11'28.456"E	57.822111	0.191238
Floating OWT (preferred)	57°48'19.876"N	0°8'20.461"E	57.805521	0.139017

Notes:
* = DMS in WGS84
FPSO = Floating production storage and offloading
OWT = Offshore wind turbine

The Avalon field is located within United Kingdom Continental Shelf (UKCS) block 21/06b and lies approximately 65 km east of the Aberdeenshire coast and approximately 79 km west of the UK/Norway transboundary line. The Norwegian coastline lies 310 km to the east.

Although the Avalon development base case is to use all produced gas for power generation; and offshore wind power when the field becomes gas deficient, the option of providing a gas import/export pipeline route is still currently being evaluated. If it is established to be part of the optimal field development solution, it will either be a 5 km pipeline to the Brittannia pipeline end manifold (PLEM) or a 40 km pipeline to the Ettrick pipeline end manifold (PLEM). The exact route of the pipeline will be confirmed after a pipeline route survey, however it is anticipated that it may pass through some UKCS blocks including 20/02, 20/03, 20/04, 20/05, 20/08, 20/09, 20/10, 21/1, 21/2, 21/6 or 21/7.

B3 – Previous Applications

None.

Contents

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

TABLE OF CONTENTS CONTINUED

APPENDICES

Non-Technical Summary

Non-Technical Summary

This Environmental Statement (ES) presents the findings of the Environmental Impact Assessment (EIA) conducted by Ping Petroleum UK PLC, hereafter PPUK, for the proposed Avalon Field Development in the central North Sea (CNS) United Kingdom Continental Shelf (UKCS) Block 21/6b (Figure 1.1).

The nearest landfall to the Avalon field is Peterhead on the east coast of Scotland, approximately 116 km to the west at its nearest point. The UK/Norway median line is situated approximately 98 km east of UKCS Block 21/6b.

The purpose of this ES is to provide an assessment of the potential environmental effects that may arise from the proposed Avalon Field Development and to identify the measures, which will be put in place to minimise significant effects.

The EIA Process and Environmental Management

Offshore oil and gas activities can involve a number of environmental interactions and impacts due to, for example, operational emissions and discharges and general physical, noise and visual disturbances. The objective of the EIA process is to incorporate environmental considerations into the project planning and design activities, to ensure that best environmental practice is followed and ultimately to achieve a high standard of environmental performance. The process also provides for the potential concerns of stakeholders to be identified and addressed, as far as possible, at an early stage. In addition, it ensures that the planned activities are compliant with legislative requirements and PPUK's own management procedures.

All PPUK activities are carried out in accordance with PPUK's Health, Safety and Environment (HSE) Policy. A copy of the HSE Policy is provided in the inside cover of this ES. The PPUK HSE Policy is the cornerstone of HSE Management. Commitments start at Board level and carry through line management to every employee and contractor engaged in PPUK activities. The Policy vision is to be a safe and environmentally responsible operator and partner. It provides a systematic approach focused on promoting a strong culture and robust risk management.

This policy forms the basis of the PPUK HSE Management System (HSEMS) with each commitment visible and linked with the processes and procedures supporting the commitment delivery. The PPUK Policy is applied to all operations to ensure the highest standards of HSE are followed regardless of the operation or operating environment.

PPUK is committed to prevent pollution and minimise the impacts to the environment from its operations. PPUK reviews the impact all activities may have on the environment and ensures that all environmental risks are adequately identified, controlled or mitigated to an acceptable level by way of formal assessment.

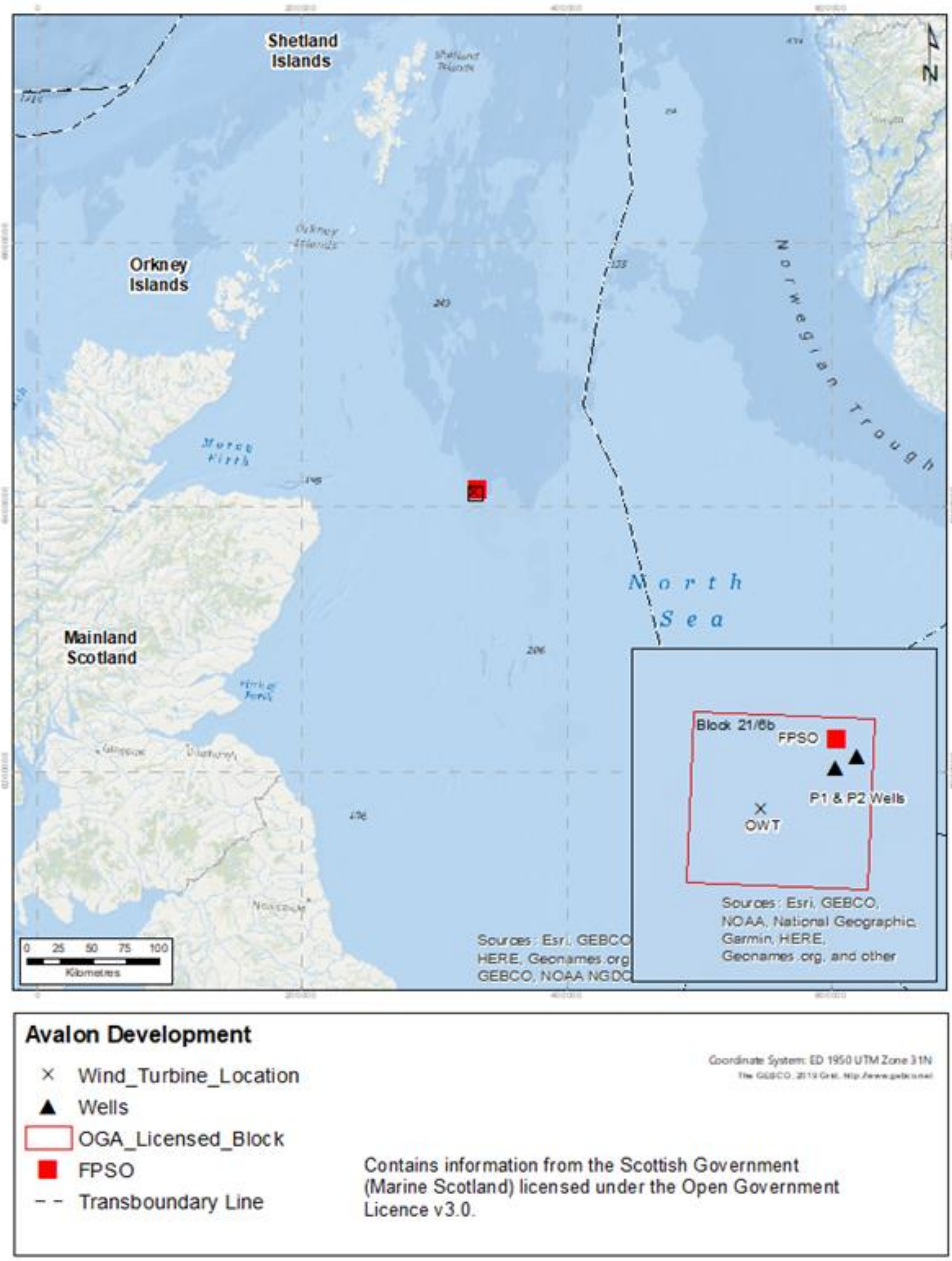


Figure 1.1: Location of the Avalon Field development

Proposed Operations

The proposed Avalon development covered by this ES will comprise two production wells (Well 21/6b-J and Well 21/6b-K), tied-back to a Floating Production Storage and Offloading vessel (FPSO) (Figure 1.2). The Avalon Field Development will further comprise the following new and already existing subsea infrastructure:

- Two subsea production wells completed with a single Xmas tree per well and covered with a fishing friendly protection structure;
- A Subsea Distribution Unit (SDU) structure installed on the seafloor, which will house equipment for controlling the production and gas lift lines, including an Umbilical Termination Assembly (UTA);
- A Riser Base Structure (RBS), housing a SDU, UTA and Subsea Isolation Valve (SSIV), connecting to the dynamic risers/umbilical with buoyancy modules;
- A 3 km pipe in pipe oil production pipeline, which will be trenched and buried, between the Avalon drill centre and RBS;
- A 3 km gas lift line, which will be trenched and buried, between the Avalon drill centre and RBS;
- A 3 km control umbilical, which will be trenched and buried, between the Avalon drill centre and RBS;
- A power cable up to 25 km in length, trenched and buried, between a floating Offshore Wind Turbine (OWT) and the FPSO; and
- Anchored mooring systems for the FPSO and OWT.

The proposed Avalon Field Development will use all produced gas from the Avalon field for power generation onboard the FPSO. When the Avalon field becomes gas deficient, the use of a floating OWT, as an alternative power source to additional diesel consumption, is currently being evaluated. As part of this evaluation, a Crown Estate Scotland Innovation and Targeted Oil & Gas (INTOG) application is presently underway to allow placement of a floating OWT at the Avalon field.

If this is permitted, a power cable between the floating OWT and the FPSO will be installed which may be up to 25 km in length depending on the final location of the floating OWT. The preferred location of the floating OWT is shown in Figure 1.1. Power generated by the floating OWT This will have the advantage of facilitating the decarbonisation of the development.

Although the base case for the Avalon Field Development is to use all produced gas for power generation, and offshore wind power when the Avalon field becomes gas deficient, the option of providing a gas import/export pipeline route is currently being evaluated. If it is established that, as part of the optimal field development solution, a gas import/export pipeline is required, it will either be a 5 km pipeline to the Britannia pipeline end manifold (PLEM) or a 40 km pipeline to the Ettrick PLEM.

For the purpose of the EIA process, the 'worst-case scenario' has been considered for all aspects of the project scope where uncertainty still exists. This specifically includes requirement for both the gas import/export pipeline and the floating OWT. In both these cases the greatest established environmental footprint has been assumed.

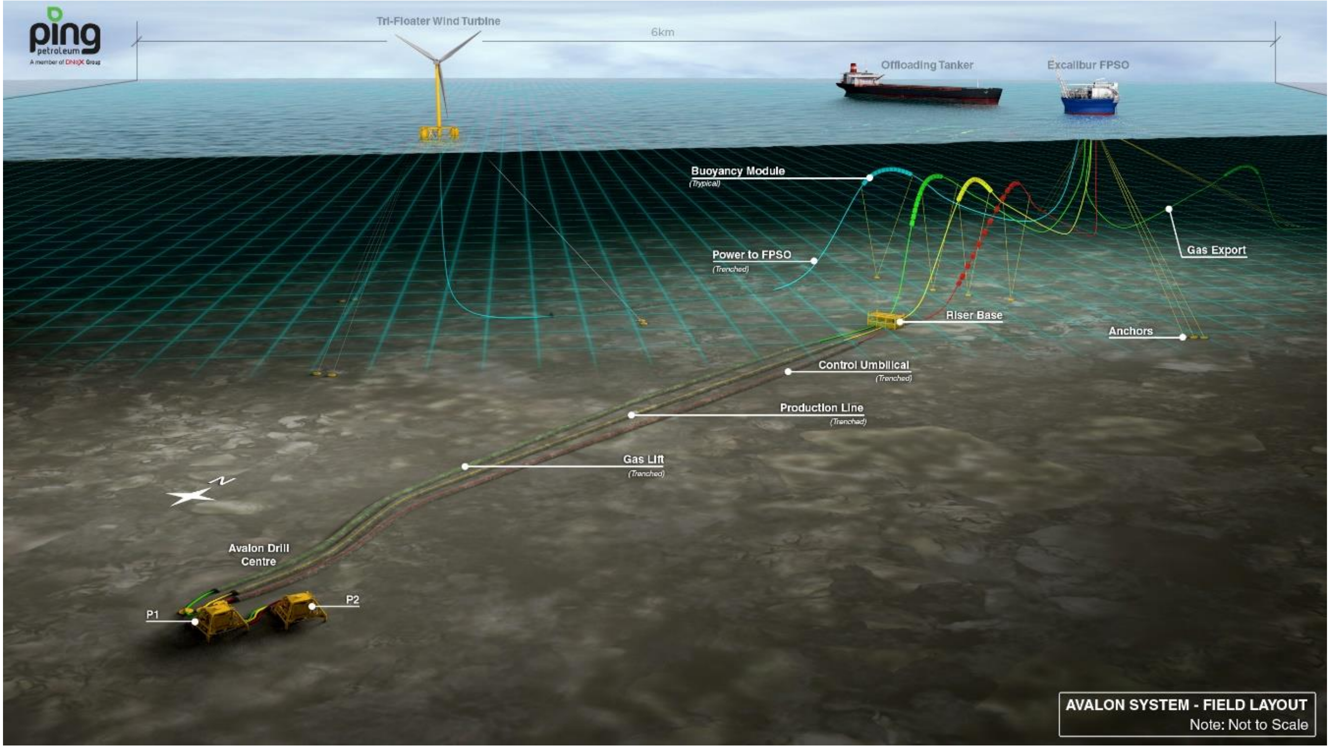


Figure 1.2: Schematic overview of the proposed Avalon Field Development

PPUK proposes to commence drilling operations in Q3 of 2023, at the earliest with first oil anticipated in Q3 2025. The Avalon Field Development is expected to produce hydrocarbons for 15 years. The moorings for the proposed floating OWT would be installed in Q2 2024 with the sub-structure and turbine tower following thereafter.

Option Selection

Various options for the Avalon Field Development were evaluated in terms of technical feasibility, environmental impact, health and safety, reputation and cost. The environmental assessment process was initiated early in the planning stage to support the option selection process, and actively drive mitigation measures, where certain impacts could not be avoided. A detailed option selection process was conducted at the outset of the project, and

a number of options were considered for development of the Avalon prospect. Options considered included:

- Newly built standalone facility (FPSO or platform),
- Long-distance Subsea Tie-back to a pre-existing Facility; and
- Re-use of an existing standalone facility (FPSO or platform).

After review of the development options, Re-use of an existing standalone facility was considered the most suitable concept option for development of the Avalon field as any modifications required would consume significantly less resources, (i.e. raw materials) and energy and result in fewer atmospheric emissions when compared to construction of a new standalone facility.

The Local Environment

Information about the local environment at the proposed Avalon Field Development and its surrounding area (Section 4) has been collated, to allow an assessment of the features, that might be affected by the proposed activities, or may influence the behaviour of potential contaminants.

Environmental Surveys Relevant to the Proposed Avalon Field Development

A number of environmental surveys have been conducted in and around the immediate project area, providing information on the seabed sediments and organisms found in the area, including any potentially sensitive features such as pockmark habitats.

The most recent seabed survey was conducted in November 2016. A new Environmental Baseline Survey (EBS) covering the Avalon Field Development area will be undertaken before drilling and installation operations commence.

Physical Environment

The proposed Avalon Field Development is located in the Central North Sea (CNS), at water depths ranging between approximately 112 m to 133 m.

Tidal currents in the offshore waters of the North Sea decrease in velocity from a south to north direction. Wind direction varies, but winds tend to dominate from south-south-west and south.

Seabed sediments are mainly composed of mud and sand, with occasional shell fragments. Potentially sensitive habitats, such as 'subtidal sands and gravels' and the 'offshore deep-sea muds' Priority Marine Feature (PMF) may be present, although both are some of the most widespread and common habitats in the Scottish offshore environment. Pockmarks and seabed depressions, are known to occur in the wider region.

Biological Environment

Benthos

Surveys undertaken in and around the Avalon Field Development location, found that biodiversity was low and distribution was sparse. The most common epifaunal organisms recorded in the area were hermit crabs, starfish and seapens, whereas the infaunal community mostly comprised polychaetes. Juvenile ocean quahog (*Arctica islandica*) were also recorded.

Fish and Shellfish

The proposed Avalon Field Development area lies within, or close to, known spawning and nursery grounds for several fish and shellfish species including *Nephrops*, cod, lemon sole, Norway pout, haddock, herring and whiting. Peak spawning for most species occurs between January and June.

Marine Mammals

A variety of cetacean species are recorded within the Avalon Field Development area, including harbour porpoise, white beaked dolphin, white sided dolphin, Risso's dolphin, minke whale, killer whale and long finned pilot whale. Two species of seal, the common and the grey seal, are resident in Scottish waters, but are unlikely to be present in the Avalon field area.

Seabirds

Seabirds are present in varying densities across at the Avalon field throughout the year. Species likely to be present include gannets, fulmar, kittiwakes and guillemots. The vulnerability of bird species to oil pollution is dependent on several factors and varies considerably throughout the year. The JNCC has produced reports on seabird density in the wider area and a Seabird Oil Sensitivity Index (SOSI), which identifies areas at sea where seabirds are likely to be most sensitive to oil pollution. The vulnerability of seabirds in the vicinity of the Avalon field is generally low to medium. However vulnerability increases in January and February particularly.

Protected Sites and Sensitive Habitats

The Avalon Field Development area is located amongst a network of protected sites including NCMPAs, Special Protection Areas (SPAs), Special Areas of Conservation (SACs) and Marine Conservation Zones (MCZs). The closest protected site is the Turbot Bank NCMPA, which lies approximately 24 km to the south-west and is designated for the presence of sandeels.

Other Users of the Sea

The North Sea is an important international fishing ground. The proposed Avalon Field Development overlaps with ICES rectangles 44E9 and 44F0. The majority of landings from these areas were demersal species, such as haddock and cod, as well as shellfish species, such as *Nephrops*. Fishing effort varies throughout the year but typically peaks in June and July.

The CNS is an area of intensive oil and gas activity. The nearest existing surface infrastructure to the Avalon Field Development is the Forties Unity, 33 km to the south, of the Avalon Field.

The area of the Avalon Field Development experiences very low to moderate levels of shipping activity and no practice and exercise areas (PEXA) are known to exist, within the vicinity of the proposed Avalon Field Development.

Assessment of Potential Impacts

To determine the activities associated with the planned operations at the proposed Avalon Field Development which could have a significant impact on the environment, PPUK has undertaken the following scoping activities:

- Scoping consultations between PPUK and the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED); and
- Environmental Issues Identification (ENVID) workshops by members of the project team.

An Early Consultation Document (ECD) was produced and the main environmental receptors and impacts arising from the project were identified/presented. The ECD was distributed to the Joint Nature Conservation Committee (JNCC), Marine Scotland and the Scottish Fishermen's Federation (SFF).

The key concerns relating to the proposed Avalon Field Development are addressed under the following headings:

- Drilling Impacts;
- Physical Presence Impacts;
- Atmospheric Emissions;
- Produced Water Discharges;
- Accidental Events; and
- Other Impacts.

Drilling Impacts

During the drilling of the two production wells at the proposed Avalon Field Development, drill cuttings and spent water-based drilling muds (WBM) will require disposal. Cement will also be used to prevent the wells from collapsing. The discharge of WBM, cuttings and cement at the Avalon site has the potential to cause a localised impact to the benthic environment, primarily through direct physical changes to the seabed and burial of seabed species and to a lesser degree by impairing the feeding and respiration activities of others. However, these impacts will be localised and short-term in duration. Any local accumulation of cuttings material will gradually disperse to the wider environment over time. The seabed communities at the Avalon Field Development are typical of those found in surrounding areas of the CNS, therefore the potential for recovery is likely to be strong.

Mitigation

Measures to mitigate adverse effects of drilling impacts have been proposed and include:

- All chemicals used for the drilling operations will be regulated under the Offshore Chemicals Regulations 2002 (as amended). All chemicals used will be included in the Offshore Chemical Notifications Scheme (OCNS) and drilling chemicals with no, or minimal potential for, impacts on the environment (PLONOR) will be used in the operations wherever feasible and the use of all chemicals will be minimised where practicable.
- For cement discharges, the amount discharged onto the seabed during installation of the top section casing will be minimised by visual monitoring of the operation by a Remotely Operated Vehicle (ROV). Once returns are observed, pumping will be stopped in order to minimise discharged volume.
- The lower well sections will be drilled with low toxicity oil-based muds (LTOBM) and which will be recycled as far as possible to reduce the quantities of mud used. The cuttings and remaining LTOBM will be skipped and shipped to shore for appropriate treatment and disposal.
- All chemicals used will be approved by Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and will be in accordance with UK chemicals regulations.

Physical Presence Impacts

Impacts on seabed habitats and species and other sea users will occur as a result of the physical presence of the MODU, FPSO and vessels and the installation of pipelines, subsea infrastructure, protection materials, OWT and power cable on the sea floor. Impacts of this nature include seabed habitat take, habitat alteration, sediment disturbances and re-deposition of suspended sediments as well as the potential displacement of shipping and commercial fisheries other sea users from areas occupied by fixed structures and associated exclusion zones.

Effects of seabed habitat take and habitat alteration, due to the placement of infrastructure on the seabed, will be highly localised and permanent lasting for the duration of the development but will be reversible on removal of seabed infrastructure at decommissioning and full recovery of affected habitats and species will occur over time.

Seabed disturbances and re-deposition of suspended sediment plumes will occur as a result of the movement of mooring lines of the OWT and FPSO, and installation of seabed infrastructure. Effects will be highly localised and recovery of affected areas of seabed habitat and associated species is forecast to occur on completion of respective seabed activities and removal of the moored infrastructure.

A 500 m exclusion zone will be established and maintained around the two proposed well sites from which local sea users will be permanently excluded. Commercial fishing may also be required to permanently avoid an area of approximately 1 500 m around the OWT (worst-case) to avoid snagging of, and damage to, bottom gears on the OWT moorings.

Mitigation

To avoid significant adverse effects associated with physical presence of infrastructure and construction vessels, several measures are proposed as follows:

- Micro-siting of seabed infrastructure, protection material and seabed trenching activities to avoid identified sensitive ecological features, such as pockmarks;
- A dedicated Emergency Response and Rescue Vessel (ERRV) to enforce the statutory safety exclusion zones around the MODU for the duration of drilling operations. The MODU and all other vessels will display the appropriate light, or daytime signals, to warn other sea users of the presence;
- The Avalon wells would be located within a 500 m safety exclusion zone and will be of a fishing friendly design to prevent damage to fishing vessels and equipment;
- The OWT will be marked in accordance with the requirements of the Northern Lighthouse Board, Civil Aviation Authority and/or the Maritime and Coastguard Agency, and its location will be marked on Admiralty Charts to aid future shipping and navigation; and
- Notices and warnings will be posted prior to vessels arriving on site to commence operations. The UK Hydrographic Office will be notified as to the location of the wells and other relevant infrastructure so that these can be marked on navigational charts.

Atmospheric Emissions

Generation of power onboard the MODU, FPSO, all support vessels and aircraft will result in the emissions of various combustion gases. All these emissions will contribute to local and global environmental effects. At a local level, such impacts are mitigated by health and safety measures in place, to control emissions onboard the vessels, as well as by the dispersive nature of the offshore environment (i.e. the wind and weather conditions). Emissions will also contribute to global environmental issues, such as climate change.

The most commonly used general indicator of atmospheric emissions is the global warming potential (GWP), expressed in tonnes of carbon dioxide (CO_2) equivalents. The GWP can be used to estimate the potential future impacts of gaseous emissions, upon the climate system. CO_2 equivalents are a unit of measurement for climate change potential, which enables various different emission gases to be compared in one single unit.

In 2018, a total of 14.63 million tonnes of CO_2 equivalent were released from oil and gas installations on the UKCS, equating to 3 % of the total UK greenhouse gas emissions. Compared to this value, the combined GWP generated by operations at the proposed Development, including flaring, is estimated to be 35,144 tonnes of CO_2 equivalents, which would account for less than 0.24%, a minor proportion of overall annual exploration and production operations undertaken on the UKCS. In this context, the atmospheric emissions generated during the proposed operations are not considered to be significant. The quantities of CO_2 equivalents, generated during the lifetime of the project also make up a small quantity of the UK's Carbon Budget (less than 0.0064 %) and the North Sea Transition Deal (NSTD) targets (less than 0.218 %).

The use of a floating OWT will help to reduce the emissions from the project, by decarbonising the power supply to the FPSO and thus, meeting the aims of UK and Scottish Government policy to decarbonise the oil and gas sector, whilst continuing to provide a reliable energy supply.

Mitigation

Measure to mitigate for potential effects of atmospheric emissions have been proposed and include the following measures:

- Use of a floating OWT, to provide power to the FPSO to reduce emissions;
- Development of a Methane Action Plan to identify, quantify and mitigate methane emissions from the Avalon Field Development;
- The burners on the flare used during well clean-up after the drilling operations will be environmentally efficient (i.e. 'green burners');
- All equipment onboard the MODU, FPSO and other vessels will be well maintained and include regular monitoring and inspections to ensure an effective maintenance regime is in place; and
- The combustion plants onboard the MODU and supply vessels will be built, to modern emission standards and be fuel efficient. Low sulphur fuels according to International Maritime Organisation (IMO) requirements will be used.

Produced Water Impacts

Produced water, a by-product of hydrocarbon extraction typically containing crude oil, polycyclic aromatic hydrocarbons (PAHs), metals and alkylphenols, will be discharged to sea during the production operations. Modelling undertaken to replicate different discharge scenarios, showed a rapid dilution of produced water in the marine receiving environment and predicted dilution rates would be well within established guidance. Under typical environmental conditions, produced water discharges are predicted to be diluted at a fast rate within, a few tens of metres, and will remain close to the sea surface during their dispersion. Discharges will therefore not reach the seabed and will not interact with seabed communities. Significant accumulation of chemicals, associated with produced waters, is not forecast, due to the nature of the receiving environment and the buoyant nature of the plumes.

Mitigation

PPUK will aim to achieve the lowest OIW concentration possible in produced water, that will be discharged after treatment and cleanup onboard the FPSO. Only pre-approved chemicals included in the OCNS, and are classed as PLONOR to the environment, will be used. Prior to use and discharge of any chemicals, chemical risk assessments will be undertaken (as part of the environmental permitting process), and submitted to the OPRED for approval.

Other Impacts

Other impacts considered in this ES relate to waste production, underwater noise, natural disasters, seabird collision with the OWT and EMF emissions from the OWT's operating power cable.

Waste such as sewage, plastic, and food waste as a result of the development can impact on the marine environment causing potential harm to marine life and a deterioration in marine water quality. Any waste generated will be recorded, processed and disposed of, in accordance with applicable legislation. This ES has identified all likely sources of waste and presents the waste management options, that will be put in place, to ensure no adverse environmental effects.

Natural disasters such as earthquakes, tsunamis and any extreme weather events have the potential to impact on the proposed infrastructure. Although infrequent, the potential for these types of natural events to occur will be taken into account, in the design and construction of the Avalon Field Development infrastructure, so that it can withstand a number of different loads and systems shut down, if required.

Underwater noise generated by construction operations, such as piling of the FPSO or floating OWT anchors, if required, may be at levels which are harmful to marine mammals and fish, if sufficiently close to the noise source. Mitigation will be needed to be implemented to ensure a safe distance between marine mammals and noisy underwater operations.

Seabird avoidance studies have shown that representative seabird species are able to avoid offshore wind turbines such that, significant numbers of collisions do not occur. With regards to the single OWT proposed for the Avalon Field Development, collision risk is considered to be very low and significant adverse effects on seabird populations, due to collisions, are not expected.

Operational subsea power cables emit electro-magnetic fields (EMF), which are considered to have the potential to disrupt migration movements, or interfere with foraging and feeding behaviours of certain species. The strongest EMF is created within 2 m of the cable and so burial to this depth, provides some shielding benefits However, burrowing species in immediately adjacent sediments will remain exposed.

Mitigation

To avoid significant adverse effects, associated with other impacts deriving from the temporary and permanent presence (during the life of the field) of infrastructure and construction/supporting vessels, several measures are proposed including:

- PPUK will ensure that all waste generated by the Avalon Field Development will be managed in line with the waste hierarchy, which gives top priority to preventing waste. Any waste generated will be recorded in the UK Environmental Emissions Monitoring System (EEMS);
- Should piling be required, appropriate mitigation following industry best practice and guidance will be followed, to ensure a safe distance separation between marine mammals and the piling noise source; and
- Burial of the proposed OWT power cable to 1-2 m depth below seabed level, will provide a distance separation between the strongest EMF emissions and marine life.

Accidental Events

The risk of an accidental hydrocarbon spillage to sea is often one of the main environmental concerns associated with oil-industry activities. The severity of impacts depend on many factors, including the volume and type of hydrocarbon spilled, the sea and weather conditions at the time of the spill, and the effectiveness of the oil spill response.

Oil spill modelling undertaken predicts that a large spill, such as from a well blow-out, or a complete loss of the FPSO inventory, would, under the majority of meteorological circumstances, drift east and north-east of the proposed well locations and has the potential to reach the coasts of Norway, but also may reach the Shetland Islands and north-east Scotland. This, however, assumes no intervention in the event of an accidental release of oil. It is a priority for PPUK to attempt to ensure no spilled oil would impact the coastline and, therefore, all appropriate oil spill response techniques would be employed immediately in the event of a spillage moving towards the shore.

Mitigation

In order to prevent an oil spill occurring, stringent safety and operational procedures will be followed at all times. Some of the specific mitigation measures identified include:

- Well control procedures will be in place, to prevent uncontrolled well flow to the surface and a full risk assessment will be performed as part of the planning phase of each well. Data on well pressure will be monitored throughout the drilling operations;
- A blow-out preventer (BOP) will be put in place. In addition to the standard control systems, the BOP typically has several other backup emergency control systems;
- All hoses (fuel/offloading) used during bunkering/offloading will be frequently inspected, tested, segmented with pressure valves, that will close automatically in the event of a drop in pressure;
- All equipment used on the MODU and FPSO will have safety measures built in (e.g. open / closed drain systems) to minimise the risks of any hydrocarbon spillage. There are also a number of spill kits available to deal with (smaller) spillages;
- PPUK is a member of Oil Spill Response Ltd (OSRL), which allows PPUK access to the OSPRAG (the Oil Spill Prevention and Response Advisory Group) Capping Device;
- PPUK will have a Temporary Operations Oil Pollution Emergency Plan (TOOPEP) in place, to cover the proposed drilling operations, and will have an Oil Pollution Emergency Plan (OPEP) in place, to cover production operations prior to the Avalon field commencing production;
- Specific members of the MODU, FPSO and standby vessel crew will have undertaken OPEP level oil spill response training. The MODU and FPSO will regularly undertake training exercises,

including vessel-based oil spill response exercises for the crew and an Offshore TOOPEP Exercise while on site;

- Booms may be used to contain a large slick on the sea surface, concentrating the oil for recovery by skimmers; and
- Sufficient finances and insurance will be put in place by PPUK, to cover the cost of responding to a large oil spill.

Overall Conclusions

The ES has considered the worst-case impact of the proposed Avalon Field Development and is therefore a conservative consideration of the potential effects on the environment. Overall, it is judged that the environmental impacts of the proposed Avalon Field Development operations, when undertaken in conjunction with the mitigation measures identified in the ES, will not incur any significant long-lasting environmental effects.

Section 1
Introduction

1. Introduction

This Environmental Statement (ES) presents the findings of the Environmental Impact Assessment (EIA) conducted by Ping Petroleum UK PLC, hereafter PPUK, for the proposed Avalon Field Development in the central North Sea (CNS). The Avalon Field Development will comprise two production wells tied back to a Floating Production Storage and Offloading (FPSO) unit and associated subsea infrastructure potentially including an optional gas import/export pipeline connected to either the Britannia Pipeline End Manifold (PLEM) or Ettrick PLEM. A floating offshore wind turbine is also proposed as part of the Avalon Field Development which would supply power to the FPSO.

The Avalon field is situated within United Kingdom Continental Shelf (UKCS) Block 21/6b, in the CNS (Figure 1.1). The location of the Avalon Field development is 57° 49' 22.819 N, 00° 10' 54.948 E. The nearest landfall to the Avalon field is Peterhead on the east coast of Scotland, approximately 116 km to the west at its nearest point. The UK/Norway median line is situated approximately 98 km east of UKCS Block 21/6b.

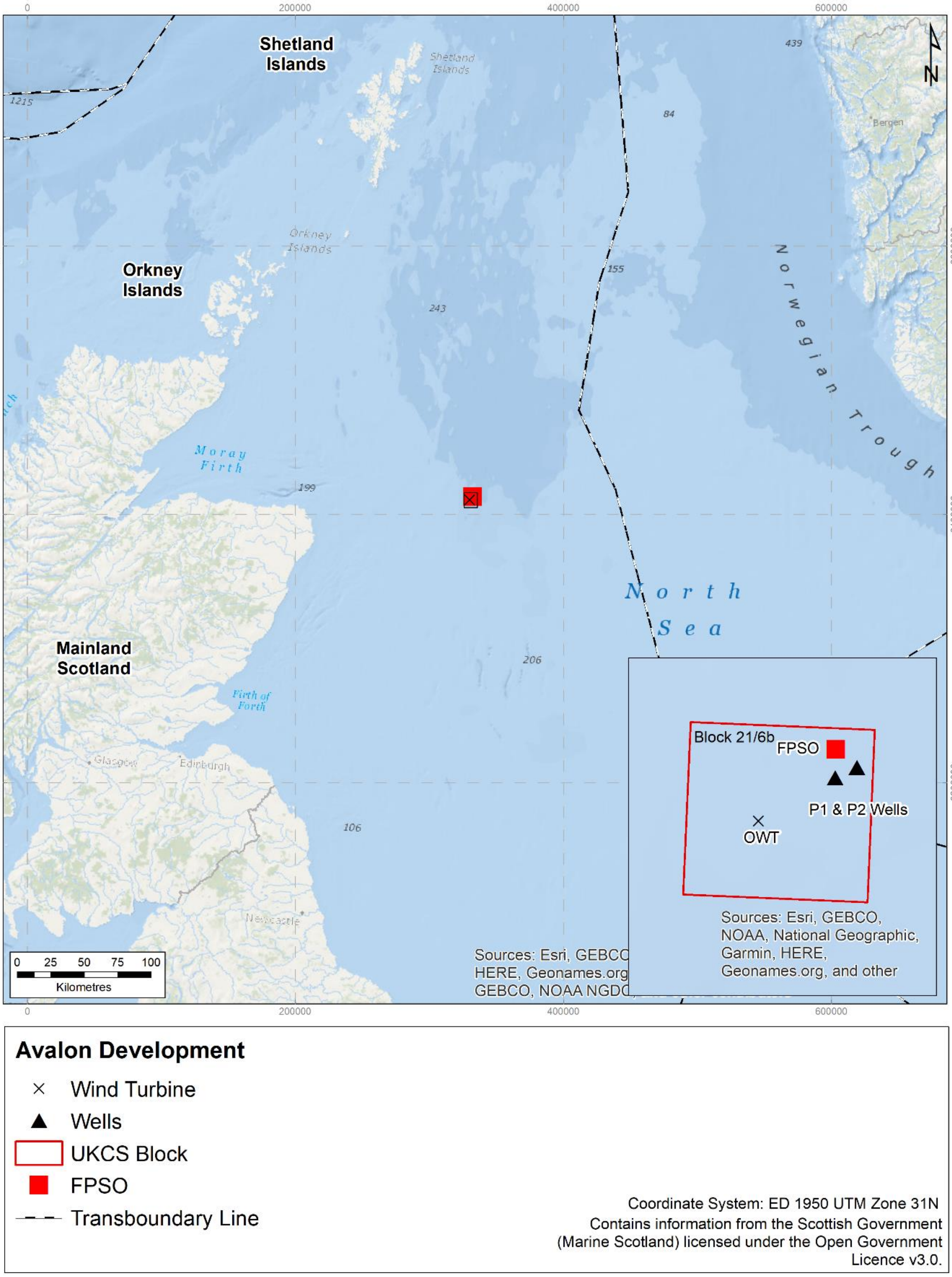


Figure 1.1: Location of the proposed Avalon Field Development

The purpose of this ES is to provide an assessment of the potential environmental effects that may arise from the proposed Avalon Field Development and to identify the measures, which will be put in place to minimise these effects.

This ES has been produced in accordance with The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 and associated guidelines. It also addresses the relevant requirements associated with the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 and the Offshore Chemicals Regulations 2002.

This Introduction explains the background and purpose of the development, the scope of the ES and the overall EIA process. The underlying regulatory and PPUK's own environmental requirements are also outlined.

1.1 Project Background

The Avalon field was discovered by Summit Exploration and Petroleum Limited in 2014, following the award of Licence No P2006 to Summit Exploration in January 2013. The exploration well found oil present in high quality tertiary sands. In 2017 an appraisal well was drilled on the prospect to confirm reserves and fluid characteristics. In June 2018, operatorship (100 %) of the prospect was transferred from Summit Exploration and Production Limited to PPUK.

PPUK proposes to develop the Avalon Development in order to produce the oil and gas contained within the reservoir. The field will be developed using a dedicated, moored FPSO to produce hydrocarbons from two production wells. Oil will be exported via shuttle tanker.

The development will include subsea infrastructure including a riser base structure (RBS) which houses a subsea distribution unit (SDU), an umbilical termination assembly (UTA) and subsea isolation valves (SSIV).

A number of pipelines, umbilicals and power cables will be required to be installed on the seabed as part of the proposed development. These will include a 3 km oil production pipeline, a 3 km control umbilical and a 3 km gas lift line between the RBS and the Avalon drill centre.

The proposed Avalon Field Development will use all produced gas from the Avalon field for power generation onboard the FPSO. When the Avalon field becomes gas deficient, the use of a floating offshore wind turbine (OWT), as an alternative power source to additional diesel consumption, is currently being evaluated. As part of this evaluation, a Crown Estate Scotland Innovation and Targeted Oil & Gas (INTOG) application is presently underway to allow placement of a floating OWT at the Avalon field.

If this is permitted, a power cable between the floating OWT and the FPSO will be installed which may be up to 25 km in length depending on the final location of the floating OWT. The preferred location of the floating OWT is shown in Figure 1.1. Power generated by the floating OWT This will have the advantage of facilitating the decarbonisation of the development.

Although the base case for the Avalon Field Development is to use all produced gas for power generation, and offshore wind power when the Avalon field becomes gas deficient, the option of providing a gas import/export pipeline route is currently being evaluated. If it is established that, as part of the optimal field development solution, a gas import/export pipeline is required, it will either be a 5 km pipeline to the Britannia pipeline end manifold (PLEM) or a 40 km pipeline to the Ettrick PLEM.

For the purpose of the EIA process, the 'worst-case scenario' has been considered for all aspects of the project scope where uncertainty still exists. This specifically includes requirement for both the gas import/export pipeline and the floating OWT. In both these cases the greatest established environmental footprint has been assumed.

It is important to note that all references to gas import/export pipeline routes and floating OWT power generation solutions stated in the ensuing sections of this report are options that may not form part of the final field development.

PPUK is currently planning to commence offshore construction and drilling activities by the end of Q3 2023. Once operational, the Avalon field is estimated to produce 3.5 million cubic metres (22 million bbls) of oil, over its expected ten year life.

1.2 Scope of the Environmental Statement (ES)

This ES presents the environmental implications of the proposed Avalon Field Development, which includes the Avalon field. The scope of the ES encompasses all new infrastructure, flowlines and associated activities, up to their connection points. As stated in Section 1.1, the scope also includes options for the installation of the floating OWT and a gas import/export pipeline and all associated installation and connection methods involved.

1.3 Legislative Framework

The proposed Avalon Field Development lies outside UK territorial waters (greater than 12 nm from land). Therefore, the majority of the activities undertaken will be governed under current legislation regarding offshore oil and gas activities. The main legislation applicable to the proposed development operations is summarised in Appendix 1 (Summary of Legislation) together with the relevant consents, authorisations and exemptions that are required. An overview of the pertinent and impending legislative requirements is given below.

1.3.1 The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020

These regulations replace The Offshore Petroleum Production and Pipelines (Assessment of Environmental Effects) Regulations 1999 (as amended) and implement the requirements of EC Directive 2011/92/EC (the EIA Directive) for offshore oil and gas operations in the UK. The EC Directive 2011/92/EU revokes the 85/337/EEC and its amendments 97/11/EC, 2003/35/EC and 2009/31/EC. These regulations require that an EIA must be undertaken for an offshore development considered to fall within the scope of a Schedule 1 project and that a public consultation document (the ES) is submitted to the Offshore Petroleum Regulator for

Environment and Decommissioning (OPRED) and made available to any interested party for comment prior to approval by the Secretary of State (SoS). OPRED has prepared guidance notes on the new regulations, issued in December 2020, which detail the information the ES must contain. Essentially the document must describe the proposed project and identify any impacts it is likely to have on the receiving environment, together with any measures to reduce the significance of any impacts. No consent in respect of an activity will be granted until the SoS is satisfied with the environmental information provided and that there will be no significant effect on the environment.

The Offshore Petroleum and Pipelines (Environmental Impact Assessment and other Miscellaneous Provisions) (Amendment) Regulations 2017 came into force on 16 May 2017. These regulations transpose the requirements of Directive 2014/52/EU into the EIA regulations. Directive 2014/52/EU amends the EIA Directive.

1.3.2 The Offshore Chemicals Regulations 2002 (as amended)

The Offshore Chemicals Regulations 2002 were developed in response to the Harmonised Mandatory Control System (HMCS) for the use and discharge of offshore chemicals, first introduced by the Convention for the Protection of the Marine Environment of the North-east Atlantic (the OSPAR Convention) in 2000.

The regulations stipulate that operators have to apply for a permit to use and discharge chemicals offshore. This permit must be in place before commencement of operations. The chemical permit applications are Subsidiary Application Templates (SATs), embedded within Master Application Templates (MATs) and are submitted electronically.

An application for the grant of a permit from OPRED is made via an electronic submission using the online UK Oil portal, and contains:

- A description of the offshore source on, or from which, the offshore chemical is to be used or discharged, and the location of the offshore source in the relevant area;
- A description of the proposed technology and other techniques for preventing or, where this is not possible, reducing the use or discharge of the offshore chemical from the offshore source;
- A description of the measures planned to monitor the use or discharge of chemicals; and
- An assessment of the risk of damage to the environment from the use and discharge of the offshore chemicals proposed.

Chemical permits last for the duration of the activity and require reporting of actual chemical use and discharge when the activity is complete. These regulations were amended in 2011, making it an offence to unintentionally release a chemical offshore. The updated regulations clarify the legal distinction between accidental “releases” and operational “discharges” and increase the powers of OPRED inspectors to investigate non-compliances/risk of significant pollution from chemical discharge.

1.3.3 The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended)

These regulations, generally referred to as the Oil Pollution Prevention and Control (OPPC) Regulations, introduced a permitting system for oil discharges to sea.

In 2011, amendments were made to the OPPC Regulations to align them with amendments to the Offshore Chemical Regulations (Section 1.3.2). The amendments made it unlawful to unintentionally release oil into the offshore environment. All oil discharges must be in accordance with the terms and conditions of an OPPC permit.

The OPPC Regulations also amend the Offshore Chemicals Regulations 2002, as discussed in Section 1.3.2, to increase the powers of OPRED inspectors to investigate non-compliances and risk of significant pollution from chemical discharges, including the issue of prohibition or enforcement notices. Operators are required to report all unpermitted oil discharges, regardless of size, to the HM Coastguard, OPRED and other relevant authorities.

Under the amendments, the OPPC regulations now also apply to offshore pipeline operations.

1.3.4 The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended)

These regulations, as amended in 2007, seek to ensure that oil and gas activities on the UKCS are carried out in a manner that is consistent with the requirements of the European Union (EU) Habitats Directive (92/43/EEC)

These Regulations are designed to ensure that the integrity of neither a Special Area of Conservation (SAC) nor a Special Protection Area (SPA) is significantly affected by activities occurring either within, or outside, those sites. Any plan or project which either alone, or in combination with, other plans or projects would be likely to have a significant effect on a site, must be subject to an appropriate assessment of its implications for a site's conservation objectives. Such a plan or project may only be agreed after ascertaining that it will not adversely affect the integrity of a SAC or SPA, unless there are imperative reasons of overriding public interest for carrying out a plan or project.

1.3.5 The Offshore Marine Conservation (Natural Habitats &c) Regulations 2007 (as amended)

These Regulations, as amended in 2010, implement the EU Habitats Directive and Birds Directive in the UKCS outside the 12 nautical mile (nm) zone. The Regulations make provision for the selection, registration, notification and management of European offshore marine sites. Competent authorities are required to ensure that steps are taken to avoid the disturbance of species and deterioration of habitat, in respect of the offshore marine sites and that any significant effects are considered before authorisation of certain plans or projects. Provisions are also in place for issuing of licences for certain activities and for undertaking monitoring and surveillance of offshore marine sites.

These Regulations also make it an offence to deliberately disturb wild animals of a European Protected Species (EPS), in such a way as to significantly affect the ability of any significant group of animals to survive or breed, or the local distribution or abundance of that species. If appropriate, a Wildlife Disturbance Licence may be required.

1.3.6 The Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations 2019

Due to the UK's exit from the European Union (EU), legislative amendments have been undertaken with respect to some of the main pieces of legislation, that afford protection to particular habitats and species in this country. These are the Conservation (Natural Habitats, &c.) Regulations 1994, the Conservation of Habitats and Species Regulations 2017, the Conservation of Offshore Marine Habitats and Species Regulations 2017 and the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, known collectively as "the Habitats Regulations", as well as The Wildlife and Countryside Act 1981.

In Scotland, these changes are enacted through The Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations 2019, which seek to ensure that Scotland maintains the standards required by the EU Habitats and Wild Birds Directives, commonly referred to collectively as "the EU Nature Directives", which set out rules for the protection and management of certain habitats and species and all wild bird species to ensure their conservation in the long term.

For Scotland and the rest of the UK, the Habitats Regulations continue to remain in force, including the general provisions for the protection of European sites and the procedural requirements to undertake Habitats Regulations Appraisal (HRA) to assess the implications of plans or projects for European sites.

1.3.7 Petroleum Act 1998 (as amended)

The Petroleum Act 1998 establishes the regulatory regime applying to oil and gas exploration and production in the UK (other than onshore in Northern Ireland). The Petroleum Act (as amended) vests all rights to the nation's petroleum resources in the Crown but allows licences to be granted, that confer exclusive rights to 'search and bore for and get' petroleum on the UKCS. The vast majority of offshore energy activities relating to oil and gas exploration and production are controlled under the Petroleum Act 1998 (as amended) and the Energy Act 2008 (as amended) or are exempted under the Marine Licensing (Exempted Activities) Order 2011 (as amended).

1.3.8 The Energy Act 2008 (as amended)

The Energy Act 2008, as amended in 2016, makes provisions for the decommissioning of offshore oil and gas installations. Part III of the Energy Act 2008 amends Part 4 of the Petroleum Act 1998 and contains provisions to enable the SoS to make all relevant parties liable for the decommissioning of an installation or pipeline; provide powers to require decommissioning security at any time during the life of the installation and powers to protect the funds put aside for decommissioning in case of insolvency of the relevant party.

Part 4a of The Energy Act, created through Section 314 of the Marine and Coastal Access Act 2009 (see below), transferred the Consent to Locate provisions of Section 34 of the Coast

Protection Act 1949 to the Energy Act. This gives the SoS power to grant Consents to Locate to an individual or organisation under Part 4a of the Energy Act, which would permit installation of an offshore structure, or the carrying out of offshore operations, providing that they are undertaken in accordance with the conditions of any consent granted.

1.3.9 Marine and Coastal Access Act 2009

The Act provides a legal mechanism for improved management and protection of the marine and coastal environment, with particular relevance to biodiversity and nature conservation. This legislation makes provision for the designation of Marine Conservation Zones (MCZs) in the territorial waters adjacent to England and Wales and UK offshore waters. Operators will need to apply for a marine licence to undertake certain licensable marine activities as per Part 4 of the regulations. The construction of the floating offshore wind turbine will require a marine licence from the Marine Scotland Licensing Operations Team (MS LOT) prior to construction commencing on this aspect of the Avalon Field Development.

1.3.10 Scottish National Marine Plan (NMP)

EU Directive 2014/89/EU introduced a framework for maritime spatial planning, with the aim to promote the sustainable development of marine areas and the sustainable use of marine resources. In accordance with this Directive, the Scottish National Marine Plan (NMP) was published in March 2015. The Scottish NMP sets out strategic policies for the sustainable development of Scotland's marine resources through informing and guiding regulation, management, use and protection of the marine plan areas. PPUK will ensure compliance with all the NMP policies throughout the proposed Avalon Field Development. Section 5.3.1 summarises the general and oil and gas specific policies and objectives, which are of relevance to the Avalon Field Development, and explains how they align with the project.

1.3.11 The Climate Change Act 2008

The Climate Change Act (2008) establishes a legally binding target for the UK, to reduce greenhouse gas emissions by at least 80% by 2050, from 1990 levels. The 2008 Act requires that the UK Government set five-yearly carbon budgets, which limit greenhouse gas emissions from all sources, excluding international aviation and shipping. In 2019, this target was revised with the UK planning to reduce all greenhouse gas emissions to net zero by 2050.

1.3.12 The Climate Change (Scotland) Act 2009

The Climate Change (Scotland) Act 2009, as amended by The Climate Change (Emissions Reductions Targets) (Scotland) Act 2019 sets targets to reduce Scotland's emissions of all greenhouse gases to net-zero by 2045. Interim targets have also been set including a 75 % reduction by 2030 and 90 % reduction by 2040.

1.3.13 UK Energy White Paper 2020

The White Paper sets out the UK Government's long-term vision for the energy system, with the goal of achieving net-zero emissions by 2050. The oil and gas industry is acknowledged to play a critical role in maintaining the country's energy security. It supports approximately 147,000 jobs and it is a major contributor to the economy. The Oil & Gas Authority (OGA) estimates that there are still 10 to 20 billion barrels of oil remaining in the UKCS. Projections for demand for oil and gas, whilst reduced, is forecast to continue for decades to come.

The White Paper makes a number of commitments to make the UKCS a net zero basin by 2050 and to reduce the emission of greenhouse gases from offshore oil and gas operations. Commitments include reducing and ultimately eliminating flaring and venting operations, repurposing of existing infrastructure, to support clean energy technologies, review and support the functions of industry regulators, support the supply chain in securing low carbon export opportunities in overseas markets and agree a 'North Sea Transition Deal' to support and promote the move away from oil and gas production.

Whilst these measures are ongoing, the White Paper also commits to ensuring a secure and resilient supply of fossil fuels during the transition to net zero emissions.

1.3.14 North Sea Transition Deal

The North Sea Transition Deal (NSTD) seeks to deliver on the commitments set out in the UK Energy White Paper. Some of the commitments detailed in the deal include a commitment from the oil and gas sector to reduce greenhouse gas emissions from production on the UKCS, amidst electrification of offshore infrastructure.

Ultimately, there will be a move away from combustion of fossil fuels, achieved through a combination of energy efficiency, electrification, alternative decarbonised energy and the use of carbon capture technologies. The NSTD recognises that oil and gas production will still be needed during this transition, but at lower levels than today.

The sector is already committed to becoming a net zero basin by 2050 and decarbonisation through, for example, electrification of offshore production installations and compliance with new standards on flaring and venting are seen as important measures, which can be taken to reduce emissions from the UKCS.

1.3.15 British Energy Security Strategy

The British Energy Strategy (UK Government, 2022) recognises the importance of the North Sea, as an area of oil and gas production. The Strategy seeks a reduction in imported fossil fuels, alongside full utilisation of the reserves available in the North Sea, with support for further developments through future licensing rounds managed by the NSTA. However, emissions from offshore oil and gas require to be reduced through electrification of assets, so that energy security is achieved, whilst also meeting Net Zero targets.

1.3.16 Shipping (Oil Pollution Preparedness, Response and Cooperation Convention) Regulations 1998

These regulations require that all operators have a formally approved Oil Pollution Emergency Plan (OPEP) in place for each offshore operation or agreed grouping of facilities. The regulations also stipulate legal oil spill reporting requirements.

These Regulations, which came into force on 19 July 2015, together with the Offshore Installations (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 and the Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015, implement the European Union Directive 2013/30/EU on the safety of offshore oil and gas operations (OSD).

1.3.17 The Offshore Installations (Offshore Safety Directive (Safety Cases etc.) Regulations 2015

The Offshore Installation (Offshore Safety Directive) (Safety Case etc.) Regulations 2015 came into force on 19 July 2015, replacing the 2005 Safety Case Regulations. The 2015 Regulations apply to all oil and gas operations in UK waters and implement the EC Directive on safety of offshore oil and gas operations 2013/30/EU. The EU has put in place a set of rules to help prevent accidents, as well as respond promptly and efficiency should one occur. The 2015 Regulations provide for the preparation of safety cases for offshore installations and the notification of specified activities to the competent authority.

1.4 Environmental Management

1.4.1 Policy and Governance

All PPUK activities are carried out in accordance with PPUK's Health, Safety and Environment (HSE) Policy. A copy of the HSE Policy is provided in the inside cover of this ES. The PPUK HSE Policy is the cornerstone of HSE Management. Commitments start at Board level and carry through line management to every employee and contractor engaged in PPUK activities. The Policy vision is to be a safe and environmentally responsible operator and partner and provides a systematic approach focused on promoting a strong culture and robust risk management. This policy forms the basis of the PPUK HSE Management System (HSEMS) with each commitment visible and linked with the processes and procedures supporting the commitment delivery. The PPUK Policy is applied to all operations, to ensure the highest standards of HSE are followed regardless of the operation, or operating environment.

PPUK is committed to prevent pollution and minimise the impacts to the environment from its operations. PPUK reviews the impact that all activities may have on the environment and ensures that all environmental risks are adequately identified, controlled or mitigated to an acceptable level by way of formal assessment. Seasonal variation in the distribution and vulnerability of species and features, such as seabirds and marine mammals, is considered in the planning of all work programmes. PPUK has a strong understanding of required environmental provisions for UKCS licensees, including compliance with standards such as the NMP, as well as environmental consenting requirements. Any significant environmental incident will be investigated and reported in a timely manner with lessons learned being disseminated around the company and integrated within PPUK Policy, where required.

1.4.2 Environmental Management System (EMS)

An assessment of the environmental consequences of the proposed Avalon Field Development has been undertaken, to ensure the integration of environmental considerations into the project planning and design activities. It is anticipated that the implementation of the mitigation measures identified during the EIA, will result in no significant environmental impacts arising from the proposed Avalon Field Development. PPUK's commitment to ensure environmental protection are set out in the PPUK's HSE Policy, as detailed on the inside of the ES front cover.

Environmental risks from major accident hazards are assessed in a similar way to safety hazards and integrated into the overall risk management approach. PPUK evaluates environmental aspects, impacts and consequences from major accident hazards throughout the lifecycle of the assets in their control. Outputs, including arrangements for preventing, responding to and mitigating incidents, that may cause environmental damage. These are described in the oil pollution emergency plans (OPEPs), as well as the aspects and impacts register.

Performance is tracked on a regular basis incorporating monitoring, audits and inspections, regulatory inspection letters and internal and external incidents. There are a number of key performance indicators (KPIs), which are agreed annually. Performance against these, is discussed at various levels within the organisation up to (and including) the board. Performance improvement will be implemented via the HSE continuous improvement plans.

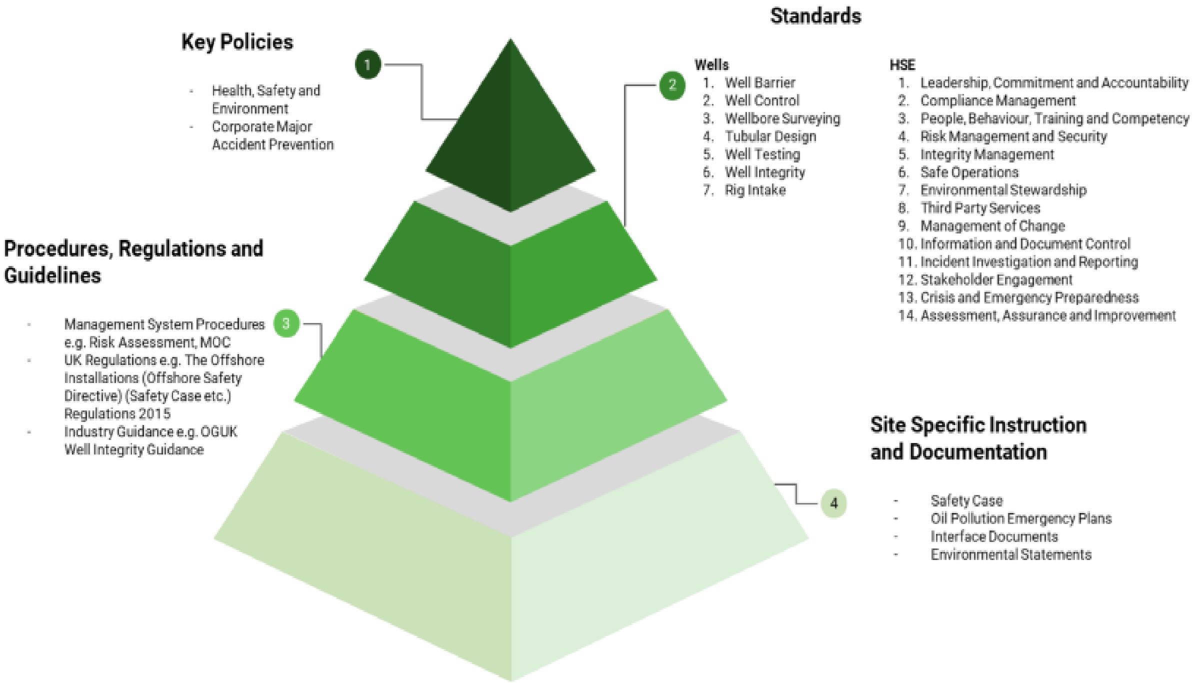


Figure 1.2: Overview of PPUK health, safety and management system hierarchy

PPUK is registered with the Offshore Pollution Liability Association Limited (OPOL) and will retain membership and registration in respect to the Avalon Field Development.

As a party to the OPOL agreement, PPUK has therefore agreed to accept strict liability for pollution damage and the cost of remedial measures and has established financial responsibility, in order to meet claims arising under OPOL.

1.5 Environmental Impact Assessment (EIA) Process

Offshore oil and gas activities can involve several environmental interactions and impacts due, for example, to operational emissions and discharges and general disturbance. The objective of the EIA process is to incorporate environmental considerations into the project planning and design activities, to ensure that best environmental practice is followed and ultimately to achieve a high standard of environmental performance. The process also provides for the potential concerns of stakeholders to be identified and addressed, as far as possible, at an early stage. In addition, it ensures that the planned activities are compliant with legislative requirements and PPUK's environmental management procedures (Section 1.4). The main elements of the EIA process followed are outlined below.

1.5.1 Scoping and Consultation

Informal consultation has been undertaken by means of two scoping meetings between PPUK and OPRED. During these consultations, the scope of the project was outlined to OPRED, along with a summary of the perceived environmental sensitivities.

Environmental concerns were identified during four Environmental Issues Identification Workshops (ENVID) between PPUK and Fugro from 2019 to 2021, based on the revised project designs and the proposed floating OWT. The latest ENVID report which summarises the impacts scoped into the EIA, is included in Appendix 6.

In October 2021, an Early Consultation Document (ECD) was produced which summarised the Avalon Field Development. The main environmental receptors considered likely to be present at the Avalon field, as well as any identified impacts arising from the project were presented. The ECD was distributed to the Joint Nature Conservation Committee (JNCC), Marine Scotland and the Scottish Fishermen's Federation (SFF), who were invited to comment on the proposals. Comments received from the consultees are summarised in Appendix 3. The formal statutory consultation process takes place following submission of the ES to OPRED and is subject to public consultation.

1.5.2 Information Gathering

Information was gathered on the natural and the socio-economic environment in the vicinity of the proposed wells, and potential sensitivities identified. Information was also gathered on the proposed operations, including the alternative options considered.

1.5.3 Commissioning Specialist Studies

Numerous environmental surveys have previously been conducted in Quadrant 21 and the surrounding quadrants, as discussed in Section 4.1.1. The most recent survey took place in 2016. As part of the EIA process, PPUK has also commissioned a Vessel Traffic Survey (Anatec, 2019) for positioning of the MODU. In addition, the following modelling studies were undertaken: produced water dispersion modelling (Fugro, 2022b) and oil spill modelling (Petrofac, 2019 and OSRL, 2022), to cover the worst-case spill scenarios which have been identified.

1.5.4 Identification and Assessment of Potential Environmental Impacts

A core element of the EIA process is the identification of all environmental effects associated with proposed project activities, which may have a 'potentially significant' impact. This process is called 'scoping'. An environmental effect can be any change to the environment or its use.

Effects can be positive or negative and can result directly or indirectly from project activities or events. A systematic approach was used, to ensure that all aspects of the project were considered in the same way.

The first step was to determine all stages in the project process, to ensure that all activities were fully considered. Those aspects of the project that have the potential to interact with the environment in a significant way were then identified. The complete life cycle of the proposed operations was reviewed for potential environmental impacts with the intention of eliminating, or reducing, the cause. Central to this process were the ENVID workshops, attended by key members of the project team. These workshops were carried out to evaluate the project for potential environmental interactions and to identify key issues for further consideration.

A series of matrices were prepared at the ENVID workshops, that identified the interactions associated with the proposed development. These interactions were then assessed for their significance, in order to determine the key environmental issues associated with each stage of the project. Details of this procedure and the key issues identified are presented in Section 5.2.

The environmental impact assessment (EIA) process then involves a detailed evaluation of each of the interactions that are judged to be of concern. The concerns included both the key issues identified by the screening process and the concerns raised by stakeholders during informal consultation. Each concern was dealt within the same manner, which involves describing PPUK's understanding of the concern, describing and quantifying the effects from the proposed project, recognising any gaps in understanding and explaining how these are dealt with, and defining measures that have been taken to mitigate the impact.

1.5.5 Development of Mitigation Measures

Identifying and assessing impacts and mitigating their significance, is an iterative process conducted throughout the project. Mitigation measures were explored throughout the assessment process, in order to eliminate or reduce the significance of the identified environmental impacts. Mitigation measures adopted are described in each of the individual impact sections (Sections 7 to 12).

1.5.6 Reporting of the Outcome of the Process by Means of the Publicly Reviewed Environmental Statement (ES)

This ES reports the findings of the EIA process and explains how the conclusions have been reached. The intention has been to present the information in such a way to allow readers to form their own opinions on the acceptability of the residual levels of impact, associated with the project. The statement covers:

- The reasons for developing the Avalon fields and the nature and role of the EIA process (Section 1);
- A description of the option selection process and proposed project (Sections 2 and 3 respectively);
- A description of the environment in the vicinity of the proposed operations (Section 4);

- The methods used to identify the environmental concerns associated with the programme (Sections 5 and 6);
- A detailed assessment of each concern, including any potential cumulative and transboundary impacts, and mitigation measures (Sections 7 to 12);
- The mitigation measures that have been recommended and
- Conclusions (Section 13).

In addition, the whole ES is summarised in the Non-Technical Summary (NTS).

Section 2
Option Selection

2. Option Selection

This section of the ES describes the alternative project options considered for the Avalon Development when developing the current preferred project design, and justifications for the options selected.

2.1 Introduction

The option selection process forms an integral part of the overall EIA process and, in line with Schedule 6 of The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 (as amended), should provide "*A description of the reasonable alternatives (for example in terms of project design, technology, location, size and scale) studied by the developer and an indication of the main reasons for the option chosen, taking into account the effects of the project on the environment and including a comparison of environmental effects.*"

The guidance notes published by the Department for Business, Energy and Industrial Strategy (BEIS) and Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) in support of the above EIA Regulations (Current version: July 2021, Revision 3, (BEIS, 2021)), provide further guidance on this topic and stipulate that the ES should "*describe the main alternatives to the proposed project that have been considered, and clearly describe the advantages and disadvantages of each option and the associated environmental implications. The main reasons for selection of the preferred option should be summarised, taking particular account of the environmental issues. Other factors influencing the final choice should also be recorded, e.g. feasibility including technical constraints and cost-effective issues relating to each option. If a formal option appraisal system has been used, it should be described, and the relevant decision factors identified.*

Where appropriate, consideration should always be given to alternative sites (including pipeline routes), alternative timing, alternative construction methods, alternative plant and equipment and alternative operating practices. Wherever possible, OPRED would always encourage the use of existing infrastructure, and if there is existing infrastructure available but its use is not the selected option then a robust justification should be provided. The consideration of alternatives may also be relevant for the drilling of a well and details of the decision-making process should be included, e.g., alternative sites, alternative rig types, alternative timing, slim hole, horizontal or extended reach technologies, alternative drilling muds and alternative cuttings treatment and disposal options.

Where final option selection has not been made before the submission of the ES, it is acceptable for more than one option to be presented in the assessment. However, sufficient detail must be provided to enable a full assessment of each option. OPRED may then provide its agreement to the grant of consent for all the options, or where applicable for a specific option, if other options are determined to have a significant effect."

The legislation and guidance document provide a solid framework for the option selection process, as undertaken by PPUK for this project.

A comprehensive option selection process has been carried out to determine the current preferred development option for the Avalon Development, including a detailed Concept Selection Study. The Avalon Development Project aims to safely develop the Avalon discovery in a responsible and sustainable manner. In order to achieve these aims, the following success criteria have been adopted for the Avalon Development:

- Safe Execution and Operations with Zero HSE Incidents;
- Minimising Environmental Footprint and Emissions from the development in accordance with Net Zero targets;
- Alignment of development concept with UKCS Electrification and the British Energy Strategy initiatives;
- Selecting Development Concepts aligned with the OGA Strategy objectives;
- Minimising Development Risk through elimination of unnecessary development scope; and
- Delivering the project on time and within budget.

2.2 Development Justification

Developing the Avalon Development will support the objectives of the UK's current energy policy, as set out in the Oil and Gas Authority (OGA), now renamed as the North Sea transition Authority (NSTA), document, the OGA Strategy (OGA, 2021) and the UK Governments Energy White Paper (UK Government, 2020). Furthermore, the proposed Avalon Development option aligns well with the targets set out in the North Sea Transition Deal (BEIS & OGUK, 2021), including those set out in the Methane Action Plan (MAP) (OGUK, 2021), as well as the British Energy Strategy (UK Government, 2022).

The central obligations set out in the OGA Strategy seek to maximise the expected net value of economically recoverable petroleum from UK waters and, in doing so, take appropriate steps in meeting the net zero target, by reducing greenhouse gas (GHG) emissions as far as reasonable in the circumstances (e.g. from sources such as flaring, venting and power generation).

The objectives for oil and gas developments detailed in the UK Governments Energy White Paper seek to reduce GHG emissions from the sector, to make the UKCS a net zero basin by 2050, eliminate routine flaring by, or prior to, the World Bank's 2030 target and support re-purposing of existing infrastructure to support clean energy technologies, all whilst ensuring a secure and resilient supply of fossil fuels during the transition to net zero emissions by 2050. At the proposed Avalon field, there will be no routine flaring.

The proposed development option for Avalon also provides a unique opportunity to deliver proof of concept for meeting the targets set out in the North Sea Transition Deal (BEIS &

OGUK, 2021) by powering an offshore oil and gas installation by locally produced offshore wind power. The North Sea Transition Deal is an agreement between the UK's oil and gas sector and the government to work together to deliver the skills, innovation and new infrastructure required to decarbonise North Sea oil and gas production, as well as other carbon intensive industries. The Avalon field development has the potential to be one of the first energy transition projects developed in the North Sea, utilising offshore wind power to decarbonise production.

As part of the North Sea Transition Deal, the UK oil and gas industry sector has agreed a set of targets to reduce the sector's total GHGs emissions (including methane) by 50 % by 2030 and achieve a 90 % reduction by 2040, relative to a 2018 baseline. The MAP, prepared by Oil & Gas UK (now Offshore Energies UK). is one of the key deliverables of the North Sea Transition Deal agreed with the UK Government and was announced in March 2021. The MAP highlights the actions the industry will take now to cut methane emissions on the UK Continental Shelf (UKCS). The MAP targets include all operators to develop a methane action plan by Q4 2022 for each individual asset, including measurement and quantifications, flare and vent management plan, and abatement plan, in order to show how they will meet the following targets:

- Zero Routine Flaring before 2030;
- UKCS methane intensity below 0.20 % by 2025; and
- Achieve 50 % methane emission reduction by 2030.

The British Energy Strategy (UK Government, 2022) recognises the importance of the North Sea, as an area of oil and gas production. The Strategy seeks a reduction in imported fossil fuels alongside full utilisation of the reserves available in the North Sea. However, emissions from offshore oil and gas should be reduced by electrification of assets, so that energy security is achieved whilst meeting Net Zero targets (UK Government, 2022).

Whilst not developing the Avalon field would avoid any potential for environmental impact, it would prevent the maximum value of economically recoverable petroleum from being recovered, in line with the OGA Strategy, whilst also helping to meet the UK's energy needs in line with the British Energy Security Strategy.

2.3 Option Selection

Various potential development options for the Avalon Field have been evaluated in terms of technical feasibility, environmental impacts, health and safety, reliability, reputation and cost, as part of the Avalon Concept Select Process (CSP). The Avalon CSP comprised three phases as outlined in Figure 2.1.

The environmental assessment process was initiated early in the planning stage. The aim was to support the option selection process and to assure appropriate mitigation measures could be included in the project design, in order to minimise the environmental impacts of the preferred development option.

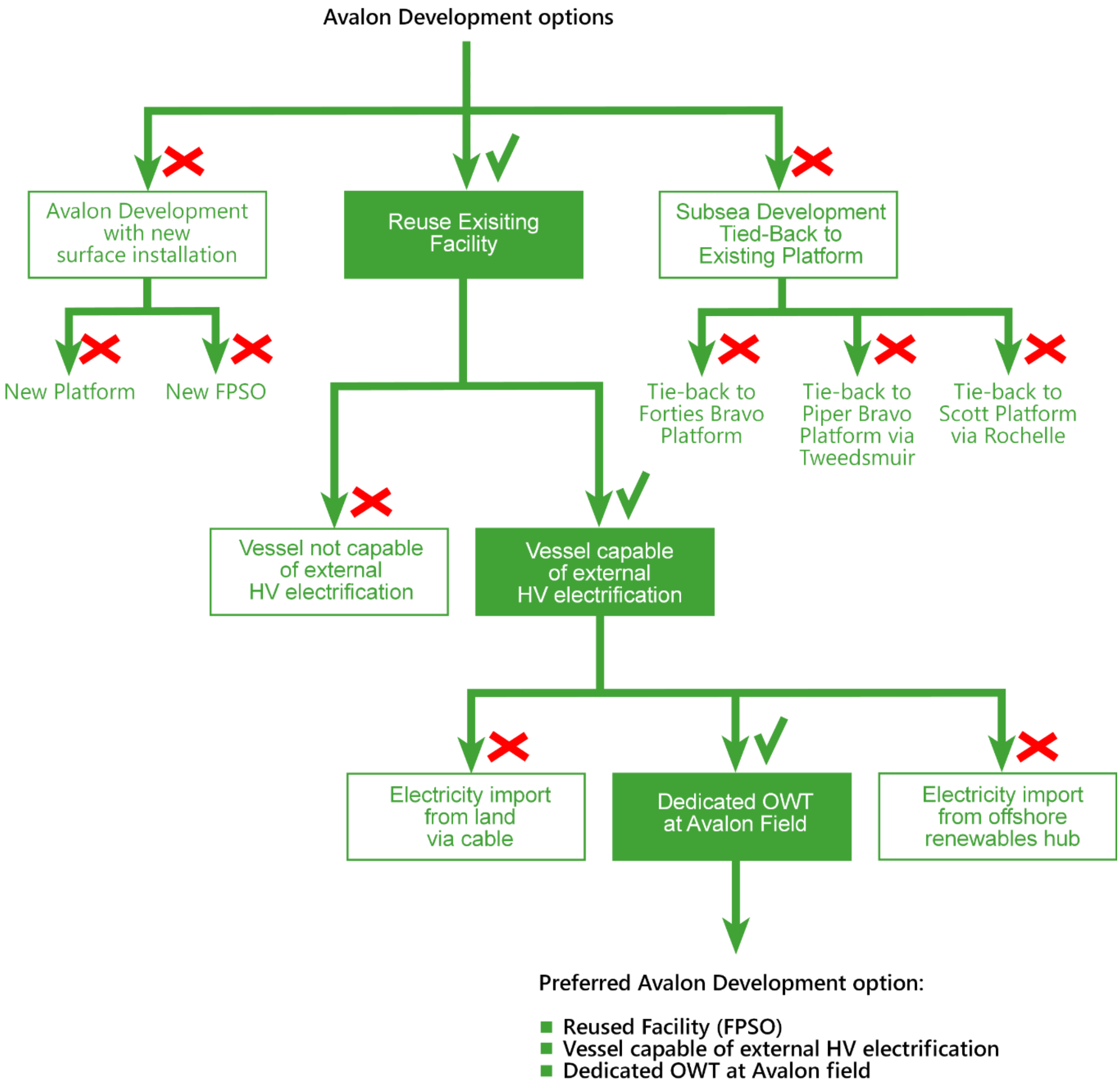


Figure 2.1: Main Development Options considered for the Avalon Field

2.3.1 Concept Select Phase 1 - Avalon Development Host Options

The three main development options under consideration were:

- New built Standalone Facility (FPSO or platform),
- Long-distance Subsea Tie-back to a Pre-existing Facility; and
- Re-used Standalone Facility (FPSO or platform).

A Concept Feasibility Assessment was undertaken on all three options to determine the preferred development option. The results of the feasibility assessment are summarised below.

2.3.1.1 Option 1 – New built Standalone Facility

A number of new built standalone platform facility options were evaluated on their technical, commercial and environmental impacts factors. The options reviewed included fixed minimal facilities production platforms (including a subsea oil storage), FPSOs and platforms with export facilities. In addition, a collaborative study with Jersey Oil and Gas (JOG) was undertaken to evaluate the potential for the Avalon and Buchan discoveries to be produced, through a single new platform located within the JOG's Buchan Field, located 13 km north-east of Avalon.

A review of all these options considered that construction of a new built facility included greater consumption of construction materials and increased atmospheric emissions (Figure 2.2), when compared to the other two Avalon Field Development host options.

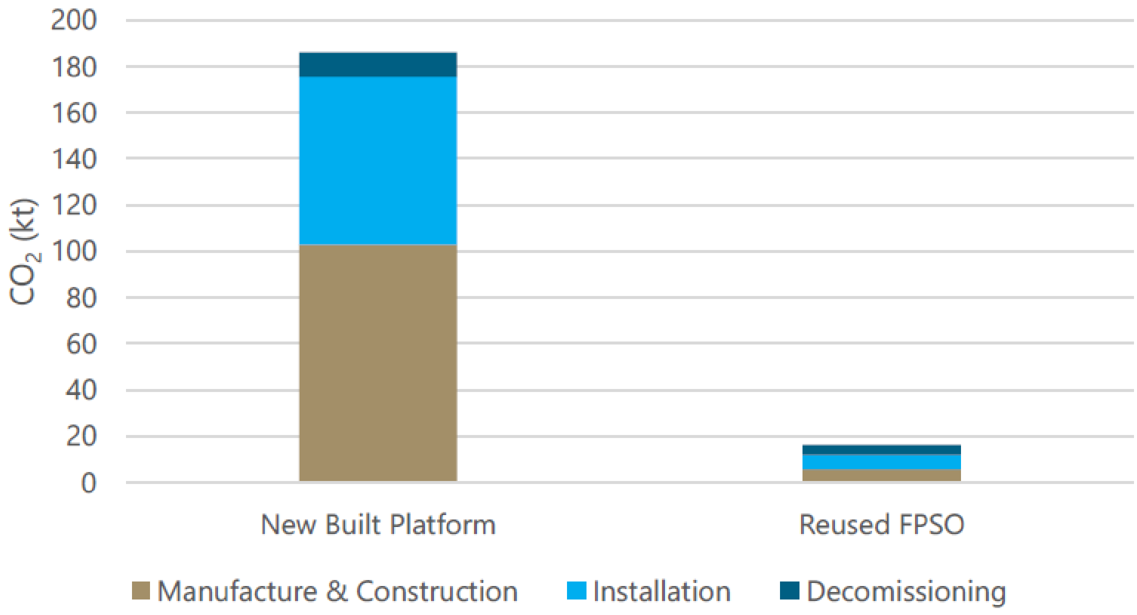


Figure 2.2: Main Development Options considered for the Avalon Field

Construction of a new built facility requires significantly increased capital expenditure (CAPEX) resulting in reduced economic return than the other two options reviewed. Construction of a new built facility would also increase project timelines and increase the potential for HSE incidents, during the construction process and risk cost overruns. Also, the construction of a shared new built facility would be contingent on other developers committing to, and securing the necessary permissions for, those developments.

In conclusion, based on these screening results, although a new built FPSO facility has the potential to offer the best technical solution for the development, for the reasons detailed above it is not considered to be as economically efficient as reuse of an existing facility. Furthermore, reuse of an existing facility mitigates certain environmental impacts associated with a new built facility. Therefore, this option was dismissed and is no longer under consideration.

New built Standalone Facility Option ✘

2.3.1.2 Option 2 - Subsea Tieback Option - Connect to a Pre-Existing Facility

PPUK reviewed all existing platforms within a 75 km radius from the Avalon Field, which would be able to support a long distance tie-back from Avalon. This review identified three potential candidate platforms, namely: Forties Bravo, Piper Bravo and Scott (Figure 2.3).

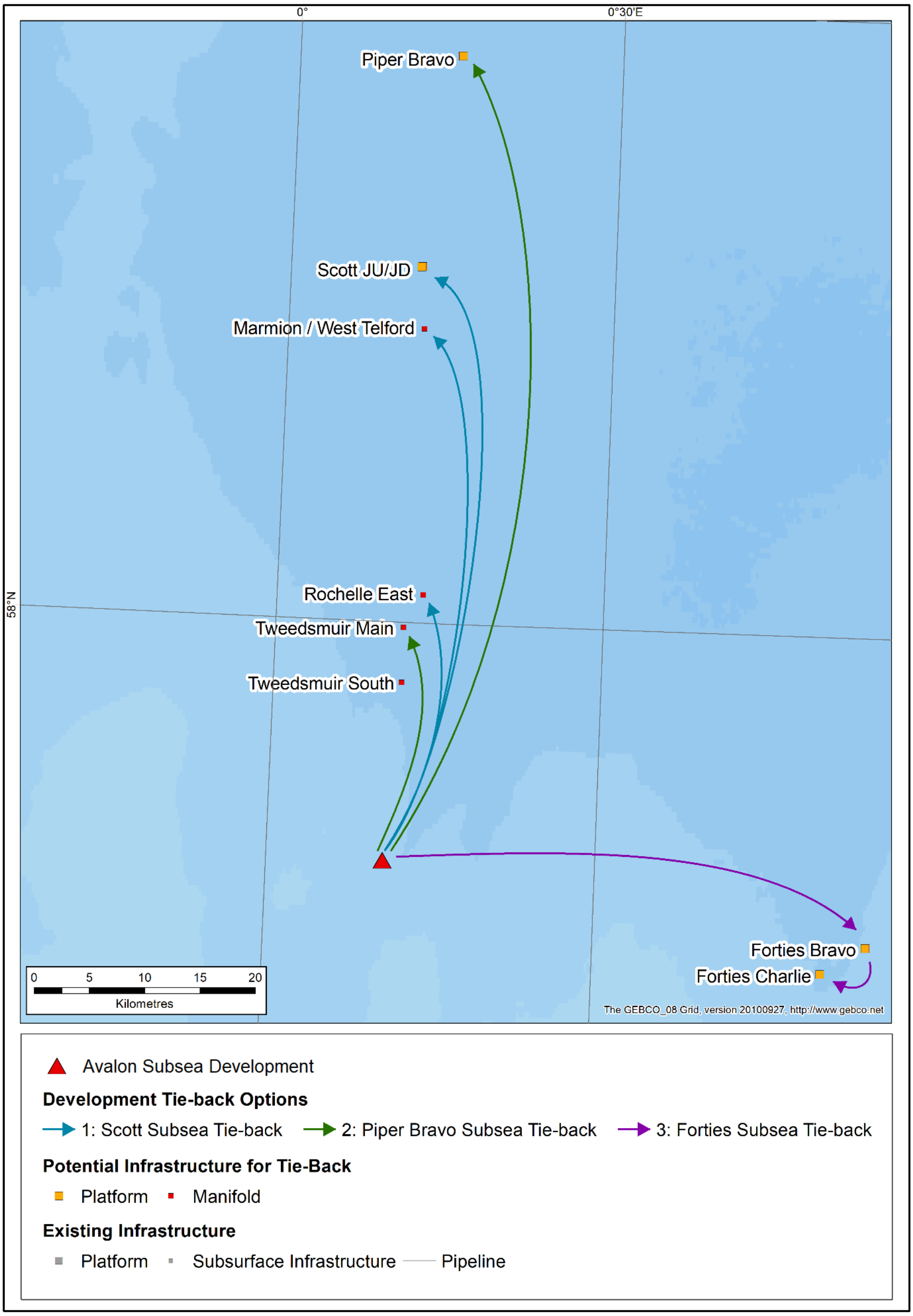


Figure 2.3: Potential hosts and illustrative pipeline routes for the three main tie-back options

2.3.1.2.1 Option 2A - Forties Bravo Platform

The Forties Bravo Platform is relatively close at approximately 44 km distance from Avalon. A tie-back to the Forties Bravo Platform would require installation of all-new subsea equipment, including flowlines, and process train onboard the platform. This option has the potential for large scope and cost escalation, if any of the mothballed equipment onboard the Forties Bravo Platform cannot be reused. On this basis, the Forties Bravo Platform tie-back option was dismissed as the preferred development option.

Tie-back to Forties Bravo Platform ✘

2.3.1.2.2 Option 2B - Piper Bravo Platform via Tweedsmuir

The Tweedsmuir/Piper Bravo concept would require the laying of a new production flowline, umbilical and gas lift line from Avalon to the existing Tweedsmuir manifold, making maximum use of existing infrastructure. No major modifications on the topside of the Piper Bravo Platform would be required.

However, the feasibility study showed that for this option, water handling issues in late-life and flow assurance issues inherent in a tieback of this distance (71 km), were likely to present considerable development challenges. Hence, the tie-back to Piper via Tweedsmuir option was dismissed as the preferred development option.

Tie-back to Piper Bravo Platform via Tweedsmuir ✘

2.3.1.2.3 Option 2C - Scott Platform via Rochelle

The Scott-Rochelle concept would re-use the existing subsea manifold, flowline, umbilical and riser to the Scott platform. Rochelle ceased production in Q2 2019, with the pipeline currently being unused. Therefore, this option would allow for maximum use of existing infrastructure with only minimal topsides modifications required at Scott.

However, there is a potential for early cessation of production at Scott, due to late-life issues and production declines faster than expected. In addition, the schedule to first oil has been delayed, due to turnaround (TAR) deferments at Scott caused by COVID-19.

In conclusion, the feasibility study concluded that, of the three potential tie back options to the Scott Platform, the Rochelle tie-back option would be the preferred option.

However, due to the uncertainties outlined above, the Scott Platform via Rochelle tie-back option was dismissed as the preferred overall development option.

Tie-back to Scott Platform via Rochelle ✘

2.3.1.3 Option 3 - Standalone Facility - Re-used Facility

Recent changes in the international oil and gas markets have resulted in an increasing number of FPSOs moving off location early on the UKCS and becoming available for re-use. This presented PPUK with an opportunity to make use of existing infrastructure thereby reducing CAPEX, project timelines and certain potential environmental impacts, such as the carbon footprint of the host facility.

PPUK did approach various owners and operators, to allow review a number of potential candidate options.

Certain potential environmental impacts are considered to be reduced as well, with fewer resources required for construction and conversion, as well as a reduction in atmospheric emissions when compared to the construction and fabrication of a new built facility.

Re-use of an FPSO at the Avalon site would also minimise the impact footprint on the seabed, by reducing impacts from operations such as trenching, to install new subsea infrastructure, associated with long distance tie-backs.

In addition, a repurposed FPSO could also be used as a future production hub for tiebacks from other prospects in the area, which may come online once the Avalon Field is in production.

In conclusion, re-use of an existing FPSO facility has been judged to represent the best environmental and economical option for the Avalon Field Development for the reasons discussed above.

Re-used Standalone Facility Option ✓

2.3.1.4 Concept Select Phase 1 - Preferred Host Option for the Avalon Development

The CSP concluded that Option 3, "Standalone Facility - Re-used Facility", offers the most suitable concept option for the Avalon development. Any modifications required to the Avalon facility, will require significantly fewer resources (including raw materials), energy use and associated atmospheric emissions, rather than a new standalone facility. Furthermore, this option offers a lower CAPEX and operating expenses (OPEX), when compared to a new built platform.

2.3.2 Concept Select Phase 2 - Host FPSO Candidates

After completion of Phase 1 of the CSP, PPUK undertook a detailed review of nine potential candidate FPSOs available on the market now, or in the near future. The review consisted of site visits to key facilities of interest and liaison with facility owners, to further inform an assessment of the most suitable FPSO for the Avalon development. The assessment considered the following criteria:

- Immediate or near future availability of the proposed FPSO;
- Compatibility with future electrification requirements for Net Zero;
- Processing capacity based on the requirements of the Avalon wells and potentially accommodating future third party production;
- Extent of modifications required for the chosen facility; and
- Modification and re-deployment costs of the FPSO.

This screening exercise resulted in three candidate FPSOs being selected for further evaluation, prior to selection of a final candidate host facility.

2.3.3 Concept Select Phase 3 - Host FPSO Shortlisted Candidates

Phase 3 of the CSP process comprised a detailed technical feasibility study of each of the remaining three FPSOs, which was undertaken by a contracted third party. Additional commercial discussions were also held with facility owners.

The technical feasibility study considered the candidate FPSOs' capability to:

- fully align with the Net Zero strategy;
- their potential for re-use of existing infrastructure with the requirement for minimal modifications to minimise environmental impacts;
- their processing capacity to handle produced oil from the Avalon field and potentially from surrounding third party discoveries,;
- high historical uptime; and
- availability within the confines of the Avalon timeframe for development of the discovery.

The selected FPSO for the Avalon Development is the Hummingbird Spirit, which has been renamed Excalibur. This is a SEVAN type FPSO, built in 2008 and on the UKCS at the Chestnut Field, approximately 60 km east of the Avalon Field. The Excalibur FPSO has been moved off location to Nigg Energy Park for inspection and installation of the required process/platform modifications and refurbishment.

2.3.4 Other Options and Considerations

Once the preferred main development option has been determined, the next level of options has to be considered, regarding the technical aspects of executing the preferred main development option. The following additional aspects will be considered by the project team in further planning of the development:

- Drilling rig selection;
- Drilling fluids and chemicals;
- Mooring systems for the FPSO and floating offshore wind turbine (OWT);
- Pipeline and powerline installation and protection methods;
- Reservoir depletion strategy;
- Produced gas management;
- Produced water treatment and disposal;
- Electrification of the FPSO; and
- Decommissioning.

2.3.5 Drilling Rig Selection

The selection of the drilling rig for the operations strongly depends on the technical requirements of the planned operations and the availability of a suitable rig. The mobile offshore drilling unit (MODU) to be used to drill the wells at the Avalon field has not yet been confirmed. The drilling operations may be undertaken from either a jack-up drilling rig, or an anchored semi-submersible drilling rig. The option selection of the MODU will be mainly based on detailed geotechnical site surveys at the Avalon field. Further considerations will include rig availability and costs, as the environmental impacts from both options are considered to be very similar.

2.3.6 Well Infrastructure Selection and Well Drilling Operations

As part of the front-end engineering design (FEED)/evaluation process PPUK considered the potential to use a CAN-ductor in the proposed operations at the Avalon field. The use of a CAN-ductor is considered to be more appropriate in developments comprising multiple wells, necessitating the use of larger vessels which would increase the quantity of atmospheric emissions during installation of the subsea infrastructure. Although the use of CAN-ductors offers other (minor) environmental benefits, such as less cement discharges during cementing operations, their use in this specific project is not considered appropriate.

2.3.7 Drilling Fluids and Chemicals

Chemical additives will be used during both the pipeline and umbilical installation, as well as during the operational life of the Avalon subsea development. The specific chemicals and additives required have not been selected at this stage and will be dependent upon the specific operational conditions of the Avalon production system.

All chemicals will be selected on their technical specifications but will also be assessed on their potential environmental impacts, using the regulatory Harmonised Offshore Chemical Notification System (HOCNS), incorporating the Chemical Hazard Assessment and Risk Management (CHARM) model, where applicable. The chemicals to be used in the drilling operations will be selected when a rig contractor and service contractor is appointed and the appropriate chemical Master Applications Template (MAT) and Subsidiary Application Template (SAT) will be applied for.

2.3.8 Reservoir Depletion Strategy

Analysis of the pre-production formation pressures of the Avalon exploration and appraisal wells and from a number of offset wells from other fields in the Cromarty sandstone reservoir over time (including Torphins, Scolty and Crathes), shows that these fields are in hydraulic communication through a shared aquifer. The Cromarty aquifer provides full pressure support to the Scolty and Crathes fields and a similar level of natural support is expected on Avalon.

Therefore, no water injection is anticipated at Avalon. The absence of water injection from the outset minimises the likelihood of water 'short-circuiting' to the two production wells and prevents potential production chemistry issues, including scaling, which would otherwise require remediation by periodic scale squeezes.

During the initial production period, production trends, including rates and downhole pressures, will be monitored, in accordance with the Avalon Well, Reservoir, Facility Management (WRFM) Strategy. In the case that aquifer support is poorer than expected and water injection becomes beneficial to the development, future injector wells may be planned and tied back to the FPSO. Similarly, if there is evidence for economically viable infill targets, or additional wells are required to maximise economic recovery, additional production wells may be drilled, as appropriate. The Avalon FPSO has existing topside water injection capability, in case this would be required in the future.

2.3.9 Produced Gas Management

The Avalon development is planned on the basis of no routine flaring. The topsides of the Avalon FPSO will be modified to ensure all associated gas can be used for power generation to run the plant and inlet/interstage heating for produced fluids. A potential gas import/export pipeline will allow for any excess gas to be exported however it is proposed that all Avalon produced gas will be used for FPSO power generation.

When Avalon becomes gas deficient, which could occur 1-3 years after first oil, it is planned to have the facility connected to a floating OWT. Topsides modifications will be designed to accept high voltage power for facility electrification and inlet heating, as required. The proposed floating OWT will minimise the routine use of imported fuel, when produced gas can no longer fully meet demand for electrical power and inlet heating.

Whilst the option of a gas import/export pipeline has been included and assessed as part of this EIA, it is recognised that there are technical and commercial challenges to be overcome to achieve this. There are no tie-in points to existing infrastructure within the immediate vicinity of the Avalon field. This means that the gas import/export pipeline may require either a lengthy (50 km+) tieback to a suitable tie-in point at Ettrick, or a high liability hot tap into the nearby (~ 10 km) strategically important Britannia gas line. Installation of a potential gas import/export line would reduce, or eliminate, the need for routine flaring at the Avalon field.

Alternative solutions and technologies will be looked at to remove the need for a 50 km pipeline, which would reduce the environmental footprint of the project through a reduction in disturbance of the seabed. Gas re-injection wells have been considered and judged to be unfeasible for this particular development. From reservoir simulations, it has been found that any gas injected into Avalon, would quickly migrate up-dip towards the producing wells and be 'back-produced' in less than one month. PPUK will continue to monitor emerging technologies, which may offer the opportunity to offer subsea gas storage.

2.3.10 Produced Water Treatment and Disposal

As part of the concept selection process, PPUK have considered various options to handle the production and disposal of produced water, during the lifetime of the Avalon field.

Options considered include re-injection of produced water via a disposal well(s), or to producing formations, treatment and discharge to sea via the FPSO. Environmental, financial and project impacts were considered as part of the assessment process and ultimately it was concluded that re-injection of produced water at the Avalon field is not appropriate.

Re-injection of produced water into the producing formation(s) would impact on the recoverability of the hydrocarbons. Successful development of the viscous Avalon oil is predicated on a reservoir management strategy, based on uniform natural pressure support for the field from the adjoining aquifer. Disposal of water into this aquifer is expected to cause rapid water breakthrough and significantly diminish the economic viability of the development.

If a standalone re-injection well was required, this would be drilled at a separate drill centre location, approximately 3 km from the Avalon field. This would result in supplementary environmental impacts, including additional atmospheric emissions and seabed disturbance from the drilling operations and installation, and decommissioning, of additional subsea infrastructure. A standalone re-injection well is also estimated to increase development costs for the project by approximately 15 % and at the same time negatively impact on recoverability of the hydrocarbons.

The Field Development Plan for the Avalon Field Development is predicated on uniform support from the aquifer for the field. Water injection is considered highly likely to lead to circulation of water, rather than increase production.

For these reasons, it is considered that re-injection of produced water is not feasible and the preferred option is to clean up the produced water, using treatment facilities onboard the FPSO such as the compact flotation unit and hydrocyclones, before discharging overboard.

2.3.11 Electrification of the FPSO

The FPSO selection considered the feasibility of future electrification of the facility, to assist in decarbonising the Avalon field. The selection process considered electrification of the topsides from an external source, such as a power cable from shore or a local wind turbine. The topside processing capabilities of the FPSO will be re-designed to use electrical power.

2.3.12 Pipeline and Powerline Installation and Protection

The overall footprint of the development will be minimised as far as possible, to reduce the potential impacts on the environment and other users of the sea. In line with industry best practice on the UKCS, safety and environmental factors, pipelines, powerlines and umbilical will be trenched and buried through a combination of a backfill pass and natural backfilling. Jet trenching has been chosen as the installation method, which minimises the extent of the seabed footprint affected by installation operations and reduces the need for mechanical backfilling. Furthermore, the use of rock dump as a protective measure for pipelines is minimised.

2.3.13 Floating Offshore Wind Turbine (OWT)

In selecting the most appropriate floating OWT for the site, PPUK have considered the size and generating capacity of the turbine, the foundation base and type, as well as its mooring system.

The minimum required generating capacity of the floating OWT to provide sufficient power for peak electrical demand onboard the FPSO is 8 MW. However, the proposed generating capacity of the floating OWT is likely to be between 10 and 14 MW, which will allow for longer up time at lower wind speeds.

A decision on the base for the floating OWT is still to be made. A tension leg platform (TLP) or semi-submersible foundation will be considered. The base of the semi-submersible foundation includes deck space which may be utilised in the future for deployment of other renewable energy sources. Use of a TLP design minimises the mooring spread and reduces the footprint of the development. Mooring lines for a semi-submersible, typically extend further outwards from the foundation, therefore increasing the development footprint.

The mooring lines will be either piled into the seabed or anchored using suction anchors. A decision on the most appropriate anchoring system will be made once a geotechnical survey of the site is completed.

2.3.14 Decommissioning

The well and subsea infrastructure designs, including the floating OWT, take into consideration decommissioning requirements in line with current guidance.

2.4 Conclusion

Following a comprehensive review of all options for the proposed Avalon Field Development, the selected concept is the re-use of an existing facility (the former Hummingbird Spirit FPSO, renamed Excalibur), which would be installed at the Avalon field, with two production wells tied back to the FPSO via flowlines.

The overall development concept aims to keep the design as simple as possible, by maximising the use of existing infrastructure. This will, in turn, maximise the value of economically recoverable hydrocarbon reserves, in line with the OGA Strategy (OGA, 2021) and the British Energy Security Strategy (UK Government, 2022) whilst minimising the development's environmental footprint through diminished atmospheric emissions, a reduction in seabed impacts and fewer natural resources consumed.

The principles of the OGA Strategy, the British Energy Security Strategy, the UK Energy White Paper and the North Sea Transition Deal have been applied throughout the option selection process.

The selected concept minimises resource use and carbon footprint by re-purposing an existing production facility. Further reductions in the project's carbon footprint will be achieved by installing a floating OWT to provide power to the FPSO. The electrification of this offshore asset is supported by the NSTA North Sea Transition Deal (BEIS and OGUK, 2021).

The proposed Avalon Field Development provides a unique opportunity to deliver proof of concept for powering offshore oil and gas installations through offshore wind installations, which will help to contribute to the 50 % emission reduction target by 2030, as set out in the North Sea Transition Deal.

Section 3
Project Description

3. Project Description

This section contains a detailed description of the selected options described in Section 2 of this ES. Where multiple options still exist, each option will be described in detail. Where the anticipated impacts between the remaining options differ noticeably, the option with the largest anticipated effect will be assessed in the subsequent impact chapters of the ES as the "worst-case" option.

3.1 The Avalon Field – History to Date

The Avalon Field is situated within the UKCS Block 21/6b, approximately 116 km east of Peterhead, Scotland, in water depths of between 115 m and 145 m.

The Avalon prospect was successfully drilled in 2014, when oil was discovered in high quality Tertiary sands. This exploration well (21/6b-8 Avalon) was drilled by EnQuest Heather on behalf of Summit as licence operator. The well encountered a gross 25.9 m (85 ft) column of 924 kg/m^3 oil in high quality Sele Formation Cromarty Sandstone Member reservoir.

A subsequent appraisal well (21/6b-9) was drilled in June 2017 with the semi-submersible mobile drilling unit (MODU), 'Stena Spey'. This appraisal was plugged and abandoned after a successful wireline logging programme was performed to obtain additional information on the well and its surrounding formations.

3.2 The proposed Avalon Development

The proposed Avalon development covered by this ES will comprise two production wells (Well 21/6b-J and Well 21/6b-K). These will be tied-back to a FPSO, located approximately 3 km west of the wells, to avoid the potential crossing of anchor lines of the FPSO and any anchored drilling units, that may be used for drilling the wells, or for any potential well intervention operations in the future.

Drilling operations are planned to commence in Q3 of 2023, at the earliest. Drilling of each well will take approximately 70 days (i.e. 140 days in total). The two production wells will be tied back to a Sevan type FPSO, which will be moored at the Avalon field (Figure 3.1).

In addition to the FPSO, the Avalon development will also comprise the following subsea infrastructure:

- Two subsea production wells completed with a single Xmas tree per well and covered with a fishing friendly protection structure;
- A Subsea Distribution Unit (SDU) Structure installed on the seafloor, which will house equipment for controlling the production and gas lift lines, including an umbilical termination assembly (UTA);
- A Riser Base Structure (RBS), housing a SDU, UTA and subsea isolation valve (SSIV), connecting to the dynamic risers/umbilical with buoyancy modules;
- A 3 km pipe in pipe oil production pipeline, which will be trenched and buried, between the Avalon drill centre and RBS;

- A 3 km gas lift line, which will be trenched and buried, between the Avalon drill centre and RBS;
- A 3 km control umbilical, which will be trenched and buried, between the Avalon drill centre and RBS;
- A power cable up to 25 km in length, trenched and buried, between the floating OWT and the FPSO;
- Anchored mooring systems for the FPSO and offshore wind turbine; and
- An optional 6" gas export / import pipeline from the Avalon field to the Ettrick pipeline end manifold (PLEM) location 40 km to the west (exact route to be determined); or
- An optional 6" gas export / import pipeline from the Avalon field to the Britannia pipeline end manifold (PLEM) location 5 km to the north/north-west (exact route to be determined).

A floating offshore wind turbine (OWT) will also be installed to provide power to the FPSO, once the natural gas in the reservoir is depleted and can no longer provide (enough) fuel to meet the power requirements of the FPSO. In addition, an import/export gas pipeline will be installed to provide fuel gas for the generator, to supplement the OWT on days when wind conditions alone cannot (fully) meet the power requirements. The exact location of the OWT is still to be determined, depending on the safety and permitting constraints of the development (Section 3.7).

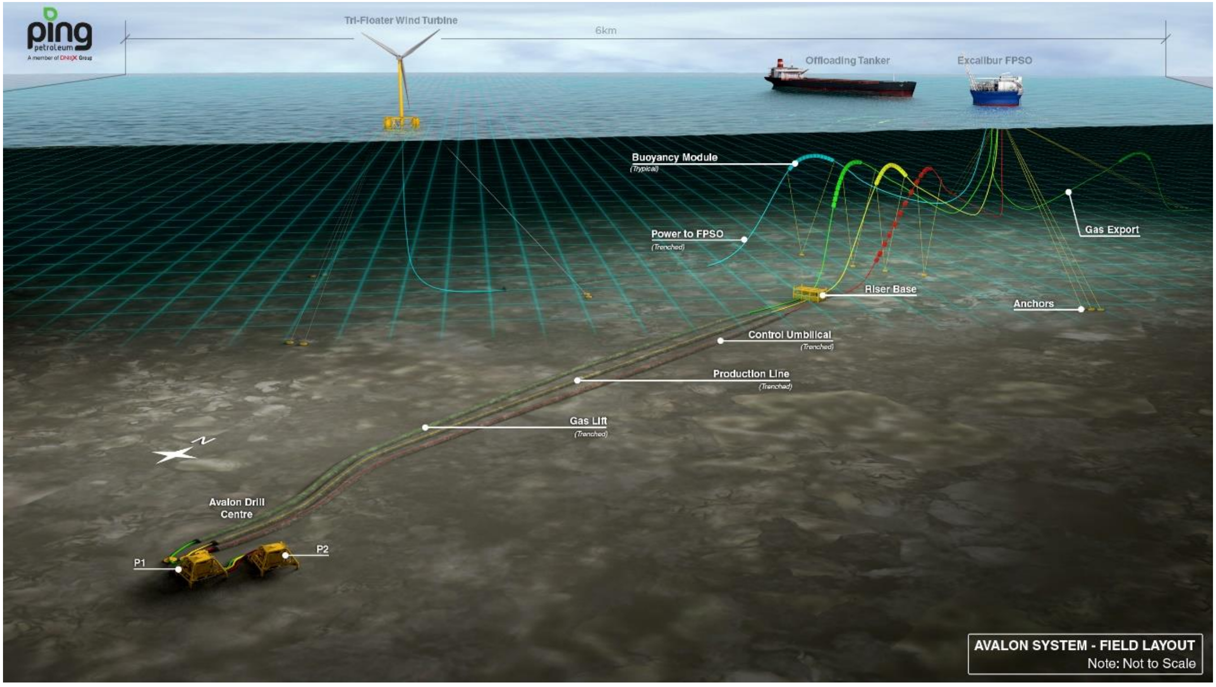


Figure 3.1: Schematic overview of the proposed Avalon Field Development

3.2.1 Crude Characteristics and Production Forecast

The Avalon fluids can be considered a heavy oil (924.2 kg/m^3), with a relatively low gas to oil ratio (GOR) of approximately 200 scf/bbl, and with relatively low reservoir pressure and temperature (140 bara and 55 °C). This leads to the requirement for artificial lift for production in the form of gas lift. Table 3.1: presents the main oil characteristics of the Avalon crude oil.

Table 3.1: Avalon Crude Oil Characteristics

Oil Characteristics	Avalon Crude
Specific gravity	0.924
API	21.6
Pour point (°C)	<-36 °C
Wax content (%)	1.8
Asphaltene content (%)	0.25
Viscosity (cP at 10 °C)	322

The Avalon Field Development is expected to produce hydrocarbons for approximately 15 years. Figure 3.2 presents the P_{10} (maximum) anticipated peak production profile for the two Avalon production wells over this period, on which the design for the development has been based. Production profiles for the High Case (P_{10}), Base Case (P_{50}) and Low Case (P_{90}) are provided in Appendix 2.

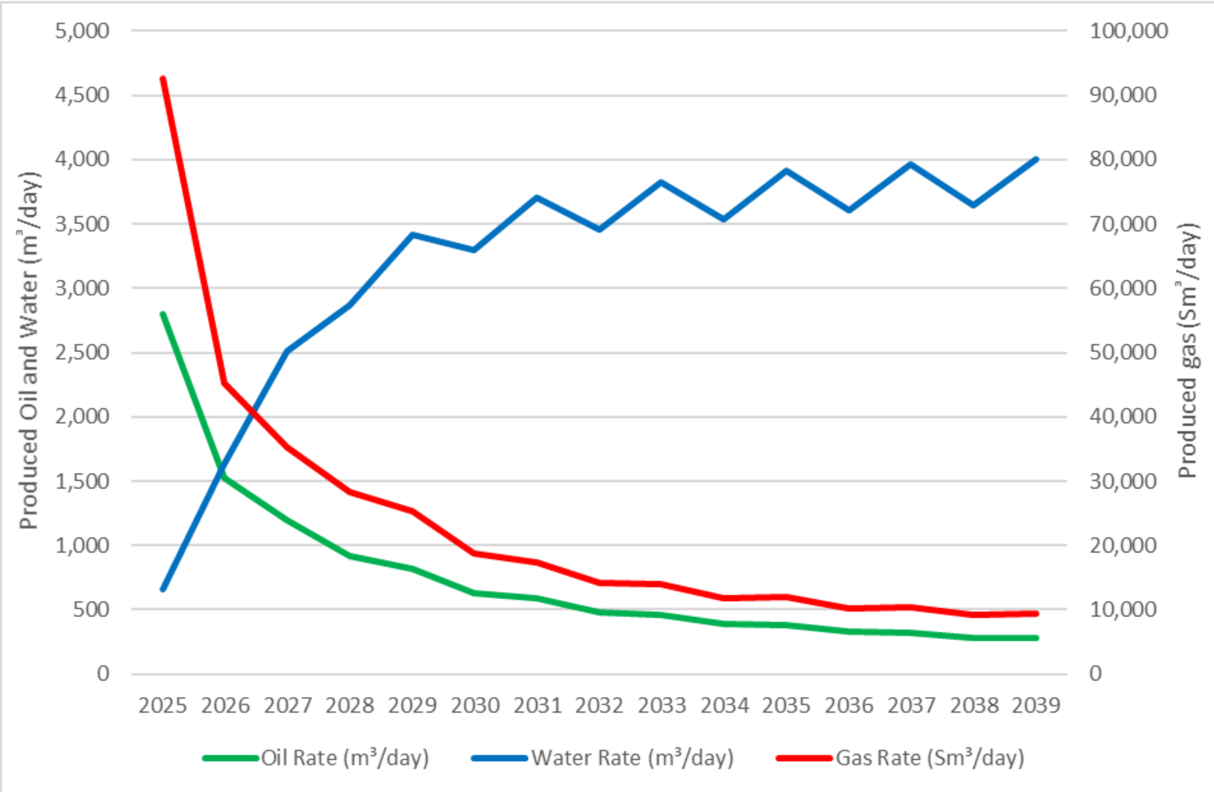


Figure 3.2: P_{10} Peak Production Profile Avalon Field Development

3.2.1.1 Schedule

The production wells will be drilled during a single drilling campaign, which will commence Q3 2023, for a period of 140 days. In Q1 2025, the FPSO will be moved to the Avalon Field and subsea infrastructure will be installed. First oil is targeted by the second half of 2025. Table 3.2 provides an indicative time schedule for the Avalon Development.

The floating offshore wind turbine (OWT) is proposed to be installed approximately 12 to 18 months after first oil.

Table 3.2: Indicative Timetable for the Proposed Avalon Development

Avalon Well	2022				2023				2024				2025				2026			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FPSO Procurement and Refurbishment																				
Procurement of FPSO		■																		
FPSO moving offsite its current location at the Chestnut Field for refurbishment		■																		
FPSO Inspection & Assessment			■	■																
Refurbishment of Excalibur FPSO					■	■	■	■	■	■	■	■								
Drilling and Completion of Avalon Wells																				
Drilling and Completion Operations							■	■												
Gas Import/Export Pipeline Installation and Commissioning																				
Pipeline laying									■											
Pipeline Commissioning										■										
FPSO Hook-up, commissioning and installation of subsea infrastructure																				
Subsea infrastructure installation													■	■						
FPSO hook-up and commissioning													■	■						
First oil															■					
Floating Offshore Wind Turbine Installation																				
Installation of mooring system and anchors										■	■									
Installation of wind turbine sub-structure														■	■					
Installation of wind turbine tower																		■	■	
First power from offshore wind																			■	

3.3 Drilling Operations

Both production wells are planned as horizontal production wells, targeting the Paleocene Cromarty sandstone reservoir. The wells will be drilled horizontally through the upper and lower Cromarty sandstone formations, adjusting the well-path as required, to maintain the wellbore in good quality sand bodies. Planned TD for both wells is 2,560.3 m (8,400 ft) measured depth below the rotary table[1] (MDBRT), or 1414.6 m (4,641 ft) true vertical depth[2] (TVD), delivering a minimum of 2 × 762 m (2 × 2,500 ft) of good sand to produce from. Well tests will be undertaken at both wells, to determine accurate production rates and inform on reservoir behaviour and management.

3.3.1 The Mobile Drilling Unit, Support Vessels and Helicopters

The MODU, which will be used to drill the wells at the Avalon Development, has not yet been confirmed. Therefore, the drilling operations may be undertaken from either a jack-up drilling rig or an anchored semi-submersible drilling rig. As detailed in Section 3.2, two wells (Well 21/6b-J and Well 21/6b-K) will be drilled as part of the Avalon Field Development.

3.3.1.1 Jack-up Drilling Rig

If a jack-up drilling rig is selected, it will be towed to the development location by up to three anchor handling vessels (AHV). When the rig arrives on location, its three legs will be lowered to the seabed and test loaded with seawater to confirm a secure foundation. The hull will then be raised (jacked-up) to operational height above the sea surface to provide a safe and stable platform for the drilling and completion operations. A large cylinder (spud can) is present at the base of each leg (three legs in total), to provide stability and to prevent the rig from sinking too far into the seabed. Once in position, a remotely operated vehicle (ROV) will monitor any potential scouring around the spud cans. It is not anticipated that there will be a requirement for further stabilisation material, such as rock dumping, or the placing of sandbags at the Avalon location, while the jack-up rig is drilling.

3.3.1.2 Semi-submersible Drilling Rig

If a semi-submersible drilling rig is selected, it will be towed to the development location by three anchor handling vessels. Once on location, the anchor handling vessels will be used to place 8 to 12 anchors to the seabed, to secure the drilling rig safely. At this water depth, each anchor line is expected to extend to approximately 1,400 m from the drilling rig, whereby up to 750 m of each anchor chain will be resting on the seabed. The exact length of anchor chain resting on the seabed may vary slightly between rigs.

3.3.1.3 Other Vessels and Helicopters

In addition to the MODU itself, the drilling operations will require support vessels (supply vessels and a statutory standby vessel) and helicopter transfer of personnel to and from the MODU during the drilling period. Helicopters may also be used to supply the MODU with

1 Measured depth below the rotary table (MDBRT) is the total length of the drill string measured from the drilling rig, including the distance from the distance from the drilling floor (i.e. the ‘rotary table’) to the sea and the water depth, as well as the actual length of the wellbore.

2 True vertical depth (TVD) is the vertical distance from a point in the well to a point at the surface (in this case, also the ‘rotary table’ on the drilling floor onboard the drilling rig).

equipment at short notice and in the event of an emergency situation. It is estimated that there will be three scheduled helicopter visits to the rig per week during each drilling campaign.

Otherwise, all transport of drilling equipment, supplies, water, fuel and food will be undertaken by supply vessels, which will also return waste and surplus equipment to shore. A supply vessel will visit the MODU approximately twice per week from the supply base in Aberdeen.

A standby vessel will be on station near the MODU throughout the drilling operations.

3.3.1.4 Fuel Consumption of MODU, Support Vessels and Helicopters

Table 3.3 shows the estimated fuel consumption of the MODU and its associated support vessels and aircraft, for the duration of the proposed drilling and completion operations of the two production wells, which will be drilled as part of the Avalon Development.

Table 3.3: Vessel Requirements and Estimated Fuel Consumption Production Wells

Activity	Vessel	Fuel Type	Consumption Rate [Tonnes/Day]	Duration [Days]	Total Fuel Consumption [Tonnes]
Anchor handling/mobilisation	Anchor handling vessels (× 3)	Marine Diesel	3×5*	6	90
MODU during drilling operations	MODU	Marine Diesel	15**	140	2,100
Support shipping	Supply vessel	Marine Diesel	10*	40	400
Support shipping	Standby vessel	Marine Diesel	4*	140	560
Estimated Vessel Diesel Consumption (Drilling)					**3,150**
Personnel transport	Helicopter	Aviation Fuel	0.5/Return flight*	60 flights	15

Notes:
* = Consumption rates taken from Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures (Institute of Petroleum, 2000)
** = Typical fuel consumption for an anchored semi-submersible drilling rig operating in the North Sea

Based on the information set out in Table 3.3, an estimated total of 3,150 tonnes of marine diesel and 15 tonnes of aviation fuel would be consumed during the drilling operations for the two production wells at the Avalon Development.

3.3.2 Well Engineering

The proposed casing design for the two production wells at the Avalon Development will follow a proven design, that has been used successfully on previous wells in this region of the North Sea.

The first step for each well will be to drill a 36" × 26" hole diameter top-hole section into the seabed, to a depth of up to 222.5 m (730 ft). The upper 15.2 m (50 ft) of the borehole will be opened up to 42" to install a 36" conductor housing joint. The conductor will be set at 219.5 m (720 ft) and cemented back to seabed level, before a 17½" hole section will be drilled to 1,014.4 m (3,328 ft). The well will be drilled vertically to 701.0 m (2,300 ft) MDBRT and will then start to build to an inclination of 15° by section TD of the 17½" section.

A 13⅜" casing string with a high-pressure wellhead housing will then be installed inside the conductor, to provide stability to the well and prevent the flow of fluids from the well into the surrounding formations. The casings of the two top-hole sections, firmly cemented into the borehole, will then provide a firm anchorage for the blowout preventer (BOP), which will be installed on top of the well at the seabed. A pipe, called the 'drilling riser' will then connect the well to the MODU, therefore providing a conduit to return the drilling fluids (mud) and cuttings from the deeper sections of the well back up to the MODU.

The 12¼" hole of each production well will be drilled through the Horda, Balder and Sele formations, building angle to 87˚ for the land out at the top of the Cromarty Sandstone reservoir. The final section will be a 9½" × 8½" section, drilled horizontally to approximately 2,560.3 m (8,400 ft) MDBRT to give a 762.0 m (2,500 ft) section of pay zone to run 5½" sand screens across. The reservoir section will be fully evaluated through the appropriate use of logging while drilling (LWD) tools and will be completed with a 5½" open hole gravel-pack lower completion, installed with 5½" sand screens. A subsea horizontal tree will be installed onto the seabed on top of the wells. The wells will be completed with a simple gas lift upper completion, with the crown plugs installed in the tree and a fishing friendly structure deployed on top of the well. The wells will be flowed back to the rig and tested using nitrogen.

3.3.3 Mud System and Cuttings Discharge

Drilling fluid (or drilling mud as it is commonly known) fulfils a number of functions, such as lubrication and cooling of the drill bit, suspension and transport of rock cuttings to the surface, and the provision of 'weight' (hydrostatic pressure), to counter-balance formation pressure. Drilling fluids can be categorised on the basis of their principal constituent (in the continuous phase). This continuous phase may be water, oil, synthetic oil or gas. The resulting drilling fluids are called water base muds (WBMs), oil base muds (OBMs), synthetic or pseudo-oil base muds (SBMs or POBMs) and foam muds, respectively. Depending upon the type of drilling fluid, the continuous phase may additionally contain dissolved organic and inorganic additives, as well as finely divided suspended solids of various types. The type of drilling mud to be used, generally depends on the downhole conditions in the well, both anticipated and those encountered in real-time, for which each of these mud types will have certain advantages and disadvantages. Where technically possible, WBMs are now most commonly used on the UKCS, although low toxicity oil base muds (LTOBMs) are also widely used for the deeper well sections, especially in deviated wells or those with challenging and unstable formations. Given the highly deviated profile of the Avalon wells and the unstable formations in the area, it is therefore planned that LTOBM will be used for the deeper deviated 12¼" and 9½" × 8½" sections.

The mud system for the two top sections of the wells (42" × 36" × 26" and 17½") will consist of seawater with high viscosity bentonite sweeps to clean out the borehole. Typically, an 8 m^3 (50 bbl) sweep for every 9.1 m to 13.7 m (30 ft to 45 ft) drilled is adequate for hole cleaning, but the frequency and volume of the sweeps will be determined by the hole conditions. The 42" × 36" × 26" sections of both wells will be displaced with bentonite mud to run the conductor. On completing the 17½" sections, they will be displaced with KCl polymer mud prior to installation of the casings.

The deeper 12¼" and 9½" × 8½" sections will be drilled, after the BOP and the marine riser have been installed, using a full LTOBM system. The drilling mud will be pumped down the drill string to the drill bit and then circulated back to the surface via the annulus (the space between the drill stem and the wall of the borehole), and through the BOP stack and the drilling riser back to the MODU. Back onboard the MODU, the mud and cuttings from these sections will pass through a mud recovery system to recover as much of the drilling mud as possible. Once reconditioned, this mud will be used again, thereby minimising the amount of drilling mud used. The remaining rock cuttings and associated LTOBM will be collected in skips onboard the MODU and will then be shipped back to shore for further treatment and recycling, or appropriate disposal. Hence, there will be no discharge of cuttings at sea, other than those from the two top-hole sections that are drilled with seawater and high viscosity bentonite sweeps. These top-hole cuttings will be deposited on the seabed in the immediate vicinity of the wellbore.

An estimate of the quantity of cuttings generated and subsequently discharged into the sea is presented in Table 3.4. Based on these estimates, a total of up to 2 076 tonnes of cuttings will be generated and discharged during drilling operations for both wells. LTOBM will not be discharged to sea, as described above.

Table 3.4: Estimated cuttings volumes for the Avalon production wells

Section	Mud System	Cuttings Disposal Route	Section Length [m]	Cuttings Volume [m3]	Cuttings Generated [Tonnes]	WBM Discharged [Tonnes]
26" × 36" × 42"	WBM, seawater and viscous sweeps	Discharged at the seabed	80	215	558	310
17½"	WBM, seawater and viscous sweeps	Discharged at the seabed	793	185	480	1 250
12¼"	LTOBM	Collected on the MODU and shipped to shore	784	66	170	N/A
8½"× 9½"	LTOBM	Collected on the MODU and shipped to shore	771	31	31	N/A
Total (for a single production well)				**496**	**1 289**	**1 560**
Total (for both production wells)				**992**	**2 578**	**3 120**

3.3.4 Cementing Operations and Associated Discharges

The casings used to prevent the wells from collapsing will be cemented into place by pumping cement down the casing string, out through a hole in the bottom and back up to the surface through the annulus (i.e. the space between the well casings and the sides of the borehole). For the conductor (36") and surface casing (20"), it is critical to get cement back to seabed, to ensure the structural integrity of the wells and therefore it is expected that some cement will be discharged to sea.

For both of the two production wells the cement will be pumped down the drill string and up the conductor annulus to the seabed. Rather than mixing a large batch, the cement will be mixed on demand. When cement is observed at seabed by the ROV, the mixing and pumping will be terminated to minimise the volume discharged. In line with good industry practice, the planning of the cementing operations will allow for up to 300 % excess cement, for safety reasons. The worst-case estimated cement discharge for this section is therefore 58.8 m^3 (370 bbls) per well, i.e. a total of 117.6 m^3 for both wells combined. This is based on the entire 300 % excess reaching to the seabed due to, for example, the hole is in gauge (so the estimated excess proves to have been unnecessary) and/or that the ROV was unable to monitor the cement returns, due to poor visibility or poor weather preventing ROV launch. It is worth noting that a number of previous wells drilled in this area of the North Sea, did require a cement top-up, i.e. even after pumping all 300 % excess cement, it did not return to the surface. Furthermore, in addition to the camera onboard the ROV, a black UV light on the ROV will be used to monitor cement returns to the seabed.

Subsequent casing strings will not be cemented up to the surface and so it is highly unlikely that cement will return to the rig. If this were to occur, then it will be captured in the skip and ship system and returned to shore for processing, due to the presence of LTOBM in the well at this time.

A small volume of cement will also be discharged, following each cement job during the process of cleaning the cement pump and mixing tank. The volume of cement being discharged will be very small and is unlikely to exceed 2 m^3 per well. This equates to 4 m^3 of cement discharge from cleaning the tanks for both wells combined.

Any cementing chemicals which will be required as part of the proposed operations, will be included in a supporting Chemical Permit (CP) Subsidiary Application Template (SAT) application, submitted to The Offshore Petroleum Regulator for Environment and Decommissioning/Department for Business Energy and Industrial Strategy (OPRED/BEIS). PPUK anticipates that up to 10 % of any cement will be discharged to sea as a result of tank and pipework cleaning and flushing. Additional cementing chemicals may be required to deal with any unplanned events and, therefore, a number of contingency chemicals will be stored on the drilling rig to manage any such eventualities, to allow the operations to be completed. A similar level of discharge is anticipated for these chemicals (10 %).

In the event that cement is mixed and there is a requirement for an emergency discharge of a larger volume of slurry, due to an issue arising downhole, then PPUK will contact OPRED/BEIS to discuss the best practicable environmental option for the disposal of the chemicals involved.

3.3.5 Chemical Additives used During Drilling Operations

The specific chemicals and additives used during drilling and cementing will be dependent upon the mud and cement composition, which in turn will be determined by the down-hole conditions encountered, whilst drilling. All chemicals will be selected on their technical specifications but will also be assessed on their potential environmental impacts, using the regulatory Harmonised Offshore Chemical Notification System (HOCNS), incorporating the

Chemical Hazard Assessment and Risk Management (CHARM) model, where applicable. Additional permitted chemical additives will be stored on the rig, to deal with any contingencies such as a stuck drill pipe or loss of circulation. All chemicals to be used in the drilling of the Avalon wells will be detailed in a Chemical Permit-Subsidiary Application Templates (CP-SATs), to be submitted via the Portal Environmental Tracking System (PETS) on the online UK Energy Portal, as part of the well consenting process.

3.3.6 Other Waste Streams Generated Onboard the MODU

During the drilling of the Avalon wells, waste will be generated both due to operational activities (e.g. cements and chemicals), and due to everyday running of the MODU (e.g. food waste, general waste, sewage). All hazardous and non-hazardous waste generated on the MODU and support vessels will be segregated, and either discharged in line with the requirements of the MARPOL Convention (where appropriate), or returned to shore and disposed of appropriately.

3.3.7 Well Clean-up and Testing

Upon completion of the production wells, they will be cleaned-up and tested to determine accurate production rates and inform on reservoir behaviour and management.

As both Avalon development wells will be drilled before the new pipeline will be installed, there will be a requirement for all hydrocarbons produced during the well clean-up and well testing operations, to be flared off. The burners on the flare will be environmentally efficient (i.e. ‘green burners’).

During the well test, fluids will be separated onboard the MODU using a test separator. The well test at each of the production well locations will take less than 96 hours to complete, during which less than 2,000 tonnes of hydrocarbons will be flared off.

Weather conditions will be monitored throughout any flaring operations. A dedicated person will be assigned for full-time fire watch duties, to ensure that all performance related conditions are monitored, and adjustments can be made accordingly.

3.4 Installation of Subsea Infrastructure

3.4.1 Xmas Trees

Once the two production wells are drilled and completed, the Xmas trees will be installed on top of each well. A Xmas tree is an assembly of valves and fittings installed on the seabed on top of the wells to control the flow of oil and gas from the target reservoir. Figure 3.3 shows an example of a typical Xmas tree. Each Xmas tree will be protected by a fishing friendly protection structure, comprising a gravity base steel structure of 5 m × 5 m with a height of 4 m above the seabed.

Figure 3.3: Example of Xmas Tree Within Protection Structure

3.4.2 Riser Base Structure

The Avalon field pipeline and umbilical will be tied-back to a 12 m × 10 m with a height of 4 m above the seabed subsea riser base structure (RBS), located close to the FPSO. This structure acts as the termination unit for the flexible risers, the production, gas import/export and gas lift pipelines and control umbilicals. The RBS will house the dynamic umbilical termination assembly (UTA) and the subsea distribution unit (SDU), as well as pipework and controls for the isolation valves for the production and gas lift lines. It will also house the subsea isolation valve (SSIV) for the gas import/export pipeline system. The RBS will be installed by a construction support vessel (CSV).

The RBS will be a gravity-based design that sits on a steel mesh mud mat and will protect the equipment located within it from dropped objects. Upon completion of the installation of the subsea infrastructure, a 500 m safety exclusion zone will be enforced around the Excalibur FPSO. Dimensions of the RBS are provided in Table 3.5 below.

Table 3.5: Subsea Infrastructure at the Avalon Field Location

Structure	Installation Method	Structure Length [m]	Structure Width [m]	Structure Height [m]	Total Area Affected [km^2]
Well 21/6b-J Xmas tree and protection structure	Run on drill pipe from MODU	5	5	4	0.000025
Well 21/6b-K Xmas tree and protection structure	Run on drill pipe from MODU	5	5	4	0.000025
RBS (including SDU, UTA and SSIV))	Lowered by crane from CSV	12	10	4	0.000120
Total					**0.000170**

3.4.3 Installation of Pipelines / Flowlines

Pipelay and trenching operations are currently scheduled to occur in the first half of 2024. These operations comprise the installation of the gas import/export pipeline, as well as the installation of the infield production and gas lift pipelines and the control umbilical.

The gas import/export pipeline will comprise a rigid carbon steel pipeline with an inner diameter of 6", which will be installed between the Excalibur FPSO and either the existing Ettrick pipeline PLEM, located 40 km to the west, or the existing Britannia pipeline PLEM, located approximately 5 km to the north. The exact route will be determined after appropriate pipeline surveys are undertaken. The gas import/export pipeline will be trenched and buried into the seabed.

Before the gas import/export pipeline is installed, a pre-lay survey will be conducted to check for obstructions and to confirm the seabed topography. This pre-lay survey will be undertaken by the CSV. After completion of the pre-lay survey a separate guard vessel will remain on site to support the subsequent pipeline laying operations until these are completed, and the gas import/export line has been successfully deployed and is trenched and buried into the seabed.

The pipelines will be laid using a dynamically positioned (DP) construction vessel (Figure 3.4). Reel lay vessels are self-propelled and deploy the pipelines from a large installation reel onboard the vessel. The pipe lay operations will be undertaken in a single trip.

The installation of all pipelines (i.e. the infield oil production pipeline, gas lift line, umbilical and import/export pipeline) is estimated to take approximately 44 days to complete, including 20 % contingency for waiting on weather and transit time to site.

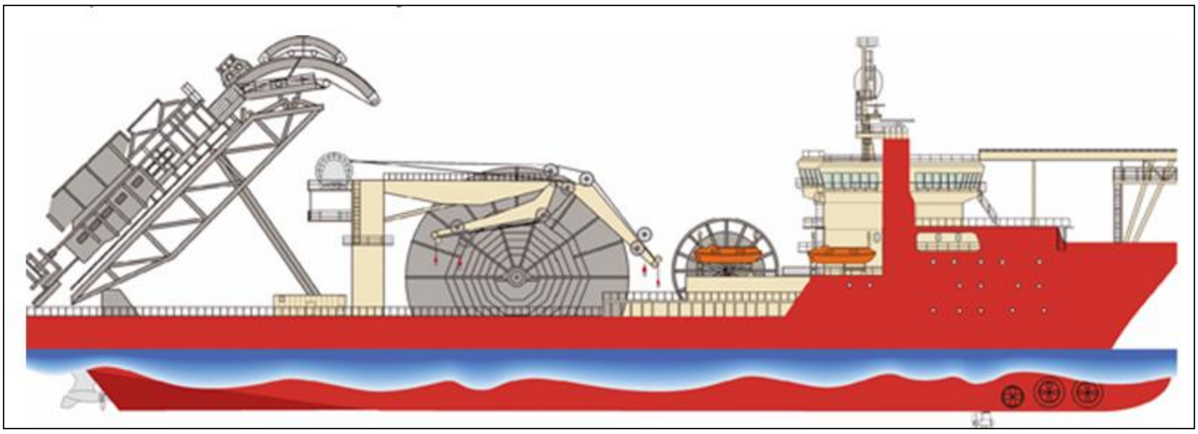


Figure 3.4: Example of Construction Vessel

The infield production and gas lift pipelines will be of flexible design, comprising a stainless steel carcass, pressure containing polymer layer, steel armour layers and a polymer outer sheath. Sacrificial anodes will be attached adjacent to the end fittings. The infield pipelines will be trenched separately and backfilled. The static section of the control umbilical will be laid in similar proximity to the pipelines and will either have its own trench, or installed in the same trench as the gas lift pipeline.

The infield pipelines and umbilical will be laid using a dynamically positioned (DP) construction vessel. A DP construction vessel will be used for the pipeline tie-ins. A (single) guard vessel will be on location during the pipelaying operations to alert fishing vessels about the pipeline and umbilical laying operations and will remain on site should the pipelay reel vessel, or construction vessel, have to return to shore.

3.4.3.1 Trenching

Once the pipelines are laid onto the seabed, they will be trenched and buried into the seabed. The pipelines and umbilical will be trenched by a jetting trencher (Figure 3.5), which will be deployed from a support vessel at the surface. Trenches will be cut to ensure a minimum depth of 1.2 m to 1.5 m below the seabed level, allowing the pipelines and umbilical to be buried below the natural seabed level to a depth sufficient to ensure a minimum of 0.6 m cover over the top of the pipe/umbilical. This depth is selected as it minimises possible (future) exposure of the flowlines.

Figure 3.5: Canyon T1200 jetting trencher

The jet trenching will be undertaken in one pass, moving along the route on tracks straddling the pre-laid pipe, or umbilical, and jet cutting the sides of the trench. Additional jets fluidise the spoil, the pipelines own weight allows the pipe to settle into the trench and the fluidised spoil falls back on top of pipe naturally backfilling the line, negating the need for mechanical backfilling. Any seabed disturbance will be limited mainly to the 5.6 m wide corridor bounded by the tracks of the J-1200 jet trencher itself.

Trenching operations are estimated to take a total of up to 27 days to complete, based on a rate of 150 m/hr, including 20 % for contingency. Once the trenching operation has been completed, a post-trenching survey will be carried out. Details of the footprint of pipeline installation are provided in Table 3.6 and the estimated fuel consumption during these operations is detailed in Table 3.7.

The pipelines and umbilical will be connected to the SDU, located within the RBS, by divers. Consents for all pipelay activities, including trenching, backfilling, protective structures and seabed deposits (concrete mattresses and rock) will be detailed in the application for a Pipeline

Works Authorisation (PWA) and associated Deposit Consent (DepCon), before these operations are undertaken.

Table 3.6: Summary of The Worst-Case Footprint of the Pipeline, Flowline Umbilical and Power Cable

Pipeline	Installation Method	Seabed Disturbance Length [km]	Seabed Disturbance Width [km]	Track Width [km]	Total Area Affected [km²]
6" gas import/export pipeline to Ettrick PLEM *	Laid / trenched and buried by T1200/T1500 jet trencher	40	0.0056	0.0048	0.2240
6" gas import/export pipeline to Britannia PLEM *	Laid / trenched and buried by T1200/T1500 jet trencher	5	0.0056	0.0048	0.0280
8" oil pipeline between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
Gas lift line between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
Control Umbilical between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
Power cable between floating OWT and FPSO †	Laid / trenched and buried by T1200/T1500 jet trencher	25	0.0056	0.0048	0.1400
Total					**0.4144**

Notes:
* = Only one of these options will be progressed as part of the proposed Avalon Field Development. The total area affected includes the worst case for seabed disturbance, the 40 km pipeline to Ettrick, in the total.
† = The area affected by the power cable between the OWT and the FPSO is based on the worst case scenario of the OWT being located 25 km from the FPSO location.

Table 3.7: Estimated Fuel Consumption During the Installation of the Pipelines, Umbilicals and Powerline

Activity	Vessel	Fuel Type	Consumption [Tonnes/Day]	Duration [Days]#	Total Fuel Consumption [Tonnes]
ROV survey of pipeline routes before installation	Survey vessel*	Diesel	4	2	8
Installation of 6" gas import/export pipeline (Avalon Field to Ettrick PLEM) ^	Pipeline vessel**	Diesel	15	4	60
Installation of 6" gas import/export pipeline (Avalon Field to Britannia PLEM) ^	Pipeline vessel	Diesel	15	2	30
Installation of 8" production pipeline (Excalibur FPSO to SDU)	Pipeline vessel †	Diesel	15	6	90
Installation of gas lift pipeline (Excalibur FPSO to SDU)	Pipeline vessel †	Diesel	15	6	90
Installation of control umbilical (Excalibur FPSO to SDU)	Pipeline vessel †	Diesel	15	3	45
Installation of power cable (OWT to Excalibur FPSO)	Pipeline vessel †	Diesel	15	4	60
Jet trenching of 6" gas import/export pipeline (Avalon Field to Ettrick PLEM) ^	CSV ‡	Diesel	13.5	13	175.5
Jet trenching of 6" gas import/export pipeline (Avalon Field to Britannia PLEM) ^	CSV ‡	Diesel	13.5	2	27
Jet trenching of 8" production pipeline (Excalibur FPSO to RBS)	CSV ‡	Diesel	13.5	2	27
Jet trenching of gas lift pipeline (Excalibur FPSO to RBS)	CSV ‡	Diesel	13.5	2	27
Jet trenching of control umbilical (Excalibur FPSO to RBS)	CSV ‡	Diesel	13.5	1	13.5
Jet trenching of power cable (OWT to Excalibur FPSO)	CSV ‡	Diesel	13.5	4	54
Post trenching and installation survey (all pipeline and umbilical routes)	CSV ‡	Diesel	13.5	2	27
Installation of RBS	DSV †	Diesel	18	3	54

Activity	Vessel	Fuel Type	Consumption [Tonnes/Day]	Duration [Days]#	Total Fuel Consumption [Tonnes]
Umbilical connections at RBS and Xmas trees	DSV †	Diesel	18	2	36
Pipeline connections at RBS and Xmas trees	DSV †	Diesel	18	4	72
System leak test	DSV †	Diesel	18	1	18
Installation of mattresses at pipelines, spools and umbilical; as built survey	DSV †	Diesel	18	2	36
Flexible installation to FPSO; system commissioning support	Pipeline vessel †	Diesel	15	6	90
Guard vessels	Guard Vessel †	Diesel	4	21	84
Total					**1 067**

Notes:
* = Fuel oil consumption rate based on Fugro Searcher, one of Fugro's Standard Survey vessels which has been used here as a proxy for typical modern North Sea survey vessel
† = Consumption rates taken from Guidelines for the Calculation of Estimates of Energy Use and Gaseous Emissions in the Decommissioning of Offshore Structures (Institute of Petroleum, 2000)
‡ = Multi-role CSV specification sheets (HELIX, 2020)
# = Number of days includes additional time for contingency
^ = Only one of these options will be progressed as part of the proposed Avalon Field Development. The estimated total fuel consumed includes only the worst case scenario, the 40 km pipeline to Ettrick, in the total.

Note that Table 3.6 and Table 3.7 presents both options for the gas import / export pipeline. However, the total area affected, and estimated fuel consumption, is based on the selection of the Ettrick option only, as this represents the theoretical worst-case scenario.

3.4.3.2 Pipeline Protection

The steel 6" gas import/export pipeline will have cathodic protection with bracelet type anodes attached at regular intervals along the pipeline. It is also anticipated that the pipeline will have anti-corrosion coatings, such as 0.5 mm of fusion bonded epoxy and 2.0 mm of three-layer polypropylene. The actual anti-corrosion coatings will be confirmed during FEED.

The pipeline/spool ends of the import/export pipeline and the infield pipelines will be protected by concrete mattresses at all pipeline spool locations. The mattresses will be standard density 6 m × 3 m × 0.15 m, laid longitudinally and overlapping at corners. The detailed engineering studies for these have not been carried out yet, but for the purposes of this ES, it has been estimated that, as a worst-case estimate, up to 174 mattresses may be required, namely:

- 80 mattresses required for trench transitions at the drill centre;
- 16 mattresses required for the spools between the RBS and Xmas Tree;
- 50 mattresses required at the gas export tie in point; and
- 20 mattresses required as a contingency.

If the gas import / export pipeline route to Ettrick is progressed, this will cross the Britannia to St. Fergus Export Line (PL1270). The exact crossing location will be confirmed following a pipeline route survey. It is estimated that this crossing may require up to 8 mattresses.

The design of the pipeline crossings will be dictated by the requirements set out by the operator of the Britannia to St. Fergus Export Line (PL1270), which may require specific crossing designs to be adhered to. This means that there may be a requirement to use protective rock dump instead of mattress protection for the pipeline crossing. If rock dump will be required, a DP flexible fall-pipe vessel will be used to place the rocks on top of the pipeline. The rock protection material will typically be 5 to 10 cm in diameter. PPUK estimate that a worst-case scenario of up to 1,800 tonnes of rock dump may be required. The total predicted rock tonnage will be revisited during detailed design and will be included as part of the PWA.

The Avalon import/export pipeline also crosses the proposed North Connect Cable route, but this project is currently on hold, and unlikely to be progressed in the near future. Consequently, no specific crossing measures have been included in this ES in respect of the North Connect Cable.

If the gas import / export pipeline route to Britannia is progressed, this route does not cross with any other pipelines, so no supporting mattresses or rock dump would be required for pipeline crossings.

In addition to the mattresses, grout bags may be installed to protect the ends of the control umbilical where it emerges from the seabed, at the RBS and between the RBS and Xmas trees. It is estimated that up to 10 tonnes of 25 kg grout bags will be required to cover an area of 2 m × 4 m at each of these areas. A slightly larger area of seabed would be covered at the RBS, due to the presence of the well control umbilicals. It is estimated that the grout bags would cover an area of 8 m^2 in total.

Therefore, a total area of seabed of up to 3320 m^2 may be covered by these mattresses and grout bags (Section 8).

3.4.3.3 Pipeline System and Umbilical Pressure Testing

Once installed on the seabed and fully connected, the 6" gas import/export pipeline, 8" production and 3" gas lift pipelines will be leak tested to confirm the integrity of all connections. Leak testing is a pressure test that works by completely filling the component with water, removing the air contained within the unit, and pressurising the system. The pressure is then held for a specific time to visually inspect the system for leaks. Dye is often used to aid spotting of leaks.

Once the test pressure is reached, the pressure is tested by shutting off the supply valve and observing whether there is a pressure loss over time.

Once installed, the umbilical cores will be pressure tested with an aqueous based hydraulic fluid.

All chemicals to be used in the pipeline leak testing operations will be detailed in a Chemical CP-SAT, to be submitted via the PETS on the online UK Energy Portal, as part of the pipeline installation consenting process.

3.4.4 Dynamic risers / umbilical

Three 350 - 450 m long dynamic flexible risers (two for production and one for gas lift) and a dynamic control umbilical will connect the Excalibur FPSO to the RBS. The configuration is to be confirmed by dynamic analysis, but the risers will potentially be supported in a 'lazy wave' configuration. A series of buoys on top of the arch will keep the risers in place.

3.4.4.1 Alternative configurations

Proposed riser configurations include a tethered 'lazy wave' or a 'steep wave' design. Both solutions feature individual hold down anchors (circa 50 – 70 tonnes), which are connected to the flexible risers and control umbilical by means of a tether and friction clamp arrangement. The subsea ends of the risers and umbilical are then connected to the RBS.

3.4.5 Subsea Tie-ins

Fabricated rigid or flexible spool-pieces will connect the production and gas lift flowlines from the Avalon Well Xmas Trees to the SDU. Any chemicals such as methanol/mono-ethylene glycol (MEG) or dye, typically used during the leak testing of the spools, will remain in the flowlines until production start-up. They will then be exported to the FPSO where they will enter the process system and eventually be discharged with the produced water.

The control umbilical will be installed filled with hydraulic fluid, whereas the chemical injection lines are likely to be filled with MEG. Electrical power, hydraulics and chemicals will be distributed from the SDU to the Xmas Trees via diver installed hydraulic flying lead (HFL) / electrical flying lead (EFL) bundles. On start-up, hydraulic fluid will be pushed into the production flowlines and be exported back to the FPSO with produced oil.

3.4.6 Pipeline Maintenance

The pipelines and umbilical associated with the Avalon Development will be subject to a rigorous maintenance regime, to ensure they are kept in optimum condition throughout the life of field. Periodic pipeline surveys, comprising ROV inspections, and an Inspection Repair and Maintenance Plan will be put in place.

3.4.6.1 Pigging

Pigging is the act of forcing a device called a pig through a pipeline for the purposes of displacing or separating fluids, and cleaning or inspecting the line. The pipelines may be pigged once, during installation. However, it is not anticipated that periodic operational pigging will be required.

3.5 Production, Storage and Offloading (FPSO) Unit

3.5.1 The Excalibur FPSO

As discussed in Sections 2.3.3 and 2.4, the Excalibur FPSO (formerly known as the Hummingbird Spirit FPSO) has been procured for the Avalon Field development. The Excalibur is a purpose-built Sevan style FPSO (Figure 3.6) with a total oil storage capacity of 42,926 m^3 (270,000 bbls).

Excalibur has been designed for a total liquid handling capacity of 7,949.4 m^3/day (50,000 bbl/day), which is ample capacity to process the anticipated maximum peak production profile (P_{10}) presented in Section 3.2.1 (i.e. up to 4,833.4 m^3 (30,401 bbl) of produced fluids (oil + produced water) per day).

Figure 3.6: The Excalibur FPSO (i.e. former Hummingbird Spirit)

3.5.2 Mobilisation, Mooring and Installation

The Excalibur FPSO will be towed from the Port of Nigg using 3 AHVs to the Avalon field in Block 21/6b. The Excalibur FPSO will be located at 57° 48' 49.530" N, 0° 7' 50.967" E. The proposed anchor pattern and other subsea infrastructure is illustrated in Figure 3.7.

The Excalibur FPSO will be permanently moored with a total of 12 mooring lines in a 3-cluster configuration with 4 anchor chains per cluster. The anchor lines will be secured to the seabed, using either suction anchors or anchor piles, depending on the results of the geotechnical survey, yet to be completed.

Regardless of what anchor type will be used, the mooring and riser systems will be designed to withstand all anticipated environmental conditions for the life of field.

If suction anchors are selected, then each suction anchor will be approximately 6 m in diameter and 15.7 m long, of which 14.5 m will penetrate the seabed upon installation leaving approximately 1.2 m protruding above the seabed.

If anchor piles are selected instead, they will be piled into the seabed. Each pile will measure approximately 40 m in length and 1.2 m across. The piles will be driven into the seabed until between 0.5 m to 1 m remains above the seabed.

Installation and hook-up of the FPSO will involve the connection of mooring lines, followed by pull-in of the risers and umbilicals.

Vessel timings for installation of the FPSO mooring system are detailed in Section 3.5.3.

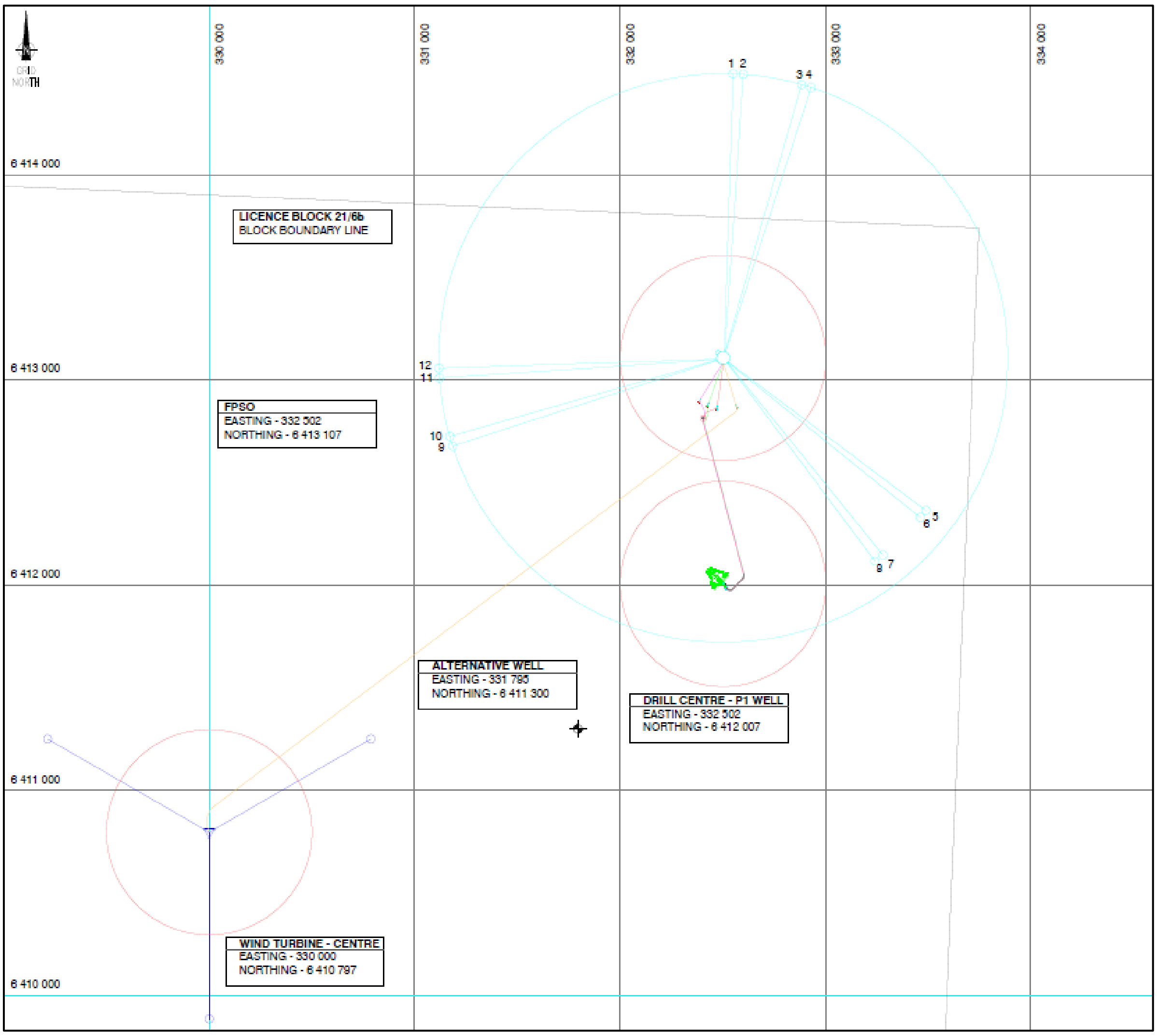


Figure 3.7: Proposed anchor pattern for the FPSO and preferred OWT location

3.5.3 FPSO Mooring System

The anchor lines of the FPSO will be secured to the seabed using either suction anchors or anchor piles, depending on the results of the geotechnical survey. If the seabed conditions are suitable for suction anchors, this is the preferred mooring option.

In this case, a total of 12 suction anchors, grouped in 3 clusters of 4, will be installed into the seabed (see Figure 3.7). The suction anchor piles are initially allowed to penetrate into the seabed under self-weight before water is pumped from the top of the pile to create a differential pressure which results in additional penetration force driving the anchor piles into the seabed. Each suction anchor will be approximately 6 m in diameter and 15.7 m long, of which 14.5 m will penetrate the seabed upon installation leaving approximately 1.2 m protruding above the seabed. The installation operations are anticipated to take 24 hours per pile; therefore, these operations are anticipated to last for up to 12 days.

If the FPSO is moored to the seabed using anchor piles, a total of 12 piles will be required. An additional pile including one spare for redundancy, will be driven into the seabed. Each pile measures up to 40 m in length and 1.2 m in diameter. Piling operations are anticipated to take 24 hours per pile; therefore, these operations are anticipated to last for up to 14 days.

The proposed mooring will accommodate re-use of mooring buoys and polyester lines from the Avalon's FPSO's previous location at Chestnut, provided the lines are found to be still in good condition. The mooring system is a passive mooring system making use of polyester ropes, to reduce the stiffness of the mooring system, and the tension forces acting in the chain.

Figure 3.8 and Table 3.8 provide the total seabed footprint of the FPSO mooring system. Once the anchor lines are secured to the seabed, the movement of the anchor chains on the seabed will be minimal. Each anchor line will comprise a 125 m long chain segment coming down from the FPSO, which will be connected to an 875 to 1025 m long polyester rope. The bottom end of the polyester rope is attached to another section of chain (375 m long), which connects the anchor line to the suction anchor, securing the FPSO safely to the seabed. Overall, each anchor line will extend up to 1,500 m from the FPSO (Figure 3.8).

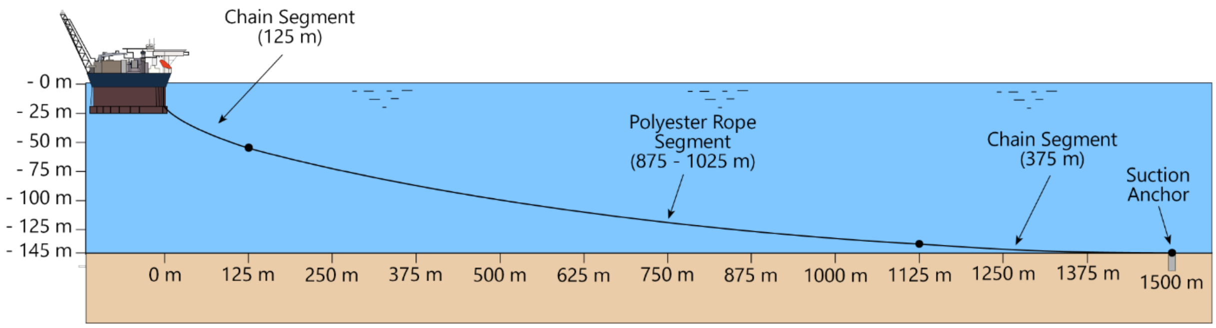


Figure 3.8: Anchor Line Profile

As a worst-case estimate, it is expected that a maximum 150 m length of anchor chain will raise and lower on the seabed during extreme weather events. Lateral movement of the anchor lines during their installation and hook up, as well as later on during bad weather events will be restricted to a maximum distance of 5 m on either side of each anchor chain. Consequently, based on 12 anchor lines being deployed in total, this would potentially result in an overall area of 18,000 m^2 of seabed being periodically disturbed throughout the life of the field.

Table 3.8: Total Mooring Footprint for the FPSO

Excalibur FPSO	Pile Diameter [m]	Individual Anchor Pile Footprint [m^2]	Number of Anchor Piles/Lines	Length of Anchor Lines [m[	Seabed Disturbance Footprint for Anchor Lines [m]	Total Footprint [m^2]	Total Footprint [km^2]
Anchor piles	1.2	1.13	12	1 500	18 000	18 013.56	0.01801
Suction anchors	6.0	28.3	12	1 500	18 000	18 339.60	0.01833

Table 3.9 and Table 3.10 provide an overview of the estimated vessel requirements and durations associated with the installation and hook up of the FPSO.

Table 3.9: Vessel Requirements and Estimated Fuel Consumption During FPSO Installation Using Suction Anchors

Activity	Vessel	Fuel Type	Consumption Rate [Tonnes/day]	Duration [days]	Total Fuel Consumption (Tonnes)
Mobilisation and hook up of FPSO moorings	CSV	Diesel	13.5	14	189
Support shipping (AHT × 3)	AHT	Diesel	5 (× 3)	10	150

Table 3.10: Vessel Requirements and Estimated Fuel Consumption During FPSO Installation Using Anchor Piles

Activity	Vessel	Fuel Type	Consumption Rate [Tonnes /day]	Duration [days]	Total Fuel Consumption (MT)
Mobilisation and hook up of FPSO moorings	CSV	Diesel	13.5	14	189
Support shipping (AHT × 3)	AHT	Diesel	5 (× 3)	10	150

3.5.4 Produced Fluids Processing

The Avalon Development wells will produce crude oil and sweet natural gas. The reservoir is also expected to start producing water in the first year of production. All produced fluids will be flowed to the Excalibur FPSO, where they will be separated and processed using the processing equipment onboard the installation. The Excalibur FPSO process systems are designed to process and separate well stream fluids before they are offloaded to a shuttle tanker where they will be exported to shore. The process systems for the FPSO are located on the topside of the structure.

3.5.5 Oil Processing

The Avalon Field will produce crude oil and sweet natural gas. Reservoir fluids from the two production wells will enter the FPSO via the flexible risers and will be routed to the separation process train onboard the Excalibur FPSO (Figure 3.9).

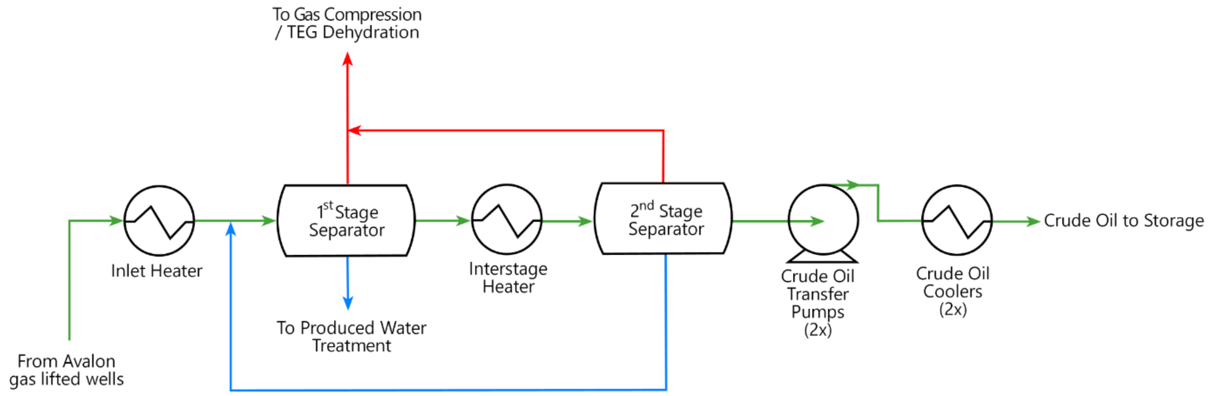


Figure 3.9: Oil Processing Flow Diagram

The oil processing system comprises a process train with two gravity separation stages. Before entering the first of the two 3-phase separators, the produced fluids will be heated by the inlet heater to 60 °C to aid the separation process. The 1st stage separator will provide bulk oil, water and gas separation. The gas is routed to the gas treatment module for compression and dehydration, the produced water is routed to a hydrocyclone for further treatment and the produced oil will be transferred to the 2nd stage separator. Before entering the 2nd stage separator, the oil is heated up to 90-110 °C by the interstage heater. In the second separator any remaining gas and water will be removed to stabilise the produced oil. The crude oil is then pumped from the 2nd stage separator into the FPSO's cargo tanks, after being cooled down again.

3.5.6 Gas Processing

The produced gas coming from the separation train described in Section 3.5.5 above, will be used to fuel the generators onboard the FPSO. Any additional surplus produced gas will be exported from the Excalibur FPSO via the gas export pipeline to the Ettrick Gas Export Pipeline and, subsequently, the Miller to St Fergus gas pipeline. Once the production rates at Avalon are no longer meeting its own fuel and gas lift requirements, additional gas can be imported instead, to supplement the FPSO's power requirements using the same pipeline until the floating OWT is installed and can provide power.

Figure 3.10 provides an overview of the gas processing facilities onboard the Excalibur FPSO.

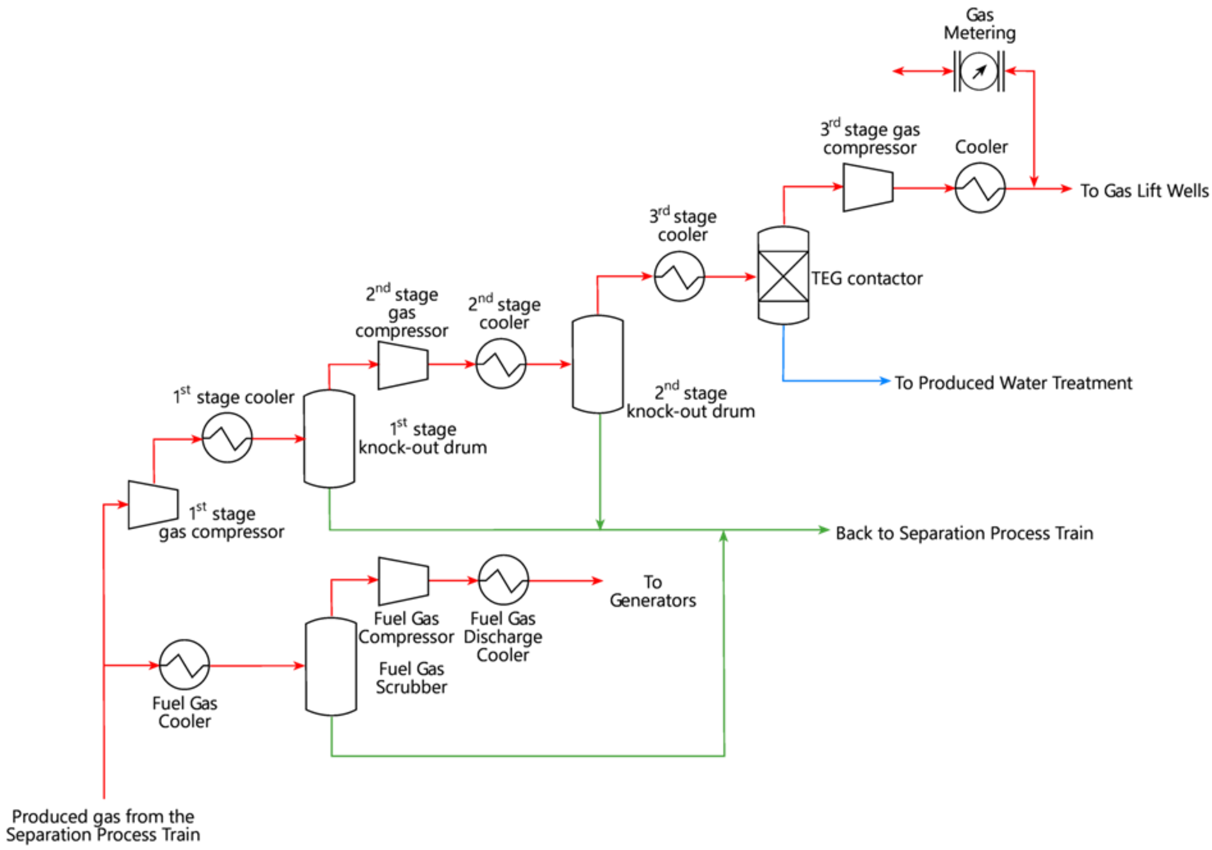


Figure 3.10: Gas Processing Flow Diagram

3.5.7 Produced Water Treatment

The volume of the produced water will gradually increase over the life of the field, with an anticipated maximum late field life water cut of 4,092.1 m^3/day (25,739 bbl/day) in the P_{90} scenario, which presents the scenario with the highest potential water cut.

Section 2.3.9 details the requirement for the produced water from the reservoir to be discharged to sea under normal operations. Before being discharged, the produced water will be treated using a combination of gravity-based oil and water separators and a hydrocyclone, to ensure to lowest practicably achievable oil in water content.

Any recovered oil from the produced water will be routed back into the existing production processing facilities (see Figure 3.9), and the cleaned-up water will be discharged to sea (Figure 3.11). The discharge of produced water on the UKCS is strictly regulated by OPRED, and PPUK will apply for a permit to discharge produced water from the FPSO. The conditions of the permit will specify the discharge limits and thresholds. Dedicated sampling points will be available to enable regular checking of separation performance before and after treatment in the hydrocyclone and prior to discharge overboard as indicated in Figure 3.11.

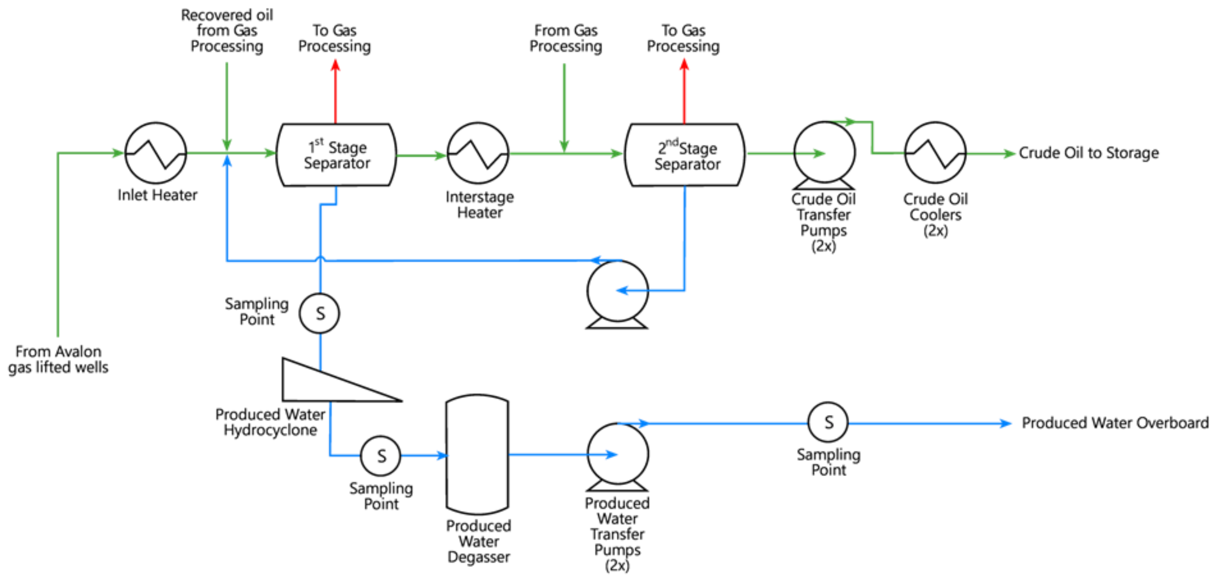


Figure 3.11: Produced Water Processing Flow Diagram

The produced water treatment system onboard the Excalibur FPSO is designed to reduce the oil content in the produced water to ≤ 15 mg/l oil in water (monthly average), prior to being discharged overboard. If oil in water specification cannot be met, produced water can be temporarily stored onboard the FPSO for later processing and disposal overboard within the required specification. Should sufficient volume be unavailable for storage of produced water, the procedure will be to restrict or shut-in production until the produced water is brought back into specification.

3.5.8 Flaring and Venting

The processing facilities on the FPSO are designed to operate without the need for routine flaring during steady state operational conditions. During upset conditions, the flare system has been designed to provide emergency flaring, when safe operating pressure limits are exceeded. This is standard industry design. The adoption of best practice plant and equipment maintenance, combined with the provision of a competent operations team, will ensure that any unnecessary flaring is avoided.

The exact flaring system that will be used on the Excalibur FPSO is still to be determined. However it is anticipated that one of the following options would be used:

- Installation of a flare gas recovery system, with a flare ignition panel which gives the greatest scope for flare reduction;
- Use of pilot flares, keeping flaring requirements as low as reasonably practical with any gas extracted utilised for fuel purposes and any excess exported to shore via the gas export pipeline. The (pilot) flare would be used for emergency purposes only with no routine flaring proposed; and
- As a contingency, in any event that the gas export route is not available, any production that increases the gas offtake to the flare would be curtailed to keep the flare at its technically smallest for emergency purpose only.

3.5.9 Sand Production and Disposal

The Avalon wells will be completed with a gravel pack and shunt screens at the bottom of the well, to prevent production of sand. Therefore, sand production to the surface is not anticipated.

In the event that sand is produced to the surface, it will be collect in the production separators and be manually removed during a production outage and disposed of onshore at an approved disposal facility.

3.5.10 Oil Storage and Offloading

The maximum amount of oil stored onboard the Excalibur FPSO at any time will be 42,926 m^3 (270,000 bbls). The cargo storage and handling system consists of six cargo tanks and two slops/settling/dirty oil tanks (Figure 3.12).

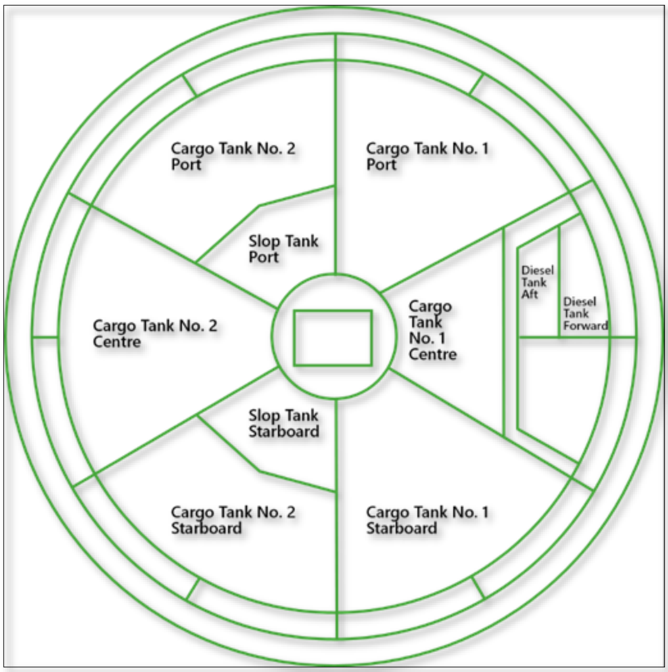


Figure 3.12: Excalibur FPSO Cargo Tank Arrangement

3.5.11 Power Generation and Fuel Use

Power requirements for the Excalibur FPSO will be between 6 to 7 MW. Electrical power will be supplied initially by gas turbines using produced gas from the Avalon field and will be supplemented later by a floating OWT and diesel power generation, as required.

Once the Avalon field starts producing, the amount of produced gas will reduce gradually over time (see Figure 3.2). After a period of 18 months to 2 years, it is expected that the amount of gas produced at Avalon will no longer be enough to meet the FPSO's power requirements. At this point, additional electrical power will be provided by an OWT, proposed to be installed 12 to 18 months after first oil. It is expected that the OWT will meet 60 to 70 % of the Avalon power requirements. The remaining 30 to 40 % of power will still be met by the FPSO's gas generators. Any short-fall of produced Avalon gas to meet these requirements will be supplemented with additional gas imported via the import/export gas pipeline.

3.5.12 Waste Management

The management of waste onboard offshore oil and gas installations on the UKCS is strictly regulated through a framework of international agreements and national UK legislation. In line with these requirements, PPUK will ensure that:

- All waste is correctly segregated to ensure recycling/reuse objectives and onward transport to shore requirements can be met;
- Appropriate authorisations and placards are displayed onboard the FPSO;
- No overboard disposal of garbage;
- All waste is contained and secured in such a way so as to prevent loss overboard;
- Waste minimisation and recycling/reuse/recovery of waste is encouraged, as far as possible; and
- Transfer Notes and Consignment Notes are retained, as required.

3.6 Chemical Usage

Chemical additives will be used during both the pipeline and umbilical installation as well as during the production phase of the Avalon development. The specific chemicals and additives required have not been selected at this stage and will be dependent upon the specific operational conditions of the Avalon production system. However, an indicative list of chemicals has been identified during the Pre-FEED, as summarised in Table 3.11.

All chemicals will be selected on their technical specifications, but will also be assessed on their potential environmental impacts, using the regulatory Harmonised Offshore Chemical Notification System (HOCNS) incorporating the Chemical Hazard Assessment and Risk Management (CHARM) model, where applicable. All chemicals to be used for the Avalon development will be detailed in the Chemical Permit Subsidiary Application Templates via the Portal Environmental Tracking System (PETS) on the online UK Energy Portal, as part of the Excalibur FPSO's annual production chemical consenting process.

All chemical usage will be reported through the Environmental and Emissions Monitoring System (EEMS). The EEMS is maintained by OPRED (BEIS) and records emissions and discharges data from all offshore oil and gas installations operating on the UKCS.

Table 3.11: Avalon Production Chemicals Requirements

Chemical Required	Injection location	Dose rate (ppmv)	Dose Rate Basis	Comments
Demulsifier	Primary point – Subsea manifold	20 to 400 ppmv continuous	Based on total fluids rate	Optimum dose rate likely to be 50ppmv
	Contingency point – Topsides upstream of 1st stage separator	20 to 400 ppmv continuous	Based on total fluids rate	Topsides contingency may be required as a top up dose which will be determined during field operation
Antifoam	Primary point – Topsides immediately upstream of 1st stage separator	3 to 15 ppmv continuous	Based on total fluids rate	-
Wax Inhibitor	Contingency point – subsea manifold	250 to 1500 ppmv continuous	Based on oil flow rate	Contingency only (allow for core in umbilical) to mitigate pigging requirements
Methanol	Subsea well chokes (Upstream)	TBC	Intermittent requirement	For hydrate management during shutdowns and restarts
Naphthenate Dispersant	Primary point – Inlet to 1st stage separator	20 to 150 ppmv continuous	Based on total fluids rate	Works in conjunction with the acetic acid to mitigate Ca naphthenate formation and fouling.
	Contingency point – Inlet to 2nd stage separator	20 to 100 ppmv continuous	Based on total fluids rate	
Inhibited acetic acid	Primary point – Inlet to 1st stage separator	Dosed to achieve 1st stage separator water pH target of 5.8 to 6.0. Typically 500 to 2000 ppmv	Based on total fluids rate	The acetic acid must contain acid corrosion inhibitor to prevent overheads corrosion issues.
	Contingency point – Inlet to 2nd stage separator	Dosed to achieve 2nd stage separator water pH target of 5.8 to 6.0. Typically 500 to 2000 ppmv	Based on total fluids rate	
Corrosion Inhibitor (Optional requirement, in case any carbon steel surfaces require protection, which will be defined by corrosion modelling.)	Primary point – Topsides flowline manifold arrival before 1sts stage separator (though depends on where any carbon steel first occurs in system)	50 ppmv continuous	Based on total fluids rate	It is assumed the subsea system, e.g. flexibles, will not require protection by subsea corrosion inhibitor injection.
Deoiler	Primary point – Upstream of hydrocyclones.	2 to 25 ppmv	Based on produced water rate	Deoiler chemicals with high molecular weight polymer are to be avoided as they are prone to sludging.
Biocide	Primary point – Inlet to slops / off spec water tank	300 ppmv dosed weekly	Based on slops/off-spec water tank fluid volume	Select a THPS based biocide for best performance.

Notes:
Scale inhibitor injection to wells not required based on Avalon scaling predictions.
Asphaltene inhibitor injection will not be required due to the low risk for Avalon oils.

3.6.1 Chemicals Used During Installation of Pipelines and Umbilicals

Chemical additives used during the pressure testing operations include an oxygen scavenger, a biocide and a dye (e.g. C-Dye). All pipeline testing fluids will be discharged to sea upon completion of the testing operations. These discharges will be subject to OPRED's chemical permitting system for such standalone operations, via the Portal Environmental Tracking System (PETS) on the online UK Energy Portal.

3.7 Floating Offshore Wind Turbine and INTOG Leasing Areas

As part of the development, PPUK proposes to install a single floating offshore wind turbine (OWT) to provide power for the development. The exact location of the OWT is still to be determined, depending on the safety and permitting constraints of the development. PPUK propose to site the OWT at a distance of approximately 5 km from the Excalibur FPSO. However, it is recognised that this proposed location is outside of any Crown Estate Scotland (CES) Innovation and Targeted Oil and Gas (INTOG) lease area.

INTOG lease sites are areas where developers may apply for the rights to build offshore windfarms, specifically for the purpose of providing low carbon electricity to power oil and gas installations and help to decarbonise the sector. The closest INTOG lease site to the Ping Avalon Field is approximately 25 km to the west (Figure 3.13).

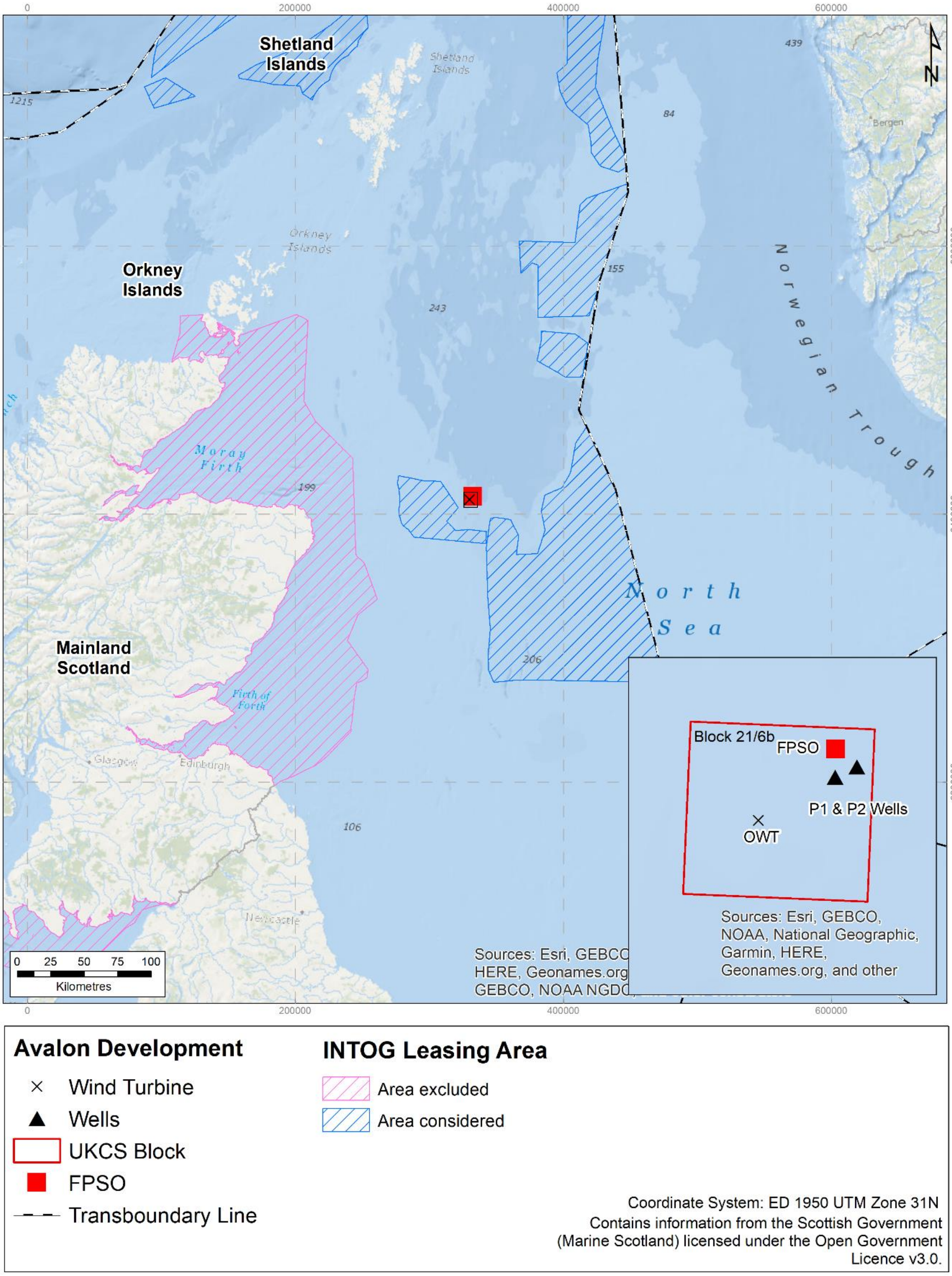


Figure 3.13: Avalon Field Development location and INTOG Leasing Areas

Although the preference is to locate the OWT as close to the proposed Avalon Field Development as possible, subject to relevant health and safety constraints, PPUK recognise that this may not be achievable as installation of the OWT may be restricted to designated INTOG lease areas. Therefore, it has been assumed that, as a worst case, the OWT will require to be situated 25 km to the west of the Avalon Field.

3.7.1 Turbine Substructure

The chosen substructure for the floating OWT is still to be confirmed. However, it will be installed on either a triangular semi-submersible platform or a tension leg platform (TLP). Illustrative examples of these substructure types are shown in Figure 3.14 (from International Renewable Energy Agency (IRENA)). Both substructure types are designed to cope with the extreme environmental conditions of the offshore North Sea environment.

The semi-submersible substructure is a buoyancy stabilised platform which floats on the surface of the water with some of the structure partially submerged. Large columns are linked by connected bracings / submerged pontoons which provide additional buoyancy. The substructure is kept in place by catenary or taut spread mooring lines.

The TLP substructure is a highly buoyant, semi-submerged structure with a central column and arms. These are connected to tensioned mooring lines which secure the substructure to the anchors. The combination of the tension in the mooring lines and the buoyancy of the substructure provides the required stability for safe operations.

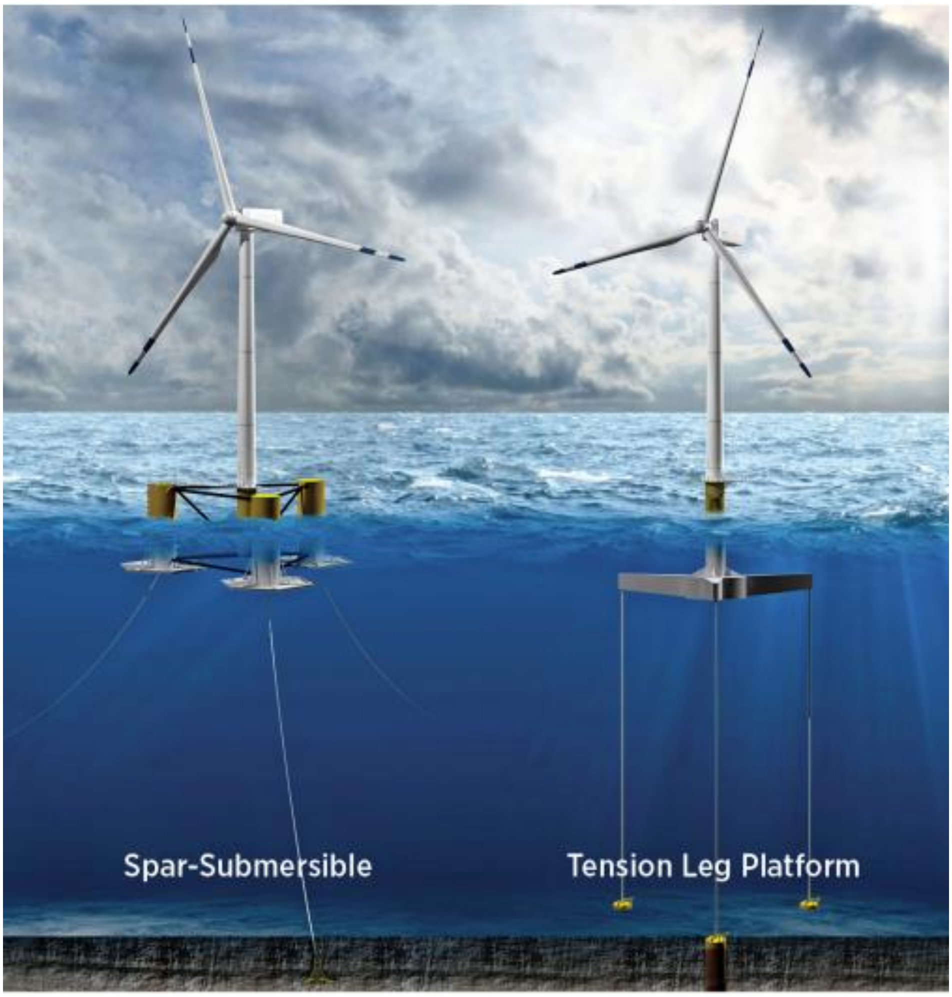


Figure 3.14: Examples of potential substructures for the Avalon floating OWT (image from IRENA)

The generating capacity of the OWT is likely to be between 10 and 14 MW allowing for longer up time at lower wind speeds. A summary of the main design parameters of the OWT are set out in Table 3.12. These are unlikely to change significantly irrespective of the selected substructure type.

Table 3.12: Offshore Wind Turbine Design Parameters

Design Parameter	Maximum Value [m]
Hub Height	119
Rotor Diameter	162
Rotor Tip Height	200

The OWT contains components that require the use of lubricating oils, hydraulic oils and coolants for normal operation. In the unlikely event of a leak of any of these fluids, the OWT components are designed and constructed in a way that contains any leaks therefore reducing the risk of release into the marine environment.

A single electricity cable will be installed to connect the OWT to the FPSO. The 25 km long cable will be trenched and buried beneath the seabed using a jet trencher, similar as the one described in Figure 3.5 in Section 3.4.3.

3.7.2 Floating OWT Subsea Infrastructure and Mooring System

The exact parameters and configuration of the mooring system that will be used with the floating OWT in the Avalon Field Development has not been finalised at this stage. The following sections describe, where possible, the proposed options under consideration and include, where necessary, examples from other similar developments as proxy examples.

3.7.2.1 Mooring Options

If a semi-submersible substructure (Section 3.7.1) is selected, a catenary mooring system will be installed. This typically comprises steel chains, wires and / or synthetic fibres whose weight and curved shape in the water column helps to hold the substructure in place. A proportion of this mooring system will lie on the seabed.

The exact parameters of this mooring system are still to be confirmed. Illustrative examples from floating offshore windfarm developments in Scotland have been used as a proxy for the Avalon Field floating OWT and are provided in Table 3.13.

If a TLP substructure (Section 3.7.1) is selected, a mooring system specific to this type of structure will be installed comprised of steel tendons or synthetic wires, which are arranged vertically from the substructure to the anchors on the seabed. The system remains under tension against the buoyancy of the substructure thereby providing the required stability.

The exact parameters of this mooring system are still to be confirmed. Illustrative examples from floating offshore windfarm developments in Scotland have been used as a proxy for the Avalon Field floating OWT and are provided in Table 3.13.

Table 3.13: Worst Case Design Parameters for Mooring Systems

Mooring Parameter	TLP	Catenary
Maximum number of moorings per WTG	6	6
Maximum mooring line length (m per line)	125	1 650
Maximum proportion of mooring line that may come into contact with the seabed (%)	0	90
Area of seabed where lateral movement can occur by mooring line (km^2 per line)	N/A	0.035
Maximum spread radius of mooring lines	300	1 500
Maximum number of clump weights per mooring line	N/A	40
Maximum seabed footprint of each clump weight (m^2)	N/A	2
Maximum thickness of mooring lines	0.8 m	175 mm

Notes:
The above parameters have used those from the Pentland Floating Offshore Wind Farm (Xodus, 2022) as proxy measurements.

3.7.2.2 Anchor Options

The Avalon OWT will be fixed to the seabed via nine anchors which will be linked to the mooring system. Two anchor options are under consideration for the Avalon development with the final selection dependent on the results of site surveys and the selected mooring configuration. The two options under consideration are impact piled anchors and suction bucket anchors.

Impact piled anchors are driven into the seabed using a pile-driving hammer. The type and size of the hammer, as well as the size of the pile affects the time taken to drive the piles into the seabed, as well as the number of blows required.

Suction bucket anchors comprise capped steel cylinders, which are lowered onto the seabed and the seawater pumped out. The resultant action of this process sees the anchor sucked into the seabed.

Similar to the mooring system, the parameters of the two anchor options under consideration are not currently know. Illustrative examples from floating offshore windfarm developments in Scotland have been used as a proxy for the Avalon Field floating OWT and are provided in Table 3.14.

Table 3.14: Worst Case Design Parameters for Anchors

Anchor Parameter	Suction Bucket Anchors	Impact Piled Anchors
Number of Anchors	9	9
Anchor / Pile Length (m)	15	25
Anchor Pile Diameter (m)	10	5
Seabed Footprint per Anchor (m^2)	78.5	19.6
Burial Depth (m)	14.5	20
Anchor Height Above or Below Seabed (m)	0.5	5

Notes:
The above parameters have used those from the Pentland Floating Offshore Wind Farm (Xodus, 2022) as proxy measurements.

3.7.3 Dynamic Export Cable

A single 66 kV export cable will be installed connecting the Avalon OWT to the Excalibur FPSO. From the Avalon OWT the cable will travel through the middle of the buoy / substructure through a J tube towards the seabed. A clump weight may be employed to anchor a buoyancy module supporting the cable. At the seabed, the cable will be trenched and buried for a distance of 25 km to the FPSO location where the cable will rise up to connect with the FPSO, supported again by a buoyancy module. At each touchdown point, where the cable enters / emerges from the seabed, there will be a requirement for scour protection to be placed.

3.7.4 Installation and Commissioning Process

As discussed in Section 3.7.2.1, the specific mooring system for the Avalon OWT is still to be confirmed and therefore the installation and commissioning sequence may vary depending on the system selected. However, it is anticipated that the anchors and the mooring system will be pre-installed and wet stored on the seabed, until they are required to be hooked up to the OWT. Connection of the power cable would take place after the OWT substructure is connected to the mooring system.

To reduce offshore construction activities as far as possible, the OWT will be assembled at the quayside and installed on top of the chosen substructure. The completed OWT and substructure will then be towed to the Avalon field where it will be connected to the selected mooring system. The power cable to / from the Excalibur FPSO will also be connected at this stage. The OWT is then commissioned for full operation.

3.7.5 Scour Protection

There may be a requirement to place scour protection around the anchor points after installation to protect the structure from erosion and sediment processes caused by the hydrodynamics at the site. The specific type of scour protection potentially required is not currently known, however typical scour protection options include:

- Rock placement;
- Concrete blocks or mattresses;
- Sand or grout bags;
- Rock bags; and
- Frond mats.

Similarly, the quantity of scour protection potentially required is not currently known and will be informed by site surveys. Illustrative examples from floating offshore windfarm developments in Scotland have been used as a proxy for the Avalon Field floating OWT and are provided in Table 3.14.

Table 3.15: Estimated Scour Protection Requirements Worst Case Design Parameters for Anchors

Anchor Parameter	Suction Bucket Anchors	Impact Piled Anchors
Height of scour protection material above seabed (m)	1	1
Estimated maximum volume of scour protection per anchor (m^3)	760	760
Estimated maximum seabed footprint of scour protection per anchor (m^2)	760	760
Estimated maximum seabed footprint of scour protection (m^2)	4 560	4 560
Notes: The above parameters have used those from the Pentland Floating Offshore Wind Farm (Xodus, 2022) as proxy measurements.		

3.7.6 OTW Maintenance and Access

The OWT and the mooring systems will be subject to routine inspection and maintenance visits, which will be carried out in accordance with the recommendations from the OWT manufacturer.

The majority of maintenance operations will be undertaken offshore. However, if major works are required the OWT and substructure would be disconnected from the mooring system and power cable, and then towed back to shallower water or a suitable port facility.

3.8 Decommissioning

The infrastructure associated with the Avalon Field Development will be decommissioned, when operations are no longer economically viable.

All decommissioning operations will be undertaken in accordance with UK Government legislation and international agreements in force at the end of field life. In the UK, decommissioning is controlled through the Petroleum Act 1998, as amended by the Energy Act 2008. The UK's international obligations on decommissioning are governed principally by the 1992 Convention for the Protection of the Marine Environment of the North-east Atlantic (OSPAR Convention).

The Avalon wells will be plugged and abandoned to below seabed level, in accordance with the prevailing Oil and Gas Authority (OGA) guidelines. With regard to the subsea infrastructure, it is anticipated that the spools will be disconnected at the extremities of the pipelines/umbilicals and will be subsequently removed, together with all other equipment and (protection) structures present on the seabed. Similarly, all pipeline protection mattresses will be removed, where feasible.

The selection of an FPSO allows it to be disconnected and towed away and the end of the field life. The decommissioning method for the pipelines and umbilical will be subject to a comparative assessment, which will be completed near the end of field life, in line with current decommissioning regulatory guidance. The two main options that will be considered during the Comparative Assessment will be either to: 1) fully recover the production flowline, gas lift pipeline, umbilical and OWT electricity cable, or 2) to abandon the buried pipelines, umbilicals and electricity cable in-situ. Option 2 would involve flushing and cleaning the pipelines internally to void them of any hydrocarbons and then leave them filled with seawater. The ends of the pipelines, umbilical and electricity cable would be trenched and buried, to ensure no physical obstructions remain above seabed level. PPUK will undertake all decommissioning activities in compliance with regulatory requirements in force at the time of decommissioning and in consultation with regulators and other stakeholders.

The OWT, including the substructure and mooring system, is designed to be easily decommissioned. All elements of the OWT will be removed from the seabed. A decision on whether to remove the power cable from the OWT to the FPSO, will be made in line with best industry practice at the time.

The main considerations of the decommissioning process will be navigational safety, the prevention of marine pollution and prevention of significant impacts on the marine environment. The ultimate intention is to leave the seabed development area in the condition that it will pose no harm to the marine environment or other users of the sea.

Prior to the decommissioning process, re-use and recycling alternatives will be considered where feasible. In advance of the decommissioning process, an inventory of all project equipment will be made and an examination for further reuse will be carried out. Pre-decommissioning surveys will be carried out to establish the environmental baseline before decommissioning. The precise decommissioning methodology will depend upon operating conditions. Discussion on what may be required in an individual case will be held with the Department for Business Enterprise and Industrial Strategy (BEIS) Offshore Decommissioning Unit before commencing.

Section 4
Local Environment

4. Local Environment

Information about the local environment at the proposed Avalon Field Development and its surrounding area has been collated to allow an assessment of the features that might be affected by the proposed activities or may influence the behaviour of potential contaminants.

The Avalon field is located within United Kingdom Continental Shelf (UKCS) block 21/06b. The proposed option for a gas import/export pipeline may transit through UKCS blocks 20/02, 20/03, 20/04, 20/05, 20/08, 20/09, 20/10, 21/01, 21/02, 21/06 or 21/07 dependent upon the chosen pipeline route to connect with either the Britannia PLEM or Ettrick PLEM (Section 3.4.3).

The Avalon Field Development lies approximately 116 km east of the Aberdeenshire coast and approximately 100 km west of the UK/Norway transboundary line. The Norwegian coastline lies 310 km to the east (Figure 4.1). The preferred locations of the principal project infrastructure are presented in Table 4.1 and Figure 4.1.

Table 4.1 Development coordinates

Location	Coordinates			
	Degrees Minutes Seconds (DMS)*		Decimal Degrees	
FPSO	57°49'38.218"N	0°10'46.251"E	57.827283	0.179514
P1 Well	57°49'8.14"N	0°10'46.552"E	57.818928	0.179598
P2 Well	57°49'19.6"N	0°11'28.456"E	57.822111	0.191238
Floating OWT	57°48'19.876"N	0°8'20.461"E	57.805521	0.139017

Notes:
* = DMS in WGS84
FPSO = Floating production storage and offloading
OWT = Offshore wind turbine

Whilst the location of the offshore wind turbine (OWT) indicated in Table 4.1 and Figure 4.1 is preferred, the location of the OWT assessed here is assumed to be 25 km from the Avalon Field Development and within a designated Innovation and Targeted Oil & Gas (INTOG) licensing area (see Section 3.7). This assumption has been carried forward to the impact assessment however it remains PPUK's preference to site the OWT at, or close to, the location presented in Table 4.1 and Figure 4.1.

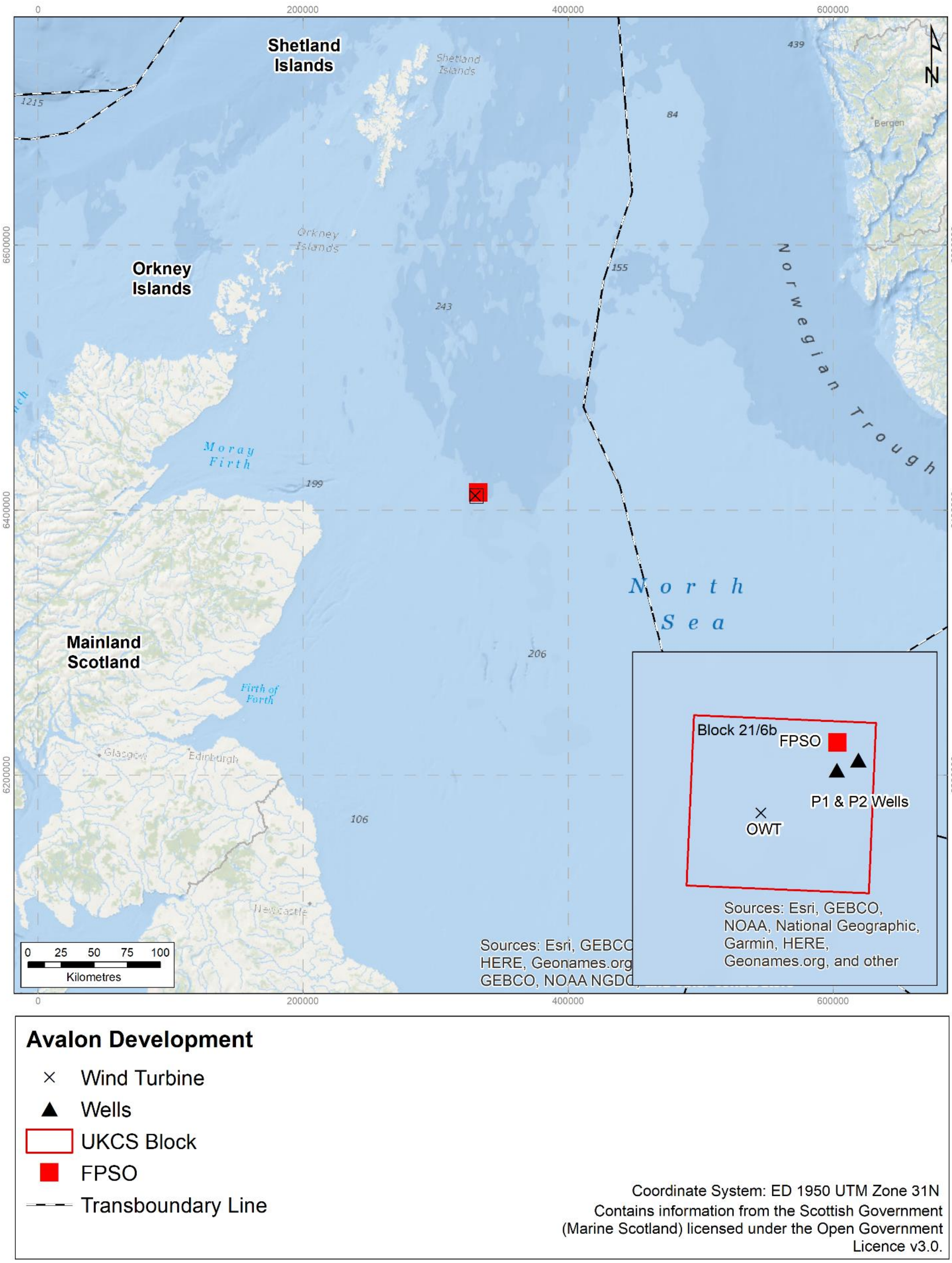


Figure 4.1: Location of the proposed Avalon development

4.1. Data Sources

Information on environmental conditions for the area of the proposed development has been gathered from a wide range of sources. Existing data has been sourced from publicly available national and regional datasets, as well as from published journals. Information on seabed features, sediment types, seabed habitats and benthic species has been sourced from regional and site-specific surveys that have been carried out in the area around the proposed development.

4.2. Environmental Surveys and Reports Relevant to the Proposed Avalon Field Development

4.2.1. Avalon Specific Surveys

A number of environmental surveys have been conducted in and around the immediate project area. Figure 4.2 shows the extents of these surveys in relation to the current planned project infrastructure. These surveys have been reviewed to provide information on the seabed conditions in the area, including any potentially sensitive features that could be classified as Annex I habitats, such as pockmark habitats.

The Summit Avalon survey was conducted in November 2016 in UKCS Block 21/6b (Gardline, 2016). This survey comprised a seafloor and high-resolution seismic hazard survey of the Avalon appraisal well. The survey used multibeam echo sounder, side scan sonar (SSS), magnetometer, pinger, sub-tow boomer and 2D high resolution seismic equipment to collect information on seabed and sub-seabed conditions.

In 2013, the Summit Site geophysical, habitat and Environmental Baseline Survey (EBS) was undertaken at the Avalon Field Development site, in UKCS Block 21/6b (Fugro, 2013a; 2013b). The surveys included the collection of geophysical data and subsequent ground-truthing using grab sampling and seabed video. The purpose of the survey was to establish the physical, chemical and biological conditions of the seabed prior to development of the site. The data from the survey was compared to two comparative surveys conducted in the nearby UKCS Block 21/12a and 21/12c in 2010 and 2012.

In 2012 the Premier Cyclone habitat assessment and environmental baseline survey was undertaken at the Avalon Field Development site (Gardline, 2012). The purpose of the survey was to establish the physical, chemical and biological conditions of the seabed prior to development of the site.

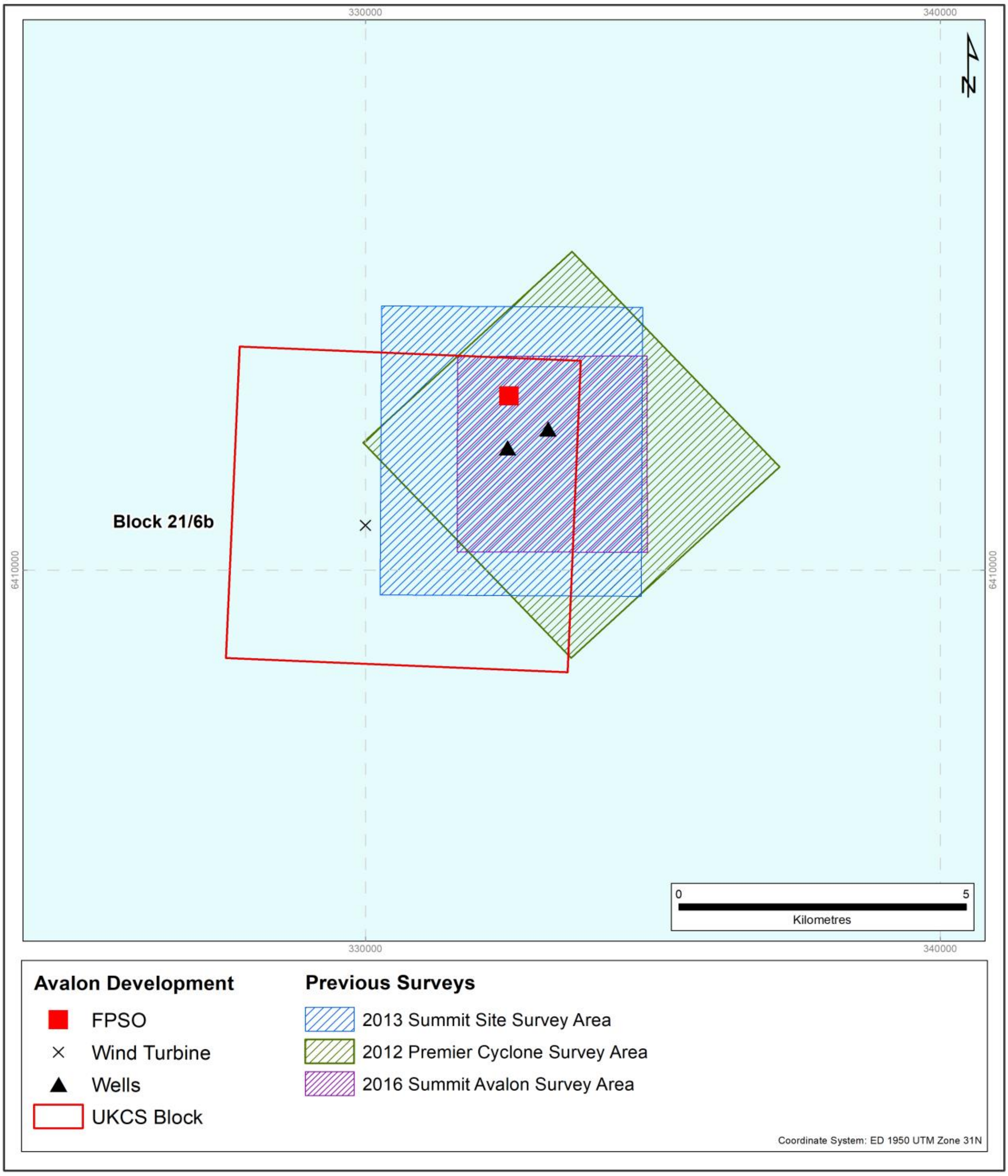


Figure 4.2: Environmental surveys carried out at the Avalon field

Sources: Gardline, 2012 & 2016 and Fugro, 2013a&b.

4.2.2. Other Environmental Surveys and Reports

Additional surveys have been undertaken at other fields in the wider area. These have also been reviewed here to draw contextual information across the wider region as well as along the proposed route options of the optional gas import/export pipelines, as summarised below.

A series of environmental surveys were undertaken at the Ivanhoe and Rob Roy fields in UKCS Block 15/12 and the Renee and Rubie fields in UKCS Blocks 15/27 and 15/18 respectively to inform pre and post decommissioning requirements and as part of longer term monitoring at these specific sites. The surveys were undertaken in 2010, 2015 and 2018 and provide information on marine environmental conditions in the wider area approximately 22 km to 33 km north of any potential Britannia PLEM tie in (Fugro, 2011a and b; Fugro, 2015a and b; Fugro, 2018).

An Environmental Impact Assessment (EIA) for the decommissioning of the Ettrick and Blackbird Field Developments in UKCS Blocks 20/2a and 20/3a (Nexen, 2017) provides additional information on marine environmental conditions along the prospective gas import/export pipeline route to Ettrick.

Environmental surveys at the Golden Eagle Area Development (GEAD), approximately 15 km northeast of a potential Ettrick PLEM tie in, were undertaken in 2007, 2008 and 2010 (Nexen, 2010). Additional habitat assessments and an Environmental Baseline Surveys at the Golden Eagle field were also undertaken in 2007, 2008 and 2010 respectively whilst additional pipeline route surveys from the Golden Eagle field to Ettrick, Buzzard and Claymore were conducted in 2010 (Nexen, 2010). These surveys collected data on the physico-chemical and macrofaunal benthic environment and identified habitats and potential hazards or obstructions across the GEAD (Nexen, 2010).

4.3. Physical Environment

4.3.1. Hydrography

Tidal currents in the offshore waters of the North Sea decrease in velocity with increasing distance northwards. The main water masses in the North Sea are Atlantic Water, Scottish coastal water, northern North Sea water, Norwegian coastal water, central North Sea (CNS) water, southern North Sea water, Jutland coastal water and Channel water. The main inflow of water into the North Sea occurs along the western slopes of the Norwegian Trench, with minor inflows from the English Channel and the Baltic Sea. These inflows are balanced by an outflow along the Norwegian coastline. This creates an anti-clockwise circulation pattern, due to the cold Atlantic waters flowing to the south-east and the warmer North Sea waters flowing to the north (DTI, 2001). An eddy forms over the Fladen Ground area, to the north-east of the proposed Avalon Field Development, as part of the current circulation.

In contrast to the southern North Sea, the central and northern North Sea waters become layered (stratified) in the summer. This isolates the surface waters from the bottom waters until the autumn gales break down the stratification (DTI, 2001). Mean surface salinities in the area around the proposed development location were found to be 35.1 % in the winter and 34.9 % during the summer months (Marine Scotland, 2022b; BODC, 1998). Mean near-bed salinities in the area were found to be 35.1 % in the winter and 35 % during the summer months (Marine Scotland, 2022b; BODC, 1998).

The wave climate is influenced by wind speed, wind duration and fetch (the distance over which the wind blows uninterrupted over the sea), which are in turn dependent on season and location. The predominant wave direction at the Avalon field is north to north north-west (Fugro, 2022a). The North Sea is considered to be frequently rough from October to March. During this time, significant wave height north of 57˚N, which includes the proposed Avalon Field Development, exceeds 4 m for 20 % to 30 % of the time. Fifty-year maximum wave heights in the North Sea are estimated to range from around 32 m in the north to 12 m in the English Channel. Annual mean significant wave height for the area around the development range from 2.20 m to 2.22 m (Marine Scotland, 2022b).

Mean sea surface temperature in the area around the proposed development fluctuated between 12.4 ºC during the summer months and 7.8 ºC during the winter months (Marine Scotland, 2022b) Mean near-bed temperatures in the area range between 8.9 ºC and 6.2 ºC throughout the year (Marine Scotland, 2022b).

4.3.2. Meteorology

Wind data for the North Sea (Figure 4.3) indicate that wind direction is variable, however, winds tend to dominate from south-south-west and south. Predominant wind speeds throughout the year represent moderate to strong breezes (6 m/s to 13 m/s), with the highest frequency of gales (wind speeds greater than 17.5 m/s) occurring in the winter months (November to March) (DTI, 2001).

The proposed Avalon Field Development area experiences more frequent strong winds and gales, particularly from the north-northwest, and southwest to south).

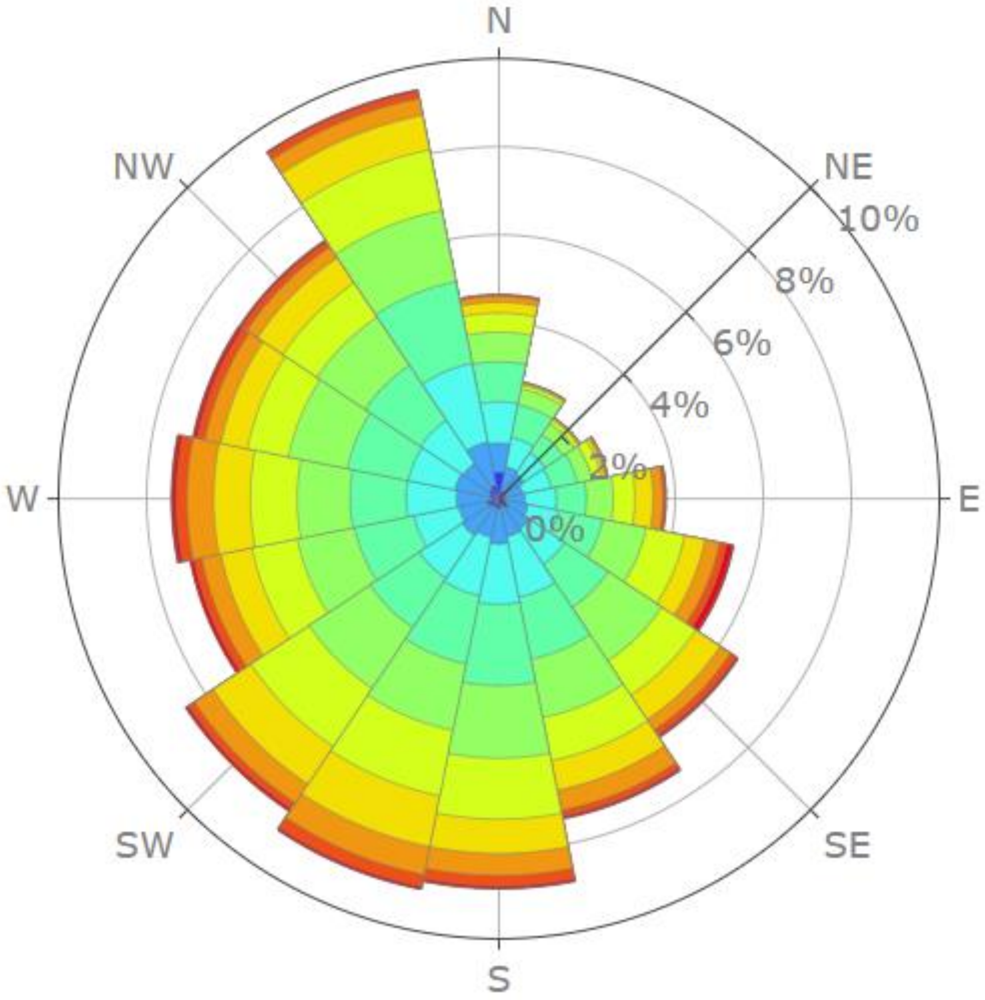


Figure 4.3: Windrose for the approximate location of the Avalon Field Development

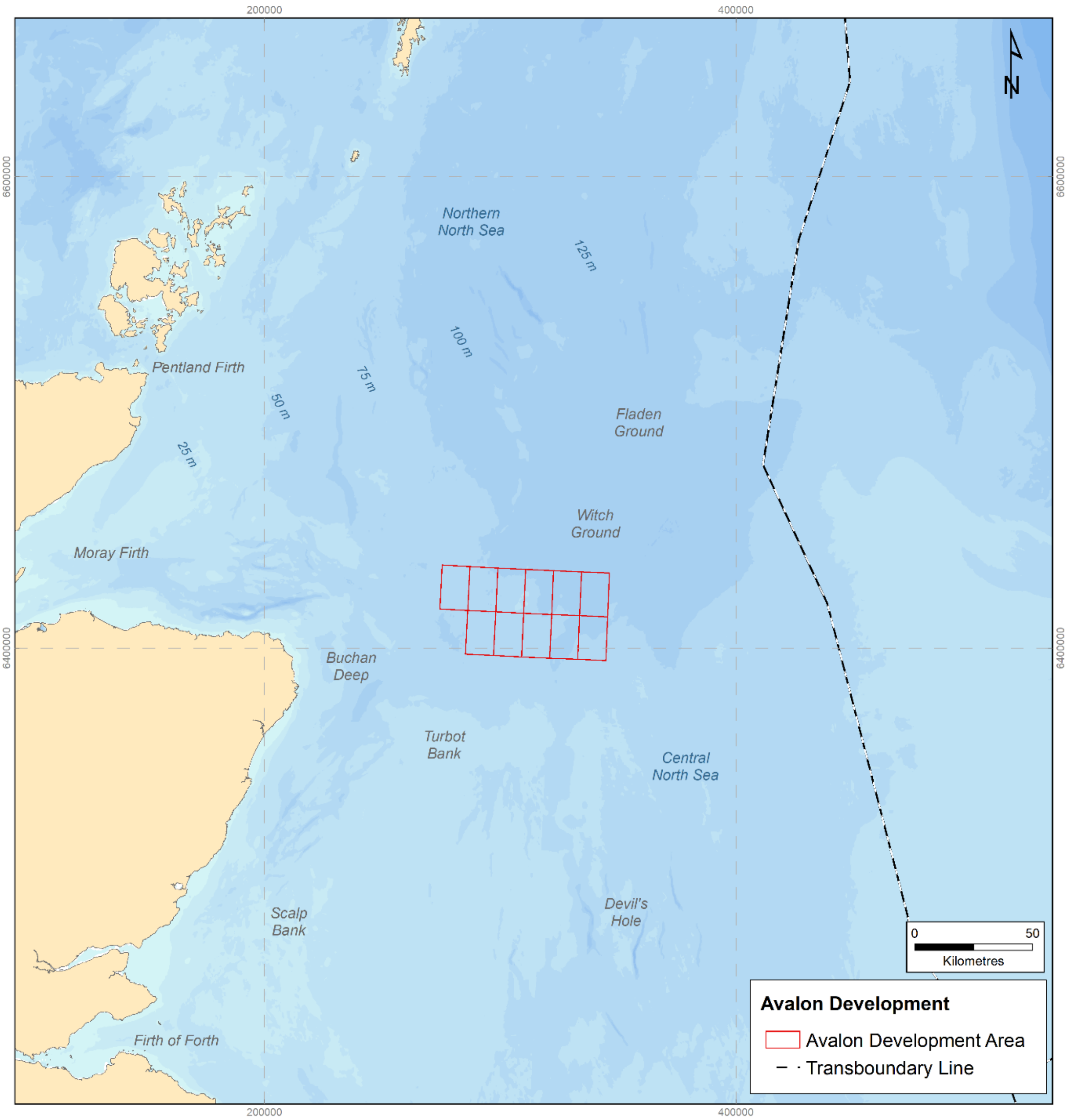
Mean wind speeds vary between 6 m/s and 10 m/s with the greatest wind speeds typically recorded in December – February (Fugro, 2022a). Average wind speed at the site is 8.3 m/s (Fugro, 2022a).

Mean annual rainfall is relatively low over much of the CNS when compared to the Atlantic seaboard and Norwegian coastal waters. Rainfall in the development area is estimated to be between 200 mm and 400 mm per annum (DTI,2001).

4.3.3. Bathymetry

The proposed Avalon Field Development area is situated in water depths ranging from approximately 112 m to 133 m. The seabed generally has a gradient of < 1°, gently sloping towards the west, gradients were found to increase to < 1.5° across some minor undulations, particularly in the western half of the survey area (Gardline, 2016). In the eastern half of the survey site, and to a lesser extent in the west, several pockmarks are present which are up to approximately 200 m across, 6.5 m deep and show gradients of up to 17° (Gardline, 2016).

The bathymetry of the proposed Avalon Field Development, including the UKCS Blocks through which the gas import/export pipeline may transit through, is illustrated in Figure 4.4.



Coordinate System: ED 1950 UTM Zone 31N The GEBCO_2019 Grid, http://www.gebco.net

Figure 4.4: Bathymetry

4.3.4. Seabed Features

Pockmarks, caused by fluid seeps, are known to be present in the general area of the current proposals (Gardline, 2016; Fugro, 2013a; JNCC, 2018a). Investigation of several of the pockmarks during previous site survey found them to be very irregular in shape, with the largest pockmarks measuring 166 m in diameter and up to 6 m deep (Gardline, 2016; Fugro 2013a).

The closest pockmark to the proposed Avalon wells is located 792 m to the north-north-east. No evidence for MDAC has been found at any pockmark location investigated (Gardline, 2016; Fugro 2013a).

Pockmarks occur widely across the region as indicated in Figure 4.5 and are predicted to occur within a number of the UKCS blocks through which the proposed Avalon gas import/export pipeline may transit (JNCC, 2018a, Figure 4.5).

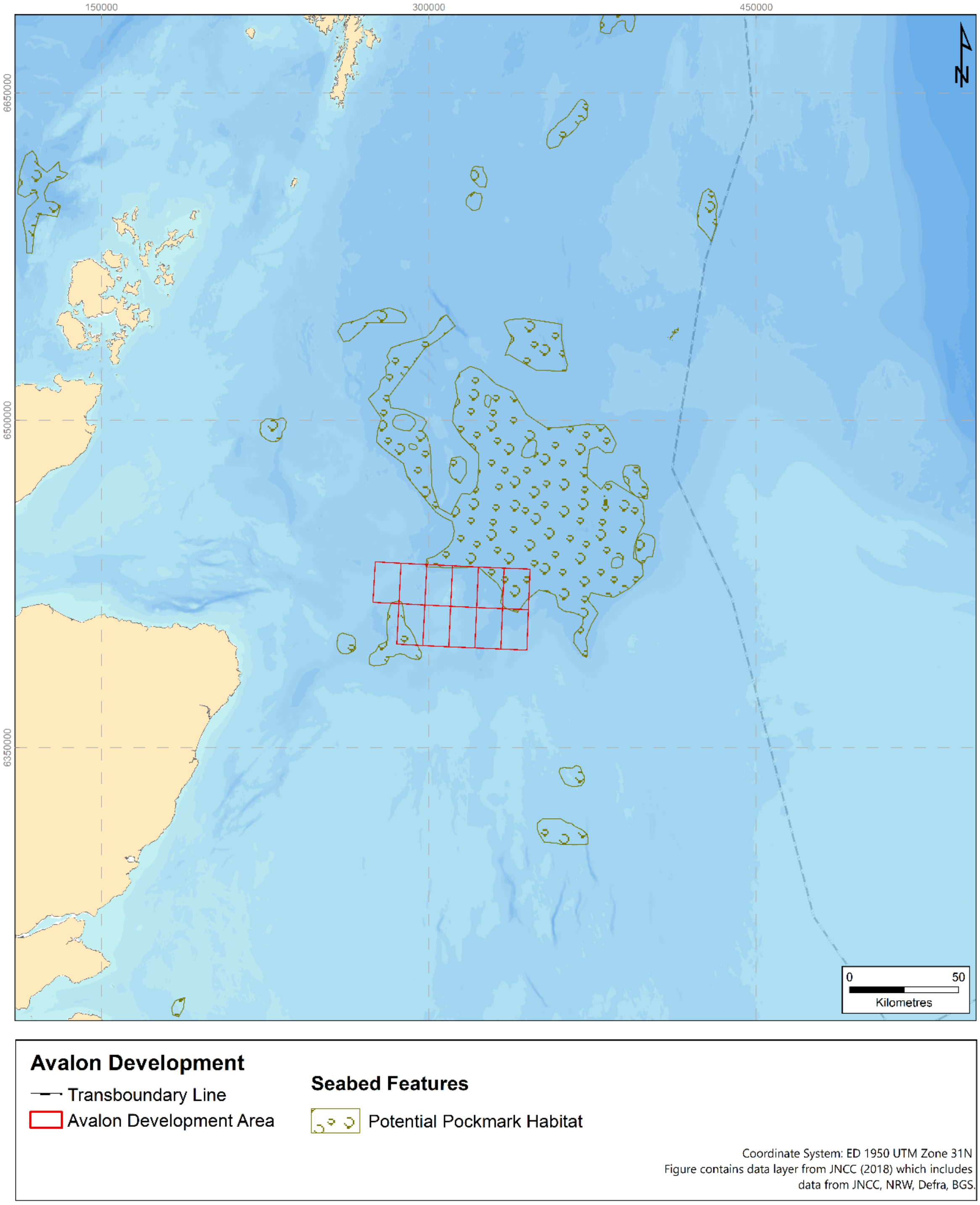


Figure 4.5: Distribution of predicted pockmarks in relation to the Avalon Field Development area

Sources: JNCC, 2018a.

Three areas of gravel accumulations and boulders were also identified in the surrounding area together with trawl and anchor scars with anchor pull-out pit depressions visible at the end of the anchor scars indicative of previous oil and gas activity.

4.3.5. Seabed Sediments

Seabed sediments in the survey area and across the wider region comprise sand and muddy sand and mud and sandy mud (BGS, 1996; Marine Scotland, 2022b) (Figure 4.6).

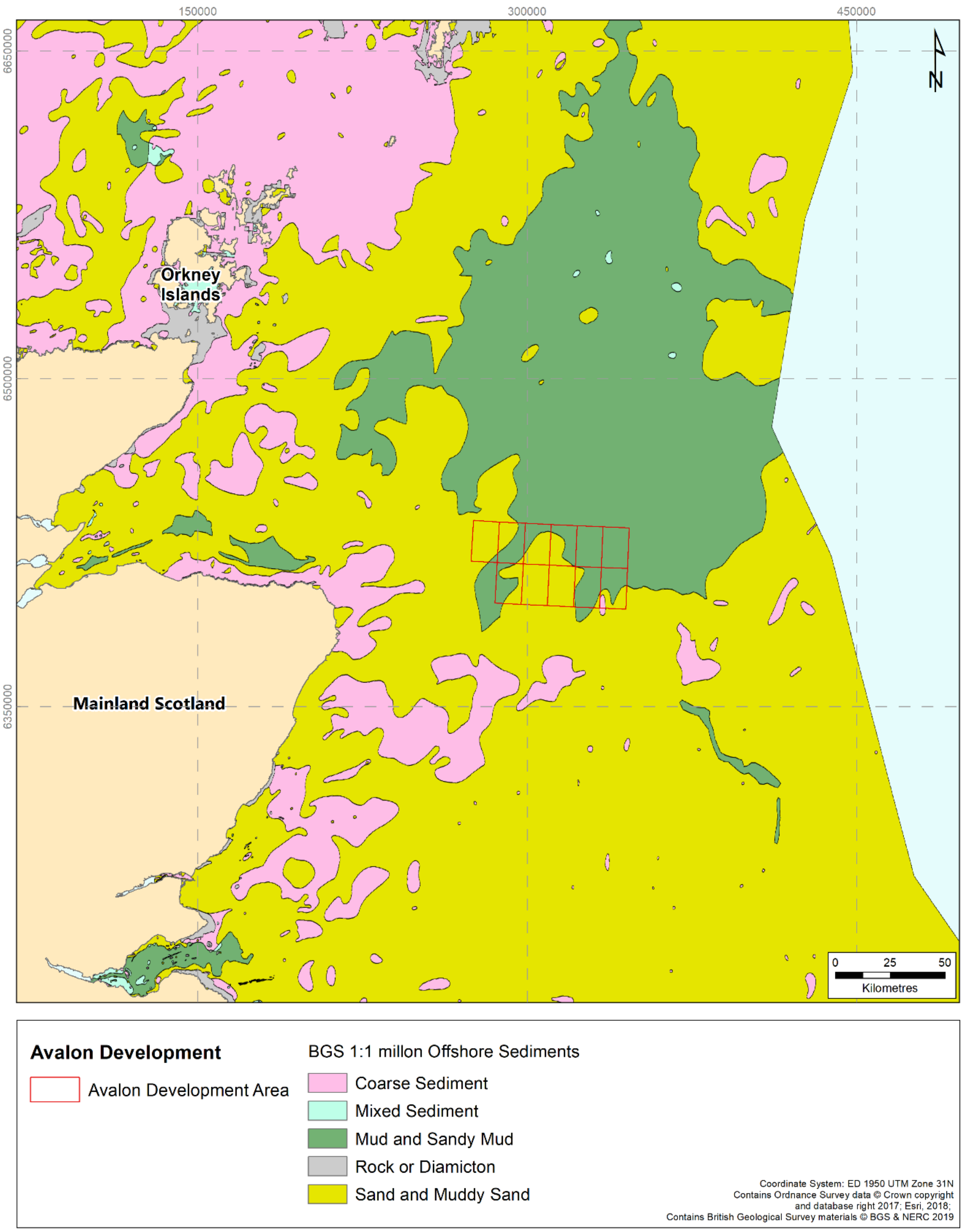


Figure 4.6: Seabed sediments

Sources: BGS & NERC, 2019; Marine Scotland, 2022b.

Sampling surveys conducted within the vicinity have identified a predominately silt/clay and sand sediment with occasional shell fragments (Gardline, 2016; Fugro, 2013a). Samples were dominated by sand fractions which made up between 52 % and 74 %. Fine sediment fractions comprised between 25 % and 48 % whilst coarse material represented 0.02 % to 5 % of the samples. Fine sediment composition increases with increasing water depth. These sediment types may be considered representative of offshore 'subtidal sands and gravels' and 'deep-sea muds' Priority Marine Features (PMF) recognising their importance in supporting biodiversity in Scotland.

The sediment composition within sampled pockmarks was significantly different to that of the adjacent seabed with a greater proportion of coarse gravel, cobbles and shell fragments (Fugro, 2013b).

Two principal EUNIS habitat classifications are present within the wider area including 'Atlantic offshore circalittoral sand' (MD52) and 'Atlantic offshore circalittoral mud' (MD62) (Figure 4.7).

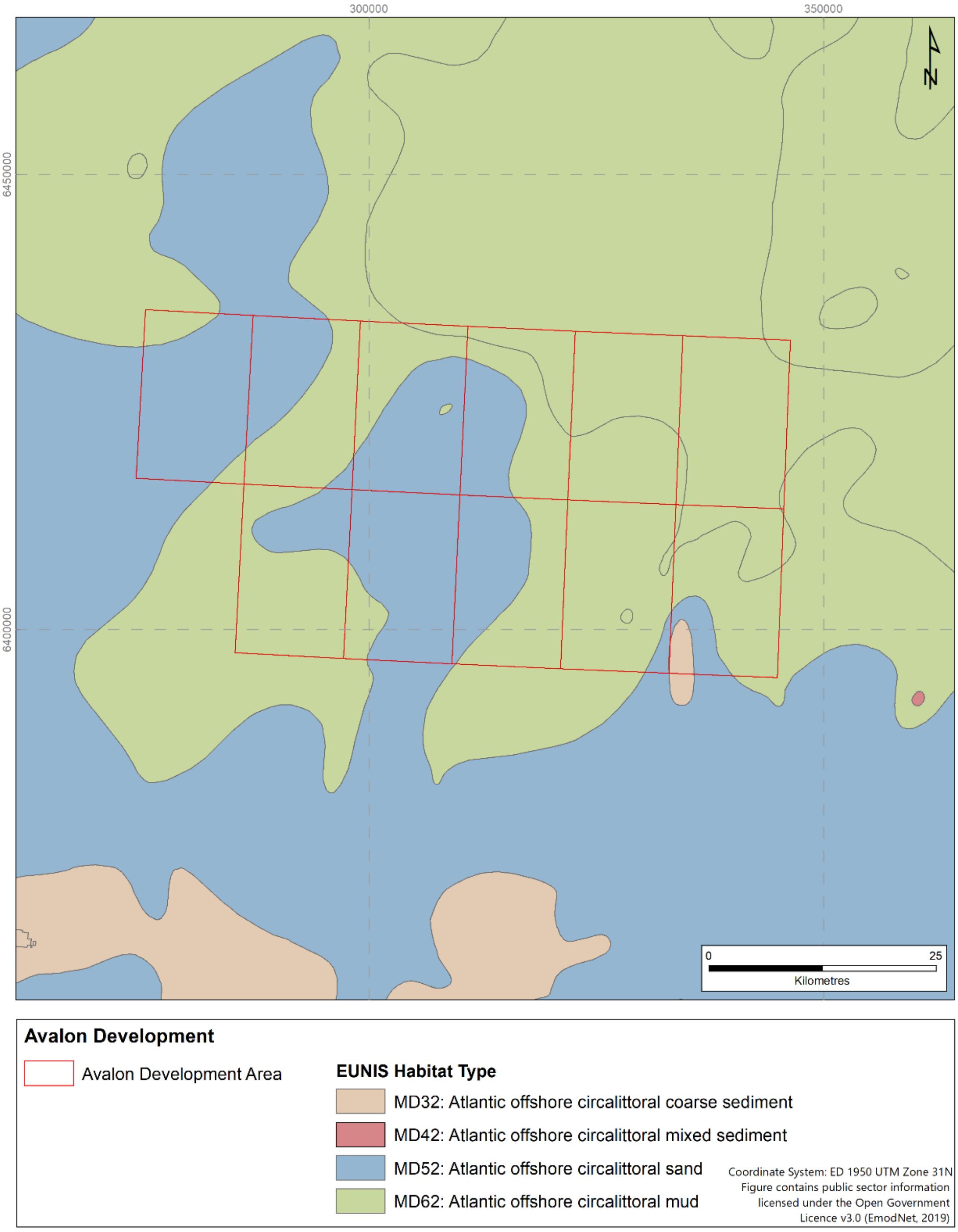


Figure 4.7: EUNIS marine habitat classification

Further afield, poorly to very poorly sorted medium silt sediment has been recorded at the Ivanhoe and Rob Roy fields, within UKCS Block 15/21, approximately 37 km from the Avalon Field (Fugro, 2011a; 2015a, b). Seabed habitats at this location were classified as 'offshore circalittoral sandy mud' (Fugro, 2015a, b).

Sediments at the GEAD include fine silty to medium sand with areas of dense clay outcrops (Nexen, 2010). Analysis of sediments obtained during the Golden Eagle to Ettrick pipeline route survey concluded that sediments in the area were fine to medium sands dominating in the western end of the pipeline route, increasing to medium sand in the shallower eastern end of the route which is indicative of slightly higher levels of exposure to current (Nexen, 2010).

During the Golden Eagle to Buzzard pipeline route survey, the seabed sediments were recorded as silty fine sand to the north, becoming medium sands to the south (Nexen, 2010).

Surface sediment in the area of the Ettrick and Blackbird fields has been recorded as predominantly fine silty sand to very find sands (Nexen, 2017).

4.3.6. Sediment Chemistry

Total sediment hydrocarbon concentrations generally increase from the south to the north in the North Sea. Analysis of spatial trends concluded that the finer, muddier sediments that are associated with deeper sites, tend to contain higher levels of all background contaminants than the coarser, less muddy sediments in shallower waters. Little difference was found between individual sediment categories, such as, sand and fine sand (UKOOA, 2001).

Total hydrocarbon concentrations (THCs) in sediments across the Avalon Field range between from 0.6 μgg^{-1} to 1.9 μgg^{-1} and on average are lower than the mean concentration for the central North Sea (UKOOA, 2001) and below mean concentrations recorded at other UKCS Blocks (Blocks 21/12a and 21/12c) in the region (Fugro, 2013b). Similarly, polycyclic aromatic hydrocarbon (PAH) levels are low across the Field area ranging between 37 μgg^{-1} to 118 μgg^{-1}. These levels are below the average for the central North Sea (UKOOA, 2001) but higher than those recorded within comparable areas at UKCS Blocks 21/12a and 21/12c).

The mean sediment concentrations of barium (Ba), chromium (Cr), iron (Fe), zinc (Zn) and nickel (Ni) within the Avalon Field exceed mean levels for the central North Sea (Fugro, 2013b). In addition, mean concentrations of Ba, Cr, Ni lead (Pb), iron (Fe) and zinc (Zn) are higher than those at neighbouring sites at Blocks 21/12a and 21/12c (Fugro, 2013b). Elevated concentrations of nickel and chromium are thought to be a result of the local geochemistry rather than any anthropogenic influence (Fugro, 2013b).

Sediment THC and PAH levels at the Renee and Rubie fields, in UKCS Block 15/21, are generally above average levels for the central North Sea whilst metals levels are within the range of natural background concentrations (Fugro, 2015a).

The surveys at the GEAD (Nexen, 2010), indicated background total organic carbon and PAH levels. Most of heavy and trace metal concentrations reported, were within published UKOOA mean concentrations for CNS (where available). Barite rich drilling mud was noted in two stations (Nexen, 2010).

The survey at the Goldeneye field (Fugro, 2010) demonstrated background levels of hydrocarbons with minimal variation across the area surveyed. Barium was the only metal reported to exceed CNS background levels (UKOOA, 2001), likely originating from water-based drilling mud.

The data described above is summarised in (Table 4.2).

Table 4.2: Sediment contaminant levels at the Avalon field and the wider region

Survey	Level	THC	PAH	Ba	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Avalon site survey 2013 (21/6b)	Mean	1.2	58	351	0.2	33.0	5.9	8984	11.1	16.9	38.0
	SD	0.5	31	25	0.1	27.9	1.4	1067	2.1	17.6	11.5
GEAD (GEL, 2010)	Mean	20.03	0.08	N/A	0.23	N/A	3.46	N/A	N/A	5.93	16.73
	SD	98.2	0.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GEAD to Buzzard (GEL, 2010)	Mean	3.22	0.02	N/A	0.08	N/A	2.7	N/A	N/A	3.6	11.2
	SD	2.56	0.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
GEAD to Ettrick (GEL, 2010)	Mean	4.92	0.05	N/A	0.15	N/A	3.5	N/A	N/A	6.7	14.4
	SD	2.64	0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
21/12a (2010)‡	Mean	2.0	36	225	0.03	12.8	8.2	7190	9.7	3.7	21.7
	SD	1.5	8	28	0.01	0.1	0.9	456	0.5	0.7	0.8
	SD	9.9	0.269	284	0.004	3.2	1.32	1072	1.82	1.0	2.6
IRR Pre-Decommissioning EBS 15/21 (2011)‡	Mean	44.4	0.357	492	0.061	29	5.22	11693	8.22	11	31.8
	SD	61.3	0.237	593	0.017	10.1	1.41	1561	3.06	1.72	4.8
IRR Pre-Decommissioning EBS 15/21 (2011)‡	Mean	87	0.942	680	0.064	25.2	6.74	10284	14	13.3	37.3
	SD	98	1.02	602	0.025	2.9	2.42	1278	8.44	1.5	8.1
21/12c (2012)‡	Mean	1.7	37	225	<0.1	15.3	7.6	6211	6.8	4.3	15.6
	SD	0.3	9	5	-	1.1	3.1	601	0.5	0.7	1.3
IVRR Post-Decommissioning Environmental Survey (Ivanhoe) 15/21 (2015)‡	Mean	23.8	-	1040	0.062	32.5	6.76	14300	10.1	16.9	34.5
	SD	28.3	-	873	0.008	5.01	2.01	1630	1.57	2.08	5.12
IVRR Post-Decommissioning Environmental Survey (Rob Roy) 15/21 (2015)‡	Mean	71.5	-	1430	0.067	32.9	7.48	14600	12	17.5	38.8
	SD	112	-	1270	0.015	3.52	1.65	887	12.6	1.86	6.95
IVRR Environmental Monitoring Survey 15/21 (2018)‡	Mean	NA	NA	889	-	33	5.61	14800	11.4	15.6	30.2
	SD	NA	NA	925	-	3.16	1.59	1270	3.27	1.75	5.47
IVRR Environmental Monitoring Survey 15/21 (2018)‡	Mean	NA	NA	1590	-	34.6	6.16	15900	12.3	16.7	33.2
	SD	NA	NA	1670	-	2.78	0.943	1080	2.93	1.24	3.60
UKOOA central North Sea Sector (2001) Mean	**Mean**	**9.5**	**266**	**349**	**0.8**	**23.9**	**6.3**	**7334**	**12.6**	**11.5**	**21.3**
	95th %	**40.1**	**855**	**720**	**1.0**	**54.0**	**18.0**	**11960**	**26.8**	**21.8**	**43.4**

Notes:
Values expressed as µg/g dry weight]
THC = total hydrocarbon concentrations; PAH = Polycyclic aromatic hydrocarbon
Ba = Barium; Cd = Cadmium; Cr = Chromium; Cu = Copper
Fe = Iron; Pb = Lead; Ni = Nickel; Zn = Zinc
SD = Standard Deviation
* = Hydrofluoric digestion used for, lead, cadmium, chromium, nickel and zinc. Iron analysed by hydrofluoric acid and boric acid digestion
† = Metals obtained by nitric/aqua regia (hydrofluoric) digestions
‡ = Metals obtained by aqua-regia digestion

Key: [light shading] > UKOOA (2001) Mean; [dark shading] > UKOOA (2001) 95th Percentile

4.4. Biological Environment

4.4.1. Benthos

Benthos is the term used for animals and plants associated with the seabed, although plants are generally limited by their light requirement to depths of less than 50 m. Benthos consists mainly of animals that burrow into the sediment or form tubes in it (known as infauna). Other species which live on the seabed, or attached to rocks or to other biota, are known as epifauna.

In general, the main influences on benthic communities are water depth and sediment type, although other factors such as sediment stability and temperature, as well as human influences, such as demersal fishing, also play important roles in determining species community distribution and composition.

An ICES coordinated North Sea Benthos Project (NSBP) conducted sampling of infaunal communities throughout the North Sea in 2000, which repeated the studies collated by Künitzer et al. in 1992 (Rees et al., 2007). Multivariate analysis was used to divide stations into discrete infaunal assemblages. The assemblage of most relevance to the development area was found throughout the northern and CNS in fine and muddy sands at depths greater than 50 m. This community was characterised by the polychaete *Paramphinome jeffreysii* (*P. jeffrysii*) and was dominated by polychaete species such as *Myriochele* spp. and *Spiophanes* spp. and the brittlestar *Amphiura filiformis* (Rees et al., 2007).

With regard to the larger and more widely dispersed benthic megafauna, large scale epibenthic trawl studies in the North Sea have shown that the starfish *Astropecten irregularis*, the sea urchins *Echinus acutus* and *Echinus tenuispinus*, anemone *Hormathia digitata*, hermit crab *Pagurus pubescens* and prawn *Pandalus borealis* are typical of the wider area (Callaway et al., 2002; Jennings et al., 1999; Cranmer, 1985).

Two main European Nature Information System (EUNIS) biotopes, 'circalittoral muddy sand' (A5.26) and circalittoral mixed sediment (A5.44), have been identified in the vicinity of the Avalon Field Development. The majority of the survey area was classified as; 'circalittoral muddy sand' (A5.26) (Figure 4.7). Photographic analysis of the epifauna within this biotope found that biodiversity was low and distribution was sparse, which is typical of sediment habitats in the North Sea, as the fine silty sediments in this area offer little attachment substrata for sedentary epifauna. The most common epifaunal organisms recorded in the area were hermit crabs (Paguroidea), sea stars (*Asterias rubens* and *Astropecten irregularis*) and seapens (*Pennatula phosphorea*). Occasional tusk shells (Scaphopoda) and possible tower shells (*Turritella communis*) were also observed (Fugro, 2013b).

The second biotope classified, 'circalittoral mixed sediments' (A5.44). are comprised of a mosaic of pebbles, gravel, shell fragments and occasional cobbles embedded within silty/clayey sand. The presence of this hard substrate, acting as attachment substratum, allows the establishment of epifaunal organisms. Hydroids (Hydrozoa) and encrusting sponges (Porifera) were observed attached to the hard substrate. Other than this, the epifaunal community mainly comprised of similar organisms to the circalittoral muddy sand biotope and there was no increase in epifaunal density (Fugro, 2013a; 2013b).

The Avalon field is characterised by a diverse and dense infaunal community of common North Sea taxa. The most common taxa recorded in the survey area predominantly comprised polychaetes which have all been identified from surveys undertaken in similar North Sea habitats. The most abundant species overall, the amphinomid polychaete *Paramphinome jeffreysii*, which was present in high abundances throughout the site. It is a widely distributed species, thought to be one of the most abundant infaunal taxa of the central and northern North Sea, associated with muddy and sandy sediments (Fugro Survey Limited, unpublished survey reports). The second most abundant species was the opisthobranch mollusc *Cylichnina umbilicata*, which is prevalent throughout European waters including the North Sea occurring within sandy sediments (Parapar, 2003). Other notable species include the spionid polychaete *Spiophanes bombyx* and the paraonid polychaete *Aricidea catherinae*, which are both associated with a variety of sediment types and have worldwide distributions. A breakdown of the fauna present is displayed in Figure 4.8 and Figure 4.9.

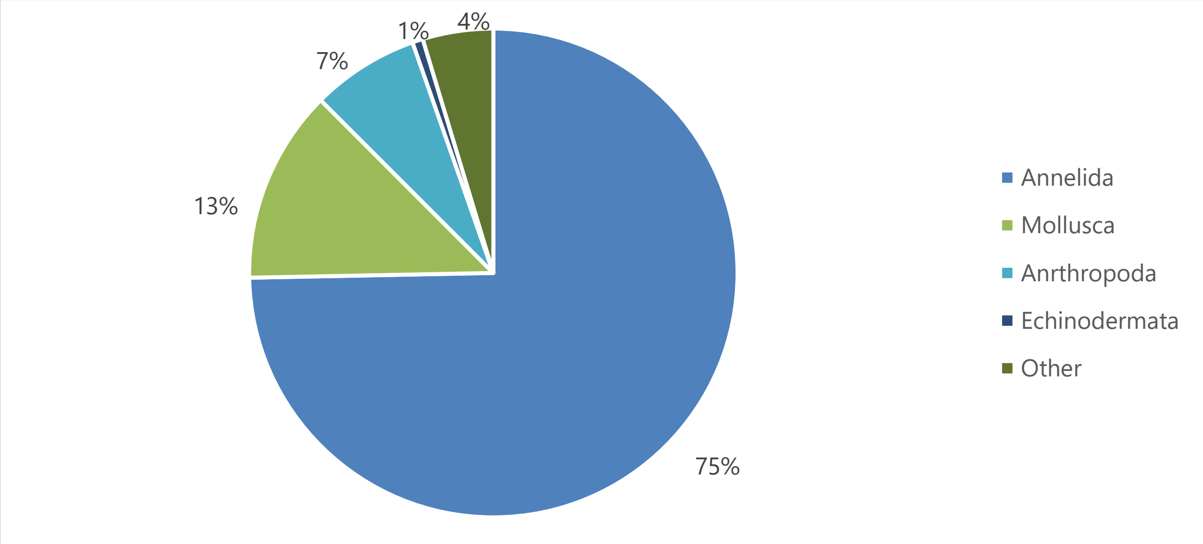


Figure 4.8: Abundance of major taxonomic groups within the Avalon site survey area
Source: Fugro, 2013b.

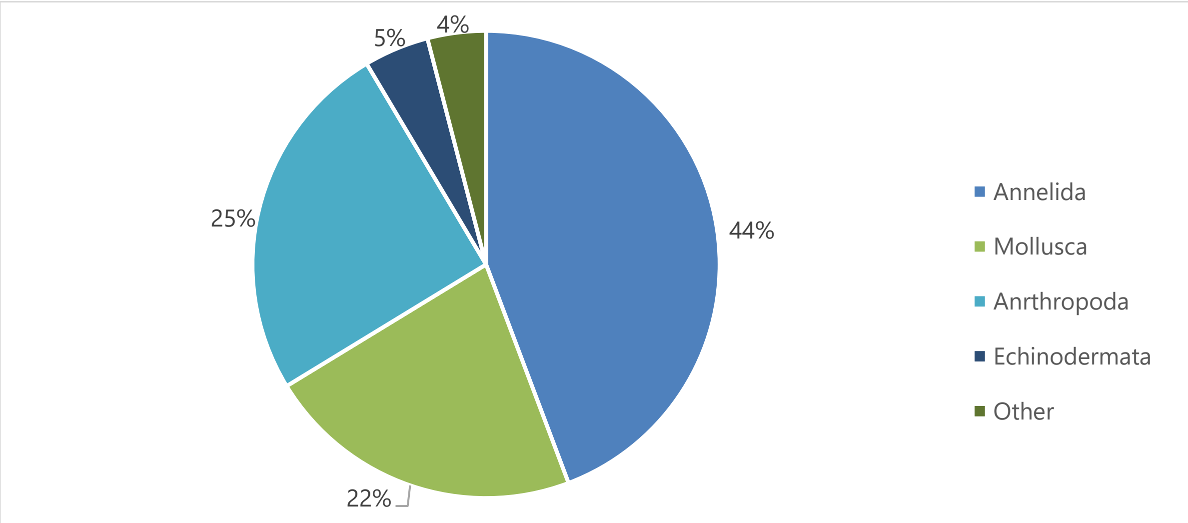


Figure 4.9: Diversity of major taxonomic groups within the Avalon site survey area
Source: Fugro, 2013b.

Juvenile ocean quahog (*Arctica islandica*) were recorded in nearly every grab sample at an average abundance of 3 individuals per 0.1 m^2 at the Avalon field (Fugro, 2013b). The ocean quahog is a long-lived cockle shaped bivalve which is found buried in sandy and muddy sediments ranging from the low intertidal zone down to 400 m (OSPAR, 2009; Section 4.10.2). The ocean quahog has been included on the Convention for the Protection of the Marine Environment and the North-east Atlantic (OSPAR) list of ‘Threatened and/or Declining Habitats and Species’ (OSPAR, 2022), and as Scottish Priority Marine Feature (PMF) (NatureScot, 2022a).

However, the absence of adults and the low density of juveniles suggests that the survey area is unlikely to be of high conservation significance for ocean quahog. One adult ocean quahog individual was identified in a sample during the 2013 site survey however, it was found to be dead. Juvenile ocean quahogs were identified in all but one grab sample, resulting in a total of 52 juveniles recorded during the survey (Fugro, 2013a; 2013b). Juvenile ocean quahogs were also identified at the Ivanhoe and Robb Roy fields which are located approximately 40 km north of the Avalon field (Fugro, 2011a).

4.5. Plankton

Plankton consists of microscopic plants (phytoplankton) and animals (zooplankton), including the larval stages of fish and many bottom living animals which drift with the ocean currents. The abundance of plankton is strongly influenced by factors such as water depth, tidal mixing and temperature stratification which determine the vertical stability of the water column; whilst the distribution of species is affected by salinity, temperature, water flow and the presence of local benthic communities.

During spring, an increase in day length and temperature, coupled with the supply of nutrients released during winter mixing of the water column, results in the rapid growth of the phytoplankton population. This phytoplankton bloom is followed by a similarly rapid increase in the zooplankton population, which prey upon phytoplankton. Zooplankton abundance is typically at its highest between May and September, providing an important source of food for a range of fish species (Johns & Reid, 2001).

The phytoplankton community in the area is dominated by the dinoflagellate genus *Ceratium*, along with *Thalassiosira* spp. and *Chaetoceros* spp diatoms. The zooplankton community is dominated by calanoid copepods, with *Paracalanus*, *Pseudocalanus* and larval stages of *Calanus* also abundant (DECC, 2016). The larger zooplankton, known as megaplankton, includes euphausiids (krill), *Acartia* and decapod larvae are important components of the zooplankton community in the region.

Research has found that there has been a significant decline in primary production in the North Sea over the past 25 years. The warming of the sea surface and reduced riverine nutrient inputs have been found to contribute to the declining levels of primary production. Significant correlations have been identified between changes in primary production and the associated reduction of zooplankton abundance and fish recruitment within the North Sea (Capuzzo et al., 2018). This reduction will have significant consequences for organisms at high tropic levels (BEIS, 2018).

4.6. Fish and Shellfish

The proposed development area will, at times, contain fish stocks of both commercial and non-commercial importance. Adult fish populations are highly dynamic, and it is difficult to define fixed patterns of their presence and distribution. However, fisheries landings data suggest that adult populations of haddock, herring, saithe, monkfish and whiting are commercially caught in this area of the CNS (Marine Scotland, 2022c). Commercially important shellfish populations of *Nephrops* are also present within the general area (Marine Scotland, 2022c). Fishing landings are discussed separately in Section 4.11.1

4.6.1. Spawning and Nursery Grounds

Extensive survey programmes have been used to predict the broad distribution of spawning grounds for a range of commercially important fish and shellfish species in UK waters (Coull et al., 1998). For many of these species, this has been supplemented by more recent data collation and review by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) (Ellis et al., 2012) and Marine Scotland (Aires et al., 2014), the latter with specific reference to the distribution of juvenile individuals. Spawning areas are not rigidly fixed, changing with the prevailing environmental conditions. Therefore, the distribution of spawning grounds given here is based on current knowledge but may be subject to change.

The Avalon Field overlaps with spawning grounds for *Nephrops*, cod, lemon sole, Norway pout and haddock whilst sandeels, sole, sprat and whiting spawn within the wider Avalon Development area (Coull et al., 1998; Ellis et al., 2012). An area of high intensity spawning grounds for Norway pout is considered to be present across much of the Avalon Field Development area (Coull et al., 1998; Ellis et al., 2012) (Figure 4.10 and Figure 4.11). Recent studies have described cod spawning in the area as 'recurrent', with a high mean abundance of spawning in the area (Gonzalez-Irusta & Wright, 2015). Spawning grounds for sprat, plaice, herring and mackerel are located adjacent to the proposed development location. For the majority of species, peak spawning activity occurs between January and June, although several species spawn over a longer period (Table 4.3).

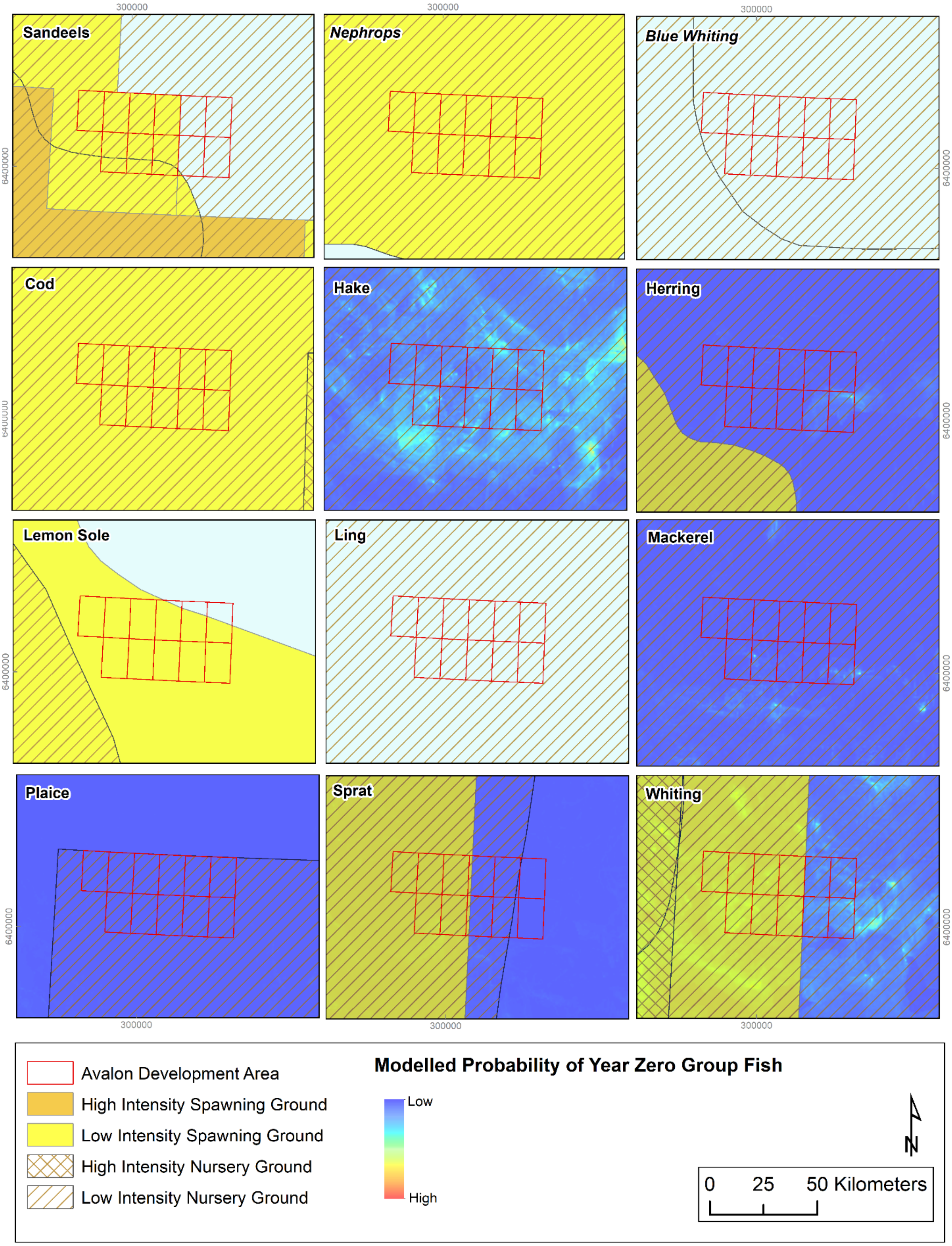
Most fish species release large numbers of eggs directly into the water column. Their spawning grounds cover extensive areas, leaving them less vulnerable to disturbance from point sources. Species such as Norway pout, lemon sole and cod spawn in the water column were the eggs and larvae are dispersed by currents. Norway pout Spawning occurs between January and March mainly over the deeper parts of the North Sea (>100 m), with a peak in spawning occurring between March and April (IUCN, 2021). Cod spawning has been found to be affected by seabed conditions, the species selecting coarse sand and avoiding areas of very high tidal flow (Gonzalez-Irusta and Wright, 2015). Cod spawning occurs from January to April, with peak spawning occurring between February and March (Ellis et al., 2012). Lemon sole spawn between April and September.

Some species, including sandeels and herring, lay eggs directly on or within the seabed, and so are more susceptible to benthic disturbance. Sandeels deposit their eggs on sandy sediments, and once hatched the larvae will drift with the currents for several weeks, after which they settle in areas of sandy seabed. This dependence on sand means that the distribution of juvenile and adult sandeels is restricted by the patchiness of their preferred habitat, leaving the species particularly susceptible to impacts resulting from physical disturbance of the seabed. Sandeels spawn between November and February (Ellis et al., 2012).

Herring are demersal spawners, depositing their sticky eggs on coarse sand, gravel, small stones and rock (Frost & Diele, 2022). Shoals of herring gather on the spawning grounds and spawn simultaneously. Females release eggs in a single batch and the resulting egg carpet may be several layers thick and cover a considerable area. The eggs take about three weeks to hatch depending on the sea temperature (Baretto et al., 2017). Herring spawning in the CNS occurs from August until October.

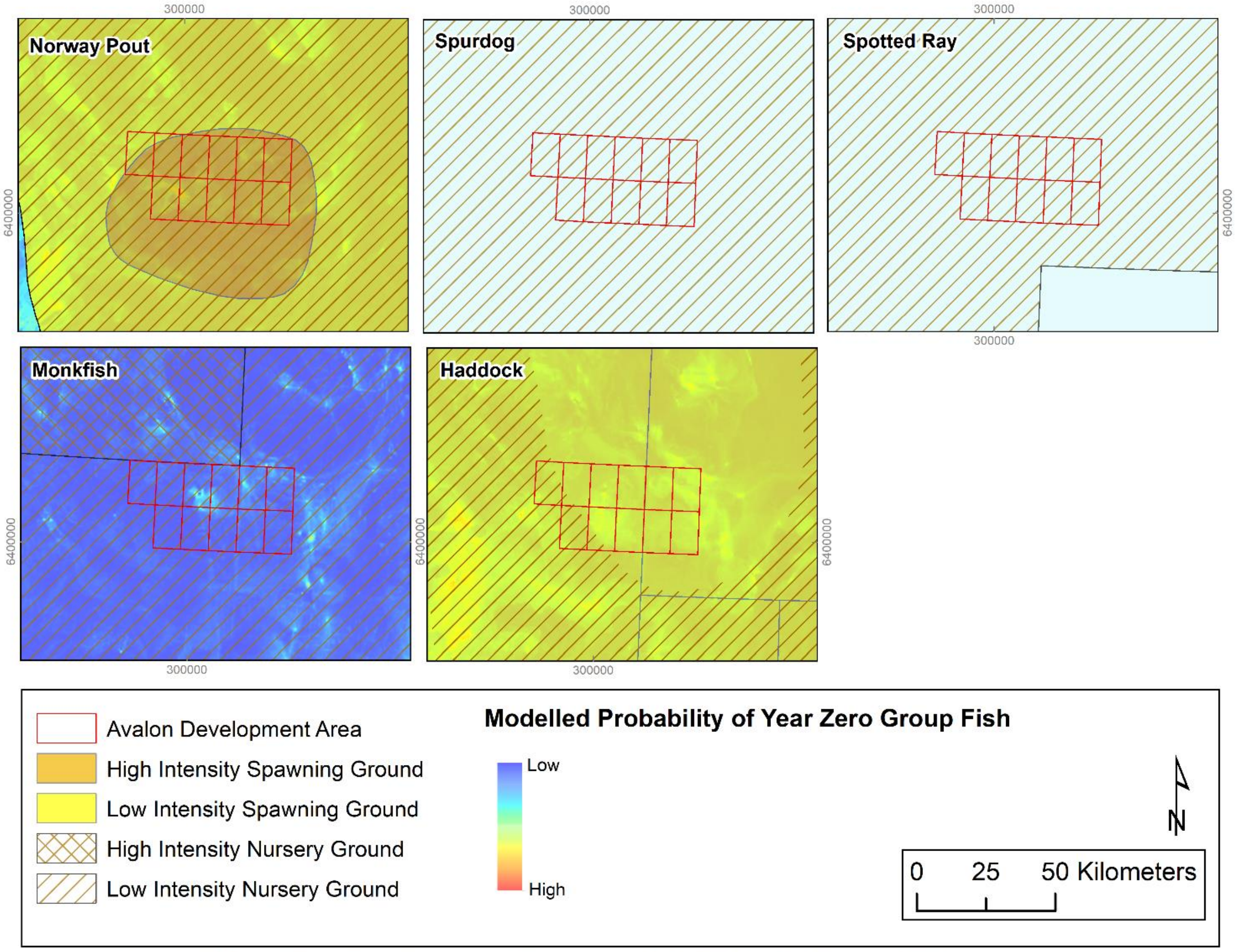
Nephrops spawn in September and carry their eggs under their tails until they hatch in April and May, whereupon larvae develop in the plankton before settling to the seabed (Barreto et al, 2017). After a relatively short pelagic phase juvenile *Nephrops* settle on the bottom and construct a burrow.

The Avalon Field Development lies in a year-round nursery area for blue whiting, cod, haddock, hake, herring, ling, mackerel, monkfish, *Nephrops*, Norway pout, plaice, sandeels, spotted ray, sprat, spurdog and whiting (Coull et al., 1998; Ellis et al., 2012; Table 4.3). Marine Scotland have published a report which provides modelled spatial representations of the predicted distribution of 0 age group fish (fish in the first year of their life) aggregations. These modelled representations are provided in Figure 4.10 and Figure 4.11. There is a low to moderate probability of the development area being utilised by year group 0 haddock, hake, monkfish, Norway pout, herring and whiting (Aires et al., 2014).



Coordinate System: ED 1950 UTM Zone 31N (Esri, 2020). Figure contains data from sources: Coull et al (1998). Ellis et al (2012), Aires et al (2014).

Figure 4.10: Commercially important fish spawning, nursery grounds and year zero group fish in the vicinity of the proposed Avalon Field Development area



Coordinate System: ED 1950 UTM Zone 31N (Esri, 2020). Figure contains data from sources: Coull et al (1998). Ellis et al (2012), Aires et al (2014).

Figure 4.11: Commercially important fish spawning, nursery grounds and year zero group fish in the vicinity of the proposed Avalon Field Development

Table 4.3: Fish Spawning and nursery grounds in the vicinity of proposed Avalon Field Development area

	Fish Spawning and Nursery Grounds											
	J	F	M	A	M	J	J	A	S	O	N	D
Anglerfish/Monk fish	N	N	N	N	N	N	N	N	N	N	N	N
	Anglerfish/monkfish are common in coastal waters around Britain and Ireland, with high abundance on the west coast of Scotland, England and Wales, and the northern, southern and eastern coasts of Ireland. They have been recorded in depths of up to 550 m. Spawning occurs offshore in deep waters between December and May with juveniles often recorded closer to coastal areas.											
Blue Whiting	N	N	N	N	N	N	N	N	N	N	N	N
	Blue whiting (*Micromesistius poutassou*) is a meso-pelagic species, usually found in shoals 30 m to 400 m from the surface in water between 150 m to 3000 m deep. Blue whiting shoals move to the surface at night. They are widely distributed across the north-east Atlantic. The species is very abundant in deep waters to the north of Orkney in February, and spawning takes place between February and April along the continental slope to the west of Scotland at depths of 300 m to 600 m.											
Cod	S/N	S/N	S/N	S/N	N	N	N	N	N	N	N	N
	Cod occur throughout the northern and central areas of the North Sea. Cod spawn all over the North Sea, although there are several areas where spawning is concentrated, particularly in the northern North Sea, the central North Sea around the Dogger Bank and in the southern North Sea and German Bight.											
Hake	N	N	N	N	N	N	N	N	N	N	N	N
	Young hake are frequently found in the Northern North Sea and will remain in the North Sea until they are 2 years old. They will then move into deeper waters. Their distribution has expanded into the central North Sea with hake ages 3+ most commonly found here during the summer months.											
Haddock	N	N	N	N	N	N	N	N	N	N	N	N
	Haddock occur mainly in the northern and central areas of the North Sea but can be found as far south as the Humber estuary. At the beginning of the 20th century, they were also abundant in the southern North Sea. Adults occur mainly at depths ranging from 75-200m.											
Herring	N	N	N	N	N	N	N	N	N	N	N	N
	Herring are found throughout the shelf waters and spawn in relatively shallow, well oxygenated, water in areas of coarse sediment. Sub-populations of North Sea herring spawn at different times of year in localised areas. The proposed development is located within close proximity to the Buchan herring stock spawning grounds, which spawns off the north-east Scottish coast during August and September.											
Lemon Sole				S	S	S	S	S	S			
	Although the centre of distribution of lemon sole is in the coastal waters of northern Scotland and the Orkney and Shetland Islands, they are also found off the north-east coast of England and throughout the central and southern North Sea. Little is known about the spawning habits of lemon sole.											
Ling	N	N	N	N	N	N	N	N	N	N	N	N
	Ling is widespread, but not abundant, in the deeper waters of the continental shelf. Their main spawning grounds occurring in deeper waters to the north and west of the British Isles.											
Mackerel	N	N	N	N	N	N	N	N	N	N	N	N
	Two main stocks of mackerel occur in the north-east Atlantic, the western stock and the North Sea stock. The North Sea stock has been at a very low level for years due to high fishing pressure and poor recruitment. North Sea mackerel overwinter in the deepwater to the east and north of the Shetland Islands. In spring, they migrate south to spawn in the North Sea between May and August.											
Nephrops	S/N	S/N	S/N	S/N	S/N	S/N	S/N	S/N	S/N	S/N	S/N	S/N
	Nephrops are mud burrowing animals and are limited in their distribution by the extent of suitable sediments which range from quite sandy mud to very soft mud. They do not migrate and spend their life in the area in which they settle as larvae. After hatching, the larval stage lasts 6 to 8 weeks, before settlement to the seabed											
Norway Pout	S/N	S/N	S/N	S/N	N	N	N	N	N	N	N	N
	Norway pout spawn in the water column were the eggs and larvae are dispersed by currents. Spawning occurs with high intensity in the development area, usually between the months of January and April.											
Plaice	N	N	N	N	N	N	N	N	N	N	N	N
	Plaice live on mixed substrates at depths up to 200 m, with older individuals generally found in deeper water. Plaice is found in greatest abundance in the southern North Sea. Plaice spawn throughout the shallower parts of the southern North Sea, including the Dogger Bank and the Southern Bight, with spawning taking place between December and March. Sandy, shallow bays on the coasts of England act as important nursery grounds for plaice, with juveniles moving further offshore as they mature.											
Sandeels	N	N	N	N	N	N	N	N	N	N	N	N
	Sandeels are a shoaling species which lie buried in the sand at night and hunt during the day. Spawning occurs throughout the Central and Southern North Sea, but especially near sandy sediments off the coast of northeast England. Spawning usually takes place between November and February.											
Spotted Ray	N	N	N	N	N	N	N	N	N	N	N	N

	Spotted ray live at depths of 100-500 m in soft, sandy substratum, with juveniles often living in shallower areas. Rocky and sandy coastal areas provide nursery grounds for the species with frequent recordings around the entire British coastline, predominantly high in the South towards the English Channel.											
Sprat	N	N	N	N	N	N	N	N	N	N	N	N
	Sprats are usually found in shallow water close to shore, where they can tolerate low salinities. They tend to range in length from 8-12cm and are a short-lived species, the abundance of which is heavily dependent on the strength of the recruiting year class. Important spawning areas in the North Sea include the English east coast and German Blight.											
Spurdog	N	N	N	N	N	N	N	N	N	N	N	N
	Spurdog or the 'spiny dogfish' is a benthopelagic species found in both inshore and offshore environments of the upper continental shelf. They are a viviparous species with complex seasonal migrations. Juveniles are recorded in high numbers in the Northern and Central North Sea, North-west Scotland, Celtic Sea and the northern Irish Sea.											
Whiting	N	N	N	N	N	N	N	N	N	N	N	N
	Although it is one of the most abundant species in the North Sea, information on whiting spawning is limited. Spawning areas are located in the central and southern North Sea and off the coast of Scotland, although other areas may be important. Juveniles can be found throughout the North Sea, particularly off the north-east coast of England.											
Key:	S	Spawning ground (peak spawning shown in **bold**)			N	Nursery area			S/N	Spawning and nursery		

Sources: Coull et al., 1998; DTI, 2001; Ellis et al., 2012; Staby et al, 2018.

Many of the fish species which have been identified within or in the vicinity of the proposed Avalon development have been designated as PMF which are of conservation importance in Scotland's seas (NatureScot, 2022a). These include monkfish, cod, ling, Norway pout, sandeels and whiting. Some of these species have been designated as PMF due to a significant proportion of their population occurring or having a functional role in Scottish seas, not necessarily due to whether they are under threat or in decline.

4.6.2. Sharks, Skates and Rays

There are a number of pelagic shark species found in the waters around the British Isles, several of which occur in the CNS, these include the spotted ray, spiny dogfish and the tope shark.

Both the spiny dogfish and spotted ray have been identified as species which have nursery grounds within the proposed development area (Ellis et al, 2012). The spiny dogfish occur on the continental shelf throughout the North Sea and is widespread within UK waters (Ellis, et al, 2012). They feed on crustaceans, cephalopods and fish. With peak spawning in June and July. The spotted ray is a widespread and relatively abundant skate species which feed on crustaceans, polychaetes and fish. The species spawns between May and July (Ellis et al, 2012).

The proposed Avalon Field Development is within a wider area known to be used by basking, and porbeagle sharks and sandy ray. However, these areas are vast, with all waters surrounding Scotland being considered as areas of known use (Marine Scotland, 2022b).

Many of shark and ray species (basking and porbeagle sharks, spiny dogfish and sandy ray) which have been identified within or in the vicinity of the proposed development have been designated as PMFs (NatureScot, 2022a). These species have also been included on the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2022).

4.6.3. Cephalopods

There are a number of cephalopod species found in the waters around the British Isles, among the most frequently recorded species within the northern and CNS are the long-finned squid, the short-finned squid and bobtail squid (DECC, 2016). Other species may occasionally be encountered in the region. Octopuses also occur waters of the CNS.

Cephalopods are short lived molluscs, characterised by rapid growth rates, and are important predators and prey in oceanic and coastal environments. Cephalopods are frequently seen as a major dietary component for many marine mammals and are landed from the area of the proposed Avalon Field Development (Marine Scotland, 2022c). The global cephalopod population has expanded over the past six decades (Doubleday et al., 2017), with fast, adaptive cephalopod species increasing in abundance over a range of habitats (BEIS,2018).

4.7. Marine Mammals

4.7.1. Whales, Dolphins and Porpoises

All cetaceans that occur in UK waters are protected under the EU Habitats Directive, transposed into UK law by the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) and

The Conservation of Offshore Marine Habitats and Species Regulations 2017. Under these regulations, it is an offence to deliberately capture, kill or recklessly disturb cetaceans. All cetacean species are listed on Annex IV of the Habitats Directive, whereby measures of protection are applied across their entire natural range within the EU. Bottlenose dolphin and harbour porpoise are also listed on Annex II of the Habitats Directive, whereby core habitat areas receive protection via Natura 2000 network designation.

The waters within the vicinity of the current proposals support a number of marine mammal populations, whose distributions are governed primarily by water depth and availability of preferred food sources. Harbour porpoise and white-beaked dolphin are the most widespread and frequently encountered marine mammal species, occurring regularly throughout most of the year. Minke whales are regularly recorded as a frequent seasonal visitor. Atlantic white sided dolphin, killer whales, Risso's dolphin and long finned pilot whale are also occasional visitors (DECC, 2016).

The distribution of cetaceans within the CNS are summarised in Table 4.4.

Table 4.4: Distribution and Abundance of Whales, Dolphins and Porpoises in the Central North Sea

Species	Cetacean Distribution and Abundance
Harbour porpoise	The harbour porpoise is common in shelf waters of the northern and central North Sea. The species is the most abundant cetacean in the whole of the North Sea, but peak sightings vary considerably between sites. This species occurs in very small groups of up to three individuals.
White beaked dolphin	White-beaked dolphins occur only in the North Atlantic and are widely distributed year-round on the UKCS. Their distribution seems to be restricted by temperature, and they are seen particularly in the cooler waters of the western central and northern North Sea. They are most frequently observed between June and October. White-beaked dolphins are generally found in groups of less than ten individuals, although they have been observed in larger aggregations.
White sided dolphin	Atlantic white sided dolphins are found only in the North Atlantic, sharing most of their range with the white sided dolphin. They tend to occur more frequently in waters to the north-west of the UK and Ireland. This species is rare in the central and north-eastern North Sea. White sided dolphins tend to form large groups of tens to hundreds of individuals.
Risso's dolphin	Risso's dolphins form groups of up to approximately ten individuals. Although often regarded as an offshore species preferring deeper continental slope waters, most sightings around Scotland have occurred over the shelf. There have been few records of the species in the central North Sea. Most sightings in the North Sea occur between July and August.
Minke whale	Minke whales appear to move into the North Sea at the beginning of May and are present until October. They occur throughout the northern and central North Sea, more frequently found in its western side. Minke whales are found mainly on coastal waters and on the continental shelf in water depths up to 200 m. These whales are generally seen singly or in pairs but can form aggregations of up to fifteen individuals when feeding.
Killer whale	This species appears to be present in the North Sea all year round, but sightings are rarer in the central North Sea. The majority of UK sightings have been of individuals or groups of less than eight animals.
Long finned pilot whale	Long-finned pilot whales occur mainly along the continental shelf slope, particularly around the 1000 m isobath, therefore, are not very common in the central North Sea.

Sources: BODC, 1998; Hammond et al., 2003; Marine Scotland, 2022**b**; Moscrop and Swift, 1999; Pollock et al, 2000, Reid et al., 2003; Swift et al., 2002; Taylor and Reid, 2001; DECC, 2016; Charif and Clark, 2000; Hammond et al, 2017, Waggitt et al., 2019, and NPWS, 2009.

Table 4.5 summarises cetaceans which have been observed directly within and around the proposed Avalon Field Development area.

Table 4.5: Distribution of cetaceans in the vicinity of the proposed Avalon Field Development

		Cetacean Presence											
		J	F	M	A	M	J	J	A	S	O	N	D
Development	Minke whale					L		L	L				
	White-beaked dolphin		L					M	L	L		L	L
	White-sided dolphin							L	L				
	Risso's dolphin							L					
	Harbour porpoise		L			L		L	L	L			

Key: (blank) No animals; L Low; M Moderate; H High; VH Very high

Sources: BODC, 1998.

Information on the feeding ecology of cetaceans in UK waters is limited, with information primarily drawn from analysis of the stomach contents of stranded or bycaught individuals, to a lesser degree from stable isotopic analyses of predator and prey tissues and from direct observations (DECC, 2016). The harbour porpoise is thought to be an opportunistic feeder, feeding mainly on fish found on or near to the seabed. Risso's dolphins are generally thought to feed on cephalopods. White-beaked dolphins have been recorded taking whiting and other gadoids, sandeels, herring and octopus. Atlantic white-sided dolphins are thought to consume a diet of pelagic species such as herring and mackerel and squid. Minke whales feed on a variety of fish, with sandeels thought to be an important prey species, together with herring, haddock and cod.

Many of the cetacean species which have been identified within, or in the vicinity of, the proposed Avalon Field Development have been designated as PMFs. These include the minke whale, white-beaked, Atlantic white-sided and Risso's, dolphins, as well as harbour porpoise (NatureScot, 2022a).

4.7.2. Seals

Two species of seal, common and grey, are resident in Scottish waters. These animals are typically found in coastal waters shallower than 200 m and are present in internationally important numbers around Shetland and Orkney. The grey and common seal are listed under Annex II an IV of the EU Habitats Directive (JNCC, 2022a). Both the common and grey seal have been designated as Priority Marine Features (PMF) in Scottish waters (NatureScot, 2022a).

4.7.2.1. Grey Seal

Approximately 35 % of the global and 82 % of the European population of grey seals breed in the UK. Of these, 76 % breed in Scotland (SCOS, 2021). They use outlying islands and remote coastlines as moulting, pupping and general haul-out sites. A number of grey seal haul out and breeding sites are distributed around the Shetland and Orkney Islands (Marine Scotland, 2022b).

Grey seals spend a high proportion of their time ashore during their pupping and moulting seasons (Hammond et al., 2001). Grey seals pup from September to late November and then moult from December to April (SCOS, 2021). Satellite tracking has shown that grey seal foraging trips can extend several hundred kilometres offshore. However, most foraging tends to occur within 100 km of a haul out site and individual seals based at a particular haul-out site will often make repeated trips to the same offshore locations using prominent corridors (SCOS, 2021; Jones et al, 2015). Grey seals are generalist feeders, with diets primarily comprising sandeels, gadoids and flatfish. It is estimated that grey seals spent 12 % of their time at distances greater than 50 km from the coast (Jones et al, 2015). This is also demonstrated by the estimated at-sea usage data presented by the Sea Mammal Research Unit (SMRU) maps for grey seal movements (SMRU and Marine Scotland, 2017). Grey seals are not expected to be encountered within the proposed development location. Lybster, Wick on the north-east coast of Scotland is the closest grey seal pupping site to the proposed development. The closest grey sea haul-out location is Ythan river mouth on the Aberdeenshire coast approximately 135 km west of the Avalon Field.

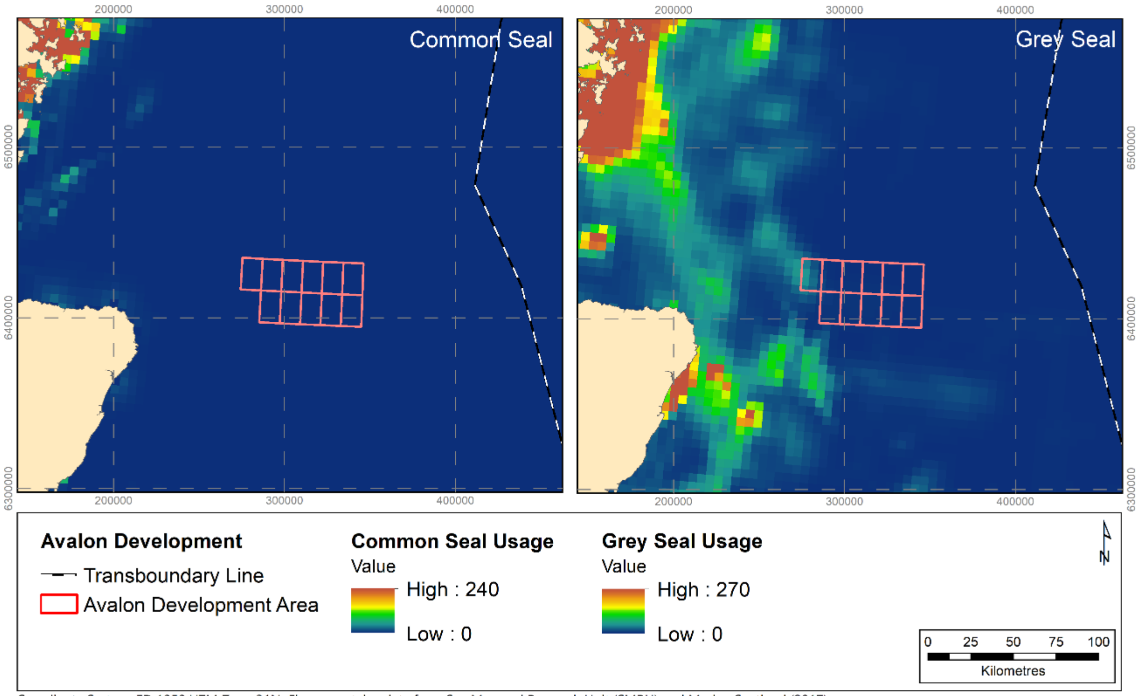
4.7.2.2. Common Seal

The UK is home to approximately 32 % of the European population of common seals (SCOS, 2021). Haul-out, breeding and moulting sites are typically situated in sheltered estuaries and on sandbanks, but they also use rocky areas. Common seals are widely distributed around the Orkney and Shetland Islands (JNCC, 2022a). The Dornoch Firth and Morrich More Special Area of Conservation (SAC) in the north-east of Scotland lies approximately 240 km west of the Avalon Field and is the closest site of importance for common seals to the Avalon Field Development.

Common seals spend a high proportion of time ashore during the pupping and moulting seasons from June to August (SCOS, 2021). During the pupping season hauled-out groups tend to be smaller and more dispersed (Duck, 2007). In contrast to grey seals, common seal pups are capable of swimming almost immediately after birth (SCOS, 2008).

Telemetry studies of common seals have observed that foraging trips are generally within 40 km to 50 km of haul-out sites. Although longer trips of over 200 km have been observed, these were between haul-out sites, rather than to offshore foraging areas (SMRU, 2013). Common seals have a varied diet comprising sandeels, gadoids, herring, sprat, flatfish, octopus and squid. It is estimated that common seals spend only 3 % of their time at greater distances than 50 km form the coast (Jones et al., 2015). This is also demonstrated in Figure 4.12 by estimated at-sea usage data presented by SMRU maps for common seal movements (SMRU and Marine Scotland, 2017). These maps show the predicted average number of seals in each 5 km × 5 km grid cell at any point in time. As with grey seals, common seals were rarely sighted in the waters around the proposed development location, hence they are considered unlikely to be present.

There has been a decline in common seal populations recorded in the Moray Firth, the North Coast and Orkney and the east coast of Scotland in recent years (Jones et al., 2015; SCOS, 2021). This may be related to interactions with grey seals, outbreaks of Phocine Distemper Virus (PDV) and exposure to toxins from harmful algae (SCOS, 2021 and 2008).



Coordinate System: ED 1950 UTM Zone 31N Figure contains data from Sea Mammal Research Unit (SMRU) and Marine Scotland (2017)

Figure 4.12: At-sea usage of grey and common seals in the vicinity of the proposed Avalon Field Development (Sea Mammal Research Unit (SMRU) and Marine Scotland, 2017).

4.8. Seabirds

4.8.1. Abundance and Distribution

Seabirds found in offshore areas around the UK include members of several families, most notably the petrels and shearwaters, gannets, gulls, skuas and auks (Table 4.6). These birds breed on the coasts of the UK, but frequently feed far offshore. In winter, they become less attached to their nesting sites and travel considerable distances in search of food. Seabirds are present throughout the year in the CNS, with mostly low to moderate densities found in the proposed development area. However, some species, e.g., guillemot, kittiwake, and fulmar, occur in high densities in the proposed development area throughout the year. Offshore surveys suggest that the area is of particular importance for a variety of seabirds from spring to autumn periods.

Seabirds tend to exhibit a more inshore distribution during the breeding season (March to June) as they are constrained by the location of their colonies. However, juvenile seabirds are not restricted in their distribution during this period and may be more widely dispersed offshore (DTI, 2002). Once breeding is complete, seabirds disperse into areas further offshore, although the extent to which they disperse varies between species.

Seabird abundance tends to decrease with increasing distance from shore, and their distribution becomes increasingly patchy in relation to many oceanographic features. The availability and distribution of prey, however, is considered to be the most important factor driving seabird distribution, particularly around colonies during the breeding season. The various seabird families also differ in the total amount of time they spend at sea, the distances they travel and how they behave when at sea, both during and outside the breeding season.

Fulmars are found in high densities from July to September, whereas gannets in January. Kittiwakes demonstrate high presence in August and September, whereas guillemots from August to November. A study by Woodward et al. (2019) discussed foraging ranges for common seabird species during the breeding season. The guillemot during breeding season has a mean foraging range of 37.8 ± 32.3 (5) km, the razorbill 23.7 ± 7.5 (2) km, the kittiwake 24.8 ± 12.1(8) km whilst the puffin has a foraging range of 4 (1) km. The gannet, although in low densities throughout the year except for January, has a high breeding season foraging range of 92.5 ± 59.9 (8) km.

It is important to note that not all the foraging ranges were formulated with high confidence, for example, the puffin data has been categorised as having low confidence, whereas all the other species above are said to hold moderate-high confidence. Also, there was no data provided for some moderate-highly present species, e.g., the fulmar and the little auk. With that said, these species hold the potential of being further present at the vicinity of the proposed development due to the extended ranges of those already in moderate-high presence within adjacent areas/blocks. Taking this into consideration, the associated impacts will be discussed further in Section 11.

Table 4.6: Density of seabirds in the vicinity of the Avalon Field Development

Species	Seabird Presence											
	J	F	M	A	M	J	J	A	S	O	N	D
Fulmar	L	L	L	M	M	M	H	H	H	M	L	M
	Wintering densities are relatively low throughout the North Sea, due to the widespread dispersion of birds. Numbers increase in the central and southern North Sea during the breeding season, leading to a peak in August.											
Sooty shearwater								L	L			
	Sooty Shearwater are recorded on passage around UK coastlines between July and October.											
Manx shearwater		L					L	L				
	Manx shearwaters are also recorded less frequently than fulmars in the North Sea. They breed in small numbers in Orkney and Shetland and are present in low numbers in the northern North Sea between May and October.											
European storm petrel							L	L	L			
	Storm petrels are present at and around the breeding colonies from May to September. Migrants best looked for in September and October as they journey south to waters off South Africa.											
Gannet	H	L	L	L	L	L	L	L	L		L	L
	Two mainland colonies at Bempton and Troup Head, Scotland											
Great skua				L	L	L	L	L	L			
	The great skua is recorded offshore throughout the North Sea. Pairs of great skuas breed around the North Sea, although mainly in Orkney and Shetland, where distribution is centred during the breeding season.											
Lesser black-backed gull				L	L	L	L	L	L	L		
	Although lesser black-backed gulls are distributed throughout the North Sea at all times of year, they are principally summer visitors, travelling through to breeding colonies around the North Sea.											
Herring gull	L	L	L	L	L	L	L	L	L	L	L	L
	Herring gulls breed on nearly all North Sea coasts, with the exception of the Wash. Densities in offshore central North Sea are highest from October to March, and very low from April to October. These gulls are relatively sedentary.											
Great black-backed gull	L	L		L	L		L	L	L		L	
	The great black-backed gull breeds on northern coasts. Although distributed throughout the North Sea, numbers are highest off the north-eastern coast of England. The highest densities are recorded at sea between September and April.											
Kittiwake		L	M	M	M	M	M	H	H	M	M	L
	During the breeding season kittiwakes spend their time in coastal breeding companies before spending the winter months out at sea.											
Arctic tern							M		L			
	Arctic terns can best be seen breeding on islands such as the Farne Islands in Northumberland or on the Northern Isles where the greatest breeding densities occur. They will be seen more frequently at sea during the autumn as they head south											
Guillemot	L	M	M	L	M	L	M	H	H	H	H	
	Guillemot are widespread on the coastal cliffs of Scotland. During the winter months they will spend the majority of time offshore, only returning to inshore areas after gales.											
Razorbill		L		L	L	L	L	L	M			
	Razorbill are present on breeding cliffs and coastal colonies all year. With some travel to offshore areas during the winter months.											
Little auk		M							L	L	M	
	Little Auks are often driven further offshore in the Autumn due to stormy weather. They will then return to the coastal colonies all around the UK during the breeding season.											
Puffin	L	L	M		L	L	L	M	M	L	L	
	Puffins are mainly found in breeding colonies at Bempton Cliffs, South Stack reserves, the Farne Islands and Coquet Island, the Isle of May (off the Fife coast) and the Shetland and Orkney Islands.											
Leach's Storm Petrel									L			
	94 % of the UK population breeds on four islands in the St Kilda archipelago (Western Isles), with the remainder on the Flannan Isles (Western Isles), three other islands in the Western Isles and two islands in Shetland.											
Pomarine Skua								L	L	L	L	
	In spring, pomarine skuas are found on the English south coast, Outer Hebrides and Shetland. In autumn, they are found on North Sea coasts.											
Arctic Skua								L	L	L		
	The Arctic skua is limited to breeding in north and west Scotland, at the southern extremity of its circumpolar, high latitude breeding range.											
Long-tailed Skua								L	L	L	L	
	It is a passage migrant to the UK, breeding in the high Arctic											

Species	Seabird Presence											
	J	F	M	A	M	J	J	A	S	O	N	D
Little gull								L	L	L	L	
	Little gulls can be seen around UK coasts from July to April. In late summer and autumn, birds are mostly found between Tayside and Yorkshire, with smaller numbers further south. In spring, birds can be seen around the Irish Sea with concentrations in places like the Alt estuary.											
Common gull	L	L					L	L	L	L	L	L
	Their breeding distribution is virtually confined to Scotland and Northern Ireland in the UK.											
Glaucous gull										L	L	
	Scarce winter visitor to entire UK & Irish coastlines; with largest numbers seen in Scotland.											
Sandwich tern							L					
	The species is distributed widely but patchily around the coasts of the British Isles, in low-lying offshore islands, islets in bays or brackish lagoons, spits or remote mainland dunes.											
Common tern							L					
	The species breeds around much of the British Isles coastline plus inland on lakes, reservoirs and gravel pits along the large river valleys of SE and Central England, notably the Thames, Ouse, Humber and Trent, and along rivers in SE Scotland.											
Black guillemot								L				
	Approximately 50 %of the UK's population breeds around the Northern Isles, with the remainder confined mainly to the coasts and islands of north and west Scotland.											
Grey phalarope	L	L	L	L	L	L	L	L	L	L	L	L
	This Arctic-breeding wader sometimes comes to the coasts of the UK after storms.											

Key:		No birds	L	Low	M	Moderate	H	High	VH	Very high

Sources: RSPB, 2022a; 2022b, 2022c; 2022d; Wakefield *et al*., 2017; Mitchell *et al*., 2004; Ratcliffe, 2004; BODC, 1998

4.9. Coastal Habitats

Oil spill modelling has been conducted to inform the assessment of potential impacts from hydrocarbon spills associated with the proposed Avalon Field Development (see Section 11). This modelling indicates that under typical climactic conditions, a hydrocarbon spill could reach the coastlines of the Scottish mainland, Shetland Islands, Orkney Islands, northeast England, Norway, Sweden, Denmark and Germany. The characteristics of the coastal habitats encountered in these areas are discussed below.

The coastlines of north-east and east Scotland, the Northern Isles, north-east England, Norway, Sweden, Demark and Germany are characterised by diverse and extensive cliff habitats and rocky shores. These are interspersed with more sheltered areas where sandy beaches are present. Small areas of mud flats and salt marshes are present in estuaries and sheltered inlets. The characteristic coastal habitats encountered in these areas identified are discussed below.

The north-east coast of mainland Scotland, over 116 km west of the Avalon field, is characterised by diverse and extensive cliff habitats, with headlands, caves, blow-holes and stacks (Dargie, 1996). These cliffs are interspersed with more sheltered areas such as the inner Moray Firth, where sandy beaches are present, backed by extensive sand dune systems and machair. A few small mudflats and saltmarshes are also present along the Grampian coast (Hill, 1996).

The extensive and diverse stretch of eastern coastline of Scotland and north-east coastline of England is characterised by sediment dominated embayments, numerous saltmarshes interspersed along the coast, and a series of intertidal caves (Magic, 2019). Several large river estuaries support large areas of intertidal mudflats and sandflats (Magic, 2019). Rocky habitats are present along the Fife, Angus, Northumberland and Yorkshire coasts, which features steep cliffs and a number of rocky islands. Beaches and sand dunes are also present along the coastlines of Fife, Angus and Northumberland (Magic, 2019).

Much of the Shetland shorelines are characterised by exposed rocky shores consisting of bedrock and boulders and by sea cliffs, which have little or no intertidal zone (MAGIC, 2019). On both the largest island, the mainland, and the surrounding islands, these areas are interspersed with more sheltered bays and inlets (voes) where sedimentary shores are more common. Both sandy and muddy areas are found in these voes. Small areas of shingle backed by coastal lagoons are also present. However, soft sediment areas are rare overall with sandy beaches making up less than 5% of the total coastline (Gammack and Richardson, 1980). There are no major rivers on Shetland and therefore areas of estuarine mudflats and sandflats are also uncommon.

The coastline of the Orkney archipelago is more diverse than that of Shetland and is generally characterised by a low profile and gentle gradient. However, exposed steep sandstone cliffs and stacks dominate the Atlantic coast of the largest Islands, the mainland, and the island of Hoy. Away from this high energy environment, there are numerous sandy shores backed by dunes and machair (heathland) on the main island. The enclosed waters of Scapa Flow are largely surrounded by bedrock and rocky shorelines with some areas of gravel, along with muddy shores in very sheltered inlets and embayments (MAGIC, 2019). The group of islands to the north of the mainland have complex coastlines of rocky headlands and shallow sheltered bays supporting stable, sandy shores. Some areas of shingle, forming coastal lagoons, are also present (University of Aberdeen and Hartley Anderson, 2004). Finally, the islands and skerries within the Pentland Firth to the south are fringed by cliffs and rocky shorelines.

The Avalon field is also located around 310 km from the west coast of Norway. This part of the Norwegian coastline is dominated by a network of deep, steep-sided fjords, dotted by numerous small, rocky islands and islets. Coastal habitats are therefore characterised by steep cliffs falling straight into deep water with no significant intertidal zone and by rocky shores (Norwegian Environment Agency, 2022). Sand and mud habitats are restricted to sheltered areas away from strong tides. Mudflats and saltmarshes are very limited and are restricted to the inner reaches of the fjords (Marthinsen et al., 1992).

Oil spill modelling (Section 12) showed a small potential for a spill from the proposed development to affect more distant shorelines, in Denmark, Sweden and Germany. The coastline of north-west Denmark supports wetlands habitats found in a series of large inlets and brackish lagoons, interspersed with stretches of sandy beaches (Birdlife International, 2022). The west coast of Sweden is characterised by a large number of rocky islands, interspersed with sandy beaches (EMODnet, 2022a). The German coastline is dominated by the Wadden Sea is characterised by mudflats, with a number of islands.

In high energy, rocky environments any oil pollution would be removed naturally to some extent by the constant wave action. However, oiling of exposed rocky shorelines can cause high levels of invertebrate mortality, resulting in dramatic changes to the structure of intertidal communities. Recruitment of fast breeding intertidal organisms from surrounding areas allows for recovery to begin relatively quickly. In more sheltered rocky areas, the lower wave energy means that oil and associated effects will persist for longer.

In exposed, sandy areas the movement of sediments is very abrasive, meaning few animals can survive. The movement of this sand, and the larger gaps between the particles, allows oil to penetrate into the sediment. However, if contaminated by light oils like diesel, the sediments may clean themselves relatively quickly as they move over each other and are washed by the surf. They are, therefore, seen as less sensitive to oil pollution than finer sediments, although they are often of importance to tourism and recreation.

The effects of oil spills on the shoreline are more severe in sheltered areas with fine sediments. Recovery times tend to be longer in these sheltered areas, due to the persistence of the oil, particularly if it penetrates into the sediment. Although oil, particularly heavier fractions, does not readily penetrate fine sediments, where it does the death of invertebrates in the sediment will remove natural pathways for oxygen penetration. The resultant anoxic conditions in the sub-surface layers mean that the oil becomes trapped in the sediments where it cannot be degraded or dispersed.

Muddy sediments such as those found in estuarine flats and very sheltered areas are also rich in organic matter, supporting large numbers of invertebrates which form a valuable food source for juvenile fish and migratory birds. Long term depletion in the animals found within the sediment may have an adverse effect on the species which use the mudflats as feeding grounds.

4.10. Protected Sites and Sensitive Habitats

4.10.1. Coastal Conservation Areas

There are numerous protected sites along the Scottish coastline (Figure 4.13). These include internationally designated Ramsar Sites (internationally important wetlands of importance, especially for waterfowl), Special Protection Areas (SPAs) and Important Bird Areas (IBAs) (protecting rare and vulnerable species of wild birds), and SACs (EC Directive (92/43/EEC) for the Conservation of Natural Habitats and Wild Flora and Fauna 1992 (The Habitats Directive)). There are also numerous nationally designated sites, including Sites of Special Scientific Interest (SSSIs).

The north-east coast of Scotland is of international ornithological significance, particularly as seabird breeding sites, and as such many coastal sites on the islands are designated as SPAs and IBAs (Figure 4.13). The Ythan Estuary and Meikle Loch and the Montrose Basin are also classified as a Ramsar sites (Ramsar, 2022). The nearest SPA to the Avalon Field Development is the Buchan Ness to Collieston coast SPA is designated as a SPA for its breeding populations of fulmar, guillemot, herring gull and kittiwake. Inshore waters adjacent to seabird colonies are used heavily by seabirds during the breeding season; this has been reflected in the recent seaward extension to breeding colony SPAs. Several SPAs, including the Ythan Eastuary, Sands of Forvie and Meikle Loch have been extended by up to 2 km (JNCC, 2022a). Some SPAs have also been selected for the presence of rare divers and overwintering waders which are concentrated near to shore or on the shoreline.

There are also a number of SACs on the north-east coast of Scotland designated for habitats and species (Figure 4.13). Important habitats which are qualifying reasons for the designation of SACs include vegetated sea cliffs at Buchan Ness to Collieston, shifting dunes at Sands of Forvie, estuaries, sandbanks, mudflats, sandflats and common seal of the Firth of Tay and Eden Estuary (JNCC, 2022b). A SAC has also been established for bottlenose dolphins in the Moray Firth (JNCC, 2022b).

Numerous SSSIs, the UK's main national nature conservation designation, have also been designated throughout the north-east coast of Scotland. Non-statutory sites include several sites owned or managed by the Royal Society for the Protection of Birds (RSPB) and the Scottish Wildlife Trust (RSPB, 2022; Scottish Wildlife Trust, 2022).

A number of candidate Emerald Network conservation sites have been designated along the Norwegian coastline closest to the proposed development for vulnerable or rare habitats and species (Norwegian Environment Agency, 2022). There are also three Ramsar sites and four IBAs designated along the south-west coast of Norway and numerous Ramsar sites and IBAs along the coasts of Denmark, Germany and Sweden (Figure 4.13; Ramsar, 2022; Birdlife International, 2022).

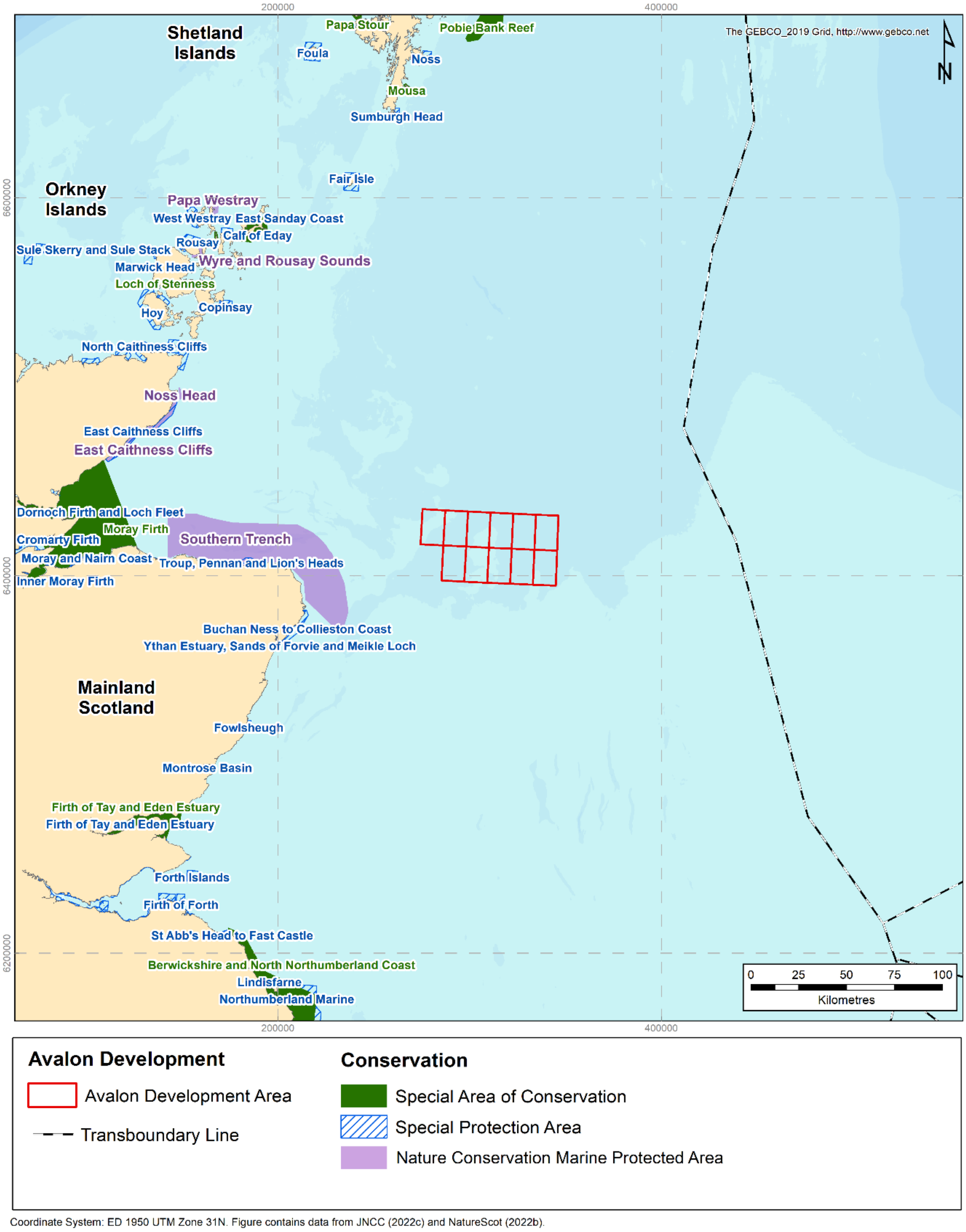


Figure 4.13: Coastal conservation sites

4.10.2. Offshore Conservation Areas

The Marine (Scotland) Act 2010 and the UK Marine and Coastal Access Act 2009 provide for the designation of Nature Conservation Marine Protected Areas (NCMPA) in Scottish waters.

Figure 4.14 illustrates the offshore conservation sites located around the proposed Avalon Field Development area.

The proposed development is located within a network of NCMPAs, the closest is the Turbot Bank NCMPA which lies approximately 24 km to the south-west. This NCMPA has been designated for sandeels (JNCC, 2020). Table 4.7 describes the NCMPAs within the vicinity of the Avalon Field Development area.

The conservation objective for these NCMPAs is to conserve the features and other protected habitats in a favourable condition. The UK Marine and Coastal Access Act 2009 requires fisheries management measures to be taken and Marine Conservation Orders (MCO)s to ensure that achievement of the conservation objectives of the offshore NCMPA's are met. Currently there are no fisheries management measures or MCOs in the vicinity of the Avalon Field Development. However, the JNCC consider that potential sandeel fisheries may require to be regulated at the Turbot Bank NCMPA to ensure that the protected feature remains in a favourable condition (JNCC, 2020).

NCMPAs have been selected to protect a range of PMFs. These features incorporate habitats and species included on the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2022), in addition to those included in the UK Biodiversity Action Plan (UKBAP) Priority List, and the Scottish Biodiversity List. PMFs most relevant for the proposed Avalon Field Development are habitat PMFs, offshore deep-sea muds and burrowed mud and species PMF ocean quahog aggregations (NatureScot, 2022a). UKBAP habitats potentially include 'subtidal sands and gravel'. The presence of 'Offshore deep-sea muds' might also be indicative of the 'Sea pen and burrowing megafauna communities' which is on the OSPAR list of threatened and/or declining species and habitats (OSPAR, 2022) and it's a designated feature in the Central Fladen NCMPA 92 km north of the proposals.

As previously described, the ocean quahog (*Arctica islandica*) is a long-lived species which is found buried in sandy and muddy sediments ranging from the low intertidal zone down to 400 m (OSPAR, 2009). Ocean quahog aggregations are found within the East of Gannet and Montrose fields and Norwegian Boundary Sediment Plain NCMPA, both within 48.5 km from the proposed development. The 2013 habitat assessment within the proposed development location identified one dead adult ocean quahog. However, juveniles were identified in all but one grab sample (Fugro, 2013a).

Offshore SACs are designated to protect fully marine habitats situated beyond the 12 nautical mile (nm) limit of UK territorial waters. The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended) apply the requirements of the European Habitats Directive and Wild Birds Directive to oil and gas activities on the entire UKCS, including within the 12 nm territorial limit. Annex I of the Habitats Directive lists three habitat types that are most likely to occur in offshore waters and be eligible for designation as offshore SAC:

- Submarine structures made by leaking gases (pockmarks);
- Reefs (bedrock, stony or biogenic);
- Sandbanks that are slightly covered by water all the time.

As a result, the proposed development area is surrounded by a range of offshore protected areas designated at European level for these important habitats, the development does not lie within any protected areas. The closest offshore SAC to the proposed development is the Scanner Pockmark SAC, located approximately 44 km north-east of the proposed development. The SAC was designated for submarine structures made by leaking gases (JNCC, 2018b; Figure 4.14 and Table 4.7).

In addition to these protected areas, the Joint Nature Conservation Committee (JNCC) has identified areas where Annex I habitats may be present. Of the three habitat types most likely to occur in UK offshore waters (reefs, sandbanks and pockmarks), submarine structures made by leaking gases are most common in the area surrounding the proposed development.

At present, there are no designated Annex I habitats within the Avalon Field Development. However, some of the UKCS Blocks within which the optional gas import/export pipeline may transit through have areas of potential submarine structures made by leaking gases (JNCC, 2018a, Figure 4.5). The 2013 site survey investigated three pockmarks within the survey area, to identify any possible methane derived authigenic carbonate (MDAC) habitats. The survey found no evidence for MDAC at any location, following examination of SSS data and review of photographic data.

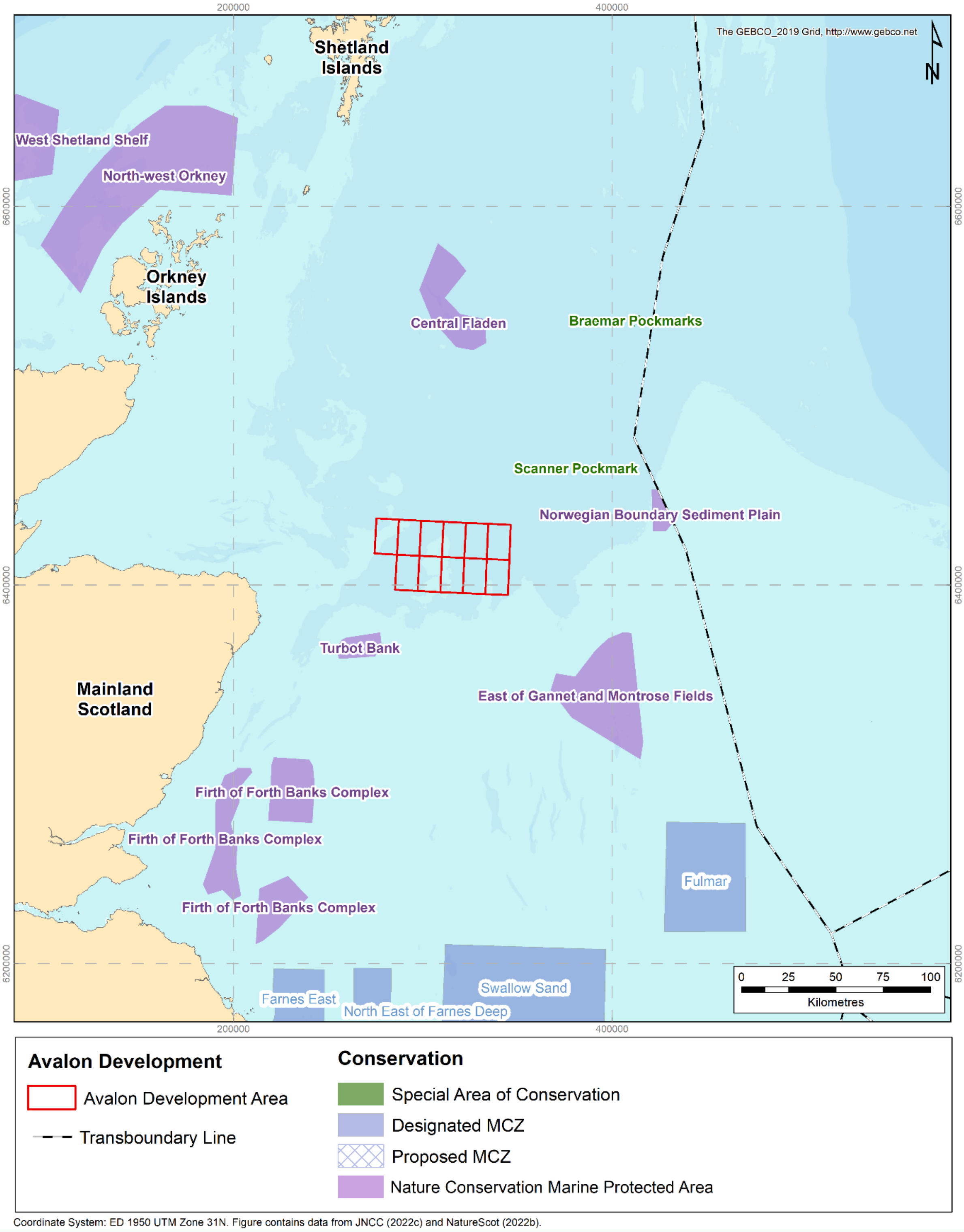


Figure 4.14: Offshore conservation sites

Table 4.7: Offshore Conservation Areas Within the Vicinity of the Avalon Field Development

Type	Protected Area	Protected Species/Habitat	Distance to Avalon [km]
NCMPA	Turbot Bank	▪ Sandeels.	24.5
NCMPA	East of Gannet and Montrose fields	▪ Offshore deep-sea muds; ▪ Ocean quahog aggregations (including sands and gravels as their supporting habitat)	48.5
NCMPA	Norwegian Boundary Sediment Plain	▪ Ocean quahog aggregations (including sands and gravels as their supporting habitat).	74.5
NCMPA	Central Fladen	▪ Burrowed mud (sea pens and burrowing megafauna with tall sea pen components); ▪ Sub-glacial tunnel valley representative of the Fladden deeps key geodiversity area.	92
NCMPA	Firth of Forth Banks complex	▪ Ocean quahog aggregations; ▪ Offshore subtidal sands and gravels; ▪ Shelf banks and mounds; ▪ Moraines representative of the Wee Bankie key geodiversity area.	101
Proposed NCMPA	Southern Trench	▪ Burrowed mud; ▪ Fronts; ▪ Minke whale; ▪ Shelf deeps.	45
SAC	Braemar pockmarks	▪ Submarine structures made by leaking gas (Annex I Habitat).	123
SAC	Scanner pockmarks	▪ Submarine structures made by leaking gas (Annex I Habitat).	44
MCZ	Fulmar	▪ Subtidal sand and mud; ▪ Subtidal mixed sediments; ▪ Ocean Quahog aggregations.	145
MCZ	Swallow sand	▪ Subtidal coarse sediment; ▪ Subtidal sand; ▪ North Sea glacial tunnel valley (swallow hole).	185

Notes:
NCMPA = Nature Conservation Marine Protected Areas
SAC = Special Areas of Conservation
MCZ = Marine Conservation Zones

4.11. Other Users of the Sea

4.11.1. Commercial Fisheries

The North Sea is an important international fishing ground. Major UK and international fishing fleets operate in the CNS, targeting a range of species, although fisheries landings are higher overall further north in the North Sea and around the Orkney and Shetland Islands (MMO, 2021, Marine Scotland, 2022c). For fisheries statistics purposes, the north-east Atlantic is divided into rectangles by the International Council for the Exploration of the Sea (ICES).

The Avalon Field Development and optional gas export / import pipeline routes lie within ICES rectangles 44E9 and 44F0. Consultation with the Scottish Fishermen's Federation (SFF) highlighted that the Avalon Field Development was situated within intensive *Nephrops* fishing grounds.

Interactions between fishing vessels and oil and gas infrastructure can result in damage to fishing gear, loss of fishing time, prevention of access to grounds, and risks to crew health and safety. A risk-model for pipeline–fishing interactions in the Fladen Ground, to the north of the development, showed that there was significant spatial heterogeneity in the risk of an incident along a pipeline according to the angle and intensity of fishing. (Rouse et al., 2018). Analysis of fisheries compensation claims from fishermen between 2012 and 2022 within a 50 km radius of the development identified 9 claims (Offshore Energies UK, pers comms., Oct 2022). The majority of these claims were as a consequence of snagging of fishing nets, with some nets becoming torn, lost or gear having to be cut. Other claims describe damage to gear or catch as a result of the recovery dropped objects. The most recent claim within the study area was a snagging incident in 2016. This data must be treated tentative as many incidents may not have generated a claim for numerous reasons, therefore incidents may be higher than those described.

Maps of fishing intensity amalgamating vessel monitoring systems (VMS) during the period 2015 to 2018 show that fishing intensity is typically low with some areas of moderate intensity (Figure 4.15). The Avalon field experiences typically low fishing intensity (EmodNet, 2022)

Figure 4.15: Fishing intensity in the vicinity of the Avalon Field Development area

Figure 4.16 and Figure 4.17 illustrate fisheries landings data and sales value within rectangles 44E9 and 44F0 between 2017 and 2021 whilst Figure 4.18 presents fishing effort with for different gear types across the same area between 2016 and 2020.

Figure 4.16 illustrates the landings data for all three species types landed from the ICES rectangles overlapping with the Avalon Field development area. The data shows that the majority of the landings from the area around the Avalon development comprised demersal species, with a higher tonnage of pelagic species landed from ICES rectangle 44E9 to the west, which encompasses one of the option routes for the gas import/export pipeline (Marine Scotland, 2022c). Pelagic landings in the area are very variable due to the mobile nature of the pelagic stocks. Within both ICES rectangle, landings for all three species types have varied over the period analysed.

Figure 4.16: Landings (tonnes) for the proposed Avalon Field Development between 2017 and 2021

Source: Marine Scotland, 2022c.

In 2021, Scottish vessels landed approximately 538 300 tonnes of sea fish and shellfish (Marine Scotland, 2022c). Approximately 4 011 tonnes of fish and shellfish species were landed between ICES rectangle 44E9 and 44F0 in 2021, which equates to approximately 0.75 % of the total landings made by Scottish vessels that year (Marine Scotland, 2022c). Detailed landing figures are detailed in Table 4.8.

Table 4.8: Landings (tonnes) for the proposed Avalon Field Development between 2017 and 2021

ICES Rectangle	Year	Demersal (tonnes)	Pelagic (tonnes)	Shellfish (tonnes)	Total (tonnes)
44E9	2017	1 749.24	485.47	1 053.74	3 288.44
	2018	1 411.56	744.03	828.87	2 984.46
	2019	1 942.66	455.95	1 352.80	3 751.41
	2020	1 166.85	17.44	518.09	1 702.37
	2021	1 037.40	265.54	967.73	2 270.67
Total		**7 307.72**	**1 968.42**	**4 721.23**	**13 997.36**
44F0	2017	1 646.34	1 187.06	859.65	3 693.05
	2018	904.24	4.07	575.89	1 484.19
	2019	1 811.52	8.39	1 677.49	3 497.40
	2020	997.57	840.85	607.79	2 446.21
	2021	850.87	0.98	888.37	1 740.22
Total		**6 210.53**	**2 041.35**	**4 609.19**	**12 861.07**

Source: Marine Scotland, 2022c.

Figure 4.17 illustrates the annual sales value of each species type within ICES rectangles 44E9 and 44F0. The shellfish sales values for both rectangles were the highest of all species types in 2021. The total sales value of all three species types from ICES rectangles 44E9 and 44F0 between 2016 and 2021 was over £49 million with annual landing value varying each year across the period analysed (Marine Scotland, 2022c).

Figure 4.17: Landing values (£) for fish caught within the Avalon Field Development area between 2017 and 2021

Source: Marine Scotland, 2022c.

In 2021, Scottish vessels landed sea fish and shellfish with a provisional gross value of over £685 million (Marine Scotland, 2022c). Sea fish and shellfish landings in 2021 between ICES rectangles 44E9 and 44F0 totalled £ 7 951 872 which equates to 1.16 % of the total value of landings made by Scottish vessels in 2021. Detailed landing values are detailed in Table 4.9.

Table 4.9: Landing values (£) for fish caught within the Avalon Field Development area between 2017 and 2021

ICES Rectangle	Year	Demersal (£)	Pelagic (£)	Shellfish (£)	Total (£)
44E9	2017	2 403 391.83	192 155.08	3 701 546.63	6 297 093.54
	2018	1 824 229.84	272 446.10	2,487 380.23	4 584 056.17
	2019	2 668 844.27	364 948.96	4,167 202.79	7 200 996.02
	2020	1 572 403.41	16 152.72	1,089 990.93	2 678 547.06
	2021	1 473 755.05	213 188.03	2,379 574.15	4 066 517.23
Total		**9 942 624.40**	**1 058 890.89**	**13,825 694.73**	**24 827 210.02**
44F0	2017	2 578 566.87	670 663.83	2 998 443.39	6 247 674.09
	2018	1 309 691.30	3 536.45	1 766, 40.80	3 079 568.55
	2019	2 634 628.80	9 966.17	5 118 127.12	7 762 722.09
	2020	1 464 501.55	825 817.53	1 427 977.30	3 718 296.38
	2021	1 265 730.38	1 359.10	2 618 265.03	3 885 354.51
Total		**9 253 118.90**	**1 511 343.08**	**13 929 153.64**	**24 693 615.62**

Source: Marine Scotland, 2022c.

Figure 4.18 illustrates the effort in days by UK vessels over 10 m in length using passive, pelagic active or demersal active gears within each of ICES rectangles which overlap with the area of the proposed Avalon Field Development. It should be noted that recent landings data is currently only made publicly available if over five vessels were active in a particular ICES rectangle. This is the case for passive and pelagic active gear types within both ICES rectangles for some of the years analysed. This means that the data presented here may be an underestimation of the actual overall fishing effort, tonnes of fish landed and/or sales value in this area (Marine Scotland, 2022b).

However, the data available does show the dominance of demersal active gear use, which corresponds to the greater quantities of demersal landings within ICES rectangle 44E9 and 44F0. There was no recorded fishing with passive gear within either ICES rectangle during the years analysed. The total effort of all three types of gears across the ICES rectangles which overlap with the proposed Avalon Field Development area, between 2016 and 2020, was 11 574 days (Marine Scotland, 2022b).

Figure 4.19 illustrates the average effort for different gear types (passive, pelagic active and demersal active) across the proposed Avalon Field Development area. As previously discussed, these figures show a high proportion of non-disclosed data for pelagic active and passive gear, resulting in a potential underestimation of fishing effort within the wider area of the proposed development. The figure illustrates that within the Avalon field average effort for demersal active gear is one of the highest within the wider area whilst average effort for pelagic active gear is one of the lowest. (Marine Scotland, 2022b).

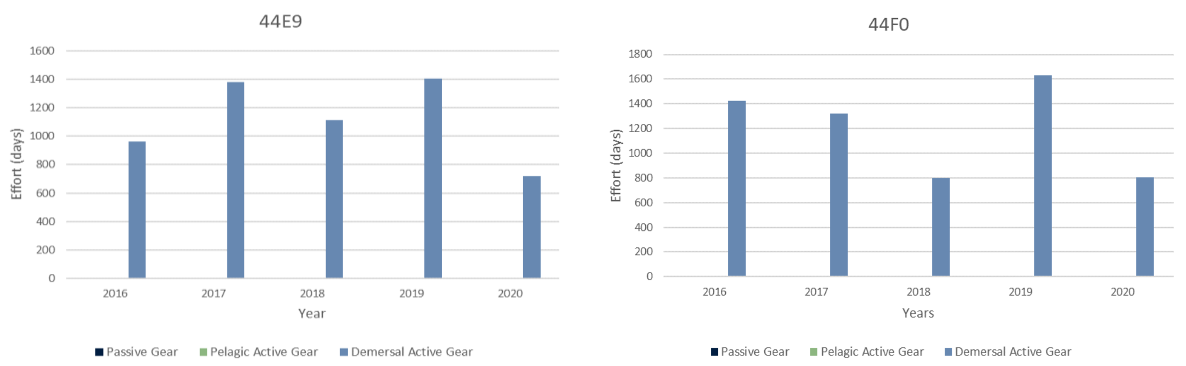


Figure 4.18: Effort (days) for different gear types used across the proposed Avalon Field Development area between 2016 and 2020

Source: Marine Scotland, 2022b.

In 2020, fishing effort amongst Scottish vessels totalled 103 842 days whilst effort within ICES rectangles 44E9 and 44F0 totalled 1 532 days (Marine Scotland, 2022c). This equates to 1.5 % of the total fishing effort by Scottish vessels in 2020. However, as described previously, this may under-represent fishing effort due to some effort not being disclosed. Detailed fishing effort in days is detailed in Table 4.10.

Table 4.10: Effort (days) for different gear types used across the proposed Avalon Field Development area between 2016 and 2020

ICES Rectangle	Year	Demersal Active Gear (days)	Pelagic Active Gear (days)	Passive Gear (days)	Total (days)
44E9	2016	961.99	0.00	Non-disclosive data	961.99
	2017	1 381.40	Non-disclosive data	Non-disclosive data	1 381.40
	2018	1 114.02	6.61	0.00	1 120.63
	2019	1 406.48	Non-disclosive data	0.00	1 406.48
	2020	717.22	0.00	0.00	717.22
Total		**5 581.12**	**6.61**	**0.00**	**5 587.73**
44F0	2016	1 423.20	Non-disclosive data	0.00	1 423.20
	2017	1 320.52	Non-disclosive data	0.00	1 320.52
	2018	797.62	Non-disclosive data	0.00	797.62
	2019	1 630.58	Non-disclosive data	Non-disclosive data	1 630.58
	2020	807.26	7.39	0.00	814.65
Total		**5 979.19**	**7.39**	**0.00**	**5 986.59**

Source: Marine Scotland, 2022b.

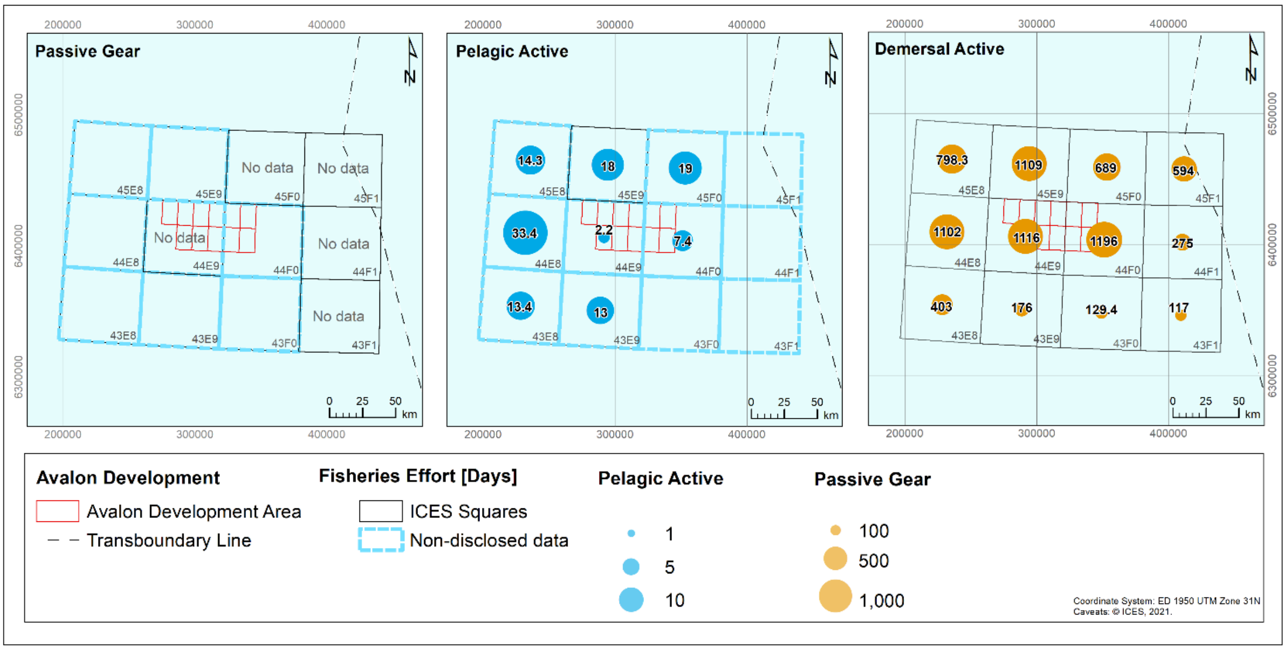


Figure 4.19: Average effort (days) for different gear types between 2016 and 2020 from ICES rectangles covered by, and surrounding, the proposed Avalon Field Development area

Source: Marine Scotland, 2022b.

Analysis of the landings per month within ICES rectangle 44E9 and 44F0 indicate that the summer is the most productive fishing season with the majority of the landings typically occurring between June and August (Figure 4.20).

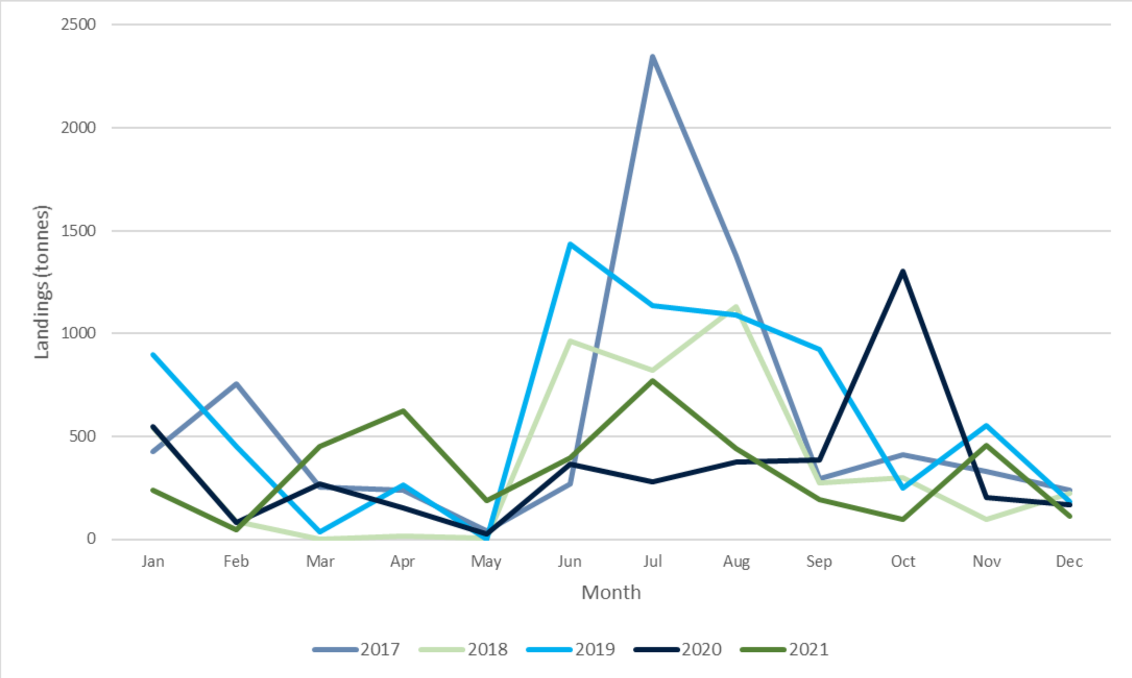


Figure 4.20: Seasonal landings distribution between 2017 and 2021 for the ICES rectangles overlapping the Avalon Field Development area

Source: Marine Scotland, 2022c.

Analysis of the average fishing effort per month within 44E9 and 44F0 between 2017 and 2021 shows peaks in June and July, with the highest fishing effort occurring during July (Figure 4.21).

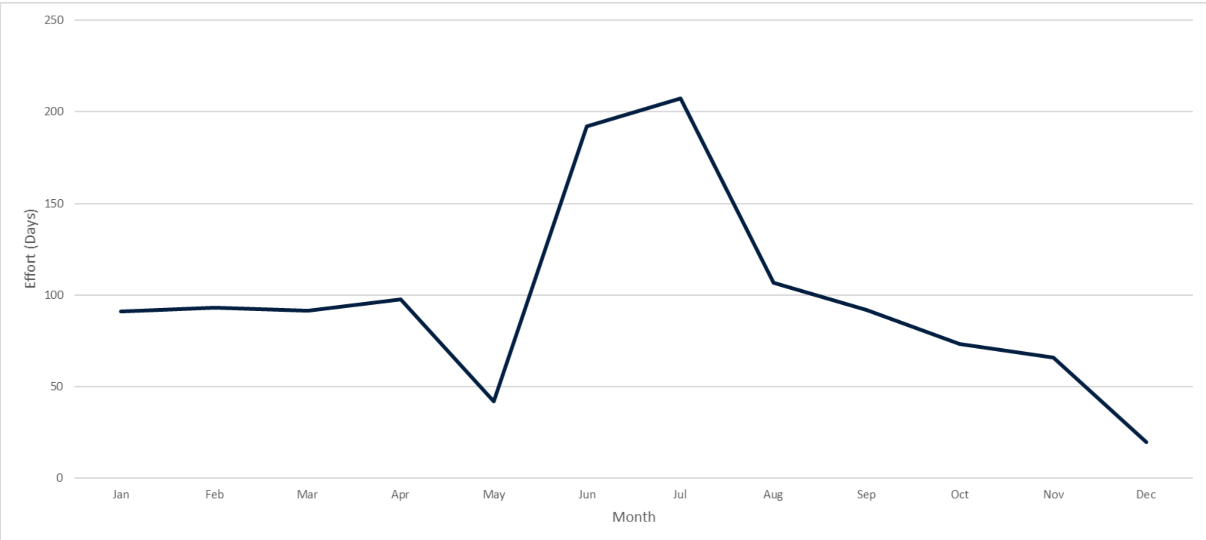


Figure 4.21: Seasonal average fishing effort distribution between 2017 and 2021 for ICES rectangles overlapping the Avalon Field Development area

4.11.1.1. Demersal Fisheries

Demersal fisheries target species which live on or near the seabed and generally feed on bottom-living organisms and other fish. Although these fisheries may be directed towards a particular species or species group, demersal fish are often caught together and comprise a mixed fishery. The main demersal species caught within ICES rectangles 44E9 and 44F0 between 2017 and 2021 were gadoids such as haddock, monkfish, cod, whiting, saithe and hake (Marine Scotland, 2022c). Figure 4.22 illustrates that average demersal landings and sales value typically decreased with distance from shore across the wider area (Marine Scotland, 2022c).

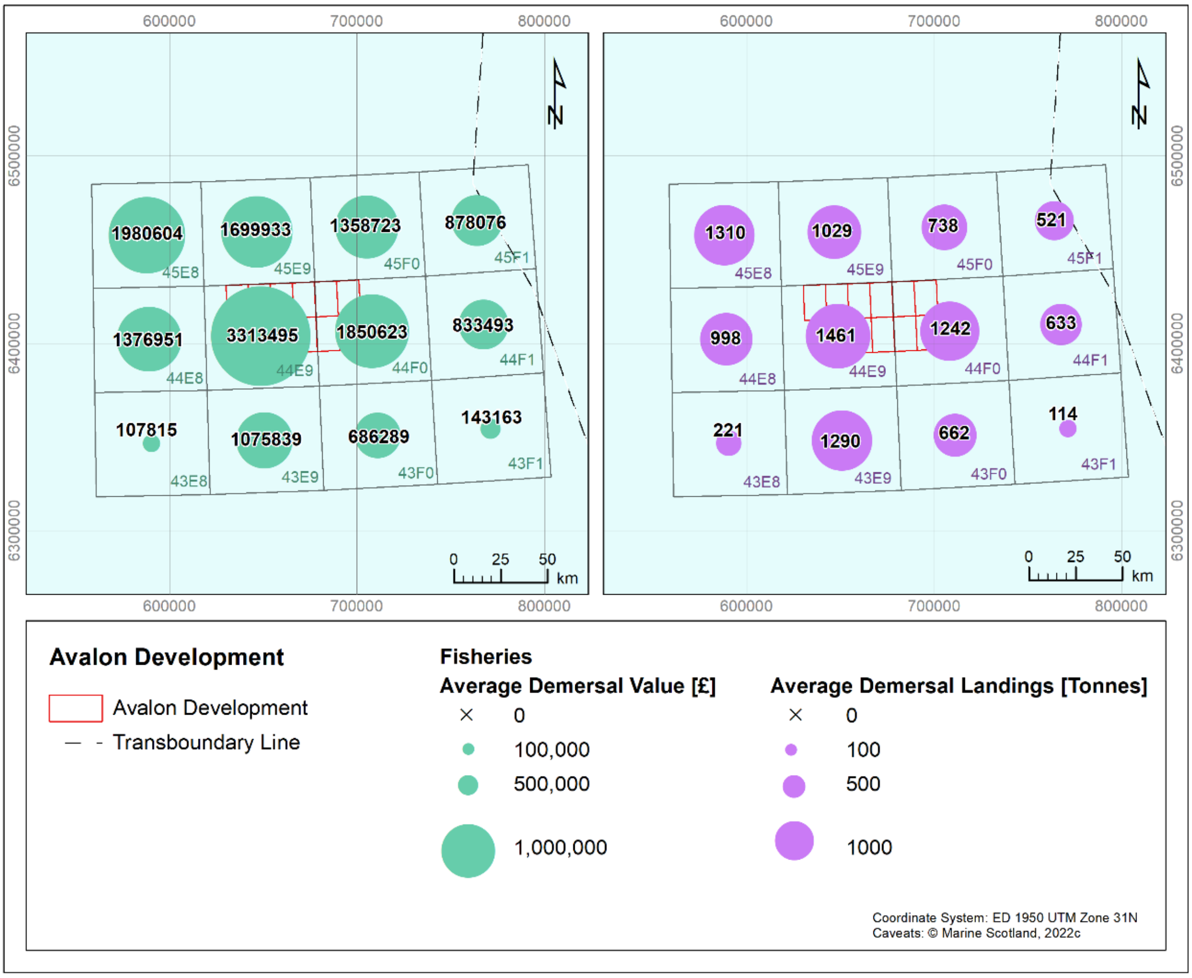


Figure 4.22: Average demersal value (£) and landings (tonnes) in the vicinity of the proposed Avalon Field Development between 2017 and 2021.

Source: Marine Scotland, 2022c.

Fishing effort by UK vessels of more than 10 m in length using demersal active gear between 2017 and 2021 within rectangles 44E9 and 44F0 was 11 391 days (Marine Scotland, 2022c). Data shows that, between 2016 and 2020, average effort for demersal active gear across the ICES rectangles covered by the Avalon Field Development area is the highest within the wider area (Marine Scotland, 2022b). The figures also show that average effort typically decreases with distance from shore (Marine Scotland, 2022b). The demersal sales value of ICES rectangles

44E9 and 44F0 to the UK fishing industry between 2017 and 2021 was £ 19 195 743, with sales value between £ 2 700 000 and £5 300 000 over the 5 years analysed (Marine Scotland, 2022c).

The demersal inshore fishery around the north and north-east coast of Scotland is largely dominated by haddock landings (Marine Scotland, 2022c). Many commercial species such as haddock, cod, whiting, and saithe are found in inshore areas during certain times of the year for spawning or as nursery grounds for juveniles.

4.11.1.2. Pelagic Fisheries

Pelagic fisheries target species which live in the water column. Pelagic fisheries in the North Sea are generally more active in deeper waters, predominantly targeting herring and mackerel. The main pelagic species caught within ICES rectangles 44E9 and 44F0 between 2017 and 2021 were herring and mackerel (Marine Scotland, 2022c). The inshore areas of the north and north-east coasts play host herring spawning and nursery grounds during certain times of the year (Ellis et al., 2012; Coull et al., 1998) and the Buchan herring stock spawning grounds is within the wider region of the proposed Avalon Development area. Average landings of pelagic species from ICES rectangles 44E9 and 44F0 are broadly similar (Figure 4.23) with landings typically highly variable year on year, due to the motility of the stock.

Fishing effort by UK vessels of more than 10 m in length using pelagic active gear between 2016 and 2020 within rectangles 44E9 and 44F0 could not be disclosed for some years for analysis. However, the data does show that pelagic fish were landed, but as previously stated, landings data is currently only made publicly available if over five vessels were active in a particular ICES rectangle (Marine Scotland, 2022b and 2022c).

The pelagic sales values of rectangles 44E9 and 44F0 to the UK fishing industry between 2017 and 2021 was £ 2 570 234, with landing values highly variable throughout this period (Marine Scotland, 2022c). Figure 4.23 illustrates that pelagic landings and value typically decrease with distance from the shore. Landings and values are lower within the ICES rectangles which overlap with the Avalon Field Development area when compared to those in the wider region.

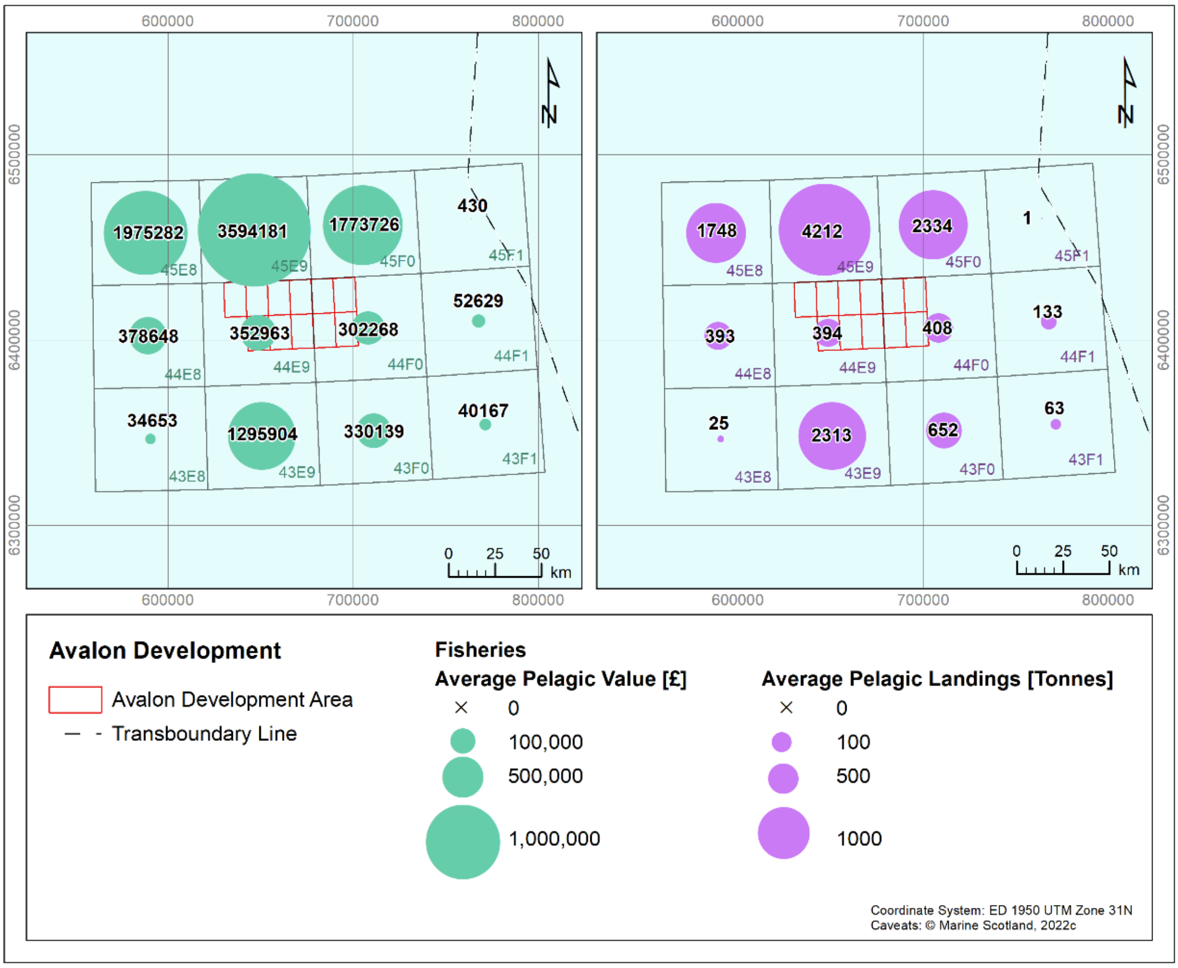


Figure 4.23: Average pelagic value (£) and landings (tonnes) in the vicinity of the proposed Avalon Field Development between 2017 and 2021

Source: Marine Scotland, 2022c.

4.11.1.3. Shellfish Fisheries

Shellfish fisheries can be broadly divided into offshore and onshore components. Static gears such as creels and pots are used in inshore areas to catch crabs and lobsters while the offshore component targets *Nephrops* and scallops using trawls. Landings data for shellfish species within rectangles 43E9 and 44F0 from 2017 to 2021 show the volumes of shellfish landed from ICES rectangles 44E9 and 44F0 are broadly similar with one another (Figure 4.24) (Marine Scotland, 2022c). The majority of shellfish landings are from ICES rectangles to the north or south of the Avalon Field Development area. The main shellfish species landed were *Nephrops* and small volumes of squid or octopus (Marine Scotland, 2022c).

Shellfish landings from ICES rectangles 44E9 and 44F0 between 2017 and 2021 had a total value of £ 27 754 848 making them the most valuable species group in the area. This catch is predominately comprised of *Nephrops*. Figure 4.24 shows that shellfish landings from ICES rectangles 44E9 and 44F0 are some of the highest in the area. The figure also illustrates that the shellfish fishery is a high value, lucrative fishing ground within the Avalon Field Development, but also across the wider area.

Inshore shellfish fisheries are present around the north and north-east coast of Scotland, where scallops, crabs and *Nephrops* are the targeted species, along with squid and lobsters (Marine Scotland, 2022c). The north and north-east coasts are *Nephrops* nursery and spawning grounds throughout the year (Section 4.6.1).

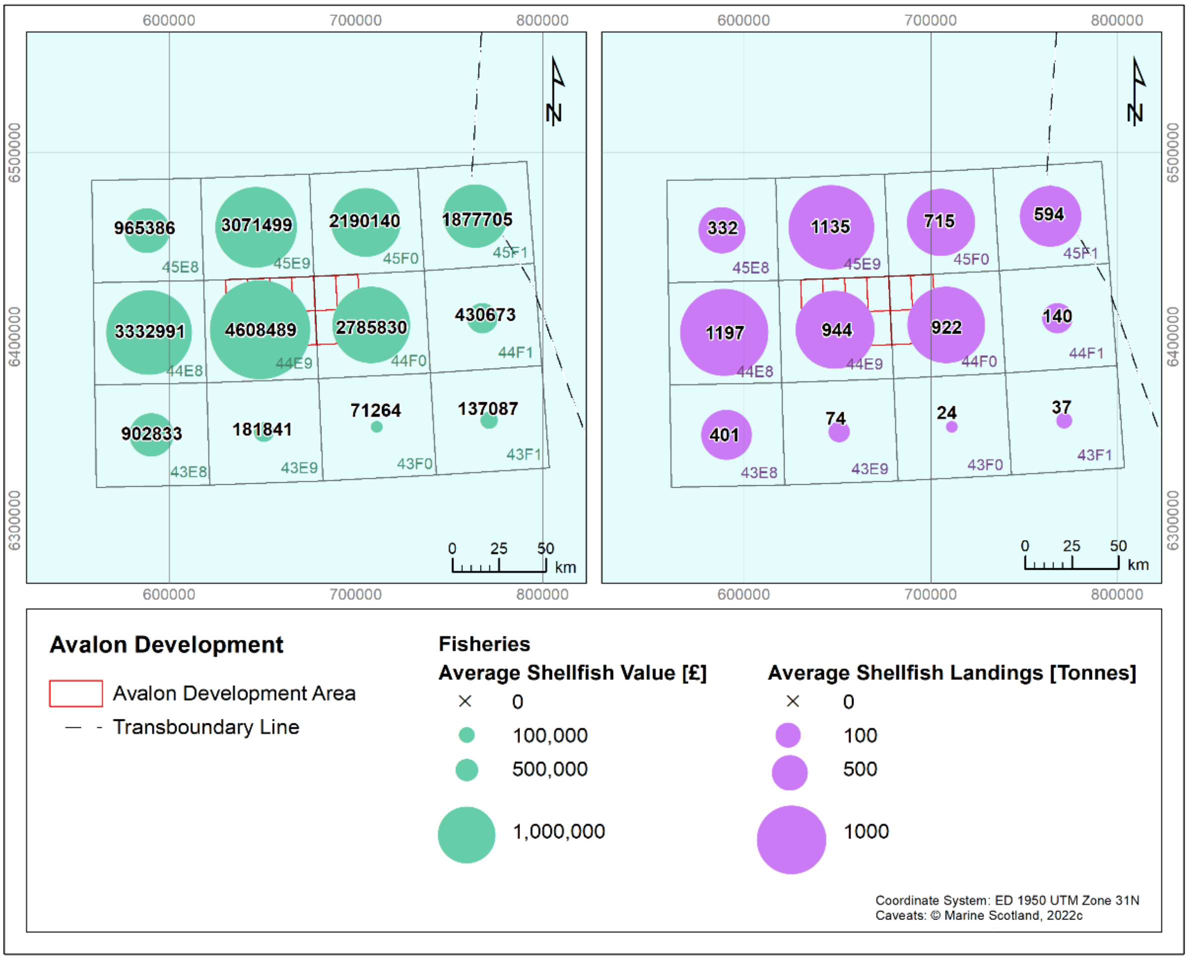


Figure 4.24: Average shellfish value (£) and landings (tonnes) in the vicinity of the proposed Avalon Field Development between 2017 and 2021

Source: Marine Scotland, 2022c.

4.11.2. Aquaculture

Currently, there are no active seawater finfish or shellfish aquaculture sites along the north and north-east coast of Scotland (Marine Scotland, 2022b). The closest aquaculture sites are located across the Orkney and Shetland Islands over 200 km to the northwest of the Avalon Field.

Aquaculture is of importance to the economy of Norway. Numerous finfish farms producing species such as Atlantic salmon, rainbow trout, Arctic char, Atlantic halibut and cod from seawater cages are present along the entire coastline. A smaller number of shellfish farms are also present, mainly producing blue mussels, with smaller amounts of great Atlantic scallop, oysters, lobsters and crayfish (Norwegian Directorate of Fisheries, 2022).

4.11.3. Shipping

The highest levels of shipping reported in the CNS from 2012 to 2017 are centred around the ports along the east coast of Scotland (including Aberdeen, Dundee and the Firth of Forth), and of north-east England (Tyneside and Teeside) (Marine Scotland, 2022b). These port approaches, along with nearshore areas of the CNS, experience a moderate to very high shipping density.

Shipping in the area of the proposed survey is largely dominated by oil industry support and service vessels (Marine Scotland, 2022b). Due to this, Block 21/6b, where the Avalon wells would be drilled and the FPSO located, has been designated as an area of moderate shipping density (NSTA, 2019). The optional gas import/export route to the Ettrick or Britannia PLEM may pass through UKCS Blocks 20/02, 20/03, 20/04, 20/05, 20/08, 20/09, 20/10, 21/1, 21/2 or 21/7 which have been designated as areas of very low (21/1 and 21/2), low (20/5 and 20/9) and moderate (20/2, 20/3, 20/4, 20/8, 20/10 and 21/7) shipping densities (NSTA, 2019).

A marine traffic survey and navigation assessment was carried out for the Avalon Field based on a previous Avalon well location which is approximately 0.5 km northeast or northwest from the two new proposed Avalon wells. The assessment showed that there are 22 shipping routes which would pass within 10 nm (18.5 km) of the provisional Avalon well location. On average, up to 4 vessels pass within 10 nm of the of the provisional Avalon well each day. The assessment identified that around 73 % of the vessels transiting the study area were associated with offshore oil and gas industry. A further 23 % of transits represented cargo vessels, and around 4 % tankers. All of vessels transiting within 10 nm of the Avalon Field Development were sized between 1 500 DWT and 5 000 DWT (Anatec, 2019). Five of the identified shipping routes pass within 2 nm of the provisional Avalon well location. The highest number of vessel movements (240 per year) occurs between Aberdeen and the Alba field by offshore support vessels. The other four routes have less activity (110 vessels per year) and are typically cargo vessels.

As fishing activity is classed as non-routine, there has not been an accurate assessment using the ShipRoutes database. However, the assessment takes account of the automated identification system (AIS) data of fishing vessels within 10 nm of the Avalon well locations. Unfortunately, AIS carriage is only mandatory for fishing vessels 15 m in length and over, therefore, the activities of smaller fishing vessels in the area may not be represented. The AIS data describes a significant level of fishing vessel activity in the vicinity of the Avalon well locations, with the majority of vessels actively fishing, with some performing guard duties at the Buchan field and supporting survey operations in the area (Anatec, 2019).

Data from AIS of shipping traffic between 2012 and 2017, found the average weekly density of tankers, passenger vessels, port service craft, fishing vessels and non-port service craft transiting the Avalon Field Development location to be between one and two transits. Cargo and recreational vessels were found to transit the site one or less times per week on average (Marine Scotland, 2022b).

4.11.4. Oil and Gas Infrastructure

The CNS is an area of intensive oil and gas activity, and the proposed Avalon Field Development is sited within this extensive zone of development (Figure 4.25). The nearest existing surface infrastructure to the Avalon Field include the Forties Unity (33 km to the south of the Avalon Field) and Forties Charlie (38 km to the south-east of the Avalon Field) (NSTA, 2022). Other surface infrastructure includes the Kittiwake platform located 39 km to the south-east.

The closest operational subsea infrastructure to the Avalon Field Development is the Repsol Sinopec operated Tweedsmuir South field 13 km north of the proposed Avalon Field. The Repsol Sinopec operated Buchan field is located 8 km to the northwest of the Avalon well. Production at the Buchan field has ceased, and the Buchan Alpha platform has been removed from the field, however subsea infrastructure may remain in situ ahead of abandonment operations completing (NSTA, 2022).

In the event that the pipeline route towards the Ettrick PLEM is chosen the import/export pipeline will cross one pipeline, the Chrysaor operated Britannia to St Fergus gas export line. No pipelines will be crossed if the route to the Britannia PLEM is progressed (NSTA, 2022).

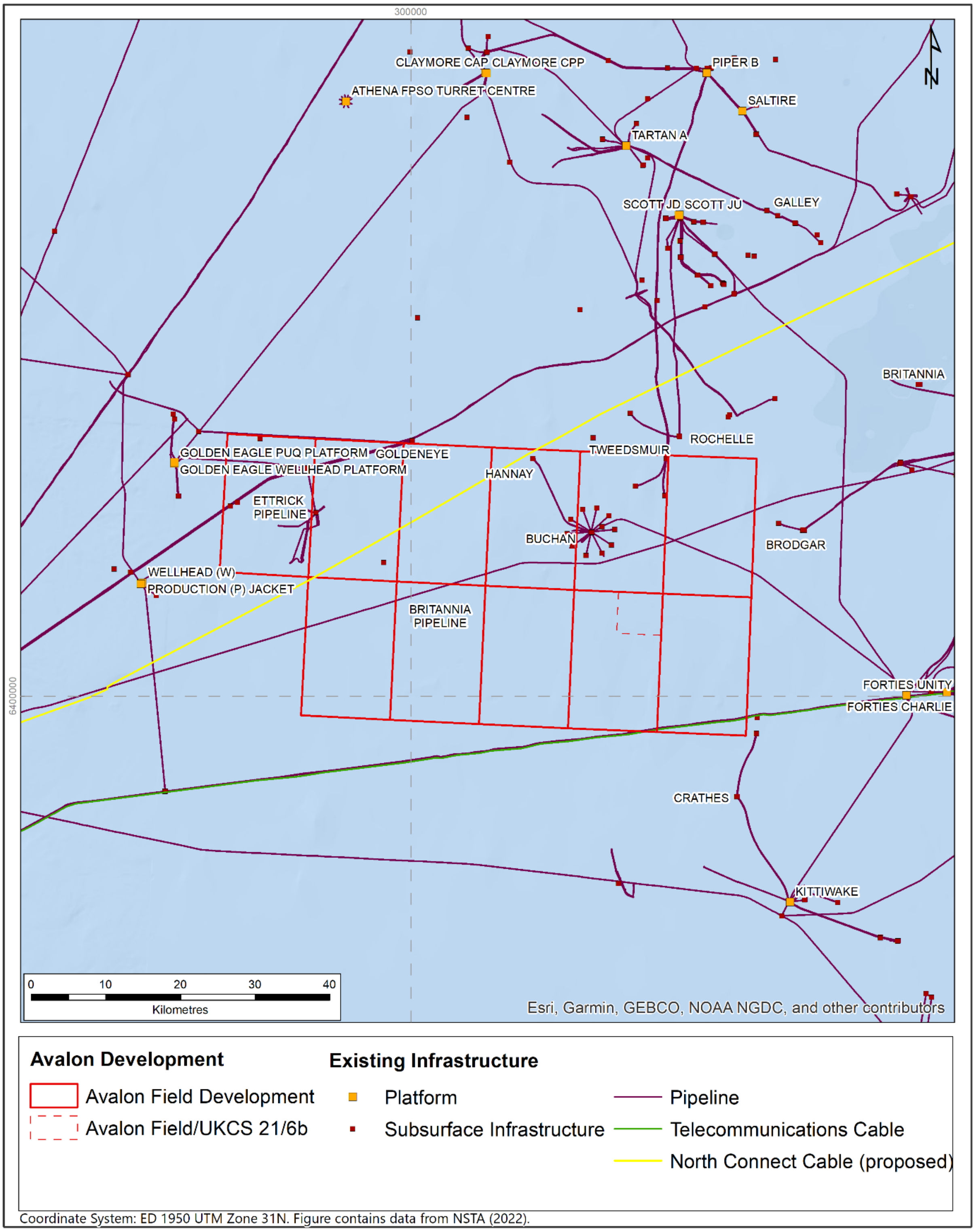


Figure 4.25: Oil and gas infrastructure and submarine cables in the vicinity of the Avalon Field Development

4.11.5. Offshore Wind Farm Operations and Gas Storage/CCS Licenses

There are currently no offshore wind farm operations within the vicinity of the Avalon Field Development. The closest offshore wind farm is the Hywind Scotland Pilot Park which is currently in production and lies 47 km to the south-west of the Avalon Field Development (Figure 4.26).

An area of the Avalon Field Development (UKCS blocks 20/02, 20/03, 20/04, 20/05, 20/08, 20/09, 20/10) overlaps with part of The Innovation and Targeted Oil and Gas (INTOG) licensing round areas. This overlap will only occur if the potential gas import/export pipeline to Ettrick PLEM is developed. Otherwise, this INTOG area lies 7 km from the Avalon Field itself (Figure 4.26).

There is also a Carbon Capture Storage (CCS) license area which overlaps with UKCS blocks 20/02, 20/03, 20/04. This area (CS003; Figure 4.26) has been acquired by Pale Blue Dot Energy (Acorn) Ltd.

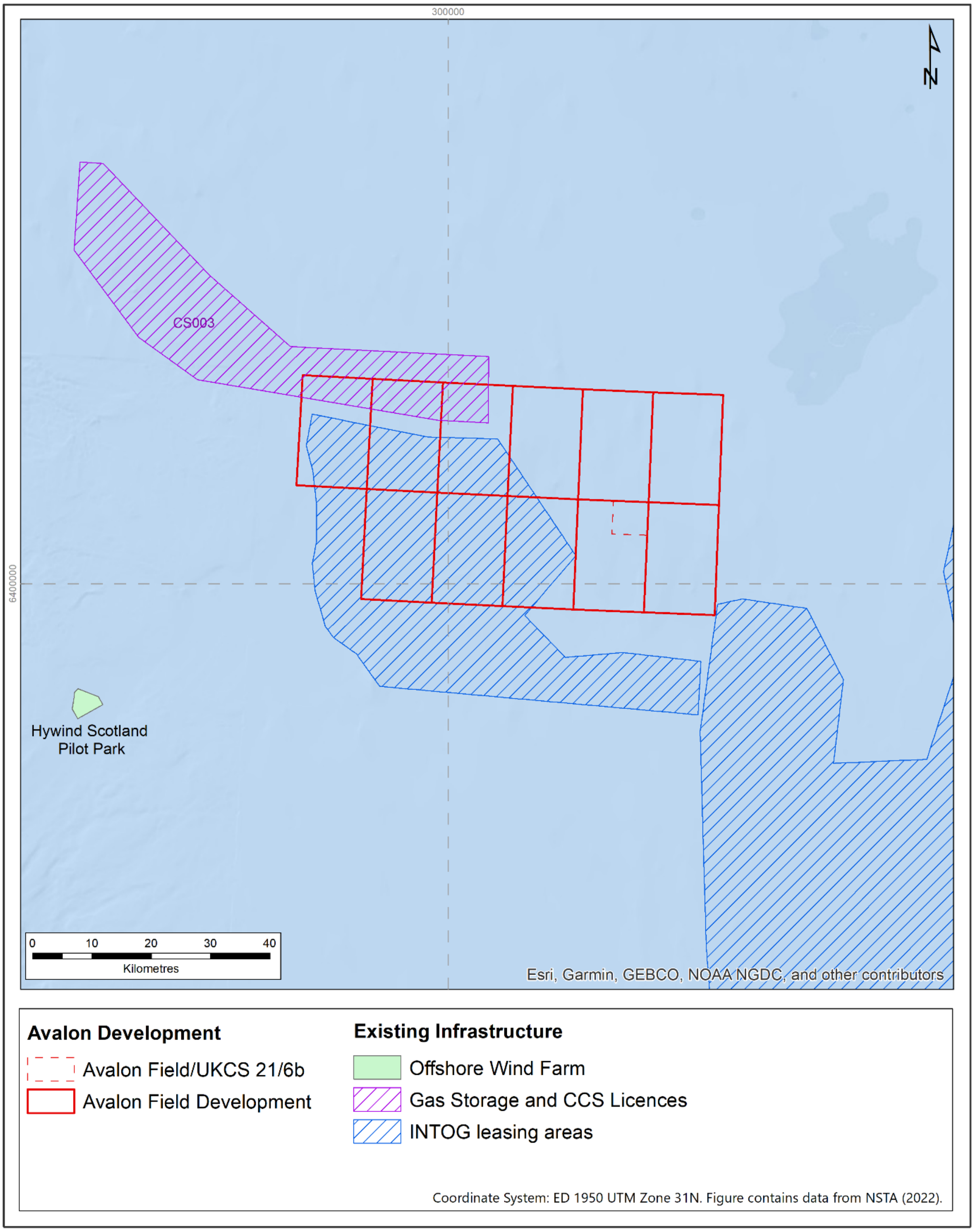


Figure 4.26. Offshore wind developments and CCS sites within/around the development area

4.11.6. Military Activity

No practice and exercise areas (PEXA) have been highlighted in the vicinity of the Avalon Field Development (Marine Scotland, 2022b). As required by Licence conditions, the Ministry of Defence (MoD) have been consulted, and it is confirmed that there are no safeguarding concerns within the area of the proposed Avalon Field Development.

4.11.7. Wrecks and Archaeology

There are no identified wrecks or sites of archaeological interest within the Avalon Field Development location (Marine Scotland, 2022b). The non-dangerous wrecks HMS Hawke, Anna Lind, are located within 10 km of the development.

4.11.8. Submarine Cables

The BP CNS Fibre Telecommunications company Limited (CNSFTC) telecoms cable is the closest submarine cable to the proposed Avalon development wells, located approximately 15 km to the south (NSTA, 2022). The offshore fibre infrastructure initiates from Cruden Bay, Aberdeenshire and runs via the Forties' and Everest oil fields, to the Ula platform.

The proposed NorthConnect high voltage direct cable (HVDC) from Scotland to Norway, currently in the planning stages, is located approximately 20 km north of the Avalon field (Figure 4.25).

4.12. Summary

Table 4.11 provides a summary of the key environmental sensitivities identified throughout this chapter for the proposed development.

Table 4.11: Seasonal Variation of Key Environmental Sensitivities

<table>
<tr><th></th><th colspan="12">Environmental Sensitivity</th></tr>
<tr><th></th><th>J</th><th>F</th><th>M</th><th>A</th><th>M</th><th>J</th><th>J</th><th>A</th><th>S</th><th>O</th><th>N</th><th>D</th></tr>
<tr><td rowspan="2">Plankton</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Phytoplankton productivity in the Central North Sea is highest in the spring and autumn with a major peak between May and August. Zooplankton productivity follows a similar pattern, but the blooms follow approximately one month later.</td></tr>
<tr><td rowspan="2">Benthos</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Life cycles of organisms within the seabed communities are not well understood. Based on the characteristic species, a spawning period for those with a planktotrophic life phase and larger macrofaunal species is thought to be between July and October, with possible winter recruitment sensitivity in November or December.</td></tr>
<tr><td rowspan="2">Fish and shellfish</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">The proposed Avalon Field Development area lies within or close to known spawning grounds for Nephrops, cod, lemon sole, Norway pout and haddock whilst sandeels, sole, sprat and whiting. The majority of species exhibit peak spawning activity between January and June, although several species spawn over a longer period. The Avalon Subsea Development lies in a year-round nursery area for blue whiting, cod, hake, herring, ling, mackerel, monkfish, Nephrops, Norway pout, plaice, sandeels, sprat and whiting.</td></tr>
<tr><td rowspan="2">Marine mammals</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Five species of cetacean have been recorded in the vicinity of the development, including minke whales, white-sided dolphin, white-beaked dolphin, Risso's dolphin and harbour porpoise. Common and grey seals are unlikely to be found within the proposed development area.</td></tr>
<tr><td rowspan="2">Seabirds</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Seabirds are present throughout the year in the Central North Sea, with mostly low to moderate densities found in the proposed development area. However, some species, such as guillemot and Fulmar, occur in higher densities in the proposed development area and the wider region throughout the year.</td></tr>
<tr><td rowspan="2">Offshore conservation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">The Turbot Bank NCMPA is the closest NCMPA to the proposed development is located approximately 24 km to the south-west. The closest offshore SACs to the proposed development are the Scanner Pockmark SAC, located approximately 44 km to the north-east.</td></tr>
<tr><td rowspan="2">Coastal conservation</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">Most of the coastal conservation areas are designated for the presence of birds, thus vulnerability is highest during the breeding season. Those designated for other reasons (e.g. vegetation) may also be more vulnerable in the summer months for the same reasons. However, vulnerability reduces throughout the winter months, when birds move offshore.</td></tr>
<tr><td rowspan="2">Other users of the sea</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="12">The Avalon Field Development is situated in an area of extensive oil and gas activity. The area is also widely used by the fishing and shipping industries. The commercial fishery within the area shows peaks in fishing effort in June and July. However, this can be highly variable year on year due to the mobility of the stock. The shellfish fishery in the area is very lucrative with Nephrops the target species. Twenty-two shipping routes pass within 10 nm of the planned Avalon well locations.</td></tr>
</table>

Key:		None		Low		Moderate		High		Very high

Section 5
Identification of Impacts (Scoping)

5 Identification of Potential Impacts

This section describes the scoping methods used to identify the environmental interactions and concerns associated with the proposed Avalon Field Development that could potentially cause a significant environmental impact. The following three scoping methods were used:

- Multiple environmental issue identification (ENVID) workshops with members of the Ping project team;
- Informal scoping consultation with the regulator and statutory consultees; and
- Consideration of national policies and guidance, including:
  - The Scottish National Marine Plan (NMP) policies, relating to the potential impacts from oil and gas activity;
  - Assessment of the sensitive features of the local environment and corresponding relevant pressures from the proposed development, based on the Feature Activity Sensitivity Tool (FEAST).

The purpose of these scoping activities was to identify the main environmental concerns at an early stage of the project, so that they could be addressed and mitigated against during the Environmental Impact Assessment (EIA) process.

5.1 The ENVID Workshop

An ENVID workshop is a scoping exercise during which members of the project team identify all potential interactions of the proposed development with the environment and score their potential environmental impacts. For the proposed Avalon Field Development, four ENVIDs were held, to reflect the evolving project design, attended by members of the project team from PPUK, as well as by environmental consultants from Fugro.

All proposed development operations, which may interact with the environment, were identified during the workshops and divided into the following categories:

- Drilling and completion operations (discussed at the second and fourth ENVIDs);
- Subsea infrastructure and infield pipeline installation and operation (discussed at the first, third and fourth ENVIDs);
- FPSO installation and production operations (discussed at the first and fourth ENVIDs); and
- Installation of the floating OWT and associated infrastructure (discussed at the fourth ENVID).

These activities are termed ‘environmental aspects’. The source and pathway of each aspect was defined, and the receptor identified. The various aspects were then scored against the environmental receptors to determine whether their impact would require further detailed assessment and, if required, appropriate mitigation in the Environmental Statement (ES). The effects of each environmental aspect were systematically assessed, by multiplying their Magnitude of the Effect (Table 5.1) and Receptor Value (Table 5.2) to produce a significance score.

Where the final significance score was below 10, a potential interaction was identified, but the associated impacts were deemed to be insignificant, and as such they would not require further assessment, i.e. these aspects have been 'scoped out' of the EIA. Where an aspect was ranked a score of 10 or higher, it had been regarded as potentially significant and would require further assessment and management measures to control it, and thus was 'scoped in' to be assessed further in the EIA process. This assessment approach is designed to score impacts upon specific environmental and socio-economic receptors.

Table 5.1: Environmental Aspect Significance Matrix

Magnitude of Effect		Receptor Value	Negligible	Low	Medium	High	Very High
			1	2	3	4	5
Negligible	a. Minor change to the natural environment which is unlikely to be noticed or measurable against background variation. b. An environmental effect not likely to last more than a few days. c. Effects that are only detectable at source. d. No implications to other users of the sea or local communities. e. No risk to reputation of the company or commercial success. f. No discernible change in the existing view or other landscape characteristics. g. Usage of renewable or non-supply-limited resources with no measurable effect on current or future supply.	**1**	1	2	3	4	5
Minor	a. A detectable change to the natural environment which is within scope of existing variability. b. A transient environmental effect not lasting more than a few weeks. c. Unlikely to contribute to cumulative effects. d. May affect behaviour, but not a nuisance to other users of the sea or general public. e. Transient issues regarding external relationships but with no long-term reputational consequences. f. Virtually imperceptible change in landscape receptors causing very minor changes to the view or other landscape characteristics over a wide area or minor changes over a limited area. g. Usage of finite resources with no measurable effect on current supply and not affecting market price.	**2**	2	4	6	8	10
Moderate	a. Change in habitats and biological communities within the footprint of the development. b. Change in habitats and biological communities leading to short term (< 2 years) damage with a good recovery potential. c. Similar scale of effect to existing variability but may have cumulative implications. d. May cause measurable nuisance to some other users of the sea or local communities. e. Risk of undermining reputation of the company within industry or with regulators. f. Moderate change in localised areas causing minor changes to the existing view or other landscape characteristics over a wide area or noticeable change over a limited area. g. Usage of finite resources that may affect short-term availability and local market price.	**4**	4	8	12	16	20
Major	a. Change in habitats and biological communities extending beyond the immediate footprint of the development. b. Change in habitats and biological communities leading to medium term (>2 years) damage, but with a likelihood of recovery within 10 years. c. Cumulative implications are understood to occur in relation to activities of this type. d. Financial loss or safety implications to other users of the sea or local communities. e. Undermining the reputation of the company with serious commercial implications. f. Notable change in landscape characteristics over an extensive area ranging to a very intensive change over a more limited area. g. Reduction in stock resource, affecting national availability and market price.	**6**	6	12	18	24	30
Severe	a. Wide scale change to the offshore environment or effects on coastal receptors. b. Change in the natural environment, leading to long term (>10 years) damage and poor potential for recovery to baseline conditions. c. Will make a significant contribution to national or global issues, individually or cumulatively. d. Long-term economic loss or strategic business changes for other users of the sea or local communities e. Damage to company reputation of sufficient gravity, to incur irreparable damage to the business. f. Extensive long lasting (>10 years) to permanent change in landscape characteristics over an extensive area. g. Reduction in stock resource, affecting global availability and market price.	**10**	10	20	30	40	50

Table 5.2: Environmental and Socio-economic Receptor Value

	Receptor Category	Selected Examples
Very High (5)	Natural environment (marine, coastal, terrestrial)	1. Internationally designated site or protected species. 2. A regularly occurring, globally threatened species or habitat essential for maintaining such species. 3. Species and habitats essential to conserve biodiversity at an international level.
	Socio-economic Other users of the sea,	4. A major fishing area contributing at a national level. 5. An internationally defined shipping lane. 6. Any areas licensed for use by other industries.
	Landscape	7. Internationally designated or recognised landscape of exceptional quality and distinctive intact character with a large number of features and strong sense of place, and uninterrupted views (visual amenity).
	Society	8. Rare, finite and non-reusable resource only scarcely available on the world market
High (4)	Natural Environment (marine, coastal, terrestrial)	1. Nationally designated site or protected species. 2. A nationally threatened species or habitat essential for maintaining such species. 3. Species and habitats of principal importance for the conservation of biodiversity at a national level.
	Other Users	4. An area of regional importance for fisheries or of local importance but with no nearby alternatives. 5. Major shipping activity located in a restricted area. 6. Extensive use by multiple other industries.
	Landscape	7. Nationally designated or recognised landscape of high quality and distinctive character, with a strong sense of place, and susceptible to change which would permanently alter key characteristics and elements of the landscape (National Parks and AONBs). Partial or interrupted views (visual amenity).
	Society	8. Finite resource with restricted availability on the world market
Medium (3)	Natural environment (marine, coastal, terrestrial)	1. Sites or species protected on a local level, or of acknowledged conservation value. 2. The presence of a locally threatened species or habitat. 3. Species and habitats of importance for the conservation of biodiversity at a local level.
	Other Users	4. Areas used by local fisheries, but with nearby alternatives. 5. Areas of moderate-high commercial shipping intensity 6. Multiple other stakeholder interest or extensive use for a single purpose.
	Landscape	7. Locally designated or recognised landscape with some distinctive character and features in reasonable condition. Capable of tolerating low levels of change without affecting key characteristics and elements (e.g. Local Green Space). Partial or interrupted views (visual amenity).
	Society	8. Non-reusable finite resource presently plentiful/abundantly available on world market
Low (2)	Natural environment (marine, coastal, terrestrial)	1. No sites or species of conservation interest. 2. No resident or regularly occurring threatened species or habitat present. 3. A natural and diverse habitat supporting widespread and common species.
	Other Users	4. Areas of low intensity fishing, not essential for supporting local communities. 5. Areas of low shipping intensity. 6. Areas of low intensity anthropogenic use.
	Landscape	7. Undesignated landscape of defined character type, but of low quality. Capable of tolerating moderate levels of change/improvement/enhancement. Views lack distinctive characteristics and/or are of low quality (visual amenity).
	Society	8. Reusable or recyclable resource, abundantly available on world market
Negligible (1)	Natural environment (marine, coastal, terrestrial)	1. No sites or species of conservation interest. 2. Not capable of supporting any threatened species or conservation interest. 3. A poor habitat with low biodiversity and productivity.
	Other Users	4. No commercially exploitable fisheries present. 5. Areas of very low shipping intensity. 6. Areas of no discernible anthropogenic use or socio-economic benefits.
	Landscape	7. Poor quality landscape, not representative of a wider type within the local area and capable of accommodating high levels of change/improvement/enhancement, with few or no views (visual amenity).
	Society	8. Renewable or non-supply-limited resource, readily available at point of use

5.1.1 The ENVID Workshops Findings

During the latest ENVID workshop, the following impacts considered as 'significant' were identified from the proposed development operations (see ENVID matrices in Appendix 4):

- Impacts on seabed fauna (including ocean quahogs and potential pockmark habitats) due to:
  - Placement of spud cans or anchors (and anchor lines) from the Mobile Offshore Drilling Unit (MODU), depending on whether a jack-up or semi-submersible drilling unit will be used;
  - Deposition of drill cuttings and associated water-based mud (WBM) and excess cement onto the seabed;
  - Trenching and laying of pipelines, flowlines, umbilicals and power cables (including any backfilling);
  - Use of rock dump to protect flowlines/pipelines, or other infrastructure;
  - Laying of concrete mattresses, grout bags etc. to protect flowlines/pipelines or other infrastructure;
  - Installation of FPSO anchors and anchor lines on the seabed; and
  - The presence of mooring lines and anchors from the floating wind turbine.

- Impact on other sea users (namely, fishing) due to:
  - The temporary presence of the MODU and accompanying support vessels, during drilling and infrastructure installation operations;
  - The temporary presence of anchors and anchor lines from the MODU during drilling operations (if a semi-submersible MODU will be used);
  - The ongoing presence of seabed infrastructure on the seabed, during the lifespan of the Avalon Field;
  - The physical presence of the FPSO and its associated anchor lines through the life of field; and
  - The presence of floating wind turbine, including its mooring system.

- Impacts of global warming arising from:
  - Atmospheric emissions generated by the MODU and accompanying vessels;
  - Atmospheric emissions generated from flaring (e.g. during well clean-up operations);
  - Atmospheric emissions generated during installation of the gas export pipeline;
  - Atmospheric emissions generated during installation and commissioning operations from FPSO and installation vessels;
  - Atmospheric emissions generated by the FPSO and support vessels during the production phase, including combustion emission from power generation, non-routine flaring and venting emissions, non-routine volatile organic compound (VOC) emissions from cargo tanks and venting from cargo tanks during offloading operations; and
  - Atmospheric emissions generated by vessels during the installation of the floating wind turbine.

- Impact on marine fauna due to:
  - Discharge of produced water into the marine environment;
  - Underwater sound generated by vessels on marine mammals and fish;
  - Piling noise generated when fixing subsea infrastructure, FPSO anchors and the mooring system of the floating wind turbine to the seabed.

- Accidental events (i.e. large hydrocarbon spill):
  - Release of oil, as a result of a well blowout;
  - Fuel oil spill from any of the vessels used during installation; and
  - Loss of inventory from the FPSO/shuttle tanker, during the production phase.

As a result, these issues will all be assessed in detail during the EIA process, and will be reported on in the ES, along with any additional issues identified during consultation with key stakeholders on the Early Consultation Document (ECD). Furthermore, any avoidance and mitigation measures identified during the ENVID and the wider scoping process, will be addressed as the project goes forward and documented in the ES.

5.2 Informal Stakeholder Consultation

Ping Petroleum UK Limited (PPUK) has carried out informal consultation with the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) and a number of key stakeholders. The organisations consulted on the proposed development include:

- OPRED;
- Marine Scotland;
- Joint Nature Conservation Committee (JNCC); and
- Scottish Fishermen's Federation (SFF).

As part of the early consultation process, meetings with OPRED took place on 5 March 2019, 11 November 2021 and 20 April 2022, in which PPUK presented an overview of planned activities for the proposed Avalon Field Development and invited OPRED to provide any comments or concerns, in relation to the proposed operations. Subsequently, in April 2019 and October 2021, an ECD was sent to Marine Scotland, JNCC and SFF inviting them to provide any comments or concerns they might have, in relation to the proposed Avalon Field Development.

5.2.1 Consultation Responses

Detailed responses were received from the consultees, which covered a wide range of issues including, but not limited to, the potential impacts from the proposed Avalon Field Development which could arise, the need for a detailed project description, additional data sources for the ES and consideration of cumulative impacts, as well as decommissioning. A full overview of all comments and feedback received during the informal stakeholder consultation and how these are addressed in the ES, is provided in Appendix 3.

5.3 National Policies and Guidance

5.3.1 Scottish National Marine Plan (NMP) Requirements

As discussed in Section 5.3.2, the Scottish National Marine Plan (NMP) has established policies relating to potential impacts from oil and gas activity and these policies have been taken into full consideration during the EIA process. A summary of the general and oil and gas specific policies and objectives which are of relevance to the Avalon Field Development is presented below. All activities will be carried out using the principles of best available technology (BAT) and best environmental practice (BEP). Consideration will be given to key environmental risks including the impacts of noise, oil and chemical contamination and habitat change.

These issues have all been considered as part of the ENVID workshop described in Section 5.1, and therefore already forms part of the EIA. The NMP also requires operators to have adequate risk reduction measures and sufficient emergency response and contingency strategies in place that are compatible with the National Contingency Plan and the Offshore Safety Directive. Furthermore, it requires that any future decommissioning operations will be undertaken in line with standard practice, and as allowed by international obligations.

The proposed Avalon Field Development has been assessed against the following general Marine Plan objectives and policies: GEN 1, 2, 3 ,4, 5, 6, 9, 10, 11, 12, 13, 14, 18, 19, 20 and 21.

5.3.1.1 GEN 1 – General Planning Principle

Development and use of the marine environment should be consistent with the National Marine Plan, ensuring all activities are undertaken in a sustainable manner that protects and enhances Scotland's natural and historic marine environment. PPUK will ensure that the project will be undertaken in accordance with this policy and any potential impacts associated with the proposed Avalon Field Development will be kept to a minimum, as discussed in Sections 7 to 12.

5.3.1.2 GEN 2 – Economic Benefit

The economic benefit of the development should be considered carefully and appropriately, as sustainable development and use of the marine environment can provide economic growth, skill development, employment and opportunities for investment. The proposed Avalon Field Development will provide jobs and tax revenue to the Scottish economy and therefore is considered to comply with this objective.

5.3.1.3 GEN 3 – Social Benefit

Sustainable development and use which provides social benefits is encouraged when consistent with the objectives and policies of the NMP. The proposed Avalon Field Development is in line with sustainable development and considers other users of the sea and impacts upon them, as discussed in Sections 4 and 8.

5.3.1.4 GEN 4 – Coexistence

Coexistence with other development sectors and activities is encouraged in planning and decision-making processes. Where conflict over space or resource exists or arises, marine planning should encourage initiatives between sectors to resolve conflict and take account of agreements where this is applicable. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy and any potential impacts on other sea users associated with the proposed Avalon Field Development will be kept to a minimum as discussed in Section 8.

5.3.1.5 GEN 5 – Climate Change

Marine planners and decision makers must act in a way best calculated to mitigate and adapt to climate change. Developers and users of the marine environment should seek to facilitate a transition to a low carbon economy through mitigation and adaptation and consider ways to reduce emissions of carbon and other greenhouse gasses. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy and any potential impacts associated with the proposed Avalon Field Development will be kept to a minimum, as discussed in Section 9.

5.3.1.6 GEN 6 – Historic Environment

Development and use of the marine environment should protect and, where appropriate, enhance heritage assets in a manner proportionate to their significance. There are no known wrecks or heritage sites within the Avalon Field Development area, as discussed in Section 4.

5.3.1.7 GEN 9 – Natural Heritage

Development and use of the marine environment must:

- Comply with legal requirements for protected areas and protected species;
- Not result in significant impact on the national status of Priority Marine Feature (PMF);
- Protect and, where appropriate, enhance the health of the marine area.

The Avalon well location and pipeline route are not within or in close proximity to (i.e. within 40 km) a Nature Conservation Marine Protected Area (Section 4). However, certain protected species may be present within or make use of the wider project areas, and these are described in (Section 4). PPUK will ensure that the Avalon Field Development will be developed in accordance with this policy and any potential impacts to these protected species will be kept to a minimum, as discussed in Sections 7 and 8.

5.3.1.8 GEN 10 – Invasive Non-Native Species

Opportunities to reduce the introduction of invasive non-native species to a minimum, or proactively improve the practice of existing activity, should be taken when decisions are being made. All vessels, including the FPSO, and the MODU, used during the proposed drilling phase, will follow International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 requirements.

5.3.1.9 GEN 11 – Marine Litter

Developers, users and those accessing the marine environment must take measures to address marine litter where appropriate. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy and any potential impacts associated with the drilling phase of the proposed Avalon Field Development will be kept to a minimum as discussed in Section 7.

5.3.1.10 GEN 12 – Water Quality and Resource

Developments and activities should not result in a deterioration of the quality of waters to which the Water Framework Directive, Marine Strategy Framework Directive or other related Directives apply. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy. Any potential impacts to water quality, associated with the drilling phase of the proposed Avalon Field Development, will be kept to a minimum as discussed in Section 7.

5.3.1.11 GEN 13 – Noise

Developments and use in the marine environment should avoid significant adverse effects of man-made noise and vibration, especially on species sensitive to such effects. PPUK will ensure that any potential impacts from noise associated with the Avalon Field Development will be kept to a minimum as discussed in Section 12.

5.3.1.12 GEN 14 – Air Quality

Development and use of the marine environment should not result in the deterioration of air quality and should not breach any statutory air quality limits. Some development and use may result in increased emissions to air, including particulate matter and gasses. Impacts on relevant statutory air quality limits must be taken into account and mitigation measures adopted, if necessary, to allow an activity to proceed within these limits. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy. Any potential impacts to air quality, associated with the proposed Avalon Field development, will be kept to a minimum as discussed in Section 9.

5.3.1.13 GEN 18 – Engagement

Early and effective engagement should be undertaken with the general public and all interested stakeholders to facilitate planning and consenting processes. The proposed Avalon Field Development has been subject to stakeholder engagement, as discussed in Section 6. The ES will also be subject to public consultation.

5.3.1.14 GEN 19 – Sound Evidence

Decision making in the marine environment will be based on sound scientific and socio-economic evidence, drawn from a wide range of sources including the scientific community, stakeholders and users of the marine area. PPUK ensures the use of sound scientific and socio-economic evidence, as demonstrated throughout this ES.

5.3.1.15 GEN 20 – Adaptive Management

Adaptive management practices should be used to take account of new data and information in decision making. PPUK will ensure the continued use of the most up-to-date data and research, when assessing the impact of the proposed Avalon Field Development, as demonstrated throughout this ES.

5.3.1.16 GEN 21 – Cumulative Impacts

Cumulative impacts affecting the ecosystem of the marine plan area should be addressed in decision making and plan implementation. PPUK will ensure that the Avalon Field Development will be undertaken in accordance with this policy. Any potential cumulative impacts, associated with the proposed Avalon Field Development, will be kept to a minimum as discussed in Sections 7 to 11.

5.3.2 Oil and Gas Policies

In addition to the General Policies stated in Section 5.3.1, the Scottish NMP identifies specific environmental issues, which are associated with different types of development or activity within the marine environment. The issues identified as being relevant to offshore oil and gas activities are summarised in the following sections.

5.3.2.1 Noise

Generated from seismic exploration activity, drilling, production facilities or vessels, burial of pipelines with some noise sources e.g. seismic surveys having the potential to cause injury and disturbance to noise-sensitive species such as cetaceans.

Potential underwater noise impacts as a result of the proposed Avalon Field Development have been assessed in Section 11, and appropriate mitigation measures have been identified.

5.3.2.2 Chemical or Oil Contamination

Causing contamination of water, sediments and fauna.

Potential impacts associated with the use and discharge of offshore chemicals has been assessed in Section 7, whilst the risk of oil contamination has been assessed in Section 11.

5.3.2.3 Habitat Changes

Construction, decommissioning and protection of infrastructure can result in the local loss of species and habitats. However, infrastructure can also provide substrate for colonisation and shelter for fish.

PPUK are to undertake an environmental site survey of the development area and pipeline route later in the year. A full habitat assessment will be undertaken as a part of this survey. The findings of the survey will be detailed in the respective MAT and SAT applications, when these are submitted to OPRED at a later date. Potential impacts associated with habitat changes are discussed in Section 7 and Section 8.

5.3.3 Feature Activity Sensitivity Tool (FEAST)

The Marine Scotland FEAST has been developed to determine potential management requirements for NCMPA's (Marine Scotland, 2021). The Avalon well location and pipeline route are not within or in close proximity to a NCMPA. Therefore, the FEAST tool has not been directly used within this EIA. However, PPUK recognise that certain protected species may be present within or make use of the wider project area and as such, FEAST has been used as an indirect reference tool within the EIA.

5.4 Concerns Identified for Further Assessment

Potentially significant concerns associated with the proposed Avalon Field Development at the early planning stage were identified, by taking into account a combination of the results from the ENVID workshop, the issues raised during the informal consultation process and the national policies and guidance (Sections 5.1, 5.2 and 5.3).

These concerns have driven the environmental considerations throughout the project. Additionally, they have helped guide mitigation measures incorporated into the project planning in order to eliminate, or reduce, the potential environmental impacts. Each concern that has been scoped in for further assessment is fully addressed in the subsequent sections of the ES.

The key concerns relating to the proposed Avalon Field Development are addressed under the following headings:

- Drilling Impacts (Section 7);
- Physical Presence Impacts (Section 8);
- Atmospheric Emissions (Section 9);
- Produced Water Discharge Impacts (Section 10);
- Accidental Events Impacts (Section 11); and
- Other Impacts (Section 12).

In line with the requirements of the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, any potential cumulative and transboundary impacts derived from this project have also been assessed, in the individual impact sections. Cumulative impacts are those resulting from activities, or events, which individually may not be significant, but when combined with impacts arising from different sources have an overlapping sphere of influence to the activities and events under consideration. Therefore, they may produce potentially significant impacts. Transboundary impacts comprise any potential environmental impacts on the seabed, water column and/or atmosphere, and which extent beyond the boundaries of the UKCS.

Section 6
Impact Assessment Methodology

6. Methodology for the Assessment of Impacts and Effects

6.1 Introduction

The assessment methodology used in this Environmental Statement (ES) is based on a 'concerns based' approach, which means that the emphasis has been placed on assessing those environmental aspects (i.e. activities and processes) that have been identified during the scoping phase as potential key issues or concerns.

The assessment methodology follows common legislative requirements and has drawn on a number of established guidance documents and best practice publications. Each concern is dealt with in the same manner, which involves outlining the concern, describing and quantifying the impacts and effects from the proposed activity, recognising any gaps in understanding and explaining how these are dealt with, and defining measures that have been taken to mitigate the impact.

The methodology follows a source-pathway receptor analysis for each potentially significant aspect describing its impacts, followed by an iterative assessment of the indicated effects and their significance, based on the value of those receptors that are affected (Figure 6.1).

The terms 'Impact' and 'Effect' are frequently used interchangeably in many published documents. However, it is important to distinguish between these two terms.

'Impacts' are defined as measurable changes to the baseline environment conditions, as a direct result of project activities (e.g. xx km^2 losses of habitat, or xx mg/l increases in a substance concentration).

Accordingly, 'Effects' are defined as the consequences of those impacts upon receptors of concern, that are subject to assessments of significance. An environmental effect can be any change to the environment, or its use. Effects can be positive (beneficial) or negative (adverse) and can result directly, or indirectly, from project activities or events.

6.2 Source-Pathway-Receptor (SPR) Analysis

Determining which receptors may be affected by a specific activity relies on Source-Pathway-Receptor (SPR) analysis for the identification of the impact and consequential effects. SPR considers all potential routes and mechanisms for impacts to affect all potential receptors, along predicted pathways. The SPR analysis forms the first part of the assessment process, establishing and quantifying the impact(s) of a certain activity.

The term 'source' describes the origin of the impact (i.e. the operational activity resulting in an impact), e.g. the discharge of drill cuttings to sea.

Pathways are processes or series of interactions (i.e. the impacts) that result in an environmental effect upon a final receptor. Hence, the 'pathway' is the means (e.g. deposition of xx m^2 of discharged cuttings onto the seabed) by which the source reaches the affected 'receptor' (e.g. benthic organisms). Pathways may be physical, chemical, biological, ecological or socio-economic processes or interactions.

A receptor is a specific component of the baseline environment or socio-economic domain that will be, or is likely to be, affected by the impacts of the project. This could be a single entity such as a species or community, or a conceptual grouping such as a population or subset of an ecosystem. A receptor may be affected only by the proposed project, or by the proposed project and other relevant projects in combination. If no likely pathway can be demonstrated, then potential receptors can be scoped out, regardless of their intrinsic sensitivity or value.

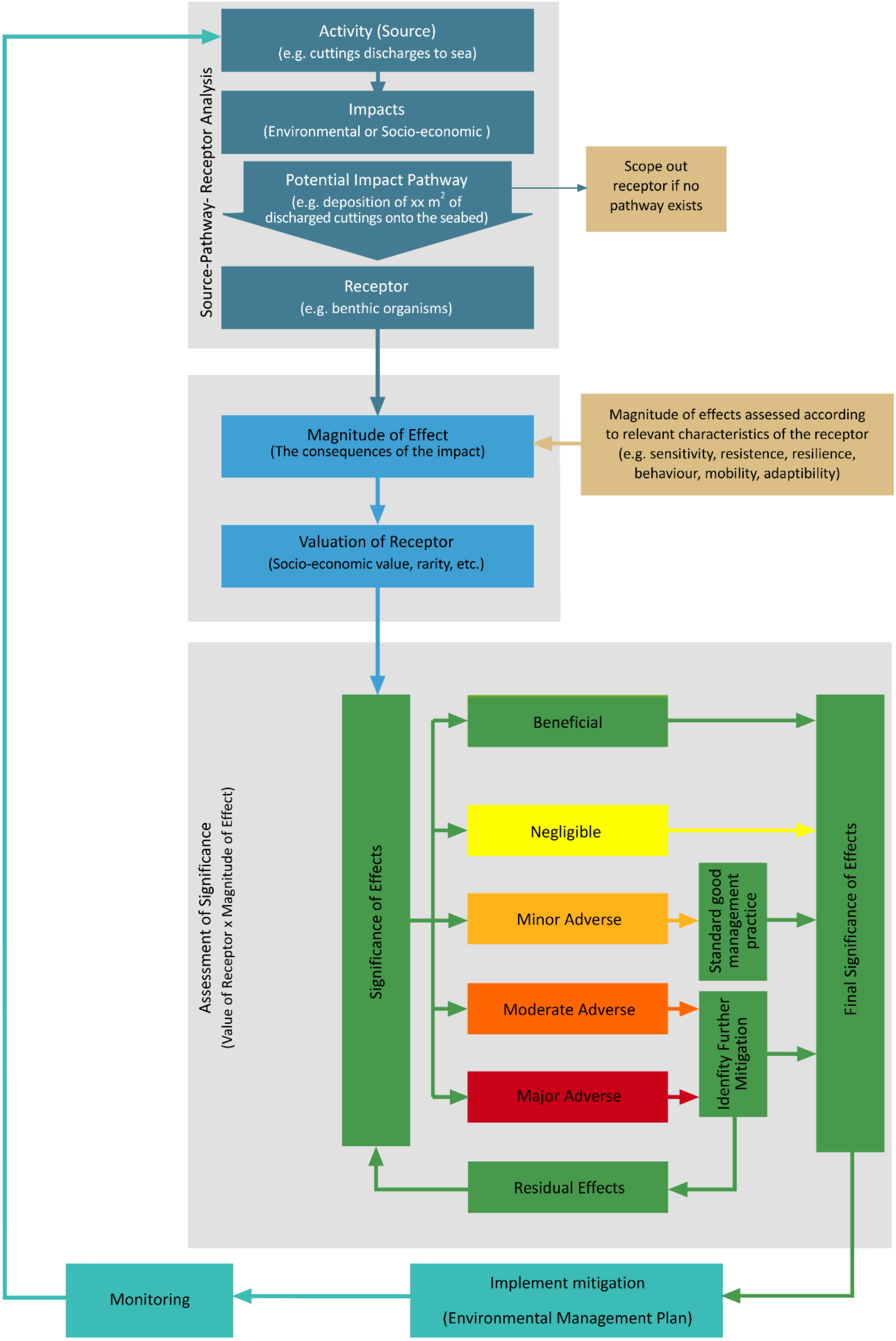


Figure 6.1: Impact assessment methodology

6.3 Assessment of Effects and Their Significance

6.3.1 Characterising and Assessing the Magnitude of Effects

Once the impact has been established, the environmental effect of the impact is determined by assessing the magnitude of the effect against its significance.

The magnitude of the potential environmental effects for each receptor is assessed independently of its value or designated status, using the same categories that were used during the scoping stage, as described in Table 5.1 in Section 5 of this ES. However, the assessment at this stage of the Environmental Impact Assessment (EIA) will be more in depth, including consideration of the sensitivity of each receptor, whilst taking into consideration the SPR analysis described in Section 6.2 above. Ecological sensitivity is the relative change of a system, or population, in relation to the level of disturbance or perturbation (Miller et al., 2010). The sensitivity of socio-economic and socio-ecological systems may be defined in a similar manner (Holling, 2001).

The magnitude of ecological effects is the product of the project-specific impacts and the receptor specific characteristics, that make those receptors sensitive or responsive to the relevant impacts.

6.3.2 Valuation of Receptors

The next stage of the assessment is to determine the nature conservation, socio-economic or heritage value of the affected receptor, following the selected examples provided in Table 5.2 in the previous chapter.

6.3.3 Assessment of Significance of Effects

The significance of each effect is determined by scoring the value of the receptor against the magnitude of the predicted effect (Table 6.1). This methodology is applied individually with respect to the specific ecology, socio-economic or heritage characteristics of each receptor.

Table 6.1: Determining Significance of Adverse Effects

Magnitude of Effect	Nature Conservation Value, Socio-economic Value or Heritage and Cultural Value				
	Negligible	Low	Medium	High	Very High
Negligible	Negligible	Negligible	Negligible	Negligible	Minor
Minor	Negligible	Minor	Minor	Minor	Moderate
Moderate	Minor	Minor	Moderate	Moderate	Major
Major	Minor	Moderate	Moderate	Major	Major
Severe	Moderate	Major	Major	Major	Major

The level of effect significance is used to determine the use and level of mitigation measures. Where a potential effect is assessed as 'moderate' or 'major', then this should be considered "significant" in EIA terms. So far as practicable, mitigation (including offsetting) that reduces the potential magnitude or significance of effects, or the likelihood of significant effects, should be identified. Minor adverse effects would not usually require any action beyond standard good management practices.

Significance categories are defined in Table 6.2. Significance criteria are generally consistent for all ES topics. However, alternative criteria may be defined on a receptor specific basis in individual ES chapters.

Table 6.2: Effect Significance Categories

Category	Definition
Negligible	An effect that is found to be not significant in the context of the stakeholder and/or regulator objectives, or legislative requirements.
Minor	An effect considered sufficiently small (with or without mitigation) to be within accepted standards. No further action is required if it can be controlled by adopting normal good working practices.
Moderate	A significant effect that exceeds accepted limits and thresholds but is less serious than a 'major' adverse effect. Moderate adverse effects may include a reduction in the integrity or quality of a protected site or habitat, or a reduction in a local population of a protected species. Predicted moderate adverse effects require mitigation recommendations.
Major	A serious effect of the highest significance, where an acceptable limit or threshold is likely to be exceeded, that would result in a breach of statutory objectives or law. Major adverse effects would include a major, or permanent loss of a protected habitat, or a local population of a protected species. Predicted major adverse effects require mitigation recommendations.

Mitigation recommendations should be explored as part of the EIA process for 'moderate' or 'major' effects. Effects are re-assessed as described above, until either the effect significance is reduced to acceptable levels ('Minor' or 'Negligible'), or no more mitigation can be applied. Residual effect significance is estimated, from which consenting decisions can be made.

At the end of each impact section in the ES, a conclusion on the level of the significance of effects will be drawn based on the methodology described in this section.

6.3.4 Environmental Risk Assessment

While some potential effects may be very improbable, they may also be extremely serious should they occur, resulting in major adverse effects on some receptors. Therefore, as the final step of the assessment, it is also important to consider the likelihood that a potential effect could occur as predicted.

For accidental events, where it may not be possible to reduce the magnitude of potential impacts or effects, the overall environmental risk may be decreased by reducing the likelihood of an adverse event occurring, through adequate designed-in mitigation measures (Gormley et al., 2011).

6.4 Cumulative and Transboundary Effects

In line with the requirements of The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, any potential cumulative and transboundary impacts derived from this project have also been assessed, in the individual impact sections.

Cumulative impacts are those that arise from activities, or events, which individually may not be significant, but when combined with impacts arising from different sources, and which overlap spatially and / or temporally, may be potentially significant.

Transboundary impacts comprise any potential environmental impacts on the seabed, water column and/or atmosphere, which extend beyond the boundaries of the UKCS.

6.5 Mitigation and Monitoring

The term mitigation is used in general, to cover all efforts used to reduce, or remove, potential impacts (and consequently, effects). These may include design changes, alteration of proposed methods, or other activities in addition to the core project-related activities, aiming to reduce or ameliorate impacts. Mitigation is often used as a catch-all term that also includes avoidance, minimisation, restoration and offsets or compensatory measures.

Mitigation measures are predominantly applied at source, to reduce or remove impacts, with the intention of a corresponding reduction in residual effects upon the receptors in question, to acceptable levels. However, mitigation may also be applied directly at the receptor-level, with the intention of reducing effects, without any influence on the source or the impact.

All mitigation recommendations described within the ES are based upon the realistic worst-case scenarios, ensuring that all measures described are adequate to ameliorate the range of predicted effects. Mitigation recommendations may be revised during the determination of application.

Countries with mature oil and gas industry and well-developed regulatory framework, such as the UK, have incorporated comprehensive mitigation measures within their permitting and consenting regime. These mitigation measures are further informed and/or augmented with good industry practice guidance from organisations and institutions such as OSPAR, Oil and Gas UK and IOGP.

PPUK's integrated management system (PIMS) will ensure all regulatory and industry standards are met, thus incorporating many inherent mitigation measures, as part of its "normal" operational procedures and practices.

The Ping Petroleum framework for environmental management sits within the overall Ping Integrated Management System and is based on the management structure described in the standard ISO14001:2015.

The functional structure of the organisation and PIMS is illustrated in Figure 6.2.

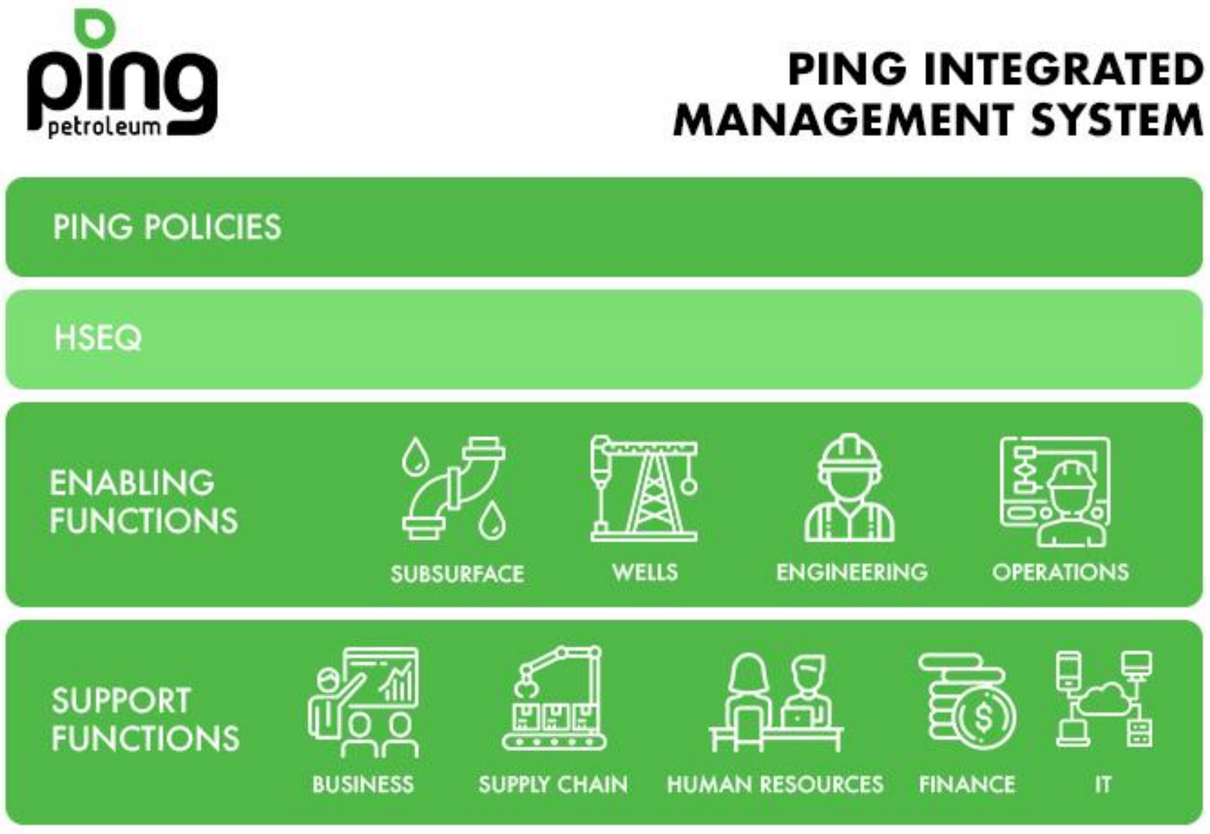


Figure 6.2: PIMS structure

During the procurement process, all major third-party contractors will be audited to ensure they have suitable management systems in place.

Environmental mitigation and monitoring requirements stated throughout the ES, will be taken forward in an Environmental Management Plan (EMP). A Commitments Register, summarising these mitigation measures, has been included in Appendix 5.

Section 7
Drilling Impacts

7. Drilling Impacts

This section addresses potential issues and concerns associated with drilling discharges, which were raised during the Environmental Issues Identification (ENVID) workshop, informal stakeholder consultation and those which are part of Scotland's National Marine Plan (NMP), namely:

- Impacts on seabed communities due to discharges to sea including:
  - Deposition of drill cuttings and associated water-based muds (WBM) from the top-hole section directly to the seabed;
  - Deposition of excess cement from the top-hole section directly to the seabed;
- The NMP, Oil and Gas Objectives and marine planning policies list the potential impacts resulting from chemical contamination. As a result, the discharge to sea of chemical additives used during the drilling process for the top-hole section has been considered in this section.

During the drilling operations associated with the proposed development, discharges will be made directly onto the seabed. These discharges have the potential to affect the marine environment through both chemical and physical mechanisms. The extent of these discharges has been quantified and the significance of their associated effects are assessed in this section.

7.1 Description and Quantification of Discharges

7.1.1 Mud and Cuttings

During the drilling of the two production wells at the proposed Avalon Field Development, drill cuttings and spent drilling muds will require disposal. A detailed description of the well design, section diameters and lengths, and drilling and cementing methods for both wells are provided in Section 3.3.

Drill cuttings consist of the chips of crushed rock broken off by the drill bit, as it extends the wellbore. Drill cuttings therefore vary in nature, depending on the characteristics of the rock layers present and the drill bit used, but generally range in size between very fine clay sized particles (<2 µm) to coarse gravels (>30 mm) (Neff, 2005).

The mud system for the top-hole sections of both wells (42" × 36" × 26" and 17½") will consist of seawater with high viscosity bentonite sweeps to clean out the borehole. These top-hole drill cuttings and associated muds will be deposited on the seabed in the immediate vicinity of the wellbore. It is estimated that 1 038 tonnes of cuttings and up to 1 560 tonnes of WBM from the two top-hole sections per well will be discharged to sea. Hence, up to 2 076 tonnes of cuttings and 3 120 tonnes of WBM may be discharged in total, for both wells drilled.

Due to the highly deviated profile of the Avalon well(s), low toxicity oil-base muds (LTOBM) will be used for the deeper deviated 12¼" and 9½" × 8½" sections of the well. The discharge of LTOBM is prohibited in UK waters. Therefore, the LTOBM will be used in a closed system where cuttings and drilling fluids will be circulated back to the rig via the conductor, passed through a mud recovery system, back onto the MODU. Back onboard the MODU the muds will be reconditioned and reused, where possible, but ultimately will be shipped to shore for appropriate treatment and disposal. Spent LTOBM and associated cuttings will not be discharged into the marine environment. In addition, LTOBM contaminated completion chemicals and wellbore clean-up chemicals will also be returned to the rig and shipped to shore for treatment and disposal.

Table 7.1 provide an overview of the estimated amounts of cuttings generated.

Table 7.1: Estimated cuttings volumes for the Avalon production wells

Section	Mud System	Cuttings Disposal Route	Section Length [m]	Cuttings Volume [m^3]	Cuttings Generated [Tonnes]	WBM Discharged [Tonnes]
26" × 36" × 42"	WBM, seawater and viscous sweeps	Discharged at the seabed	80	215	558	310
17½"	WBM, seawater and viscous sweeps	Discharged at the seabed	793	185	480	1 250
12¼"	LTOBM	Collected on the MODU and shipped to shore	784	66	170	N/A
8½"× 9½"	LTOBM	Collected on the MODU and shipped to shore	771	31	31	N/A
Total (for a single production well)				**496**	**1 289**	**1 560**
Total (for both production wells)				**992**	**2 578**	**3 120**

7.1.2 Cement

The casings used to prevent the wells from collapsing will be cemented into place by pumping cement down the casing string, out through the bottom and back up to the surface through the annulus (i.e. the space between the casing pipes and the side of the borehole). For the conductor (36" × 30") and surface casing (20") it is critical to get cement back to seabed to ensure the structural integrity of the well and therefore it is expected that some cement will be discharged to the seabed. Therefore, to ensure the cement will reach the seabed level in the annulus an excess of up to 300 % cement has been planned for.

Consequently, it is anticipated that up to 87.4 tonnes (35 m^3) of cement slurry per well (174.8 tonnes (70 m^3) in total for both wells) may be discharged in this fashion for the conductor. This is based on the entire amount of 300 % excess cement reaching the seabed, in the very unlikely event that the holes are in gauge and the full amount of 300 % excess cement would be pumped. As explained in Section 3.3.4, subsequent casing strings will not be cemented up to the surface, so it is highly unlikely that any cement will return to the rig from these, however, in the event that it does, it will be captured in the skip and ship system and returned to shore for processing due to the presence of LTOBM in the well at this time.

A small volume of cement will also be discharged following each cement job during the process of cleaning the cement pump and mixing tank. The volume of cement being discharged at this time will be very small and is unlikely to exceed 2 m^3 per well, i.e. a combined total of up to 4 m^3 of cement discharges from cleaning the tanks is estimated, when both wells are drilled.

7.2 Impacts from Muds and Cuttings Discharges

7.2.1 Effects on Benthic Communities

Considerable data have been gathered from studies into the effects of drill cuttings and WBM on benthic communities, conducted at various sites on the UKCS and worldwide as part of academic research and general environmental monitoring of the oil and gas industry e.g. DTI, 2001; Neff, 2005; OSPAR, 2007, Neff, 2010, Bakke et al., 2013 and Henry et al., 2017. This work has led to a broad consensus on the potential effects that discharged cuttings and associated fluids can have on benthic organisms and communities as follows

7.2.1.1 Physical Impacts on Benthic Communities

The primary impact identified with regard to WBM cuttings discharges is the direct smothering effect of burial by material discharged as it settles on the seabed (Neff, 2005; OSPAR, 2007; Gates & Jones, 2012; Jones et al., 2012). Sedimentation can be very high near oil and gas installations, because drill cuttings typically settle on the seabed, when discharged directly to sea (Ellis et al., 2012). However, the use of WBM in drilling operations, significantly helps to reduce the environmental impacts from discharge of drill cuttings (Bakke et al., 2013).

Vulnerability to the impact caused by cuttings discharges varies between different benthic groups, depending on their physiology and ecology, and some species (such as sessile species among others) are likely to be more sensitive than others. For example, in the case of burrowing organisms, which feed on subsurface sediments, many such species are capable of burrowing up through deposited sediment ranging from 10 mm to 300 mm in thickness to live at the new sediment surface (e.g. Maurer et al., 1979; Kukert, 1991). However, it is unlikely that whole communities would survive burial under more than a few centimetres, leading to a reduction in species diversity and an increase in the abundance of opportunistic species (Ellis et al., 2012).

The presence of cuttings material on the seabed also prevents the flow of oxygen and nutrients to the affected areas. This oxygen depletion and associated disruption of nutrient flow can be sufficient to reduce the abundance and diversity of the benthos (Neff, 2005; Trannum et al., 2010).

An Oslo and Paris convention (OSPAR) review of environmental monitoring results from the United Kingdom, the Netherlands and Norway concluded that the effects of WBM cuttings discharge on the seabed fauna, tend to be very subtle or undetectable. Any disturbance of the fauna typically only occurs within 50 m from single well locations, although the presence of drilling material at the seabed is often detectable chemically at distances beyond this (OSPAR, 2007). Other studies on the effects of WBM cuttings on sediment fauna consider, that any impacts are typically restricted to within 100 m to 250 m of the discharge location and recovery seems rapid (Bakke et al., 2013).

Although there are no studies available into the specific effects of cement discharges, it is anticipated that the primary effects of discharge will also arise from the physical smothering of organisms within the area of cement deposition.

Increased concentrations of suspended particles in the water near the seabed may also cause damage to feeding and respiratory organs, causing metabolic stress and reducing growth, and also affecting reproductive and survival rates. This, for example, has been demonstrated in scallops and other bivalves (Cranford et al., 1999; Bechmann et al., 2006), but may also affect pelagic organisms, sponges and corals (Bakke et al., 2013). Larger individuals are generally more resistant to elevated levels of suspended solids in the water column, and some species are likely to be more sensitive than others. It should also be noted that effects related to increased suspended sediment levels will mostly take place close to the well location and be short-term, episodic and pulse-wise depending on plume behaviour (Bakke et al., 2013) The discharge of WBM cuttings may cause biological effects both during suspension in the water masses and after sedimentation.

There is also limited evidence available, indicating that rock material brought up from within wells has a lower nutrient value than natural sediments. This may lead to increased mortality, due to starvation in affected communities (Trannum et al., 2010). Alteration of the substrate by drilling discharges can also affect the settlement of benthic organisms that subsequently colonise the area (Trannum et al., 2010).

The accumulation of cuttings, WBM particles and cement at the Avalon Field Development is, therefore, likely to mainly affect the local benthic community, by burying animals and, to a lesser degree, impairing the feeding and respiration activities of others. However, these impacts will be highly localised and short-term in duration. Near-bed current velocities and sediment mobility in the CNS are generally sufficient to prevent detectable local accumulation of cuttings after drilling has ceased (DTI, 2001; OSPAR, 2007; Bakke et al., 2013 and Henry et al., 2017). Any local accumulation of cuttings material will gradually disperse to the wider environment over time.

The magnitude of physical impacts from the discharge of drill cuttings to benthic communities is thus judged to be minor, on representative or 'low' value receptors, resulting in a 'minor' effect significance.

7.2.1.2 Chemical Impacts on Benthic Communities

The majority of constituent chemicals used in both the WBM itself and additional drilling and completion chemicals, are generally highly water soluble and show low persistence, toxicity and likelihood to be incorporated into the tissues of marine organisms. Typically, modern WBMs contain fresh, or salt, water as the base fluid, and a weighting agent such as barite ($BaSO_4$), or ilmenite ($FeTiO_3$). Clays or organic polymers are incorporated to create a homogeneous fluid. These weighting agents may contain elevated levels of barium and other metals, which will typically be higher than those found in naturally occurring seabed sediments.

However, the metals and metal salts associated with barite, clay, and cuttings particles are not readily bio-accumulated by animals living in close association with cuttings piles and the metals are not passed efficiently through marine food chains (Neff, 1987; Leuterman et al, 1997; URS, 2002; Neff, 2010). Since 2001, the chemicals used as additives in drilling muds are mostly classified as PLONOR (Pose Little or No Risk to the Environment) by the OSPAR Commission.

Field studies of organisms around cuttings piles have observed that upon intake by ingestion or adhesion to epithelial surfaces, the majority of metals remain bound to cuttings grains in an insoluble form and are not bioavailable. Jenkins et al. (1989) found that around 97 % of the barium content remained in granular form and were not assimilated into the study species' tissues. The acute toxicity of WBM is considered to be low (Neff, 1987) and in general, any toxic effects of WBM associated with cuttings discharge have been deemed to be negligible (Neff, 2005; 2010; OSPAR, 2007).

Furthermore, monitoring in the North Sea has not identified any in situ effects of WBM cuttings on sediment macrofauna community structure (Bakke et al., 2013). The hydrodynamic regime of the central North Sea (CNS) is conducive to rapid dilution and dispersion of solutes. The chemical additives in the WBM are generally water-soluble and will therefore dissolve and disperse naturally in the water column.

The magnitude of chemical impacts from the discharge of drill cuttings is thus minor on benthic communities, a 'low' value receptor, so that effect significance is 'minor'.

7.2.1.3 Impacts on Protected Sites, Important Species and Annex I Habitats

Table 7.2 shows that the nearest protected areas are at considerable distances from the proposed drilling location at the Avalon field.

Table 7.2: Proximity of Avalon field to nearest protected areas

Habitat or Protected Area	Distance [km]
Turbot Bank NCMPA	66
East of Gannet and Montrose Fields NCMPA	70
Scanner Pockmarks SAC	68

In general, when the cuttings are not displaced from the wellhead during drilling, top-hole cuttings piles may accumulate up to a few metres thick near the drill centre (i.e. close to the point of discharge), becoming more thinly dispersed with increasing distance from the well head to typically less than 1 mm beyond 100 m from the well location.

Although the Avalon Field Development is situated within an area of pockmarks, no potential Annex I pockmark habitat has been identified in the immediate vicinity of the proposed well location which are considered likely to be impacted by drilling discharges (Fugro, 2013b).

The PMFs 'subtidal sands and gravels' and 'offshore deep-sea muds' habitats are also, potentially, present within the proposed Avalon Field Development. However, the habitat is one of the most widespread and common habitats in the Scottish offshore environment (Marine Scotland, 2022a) and is also unlikely to be significantly affected due to the limited zone of influence of the drilling discharges.

Juvenile ocean quahog (*Arctica islandica*) specimens were observed during the 2013 site survey at the Avalon Field Development. The ocean quahog has been included on the Convention for the Protection of the Marine Environment and the North-east Atlantic (OSPAR) list of 'Threatened and/or Declining Habitats and Species' (OSPAR, 2022), and as a Scottish Priority Marine Feature (PMF) (NatureScot, 2022a). Juvenile ocean quahogs were also identified during the 2013 Summit Site Survey at the Avalon field (Fugro, 2013b).

Studies have shown that populations of *A. islandica* are able to tolerate changes in smothering and siltation rates with almost no negative effect on their population structure or growth rate (Powilleit et al., 2006 and Powilleit et al., 2009). When *A. islandica* experiences an increased amount of smothering, organisms have been shown to be able to burrow to the sediment surface (MarLIN, 2020) and *A. islandica* has been known to tolerate being smothered under 1.5 m of sediment (Powilleit et al., 2006). Any disturbance of ocean quahogs in the area would be limited to a very small proportion of the population.

However, the Feature Activity Sensitivity Tool (FEAST) shows ocean quahogs are sensitive to the discharge of non-synthetic compound contamination (including heavy metals, hydrocarbons, produced water) and synthetic compound contamination (including pesticides, antifoulants, pharmaceuticals) (Marine Scotland, 2022d). Nonetheless, as described previously, the toxic effects of WBM cuttings discharges have been generally deemed to be negligible (Neff, 2005; 2010; OSPAR, 2007) and monitoring in the North Sea has not identified any in situ effects of WBM cuttings on other sediment macrofauna community structures (Bakke et al., 2013).

The magnitude of impact from the discharge of drill cuttings is thus low on protected sites, important species and Annex I habitat receptors of 'high' value receptor, and so effect significance is 'minor'.

7.2.2 Potential for Recovery

As the physical and chemical effects of the cuttings and mud discharges are of greatest concern, the long-term recovery of affected communities will be influenced by the persistence of the discharged material itself. Cuttings piles associated with WBM are known to have a reduced tendency to aggregate, compared to historic discharges of OBM contaminated cuttings (Niu et al., 2008). Top-hole cuttings piles in the central and northern North Sea will typically disperse over a timescale of 1 year to 10 years, through re-suspension and sediment transport chiefly influenced by currents (DTI, 2001). The process of dispersion and erosion of the cuttings pile would begin during the drilling operations and continue after they end (DTI, 2001; Henry et al., 2017).

Recovery of the benthic communities has been shown to begin soon after the discharge has ceased, via colonisation from surrounding areas and planktonic recruitment (Daan & Mulder, 1996). As mentioned in Section 4 Local Environment, the seabed communities at the Avalon Field Development are typical of those found in surrounding areas of the CNS, suggesting the presence of reproducing populations in adjacent sediments so that the potential for such recruitment is likely to be strong. The altered substrate will be dispersed relatively quickly, particularly where it is more thinly deposited, allowing communities consistent with those present pre-drilling, to be re-established.

The time taken for benthos to recover from impacts arising from drill cuttings varies across the North Sea. Henry et al., 2017 studied 19 historic drilling sites across the North Sea for the potential impacts on the benthos from drill cuttings. Where strong impacts were detected, more than half of the sites exhibited effects from drill cuttings for at least six years after drilling operations ceased, with sites located in the northern North Sea exhibiting the slowest rate of recovery, whilst benthos in the southern North Sea were typically not altered by drill cuttings (Henry et al., 2017).

This difference is likely explained by the higher levels of OBM previously used in the northern North Sea, as well as the stronger current regime in the southern North Sea, which may aid dispersion of cuttings (Henry et al., 2017). The study did not consider any sites in the northern North Sea drilled with WBM.

After each drilling operation at the Avalon Field Development, there will be a localised accumulation of top-hole cuttings and spent WBM in the immediate area around the well location. The main effects associated with WBM cuttings, relate to physical presence and temporary reduced sediment oxygen concentration (SOC). As described above, near-bed current velocities and sediment mobility in the CNS will typically disperse top-hole hole cuttings piles over a timescale of 1 year to 10 years, (DTI, 2001), whereas the SOC in the surface sediments will typically recover within 3 to 6 months (Bakke et al., 2013). Therefore, over time, full recovery of the benthos is expected.

7.3 Cumulative and Transboundary Impacts

The CNS is an area of intensive oil and gas activity, with several developments located in the wider region surrounding the Avalon Field Development. The nearest producing fields to the Avalon Field Development are Tweedsmuir South, approximately 13 km to the north, Tweedsmuir, approximately 17 km to the north, and Brodgar, 20 km to north-east. It is expected that cuttings material deposited at the well may overlap with cuttings from the previously drilled exploration and appraisal wells. However, it is unlikely that there will be cumulative effects between the Avalon Field Development and the cuttings from the previously drilled wells due to the distance between fields which is greater than the likely extent of drill cuttings spread.

The cumulative effect of the Avalon Field Development and the previously drilled wells will be in the same order of magnitude as those assessed for the Avalon Field Development by itself and thus no significant cumulative impacts are expected from the discharge of the top-hole cuttings, mud and cement.

At its nearest point, the UK/Norway median line is situated approximately 107 km north-east of the Avalon Field Development. As the zone of influence of the drilling discharges is anticipated to be primarily limited to 50 m from the well, no transboundary impacts are anticipated.

7.4 Mitigation

An environmental baseline survey (EBS) and habitat investigation of the proposed Avalon Field Development location was undertaken in 2013 to ensure no features of conservation importance were present in the immediate vicinity of the well location, where the main impacts from drilling discharges are anticipated.

All chemicals used for the drilling operations are regulated under the Offshore Chemicals Regulations 2002 (as amended), which aim to replace chemicals with poor environmental characteristics by more environmentally friendly chemicals. Selection of all chemicals that may be used in drilling the proposed well, will be based upon both their technical specifications, including their environmental performance. Drilling chemicals with no or minimal potential for impacts on the environment (PLONOR) will be used in the operations, wherever feasible, and the use of all chemicals will be minimised where practicable.

For cement discharges, the amount discharged onto the seabed during installation of the top-hole casings will be minimised by visual monitoring of the operation by a remotely operated vehicle (ROV). To aid the visual monitoring a black UV light on the ROV will be used to monitor cement returns to the seabed. Once returns are observed, pumping will be stopped, to minimise discharged volume. Subsequent casing strings will not be cemented up to the surface, so it is highly unlikely that cement will return to the rig. However, in the event that it does, it will be captured in the skip and ship system and returned to shore for processing, due to the presence of OBM in the well at this time.

The lower well sections will be drilled with LTOBM, whereby all cuttings and drilling fluids are returned to the drilling rig. These drilling muds will be recycled as far as possible, which will reduce the quantities of mud used. Ultimately, the cuttings and remaining LTOBM will be skipped and shipped to shore for appropriate treatment and disposal. This will eliminate any potential for the LTOBM contaminated cuttings and drilling fluids discharged at sea during the drilling process.

All chemicals used will be approved by Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and will be in accordance with UK chemicals regulations. Wherever practicable and technically feasible, chemicals without substitution warnings will be prioritised over those that do have warnings. The actual mud and chemical usage will be monitored during drilling operations and subsequently reported to Environmental and Emissions Monitoring System (EEMS), which is maintained by the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED).

7.5 Conclusion

The effects of WBM and cuttings discharges on the benthic environment are closely related to the total quantity discharged and the oceanic energy regime encountered at the discharge site, particularly the currents close to the seabed itself (Neff, 2005).

The discharge of cuttings and WBM at the Avalon Field Development location has the potential to cause a localised impact to the benthic environment, primarily through direct physical changes to the seabed. This is expected to affect benthic communities within 50 m of the well location, over a medium to long time period (i.e several to ten years). Any effects on the benthos at distances over 50 m from the well locations, is expected to start recovering soon after discharges cease. Physico-chemical effects may be detected at distances up to 250 m from each well location.

Ocean quahogs have been documented in the vicinity of the proposed development. However, the species is known to exhibit high resilience to the effects of smothering (Powilleit et al., 2006; 2009). The PMFs 'subtidal sands and gravels' and 'offshore deep-sea muds' habitats are also, potentially, present within the proposed Avalon Field Development. However, the habitat is one of the most widespread and common habitats in the Scottish offshore environment (Marine Scotland, 2022a) and is unlikely to be significantly affected due to the limited zone of influence of the drilling discharges.

The toxicity of WBM is considered to be low (Neff, 1987) and in general, any toxic effects of WBM associated with cuttings discharge have been deemed to be negligible (Neff, 2005; 2010; OSPAR, 2007).

Bearing these factors in mind, the impacts arising from the discharge of WBM during drilling operations at the Avalon Field Development are considered to have the potential to impact on receptors of a 'high' value, but the magnitude of any impact would be 'minor', due to the resilience of ocean quahogs to smothering and siltation impacts and the localised alteration of the seabed at distances over 50 m from the well locations. Therefore, the level of significance of effects from discharge of drill cuttings into the marine environment at the Avalon Field Development site are considered to be 'minor' and thus not significant.

Section 8

Physical Presence Impacts

8. Physical Presence Impacts

This section assesses the potential impacts arising from the physical presence of the proposed Avalon Field Development infrastructure. This includes the presence of infrastructure associated with associated drilling, construction and ongoing operation activities, as defined in Section 3 (Project Description), upon benthic communities, and other users of the sea. The scope of this assessment has been informed by the outcomes of the Environmental Issues Identification (ENVID) exercise (Appendix 4), informal statutory consultation and National Marine Plan (NMP) policies and statutory guidance as explained in Section 5 (Identification of Impacts).

Potential impacts of the physical presence of the proposed Avalon Field Development assessed in this Section, relate to the following aspects:

- Installation, presence and removal of mobile offshore drilling unit (MODU) impacting on seabed communities and other users of the sea;
- Physical presence of the MODU and support vessels at the sea surface impacting other users of the sea;
- Physical presence of the Riser Base Structure (RBS) and Xmas trees impacting other users of the sea;
- Physical presence of the anchored mooring systems for the FPSO and offshore wind turbine and support vessels at the sea surface impacting other users of the sea
- Laying of pipelines, umbilical and power cables (including trenching and backfilling) impacting on seabed communities;
- The placement of protection material (including concrete mattresses, grout bags, or scour protection) on flowlines or other infrastructure impacting on seabed communities;

This section also assesses the potential impacts of the physical presence of a floating offshore wind turbine (OWT) and installation of a subsea power cable, up to 25 km in length, connecting the OWT to the Excalibur FPSO and for which a Crown Estate INTOG application is currently in progress. Impacts associated with the possible installation of a 5 km gas import/export pipeline to the Britannia pipeline end manifold (PLEM) or a 40 km pipeline to the Ettrick PLEM is also considered here.

8.1 Physical Extent of the Area Affected by the Proposed Operations

8.1.1 The Mobile Drilling Unit

The MODU to be used for drilling operations to is still to be determined but will involve either a jack-up drilling rig or an anchored semi-submersible drilling rig (see Section 3). Wells 21/6b-J and 21/6b-K tied-back to the Excalibur FPSO are currently planned to be drilled in Q3 of 2023 at the earliest.

8.1.1.1 Jack-up Drilling Rig

If selected, the jack-up drilling rig will be towed to the well locations by up to three vessels. When the rig arrives on location, its three legs will be lowered to the seabed and test loaded with seawater to confirm a secure foundation. The hull will then be raised (jacked-up) to operational height above the sea surface to provide a safe and stable platform for the drilling and completion operations. As described in Section 3, a large cylinder (spud can) is present at the base of each leg (three legs in total), to provide stability and to prevent the rig from sinking too far into the seabed.

Assuming that the diameter of a typical spud is 14 m diameter (Parker et al, 2008) then the total footprint of the rig on the seabed will be 0.000154 km², or 0.000462 km² for all three legs. If both wells are drilled, then the maximum footprint on the seabed will be 0.000924 km².

Note that stabilisation material, such as rock dumping, or the placing of sandbags for the spud cans is not anticipated to be required in the event of a jack-up rig being selected.

8.1.1.2 Semi-submersible Drilling Rig

If a semi-submersible drilling rig is selected, it will be towed to the development location by three anchor handling vessels. Once on location, the vessels will be used to place 8 to 12 anchors on to the seabed, to secure the drilling rig safely. Each anchor line is expected to extend to approximately 1 400 m from the drilling rig. As a worst-case estimate it is assumed that 750 m of this chain will raise and lower on the seafloor over a lateral distance of up to 5 m either side, i.e. due to swell movement during adverse weather conditions. This would result in a worst-case scenario of the periodic disturbance of 7 500 m² (0.0075 km²) of seabed per anchor chain. Assuming that as many as 12 anchors could potentially be used by a semi-submersible drilling rig this would equate to an overall worst-case area of seabed disturbance of 90 000 m² (0.09 km²) per deployment. If both wells are drilled, the maximum area of seabed potentially impacted by the anchors and chains from the semi-submersible drilling rig is approximately 180 000 m² (0.18 km²).

8.1.2 Summary of worst-case MODU Footprint

Table 8.1 summarises the estimated worst-case footprint of seabed disturbance impacts due to the presence of both MODU options at the Avalon field.

Table 8.1: Estimated worst case footprint of the MODU anchor options

MODU Option	Spud Can or Line Footprint [m²]	Number of Spud Cans / Anchor Lines	Impact Footprint (per well) [m²]	Total Footprint of Impact [m²]	Total Footprint of Impact [km²]
Jack-up MODU (x2 wells)	154	3	462	924	0.000924
Semi-submersible MODU (x2 wells)	7 500	12	90 000	180 000	0.1800

8.1.3 Infield Subsea Infrastructure and Optional Import/Export Gas Pipeline

Infield seabed infrastructure to be installed as part of the proposed Avalon Field Development will include Xmas trees for both production wells within protective structures and the Riser Based Structure (RBS) which houses the Subsea Distribution Unit (SDU), subsea isolation valve (SSIV) and umbilical termination assembly (UTA) as described in Section 3.2. Table 8.2 summarises the total area of footprint on the seabed for the Xmas trees and RBS.

The RBS will house the dynamic UTA and the SDU, as well as pipework and controls for the isolation valves for the production and gas lift lines. It will also house the SSIV for the optional gas import/export pipeline system. The RBS will be contained within a fishing friendly structure with a total footprint on the seafloor of 12 m × 10 m and with a height of 4 m from the seabed. The total area of seabed occupied by the RBS will thus be 0.00012 km^2.

The Avalon Xmas trees will be gravity-based steel structures measuring 5 m by 5 m and with a height of 4 m above the seabed. Each structure comprises an assembly of valves and fittings installed on the seabed on top of the wells, to control the flow of oil and gas from the target reservoir. The Xmas trees will be protected by a fishing friendly protection structure. The total area of footprint on the seabed by both Xmas trees will be 0.00005 km^2.

All subsea structures have been designed to be fishing friendly.

All pipeline flowlines and umbilicals associated with the infield base case development will be trenched and backfilled by a Canyon T1200/T1500 jetting trencher. These include the 8’ oil pipeline, gas lift line and control umbilical from the Avalon drill centre to the RBS. The area disturbed due to the trenching of each line will be 0.0168 km^2 (0.0504 km^2 in total) (Table 8.2).

Trenches will be cut to ensure a minimum depth of burial of 1.2 m to 1.5 m below the seabed allowing the pipelines, umbilical and cable to be buried below the natural seabed level to a depth sufficient to ensure a minimum of 0.6 m cover. The jet trenching will be undertaken in one pass, moving along the route. The trenching tool will be positioned on tracks straddling the pre-laid pipe, or umbilical, and jet cutting the sides of the trench. Jets fluidise the sediment, allowing the pipe to settle into the trench under its own weight. The fluidised spoil then falls back on top of pipe naturally backfilling the line, negating the need for mechanical backfilling. Any direct seabed disturbance caused by the trenching will be temporary and spatially limited to the 5.6 m wide corridor bounded by the tracks of the J-1200 jet trencher itself. Table 8.2. presents the total area of seabed disturbance associated with the planned trenching on infield pipeline flow lines and umbilicals.

If adopted as part of an optimal field design, a gas import/export pipeline will be installed between the Excalibur FPSO and the existing Ettrick pipeline PLEM, located 40 km to the west. Installation of this pipeline will involve burial to minimum target depth using the Canyon T1200/T1500 jetting trencher. Assuming that seabed disturbance caused by the trenching tool will be limited to the area between its tracks (5.6 m) then the total area of seabed disturbance will be 0.244 km^2 for a 40 km pipeline. If the Britannia option is selected (5 km away) then the area of seabed disturbance due to the installation of the pipeline will be less (0.028 km^2). Table

8.2. presents the worst-case footprint of seabed disturbance due to the installation of the optional import/export pipeline (Ettrick PLEM option).

Table 8.2: Estimated worst case footprint of subsea infrastructure for the Avalon Field Development

On the seabed (footprint)	Installation Method	Seabed Disturbance Length [km]	Seabed Disturbance Width [km]	Track Width [km]	Total Area Affected [km²]
Xmas trees (x2)	Run on drill pipe from MODU	0.005	0.005	-	0.00005
RBS (including SDU, UTA and SSIV)	Lowered by crane from CSV	0.012	0.010	-	0.00012
Area of seabed habitat take					**0.00017**
Buried (disturbance)					
8" oil pipeline between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
Gas lift line between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
Control Umbilical between the Avalon drill centre and RBS	Laid / trenched and buried by T1200/T1500 jet trencher	3	0.0056	0.0048	0.0168
OPTION 6" gas import/export pipeline to Ettrick PLEM *	Laid / trenched and buried by T1200/T1500 jet trencher	40	0.0056	0.0048	0.2240
Worse case area of seabed disturbance					**0.2744**
Total					**0.27457**

Notes:
* = Only one of these options will be progressed as part of the proposed Avalon Field Development. The total area affected includes the worst case for seabed disturbance, the 40 km pipeline to Ettrick, in the total.

8.1.4 Pipelines and Control Umbilicals Protection

Protection material is anticipated to be required to be placed on the seabed at several points within the Field Development including the drill centre and the points of emergence of the buried pipelines and umbilicals from the seabed. If the gas import/export pipeline route option to the Ettrick PLEM is adopted this will necessitate the crossing of the Britannia to St. Fergus oil pipeline (PL1270) for which additional protection will be required.

Pipeline protection options are presented in Section 3 and comprise concrete mattresses and grout bags. Placing of this material on the seafloor will alter the ambient seabed from predominately sediment habitats to hard substrata within the footprint of the placed material.

Each concrete mattress measures 6 × 3 × 0.15 m and the number required, together with the estimated area of seabed covered, is summarised in Table 8.3. This includes a worse case contingency of 20 additional mattresses should these be required.

Table 8.3: Estimated area of seabed covered by concrete mattresses

Location	Mattress Dimension [m]	Number of Mattresses	Area Covered [m²]	Area Covered [km²]
Avalon Drill Centre	6 × 3 × 0.15	80	1440	0.00144
Spools between RBS and Xmas Tree	6 × 3 × 0.15	16	288	0.000288
Gas import/export tie in point	6 × 3 × 0.15	50	900	0.0009

Britannia to St. Fergus Pipeline Crossing *	6 × 3 × 0.15	8	144	0.000144
Contingency	6 × 3 × 0.15	20	360	0.00036
Total		**174**	**3 132**	**0.003132**

Ten tonnes of 25 kg grout bags will be required to protect the ends of the control umbilical where it emerges from the seabed, at the RBS and between the RBS and Xmas trees. This will cover an area of 2 m × 4 m at each of these areas, hence a total area of seabed of 8 m^2 (0.000008 km^2) is expected to be covered on the seabed by grout bags.

In summary the worst-case seabed footprint covered by protective material including concrete mattresses, grout bags will be 0.00314 km^2 (Table 8.4).

Table 8.4: Summary of Worst-Case Seabed Footprint Covered by Protective Material

Protection Material	Temporary/ Project Lifetime/ Permanent	Total Area Affected [km^2]
Mattresses	Project lifetime	0.003132
Grout bags	Project lifetime	0.000008
Total		**0.00314**

Note that the final crossing designs will be determined during the front-end engineering design (FEED) and be informed by the requirements of the respective pipeline operators in the area who will require specific designs to be adhered to. This means that for some (or all) pipeline crossings there may be a requirement to use protective rock dump instead of mattress protection. Should rock dump be required, a DP flexible fall-pipe vessel will be used to place the rocks on top of the pipeline. For the purposes of this assessment, it is assumed that up to 1,800 tonnes of rock dump will be required per crossing as a worst-case scenario. There will be one crossing if the Ettrick option is chosen. The total predicted rock tonnage will be revisited during detailed design and will be included as part of the pipeline works authorisation (PWA).

Scour protection around the anchor points of the OWT is also anticipated to be required and is addressed in Section 8.1.6 below.

8.1.5 FPSO Mooring System

The FPSO will be anchored to the seafloor using either suction anchors or piled anchors and anchor lines will connect to the FPSO (Section 3.5.3). A total of 12 suction or piled anchors will be used to moor the FPSO. Table 8.5 summarises the seabed footprint of the FPSO anchors and moorings.

Each suction anchor (if used) will be approximately 6 m in diameter and 15.7 m long, of which 14.5 m will penetrate the seabed upon installation leaving approximately 1.2 m protruding above the seabed. For 12 suction anchors of 6.0 m diameter each then the total area of seabed that will be occupied will be 0.00034 km^2.

The piled anchors (if used) have a diameter of 1.2 m and measure up to 40 m in length. For 12 anchor piles of 1.2 m diameter each then the total area of seabed occupied will be 0.000014 km^2.

It is expected that a maximum 150 m length of anchor chain will raise and lower on the seabed during extreme weather events. Lateral movement of the anchor lines during their installation and hook up, as well as later on during bad weather events will be restricted to a maximum distance of 5 m on either side of each anchor chain. This equates to 0.018 km^2 of seabed disturbance for 12 mooring lines regardless of mooring anchor design used.

In summary therefore, with 12 anchor lines being deployed, this would result in an overall area of 0.01801 km^2 (anchor piles) or 0.01833 km^2 (suction anchors) of seabed being affected throughout the life of the field.

Table 8.5: Estimated mooring footprint for the FPSO

Avalon FPSO	Pile Diameter [m]	Individual Pile Footprint [m^2]	Number of Piles/Lines	Area of mooring line on seafloor [m^2]	Total Seabed Disturbance Footprint for Anchor Lines [m^2]	Total Footprint (Anchors + Mooring Lines) [km^2]
Anchor piles	1.2	1.13	12	1 500	18 000	0.01801
Suction anchors	6.0	28.3	12	1 500	18 000	0.01834

8.1.6 The Offshore Wind Turbine (OWT)

The exact location of the OWT is still to be determined and is subject to safety and permitting considerations of the development. The OWT substructure will be a floating design and fixed to the seabed via 9 anchors linked to the mooring system. The foundation and mooring system are still to be confirmed but will comprise either a triangular semi-submersible platform or a TLP installation. Both types of platforms will utilise their own mooring system and anchors (impact piled or suction bucket), which are still to be confirmed. Suction bucket anchor types present the largest footprint on the seabed, compared to piles, and are thus considered in this assessment. It is anticipated that the anchors and the mooring system will be pre-installed and wet stored on the seabed, until they are required to be hooked up to the OWT. Connection of the power cable would take place after the OWT substructure is connected to the mooring system.

Scour protection (rock) is expected to be required to be placed on the seabed around each mooring anchor. The total quantity of protection material required, and the area that it will occupy on the seabed is not known at present but for the purposes of this assessment it is assumed to occupy an area of seabed of 0.04104 km^2 in total.

As the exact dimensions of the Avalon floating OWT and quantities of associated scour protection material, are not currently known, illustrative examples from floating offshore wind farm developments in Scotland have been used as a proxy for this assessment. These are provided in Section 3. Worse case design parameters for the OWT are presented in Section 3 and summarised in Table 8.6.

The distance of the power cable connecting the OWT to the FPSO on the seafloor is considered to be 25 km for the purposes of the assessment and represents the distance to the nearest INTOG sites. The cable will be trenched and buried by the Canyon T1200/T1500 jet trencher as described above. Given that the trenching tool will disturb 5.6 m of seabed between its tracks during trenching operations, a maximum area of disturbance 0.14 km² is therefore predicted, due to the installation of the OWT power cable.

Table 8.6: Total Area Affected (Worst-Case Scenario) Due to the OWT

Pipeline	Installation Method	Seabed Disturbance		Track Width [km]	Total Area Affected [km²]
		Length [km]	Width [km]		
Power cable between floating OWT and FPSO *	Laid / trenched and buried by T1200/T1500 jet trencher	25	0.0056	0.0048	0.14
Suction Bucket Anchors (x9)	Under consideration	NA	NA	NA	0.000707‡
Impact Piled Anchors (excluded from total)	Under consideration	NA	NA	NA	0.000176
Semi- submersible Catenary mooring option	Under consideration	NA	NA	NA	0.000006†
Tension leg platform mooring option	Under consideration	NA	NA	NA	NA
Scour protection (9 anchors)	Under consideration	NA	NA	NA	0.04104
Total					**0.181929**

Notes:
* = The area affected by the power cable between the OWT and the FPSO is based on the worst-case scenario of the OWT being located 25 km from the FPSO location.
† = Calculation on the assumption that 3 mooring points will be used for the catenary option
‡ = Calculation for 9 anchors
# = Calculation includes a 25 km power cable, Semi- submersible Catenary mooring option, suction bucket anchors and scour protection

8.1.7 Summary of Total Area of Seabed Impacted

In summary, the worst-case area of seabed affected by the proposed development infrastructure will be 0.657803 km² (see Table 8.7).

Table 8.7: Total Area of Seabed Impacted at the Avalon Field Development Infrastructure

Infrastructure	Duration of impact	Total Area Affected [km^2]
Semi-submersible Drilling Rig (x2 wells)	Temporary	0.18
FPSO mooring (suction anchors)	Project lifetime	0.00034
FPSO mooring (lines)	Project lifetime	0.018
6" gas import/export pipeline to Ettrick PLEM	Temporary	0.2240
8" oil pipeline between the Avalon drill centre and RBS†	Temporary	0.0168
3" Gas lift line between the Avalon drill centre and RBS†	Temporary	0.0168
Control Umbilical between the Avalon drill centre and RBS†	Temporary	0.0168
Xmas Trees (x2)	Project lifetime	0.00005
RBS	Project lifetime	0.00012
Mattresses	Project lifetime	0.003132
Grout bags	Project lifetime	0.000008
Total for Ettrick and Semi-Submersible Drilling Rig (x2 wells) Option		**0.47605**
Power cable between floating OWT and FPSO (25 km)†	Temporary	0.1400
Semi- submersible Catenary mooring option	Project lifetime	0.000006‡
Suction Bucket Anchors (9x anchors)	Project lifetime	0.000707
Scour protection (9x anchors)	Project lifetime	0.04104
Total for OWT using Suction Bucket Anchors		**0.616763**
Total for Ettrick, Semi-Submersible and OWT with Suction Bucket Anchors		**0.657803**

Notes:

† = It is assumed that the jet trencher will trench the same width for pipeline, gas lift line, control umbilical and OWT power cable as a worse-case scenario

‡ = Calculation on the assumption that 3 mooring points will be used for the catenary option

8.2 Potential Effects on Seabed and Benthic Communities

Potential impacts due to the physical presence of the proposed development infrastructure on seabed communities include seabed habitat take, habitat alteration, deposition of suspended sediment plumes and seabed disturbances.

8.2.1 Seabed Habitat Take

Seabed habitat take relates to the loss of seabed habitat due to the permanent placement of infrastructure on the seabed. In this regard, the proposed development will result in a seabed take of 0.045397 km^2 (Table 8.7) as a worst case due to the placement of protection material at the infield infrastructure and OWT, (0.04418 km^2), suction anchors for the FPSO and OWT (0.001047 km^2) and the RBS and Xmas tree structures on the seafloor (0.00017 km^2). The effects of seabed habitat take will be highly localised, limited to the extent of the infrastructure and will be permanent, lasting for the duration of the proposed development but will be reversible on decommissioning and removal of the seabed infrastructure. Removal will allow seabed habitats and species to recover over time.

Habitats 'taken' in this way will include circalittoral muddy sand and circalittoral mixed sediment habitats both of which are indicative of 'subtidal sands and gravels' UKBAP and 'offshore deep-sea muds' Priority Marine Feature (PMF), considered important components of the biodiversity of Scotland's Seas (Tyler Walters et al., 2016). Pockmarks indicative of Annex I (Habitats Directive) 'submarine structures made by leaking gases' may also be affected although none have been found in previous geophysical and benthic studies within the immediate site of the proposed wells. The nearest pockmark feature is 792 m away from the proposed well sites. Nevertheless, pockmarks are known across the wider region and are considered here as a precaution in respect of any habitat take associated with the optional gas import/export pipeline crossings and the OWT.

At the moment of the placement of the infrastructure on the seafloor, sessile and sediment burrowing species within the direct footprint will likely be damaged or killed due to compaction and abrasion forces. For some deeper burrowing species directly below placed infrastructure on the seafloor may be prevented from accessing the sediment - water interface limiting feeding, oxygenation of deep burrows and dispersal of larvae. Such effects will result in species mortality and a reduction of species diversity, abundance and biomass of benthic species within the direct footprint of the placed infrastructure for the duration of its placement. This may include individuals of ocean quahog (*Arctica islandica*) PMF species (and classified OSPAR threatened and/or declining species), juveniles of which have been recorded during local grab sampling surveys (see Section 4). Installation of the infrastructure could damage or kill individuals of ocean quahog if present although significant impacts at population levels are highly unlikely given the limited footprint of the effects and the wider distribution of ocean quahog populations. Mobile fauna, such as fish and crabs may be able to avoid infrastructure as it is set on the seabed.

Sediments PMF habitats within the development area are representative of those of the wider region (Dando, 2001; Judd, 2001; DECC, 2016; Marine Scotland, 2020), (Section 4, Local Environment) and so a reduction in habitat diversity at the regional scale is not expected due to the current proposals.

Sedimentary benthic habitats and communities are expected to recover once the infrastructure is removed on decommissioning. The timescale for sediment habitat recovery post-decommissioning is dependent on a number of factors, including the cohesiveness of the affected sediment, the degree of local seabed mobility and the quantities of fine transient sediment available for infilling. Studies of seabed recovery following offshore wind farm construction (English et al., 2017), for example, show that seabed impacts from the placement of spud legs of construction vessels and from cable laying may take months to years to be infilled. Seabed habitats in lower energy environments may take a number of years to recover compared to those in higher energy and more mobile sediment areas. Pockmark features may take comparatively longer to recover depending on the severity of any damage to structures or may not recover at all.

Species will begin to re-colonise affected seabed areas as seabed topography and stability is gradually restored. Re-colonisation will be achieved through the passive import and settlement of larvae and migration of adults and mobile benthos depending on the availability of local reproducing populations, local hydrodynamic conditions and the severity of the original impact and is expected to follow classic models of species succession (e.g. Newell et al., 1998; Pearson & Rosenberg, 1978). These typically involve an initial influx of small, short-lived and highly fecund species (opportunists) which are capable of tolerating disturbed conditions, but which are gradually replaced by larger, competitively superior species until an equilibrium community, reflective of the prevailing habitat conditions, is achieved. Timescales for seabed communities to return to pre-installation conditions are not known at present. However, studies in coastal shelf waters following the cessation of commercial aggregate dredging suggests that recovery of benthic community structure following physical impacts may require several years (Boyd et al., 2005; Cooper et al., 2007). Benthic communities present in the development area (Fugro, 2013b) are characteristic of the wider CNS region. Consequently, there is strong potential for re-colonisation of via recruitment from surrounding reproducing populations in adjacent unaffected areas.

Ocean quahog are a long-lived and slow growing species and may require longer periods of time to recover following seabed disturbances. Recruitment is thought to be continuous at a low level (Tyler-Walters & Sabatini, 2017) with successful peaks in recruitment occurring at intervals in excess of 10 years or even longer depending on location. Because of its slow growth to maturity, populations suffering significant mortality will likely take in excess of ten years to recover (Tyler-Walters & Sabatini, 2017). However, where only a few individuals of a population are lost, then recovery may be quicker. The widespread distribution of ocean quahog juveniles within and around the Avalon Field Development, as identified from local grab sampling, suggests the presence of reproducing populations within the vicinity to allow recovery of denuded areas to occur.

In conclusion, the effects of seabed habitat take will be highly localised to within the footprint of the infrastructure. Effects will be permanent but reversible on decommissioning and unlikely to be significant within the context of the wider region. Representatives of the habitats and species affected will remain at the regional level such that total habitat and species diversity will not be reduced across the wider area. Effect magnitude is thus judged to be Minor.

The seabed sediments and ocean quahog are representative of PMF habitats and species and are thus acknowledged to be of conservation value at national level and are thus judged to be of High value. Therefore, the impact significance of seabed take in respect of sediment habitats and ocean quahog is judged to be Minor.

Pockmarks are indicative of Annex I (Habitats Directive) 'submarine structures made by leaking gases' important at international level and are thus considered to be of Very High value. Therefore, the impact significance of seabed take on pockmarks is judged to be Moderate.

To mitigate for potential Moderate impacts, it is proposed to micro-site any placed infrastructure, for example protection material at crossing points, to avoid any identified pockmarks. This will eliminate the potential for effects of seabed habitat take on pockmarks to occur. With mitigation in place therefore, impact significance of seabed habitat take on pockmarks will be reduced from Moderate to Negligible or no effect.

8.2.2 Habitat Alteration

Whilst 0.045397 km^2 is assessed as habitat take (see above) a total of 0.04418 km^2, or 97 % of this area may be more accurately assessed as habitat alteration.

Habitat alteration relates to the placement of the protection materials (concrete mattresses, grout bags and rock scour protection) onto a predominately sedimentary seabed. This will alter the particle size distribution characteristics of ambient sediment habitat, to a hard substrata, rocky and stony habitat. This new (albeit) artificial habitat may subsequently be colonised by attaching and encrusting species which will be different from those colonising the original sediment seabed habitat but which may be representative of hard substrata habitats within the wider region. The effect of habitat alterations will be localised, limited to the immediate footprint of the protection materials, and permanent, lasting for the duration of the proposed development, but will be reversible on decommissioning and removal of the mattressing, grout bags and rock. Removal will allow for the original sediment habitats and communities to recover over time, as assessed above.

Sessile or sediment dwelling fauna within the direct footprint of the protective concrete mattresses, grout bags and scour protection will likely be damaged, displaced or smothered resulting in the mortality and loss of individuals of species as assessed above but the material itself could, over time, function as reef habitat providing additional attachment sites for the indigenous sessile communities, such as sponges and hydroids (Fugro, 2013b), as well as refuge for mobile epibenthos or fish. Pidduck et al (2017) highlight that scour protection has the potential to act as an artificial reef supporting reef communities. Fish, crabs and lobster have been reported to find shelter below concrete mattresses at offshore wind farms in US and North Sea (HDR, 2018; Krone et al., 2017).

The rate of colonisation of the protection materials will be dependent on recruitment rates from local reproducing populations as well as a wide range of physical factors including temperature, substrate stability and degree of sediment scouring. There have been a large number of studies and observations of colonisation of artificial structures of offshore wind farm foundations in the North Sea. These have in general shown rapid colonisation of structures being placed in the sea by pioneer communities of algae, hydroids, barnacles, anemones and tube dwelling amphipods within one year followed by the development of more stable communities dominated by mussels (*Mytilus edulis*) over subsequent years. Biomass has been reported to increase 4 000-fold in offshore turbines in the southern North Sea, compared to the biomass originally present in the sediments (Rumes et al., 2013). Scour protection material provides additional microhabitats for a multitude of species although communities may differ from those found among natural hard substrates (Coolen et al., 2020). Karlsson et al. (2021) reported that during a survey on artificial hard substrate colonisation in the offshore Hywind Scotland Pilot Park, epifouling colonisation showed overall similarities with the colonisation of other artificial structures in the North Sea regarding early colonisers and epifouling.

In conclusion, the effects of habitat alteration will be highly localised to within the footprint of the protection material and permanent, but reversible on decommissioning and unlikely to be significant within the context of the wider region. Effect magnitude is thus judged to be Minor. Sediment habitats are representative of PMF habitats recognising their importance at a national level and are thus judged to be of High value. The impact significance of habitat alteration is thus judged to be Minor in respect local sediment habitats.

Pockmarks are indicative of Annex I (Habitats Directive) 'submarine structures made by leaking gases' important at international level and are thus considered to be of Very High value. The structures associated with pockmarks already provide hard substrata for attachment of sessile species and thus function in a similar way as that predicted for the protection materials. In terms of functioning therefore, there will be no significant alteration of habitat. However, it is recognised that the habitat will change from an Annex I habitat to an artificial habitat should any protection material be placed over a pockmark. In this instance, the effect magnitude will be Minor on a Very High value receptor and so the impact significance is assessed to be Moderate with respect to pockmarks.

Micro-siting of protection materials on the seabed to avoid any identified pockmarks will eliminate the potential for effects of habitat alteration to occur. With mitigation in place therefore, impact significance of habitat alteration on pockmarks will be reduced from Moderate to Negligible, or no effect.

8.2.3 Deposition of Suspended Sediment Plumes

The placement and removal of the spud cans of the jack-up, the anchors and anchor chains for the semi-submersible drilling rigs as well as trenching operations for the power cable between the OWT and FPSO and the gas pipeline and umbilicals may result in raised sediment plumes and the subsequent deposition of disturbed sediments on to the seafloor over adjacent areas. Fine particles may also be re-suspended into the water column due to the discharge of water-based muds and cuttings and are assessed in Section 7.

Significant deposition of sediment plumes can smother or bury seabed communities, causing damage to sensitive respiratory organs, or preventing feeding resulting in the loss of sensitive species within affected areas. Sediment dwelling species, on the other hand, will be largely tolerant to the effects of light sediment deposition and are expected to be able to relocate to preferred feeding depths if buried. Mobile fauna are expected to be able to move away from temporary adverse areas of raised sediment plumes.

Sand and gravel size particles ejected into the water column by these disturbances will re-settle very quickly (within seconds) and in close proximity to the original disturbance. Finer silt and clay sized particles, on the other hand, will take longer to re-settle (minutes to hours) and may be dispersed over adjacent seabed areas, depending on the tidal state and bottom current strengths at the point of disturbance.

The effects of the deposition of raised sediment plumes will be localised, limited to the immediate area of sediment disturbance and adjacent areas within the influence of the plume, and will be very short-lived lasting for the duration of the activity only, after which recovery to pre-construction conditions are forecast to occur. The trenching tool will be continually moving along the trench route so that there will not be any prolonged raised sediment plumes or sediment deposition at any one location. In addition, the tool will aim to minimise any sediment loss from the trench as this will be required for backfilling and burial of the pipelines and power cable to the target depth. Any fine sediments that are deposited over adjacent seabed areas will be rapidly re-mobilised due to water current movements, or periods of increased bottom current velocities and will be eventually diluted and dispersed out of the area. Effects of deposition of sediment plumes are thus expected to be temporary and short-lived.

Local seabed communities are dominated by sediment dwelling species and are expected to be naturally tolerant to temporary and short-lived light sediment accumulation as a result of periodic storm events and the natural stirring of bottom sediments. Burrowing species, including ocean quahog are unlikely to be significantly affected by temporary deposition of sediment and are expected to relocate to preferred feeding depths and retain connection to the sediment / water interface if buried. Local sessile epifaunal species, including sponges, hydroids and other encrusting fauna inhabiting the coarser pebble and cobbled substrates (Fugro, 2013) are similarly expected to be naturally tolerant with some species, such as some soft coral and sponges, having the ability to naturally clear sediment from their systems albeit at some energetic cost.

In conclusion, the effects of the deposition of sediment plumes will be localised to the area of influence of the sediment plume and will be temporary and short-lived. Local habitats and species and communities are indicative of sediment benthic environments and are expected to be naturally tolerant to the effects of sediment deposition. Effect magnitude is thus judged to be Negligible. Habitats and species likely to occur within the influence of the deposition of raised sediment plumes are representative of offshore sand and gravel and deep-sea muds PMFs and Annex I (submarine structures made by leaking gases) feature and are thus judged to be of High and Very High value respectively. Overall, therefore, the impact significance is considered to be Negligible in respect of sediments habitats and Minor in respect of pockmark habitats.

Receptors are expected to be tolerant of temporary effects of deposition of the sediment plume. Consequently, mitigation measures are not considered to be required in this respect

8.2.4 Seabed Disturbance

Seabed disturbances will occur as a result of the movements of the moorings of the mobile drilling facility and FPSO on the seafloor, and the trenching of the optional gas import/export pipeline (Ettrick option as a worst case), the OWT power cable and the infield pipelines and umbilicals. In total, an area of seabed of 0.6124 km^2 (worst case) will be disturbed due to the proposals. The placement and removal of the spud cans of the jack-up drill rig is a further source of seabed disturbance should this option be adopted in place of the semi-submersible drill rig.

The majority of seabed disturbances will be temporary lasting for the duration of the construction phase only (see Table 8.7). A total of 0.5944 km^2 of the seabed area will be affected by temporary disturbances and which will cease on completion of the construction activities. The remaining 0.018 km^2 of seabed will be subject to permanent disturbances and relate to the predicted movement of the FPSO anchor chains on the seafloor.

The anchor chains of the FPSO are not expected to penetrate the seabed to any appreciable depth and are only likely to agitate the surficial sediment layers during any significant movement of the anchor lines as a result of high energy wave events. Consequently, effects will be intermittent throughout the operation of the development. Burrowing species which may be present at depth below the seabed surface, such as ocean quahog, are therefore not expected to be significantly affected. However, sessile epibenthic species attaching to and encrusting the seabed surface may be damaged, or dislodged, resulting in a reduced abundance and biomass of these populations locally and for the duration of the FPSO installation. Effects however are reversible on decommissioning after which seabed habitats and associated communities are expected to recover to pre-construction conditions. Recovery of benthic communities will be via passive import and settlement of larvae from surrounding reproducing populations over adjacent unaffected areas and from migration of adults.

Seabed disturbances caused by the movement of the anchor chains of the drilling facility will be short-lived lasting for the duration of drilling operations only (70 days for drilling of each of the production wells). Full recovery of the seabed within the influence of the movement of the anchor chains is anticipated following the removal of the drilling rig as assessed above.

Seabed disturbances caused by the trenching tool will occur for the entire lengths of the optional gas import/export pipeline (Ettrick worst cast), infield pipelines, umbilicals and OWT power cable (assuming a 25 km distance), equating to an area of 0.4144 km^2 (worst case). Disturbances will be temporary and will cease on completion of the respective installations and backfilling of all trenches.

The trenching tool operates by jetting which fluidises the substrate through which the trenching tool passes and reduces the sediment structure and density (BERR, 2008). This may result in the displacement of sediment dwelling species to lower depths within the sediment profile within the trench footprint while sensitive fauna may also be damaged or suffer mortality due to associated erosion and scour effects. Depending on the jet pressure over the seabed surface, individuals of species may be ejected into the overlying water column within the sediment plume and may become available for mobile scavenging and predatory fauna. Loss of sediment out of the trench, will be minimised ensure sufficient material remains for backfilling and burial to target depth. Larger, robust species, such as the ocean quahog which has a thick shell, may be able to tolerate the effects of the jetting although individuals may be displaced to deeper depths below the seabed surface. Any individuals displaced in this way would be expected to be able to re-locate to preferred feeding depths although at some energetic cost. Sponges, and other sessile epifauna, which attach to and encrust the seabed surface however, may be more sensitive to the effects of the trenching and are likely to suffer damage to tissues or be dislodged or buried if in the direct path of the trenching tool (BERR,

2008) resulting in a reduced abundance and biomass of these species locally. Mobile species, such as fish and crabs, are likely to be able to move away from the trenching tool.

Effects of trenching will only occur once and will cease when the trenching tool has passed after which habitat and species recovery will occur.

Recovery characteristics of disturbed seabed sediments will be dependent on a number of factors including the nature of the seabed and the communities present, the severity of the original impact and local and regional hydrodynamic conditions. Studies have shown that initial re-colonisation takes place rapidly following a disturbance event with certain species returning almost immediately to the disturbed site (BERR, 2008). BERR (2008) highlights that in general, recovery where seabed disturbances are more frequent and opportunistic species are more likely to dominate the community, is relatively rapid whilst recovery of complex communities indicative of more stable sediment habitats occurs over longer timescales.

In contrast, effects of disturbances to pockmark structures and associated sessile communities may be irreversible where significant structural damage and/or burial of submerged structures has occurred. Restoration of benthic communities may occur over time where submarine structures remain. Any damaged or lost MDAC may recover due to natural accretion although this will take a long period of time and will be dependent on the continual seepage of gas and the presence of specific chemo-synthetic micro-organisms.

In conclusion, the effects of seabed disturbance sediment habitats and robust sediment burrowers such as ocean quahog, will be highly localised to the point of disturbance, temporary and reversible and likely insignificant within the context of the wider region. Effect magnitude is thus judged to be Minor in this regard.

PMFs are considered to be of national importance and are judged to be of High value accordingly. Impact significance of seabed disturbance is therefore considered to be Minor in respect of sediment habitats and ocean quahog.

Effects on pockmarks ‘submarine structures made by leaking gases’ will be similarly localised but may be longer-lasting or irreversible. Effect magnitude is thus judged to be Major on a Very High value receptor and impact significance is assessed to be Major accordingly.

Micro-siting of moorings and trenching operations to avoid pockmarks will eliminate the potential for any effects of seabed disturbance on this feature to occur. In the presence of mitigation, therefore, impact significance of seabed disturbance on pockmarks will be reduced from Major to Negligible or no effect.

8.2.5 Effect on Conservation Features

Several features of conservation have been identified within the Avalon Field Development:

- Ocean quahog (PMF);

- Pockmarks (indicative of Annex I habitat 'Submarine structures made by leaking gases'); and
- Subtidal sands and gravels and deep-sea muds (PMF).

The FeAST (Marine Scotland, 2022d) tool has been used to identify specific activities of the Avalon proposals and associated pressures to which these features are sensitive as assessed below. The tool is a web-based application allowing users to investigate the sensitivity of marine features (habitats, species, geology and landforms) in Scotland's seas, to pressures arising from human activities (i.e. Physical change from oil and gas infrastructure).

The level of significance of effects on the afore mentioned conservation features was assessed using the methodology presented in Sections 5 and 6.

8.2.5.1 Ocean quahog

Ocean quahog juveniles were identified during the 2013 Avalon site survey (Fugro, 2013b). The ocean quahog has been included on the Convention for the Protection of the Marine Environment and the North-east Atlantic (OSPAR) list of 'Threatened and/or Declining Habitats and Species' (OSPAR, 2022), and is a Scottish PMF (NatureScot, 2022a). Using the FeAST tool, ocean quahogs are described as being highly sensitive to physical change (to another seabed type) and high siltation changes (Marine Scotland, 2020d). These pressure types may arise as a result of the proposed development due to drilling operations, installation of subsea infrastructure, anchors, mooring lines, trenching operations for a power cable, pipeline and control umbilical and scour protection. The worst-case area of seabed effect will be 0.6578 km^2.

Ocean quahog has been known to tolerate being smothered under 1.5 m of sediment (Powilleit et al., 2006). Significant adverse effects of siltation arising from the proposals on ocean quahog are not expected.

Ocean quahog may be displaced, damaged or killed during trenching operations for the infield pipelines and umbilicals, the OWT power cable and during the optional gas import/export pipeline if adopted. Given the widespread distribution of suitable habitat in which ocean quahog may occur throughout the wider region, coupled with the absence of any knowledge of the locations of any population centres for this species, it will not be possible to micro-site infrastructure and installation activities to avoid individuals of ocean quahog if present. Effects will be highly localised to the direct footprint of placed infrastructure on the seabed and to the point of seabed construction activity. Such localised effects are unlikely to significantly affect regional populations.

Recovery of ocean quahog will occur on completion of the construction and also on the eventual removal of the infrastructure on decommissioning. Ocean quahog recruitment is thought to be continuous at low levels with peak recruitment periods occurring every ten year or more. Recovery of ocean quahog is therefore expected to occur over a long period of time compared to other benthic communities. The occurrence of juveniles in grab samples collected at the Avalon Field supports the presence of reproducing populations in the surrounding sediments and suggests that there is a high potential for recovery once the environmental pressures are removed.

8.2.5.2 Pockmarks

Pockmarks Annex I habitat 'Submarine structures made by leaking gases' are present within the wider area of the Avalon Field. They are highly sensitive to physical removal for cable/pipeline installation, according to the FeAST tool (Marine Scotland, 2022d).

Current survey data suggests that there are no pockmarks within the immediate vicinity of the planned well sites but they may be present within the wider region. The nearest pockmark identified to date is located 792 m away from the wells.

The proposed development includes options to install a 40 km 6" gas import/export pipeline to Ettrick or a 5 km pipeline to Britannia PLEM and may also involve trenching of a power cable connecting the Excalibur FPSO to a floating OWT which may be up to 25 km on length. In light of their high sensitivity to the effects of possible pipeline and cable installation and their conservation importance, mitigation is proposed to micro-site installation activities to avoid identified pockmarks. Such mitigation will reduce or remove the potential for adverse effects on pockmarks to occur.

8.2.5.3 Offshore subtidal sands and gravel and offshore subtidal deep-sea muds

Sediment PMFs (Tillin et al., 2010) have high sensitivity to physical change to another sediment type, siltation changes and surface and sub-surface abrasion/penetration (Marine Scotland, 2022d).

Physical change to another sediment type is expected to occur as a result of the current proposals due to the installation of protection material. Siltation changes are expected as a result of trenching and burying activities for the installation of pipelines, gas lift lines, control umbilical and OWT power cable. Sub-surface abrasion/penetration is expected as a result of the installation of the anchors for the FPSO and OWT as well as the feet of the jack-up drilling rig, should this option be adopted.

The worst-case area of sediment habitat PMF affected will be 0.6578 km^2.

Due to the widespread distribution of sediment habitats representative of offshore subtidal sands and gravels' and 'offshore subtidal deep-sea muds PMFs throughout the wider region, it will not be possible to micro-site infrastructure and installation to avoid these features. However, it is considered that the total area of potential effect (0.6578 km^2) is very small in the context of the wider region where representative habitat occurs. It is also noted that the majority of effects on the seabed will be very short-lived and will occur during the construction phase only and will cease on completion of the installation activities. In addition, the total extent of PMF habitat will be fully restored, and remaining effect pressures will be removed, at the end of the project life and on decommissioning and removal of seabed infrastructure.

8.3 Other Users of the Sea

8.3.1 Impacts on Commercial Fisheries

The fishing industry is important to the economy of the north-east and east of mainland Scotland and the Northern Isles. As described in Section 4.11, the fishing activity in ICES rectangles 44E9 and 44F0, which encompasses the proposed Avalon Field Development and associated pipelines, is dominated by a year-round mixed demersal fishery targeting scallops, crabs, *Nephrops* and others (Marine Scotland, 2022c). The seasonal pelagic fishery is also an important fishery in the region, but highly variable year on year due to the motility of the stock.

A formal 500 m safety exclusion zone will be established around the each of the wells once drilled (Petroleum Act, 1987) (Marine Scotland, 2021b). This will result in an overall exclusion area of 0.785 km^2 around each site or 1.57 km^2 around both wells.

An area of exclusion is also likely to be required around the installed OWT due to the presence of the mooring lines and anchors although the distance over which this will be applied is currently not known and is dependent on the final foundation selection and mooring design. As a worst case, the maximum spread radius of mooring lines is taken to be 1 500 m if using the catenary mooring system (see Section 3). Commercial fisheries may be required to avoid the OWT for a distance of up to 1 500 m to prevent damage to, and snagging of gears in the event that this OWT mooring system is deployed. This equates to a worse case area of exclusion around the OWT of 7.07 km^2.

Commercial fishing activities will be permanently displaced from exclusion zones for the life of the development but will be able to return on removal of the infrastructure following decommissioning. Considering both the well sites and the OWT , commercial fisheries will be displaced from an area of 8.64 km^2 as a worst case.

Commercial fishing activities will remain unaffected over the wider region during the period of displacement although the displacement itself may result in some local increases in cumulative fishing effort, especially in waters that are already exploited. This may lead to reduced catch per unit effort (CPUE) within the immediate surrounding area but is unlikely to result in significant reductions in CPUE over the wider region where the characteristic offshore fisheries activities take place.

In addition to the permanent exclusion around the well sites and OWT, commercial fishers will be temporarily excluded from areas around construction vessels conducting trenching and laying activities associated with the pipelines and power cable. Displacement in these regards will be temporary and short-lived lasting for the duration of the construction after which the sea area will become available for use. The trenching and pipe laying for all proposed pipelines, power cables and umbilicals is scheduled for approximately 69 days. However, during this time, the construction vessel will be travelling along the proposed pipeline or cable route so that fishing vessels may not be excluded from any one area during this time.

Automatic Identification System (AIS) data for fishing vessels describe a significant level of fishing vessel activity in the vicinity of the Avalon field, with the majority of vessels actively fishing (Anatec, 2019). The area is thus considered to be important for fishing at a regional level and is assessed to be of High value accordingly. Permanent exclusion of commercial fishing will be reversible on decommissioning, localised to the immediate exclusion zones and adjacent areas where increased fishing effort may occur, and is assessed to be of minor magnitude. The effect of the temporary exclusion around the cable and pipe laying vessels will be transient as the vessel progresses along the cable/pipeline route and is consequently assessed to be of Negligible magnitude. Overall, therefore impact significance is considered to be minor (for permanent exclusion) and negligible (for temporary exclusion).

8.3.2 Impacts on Shipping and Navigation

The installation of the proposed development and OWT will require several construction and support vessels and a drilling rig, which could pose obstructions to local sea users. Section 3 (Project Description) itemises the numbers and types of construction and support vessels that are proposed to be used and presents a schedule for the installation activities. These obstructions will be temporary and will cease following completion of the installations and are not considered to have potential significant effects on other users (see ENVID Appendix 4).

Following installation activities, the FPSO and the OWT will remain as permanent features on the sea surface and will represent potential surface obstructions to local sea users for the life of the development.

Section 4 (Local Environment) explains that there is currently a moderate level of shipping activity (NSTA, 2019) where the Avalon wells are planned to be drilled and the FPSO located, and low to moderate shipping activity within the wider region where the pipeline routes options to either the Ettrick or Britannia PLEM are expected to be installed.

The presence of the drilling rig will temporarily displace shipping and navigation activities from an imposed safety area of 500 m around the rig, whereas the CSV, DP construction vessel and other support vessels may further displace vessels during trenching, pipeline laying and the OWT installation. These displacements are only expected to be temporary as drilling operations are scheduled for up to 140 days for both wells, whilst trenching and pipe laying operations are scheduled for approximately 69 days. Also, the CSV, DP construction vessel and other support vessels will be travelling along the proposed pipeline route, during the installation period and so vessels will not be excluded from any one area during this time, so any obstruction would be of a short-term duration. Once the installations are complete, any obstruction will be removed.

The Marine Traffic Survey and Navigation Assessment (NA) carried out for the Avalon Field Development showed that there are 22 shipping routes which pass within 10 nm (18.5 km) of the Avalon field location. Around 73 % of the vessels transiting the area were associated with the offshore oil and gas industry. A further 23 % of transits represented cargo vessels, and around 4 % tankers (Anatec, 2019). Vessels passing at this distance are unlikely to be significantly displaced by the permanent presence of the FPSO and temporary drill rig and installation vessels.

Five routes pass within 2 nm of the Avalon Field Development location. The NA concluded that vessels using these routes may be affected by the temporary presence of the drilling rig when on location and permanent presence of the FPSO once installed, but that there would be sufficient room available for all mariners to achieve a safe passing distance.

The Donegal Bay to Esbjerg, Moray Firth to the Baltic and the Kattegat to Moray Firth shipping routes lie close to the proposed Avalon Field Development. The vessels which use these shipping routes are predicted to require a temporary increase in passing distances during drilling and pipe laying operations. As discussed in Section 3, drilling operations for the two production wells will take up to 140 days. Trenching and pipelaying operations will take approximately 69 days.

Depending on the final location, the OWT may displace shipping and navigation activities over the life of the development (i.e. 15 years). It is preferred to site the OWT close to the FPSO where vessel activity is predominately low and where effects on shipping likely be insignificant. However, as a worst case, the OWT location is assumed to be up to 25 km from the Avalon Field Development and within a designated Innovation and Targeted Oil & Gas (INTOG) licensing area (see Section 3.7).

The OWT will be marked in accordance with the requirements of the Northern Lighthouse Board, Civil Aviation Authority and / or the Maritime and Coastguard Agency and its location will be marked on Admiralty Charts to aid future shipping and navigation. With the relevant development design mitigation measures in place it is expected that any risks relating to the presence of the OWT will be acceptable and therefore assessed as not significant.

8.3.3 Impacts on Military Operations

No practice or exercise areas (PEXA) are located within the vicinity of the proposed Development. As such, there will be no impact on military activities.

8.4 Mitigation Measures

Pockmarks are indicative of Annex I (EC Habitats Directive) 'submarine structures made by leaking gases' and are assessed as highly valued receptors. No pockmark features have been identified within the immediate vicinity of the proposed well sites to date, although pockmarks have been recorded within the wider region and may thus be encountered during installation of the import/export pipelines and / or OWT power cable. The effect of seabed disturbance on pockmarks, due to the trenching of the pipelines and / or power cable for example, was predicted to result in an impact of Major significance due to the irreversible / no recovery nature of the effect on a Very High value receptor. To mitigate for any potential seabed disturbance effect on pockmarks it is proposed to micro-site trenching activities to avoid any these features where identified. This will eliminate the potential for seabed disturbance effects to occur on pockmarks and will reduce the impact significance from Major to Negligible / no effect.

Effects of seabed habitat take and habitat alteration on pockmarks are predicted to have impacts of moderate significance. To mitigate for these effects it is proposed to microsite any seabed infrastructure, including protection materials to avoid pockmark features. With mitigation in place, the potential of these effects on pockmarks to occur will be removed and the impact significance will be reduced from Moderate to Negligible / no effect.

The statutory safety exclusion zones around the MODU will be enforced by a dedicated Emergency Response and Rescue Vessel (ERRV) for the duration of drilling operations, preventing vessels from moving too close to the drilling rig. The MODU, construction vessels and any other vessels operating in the area, will be highly visible and display the appropriate light, or daytime signals, to warn other sea users of the presence and their activities.

The wells and associated subsea infrastructure will have a 500 m safety exclusion zone. They will also have appropriate protection, in line with good practice for the protection of subsea structures and to prevent potential damage to fishing vessels and equipment. An exclusion zone around the OWT is also expected to be required, the extent of which is yet to be determined. Fishing vessels with bottom towed gears would need to avoid the maximum radial spread of moorings of the OWT to avoid snagging or damaging gears.

A Vessel Traffic Study (VTS) was carried out within the Avalon Field Development area (Block 21/06b) and a further VTS will be undertaken as part of the permitting application process to support a Consent to Locate application, before drilling and installation operations commence.

To aid navigational safety, the Aberdeen Coastguard Operations Centre (CGOC) will be notified and a Notice to Mariners and Navtex and NAVAREA warnings will be posted prior to the MODU and FPSO moving onto location. This will ensure that all vessels, including fishing vessels are aware of planned operations at the Avalon Field Development. In addition, the Seafish Kingfisher Information Service will be notified of the exact location of the MODU, FPSO, pipelay vessel, subsea infrastructure and OWT, allowing their inclusion in their fortnightly bulletin to fishing vessels. The Hydrographic Office will be notified as to the location of the Avalon well(s) location, MODU, FPSO, pipelines, other subsea infrastructure and OWT, so that these can be marked on navigational charts.

8.5 Cumulative and Transboundary Impacts

The Avalon Field Development is planned within a region with multiple oil and gas developments. The nearest existing surface oil and gas infrastructure includes the Forties Unity platform and the Forties Charlie platform. These structures are located 33 km and 38 km to the south and south-east of the current proposal respectively. Other surface infrastructure includes the Kittiwake platform located 39 km to the south-east.

No significant effects on shipping and navigation are forecast due to the proposals and thus any contribution to cumulative vessel displacements with other developments in the region are not expected.

The current proposals will reduce the total area of fishing grounds within the region and will add to other losses of fishing ground arising from neighbouring oil and gas developments and other developments. However, the reduction of fishing grounds due to the current proposals is considered to be very small in proportion to the total available fishing ground within the area so that any cumulative increase in fisheries pressure, as a result of displaced fishing effort, would be undetectable against background variation in landings statistics. Displacement will be temporary and reversible on decommissioning.

With regard to the current proposals, only a small area of seabed habitat take (up to 0.045397 km^2) will occur as a result of the placement of infrastructure on the seabed. The contribution of the current proposals to the cumulative habitat take is therefore very small, and will be reversed on decommissioning.

The proposed Development lies approximately 107 km from the UK/Norway transboundary line at its nearest point. No potential for transboundary effects has been identified as a result of any physical impacts from the project.

8.6 Conclusions

Considering the worst-case development scenario, the predicted impacts of physical presence range between Negligible / no effect to Minor with mitigation in place.

Proposed mitigation measures include micro-siting of seabed infrastructure, protection material and seabed trenching activities to avoid identified pockmark features. Without mitigation, Moderate to Major impacts are predicted on Very High value [pockmark] receptors.

A 500 m exclusion zone will be established and maintained around the two proposed well sites from which commercial fishing (and other local sea users) will be permanently excluded. Commercial fishing may also be required to permanently avoid an area of 1500 m around the OWT (worst-case) to avoid snagging of, and damage to, bottom gears on the OWT moorings.

A safety vessel will be available throughout installation and operational phases, to ensure other vessel users maintain a safe distance from the infrastructure. During drilling and installation operations radio navigation warnings will be issued and the rig and vessels appropriately marked and lit. Shipping density for the UKCS Block 21/06b, has been described as moderate (Oil and Gas Authority, 2019).

Vessels passing within 2 nm of the Avalon Field Development location may be affected by the temporary presence of the drilling rig and the permanent presence of the FPSO, but sufficient room is forecast to remain available for all mariners to achieve a safe passing distance.

Depending on the final location, the OWT may displace shipping and navigation activities over the life of the development (i.e. 15 years). The OWT will be marked in accordance with the requirements of the Northern Lighthouse Board, Civil Aviation Authority and / or the Maritime and Coastguard Agency and its location will be marked on Admiralty Charts. With the relevant development design mitigation measures in place, it is expected that any risks relating to the presence of the OWT will be acceptable.

No significant cumulative or transboundary effects are forecast due to the Avalon Field Development.

Section 9
Atmospherics Emissions

9. Atmospheric Emissions

This section addresses issues and concerns associated with atmospheric emissions, which were raised during the Environmental Issued Identification (ENVID), informal stakeholder consultation and those which are part of Scotland's National Marine Plan, (NMP) namely:

- Contribution to air pollution and climate change as a result of:
  - Atmospheric emissions from routine operations – energy generation onboard the MODU, FPSO, installation and construction vessels, support vessels, tankers and helicopters; and
  - Atmospheric emissions from flaring during well clean-up.

The NMP, objectives and policies list the potential impacts resulting from reduced air quality and climate change. Therefore, the atmospheric emissions discharged during installation and production operations are considered in this section. Emissions from the end use of oil produced from the Avalon field is not considered within the scope of this ES as it is considered elsewhere, for example, as part of emissions associated with gas fired power stations, other industrial emissions, and transport (DECC, 2016).

During the operations at the proposed Avalon Field Development, various atmospheric emissions will be generated. The individual climate change impact of the planned operations at the Avalon Field Development are comparatively so small that they are impossible to assess on their individual merit. However, it is acknowledged that they will contribute to the overall cumulative issue of climate change, which is of key concern to overall sustainability objectives and atmospheric emissions are therefore considered further in this section of the Environmental Statement (ES). As the individual climate change effects from a single development cannot be assessed, the estimated atmospheric emissions and their associated Global Warming Potential (GWP) in this chapter are presented to provide context to the proposed operations and to allow for generic comparison with the overall values for emissions for the UK offshore oil and gas industry.

9.1 Description and Estimation of Atmospheric Emissions

Atmospheric emissions contribute to a variety of environmental effects and associated impacts, including climate change. Table 9.1 provides a summary of potential sources of atmospheric emissions produced by operational activities and accidental events at the proposed Avalon Field Development.

Table 9.1: Summary of the Activities with the Potential to Increase Atmospheric Emissions

Phase	Operational Activity
Drilling and completion operations	▪ Energy consumption during drilling and completion. ▪ Emissions from flaring during well clean-up
Installation of subsea infrastructure	▪ Energy consumption during pipeline trenching; ▪ Energy consumption during pipeline and umbilical installation.
Installation of the FPSO and associated mooring system	▪ Energy consumption during anchor and mooring line installation; ▪ Energy consumption during hook up of the FPSO
Installation of the floating OWT	▪ Energy consumption during anchor and mooring line installation; ▪ Energy consumption during hook up of the floating OWT
Excalibur FPSO operations and tanker movements during the production phase	▪ Energy consumption during production operations from the Avalon field; ▪ Energy consumption of offloading tanker vessels transporting hydrocarbons
Notes: FPSO = Floating production storage and offloading vessel OWT = Offshore wind turbine	

The quantification of emissions in this section of the ES is based on generic emission factors and should be used as an indication of the order of magnitude only. The calculations are based on the fuel consumption estimates presented in Section 3 (Project Description), which set out the likely vessel requirements and estimated fuel consumption for the drilling and installation operations.

9.1.1 Estimation of Emissions from Drilling Operations

During drilling operations at the Avalon site, generation of power onboard the MODU and support vessels will result in the emissions of various combustion gases.

It is estimated that the MODU will consume 15 tonnes of diesel per day, based on general industry figures for MODUs working in the North Sea without the use of dynamic positioning (DP). Drilling operations for a single production well are estimated to take up to 70 days to complete. Therefore, the maximum number of days to undertake drilling operations at the Avalon field is estimated to be up to 140 days to drill both of the proposed production wells. This will amount to approximately 2 100 tonnes of diesel being used by the MODU for these operations (see Table 9.2).

In addition to the fuel used by the MODU itself, support vessels employed in the drilling operations such as Anchor Handling Tugs (AHT), supply vessels, standby vessels and helicopters will also consume fuel and produce exhaust emissions.

Table 9.2 sets out the estimated emissions from these sources, based on their approximate total fuel consumption, during the drilling of the two production wells proposed at the Avalon field.

Table 9.2: Estimated emissions during drilling operations

		MODU	Anchor Handling Tug	Standby Vessel	Supply Vessel	Helicopter Flights	Total
Consumption [MT]		2100.00	180.00	560.00	400.00	60.00	3,270.00
Emissions [tonnes]	CO_2	6,720.00	576.00	1,792.00	1,280.00	96.00	10,464.00
	CO	17.43	1.44	4.48	3.20	0.16	26.71
	NO_x	76.44	10.62	33.04	23.60	0.38	144.08
	N_2O	0.46	0.04	0.12	0.09	0.01	0.72
	SO_2	8.40	0.72	2.24	1.60	0.12	13.08
	CH_4	0.23	0.05	0.15	0.11	0.00	0.54
	VOC	2.52	0.43	1.34	0.96	0.02	5.28
	GWP	**7,297.94**	**646.44**	**2,011.13**	**1,436.52**	**267.25**	**11,659.28**

Note:
Calculations according to the United Kingdom Offshore Operators Association (UKOOA) atmospheric emissions guidance (1999) and the GWP conversion factors as shown in
Table 9.6.
GWP = Global Warming Potential
VOC = Volatile organic compound

9.1.2 Estimation of Emissions from Flaring Operations

After drilling operations are complete, flaring may take place from the drilling rig as part of the well clean-up operations at each of the two production wells. A maximum of 2 000 tonnes of hydrocarbons will be flared at each well with the well clean-up taking less than 96 hours per well. Table 9.3 sets out the estimated emissions during the combined well clean-up operations for both production wells. There are no plans to conduct routine flaring from the FPSO during production operations.

Table 9.3: Estimated Emissions During Flaring Operations

		Well Clean-up Flaring at Avalon
Consumption [MT]		4000.00
Emissions [tonnes]	CO_2	13736.73
	CO	222.61
	NO_x	75.97
	N_2O	104.49
	SO_2	24.00
	CH_4	2870.19
	VOC	101.65
	GWP	**17,135.65**

Note:
Calculations according to the United Kingdom Offshore Operators Association *(UKOOA)* atmospheric emissions guidance (1999) and the GWP conversion factors as shown in Table 9.6.
GWP = Global Warming Potential
VOC = Volatile organic compound

9.1.3 Estimation of Emissions from Subsea Installation Operations

During subsea installation operations, including jet trenching and installation of pipelines, umbilicals and power cables between the production wells, FPSO and floating OWT at the Avalon Field Development, generation of power onboard the vessels involved in these operations will result in the emissions of various combustion gases.

It is estimated that the pipelay vessel (PLV) will consume 15 tonnes of diesel per day, the dive support vessel (DSV) will consume 18 tonnes of diesel per day and the construction support vessels (CSV) will consume 13.5 tonnes of diesel per day. In addition to the fuel used by the CSV, DSV and PLV, support vessels will be employed in the pipeline laying operations such as guard and survey vessels, which will also consume fuel and produce exhaust emissions. Table 9.4 sets out the estimated emissions from these sources, based on their approximate total fuel consumption. These estimates are based on all the worst-case scenario for installation of subsea infrastructure as detailed in Section 3.4.3.1.

Table 9.4: Estimated Emissions During Subsea Installation Operations

		Survey Vessel	PLV	CSV	DSV	Guard Vessel	Total
Consumption (MT)		8.00	435.00	324.00	216.00	84.00	1067.00
Emissions [Tonnes]	CO_2	25.60	1392.00	1036.80	691.20	268.80	3414.40
	CO	0.06	3.48	2.59	1.73	0.67	8.54
	NO_x	0.47	25.67	19.12	12.74	4.96	62.95
	N_2O	0.00	0.10	0.07	0.05	0.02	0.23
	SO_2	0.03	1.74	1.30	0.86	0.34	4.27
	CH_4	0.00	0.12	0.09	0.06	0.02	0.29
	VOC	0.02	1.04	0.78	0.52	0.20	2.56
	GWP	**28.73**	**1562.22**	**1163.58**	**775.72**	**301.67**	**3831.93**

Note:

Calculations according to the United Kingdom Offshore Operators Association (UKOOA) atmospheric emissions guidance (1999) and the GWP conversion factors as shown in Table 9.6.

PLV = Pipelay vessel

CSV = Construction support vessel

DSV = Dive support vessel

VOC = Volatile organic compound

9.1.4 Estimation of Emissions from FPSO Installation Operations

The FPSO will be anchored to the seabed using either suction anchors or anchor piles as described in Section 3.5.3. The installation and hook-up of the FPSO moorings will be undertaken using the CSV and will take approximately 14 days to complete. These operations will be supported by 3 AHT which will each be present for approximately 10 days. The estimated number of days taken to install the FPSO mooring system remains the same irrespective of the anchor option selected. Table 9.5 sets out the estimated emissions from the vessels, based on their approximate total fuel consumption.

Table 9.5: Estimated emissions FPSO installation operations

		AHT	CSV	Total
Consumption [MT]		150.00	189.00	339.00
Emissions [tonnes]	CO_2	480.00	604.80	1084.80
	CO	1.20	1.51	2.71
	NO_x	8.85	11.15	20.00
	N_2O	0.03	0.04	0.07
	SO_2	0.60	0.76	1.36
	CH_4	0.04	0.05	0.09
	VOC	0.36	0.45	0.81
	GWP	**538.70**	**678.76**	**1217.45**

Note:
* Calculations according to the United Kingdom Offshore Operators Association (UKOOA) atmospheric emissions guidance (1999) and the GWP conversion factors as shown in
Table 9.6.
AHT = Anchor Handling Tug
CSV = Construction support vessel
VOC = Volatile organic compound

9.1.5 Estimation of Total Estimated Emissions from the installation of the floating OWT

The proposed floating OWT will be pre-assembled at the quayside and installed on top of the selected substructure and towed out to the selected installation location (Section 3.7.4). The proposed floating OWT will be installed using either suction or piled anchors and connected to the OWT substructure via a mooring system as described in Section 3.7.2. The exact timing of these operations, and the vessels that would be involved, are not currently confirmed. Therefore, a best estimate of the likely vessels required, and the duration of their involvement in the installation operations, has been made after a review of similar operations involving installation of floating offshore wind turbines within UK waters.

Vessels considered likely to be involved in the installation operations will be a CSV, an AHT, a guard vessel and two specialist tugs. Installation of the impact piles is estimated to take up to 10 days, installation of the mooring lines is estimated to take up to 5 days and hook up of the mooring lines to the floating OWT is estimated to take approximately 1 day.

Table 9.6 sets out the estimated emissions from the vessels, based on their approximate total fuel consumption.

Table 9.6: Estimated Emissions During Floating OWT Installation Operations

		CSV	AHT	Guard Vessel	Tugs	Total
Consumption (MT)		216.00	80.00	64.00	2.00	362.00
Emissions [Tonnes]	CO_2	691.20	256.00	204.80	6.40	1158.40
	CO	1.73	0.64	0.51	0.02	2.90
	NO_x	12.74	4.72	3.78	0.12	21.36
	N_2O	0.05	0.02	0.01	0.00	0.08
	SO_2	0.86	0.32	0.26	0.01	1.45
	CH_4	0.06	0.02	0.02	0.00	0.10
	VOC	0.52	0.19	0.15	0.00	0.87
	GWP	**775.72**	**287.30**	**229.84**	**7.18**	**1300.05**

Note:
* Calculations according to the United Kingdom Offshore Operators Association (UKOOA) atmospheric emissions guidance (1999) and the GWP conversion factors as shown in
Table 9.6.
CSV = Construction support vessel
AHT = Anchor Handling Tug
VOC = Volatile organic compound

9.1.6 Estimation of Total Estimated Emissions from FPSO Operations over the life of the Avalon Field

As described in Section 3.5.11, the FPSO will be powered using gas from the Avalon field to drive the gas turbines onboard the FPSO. This will be supplemented later by a floating OWT and diesel power generator as required.

After approximately 2 years it is anticipated that the volume of gas produced at Avalon will no longer be sufficient to power the FPSO. Additional electrical power will be provided using a floating OWT which is estimated to meet up to 70 % of the power requirements of the FPSO. The remaining power requirements will be met from the gas generators onboard the FPSO with diesel used if required.

It is estimated that a crude oil tanker will visit the FPSO approximately 102 times over the lifetime of the project to offload hydrocarbons for transport to shore (based on the P_{10} production scenario).

These production and offloading operations will result in atmospheric emissions being generated by the FPSO using fuel gas and diesel for power and crude oil tankers involved in the offloading and transporting hydrocarbons. As a worst-case scenario, if the floating OWT is not constructed, the FPSO will rely on diesel and gas as power sources for the life of the development. An estimate of the emissions generated based on this worst-case scenario are presented in Table 9.7.

Table 9.7: Estimated Emissions During Production Operations

		FPSO	Crude Oil Tanker	Total
Consumption [MT]		94,873.01	1428.00	96,301.01
Emissions	CO_2	273,410.63	4,569.60	277,980.23
	CO	330.39	11.42	341.81
	NO_x	840.39	84.25	924.65
	N_2O	20.87	0.31	21.19
	SO_2	35.65	5.71	41.36
	CH_4	80.29	0.39	80.67
	VOC	13.47	3.43	16.89
	GWP	286,830.84	5,128.39	291,959.23

Notes:
* Calculations according to the United Kingdom Offshore Operators Association (UKOOA) atmospheric emissions guidance (1999) and the GWP conversion factors as shown in
Table 9.6.
FPSO = Floating production storage and offloading vessel
VOC = Volatile organic compound

9.1.7 Estimation of Total Estimated Emissions from Decommissioning the Avalon Field Development

Decommissioning of the Avalon Field Development is described in Section 3.8. The exact extent of the decommissioning operations is not known at this time however it is envisaged that a range of specialist and support vessels will be employed at various times.

It is assumed that a MODU would be utilised to plug and permanently abandon the wells. AHT vessels may also be required in support of the MODU. In addition, a CSV would likely be used to remove development infrastructure which is installed on the seabed as well as undertake post decommissioning surveys. Guard vessels and a survey vessel may also be used in the decommissioning activities.

The exact duration of the decommissioning operations is not known however it is estimated that they would be broadly similar to the drilling operations (Table 9.2), the subsea installation operations (Table 9.4), the FPSO installation operations (Table 9.5) and the OWT installation operations (Table 9.6).

The environmental impacts from the decommissioning operations will be considered in the Environmental Appraisal submitted in support of the Decommissioning Programme when the Avalon Field Development is decommissioned.

9.1.8 Estimation of Cumulative Emissions from the Avalon Field Development

The total estimated atmospheric emissions of various combustion gases arising during the drilling and well clean-up operations as well as the installation operations for the subsea infrastructure, FPSO and floating OWT and associated anchor system at the Avalon Field Development are detailed in Table 9.8. These estimates are based on full build out of the development and includes the (optional) worst-case scenario of a 40 km gas import/export pipeline to Ettrick as described in Section 3.

Furthermore, production operations at the Avalon field will involve the consumption of diesel and gas to power the FPSO and from visiting oil tankers offloading hydrocarbons for transport to shore. A floating OWT is proposed as part of the Avalon Field Development which will provide the majority of power to the FPSO approximately 12 to 18 months after first oil. However, in worst-case scenario where the floating OWT is not built, additional diesel and fuel gas will require to be consumed by the FPSO.

An estimate of likely emissions associated with the Avalon Field Development is presented in Table 9.8.

Table 9.8: Estimated emissions from the Avalon field over the lifetime of the project

		Drilling	Flaring	Subsea Installation	FPSO Installation	Floating OWT Installation	Production	Total
Consumption (MT)		3,270.00	4000.00	1067.00	339.00	362.00	96,301.01	105,339.01
Emissions (tonnes)	CO_2	10,464.00	13736.73	3414.40	1084.80	1158.40	277,980.23	307,838.56
	CO	26.71	222.61	8.54	2.71	2.90	341.81	605.28
	NO_x	144.08	75.97	62.95	20.00	21.36	924.65	1,249.01
	N_2O	0.72	104.49	0.23	0.07	0.08	21.19	126.78
	SO_2	13.08	24.00	4.27	1.36	1.45	41.36	85.52
	CH_4	0.54	2870.19	0.29	0.09	0.10	80.67	2,951.88
	VOC	5.28	101.65	2.56	0.81	0.87	16.89	128.06
	GWP	11,659.28	17,135.65	3831.93	1217.45	1300.05	291,959.23	327,103.59

Note:
Calculations according to UKOOA atmospheric emissions guidance (1999) and the GWP conversion factors as shown in Table 9.6.
OWT = Offshore wind turbine
FPSO = Floating production storage and offloading vessel
VOC = Volatile organic compound

9.2 Environmental Impacts Resulting from Atmospheric Emissions

The installation and operation of the Avalon Field Development will result in increased concentrations of CO_2, NO_x, SO_2 and VOCs being released into the atmosphere. The emissions produced from the planned operations are known to have the potential to contribute to a number of environmental processes and impacts including global warming (greenhouse gases), acidification (acid rain), the formation of low-level ozone, and local air pollution (Lee et al., 2022). Approximately 88 % of emissions on the UKCS are CO_2 and 10 % are methane (OGA, 2021).

The most commonly used general indicator of atmospheric emissions is the global warming potential (GWP), expressed in tonnes of carbon dioxide (CO_2) equivalents. GWP is a measure of the relative radiative effect of a given gas compared to that of CO_2, integrated over a chosen time horizon (often a 100-year time period). Simply stated, the GWP of a specific gas is a measure of its climate change impact relative to carbon dioxide (AEA, 2007). All gaseous substances that contribute towards global warming (e.g. CO_2, CH_4, N_2O, CO, and NO_x) have a GWP factor that allows the conversion of individual emissions into CO_2 equivalents. As such, GWP can be used to estimate the potential future impacts of gaseous emissions upon the climate system. The GWP factor of each of the most common combustion gases is provided in Table 9.9.

Table 9.9: Environmental Effects of Atmospheric Emissions

Gaseous Emission	Environmental Effect	100-Year GWP Factor*
Direct Greenhouse Gases		
Carbon dioxide (CO_2)	CO_2 is a greenhouse gas, meaning that it inhibits the radiation of heat into space, which may increase temperatures at the Earth's surface.	1
Methane (CH_4)	May contribute to climate change.	25
Nitrous oxide (N_2O)	May contribute to climate change.	298
Indirect Greenhouse Gases		
Carbon monoxide (CO)	Direct effects upon human health (asphyxiant). May contribute indirectly to climate change.	3
Oxides of nitrogen (NO_x)	NO_2 has direct effects upon human health and vegetation and has the potential to cause respiratory illness and irritation of the mucous membranes. NO_x acts as a precursor to low-level ozone formation. NO_x contributes to acid deposition (wet and dry) which impacts both freshwater and terrestrial ecosystems.	5**
Volatile organic compounds (VOC)	Volatile organic compounds (VOC), which include non-methane hydrocarbons (NMHC) and oxygenated NMHC (e.g. alcohols, aldehydes and organic acids), have short atmospheric lifetimes (fractions of a day to months) and small direct impact on radiative forcing. VOC influence climate through their production of organic aerosols and their involvement in photochemistry, i.e. production of ozone (O_3) in the presence of NO_x and light. Generally, fossil VOC sources have already been accounted for as the release of fossil C in the CO_2 budgets and therefore are not counted as a source of CO_2.	-
Sulphur dioxide (SO_2)	SO_2 has direct health effects - causes respiratory illness. SO_2 contributes to acid deposition (wet and dry) which impacts both freshwater and terrestrial ecosystems.	-
Other		
Particulate matter (PM)	The environmental effect of particulate matter is mainly determined by the size (and shape) of the particles. Particles emitted from modern diesel engines (commonly referred to as Diesel Particulate Matter, or DPM) are typically in the size range of 100 nanometres (0.1 µm) and can penetrate the deepest part of the lungs. In addition, these soot particles also carry carcinogenic components. In high concentrations particulate matter can also affect plant growth.	-

Notes:
* = Direct GWPs are from IPCC (2007) and indirect from IPPC (2001) and refer to the 100-year horizon values
** = The GWP factor of 5 is for surface emissions. Higher altitude emissions (i.e. from aircraft) have greater impacts both because of longer NO_x residence times and more efficient tropospheric O_3 production, as well as enhanced radiative forcing sensitivity. NO_x emissions from aircraft can therefore have GWPs in the order of 450 for considering a 100-year time horizon. It must be noted however that these numerical values are subject to very large quantitative uncertainties

Greenhouse gases can be divided into 'direct' and 'indirect' greenhouse gases. Direct greenhouse gases influence the balance of energy entering and exiting the atmosphere ('radiative forcing') and include combustion gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as well as naturally occurring gases such as tropospheric ozone (O_3). Reactive gases such as carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NO and NO_2) and sulphur dioxide (SO_2) are termed indirect greenhouse gases. These pollutants are not significant as direct greenhouse gases but, through atmospheric chemistry, they impact upon the abundance of the direct greenhouse gases thereby increasing the overall greenhouse effect. The environmental effects of the most common combustion gases are presented in Table 9.9.

9.2.1 Localised Impacts

Combustion emissions have the potential to reduce local air quality through the introduction of contaminants such as oxides of nitrogen (NO_X), volatile organic compounds (VOCs) and particulates which contribute to the formation of local low-level ozone and photochemical smog. However, seafaring vessels, such as ships, FPSOs and MODUs, are built and operated to standards that preclude impacts to the health of crews, whilst other environmental receptors present in the immediate vicinity of the operations (e.g. flora and fauna) tend to be sparsely distributed and/or mobile in their distribution. Local impacts are further mitigated by the open and dispersive nature of the offshore environment allowing for significant spreading and therefore effects are unlikely to be significant (DECC, 2016).

9.2.2 Wider Scale Impacts

The estimated GWPs of the emissions associated with the proposed operations are presented in Tables 9.2 to 9.7 and summarised in Table 9.8. All UK operators report their atmospheric emissions to the Environmental Emissions Monitoring System (EEMS). The EEMS report does not account for emissions from support vessels and helicopters, hence those values are not included in the following comparisons.

Approximately 3.5 million CO_2 equivalents were flared on the UKCS in 2018 (OGUK, 2019). Flaring as part of the clean-up operations performed after drilling both production wells would total approximately 17,136 tonnes of CO_2 equivalents which would account for less than 0.49 % of the annual flaring on the UKCS. The short duration of these operations suggests that contributions to overall UKCS emissions from flaring will be very small whilst the highly dispersive, offshore environment means that significant impacts from flaring operations as part of the well clean-up operations are not expected.

In 2018, a total of 14.63 million tonnes of CO_2 equivalent were released from oil and gas installations on the UKCS, equating to 3 % of the total UK GHG emissions (Oil and Gas UK, 2019). Compared to this value, the combined GWP generated by the planned drilling and installation operations at the proposed Avalon Field Development, including flaring for well clean up, is estimated to be 35,144 tonnes of CO_2 equivalents which would account for less than 0.2433 % of the total UK GHG emissions for operations undertaken on the UKCS.

9.2.3 Cumulative and Transboundary Impacts

The assessment of the impacts of atmospheric emissions, as discussed above, is unchanged by the consideration of other emission sources local to the proposed operations. Whilst emissions from the proposed operations have the potential to combine with those from local shipping, and the oil and gas infrastructure in the CNS region, this is not expected to increase any local impacts significantly due to the relative distance between the Avalon Field Development well site and these other developments, and the highly dispersive nature of the offshore environment. The proposed operations are therefore not expected to have any significant cumulative impacts in combination with other local sources of emissions.

The UK/Norway transboundary lies approximately 79 km east of the Avalon Field Development. Due to the distance from the transboundary line and the localised nature of emissions from the Avalon Field Development no transboundary impacts are considered likely to arise.

As indicated in Section 9.2.2 above, on a wider scale, the additive contribution to the emissions of the overall UK oil and gas industry from the proposed operations can be viewed as of little significance and therefore their cumulative effect is also expected to be minimal. PPUK acknowledges that the atmospheric emissions from the proposed development to wider global environmental impacts, such as global climate change.

Local wind conditions may result in the transboundary transport of atmospheric emissions generated at the proposed Avalon Field Development. However, as the quantities involved are minimal in relation to national scale emissions and will be temporary in their duration, the resulting incremental effects of transboundary emissions on other nation's total emissions levels are not expected to be detectable.

9.3 Avalon Field Development Emissions in the Future Context for the Oil and Gas Sector

As described in Section 1.3.11, the UK Government has a legal obligation under The Climate Change Act 2008 to reduce greenhouse gas emissions by at least 80 % by 2050 (compared to 1990 levels). The Act requires that the UK Government set carbon budgets every five years which limit greenhouse gas emissions from all sources with the exception of international aviation and shipping. In Scotland, The Climate Change (Scotland) Act 2009 imposes a legal obligation on the Scottish Government to reduce greenhouse gas emissions to zero by 2045 as described in Section 1.3.12.

Table 9.10 presents the five-yearly carbon budgets, set under The Climate Change Act 2008, of which the 4th, 5th and 6th Carbon Budget will overlap with the life of the Avalon Field Development.

Table 9.10: Avalon Field Development Estimated Emissions in the Context of the UK Carbon Budgets

Carbon Budget	Budget Period	Budget Allocation [$MTeCO_2e$]	Avalon Field Development Contribution	
			$MTeCO_2e$	% of Budget Allocation
1	2008 – 2012	3,018	-	-
2	2013 – 2017	2,782	-	-
3	2018 – 2022	2,544	-	-
4	2023 – 2027	1,950	0.1258	0.0064
5	2028 – 2032	1,725	0.0394	0.0023
6	2033 - 2037	965	0.0325	0.0019

Notes:
Source: https://www.gov.uk/guidance/carbon-budgets

In line with the drive to reach net-zero by 2050 (2045 in Scotland), the North Sea Transition Deal (NSTD), published in 2021 (BEIS, 2021) and described in Section 1.3.14, builds on the commitments made in the UK Energy White Paper (Section 1.3.13). The NSTD, whilst recognising the role that the oil and gas industry will play in maintaining the UK's energy supply, still requires that the sector reduce emissions by 10 % in 2025, 25 % in 2027 and 50 %

in 2030 set against the 2018 baseline. By 2050 the expectation is that the UKCS will be a net-zero basin.

Table 9.11: Avalon Field Development Estimated Emissions in the Context of the UK Carbon Budgets

Carbon Budget	North Sea Transition Deal Targets		Avalon Field Development Contribution	
	% of 2018 Baseline	$MTeCO_2e$	$MTeCO_2e$	% of Budget Allocation
2018	100	19.00*	-	-
2025	90†	17.10	0.0172	0.101
2027	75†	14.25	0.0310	0.218
2030	50†	9.50	0.0075	0.079
2050	0†	0.00	-	-

Notes:
* = (BEIS, 2022)
† = (BEIS, 2021)

The estimated emissions from the proposed Avalon Field Development represent a small proportion of the overall UKCS and UK yearly totals as well as making up a small proportion of the 4th, 5th and 6th UK Carbon Budgets and UKCS emission reduction targets established under the NSTD (Table 9.10 and Table 9.11).

9.4 Mitigation Measures

The burners on the flare used during well clean-up after the drilling operations will be environmentally efficient (i.e. 'green burners') and will have propane-fuelled pilot lights with the option to use a dedicated fuel spiking line. Various techniques, such as the addition of air, steam, demulsifiers and diesel to aid combustion, and the optimisation of the pressure and vortex at the burners will be available to aid complete combustion and therefore minimising the probability of hydrocarbon drop-out.

Weather conditions will be monitored throughout flaring operations during well clean up. A dedicated person will be assigned for full-time fire watch duties to ensure that all performance related conditions are monitored, and adjustments can be made accordingly.

The use of vessels will be optimised so as to minimise the number of vessels required during the drilling and installation operations and their length of time at the Avalon field.

PPUK will develop and implement a Methane Action Plan, in accordance with OEUKs Methane Action Plan Guidelines, which will identify, quantify and mitigate methane emissions from the Avalon Field Development.

All equipment on-board the MODU, FPSO and other vessels will be well maintained according to a strict maintenance regime; including regular monitoring and inspections to ensure an effective maintenance regime is in place. The maintenance regime will ensure all equipment will operate at optimum efficiency, and therefore minimise the overall fuel consumption. Low sulphur fuels according to International Maritime Organisation (IMO) requirements will be used. The atmospheric emissions from the MODU will be reported under EEMS.

Installation of a floating OWT is proposed which will significantly reduce atmospheric emissions during the production phase by providing the majority of power to the FPSO.

9.5 Conclusions

Atmospheric emissions will be produced during drilling and installation operations, as a result of power generation onboard the MODU as well as on the standby vessel, supply vessels, PLV, CSV and helicopter activity. In addition to these, there will be flaring emissions during well clean-up operations undertaken from the MODU. Emissions will also be produced by the vessels involved in the subsea infrastructure and FPSO installation operations These emissions will be localised, short term in their duration and occur approximately 116 km from the nearest shoreline. It is considered that these emissions will contribute to local and global environmental effects at a local level, impacts are mitigated by Health and Safety measures in place to control emissions and by the dispersive nature of the offshore environment. As such, any local air pollution effects are expected to be 'minor' to negligible.

Impacts from the additional emissions from the proposed Avalon Field Development are difficult to assess in isolation as any impacts typically would arise from the cumulative release of emissions. It is considered that, cumulatively, emissions will contribute to global environmental issues, including climate change. The contribution of the proposed programme of works is comparable to similar operations, and small in comparison to emissions at an industry wide level. The estimated emissions from the Avalon Field Development will account for a very small proportion of the available budget from forthcoming UK Carbon Budgets and North Sea Transition Deal targets for emissions.

The installation of a floating OWT to provide power for the FPSO will assist in the reduction of atmospheric emissions through a reduction in use of fuel gas and/or diesel to power the development. Electrification of the Avalon Field Development is consistent with UK and Scottish Government targets to decarbonise the sector whilst also aligning with the aims of the NSTD and the British Energy Strategy to utilise North Sea hydrocarbon reserves to maintain energy security whilst meeting Net Zero targets.

Section 10

Produced Water Impacts

10. Produced Water Impacts

This section assesses the potential impacts associated with the discharge of produced water on the marine environment. The scope of this assessment has been informed by the outcomes of the Environmental Issues Identification (ENVID) exercise (Appendix 4), informal statutory consultation and National Marine Plan (NMP) policies and statutory guidance as explained in Section 5 (Identification of Impacts).

10.1 Produced Water

Produced water can be defined as water from the formation which is produced together with oil and gas (Igunnu & Chen, 2012). Produced water may contain residues of reservoir hydrocarbons as well as chemicals added during the production process, inorganic salts, organic acids, heavy metals, alkylphenols, polycyclic aromatic hydrocarbons (PAH) and naturally occurring radioactive materials (NORM) (Beyer et al., 2020). The composition of produced water can vary between wells and over the lifetime of a well (Bakke *et al., 2013*).

The Avalon Field is expected to start producing produced water in the first year of production. All produced fluids will be flowed to the Avalon FPSO, where they will be separated and processed using the processing equipment onboard the installation and following this, the produced water will be discharged to sea. The volume of the produced water will gradually increase over the life of the field, with an anticipated maximum late field life water cut of 4 092.1 m^3/day (25 739 bbl/day) in the P90 scenario, which presents the scenario with the highest potential water cut.

10.2 Produced Water Treatment

As mentioned in Section 3.5.7, the treatment process is designed to reduce the oil content in the produced water to 15 mg/l or less (monthly average) prior to being discharged overboard. This target concentration is below the OSPAR recommended performance standard of 30 mg/l limit for oil in produced water, as implemented by the Oil Pollution Prevention and Control Regulations, 2005 (as amended).

The Avalon produced water will be treated using a combination of gravity-based oil and water separators, and a hydrocyclone onboard the FPSO to ensure to lowest practicably achievable oil in water (OIW) content. Any recovered oil from the produced water will be routed back into the existing production processing facilities, and the cleaned-up water will be discharged to sea. The discharge of produced water on the United Kingdom Continental Shelf (UKCS) is strictly regulated by OPRED, and PPUK will apply for a permit to discharge produced water from the FPSO.

If OIW specification cannot be met, produced water can be temporarily stored onboard the FPSO for later processing and disposal overboard within the required specification. Should sufficient volume be unavailable for storage of produced water, the procedure will be to restrict or shut-in production until the produced water is brought back into specification.

10.3 Produced Water Modelling

Numerical modelling was undertaken to determine the fate and dispersion of produced water following discharge to sea and to inform assessment of potential environmental impacts. A modelling study was undertaken using Visual Plumes (Fugro 2022b); this considered the variability associated with the free fall produced water discharge from the deck of the FSPO (Fugro 2022b). The model is an industry standard technique employed by the US Environmental Protection Agency (US EPA) for simulation and as a decision support system for environmental assessment and generated comparable results.

10.3.1 Ambient Characteristics

The prevailing normal current, temperature and salinity conditions used for the modelling study have been sourced from the *Atlantic - European North West Shelf - Ocean Physics Analysis and Forecast* made publicly available by the E.U. Copernicus Marine Service Information. This was intended to simulate the water circulation on a regional scale. Model validation was achieved using extracted hourly data of velocity, temperature and salinity along the water column over a one year period at the FPSO location.

As part of this investigation, the modelling considered two stages of dispersion in receiving waters as follows:

- Near-field stage;
- Far-field stage;

The near-field stage is the area of strong initial mixing which is sensitive to the discharge design conditions. It is defined here as the area within which the discharge reaches the surface or when it achieves vertically stability within the water column. Typically, this stage occurs over a matter of minutes.

The far-field stage relates to the area beyond this initial mixing zone and beyond the influence of the initial discharge momentum. At this stage, plume dispersion is largely dependent on ambient current conditions. To assess the far-field plume dispersion, two model simulations were performed on four different dates:

- 1 September 2021;
- 1 December 2021;
- 1 March 2022; and
- 1 June 2022.

This allowed the model to be representative of prevailing currents during different seasons. The modelling scenarios considered releases to account for the variability associated with the tidal excursions. The simulations comprised releases initiated every hour during a full day for each of these dates (Fugro, 2022bb).

10.3.2 Discharge Characteristics and Scenarios

Produced water discharge will occur from the FPSO at deck level and undergo free fall for 10 m before reaching the sea surface and mixing with the seawater. To assess the variability associated with the free fall from the discharge, two scenarios were considered:

- Scenario 1 - The discharge jet maintains its velocity and diameter of 20 cm (8 in) during its fall (the lower flow velocity will induce less mixing with the ambient seawater, hence lower dilution rates);
- Scenario 2 - The discharge jet falls from the point of discharge with theoretical acceleration without considering the effect of turbulence (the diameter of the discharge jet when it reaches the sea level is set to 6.5 cm).

The temperature of the released produced waters, therefore its density, is expected to significantly affect the plume dynamics, with the plume either sinking to greater water depth or rising towards the sea surface. The vertical stabilization of the produced water plume is highly dependent on its release temperature and its rate of cooling. The temperature of Avalon produced water discharge will be 40 °C. Local ambient stratification also has the potential to affect the plume, resulting in its sinking or stabilisation. A salinity of 66,000 ppm was used for the produced water during the modelling.

10.4 Model Results

The modelling results from Scenario 1 (20 cm produced water jet diameter at sea surface), 1 September 2021, found that the modelled plume did not reach the seabed or return to the surface. Therefore, the near-field dilution was found to end when it was vertically stable. At the end of the near-field propagation, the dilution factor varied from 569 to 2823, and the plume horizontal distance from the release location varied from 1 to 66 m. Figure 10.1 summarises the evolution of the near-field vertical plume extent and its dilution on 1 September 2021.

Table 10.1 summarises the plume characteristics at the end of the near-field propagation for each considered scenario. The modelling simulation of scenario 1 for the release on 1 September 2021 showed that far-field propagation was less dependent on the discharge characteristics and more dependent on the plume dilution and width, as well as the ambient conditions. Figure 10.2 illustrates the evolution of the near-field and far-field dilution with horizontal distance from the release location on 1st September 2021.

The modelling results for Scenario 1, with release dates of 1 December 2021, 1 March 2022, and 1 June 2022, showed that the tidal currents were stronger during these periods when compared with the conditions found on 1 September 2021 (Figure 10.3 to Figure 10.5). The simulation, therefore showed that the north/south distance of the plumes was significantly longer during December, March and June (Figure 10.6 to Figure 10.8; Fugro, 2022bb).

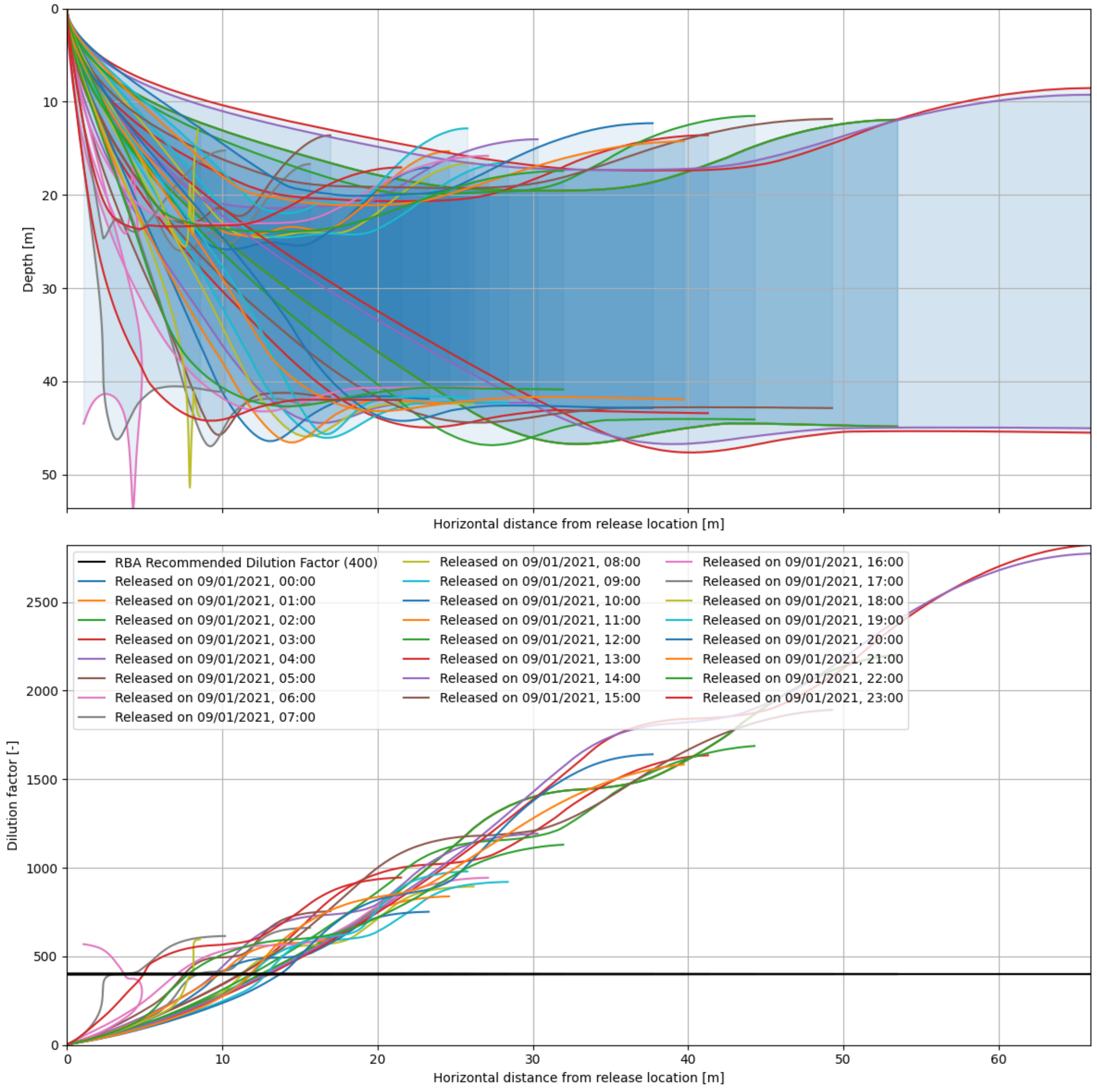


Figure 10.1:Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 1 (1 September 2021 release) (Fugro, 2022b)

Table 10.1 Plume characteristics after the near-field propagation for the different scenarios

Scenario		Horizontal distance from discharge location (m)	Near-field dilution factor (-)	Plume diameter (m)	Propagation time (s)
Scenario 1 Release 1st September 2021	Min	1	569	23.5	381
	Max	66	2823	37	593
	Mean	33	1351	29.2	451
Scenario 1 Release 1st December 2021	Min	23	10003	36.8	558
	Max	251	10200	72.7	1475
	Mean	154	10057	50.1	745
Scenario 1 Release 1st March 2022	Min	56	10008	32.4	535
	Max	306	10172	73.2	1016
	Mean	182	10080	47.4	678
Scenario 1 Release 1st June 2022	Min	12	630	30.5	431
	Max	208	10163	93.7	968
	Mean	129	7308	48.4	702
Scenario 2 Release 1st September 2021	Min	1	713	25.9	358
	Max	60	2787	28.1	534
	Mean	31	1445	30.9	416
Scenario 2 Release 1st December 2021	Min	22	10003	36.6	508
	Max	230	10188	74.2	1374
	Mean	143	10092	50.4	700
Scenario 2 Release 1st March 2022	Min	50	10001	32.4	488
	Max	278	10168	73.1	958
	Mean	169	10087	47.5	632
Scenario 2 Release 1st June 2022	Min	11	737	33.2	406
	Max	201	10166	116.6	903
	Mean	122	7139	49	660

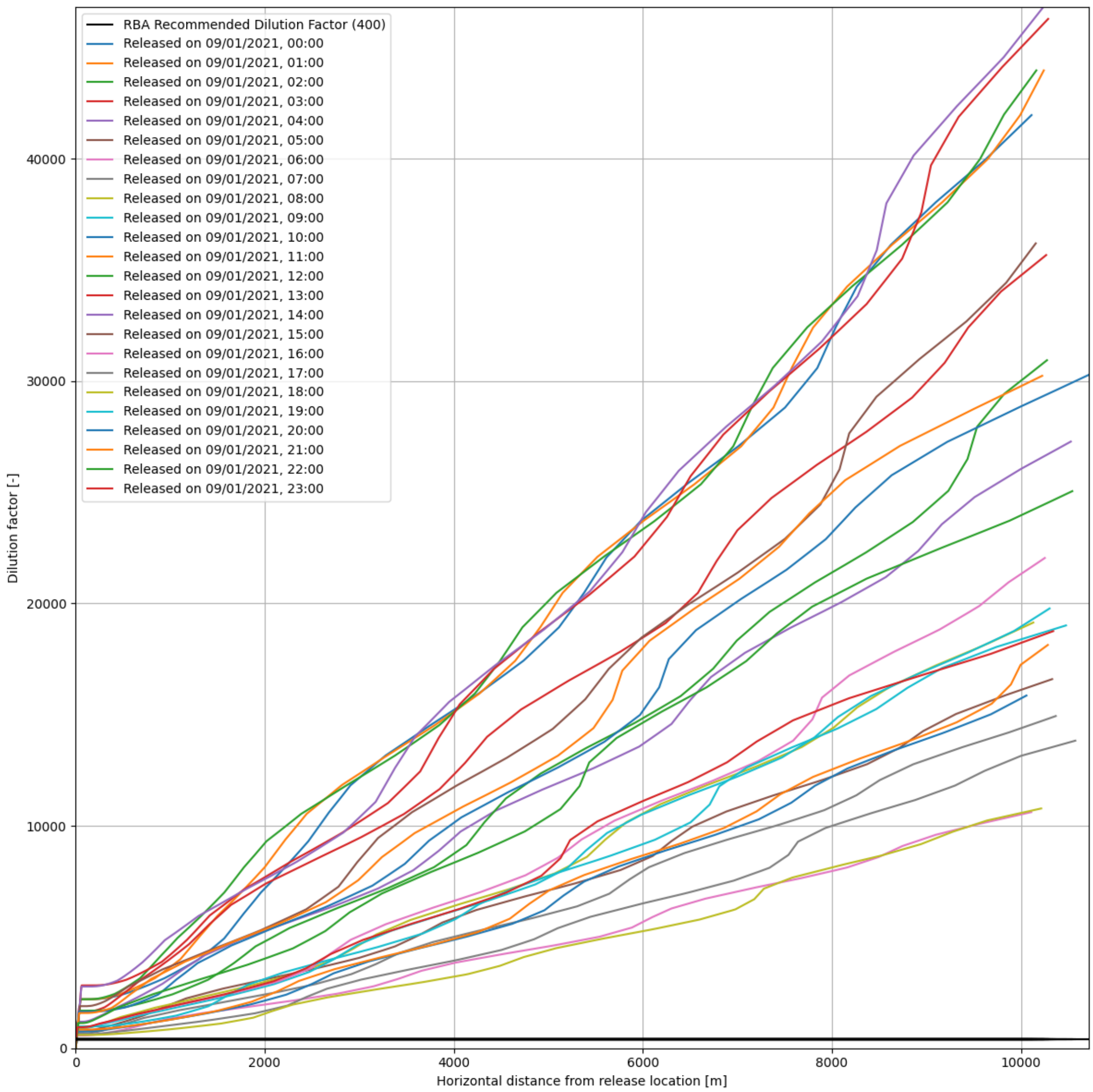


Figure 10.2: Modelled evolution of the near-field and far-field dilutions from Scenario 1 (1 September 2021 release) (Fugro, 2022b)

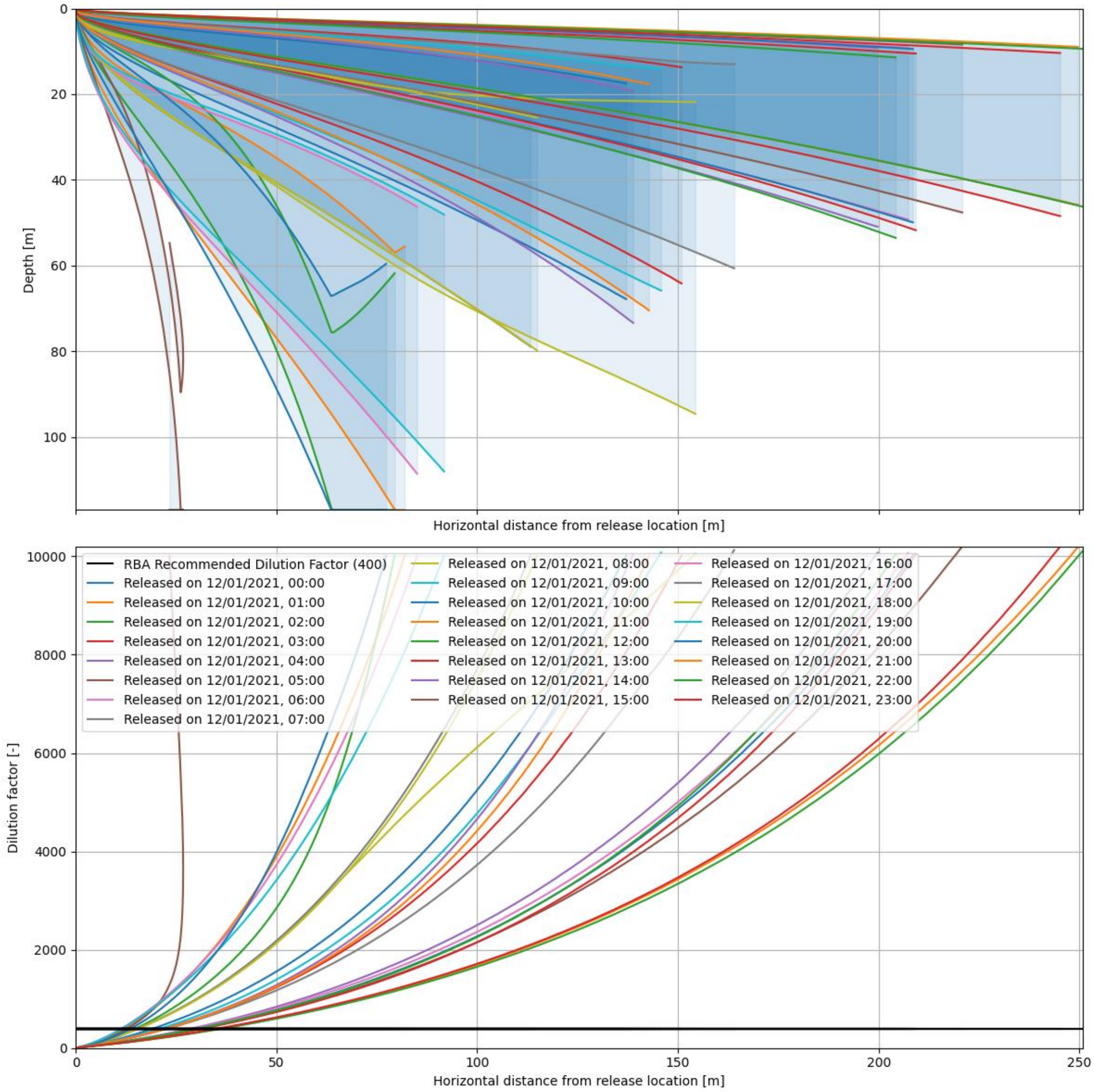


Figure 10.3: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 1 (1 December 2021 release) (Fugro, 2022b)

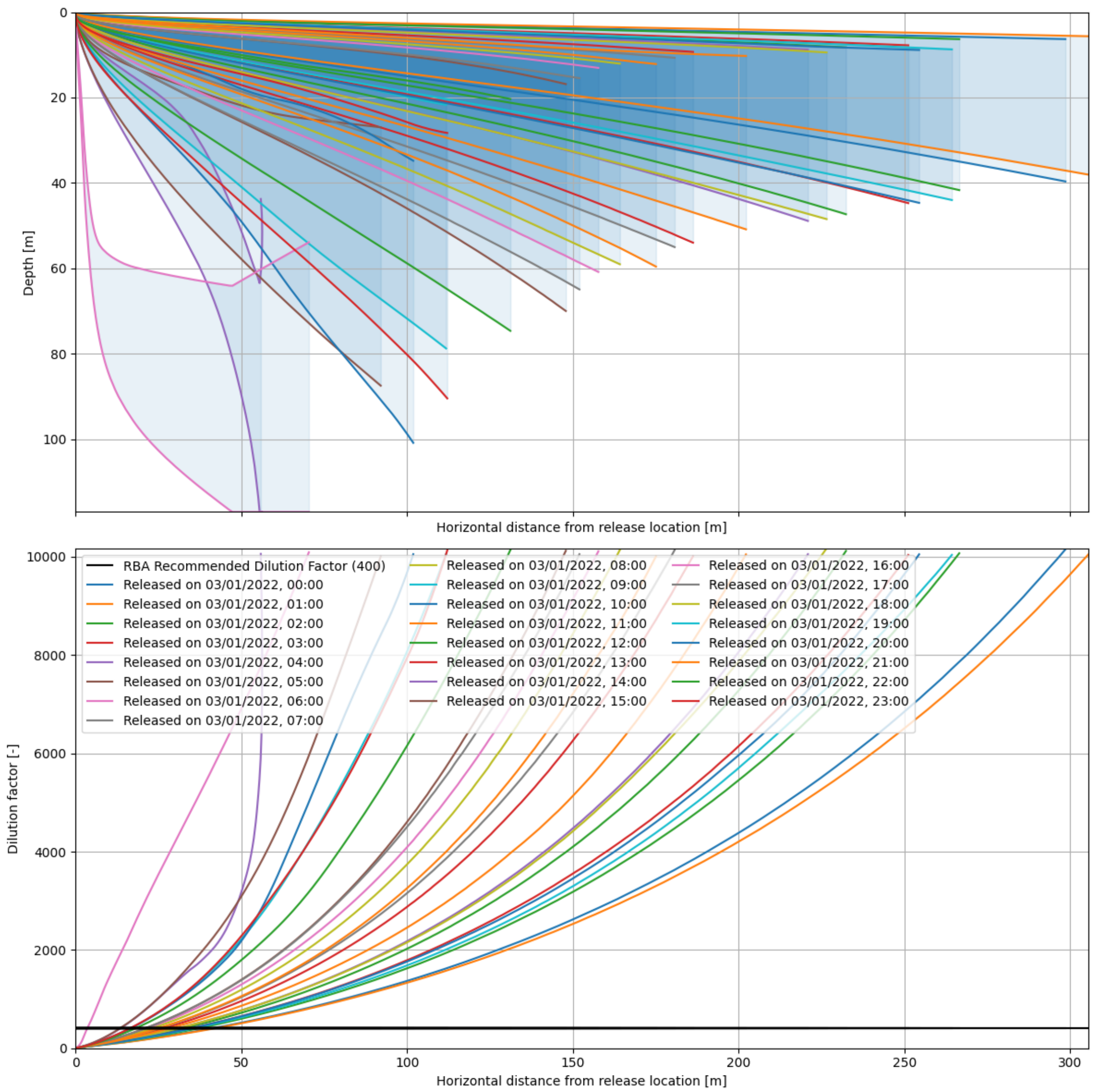


Figure 10.4: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 1 (1 March 2022 release) (Fugro, 2022b)

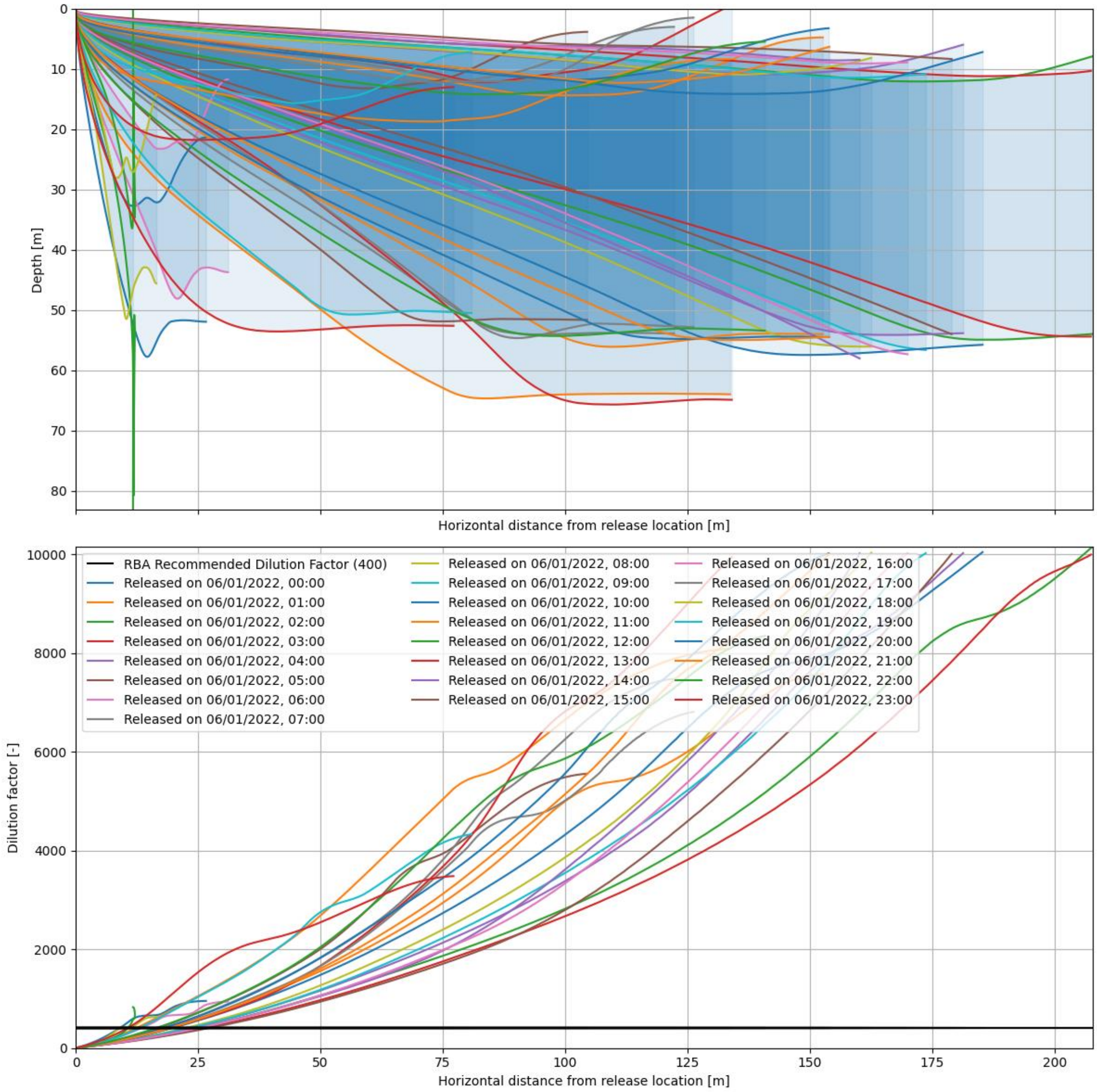


Figure 10.5: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 1 (1 June 2022 release) (Fugro, 2022b)

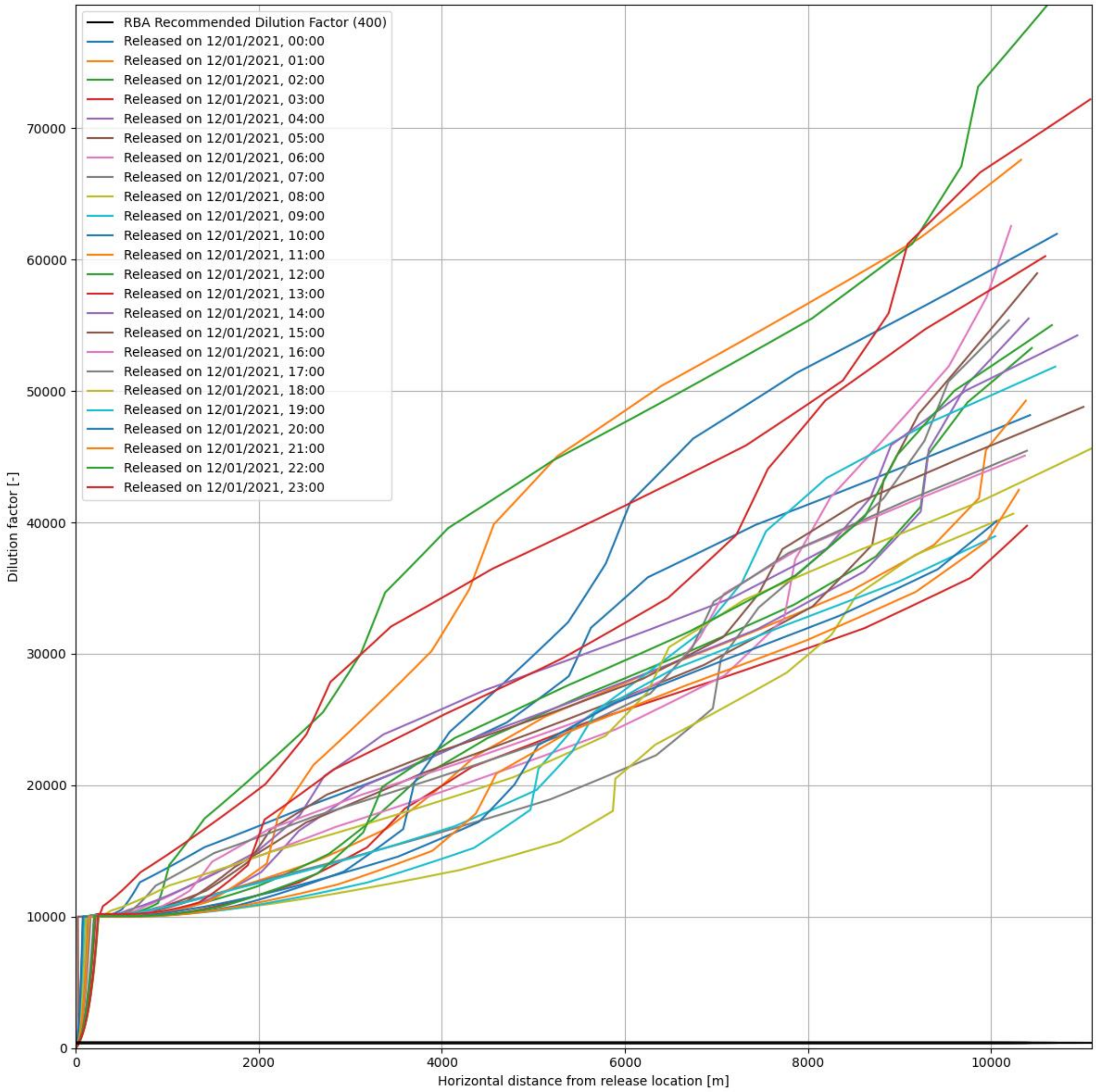


Figure 10.6: Modelled evolution of the near-field and far-field dilutions from Scenario 1 (1 December 2021 release) (Fugro, 2022b)

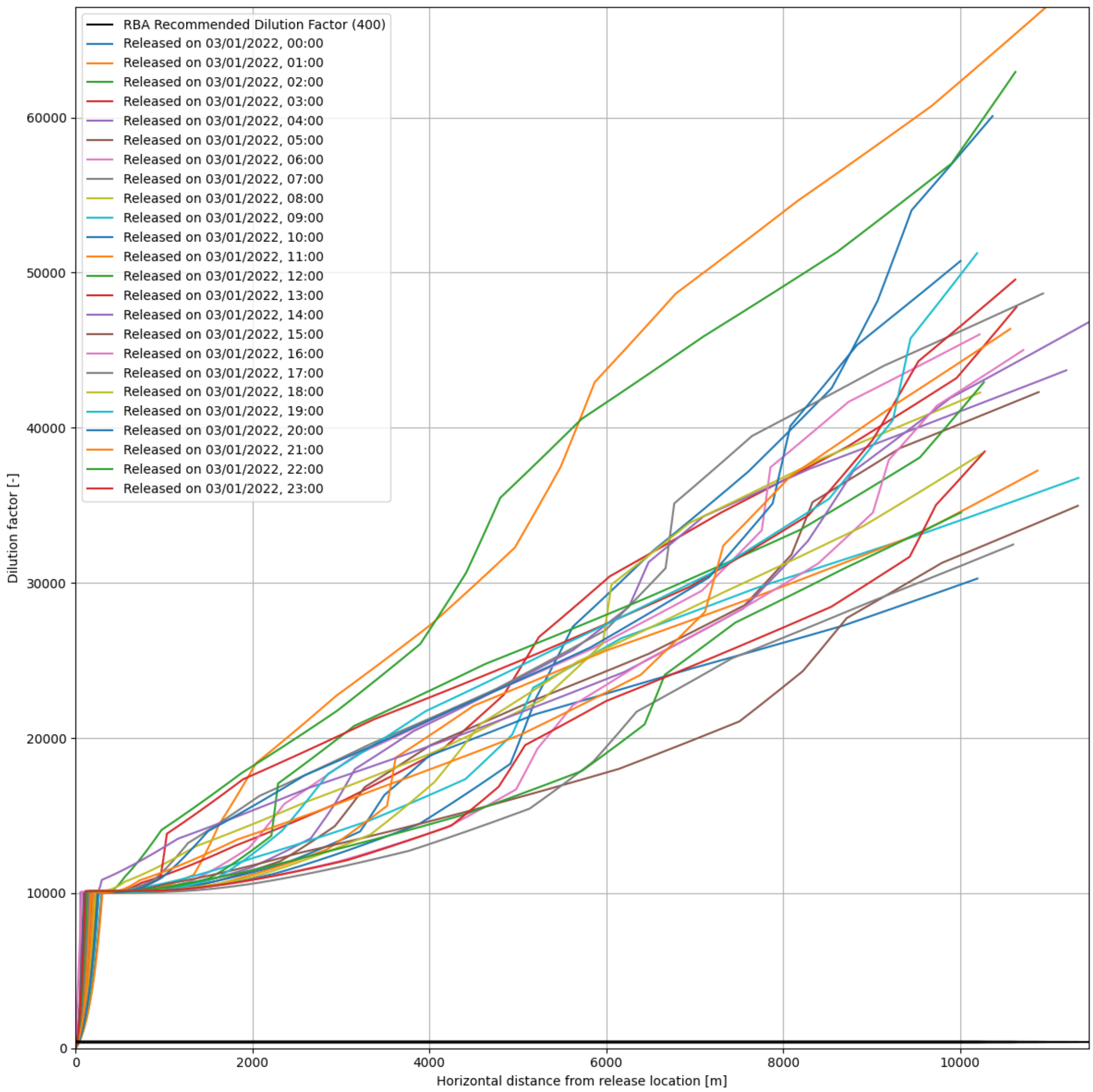


Figure 10.7: Modelled evolution of the near-field and far-field dilutions from Scenario 1 (1 March 2022 release) (Fugro, 2022b)

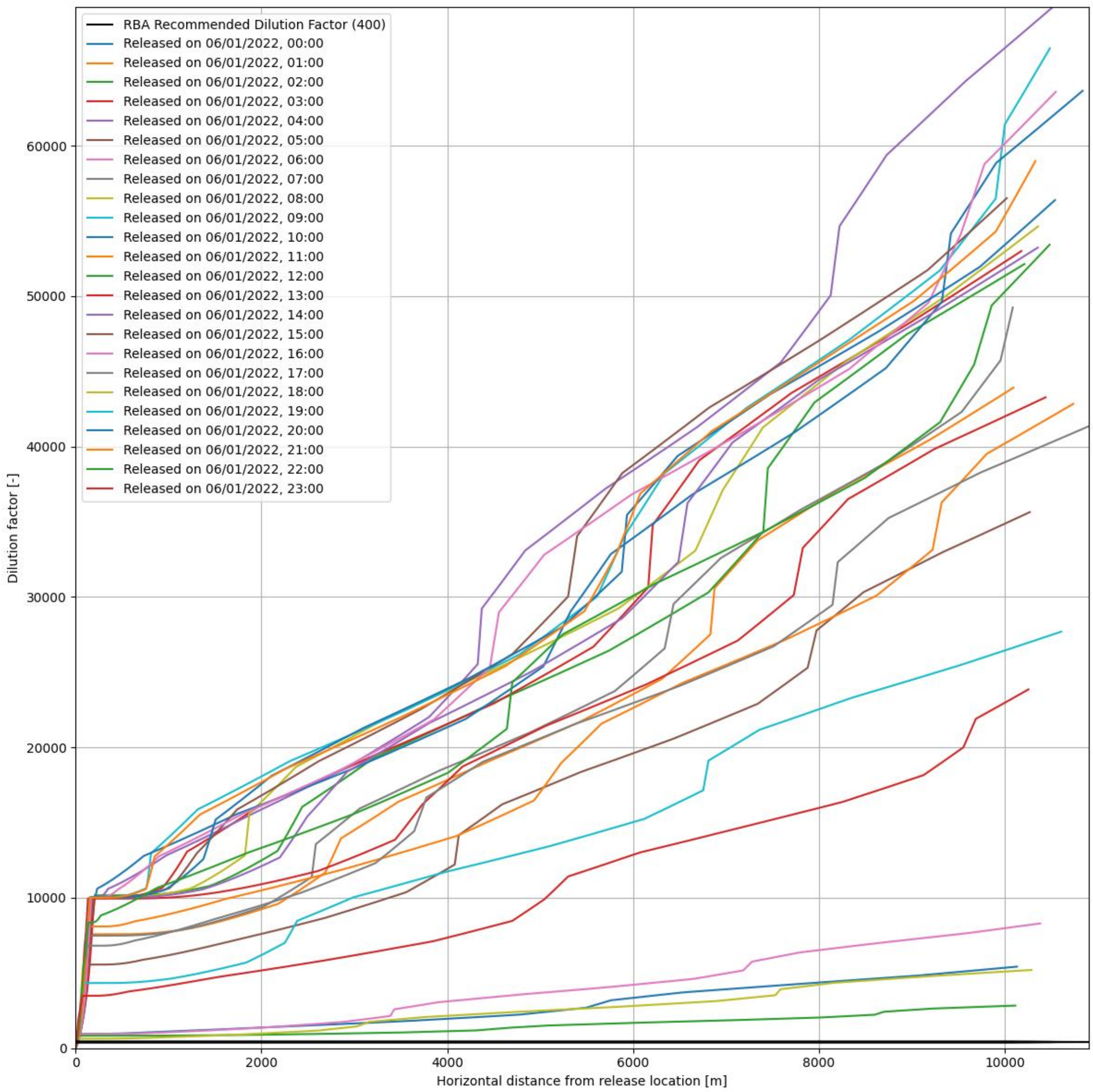


Figure 10.8: Modelled evolution of the near-field and far-field dilutions from Scenario 1 (1 June 2022 release) (Fugro, 2022b)

The modelling outputs include a range of predicted dilution factors of the produced water at selected distances from the discharge point. These are compared against the OSPAR Recommendation for a Risk Based Approach (RBA) to the Management of Produced Water Discharges from Offshore Installations (RBA Recommendation) which recognises that other potentially hazardous substances other than oil, may be entrained within discharged produced water. It is based on the ratio of the calculated predicted environmental concentration (PEC) and the predicted no effect concentration (PNEC) with an acceptance criterion of a PEC:PNEC ≤ 1 within a specified body of water as indicative of a discharge that is unlikely to result in significant harm in the marine environment. As part of the implementation of the RBA Recommendation in the UK, discharges of produced water may be screened out from further assessment if the whole effluent PEC:PNEC at 500 m from the discharge point is ≤ 1 using generic dilution factors.

Table 10.2 summarises the plume characteristics at different dilution levels for each considered scenario. For discharges between one million and eight million cubic metres per year in waters between 50 m and 125 m deep, the methodology for RBA described by the Department for Business, Energy & Industrial Strategy (BEIS, 2020) estimated a generic dilution factor of 400 at 500 m from the discharge point. It is therefore preferred that the proposed Avalon produced water discharges achieve a dilution of 400 times at a distance of 500 m.

For Scenario 1, with release on 1 September 2021, the site-specific plume dilution level of 400 was achieved at a distance fluctuating from 3.1 m to 13.7 m, with an average distance of 10 m. These distances are significantly lower than the generic estimation of 500 m. Figure 10.9 shows the evolution of the horizontal plume during the propagation on 1 September 2021. The tidal effect was visible through the North/South oscillations, while the simulation showed that there was net residual transport in an easterly direction.

Table 10.2: Plume characteristics when it reaches different dilution levels, (Fugro, 2022b)

Scenario	Dilution factor (-)	Horizontal distance from discharge location (m)			Plume width (m)		
		Min	Max	Mean	Min	Max	Mean
Scenario 1 Release date 1 September 2021	10	0.1	0.5	0.4	1.4	1.4	1.4
	25	0.5	1.5	1.1	2.5	2.7	2.6
	50	0.9	2.9	2.2	3.8	4.1	4
	100	1.5	5.2	3.9	5.8	6.3	6
	250	2.3	10.4	7.5	9.9	32.1	11.3
	400	3.1	13.7	10	7.3	23.5	14.6
	1000	20	1321.2	260.5	21.1	77.1	35.2
Scenario 1 Release date 1 December 2021	10	0.4	0.7	0.6	1.1	1.5	1.3
	25	1.1	2.4	1.8	1.8	2.7	2.3
	50	2.2	5.5	3.8	2.5	4.1	3.4
	100	4	11.2	7.4	3.6	6.3	5
	250	8.1	25.2	15.9	5.6	10.7	8.1
	400	11.5	36.8	22.8	7.1	13.9	10.4
	1000	21.4	72	43.9	11.4	22.4	16.4
Scenario 1 Release date 1 March 2021	10	0.2	0.7	0.6	1	1.5	1.3
	25	0.5	2.7	2	1.6	2.7	2.2
	50	1	6.2	4.1	2.3	4.1	3.2
	100	1.6	12.6	8	3.2	6.2	4.6
	250	2.6	28.5	17.4	5	10.6	7.5
	400	3.5	41.6	25.2	6.4	13.8	9.6
	1000	7.4	82.2	49.2	10.1	22.6	15.3
Scenario 1 Release date 1 June 2021	10	0.3	0.7	0.6	1.3	1.5	1.4
	25	0.9	2	1.6	2.1	2.7	2.5
	50	1.7	4.3	3.3	3	4.1	3.7
	100	3.1	8.5	6.1	4.3	6.3	5.4
	250	6.4	18.6	12.8	6.8	10.5	8.8
	400	8.9	26.9	18.2	8.7	17.4	11.5
	1000	18.6	3100	303.1	13.9	151	26.9
Scenario 2 Release date 1 September 2021	10	0	0	0	0.6	0.6	0.6
	25	0.1	0.3	0.2	1.6	1.6	1.6
	50	0.2	1	0.7	2.9	3	3
	100	0.7	2.5	1.8	5.2	5.3	5.2
	250	1.8	6.9	5	9.3	10.1	9.8
	400	2.1	10.1	7.4	13	38.3	14.5
	1000	16.2	1057.5	158.5	21	72.4	31.8
Scenario 2 Release date 1 December 2021	10	0	0.2	0.1	0.6	0.6	0.6
	25	0.2	0.6	0.5	1.4	1.6	1.5
	50	0.7	1.5	1.2	2.3	3	2.7

Scenario	Dilution factor (-)	Horizontal distance from discharge location (m)			Plume width (m)		
		Min	Max	Mean	Min	Max	Mean
	100	1.8	3.3	2.8	3.5	5.3	4.5
	250	5.2	10.6	8	5.6	10.1	7.9
	400	8.1	18.9	13.3	7.2	13.5	10.2
	1000	17.7	49.9	32.3	11.4	22.2	16.3
Scenario 2 Release date 1 March 2021	10	0	0.2	0.1	0.6	0.6	0.6
	25	0.1	0.7	0.5	1.4	1.6	1.5
	50	0.3	1.5	1.3	2.1	3	2.6
	100	0.8	3.5	2.9	3.1	5.2	4.3
	250	2	11.6	8.4	5	10	7.3
	400	2.7	20.8	14.2	6.4	13.4	9.5
	1000	6	56	35.6	10.1	22.4	15.2
Scenario 2 Release date 1 June 2021	10	0	0.1	0.1	0.6	0.6	0.6
	25	0.1	0.6	0.4	1.5	1.6	1.5
	50	0.5	1.4	1.1	2.6	3	2.8
	100	1.5	3	2.6	4.1	5.3	4.8
	250	4.3	8.7	7	6.8	10	8.6
	400	6.7	14.9	11.3	8.7	13.8	11.1
	1000	15.1	2301.3	190	13.9	161.9	26.1

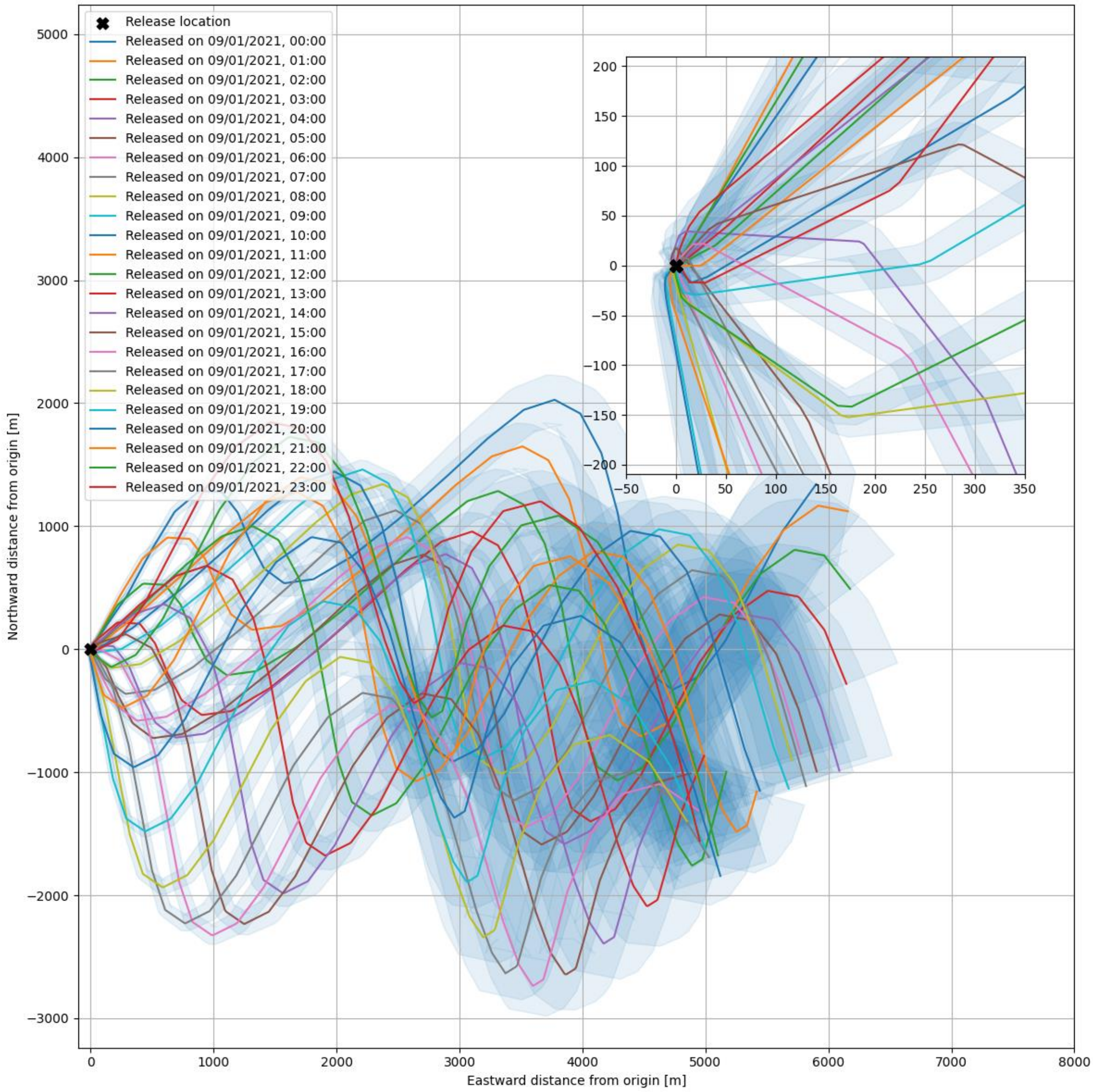


Figure 10.9: Modelled horizontal plume extent from Scenario 1 (1 September 2021 release) (Fugro, 2022b)

As previously discussed, the modelling results showed that the tidal currents were stronger during 1st December 2021, 1st March 2022, and 1st June 2022 when compared with the conditions found on the 1st of September 2021. Due to these stronger currents, higher dilution factors were obtained at the end of the near-field stage (Table 10.1). Figures 10.10 to 10.12 illustrate the horizontal plume extent for scenario 1 for the December, March and June release dates. Table 10.2 shows that a dilution factor of 400 is predicted at distances from 2.1 m to 41.6 m from the discharge location, which is significantly shorter than the generic 500 m distance estimated by BEIS (2020).

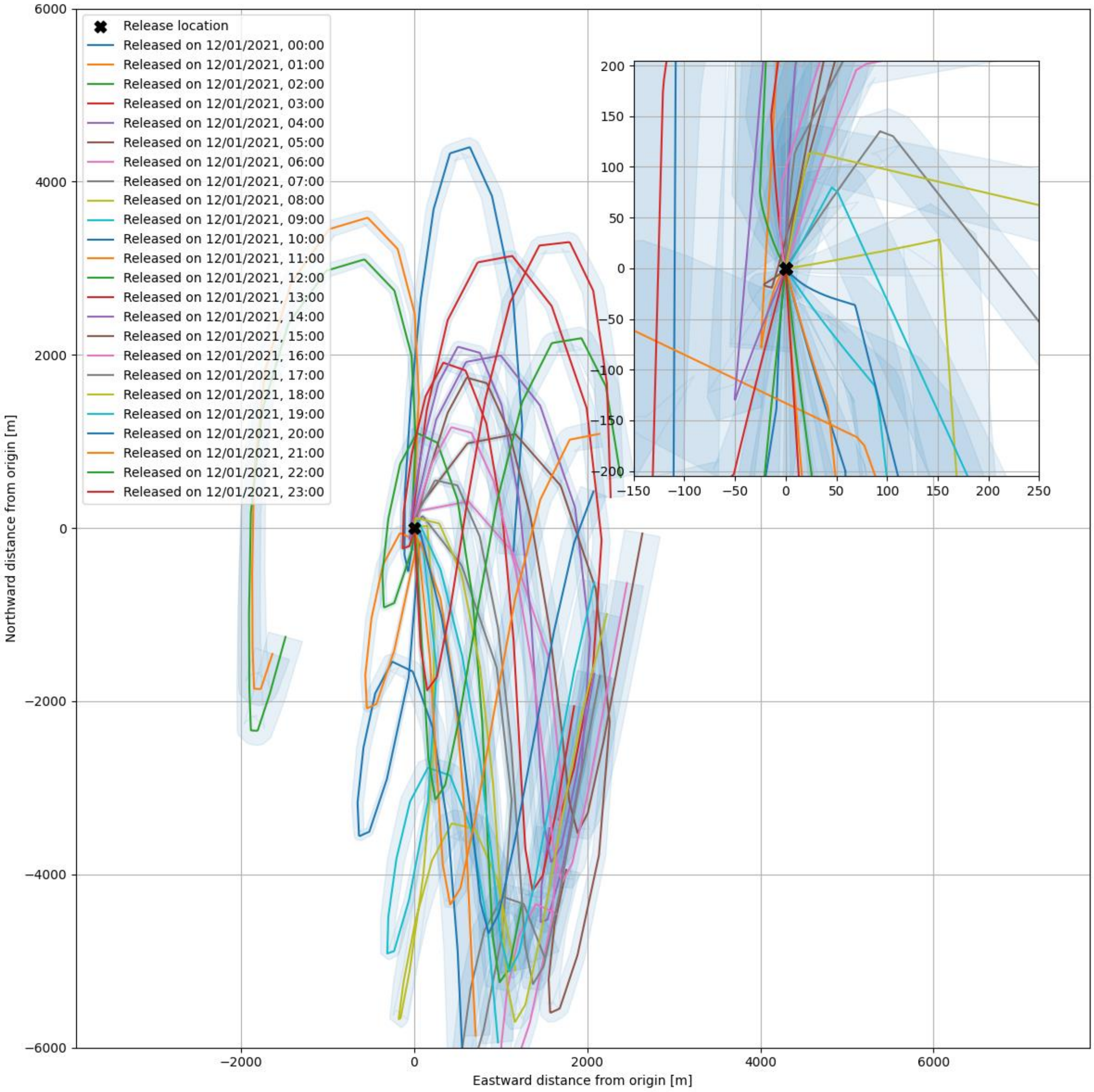


Figure 10.10: Modelled horizontal plume extent from Scenario 1 (1 December 2021 release) (Fugro, 2022b)

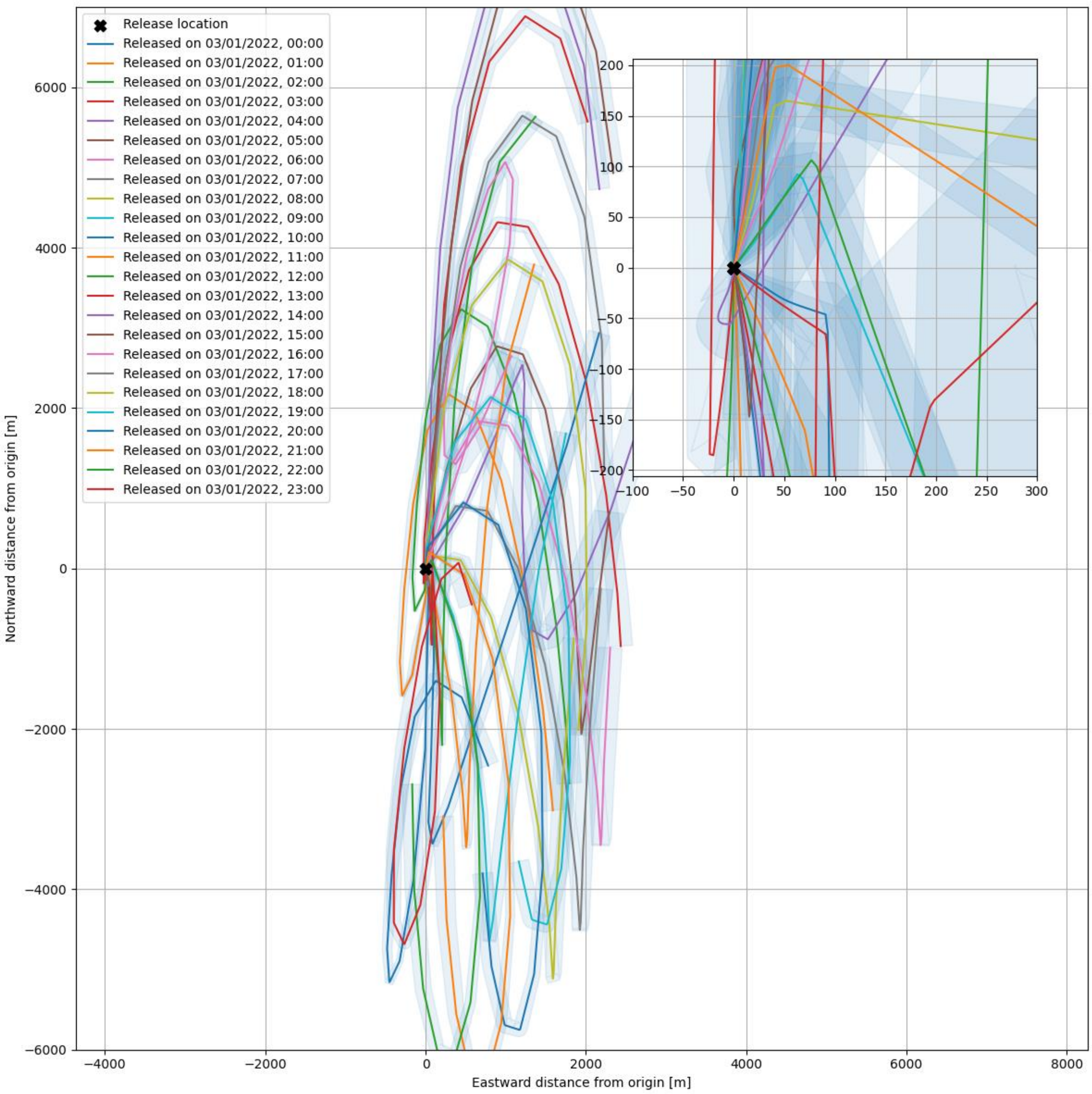


Figure 10.11: Modelled horizontal plume extent from Scenario 1 (1 March 2021 release) (Fugro, 2022b)

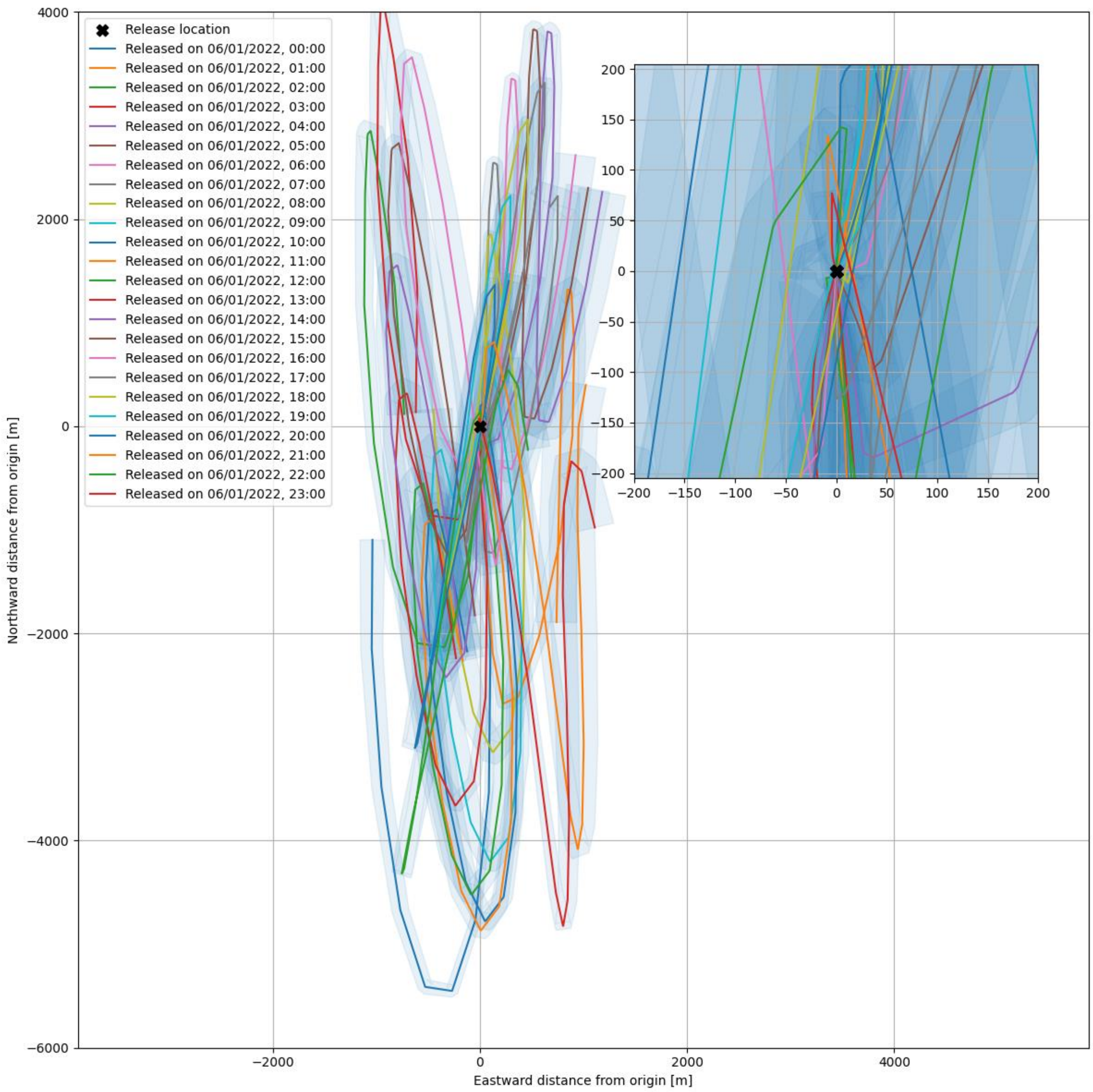


Figure 10.12: Modelled horizontal plume extent from Scenario 1 (1 June 2021 release) (Fugro, 2022b)

The modelling results for Scenario 2 (a jet of 6.5 cm diameter when it reaches the sea surface) found that the distances to reach a dilution factor of 400 were slightly reduced in comparison with Scenario 1. Table 10.2 shows that a dilution factor of 400 is predicted at distances from 10.1 m to 20.8 m from the discharge location for all four seasons. This is significantly shorter than the generic 500 m distance estimated by BEIS (2020). This was as a result of the higher mixing with ambient water when the discharge jet reached the sea surface. However, these changes were found not to be significant, and the two scenarios behave rather similarly. Figure 10.13 to Figure 10.24 illustrate the modelling output for Scenario 2.

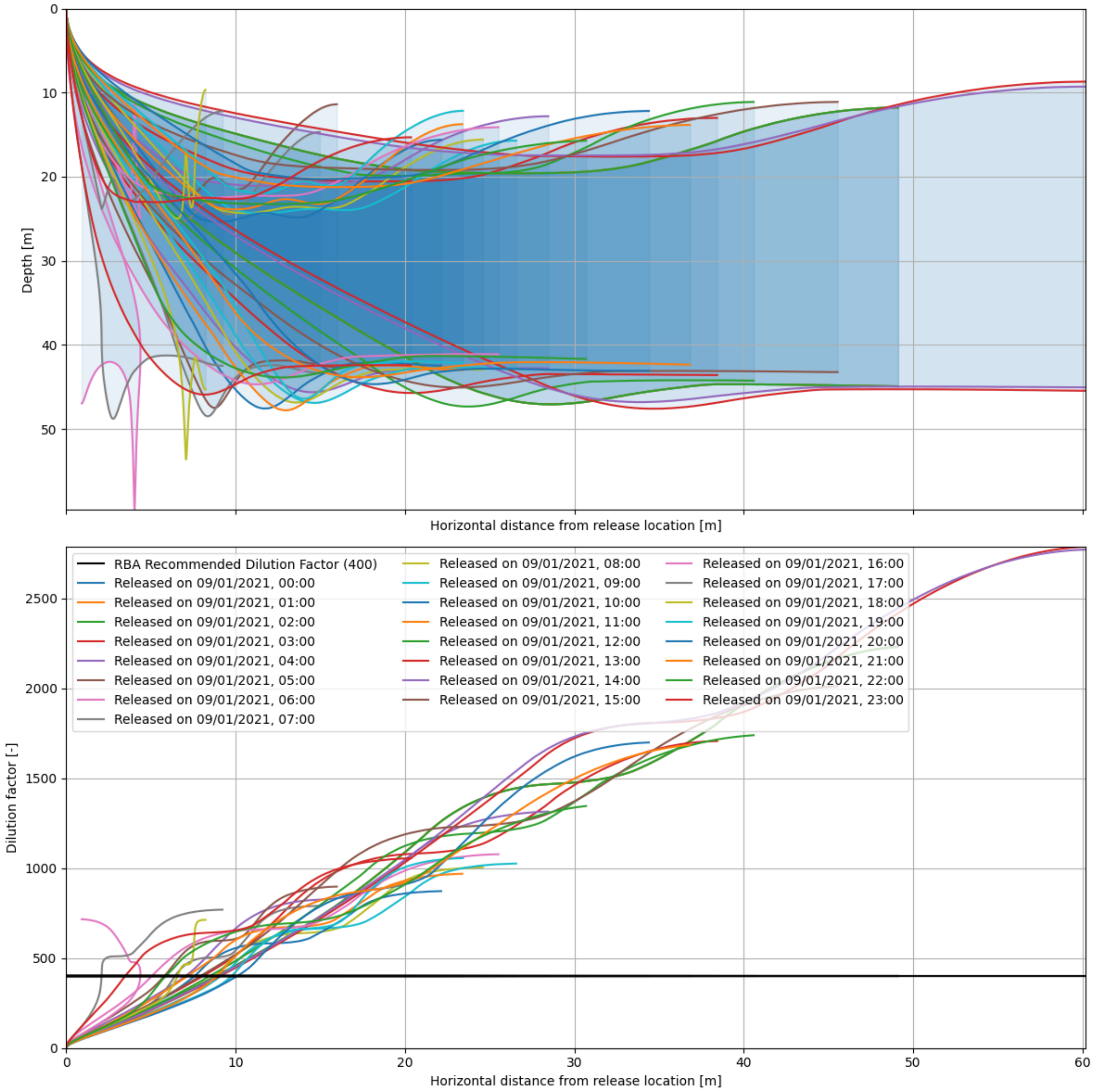


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Figure 10.13: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 2 (1 September 2021 release) (Fugro, 2022b)

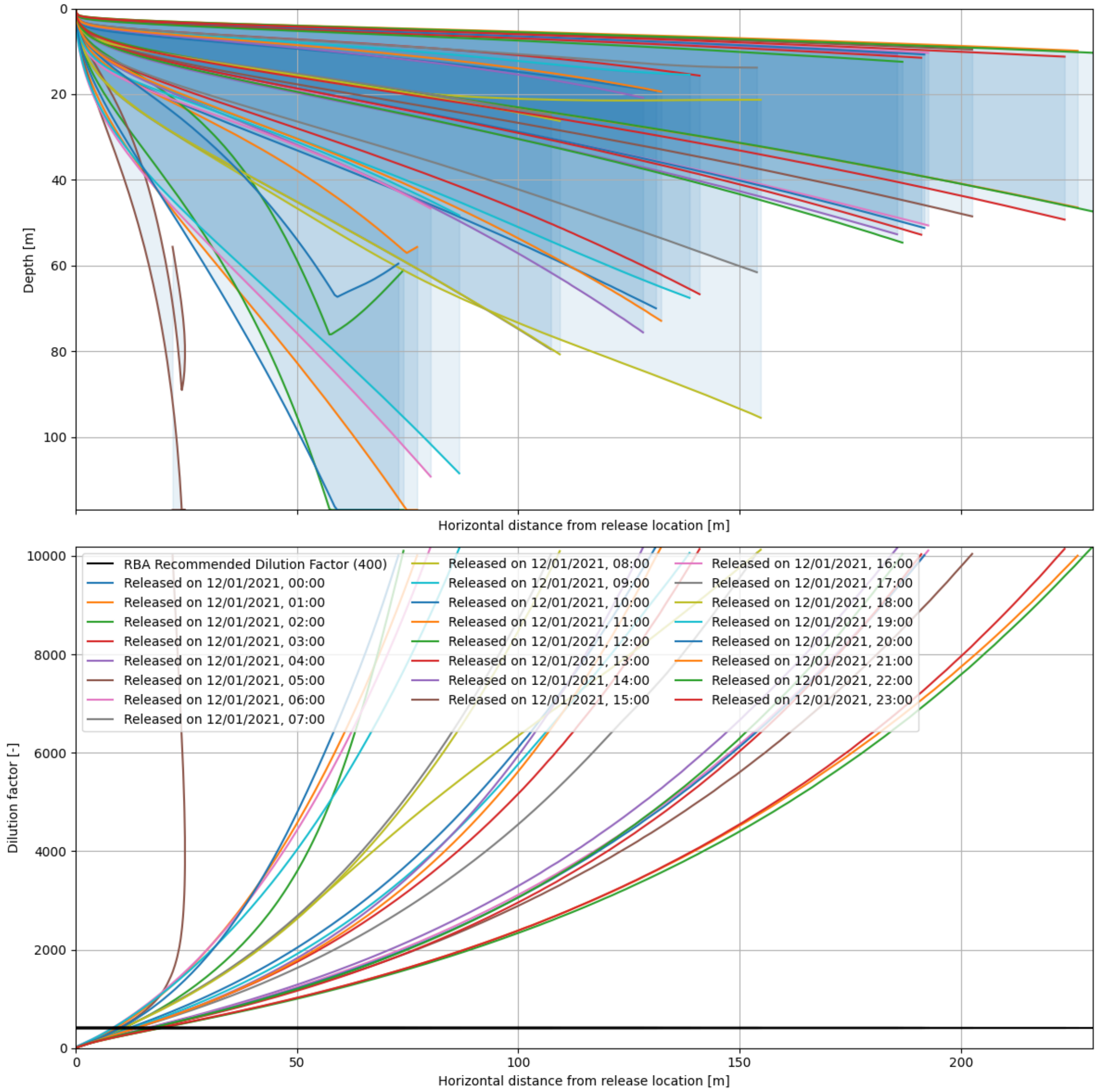

Figure 10.14: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 2 (1 December 2021 release) (Fugro, 2022b)

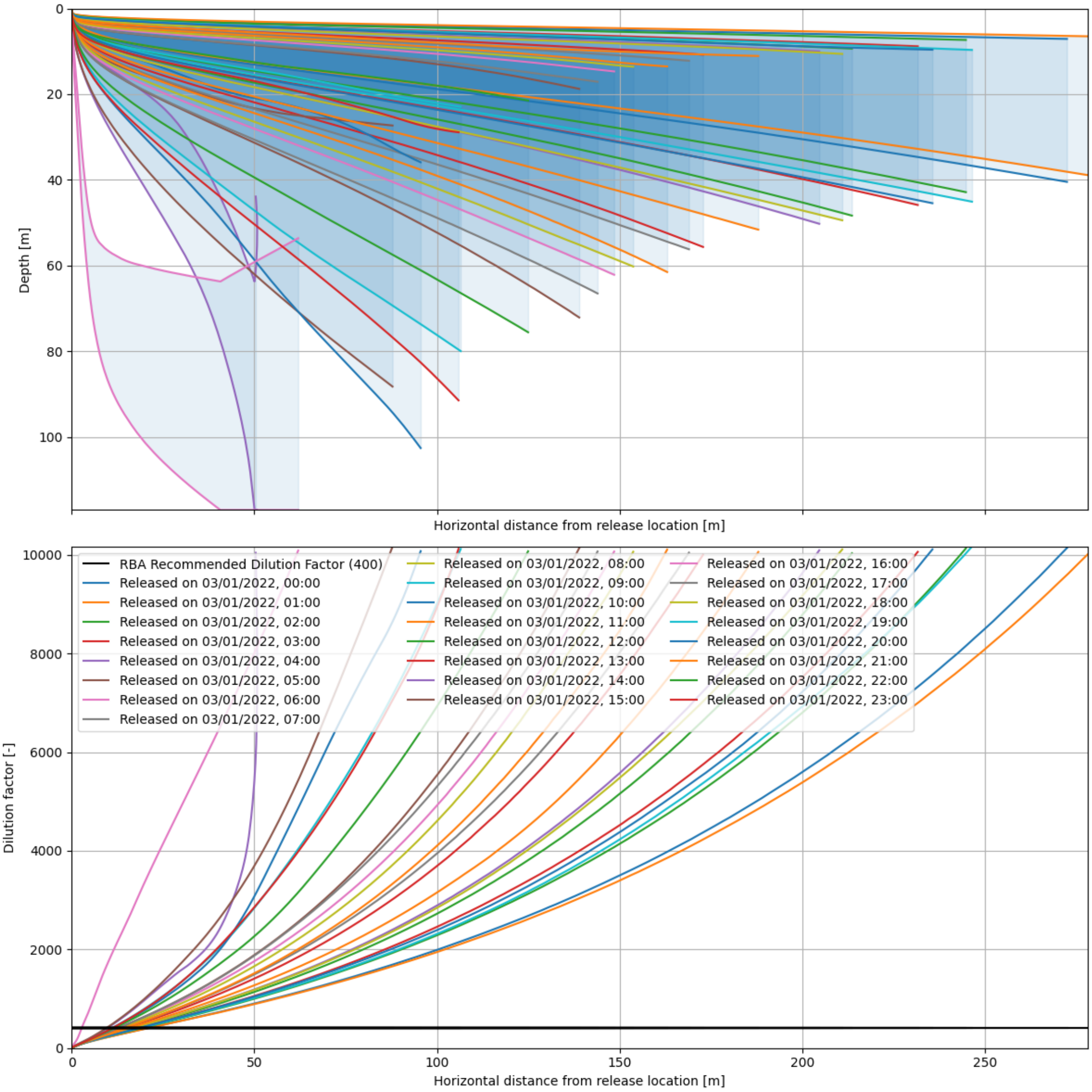

Figure 10.15: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 2 (1 March 2022 release) (Fugro, 2022b)

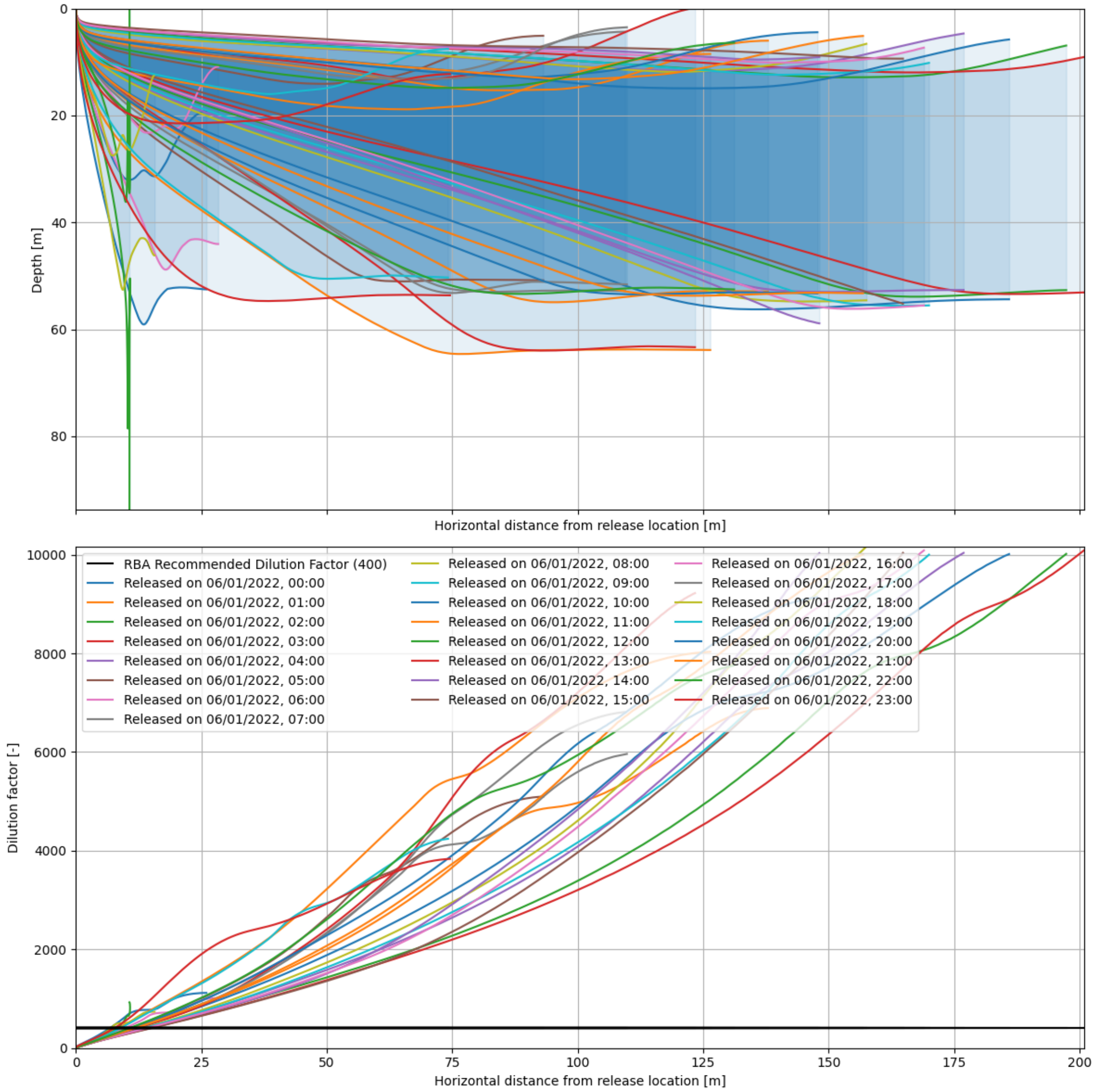

Figure 10.16: Modelled evolution of near-field vertical plume extent (up) and dilution (down) from Scenario 2 (1 June 2022 release) (Fugro, 2022b)

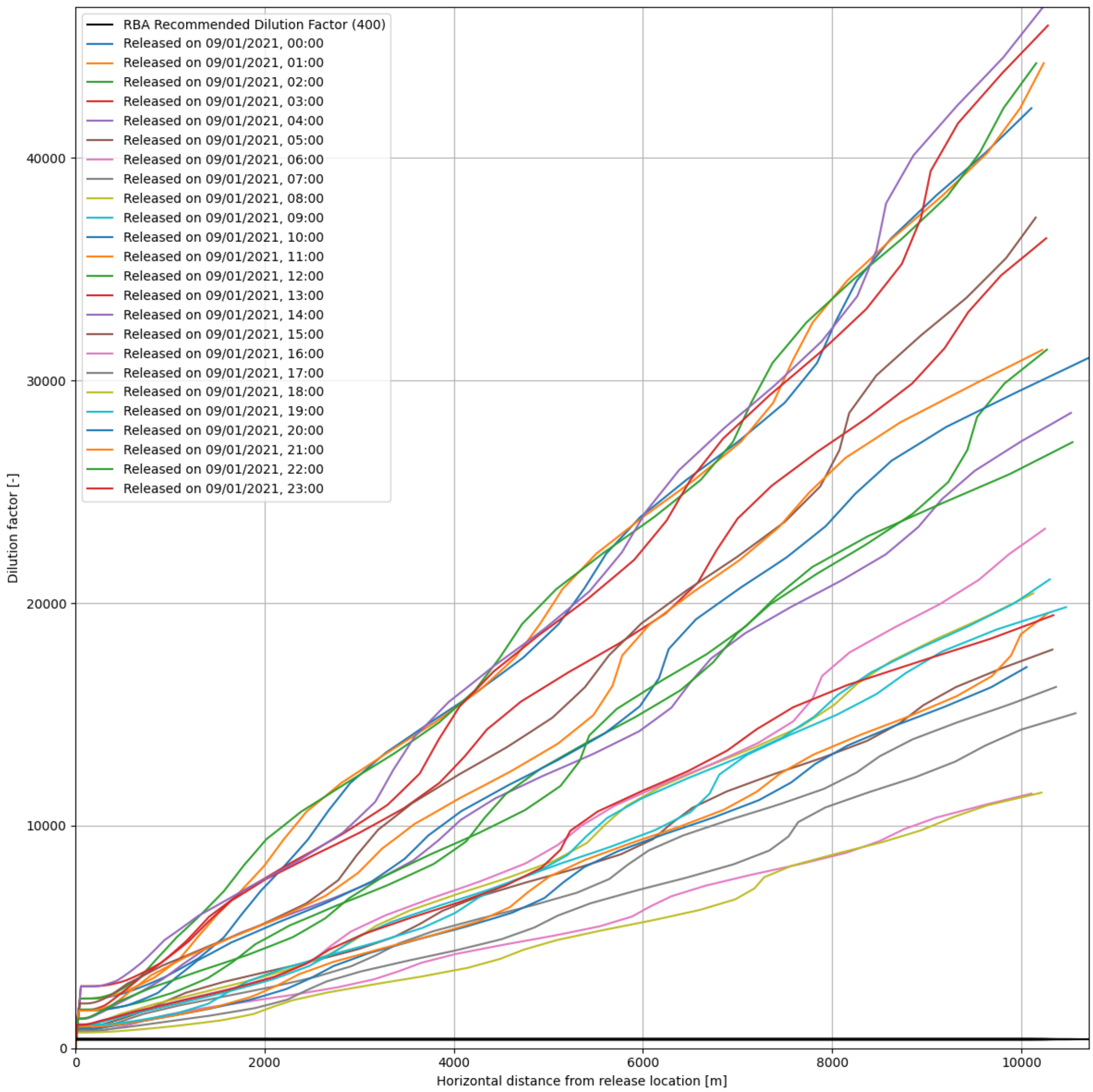

Figure 10.17: Modelled evolution of the near-field and far-field dilutions from Scenario 2 (1 September 2021 release) (Fugro, 2022b)

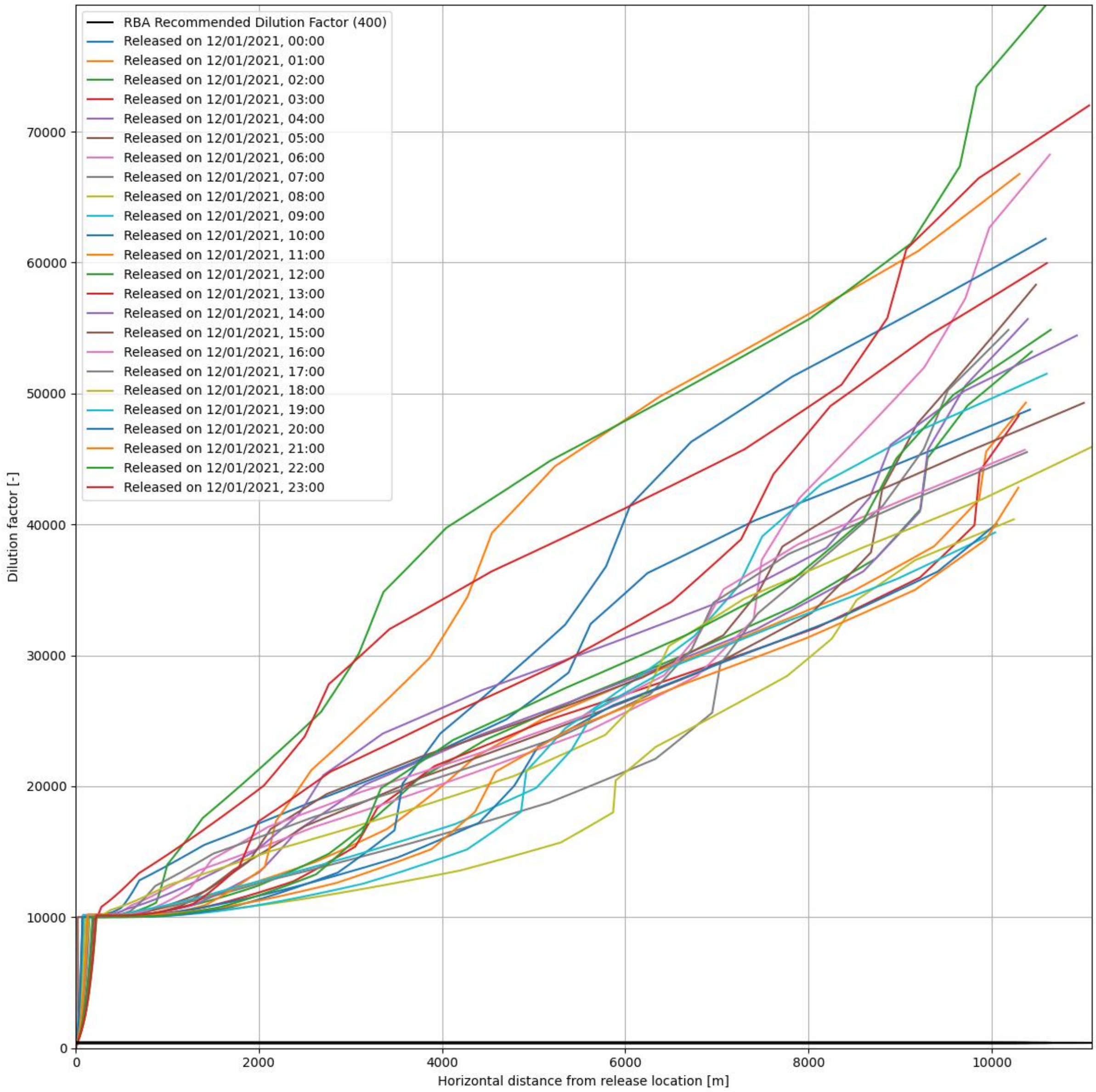

Figure 10.18: Modelled evolution of the near-field and far-field dilutions from Scenario 2 (1 December 2021 release) (Fugro, 2022b)

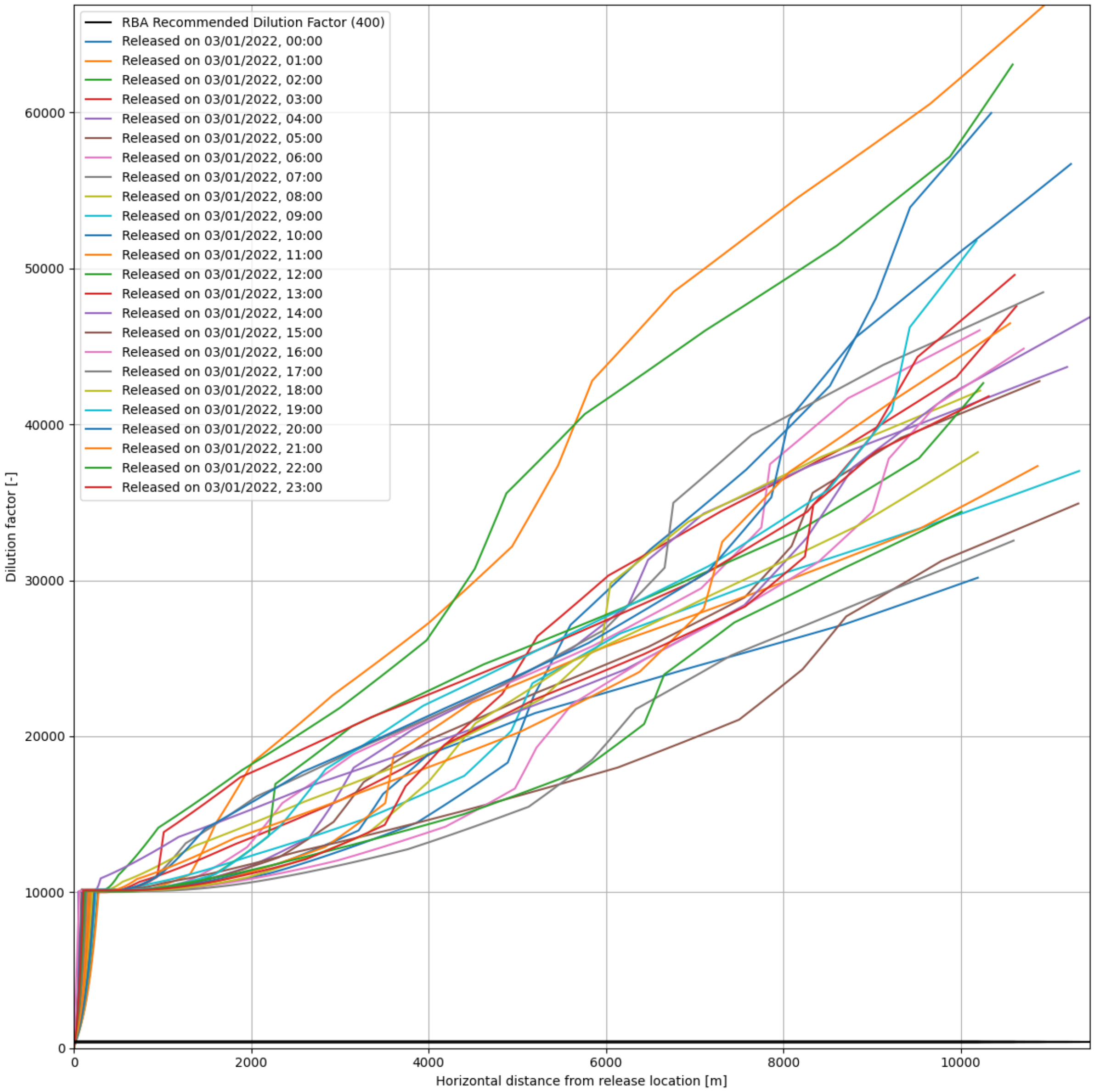

Figure 10.19: Modelled evolution of the near-field and far-field dilutions from Scenario 2 (1 March 2022 release) (Fugro, 2022b)

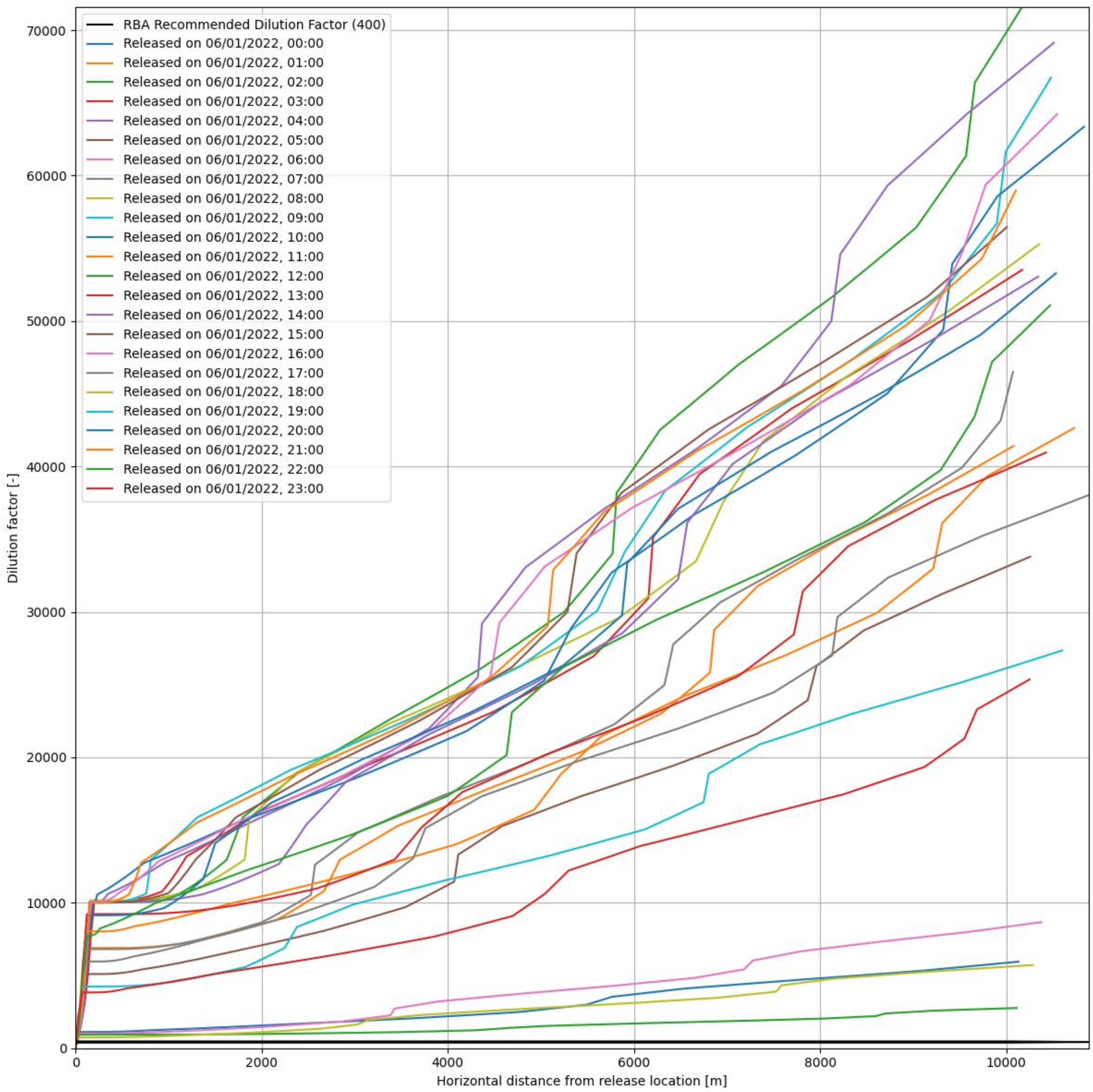

Figure 10.20: Modelled evolution of the near-field and far-field dilutions from Scenario 2 (1 June 2022 release) (Fugro, 2022b)

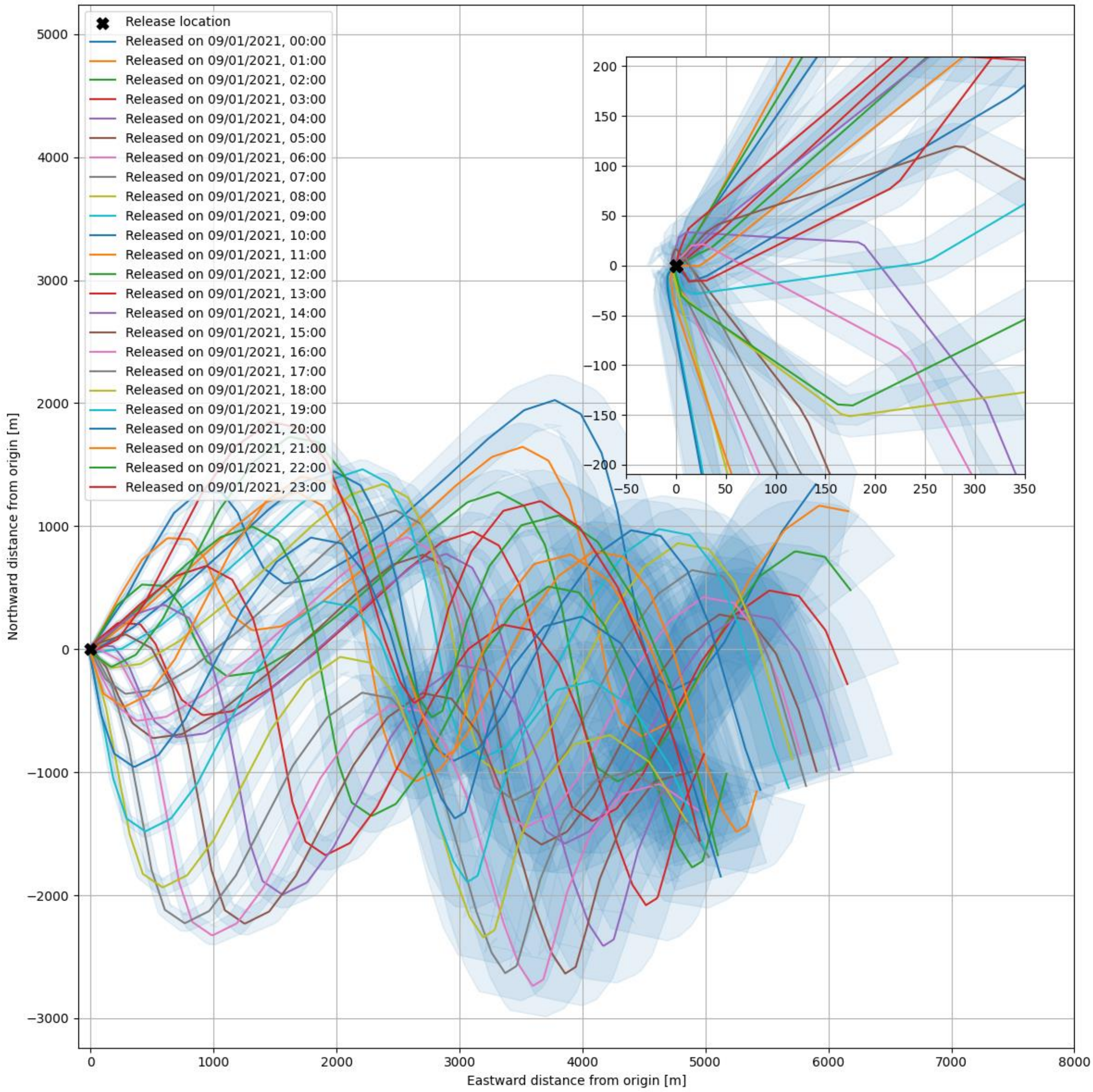

Figure 10.21: Modelled horizontal plume extent from Scenario 2 (1 September 2021 release) (Fugro, 2022b)

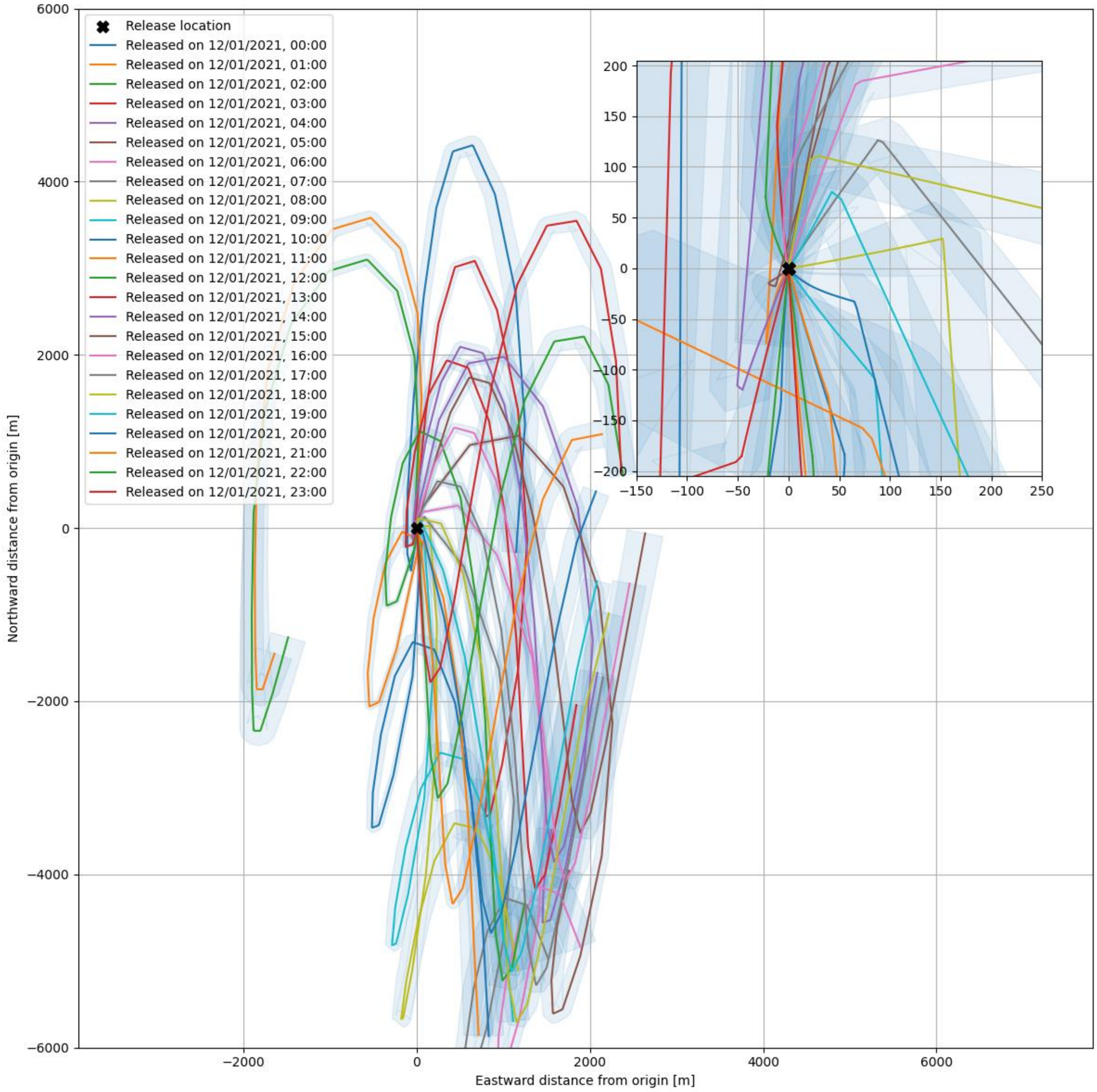

Figure 10.22: Modelled horizontal plume extent from Scenario 2 (1 December 2021 release) (Fugro, 2022b)

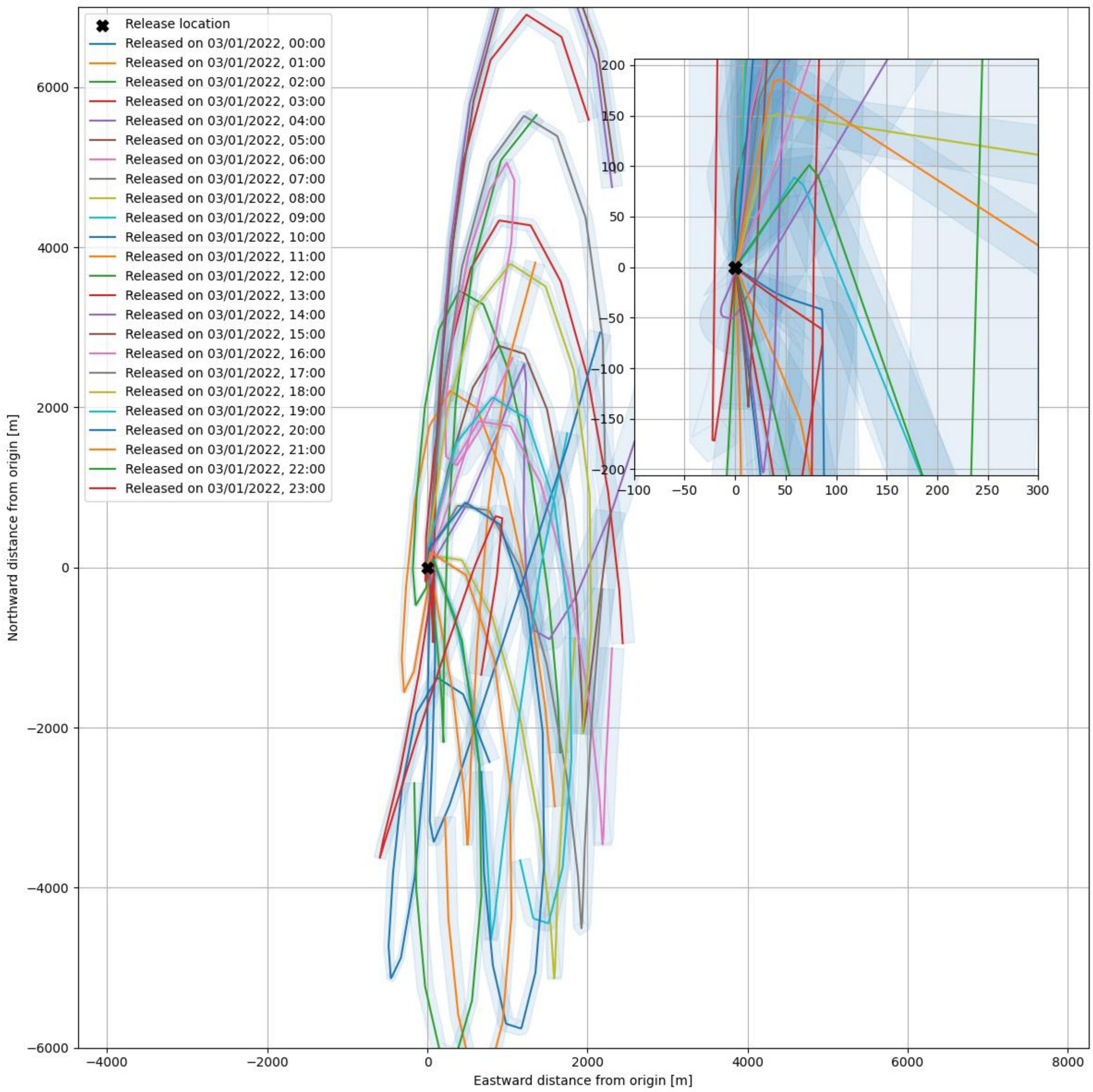

Figure 10.23: Modelled horizontal plume extent from Scenario 2 (1 March 2022 release) (Fugro, 2022b)

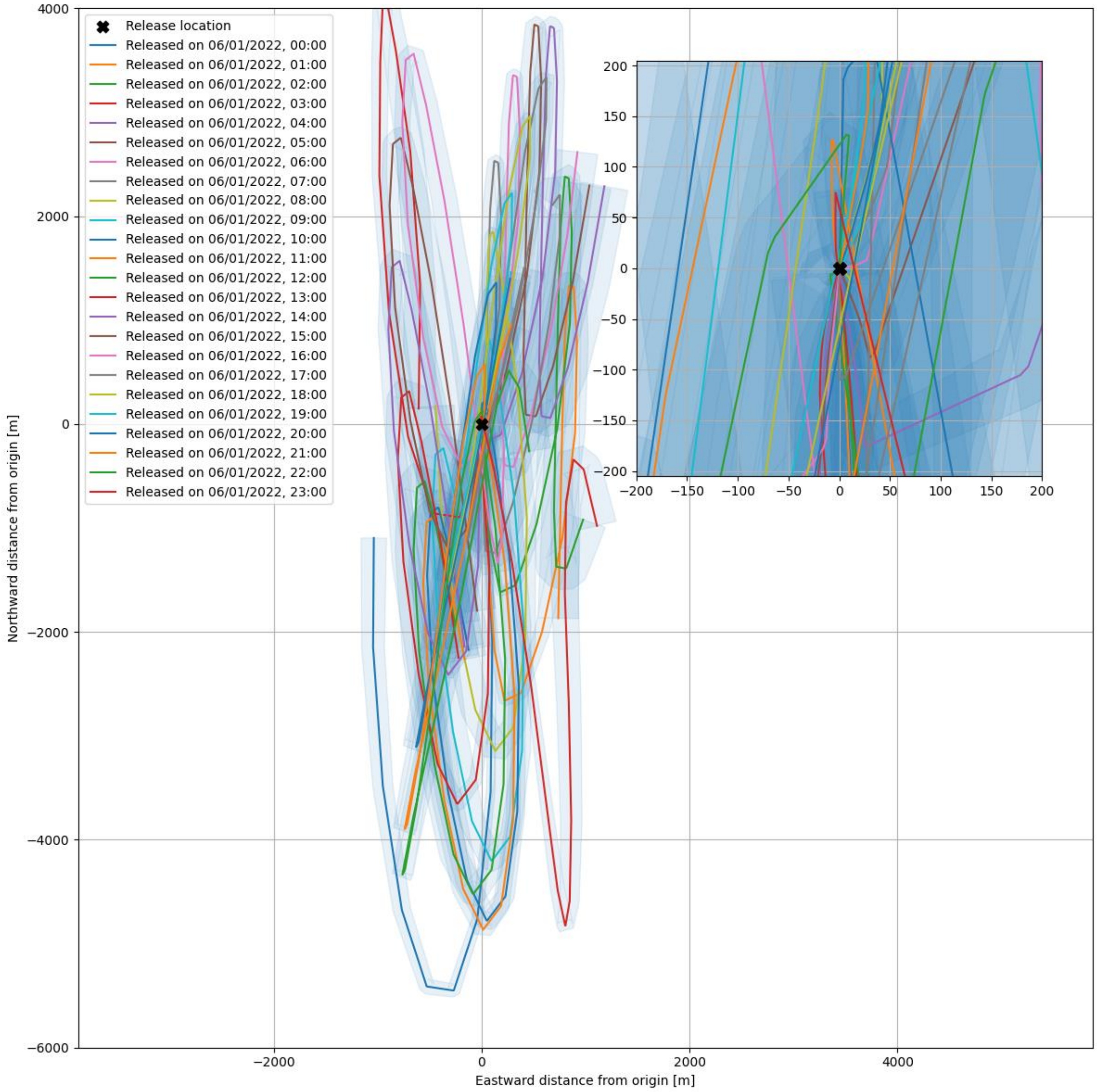

Figure 10.24: Modelled horizontal plume extent from Scenario 2 (1 June 2022 release) (Fugro, 2022b)

As described above, produced water discharges between 1 million and 8 million cubic metres per year in waters between 50 m and 125 m deep, have an estimated generic dilution factor of 400 (BEIS, 2020). The modelling study allowed this generic value to be refined and propose site-specific dilution factors by considering ambient currents and density as well as produced waters characteristics and jet configuration. Site-specific dilution of 400 was estimated at distances varying from 2.1 m to 41.6 m, which is significantly lower than the 500 m generic estimation. These results are positive in terms of PEC. However, as the fluid composition and concentration data were unavailable for this modelling study, PNEC was unable to be calculated at this time. However, PPUK will ensure that the PEC:PNEC ratio at 500 m is less than 1, in according with the BEIS (2020) guidance.

10.4.1 Impacts on Water Column and Benthic Communities

Significant impacts on benthic communities due to discharges of produced water at the proposed Avalon Development are considered highly unlikely to occur due to the rapid dilution of discharge plumes. As PEC:PNEC ratio could not be calculated at this time, PPUK will ensure that produced waters release from the Avalon Field Development will be below the acceptable RBA thresholds which is predicted to occur within close proximity of the discharge point.

Under typical environmental conditions, produced water discharges at the proposed Avalon Field Development are predicted to be diluted at a fast rate, with the modelling study forecasting that plumes of produced water discharged will remain close to the sea surface (within approximately 50 m) during their dispersion and therefore will not interact significantly with sea bed communities within and around the site (water depths between 115 m and 145 m).

Equally, significant accumulation of chemicals that may be contained within the produced water discharges within seabed sediments is not anticipated due to the open ocean nature of the proposed Avalon Field Development site, the rapid dilutions predicted to be achieved and the buoyant nature of the plumes. Significant impacts on benthic communities, including potential ocean quahog populations, and benthic environmental quality conditions are therefore not expected.

Results of monitoring of effects of oil and gas activity indicate that ecological effects of discharges of produced water are not probable (Research Council of Norway, 2012) while the risk of widespread, long term ecological impact from operational discharges can be considered as low (Bakke et al., 2013), although evidence in the available literature is lacking in this regard with the majority of studies on fish and certain invertebrates (Beyer *et al.*, 2020; Blanchard et al., 2013; Bakke et al, 2013). Because of the rapid dilution, dispersion and transformation rates of most chemicals in produced water in open-ocean conditions, harmful biological effects of produced water discharges are expected to be minimal and localised (Neff et al., 2002).

Furthermore, although several substances potentially harmful to the reproductive success of fish may be present in some produced water discharges, the concentrations that have given rise to adverse effects are normally only found within a few kilometres of the discharge sites and extensive and long-term reproductive effects of produced water on fish are not very probable (Research Council of Norway, 2012). Additionally, studies have shown that fish will actively avoid environments contaminated with PAH or oil above certain thresholds and may avoid produced water plumes from offshore installations (Breyer et al., 2020).

Other effects of the components of produced water include alteration in fish enzyme activity, liver oxidative metabolism and cell death, deoxyribonucleic acid (DNA) damage, impaired immunity and gene modification which can affect overall fish health while among invertebrate groups, adverse effects on mussel egg development and DNA damage in mussel larvae after hatching have been observed (Research Council of Norway, 2012; Gagnon, 2011; Hamoutene et al., 2011). However, ecological effects that have been detected have typically been associated with a dilution of produced water of 0.1 % to 1 % or higher which is found very close to discharge points indicating that effects are usually local (Research Council of Norway, 2012).

Controlled studies have noted subtle effects on marine planktonic communities due to exposure to produced water discharges (Neff et al., 2002). However, these control studies do not account for the degradation of the produced water chemicals in well mixed marine environments (Neff et al., 2002) and it is thus possible that effects on plankton are very limited or negligible in open sea receiving waters.

Given that benthic communities are highly unlikely to significantly interact with rapidly diluted and buoyant plumes of produced water coupled with the general improbability of ecological effects occurring beyond the immediate discharge and mixing zone, then it is considered that the effects of produced water discharges at the proposed Development on benthic and water column communities will be of negligible significance.

10.4.2 Impacts on Protected Habitats and Species

The Avalon field is not situated within an area of potential Annex I habitat. However, submarine structures made by leaking gases are most common in the wider development area (Section 4.3.4). As previously described in Section 4, there are a number of PMF known to occur within the Avalon Field Development area including offshore deep-sea muds, sand and gravels, Ocean quahog, fish species such as cod and Norway pout and cetaceans such as Harbour porpoise and Risso's dolphins. As well as being designated PMFs, Ocean quahogs are also included on the OSPAR list of 'Threatened and/or Declining Habitats and Species' (OSPAR, 2022) and cetaceans are listed under Annex IV of the Habitats Directive.

The modelling undertaken for the discharge of produced water from the FPSO showed that the produced water discharge plume would not reach the seabed and therefore no impact upon protected habitats or species, such as pockmarks or Ocean quahogs which are present on the seabed, is anticipated.

Studies undertaken have shown that whilst some contaminants synonymous with produced water discharges, such as alkylphenols and PAH, may accumulate in cod, the compounds were rapidly metabolised and the risk of widespread impact from discharges is considered to be low with concentrations less than those commonly associated with narcotic effects (Nepstad *et al*., 2021; Bakke et al., 2013). Furthermore, as noted in Section 10.4.1, fish have been shown to actively avoid environments contaminated with PAH and oil above certain thresholds (Beyer *et al*., 2020).

No studies considering the impacts of produced water on marine mammals have been identified as part of this review. However, given the relatively low distribution of marine mammals within the vicinity of the Avalon field (Section 4.7.1) and the localised area of effect of the discharge, they are considered unlikely to be significantly impacted.

Therefore, the magnitude of any impact on protected habitats or species, judged to be of a medium to high value, is considered to be negligible to minor, and therefore impact significance is minor.

10.5 Mitigation

PPUK will aim to achieve as low an OIW concentration as possible (≤ 15 mg/l) in produced water that will be discharged after treatment. Only industry standard production chemicals will be used and discharged in relation to operations at the Avalon Field. All chemicals used will be included in the Offshore Chemical Notifications Scheme (OCNS) and the most environmentally friendly options evaluated and, where possible, chemicals that pose little or no risk (PLONOR) to the environment will be used. Additionally, chemical risk assessments will be undertaken as part of the environmental permitting process which PPUK will submit to the OPRED to obtain approval prior to use and discharge of any chemicals.

10.6 Cumulative and Transboundary Impacts

The Central North Sea (CNS) has high levels of oil and gas activity, with multiple developments in the region of the Avalon Development location. The nearest existing surface infrastructure to the Avalon FPSO, located 3 km from the wells, are the INEOS operated Forties Unity and Forties Charlie platforms. These structures are located 33 km and 38 km to the south and southeast of the Avalon field, respectively. The Avalon Development is situated approximately 79 km west of the UK/Norway transboundary line.

The additional produced water generated from the Avalon Development coming online would add to the overall amount of produced water discharged into the CNS and into the wider environment. Discharges of produced water from the FPSO will be monitored and managed to ensure that the discharge remains within permitted specifications (≤ 15 mg/l). The dominant movement of produced water discharges from the FPSO location within the ambient current flows is north to northwest and away from the UK/Norwegian boundary and rapid dilution is forecast to be achieved within a few hundred metres even under worst-case conditions. As a result, the magnitude of the cumulative impact from the discharge of produced water is considered to be minor on receptors of a medium to high value and therefore is judged to be of minor significance. Therefore, no significant cumulative or transboundary effects are expected as a result of the additional discharge of the Avalon Development produced water discharge.

10.7 Conclusions

Produced water will be discharged from the FPSO at the Avalon field which may include reservoir hydrocarbons, chemicals and dissolved organic and inorganic compounds (Bakke *et al.*, 2013) and which may affect marine fauna within the water column and at close range to the discharge. Seabed habitats and species on the seabed and marine life at distance from the discharge are not forecast to be significantly affected.

Modelling of the discharge of produced water from the FPSO found that discharges of produced water are predicted to be diluted at a rapid rate and that plumes would remain close to the sea surface (within 50 m) during dispersion.

The increased quantity of produced water discharged from the Avalon FPSO as a result of the Avalon Development is considered likely to impact on receptors in the water column of a medium to high value and the magnitude of effect is considered to be minor. Therefore, the impact significance from increased produced water discharges from the FPSO is considered to be minor and therefore not significant. No significant cumulative or transboundary effects are considered likely to occur.

In conclusion, the effect of the discharge of produced water from the FPSO at the Avalon field, either alone or cumulatively with other produced water discharges in the region, is considered minor and not significant.

Section 11

Accidental Events

11. Accidental Events

As well as assessing operational processes, the Environmental Impact Assessment (EIA) process also examines potential accidental events that may result in impacts upon the environment and for which mitigation measures may be implemented. The following issues and concerns were raised during the Environmental Issues Identification (ENVID) workshop and informal consultation and are considered in this section on the potential impacts from accidental events that could occur during operations at the proposed Avalon Field Development. These include:

- Impacts on marine environment, the coastal environment and other users of the sea by a large spill of hydrocarbons to sea; and
- Impacts on seabed communities as a result of the loss of the Floating Production, Storage and Offloading Vessel (FPSO), installation vessels, support vessels, the Mobile Offshore Drilling Unit (MODU) or a helicopter.

The remainder of this Section describes the potential impacts of hydrocarbon spills and from a collision causing the loss of an installation vessel, support vessel the FPSO or the MODU.

11.1 Sources of Hydrocarbon Spill

The risk of an accidental hydrocarbon spillage to sea is often one of the main environmental concerns associated with oil-industry activities. Spilled oil at sea can have a number of environmental and economic impacts, the most conspicuous of which are on seabirds and coastal areas. The actual impact depends on many factors, including the volume and type of hydrocarbon spilled, the sea and weather conditions at the time of the spill, the sensitivity of receptors and the oil spill response.

The following events associated with the proposed development have been identified as having the potential to cause an oil spill:

- Uncontrolled well blow-out;
- Complete loss of the FPSO inventory;
- A fuel oil spillage from an installation vessel, support and supply vessel or the MODU;
- An oil spillage when carrying out offloading operations to shuttle tanker; and
- Loss of inventory of an infield flowline or riser.

The Avalon field will produce crude oil with a density of 924.2 kg/m^3. A crude oil spill from either a well blow-out, or a loss of the FPSO inventory, have been identified as the two worst case oil spill scenarios and could potentially result in a Major Environmental Incident (MEI).

11.1.1 Potential Crude Oil Spillages

11.1.1.1 Uncontrolled Well Blow-out

During drilling operations, a well blow-out would represent the largest potential source of a large hydrocarbon spill. For a blow-out to occur, the primary well control element, the hydrostatic pressure exerted by the drilling mud, would have to be overcome by the inflowing hydrocarbons. The secondary well control measure, the blow-out preventer (BOP), would also have to fail in closing off the well. The actual flow rate and duration of any such event, and hence the severity of the incident, are dependent upon the pressure and geology of the well, which vary with each well.

The flow rate encountered during an uncontrolled blow-out event may be very different from that expected during production, as there may be no equipment or other measures in place to restrict the flow. To consider the worst-case scenario, it was assumed that there would be no physical restriction to the flow inside the well, such as drill string or tubing obstructing the wellbore, chemical build-up coating in the wellbore, a disconnected riser, or damaged wellhead and well control equipment on top of the well.

11.1.2 Potential Diesel (Fuel Oil) Spillages

Diesel will be the main fuel used for power generation during the proposed Avalon Field Development operations, and will be used by the MODU, the pipeline laying vessel, and other support vessels. The largest volume of diesel will be stored on the MODU. The diesel will be split between multiple fuel oil bunker tanks. The worst-case diesel spill scenario is considered to be the complete loss of the diesel inventory from all of the fuel tanks on the MODU.

Smaller diesel spills can result from equipment failures, such as the rupture of pipes or open valves. Small spills most frequently occur during bunkering operations and are generally caused by hose failures (Section 11.2.1). Diesel will be supplied from a supply vessel to the MODU as needed during the drilling operations, via a flexible hose. No other vessels will require bunkering whilst infield. As the hose is suspended between the two vessels, there is the potential for a direct diesel release to sea, if the hose or any of its connections are damaged during the bunkering operations.

11.1.3 Other Potential Sources of Oil

As detailed in Section 3.3.1, the MODU to be used in the planned operations has not yet been selected, so a generalised inventory for other hydrocarbons is presented here. PPUK plans to use low toxicity oil-base muds (LTOBM) to drill the lower sections of the well. The LTOBM will be stored in dedicated mud tanks. Based on other MODU inventories, it can be assumed that the overall volume of LTOBM held onboard the MODU will be around 500 m^3. Lubricating and hydraulic oils are stored separately in tanks or sealed drums. Storage tanks for lubricating oil range in size, but each will normally contain a maximum of 15 m^3, while hydraulic oils are stored in much smaller 2 m^3 tanks. Additional oils may be transported and stored in sealed 0.025 m^3 or 0.21 m^3 drums, or 1 m^3 tote tanks. Up to approximately 12 m^3 of aviation fuel will also be held on the MODU. All oils will be stored in dedicated, bunded storage areas, with oil spill kits located nearby. Therefore, the possibility of a spillage to sea from any of these sources is considered to be very small.

Waste oil will be generated onboard the FPSO and the MODU from a variety of sources, including waste engine, gear and hydraulic oil. These waste oils will be held in designated storage tanks and their volumes kept to a minimum before being transferred to shore on regular intervals.

The amounts of LTOBM, lubricating, hydraulic and waste oil stored onboard the FPSO and MODU will be very small in comparison to the main fuel supply. The probability of any spillages from any of these sources is considered to be minimal, as the containers are relatively small, sealed and stored in bunded areas. Therefore, the risk to the environment from these oils is regarded as negligible and is not considered further within this section.

11.2 Likelihood of a Hydrocarbon Spill

11.2.1 Mobile Operated Drilling Unit (MODU) Release

Historical data, covering the period between January 1990 and December 2021, indicate that the possibility of a large hydrocarbon spill from a MODU operating on the UKCS is very low. As shown in Figure 11.1, most spillages from MODUs are caused by OBM/base oil (234) and hydraulic/lube oils (229). However, these are typically very small spillages and the data shows there have been no OBM/base spills from MODUs since 2010. As stated in Section 11.1.3, the volume of OBM present during the planned drilling operations at the Avalon field will be relatively low, in comparison to the volumes of diesel and reservoir hydrocarbons.

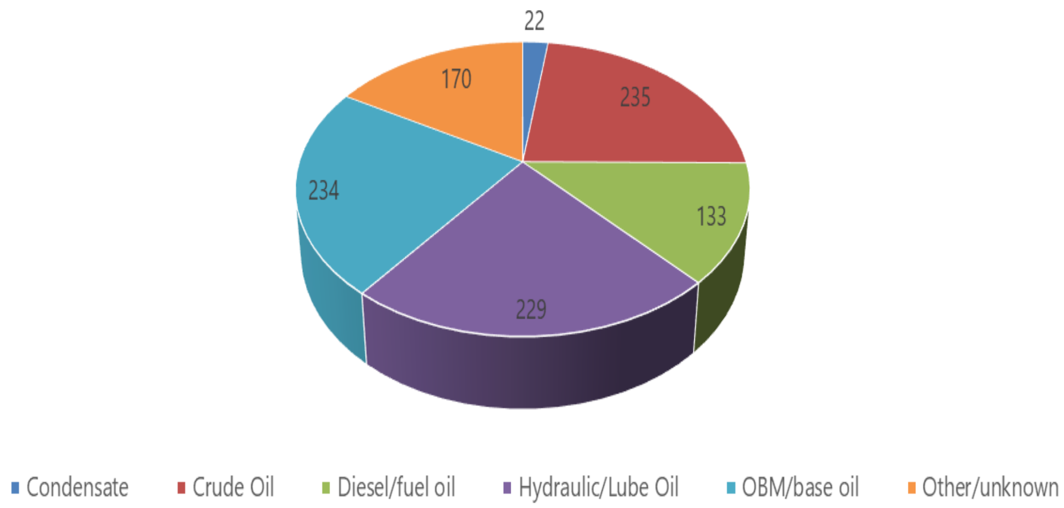

Figure 11.1: Oil spills on the UKCS from MODUs between 1990 and 2021

Source: Fugro, 2022.

Using data presented in HSE (2007), it can be calculated that on average, the probability of an oil spill from a MODU is 0.0015 spills per rig day, or one spill every 647 rig days.

Next to frequency, the size of a potential hydrocarbon spill is also very important in spill response planning. Figure 11.2 illustrates the proportion of oil spills from MODUs which fall into each of three size categories. The dataset shows that the majority of spills (81 %) are smaller than 1 tonne (Fugro, 2022). It is expected that the response to a spill of this size could be undertaken and fully managed by the MODU itself, requiring only monitoring while the slick evaporates and disperses naturally.

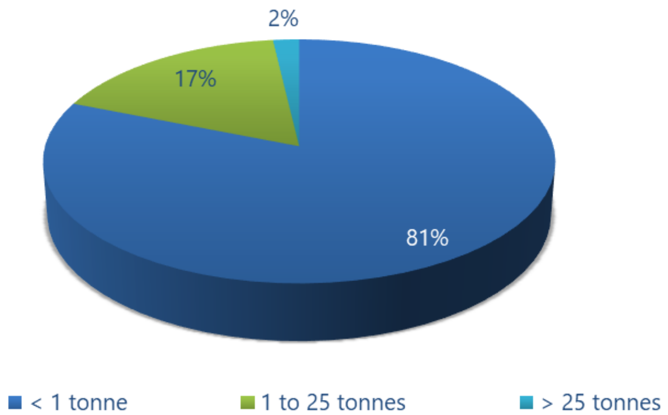

Figure 11.2: Percentage of hydrocarbon spills from MODUs, by size, between 1990 and 2021

Source: Fugro, 2022.

11.2.2 Uncontrolled Well Blow-out

The probability of an uncontrolled well blow-out event occurring is very low. Well blow-outs resulting in the uncontrolled release of hydrocarbons have happened too infrequently on the United Kingdom Continental Shelf (UKCS) for a meaningful analysis of the historic frequency to be carried out. However, the International Association of Oil and Gas Producers (IOGP) has released international well blow-out frequency data based upon historical datasets compiled by SINTEF (worldwide; 1980 to 2014) and Lloyds Register (North Sea; 1980 to 2014 and USA Gulf of Mexico; 1980 to 2011). The frequency data indicate that, overall, the possibility of a blow-out and well release occurring during offshore drilling operations is very low (IOGP, 2019). At North Sea Standards, such as will be followed during drilling operations at the Avalon field, the frequency of occurrence of a blow-out for the average exploration well at normal pressure is 1.4×10^{-4}, or one blow-out for every 7 142 wells. The frequency of occurrence for any release of reservoir oil is 1.2×10^{-3}, or one release for every 833 wells.

The IOGP data includes releases of all sizes, and therefore does not present an analysis of what proportion of such incidents result in significant oil pollution events. However, only a very small proportion of blow-outs would be expected to result in a significant release. It should also be noted that the majority of the data was collected prior to the Gulf of Mexico Macondo event in 2010, and that significant improvements in offshore safety and blow-out prevention have since been implemented across the industry as a result of this event. Therefore, these frequency estimates should be viewed as conservative.

The following paragraphs give a brief overview on historic well control events on the UKCS.

Prior to 1990, only two significant uncontrolled blow-outs occurred in the North Sea. These events occurred during drilling operations on the West Vanguard semi-submersible on the Norwegian continental shelf and on the Ocean Odyssey semi-submersible on the UKCS, during 1985 and 1988 respectively (DTI, 2007). Both blow-outs involved gas and did not result in hydrocarbon spills to sea. Moreover, lessons learnt from these events resulted in major legislative and operational changes for offshore drilling on the UKCS to prevent such events from happening again.

Between 1990 and 2007, a total of 343 well incidents were recorded from MODUs (both drilling and production). These incidents included several issues of varying severity, but only 17 resulted in loss of well control. This translates to 0.00004 incidents per rig day. Furthermore, none of the 17 recorded incidents resulted in an uncontrolled well blow-out with a crude oil spill of any size (OGUK, 2009).

The most recent well control incident in the North Sea involved a gas and condensate blow-out from Well 22/30c-G4, located close to the Elgin platform, in March 2012. This incident resulted in the temporary cessation of production from the Elgin/Franklin area. PPUK will review the lessons learnt from this incident, with consideration to the proposed drilling operations at Avalon.

11.2.3 Diesel Spill

Diesel spills from mobile drilling units account for 133 oil spill incidents (6 %) on the UKCS from MODUs (Figure 11.3). Diesel will be the main fuel used for power generation during the proposed drilling operations and, therefore, will be the largest volume of hydrocarbons stored on the MODU. Historical oil spill data indicate that the probability of a diesel spill is 0.0002 spills per day. When extrapolating this probability to the Avalon well, this equates to a probability of 1.4 % of a diesel spill occurring (Fugro, 2022b; HSE, 2007).

Spill records indicate that most diesel spills tend to occur during bunkering operations and that they are mostly caused by hose failures. Therefore, the volumes of diesel spilled tend to be relatively small. For example, of the 133 recorded diesel spills, 119 (93 %) were less than 1 tonne (Fugro, 2022b). If a diesel spill of this size were to occur, it is likely that only onsite response personnel and equipment would be required to control the incident, due to the tendency of diesel to evaporate and disperse relatively quickly from the sea surface (see Section 11.3). Only three of the recorded diesel spills were greater than 5 tonnes.

The worst-case scenario, complete loss of the diesel inventory, will only occur as a result of a major accident, such as a catastrophic collision with another vessel. The probability of such an event occurring is very low.

11.2.4 Pipeline Release

Historical data, covering the period between January 1990 and April 2021, indicate that the possibility of a large hydrocarbon spill from a subsea pipeline on the UKCS is very low; only 54 oil spills from pipelines have been recorded during this time. In contrast to spillages from MODUs, the largest number of spills from pipelines are of crude oil (Figure 11.3). During the period analysed, 50 crude spills (93 %) from a pipeline were smaller than 1 tonne. It is expected that the response to a spill of this size could be undertaken and fully managed offshore, requiring only monitoring while the slick evaporates and disperses naturally. Spills larger than 1 tonne would potentially require appropriate action to be taken to control the spill in line with the relevant Oil Pollution Emergency Plan (OPEP).

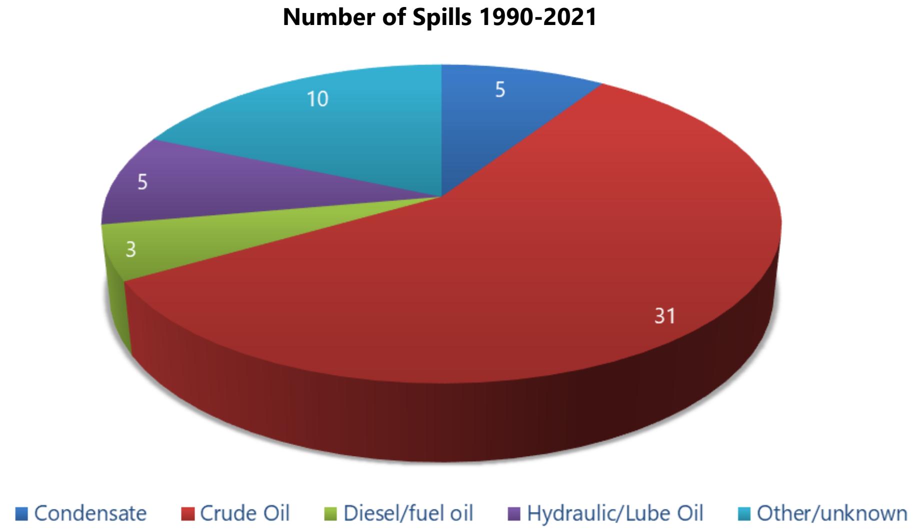

Figure 11.3: Oil spills on the UKCS from pipelines between 1990 and 2021

Source: Fugro, 2022.

As so few pipeline spills have occurred, it is difficult to extract meaningful data on the frequency or likelihood of such an incident. Using data presented in HSE (2007) and Fugro (2022b), it can be calculated that on average, the probability of an oil spill from a pipeline is 0.004 spills per day, or one spill every 221 days, divided between the 3 476 pipelines on the UKCS.

11.3 The Fate and Behaviour of a Hydrocarbon Spill at Sea

Oil characteristics, spill location and the wave, wind and current conditions all govern the fate of spilled hydrocarbons. The behaviour of hydrocarbons when released from the sea surface and from the seabed are described in the following section. During the proposed drilling operations, it is expected that the most likely release point for a release of reservoir hydrocarbons (crude oil) would be at the seabed. Meanwhile, the most likely release point for a spill of diesel from the MODU or oil from the FPSO storage tanks would be from the sea surface.

The fate of hydrocarbons spilled at sea is relatively well understood. As soon as oil is released, the weathering process begins, and the oil begins to move across the sea surface. Oil characteristics, spill location and wave and wind conditions govern the fate of the spilled oil. These processes are described in Section 11.3.1 below.

11.3.1 Oil Spill Movement

11.3.1.1 Spreading

Due to the influence of gravity, oil starts to spread out over the sea surface as soon as it is spilled. Oil slicks can spread very quickly to cover extensive areas of the sea surface, the speed of which depends mainly on the viscosity of the oil. Lighter oils spread out more quickly than heavier crudes. Although a spill will spread quickly in the first few days, the processes of evaporation and dispersion quickly remove the lighter, more volatile and water soluble, fractions of a slick from the sea surface. Then, as only the heavier, more viscous fractions are left, slick spreading will slow down.

Initially an oil spill will spread out as a single slick, covering an increasingly larger area while the slick becomes correspondingly thinner. However, as the slick spreads further, it will start to break up into smaller breakaway slicks due to the wind and water movement. Wind and wave conditions in the central North Sea (CNS) can be regarded as dynamic, due to a combination of the relatively high wind speeds and increased water movement, created by a combination of the wind speed and tidal movements across the region. As such, it is expected that a large oil slick in this area would tend to break up quickly into smaller patches.

11.3.1.2 Direction of Movement

Wind and surface current speed and direction are the main parameters influencing the movement of an oil slick. Any oil slick will travel roughly at the same speed and direction as the surface water current, while the prevailing wind drives a slick downwind at 3 % to 4 % of the wind speed.

Currents in the CNS circulate in an anticlockwise direction, with cold Atlantic waters flowing to the south-east and warmer North Sea waters flowing to the North (Section 4.2.1). In the area around the Avalon development, currents predominantly move to the east, suggesting that any slick occurring in the surface waters would move with the dominant current in this direction.

Although offshore winds in the CNS are very variable and may blow from any direction, they most frequently originate from the south to southwest (Section 4.3.2). This suggests that a slick occurring on the sea surface would generally be directed to the north and north-east by the wind.

11.3.2 The Weathering Process

When oil is released into the marine environment it undergoes a number of physico-chemical changes, some of which assist in the degradation of the spill, while others may cause it to persist. These changes are dependent upon the type and volume of oil spilled, and the prevailing weather and sea conditions. An overview of the main processes influencing the fate and behaviour of spilled oil at sea is given in Figure 11.4. Evaporation and dispersion are the two main mechanisms that act to remove oil from the sea surface.

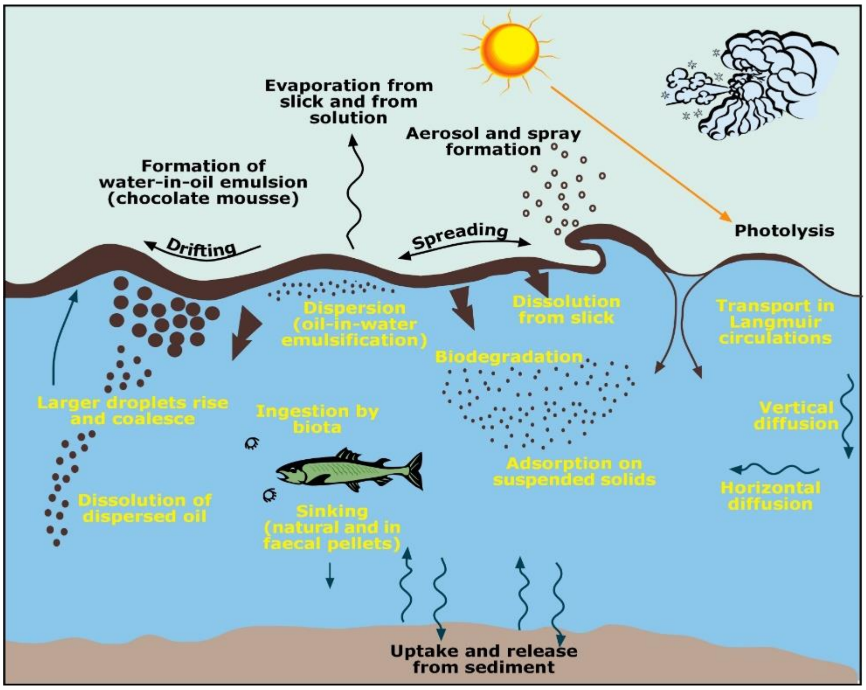

Figure 11.4: Fate and behaviour of spilled oil at sea

11.3.2.1 Evaporation

Following a hydrocarbon spill, evaporation is the initial predominant mechanism of reducing the mass of oil, as the light fractions (including aromatic compounds such benzene and toluene) evaporate quickly. Evaporation can cause considerable changes in the density, viscosity and volume of the spill. If the spilled oil contains a high percentage of light hydrocarbon fractions, a large part of it will evaporate relatively quickly in comparison to heavier oil.

Diesel displays very high evaporative losses upon exposure to air. Under ideal environmental conditions, i.e. a warm, sunny day with only moderate wind, a large proportion of the spill volume may be lost by evaporation in the first few hours after release. The evaporation process will be enhanced by warm temperatures and moderate winds.

11.3.2.2 Dispersion

After the light fractions have evaporated from the slick, natural dispersion becomes the dominant mechanism in reducing slick volume. The speed at which oil disperses is largely dependent upon the nature of the oil and the sea state. Lighter and less viscous oils tend to have more water-soluble components, allowing them to mix and remain suspended within the water column.

The process of dispersion is dependent upon waves and turbulence at the sea surface, which can cause a slick to break up into fragments and droplets of varying sizes. This turbulence mixes these droplets into the upper levels of the water column, where some of the smaller droplets will remain suspended, while the larger ones will tend to rise back to the surface. Therefore, rough seas will break up a slick and disperse the oil at a faster rate than calm seas. There have been incidences of large oil spills being broken up and dispersed into the water column during large storm events, with little visible effect on the surrounding environment. As oil droplets are dispersed into the water column, the oil has a greater surface area which encourages the natural processes of dissolution, biodegradation and sedimentation.

Water movement at the sea surface is affected by wind speed. The CNS is an active environment, with relatively high average wind speeds. Predominant wind speeds throughout the year represent moderate to strong breezes (6 m/s to 10 m/s) (Fugro, 2022a), with the highest frequency of gales (wind speeds greater than 17.5 m/s) occurring in the winter months (November to March) (DTI, 2001). In January, the development area will experience winds of Beaufort Scale 7 (near gale) and above approximately 30 % of the time.

Water movement and wave size is also related to fetch, the distance over which the wind can blow without being interrupted. The enclosed environment of the North Sea therefore limits the size of waves here to a certain extent.

11.3.2.3 Emulsification

The immiscible components of an oil spill may either emulsify and disperse as small droplets in the water column (an oil-water emulsion) or aggregate into tight water-in-oil emulsions, often referred to as 'chocolate mousse'. The rate at which this happens, and the type of emulsion formed, is dependent upon the oil type, sea state and the thickness of the oil slick. Large, thick oil slicks tend to form water-in-oil emulsions, while smaller thinner slicks tend to form oil-in-water emulsions that usually disappear by natural dispersion. In practice, usually only one of the two processes will dominate.

When a water-in-oil emulsion (chocolate mousse) is formed, the overall volume of the slick increases significantly, as it may contain up to 70 % or 80 % water. This chocolate mousse will form a thick layer on the sea surface reducing slick spreading and inhibiting natural dispersion. The formation of this thick layer causes the surface area available to weathering and degradation processes to diminish, which can make 'chocolate mousses' difficult to break up using dispersants. In their emulsified form, and with their drastically increased volume, they can also cause difficulties for mechanical recovery devices. A water-in-oil emulsion is therefore very unlikely to occur in diesel spills, for example.

11.4 Oil Spill Modelling

The amount of time a hydrocarbon spill remains on the sea surface before becoming insignificant, and the extent to which it spreads from the point of release, may dictate the severity of any impacts on the marine life, particularly seabirds. Whether it reaches the shore is also a major consideration, due to the sensitivity of the nearest coastline of north-east Scotland, and the additional clean up resources required. Stochastic oil spill modelling has been conducted to provide information on whether a spill might beach, and if so, how much time this would take. In view of this, the end points for the oil spill risk assessment are considered to be:

- Probability of oil reaching a shoreline, or crossing a median line to reach international waters; and

- Minimum time taken for oil to reach a shoreline or crossing a median line to reach international waters.

Stochastic oil spill modelling has been conducted to assess these two criteria. Stochastic oil spill modelling is based on actual statistical wind speed and direction frequency data and provides a probability range of sea surface oil and beaching, representative of the prevailing conditions.

As discussed in Section 11.1, the two scenarios which may result in a large release of hydrocarbons to sea are an uncontrolled well blow-out resulting in the release of crude oil, or a loss of the FPSO inventory. The FPSO inventory release and diesel release scenarios both involve the loss of a static inventory, however the FPSO inventory loss scenario represents a much larger release, and a more persistent hydrocarbon. Therefore, the FPSO inventory loss scenario has been modelled, along with the uncontrolled well blow-out scenario.

All modelling has been undertaken using SINTEF's Oil Spill Contingency and Response (OSCAR) model. Version 10.0.1 was used for the uncontrolled well blow out scenario in 2019 whilst version 13.1.0 was used for the FPSO Inventory Release scenario in 2022. Oil spill modelling for both scenarios has been carried out for all four seasons i.e. winter, spring, summer and autumn. This provides a range of risk profiles throughout the year in the event of a delay to operations.

The well location used in the 2019 modelling study represents an earlier project design which has been superseded by the current well locations. The previous well location is approximately 0.5 km north and northwest from the revised Avalon well locations. This is not considered to significantly affect the results of the modelling.

11.4.1.1 Uncontrolled Well Blow-out

The parameters used in modelling an uncontrolled well blow-out are detailed in Table 11.1. The results of the well blow-out modelling scenario are provided in Table 11.2. Minimum arrival time of surface oiling is shown in Figure 11.5 and the probability of surface oiling in Figure 11.6. It should be noted that surface oiling is shown with a thickness threshold of 0.3 micro metre (μm) (equal to 0.0003 mm), in accordance with OPRED's oil spill modelling requirements. Potential impacts relating to the modelling results are described in Section 11.5.

Table 11.1: Well Blow-out Modelling Parameters

Well Blow-out Parameters								
Loss from Well/FPSO/Rig/Other		Well		Instantaneous Loss?			No	
Worst Case [m^3]		128 781.9 /81 days		Will the Well Self-Kill?			No	
Flow Rate [m^3/day]		1 589.9						
Justification for Predicted Worst Case Volume		It would be expected to take 81 days to drill a relief well						
Location								
Spill Source Point		57° 49' 22.819" N, 0° 10' 54.948" E						
Installation/Facility Name		Well 21/6b-J (Avalon)		Quad/Block			21/6	
Hydrocarbon Properties								
Hydrocarbon Name		Avalon crude						
Assay Available		Yes		Was An Analogue Used For Spill Modelling?			Yes	
	Name	ITOPF Category	Specific Gravity	API	Viscosity [cP]	Pour Point [°C]	Wax Content [%]	Asphaltene Content [%]
Hydrocarbon	Avalon crude	3	0.924	21.6	322	-36	1.8	0.25
Analogue	Clair	3	0.913	23.5	100	-15	4.7	0.9
Metocean Parameters								
Air Temperature (°C)		Variable		Sea Temperature (°C)			Variable	
Wind Data		6 years' (2008 to 2014) European Centre for Medium-Range Weather Forecasts (ECMWF) Wind Data						
Current Data		6 years' (2008 to 2014) Hybrid Coordinate Ocean Model (HYCOM)						
Modelled Release Parameters								
Surface or Subsurface		Subsurface		Depth [m]			120 m	
Release Duration [days]		81 days		Instantaneous?			No	
Persistence Duration [days]		10 days		Release Rate [m^3/hour]			66.2 m^3	
Total Simulation Time [days]		91 days		Total Release [m^3]			128,781.9 m^3	
Oil Spill Modelling Software								
Name of Software		MEMW-OSCAR		Version			10.0.1	

Source: Petrofac, 2019.

Table 11.2: Well Blow-out Modelling Results

Well Blow-out Modelling Summary				
Spill Scenario/Descriptor	Avalon well blow-out			
Median Crossing				
Identified Median Line	**Highest Probability and Shortest Time to Reach**			
	Dec to Feb	Mar to May	Jun to Aug	Sep to Nov
Norway	1 day 12 hrs	2 days 2 hrs	2 days 7 hrs	1 day 17 hrs
	90 – 100 %	90 – 100 %	90 – 100 %	90 – 100 %
The Faroe Islands	10 days	-	-	>20 days
	1 – 5 %	-	-	1 – 5 %
Denmark	7 days	12 days	15 days	10 days
	60 – 70 %	70 – 80 %	70 – 80 %	50 -60 %
Sweden	19 days	>20 days	>20 days	19 days
	40 – 50 %	60 – 70 %	50 – 60 %	30 - 40
Germany	>20 days	19 days	>20 days	13 days
	20 – 30 %	20 – 30 %	20 – 30 %	20 – 30 %
The Netherlands	>20 days	>20 days	>20 days	13 days
	10 – 20 %	10 – 20 %	10 – 20 %	10 – 20 %
Landfall				
Predicted Locations	**Highest Probability and Shortest Time to Reach**			
	Dec to Feb	Mar to May	Jun to Aug	Sep to Nov
UK Coastlines				
The Shetland Islands	7 days	13 days	>20 days	4 days
	60 – 70 %	20 – 30 %	10 – 20 %	50 – 60 %
Orkney	5 days	4 days	>20 days	11 days
	40 – 50 %	5 – 10 %	5 – 10 %	30 – 40 %
Highlands	12 days	7 days	-	13 days
	20 – 30 %	5 – 10 %	-	5 – 10 %
Grampian	5 days	4 days	10 days	6 days
	40 – 50 %	20 – 30 %	20 – 30 %	50 – 60 %
Tayside and Fife	13 days	12 days	>20 days	10 days
	20 – 30 %	10 – 20 %	5 – 10 %	30 – 40 %
Lothian and Borders	13 days	10 days	>20 days	10 days
	20 – 30 %	10 – 20 %	1 – 5 %	10 – 20 %
North East England	15 days	18 days	>20 days	>20 days
	20 – 30 %	10 – 20 %	1 – 5 %	10 – 20 %
Yorkshire and The Humber	>20 days	>20 days	-	>20 days
	5 – 10 %	5 – 10 %	-	5 -10 %
International Coastlines				
Norway	10 days	9 days	14 days	9 days
	70 – 80 %	60 – 70 %	80 – 90 %	70 – 80 %
Sweden	>20 days	>20 days	>20 days	>20 days
	10 – 20 %	20 – 30 %	30 – 40 %	20 – 30 %
Denmark	14 days	17 days	>20 days	18 days
	40 – 50 %	20 – 30 %	30 – 40 %	30 – 40 %
Germany	>20 days	>20 days	-	>20 days
	5 – 10 %	1 – 5 %	-	1 – 5 %
Shoreline Impact				
Maximum mass of oil onshore [m^3]	8 922	1 2640	2 866	5 026
Key Sensitivities At Risk				
Discussed in Section 11.6				

Source: Petrofac, 2019.

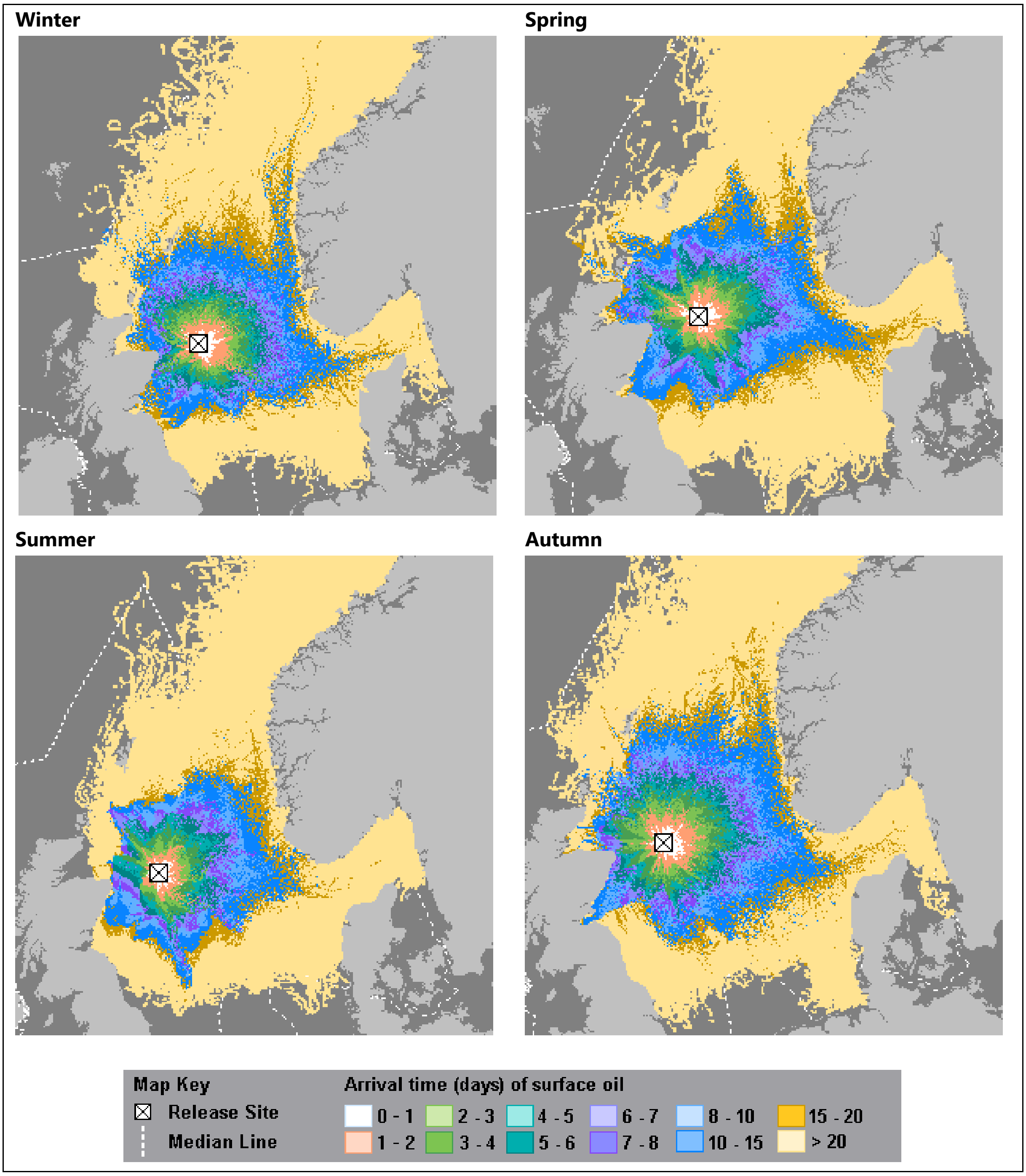

Figure 11.5: Well blow-out modelling: arrival time plot

Source: Petrofac, 2019.

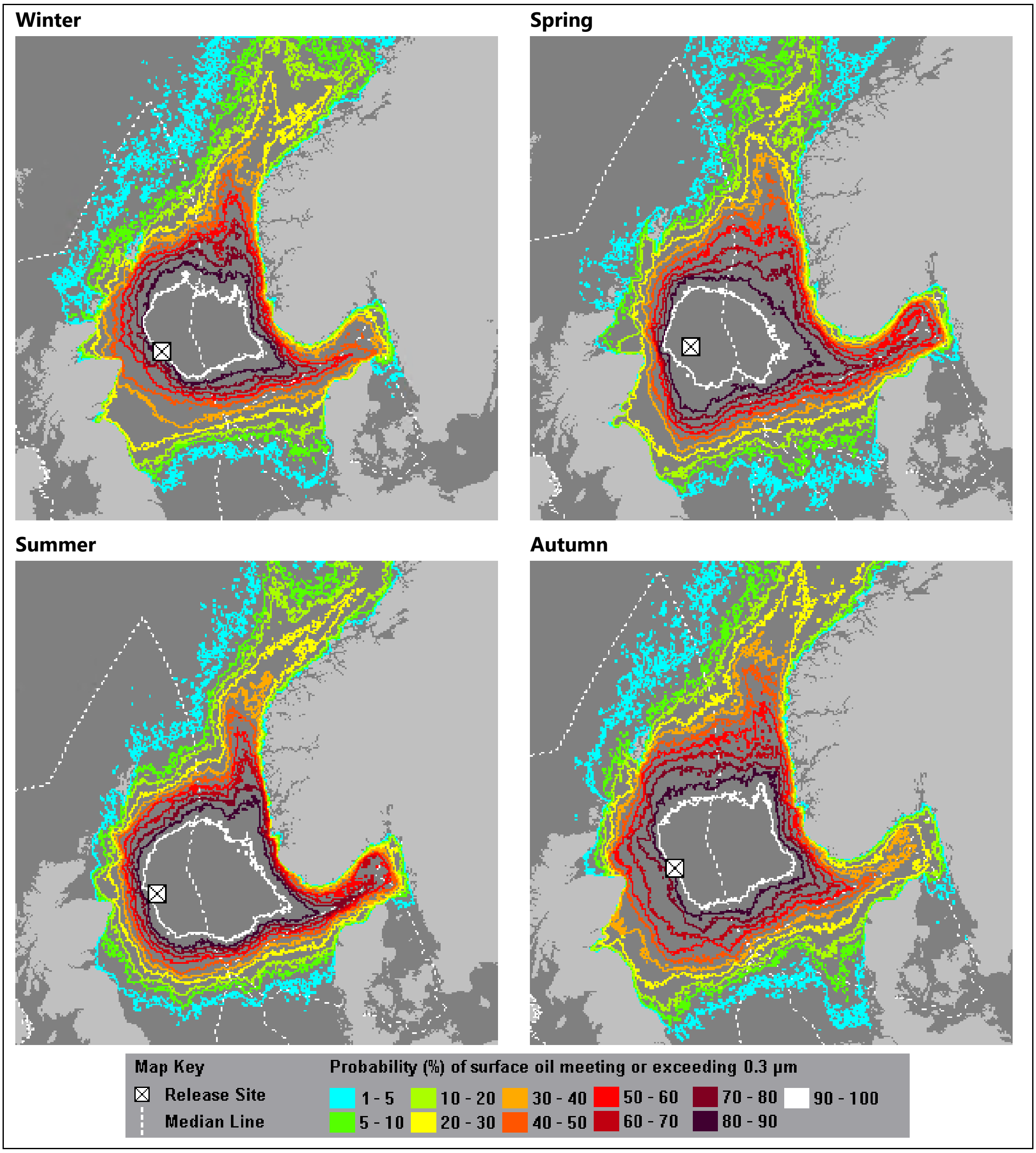

Figure 11.6: Well blow-out modelling: probability plot

Source: Petrofac, 2019.

11.4.1.2 Loss of FPSO Inventory

The parameters used in the modelling on a pipeline inventory release are detailed in Table 11.3. The results of the pipeline release modelling scenario are provided in Table 11.4. Minimum arrival time of surface oiling is shown in Figure 11.7 and the probability of surface oiling in Figure 11.8. It should be noted that surface oiling is shown with a thickness threshold of 0.3 µm (equal to 0.0003 mm), in accordance with OPRED's oil spill modelling requirements. Potential impacts relating to the modelling results are described in Section 11.5.

Table 11.3: Complete Loss of FPSO Inventory Spill Modelling Parameters

FPSO Inventory Loss Parameters								
Loss from Well/FPSO/Rig/Other		FPSO Inventory		Instantaneous Loss?			No	
Worst Case [m^3]		42 927		Will the Well Self-Kill?			N/A	
Flow Rate [m^3/hr]		998.3						
Justification for Predicted Worst Case Volume		Maximum volume to which the FPSO will be allowed to fill before offloading via shuttle tanker						
Location								
Spill Source Point		58° 03' 20.0844" N, 0° 13' 3.6048" W						
Installation/Facility Name		Avalon FPSO		Quad/Block			21/6b	
Hydrocarbon Properties								
Hydrocarbon Name		Clair						
Assay Available		No		Was An Analogue Used For Spill Modelling?			Yes	
	Name	ITOPF Category	Specific Gravity	API Gravity	Viscosity [cP]	Pour Point [°C]	Wax Content [%]	Asphaltene Content [%]
Hydrocarbon	Avalon crude	3	0.924	21.6	322	-36	1.8	0.25
Analogue	Clair	3	0.913	23.5	100	-15	4.7	0.9
Metocean Parameters								
Air Temperature (°C)		2°C to 15°C		Sea Temperature (°C)			7°C to 14°C	
Wind Data		2 years' (2012 to 2013) Oil & Gas UK Data from the European Centre for Medium-Range Weather Forecasts (ECMWF) Wind Data						
Current Data		2 years' (2011 to 2013) Oil & Gas UK Data: Shelf daily currents						
Modelled Release Parameters								
Surface or Subsurface		Surface		Depth [m]			0	
Release Duration [hours]		43		Instantaneous?			No	
Persistence Duration [days]		15		Release Rate [m^3/hour]			998.3	
Total Simulation Time [days]		17		Total Release [m^3]			42 927	
Oil Spill Modelling Software								
Name of Software		MEMW-OSCAR		Version			13.1.0	

Source: OSRL, 2022.

Table 11.4: Complete Loss of FPSO Inventory Spill Modelling Results

Complete Loss of FPSO Inventory Modelling Summary				
Spill Scenario/Descriptor	FPSO Release			
Median Crossing				
Identified Median Line	**Highest Probability and Shortest Time to Reach**			
	Dec to Feb	Mar to May	Jun to Aug	Sep to Nov
Denmark	4 %	2 %	<1 %	<1 %
	14 days, 21 hrs	16 days, 3 hrs	16 days, 15 hrs	16 days, 18 hrs
Norway	94 %	54 %	67 %	93 %
	2 days, 6 hrs	2 days, 18 hrs	2 days, 18 hrs	2 days, 3 hrs
UK	100 % (spill originates in UK waters)			
	0 days, 0 hours (spill originates in UK waters)			
Landfall				
Predicted Locations	**Highest Probability and Shortest Time to Reach**			
	Dec to Feb	Mar to May	Jun to Aug	Sep to Nov
UK Coastlines				
Aberdeen	N/A	2 % 8 days, 20 hrs	N/A	N/A
Aberdeenshire	N/A	5 % 6 days, 1 hr	2 % 8 days, 7 hrs	1 % 6 days, 19 hrs
Angus	N/A	3 % 11 days, 13 hrs	N/A	N/A
Fife	N/A	1 % 14 days, 18 hrs	N/A	N/A
Highland	N/A	2 % 14 days, 12 hrs	N/A	N/A
Moray	N/A	1 % 15 days, 5 hrs	N/A	N/A
Orkney Islands	N/A	1 % 15 days, 23 hrs	N/A	N/A
Shetland Islands	4 % 12 days, 6 hrs	N/A	N/A	N/A
International Coastlines				
Norway	4 %	N/A	N/A	3 %
	13 days, 24 hrs	N/A	N/A	13 days, 17 hrs
UK	4 %	9 %	1 %	3 %
	12 days, 6 hrs	6 days, 10 hrs	15 days, 15 hrs	7 days, 0 hrs
Shoreline Impact				
Volume of oil onshore [m^3]	21	24 345	3 584	11 698
Key Sensitivities At Risk				
Discussed in Section 11.6				

Source: OSRL, 2022.

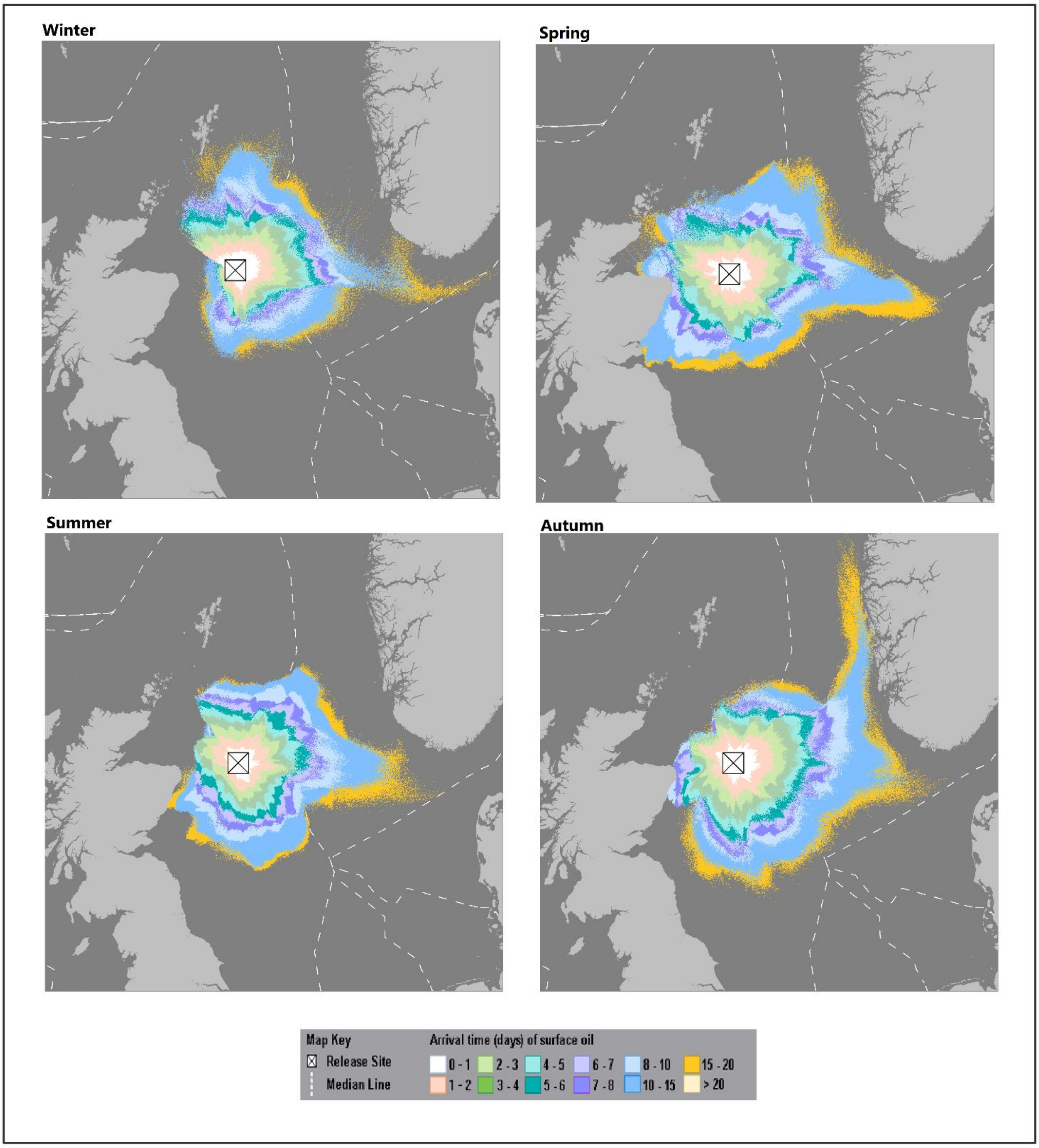

Figure 11.7: Complete loss of FPSO inventory spill modelling: Arrival Time Plot

Source: OSRL, 2022.

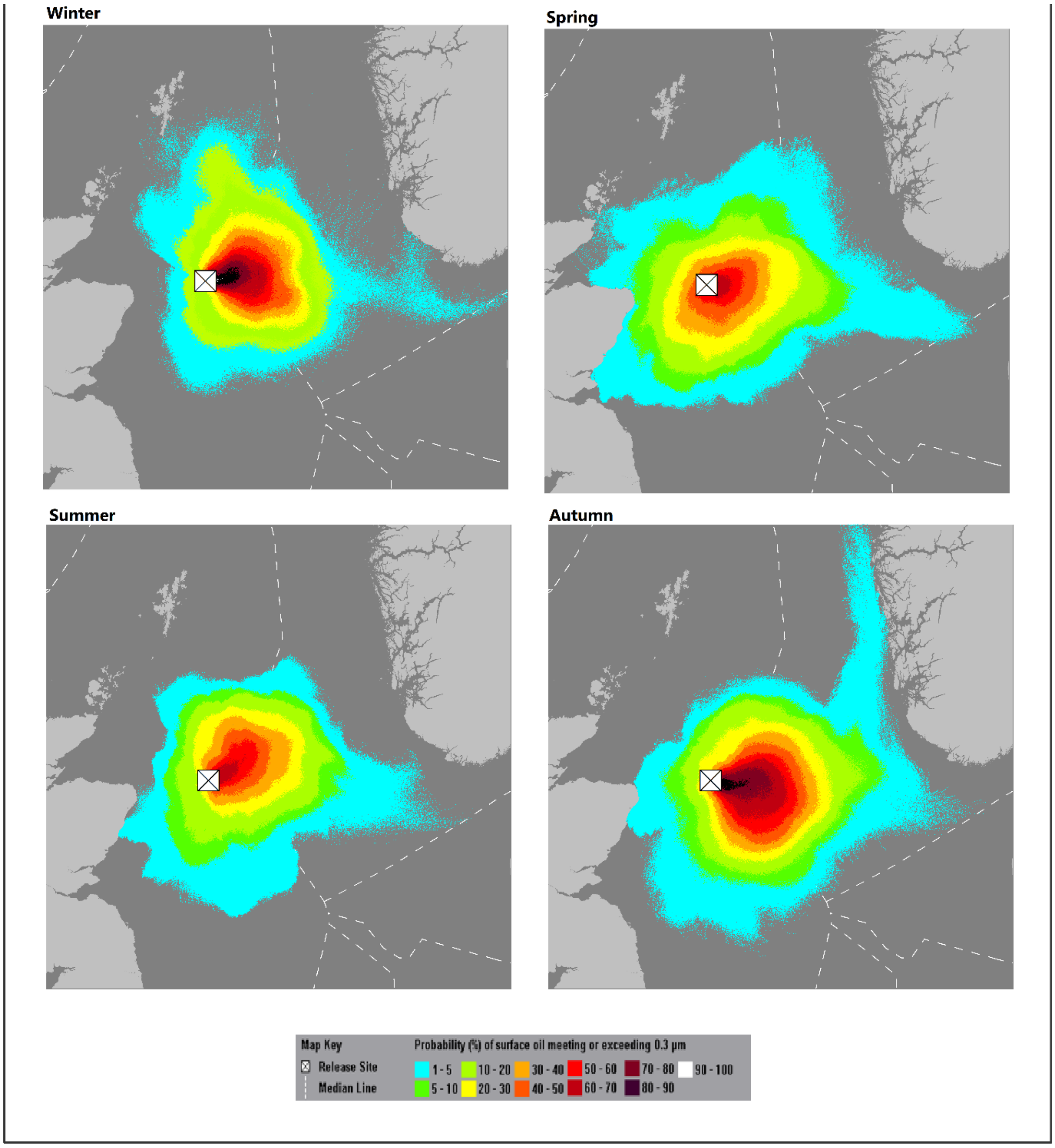

Figure 11.8: Complete loss of FPSO inventory spill modelling: Probability of Surface Oil Plot

Source: OSRL, 2022.

11.4.1.3 Fate of Oil

In addition to the stochastic modelling detailed above, the scenario from the blow-out modelling which resulted in the largest amount of oil onshore was investigated further as a deterministic model. The deterministic model shows the mass balance of oil over the duration of the release (Figure 11.9), along with the resulting fate of the oil after the 91 day modelling period (Table 11.5). The model showed that the majority of the oil (approximately 35 %) would remain in the water column after 91 days, whilst approximately 25 % would evaporate. Approximately 7 % of the oil was shown to beach. Around 5 % of the oil was expected to be subsumed in seabed sediments by the end of the modelled period, with a concentration not exceeding 50 µg/g. It should be noted that the deterministic model was designed to show a worst-case scenario, with winds and currents forcing oil to shore.

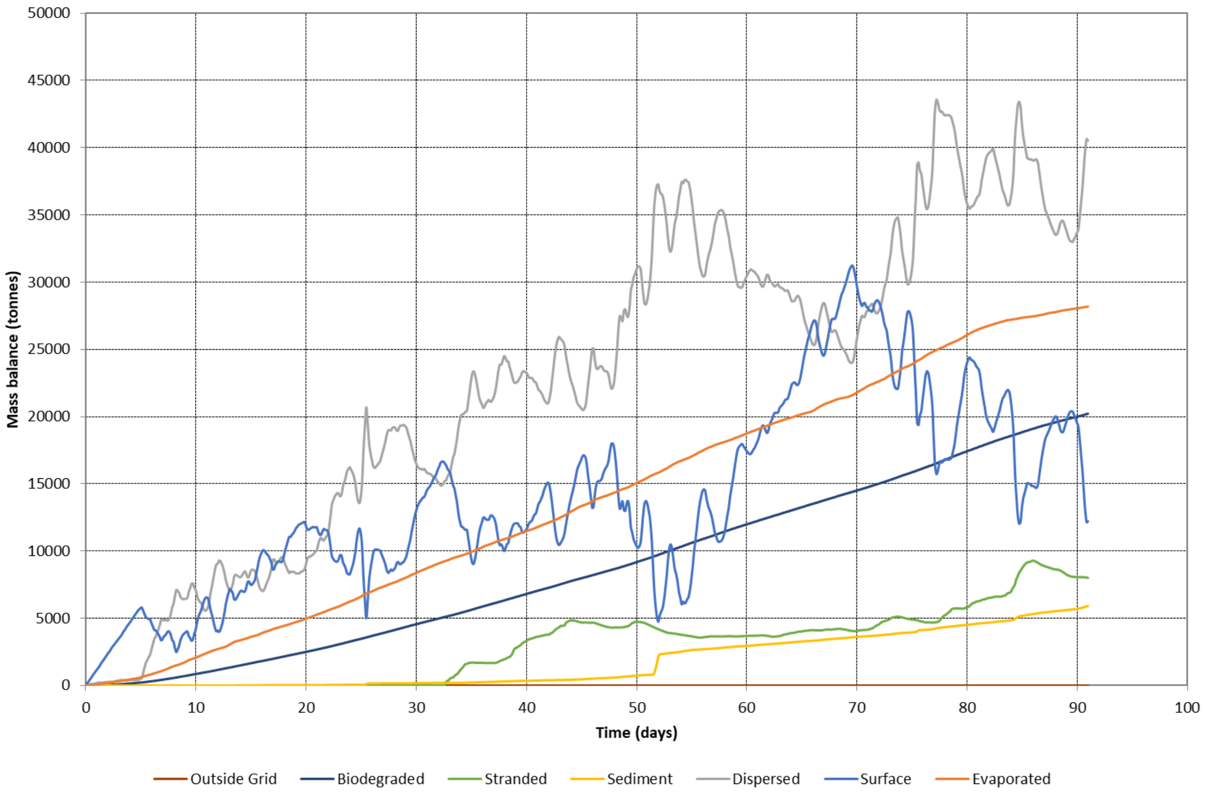

Figure 11.9: Mass balance of oil from well blow-out scenario throughout simulation

Source: Petrofac, 2019.

Table 11.5: Mass balance of oil from well blow-out scenario after 91 days

Fate	Mass [te]	Percentage [%]
Surface	12 220	10.62
Atmosphere	28 210	24.51
Water Column	40 510	35.19
Sediments	5 915	5.14
Ashore	8 027	6.97
Biodegraded	20 230	17.57
Outside Gridded Area	0	0%

Source: Petrofac, 2019.

11.5 Potential Environmental Impacts

11.5.1 Impacts on Marine Life

The risk of accidental hydrocarbon spillage to the marine environment is one of the main environmental concerns associated with oil-industry activities. Although the effects of oil spills are well understood, the effects of each individual spill are unique, and some assumptions have been made regarding predicting the effects of a large crude oil spill at the proposed Avalon Field Development.

11.5.1.1 Plankton

Oil, particularly diesel, is toxic to a wide range of planktonic organisms (Quigg et al., 2021; Siron et al., 1993). Oil slicks can inhibit light penetration which is essential for phytoplankton growth and photosynthesis whilst those living near the sea surface are particularly at risk, as water-soluble components leach from floating oil (Quigg et al., 2021). However, the extent of any effect is largely dependent on the structure of their communities whilst some studies have shown the phytoplankton growth responses vary in response to exposure to contaminants such as crude oil with some finding growth increases and others find growth decreases (Quigg et al., 2021; Tang et al., 2019; Varela et al., 2006).

Although oil spills may kill individuals, the effects on whole plankton communities generally appear to be short-term. Following an oil spill incident, plankton biomass may fall dramatically, due either to animal deaths or avoidance of the area leading to community shifts (Severin & Erdner, 2019). Taxon specific responses are complex and will ultimately vary according to the specific plankton species and depend on factors such as oil type and concentration as well as environmental influences (Severin & Erdner, 2019). However, some studies not that after only a few weeks, some populations may be expected to return to previous levels through a combination of high reproductive rates and immigration from outside the affected area (NSTF, 1993).

The impact of an oil spill on plankton species, a receptor of low value due to large, widespread populations, is considered to be major and therefore overall effect significance is moderate.

11.5.1.2 Benthos

Shallow Coastal Communities

It is generally assumed those animals associated with the seabed will remain unaffected by a surface slick as the floating oil moves above them. In offshore areas such as the Avalon field, impacts on the benthos from a release of oil are likely to be very minimal due to the water depth and the direction of travel which will typically be upwards away from the benthos and into the water column (Ji et al., 2020).

However, a fraction of the water-soluble components of a slick may dissolve into the water column, assisted by rough seas or agitation of the sea surface, where these could potentially be harmful to benthic organisms. In deeper offshore areas, these impacts will be very limited. However, if the spilled oil drifts inshore, the benthic communities of the shallow coastal areas may be affected. Parameters such as local bathymetry and sediment types would significantly influence the distribution of oil contamination at the seabed.

It should be noted that any oil that reaches these shallow areas will have travelled a considerable distance through the water column and across the sea surface and will therefore have been affected by the range of degradation processes described in Section 11.3. These mechanisms will have contributed to remove the various toxic components of the oil and the primary impact of the oil deposition on benthic communities is anticipated to be related to smothering. As the oil will also have become widely dispersed by this point, the physical effects of smothering are expected to be limited.

The shoreline itself is particularly susceptible to oil beaching. The potential impacts arising from beached oil in coastal habitats are discussed separately in Section 13.5.2.

Deepwater Communities

As described above, the buoyancy of the produced oil will carry hydrocarbons straight up to the sea surface in the event of a subsea spill. Therefore, it is expected to be unlikely for the crude oil to reach the surrounding benthic communities. However, the worst-case deterministic model (Section 11.4) showed the potential for some of the oil to remain in the water column, with very low concentrations in seabed sediments.

It is unknown how exactly a subsea oil spill would affect the benthos. Assessing the effects of toxic contamination on biotopes is extremely difficult because varying quantities of different contaminants can have very different effects on marine organisms. However, reported effects from large oil spills, such as the Ekofisk blowout in 1977 and the Braer oil spill in 1993, were limited to some chemical contamination of seabed sediments at the latter, with neither spill appearing to have resulted in any acute biological effects (Kingston et al., 1995).

The majority of the seabed in the area across the Avalon Field Development area is classed as circalittoral muddy sand (Section 4.4.1), with a low biodiversity and sparse distribution of epifaunal species. Species present include hermit crabs, sea stars and sea pens. A small area of circalittoral mixed sediments is also present, with a hard substrate supporting the presence of hydroids and encrusting sponges, again in low densities. The infaunal community in the area is much denser and diverse, and is dominated by an amphinomid polychaete worm. Other species present include the opisthobranch mollusc, the spionid polychaete and the paraonid polychaete.

Low densities of juvenile ocean quahog, a species protected both as a Scottish Priority Marine Feature (PMF) and under the OSPAR list of ‘Threatened and/or Declining Habitats and Species’ were also observed in the infauna of the survey area. However, the low density and absence of adults indicates that the area is unlikely to be of high conservation importance for this species.

Suspension and filter feeders, such as sea pens, hydroids and encrusting sponges, gather their food directly from the seawater and would, therefore, take in any oil present within the surrounding water leaving them more vulnerable to the toxic effects of oil dispersed in the water column.

Deposit feeders, such as polychaetes and ocean quahog, are supported by the fine organic matter trapped between the fine sediments and these animals would only be affected if the dispersed oil settled on the seabed. The low amounts of oil expected to be present in the sediment mean that deposit feeders, and infaunal species, would unlikely be impacted by oil in the event of a spill.

Nonetheless, if an oil spill was to occur and oil settles on the seabed it is considered that the impact would be major on receptors of low to high value and therefore overall effect significance is moderate to major.

11.5.1.3 Fish

Offshore fish populations remain relatively unaffected by oil pollution, as oil concentrations below the surface slick are generally low (Clark, 2001). There is also evidence that fish are able to detect and avoid oil-contaminated waters (IPIECA, 2000). This avoidance may, however, cause disruption to migration or spawning patterns.

Rather than impacting the fish directly, heavily contaminated sediments may have an adverse effect on local populations of demersal fish species, due to the impact it has lower down the food chain. However, as described in the benthos section above, heavy contamination of the sediments is not expected.

Few studies have demonstrated increased mortality in fish species as a result of oil spills (Langangen et al., 2017). However, fish eggs and larvae are more vulnerable to oil pollution than adult fish as, in many fish species, these stages float to the surface where contact with spilt oil is more likely. Therefore, fish stocks may be vulnerable to spills that occur close to spawning or nursery grounds as fish eggs and larvae are susceptible to toxic oil compounds which can kill or cause sub lethal effects (Carpenter, 2019; Langangen et al., 2017).

A number of commercial species have spawning grounds in the wider region around the proposed development area (see Figure 4.10 and 4.11 in Section 4.5.1). However, as the majority of these species have extensive spawning grounds and produce large numbers of pelagic young, there is unlikely to be any significant, long-lasting effect on numbers in the adult populations. Certain fish stocks may be more affected than others, particularly if the spill is very large, coincides with spawning periods, or enters the grounds of species with restricted spawning areas.

The impact of an oil spill on fish species, a receptor of medium value due to the presence of spawning and nursery grounds in the area, is considered to be major and therefore overall effect significance is moderate.

11.5.1.4 Shellfish

If oil reaches the seabed, shellfish species that cannot swim away from oiled sediments are susceptible to its effects. Mortalities may occur if shellfish become smothered by settling oil. Only low levels of oil in seawater may cause tainting in shellfish, which may be commercially damaging to shellfish fisheries. This is more common in filter feeding shellfish, principally bivalves, as they would take up fine oil droplets from the water column. As explained above, it is extremely unlikely that hydrocarbons released from a subsea blow-out would remain near the seabed in significant concentrations to have such an effect. The inshore waters around north-east Scotland do, however, support commercially important shellfish fisheries, which may be at risk if a spill reaches these waters.

Although the proposed development lies within a wider region known to be a spawning ground and habitat for *Nephrops*, a burrowing crustacean, this species is limited to areas of sandy to soft mud which are present across the Avalon Field Development area. However, as described in Section 11.5.1.2, deterministic modelling estimates that only very small concentrations of oil would be expected to impact on the seabed and therefore no significant effect on *Nephrops* spawning grounds are anticipated.

The impact of an oil spill on shellfish species, a receptor of medium value due to the presence of spawning and nursery grounds in the area, is considered to be major and therefore overall effect significance is moderate.

11.5.1.5 Marine Mammals

Whales, dolphins and porpoises are not considered to be affected by an oil spill in similar ways as birds, fish and marine mammals such as otters. Oil is unlikely to adhere to their skin due to its slickness and is not expected to accumulate in or around the eyes, mouth, blow hole or other potentially sensitive areas (Helm et al., 2015).

Furthermore, these marine species do not consume large quantities of seawater, do not groom themselves and are unlikely to consume oil-contaminated prey, therefore they are unlikely to ingest significant quantities of oil (Helm et al., 2015).

The greatest risk to most cetaceans from an oil spill is likely to occur if they come into contact with an oil spill when they surface to breathe and inhale oil and/or toxic petroleum vapours. This may impact on the individuals' respiratory system (Schwacke et al., 2013; Frasier et al., 2019; Helm et al., 2015).

Previous studies have shown that some species of cetacean may be able to detect and avoid oil spills but this was dependent on oil thickness and colour (Aichinger Dias et al., 2017). However, the same authors noted that, after the Deep-Water Horizon spill in the Gulf of Mexico, cetaceans that were present in the area came into direct contact with oil and show any avoidance of a slick (Aichinger Dias et al., 2017).

A thick layer of blubber protects cetaceans and adult seals from the cold and these animals are less vulnerable to the physical impacts of oil lowering their resistance to the cold (Helm et al., 2015). Seal pups and otters are, however, at risk from hypothermia if their fur becomes oiled and loses its thermal properties, as they do not have sufficient blubber underneath their fur to keep them warm (Helm et al., 2015). Unlike cetaceans, the mucous membranes, eyes and ears in seals are likely to be negatively affected by exposure to an oil slick (Helm et al., 2015).

Both grey and common seals are known to breed on the coastline of north-east Scotland (Section 4.7.2). These marine mammals may be at risk if a slick reaches coastal areas.

The impact of an oil spill on marine mammals, a receptor of high value due to their protected status, is considered to be major and therefore overall effect significance is major.

11.5.1.6 Seabirds

Seabirds are particularly susceptible to oil pollution on the sea surface, especially during large oil spills. After exposure to oil, birds may experience negative effects on their reproductive success as well as their cardiovascular and respiratory systems, cellular damage and heightened metabolic cost through increased foraging time (Takeshita et al., 2021; Troisi et al., 2016). Ingested oil may also result in pathological changes in the intestinal tract, lungs, liver and kidneys leading to a range of negative impacts on survivability (Troisi et al., 2016).

Seabirds that survive with oil contaminated feathers may be able to remove traces of oil by preening. There is little information on the extent and speed with which full functionality is restored, however, some wild gulls and terns have been shown to remove visible oil within 10 weeks (King et al., 2021).

Despite considerable effort to rescue, clean and reintroduce seabirds which have been impacted by an oil spill, post release survival is low with successful rehabilitation requiring high quality facilities and veterinary skills (Troisi et al., 2016; Heubeck et al., 2003).

The aerial habits of the fulmar and gulls, together with their large populations and widespread distribution, reduce vulnerability of these species. Gannets, skuas and auk species are considered to be most vulnerable to oil pollution due to a combination of heavy reliance on the marine environment, low breeding output with a long period of immaturity before breeding, and the regional presence of a large percentage of the biogeographical population (DTI, 2003).

The wider region which has been considered as important for seabirds (Kober et al., 2010), for black-legged kittiwake, common guillemot and northern gannet during breeding/moulting season and for Atlantic puffin during wintering.

The vulnerability of bird species to oil pollution is dependent on several factors and varies considerably throughout the year. The JNCC has produced a Seabird Oil Sensitivity Index (SOSI) which identifies areas at sea where seabirds are likely to be most sensitive to oil pollution. The SOSI uses seabird survey data collected between 1995 and 2015, in addition to individual species sensitivity index values, combined at each location to create a single measure of seabird sensitivity to oil pollution (JNCC, 2016).

Monthly vulnerability for seabirds in Block 21/06 and the UKCS blocks which surround it is presented in Table 11.6 and Figure 11.10. With increasing distance from shore, seabird abundance decreases, and their distribution becomes increasingly patchy. These patterns are generally governed by the availability and distribution of prey, and also oceanographic features such as water depth and sea temperature. As a result, in the offshore location of the proposed Avalon Field Development, seabird abundance in the area of the proposed development remains relatively low for much of the year (Section 4.8).

The vulnerability of birds in the vicinity of the proposed Avalon Field Development declines during the breeding season, generally between March and June, when large numbers of birds congregate in coastal breeding colonies. Seabird sensitivity in the area of the Avalon Field is generally high to extremely high to very high in January to May (Table 11.6; Figure 11.10). The vulnerability is increased by the numbers of auks, primarily guillemots, but also puffins, found at sea during this time (BODC, 1998; DTI 2001). Congregating into large groups referred to as 'rafts', these birds undergo a full moult at sea, rendering them flightless and leaving them highly susceptible to surface pollution (Richards et al., 2019; Carter et al., 2016).

Seabird vulnerability in the inshore waters around the north-east coast of Scotland is classified as high to very high for much of the year due to breeding seabirds foraging. The north-east coast of Scotland is of international importance for the seabird breeding colonies it supports, with many coastal sites and their surrounding inshore waters designated as Special Protection Areas (SPAs) under the European Birds Directive. These colonies may be at risk from a large surface slick.

Overall, Block 21/06, in which the Avalon Field Development will lie, shows a predominantly low sensitivity to oil and surface pollutants for much of the year, with a peak in sensitivity occurring in January and February (JNCC, 2016).

The impact of an oil spill on sea birds, a receptor of high value due to their protected status, is considered to be major and therefore overall effect significance is major.

Table 11.6: Seabird Vulnerability to Surface Pollution in the Vicinity of the Proposed Development

UKCS Block	January	February	March	April	May	June	July	August	September	October	November	December
20/5	1	1*	3	ND	5*	5	5	5	5	5*	4*	4
20/10	1	1*	4	ND	5*	5	5	5	5	5*	4*	4
20/15	5*	2	4	3*	3	5	5	5	5	5*	5*	5
21/1	1	1*	2	ND	5*	5	5	5	4	4*	ND	4*
21/2	1	5	5*	ND	5*	5	5	5	4	4*	ND	ND
21/6	1	1*	3	ND	5*	5	5	5	5	5*	ND	4*
21/7	2	5	2	ND	5*	5	4	5	5	5*	ND	ND
21/11	2	1	5	2*	2	5	5	5	5	5*	ND	5*
21/12	2	2	5	2*	2	5	5	5	5	5*	ND	ND

Key:

1 Extremely high; 2 Very high; 3 High; 4 Medium; 5 Low

ND No data; * Indicates blocks for which no data was available, and therefore score has been calculated using that of an adjacent month or block

Source: JNCC, 2016.

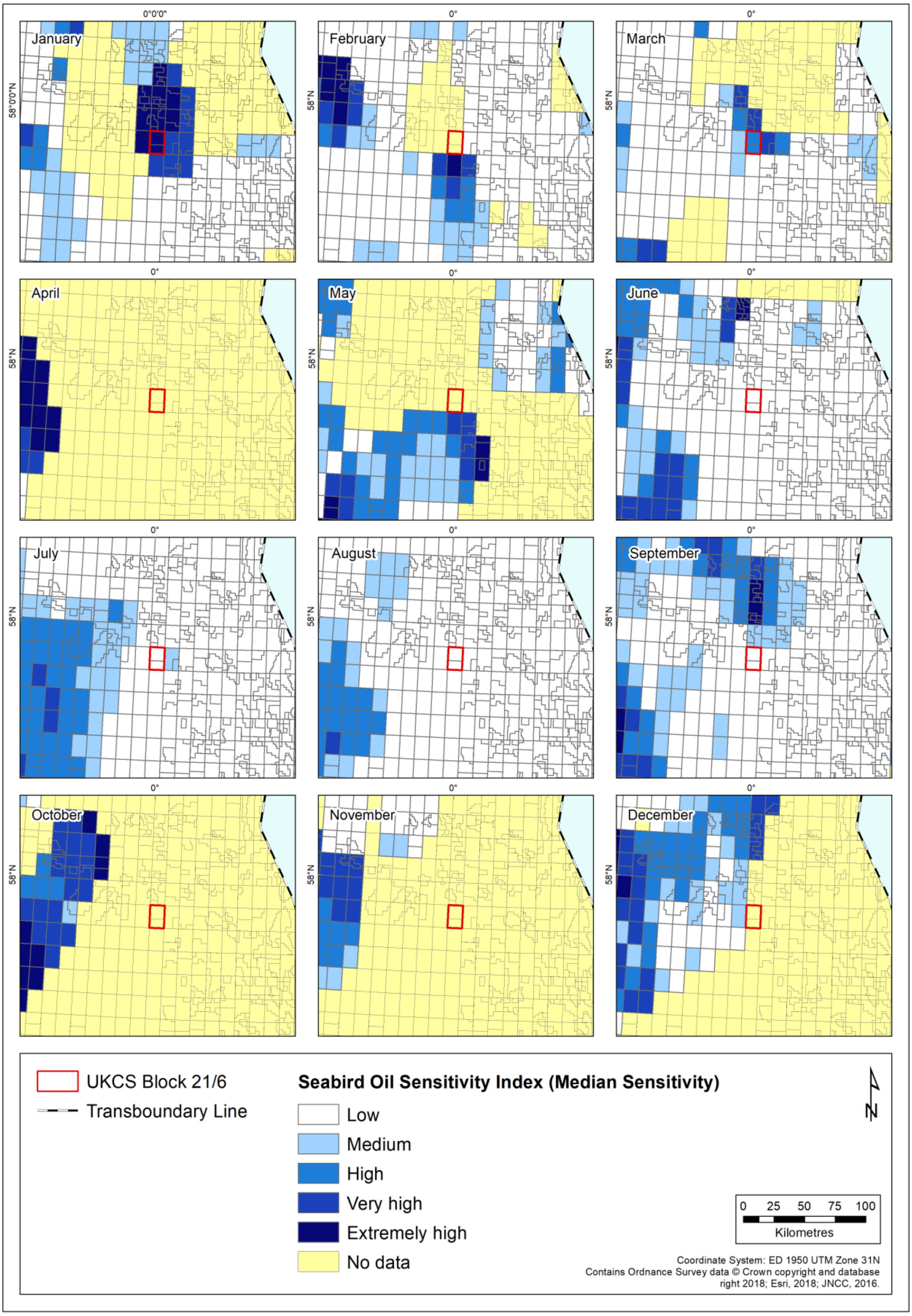

Figure 11.10: Seabird vulnerability to surface pollution in the vicinity of the proposed development

11.5.2 Impacts on Coastal and Inshore Habitats

Oil spill modelling has shown that the coastlines of eastern Scotland, the Shetland and Orkney Islands, eastern England, Norway, Denmark, Sweden and Germany have the potential to be impacted in the unlikely event of a spill from the Avalon Field Development (Section 11.4). However, the probability of such a spill reaching shore, and the amount of crude oil that would do so, is low. These coastlines support a range of different habitat types, and are important for nature conservation, with numerous sites designated under national and international legislation (Section 4.10).

11.5.2.1 Rocky Shores

Rocky shores can be very varied in structure, ranging from exposed vertical walls to flat bedrock, or stable boulder fields to aggregations of cobbles. These shores can support a variety of sessile animal and plant communities which live attached to the rock surface, as well as a range of associated mobile invertebrates and fish. More exposed rocky shores are generally dominated by sessile animals and smaller more robust seaweeds, while the more sheltered shores are characterised by the large brown kelps.

Rocky shores are generally high energy beaches and, while oil may have an impact on the animals and plants which live on them, stranded oil is often quickly removed by wave action and water movement. The vulnerability of rocky shore habitats to oiling is dependent on the type of rocky shore and its exposure. The action of the waves may start to remove the oil from an exposed vertical wall almost immediately, but the oil may remain for longer in more sheltered, kelp dominated areas.

Many of the animals and small seaweeds found on rocky shores would be killed by exposure to fresh and light oils, but much of the crude oil potentially reaching the shore from a large spill from the proposed Avalon Field Development location would have been at sea for several days (a minimum of 4 days) and would have lost some degree of its toxic constituents through the oil weathering process (Keramea et al., 2021). Various shoreline species have been observed to survive shoreline oiling and continue feeding in oiled areas, suggesting that the toxic impacts would be minimal (Clark, 2001). However, even if the beached oil is relatively non-toxic, heavily weathered oil may still cause damage due to its physical properties. Large amounts of stranded oil may impact upon shoreline animals by smothering them. Those animal species that are large enough to protrude above the oil or can move away quickly may survive, but smaller species would be killed by inhibition of their feeding and respiration mechanisms. Many of the larger brown seaweeds which dominate the more sheltered rocky shores secrete mucus which would prevent oil adhering to them. However, if oil does adhere to the seaweed fronds, instead of killing the seaweeds directly, the oil will increase their overall weight causing them to be pulled from the rocks by the wave action.

The rate of recovery and the form it takes will depend upon the type of rocky shore and the animals and plants that live on it. The general experience of oil spills on rocky shores is that substantial recovery can be achieved within 2 to 4 years (Park et al., 2022), but biological factors may intervene and cause a prolonged change. Rocky shores are high energy, highly productive environments, where the physical and biological factors exerted upon them lead to intense competition between the species which live there. The physical factors, such as desiccation, extremes of temperature, and changes in salinity, can cause mortalities in rocky shore communities, while the severe winter storms can pull many animals and plants from the shore each year (Little & Kitching, 1996). As a result, these communities have the capability to regenerate quickly in order to take advantage of the newly available space.

Oil spill modelling indicates that, under the majority of meteorological circumstances, a large oil slick will drift northeast and east from the Avalon Field Development, leaving the coastlines of Norway and the Shetland Islands at the greatest risk of oil impacting on the shoreline (Section 11.4). These shores are all dominated by steep sea cliffs and high energy rocky shores (Section 4.9). Rocky shores are also present in areas further down the east coast of Scotland and in north-east England. It may be assumed that these areas could recover relatively quickly from a beaching oil spill.

11.5.2.2 Sedimentary Shores

The fate of oil stranded on sediment shores depends on the nature of the substratum (IPIECA, 2008). Due to the increased sediment movement and relatively large gaps between the particles, beached heavy oil can penetrate further into the more mobile shingle or coarse sand shores. These coarse sediment shores tend to be less productive than sheltered mudflats, where waterlogged sediments, rich in organic matter, can accommodate huge numbers of invertebrates. Gaps between the shingle or sand grains allow the water to drain away quickly between the tides and the movement of the sediment itself is very abrasive, meaning few animals can survive in it. If the beaching of an oil spill becomes inevitable, sandy beaches have in the past been considered as sacrificial areas. A spill may be directed towards a sandy beach in order to protect other, more sensitive, shorelines. Soft sediment areas are rare on the coast of Norway and the Shetland Islands, with sandy beaches making up a very small proportion of the total coastline (Section 4.9). Sandy beaches make up a larger proportion of coastlines in areas such as the Orkney Islands, the inner Moray Firth, Angus, Fife, Berwickshire, Northumberland and Yorkshire, as well as in Denmark, Sweden and Germany.

In contrast, oil does not readily penetrate the sediments in areas of firm waterlogged mud or fine sand and tends to be carried away with the next tide (Clark, 2001). However, there is a concern over oil beaching on sheltered mudflats or associated sensitive areas of saltmarsh and these are often priority areas for protection following oil spills. These are generally highly productive areas, with high numbers of invertebrates living within the sediments which may provide a valuable food source for juvenile fish and birds (Little, 2000). Recovery times tend to be longer in these sheltered areas, due to the reduced bacterial degradation and persistence of the oil, particularly if it penetrates into the sediment (IPIECA, 2008). The process of cleaning the sediments and vegetation can be very difficult in these areas and could potentially exacerbate any damage to the habitat. In the most sheltered of intertidal areas, where very fine sediments accumulate, saltmarshes may be found. Only small patches of saltmarsh are found on the Shetland Islands, but this habitat is present in small areas of the Grampian coast, as well as more extensively in south-east Scotland and in Northumberland (Section 4.9).

The impact of an oil spill on coastal and inshore habitats, a receptor of high value due to their protected status, is considered to be major and therefore overall effect significance is major.

11.5.3 Impacts on Other Users of the Sea

11.5.3.1 Commercial Fisheries

The effects of oil spills on commercial fish and shellfish, and the indirect impacts on their habitats, are described above. Fish and shellfish exposed to oil may become tainted which could prevent an entire catch from being sold (Clark, 2001). There is evidence that fish are able to detect and avoid oil-contaminated waters (IPIECA, 2000), therefore tainting is more a concern for immobile shellfish which cannot swim away. This is more common in filter feeding shellfish, such as scallops, as they could take up fine oil droplets from the water column. *Nephrops* are the principal species of shellfish taken from the area overlapping with the proposed Avalon Field Development (Section 4.11.1).

If fishing in the area of an oil spill, nets may become fouled with floating oil. This not only causes damage to the nets themselves but contact with fouled fishing gear may also contaminate subsequent catches. The mixed demersal fisheries take the greatest proportion of fish landed from the area around the proposed Avalon Field Development, and these trawl fisheries operate year-round. Pelagic fisheries are also present, but landings are highly variable due to the mobile nature of the pelagic stock. *Nephrops* is the most important species landed from the area around the proposed Avalon Field Development in terms of value (Section 4.11.1). For all species groups, nets could potentially become tainted in the unlikely event of a large oil spill occurring. Major spills may also result in loss of fishing opportunities with boats unable or unwilling to fish due to the risk of fouling causing a temporary financial loss to commercial fishermen.

The impact of an oil spill on commercial fisheries, a receptor of medium value due to the importance of the area for fishing, is considered to be major and therefore overall effect significance is moderate.

11.5.3.2 Aquaculture

Numerous fish and shellfish farms are distributed across the coast of Norway and the Shetland Islands (Section 4.11.2) and, therefore, aquaculture is an important contributor to the economies of these areas. Tainting is of concern for all caged fish and shellfish farms as the animals are unable to swim away. If a large surface spill can reach these islands the many mariculture farms which cultivate fish and shellfish may be at risk from tainting and fouling, potentially leaving their stock unmarketable.

Although all oils can cause taint, lighter oils are generally more potent (Clark, 2001). Any large oil spill from the proposed Avalon Field Development would have undergone the weathering processes described above (Section 11.3.2) and, therefore, will have lost many of its lighter fractions by the time it reached the shore. Although this would not completely prevent the impact of the oil with regard to tainting, it may limit the severity.

The impact of an oil spill on aquaculture sites, a receptor of medium value, is considered to be major and therefore overall effect significance is moderate.

11.6 Potential for a Major Environmental Incident

The Offshore Safety Directive (2013/30/EU) came into force, via UK Regulations on 19 July 2015. These Regulations require that a Safety Case defining Major Accident Hazards (MAH) with the potential to cause Major Accidents (MA) must be in place to cover all relevant offshore operations. The potential for MAs to cause a Major Environmental Incident (MEI) must also be defined in the Safety Case. For the proposed Development, two scenarios with the potential to cause a MEI have been identified (Section 11.1.1):

- Spillage of hydrocarbons in the event of an uncontrolled well blow-out; and
- Rupture of crude oil storage tanks on the FPSO leading to a loss of crude inventory.

The oil spill modelling results (Section 11.4) show that of these two scenarios, an uncontrolled well blow-out would be expected to result in a greater extent of sea surface and shoreline oiling. Therefore, this scenario has been used as the basis for the MEI Assessment.

11.6.1 Major Environmental Incident (MEI) Assessment Methodology

The Offshore Safety Directive defines a MEI as an incident which results, or is likely to result, in significant adverse effects on the environment (Article 2[37]). Environmental vulnerability to oil spills is dependent on both the size of the spill and also the sensitivity of receptors. There is no standard quantitative method of determining the environmental impact likely to be associated with an oil spill, and so a qualitative approach based on the "Impact Scales and Gradation of Oil Spill Ecological Hazards and Consequences in the Marine Environments" classification guide by Patin (2004) has been used for this MEI assessment.

Table 11.7 shows the consequence assessment methodology defined by Patin (2004). These criteria have been used to consider the potential impact of a worst-case scenario oil spill from the proposed Development on UK protected sites, including Special Protection Areas (SPA), Special Areas of Conservation (SAC) and Nature Conservation Marine Protected Areas (NCMPA), which have been designated for the protection of habitats and species. Whilst the MEI Assessment is solely required to consider the impact to UK sites, it is acknowledged that the oil spill modelling results show potential for oil reaching the waters of the Faroe Islands, Norway, Denmark, Sweden, Germany or the Netherlands, and potential for oil beaching in Norway, Denmark, Sweden or Germany. In the event of an incident that could impact the waters of an adjacent State, PPUK would liaise with the relevant national authorities to assess the scale of any potential impacts.

Table 11.7: Consequence Assessment Methodology based on Patin (2004)

A. Spatial Scale (Area)	
Spatial Scale	**Area Under Impact**
Point	Less than 100 m^2
Local	Range from 100 m^2 to 1 km^2
Confined	Range from 1 km^2 to 100 km^2
Sub-regional	More than 100 km^2
Regional	Spread over shelf area

B. Temporal Scale	
Temporal Scale	Longevity
Short term	Several minutes to several days
Temporary	Several days to one season
Long-term	One season to 1 year
Chronic	More than 1 year

C. Reversibility of Changes	
Reversibility of Changes	Longevity of Disturbance
Reversible (acute stress)	Acute disturbances in the state of environment and stresses in biota that can be eliminated either naturally or artificially within a short time span (several days to one season)
Slightly reversible	Disturbances in the state of environment and stresses in biota that can be eliminated either naturally or artificially within a relatively short time span (one season to 3 years)
Irreversible (chronic stress)	Prolonged disturbances in the state of environment and stresses in biota that exist longer than 3 years

D. Consequence Assessment – General Assessment	
General Assessment	Disruption
Insignificant	Minimal changes that are either absent or not discernible.
Slight	Slight disturbances to the environment and short-term stresses in biota are discernible (below minimum reaction threshold 0.1% of natural population reaction).
Moderate	Moderate disturbances to the environment and stresses in biota are observed (changes up to 1% of natural population reaction are feasible).
Severe	Severe disturbances to the environment and stresses in biota are observed (up to 10% of natural population).
Catastrophic	Catastrophic disturbances to the environment and stresses in biota are observed (up to 50% of natural population). Changes are irreversible and stable structural and functional degradation of a system is evident.

The oil spill modelling results show that the majority of crude oil would be expected to move to the northeast and east, with the coastlines of Norway, the Shetland Islands and north-east Scotland most likely to be affected, followed by eastern Scotland, the Orkney Islands, north-east England, Denmark, Sweden and Germany (Section 11.4).

Table 11.8 lists the protected sites that have been shown by the modelling to have the potential to be affected by a large oil spill from the proposed Avalon Field Development. As shown by the mass balance modelling (Section 11.4), a proportion of the oil released from the seabed in the event of an uncontrolled well blow-out may remain in the water column or sediment. Therefore, marine protected sites designated for the protection of benthic habitats may be affected in the event of a spill from the proposed development and have been included in the assessment.

The potential impact of surface, shoreline or sediment oiling on the habitats and species of the protected sites listed in Table 11.8 has been assessed. As an initial step in the assessment, thresholds have been applied in terms of the minimum arrival time and maximum probability of oiling. The modelling results provide a worst-case scenario with the assumption that there would be no intervention in the slick. In practice, oil spill response resources would be mobilised immediately if a spill occurred, and oil spill response efforts would prioritise the protection of sensitive habitats and species. Therefore, it is assumed that sites at which oil would be expected to take more than three weeks to reach, or with a probability of less than 5 % for any oiling, would be very unlikely to be subject to significant adverse effects. Therefore, only sites with an expected minimum arrival time for oiling of 20 days or less, and a probability of more than 5 %, have been assessed according to the consequence assessment methodology detailed above.

Table 11.8: Protected Sites which may be Impacted by a Large Oil Spill from the Proposed Avalon Field Development

Name	Designation	Location	Minimum Arrival Time [days]	Maximum Probability [%]	Qualifying Features (SAC: Only marine and intertidal habitats are listed; SPA: individual species of international importance refers to relevant biogeographic area for each species; MPA/MCZ: Geodiversity Features not listed)
Scanner Pockmark	SAC	Offshore	< 1	90	Annex I Habitats: submarine structures made by leaking gases
East of Gannet and Montrose Fields	NCMPA	Offshore	1	90	Biodiversity: ocean quahog aggregations; offshore subtidal sands and gravels; offshore deep-sea muds
Norwegian Boundary Sediment Plain	NCMPA	Offshore	1	90	Biodiversity: ocean quahog aggregations; offshore subtidal sands and gravels
Braemar Pockmarks	SAC	Offshore	2	90	Annex I Habitats: submarine structures made by leaking gases
Central Fladen	NCMPA	Offshore	2	90	Burrowed mud
Turbot Bank	NCMPA	Offshore	2	70	Sandeels
Fair Isle	SAC	The Shetland Islands	4	70	Annex I Habitats: Vegetated sea cliffs of the Atlantic and Baltic coasts
Fetlar	SPA	The Shetland Islands	4	70	Breeding seabird assemblage and individual species of international importance
Bluemull and Colgrave Sounds	SPA	The Shetland Islands	4	70	Breeding habitat for Red-throated diver of national importance
Fetlar to Haroldswick	NCMPA	The Shetland Islands	4	70	Biodiversity: black guillemot; circalittoral sand and coarse sediment communities; horse mussel beds; kelp and seaweed communities on sublittoral sediment; maerl beds; shallow tide-swept coarse sands with burrowing bivalves
Foula	SPA	The Shetland Islands	4	70	Breeding seabird assemblage and individual species of international importance
Hermaness, Saxa Vord and Valla Field	SPA	The Shetland Islands	4	70	Breeding seabird assemblage and individual species of international importance
Mousa	SAC	The Shetland Islands	4	70	Annex II species: Common seal
Mousa to Boddam	NCMPA	The Shetland Islands	4	70	Biodiversity: sandeels
Noss	SPA	The Shetland Islands	4	70	Breeding seabird assemblage and individual species of international importance
East Mainland Coast, Shetland	SPA	The Shetland Islands	4	70	Breeding habitat for Red-throated diver, Great northern diver and Slavonian grebe of national importance
Pobie Bank	SAC	Offshore	4	70	Annex I Habitats: reefs
Sumburgh Head	SPA	The Shetland Islands	4	70	Breeding seabird assemblage and individual species of international importance
Yell Sound Coast	SAC	The Shetland Islands	4	70	Annex II species: otter
Fulmar	MCZ	Offshore	5	70	Broadscale habitat: subtidal sand; subtidal mud; subtidal mixed sediments. Habitat features of conservation importance: ocean quahog.
Fair Isle	SPA	The Shetland Islands	4	70	Breeding seabird assemblage of international importance and breeding species of European importance

Name	Designation	Location	Minimum Arrival Time [days]	Maximum Probability [%]	Qualifying Features (SAC: Only marine and intertidal habitats are listed; SPA: individual species of international importance refers to relevant biogeographic area for each species; MPA/MCZ: Geodiversity Features not listed)
Buchan Ness to Collieston Coast	SPA	Grampian	4	60	Breeding seabird assemblage of international importance
Southern Trench	NCMPA	Grampian	4	60	Annex II species minke whale and protected habitats (burrowed mud, fronts and shelf deeps)
Fowlsheugh	SPA	Grampian	4	60	Breeding seabird assemblage and individual species of international importance
Ythan Estuary, Sands of Forvie and Meikle Loch	SPA	Grampian	4	60	Non-breeding waterfowl assemblage of international importance
Montrose Basin	SPA	Grampian	4	60	Overwintering seabird assemblage and individual species of international importance
Troup, Pennan and Lion's Heads	SPA	Grampian	4	60	Breeding seabird assemblage and individual species of international importance
Firth of Forth Banks Complex	NCMPA	Offshore	7	60	Biodiversity: ocean quahog aggregations; offshore subtidal sands and gravels; shelf banks and mounds
Swallow Sand	MCZ	Offshore	8	60	Broadscale habitat: subtidal coarse sediment; subtidal sand
Calf of Eday	SPA	The Orkney Islands	4	50	Breeding seabird assemblage of international importance
Copinsay	SPA	The Orkney Islands	4	50	Breeding seabird assemblage of international importance
East Sanday Coast	SPA	The Orkney Islands	4	50	Overwintering species of European importance
Faray and Holm of Faray	SAC	The Orkney Islands	4	50	Annex II species: grey seal
Hoy	SAC	The Orkney Islands	4	50	Annex I Habitats: vegetated sea cliffs of the Atlantic and Baltic coasts
Hoy	SPA	The Orkney Islands	4	50	Breeding seabird assemblage and individual species of international importance
North-West Orkney	NCMPA	Offshore	4	50	Biodiversity: sandeels
Papa Westray	NCMPA	The Orkney Islands	4	50	Black guillemot
Rousay	SPA	The Orkney Islands	4	50	Individual species of international importance
Sanday	SAC	The Orkney Islands	4	50	Annex I habitats: reefs. Annex II species: common seal
Seas off Foula	SPA	Offshore	4	50	Breeding seabird assemblage and individual species of international importance (including at least 5% of British population of Great Skua), as well as migratory seabird assemblage during non-breeding season.
Wyre and Rousay Sounds	NCMPA	The Orkney Islands	4	50	Biodiversity: kelp and seaweed communities on sublittoral sediment; maerl beds
Dogger Bank	SAC	Offshore	10	40	Annex I Habitats: Sandbanks which are slightly covered by sea water all the time
Firth of Forth	SPA	Tayside and Fife	10	40	Overwintering wetland assemblage of international importance and individual species of international importance on passage and over-winter
Firth of Tay and Eden Estuary	SPA	Tayside and Fife	10	40	Overwintering wetland assemblage of international importance and individual species of international importance during breeding season and over winter
Firth of Tay and Eden Estuary	SAC	Tayside and Fife	10	40	Annex I Habitats: Estuaries. Annex II Species: common seal

Name	Designation	Location	Minimum Arrival Time [days]	Maximum Probability [%]	Qualifying Features (SAC: Only marine and intertidal habitats are listed; SPA: individual species of international importance refers to relevant biogeographic area for each species; MPA/MCZ: Geodiversity Features not listed)
Firth of Forth Islands	SPA	Tayside and Fife	10	40	Breeding seabird assemblage and individual species of international importance
Outer Firth of Forth and St Andrews Bay Complex	SPA	Tayside and Fife	10	40	Breeding and non-breeding seabird assemblage of international importance
Isle of May	SAC	Tayside and Fife	10	40	Annex II species: grey seal
Southern North Sea	SAC	Offshore	15	40	Annex II species: harbour porpoise
Berwickshire and North Northumberland Coast	SAC	Lothian and Borders	10	30	Annex I Habitats: Mudflats and sandflats not covered by seawater at low tide; Large shallow inlets and bays; Reefs; Submerged or partially submerged sea caves. Annex II Species: grey seal
St Abbs Head to Fast Castle	SPA	Lothian and Borders	10	30	Breeding seabird assemblage of international importance
St Abbs Head to Fast Castle	SAC	Lothian and Borders	10	30	Annex II Habitats: Vegetated sea cliffs of the Atlantic and Baltic Coasts
Berwick to St Mary's	MCZ	North-east England	15	30	Highly mobile species: common eider
Coquet to St Mary's	MCZ	North-east England	15	30	Broadscale marine habitat: high energy infralittoral rock; high energy intertidal rock; intertidal coarse sediment; intertidal mixed sediments; intertidal mud; intertidal sand and muddy sand; low energy intertidal rock; moderate energy circalittoral rock; moderate energy infralittoral rock; moderate energy intertidal rock; subtidal coarse sediment; subtidal mixed sediments; subtidal mud; subtidal sand; intertidal under-boulder communities; peat and clay exposures
Northumberland Marine	SPA	North-east England	15	30	Breeding seabird assemblage and individual species of international importance
Northumbria Coast	SPA	North-east England	15	30	Individual species of international importance during the breeding season and over winter
Runswick Bay	MCZ	North-east England	15	30	Broadscale habitat: low energy intertidal rock; Moderate energy intertidal rock; High energy intertidal rock; Intertidal sand and muddy sand; Moderate energy infralittoral rock; Moderate energy circalittoral rock; Subtidal coarse sediment; Subtidal mixed sediments; Subtidal sand; Subtidal mud. Species features of conservation importance: ocean quahog.
Teesmouth and Cleveland Coast	SPA	North East England	15	30	Seabird assemblage and individual species of international importance, including during breeding season, overwintering and on passage
Cromarty Firth	SPA	Highlands	7	30	Overwintering wetland assemblage of international importance and Individual species of international importance
Dornoch Firth and Loch Fleet	SPA	Highlands	7	30	Wetland assemblage of international importance and individual species of international importance during breeding season
Dornoch Firth and Morrich More	SAC	Highlands	7	30	Annex I Habitats: Estuaries; Mudflats and sandflats not covered by seawater at low tide; Salicornia and other annuals colonizing mud and sand; Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*); Embryonic shifting dunes. Annex II Species: otter; common seal.
East Caithness Cliffs	NCMPA	Highlands	7	30	Biodiversity: Black guillemot
East Caithness Cliffs	SAC	Highlands	7	30	Annex I Habitats: Vegetated sea cliffs of the Atlantic and Baltic coasts
East Caithness Cliffs	SPA	Highlands	7	30	Breeding seabird assemblage and individual species of international importance

Name	Designation	Location	Minimum Arrival Time [days]	Maximum Probability [%]	Qualifying Features (SAC: Only marine and intertidal habitats are listed; SPA: individual species of international importance refers to relevant biogeographic area for each species; MPA/MCZ: Geodiversity Features not listed)
Moray and Nairn Coast	SPA	Highlands	7	30	Seabird assemblage and individual species of international importance, including during breeding season and overwintering
Moray Firth	SAC	Highlands	7	30	Annex II Species: bottlenose dolphin
Noss Head	NCMPA	Highlands	7	30	Biodiversity: horse mussel beds

Source: Petrofac, 2019; NatureScot, 2022b; JNCC, 2022c.

11.6.2 Sea Surface Oiling

Section 11.5.1.6 describes the sensitivities of birds on the sea surface to oiling, and Figure 11.10 demonstrates that at certain times of year there is potential for high densities of birds to be present on the sea surface in the wider vicinity of the proposed Avalon Field Development. Thirty-two of the protected sites listed in Table 11.8 are SPAs designated for the protection of birds listed under Annex I of the Birds Directive. Three NCMPAs are also designated for the black guillemot, and the Berwick to St Mary's MCZ is designated for the common eider. The majority of these sites are designated for the assemblage of birds that they support, and some are additionally designated for supporting a significant proportion of the population of certain species. It would be very unlikely for a spill to affect all of these sites, and so it would be expected that in the event of an oil spill affecting one of the sites, population recruitment would likely occur from other neighbouring sites by the following breeding season. The Fair Isle SPA supports 100 % of the breeding population of Fair Isle wren, and so this species would not be able to recruit from neighbouring populations. However, this species forages inland and would therefore not be expected to be impacted by an oil spill.

Marine mammals may also be sensitive to sea surface oiling, as discussed in Section 11.5.1.5. Ten of the SACs and one NCMPA listed in Table 11.8 have been designated for the protection of marine mammals under Annex II of the Habitats Directive, as follows:

- Common seals: Sanday; Mousa; Firth of Tay and Eden Estuary; and Dornoch Firth and Morrich More SACs;
- Grey seals: Faray and Holm of Faray; Isle of May; and Berwickshire and North Northumberland Coast SACs;
- Otters: Yell Sound Coast and Dornoch Firth and Morrich More SACs;
- Harbour porpoise: Southern North Sea SAC;
- Bottlenose dolphin: Moray Firth SAC; and
- Minke whale: Southern Trench NCMPA.

However, some species marine mammals may be able to avoid surface oiling however studies in the Gulf of Mexico noted that avoidance of oil by some cetaceans did not occur (Aichinger Dias et al., 2017). Therefore, given the temporary nature of an oil spill to surface and the low density of marine mammals across the Avalon Field Development area, it would not be expected that marine mammals would suffer a significant adverse effect.

Using the environmental consequence assessment method (Table 11.7; Patin, 2004), the assessment of this scenario is summarised in Table 11.9.

Table 11.9: Environmental Consequence Assessment for Sea Surface Oiling

Scale	Assessment	Justification
Spatial	Sub-regional	Maximum extent of spill
Temporal	Long-term	Expected recovery by the following breeding season, in around 1 year
Reversibility	Reversible	The disturbance to the environment would be removed within 1 year
General	Moderate	Change expected in no more than 1 % of the population

In summary, although potential for recovery would be good, surface oil contamination has the potential to cause a measurable significant adverse effect to protected species. Therefore, there is the potential for a MEI to occur as a result of sea surface oiling at the following protected sites:

- SPAs: Fetlar; Bluemull and Colgrave Sounds; Foula; Hermaness, Saxa Vord and Valla Field; Noss; East Mainland Coast, Shetland; Sumburgh Head; Fair Isle; Buchan Ness to Collieston Coast; Fowlsheugh; Ythan Estuary, Sands of Forvie and Meikle Loch; Montrose Basin; Troup, Pennan and Lion's Heads; Calf of Eday; Copinsay; East Sanday Coast; Hoy; Rousay; Firth of Forth; Firth of Tay and Eden Estuary; Firth of Forth Islands; Outer Firth of Forth and St Andrews Bay Complex; St Abbs Head to Fast Castle; Northumberland Marine; Northumbria Coast; Teesmouth and Cleveland Coast; Cromarty Firth; Dornoch Firth and Loch Fleet; East Caithness Cliffs; Moray and Nairn Coast and Seas off Foula;
- NCMPAs: Southern Trench; East Caithness Cliffs; Fetlar to Haroldswick; and Papa Westray; and
- MCZ: Berwick to St Mary's.

11.6.3 Shoreline Oiling

A number of the SACs listed in Table 11.8 have been designated for the protection of coastal or shallow water habitats. These habitats include:

- Estuaries (Firth of Tay and Eden Estuary; Dornoch Firth and Morrich More);
- Mudflats and sandflats (Dornoch Firth and Morrich More; Berwickshire and North Northumberland Coast);
- Salt meadows (Dornoch Firth and Morrich More);
- Dunes (Dornoch Firth and Morrich More);
- Large shallow inlets and bays (Berwickshire and North Northumberland Coast);
- Reefs (Sanday);
- Submerged or partially submerged sea caves (Berwickshire and North Northumberland Coast); and
- Vegetated sea cliffs (Fair Isle; Hoy; East Caithness Cliffs; St Abbs to Fast Castle).

Additionally, two NCMPAs have been designated for kelp and seaweed communities on sublittoral sediment and maerl beds (Fetlar to Haroldswick; Wyre and Rousay Sounds) and for circalittoral sand and coarse sediment communities; horse mussel beds; and shallow tide-swept coarse sands with burrowing bivalves (Fetlar to Haroldswick). These habitats have varying vulnerability to oiling, as discussed in Section 11.5.2.

The impact of oiling on sublittoral benthic habitats such as reefs, kelp and seaweed communities, horse mussel beds and maerl beds is assessed below in the context of sediment oiling.

Rocky shores are high energy environments which generally have the ability to recover quickly in the event of oiling. Sea caves would therefore not be expected to be a vulnerable habitat. Tide swept coarse sands and coarse sediment communities are similarly high energy environments and tend to be less productive than more sheltered areas. Although oil would be able to penetrate into these sediments, the high degree of disturbance and mixing would mean that recovery would be expected to be relatively fast.

Exposure to the sea is a key determinant for which vegetated sea cliff habitats are designated, and this habitat is found in the spray zone of high energy cliffs. However, this small amount of exposure to sea water means that the potential for oil to cause significant adverse effect to this habitat is minimal. Likewise, the position of sand dunes and salt meadows at the most inland extent of coastal environments minimises the risk of these habitats being affected.

Estuaries, mud flats, sand flats and shallow inlets and bays are likely to be the most vulnerable habitats to the effects of oil spills (Section 11.5.2.2). These lower energy environments are highly productive and are likely to take a longer time to recover in the event of significant adverse effect.

The SPAs (and the NCMPAS / MCZ designated for birds) listed in Table 11.8 are considered less vulnerable to shoreline oiling than to sea surface oiling (discussed above). Breeding and overwintering sites used by birds tend to be on the upper stretches of cliffs or on grassy slopes beyond the high-water mark, and so shoreline oiling is likely to have less of an impact on birds than that on the sea surface.

Using the environmental consequence from Table 11.7 (Patin, 2004), the assessment of this scenario is summarised in Table 11.10.

Table 11.10: Environmental Consequence Assessment for Shoreline Oiling

Scale	Assessment	Justification
Spatial	Sub-regional	Maximum extent of spill
Temporal	Chronic	Expected recovery to soft sediment habitats to take more than 1 year
Reversibility	Slightly reversible	The disturbance to the environment would take longer than 1 year to be removed from soft sediment environments
General	Moderate	Change expected in no more than 1% of the population

In summary, shoreline oil contamination has the potential to cause a measurable significant adverse effect to protected sedimentary shores. Therefore, there is the potential for a MEI to occur as a result of shoreline oiling at the following protected sites:

- Firth of Tay and Eden Estuary SAC;
- Dornoch Firth and Morrich More SAC; and
- Berwickshire and North Northumberland Coast SAC.

11.6.4 Sediment Oiling

A number of the protected sites listed in Table 11.8 have been designated for offshore benthic habitats and the species associated with these habitats, with the potential to be affected by sediment oiling. Four SACs have been designated for Annex I habitats:

- Reefs (Pobie Bank);
- Sandbanks (Dogger Bank); and
- Submarine structures made by leaking gases (Scanner Pockmarks; Braemar Pockmarks).

Six NCMPAs have been designated for the following habitats:

- Offshore subtidal sands and gravels (East of Gannet and Montrose Fields, Norwegian Boundary Sediment Plain, Firth of Forth Banks Complex);
- Offshore deep-sea muds (East of Gannet and Montrose Fields);
- Burrowed mud (Southern Trench, Central Fladen).

Additionally, four NCMPAs have been designated for species present in these habitats;

- Ocean quahog (East of Gannet and Montrose Fields, Norwegian Boundary Sediment Plain, Firth of Forth Banks Complex);
- Sandeels (North-West Orkney and Turbot Bank).

One MCZ, Fulmar, is also present, and has been designated for the habitats subtidal sand; subtidal mud and subtidal mixed sediments, as well as for the species ocean quahog.

Additionally, some coastal protected sites (as discussed above under shoreline oiling) have designations for sublittoral benthic habitats including reefs, kelp and seaweed communities, horse mussel beds and maerl beds.

The potential impact of oiling on benthic habitats and the species associated with them is discussed in Section 11.5.1.2. The deterministic oil spill modelling carried out for the Avalon Field Development provided a mass balance for the fate of oil, which indicated that around 5 % of the oil in the event of a worst-case scenario spill may end up in seabed sediments. However, the modelling indicated that sediment oiling would not reach a concentration higher than 50 µg/g in any location. Temporal studies into levels of hydrocarbons in sediments in the CNS have shown that a concentration of 50 µg/g is common in this area, meaning that any sediment oiling from the proposed Avalon Field Development would be unlikely to be higher than background levels (Marine Scotland, 2008). Therefore, it would not be expected that benthic habitats and species would be subject to significant adverse effect.

Using the environmental consequence assessment (Table 11.7; Patin, 2004), the assessment of this scenario is summarised in Table 11.11.

Table 11.11: Environmental Consequence Assessment for Sediment Oiling

Scale	Assessment	Justification
Spatial	Sub-regional	Maximum extent of spill
Temporal	Temporary	Expected recovery within one season
Reversibility	Reversible	The disturbance to the environment would be removed within 1 year
General	Moderate	Change expected in no more than 1% of the population

In summary, shoreline oil contamination is not expected to have the potential to cause a measurable significant adverse effect to protected seabed sediments. Therefore, there is no potential for a MEI to occur as a result of sediment oiling.

11.6.5 MEI Assessment Conclusions

The MEI assessment shows that a large oil spill from the Avalon Field Development will have the potential to cause a significant adverse effect to up to 32 SPAs, 4 NCMPAs and one MCZ as a result of surface oiling, and to 3 SACs as a result of shoreline oiling. It should be noted however, that this assessment is based on stochastic modelling results. Stochastic modelling results are not representative of the effects of a single spill event but illustrate the potential total geographic range of any oil spill event, based on hundreds of individual spill scenarios using a wide variety of metocean conditions. In the event of an actual oil spill, the affected area(s) will be much more localised and will depend on the volume of oil spilled and local metocean conditions at the time.

11.7 Mitigation Measures

11.7.1 Preventative Measures

In order to prevent an oil spill occurring, stringent safety and operational procedures will be followed at all times.

11.7.1.1 Training, Experience and Suitability of Equipment

PPUK is aware of the risk of a hydrocarbon spill at the proposed Avalon Field Development. Before offshore operations commence, PPUK and their appointed Installation/Well Operator will fully assess the competence and experience of all contractors, and the suitability of all equipment to operate in the CNS area. All offshore personnel will be appropriately trained, experienced and certified to carry out their specific duties. The crew of the MODU and FPSO will also undergo environmental awareness and safety training.

11.7.1.2 Well Design

The Avalon wells have been designed to minimise the potential for well control problems. A thorough and formal peer-review approach will be used to review all critical elements of the well design and the execution of drilling and abandoning the well. In addition, the well design will be independently reviewed by a Well Examiner, as is required for all wells in the UK. The Well Examiner will also monitor the actual construction and any modifications to the well.

Any change or deviation to the drilling programme, the subsurface parameters for the well design, or the well construction itself, will be subject to a formal management of change process. The purpose of this process is to identify, assess and document any changes prior to them being made. Each change requires management approval.

11.7.1.3 Well Control

Well control procedures will be implemented, to prevent uncontrolled well flow to the surface and a full risk assessment will be performed as part of the planning phase of each well. Data on well pressure will be monitored throughout the drilling operations, to allow suitable mud composition and mud weights to be used.

A BOP will be put in place once the 17½" section has been drilled and 13⅜" casing run in order to prevent the uncontrolled release of hydrocarbons from the well. The BOP stack and associated well control equipment on the MODU will be all rated to at least 15 000 psi working pressure. The BOP will be fully redundant, which means it can be operated independently from two physically separated locations onboard the MODU. In addition to the standard control systems, the BOP typically has several other backup emergency control systems, namely:

- Emergency Disconnect System (EDS). A single activation button closes the shear rams (large valves) on the BOP, followed by Choke and Kill line fail safe valves. The control system then automatically unlatches the top section of the BOP, i.e. the Lower Marine Riser Package (LMRP), from the main BOP;
- Autoshear System. In the event of an unplanned unlatch of the LMRP from the BOP, a pre-selected series of BOP rams shut and will close off the well;
- Acoustic Control System. Remote activation of the BOP via acoustic transponders can be used to operate a number of the BOP functions to make the well safe;
- Remotely Operated Vehicle (ROV) Intervention Panel. Numerous functions on the BOP can be operated by an ROV either by manual valve operation or stabbing into the BOP and using a pump on the ROV; and
- Automatic Mode Function (AMF). On total loss of electric controls and hydraulic supplies, the BOP shear rams close automatically by means of a dedicated accumulator supply.

The BOP will be independently inspected and verified periodically. Regular testing of the BOP and its back up systems will take place onboard the MODU, typically at 7- and 21-day intervals.

11.7.1.4 Diesel/Fuel Oil Bunkering Procedures

The highest risk of spillages occurs during bunkering operations between the FPSO/MODU and supply vessels and during the transfer of crude oil from the FPSO to shuttle tankers for export. Vessel audits will be performed to confirm sea worthiness of bunkering vessels, and only Dynamically Positioned (DP) vessels will be used, thus reducing likelihood of collision and potential tank rupturing. Bunkering and offloading operations will only take place during hours of good visibility, in suitable weather conditions, and with a dedicated and continuous watch posted at both ends of the fuel/offloading hose. Where offtake operations require to be undertaken during periods of low visibility, initial connection operations for crude offtake will be limited to connection and planned disconnection during daylight hours only, with offloading within the prescribed weather limitation continuing throughout the night.

All hoses used during bunkering/offloading will be segmented with pressure valves that will close automatically in the event of a drop in pressure, such as might be caused by a broken connection or a leaking hose. In addition, the bunkering/offloading hoses will be stored on reels, to prevent wear and damage. These hoses will be visually inspected, and their connections tested prior to every loading operation. Bunkering/offloading procedures will be followed throughout all bunkering/offloading operations. In addition, vendor specific hose leak detection systems will be reviewed and assessed during the procurement of the hoses.

11.7.1.5 FPSO Design

The loss of crude oil from one or all of the cargo storage tanks onboard the FPSO is extremely unlikely and would only be expected to occur during a major collision with another vessel or as a result of a natural disaster or similar event, whereby the integrity of the FPSO itself would be compromised. The FPSO will be designed with double bottom/doubled-sided hull. In addition, the cargo tanks will be configured with ballast tanks on the outside, offering protection from cargo tanks and reduced probability of loss. Section 11.8, on the potential impacts in case of catastrophic loss of the FPSO, describes further mitigation measures in place to prevent a serious collision event from happening.

11.7.1.6 Other Safety Measures

All equipment used on the FPSO and the MODU will have safety measures built in to minimise the risks of any hydrocarbon spillage. For example, the FPSO and the MODU will have open and closed drain systems in place that will route any operational spills onboard the FPSO and MODU to the slop tanks where they can be contained and recovered. A number of spill kits will be available to deal with (smaller) spillages. All supply vessels will operate via DP, in order to reduce likelihood of collision and therefore potential tank rupturing.

11.7.1.7 Pipeline Maintenance and Control

The pipelines and umbilicals associated with the Avalon Field Development will be subject to a rigorous inspection and maintenance regime to ensure they are kept in optimum condition through the life of field. Periodic pipeline surveys, comprising ROV inspections, and an inspection repair and maintenance plan will be in place. Inspection intervals will be reviewed following receipt of inspection information and, where appropriate, future intervals are adjusted.

11.7.2 Action to Stop a Subsea Spill During Drilling with the MODU

11.7.2.1 Initial Actions

The initial response to a subsea spill will be to use the ROV to identify the source of the leak. However, if at any time the safety of the MODU becomes compromised, the first priority will be to close the BOP, disconnect the MODU from the well, and move off location. While the BOP is designed as fail safe closed, ROV and acoustic overrides are available should this not work correctly. This will allow the BOP to be closed within 24 hours, even if the MODU has to move off location first. Once at a safe distance from the well location, the ROV can be deployed to verify the BOP is properly closed, and no more oil is being spilled.

In a situation where the MODU is not disconnected from the well, and depending on when in the programme of operations a blow-out occurs, there may be various other methods available to control the flow of hydrocarbons to the surface. These include varying the pump rate and the use of various chemicals, such as weighting material (barite or calcium carbonate) and cement. Therefore, a contingency stock of cement and barite will be kept onboard the MODU. Although the time required to kill the well will be dependent on the how and why it has failed, a standard well kill operation takes between 12 and 48 hours. Once control of the well has been regained, the well can be fully abandoned with cement plugs.

11.7.2.2 Capping the Well

In the event of a subsea blow-out, whereby the BOP has failed, and oil is freely flowing into the sea, the possibility of fitting a temporary capping device to the well will be considered. Once installed, this type of cap will completely seal off the well and stop oil from spilling into the sea whilst a relief well is drilled, and the original well is killed. This is currently regarded as the most likely successful approach to containing an uncontrolled subsea blow-out.

PPUK is a member of Oil Spill Response Ltd (OSRL), which allows PPUK access to the Oil Spill Prevention and Response Advisory Group (OSPRAG) Capping Device. The OSPRAG well capping device is of a modular design which will allow installation at various points of the subsea wellhead or the BOP. PPUK has reviewed the technical specifications of the cap and has confirmed that it is compatible with the subsea equipment proposed for use at Avalon. The Avalon wells fall within the maximum technical specifications for well flow rate, pressure and temperature, confirming that this device is suitable for use. This capping device would be PPUK's primary option for sealing the well, if required.

At approximately 40 tonnes, the capping device is suitable for installation by a light intervention vessel. In the event that it is required, the device would be transported from Aberdeen to the Avalon field, for deployment from a light well intervention vessel. Although no contract is in place for such a vessel, the type of vessel required to install the cap is relatively easy to procure and deploy. PPUK is confident that a suitable vessel would be able to be procured at very short notice.

In the event of an uncontrolled well blow-out, it is anticipated that it would take a total of 33 days until the capping device could be deployed and the well contained. This timeframe would include sourcing of an appropriate vessel, mobilisation of the capping device to the Avalon field, site preparation and clearance at the well location, deployment of the capping device and well containment. A full timetable for this procedure will be provided in PPUK's Temporary Operations Oil Pollution Emergency Plan (TOOPEP) covering the Avalon drilling operations.

11.7.2.3 Drilling a Relief Well

In the extremely unlikely event where a blow-out situation occurred and all options to kill the well failed, the only remaining option to bring the well back under control to stop the spill may be to drill a relief well. This would also apply as the required operation to permanently close the well once the well capping device (described above) was fitted. In this situation, PPUK will comply with the latest version of the Offshore Energies UK (OEUK), formerly Oil & Gas UK, "Guidelines on Relief Well Planning – Subsea Wells" (currently Issue 2, January 2013) which has been prepared by the OEUK Well Life Cycle Practices Forum.

11.7.2.4 Securing Required Equipment

As a worst-case scenario, it is assumed that an additional suitable MODU would be required to conduct the relief well operations. It has been confirmed that the metocean conditions and water depths present in the CNS mean that there are no special technical requirements for MODUs to be capable of drilling in this area. The availability of suitable alternative MODUs will be monitored throughout the drilling operations at the Avalon Field. It has been estimated that it would take around three weeks to source an alternative suitable MODU, for the current operations to be suspended, and to move the unit onto the well location.

In addition to the drilling unit, all of the required drilling equipment will also have to be sourced and mobilised. In order to minimise the time involved, equipment would be sourced from off the shelf supplies and borrowed from other operators. Throughout this planning and preparation process, it is assumed that other license holders, drilling rig contractors and the government agencies would co-operate where required.

Planning for the relief well will include a review of the original well design and the reasons for the uncontrolled well blow-out, allowing any required changes to well design, equipment and operating procedures to be implemented. Preparation of equipment, procedures and consent applications will all be conducted in parallel with the activities required to gain access to a suitable replacement drilling unit.

11.7.2.5 Drilling the Relief Well

Several alternative relief well locations around the Avalon field will be identified in the Relief Well Plan. All of these locations will be covered by digital site survey lines, enabling shallow gas and drilling hazard studies to be carried out within 5 days of the best relief well site being selected. A well path will be created to ensure that the suggested well surface locations are suitable and can be quickly tailored to the actual relief well programme if required in a blow-out situation. In order to optimise the relief well design, planning at the time of an incident will include a review of the current location and directional plans, along with the reasons for well failure and the resultant uncontrolled blow-out. This will allow any required changes to be made to relief well design and equipment, and additional operating procedures to be implemented if required.

Once a suitable MODU has been sourced and mobilised to location (expected to take three weeks, as stated above), and a relief well design selected, is anticipated that it would then take approximately 60 days to drill a relief well and kill the original well. Once the relief well reaches the original well, well kill operations would be carried out to permanently abandon it.

11.7.3 Oil Spill Response

If a large well control incident were to occur, it would be a priority to avoid spill hydrocarbons impacting the coastline and, therefore, PPUK would employ all available and suitable oil spill response techniques in the event of a spillage moving towards the shore.

11.7.3.1 Oil Pollution Emergency Plan

PPUK will have a TOOPEP in place to cover the proposed Avalon drilling operations and an OPEP in place to cover production operations prior to the Avalon field commencing production.

The TOOPEP and OPEP will conform to the Merchant Shipping (Oil Pollution, Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015 and the Offshore Installations (Emergency Pollution Control) Regulations 2002. The TOOPEP and OPEP will fully consider the specific oil spill response requirements for the Avalon Field Development, taking into account the location, the prevailing meteorological conditions and the environmental sensitivities of the area. The plans will be designed to assist the decision-making process during a hydrocarbon spill, indicate what resources are required to combat the spill, minimise any further discharges and mitigate its effects.

11.7.3.2 Training, Exercises and Experience

Offshore Personnel

Specific members of the FPSO/MODU and standby vessel crew will have undertaken OPEP level oil spill response training. The Offshore Installation Manager (OIM) and the Installation/well Operator offshore representative will have undertaken the OPRED course for On-Scene Commander (OPEP Level 1).

As a minimum, the TOOPEP and OPEP will be distributed to personnel with designated duties in the event that an oil spill response is required, and to the regulatory authorities and statutory consultees. On receipt of the TOOPEP and OPEP, personnel will undergo awareness training in oil spill response prior to the commencement of drilling operations. The aim of this training is to familiarise offshore personnel with PPUK’s oil spill procedures, levels of response effort, equipment orientation and use, and communication and reporting during an oil spill of any size.

During the proposed drilling operations, the MODU will regularly undertake training exercises, including vessel-based oil spill response exercises for the crew and an Offshore TOOPEP Exercise while on site, to ensure that offshore personnel are familiar with the TOOPEP and their responsibilities during a response. Similar offshore exercises will be held periodically for the FPSO’s OPEP once it has been implemented to ensure familiarity with its requirements.

Onshore Personnel

External oil spill response training will be organised for key onshore personnel, in line with the OPRED requirements and the internal requirements of environmental training and continual improvement in PPUK’s Management System. Relevant PPUK Duty Managers will, as a minimum, have undertaken the OPRED course, Corporate Management oil spill response awareness (OPEP Level 2). PPUK is a member of OSRL, and a response advisor with OPEP Level 4 training would also be provided by OSRL.

Desktop exercises will be undertaken prior to commencement of operations to test the effectiveness of the TOOPEP and OPEP. PPUK will conduct these oil spill response exercises to ensure that all personnel are aware of their roles in an actual oil spill incident. The exercises will also familiarise personnel with the lines of communication between the FPSO/MODU, offshore, the Installation/Well Operator and PPUK onshore. The exercises will include familiarisation of the roles and responsibilities of the various interested parties, and the chosen response strategies. If necessary, the TOOPEP and/or OPEP will be updated to reflect any changes required as a result of these exercises.

11.7.4 Oil Spill Response Strategies

The most appropriate response to a hydrocarbon spill from the planned drilling operations will be determined by oil type, logistics and prevailing physical conditions. A precise response strategy, which may employ one or more of the response options described below, can only be decided at the time of the spill. Oil spill response personnel must be prepared to adapt their actions as the spill develops as changes in both the prevailing conditions and the oil properties dictate.

In general, there are four groups of response strategies which could be deployed in the event of an oil spill:

- Natural dispersion and monitoring;
- Application of chemical dispersants;
- Containment and recovery (surface and subsea); and
- Shoreline protection and clean-up.

11.7.4.1 Natural Dispersion and Monitoring

Small to medium crude spill and diesel spills of all sizes are often best monitored but otherwise left to naturally degrade, if spilled offshore far away from any coastline. The natural evaporation and dispersion processes described in Section 11.3.2 will often be enough to successfully disperse the crude or diesel. These processes can be enhanced, where practicable, by physical agitation of the slick by the standby vessel and other vessels on site.

It is proposed that, in the event of a crude or diesel spill incident, the principal response strategy will be the monitoring and surveillance of the slick, where evaporation and natural dispersion will be the principle mechanisms for removal of oil from the sea surface.

On-site and Aerial Surveillance

A standby vessel will be on site at all times during drilling operations in the Avalon field. In the early stages of an incident, the slick may be monitored by this onsite standby vessel, provided it can still meet its safety function. In the short term, aerial surveillance may also be undertaken by the helicopter contractor. However, for larger, ongoing spills, aircraft may be mobilised to undertake aerial surveillance.

A contract with OSRL will be put in place, allowing the rapid deployment of a dedicated aerial surveillance aircraft. The use of aerial surveillance in the monitoring of oil spills, as opposed to sea level vessels, allows for a more accurate picture of spill size and movement to be formed, especially in the monitoring of larger, more mobile spills. This would enable the development of various response options, including the decision to monitor the spill as it disperses naturally.

Oil Spill Modelling

Tracking and monitoring of the spilled oil would commence as soon as possible after the incident has occurred and continue for the duration of the response. This will be used to evaluate the extent of the slick, monitor its movement and dispersal, and decide on the appropriate response.

Initially, manual predictions can be used to estimate the movement of the oil on the sea surface as a function of the wind and current speed and direction. Oil spill modelling would also be employed to gain a more accurate indication of oil spill movement, using real time parameters to assist the predictions.

11.7.4.2 Chemical Dispersants

To aid natural dispersion of a large oil spill, or when sensitive receptors such as flocks of seabirds are at risk, PPUK will consider applying chemical dispersants. As a member of ORSL, PPUK will have access to the UK Dispersant Stockpile. The use of chemical dispersants has been found to be effective when sprayed onto fresh oil in moderate sea states, which are often present in the Avalon area. However, chemicals dispersants are ineffective on emulsified or weathered oils spills. Before use, the effectiveness of the available dispersant must always be tested on an actual sample of the spilled oil before using dispersants on the slick itself.

The use of chemical dispersants may therefore be considered for oil spills which are observed to not disperse naturally, in order to protect vulnerable concentrations of seabirds at sea or to prevent the oil slick from reaching a sensitive coastline. Dispersants can be sprayed directly onto floating oil as a fine mist, either from aircraft or boats. Large slicks can be treated quickly, deterring the formation of emulsions and accelerating the biodegradation of oil in the water column.

The natural processes of evaporation and dispersion will usually remove the lighter fractions from the spilled oil rapidly, without the need for chemical treatment. Dispersants are generally less effective on light oils, such as diesel, as the dispersants sink through the oil, reducing the contact time between the oil and water interface. As a result, chemical dispersants should generally not be used on these spilled light oils.

The use of chemical dispersants will result in increased concentrations of toxic components within the upper water column. Many spawning species have pelagic eggs and larvae which are vulnerable to oil which is chemically dispersed into the water column. These eggs and larvae may become exposed to higher concentrations of oil if dispersants were used, than if the oil had been allowed to evaporate and disperse naturally.

Therefore, the decision to use chemical dispersants will always need to consider its positive benefits against any resulting impacts in the water column.

11.7.4.3 Containment and Recovery

Booms may be used to contain a large slick on the sea surface, concentrating the oil for recovery by skimmers. The effectiveness of both booms and skimmers depends on the sea and weather conditions, with the most efficient containment and recovery of oil only achieved under calm conditions. In order to create a barrier with which to prevent the oil escaping, booms must move with the surface water. However, with the increasing flexibility required to achieve this in rougher seas, comes reduced boom rigidity and a corresponding reduction in its ability to contain oil. As skimmers float on the sea surface, they also experience many of the operational difficulties that apply to booms. The increased wind and water movement experienced in the CNS offshore environment suggests that surface containment and recovery equipment are unlikely to be effective on a spill at the proposed Avalon Development.

Recovery equipment requires the spilled oil to be of sufficient thickness to allow it to be lifted and sucked from the surface while disturbing the underlying water as little as possible. If the slick is too thin large quantities of water will be taken up by the process not only reducing the effectiveness of oil collection, but also causing additional issues for containment and disposal of the oily water. As the slick becomes increasingly spread out and broken up, the effectiveness of this response option decreases.

11.7.4.4 Shoreline Protection and Clean-up

Shoreline Protection

Where possible, the first priority should be to prevent spilled hydrocarbons from reaching coastal areas. As described above, a number of different response options are available to contain the spilled oil offshore or to limit the movement of the slick across the sea surface. However, there remains the potential for a large slick to threaten the shoreline communities.

The initial response to any spill will be onsite and aerial surveillance to track its movement, supplemented by modelling to predict which shorelines the spilled oil may threaten. With a better understanding of the shorelines at risk from the spill, information will be gathered on the coastal habitats present in these areas and their associated communities. Any coastal sensitivities, including vulnerable shoreline types, coastal and inshore protected areas (including those designated under the European Habitats and Birds Directives), areas of inshore fisheries or aquaculture, coastal tourist or recreational areas, and other coastal industries, will be identified. Throughout the well planning process, basic information has been gathered on the surrounding coastal sensitivities and this will be included within the TOOPEP during drilling and subsequent OPEP during the production phase to assist in any required oil spill response. This will be supplemented by the OSRL GIS facility (which maps coastal sensitivities around the UK), local authority plans, strategy documents, maps, and other available resources. The UK shoreline at the highest risk of oiling according to the oil spill modelling (Section 11.4) is the Shetland Islands; the Shetland Oil Terminal Environmental Advisory Group (SOTEAG) has produced shoreline sensitivity maps for the Shetland coastline. Broad-scale surveys, from vehicles, inshore vessels or helicopters, will be mobilised to gain an overview of the shoreline types and main sensitivities along the potentially affected stretch of coast, and consideration will be given to carrying out more detailed surveys of particularly environmentally sensitive or commercial important areas of shoreline prior to any oil beaching.

Once the coastal sensitivities under immediate threat have been identified, coastal protection resources will be deployed to protect priority areas. Although PPUK will provide all necessary assistance as required, all shoreline protection strategies will be determined by the local authority in consultation with their environmental advisors. Details of local equipment suitable and available for shoreline booming will be available through coastal strategy documents. Additional response personnel and appropriate shoreline protection equipment will be provided by OSRL as PPUK's oil spill response contractor.

Oil spill modelling has indicated that the coastlines of Norway and the Shetland Islands are under the greatest threat from beaching of crude oil (Section 11.4). These high energy coastlines are characterised by sea cliffs with little or no intertidal zone or exposed rocky shores consisting of bedrock platforms and boulders. Although oil may persist on more sheltered shores for longer, wave action may start to remove the oil from more exposed rocky shores more rapidly. With the dominance of exposed, vertical cliffs, it could be assumed that these northerly rocky shores would recover relatively quickly from a beaching oil spill, with minimum requirement for human intervention. These shores will also be the most difficult to protect with booms, due to access issues and the size of the approaching waves. As a result, priority is likely to be given to the more sensitive muddy shores and areas which hold fish and shellfish farms.

Shoreline Clean-up

Every effort will be made to clean-up up any oil that reaches the shoreline. Depending on the type of coastline affected, various methods exist to remove oil from the shore. Sediment shores are generally more amenable to methods that will physically 'scoop' the oil from the beach, whereas appropriate washing and rinsing techniques are likely to be more effective on rocky substrata.

If a spill does reach the shoreline, aerial surveillance will be used to gain a broad overview of where it has beached, while vehicles or vessels will be used to make a more detailed, shore specific assessment. Through OSRL, stretches of shoreline will be surveyed, recording the type of shoreline (sediment type, slope, exposure etc), its use (tourism, recreation, etc), and any environmental sensitivities (protected areas, seal breeding sites, otter holts, etc), as well as the severity of any oiling (mobile oil, surface or subsurface oil, stranded oil, sheen etc). Information on access arrangements, parking and storage arrangements, and proximity to other facilities will also be recorded. This information will be used to determine where to focus the clean-up effort by making the optimum use of the available clean-up resources.

In certain instances, the physical disturbances caused by some clean-up methods may be more damaging to shorelines and their associated communities than the direct effects of an oil spill. This is particularly true in more sensitive, less dynamic habitats, such as mudflats or saltmarsh. In addition, steeply sloping and unstable rocky shores or large soft mudflats are often difficult to access. Therefore, if oil does reach the shore, clean-up methods should be chosen carefully so as to not cause a greater degree of damage.

With all required assistance and information provided by PPUK and the Installation/Well Operator, the strategy for shoreline clean-up ultimately will be directed by the affected local authorities. Adequately trained personnel and clean-up equipment will be made available to assist any clean-up operations, through OSRL.

11.7.5 Liability and Insurance

PPUK will ensure that it has sufficient finances and insurance in place to cover the cost of responding to a large oil spill (including the use of a well capping device and drilling a relief well, if required). PPUK is a member of the Offshore Pollution Liability Association Limited (OPOL). OPOL is a voluntary oil pollution compensation scheme to which all offshore operators currently active on the UKCS are party to. OPOL is accepted as representing the committed response of the oil industry in dealing with compensation claims arising from offshore oil pollution incidents from exploration and production facilities. At present the OPOL Limit of Liability is US $250 million per incident. Based on a recent oil spill modelling study undertaken on behalf of the Oil Spill Prevention and Response Advisory Group (OSPRAG), the current occurrence limit should be sufficient to cover the third-party pollution compensation and remediation costs associated with the majority of spill scenarios, with only a small number of wells having the potential to exceed the OPOL Limit (OGUK, 2012).

While OPOL provides for third party clean-up and compensation costs to a predetermined limit, there may be additional extra expenses that the PPUK as the Licence Operator may have to cover in the event of a blow-out, such as those related to bringing the well back under control and drilling a relief well. PPUK will ensure that sufficient finance or insurance/indemnity provision is available to cover the drilling of relief wells.

11.8 Catastrophic Loss of the FPSO, MODU, Vessel or Helicopter

Under extreme circumstances, the FPSO, MODU, a support vessel or a helicopter may sink. This could be caused by a variety of reasons, such as a serious blow-out situation, shallow gas release, a collision with another vessel, a freak weather event or other natural disaster, a catastrophic error during ballasting or offloading of the FPSO or ballasting of the MODU. These events are extremely rare and happen so infrequently that no reliable statistics could be obtained to quantify them.

A raft of mitigation measures are in place for preventing such an event from happening, including the mitigation measures described in Section 11.7.4, as well as the following:

- The FPSO and MODU will be inspected for sea worthiness and the Well Operator/Installation Operator audited prior to operations commencing;
- Personnel will be appropriately trained, experienced and certified;
- The competence and experience of all contractors will be assessed before they are contracted;
- All supply vessels will operate via DP, to reduce the likelihood of a collision;

- A digital site survey for drilling hazards has been carried out to confirm that there is no shallow gas in the area;
- A 500 m exclusion zone will be enforced around the FPSO and MODU for general shipping in the area;
- A standby vessel will be on site through the life of the field to enforce the 500 m exclusion zone;
- The FPSO and MODU and associated vessels will use appropriate lighting;
- The suitability of supply, other support vessels and the helicopter will be assessed before they are contracted;
- The standby vessel will be equipped with radar and communication equipment so that any vessel in the area can be detected and contacted, if required; and
- The United Kingdom Hydrographic Office (UKHO) will be kept informed of drilling activities.

In the event of the loss of the FPSO, the MODU, a support vessel or helicopter, it would be unlikely that the vessel would be salvageable and, therefore, would most probably remain on the seabed as a wreck. Attempts would be made to salvage any remaining hydrocarbons and other potentially harmful products onboard the FPSO, MODU, vessel or helicopter, although it should be noted that, in practice, these types of operations are prone to causing pollution incidents. The potential impact of the release of oil to the marine environment is described above in Section 11.5.

The wreck of the FPSO, MODU, vessel or helicopter would be marked on navigational charts to prevent the snagging of fishing nets and other towed equipment. Shipwrecks UK (2022) has identified more than 50 000 wrecks in the waters around the UK and Ireland. In general, the presence of wrecks on the seabed is not considered to have any long lasting negative environmental effects. Therefore, given the remote chance of such an event happening due to appropriate mitigation measures in place, and minimal negative long-term environmental impacts, the residual impact of a loss of the MODU or a vessel is considered to be insignificant.

11.9 Conclusions

The risk of a large-scale hydrocarbon spill during drilling operations or during the subsequent production phase of the proposed Avalon Field Development is very low. Historic spill data shows that large (crude) oil spills from oil and gas installations are very rare on the UKCS, and the overall volume spilled each year continues to reduce gradually over time. There has never been an oil spill as a result of a well blow-out on the UKCS. Seven crude oil spills of more than 25 tonnes have been recorded during the period 1990-2021. Similarly, large oil spills from pipelines are also very rare, with 31 crude oil spills from pipelines in the period 1990 to 2021, four of which weighed more than 1 tonne.

The oil spill modelling scenario shows that a large spill, such as from a well blow-out or a complete loss of inventory from the pipeline, would, under the majority of meteorological circumstances, drift east and northeast of the proposed well location. A large oil spill would have the potential to reach the coasts of Norway, the Shetland Islands and north-east Scotland, with a lower probability of also reaching eastern Scotland, the Orkney Islands, north-east England, Denmark, Sweden and Germany. These conclusions are based on modelling results that assume no intervention in the slick whereas, in practice, oil spill response resources would be mobilised immediately if a spill occurred. It would be a priority for PPUK to attempt to ensure no spilled oil would impact the coastline and, therefore, all appropriate oil spill response techniques would be employed in the event of a spillage moving towards the shore.

It should be noted that these potential impacts would only occur under extreme circumstances in the event of a very large oil spill, as modelled in this ES. Historic data on oil spills from oil and gas installation operating on the UKCS show, that there has only been one crude oil spill of such a large size (112 tonnes) in the period 1990 to 2021. This spill happened in 1990. Historic data suggest small spills of less than 1 tonne represent the most likely spill scenarios.

Throughout the life of field, the focus will be on the prevention of oil spills. Stringent safety and operational procedures will be adhered to throughout the operations. A robust well design has been developed to minimise the potential for well control issues, and all critical elements of this design and the execution operations have been both peer and independently reviewed.

PPUK will ensure that the Installation Operator and Well Operator will have a detailed operation specific TOOPEP and OPEP in place, to ensure that immediate and appropriate action is taken in the event of any hydrocarbon spillage, minimising any impact to the marine environment. A contract with OSRL is in place, allowing the rapid deployment of oil spill response equipment and personnel in the event of a large oil spill incident. Specific response equipment would be available including booms, to contain surface spills at sea or protect sensitive shorelines. Ultimately, the type and size of spill, along with the metocean conditions at the time of the spill, will dictate which of these resources is most suitable for the spill event. Additional shore clean-up equipment is also available.

With the preventative steps and mitigation measures in place to avert an oil spill incident from occurring, and the oil spill contingency planning and response resources available to PPUK in the event of a large oil spill event, the residual effect of a release of oil from the proposed Avalon Field Development is judged to be minor and therefore not significant.

Section 12

Other Impacts

12. Other Impacts

This section assesses the potential impacts arising from waste production, natural disasters, underwater noise generation and collision risks, due to the construction and operation of the Avalon Field Development. The scope of this assessment has been informed by the outcomes of the Environmental Issues Identification (ENVID) exercise (Appendix 4), informal statutory consultation and National Marine Plan (NMP) policies and statutory guidance as explained in Section 5 (Identification of Impacts).

12.1 Waste Management

This Section provides a high-level description of waste management with regard to the proposed Avalon Field Development.

The management of waste is well regulated in the UK. The principal legislation governing waste from offshore vessels and facilities (including from FPSOs) is the Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008. These Regulations implement both the revised Annex IV of MARPOL 73/78 - Regulations for the Prevention of Pollution by Sewage from Ships, and the Annex V of MARPOL 73/78 (including amendments) - Regulations for the Prevention of Pollution by Garbage from Ships. Under these Regulations it is prohibited to dispose of any garbage (including plastics) and galley waste (except for ground food waste to < 25 mm and treated sewage) from any offshore installations or vessels.

Consequently, the sewage treatment system onboard the FPSO will be designed to meet the following standards in line with regulation 21(3) of the 2008 Regulations:

- Faecal Coliform Standard: Faecal coliform bacteria in the effluent should not exceed 1000/100 cm^3 Most Probable Number (MPN);
- Chlorine residual level to be no more than 0.5 mg/l, (by test) post maceration;
- Comminuting Standard: A sample of 1 litre is passed through a US Sieve No. 12 (with openings of 1.68 mm). The weight of the material retained on the screen after it has been dried to a constant weight in an oven at 103 °C must not exceed 10 % of the total suspended solids (TSS) and shall not be more than 50 mg; and
- The holding tanks used for the temporary storage of sewage will be constructed to prevent leakage of its contents under the normal operation of the FPSO and in all likely weather conditions, until such times as it can be discharged, in accordance to the Regulations.

All other waste generated offshore by the proposed Development will be returned to shore for appropriate treatment and disposal. All waste will be segregated in a manner that will encourage the reuse and recycling and to reduce, for as far as is possible, disposal of this waste to landfill.

The eventual disposal of any waste is intrinsically related to its nature. Waste handling onboard the MODU, FPSO and associated support vessels will be the responsibility of the vessel contractors. However, PPUK will ensure that the collection, handling and disposal of all waste generated by the proposed Development is achieved, in compliance with current environmental legislation and meets the objectives stated within its own Environmental Care Policy.

12.1.1 The Waste Hierarchy

PPUK will ensure that all waste generated by the Avalon Field Development will be managed in line with the waste hierarchy. The waste hierarchy ranks waste management options according to the best environmental outcome, taking into consideration the lifecycle of the material. The lifecycle of a material is an environmental assessment of all the stages of a product's life from-cradle-to-grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling).

In its simplest form, the waste hierarchy gives top priority to preventing waste. When waste is created, it gives priority to preparing it for reuse, then recycling, then other recovery, and last of all disposal (i.e. landfill). For example, one tonne of food waste in landfill produces 450 kg CO_2eq (equivalents), whereas preventing one tonne of food waste saves 3,590 kg CO2eq. The benefits of selecting options higher up the hierarchy extend beyond carbon savings and include reduced water consumption, protection of important raw materials, creation of jobs and other economic opportunities (Scottish Government, 2017b).

12.1.2 Monitoring and Recording of Offshore Waste

All waste for disposal onshore will be accurately described and appropriately segregated for onshore disposal at appropriate licensed sites through properly licensed waste disposal contractors. Every offshore installation and vessel must have a Garbage Management Plan (per guidance in Merchant Shipping Notice No.1807) and Garbage Record Book.

In addition, the amount and disposal route of any waste will be recorded in the UK Environmental Emissions Monitoring System (EEMS). EEMS records operator and installation specific data for all atmospheric emissions, liquid discharges and solid wastes. It also provides a starting point for monitoring the final disposal site of offshore wastes.

Bulk wastes generated offshore will be segregated by type, and periodically transported to shore for disposal or recycling in an auditable manner through authorised waste contractors. Waste is typically segregated and recorded according to the following categories:

- Group I: Special waste, such as oils, paints, adhesives, solvents, surplus chemicals, etc, and these are mainly recycled;
- Group II: General waste, including non-hazardous work-over/completion/drilling fluids, brines, galley waste, accommodation waste, compactor waste, and much of this has to go to landfill. Segregated materials such as scrap metal, plastics, aluminium cans, paper/cardboard, glass, cooking oil and clean wood are recycled;
- Group III: Other waste, including asbestos, clinical and explosive materials;
- Group IV: Backloaded cuttings, including oil based mud (OBM) or synthetic based mud (SBM) drill cuttings backloaded for treatment, as well as Water Based Mud (WBM) drill cuttings backloaded for disposal onshore. This also includes any solid material (e.g. powder

or stabilised products) generated by the treatment process, Oil recovered from the backloaded cuttings through the treatment process and any water separated from the oil and solids through the cuttings treatment process; and
- Group V: Naturally occurring radioactive material (NORM) from mineral scales which build up in processing equipment and pipework (generally from production installations only).

12.1.3 Waste Disposal Management Onboard the FPSO

All waste will be transferred to shore via supply vessel, as and when required. Suitable and adequate facilities and procedures will be provided onboard the FPSO and its support vessels to enable efficient segregation, storage and handling of waste streams.

The FPSO will be designed with adequate space for waste storage and segregation facilities, including laydown areas for skips and deck space for other waste storage receptacles. Waste will be segregated into hazardous and non-hazardous waste types. Solid domestic waste will normally be compacted with a garbage compactor, placed in disposal bags and returned to the mainland in waste skips. Separate storage areas will be provided for solid and liquid waste that can be reused. Waste storage areas will be well ventilated and bunded with drainage to appropriate storage or treatment areas. Hazardous waste containers will be covered to reduce rainwater contact in the containment structure. Furthermore, segregation of recyclable materials will be implemented to avoid contamination and consequent reduction of the quality of recycled products.

12.1.4 Conclusions

Several different waste streams will be generated throughout the development's lifespan. Waste management will be undertaken in compliance with current environmental legislation and in line with the waste hierarchy, as described above. The management of offshore waste generated on the UKCS is strictly regulated and the UK has well-established infrastructure in place to manage this waste effectively. Therefore, no significant impacts are anticipated.

12.2 Natural Disasters

The most recent EIA Directive 2014/52/EU requires that the vulnerability of projects to risks of major accidents or natural disasters relevant to the project are considered. The potential for a hydrocarbon release from a well blow out, diesel release or pipeline release is described in detail in Section 11 (Accidental Events) and is considered to be the most likely major accidental event which could occur at the proposed Avalon Field Development.

The potential for natural disasters such as earthquakes and tsunamis is very low as these events are themselves rare (DEFRA, 2005). Nonetheless, the infrastructure of the proposed development must be able to withstand the rigours of the North Sea environment.

As a result of climate change, more extreme weather events have been recorded in recent years, this is in conjunction with rising sea levels. These effects must be considered when embarking on operations such as the Avalon Field Development. To this end, the infrastructure and installations used for the Development will be structurally sound, designed to withstand a number of different loads. Safety procedures will also be implemented, such as making the operations/installations safe or potentially shutting down operations, if such extreme weather events are experienced. This is in combination with emergency procedures described in Temporary Operations Oil Pollution Emergency Plan (TOOPEP).

12.3 Underwater Noise Generation

The following issues and concerns were raised during the Environmental Issues Identification (ENVID) workshop, informal consultation and/or are referred to in national policies and guidance, and will therefore be considered in this Section on underwater noise generation.

The finalised mooring mechanism for the FPSO is dependent upon the results of the geotechnical survey. Suction anchors are the preferred mooring option, however, as a worst-case scenario (in terms of underwater noise levels) the impacts of anchor pilling have been assessed. Likewise, the specific mooring system for the Avalon OWT is still to be confirmed and therefore a worst-case scenario of anchor pilling has been assessed.

- The ENVID identified underwater noise generated by piling to install the FPSO anchors to the seabed, as having a potential significant effect on the marine environment, namely on marine mammals and fish. Anchor piling for the floating OWT mooring was not assessed at the time of the ENVID, however, this is now considered within this Section.
- The Scottish National Marine Plan identifies noise generated from drilling, production facilities or vessels, burial of pipelines as having the potential to cause injury and disturbance to noise-sensitive species such as cetaceans;
- The Scottish National Marine Plan identifies cumulative impacts (GEN21) as one of its General Policies.

The main underwater sound source to be assessed is the piling noise associated with the installation of the FPSO and floating OWT anchors. These sources will emit low frequency noise into the water column.

This section will also assess the requirement for a wildlife disturbance licence, using the criteria for undertaking such an assessment outlined in the latest version of the JNCC draft guidance notes (JNCC, 2010a).

12.3.1 Quantification of Noise

12.3.1.1 Ambient Noise

Ambient or background noise in the ocean consists of a broad range of individual sound sources and is made up of natural as well as manmade sources (Hildebrand, 2004). The ambient acoustic environment of the ocean is highly variable.

The dominant source of naturally occurring noise is associated with ocean surface waves generated by the wind. This noise occurs across a range of frequencies from 1 Hz to 100 kHz (NRC, 2003). Other natural sounds in the sea include currents, rain, ice-breaking, echo-location and communication noises generated by cetaceans and other natural sources such as tectonic activity. Table 12.1 displays some of the different types of sounds found naturally in the marine environment.

Table 12.1 Examples of Natural Sounds in the Marine Environment

Sound Source	Dominant Frequency Range	Sound Pressure Density Spectrum Level (dB re 1 µPa2/Hz)	Noise Characteristics
Wind	1 to 25 kHz	100 to 200 Hz 65 dB (force 3) 85 to 95 dB (force 12)	Greatest levels at higher wind speeds, noise is continuous on a scale of hours to days
Rain	Broad spectrum	0 dB (no rain) to 80 dB (heavy rainstorm)	Flat frequency spectra (white noise)
Earthquakes	5 to 15 Hz	0 dB (no earthquake) to 200 to 240 dB (at 10 km from earthquake of ML 4 to 6, broadband)	Short term transitory events on a scale of minutes, noise levels may be high
Baleen whales	16 to a few hundred Hz	128 to 190 dB re µPa @ 1 m	Communication (low frequency moans, grunts, down sweeps)
	2 kHz to 25 kHz	151 dB re µPa @ 1 m	Communication (clicks)
Toothed whales	100 Hz to 20 kHz	to 180 dB re µPa @ 1 m	Communication
	6 kHz to 325 kHz	120 to 228 dB re µPa @ 1 m	Echolocation

In addition to naturally occurring sounds, anthropogenic noise is generated by air traffic, shipping activity and the oil and gas industry, amongst other activities. Of these, shipping is the dominant source of sound in the world's oceans, generally within a range from five to a few hundred Hertz (NRC, 2003). All vessels generate noise as a consequence of their operation. Modern powered vessels typically produce low-frequency (i.e. less than 1000 Hz) sound from hydrodynamic flow noise, onboard machinery, and, primarily, from propeller cavitation (Southall et al., 2007).

However, sound generated by airguns is also a major contributor to the low-frequency background sound recorded in certain areas, such as the North Atlantic (Nieukirk et al., 2004; Tyack, 2008). These anthropogenic noise levels in the oceans have increased significantly over the last few decades (e.g. Hatch and Wright, 2007; Andrew et al., 2002) giving marine animals little time to adapt to these changes in an evolutionary sense.

Table 12.2 shows various anthropogenic sources and received levels of sound in the marine environment.

Table 12.2 Sound Sources from Various Maritime Activities

Activity	Dominant Frequency Range (kHz)	Average Source Level (dB re 1µPa-m)	Estimated Received Level at Different Ranges (km)			
			0.1 km	1 km	10 km	100 km
High resolution geophysical survey; pingers, side scan, fathometer	10 - 200	<230	190	169	144	69
Low resolution geophysical seismic survey; seismic air gun	0.008 - 0.2	248	210	144	118	102
			208	187	162	87
Production drilling	0.25	163	123	102	77	2
Jack-up drilling rig	0.005 - 1.2	85 – 127	45 - 87	24 - 66	<41	0
Semi-submersible rig	0.016 - 0.2	167 – 171	127 - 131	106 - 110	81 - 85	6 – 10
Drill ship	0.01 - 10	179 – 191	139 - 151	118 - 130	93 - 105	18 – 30
Large merchant vessel	0.005 - 0.9	160 – 190	120 - 150	99 - 129	74 - 104	<29
Military vessel	Not known	190 – 203	150 - 163	129 - 142	104 - 117	29 – 42
Super tanker	0.02 - 0.1	187 – 232	147 - 192	126 - 171	101 - 146	26 – 71

Sources: Adapted from: Evans and Nice, 1996 and Richardson et al., 1995.

Figure 12.1 represents ambient noise as a function of frequency; the ambient noise spectrum normally lies between the two thick green lines shown.

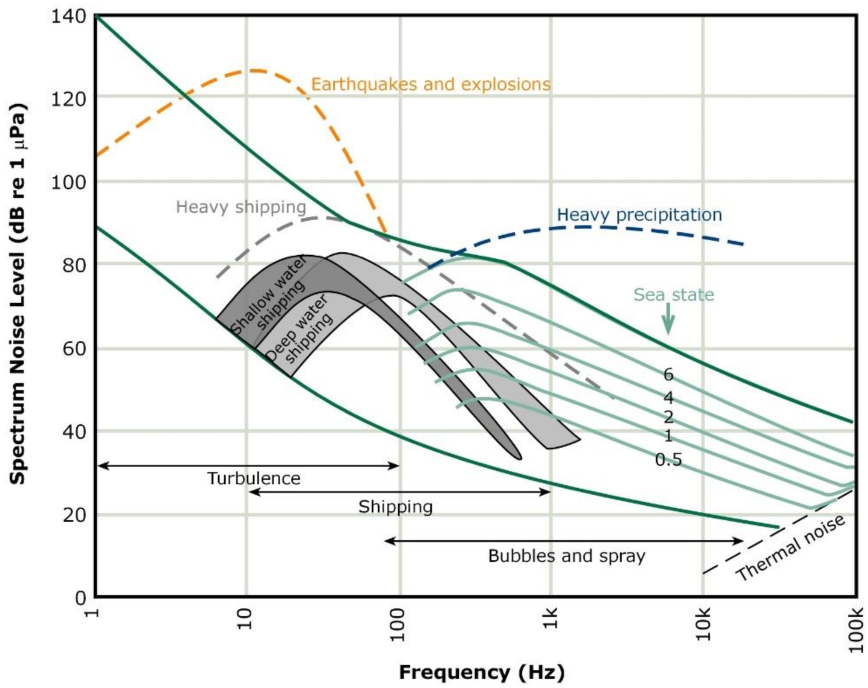

Figure 12.1: Ambient Noise Spectra in the Open Ocean
Sources: Adapted from Wenz, 1962; NRC, 2003; and Harland et al., 2005.

At the lower frequencies, shipping noise predominates, while at the higher frequencies noise from waves and precipitation dominates (Figure 12.1). The frequency at which the change occurs is a complex function of local bathymetry, propagation conditions, shipping levels and weather conditions.

12.3.1.2 Underwater Sound Behaviour

As sound spreads underwater, it decreases in strength with distance from the source. This transmission loss is the sum of spreading loss and attenuation loss. Spreading loss is the geometric weakening of a sound signal as it spreads outwards from a source. Attenuation losses are the physical processes in the sea that distort the mathematical spreading laws. A number of factors including sound absorption or scattering by organisms in the water column, reflection or scattering at the seabed and sea surface, and the effects of temperature, pressure, stratification and salinity affect these physical processes. Variations in temperature and salinity with depth cause sound waves to be refracted downwards or upwards causing increases or decreases in sound attenuation and absorption. Actual sound transmission therefore has considerable temporal and spatial variability that is difficult to quantify.

In the areas with a large asymmetry between upslope and downslope propagation can be expected over larger distances. Sound propagating downslope may connect with the deep sound channel, allowing it to propagate to long range with little attenuation. In contrast, sound propagating upslope can be expected to suffer rapid attenuation due to frequent interactions with the seabed.

In general, in waters >50 m in depth with a relatively flat seabed, it can be assumed that, in the immediate vicinity of the sound source (i.e., within a few km of the source), attenuation will more or less follow the laws of spherical spreading and can be calculated as:

$$SPL_R = SPL_{Source} - 20 \cdot Log_{10}(R) + A \cdot R \quad \text{(Formula 1)}$$

SPL_R = Sound Pressure Level at distance 'R' from the sound source (dB re 1µPa at 1 m)
SPL_{Source} = Sound Pressure Level at 1 m distance from the sound source (dB re 1µPa at 1 m)
R = Distance from sound source (in metres)
A = Attenuation loss/absorption loss coefficient (0.00043 dB/m)

For longer distances (>10 km), moving downslope into deep-water, the sound attenuation is more likely to follow the laws of cylindrical spreading, which generally means it will attenuate much more slowly and propagate further, with the potential for sound to become 'trapped' in the deep sound channel. To calculate cylindrical spreading the number 20 in the formula above should be replaced by the number 10.

A second metric that is often used to quantify underwater sound is the Sound Exposure Level (SEL), which is the dB level of the time integral of the squared instantaneous sound pressure normalised to a 1 second period (Southall et al., 2007). SEL effectively averages the total acoustic energy released over a one second period and is a particularly useful metric for estimating the (cumulative) impact over a set period of time.

12.3.1.3 Underwater Sound from Piling during Installation of FPSO

The amount of underwater sound generated during the proposed piling operations for the FPSO anchors (should they be selected) depends on many factors, including size (length and diameter) and material of the pile itself, properties of the hammer, water depth, and underlying geology, and is therefore very hard to estimate. Wyatt (2008) shows there is a strong correlation between the diameter of the pile and the piling noise generated.

Section 3.5.3 describes the piling operations required to install the FPSO anchor piles. The FPSO will have a total of 12 piles of 1.2 m diameter, corresponding to an estimated peak to peak sound pressure level of 233 dB re 1µPa at 1 m, based on the correlation between pile diameter and generated piling noise presented in Wyatt (2008). Consequently, the associated or 'flat peak' or '0-peak' value will be approximately 227 dB re 1µPa at 1 m.

Although the SEL can be measured in the field fairly easily, it is very hard to predict accurately beforehand. Therefore, an analogue SEL value has been calculated using a linear regression on the normalised SEL_{Max} values of various piling operations reviewed by Betke (2008). The SEL_{Max} for piling operations at Avalon FPSO has been estimated at 204 dB re 1µPa^{2}s for a single strike at 1 m distance.

A typical hammer size for this type of construction activity will have an average blow count of 509 blows/pile, this should be considered typical for the new structure piling i.e., a total blow count for the FPSO anchor piling of 6,108 is anticipated. It is estimated that three piles will be installed per day, this would equate to potentially four days of piling of the FPSO anchors.

12.3.1.4 Underwater Sound from Piling during installation of the Floating Offshore Wind Turbine

As previously discussed, the amount of underwater sound generated during the proposed piling operations for the installation of the Avalon floating OWT depends on many factors, including size (length and diameter) and material of the pile itself, properties of the hammer, water depth, and underlying geology, and is therefore very hard to estimate.

Section 3.7.2.2 describes the piling operations required to install the floating OWT anchor piles. Two anchor options are under consideration for the Avalon OWT with the final selection dependent on the results of site surveys and the selected mooring configuration. It is predicted that the OWT will have a total of nine piles of 5m diameter, corresponding to an estimated peak to peak sound pressure level of 241 dB re 1µPa at 1 m, this is based on the correlation between pile diameter and blow energy of the hammer presented in a proxy floating OWT study. Consequently, the associated or 'flat peak' or '0-peak' value will be approximately 235 dB re 1µPa at 1 m.

As described above, an analogue SEL value has been calculated using a linear regression on the normalised SEL_{Max} values of various piling operations reviewed by Betke (2008). The SEL_{Max} for piling operations at the Avalon OWF has been estimated at 220 dB re 1µPa^{2}s for a single strike at 1 m distance.

As the final hammer design has not been finalised, the assessment has been carried out using data from other floating offshore windfarm developments in Scotland. A typical hydraulic hammer will be used, with a maximum hammer energy of 2,500 kJ. It is estimated that three piles will be installed per day, this would equate to potentially three days of piling of the OWT anchors. Data from other floating offshore windfarm developments estimate that the hydraulic hammer will have a worst-case soft start blow count of 14,912 blows/pile.

12.3.1.5 Impacts from Sound Generated by Activities Associated with the Proposed Avalon Field Development

This section assesses potential impacts from underwater sound, focussing on marine mammals and fish which are the receptors believed to be most at risk from noise impacts.

Sound is a particularly efficient way to propagate energy through the ocean, and many marine animals use hearing as their primary sense. Cetaceans, in particular, are heavily dependent on sound for food finding, communication, reproduction, detection of predators, and navigation (Weilgart, 2007; Hildebrand, 2004).

As described in Section 12.3.1.1, the ocean is a naturally noisy environment and cetaceans in particular have evolved ears that function well within this context. Recent anatomical and behavioural studies suggest that whales and dolphins may be more resistant than many land mammals to temporary threshold shifts. However, these data also show that they are subject to disease and aging processes and are therefore not immune to hearing loss. Increasing ambient noise via human activities is a potential candidate for exacerbating or accelerating such losses (Ketten, 2004).

The introduction of additional noise into the marine environment could potentially interfere with the animals' ability to determine the presence of other individuals, predators, prey and underwater features and obstructions. This increase in noise could therefore cause short term behavioural changes and, in more extreme cases, cause auditory damage. In addition to marine mammals, underwater sound may also cause behavioural changes in other animals such as fish and diving seabirds.

12.3.2 Impacts on Marine Mammals

Marine mammals use sound in various important contexts, such as in social interactions, foraging, and response to predators (Southall et al., 2007). Hearing is the primary sensory system for marine mammals, which is clearly shown by their level of ear and neural auditory centre development (Ketten, 2004). As the sea has never been a silent place, the ears of marine mammals, and those of whales and dolphins in particular, have evolved to function well within this context of ambient noise. However, little information exists to describe how marine mammals respond physically and behaviourally to intense sounds and to long term increases in ambient noise levels (NRC, 2003).

Marine mammals vary in regard to their hearing sensitivities and in order to assess the impacts of sound can be classed into functional hearing groups (Southall et al., 2007; NOAA, 2016; NOAA, 2018; and most recently Southall et al., 2019). The classification into functional hearing groups takes into account that not all marine mammal species have identical hearing or susceptibility to noise-induced hearing loss. Table 12.3 applies the most up to date classification by Southall et al (2019) to the species that may be present in the wider area around the proposed Development. Outside their generalized hearing ranges, the risk of auditory impacts from sounds is considered highly unlikely or very low. According to this classification, harbour porpoises are regarded as 'very high-frequency cetaceans', white-beaked dolphins and Atlantic white-sided dolphins are classified as 'high-frequency cetaceans'. This classification is based on the fact that odontocetes have highly advanced echolocation systems that use intermediate to very high frequencies. They also produce social sounds in a lower-frequency band, including generally low to intermediate frequencies (1 kHz to tens of kHz). Consequently, their functional hearing is expected to cover this whole range; however, their hearing sensitivity typically peaks at or near the frequency where echolocation signals are strongest (Southall et al., 2019).

All mysticetes (i.e. the large baleen whales) are all categorised as 'low-frequency cetaceans'. No direct measurements of hearing exist for these animals and theories regarding their sensory capabilities are consequently speculative. In these species, hearing sensitivity has been estimated from behavioural responses (or lack thereof) to sounds at various frequencies, most common vocalisation frequencies, body size, ambient noise levels at the frequencies they use most, and cochlear morphology. At present, the lower and upper frequencies for functional hearing in mysticetes, collectively, are estimated to be 7 Hz and 35 kHz (NOAA, 2016).

Table 12.3: Functional Hearing Groups for Marine Mammals Potentially Present in the Avalon Area

Functional Hearing Group	Estimated Auditory Band Width	Species Potentially Present in the Avalon Area
Low-frequency cetaceans	7 Hz to 35 kHz	Minke whale
High-frequency cetaceans	150 Hz to 160 kHz	Atlantic white-sided dolphin; White-beaked dolphin; Risso's dolphin; Killer whale; Long finned pilot whale
Very High-frequency cetaceans	275 Hz to 160 kHz	Harbour porpoise
Pinnipeds in water	50 Hz to 86 KHz	Grey seals; Common seal

Sources: NOAA,2018; Pollock et al., 2000; Reid et al., 2003; DECC, 2016.

Research indicates that marine mammals can react differently to the introduction of additional noise into the marine environment. Reactions may vary depending on sound source level, propagation conditions and ambient noise, in addition to species, age, sex, habitat, individual variation, and previous habituation to noise (Richardson et al., 1995). It should also be noted that marine mammals react differently to stationary noise, compared to sudden bursts of noise and noises that appear to be coming towards them. Studies suggest that most cetaceans will alter their course or display avoidance reactions to a noise that appears to be moving directly towards them.

12.3.2.1 Injury Thresholds for Cetaceans

The underwater sound generated during the proposed piling operations will produce intermittent, or 'impulsive' sound pulses which are considerably more intense than the continuous noise emitted by most industrial noises in the ocean.

There are few direct data regarding the effects of intense sound on cetaceans, making it difficult to predict accurate safe exposure levels for these mammals (Finneran et al., 2000). Nonetheless attempts have been made to create a set of injury criteria for individual marine mammals exposed to discrete noise events, by Southall et al. (2007), and more recently by the US National Oceanic and Atmospheric Administration (NOAA) which introduced a new set of injury criteria in 2016 (NOAA, 2016), which were updated in 2018 (NOAA, 2018) and are maintained in Southall et al. (2019).

These injury criteria aim to set acoustic thresholds, at which individual marine mammals are predicted to experience changes in their hearing sensitivity (either temporary or permanent) for acute, incidental exposure to underwater anthropogenic sound sources. These thresholds are referred to as 'Temporary Threshold Shift' (TTS) and Permanent Threshold Shift (PTS), respectively. The NOAA guidance makes a clear distinction between impulsive and non-impulsive sound sources, based on their physical characteristics at the source, with impulsive sound having physical characteristics making them more injurious (NOAA, 2018).

The cumulative SEL is calculated as the summation of the total sound energy to which the receptor is exposed during a set period of time (in this case 24 hrs). The SEL_{CUM} can be calculated as:

$$SEL_{CUM} = 10 \cdot Log_{10} \sum_{i=1}^{n} 10^{\frac{SEL_{Max} - 20 \cdot \log(R_i) + A \cdot R_i}{10}} \qquad (Formula\ 2)$$

SEL_{CUM} =Cumulative Sound Exposure Level received by the receptor
SEL_{Max} =Source Exposure Level at distance 'R' at time interval 'i'

Assuming that any marine mammal would never be closer than 10 m from the sound source and that any animal experiencing high sound levels will move out of the area causing it discomfort, Formula 2 can be used to calculate the cumulative amount of sound energy any animal would receive in 24 hours, when swimming away from the sound source at a constant speed of 1.5 m/s.

For 'impulsive' sounds, such as the piling noise during the installation of the FSPO and OWT anchors, dual metric acoustic thresholds for either the unweighted ('flat') sound pressure level (SPL) of a single impulse, or the cumulative sound exposure level over a 24 hr period (whichever results in the largest isopleth for calculating PTS onset) should be used.

The weighted auditory thresholds for the SEL_{CUM} during the piling operations, can be computed as described above for continuous underwater noise, but by using 4 second intervals between each hammer strike instead. The model does also take a soft start into account, during which the hammer energy is gradually increased over a 20 minute period for each pile.

Table 12.4 shows the PTS and TTS onset thresholds for impulsive sounds for the piling noise generated during the installation of the FPSO and floating OWT anchors.

Table 12.4 PTS and TTS Onset Thresholds for Impulsive Sounds (NOAA, 2018) for Marine Mammals in the Avalon area

Hearing group	PTS Onset, SPL_R, 0-pk, Flat (dB re 1μPa)	PTS Onset SEL_{cum}, Weighted*, 24hr (dB re $1μPa^2s$)	TTS Onset, SPL_R, 0-pk, Flat (dB re 1μPa)	TTS Onset SEL_{cum}, Weighted*, 24hr (dB re $1μPa^2s$)
Low frequency hearing group (e.g. Minke whale)	219	184	213	169
Mid-frequency hearing group (e.g. Atlantic white-sided dolphin, White-beaked dolphin, Risso's dolphin, Killer whale, Long finned pilot whale).	230	224	224	209
High frequency hearing group (e.g Harbour porpoise)	202	203	196	188
Pinnipeds in water (e.g. Grey and common seals)	218	196	212	181
Notes: * SEL_{CUM} values have been adjusted for peak frequency at 500 Hz				

The unweighted, or 'flat', threshold value for impulsive sounds is based on the 0-peak SPL of a single exposure (i.e. in this case one single hammer blow). Using the spreading model presented in Section 12.3.1.2, the distances to the PTS and TTS thresholds for a single hammer strike can be calculated.

Table 12.5 shows that the PTS and TTS isopleths for a single hammer strike for low and mid frequency cetaceans and seals are all within 10 m of the FPOS piling sound source. PTS and TTS thresholds for harbour porpoise are achieved within 35 m. The PTS and TTS thresholds for a single hammer strike during the floating OWT piling are achieved within 15 m for low and mid frequency cetaceans and phocid pinnipeds, and within 100 m for harbour porpoise.

Assuming the piling operations will only be started with no marine mammals present within 500 m from the piling location in line with the JNCC guidelines on underwater piling noise (JNCC, 2010b), the cumulative SEL over 24 hours received by any animal swimming away from the sound source would be approximately 163 dB re $1μPa^2s$, for the FPSO and 179 dB re $1μPa^2s$ for the floating OWT which are below all NOAA PTS and TTS threshold values quoted in Table 12.4 with the exception of TTS threshold for minke whale with reference to the OWT SEL_{Cum} levels.

Table 12.5: PTS and TTS Isopleths for Single Hammer Strike

PTS/TTS Isopleths		NOAA PTS/TTS Thresholds and Distance (metres) from Sound Source in which these Threshold Values are Exceeded per Species			
		Low frequency hearing group	Mid-frequency hearing group	High frequency hearing group	Pinnipeds in water
Single strike PTS Isopleth to Threshold 'flat' peak	FPSO	2.5m	0.7 m	17.8 m	2.8 m
	OWT	6.3m	1.8 m	44.7 m	7.1 m
Single strike TTS Isopleth to Threshold 'flat' peak	FPSO	5 m	1.4 m	35.5 m	5.6 m
	OWT	12.6 m	3.5 m	89.1 m	14.1 m
PTS Isopleth to weighted cumulative SEL Threshold	FPSO	SEL below threshold	SEL below threshold	SEL below threshold	SEL below threshold
	OWT	SEL below threshold	SEL below threshold	SEL below threshold	SEL below threshold
TTS Isopleth to weighted cumulative SEL Threshold	FPSO	SEL below threshold	SEL below threshold	SEL below threshold	SEL below threshold
	OWT	3.2m	SEL below threshold	SEL below threshold	SEL below threshold

Therefore, taking into account the above assessment for a single strike as well as cumulatively over a 24-hour period, together with the use Marine Mammal Observers (MMOs) to ensure there are no marine mammals present with 500 m at the commencement of the piling operations, it is deemed unlikely that the piling operations would cause any physical injury to marine mammals in the area.

12.3.2.2 Behavioural Responses of Small Odontocetes to Piling Operations

Although it is unlikely that any piling operations will cause injury, they may very well evoke some behavioural responses from any cetaceans in the vicinity of such operations.

There is limited information available of the behavioural effects of the larger baleen whale species to piling operations. However, as sound levels and dominant frequencies of piling sound are in many ways quite similar to the sound generated during offshore geophysical (i.e. seismic) surveys, the following examples have been used as a proxy to describe some of the anticipated effects and spatial extent.

Baleen whales have hearing sensitivity ranges between 10 Hz and 10 kHz, with greatest sensitivities usually below 1 kHz (Evans, 1998; Southall et al., 2007). This hearing range overlaps the low frequency sounds produced by the planned piling operations, which may mask long distance communication between whales and prevent the detection of other faint sounds (Evans and Nice, 1996).

Most studies on low-frequency cetaceans report behavioural responses to 'pulsed sound', such as that produced by piling operations or seismic surveys, at received sound levels around 140 to 160 dB re 1 μPa, and sometimes even higher (e.g. Southall et al., 2007; Richardson et al., 1995). These responses typically consist of subtle effects on surfacing and respiration patterns. Sound levels of 150 dB to 180 dB will generally evoke behavioural avoidance reactions (Richardson et al., 1995).

JNCC (2020) uses the term 'Effective Deterrent Radius' (EDR) to define the displacement range, based on the empirically derived displacement range of harbour porpoise from piling operations. JNCC proposed a minimum EDR of 15 km based on a study of harbour porpoise responses to pile driving operations (Graham et al., 2019). The study identified a 50% probability of pin piling operations eliciting a behavioural response in Harbour porpoises within 7.4 km in the 12 hours after piling operations had ended as well as showing a 25% probability of a response within approximately 18 km. Potential habituation was also recorded with response distances decreasing over the duration of the piling operations. Therefore, an EDR of 15 km has been adopted due to the likelihood that the majority of effects during piling would be detected at distances greater than 7.4 km.

Given the intermittent nature and short overall duration of the piling operations (total seven days for the FPSO and OWT anchors), the fact that the impact on cetaceans is expected to be limited to some potential avoidance responses for individual animals up to a distance of 15 km from the piling operations and that mitigation measures outlined in the JNCC Guidelines for piling operations (JNCC, 2010b) will be followed, the impact of piling operations on cetaceans is considered to be not significant.

12.3.2.3 Impacts on Pinnipeds

Pinnipeds (seals, sea lions, and walruses) also produce a diversity of sounds, although generally over a lower and more restricted bandwidth (generally from 100 Hz to several tens of kHz). Their sounds are used primarily in critical social and reproductive interactions (Southall et al., 2007). Most pinniped species have peak sensitivities between 1 and 20 kHz (NRC, 2003). Common seals are most sensitive to sounds between 6 to 12 kHz (Wolski et al., 2003), although their threshold for hearing and responding to sound lies at frequencies much lower than that. Kastak and Shusterman (1998) measured the underwater sound detection threshold of a common seal, which ranged between 101.9 dB and 62.8 dB for frequencies between 75 Hz and 6,400 Hz respectively. The audiograms of common and grey seals are very similar (Thompson, 1998), and their reaction to anthropogenic underwater sound is therefore expected to be similar as well.

Very few studies have been conducted on the effects of impulsive noise on pinnipeds, even though they are known to have good underwater hearing and their feeding grounds often overlap with areas subject to manmade high intensity underwater noise activities.

Russell et al. (2017) found that seal usage (abundance) was significantly reduced up to 25 km from piling operations at a wind farm location in the southern North Sea. Within 25 km of the centre of the wind farm, there was a 19% to 83% decrease in usage of the area compared to during breaks in piling. This amounted to significant displacement starting from predicted received levels of between 166 and 178 dB re 1 μPa(p-p). Within 2 hours of cessation of pile driving, seals were distributed as per the non-piling scenario. However, these piling operations were much larger in scale than required for the Avalon installation assessed in this ES and therefore the sound levels and intensity can perhaps better be compared to that of a small seismic survey instead.

A review of the effects of seismic survey impacts on marine mammals by Gordon et al. (2003) quotes a study by Thompson et al. (1998) on the behavioural and physiological responses of grey and common seals to small airguns. The study indicated that reactions observed in common seals included initial fright responses as the air guns were switched on, generally followed by strong avoidance behaviour, demonstrated by swimming rapidly away from the sound source. However, the study also reported that one seal showed no detectable response and approached to within 300 m of the airgun (source levels of the airgun were 215 to 224 dB re 1 μPa at 1 m peak-to-peak). The seals ceased feeding during this time. The behaviour of the common seals seemed to return to normal soon after the air guns were switched off.

Bearing in mind that the piling operations will be intermittent over a short overall period of four days and three days for the FPSO and OWT respectively, the unlikely nature of seals being present in the area (see Section 4) and that any affected seals (if present) are expected to return to the area quickly after piling operations have seized, the overall impacts from piling are not forecast to have any long term effects on pinnipeds and therefore are judged to be insignificant.

12.3.2.4 Impacts on Fish

This section assesses the potential effect of the proposed piling operations on fish. The inner ear of fish including elasmobranchs (sharks, skates and rays), is very similar to that of terrestrial vertebrates, and hearing is understood to be present in virtually all fish (NRC, 2003). Most species of fish are able to detect sounds from below 50 Hz (some as low as 10 Hz or 15 Hz) to upward of 1,000 Hz. Moreover, a number of fish species have auditory adaptations that enhance sound detection and enable them to detect sounds of 3 kHz and above, giving them better sensitivity than non-specialist species at lower frequencies (NRC, 2003; Popper, 2003). Many species of fish use sound to find prey, to avoid predators, and for social interactions. In addition, the sensory systems used by fish to detect sounds are very similar to those of marine (and terrestrial) mammals, and, as a consequence, sounds that damage or affect marine mammals could in other ways have similar consequences for fish (Popper, 2003). Some fish species, such as herring, have swim bladders which may be susceptible to damage by underwater high noise levels, making these species comparatively more sensitive.

The effect of piling operations on fish is strongly related to their life cycle stage. Adult and juvenile fish are rarely affected by piling operations because they are able to detect and physically avoid the area but fish eggs and larvae may be more vulnerable. Fish can detect impulsive sound sources over large distances (up to 30 km), yet they seldom react to the sound before it is above a certain threshold. Alarm responses in adult or juvenile fish can be expected at distances of 1 km to 5 km from the piling operations, depending upon their auditory thresholds and the level of sound transmission loss (Nakken, 1992). Given the limited spatial extent of the anticipated impact and the limited (4 days and 3 days) period over which the piling will take place, and the ability of fish to temporarily avoid areas of adverse noise, the proposed piling operations is not anticipated to cause any significant impacts on fish.

12.3.3 Assessment of the Requirement for a Wildlife Disturbance Licence

Under the Offshore Marine Conservation (Natural Habitats, and c.) Regulations 2007 (or Offshore Marine Regulations, OMR), as amended by the Offshore Marine Conservation (Natural Habitats, and c.) (Amendment) Regulations 2009, it is an offence to deliberately disturb European Protected Species (EPS; species listed in Annex IV of the Habitats Directive), in such a way that is likely to:

- Impair their ability to survive, to breed or reproduce, or to rear or nurture their young; or in the case of a hibernating or migratory species, to hibernate or migrate;
- Affect significantly the local distribution or abundance of the species to which they belong.

PPUK has therefore assessed if the proposed piling operations would potentially cause a 'disturbance offence' to any EPS, and subsequently would require a disturbance licence under these regulations. The potential disturbance caused by piling operations mainly refers to (underwater) noise.

The EPS include all cetaceans, turtles and sturgeon. In UK waters, the latter two are at the limits of their global distributions (which are centred elsewhere in the western Atlantic or Europe) and only occur in low numbers around the UK. It is therefore extremely unlikely that a significant group of these animals would be present, or that their local abundance or distribution would be significantly affected by marine impacts (JNCC, 2010a). Therefore, only cetaceans will be considered from hereon.

As described in Section 12.3.2.1, none of the proposed piling operations are expected to cause any injury to cetaceans, and only a certain level of avoidance responses are expected within 15 km of the piling operations. Therefore, this assessment will be based on whether any of these behavioural responses could potentially result in a disturbance offence in relation to marine EPS, as defined under regulations 41(1)(b) and 39(1)(b) of the Habitats Regulations and Offshore Marine Regulations, respectively.

Table 12.6 identifies the cetacean species that have been recorded in the Central North Sea, and therefore may be present in the wider area during the piling operations. It also specifies the number of individuals per species that can be expected to show any behavioural response (i.e. within a radius of 15 km from the piling operations) to represent the worst-case estimate for the area in which potential 'disturbance' effects could be expected to occur. Abundance data has been used from the Small Cetacean Abundance in the North Sea (SCANS) III surveys (Hammond et al ,2017). Where species were reported during the survey, the higher abundance estimates has been used. Further information on the cetacean species is presented in Section 4.7.

Table 12.6: Numbers of Cetaceans Present within 15 km from the proposed Piling Operations

Cetacean Species	Abundance Data (Animals/km²)	Data Source	Estimated Number of Animals Within 15 km Radius of Piling Operations	% of Population Affected
Minke whale	0.039	SCANS III (Block R)	27.6	0.19
Atlantic white-sided dolphin	0.010	SCANS III (Block R)	7.1	0.05
White-beaked dolphin	0.243	SCANS III (Block R)	171.8	0.47
Risso's dolphin	No data	-	-	-
Killer whale	No data	-	-	-
Long finned pilot whale	No data	-	-	-
Harbour porpoise	0.599	SCANS III (Block R)	423.4	0.0

Table 12.6 shows that only a few individual cetaceans would potentially be affected by the proposed piling operations at the proposed Avalon Development. Of these, harbour porpoise and white-beaked dolphins appear to be relatively more abundant than the other species. As the abundance data in Table 12.6 is based on the mean values, it does not take account of the fact some of these animals live in larger pods, which means that in reality their distribution will be much more clustered. It should also be noted that both species are classed as the more abundant cetacean species living in the water surrounding the UK, as can be seen by the very low percentage of the wider 'population' (based on the estimated total numbers of individuals present in the SCANS III survey area) being affected. Moreover, it is expected that any effects would be of short duration and limited to small behavioural changes of a few individual animals. Any affected individuals would also be expected to move back into the area once the piling operations have finished.

Risso's dolphins and coastal bottlenose dolphins have been identified by the JNCC as the two EPS most likely to require a wildlife disturbance licence for any activity in UK offshore waters that might affect their distribution or abundance (JNCC, 2010a). There are no known resident bottlenose dolphins in the vicinity of the proposed piling operations. The proposed operations are not believed to pose any risk to bottlenose dolphins.

Scans III data is unavailable for Risso's dolphins within Block R or the surrounding blocks, however, if present, they may show some behaviour response to the piling operations. Risso's dolphins are mainly distributed off western and northern coasts of Britain and Ireland and along the continental shelf. They are known to use only a portion of UK waters and this is highly variable both seasonally and inter annually. Greatest numbers have been observed from western Scotland with the waters around the Hebrides forming an obvious concentration (JNCC, 2010b). Risso's dolphins are not as common as other dolphin species around Scotland. As discussed in Section 4, there have been few records of the species within the Central North Sea, with most sightings occurring between July and August.

As described in Section 12.3.2, any behavioural reactions of any of the cetacean species to underwater sound produced by the piling operations are expected to be limited to within a few km. The strongest anticipated response would be the temporary avoidance of certain individuals within a 15 km radius. It is believed that the relatively small area, in which this temporary avoidance behaviour may occur, can be easily avoided by any individual, without causing a serious degree of nuisance to the animals involved or the larger population as a whole.

It seems therefore extremely unlikely that the proposed piling associated with the proposed Development would adversely affect animals in such a way as to cause 'deliberate disturbance' of a European Protected Species, as such, PPUK believes it is unnecessary to apply for a wildlife disturbance licence.

12.3.4 Cumulative and Transboundary Impacts

Noise is transmitted through water very efficiently and may be detectable over many kilometres from its source. This has led to concern that increasing anthropogenic activity in the sea, and consequent increasing noise levels, may have effects on marine mammals through interruption of their communication and hearing mechanisms. The potential outcomes of having multiple noise sources in the sea include more frequent masking, behavioural disruptions and short term displacement, although this could potentially be mitigated by a certain level of habituation. Prolonged or repeated disturbance is generally considered to be of more concern than isolated short-term disturbance.

The long term, synergistic and cumulative impact of sound sources is not known, and the introduction of additional low frequency noise into the marine environment from the proposed Development should be considered to have the potential to contribute to the overall cumulative effect of anthropogenic generated underwater noise. However, the risks in this instance are considered to be low as piling noise will be transitory, lasting only for 4 days and 3 days, non-consecutively.

There is potential for overlap with noise from existing oil and gas activities, as CNS is an area of intensive activity. The Tailwind Evelyn development will require two days of piling for a manifold installation (planned for Q2/Q3 2022) within UKCS Block 21/30, located approximately 30 km south-east from the proposals (Tailwind Mistral Ltd, 2020). Moreover, a Subsea Distribution Unit (SDU) would require piling (potentially 1 day) at the Eagle well location (planned for Q3/4 2021), within UKCS Block 21/19a, located approximately 50 km south-east from the proposals (RPS, 2019). Due to the short duration of piling activities, any cumulative impacts of underwater sound from these activities are not considered significant.

With regard to potential transboundary effects, the proposed piling operations will be undertaken over 79 km west of the UK/Norway transboundary line. Although underwater sound produced during the planned piling may have the potential to travel into Norwegian waters, at these distances the sound levels will have attenuated to such a low level, that no observable effects would be expected to occur.

Therefore, no significant cumulative and/or transboundary impacts from noise generated during the proposed piling operations associated with the proposed Development.

12.3.5 Mitigation Measures

The main priority will be to minimise the time over which sound energy is emitted into the marine environment during the proposed piling operations (4 days and 3 days). Therefore, any noise associated with the operations will be transitory.

The parameters used for piling are a worst case, and should impact piling of anchor piles be required, there is potential that the actual piling parameters may result in a lesser impact. The impacts would be reduced by using smaller diameter piles, reduce hammer energy, and reduction in the total duration of active piling. Therefore, the impacts described in this section could be considered highly precautionary.

The planned piling operations will be conducted in accordance with the JNCC Protocol for minimising risk of injury to marine mammals from piling noise (JNCC 2010b), at all times. PPUK will ensure that any updates to the guidance will be followed. This will include the use of a trained and dedicated MMO to undertake cetacean monitoring duties before any piling operations commence and the use of “soft start” procedures. If visibility is poor during the piling operations a Passive Acoustic Monitoring (PAM) system may be used. A report at the end of the piling activities will be submitted to the JNCC, documenting the soft start procedures used, any PAM/visual observation made by the MMO, and describe any complications encountered and recommendations for future piling work. Marine Mammal Recording forms will also be submitted as part of this process.

12.3.6 Conclusions

Anthropogenic noise from shipping, and potentially also from existing oil and gas installations, is currently believed to be the main source of anthropogenic background noise in the area of the proposed Avalon Field Development. The addition of the planned piling operations of the FPSO and floating OWT anchors to the seabed (should piled anchors be selected as part of the installation design) may cause avoidance responses and other, more subtle, behavioural reactions in cetaceans within a few kilometres of the piling operations. Given the short duration of such operations (4 days and 3 days), any such effects are expected to be transient and are therefore also not considered likely to be significant. Impact significance is thus judged to be Negligible.

12.4 Impact of Floating OWT to Seabirds

This section considers the risk of potential seabird collision with the planned OWT at the Avalon Development Field.

Offshore wind turbines can effect seabird populations in a variety of different ways (RSPB, 2022f) depending on the use and importance of the area to seabirds, the annual life cycle stage (i.e. breeding, migrating and moulting) of the species in question and the species specific behaviours (Peschenko et al., 2020) in the presence of turbines. Birds that are easily disturbed by visual and/or noise disturbances, such as divers, are noted to generally avoid offshore turbines and associated construction traffic resulting in potential displacement from preferred habitat. Other species may demonstrate attraction (for example black-legged kittiwake and guillemot in some studies) or may be indifferent but which typically fly at the height of rotor swept areas and thus are at risk of collision if avoidance action is not taken. In addition, large arrays of offshore wind turbines may present a barrier to migrating birds causing them to deviate from typical migrating route at some additional energetic cost. In this regard, the single OWT planned at the Avalon Field Development is unlikely to represent a significant barrier to migrating bird species and thus potential barrier effects arising from the current proposal are not considered further here.

The desk study of seabird distributions (Section 4) identified a variety of seabirds that may potentially be present within the vicinity of the proposals for at least some of the year. Birds present in the greatest densities include fulmar, gannet, kittiwake and guillemot with highest densities occurring between mid-summer and autumn months (June to November). Highest densities of gannet occurred in January. Further to this, tagging studies of razorbills and guillemots at colony sites on the east coast of Scotland suggested that these species may also be widely distribution across the region of the current proposals (MacArthur, 2019).

One year of observations of seabirds at the Hywind offshore floatation wind farm located 30 km offshore of Peterhead and prior to the wind farm being constructed, estimated that in general, the seabirds recorded represented just < 0.01% of respective receptor populations and that the area within 1 km of the Hywind project was considered to be of low importance to seabirds (Statoil, 2015). Translating these numbers to the proposed Avalon Field Development is difficult at present but given that it is considerably further offshore away from coastal and seabird nesting locations sites then the importance of the site to seabirds is assumed to be similar (negligible) or lower, although this is uncertain at present.

Comprehensive studies to quantify parameters of bird avoidance behaviours of wind turbines has been undertaken at the Thanet Offshore Wind Farm site located in the southern North Sea (Skov et al., 2018). Five target species were selected for study representing typical UK seabird species and species that typically fly at rotor height including Northern Gannet, Black-legged Kittiwake, Lesser Black-backed Gull, Herring Gull, Great Black-backed Gull. Three different types of avoidance behaviour were investigated including macro-avoidance (bird avoidance up to 3 km from the perimeter of the wind farm), meso-avoidance (bird avoidance responses within the wind farm and up to 10 m from rotor swept areas) and micro-avoidance (responses to single blades and representing the ‘last-second’ reactions taken to avoid collision). The quantifiable parameter derived from these studies was the Empirical Avoidance Rate (EAR). The total EAR represents a combination of the individual EARs at macro, meso and micro scales.

Gannets and kittiwake demonstrated moderate avoidance at macro scales and both species seemed to aggregate at distance from the turbines suggesting some reluctance to venture closer. Lesser black backed gulls demonstrated a slight change in behaviour at distance from the turbines whilst Great Black-backed Gull and Herring Gull exhibited comparatively lower avoidance aggregating at closer distances to the wind farm. Although large gulls seemed to generally avoid the wind farm, local factors such as the presence of fishing vessels may have also influenced their re-distribution to a greater or lesser degree.

Individuals of seabirds that approached the turbines at closer ranges exhibited very high avoidance rates. The vast majority of birds (96.8 %) were observed to avoid the turbines by flying between the rows whilst the remaining 3.2 % were able to adjust their flight height to below the rotor swept area. The total EARs calculated for the observed species are presented in Table 12.7 and indicate a high or very high rate of avoidance within little risk of collision. Whilst seabirds were observed to transit safely through the wind fam between the turbines, the authors noted that there remained a high risk of collision by seabirds when crossing perpendicularly to the spinning blades.

Table 12.7 Empirical Avoidance Rates for observed species

Species	Empirical Avoidance Rate (EAR)	Standard deviation
Northern Gannet	0.998	±0.006
Herring Gull	0.999	±0.005
Great Black-backed Gull	0.996	±0.011
Lesser Black-backed Gull	0.998	±0.006
All large gulls	0.998	±0.007

12.4.1 Conclusions

The observed species exhibit behaviours at various spatial scales that lead to avoidance of rotor swept areas of operational offshore turbines and that these behaviours significantly reduce the risk of those seabirds colliding with rotating turbine blades. Gulls exhibit highly variable avoidance behaviours at macro-scales, and which may considered to be negligible with other factors, such as fishing vessels at the periphery of wind farms, influencing their re-distributions although this remains uncertain. At close meso and micro ranges however, seabirds were observed to exhibit high avoidance capable of flying through the turbine arrays or, to a lesser degree, adjusting their flight heights to avoid the rotor swept area.

Therefore, the area of sea at the Avalon Field Development and location of the OWT 116 km from the coast may be of negligible importance to seabirds supporting < 0.01% of respective populations, although this is uncertain at present. Seabirds flying over the site are expected to be capable of a high rate of avoidance so that there will be little or negligible risk of collisions with the rotating blades turbine. Collisions are thus expected to be rare events and are not expected to have any significant affect at the population level. Impact significance is thus judged to be Negligible.

12.5 Electro-magnetic field (EMF) effects from operational power cable

Operational subsea power cables may emit electro-magnetic fields (EMF) for the length of the cable (up to 25 km as a worst case). EMF emissions from power cables include both electric and magnetic field although typically the direct electric field is blocked by the cables conductive sheathing and it is only the magnetic field and an associated induced electric field that is radiated into the marine environment.

The emissions may affect electro-sensitive fish, such as elasmobranchs, through the emittance of small electrical fields and may disrupt migration movements of certain species through local distortions of the earth's natural magnetic field.

For species that have natural sensitivity to electric or magnetic sources for navigation, orientation or feeding, such as elasmobranchs or migratory fish for example, these additional EMF sources have the potential to affect these functions although there is high uncertainty in these regards. A compilation of research undertaken by U.S. Offshore Wind SEER (2022) notes that whilst some scientific experiments have demonstrated that some species are able to respond to EMF, there is no conclusive evidence to suggest that EMFs from operational offshore wind farms will cause any impact on individuals or populations (Love et al., 2016). Similarly, Hemery (2021) note that despite some stakeholder concern regarding effects on crustaceans, a laboratory experiment showed that anthropogenic EMFs at intensities similar to those of marine energy systems did not significantly affect juvenile lobster sheltering behaviour. Mussels exposed to magnetic fields for three months showed no response and no effect on brown shrimp and the flatfish lounder have been fond (Bochert & Zettler, 2004). With respect to elasmobranchs, studies have shown that skates have negligible effects to EMF although Hutchison et al. (2018 & 2020) observed increases in foraging of Little skate in the presence of EMF from a high voltage (HVDC) cable. Swimming speeds of non-exploratory haddock larvae were reduced in the presence of a magnetic field although exploratory larvae were unaffected (Cresci et al., 2022). Monitoring of the Robin Rigg operational export cable found no significant effect on electrosensitive species, although sampling design was mooted as a possible causal factor for the lack of any detectable effect on this occasion (Malcolm et al., 2013).

The extents of EMF effects from the cable is determined by cable design and by the amount of power flowing though it amongst other factors. Modelling has determined that the strongest EMF is found within 2 m of the cable with lower levels occurring beyond 10 m. The strength of the EMF along an energized cable in California diminished to background levels about one meter away from the cable (Love et al., 2016). Monitoring of the Block Island offshore wind farm export cable found that EMF from the operational AC cable was 10 times less than that predicted.

Species living on the seafloor will encounter EMFs more frequently than those living within the water column and may therefore be considered to be a greater risk from EMF effects. However as stated above, evidence is lacking as to presence of adverse effects of EMFs from submarine power cables on marine species and observations of impacts on individuals and populations are currently lacking.

The cable is proposed to be buried. Burial to 1 -2 m depth below seabed level would provide a distance separation from the highest EMF levels although burrowing fauna would remain exposed in the immediately adjacent sediments. The cable will only be exporting power from one turbine suggesting that the total amount of power flowing through it will be low compared to that exported from wind farm arrays and the corresponding field will be less. Depending on the final cable design option, significant reductions of the induced field may be achieved or eliminated altogether where there is effective screening of the conductor.

12.5.1 Conclusions

In light of the distance separation between the strongest EMF and marine species that will be achieved due to cable burial and the general absence of observations of significant effects of operational cable on marine life, the magnitude of effect of EMF is judged to be minor on low to high valued species receptors and thus impact significance is assessed to be Minor.

This Impact Statement is associated with high uncertainty as it is recognised that further research on the environmental effects of EMF from operational subsea cable is required.

Section 13
Conclusions

13. Conclusions

Ping Petroleum UK PLC (PPUK) proposes to construct the Avalon Field Development in the central North Sea (CNS) located approximately 116 km from the east coast of Scotland.

The proposed Avalon development will comprise two production wells (Well 21/6b-J and Well 21/6b-K). These will be tied-back to a Sevan type Floating Production Storage and Offloading (FPSO) facility, located approximately 3 km west of the wells. Drilling of the wells is planned to commence in Q3 of 2023, at the earliest and will take approximately 70 days for each well (i.e. 140 days in total).

In addition to the FPSO, the Avalon development will comprise the following subsea infrastructure:

- Two subsea production wells completed with a single Xmas tree per well and covered with a fishing friendly protection structure;
- A Subsea Distribution Unit (SDU) Structure installed on the seafloor, which will house equipment for controlling the production and gas lift lines, including an umbilical termination assembly (UTA);
- A Riser Base Structure (RBS), housing a SDU, UTA and subsea isolation valve (SSIV), connecting to the dynamic risers/umbilical with buoyancy modules;
- A 3 km pipe oil production pipeline, which will be trenched and buried, between the Avalon drill centre and RBS;
- A 3 km gas lift line, which will be trenched and buried, between the Avalon drill centre and RBS;
- A 3 km control umbilical, which will be trenched and buried, between the Avalon drill centre and RBS;
- A power cable up to 25 km in length, trenched and buried, between a floating offshore wind turbine (OWT) and the FPSO;
- Anchored mooring systems for the FPSO and OWT; and
- An optional 6" gas export / import pipeline from the Avalon field to the Ettrick pipeline end manifold (PLEM) location 40 km to the west (exact route to be determined); or
- An optional 6" gas export / import pipeline from the Avalon field to the Britannia pipeline end manifold (PLEM) location 5 km to the north/north-west (exact route to be determined).

A floating offshore wind turbine (OWT) sited close to the FPSO is proposed which will provide power to the FPSO, once the natural gas in the reservoir is depleted and can no longer provide (enough) fuel to meet power requirements. In addition, the proposals include an optional import/export gas pipeline to provide fuel gas for the generator and to supplement the OWT on days when wind conditions alone cannot (fully) meet power requirements. The exact location of the OWT is still to be determined, depending on the safety and permitting constraints of the development (Section 3.7).

The proposed activities and available options have been described (Section 2 and 3), together with a description of the local environment (Section 4). The interactions between the project and the environment have been identified (Section 5) and all potentially significant environmental impacts assessed (Sections 7 to 11). The key environmental concerns identified as requiring consideration for impact assessment were:

- Drilling Impacts (Section 7);
- Physical Presence Impacts (Section 8);
- Atmospheric Emissions (Section 9);
- Produced Water Discharges (Section 10);
- Accidental Events (Section 11);
- Other Impacts (Section 12).

The main issues identified and conclusions on their residual impacts following the incorporation of mitigation measures are summarised below.

13.1 Drilling Impacts

During the drilling operations, water-based mud (WBM) and drill cuttings will be discharged when drilling the upper sections of the Avalon wells. The effects of WBM and cuttings discharges on the benthic environment are related to the total quantity discharged and the oceanic energy regime encountered at the discharge site, particularly the currents close to the seabed itself (Neff, 2005).

The discharge of cuttings and WBM at the Avalon Field Development has the potential to cause a localised effects on the benthic environment, primarily through direct physical changes to the seabed. This effect is expected to be predominantly limited to within 50 m of the well location. Physico-chemical effects may be detected at distances up to 250 m from the well location. Recovery of the benthos is expected to begin soon after discharges cease.

Important ocean quahogs (Scottish Priority Marine Feature (PMF)) have been documented in the vicinity of the proposed development however the species is known to exhibit high resilience to the effects of smothering (Powilleit et al., 2006 and Powilleit et al., 2009).

The acute toxicity of WBM is considered to be low (Neff, 1987) and in general, any toxic effects of WBM associated with cuttings discharge have been deemed to be negligible (Neff, 2005; Neff, 2010; OSPAR, 2007).

With mitigation in place (Section 7.4), the significance of the effects of the discharge of drilling muds from the proposed drilling operations is considered to be ‘minor’ and therefore not significant.

13.2 Physical Presence Impacts

The action of trenching and burial of pipelines and cables together with the placement of infrastructure on the seabed cause seabed disturbances, raises suspended sediment plumes and reduces the total area of original habitat available. However, given the temporary, reversible, and localised nature of the effects, impact significance is judged to be minor. With mitigation in place (micro-siting), adverse effect on important pockmark habitats is not expected.

A 500 m exclusion zone will be imposed around the wells in line with regulations. In addition, bottom fisheries may be excluded from an area of up to 1,500 around the OWT, depending on the final mooring design, to avoid snagging of, and damage to bottom gears on the OWT mooring system. This exclusion may displace local fisheries for the duration of the project increasing fishing effort in immediate surrounding areas.

Vessels passing within 2 nm of the Avalon Field Development location may be affected by the temporary presence of the drilling rig and the permanent presence of the FPSO, but sufficient room is forecast to remain available for all mariners to achieve a safe passing distance.

13.3 Atmospheric Emissions

Atmospheric emissions will be produced during drilling, installation and production operations, as a result of power generation onboard the mobile offshore drilling unit (MODU) and floating production storage and offloading (FPSO) unit as well as accompanying vessels such as the construction support vessel (CSV), pipeline laying vessel (PLV), support vessels and helicopter activity. In addition to these, there will be flaring emissions during well clean-up operations undertaken from the MODU. These emissions will contribute to local and global environmental effects. At a local level, impacts are mitigated by Health and Safety measures in place to control emissions and by the dispersive nature of the offshore environment. As such, the any local air pollution effects are expected to be 'minor' to negligible and therefore insignificant.

Emissions will contribute to global environmental issues, including climate change. The contribution of the proposed drilling programme is comparable to similar operations, and small in comparison to emissions at an industry wide level. The emissions arising from the Avalon Field Development are forecast to make up a very small proportion of forthcoming UK Carbon Budgets and North Sea Transition Deal targets.

The installation of a floating OWT to provide power for the FPSO will assist in the reduction of atmospheric emissions through a reduction in use of fuel gas and/or diesel to power the development. Electrification of the Avalon Field Development is consistent with UK and Scottish Government targets to decarbonise the sector whilst also aligning with the aims of the NSTD and the British Energy Strategy to utilise North Sea hydrocarbon reserves to maintain energy security whilst meeting Net Zero targets.

13.4 Produced Water Discharges

Produced water, a by-product of oil and gas extraction, will be discharged from the FPSO during production operations at the Avalon field. Modelling undertaken to simulate the release of produced water from the FPSO shows that rapid dilution of produced water in the receiving marine environment will occur and that the predicted dilution rates would be well within established guidance thresholds. Typically, produced water discharges are predicted to be diluted rapidly within a few tens of metres and remain close to the sea surface. Any discharge of produced water would not reach the seabed and impact on benthic communities, including ocean quahog. No significant accumulation of chemicals associated with produced water discharge is anticipated due to the nature of the receiving environment and the buoyant nature of the plumes.

Prior to discharge, PPUK will aim to achieve the lowest possible oil in water (OIW) concentration in produced water through treatment and cleaning up of the produced water using facilities onboard the FPSO. This treatment process is designed to reduce the OIW content in produced water to 15 mg/l or less (monthly average) which is below the OSPAR recommended performance standard of 30 mg/l as implemented by the Oil Pollution Prevention and Control Regulations, 2005 (as amended).

Only industry standard production chemicals will be used and discharged in relation to operations at the Avalon Field. All chemicals used will be included in the Offshore Chemical Notifications Scheme (OCNS) and the most environmentally friendly options evaluated and, where possible, chemicals that pose little or no risk (PLONOR) to the environment will be used. Additionally, chemical risk assessments will be undertaken as part of the environmental permitting process which PPUK will submit to the OPRED to obtain approval prior to use and discharge of any chemicals.

13.5 Accidental Events

The risk of a large-scale hydrocarbon spill during drilling operations or during the subsequent production phase of the proposed Avalon Field Development is very low. Stringent safety and operational procedures will be adhered to throughout the operations as described in the ES. A robust well design has been developed to minimise the potential for well control issues, and all critical elements of this design and the execution operations have been both peer and independently reviewed.

PPUK will have a detailed operation specific Temporary Operations Oil Pollution Emergency Plan (TOOPEP) in place during the drilling of the Avalon production wells. During the production phase, the Avalon Field Development will be covered by a separate Oil Pollution Emergency Plan (OPEP) to ensure that immediate and appropriate action is taken in the event of any hydrocarbon spillage, minimising any impact to the marine environment.

A contract with Oil Spill Response Limited (OSRL) is in place, allowing the rapid deployment of oil spill response equipment and personnel in the event of a large oil spill incident. Specific response equipment would be available including booms to contain surface spills at sea or protect sensitive shorelines. Ultimately, the type and size of spill, along with the metocean conditions at the time of the spill, will dictate which of these resources is most suitable for the spill event.

With the measures in place to prevent an oil spill incident from happening and the oil spill contingency planning and response resources available to PPUK in the event of a large oil spill event, the residual environmental risk posed by the proposed Avalon Field Development is judged to be reduced to an acceptable level.

13.6 Other Impacts

Waste management will be undertaken in compliance with current environmental legislation. The management of offshore waste generated on the UKCS is strictly regulated and the UK has well-established infrastructure in place to manage this waste effectively. Therefore, no significant impacts regarding the production and treatment of waste are anticipated.

Piling of seabed anchors of the FPSO and OWT (if required) may generate noise at levels which are harmful to marine life if in close proximity and may disturb sensitive species over longer distances. In the event that piling is required, then standard mitigation practice will be implemented to ensure a safe distance separation between marine mammals and the noise source. Given the anticipated short duration of such operations (a few days each at the FPSO and OWT), effects are expected to be very short lived. Impact significance is thus judged to be Negligible, in the place of mitigation.

Seabirds flying over the site are expected to be capable of a high rate of avoidance so that there will be little or negligible risk of collisions with the rotating blades turbine. Collisions are thus expected to be rare events and are not expected to have any significant effect on the receptor population level. Impact significance is thus judged to be Negligible in this regard.

Operational subsea cables emit electro-magnetic fields (EMF) which have potential to disrupt orientation, migration and feeding of sensitive marine species, although there is a high level of uncertainty in this regard. The planned burial of the cable below the seabed level will provide a distance separation between the strongest EMF and marine species. The magnitude of effect of EMF on marine species is thus judged to be minor although the need for further data on EMF interactions is acknowledged.

13.7 Overall Conclusions

The ES has considered the worst-case impact of the proposed Avalon Field Development and is therefore a conservative consideration of the potential effects on the environment. Overall, it is judged that the environmental impacts of the proposed Avalon Field Development operations, when undertaken in conjunction with the mitigation measures identified in the ES, will not incur any significant long-lasting environmental effects.

Section 14
References

14. References

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Section 15

Glossary

15. Glossary

Acid rain	Precipitation of acidic pollutants, chiefly sulphur dioxide and nitrogen oxide, released into the atmosphere by the burning of fossil fuels such as oil.
Acidification	The decrease in pH of the oceans, caused by their uptake of atmospheric carbon dioxide.
Annex I habitat	A rare or characteristic habitat which is affords protection under on the EU Habitats Directive.
Annex II species	Animal or plant species requiring designation of Special Areas of Conservation under the EU Habitats Directive.
Annex IV species	Animal or plant species in need of strict protection under the EU Habitats Directive.
Annulus	The space between wellbore and casing.
Appraisal well	A well drilled after a discovery well to gain more information on the reservoir.
Atmospheric emissions	A collective term for gases and particulates released to the atmosphere.
Barite	Barium sulphate ($BaSO_4$).
Bathymetry	The measurement of underwater depth in ocean, seas or lakes.
Benthic	Of or relating to the seabed.
Benthos	Animals that occur on or in the seabed.
Biogenic reef	This reef may be composed almost entirely of the reef building organisms and their tubes or shells, or may include sediments, stones and shells bound together by the organism.
Biota	The flora or fauna occurring in a particular area.
Biotope	The region of a habitat associated with a particular ecological community.
Block	Sub-division of territorial seas for the purpose of licensing to a company or group of companies for exploration and production rights. A UK block is approximately 200 to 250 km^2.
Blowout	A blowout occurs when gas, oil or saltwater escapes in an uncontrolled manner from a well.
Blowout preventer	A hydraulically operated wellhead device that can be actuated to close a well in order to prevent an uncontrolled release of fluids (a blow-out).
CAN-ductor	A Conductor Anchor Node suction pile with integrated conductor. The CAN is a combination of suction anchor and guide pipe. The

	suction anchor pushes the guide pipe into the seabed, providing top support for the conductor.
Casing	Steel lining inserted into a well as drilling progresses to prevent the wall of the hole from caving in during drilling, to prevent the inflow of unwanted fluids from surrounding formations and to provide a means of extracting oil (and gas) if a well is productive.
Cephalopods	Class of mollusc characterised by having a prominent head, and a modified mollusc foot in the form of arms or tentacles. Examples include the squid and the octopus.
Cetacean	Aquatic mammals of the order Cetacea, which comprise porpoises, dolphins, and whales.
Circalittoral	The region under shoreline which extends from the lower limit of the shallow waters closest to the shore to the maximum depth at which photosynthesis is still possible.
Concrete Mattress	A structure made from concrete used to support and protect infrastructure on the seabed.
Conductor	First string of casing to be inserted and cemented into the borehole. Its purpose is to prevent the soft formations near the surface from caving in and to conduct drilling mud from the bottom of the hole to the surface when drilling starts.
Continental shelf	The continental shelf refers to the extension of the continent into the ocean.
Continental slope	The continental slope refers to the sloping margin between the shelf break and the shelf basin.
Copepods	Small free-living or parasitic crustaceans of the subclass Copepoda, living in marine and fresh waters. The free-living forms are an important constituent of plankton.
Cuttings	Rock chips produced by chipping and crushing action of the drill bit.
Cuttings pile	An accumulation of rock chips or formation debris, produced by the action of the drill bit, and deposited on the seabed.
Demersal	Living in the water column at or near seabed. Usually in relation to fish.
Deterministic Oil Spill Modelling	Oil spill trajectory predictions for actual spills or exercises. Provides single expected forecasts for spills.
Diatoms	Unicellular planktonic algae with silica shells.
Dinoflagellates	Unicellular planktonic organisms often bearing a tough cellulose shell (theca).

Dispersant	A chemical that breaks up concentrations of oil in water, reducing the oil to small droplets (an emulsion).
Diversity	The variety of life forms i.e. distinct organisms within an area.
Drilling mud/fluid	A mixture of base substance and additives used to lubricate the drill bit and to counteract the natural pressure of the formation.
Dynamic positioning/ dynamically positioned	The stationing of a drilling rig at a specific location in the sea by the use of computer-controlled thrusters.
Environmental aspect	An activity that causes an environmental effect.
Environmental effect	A change to the environment or its use.
Epifauna	Benthic organisms that live on the surface of the seabed, either sessile or free moving.
European Protected Species	Species listed in Annex IV of the Habitats Directive.
Field	An accumulation of hydrocarbons in the subsurface. Consists of a reservoir in a shape that will trap hydrocarbons and that is covered by an impermeable, sealing rock.
Flare	A vent for burning and therefore disposing of unwanted gases or to burn off hydrocarbons when there is no way to transport or utilise them.
FPSO	Floating production storage and offloading unit used to gather, process and store hydrocarbons produced from subsea wells before being offloaded to vessels
Gadoids	Fish belonging to the family Gadidae, which includes cod, haddock and whiting.
Global Warming Potential	A measure of how much a given mass of gas is estimated to contribute to global warming, relative to the same mass of carbon dioxide.
Greenhouse Gas	Gas that contributes to the greenhouse effect. Includes gases such as carbon dioxide (CO_2) and methane (CH_4). The greenhouse effect results in a rise in temperature due to incoming solar radiation being trapped by carbon dioxide and water vapour in the Earth's atmosphere.
Hydrocarbon	A compound containing only the elements hydrogen and carbon. May exist as a solid, a liquid or a gas. The term is mainly used in a catch-all sense for crude oil, natural gas, condensate and their derivatives.
Important Bird Areas	A global network of sites for the conservation of birds and bird habitats, set up by BirdLife International.
Immiscible	Fluids that do not mix one another (e.g. oil and water).

Infauna	Animals living within seabed sediments mostly within the top 10 to 15 cm.
Macrofauna	Benthic organisms that are retained in a 0.3 mm sieve.
Machair	Fertile low-lying grassy plain found on some north-west coastlines of Ireland and Scotland.
Megafauna	Large or giant animals.
Mud	Fine materials (< 0.063 mm), such as clay and silt.
Nature Conservation Marine conservation of Protected Area	An area of the marine environment designated for the nationally important marine habitats and species and features of geological or geomorphological interest.
Nautical mile	Nautical measurement of distance, equivalent to 1.852 km or 1.15 miles.
Ocean quahog	A long lived species of clam which lives buried in sediments
Oil based mud	Drilling mud with oil as the fluid continuous phase.
Ozone	Atmospheric gas which acts as a pollutant creating smog at ground level, and in the upper atmosphere filters out ultra-violet light from reaching the earth.
Pelagic	Inhabiting the water column of the sea.
Phytoplankton	Free floating microscopic plants
Plankton	Free floating organisms found in the oceans and other aquatic systems.
Pockmarks	Craters in the seabed formed by fluids such as liquid and gas, erupting and streaming through the sediments. They can be classed as Annex 1 habitats "Submarine structures made by leaking gasses", by the Joint Nature Conservation Committee.
Polychaete	A class of marine annelid worms.
Priority Marine Feature	Priority Marine Features (PMFs) are species or habitats which the national conservation bodies responsible for Scottish waters (Scottish Natural Heritage (SNH) and Joint Nature Conservation Committee (JNCC)) consider to be marine nature conservation priorities. The aim of the PMFs work is to produce a focused list of marine habitats and species to help target future conservation work in Scotland.
Pseudo-oil/synthetic based mud	Synthetic alternative to oil-based mud, created from esters or vegetable oil.
Ramsar sites	Wetlands of international importance.
Reef	A collection of rocks, corals or ridge of sand just above or below the surface of the sea.

Reservoir	The underground formation where oil and gas has accumulated. It consists of a porous rock to hold the oil or gas, and a cap rock that prevents its escape.
Riser	A pipe which connects an offshore installation to a subsea wellhead or pipeline during drilling or production operations.
Seabed Take	A reduction in the total extent of the original seabed habitat (take) resulting from development infrastructure on the seabed.
Semi-submersible mobile drilling unit	A semi-submersible mobile drilling unit is a floating drilling rig that is capable of working in water depths ranging from shallow through to ultra-deepwater.
Separator	A pressure vessel used for separating gas and liquid components from processed fluids.
Spawning	The production and release of gametes (eggs or sperm) by animals.
Special Area of Conservation	Protected sites designated under the EC Habitats Directive in order to conserve important habitats and species (excluding birds).
Special Protection Area	Sites designated by the UK Government under the EC Birds Directive to protect certain rare, vulnerable, and regularly occurring migratory species of birds.
Stochastic Oil Spill Modelling	Modelling based on actual statistical wind speed and direction frequency data. Provides a probability range of sea surface oil and beaching, representative of the prevailing conditions.
Subsea Distribution Unit	Located subsea and provides the hydraulic, chemical, fibre optic and electrical distribution between the UTA (Umbilical Termination Assembly) and the rest of the subsea system.
Umbilical	Connections used offshore between the subsea equipment and platforms or floating production units and enabling the control from the surface.
Umbilical Termination Assembly	Provides the hydraulic, chemical, fibre optic and electrical distribution between the control umbilical and the subsea system.
Venting	The discharge of un-burnt, unwanted gases or hydrocarbons.
Water based mud	A type of drilling fluid (mud) consisting mainly of water, which has additives to modify it and make it more effective.
Wellhead	The unit at the surface of a well which controls pressure and connects to drilling and production equipment. The wellhead is the upper part of the well, located above the casing and under the drilling floor.
Xmas Tree	Assembly of valves and fittings to control the flow of oil and gas from the target reservoir.

Zooplankton	Animals which drift in the water column along with prevailing currents, mostly microscopic.

Section 16

Abbreviations

16. Abbreviations

AHT	Anchor handling tug
AIS	Automatic Identification Systems
AMF	Automatic Mode Function
Ba	Barium
BAP	Biodiversity Action Plan
BAT	Best available technology
BEIS	Department for Business Energy and Industrial Strategy
BEP	Best environmental practice
BOD	Biological oxygen demand
BOP	Blowout preventer
CAPEX	Capital expenditure
Cd	Cadmium
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CH_4	Methane
CHARM	Chemical Hazard Assessment and Risk Management
CNS	Central North Sea
CNSFTC	Central North Sea Fibre Telecommunications company Limited
CO_2	Carbon dioxide
CP	Chemical permit
CP-SATs	Chemical permit subsidiary application templates
CPUE	Catch per unit effort
Cr	Chromium
CSP	Concept Select Process
CSV	Construction support vessel
Cu	Copper
DECC	Department of Energy & Climate Change
DepCon	Deposit consent
DP	Dynamic positioning
DPM	Diesel Particulate Matter
EAR	Empirical Avoidance Rate
EBS	Environmental baseline Survey
ECD	Early Consultation Document
ECMWF	European Centre for Medium-Range Weather Forecasts
EDS	Emergency Disconnect System
EDR	Effective Deterrent Radius
EEMS	Environmental and Emissions Monitoring System

EFL	Electrical flying lead
EIA	Environmental impact assessment
ENVID	Environmental Issues Identification Workshop
ES	Environmental Statement
EUNIS	European Nature Information System
Fe	Iron
FEAST	Feature Activity Sensitivity Tool
FEED	Front end engineering design
FPSO	Floating production storage and offloading vessel
GEAD	Golden Eagle Area Development
GHG	Greenhouse gases
GOR	Gas in oil ratio
GWP	Global warming potential
HFL	Hydraulic flying lead
HSE	Health, Safety and Environment
HSEMS	Health, Safety and Environment Management System
HOCNS	Harmonised Offshore Chemical Notification System
HR	High resolution
HVDC	High voltage direct cable
HYCOM	Hybrid Coordinate Ocean Model
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organisation
INTOG	Innovation and Targeted Oil & Gas
IOGP	International Association of Oil and Gas Producers
JNCC	Joint Nature Conservation Committee
JOG	Jersey Oil and Gas
KCl	Potassium chloride
LMRP	Lower Marine Riser Package
LTOBM	Low toxicity oil-based muds
LWD	Logging while drilling
MA	Major Accidents
MAH	Major Accident Hazards
MAP	Methane Action Plan
MARLIN	Marine Life Information Network
MARPOL	International Convention for the Prevention of Pollution from Ships
MAT	Master applications template
MDBRT	Measured depth below the rotary table
MCO	Marine Conservation Order

MCZ	Marine Conservation Zones
MDAC	Methane derived authigenic carbonates
MEG	Methanol/mono-ethylene glycol
MEI	Major Environmental Incident
MER-UK	Maximising Economic Recovery Strategy for the United Kingdom
MMO	Marine Mammal Observer
MODU	Mobile offshore drilling unit
MPN	Most Probable Number
MWA	Mid-water arch
N_2O	Nitrous oxide
NA	Navigational assessment
NCMPA	Nature Conservation Marine Protected Area
Ni	Nickel
NMP	National Marine Plan
NO_2	Nitrogen Oxide
NOAA	National Oceanic and Atmospheric Administration
NORM	Naturally occurring radioactive material
NOx	Nitrogen oxide
NSBP	North Sea Benthos Project
NSTA	North Sea transition Authority
NSTD	North Sea Transition Deal
O_3	Ozone
OBM	Oil base mud
OCNS	Offshore Chemical Notifications Scheme
OFWT	Offshore wind turbine
OGA	Oil and Gas Authority
OIM	Offshore Installation Manager
OPEP	Oil Pollution Emergency Plan
OPEX	Operating expenses
OPOL	Offshore Pollution Liability Association Limited
OPRED	The Offshore Petroleum Regulator for Environment and Decommissioning
OSCAR	Oil Spill Contingency and Response
OSRL	Oil Spill Response Ltd
OSPAR	Oslo and Paris convention
OSPRAG	Oil Spill Prevention and Response Advisory Group
OWF	Offshore wind turbine
OWT	Offshore wind turbine
PAH	Polycyclic aromatic hydrocarbon

PAM	Passive Acoustic Monitoring
Pb	Lead
PETS	Portal Environmental Tracking System
PEXA	Practice and exercise areas
PLEM	Pipeline end manifold
PLONOR	Pose little or no risk
PLV	Pipeline laying vessel
PM	Particulate matter
PMF	Priority Marine Feature
POBM	Pseudo oil base mud
PPUK	Ping Petroleum UK Limited
PTS	Permanent Threshold Shift
PWA	Pipeline works authorisation
RBS	Riser Base Structure
ROV	Remotely operated vehicle
SAC	Special Area of Conservation
SAT	Subsidiary application template
SBM	Synthetic base muds
SDU	Subsea Distribution Unit
SEL	Sound Exposure Level
SFF	Scottish Fishermen's Federation
SOC	Sediment oxygen concentration
SoS	Secretary of State
SOSI	Seabird Oil Sensitivity Index
SOTEAG	Shetland Oil Terminal Environmental Advisory Group
SO_X	Sulphur dioxide
SPA	Special Protection Areas
SSIV	Subsea isolation valve
TAR	Turnaround
THC	Total hydrocarbon concentrations
TOOPEP	Temporary Operations Oil Pollution Emergency Plan
TSS	Total suspended solids
TTS	Temporary Threshold Shift
TVD	True vertical depth
UK	United Kingdom
UKBAP	The UK Biodiversity Action Plan
UKCS	The United Kingdom Continental Shelf
UKOOA	United Kingdom Offshore Operators Association

UTA	Umbilical termination assembly
VOC	Volatile organic compound
WBM	Water-based mud
Zn	Zinc

Appendix 1
Summary of Legislation

Appendix 1 Summary of Legislation

The main environmental legislation relevant to the proposed Avalon field development.

Topic	Legislation
Consenting	
Environmental Statement (ES)	▪ The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020; ▪ The Offshore Chemicals Regulations 2002 (as amended); ▪ The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005 (as amended); ▪ The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (as amended); ▪ The Offshore Marine Conservation (Natural Habitats &c) Regulations 2007 (as amended); ▪ The Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations 2019; ▪ Petroleum Act 1998 (as amended); ▪ The Energy Act 2008 (as amended); ▪ Marine and Coastal Access Act 2009; ▪ Scottish National Marine Plan (NMP); ▪ The Climate Change Act 2008; ▪ The Climate Change (Scotland) Act 2009; ▪ UK Energy White Paper 2020; ▪ North Sea Transition Deal; ▪ British Energy Security Strategy; ▪ Shipping (Oil Pollution Preparedness, Response and Cooperation Convention) Regulations 1998; ▪ Offshore Chemical Regulations 2002, as amended; ▪ The Offshore Installations (Offshore Safety Directive (Safety Cases etc.) Regulations 2015.
Well Consent	▪ The Petroleum Act 1998 (as amended). ▪ The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020; ▪ Well Operations Notification System (WONS); ▪ Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015 (2015 licensing regulations); ▪ Drilling Operations Application (DRA) and Chemical Permit Subsidiary Application Template(SAT).
Well Test Consent	▪ The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020; ▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended; ▪ Petroleum Licensing (Exploration & Production) (Seaward and Landward) Regulations 2004; ▪ Convention on the Protection of the Marine Environment of the North East Atlantic 1992 (OSPAR Convention).
Consent to Locate	▪ Marine and Coastal Access Act 2009; ▪ Marine Scotland Act 2010; ▪ The Energy Act 2008 (as amended)
Pipeline Consent	▪ Petroleum Act 1998 (as amended); ▪ The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020; ▪ Pipeline Safety Regulations 1996, as amended;

	▪ Marine and Coastal Access Act 2009; ▪ Marine Scotland Act 2010. ▪ Pipeline Operations MAT (PLA), Chemical Permit SAT (CP), EIA Direction for Pipeline Operations SAT (PL), and EIA Direction for Deposits SAT (PL).
Production Consent	▪ Petroleum Act 1998 (as amended); ▪ The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020; ▪ Offshore Petroleum Licensing (Offshore Safety Directive) Regulations 2015 (2015 licensing regulations); ▪ Production Operations MAT (PRA) and EIA Direction for Commencement of Production SAT (PR).
Produced Water	▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended; ▪ Production Operations MAT (PRA) and Oil Discharge Permit (Life) SAT (OLP).
Topic	**Legislation**
Routine Drilling Operations and Routine Installation Operations	
Sewage from Drilling Rig	▪ MARPOL 73/78 Annex IV Prevention of Pollution by Sewage from Ships; ▪ Annex V of MARPOL 73/78 (including amendments) - Regulations for the Prevention of Pollution by Garbage from Ships ▪ Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008; ▪ Food and Environment Protection Act 1985 (FEPA); ▪ Deposits in the Sea (Exemption) Order 1985; ▪ Convention on the Protection of the Marine Environment of the North East Atlantic 1992 (OSPAR Convention).
Oil Contaminated Discharges	▪ Offshore Chemical Regulations 2002, as amended; ▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) (OPPC) Regulations 2005, as amended; ▪ Food and Environment Protection Act 1985 (FEPA); ▪ Convention on the Protection of the Marine Environment of the North East Atlantic 1992 (OSPAR Convention); ▪ OSPAR Decision 2000/3 on the Use of Organic-phase Drilling Fluids (OPF) and the Discharge of OPF-Contaminated Cuttings; ▪ OSPAR Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles.
Water Based Mud (WBM) Cuttings	▪ Offshore Chemical Regulations 2002, as amended; ▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) (OPPC) Regulations 2005, as amended; ▪ Food and Environment Protection Act 1985 (FEPA); ▪ Deposits in the Sea (Exemptions) Order 1985; ▪ OSPAR Recommendation 2006/5 on a Management Regime for Offshore Cuttings Piles.
Chemical Use	▪ The Offshore Chemicals Regulations 2002, as amended; ▪ The REACH Enforcement Regulations 2008, as amended; ▪ Convention on the Protection of the Marine Environment of the North East Atlantic 1992 (OSPAR Convention); ▪ OSPAR Recommendation 2006/3 on Environmental Goals for the Discharge by the Offshore Industry of Chemicals that are, or which contain Substances Identified as Candidates for Substitution; ▪ OSPAR Recommendation 2005/2 on Environmental Goals for the Discharge by the Offshore Industry of Chemicals that Are, or Contain Added Substances, Listed in the OSPAR 2004 List of Chemicals for Priority Action; ▪ OSPAR Recommendation 2000/2 on a harmonised mandatory control system for the use and reduction of the discharge of offshore chemicals as amended by OSPAR Decision 2005/1; ▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended (OPPC);

	▪ Food and Environment Protection Act 1985 (FEPA); ▪ Deposits in the Sea (Exemptions) Order 1985.
Rig Drainage Water	▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) (OPPC) Regulations 2005, as amended; ▪ Convention on the Protection of the Marine Environment of the North East Atlantic 1992 (OSPAR Convention); ▪ PARCOM Recommendation 86/1 of a 40 mg/l Emission Standard for Platforms; ▪ Merchant Shipping (Prevention of Oil Pollution) Regulations 1996, as amended; ▪ Merchant Shipping Act 1995; ▪ International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78; ▪ Merchant Shipping (Prevention of Oil Pollution) (Amendment) Regulations 1994.
Topic	**Legislation**
Atmospheric Emissions	
Turbine/Combustion Emissions	▪ MARPOL 73/78 Annex VI Prevention of Air Pollution from Ships; ▪ The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008, as amended; ▪ Offshore Combustion Installations (Prevention and Control of Pollution) Regulations 2001, as amended; ▪ The Offshore Combustion Installations (Pollution Prevention and Control) Regulations 2013; ▪ Climate Change Act 2008; ▪ National Emission Ceilings Regulations 2002; ▪ Pollution Prevention and Control Act 1999.
Halocarbons (halons, CFCs)	▪ Ozone Depleting Substances Regulations 2015; ▪ Fluorinated Greenhouse Gases Regulations 2015; ▪ MARPOL 73/78 Annex VI Prevention of Air Pollution from Ships; ▪ The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008, as amended.
Flaring and Venting	▪ Energy Act 1976; ▪ Energy Act 2016 ▪ Petroleum Act 1998 (as amended); ▪ Petroleum Licensing (Exploration & Production) (Seaward and Landward) Regulations 2004; ▪ The Petroleum (Current Model Clauses) Order 1999; ▪ Climate Change Act 2008; ▪ National Emission Ceilings Regulations 2002; ▪ Waste and Emissions Trading Act 2003.
Routine Drilling Operations **Chemical Transport**	
Bulked Chemicals	▪ Environmental Protection Act 1990; ▪ Merchant Shipping (Dangerous or Noxious Liquid Substances in Bulk) Regulations 1996, as amended.
Dangerous Goods	▪ Environmental Protection Act 1990; ▪ Controlled Waste Regulations 1992, as amended; ▪ The Merchant Shipping (Dangerous Goods and Marine Pollutants) Regulations 1997; ▪ The Environmental Protection (Duty of Care) (Scotland) Regulations 2014;

	▪ The Waste (Scotland) Regulations 2011.
Hazardous Chemicals	▪ Environmental Protection Act 1990; ▪ Controlled Waste Regulations 1992, as amended; ▪ Chemicals (Hazard Information and Packaging for Supply) Regulations 2009; ▪ The Environmental Protection (Duty of Care) (Scotland) Regulations 2014; ▪ The Waste (Scotland) Regulations 2011, as amended.
Topic	**Legislation**
Wildlife Protection (Offshore)	
Habitats and Species	▪ Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (Offshore Marine Regulations, OMR), as amended; ▪ The Conservation of Habitats and Species Regulation 2010, as amended; ▪ The Conservation of Offshore Marine Habitats and Species Regulations 2017; ▪ The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001; ▪ The UK Marine and Coastal Access Act 2009; ▪ The Marine (Scotland) Act 2010;
Cetaceans	▪ The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, as amended; ▪ Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas 1991 (ASCOBANS); ▪ Wildlife and Countryside Act (1981); ▪ Offshore Marine Conservation (Natural Habitats, &c.) Regulations 2007 (Offshore Marine Regulations, OMR), as amended.
Waste Handling	
Transfer of Oil Contaminated Wastes	▪ Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended.; ▪ Merchant Shipping (Prevention of Oil Pollution) Regulations 1996; ▪ Prevention of Pollution (Reception Facilities) Order 1984; ▪ Merchant Shipping and Maritime Security Act 1997.
Garbage	▪ Food and Environment Protection Act 1985, as amended; ▪ Deposits in the Sea (Exemptions) Order 1985; ▪ Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008.
Transfer of waste/garbage from installations	▪ Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008; ▪ Food and Environment Protection Act 1985, as amended; ▪ Deposits in the Sea (Exemptions) Order 1985; ▪ Environmental Protection (Duty of Care) Regulations 1991; ▪ Waste Management Licensing (Scotland) Regulations 2011; ▪ Waste (Scotland) Act 2011.
Transfer of special waste	▪ Environmental Protection Act 1990; ▪ Controlled Waste Regulations 1992, as amended; ▪ Special Waste Regulations 1996, as amended; ▪ The Special Waste Amendment (Scotland) Regulations 2004; ▪ The Environmental Protection (Duty of Care) (Scotland) Regulations 2014; ▪ The Waste (Scotland) Regulations 2011, as amended.

Radioactive waste	▪ Radioactive Substances Act 1993 (RSA 93), as amended; ▪ Radioactive Substances (Phosphatic Substances, Rare Earths etc.) Exemptions Order 1962; ▪ Radioactive Substances (Substances of Low Activity) Exemption Order 1986, as amended; ▪ Merchant Shipping (Dangerous Goods and Marine Pollutants) Regulations 1997.
Topic	**Legislation**
Support Vessels	
Machinery Space Drainage from Shipping	▪ The Merchant Shipping (Prevention of Oil Pollution) Regulations 1996, as amended; ▪ Merchant Shipping Act 1995; ▪ International Convention for the Prevention of Pollution from Ships (MARPOL) 73/78.
Sewage from Vessels	▪ MARPOL 73/78 Annex IV Regulations for the Prevention of Pollution by Sewage from Ships; ▪ Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008; ▪ Deposits in the Sea (Exemption) Order 1985; ▪ Food and Environment Protection Act 1985, as amended.
Garbage from Vessels	▪ Food and Environment Protection Act 1985, as amended; ▪ Deposits in the Sea (Exemption) Order 1985; ▪ Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008.
Atmospheric Emissions from Vessels	▪ The Merchant Shipping (Prevention of Air Pollution from Ships) Order 2006; ▪ MARPOL 73/78 Annex VI - Prevention of Air Pollution from Ships, the regulations in this annex set limits on sulphur oxide and nitrogen oxide emissions from ship exhausts and prohibit deliberate emissions of ozone depleting substances; ▪ The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008.
Accidental Events (Installations)	
Oil Pollution Emergency Planning	▪ Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations 1998, as amended; Offshore Installations (Emergency Pollution Control) Regulations 2002; ▪ Offshore Installations (Prevention of Fire and Explosion, and Emergency Response) Regulations 1995; ▪ The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended. ▪ Merchant Shipping (Oil Pollution, Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015 ▪ Offshore Installations (Emergency Pollution Control) Regulations 2002
Spill Reporting	▪ Model Clauses of Licence; ▪ Petroleum Operations Notice no 1. ▪ Offshore Installations (Emergency Pollution Control) Regulations 2002
Accidental Events (Vessels)	
Spills, Release or Possible Escape of Oil, Noxious Substance or Marine Pollutant	▪ Merchant Shipping (Oil Pollution Preparedness, Response and Co-operation Convention) Regulations 1998, as amended; ▪ Merchant Shipping (Oil Pollution, Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015; ▪ Merchant Shipping (Reporting of Pollution Incidents) Regulations 1987; ▪ Merchant Shipping (Reporting Requirements for Ships Carrying Dangerous Polluting Goods) Regulations 1995; ▪ Petroleum Operations Notice no 1. ▪ Offshore Installations (Emergency Pollution Control) Regulations 2002?

Topic	Legislation
Decommissioning	
Well Suspension and Abandonment	▪ Petroleum Act 1998(as amended); ▪ Energy Act 2008; ▪ The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005, as amended; ▪ Offshore Chemicals Regulations 2002; ▪ Offshore Chemicals (Amendment) Regulations 2011; ▪ Marine and Coastal Access Act 2009 (MCAA); ▪ Marine Scotland Act 2010; ▪ Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001, as amended; ▪ The Offshore Petroleum Activities (Conservation of Habitats) (Amendment) Regulations 2007; ▪ Petroleum (Production) (Seaward Areas) Regulations 1988, as amended; ▪ Offshore Installations and Wells (Design and Construction etc) Regulations 1996; ▪ Food and Environment Protection Act 1985; ▪ Well intervention Permit via the UK Oil Portal, FEPA licence may be required, or a Marine Licence for deposits on the seabed. A MCAA licence via the UK Oil Portal.

Appendix 2
Production Profiles for the Avalon Field Development

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Appendix 2 Production Profiles for the Avalon Field

Table A2.1: Production Profiles for both production wells with High Case (P_{10}), Base Case (P_{50}) and Low Case (P_{90}) presented.

Year	High Case (P_{10})						Base Case (P_{50})						Low Case (P_{90})					
	Oil Rate		Water Rate		Gas Rate		Oil Rate		Water Rate		Gas Rate		Oil Rate		Water Rate		Gas Rate	
	BOPD	m^3/day	BWPD	m^3/day	MMscfd	m^3/day	BOPD	m^3/day	BWPD	m^3/day	MMscfd	m^3/day	BOPD	m^3/day	BWPD	m^3/day	MMscfd	m^3/day
1	17,612	2,800	4,134	657	3.27	92,662	12,595	2,002	899	143	2.75	77,887	6,867	1,092	1,180	188	5.89	166,896
2	9,594	1,525	10,269	1,633	1.60	45,293	6,817	1,084	3,425	545	1.36	38,370	6,134	975	3,102	493	1.38	39,198
3	7,528	1,197	15,820	2,515	1.25	35,308	5,627	895	6,143	977	1.02	28,864	5,635	896	5,461	868	1.15	32,530
4	5,785	920	18,036	2,867	1.00	28,337	4,395	699	7,666	1,219	0.81	22,872	4,138	658	7,195	1,144	0.92	26,038
5	5,140	817	21,464	3,412	0.90	25,384	4,009	637	9,649	1,534	0.73	20,703	3,597	572	9,560	1,520	0.83	23,493
6	3,961	630	20,729	3,296	0.66	18,785	3,337	530	10,419	1,656	0.63	17,835	2,745	436	10,120	1,609	0.66	18,611
7	3,690	587	23,292	3,703	0.62	17,426	3,181	506	12,183	1,937	0.59	16,651	2,524	401	11,949	1,900	0.61	17,149
8	3,014	479	21,750	3,458	0.50	14,135	2,756	438	12,614	2,005	0.52	14,780	2,041	324	11,892	1,891	0.48	13,498
9	2,905	462	24,077	3,828	0.49	13,918	2,656	422	14,220	2,261	0.49	13,832	1,944	309	13,511	2,148	0.45	12,725
10	2,441	388	22,249	3,537	0.42	11,788	2,353	374	14,412	2,291	0.44	12,503	1,601	255	12,945	2,058	0.38	10,802
11	2,393	380	24,589	3,909	0.42	11,914	2,278	362	15,879	2,525	0.42	11,805	1,560	248	14,491	2,304	0.35	9,891
12	2,057	327	22,707	3,610	0.36	10,253	2,049	326	15,914	2,530	0.38	10,848	1,316	209	13,841	2,200	0.29	8,337
13	2,041	324	24,940	3,965	0.37	10,439	1,992	317	17,271	2,746	0.36	10,297	1,287	205	15,211	2,418	0.29	8,241
14	1,777	282	22,913	3,643	0.32	9,098	1,803	287	17,137	2,724	0.33	9,431	1,097	174	14,386	2,287	0.23	6,563
15	1,788	284	25,194	4,005	0.33	9,318	1,765	281	18,481	2,938	0.32	8,994	1,089	173	15,848	2,520	0.23	6,509

Appendix 3
Summary of Scoping Feedback

Appendix 3 Summary of Scoping Feedback

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
OPRED	The ES should assess the worst-case anticipated impacts	The worst-case scenario has been considered when assessing impacts to the environment	3, 7 to 12
OPRED	Information on the preferred / selected pipeline protection should be provided in the ES	Information on pipeline protection is provided in the Project Description and considered in the relevant impact section	3 and 8
OPRED	If PPUK propose to protect the pipeline through the use of rock dump justification for this along with a worst-case estimate of the quantity to be used	Information on pipeline protection is provided in the Project Description and considered in the relevant impact section	3 and 8
ORPED	Ocean quahogs should be considered to be present in the area on account of samples being recorded in previous surveys	The (potential) presence of Ocean quahogs have been considered in the respective impact assessment chapters	7 to 12
OPRED	The production profile used in the ES should be based on the P_{10} highest case and be consistent with the information in the Field Development Plan (FDP). The same units should also be used (oil in tonnes, gas in m^3)	Information on the highest case production profile is detailed in the ES and used in the impact assessments. Production profiles are also presented in the Appendices	3, 9, 11 and Appendix 2.
OPRED	In the absence of a survey of the Avalon site and pipeline route the ES should discuss and justify that benthic impacts can be adequately assessed without site specific survey data	Information on survey data used is provided in Local Environment	4.1.1
OPRED	Any impacts from produced water should be considered in the ES	Impacts from produced water are considered in the ES and supported by a modelling study	10
JNCC	Where possible it is recommended that existing infrastructure is utilised, pipelines and cables are trenched and buried, and rock protection is kept a minimum. Decommissioning options should be considered.	Information on the option selection and project details are provided in the ES	2 and 3
JNCC	The amount of hard substrate introduced to the environment for the purposes of protecting the subsea infrastructure should be minimised. JNCC request information be provided on, but not limited to, location of deposit sites, size of rock to be used, volume to be deposited, method of delivery, footprint, assessment of the impact and fate after deposition.	Information pertaining to proposed rock dumping is detailed in the ES and the Physical Impacts assessment chapter	3 and 8
JNCC	The ES should present the worst-case scenario for the project and include all relevant stages of the proposed development	The worst-case scenario has been considered when assessing impacts to the environment	3, 7 to 12
JNCC	Cumulative effects should be considered in the ES	Cumulative effects are considered in each impact assessment chapter	7 to 12
JNCC	The use of the Seabird Oil Sensitivity Index (SOSI) should be used to identify areas where seabirds are likely to be the most sensitive to oil pollution and this should be considered when assessing the impacts of accidental events on seabird populations. It should be used to inform the environmental baseline where more appropriate data sources already exist.	The SOSI has been used in the Accidental Events impact assessment chapter	11
JNCC	Ocean quahog (*Artica islandica)* is inferred to be present in the wider region. Where possible this species should be avoided as much as possible during the proposed operations.	The ES has considered potential impacts on Ocean quahog in the respective impact assessment sections	7, 8, 10 and 11
JNCC	If presence of MDAC in area, provide video/still footage and side-scan for determination, undertake carbon isotope tests of the submarine structure using an ROV (if required), and propose mitigation to minimise damage to habitat.	No presence of MDAC has been identified from previous surveys	4.3.4

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
JNCC	As per BEIS 20213, 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. If survey data are not site-specific, justification should be provided as to why wider area surveys are sufficiently representative of conditions at the site of proposed operations.	Surveys in the local area are discussed within the ES. Surveys considered relevant in the wider area are summarised with context to the Avalon field. A further EBS will be undertaken at the Avalon field	4.2
JNCC	Survey data should provide adequate evidence that habitat and species of nature conservation concern (including Annex I habitats) are or are not present.	Surveys in the local area are discussed within the ES. A further EBS will be undertaken at the Avalon field	4.2
JNCC	Any gaps or limitations in environmental information should be acknowledged with, as appropriate, strategies to address these gaps or limitations.	Information regarding gaps and limitations in environmental information is provided throughout the ES	
JNCC	It is good practice to include a diagram indicating the surveyed area in the context of the proposed operations, 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.	A summary of previous local surveys is provided in the ES. The findings of the recent Avalon field EBS will be provided upon completion	4.2
JNCC	Any areas of habitats of conservation concern (including Annex I habitats) should be clearly indicated on a map in the context of proposed operations.	Information on areas of conservation concern are provided in the ES	4
JNCC	Consider other data sources as well as SOSI when discussing seabird vulnerability, e.g., Kober et al 2010.	This paper has been considered in the ES	11
JNCC	Note the terminology between noise threshold documents (NMSF, 2018; Southall et al 2019) differs, be clear which reference you are referring to.	Thresholds are referenced in the relevant assessment chapter	12
JNCC	Additionally, we highlight that the following mitigation requirements will be requested as a condition of any consent issued in relation to this application, should piling be included in the finalised project scope: • The JNCC 2010 Statutory nature conservation agency protocol for minimising the risk of injury to marine mammals from piling noise are followed at all times during the piling operation. • The pre-piling search and soft start should be timed to occur during hours of daylight/good visibility to allow an MMO to observe for any marine mammals within 500m of the sound source and if necessary, delay the soft start if animals are detected within this zone. • If the pre-piling search and soft start cannot be timed to occur during daylight hours/good visibility, then consider using a PAM system to allow effective mitigation during the hours of darkness/ periods of poor visibility. • As a minimum one dedicated MMO should be used. They should be fully trained and not have a dual role onboard (for example, in addition to being an MMO also work as a Fisheries Liaison Officer (FLO)). • At the end of the piling operations, a report (indicating the BEIS reference number) should be sent to the JNCC. This report should detail the soft start procedures, any visual observations/PAM detections and include the Marine Mammal Recording Forms (i.e., the excel spreadsheet) in its original format (i.e. not converted to a pdf). Any difficulties encountered, or recommendations that may be of use for future work should be included within the report.	Information relating to piling operation impacts is discussed in Section 12 of the ES together with proposed mitigation measures	12
JNCC	We note that the fate of drill cuttings and associated muds is to be assessed within the ES. We request that, should any of these materials be discharged to the seabed, the cuttings pile be included within the total seabed footprint of the operations.	Impacts arising from the discharge of drill cuttings and muds are discussed within the ES	7

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
Marine Scotland	Option selection and consideration of alternatives should be included in the ES	Information on the option selection process is provided in the ES	2
Marine Scotland	An overview of the installation methodology for adjacent pipelines would be beneficial	Information on the proposed installation method is provided in the ES	3.3.3
Marine Scotland	A detailed schedule of works should be provided with any contingency periods clearly stated	An indicative timetable for the proposed Avalon Field Development is provided in the ES. Estimated timings for operations include contingency time as well, where relevant	3.1.2, 3.2.1, 3.3.3
Marine Scotland	Cementing operations should be considered in the ES and any associated environmental / socioeconomic impacts from cementing activities discussed	Cementing operations and their potential impacts are detailed and considered in the ES	3.2.4 and 7.1.2
Marine Scotland	A detailed chemical risk assessment will be undertaken at the chemical permitting stage however an overview of any potential concerns from a chemical discharge perspective is advised	An overview of potential impacts from chemicals in the operations is provided in the ES	7 and 10
Marine Scotland	Produced water management and worst-case discharge profiles should be provided in the ES	Impacts from produced water are considered in the ES. Production profiles, including produced water, are provided	3.6.1, 10.1 and Appendix 2
Marine Scotland	An upfront description of the environmental surveys used in support of the application is provided	Information on survey data from the proposed well location and other nearby locations is provided in the ES	4.1.1
Marine Scotland	A local scale bathymetry map for the development area is advised, highlighting any significant seabed features	A map of the bathymetry in the area, as well as other relevant environmental information, is provided in the ES	4.2
Marine Scotland	The physical characteristics of the environment at the location should be fully described and include, for example, information on currents, wind speed, wave height / power, temperature and salinity	Information on the local environment is detailed in the ES	4.2
Marine Scotland	Good quality, high resolution images of the local sediment / benthic community, clearly linked to a map showing the location of the photographs, would be a useful addition	Information on local sediment / benthic communities is summarised in the ES	4.2.5
Marine Scotland	A summary of any particle size analysis and contaminant analysis of sediments should be provided	Information on local sediment / benthic communities is summarised in the ES	4.2.5
Marine Scotland	A section discussing plankton is advised.	Information on plankton communities is summarised in the ES	4.4
Marine Scotland	Where species of conservation concern or species indicative of habitats of conservation concern are identified, it is advised that the abundance of animals is discussed per unit area (m^2)	Abundance of Ocean quahogs have been considered in m^2	4.3.1
Marine Scotland	A recent paper (José M. González-Irusta, Peter J. Wright; Spawning grounds of Atlantic cod (*Gadus morhua*) in the North Sea, ICES Journal of Marine Science, Volume 73, Issue 2, 1 February 2016, Pages 304–315, https://doi.org/10.1093/icesjms/fsv180) provides an update to the cod spawning areas and describes the Avalon area as a 'recurrent' cod spawning area, which would be useful to highlight.	This paper has been considered in the ES	4.5.1
Marine Scotland	It is advised that the area is also considered to be a haddock nursery area (Coull *et al*, 1998). Coull *et al*, 1998 also described higher egg concentrations of Norway pout in ICES rectangle 44F0, which would be useful to highlight.	Fish spawning / nursery location information has been described and considered in the ES	4.5.1
Marine Scotland	Scottish Natural Heritage, The Joint Nature Conservation Committee (JNCC) and Marine Scotland have developed a priority list of marine habitats and species in Scotland's seas, known as Priority Marine Features (PMF's), which it is advised are referenced in the ES	PMFs are discussed in the ES and considered in relevant impact assessment sections	4, 7 to 11

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
Marine Scotland	New maps showing the distribution of grey and harbour seals around the UK are now available and provide an update of the previous seal usage maps described in Jones *et al.* (2015).	Seal usage maps using data from NMPi have been included in the ES when discussing the local environment	4.6.2
Marine Scotland	It is advised that fisheries statistics for landings (tonnages), value and effort are shown in a tabular format	This information is detailed in the ES	4.10.1
Marine Scotland	It is advised that context is provided by comparing landings and effort figures for the ICES rectangles in question to the wider UK.	A comparison has been included in the ES	4.10.1
Marine Scotland	An assessment of 'within-year' seasonality is recommended for fishing effort as this may highlight additional mitigation opportunities.	Information on peaks in fishing activity is detailed and considered in the ES	4.10.1 and 8.3.1
Marine Scotland	The location of existing oil and gas infrastructure and previously drilled wells would benefit from being shown in a visual format.	A figure illustrating the locations of existing oil and gas infrastructure is provided in the ES	4.10.4
Marine Scotland	It is advised that the location of any power cables, telecommunications cables and wrecks are clearly identified. Of particular note is the proposed development corridor of the North Connect cable. This corridor would be crossed with the proposed tie-ins to the North and it is advised this is considered	The location of telecommunications cables, including the proposed North Connect cable, is considered in the ES	4.10.4
Marine Scotland	It is advised that a systematic impact assessment methodology is applied to allow impacts to be ranked. An overview of the method used is advised and an indication of the criteria used to determine whether an impact is 'likely' and whether it is 'significant'	The impact assessment methodology used in the EIA is described in the ES	5 and 6
Marine Scotland	It is advised that the potential for in-combination, cumulative and transboundary impacts are discussed in the ES.	Cumulative and transboundary impacts are considered in the impact assessment chapters	7 to 12
Marine Scotland	It is advised that the worst-case volumes and locations of protective materials are included in the ES. Marine Scotland recommend that the extent of any 500 m safety zone is shown on a figure in relation to the proposed infrastructure and location of any protective materials.	The worst-case volume / area of protective materials (mattresses / rock dump) have been described in the ES and considered in the impact assessment chapters	3 and 8
Marine Scotland	Details of whether any proposed infrastructure will be fitted with fishing friendly / overtrawlable structures should be provided.	The Avalon infrastructure will be fishing friendly and this is detailed in the ES	3 and 8
Marine Scotland	It is assumed that the worst-case potential release of hydrocarbons will be modelled and included in the ES.	The worst-case potential release of hydrocarbons has been considered in the ES	11
Marine Scotland	Where modelling demonstrates the possibility of surface oiling on the Scottish coastline, if an accidental event were to occur, it is advised that impacts on aquaculture and Shellfish Water Protected areas are considered.	As part of the Accidental Events impact assessment chapter potential impacts on aquaculture sites have been considered in the ES	11.4.3
Marine Scotland	The predicted effectiveness of the stated mitigation measures should be made clear, and the ES should demonstrate a firm commitment to implementing the proposed measures, where appropriate, indicating how and when the measures will be implemented and confirming lines of responsibility for ensuring implementation. It is useful to provide a tabulated summary of the mitigation measures which is then taken forward into to the ES.	Mitigation measures are, where appropriate, discussed in each impact assessment chapter and summarised in the Commitments Register	7 to 11 and Appendix 4
Marine Scotland	Any commitments relating to matters addressed in the ES should be drawn together into one section or table and be clearly identifiable. It should also be indicated how these commitments are to be monitored to ensure compliance. It is useful to provide a tabulated summary of the environmental commitments which is then taken forward into to the ES.	Mitigation measures are detailed in each impact assessment chapter and summarised in the Commitments Register	7 to 11 and Appendix 4

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
Marine Scotland	It is recommended that the ES considers decommissioning upfront and details how all installed infrastructure / protective material would be removed should this be the policy in place at that time.	The ES discusses the proposed approach to decommissioning the Avalon Field Development	3.7
Marine Scotland	Given the intensity of the Nephrops fishery in this area, it is advised that consideration is given to the seasonality of fishing in the area and in the case of anchors extending outwith the 500 m safety zone, or anchors being 'pre-laid', it would be useful to detail what mitigation is proposed to ensure these do not pose a hazard to other sea users.	Information relating to the proposed drilling rig and the physical presence of the mooring system is discussed in the ES alongside proposed mitigation	3 and 8
Marine Scotland	It is advised that any flaring activities follow Best Available Technology (BAT) and Best Environmental Practice (BEP).	Flaring operations during well clean-up will be monitored by a dedicated person ensuring all performance conditions are met and adjustments made accordingly	3.2.7
Marine Scotland	It is noted that a 300% excess cement may be used and it is advised that the application discusses whether any cement deposits as a result of this are likely to pose a hazard to towed fishing gear or impact decommissioning operations in future.	Potential cement discharges are considered in the ES	3.2.4 and 7.1.2
Marine Scotland	It is advised that worst-case cement quantities expected to be discharged are detailed. It is understood that an ROV will monitor cement returns, which is welcomed, but it is questioned how this will be managed in inclement weather or poor visibility.	Potential worst-case cement discharges are detailed and considered in the ES	3.2.4 and 7.1.2
Marine Scotland	Does the technology used in the drilling of this well represent the Best Available Technology (BAT)? Does the sediment type at the site lend itself to alternative technologies for the conductor section that would reduce the amount of cuttings and discharge of cement to the seabed? It would be useful to discuss this in the option selection section of the EIA.	Information on the alternative technologies considered for drilling of the Avalon well (e.g. use of CAN-ductors) are detailed in the ES	2.3.6 and 3
Marine Scotland	It is advised that potential impacts on other sea users from anchor pull out/ chain scour / spud can depressions are considered.	Impacts from the drilling rigs anchors / spud cans have been considered in the ES	8.2
Marine Scotland	Please also note that final fisheries statistics for 2018 were published in September 2019 and should be used for future applications.	Updated fisheries information from the Scottish Government has been included in the ES	4.10
Marine Scotland	It is advised that references to the work by 'Kafas et al, 2012' should now be replaced with new aggregated VMS fishing effort data sets for 2009 - 2016 available on the National Marine Plan Maps interactive web site (NMPi). The data are split into three groups of fishing method: bottom trawls, dredges and crustaceans caught by bottom trawl (i.e. Nephrops). The Nephrops and crustaceans layer is a subset of the dredges layer but also includes data for 2017.	Updated fisheries information from NMPi has been included in the ES using data from NMPI and EMODNet	4.10
Marine Scotland	It is advised to include a brief overview of the status of the Buchan Alpha FPV decommissioning programme within the EIA	Information on the Buchan Alpha FPV is provided in the ES	4.11
Marine Scotland	The revised proposal has the potential to displace fishermen over a relatively large area, particularly if fishing in-between the mooring lines is not possible. The FPSO is located in a high intensity *Nephrops* area.	Information on the impacts on commercial fisheries is provided in the ES	8.3
Marine Scotland	Impacts on aquaculture and shellfish water protected areas to be considered	Information on the impacts on aquaculture/shellfish water protected areas is provided in the ES	11.5.3
Marine Scotland	Regarding section 2.1 and the reuse of existing FPSO, please note that the complex reserved/devolved matters surrounding the electrification of oil and gas assets are important issues to be resolved and Marine Scotland continue to be in discussions with BEIS regarding these.	PPUK note and remain involved in ongoing dialogue with the regulators to identify the appropriate path to determination of the project	-

Origin	Comment/Issued Raised	PPUK Response Summary	ES Section
SFF	Information on the diameter of the pipeline(s)and whether they will be surface laid or trenched and buried should be provided in the ES. Information on how the pipelines would be trenched and buried should be provided as well.	Information on the proposed pipelines and the installation methodology is provided in the ES	3.3.3
SFF	Post trenching formation of clay berms should be mitigated to reduce potential impacts on fishermen in the area	A post trenching and installation survey will take place. Information on the proposed trenching operations is detailed in the ES	3.3.3
SFF	Pipeline and cable crossings should be kept to a minimum	Pipeline crossings will be minimised as far as possible. Information on pipeline crossings are detailed in the ES together with proposed protection measures	3 and 8
SFF	Rock placement should be kept to a minimum	Information on proposed rock placement is detailed in the ES	3 and 8
SFF	During the initial drilling phase should any pre-laid anchors be deployed before a MODU arrives on site we would expect an ERRV or guard vessel to be deployed to warn fishermen of the existence of the moorings.	Guard vessels will be involved in the drilling operations and will be present on site	3
SFF	We would strongly recommend that any trenches are back filled and not left to naturally back-fill. Berms left in situ can cause significant safety issues for fishing vessels, thus the reasoning for open trenches to be back filled. Any rock placement must meet industry standard, e.g., slopes to be in 1:3 gradient.	Information on trenching operations is provided in the ES. A post installation survey will be undertaken as part of the installation operations	3
SFF	Once the FPSO piles are installed we would expect an ERRV or guard vessel to be deployed to warn fishermen of these hazards until the FPSO is on site.	Guard vessels will be involved in the installation operations and will be present on site	3
SFF	Since the Avalon Field is out with the recently released Innovation and Targeted Oil and Gas Decarbonisation areas can you explain how the installation of the turbine will be licenced? Assuming that a licence will be granted can you state where the turbine will be located? Close proximity can be interpreted in many ways. A floating wind turbine using spread mooring system also has the potential to also encroach on important fishing grounds, siting of these should be discussed with the fishing industry to minimise conflict between both industries.	Information on the potential turbine is provided in the ES. The impact assessment has been based on a 'worst case' scenario where the turbine is located, approximately, 25 km away within an INTOG lease area. PPUK remain in ongoing dialogue with regulators to identify an appropriate path for determination of the project	3 and 8
SFF	Can Ping advise on their plans for decommissioning the development and end of field life.	A summary of decommissioning plans provided in the ES	3

Appendix 4
ENVID Matrices

Table: Impact Significance Scoping Matrix 1: Drilling and Completion Operations (September 2021)

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Mooring the Drilling Rig							
Installation and presence of spud cans on the seabed (jack-up)	Disturbance to seabed	Marine environment (seabed communities)	Seabed impacts	4	3	12	▪ Potential presence of ocean quahogs elevates the environmental receptor value to 3; ▪ No rock dump required for spud cans.
Installation, presence and removal of anchors and anchor lines (semi-sub)	Disturbance to seabed	Marine environment (seabed communities)	Seabed impacts	4	3	12	▪ Potential presence of ocean quahogs elevates the environmental receptor value to 3; ▪ 8 to 12 anchors will be used.
Installation, presence and removal of anchors and anchor lines (semi-sub)	Disturbance to fishing extending beyond 500 m	Impact on commercial fishing	Socio-economic impacts	4	3	12	
Physical presence of the MODU and support vessels at the sea surface	Physical presence of the rig (potential navigation hazard)	Other users (shipping and commercial fisheries)	Socio-economic impacts	4	3	12	
Physical presence of the Xmas trees and fishing friendly structures	Obstruction on the seabed to commercial fishing	Other users (fisheries)	Socio-economic impacts	4	2	8	
Drilling Activities							
Lighting during operations	Artificial light is emitted from the MODU	Birds	Noise and visual impacts	2	2	4	Light from drilling rig on well location will be temporary
Drilling of the top-hole sections	Deposition of drill cuttings and associated muds directly to the seabed	Marine environment (seabed communities)	Marine pollution	6	4	24	

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Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Drilling Activities (continued)							
Drilling of the top-hole sections	Deposition of excess cement directly to the seabed	Marine environment (seabed communities)	Marine pollution	6	4	24	300 % excess cement will be pumped; two out of four wells previously drilled in the area (also with 300 % excess cement) did not have any cement returns to surface and required no additional cement top-ups.
Drilling of deeper well sections	Cement discharges at the sea surface	Marine environment (seabed communities and water column)	Marine pollution	2	3	6	
Drilling of reservoir sections	Backloading of oil contaminated pay-zone cuttings and muds for onshore treatment and disposal	Landscape; Local communities	Waste generation	1	1	1	Cuttings will be cleaned and muds reconditioned for re-use offshore. The clean cuttings may be re-purposed in other industries. However, as a worst-case scenario, it has been assumed the cuttings will be disposed to landfill.
Well Logging							
Logging while drilling	Generation of electromagnetic fields, acoustic waves, microwaves, etc	Resource use, natural environment (fish)	Marine pollution	1	1	1	
	Use of radioactive sources	Natural environment	Resource use	1	1	1	
Well Clean-up/Testing							
Flaring during well clean-up/well testing	Impact of flaring on birds	Natural environment (birds)	Noise and visual impacts	2	2	4	
Atmospheric emissions from flaring	Combustion of hydrocarbons resulting in emissions of greenhouse gases to the atmosphere	Natural environment	Atmospheric emissions	4	5	20	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Well Clean-up/Testing (continued)							
Discharges of fluids	Discharge of fluids contaminated with reservoir hydrocarbons during flaring (produced water)	Natural environment (water column and seabed communities)	Marine pollution	2	3	6	
Discharges and Emissions							
MODU/support and supply vessels - discharge of domestic sewage	Sewage has high BOD resulting from organic and other nutrient matter in the detergents and human wastes	Marine environment (water column)	Marine Pollution	1	2	2	
MODU/support and supply vessels - release of food waste to sea	Waste has high BOD resulting from organic and other nutrient matter. Positive impact of nutrients provided for fish	Marine environment (water column)	Marine Pollution	1	2	2	
Oily water discharge from MODU	Discharges of oily water. Oily residues in the discharge may include reservoir hydrocarbons	Marine environment (water column)	Marine Pollution	2	2	4	
Atmospheric emissions from routine operations	Energy generation on board the MODU contribute to atmospheric emissions of green house gases (CO_2, CO, SO_X, NO_X etc.)	Marine environment	Atmospheric emissions	4	5	20	Power generation on MODU will only be switched on when required. Power Management System will match generation requirements to the load to minimise environmental impacts.
Discharge of ballast water from MODU	Potential to introduce alien species	Marine environment (water column)	Discharge to sea	1	2	2	It is anticipated a MODU that is already working in the North Sea will be used.

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Waste							
General operational 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	Landscape (landfill sites)	Solid waste	2	2	4	All waste will be segregated, and containers marked and labelled with waste types
Accidental Events – Large Release into the Sea							
MODU/support and supply vessels - fuel oil spillage (e.g. vessel collision)	Potential water borne pollution with consequential impacts on marine fauna	Marine environment, coastal environment, other users of the sea	Marine ecology impacts	6	4	24	
MODU - blowout/uncontrolled well flow of hydrocarbons	Water quality will be reduced and become deoxygenated. Oil could beach along coastlines effecting designated sites	Marine environment, coastal environment, other users of the sea	Marine ecology impacts	10	5	50	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Accidental Events – Small Release into the Sea							
MODU - chemical spills	Water quality will be reduced. Fish avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Marine ecology impacts	4	2	8	
MODU - Spillage of diesel or other oils during bunkering operations and storage	Water quality will be reduced and become deoxygenated. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Marine ecology impacts	2	2	4	
Small release of hydraulic fluid, lubes, helifuels etc	Fluid leak into marine environment	Marine environment	Marine ecology impacts	2	2	4	
Spillage during OBM/diesel/base oil transfer	Fluid leak into marine environment	Marine environment	Marine ecology impacts	4	2	8	

Table: Impact Significance Scoping Matrix 2: Subsea Infrastructure and Infield Pipeline Installation and Operation (September 2021)

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Installation of trees, jumpers, manifolds and infield flowlines and umbilicals							
Presence of installation and support vessels	Physical presence of vessels on sea surface	Other users of the sea	Physical presence	2	2	4	
Fuel use during installation operations	Use of diesel for power generation	Society	Resource use	2	2	4	
Onboard non-renewable consumables during installation operations	*The use of various consumables on board CSV, including furniture, stationary and electrical equipment, has environmental impacts both upstream and downstream. *Use of refrigerants	Society (future users of given resource)	Resource use	2	2	4	
Trenching and laying of infield flowlines and umbilicals (including any backfilling and potential OFWT)	Laying of pipelines, flowlines and umbilicals on the seabed	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Positioning of infrastructure on the seabed	Installation of trees, jumpers, manifolds, drill centres on seabed	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Piling to fix infrastructure to the seabed	Installation of trees, jumpers, manifolds, drill centres on seabed	Marine environment (seabed communities)	Noise impacts	4	4	16	Infrastructure will be gravity structures and piling is not anticipated to be required.

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Installation of trees, jumpers, manifolds and infield flowlines and umbilicals (continued)							
Rock dumping protection of flowlines or other infrastructure	Laying of pipelines flowlines and umbilicals on the seabed	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Laying of concrete mattresses, grout bags etc for protection of flowlines or other infrastructure	Laying of pipelines flowlines and umbilicals on the seabed	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Use of equipment	Use of steel, pipes etc	Society (future users of given resource)	Resource usage	2	2	4	
Installation and support vessels – General noise and vibration of equipment whilst operating (below sea level)	Production of sound below sea level (e.g. from thrusters)	Marine environment (marine mammals and fish)	Noise and visual impacts	2	2	4	
Installation and support vessels – General noise and vibration of equipment whilst operating (on sea surface)	Production of sounds on the sea surface (including transfer routes)	Marine environment (seabirds and marine mammals)	Noise and visual impacts	2	2	4	
Lighting during operations	Artificial light is emitted from vessels	Birds	Noise and visual impacts	1	2	2	
Production Operations							
Ongoing presence of pipelines/flowlines/subsea infrastructure on the seabed	Physical presence of infrastructure on the seabed	Other users of the sea (fisheries), marine environment (seabed communities)	Physical presence	4	3	12	Pipelines will be buried so only applies to rock dump (if used)

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Discharges and Emissions							
Use and discharge of chemicals during testing and commissioning of infield flowlines	Discharge of chemicals, including those used during riser connections and commissioning, domestic chemicals and fire protection system chemicals into the marine environment	Marine environment (water column)	Discharge to sea	2	2	4	
Discharge of oily fluids during testing and commissioning of flowlines and other infrastructure	Testing and commissioning of flowlines and facilities may result in discharges containing oil	Marine environment (water column and seabed communities)	Discharge to sea	2	2	4	
Atmospheric emissions during installation and commissioning	Energy generation during installation and operation of the CSV contribute to atmospheric emissions of greenhouse gases	Air pollution	Atmospheric emissions	4	5	20	
Installation and support vessels – discharge of domestic sewage	Sewage has high BOD resulting from organic and other nutrient matter in the detergents and human wastes	Marine Environment (water column)	Discharge to sea	2	2	4	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Discharges and Emissions (continued)							
Installation and support vessels – release of food waste to sea	Waste has high BOD resulting from organic and other nutrient matter. Positive impact of nutrients provided for fish	Marine environment (water column)	Discharge to sea	2	2	4	
Discharge of ballast water from installation vessels	Potential to introduce alien species	Marine environment (water column)	Discharge to sea	2	2	4	
Waste							
General operational waste generated onboard the installation vessels	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	Landscape (landfill sites)	Solid waste	2	2	4	
Accidental Events – Large Release into the Sea							
Installation vessels/ support and supply vessels – fuel oil spillage (e.g. vessel collision)	Potential water borne pollution with consequential impacts on marine fauna	Marine environment, coastal environment, other users of the sea	Discharge to sea	6	4	24	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Accidental Events – Small Release into the Sea							
Chemical spills during installation operations	Water quality will be reduced. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Discharge to sea	2	2	4	
Spill of hydrocarbons due to loss of infield flowline leak (pipeline inventory)	Water quality will be reduced and become deoxygenated. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species. Oil could beach along coastlines affecting designated sites	Marine environment	Discharge to sea	6	4	24	Based on 700 bbls being released due to flowline release (max estimated release based on Day 1 production rates)
Small release of hydraulic fluid, lubes, helifuels etc	Fluid leak into marine environment	Marine environment	Discharge to sea	2	2	4	

Table: Impact Significance Scoping Matrix 3: FPSO Installation and Production Operations (September 2021)

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
General Operations – FPSO Installation							
Fuel use during FPSO installation operations	Use of diesel for power generation	Society	Resource use	2	2	4	
Atmospheric emissions during installation and commissioning	Combustion of hydrocarbons resulting in emissions of greenhouse gases to the atmosphere	Air pollution	Atmospheric emissions	4	5	20	
Positioning of infrastructure on the seabed	Installation of FPSO anchors and anchor lines on seabed	Marine environment (seabed communities)	Seabed impacts	4	3	12	Based on 12-point mooring system, 1.5 km per mooring line, half of the length of the mooring line is on seabed
Piling to fix infrastructure to the seabed	Installation of FPSO anchors on seabed	Marine environment (marine mammals)	Noise and visual impacts	6	4	24	24 hours piling for 3 piles
Use of non-renewable resources	Use of steel etc	Society (future users of given resource)	Resource use	2	2	4	
FPSO/installation and support vessels - General noise and vibration of equipment whilst operating (below sea level)	Production of sound below sea level (e.g., from thrusters)	Marine environment (marine mammals and fish)	Noise and visual impacts	2	2	4	
FPSO/installation and support vessels - General noise and vibration of equipment whilst operating (on sea surface)	Production of sounds on the sea surface (including transfer routes)	Marine environment (seabirds and marine mammals)	Noise and visual impacts	2	2	4	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Lighting during operations	Artificial light is emitted from vessels	Birds	Noise and visual impacts	1	2	2	
Chemical use during installation, commissioning	Use of chemicals during riser connections and commissioning, domestic chemicals, fire protection system, laboratory	Marine environment	Discharge to sea	2	2	4	
Production Operations							
Ongoing presence of FPSO	Physical presence of FPSO on sea surface	Other users of the sea	Physical presence	6	3	18	
Ongoing presence of anchors	Physical presence of FPSO anchors on seabed (extending outside 500 m exclusion zone)	Other users of the sea (fisheries)	Physical presence	6	3	18	
Consumables used onboard the FPSO	Use of various consumables on board the FPSO, including furniture, stationary and electrical equipment	Society (future users of given resource)	Resource use	2	2	4	
Discharge of produced water	Discharges containing oil and chemical additives into the marine environment	Marine environment (water column)	Discharge to sea	4	3	12	
Flaring (non-routine time only)	Combustion of flare gas and hydrocarbons also results in emissions of greenhouse gases to the atmosphere	Air pollution	Atmospheric emissions	6	4	24	Flaring will only occur in the event that safe operating pressure limits are exceeded, as per standard industry design.

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Venting (Non routine venting during process upsets through the non-flare system)	Release of uncombusted hydrocarbons contributing to greenhouse gases in the atmosphere	Air pollution	Atmospheric emissions	6	4	24	
Atmospheric emissions from fuel combustion by FPSO and shuttle tankers	Combustion of hydrocarbons resulting in emissions of greenhouse gases to the atmosphere	Air pollution	Atmospheric emissions	6	4	24	
Fugitive emissions from cargo tanks	Non routine Fugitive (VOC) emissions release from the FPSO cargo tanks (either vented or flared)	Air pollution	Atmospheric emissions	6	4	24	
Venting from cargo tanks and during offloading operations	Cargo offloading	Air pollution	Atmospheric emissions	6	4	24	
FPSO – discharge of domestic sewage	Sewage has high BOD resulting from organic and other nutrient matter in the detergents and human wastes	Marine environment (water column)	Discharge to sea	1	2	2	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Waste							
General operational waste - hazardous	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	Landscape (landfill sites)	Solid waste	2	2	4	All waste will be segregated, and containers marked and labelled with waste types
	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	Landscape (landfill sites)	Solid waste	2	2	4	All waste will be segregated, and containers marked and labelled with waste types

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Underwater Noise							
FPSO thrusters – general noise and vibration of equipment whilst operating (below sea level)	Intermittent use of thrusters for heading control producing sound below sea level (e.g., from thrusters)	Marine environment (marine mammals and fish)	Noise and visual impacts	2	2	4	
Accidental Events – Large Release into the Sea							
FPSO/installation vessels/ support and supply vessels – fuel oil spillage (e.g., vessel collision)	Potential water borne pollution with consequential impacts on marine fauna	Marine environment, coastal environment, other users of the sea	Discharge to sea	6	4	24	
Large spill of hydrocarbons due to loss of FPSO/shuttle tanker inventory	Water quality will be reduced and become deoxygenated. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species. Oil could beach along coastlines effecting designated sites	Marine environment, coastal environment, other users of the sea	Discharge to sea	10	5	50	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Accidental Events – Small Release into the Sea							
Chemical spills	Water quality will be reduced. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Discharge to sea	4	2	8	
Spillage of diesel or other oils during bunkering operations and storage	Water quality will be reduced and become deoxygenated. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Discharge to sea	2	2	4	
Small release of hydraulic fluid, lubes, helifuels etc.	Fluid leak into marine environment	Marine environment	Discharge to sea	2	2	4	
Other Accidental Event							
Dropped objects	Dropped objects may pose a risk to subsea infrastructure or a hazard to other users of the sea	Other users of the sea	Seabed impacts	4	2	8	Based on a half-height drop from a PSV

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Subsea Infrastructure and Pipeline Installation							
Presence of installation and support vessels	Physical presence of vessels on sea surface	Other users of the sea	Physical presence	2	2	4	Based on very low to moderate shipping intensity in the development area and temporary nature of the presence.
Fuel use during installation operations	Use of diesel for power generation	Society	Resource use	2	2	4	
Onboard non-renewable consumables during installation operations	The use of various consumables on board the installation vessels, including furniture, stationary and electrical equipment, has environmental impacts both upstream and downstream Use of refrigerants	Society (future users of given resource)	Resource use	2	2	4	
Laying of pipelines flowlines and umbilicals on the seabed	Trenching and laying of flowlines (including any backfilling)	Marine environment (seabed communities)	Seabed impacts	4	4	16	▪ 22 km production flowline from Avalon well to east Rochelle manifold ▪ 22 km well control umbilical from Avalon well to east Rochelle manifold ▪ 44 km gas lift line from Avalon well to west Telford manifold ▪ 52 km electrical power cable from MPP to Scott platform ▪ 55 km water injection pipeline from Avalon to Scott South manifold ▪ Higher risk of passing nearby pockmarks

Notes
MODU = Mobile offshore drilling unit
BOD = Biological oxygen demand
CO_2 = Carbon dioxide
SO_X = Sulphur dioxide
NO_X = Nitrogen oxide
CSV = Construction support vessel
OFWT = Offshore wind turbine
FPSO = Floating production storage and offloading vessel
VOC = Volatile organic compound

Table: Impact Significance Scoping Matrix 4: Floating Offshore Wind Turbine (October 2021)

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
General Installation Operations							
Presence of vessels / barges during installation operations	Disturbance due to noise from the installation vessels / barges	Marine Mammals	Noise and visual impacts	2	2	4	OWT will be pre-assembled before being sailed out to be installed. As a result, installation timing is very short and vessels will only be present for a short period of time.
	Physical presence of vessels / barges displaces fishing activity to other fishing grounds	Natural environment Other users of the sea (fisheries)		2	3	6	Short term (~ 24 hours) activity on site.
	Displacement of other (non-fishing) vessels during installation operations	Natural environment Other users of the sea (shipping)	Socio-economic impacts	2	3	6	Short term (~ 24 hours) activity on site.
	Introduction of MNNS	Marine Environment (seabed communities)	Marine ecology impacts	4	3	12	
Fuel use during installation operations	Use of diesel for power generation.	Society	Resource use	2	2	4	
Atmospheric emissions from vessels / barges during operations	Operation of vessels in the installation process contributes to greenhouse gas emissions	Natural environment and society as a whole	Atmospheric emissions	4	5	20	
Use of lighting during installation and commissioning	Artificial light is emitted from vessels	Birds	Noise and visual impacts	1	2	2	
Installation of the Floating OWT mooring system							
Installation / Positioning of the OWT mooring system (gravity base foundation)	Loss of, or alteration to, seabed bathymetry / sediment type during placement of the gravity base foundations	Marine environment (seabed communities)	Seabed Impacts	4	4	16	Receptor value is considered to be "4" rather than "3" due to the potential presence of Ocean quahogs

Description of Aspect				Impact Significance Evaluation			
Operational Activity (Source)	Impact (Pathway)	Receptor	Environmental Issue	Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	Comments
Installation / Positioning of the OWT mooring system (gravity base foundation)	Increase in suspended sediments during placement of the gravity base foundations	Marine environment (seabed communities)	Seabed Impacts	4	4	16	Receptor value is considered to be "4" rather than "3" due to the potential presence of Ocean quahogs
Installation of the sub surface / subsea infrastructure							
Movement of submarine cables on the seabed	Disturbance to seabed from export power cable (e.g., at dynamic / static transition point)	Marine environment (seabed communities)	Seabed impacts			0	N/A. Cable will be trenched and held in place and therefore there will be no movement of the cable on or close to the seabed.
Trenching and laying of inter array / export power cable to FPSO	Disturbance of seabed during cable trenching / laying operations	Marine environment (seabed communities)	Seabed impacts	4	4	16	Receptor value is considered to be "4" rather than "3" due to the potential presence of Ocean quahogs
Positioning of infrastructure on the seabed	Disturbance of the seabed when equipment (e.g., clump weights placed on the seabed)	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Placement of any scour protection	Disturbance of the seabed	Marine environment (seabed communities)	Seabed impacts	4	4	16	Assumption is that there will be a requirement for scour protection.
	Touchdown scour protection of inter array / export cable at both ends (FPSO end and OWT end)	Marine environment (seabed communities)	Seabed impacts	4	4	16	
Installation / Positioning of the OWT mooring system (gravity base foundation)	Increase in suspended sediments during placement of the gravity base foundations	Marine environment (seabed communities)	Seabed Impacts	4	4	16	Receptor value is considered to be "4" rather than "3" due to the potential presence of Ocean quahogs
Piling to fix infrastructure to the seabed	Disturbance due to noise from the piling operations	Marine environment (marine mammals)	Noise and visual impacts			0	N/A. No piling for the OWT or associated infrastructure.

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
O & M of the OWT and infrastructure							
Physical presence of wind turbine	Effects of EMF from operational subsea electrical cables	Marine environment (fish)	Marine ecology impacts	4	3	12	
	Increase in suspended sediment due to movement of cables	Marine environment (seabed communities)	Marine ecology impacts			0	N/A. Cable will be trenched and held in place and therefore there will be no movement of the cable on or close to the seabed.
	Loss of access and / or displacement of fishing vessels to other areas	Other Users of the Sea	Socio-economic impacts	4	3	12	This will be for a longer period as assessed above for installation operations only, which may affect the scoring
	Obstruction to other vessels due to the presence of the OWT	Other Users of the Sea	Shipping and Navigation	4	3	12	
	Interference with flying operations (e.g., helicopter flights, military operations)	Other users of the sea (Helicopters and Military)	Shipping and Navigation	4	2	8	
	Interference with radar / SAR operations	Other users of the sea	Shipping and Navigation	2	2	4	
Operational noise from the OWT	Disturbance of marine mammals	Marine mammals	Marine ecology impacts	4	3	12	
Presence of tension wires	Injury risk to marine mammals (entanglement)	Marine mammals	Marine ecology impacts			0	N/A. Not considered for the FPSO.
Collision risk for seabirds	Injury or fatality amongst seabird species if struck by the turbine rotors	Seabirds	Marine ecology impacts	4	3	12	
Release of domestic sewage to sea from maintenance vessel(s)	Sewage has high BOD resulting from organic and other nutrient matter in the detergents and human wastes	Marine environment (water column)	Marine pollution	2	2	4	

Description of Aspect			Environmental Issue	Impact Significance Evaluation			Comments
Operational Activity (Source)	Impact (Pathway)	Receptor		Magnitude of Effect (1 to 10)	Environmental and Socio-economic Receptor Value (1 to 5)	Significance (> 10 Considered Significant)	
Release of food waste to sea from maintenance vessel(s)	Waste has high BOD resulting from organic and other nutrient matter. Positive impact of nutrients provided for fish	Marine environment (water column)	Marine pollution	2	2	4	
Atmospheric emissions from vessel(s) during maintenance operations	Energy generation on board the MODU contribute to atmospheric emissions of greenhouse gases (CO_2, CO, SO_X, NO_X etc.).	Natural environment and society as a whole	Atmospheric emissions	4	5	20	
Discharge of ballast water from maintenance vessel(s)	Potential to introduce alien species	Marine environment (water column)	Marine pollution	2	2	4	
Accidental Events							
Installation vessels / support and supply vessels - Fuel oil spillage (e.g., vessel collision)	Water quality will be reduced and become deoxygenated. Fish will avoid contaminated areas and could potentially reduce their foraging areas. Contaminated deposits could cause fatality/disturbance to benthic dwelling species	Marine environment	Marine ecology impacts	4	4	16	
Small release of hydraulic fluid, lubes etc from the vessel or the turbine	Fluid leak into marine environment	Marine environment	Marine ecology impacts	2	2	4	

Appendix 5
Commitments Register

Appendix 5 Commitments Register

Table A5.1 summarises the mitigation commitments made in each of the impact sections of this Environmental Statement (ES) (Sections 7 to 12). These commitments will inform the planning stages for the Avalon Field Development and will be incorporated into the PPUK Project Statement of Requirements and Operations Philosophy. Where relevant, they will also form the basis of the Environmental Management Plan (EMP), which will be prepared closer to the start of the operations.

Table A5.1: Commitments Register

Impact	Mitigation	Regulatory Commitment	Stage of Operations		
			Planning/ Preparation	Installation/ Drilling	Production
Drilling Discharges					
Drilling discharges affecting protected sites and / or species	▪ An Environmental baseline survey covering the footprint of the Avalon Field Development, including the proposed pipeline route will be undertaken before any operations drilling or pipeline installation operations commence.		✓		
Discharge of chemicals into the marine environment during drilling activities	▪ Only chemicals that have an approved CEFAS Template will be used.	✓	✓	✓	
	▪ PLONOR chemicals and Chemicals without substitution warnings will be prioritised for use, where practicable and technically feasible.		✓	✓	
	▪ Only WBM will be discharged to the marine environment.	✓	✓	✓	
	▪ All LTOBM returned to the rig will be skipped and shipped to shore for treatment and disposal.	✓	✓	✓	
	▪ Mud and chemical usage will be monitored during drilling operations and subsequently reported to EEMS.	✓	✓	✓	
Discharge of cement into the marine environment during drilling activities	▪ Use of ROV to visually monitor cement returns to seabed surface from top hole sections.			✓	
	▪ A black UV light on the ROV will used to monitor cement returns to the seabed. Once returns are observed pumping will be stopped to minimise discharged volume.	✓		✓	
	▪ LTOBM contaminated cement returns from deeper sections will be skipped and shipped to shore for appropriate treatment and disposal.	✓		✓	
Physical Presence					
Potential for MODU, FPSO, PLV or CSV to be a navigation hazard for shipping and other users	▪ Safe working distances will be imposed for the duration of the operations.	✓		✓	✓
	▪ 500 m safety zone will be in place around the MODU, FPSO and infield infrastructure and will be enforced by a dedicated Emergency Response and Rescue Vessel (ERRV). This will may apply to the potential offshore wind turbine depending on final location.	✓		✓	✓
	▪ The MODU, FPSO, supporting vessels will be highly visible and display the appropriate light or daytime signals. If installed, the turbine will also be appropriately marked and lit.	✓	✓	✓	✓
	▪ An updated Vessel Traffic Study (VTS) will be undertaken as part of the permitting application process to support a Consent to Locate application, before drilling and installation operations commence.	✓	✓		
	▪ The Aberdeen Coastguard Operations Centre (CGOC) will be notified, a Notice to Mariners and Navtex and NAVAREA warnings will be posted prior to commencement of drilling and installation operations. Warnings will be regularly updated as required.	✓	✓	✓	✓

Impact	Mitigation	Regulatory Commitment	Stage of Operations		
			Planning/ Preparation	Installation/ Drilling	Production
	▪ Kingfisher will be notified of the exact location of the MODU, FPSO, support vessels and subsea infrastructure, allowing their inclusion in their fortnightly bulletin to fishing vessels.	✓	✓	✓	✓
Presence of MODU and seabed infrastructure on seabed communities	▪ Physical disturbance to the seabed will kept to a minimum where practicable.		✓	✓	
	▪ The rock material to be used for the rock dump will be clean, inert and contain few entrained fines.		✓	✓	
	▪ Pipeline routing and the volumes and locations of rock dump and mattress placement will be designed to minimise the footprint on the seabed, as far as practicable.		✓	✓	
	▪ An environmental baseline survey and habitat assessment will be undertaken to identify the presence of any potential Annex I habitats along the potential pipeline route prior to operations commencing.		✓	✓	
	▪ Microsite any trenching activities and seabed infrastructure.		✓	✓	
Presence of subsea infrastructure on other users of the sea	▪ 500 m exclusion zone will be established around the Avalon well(s) and infield infrastructure.	✓		✓	✓
	▪ Potential pipeline routing and the volumes and locations of protective material will be designed to minimise the footprint on the seabed, as far as practicable.		✓	✓	✓
	▪ The UK Hydrographic Office (UKHO) will be notified so that charts can be amended to mark the position of the new project infrastructure.		✓	✓	✓
	▪ Microsite any trenching activities .				
Atmospheric Emissions					
Emissions to the atmosphere during drilling and installation operations	▪ All equipment onboard the FPSO, MODU and support vessels will be well maintained according to a strict maintenance regime. including regular monitoring and inspections.			✓	✓
	▪ The burners on the flare used during well clean-up after the drilling operations will be environmentally efficient (i.e. 'green burners') and will have propane-fuelled pilot lights with the option to use a dedicated fuel spiking line.			✓	
	▪ Various techniques, such as the addition of air, steam, demulsifiers and diesel to aid combustion of the flare, and the optimisation of the pressure and vortex at the burners will be available to aid complete combustion and therefore minimising the probability of hydrocarbon drop-out.			✓	
	▪ Weather conditions will be monitored throughout flaring during flaring operations. A dedicated person will be assigned for full-time fire watch duties to ensure that all performance related conditions are monitored, and adjustments can be made accordingly.			✓	
	▪ Low sulphur fuels according to International Maritime Organisation (IMO) requirements will be used.			✓	✓
	▪ Atmospheric emissions from the FPSO and the MODU will be reported under EEMS.	✓		✓	
Emissions to the atmosphere during subsea infrastructure installation operations	▪ Operational scheduling will reduce the potential for weather down time, thus avoiding unnecessary fuel use.		✓	✓	

Impact	Mitigation	Regulatory Commitment	Stage of Operations: Planning/ Preparation	Stage of Operations: Installation/ Drilling	Stage of Operations: Production
	▪ All equipment will operate at optimum efficiency and be well maintained according to a strict maintenance regime.			✓	
Produced Water					
Contents of the discharge	▪ All chemicals used will be included in the Offshore Chemical Notifications Scheme (OCNS) and the most environmentally friendly options evaluated and, where possible, chemicals that pose little or no risk (PLONOR) to the environment will be used.	✓	✓		✓
	▪ Chemical risk assessments will be undertaken as part of the environmental permitting process.	✓	✓		✓
Dispersed oil	▪ Produced water discharges will comply with OSPAR 30 mg/l dispersed oil standard. PPUK anticipate that the FPSO will achieve a lower dispersed oil content, with a target of ≤15 mg/l (on a monthly average basis).		✓		✓
Accidental Events - Preventative Measures					
Training, experience and suitability of equipment	▪ In order to prevent an oil spill occurring, stringent safety and operational procedures will be followed at all times. Before offshore operations commence, the competence and experience of all contractors, and the suitability of all equipment to operate in the Central North Sea will be assessed.	✓	✓	✓	
	▪ All offshore personnel will be appropriately trained, experienced and certified to carry out their specific duties. The crew of the MODU, FPSO and any relevant vessels will also undergo environmental awareness and safety training.	✓	✓		
Well design	▪ The wells will be designed to minimise the potential for well control problems.	✓	✓		
	▪ A thorough and formal peer-review approach will be used to review all critical elements of the well designs and the execution of drilling and abandoning the well(s). The design of the wells will be independently reviewed by a Well Examiner, who will also monitor the actual construction and any modifications to the wells.	✓	✓		
	▪ Any deviation to the drilling programme, well designs or construction, will be subject to a formal Management of Change process.	✓	✓	✓	
Well control	▪ A full risk assessment will be performed as part of the planning phase of each well.	✓	✓		
	▪ Data on well pressure will be monitored throughout the drilling operations.	✓		✓	

Impact	Mitigation	Regulatory Commitment	Stage of Operations: Planning/ Preparation	Stage of Operations: Installation/ Drilling	Stage of Operations: Production
	▪ A blow-out preventer (BOP) will be put in place to prevent the uncontrolled release of hydrocarbons from the well. The BOP will be fully redundant and has several other backup emergency control systems, namely: □ Emergency Disconnect System □ Autoshear System □ Acoustic Control System □ Remotely Operated Vehicle □ Automatic Mode Function ▪ The BOP will be independently inspected and verified periodically. Regular testing of the BOP and its back up systems takes place onboard the MODU, typically at 7 and 21-day intervals.	✓	✓	✓	
	▪ Bunkering and offloading operations will only take place during hours of good visibility, in suitable weather conditions, and with a dedicated and continuous watch posted at both ends of the fuel/offloading hose. ▪ All hoses used during bunkering/offloading will be segmented with pressure valves that will close automatically in the event of a drop in pressure. Bunkering/offloading hoses will be stored on reels, to prevent wear and damage. ▪ Hoses will be visually inspected, and their connections tested prior to every loading operation. Bunkering/offloading procedures will be followed throughout all bunkering/offloading operations.	✓	✓	✓	✓
	▪ Vessel audits will be performed to confirm sea worthiness of bunkering vessels, and only Dynamically Positioned (DP) vessels will be used, thus reducing likelihood of collision and potential tank rupturing.		✓	✓	✓
Loss of crude oil from FPSO	▪ The FPSO will be designed with double bottom/doubled-sided hull. In addition, the cargo tanks will be configured with ballast tanks on the outside, offering protection from cargo tanks and reduced probability of loss.		✓	✓	✓
Other safety measures	▪ All equipment used on the MODU and FPSO will have safety measures built in to minimise the risks of any hydrocarbon spillage. The MODU and FPSO will have open and closed drain systems in place that will route any operational spills onboard the MODU or FPSO to the slop tanks. All supply vessels will operate via DP.		✓	✓	✓
Accidental Events - Action to Stop a Subsea Spill During Drilling with the MODU					
Initial actions	▪ Use the ROV to identify the source of a leak.			✓	

Impact	Mitigation	Regulatory Commitment	Stage of Operations: Planning/ Preparation	Installation/ Drilling	Production
	▪ If at any time the safety of the MODU becomes compromised, the first priority will be to close the BOP, disconnect the MODU from the well, and move off location. The ERRV would monitor the spill.			✓	
	▪ If MODU has not been disconnected, other methods include: varying the pump rate and the use of various chemicals, such as weighting material. Therefore, a contingency stock of cement and barite will be kept onboard the MODU. Once control of the well has been regained, the well can be fully abandoned with cement plugs.			✓	
Capping the well	▪ If BOP has failed, the possibility of fitting a temporary capping device to the well will be considered. PPUK is a member of Oil Spill Response Ltd (OSRL), which allows PPUK access to the OSPRAG (the Oil Spill Prevention and Response Advisory Group) Capping Device stored at the Cameron facility in Aberdeen.		✓	✓	
	▪ A full timetable for the capping device procedure will be provided in the Well Operator's Temporary Operations Oil Pollution Emergency Plan (TOOPEP) covering the drilling operations at Avalon operations.		✓	✓	
Drilling a relief well	▪ If attempts to cap the well fail, the only remaining option to bring the well back under control to stop the spill may be to drill a relief well. PPUK would comply with the Oil and Gas UK(now Offshore Energies UK) "Guidelines on Relief Well Planning – Subsea Wells".		✓	✓	
	▪ An assessment of the suitability of available MODUs will be undertaken and the availability of these rigs will continue to be monitored throughout the drilling operations at Avalon.		✓	✓	
	▪ Relief well plans, and trajectories, will be created for each well drilled along with a relief well kill analysis.		✓	✓	
Accidental Events - Oil Spill Response					
Oil Pollution Emergency Plan (OPEP) and Temporary Operations OPEP (TOOPEP)	▪ An OPEP/TOOPEP will be in place, conforming to the Merchant Shipping (Oil Pollution, Preparedness, Response and Co-operation Convention) (Amendment) Regulations 2015 and the Offshore Installations (Emergency Pollution Control) Regulations 2002. The OPEP/TOOPEP will fully consider the specific oil spill response requirements for Avalon, taking into account the location, the prevailing meteorological conditions and the environmental sensitivities of the area.	✓	✓	✓	✓
Training, exercises and experience	▪ Specific members of the MODU and ERRV crew will have undertaken OPEP level oil spill response training. The Offshore Installation Manager (OIM) and the Installation/Well Operator offshore representatives will have undertaken the OPRED course for On-Scene Commander (OPEP Level 1).		✓	✓	✓

Impact	Mitigation	Regulatory Commitment	Stage of Operations: Planning/ Preparation	Installation/ Drilling	Production
	▪ The OPEP/TOOPEP will be distributed to personnel with designated duties in the event that an oil spill response is required, and to the regulatory authorities and statutory consultees. On receipt of the OPEP/TOOPEP, personnel will undergo awareness training in oil spill response prior to the commencement of drilling operations.	✓	✓	✓	✓
	▪ The ERRV and MODU will regularly undertake training exercises, including vessel-based oil spill response exercises for the crew and an Offshore TOOPEP Exercise while on site, to ensure that offshore personnel are familiar with the TOOPEP and their responsibilities during a response.	✓		✓	✓
	▪ Training will also be organised for key onshore personnel in line with the OPRED requirements and the internal requirements of environmental training and continual improvement in the Well Operator's Management Systems. PPUK is a member of Oil Spill Response Ltd (OSRL), with activation rights being provided to the Installation/Well Operator. A response advisor with OPEP Level 4 training would also be provided by OSRL.		✓	✓	✓
Accidental Events - Oil Spill Response Strategies					
Natural dispersion and monitoring	▪ Small to medium crude spill and diesel spills of all sizes are often best monitored but otherwise left to naturally degrade but will be monitored. ▪ A standby vessel will be on site at all times during drilling and production operations. A contract with OSRL is in place, allowing the rapid deployment of a dedicated aerial surveillance aircraft.			✓	✓
Chemical dispersants	▪ To aid natural dispersion of a large oil spill, or when sensitive receptors such as flocks of seabirds are at risk, PPUK will consider the applying chemical dispersants. The decision to use chemical dispersants will always need to consider its positive benefits against any resulting impacts in the water column. Dispersants will not be used without the correct authorisations in place and PPUK will discuss their use with the appropriate regulators.			✓	✓
Shoreline protection and clean-up	▪ In the event of a spill the first priority should be to prevent spilled hydrocarbons from reaching coastal areas. The initial response to any spill will be onsite and aerial surveillance to track its movement supplemented by modelling to predict which shorelines the spilled oil may threaten. Once the coastal sensitivities under immediate threat have been identified, coastal protection resources will be deployed to protect priority areas. Although PPUK will provide all necessary assistance as required, all shoreline protection strategies will be determined by the local authority in consultation with their environmental advisors. Additional response personnel and appropriate shoreline protection equipment will be provided by OSRL.	✓	✓	✓	✓

Impact	Mitigation	Regulatory Commitment	Stage of Operations: Planning/ Preparation	Stage of Operations: Installation/ Drilling	Stage of Operations: Production
	▪ The strategy for shoreline clean-up ultimately will be directed by the affected local authorities. Adequately trained personnel and clean-up equipment will be made available to assist any clean-up operations, through OSRL.	✓	✓	✓	✓
Accidental Events - Liability and Insurance					
Liability and insurance	▪ PPUK will ensure that it has sufficient finances and insurance in place to cover the cost of responding to a large oil spill.	✓	✓	✓	✓
	▪ PPUK is a member of the Offshore Pollution Liability Association Limited (OPOL). OPOL is a voluntary oil pollution compensation scheme to which all offshore operators currently active on the UKCS are party to.	✓	✓	✓	✓
Catastrophic Loss of the FPSO, MODU, Vessel or Helicopter					
Loss of the FPSO, MODU, Vessel or Helicopter	▪ The FPSO and MODU will be inspected for sea worthiness and the Well Operator/Installation Operator audited prior to operations commencing.		✓		
	▪ Personnel will be appropriately trained, experienced and certified and the competence and experience of all contractors will be assessed before they are contracted.		✓		
	▪ All supply vessels will operate via DP, to reduce the likelihood of a collision.		✓		
	▪ A digital site survey for drilling hazards has been carried out to confirm that there is no shallow gas in the area.		✓		
	▪ A 500 m exclusion zone will be enforced around the FPSO and MODU for general shipping in the area.		✓	✓	✓
	▪ A standby vessel will be on site through the life of the field to enforce the 500 m exclusion zone and be equipped with radar and communication equipment so that any vessel in the area can be detected and contacted, if required.		✓	✓	✓
	▪ The FPSO and MODU and associated vessels will use appropriate lighting.		✓	✓	✓
	▪ The suitability of supply, other support vessels and the helicopter will be assessed before they are contracted.		✓		
Other Impacts					
Electromagnetic Fields (EMF)	▪ Power cables will be trenched and buried to a suitable depth (estimated 1 – 2 m) which will reduce the effects of EMF.		✓	✓	
Underwater Noise	▪ Logistics will be optimised to minimise unnecessary or low payload helicopter flights and vessel sailings.		✓	✓	
	▪ Underwater sound generated during drilling and piling operations will be kept to a minimum where possible.		✓	✓	

Impact	Mitigation	Regulatory Commitment	Stage of Operations		
			Planning/ Preparation	Installation/ Drilling	Production
	▪ Piling operations at the pipeline tie in will be conducted in accordance with the JNCC Protocol for minimising risk of injury to marine mammals from piling noise. Use of a trained Marine Mammal Observer (MMO) to undertake cetacean monitoring duties before any piling operations commence and the use of "soft start" procedures.	✓		✓	
	▪ Impacts will be reduced by using smaller diameter piles, reduced hammer energy, and a reduction in the total duration of active piling.				
	▪ The planned piling operations will be conducted in accordance with the JNCC Protocol for minimising risk of injury to marine mammals from piling noise.	✓	✓	✓	
	▪ A trained and dedicated MMO will undertake cetacean monitoring duties before any piling operations commence and PPUK will incorporate the use of "soft start" procedures. If visibility is poor during the piling operations a Passive Acoustic Monitoring (PAM) system may be used.	✓	✓	✓	
	▪ A report at the end of the piling activities will be submitted to the JNCC, documenting the soft start procedures used, any PAM/visual observation made by the MMO, and describe any complications encountered and recommendations for future piling work. Marine Mammal Recording forms will also be submitted as part of this process.	✓	✓	✓	
Waste Management	▪ Relevant waste legislation will be followed throughout the lifetime of the project.	✓	✓	✓	✓
	▪ The sewage treatment system onboard the FPSO will be designed to meet regulation 21(3) of the Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008.	✓			✓
	▪ Waste generated by the development will be returned to shore for appropriate treatment and disposal, with recycling encouraged.		✓	✓	✓
	▪ Waste will be segregated onboard the MODU and FPSO. Each will be designed with adequate space for waste storage and segregation facilities, including laydown areas for skips and deck space for other waste storage receptacles. Waste will be segregated into hazardous and non-hazardous waste types.	✓	✓	✓	✓
	▪ The vessels involved in the development will follow their respective Garbage Management Plans and record waste in their respective Garbage Record Book. The amount and disposal route of any waste will be recorded in the UK Environmental Emissions Monitoring System (EEMS).	✓	✓	✓	✓