APPENDIX 2 OFFSHORE ENVIRONMENTAL STATEMENT

Enclosed in this Appendix 2 is the Offshore Environmental Statement that will be submitted to OPRED as part of the process of securing approval for the Offshore Elements from the NSTA

Offshore Environmental Statement for the Northern Endurance Partnership

BEIS Reference: D/4271/2021

Document: NS051-EV-REP-000-00021

<<tbc, on submission to OPRED>> 2023

VOLUME 1/2: ENVIRONMENTAL STATEMENT

Project Name	Northern Endurance Partnership
Development Location	Southern North Sea
Licence No	CS001
OPRED Reference No	D/4271/2021
Type of Project	Carbon Transport and Storage
Undertaker	BP Exploration Operating Company Limited (BPEOC) Building B, ICBT, Chertsey Road, Sunbury On Thames, Middlesex, TW16 7LN
Licensees/Owners	(see table below)
Nearest Coastline and Median Line	The Endurance Store is located approximately 63 km east of the North Yorkshire (England) coast and approximately 105 km from the Dutch median line.
Short Description	The Development will route carbon dioxide (CO_2) which has been captured from onshore industrial clusters at Teesside and Humber, to an offshore geological storage site named the Endurance Store. CO_2 will be transported offshore via two 28" pipelines, one originating at Teesside (approximately 142 km in length), and the other at Humber (approximately 100 km in length). An electric power and fibre-optic communications control cable will run from Teesside to the subsea infrastructure at the Endurance Store. The Endurance Store is the UK's largest and most well-understood saline aquifer formation for carbon dioxide storage. At the Endurance Store, all installed infrastructure will be subsea. The subsea facilities will consist of two manifolds which combine, distribute, control, and monitor flow of CO_2 to five injection wells. One monitoring well will be used to monitor CO_2 within the Endurance Store. Infield flowlines will connect the five injection wells to the manifolds and power and communication cables will connect all six wells to the manifolds. An average injection capacity of 4 million tonnes per annum of CO_2 is planned for the Development. First injection is planned for 2027.
Latitude and Longitude	(see table below)

Licensees/Owners:

Co-venturers	% Holding
BPEOC	45%
Equinor New Energy Limited	45%
TotalEnergies CCS UK Limited	10%
CS001 Licensees	**% Holding**
BPEOC	50%
Equinor New Energy Limited	50%

Latitude and Longitude:

Feature	Co-ordinates (WGS84)
SSIV	000° 56' 27.893" E 54° 14' 09.870" N
Co-mingling manifold	001° 00' 57.035" W 54° 39' 00.168" N
Four-slot manifold	001° 01' 17.868" E 54° 12' 40.160" N

	Teesside Pipeline (start)	KP0 (onshore) 001° 06' 51.291" W 54° 37' 23.144" N	MLWS 001° 06' 03.985" W 54° 37' 34.588" N
	Teesside Pipeline (end, co-mingling manifold)	000° 56' 27.893" E 54° 14' 09.870" N	
	Humber Pipeline (start)	KP0 (onshore) 000° 06' 30.485" E 53° 39' 55.433" N	MLWS 000° 06' 46.529" E 53° 40' 03.196" N
	Humber Pipeline (end, co-mingling manifold)	000° 56' 27.893" E 54° 14' 09.870" N	
	Injection well EC01	000° 59' 24.745" E 54° 11' 57.992" N	
	Injection well EC02	000° 58' 31.859" E 54° 14' 39.729" N	
	Injection well EC03	001° 02' 01.155" E 54° 13' 54.293" N	
	Injection well EC04	001° 03' 00.023" E 54° 11' 49.234" N	
	Injection well EC05	000° 57' 40.574" E 54° 13' 03.915" N	
	Observation well EM01	001° 06' 53.408" E 54° 11' 50.283" N	

Key Dates	Activities	Date
	Landfall construction	Q3 – Q4 2025
	Offshore installation	Q1 – Q3 2026
	Drilling	Q1 – Q4 2026
	Commissioning	Q2 & Q3 2027
	First injection	Q4 2027

Significant Environmental Effects Identified	The Environmental Statement (ES) assesses the worst case impact of the Development on the environment and is therefore very conservative. Despite this, the ES concludes that the current proposal for the North Endurance Partnership can be completed without causing any significant long term environmental impacts, cumulative or transboundary effects.	
Statement Prepared by	BP Exploration Operating Company Limited and Xodus Group Ltd.	
Company	**Job Title**	**Relevant Qualifications/Experience**
BPEOC	Senior Environmental & Social Advisor	11 years' experience, environment/oil and gas
	Regulatory Compliance, Environmental and Social Manager	25 years' experience, onshore and offshore environment

Xodus Group Ltd.	Principal Environmental Consultant	19 years' experience, environment/oil and gas
	Environmental Specialists	37 years' experience, environmental science 17 years' experience, environmental chemistry 10 years' experience, environmental science
	Principal Geospatial Consultant	16 years' experience in oceanography

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GLOSSARY

Term	Definition
Bunter Sandstone Outcrop	The location where the Bunter Sandstone Formation forms an outcrop at the seabed ~25 km east of the Endurance Store structure.
Development	Subject of this ES. Project to route carbon dioxide (CO_2) captured from onshore industrial clusters at Teesside and Humber to an offshore geological storage site via two pipelines. The offshore site, the Endurance Store is located approximately 63 km from the nearest coastline in the Southern North Sea in water depths of approximately 65 m.
Endurance Store	As described in licence CS001.
Flowline	Up to 8" line to transport CO_2 from manifold to well at the Endurance Store, i.e. infield.
Formation Water	Water that occurs naturally within the pores of rocks. Store Formation Water: formation water in the Endurance Store structure. Outcrop Formation Water: formation water in the upper 140 m of the Bunter Sandstone Formation at the Bunter Sandstone Outcrop.
Low toxicity oil based mud	Synthetic-based fluids which were developed to reduce the environmental impact of offshore drilling operations, while maintaining the cost-effectiveness of oil-based systems. Formulated with low toxicity linear alphaolefins and isomerized olefins.
Manifold	Structure located on the seabed at the Endurance Store which combines, distributes, controls, and monitors flow of CO_2 to injection wells.
Monitoring Plan	Describes the monitoring that is designed to demonstrate conformance and verify containment, and to detect and measure any significant irregularity or leakage event, at the Endurance Store. One of eight documents required for CS001 Storage Permit Application.
Pipeline	Up to 28" line to transport CO_2 from onshore to manifolds (Teesside Pipeline, Humber Pipeline) and between manifolds (Infield pipeline).
Pre-cut shore approach trench	Constructed from the punch-out location to 8 m LAT from where shallow water pipelay commences.
Pre-cut trench	Constructed in the nearshore section, from 8 m LAT as the pipeline will not be stable in the temporary installed condition due to hydrodynamic forces and seabed conditions.
Subsea Infrastructure	Refers to equipment located beneath the surface of the sea.

Term	Definition
Subsurface	Refers to strata below the seabed.
Water based mud	WBM drilling fluids contain bentonite and barite, both of which are included on the OSPAR List of Substances Used and Discharged Offshore and which are considered to be PLONOR.

NON-TECHNICAL SUMMARY

This Non-Technical Summary provides an overview of the ES for the offshore aspects of the Northern Endurance Partnership (NEP) Development (the Development)

An **Environmental Statement (ES)** is a document that reports the results of an **Environmental Impact Assessment (EIA).** The goal of an EIA is to identify any potential adverse impacts to the environment from a development and to inform efforts to prevent, reduce or offset those impacts. An EIA contributes to a regulator's determination of whether consent should be given to a development and if any conditions need to be attached to that consent.

The ES is required under the **Offshore Oil And Gas Exploration, Production, Unloading And Storage (Environmental Impact Assessment) Regulations 2020** AND is submitted to the **Offshore Petroleum Regulator For Environment And Decommissioning (OPRED)**.

Introduction to the Development

The Development will route carbon dioxide (CO_2) which has been captured from onshore industrial clusters at Teesside and Humber, to an offshore geological storage site via two pipelines. The offshore site, the Endurance Store is located approximately 63 kilometres (km) from the nearest coastline in the Southern North Sea (SNS) in water depths of approximately 65 m. NEP is formed of BP Exploration Operating Company Limited (bp), Equinor New Energy Limited and TotalEnergies CCS UK limited.

The Development is one component of the East Coast Cluster (ECC), a strategic initiative that aims to deliver the UK's first zero carbon industrial cluster with an ambition to capture 23 million tonnes per annum of CO_2. The Development represents the initial phase (Phase 1) of the ECC and has an ambition to capture the initial 4 million tonnes per annum.

The Development objective is to deliver technical and commercial solutions required to implement innovative First-of-a-Kind offshore transportation and storage infrastructure in the United Kingdom (UK) i.e. transporting and storing CO_2 emissions from both onshore clusters for offshore injection (Figure 1). The Teesside Pipeline, approximately 142 km in length, has landfall on the Tees coast to the south of the mouth of the Tees Estuary. An electric power and fibre-optic communications control cable will be installed from Teesside to the subsea infrastructure at the Endurance Store. For the purposes of the ES, it is assumed a Subsea Safety Isolation Valve (SSIV) will be installed approximately between 6-8 km along the Teesside Pipeline from the Tees coast with a power, control and hydraulics cable installed from Teesside to the SSIV.

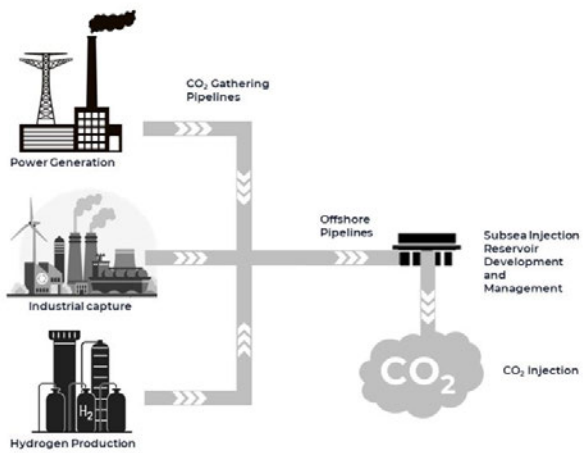

Figure 1 - Overview of CO2 transportation and storage

The Humber Pipeline, approximately 100 km in length, has landfall on the Holderness coast in East Riding of Yorkshire to the north of the Dimlington gas terminal.

The Endurance Store (Figure 2), an offshore geological storage site, is the UK's largest and most well-understood saline aquifer formation for CO_2 storage. At the Store, all installed infrastructure will be located on or below the seabed, with no infrastructure permanently located on or at the sea surface. The electrically powered subsea facilities will consist of two structures (manifolds) which combine, distribute, control, and monitor flow of CO_2 to five injection wells. One monitoring well will be used to monitor CO_2 within the Endurance Store. The wells will be drilled in one stage from a jackup rig. Infield flowlines will connect the five injection wells to the manifolds and power and communication cables will connect all six wells to the manifolds.

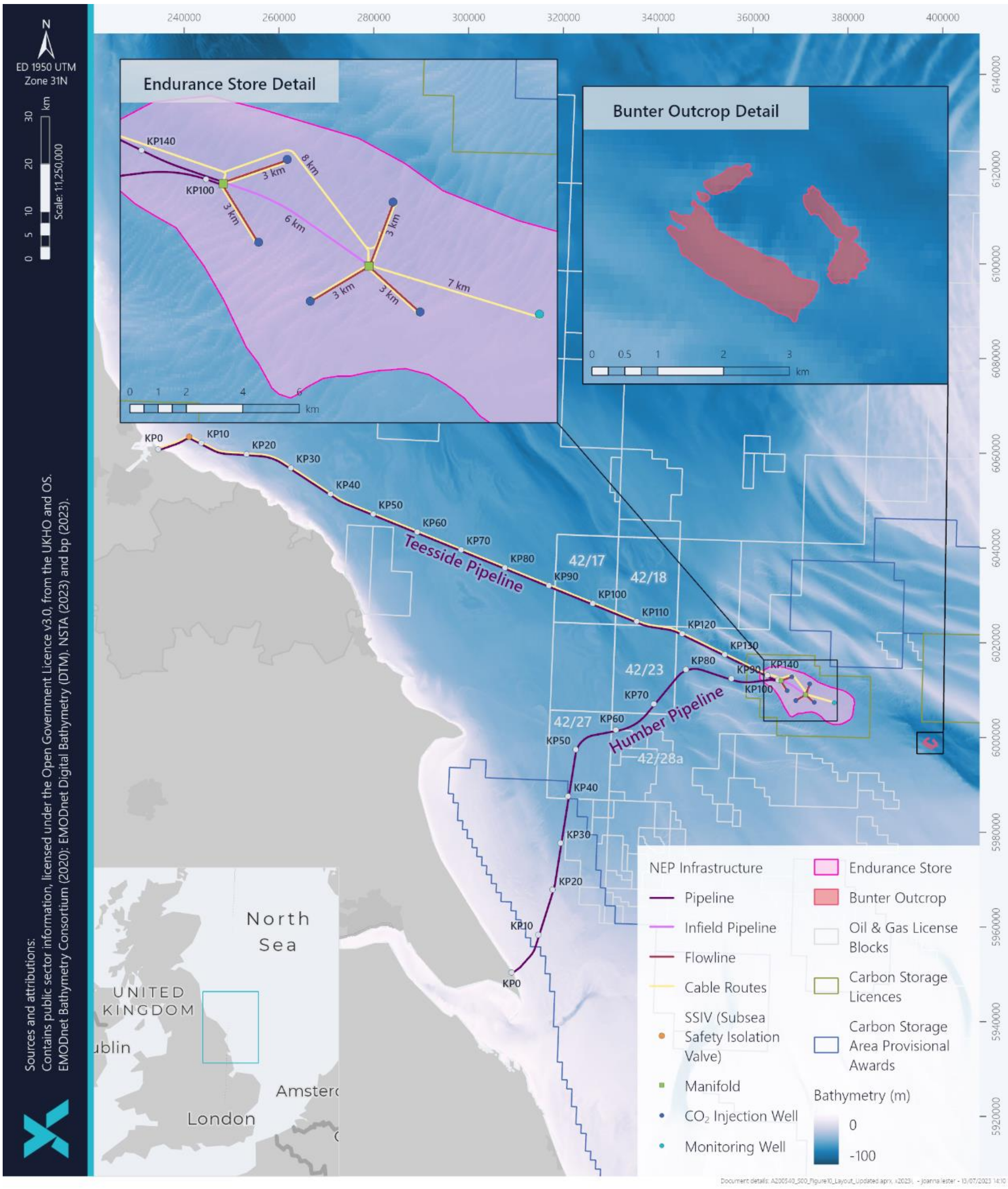

Figure 2 - Overview of Development area showing the Endurance Store and the Teesside and Humber Pipelines

bp, as operator of NEP, proposes to progress the Development with a view to achieving first CO_2 injection from 2027. 100 million tonnes (Mt) of CO_2 are planned to be stored over the anticipated 25-year operational period of the Development.

Subject to future expansion in line with the UK government cluster selection process, the ECC stands ready to remove almost 50% of the UK's total industrial cluster CO_2 emissions, create and protect thousands of jobs and establish the Teesside and Humber regions as globally competitive climate-friendly hubs for industry and innovation.

The ECC includes a diverse mix of low-carbon projects, including industrial carbon capture, low-carbon hydrogen production, negative emissions power, and power with carbon capture. All these technologies, delivered by companies with experience in successfully delivering ambitious and world changing projects, are essential for the UK to meet its net zero targets.

Humber and Teesside will benefit from an influx of green jobs, skills development and supply chain benefits. The ECC aims to create and support an average of 25,000 jobs per year between 2023 and 2050.

Consideration of Alternatives

The development options selected have been arrived at through a holistic, documented technical and commercial concept selection process. A gated project development process was used that conforms with the applicable bp guidelines and requirements and considers Best Available Techniques (BAT) and Best Environmental Practice (BEP). The selection process has taken into account environmental, social, health and safety, technical, project execution and commercial issues and risks, and included a comprehensive value assurance review.

The Endurance Store was selected as the storage location to enable a CCS project on the east coast, to allow for wider east coast decarbonisation of industry and to take advantage of relatively shallow water depths. A saline aquifer formation structural trap was selected versus a depleted gas field given the lower power demand associated with injecting CO_2 into an aquifer, industry experience of CO_2 injection into a saline aquifer and anticipated lower development costs. Pipeline route selection requires holistic consideration of offshore, nearshore and landfall options, including connection locations to the onshore pipeline or infrastructure. Route selection considered other nearby projects and third-party infrastructure and aimed to minimise impacts on designated sites.

During design of the Development, environmental and social concerns have been discussed with key stakeholders. The concerns of key stakeholders have been incorporated into the Development and the routes and installation methods are being designed to minimise disruption to protected areas and key stakeholders, including fisheries. Coastal erosion and sediment transport processes that occur along the Holderness coastline are also considered in the design and installation methodology of the Humber Pipeline.

Figure 3 and Figure 4 provide an overview of the decisions made (and outstanding) for the Development. Where decisions are outstanding, these options will be taken forward as further design work is undertaken. This assessment adopts a precautionary approach and considers the design envelope parameters which are predicted to result in the greatest environmental impact, i.e. the 'realistic worst case scenario'.

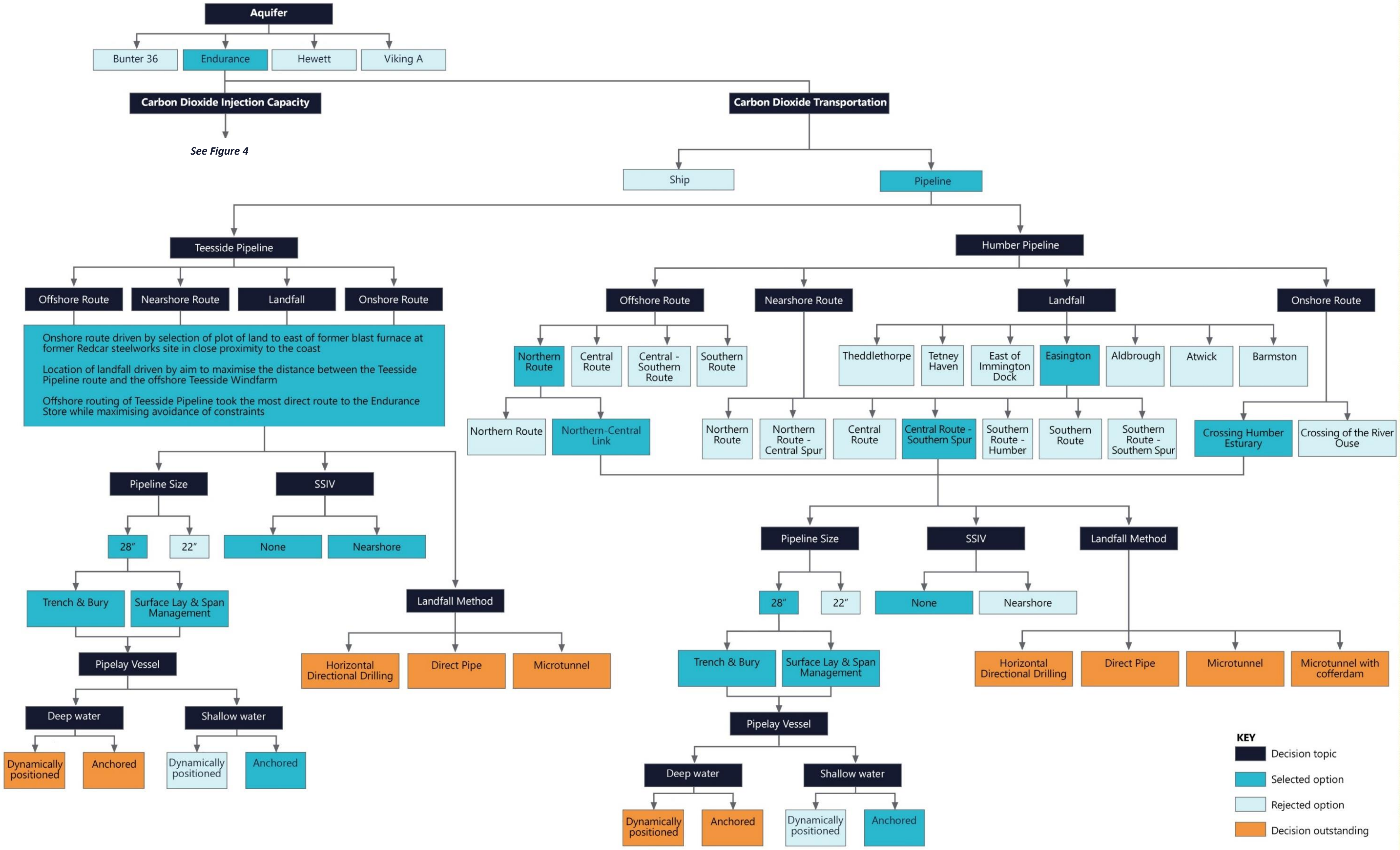

Figure 3 - NEP Development consideration of alternatives: Aquifer and CO_2 transportation

See Figure 3

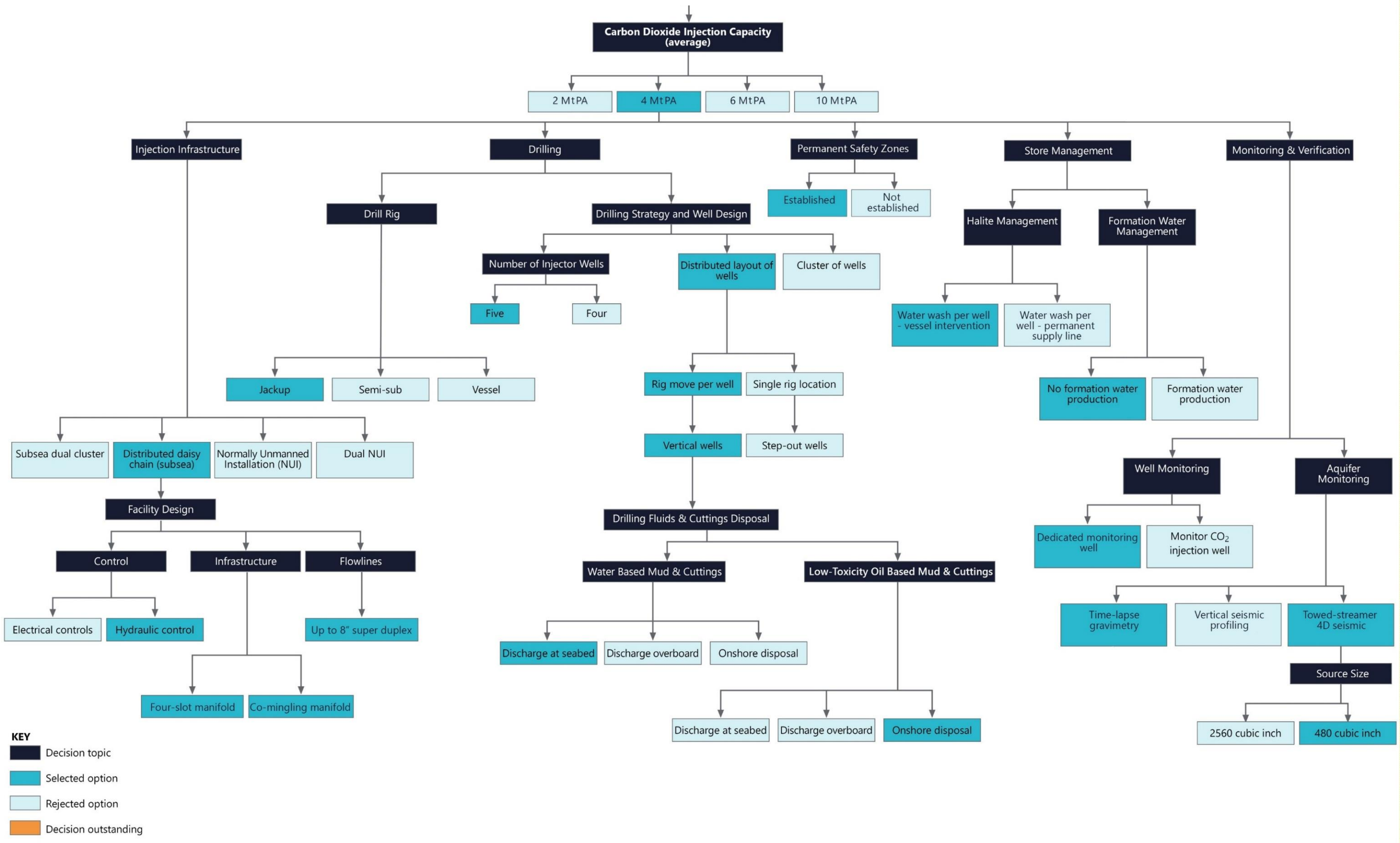

Figure 4 - NEP Development consideration of alternatives: CO_2 injection

Pipelines and Subsea Infrastructure

Construction and installation will involve the following activities (sequencing depending on technical, commercial and environmental factors):

- Surveys;
- Onshore section constructed, excavation of pre-cut shore approach trench;
- Boulder and debris clearance throughout the route;
- Sweeping of the seabed to clear obstructions and reduce freespan stresses where required;
- Crossing preparation for third-party cable and pipeline crossings;
- Installation of landfall pipeline and cables;
- Installation of the pipelines nearshore, installation of the pipelines offshore, cable installation;
- Placement of rock for trench transitions, crossing completion and areas of insufficient cover;
- Flooding, cleaning, gauging and hydrotesting of the pipelines;
- Installation of subsea infrastructure, including two subsea manifolds at the Endurance Store and the nearshore SSIV on the Teesside Pipeline;
- Subsea spool-piece tie-ins and leak testing and installation of protection measures; and
- Dewatering of pipelines.

Wells and Drilling

Six wells will be drilled, comprising five CO_2 injection wells and one monitoring well. The six wells are of identical design and it may take about 63 days to drill each well. A jackup rig may be used, which is a mobile, self-elevating, drilling platform that consists of a buoyant hull fitted with three movable legs. The overall target depth for each well is between 1,300 and 1,500 metres (m) True Vertical Depth Sub Sea. Drilling mud will lubricate the drill mechanism and bring rock cuttings to the surface.

Endurance Store

The structure that forms the CO_2 store is a four-way dip closure, meaning that the structure dips away in all four possible directions, acting to prevent injected CO_2 from migrating laterally. The structure is described as a closure as the overlying rock layers acts as a sealing layer, trapping CO_2 injected into the Store and preventing vertical migration of CO_2. The CO_2 storage site is a saline aquifer known as the Bunter Sandstone Formation.

The Bunter Sandstone Formation forms an outcrop at the seabed ~25 km east of the Endurance Store structure. As CO_2 is injected into the Endurance Store, pressure will increase within the Bunter Sandstone Formation. The seal rocks directly above the Bunter Sandstone Formation, are geomechanically strong and able to withstand changes in pressure, therefore injected CO_2 remains trapped within the Endurance Store. Pressure increases within the Bunter Sandstone Formation will dissipate throughout the formation in the surrounding area, including to the Bunter Sandstone Outcrop. The maximum displacement of formation water will be < 1,600 cubic metres (m^3)/day.

A Monitoring Plan for the Endurance Store across the Development lifecycle is being developed and agreed with the North Sea Transition Authority as part of the storage permitting process. The plan objectives are to verify containment of the injected CO_2 plume, to monitor Store behaviour and environmental impact, to provide early warning of risk evolution and inform appropriate response, to verify injected CO_2 quantity and composition and to demonstrate competent, safe operation of the CO_2 store to stakeholders.

Environmental Description

The environmental description considers receptors as being part of the physical environment, the biological environment, or other sea users. The following table provides a brief summary of the key information collated.

Physical Environment

Weather and water
The SNS is highly dynamic, characterised by shallow, well-mixed waters, which undergo large seasonal temperature variations. Winds at the Endurance Store occur from all directions but come predominantly from the southwest and west. The majority of waves come from the north and are typically 0.5-1.5 m in height. Near-bed currents are about 0.2-0.8 metres per second (m/s) and flow in a northwest-southeast direction. Close to Teesside Pipeline landfall, the spring tidal range at the shore is approximately 4.34 m and the neap tidal range is approximately 2.22 m. The annual mean significant wave height at the Teesside Pipeline landfall is 1 m compared to a maximum of approximately 1.66 m along the pipeline route near the Endurance Store. Surface current speeds increase with distance from shore; currents at the shore are most likely to be 0.1-0.4 m/s, compared to speeds of 0.3-0.5 m/s nearer the Store. Near-bed current directions are predominantly southeast and northwest along the Teesside Pipeline route. Close to the Humber Pipeline landfall, the spring tidal range is approximately 5.27 m and the neap tidal range is approximately 2.34 m. Most waves are below 2 m in height with occasional storm events generating waves of up to or greater than 4 m. The most frequent direction of wave approach is north-northeast. Close to the Holderness coast, mean spring tidal currents are 0.75-1.25 m/s.
Bathymetry and seabed
Across the Endurance Store, water depth varies from 40.1 m below lowest astronomical tide (LAT) to 63.8 m LAT. The seabed across the Store is mostly flat with the exception of some prominent sandwaves. The sandwaves are oriented northeast to southwest and were up to 8 m high in places. Coarser sediment often lies in the troughs between sandwaves. Generally, sediment chemistry is in line with regional expectations. The water depth along the Teesside Pipeline route varies from 1.2 m LAT at landfall to 67.1 m LAT at the offshore end. The seabed along the route is largely flat and composed of sand, although in places the seabed gradient is higher due to areas of outcropping underlying bedrock. Sandwaves occur frequently. Generally, sediment chemistry is typical of the wider region although some contamination is evident within the first 20 km of the route. The water depth along the Humber Route varies from 10.9 m LAT at landfall to 60.9 m LAT midway along the route. With the exception of outcropping bedrock areas, the seabed is relatively flat. Sediment along the Humber Pipeline route is largely sand, except closer to landfall in shallower water where gravel, silt and clay dominate. Isolated areas of contamination along the route may be attributable to historic drilling activity.
Sediment transport and coastal processes
The sediment transport pathway across the offshore SNS region is largely in a north to northwest direction. The presence of sandwaves within the Endurance Store area indicates the area is highly dynamic and the orientation of the features is typically aligned with the direction of movement. In proximity to the Teesside Pipeline landfall, the underlying geology of the area has resulted in a coastline of sandy bays between harder rock headlands – Tees Bay being one such bay. Sediment transport processes are dictated by seasonal changes and are also strongly influenced by changes in orientation of the shore. Within Tees Bay the overall direction of transport is to the south. Close to the Teesside Pipeline landfall, the dune systems at Coatham Sands are thought to be accreting and beach levels remain consistently high. This section of coastline is not currently being actively managed in any way. The Holderness coast, where the Humber Pipeline landfall is located, is known for being a highly erosive coastline. Net movement of this sediment freed by erosion is to the south. Sediment transported along this coastline is important for the replenishment and maintenance of Spurn Head – a sandy promontory which extends into the Humber Estuary. The Humber landfall intersects with the Holderness Cliffs and is in proximity to Spurn Head. The level of coastal defence and intervention is variable along the Holderness coast, according to the level and type of local land use and coastal processes exhibited in the area. At certain locations along the coastline coastal defences protect the cliffs, such as at Easington.
Water quality
In the Endurance Store area concentrations of possible chemical contaminants are typically below their respective limits of detection. Concentrations are not noticeable above background levels, and the water quality in the area is not significantly compromised by any local contamination. Analysis of fluids within the Endurance Store structure and the adjacent Bunter Sandstone Outcrop provided baseline salinity and metal concentrations. The Teesside Pipeline route passes through the Tees Coastal water body, which is designated under the Water Framework Directive (WFD) and which is classified as being a heavily modified water body as it supports a number of land uses. The Humber Pipeline route runs through the Yorkshire South coastal WFD water body prior to landfall. This water body is also considered heavily modified water body.

Biological Environment

Plankton

Phytoplankton abundance in the SNS fluctuates less than in the Central North Sea (CNS) and Northern North Sea (NNS) due to the water column remaining consistently well mixed throughout the year and considerable nutrient rich run-off year-round.

Biota living near, on or in the seabed (benthos)

Across the Endurance Store area, faunal abundance and diversity is relatively low, consisting mainly of annelid worms, prawns, starfish, bivalves, fish and sponges. Areas with more heterogenous seabed exhibit higher diversity. Some species and habitats of conservation interest were identified in the survey area, including the presence of Ross worm (*Sabellaria spinulosa)*, a tube-dwelling worm which can form dense aggregations creating a biogenic reef structure. Areas with 'low' resemblance to biogenic reef were found in the Store area. Other species and habitats of interest were found at low densities and no significant aggregations were identified.

Along the nearshore section of the Teesside Pipeline route, sandier sediments exhibit few visible fauna or features. Overall, benthos composition is relatively similar to that at the Store. Some areas of rocky reef habitat identified at the start of the route broadly correspond to areas of outcropping bedrock. Evidence of *S. spinulosa* biogenic reef was observed. A number of other species and habitats of conservation interest occur at low densities along the route.

Along the Humber Pipeline route, benthos composition is relatively consistent. Visible fauna are relatively sparse and mainly limited to starfish species. Evidence of animal tubes, burrows and faunal turf are found in areas of sandier sediment. Areas of rocky reef occur, however *S. spinulosa* biogenic reef is less prevalent relative to the Teesside Pipeline route. A number of other species and habitats of conservation interest occur at low densities along the route.

Fish and shellfish

The Store is located in high intensity nursery areas for cod and whiting, and low or undetermined intensity nursery areas for herring, lemon sole, sandeel, sprat, anglerfish, blue whiting, mackerel, European hake, and spurdog. Spawning grounds are generally regarded as having higher sensitivity than nursery areas. The Store is located within spawning grounds for cod, lemon sole, sprat and whiting. The area also overlaps a high intensity spawning location for plaice and sandeel.

Along the Teesside and Humber pipeline routes, most species are consistent with those found at the Store. Along the Humber Pipeline route only, sole may also be found spawning.

Marine reptiles

Five turtle species have been recorded in UK waters before. Of these, leatherback turtles have been recorded the most times. The majority of these sightings occur along coasts far from the Development area. A single turtle sighting or stranding event between 2010 and 2020 occurred approximately 40 km south of the Teesside Pipeline landfall indicating the rarity of such an occurrence.

Birds

Most bird species in the Development area are likely to originate from coastal colonies. The Development area may be of some importance to a number of species throughout the year, during both breeding and non-breeding periods. The large variety of seabirds that use the area include black-legged kittiwake, herring gull, and cormorant.

Marine mammals

Offshore, at the Store, the density of grey and harbour seals is relatively low. Generally, of the two seal species, grey seals are more likely to be found at higher densities. Grey seal densities are highest along the Humber Pipeline route and are concentrated close to the coast; the Humber Estuary is known to support a number of seal haul-out points and colonies. Within the Development area, bottlenose dolphin, harbour porpoise, white-sided dolphin, pilot whale, minke whale, white-beaked dolphin, bottlenose dolphin and common dolphin have all been observed at various times of year in differing numbers. Harbour porpoise are most likely to be present in the highest densities across the Development area and their presence is almost ubiquitous throughout the year. The photo of a grey seal, shown on the right, was taken in the Development area during a 2022 survey.

As the Development spans a large geographical area, there are a number of designated sites close to or interacting with the Development (Figure 5). The Endurance Store is located within the SNS Special Area of Conservation (SAC). The Teesside Pipeline intersects the Teesmouth and Cleveland Coast Special Protection Area (SPA). The Humber Pipeline intersects the Greater Wash SPA, Holderness Offshore Marine Conservation Zone (MCZ) and Holderness Inshore MCZ.

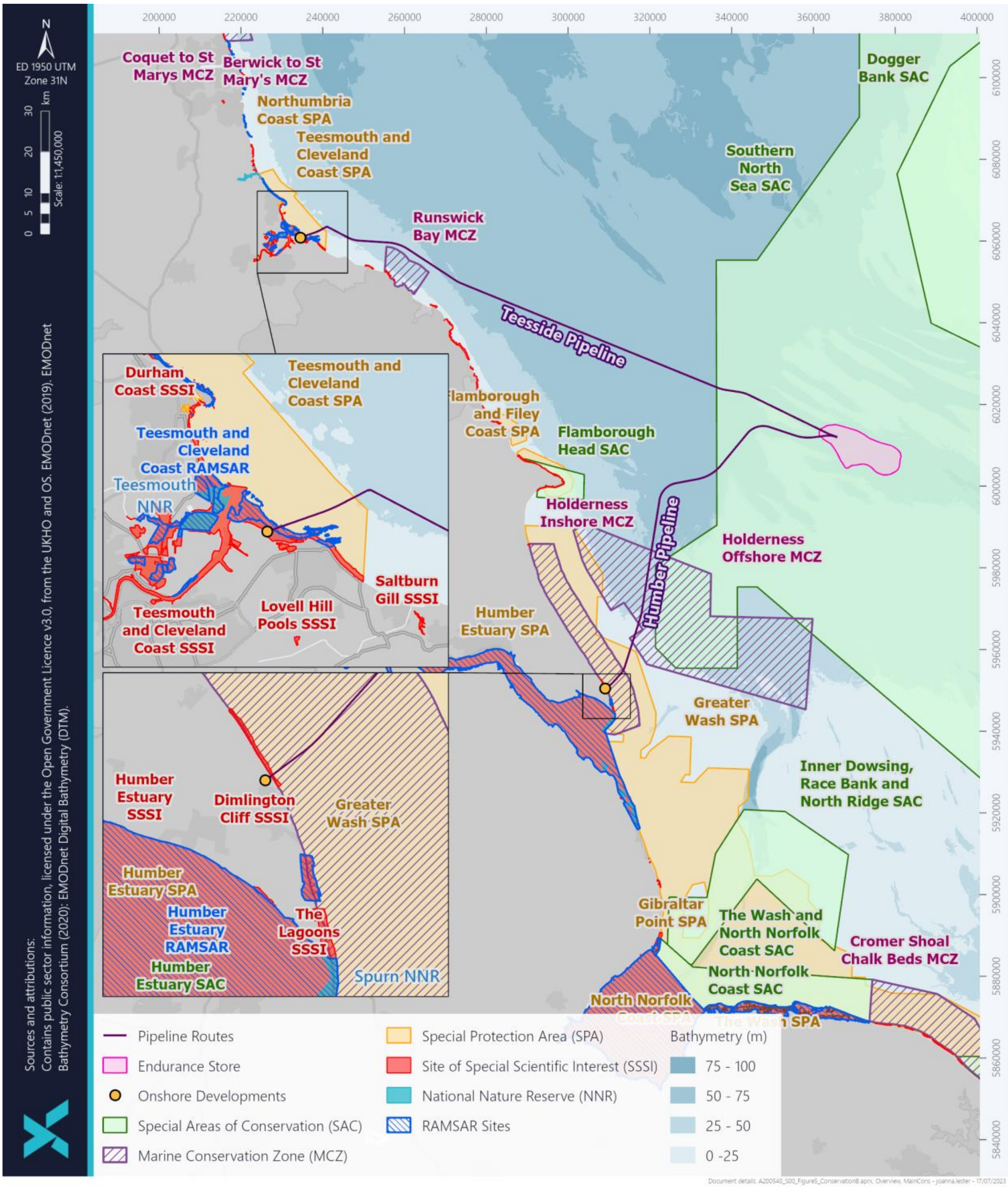

Figure 5 - Conservation sites in the vicinity of the Development

Other Sea Users

Commercial fisheries

Demersal species are principally targeted by fisheries in the Development area. Closer to shore along the pipeline routes, shellfish landings are often higher. Fishing effort in the wider Development area is high, in particular at points along the Humber Pipeline route where the total value of shellfish caught in 2019 was > £10 million. Fisheries along the Teesside Pipeline route are comparatively less productive in terms of total catch tonnage and value. Brown crabs, lobsters, scallops and Norway lobster are amongst the main species caught within the Development area.

Offshore infrastructure

The Development is located in an area of prominent oil and gas activity as well as significant offshore renewables presence. There are numerous wells, pipelines, platforms, Offshore Windfarms (OWFs) and subsea cables in the area. The closest platform to the Development is located 2 km from the Endurance Store. The two pipeline routes will cross a number of used and disused cables, and some yet to be installed.

Military activity

Some of the Development lies within Ministry of Defence training ranges. This is not a prohibitive factor to Development but requires the MoD be notified of any proposed activities in advance.

Shipping activity

Vessel presence within the Development area is high, particularly along the Humber Pipeline route, due to its proximity to the Humber Estuary, a major port location. Cargo and passenger vessels (and other service craft etc.) originate from the Humber. Cargo vessels originate from Teesside.

Archaeology

A number of wrecks occur within the Development area, none are designated or considered dangerous. There is potential for the discovery of unexploded ordnance along the two pipeline routes however munitions encounters are rarely reported in the Development area.

Aggregate and mineral extraction

Ten licensed aggregate extraction sites occur close to the Humber Pipeline route on approach to shore. No areas occur within 10 km of the Teesside Pipeline route, or offshore at the Store.

Recreation and tourism

Marinas and slipways are located along the coast at both Teesside and Humberside. In addition to recreational boating/yachting activities, there are a number of scuba diving clubs and popular beaches/bathing waters along the coast near both pipeline landfall points.

Coastal land use (pipelines)

Excluding densely industrialised areas at Teesside and within the Humber Estuary, coastal land use is predominantly agricultural. Note: any terrestrial implications are out of scope of this ES.

Environmental Impact Assessment (EIA) Methodology

The EIA process considers impacts and the resulting effects on receptors. The impact assessment has been carried out in three stages as follows:

1. Definition of the existing baseline environment surrounding the Development, in terms of the physical, biological and human environments.

2. Identification of the activities that have the potential to impact the baseline environment and their subsequent assessment. The assessment has been based on the potential magnitude of an impact and sensitivity of the receptor. The assessments assume that activities will be carried out in accordance with all current legislation and industry best practice.

> EIA Terminology
>
> **Impact** – a measurable change to the environment resulting from an action.
>
> **Receptor** – an element of the environment, such as an organism or habitat.

3. The potential for transboundary and cumulative impacts have been assessed, both within the Development, or when combined with other external activities.

The following issues were selected for assessment in the EIA:

- Seabed impacts;
- Underwater sound;
- Discharges to sea and Outcrop Formation Water displacement;
- Physical presence interactions with ornithology, marine mammals and other sea users;
- Accidental events and
- Atmospheric emissions.

Impact Assessment Summary

A summary of the impacts identified and assessed in the EIA are summarised below:

Seabed Impacts

The Development has the potential to cause both direct and indirect impacts to seabed habitats and species.

Direct impacts occur where the seabed is disturbed or manipulated in some way. Many of these impacts will only occur during the installation phase and are temporary and short-term. Where structures such as rock berms, surface-laid pipelines and subsea infrastructure will remain on the seabed during the operational phase, their presence represents a very localised but long-term change to the seabed environment.

Indirect impacts may occur due to the resuspension of sediments during installation (and decommissioning) activities. These impacts would be temporary in nature.

In addition, the construction of the landfalls during the installation phase, and the presence of infrastructure on the seabed in the nearshore and intertidal areas during the operational phase, have the potential to result in longer-term impacts including localised scouring and interruption of sediment transport processes.

Benthic Ecology

With respect to temporary direct disturbance, seabed preparation, trenching and installation activities along the Teesside Pipeline and Humber Pipeline routes, sporadic disturbance caused by the use of anchors of pipelay vessels, and trenching of infield flowlines and cables at the Endurance Store will affect the seabed. The Development area supports a range of benthic habitats, all of which are widespread in the region and likely to recover in time.

In the longer term, the presence of the infrastructure that remains on the seabed surface, such as rock protection, surface-laid portions of the pipelines, and the subsea infrastructure in the Endurance Store area, will represent highly localised changes to the seabed habitat. The presence of hard substrate is not expected to interfere with the functioning of surrounding communities and is not expected to degrade the function or value of the benthos. The hard substrate will become colonised. The consequence of the direct impact is assessed as minor and **not significant**.

Impacts arising from sediment resuspension generally last for a few days to a few weeks. The water column in the Development area frequently becomes turbid naturally, especially during storm events, creating disturbance on a much larger scale than that caused by the proposed Development activities. To conclude, indirect impacts associated with seabed disturbance are assessed as **not significant**.

Fish and Shellfish

Direct impacts to fish could occur during installation activities such as trenching and backfilling, but most fish in the path of the operations are expected to avoid physical damage. Fish are likely to move outside the area of disturbance during such activities and to return when they are finished. Some types of shellfish in the area (brown crab, lobster and scallops) are less capable of moving rapidly away from disturbance and may be more vulnerable, although disturbed individuals are likely to survive and re-establish themselves.

Several species might be spawning in the area during the installation works. Since most of these spawn in the water column over large areas, only a small proportion of the spawning adults, spawn and juveniles will be affected. Direct impacts on fish or shellfish populations are assessed as **not significant**.

Local increases in suspended sediment concentrations during the installation phase may cause indirect impacts through smothering, although adult and sub-adult fish and shellfish are expected to move away from areas of disturbance and return once it has ceased. Fish eggs, particularly of those species that lay eggs on the sediment, are expected to be vulnerable to smothering. Any impacts arising from sediment resuspension are resettlement are expected to be very short-term and therefore are assessed as **not significant**.

Birds

Habitat loss may result in the removal or fragmentation of habitat supporting the prey species of foraging seabirds. Bird species that have smaller foraging ranges or use fewer specific habitats are more sensitive to habitat loss generally. Based on the location of the Development, the timing of installation activities and published sensitivity scores, red-throated diver and little tern have been identified as the species more likely to be sensitive to impacts from the Development and therefore the assessment of impacts is focussed on these two species.

The total affected area of seabed affected by landfall and nearshore pipeline installation activities is an extremely small proportion of the total area of the SNS used by these species. Considering that the installation activities will be localised and short-term, the impact associated with seabed disturbance on red-throated diver and little tern is assessed as being **not significant**.

Marine Archaeology

Cultural heritage receptors are finite and non-renewable, and particularly vulnerable to any direct damage. Impacts to known sites will be avoided by the implementation of Archaeological Exclusion Zones (AEZs) in these areas, or through the micrositing of the facilities to avoid them. If previously unknown sites or material are encountered during the different phases of the Development, a Protocol for Archaeological Discoveries will be adopted to reduce the level of impact. The PAD is a system for reporting, investigating and protecting unexpected archaeological discoveries encountered. Although damage to important archaeological receptors, should it occur, might be significant, the detailed studies conducted to date and the mitigation measures to be followed will reduce the risk of impact so that, overall, it is assessed as **not significant**.

Coastal Processes

Tees Bay is a sediment sink and so under calm or normal metocean conditions, sediment is drawn towards the coast. Therefore, the water is likely to be relatively turbid close to shore. While there may be some increase in suspended sediments during the proposed operations, this is not expected to be noticeable above natural variation. Any disturbed sediment will be readily reincorporated into the local sediment regime. Overall, the impact on coastal processes at the Teesside Pipeline landfall is assessed to be **not significant**.

The Holderness coast is influenced by an energetic and changeable current regime. Even when the water is calm it is visibly turbid, especially close to shore. It is therefore expected that the coastal processes regime will be generally tolerant of increases in suspended sediment, and changes to sediment transport processes. Therefore, the impact is assessed to be **not significant**.

Underwater Sound

Many species found in the marine environment use sound to understand their surroundings, track prey and communicate with members of their own species. Some species, mostly toothed whales, dolphins and porpoise, also use sound to build up an image of their environment and to detect prey and predators through echolocation. The potential impacts of industrial sound on species may include effects on hearing and displacement of the animals themselves and potential indirect impacts which may include displacement of prey species or stress.

Of the sound sources which are likely to occur during the Development, piling and seismic surveys have been taken forward for assessment, as they represent the worst case sound sources as they are likely to result in greater disturbance (both spatially and temporarily) to marine mammals. Sound modelling was undertaking to determine the potential impacts on marine mammals.

Sound from piling during subsea installation and from seismic surveys has the potential to result in auditory injury on marine mammals. However, bp, as operator of NEP, will adopt embedded mitigation measures that includes both a soft-start (i.e. a slow build-up of hammer power or of the seismic sound source), and a monitoring zone of 500 m. The potential for injury of marine mammals from piling and seismic surveys is significantly reduced through the adoption of these guidelines.

Additionally, it is possible that sound emissions from piling and seismic activities could disturb marine mammals undertaking normal foraging activities and passing through the Development area. However, the assessment concluded that the percentage of marine mammals population likely to be impacted was low and no impacts at population levels are expected.

Any disturbance to fish species from piling and seismic surveys will likely be localised with higher levels of disturbance only occurring in regions near to the piling location (e.g. within a few hundred metres). At further distances from the piling locations (e.g. beyond one kilometre), the risk of behavioural disturbance to fish is likely to be low.

Considering the assessment undertaken and the embedded mitigation measures which will be implemented as per the Joint Nature Conservation Committee (JNCC) protocols, the residual impact of underwater sound generated by the Development is assessed to be **not significant**.

Discharges to Sea and Formation Water Displacement

The main discharges to sea during the drilling programme of the Development include mud, cuttings and cement. Discharges arising from installation of subsea infrastructure will include chemicals used in pipeline flooding, hydrotesting and dewatering. In addition, Formation Water is predicted to be displaced from the Bunter Sandstone Formation at the outcrop with maximum displacement of <1,600 m^3 per day. These discharges and displacement may lead to potential impacts to the seabed or water column.

Drilling Discharges

Drill cuttings dispersion modelling was undertaken to determine the potential pathway, fate and spread of cuttings on the seabed in the Development area, to assess their environmental impact.

Burial of benthic organisms may result in their mortality depending on the depth of cuttings deposition. More mobile species may be able to avoid unfavourable conditions, and to work their way back through the cuttings to the surface. Studies of the impacts of water based mud (WBM) cuttings discharges indicate that measurable benthic impacts are localised to the source and that recovery is rapid. While some species of conservation importance are present in the Store area, they are representative of the wider area and are found across much of the North Sea. Due to the localised nature of this impact, the dynamic nature of the receiving environment and the good prospects for recovery, impacts to the benthic environment are considered likely to be **not significant**.

Both the physical and chemical impacts of drilling discharges in the sea can also result in potential impacts to the water column. Discharges to the water column have the potential to affect fish, planktonic organisms and organisms living at or near the seabed. Modelling predicted a transient impact. The actual concentration of chemicals in the water column is predicted to be low and water column impacts from drilling are expected to last for eight to nine days during the drilling of the wells. Consequently, overall impact magnitude is assessed as likely to be negligible and **not significant**.

Aqueous Discharges

During pipeline pre-commissioning, there will be discharges of chemically treated seawater and Mono-Ethylene Glycol. Modelling of the Development pipeline pre-commissioning process (flooding, hydrotesting and dewatering) showed that the operations are likely to cause a small and short-lived plume which potentially could contain toxic levels of some of the chemicals used during pipeline installation. However, the potential for toxicity depends on the duration of exposure. This type of discharge is closely regulated both in terms of the chemicals selected for use and their concentration and will be subject to permitting closer to the time of the actual activity. Due to the dynamic receiving environment, receptor transience and small plume size, impacts are assessed to be **not significant** on the water column and the organisms within it.

Bunter Sandstone Outcrop Formation Water Displacement

It is anticipated that injection into the Store will indirectly displace Formation Water from the Bunter Sandstone Formation into the sea at the outcrop location during the operational phase of the Development. This displacement is linked to the increase in pressure at the Bunter Sandstone Outcrop. It is expected that pressurisation of the Formation Water at the outcrop will first occur four years after first CO_2 injection. As a worst case, displaced Formation Water at the Bunter Sandstone Outcrop may be associated with low pH, low oxygen concentration and a range of anions and cations, resulting in potential impacts on the water column and seabed. Modelling found there may be a localised increase in metals within the water column following displacement; however, these concentrations are expected to be limited as the majority of contaminants will not remain in solution, limiting the potential for large-scale contamination over the life of the Development. Additionally, following displacement most metal species are expected to be retained in the sediments and will not be released into the marine environment. Therefore, impacts associated with Outcrop Formation Water displacement are assessed as **not significant**.

Physical Presence

The physical presence of vessels and Development infrastructure and equipment has the potential to obstruct or exclude shipping, fisheries, other sea users and ecological receptors, such as birds and marine mammals. The assessment took into consideration the presence of other industries and sea users in the vicinity of the Development, to determine the maximum extent of disturbance and displacement.

Shipping

Shipping activities in the area are likely to be able to accommodate a temporary increase in vessel presence. Any interactions with other vessels or increased vessel collision risk will be mitigated through mitigation measures put in place, including the presence of a 500 m safety zone around the jackup rig, and adequate communication to other vessels to with a view to creating awareness among other vessels regarding the Development activities.

Fisheries

While fishing effort across the Development is variable and, in some cases, high, the industry as a whole is able to tolerate some displacement and is capable for recovery from any short-term exclusion or obstruction of access. All subsea infrastructure at the Endurance Store, the SSIV and the rock /

gravel protection will be designed to be fishing friendly and the locations of all infrastructure will be charted and communicated to the fishing industry. Longer term, the subsea infrastructure will be surveyed on a regular basis to identify and remediate any snagging risks, should they arise. Industry standard practice and protocols will apply to dropped objects and pre-and post-installation debris surveys will aim to identify any such deposits.

Other Sea Users

The Development is located in a busy area of the North Sea, but other sea users are expected to be able to tolerate at least short-term disturbance. However, aspects of the Development will overlap long-term with some other sea users. Impacts will be mitigated through adequate promulgation of information to other users and charting of infrastructure. bp, as operator of NEP, will aim to minimise disruption to other sea users and promote co-existence and will consult relevant parties to achieve this.

Beach Users

The landfall areas may provide recreational amenity at a regional scale. Impacts on beach users are expected to be minimal at the Teesside Pipeline landfall where the landfall methodology involves HDD. At the Humber Pipeline landfall, the impact should be localised in scale, temporary and short-term.

Marine Mammals

The Development will not result in long-term changes to the functioning of any marine mammal population. The risk of collision arising from the Development is expected to be greatest during the construction phase. However, vessels will likely be travelling at slow speeds, meaning the collision risk is low. Disturbance is also expected to minimal, when placed in the context of the vessels already present in the region. In addition, no impacts to seals at haul-out locations are expected.

Birds

Any disturbance to birds will predominantly occur during the construction period. The bird species most likely to be found in the Development area mostly have some degree of habitat flexibility and are not generally considered vulnerable to disturbance. In the case of those species which are more sensitive, the extent of disturbance predicted in line with the construction of the Development is such that an impact is not anticipated.

Taking into account the physical presence of the Development, given the short-term and mostly temporary scope of disturbance, the impact on receptors is assessed to be **not significant.**

Accidental Events

Accidental events related to the Development could impact the environment through releases of:

- Diesel from the jackup rig and installation vessels;
- CO_2 from the pipelines, the wells or the Endurance Store; and
- Brine from wells.

Hydrocarbon Release

Accidental hydrocarbon releases can impact on wildlife, particularly birds and sensitive coastal habitats. Modelling indicated the potential worst case releases would result from a loss of entire rig diesel inventory at the Endurance Store or nearshore loss of vessel diesel inventory during pipelay for the Teesside or Humber Pipeline. Worst case modelling demonstrated the potential for beaching on the east coast of Northern England between North Tyneside and Great Yarmouth District. In the unlikely event of a loss of diesel inventory at the Endurance Store will result in surface contamination in the SNS SAC. Loss of diesel inventory in the nearshore at Humber may also lead to surface contamination in the SNS SAC.

Marine diesel is a refined hydrocarbon and will be rapidly removed from the sea surface and the marine environment due to evaporation and biodegradation. Marine diesel would be expected to dissipate from the sea surface within 18 to 36 hours of release, and any reaching the shore would be in low amounts that may well not be discernible to an observer on the shoreline. Given the mitigation measures that are in place and the remote likelihood of the release happening, the consequence is considered low and the impact is assessed to be **not significant.**

CO_2 Leakage

While considered low probability, the accidental leakage of CO_2 from pipelines, wells or the Endurance Store could potentially impact the environment. Figure 6 illustrates potential leakage pathways.

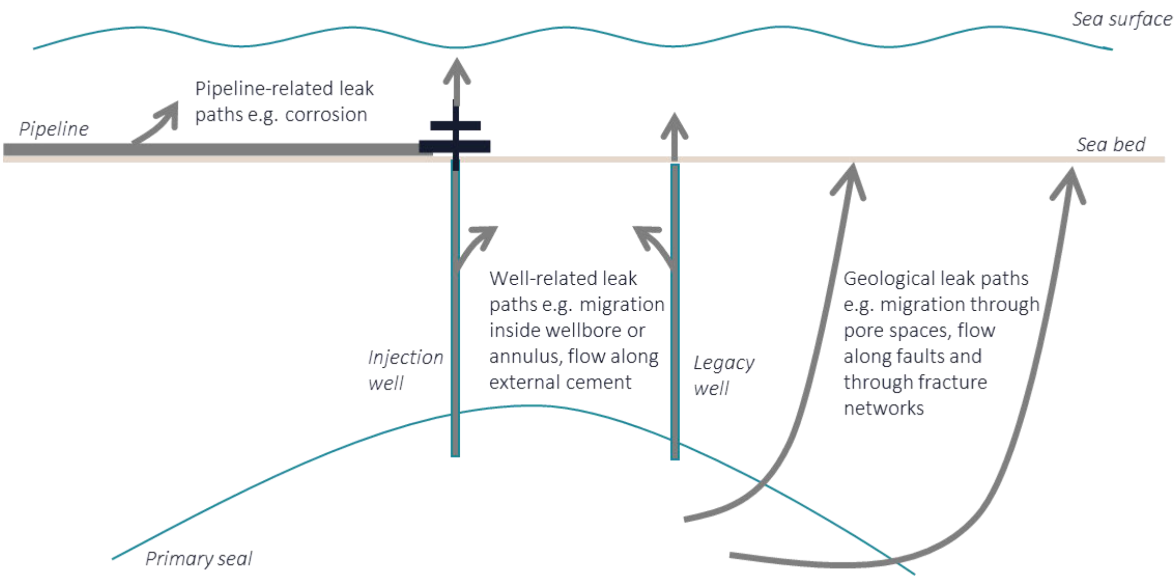

Figure 6 - Potential CO_2 leak pathways

A limited number of hydrocarbon containing pipeline incidents have taken place offshore in the UKCS. Considering the comparatively lower number of CO_2 pipelines in the UKCS, even fewer incidents have occurred involving CO_2 pipelines. The likelihood of such an occurrence is low.

Once CO_2 injection is initiated, the aquifer will pressurise over time. Theoretically, surface blowout at the injection wells could occur if a well experiences primary loss of containment. However, this is very unlikely. Technical specifications of the wells will seek to minimise any leakage. Post-closure monitoring, will be utilised to mitigate any risk of post-injection leaks.

A leak from the Store is unlikely as the caprock[1] forms a very robust barrier due to its low porosity and permeability. The likelihood of seismic activity resulting in damage to the Store seal or offshore infrastructure and causing environmental harm is considered extremely remote, and the residual risk of such an occurrence is low. In the unlikely event of a CO_2 leak, CO_2 may reach the seabed sediment where the majority will dissolve in the sediment pore water and reduce the pH, precipitate in the mineral phase, or accumulate as gas pockets within the sediment. However, some may emerge into the water column. On release into the marine environment, CO_2 is less dense than the surrounding water so will rise towards the surface as bubbles before dissolving. All CO_2 leak events which reach the water column will create a change in pH and other chemicals on a gradient which will decrease with distance from the leak location to the periphery of the affected area. Some scientific evidence suggests that benthic biological systems recovered within a few weeks of exposure to lowered pH levels. Furthermore, exposure to CO_2 must be of a long duration rather than short-term to display a change in organisms. Larger, mobile species feed over larger areas; therefore, are unlikely to be affected by a temporary CO_2 leak which is highly dispersive.

It is recognised that an accidental CO_2 leak could result in demonstrable change in receptors. However, given the mitigation measures that are in place and the remote likelihood of an accidental CO_2 leak happening, the impact is assessed to be **not significant**.

Store Formation Water Leakage

A number of legacy wells[2] are already present in the Endurance Store. As CO_2 is injected into the Store, the legacy wells will experience an increase in pressure due to displacement of Store Formation Water by CO_2 from the Store. Store Formation Water could potentially leak from these wells should corrosion occur. The chance of such a leak occurring is estimated to be remote.

In their undiluted form, brines such as Store Formation Water have the potential to be detrimental to ecosystems. However, dispersion and dilution act to reduce this impact potential. This is the case in the relatively shallow and well mixed environments above the Endurance Store. Tidal currents will prevent significant accumulation of brines within sandwave troughs.

Modelling showed that the brine plumes were generally expected to disperse rapidly and that impacts in the water column were found to be localised. In the unlikely event of Store Formation Water leakage, minor localised influence on the marine environment may occur, however this is likely to be short lived and highly localised. Therefore, this impact is assessed as **not significant**.

Atmospheric Emissions

Atmospheric emissions from the Development will arise from vessel fuel combustion during installation, commissioning, drilling of wells and operations and maintenance (O&M). Atmospheric emissions from the Development, which will primarily result from complete or in-complete combustion of fuels, will contribute to impacts at a local, regional, national, transboundary and global scale.

[1] *Caprocks are relatively impermeable rocks layers that seal the top of reservoirs and other geologic formations.*

[2] *Wells that were drilled previously and which have been made incapable of flowing (plugged) in accordance with industry and regulatory guidance at the time of plugging.*

A carbon assessment was conducted as part of the EIA. The assessment quantified the total carbon emissions from the Development. Opportunities to manage and reduce atmospheric emissions during the O&M phase of the Development will be identified and implemented to minimise emissions as far as reasonably practical.

Global climate change

In terms of global climate change (i.e. cumulative and transboundary impacts), the Development will add a relatively small increment to UK emissions and the release of Green House Gases into the environment, and its contribution to global warming will be negligible. Indeed, the emissions associated with the Development are an integral element of the overall East Coast Cluster development that will deliver CO_2 transport and storage, contributing to reductions in UK emissions and achievement of net zero goals.

The majority of emissions are short term in duration and intermittent. On a global scale, the low level of additional emissions of CO_2e resulting from the Development relative to the wider UK context is minimal. The impact on global climate change is assessed as **not significant**.

Local air quality

Offshore wind conditions at the Endurance Store are highly dispersive for gaseous emissions (e.g. CO_2, CO, NO_x, N_2O, SO_x, CH_4 and non-methane volatile organic compounds). Local wind patterns will widely disperse pollutants, including vessel fuel combustion emissions, to levels well below those expected to be of concern.

The majority of activity will only occur in the highly dispersive marine environment and therefore unlikely to be discernible or measurable. The impact on local air quality is assessed as **not significant**.

Environmental Management

bp, as operator of NEP, is committed to conducting activities in compliance with all applicable legislation and in a manner that will minimise impacts on the environment. The bp Health, Safety, Security and Environment (HSSE) performance policy goals are simply stated:

- No accidents;
- No harm to people; and
- No damage to the environment.

bp's HSSE goals are enshrined in the bp Code of Conduct and the bp Operating Management System (OMS). The bp OMS is aligned with the requirements of ISO 14001:2015, a globally recognized international standard which sets specific requirements for an effective Environmental Management System.

All activities associated with the design, installation and commissioning of the Development will be carried out under the bp NEP Environmental and Social Management and Monitoring Plan. This plan will set out the approach to avoiding or mitigating potential environmental impacts, to delivering regulatory compliance and to carrying out the commitments made. As part of the storage permitting process, a Monitoring Plan for the Endurance Store is being developed and agreed with the NSTA.

In 2020, bp announced its ambition to be a net zero company by 2050 or sooner and to help the world get to net zero. As part of continual improvement in the reduction of direct and indirect operational emissions, bp will seek emissions reduction opportunities through all phases of the Development.

Conclusions

Development activities have the potential to impact a number of physical, environmental and socio-economic receptors, as outlined in preceding sections. The definitive list of commitments made by the Development in this Environmental Statement is set out in the Commitments Register (Appendix C).

All activities associated with the design, installation and commissioning of the Development will be carried out under the bp NEP Environmental and Social Management and Monitoring Plan. This plan will set out the approach to avoiding or mitigating potential environmental impacts, to delivering regulatory compliance and to carrying out the commitments made within this ES. Furthermore, when operating, bp will conduct the operational phase activities associated with the Development in accordance with its mature EMS. bp will work towards continual improvement in environmental performance.

Overall, based on the assessment undertaken, no significant impacts are predicted as a result of the Development.

1 INTRODUCTION

1.1 The Proposed Development

The proposed Development forms the offshore part of the wider East Coast Cluster (ECC) development (Section 1.4) and comprises the following activities:

- Installation, connection to subsea infrastructure and commissioning of two CO_2 export pipelines from Teesside and Humber clusters mean low water spring (MLWS) to the Endurance Store, including a Subsea Safety Isolation Valve (SSIV) nearshore Teesside;
- Installation of subsea infrastructure including two manifolds, infield flowlines and an infield pipeline;
- Drilling of five CO_2 injection wells and one Endurance Store monitoring well and installation of six subsea trees[3];
- O&M of subsea infrastructure and pipelines;
- Monitoring and management of the storage aquifer during and after CO_2 injection; and
- Installation, commissioning and O&M of cables;
  - One electric power and fibre-optic communications control cable running from Teesside to the subsea infrastructure at the Endurance Store;
  - One electric power and fibre-optic communications control cable between the two manifolds and six cables from the manifolds to each of the wells; and
  - One power, control and hydraulics umbilical running from Teesside to the SSIV (hereafter referred to as the Teesside - SSIV cable).

The relevant regulatory Environmental Impact Assessment (EIA) regimes and scope of this assessment are summarised in Table 1-1. Decommissioning activities are subject to a separate environmental appraisal process and are not covered by the EIA Directive requirements. Where relevant, the EIA scope indicates how future decommissioning requirements may influence Development design (including pipelines and wells).

The storage site is in the Endurance saline aquifer[4] beneath the SNS, located approximately 145 km to the southeast of Teesside and 63 kilometres (km) from the nearest coastline. The aquifer is referred to as the Endurance Store, and is considered to be the most mature large scale saline aquifer for CO_2 storage in the offshore UK Continental Shelf (Gluyas and Bagudu, 2020).

Dehydrated and compressed CO_2 will be transported offshore via two new approximately 28" diameter[5], concrete-coated CO_2 export pipelines that will direct the dense phase[6] CO_2 to the Endurance Store, these pipelines are referred to as the Teesside Pipeline and the Humber Pipeline. The Teesside Pipeline will be approximately 142 km in length and the Humber Pipeline approximately 100 km in length from MLWS. The SSIV will be located between KP6 and KP8 on the Teesside Pipeline.

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[3] Subsea/wellhead trees are structures above each well that are used in well monitoring and control.

[4] Porous rocks containing brine overlain by a robust seal.

[5] Assume outer diameter unless otherwise stated

[6] Dense phase means the CO_2 demonstrates properties of both liquid and gas. The dense phase has a viscosity similar to that of a gas, but a density closer to that of a liquid. The unique properties of this phase, are favourable for the transportation of CO_2 over long distances.

Table 1-1 - The whole scheme and associated regulatory EIA regimes

Application	Regulations	Regulator	Scope
Northern Endurance Partnership (NEP) Environmental Statement (ES)	The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020	OPRED	All development and activities seaward of MLWS
The Net Zero Teesside Project Development Consent Order (DCO)	Planning Act 2008	PINS	All development and activities at Teesside landward of MLWS[7]
Onshore Humber application[8]	Planning Act 2008	PINS	All development and activities at Humber landward of MLWS

At the Endurance Store, drilling of the wells into the Endurance Store is intended to occur in one stage. The electrically powered, subsea facilities consist of two manifolds[9]:

- A crossover co-mingling manifold to combine the flows from the Teesside and Humber Pipelines and distribute it for injection into two wells at the Endurance Store; and
- A four-slot manifold at the Endurance Store connected to the other three injection wells, with the potential to support a further two injection wells.

An electric power and fibre-optic communications control cable is intended to be installed from Teesside to the subsea infrastructure at the Endurance Store. A carbon steel, infield pipeline is intended to run between the two manifolds (approximately 28” diameter; maximum length of 6 km) and infield flowlines are intended to run from the manifolds to the injection wells (up to 8” diameter; maximum 3 km in length). Power and communications are provided between the two manifolds and from the manifolds to each of the six wells, including the Endurance Store monitoring well at which pressures and temperatures will be monitored.

During operations, water washing may be required on each injection well on an annual basis to avoid loss of CO_2 injectivity. A Monitoring Plan (MP) for the Endurance Store will be developed and agreed with the NSTA as part of the store permitting process.

Based on current schedule estimates, a final investment decision for the Development will be made in 2024. Subject to that decision, bp, as operator of the Development, plans that preparatory works and landfall construction will commence in 2025 with installation of the pipelines and subsea infrastructure (including manifolds) and drilling of the wells into the Endurance Store expected to commence in 2026. CO_2 injection is anticipated from 2027.

[7] Including the NEP onshore CO_2 pipeline gathering network to other emitters on Teesside and an extension below MLWS to accommodate waste water disposal connections.

[8] Consenting landward of MLWS at Humber will be subject to a future DCO application under the Planning Act 2008. For ease of reference, the onshore development and consent application are referred to as 'Onshore Humber' and 'Onshore Humber application'

[9] Arrangement of piping and/or valves designed to combine, distribute, control, and monitor flow of CO_2.

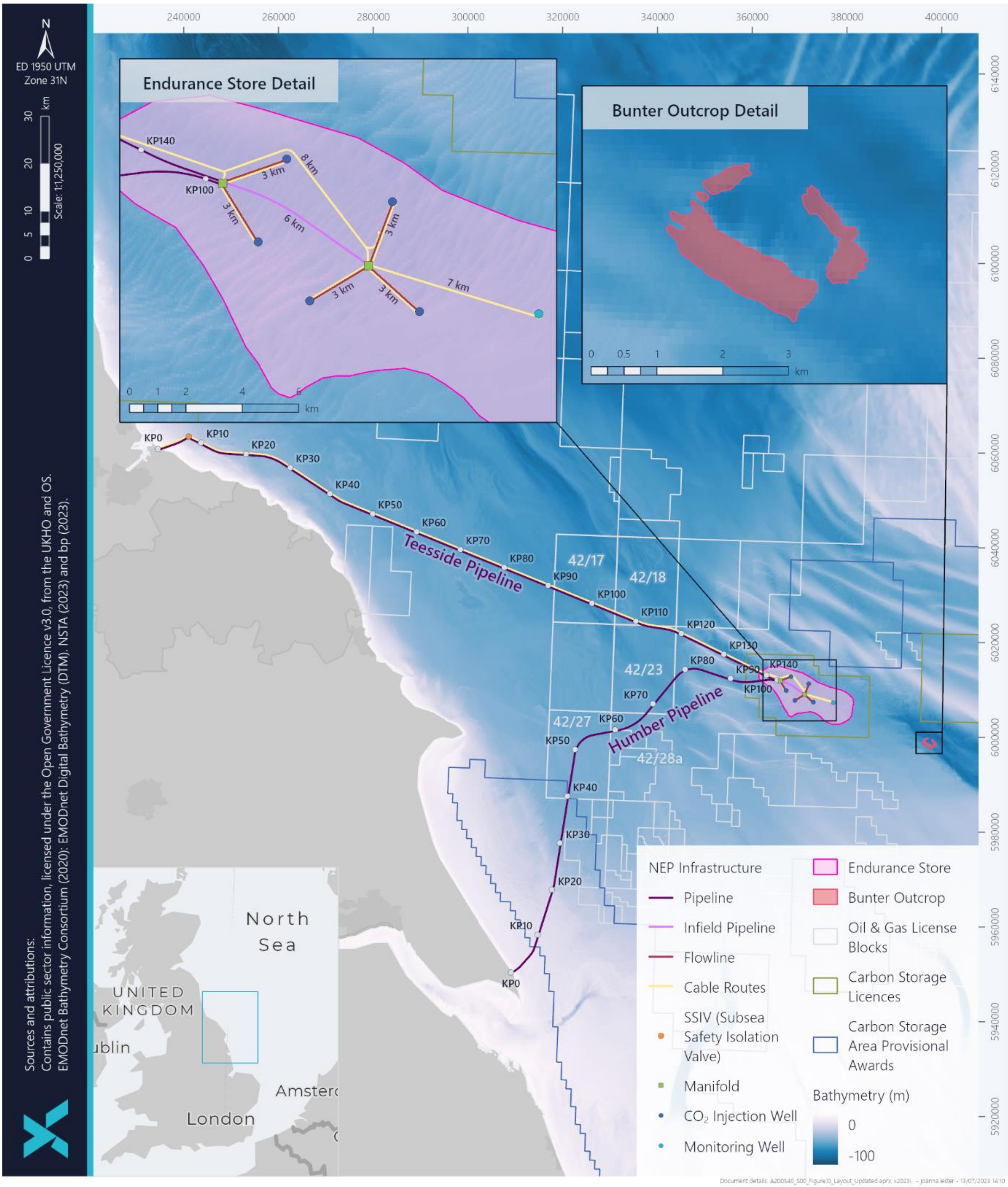

Figure 1-1 - Schematic (to scale) of pipeline routing and infrastructure locations

1.2 Scope of Environmental Impact Assessment

The overall aim of the EIA is to identify and assess the potential environmental impacts that may arise from the Development and to identify the measures that will be put in place to reduce these potential impacts.

The EIA process is integral to the design and implementation of the Development, assessing potential impacts and alternatives, and identifying design and operational elements to help reduce the potential impacts of the Development as far as reasonably practical. The process also provides for stakeholder involvement so that issues can be identified and addressed as appropriate at an early stage, and helps the planned activities comply with environmental legislative requirements and with bp's environmental policy.

The EIA scope includes installation, commissioning, operational and maintenance activities of the Development over which bp has operational control (Section 1.1).

The EIA considers both routine and accidental events where there are potential environmental impacts.

The results of the EIA process for the offshore aspects of the Development are presented in this ES. The scope of the EIA was developed in conjunction with stakeholders; full details of the method applied during the EIA process are described in Chapter 5: EIA Methodology.

Key elements of this ES include the following:

- A non-technical summary of the ES;
- Description of the background to the Development; role of the EIA and legislative context (this chapter);
- Alternatives considered (Chapter 2: Consideration of Alternatives);
- Description of the Development (Chapter 3: Project Description);
- Description of the environment and identification of the key environmental sensitivities which may be impacted by the Development (Chapter 4: Environmental Description);
- Description of the methods used to identify and evaluate the potential environmental impacts (Chapter 5: EIA Methodology);
- Detailed assessment of key potential impacts, including assessment of potential cumulative and transboundary impacts (Chapters 6: Seabed Disturbance to 11: Atmospheric Emissions);
- Assessment of shared receptors potentially affected by both the onshore and offshore works (Chapter 12: Whole Scheme Assessment);
- Description of the environmental management measures that will be in place during the Development (Chapter 13: Environmental Management); and
- Conclusions (Chapter 14: Conclusion).

1.3 Need for the Development

Climate change is a global issue, resulting from greenhouse gas (GHG) emissions released into the atmosphere, largely due to human activity. Evidence of the effects of climate change include widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere (IPCC, 2021).

The United Kingdom (UK) Parliament announced a climate change emergency in May 2019, publicly declaring concern over the findings around climate change and its consequences. The Climate Change Act 2008 (2050 Target Amendment) Order 2019 introduced a legally binding commitment that the net UK carbon account for the year 2050 must be at least 100% lower than the 1990 baseline i.e. 'net zero'. The Committee on Climate Change (CCC[10]) concluded that net zero is (CCC, 2019):

- ***necessary*** to respond to the overwhelming evidence of the role of GHGs in driving global climate change;
- ***feasible*** as the technologies and approaches to deliver net zero are understood and can be implemented with strong government leadership; and
- ***cost-effective*** given the falls in the costs of key technologies that permit net zero.

To achieve the UK Net Zero target, it is thought that industrial emissions in the UK will need to reduce by at least two thirds by 2035 and at least 90% by 2050 and to achieve this, the deployment of carbon capture and storage (CCS) is considered to be essential (CCC, 2019). CCS refers to a set of processes that capture CO_2 from waste gases produced at industrial or power generation facilities and permanently store it in offshore geological storage sites (Figure 1-2, Tiley, 2020)[11]. CCS is proven technology and is already in use around the world (Global CCS Institute, 2021).

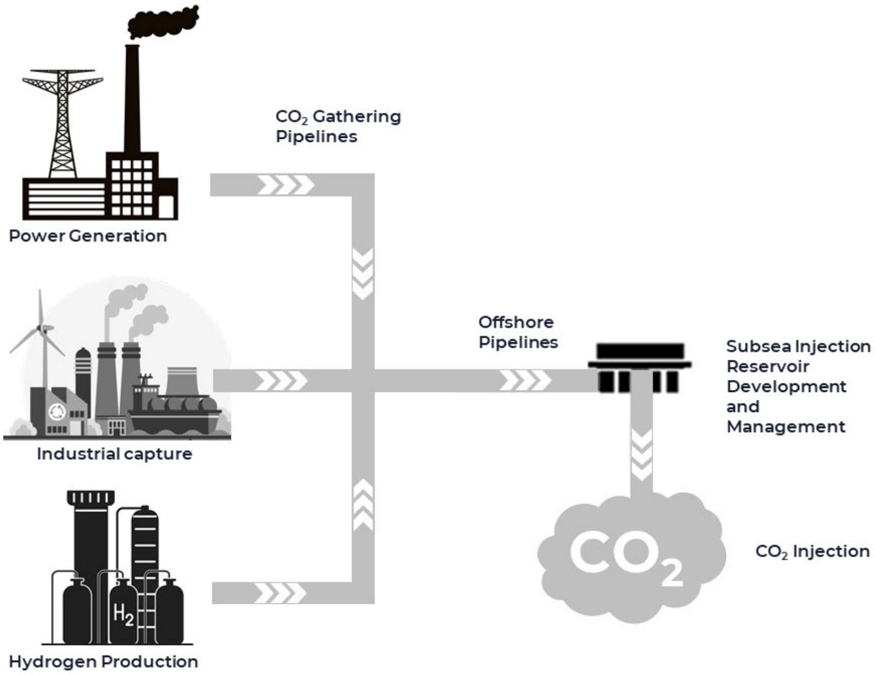

Figure 1-2 - Overview of CO_2 transportation and storage

[10] An independent, statutory body established under the Climate Change Act 2008 to advise the UK and devolved governments on emissions targets and to report to Parliament on progress made in reducing greenhouse gas emissions and preparing for and adapting to the impacts of climate change.

[11] CCS is a subset of carbon capture utilisation and storage (CCUS). The term CCS additionally incorporates CO_2 captured from industrial processes being used in the production of chemicals, minerals, plastics and synthetic fuels (Tiley, 2020).

Forecasts of the UK's future energy scenarios require CCS to be utilised with industrial processes where there are limited available alternatives to fossil fuels e.g. producing steel, concrete and chemicals (BEIS, 2022a; IEA, 2020). Gas-fired power plants with CCS provide reliable lower carbon generation capacity and are intended to reduce emissions compared to unabated gas-fired plants by 90% or more. Power plants equipped with post-combustion CCS could provide flexible generation that is able to ramp up or down to meet demand and balance variable generation from renewable electricity sources (National Grid, 2020).

In November 2020, the UK Government published the Ten Point Plan for a Green Industrial Revolution, to decarbonise the economy with commitments focused on driving innovation, boosting export opportunities, and generating green jobs and growth across the country to level up regions of the UK. Included in the Plan was the first UK commitment to deploy CCS in two industrial clusters by the mid-2020s, and a further two clusters by 2030 with an ambition to capture 10 million tonnes per annum (MtPA) CO_2 by 2030 (UK Government, 2020). The UK Government is committed to investing up to £1 billion to support the establishment of CCS in four industrial clusters in areas such as the North East, the Humber, North West, Scotland and Wales (UK Government, 2021). CCS infrastructure is needed to decarbonise the industrial heartlands of Teesside and the Humber which together account for nearly half of carbon emissions from UK industrial clusters.

As part of encouraging CCS cluster[12] development, the Government established a cluster sequencing process in February 2021 which seeks to provide industry with the certainty to deploy the technology at pace and at scale (BEIS, 2021a). In October 2021, the UK Government published the UK Net Zero Strategy which set out to at least double the commitments from the UK Government's Ten Point Plan by aiming to capture between 20 and 30 MtPA of CO_2. In the same month, the Department for Business, Energy and Industrial Strategy (BEIS) (now the Department for Energy Security and Net Zero (DESNZ)) confirmed two Track-1 clusters, i.e. clusters expected to be operational by mid-2020s and having the first opportunity to receive support from the government's CCS Programme[13].

The ECC is one of the two selected Track-1 clusters and includes the Northern Endurance Partnership Development, 'the Development' (Section 1.1). The ECC aims to deploy CCS to remove up to 23 MtPA CO_2 by mid-2030s, i.e. almost 50% of the UK's industrial cluster CO_2 emissions and 100% of the UK Government CCS target[14]. Achieving these aims bolsters the UK's leadership in the energy transition and the emerging global low-carbon and hydrogen market and plays a major role in the desire to level up across the country. The Development is critical to delivery of the wider ECC by providing the onshore and offshore pipelines for transporting CO_2 from Teesside and Humber to the Endurance Store.

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[12] Industrial clusters are places where related industries have co-located. DESNZ specifically define a cluster as a transport and storage (T&S) network and an associated first phase of at least two CO_2 capture projects. A T&S network is defined as a set of onshore pipelines, offshore pipelines and an associated offshore storage facility. The pipelines must be capable of transporting CO_2 to the storage site (for example a saline aquifer or depleted oil and gas field) that must be able to store this CO_2 safely and permanently (BEIS, 2021a).

[13] https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-deployment-phase-1-expressions-of-interest/october-2021-update-track-1-clusters-confirmed

[14] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf

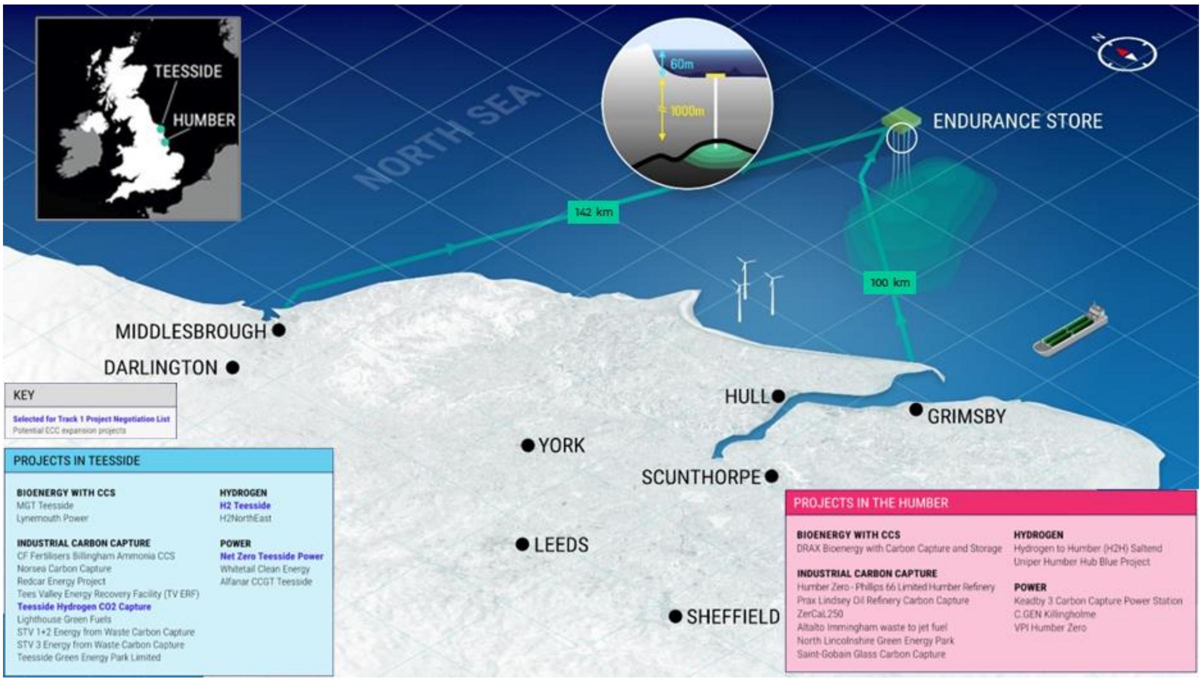

Figure 1-3 - Overview of the ECC (not to scale)

1.4 East Coast Cluster and the Northern Endurance Partnership

ECC is a carbon capture, usage and storage project which serves to decarbonise a range of businesses across the industrial regions of Teesside and Humber. These carbon capture projects are deemed by DESNZ to fit into four broad categories – power with carbon capture, industry with carbon capture, hydrogen and bioenergy with carbon capture and storage. DESNZ has put in place a process – The Cluster Sequencing Process for carbon capture, utilisation and storage – through which carbon capture projects are selected by UK Government for sequenced connection to ECC. In March 2023, DESNZ selected three ECC projects – Net Zero Teesside Power, H2Teesside and Teesside Hydrogen CO_2 Capture – who will connect first to the cluster by 2027 (Figure 1-3). DESNZ has announced that a process will be launched to enable further expansion of the ECC, identifying and selecting projects for the ECC – including from Humber – to be operational by 2030[15].

1. NEP is the CO_2 transportation and storage provider for the ECC. Consisting of BP Exploration Operating Company Limited (bp), Equinor New Energy Limited and TotalEnergies CCS UK Limited, NEP was formed to develop offshore CO_2 transport and storage infrastructure in the UK Southern North Sea (SNS).

   NEP will route CO_2 from the Teesside and Humber clusters to the offshore geological storage site, the Endurance Store which is located approximately 63 km from the nearest coastline in the SNS, in water depths of approximately 65 metres (m) (Figure 1-1; subject of this ES). The Development objective is to deliver technical and commercial solutions required to implement innovative First of a Kind (FOAK) offshore low-carbon CCS infrastructure in the UK.

[15] *https://www.gov.uk/government/publications/cluster-sequencing-phase-2-eligible-projects-power-ccus-hydrogen-and-icc/cluster-sequencing-phase-2-track-1-project-negotiation-list-march-2023*

This includes CO_2 pipelines connecting from Humber and Teesside compression/pumping systems to a common subsea manifold and well injection site at the Endurance Store, i.e. transporting and storing CO_2 emissions from both onshore clusters (Figure 1-1). The Endurance carbon storage licence CS001[16], awarded by the Oil and Gas Authority (OGA, now the North Sea Transition Authority (NSTA)), is held by BP Exploration and Operating Company Limited (BPEOC, 50%) and Equinor New Energy Limited (50%).

The offshore aspects of consenting will be undertaken by bp as operator on behalf of the relevant Partners and Net Zero North Sea Storage Limited (as appropriate). As part of the offshore consenting process bp will apply to the NSTA for the store permit under CS001. bp is also the company that is progressing the offshore environmental impact assessment and subsequent ES that will be submitted to the Offshore Petroleum Regulator for Environment and Decommissioning (OPRED) under the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020.

2. NZT Power will potentially be the world's first commercial scale gas fired power station with CCS. This technology, i.e. power plants with carbon capture, has been identified as a key contributor towards full decarbonisation of the UK grid (BEIS, 2021b). NZT Power will provide dispatchable[17] low carbon power which will enable and compliment increasing renewable energy deployment by providing low carbon power to back up intermittent forms of renewable energy such as wind and solar. NZT Power is a joint venture between bp and Equinor. bp is currently the operator of NZT Power, leading development on behalf of the Project Partners pursuant to an agreement known as the Cooperation Agreement (COOPA). bp will continue to serve as operator by providing services to the Applicants for the development (and operation) of NZT Power.

   An application was made in July 2021 to the Secretary of State (SoS) for BEIS (now DESNZ) for a DCO[18] to authorise this Nationally Significant Infrastructure Project (NSIP), pursuant to the Planning Act 2008. This application, referred to as the NZT Project DCO, is now undergoing examination.

3. National Grid Ventures (NGV) are in commercial discussions with NEP partners on the sale of the CO_2 elements of the Humber onshore pipeline proposals ('Onshore Humber'; ECC, 2023) and are committed to managing a smooth transition for ECC, partners and stakeholders across both Teesside and the Humber (ECC, 2023). A scoping report was submitted by NGV in April 2022 to the SoS for BEIS (now DESNZ) for a NSIP consisting of the terrestrial elements of an onshore pipeline connection network to transport CO_2 and hydrogen. The network originated at the Drax Power Station in the east and finished at MLWS at a landfall location of the Holderness Coast (HLCP, 2022). The work undertaken to date by NGV in relation to Onshore Humber will form the basis for NEP partner progression of the NSIP and is therefore referenced in this ES.

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[16] *NEP has acquired additional store licences (CS006/CS007) in proximity to Endurance that would allow for future expansion from existing Phase 1 development. Development associated with these licences would be subject to subsequent ES submission.*

[17] *i.e. the power plant can be turned on or off to adjust power supplied to the electricity grid, mitigating the intermittency associated with energy harnessed by windfarms.*

[18] *https://infrastructure.planninginspectorate.gov.uk/application-process/the-process/*

The ECC could help protect up to 70% of existing jobs in heavy industry on Teesside, and enable many thousands of new, high quality employment opportunities.

The "Do Nothing" alternative for the Development would mean that a FOAK power and industrial CCS scheme of this design and within the time frame to support the UK Net Zero Target would not be developed at these locations. The result would be that carbon emissions from industrial sources on Teesside and Humber, which constitute almost 50% of the UK's industrial cluster CO_2 emissions (BEIS, 2019)[19], would continue unabated or the industries producing them would cease. The Development is anticipated to enable up to 23 MtPA average (MtPAa) of CO_2 transport and storage by mid-2030s (assuming future expansion phases, outwith the scope of this ES). Further, CO_2 transportation and storage would not be available to support the increased deployment of dispatchable power with carbon capture, to enable the decarbonisation of the UK grid in tandem with increased electricity generation from renewable energy sources. This may limit UK achievement of targets and policies relating to climate, green energy and decarbonisation (Section 1.5). For these reasons the "Do Nothing" alternative scenario is discounted.

1.5 Legislation and Policy

The UK Government supports CCS, considering it likely to be essential in tackling climate change, meeting the ambitions of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement and the UK net zero target (Tiley, 2020). Key legislation guiding the roll out of CCS includes:

- ***Climate Change Act: 2008***: Forms the basis for the UK's approach to tackling and responding to climate change, including a system of carbon budgeting. It requires that emissions of CO_2 and other GHGs are reduced and that climate change risks are adapted to. The Act established an independent body, the CCC which provides advice to the UK Government and Parliament on carbon budgets;
- ***Clean Growth Strategy:*** The Clean Growth Strategy[20] was announced by the UK Government in October 2017, setting out a strategy to deliver increased economic growth while cutting GHG emissions. Commitments were made to demonstrate international leadership in CCS, by collaborating with global partners and investing in leading edge CCS and industrial innovation to drive down costs (BEIS, 2017);
- ***Net Zero Target:*** In July 2019, the UK Government amended the Climate Change Act 2008 to commit the UK to a legally binding target of net zero emissions by 2050 whereby any emissions would be balanced by schemes to offset an equivalent amount of GHGs from the atmosphere, such as using technology like CCS[21];
- ***Ten Point Plan for a Green Revolution:*** In November 2020 the UK Government published the Ten Point Plan for a Green Revolution which included an ambition to invest up to £1 billion to

[19] *Based on BEIS CO_2 estimates for industrial clusters across the UK, reported as part of the Industrial Clusters missions which aims to reduce emissions within industrial areas in the effort to achieve Net Zero (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/803086/industrial-clusters-mission-infographic-2019.pdf).*

[20] https://www.gov.uk/government/publications/clean-growth-strategy

[21] https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

establish CCS in at least two industrial clusters by mid 2020s and aim for four of these sites by 2030, capturing up to 10 MtPA of CO_2[22];

- ***Energy White Paper:*** Building on the Ten Point Plan, the paper addresses the transformation of the UK energy system, promoting high-skilled jobs and clean, resilient economic growth as net zero emissions are delivered by 2050. Estimates indicate that exports of new technologies such as CCS have the potential to add £3.6 billion gross value added (GVA) by 2030. The UK Government committed to putting in place the commercial frameworks required to help stimulate the market to deliver a future pipeline of CCS projects[23];
- ***North Sea Transition Deal:*** A sector deal between the UK Government and the offshore oil and gas industry to deliver the skills, innovation and new infrastructure required to meet stretching GHG emissions reduction targets. Published in March 2021, the deal identifies commitments that encompass action to facilitate the deployment of CCS, in line with the Ten Point Plan[24]; and
- ***UK Net Zero Strategy – 'Build Back Greener'***: Published in October 2021, the UK Government furthered its CCS ambitions for 2030 but increasing the CO_2 injection capacity target from 10 MtPA to between 20 and 30 MtPA, strengthening its commitments to achieving net zero by 2050. The UK Government's renewed 2030 target is now aligned to the CCC's Sixth Carbon Budget (December 2020) which recommends that 22 MtPA of CO_2 injection capacity is required by 2030[25]. In April 2022, the British Energy Security Strategy was published which cemented the UK Government's ambitions to deliver its updated CCS targets by 2030[26]. OPRED regulates the environmental aspects of offshore CCS with statutory advisors including the Marine Management Organisation (MMO), the Joint Nature Conservation Committee (JNCC), Natural England (NE) and the National Federation of Fishermen's Organisation (NFFO).

The key piece of environmental legislation for the Development is The Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, with associated guidance[27]. These regulations mandate the undertaking of an EIA and the production of an ES for certain types of offshore developments, including activities related to the geological storage of CO_2, as per the Energy Act 2008. The ES is the means whereby the SoS can assess that the environmental implications of the proposed Development have been properly considered and, subject to all other requirements being satisfied, the SoS can agree that consent for the Development can be granted by the NSTA via a Storage Permit.

The Energy Act 2008 (the Act) provides for a licensing regime that governs the offshore storage of CO_2. It forms part of the transposition into UK law of European Nature Information System (EU) Directive

[22] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

[23] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945899/201216_BEIS_EWP_Command_Paper_Accessible.pdf

[24] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/972520/north-sea-transition-deal_A_FINAL.pdf

[25] https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf

[26] https://www.gov.uk/government/publications/british-energy-security-strategy

[27] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005109/The_Offshore_Oil_and_Gas_Exploration__Production__Unloading_and_Storage__Environmental_Impact_Assessment__Regulations_2020_-_A_Guide__July_2021.pdf

2009/31/EC on the geological storage of CO_2. The Carbon Dioxide (Licensing etc.) Regulations 2010 (SI 2010/2221) transposes many other requirements of the directive. The Energy Act 2008 (Consequential Modifications) (Offshore Environmental Protection) Order 2010 applies the provisions of the following regulations to offshore CCS activities:

- The Offshore Petroleum Activities (Conservation of Habitat) Regulations 2001;
- The Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007[28];
- The Offshore Chemicals Regulations 2002;
- The Offshore Petroleum Activities (Oil Pollution Prevention and Control) Regulations 2005;
- The Greenhouse Gas Emissions Trading Scheme Regulations 2005[29];
- The Offshore Installations (Emergency Pollution Control) Regulations 2002; and
- The REACH Enforcement Regulations 2008.

A number of key environmental approvals required for the Development, include (but are not limited to):

- Oil Pollution Emergency Plans (OPEP) (drilling);
- Permits for chemical use and discharge (drilling and pipeline);
- Pipeline Works Authorisation (PWA) and associated environmental screening directions (PLA MAT);
- Deposit of Materials Consent (DepCon);
- Consent to Locate (CtL); and
- Other operational permits including Well Operations Notification System (WONS) consents and environmental screening directions for drilling activities.

A number of other key regulatory drivers applicable to the Development include (but are not limited to):

- The Marine Strategy Regulations 2010;
- The Marine and Coastal Access Act (MCAA) 2009;
- The Energy Act 2008, Part 4A;
- The Merchant Shipping (Prevention of Pollution by Garbage from Ships) Regulations 2020;
- The Merchant Shipping (Prevention of Pollution by Sewage from Ships) Regulations 2020;
- The Merchant Shipping (Control and Management of Ships' Ballast Water and Sediments) Regulations 2022;
- The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 (as amended); and
- The Merchant Shipping (Oil Pollution Preparedness, Response & Co-operation Convention) Regulations 1998 (as amended).

The EIA Regulations require that the EIA consider the likely significant impacts of a project on the environment; the potential impacts that have been considered in the EIA were selected following

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[28] *The Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007 has since been revoked and replaced by the Conservation of Offshore Marine Habitats and Species Regulations 2017.*
[29] *The Greenhouse Gas Emissions Trading Scheme Regulations 2005 has since been replaced by The Greenhouse Gas Emissions Trading Scheme Order 2020*

environmental issues identification (ENVID) and consultation with a number of stakeholders. Following this, the decision process related to defining whether or not a project may potentially significantly impact on the environment is the core principle of the EIA process. The EIA Regulations themselves do not provide a specific definition of significance, but they indicate that the methods used for identifying and assessing potential impacts should be transparent and verifiable. Despite this being inherently a subjective process, a defined methodology has been developed to make the assessment as objective as possible.

Distinct from, but closely related to the EIA Regulations, is the requirement to consider the potential impacts on the integrity of protected habitats[30]. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) are protected areas in the UK and form part of the UK's national site network. The sites are designated under the Conservation of Habitats and Species Regulations 2017 (as amended) within 12 nautical miles (NM) and under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended) outwith 12 NM. OPRED is the Competent Authority for the Habitats Regulations Assessment (HRA) process, with the advice of relevant Statutory Nature Conservation Agencies. All necessary information to support the HRA process is provided within the Impact Assessment sections of this ES, such that the Competent Authority will have sufficient information to undertake an Appropriate Assessment (AA), if required (i.e. if approval of the Development was considered likely to result in a significant effect on a protected area). Whilst HRA focuses on SACs, SPAs and Ramsar sites, information is also presented within this ES to assess the potential for impact on all other relevant marine protected areas (MPAs) (for example, Marine Conservation Zones (MCZs)).

1.5.1 The East Inshore and East Offshore Marine Plans

The East Inshore and East Offshore Marine Plans are the first plans produced for English seas and came into force in April 2014. The aim of Marine Plans is to help support sustainable development of the marine area through informing and guiding regulation, management, use and protection of the Marine Plan areas.

The key principles of the Marine Plan policies considered relevant to the Development are summarised below, with comment on the degree to which the Development is aligned with such objectives and policies provided in Appendix E:

- ***Co-existence:*** Opportunities for co-existence should be maximised wherever possible;
- ***Biodiversity:*** Appropriate weight should be attached to biodiversity, reflecting the need to protect biodiversity as a whole, taking account of the best available evidence including on habitats and species that are protected or of conservation concern in the East Marine Plans and adjacent areas (marine and terrestrial);
- ***Air quality:*** Proposals for development should minimise emissions of GHGs as far as is appropriate;
- ***Climate change:*** Proposals should take account of how they may be impacted upon by, and respond to, climate change over their lifetime and how they may impact upon any climate change adaptation measures elsewhere during their lifetime. Where detrimental impacts on

[30] https://jncc.gov.uk/

climate change adaptation measures are identified, evidence should be provided as to how the proposal will reduce such impacts;

- ***CCS:*** Proposals should demonstrate that consideration has been given to the re-use of existing oil and gas infrastructure rather than the installation of new infrastructure (either in depleted fields or in active fields via enhanced hydrocarbon recovery);
- ***Fishing:*** Proposals should seek to minimise impacts on the fishing industry as much as possible;
- ***Heritage assets:*** Proposals that may affect heritage assets should seek to minimise compromising or harming elements which contribute to the significance of the heritage asset as far as possible;
- ***Socio-economic:*** Proposals for development should demonstrate that during construction and operation, adverse impacts on tourism and recreation activities should be minimised as far as possible; and
- ***Cumulative impacts:*** Cumulative impacts affecting the ecosystem of the East Marine Plans and adjacent areas (marine and terrestrial) should be addressed in decision-making and plan implementation.

1.5.2 The North East Inshore and North East Offshore Marine Plans

The North East Marine Plan (Defra, 2021), encompasses the North East Inshore Marine Plan and the North East Offshore Marine Plan. The Marine Plan aims to enhance and protect the marine environment and achieve sustainable economic growth, whilst respecting local communities both within and adjacent to the marine plan areas. Policies of the North East Marine Plan include support for proposals associated with the deployment of low carbon infrastructure for industrial clusters.

The key principles of the Marine Plan policies considered relevant to the Development are summarised below, with comment on the degree to which the Development is aligned with such objectives and policies provided in Appendix E:

- ***Co-existence:*** Proposals that optimise the use of space and incorporate opportunities for co-existence and cooperation with existing activities will be supported;
- ***Biodiversity:*** Proposals that may have significant adverse impacts on the distribution of priority habitats and priority species must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate - adverse impacts so they are no longer significant d) compensate for significant adverse impacts that cannot be mitigated;
- ***Air quality and emissions:*** Proposals must assess their direct and indirect impacts upon local air quality and emissions of GHGs;
- ***Climate change:*** Proposals should demonstrate for the lifetime of the Development that they are resilient to the impacts of climate change and coastal change;
- ***Carbon capture usage and storage:*** Proposals associated with the deployment of low carbon infrastructure for industrial clusters should be supported;
- ***Fishing:*** Proposals that may have significant adverse impacts on access for fishing activities must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate adverse impacts so they are no longer significant;
- ***Renewables:*** Proposals that enable the provision of renewable energy technologies and associated supply chains, will be supported;

- ***Heritage assets:*** Where proposals may cause harm to the significance of heritage assets, proponents must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate any harm to the significance of heritage assets;
- ***Marine protected areas:*** Proposals that may have adverse impacts on the objectives of marine protected areas must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate adverse impacts, with due regard given to statutory advice on an ecologically coherent network;
- ***Invasive non-native species:*** Proposals must put in place appropriate measures to avoid or minimise significant adverse impacts that would arise through the introduction and transport of invasive non-native species, particularly when introducing structures suitable for settlement of invasive non-native species, or the spread of invasive non-native species known to exist in the area; and
- ***Cumulative effects:*** Proposals which may have adverse cumulative effects with other existing, authorised, or reasonably foreseeable proposals must demonstrate that they will, in order of preference: a) avoid b) minimise c) mitigate - adverse cumulative and/or in-combination effects so they are no longer significant.

1.6 Environmental Management

bp, as operator of the Development, is committed to managing all environmental impacts associated with its activities on the United Kingdom Continental Shelf (UKCS). Continuous improvement in environmental performance is sought through effective project planning and implementation, emissions reduction, waste minimisation, waste management, and energy conservation. bp's commitment to Health, Safety, Security and Environment (HSSE) performance is shown in Figure 1-4.

BP's Commitment to **health, safety, security** and **environmental** (HSSE) performance

Our HSSE goals are simply stated – no accidents, no harm to people and no damage to the environment.

We strive to be a safety leader in our industry, a world-class operator, a good corporate citizen and a great employer.

Nothing is more important to us than the health, safety and security of our workforce and the communities in which we operate, and behaving responsibly towards our shared environment. We must be vigilant, disciplined and always looking out for one another.

We are committed to:

– Complying with applicable laws and company policies and procedures.
– Systematically managing our operating activities and risks.
– Reporting our HSSE performance.
- Learning from internal and external HSSE events.

Everyone who works for BP has a part to play in meeting our HSSE commitment.

[redacted]

Bernard Looney,
Group Chief Executive
5 February 2020

Figure 1-4 - bp commitment to HSSE performance

1.7 Consultation

Consultation with statutory bodies and other interested parties is an important part of assessing the environmental impacts of a proposed development. The aim of the consultation process has been to identify the views of key stakeholders early on in the EIA process, and also to maintain communication as necessary throughout the EIA process. Further information on consultation undertaken for the Development is provided in Chapter 5: EIA Methodology.

1.8 Data Gaps and Uncertainties

The Development is first of a kind for this type of infrastructure project in the UK. Consequently, at this early stage a degree of flexibility in the design and configuration of infrastructure is required. Future definition of the preferred methodology and contractor(s) will be available when further studies have been carried out, and more detailed information produced to inform the design.

In order to ensure a robust assessment of the likely significance of the environmental effects of the Development therefore, the EIA will assess the maximum (or where relevant, minimum) parameters for the elements where flexibility needs to be retained due to stage of design. Where this approach is applied to specific aspects of the EIA, this will be confirmed within the relevant chapters of the ES. As such, the ES should represent a realistic worst case assessment of the potential impacts of the Development identified at its current stage of design. Detailed design after this point is not expected to result in greater significance of impacts than those presented in the ES.

2 CONSIDERATION OF ALTERNATIVES

2.1 Introduction

As discussed in Section 1.1 the "Do Nothing" alternative scenario is discounted and therefore the information in this consideration of alternatives chapter of the ES focuses on the means of delivering an offshore CO_2 transportation and storage scheme. The options selected for the Development have been arrived at through a holistic, documented technical and commercial concept selection process. A gated project development process was used that is conformant with the applicable bp guidelines and standards and considers BAT and BEP. Environmental, social, health and safety, technical, project execution and commercial issues and risks, have been taken into account in the selection process which also included a comprehensive value assurance review (Table 2-1). Environmental considerations and development optimisation have been part of the option selection process throughout, with views being sought via direct consultation with regulators and key stakeholders.

Table 2-1 - Decision selection criterion applied to the Development

Category	Selection criteria
Safety & Operational Risk	Demonstration of inherently safer design Minimisation of novel technology Minimisation of Major Accident Hazards
Environmental & Social Impact	Fulfilment of regulatory requirements Minimisation of emissions Demonstration of Inherent Environmentally Robust Design[31] Minimisation of environmental footprint
Operations	Demonstration of long-term operability Minimisation of total lifecycle cost
Project Execution	Minimisation of technical and technology risks Enabling opportunities for development of UK supply chain and local content Maximisation of industry skillsets and available or transferable labour pool Maximisation of constructability
Subsurface	Minimisation of technical uncertainty via proven operational analogues. Minimisation of long-term CO_2 storage risks Maximisation of SNS store development potential, enabling decarbonisation
Commercial/Financial	Concept which can be supported by the UK government Concept with long-term viability, per UK government funding mechanisms Maximisation of value to partnership Reduction of commercial complexity and risks
Other	Facilitation of knowledge transfer, collaboration and deployment at scale, underpinning long-term unit cost reduction Supports 1st UK decarbonised cluster by 2030; national 2050 Net Zero target Supports UK national and local government policies and ambitions

[31] *bp process to integrate environmental considerations into the assessment and selection of concepts during early project stages*

Further detail is provided throughout the remainder of the chapter about the assessment against the criteria in Table 2-1. A summary overview of the alternatives considered and the outcome of the assessment is presented schematically at the end of the chapter in Figure 2-7 and Figure 2-8.

The results of the decision-making process demonstrate that the optimum solution for the Development is to utilise the Endurance Store in the SNS to store CO_2. CO_2 captured by the onshore ECC development, will be transported offshore via the Teesside and Humber Pipelines. The pipelines will be connected via subsea infrastructure to five CO_2 injection wells, drilled by a jackup rig. A sixth well, also drilled from the jackup rig, will be a dedicated monitoring well to monitor movement of CO_2 within the Store.

Subsequent to the selection of the Endurance Store as the primary store for the Development, the NSTA agreed to the addition of bp and Equinor to the NGV's carbon storage licence (CS001). At this point, the NEP partnership was formed, introducing the Humber element of the scope into the Development. Initial appraisal work for the Humber Pipeline (Section 2.5.3.3) was therefore conducted by NGV and transferred into the Development.

2.2 Aquifer

2.2.1 Selection of Endurance Store

Early work summarised in the Oil and Gas Climate Initiative (OGCI) (2018) was extended by NEP to assess the storage location against the criteria provided in Table 2-1 (store capacity is given in Mt). A store location in the SNS was considered to be an enabler for a CCS project on the east coast and allow for wider east coast decarbonisation of industry. A store in the SNS also takes advantage of relatively shallow water depths and avoids the complexity of trans-border shipment which would be required if CO_2 captured in the UK were transported to another country for storage.

Evaluation of four potential offshore CO_2 stores in the SNS initially built on the early work sponsored by the Energy Technologies Institute (ETI) (OGCI, 2018). All four stores are large (to realise economies of scale), and all had been subject to appraisal specifically for CO_2 storage (to a greater or lesser degree). Endurance Store and Bunter Closure 36 (BC36) are saline aquifers while, Viking A and Hewett are depleted gas fields. Key parameters of the four stores are summarised in Table 2-2 and their locations are shown in Figure 2-1.

Table 2-2 - Overview of potential offshore CO_2 stores

	Endurance	Hewett	Viking A	BC36
Type and Formation	Saline Aquifer Bunter	Depleted Gas Lower Bunter	Depleted Gas Leman	Saline Aquifer Bunter
Capacity (P50)	450 Mt	280 Mt	96 Mt	400 Mt
Sea depth (m)	65	35	26	72
Pipeline from Teesside (km)	145	280	260	210
Pipeline/Cable Crossings	3/5	9/13	6/9	5/7

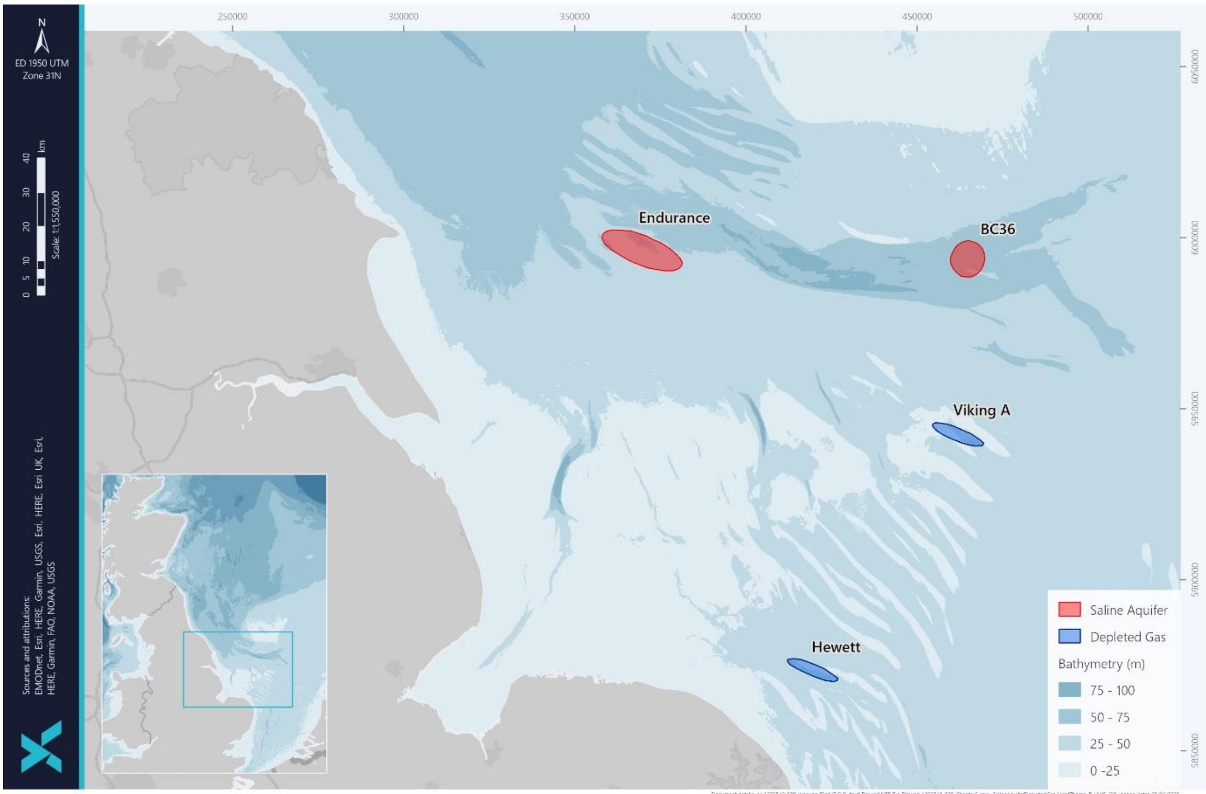

Figure 2-1 - Location of the four potential offshore CO_2 stores

The Development team utilised criteria aligned with the Energy Act 2008 and the Carbon Dioxide (Licensing etc.) Regulations 2010 (SI 2010/2221) to evaluate the four potential offshore CO_2 stores in the SNS. The five criteria applied were Capacity, Injectivity, Containment, Hydrodynamics and Monitorability. Additionally, the Development team assessed the stores against the criteria of characterisation maturity and accessibility.

Two options, Viking A and BC36, were discounted for the Development as these required further work to address the uncertainties associated with:

- ***Injectivity***: The Viking A depleted gas field is associated with low permeability, while BC36 has no dynamic performance data (e.g. well test) available for the Bunter aquifer in addition to there being a known halite risk. If unmanaged, halite (a type of salt), will reduce the potential to inject further CO_2;
- ***Containment***: Direct intervention would be required at both sites to ensure that the multiple wells previously drilled into the stores would not release injected CO_2; and
- ***Capacity***: To date, the appraisal of both stores has only been conducted at a relatively high level. Extensive further study, and possibly the drilling of an appraisal well at BC36 would be required, incurring significant cost and time to progress.

Further assessment was conducted of the Endurance Store, a saline aquifer formation structural trap, and 'Hewett', a depleted gas field. The storage capacity requirement was for either store to accept 6+ million tonnes per annum instantaneous (MtPAi) CO_2 continuously for 25 years. The result of this assessment after maturation of both options led to the Endurance Store being selected as the primary store for the Development. This selection was based on the following key conclusions:

- The storage capacity of Endurance Store is three to four times greater than that of Hewett;
- The development base cost for the Endurance Store is estimated to be 30 to 50% less than Hewett as being a saline aquifer, no heating facilities are required at the Endurance Store (which is not the case for a depleted gas field such as Hewett[32]), thus simplifying the offshore scope, and reducing the offshore footprint;
- Power demand associated with development of the Endurance Store would be significantly lower than for Hewett as power demand during the period that CO_2 is injected into the aquifer is lower: 25-80 kilowatt (kW) peak for the Endurance Store as opposed to approximately 60 megawatts (MW) required for heating alone for Hewett; and
- CO_2 injection into a saline aquifer is a worldwide proven concept[33].

Selection of the CO_2 store, a location-specific geological feature, fixed other elements of the Development, including but not limited to, the infrastructure required to utilise the Store, pipeline lengths, proximity to legacy wells[34] and operational water depths which influence e.g. the type of rig used to drill wells. The Endurance Store is associated with a Bunter Sandstone Formation which forms an outcrop at the seabed about 25 km east of the Endurance Store structure (Section 3.4.4).

2.2.2 Injection Capacity and Phasing

Evaluation of the injection capacity of the Development, in terms of tonnes of CO_2 sequestered per annum, incorporated the high degree of uncertainty in estimates of the volumes of CO_2 to be sequestered from current, planned and potential future emitters in Teesside and Humber. The

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[32] Heating would be required to overcome the temperature drop which occurs as a result of the Joule-Thomson cooling effect when CO_2 is injected into a depleted gas field.

[33] According to industry body, the Global CCS Institute e.g. https://www.globalccsinstitute.com/wp-content/uploads/2018/12/2017-Global-Status-Report.pdf.

[34] Wells that were drilled previously and which have been made incapable of flowing (plugged) in accordance with industry and regulatory guidance at the time of plugging.

uncertainty is caused by the lack of maturity of industrial business models; by the economic uncertainty of the existing industries and as building the infrastructure is likely to attract future low carbon industries.

Given this uncertainty, ECC CCS infrastructure is being developed in a number of phases, of which this ES supports the offshore elements of the initial phase (Phase 1). Subsequent phases may be associated with additional onshore facilities to further decarbonise the Teesside and Humber areas and may require further infrastructure for additional storage at the Endurance Store. These would be the subject of separate regulatory submissions and approvals.

The injection capacity for design of Phase 1 was evaluated against criteria including technical feasibility, operability, supply chain capability, lifecycle CO_2 emissions, environmental impact, regulatory complexity, and cost. A range of different injection capacities were evaluated: 4 MtPAa injection[35] (or 5.9×10^6 cubic metres (m^3)/day); 2 MtPAa (2.9×10^6 m^3/day); 6 MtPAa (8.7×10^6 m^3/day); and 10 MtPAa (14.5×10^6 m^3/day), with a range of assumptions made for the sources of CO_2 to be sequestered in each scenario. Larger design capacities (6 to 10 MtPAa) are associated with higher risks of under-utilisation of the installed facilities. Smaller design capacities (less than 4 MtPAa), of equivalent size to existing offshore CCS developments, do not enable technology scaling and proving of a larger, full chain integrated CCS system. The decision was therefore made to size the offshore injection facilities for a maximum 4 MtPAa as:

- The maximum injection capacity of 4 MtPAa allows for infrastructure development to kick-start industrial decarbonisation in the UK and minimises capital expenditure (CAPEX) and operational expenditure (OPEX) investment while proving large scale integrated CCS chains. The Development contributes towards the CCC's recommendation and the UK Government's Ten Point Plan targeting at least two clusters storing up to 10 MtPAa of CO_2 by 2030 (Chapter 1: Introduction);
- 4 MtPAa injection capacity allows for continuous minimum throughput from industrial sources to support transportation and storage facilities while the new NZT Power Combined Cycle Gas Turbine (CCGT) power generation facility operates in dispatchable[36], abated mode. Maintaining a minimum continuous injection rate into the offshore wells reduces the risk of reductions in injectivity which result from halite[37] precipitation;
- Volumes greater than 4 MtPAa require more complex offshore facilities whereas injection of 4 MtPAa optimises the potential for ongoing appraisal of the Endurance Store for future phases via the MP, minimises offshore footprint and proves full chain integration of the CCS system; and
- 4 MtPAa injection capacity provides the potential for future expansion phases to utilise lower carbon construction methodologies and equipment as decarbonisation progresses globally.

As described in Section 2.5.1, pre-investment has been made in Phase 1 and the pipelines over-sized to provide the most cost-effective transportation solution which limits environmental impact, to

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[35] *MtPAi describes instantaneous injection capacities, rather than average values. Where average values are presented, the acronym MtPAa is used.*

[36] *i.e. the power plant can be turned on or off to adjust power supplied to the electricity grid, mitigating the intermittency associated with energy harnessed by windfarms.*

[37] *The minerally occurring form of sodium chloride, commonly known as "table salt".*

enable expansion beyond Phase 1 and to tie-in future emitters (Teesside Pipeline has a maximum capacity of 10 MtPAa; Humber Pipeline has a maximum capacity of 17 MtPAa (24.7 x 10^6 m^3/day)).

The reuse of existing offshore infrastructure for the Development was assessed as there are many pipelines, platforms and other infrastructure across the SNS which could be repurposed (OGCI, 2018). The assessment did not identify any suitable platforms or pipelines available within the timeframes required by the Development (i.e. available for repurposing within the 2025 – 2050 time period) and concluded that the Development should proceed with the installation of new infrastructure. There are however potential synergies with nearby gas field assets which will continue to be evaluated during detailed engineering for the Development. This includes assessing the potential to share operating infrastructure e.g. power, chemicals and communications.

2.2.3 Store Management

2.2.3.1 Halite Management

As CO_2 is injected, it is expected that halite will form and, if unmanaged, will reduce the potential to inject further CO_2. To reduce halite levels near each well bore and maintain CO_2 injectivity, each well must be flushed with a low salinity water dilution treatment which subsequently remains in the formation. This “water washing” will occur:

1. At the time of well construction to prevent halite precipitation when the well is first started-up; and
2. Annually over the lifetime of the Development (frequency may be reduced based on monitoring results).

Once CO_2 injection has commenced, nitrogen (N_2) will also be injected before and after each washing to mitigate the risk of hydrate[38] blockages when water comes into contact with CO_2[39].

Options to supply the wash water and N_2 were evaluated, including:

- Permanent supply lines from shore: these would either be integrated into the power cable to form an umbilical or installed as stand-alone lines; and
- Intervention vessel: mobilisation of a vessel to inject N_2 and conduct water washing.

There are no significant environmental or social differentiators between the two options given the potential seabed disturbance associated with installation of permanent supply lines and the potential emissions and releases associated with the use of intervention vessels. A permanent N_2 supply line from shore would require installation of a compressor and would need to be sized to transport N_2 gas, a technically complex and commercially unfeasible solution. As the frequency of water washing requirement is uncertain and may reduce during the Development, the decision was made to supply the wash water and N_2 via an intervention vessel (bp, 2021a).

[38] *Hydrates are ice-like solids which form when free water and gas combine at high pressure and relatively low temperature.*
[39] *N_2 is the base case for hydrate mitigation, Monoethylene Glycol (MEG) was also considered but N_2 selected for its technical performance.*

2.2.3.2 Store Formation Water Management

As any gas or fluid is injected into a formation, it can displace pre-existing gas or fluid and increase pressure in the vicinity of the injection location. Pressure in the formation needs to be managed within pre-defined thresholds to maintain formation integrity and security of storage.

At the Endurance Store, Store Formation Water management was assessed for the period during which CO_2 will be injected. The injection of CO_2 will increase pressure in the Store over time, potentially requiring active management (i.e. the removal of Formation Water from the Store via additional wells which will require to be drilled remote from the CO_2 injection locations). The removal of Store Formation Water would require surface infrastructure (e.g. a platform) to be constructed at the Store to manage the water received from the Store.

However, the Endurance Store is estimated to have a potential storage capacity of at least 100 Mt of CO_2 without requiring active Store Formation Water management. As the volume of CO_2 to be injected during the operational life of the Development is approximately 100 Mt, studies concluded that no active removal of Store Formation Water is required for the Development (bp, 2020a). This minimises the infrastructure associated with the Development and therefore the seabed footprint, interaction with other sea users and embodied carbon content.

2.2.4 Monitoring, Measurement and Verification

The aim throughout the life cycle of the Development (site selection and design, installation, O&M, decommissioning) is to retain CO_2 in the aquifer. A MP is being developed to monitor the injected CO_2 in the Store, and will provide a mechanism to confirm that the injected CO_2 is contained within the geological store during and after injection and flag the occurrence of any unexpected migration of CO_2. The scope of the MP also includes monitoring for Store Formation Water[40] from legacy wells (Section 3.4.5) and Outcrop Formation Water[41] from the Bunter Sandstone Formation (Section 3.4.4).

The MP will be site specific and tailored to the individual site characterisation and risk assessment. It will be reviewed and updated, if required, to incorporate monitoring results during the period CO_2 is injected into the aquifer. The MP will be submitted to, and approved by, the NSTA as part of the Storage Permit Application (Section 3.4.7 e.g. Shell, 2015).

The MP is developed via the identification and evaluation of available offshore monitoring technologies according to their reliability, efficiency, cost and benefit. Once the CO_2 has entered the storage formation, geophysical methods[42] will be utilised to monitor the CO_2 migration within the formation, as is typical for monitoring geological formations.

An environmental MP is also being developed with input from an independent academic review of seabed monitoring technology, practices and experience. The output of the review will be a recommended approach to environmental monitoring that will form the basis of the MP. A high-level summary of initial seabed monitoring options and recommendations is provided in Section 2.2.4.3.

[40] *Unplanned release of Store Formation Water from wells which have previously been drilled in the vicinity but are no longer in use.*
[41] *Displacement of Outcrop Formation Water in the upper 140 m of the Bunter Sandstone Formation at the outcrop.*
[42] *Methods which involve the observation of variations in electrical, magnetic seismic, or other physical properties of subsurface materials.*

2.2.4.1 Well Monitoring

Monitoring of pressure within the Endurance Store will be undertaken at the five injection wells as well as a dedicated monitoring well to assess conformance with expectations of CO_2 behaviour in the Store (Figure 2-2).

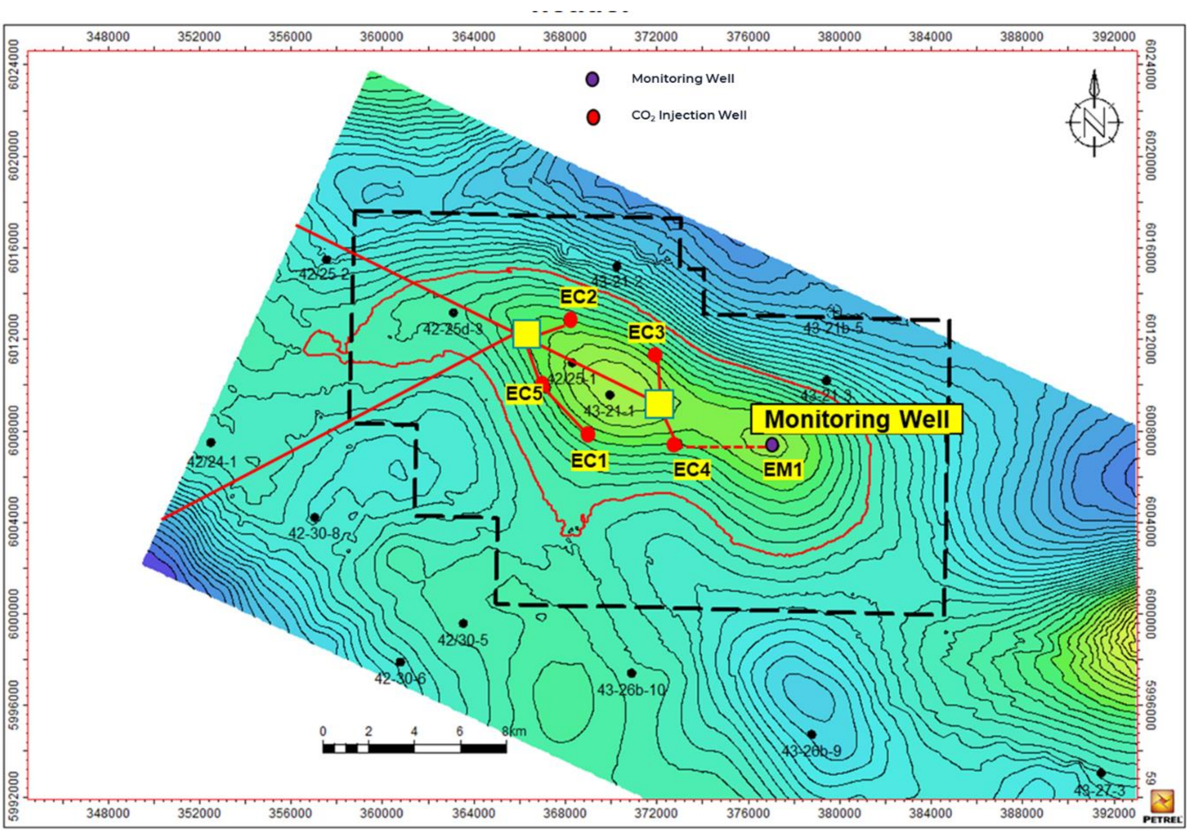

Figure 2-2 - Location of monitoring well in relation to five CO_2 injection wells

A dedicated monitoring well for the Development was selected, rather than relying solely on the CO_2 injection wells for monitoring purposes, based on the following factors:

- The location of the injection wells in the lower sections of the aquifer makes them less suitable for the direct measurement of pressure in the top sections of the aquifer (crestal) where pressure is important to control to keep within agreed operating limits during injection; and
- Direct measurement of pressure remote from the injection wells and closer to the crest (at the monitoring well), will be used to verify models used to predict the behaviour of CO_2 injected into the Store.

The location of the monitoring well is such that, if sufficient monitoring information can be obtained from the five injection wells, it may subsequently be used to serve a dual purpose with both pressure monitoring and CO_2 injection.

2.2.4.1.1 In-well Monitoring

In-well monitoring is focused on the verification that CO_2 moves, as predicted, within the aquifer and is contained within the wells. Parameters which will be monitored over time are pressure, temperature, zonal allocation (distribution across the aquifer), CO_2 saturation, fluid chemistry and cement integrity. In addition to monitoring these downhole parameters, in-well activity (as considered within the MP) will include gas and water tracer injection for detecting leakage at seabed and understanding plume migration in the aquifer.

Tracers (liquid perfluorocarbon based) will be utilised at the Store, with each of the five injection wells having its own individual tracer signature. Perfluorocarbon-based tracers have been successfully deployed on projects in the North Sea: Snorre in Norway (oil and gas development, Huseby *et al*., 2008) and at K12-B in the Netherlands (CCS demonstration, TNO, 2007), and were selected for inclusion in the MP. Noble gas isotope tracers may be a potential alternative to perfluorocarbon tracers, but are not included within the initial MP as the tracers are associated with a low technology readiness level. Research and development is actively ongoing into noble gas isotope tracers and future revisions of the MP will revisit the potential for their utilisation. Any tracers injected in well interventions will be registered with Cefas prior to use and fully risk assessed and permitted.

The following technologies have been selected for in-well monitoring due to being established best practice technologies:

- Pressure/ temperature gauges (PTGs) at selected locations within each well;
- Saturation logging (with Pulsed Neutron Log) i.e. measurement of the interaction between neutrons and the surrounding medium (formation) to monitor the percentage of pore volume occupied by CO_2;
- Injection logging; and
- Cement Bond Logs i.e. acoustic logs to evaluate the integrity of the cement bond between each well and the formation.

2.2.4.2 CO_2 Plume Migration and Aquifer Management

In assessing CO_2 plume migration within the Endurance Store, the size of the area to be monitored is determined by the predicted plume extent and size of the storage complex[43] and must be agreed with the NSTA. Aquifer monitoring will provide information about the migration of the injected CO_2 plume. The MP will be phased to generate a comprehensive dataset over time, and will detail monitoring conducted to establish a baseline, during injection, and at and after site closure.

The change in seismic reflectivity when CO_2 displaces fluids in the aquifer has been modelled to be very large (Neep and Koryakova, 2023). Technology assessment for CO_2 plume monitoring identified that 4D towed-streamer seismic[44], which is proven and available technology, is suitable for monitoring CO_2 movement. Assessment concluded that 4D seismic is the current best available technical solution for monitoring of CO_2 plume migration in the Endurance Store aquifer (bp, 2021b). This will be complemented by time-lapse gravimetry[45] (subject to technical feasibility) which is being investigated to reduce the frequency of 4D seismic campaigns and therefore the underwater sound associated with

[43] *The storage complex includes both a) a defined volume area within a geological formation used for the geological storage of CO_2 and associated surface and injection facilities and b) the surrounding geology which can influence overall storage integrity and security.*
[44] *Three-dimensional (3D) seismic data acquired at different times over the same area.*
[45] *Repeat gravitational field measurements via sensors temporarily deployed at seabed or in wellbore to identify bulk-rock density variations.*

the equipment used to monitor CO_2 plume migration. Ocean bottom nodes (OBN[46]) were considered but were not selected due to the prohibitively high costs currently associated with the technology and the challenge of delivering a sufficiently good image of the shallow overburden even if a high density of nodes is used. Time-lapse vertical seismic profiling (VSP[47]) is an additional technology also being investigated (as a triggered[48] monitoring option) but which is not part of the base case MP. The monitoring technology selected will depend on technology readiness and environmental assessment and will be presented within the MP to be submitted to the NSTA.

2.2.4.3 Seabed Monitoring

A number of technologies and approaches exist that are capable of detecting anomalies resulting from the highly unlikely event of CO_2 or Store Formation Water release into the environment or the displacement of Outcrop Formation Water into the environment. Detection is possible at rates well below those where significant environmental impact may be expected. The in situ operational capability and sensitivity of many of these methods, including acoustic, optical and chemical sensors, has been demonstrated within the North Sea, with many of the tested techniques commercially available or near-market release.

Based on assessment (NOC, 2022) and current monitoring capabilities, recommendations for the seabed monitoring approaches to be applied as part of the MP have been made, given known benefits and limitations (Table 2-3). The assessment concluded that for the MP, the application of acoustic and chemical approaches should be considered for the monitoring of CO_2 releases into the water column and chemical approaches for Formation Water. For CO_2 release monitoring, a combination of mobile and fixed platforms was recommended and deployment of fixed platforms recommended for Formation Water monitoring. Landers will be deployed at pre-existing on-structure legacy wells (43/21-1; 42/25-1 and 42/25d-3) from pre-injection through to closure. A lander will also be deployed at the outcrop every 6-10 years through life of operations. Regular surveys of the Endurance Store and Bunter Sandstone Outcrop area will be conducted using mobile platforms e.g. vessels and Autonomous Underwater Vehicles (AUVs). Integrated data will be interpreted against the baseline and inform positioning of landers. The positioning of the landers and mobile survey requirements will be reviewed throughout the operational lifespan of the Development.

Environmental monitoring through to post-injection is required as part of contingency monitoring and regulatory assurance. The technology deployed will be selected to deliver a comprehensive environmental baseline of the Endurance Store and Bunter Sandstone Outcrop area that establishes pre-injection conditions and allows assessment of the impacts of a CO_2 or Store Formation Water leak or Outcrop Formation Water displacement. Environmental monitoring will utilise an array of existing technologies and survey approaches that are accepted as industry standard (OGUK, 2019).

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[46] *Individual units placed on seabed.*

[47] *Seismic acquisition technique in which a seismic receiver array is deployed down the wellbore.*

[48] *Monitoring activities not in the base case MP which if appropriate are utilised in response to deviations from predicted CO_2 behaviour.*

Table 2-3 - Benefits, limitations and recommendations of monitoring approaches and platforms for CO_2 and Formation Water detection and monitoring (NOC, 2022)

	Benefits	Limitations	Recommendations	
			CO_2 detection and monitoring	Formation Water detection and monitoring
Monitoring approach				
Acoustic Methods e.g. multibeam echosounder (MBES), side scan sonar, sub-bottom profiler, hydrophone	High detection probability. Deployable on variety of mobile and fixed platforms. Rapid return/visualization of results from active acoustic methods, which also provide bathymetric information of the seafloor when deployed on mobile platforms. Passive approaches can detect and quantify CO_2.	Unable to distinguish gas type or source. Unable to detect CO_2 after it has dissolved into seawater. Passive approaches are limited to fixed platforms only. Data interpretation can take a long time (days-weeks).	Active acoustic methods should be included on mobile platform surveys as a primary means for identifying sites of potential leakage. Passive acoustic hydrophones could be included onto fixed landers to aid detection and quantification of low levels of CO_2, but are considered less effective than other approaches.	Neither active nor passive acoustic methods are an effective means of detecting Formation Water.
Optical Imaging e.g. high resolution underwater cameras, satellite based observations	Can verify the presence (or absence) of a CO_2 leak and can be used to quantify the rate of release. Established approaches for characterising the diversity and composition of benthic megafaunal communities. Satellite observations of ocean colour can be used to monitor inter-annual variations in phytoplankton blooms that impact marine environments above Endurance Store area.	Underestimate CO_2 leakage rates: small bubble sizes are not detected. High degree of natural spatial heterogeneity and temporal variability in benthic ecosystems. Satellite based observations only show broadscale (regional) changes that require incorporation into biogeochemical models to assess impacts on the monitoring area.	Underwater imaging approaches do not currently represent a cost-effective means for CO_2 leakage detection or quantification, but should be conducted routinely as part of the MP. Satellite based observations and productivity data to be incorporated into biogeochemical when assessing regional and/or inter-annual variability over long timescales.	Seafloor imaging approaches not an effective means for detecting Formation Water, but to be conducted routinely as part of the MP. Satellite based observations cannot currently be used to detect Formation Water.
Chemical approaches e.g. in situ membrane based sensors, pH sensors, lab on chip sensors	Facilitate detection, attribution and quantification of CO_2 leakage in marine environments. Can be used to detect CO_2 in dissolved and gaseous forms, and can be applied in both the water column and in seafloor sediments. Sensors can be deployed on both mobile and fixed platforms and can detect low levels of CO_2. The same chemical parameters can be measured by different techniques, enabling cross-validation and increasing confidence in results.	Data return is dependent on both sensor type and deployment platform, and it may take a long time (days-months) before results are available. Although most techniques are commercially available, some approaches (such as pH eddy covariance) are still in development. Sensor deployment duration and/or sampling rate may be limited by power consumption, reagent availability and factors such as biofouling.	Chemical monitoring techniques currently represent the most robust and cost-effective means for long-term monitoring of the storage complex. Where possible, both fixed and mobile platform surveys of the complex should include the following sensors: • Integrated current, temperature and depth sensors (CTDs); • Dissolved oxygen (DO); • pH and total alkalinity; and • Phosphate and Nitrate. Sensor data from long-term deployments to be validated using mobile surveys and/or physically collected samples at regular intervals.	The deployment of standard CTD sensors (monitoring salinity, temperature and depth) on the seafloor offers the most effective means for monitoring Formation Water. Metal concentrations and DO levels should also be monitored to help quantify the extent of plume dilution.

	Benefits	Limitations	Recommendations	
			CO_2 detection and monitoring	Formation Water detection and monitoring
Other approaches e.g. gravimetric surveys, Thermistor strings (T-Strings)	The deformation of the seafloor as a consequence of gas release (i.e. formation of pockmarks) can be detected via bathymetric and/or gravimetric surveys. T-Strings can be used to assess temperature variations at the sediment surface that may be indicative of CO_2 dissolution.	Seafloor deformation cannot be attributed to gas release from the storage reservoir without further investigative work. Natural variability in seawater temperature limits the ability to relate any changes in temperature to CO_2 release without further assessment.	The relatively shallow marine environment and presence of migrating sand dunes on the seafloor within the Endurance monitoring area mean these techniques are unlikely to offer effective approaches for CO_2 leakage detection.	Although temperature variations can be used to identify Formation Water, the temperature change predicted from the modelled scenarios is negligible relative to background variations, thus the deployment of T-Strings is unlikely to be an effective approach.
Platform				
Mobile platforms e.g. ship, Remotely Operated Vehicle (ROV), AUV	Capable of assessing a whole storage complex within a short time frame. Ship-based surveys enable results to be assessed in near-real time, meaning features of interest can be re-examined in more detail. Multiple approaches can be simultaneously deployed on mobile platforms. Technological advances are improving AUV deployment capabilities, offering the potential to conduct surveys without ship-based deployment/recovery.	Mobile surveys are expensive to conduct, with ship-based surveys having very high operational costs. Data recorded during a mobile survey only represents a snapshot in time thus may miss leakage events; repeat surveys are required to establish long-term changes. Both ship and AUV survey patterns are limited by physical constrains within the water column (platforms, turbines etc.).	AUV surveys equipped with acoustic and chemical sensors represent the most cost-effective means of monitoring for CO_2 across the Endurance Store but cannot currently be used for long-term deployments. It is recommended that mobile platforms are used to conduct CO_2 surveys alongside environmental impact monitoring assessment surveys and/or following anomalous results detected by other surveys.	Formation Water detection capabilities on AUVs are likely to be limited by the minimum distance that the AUV must operate above the seafloor. The collection and laboratory-based analysis of samples using ships is currently the only viable approach for determining metal concentrations.
Fixed platforms e.g. landers, fixed moorings	Facilitate long-duration deployments of an array of sensor types. Can be positioned at the desired water depth(s) and used to monitor sites at high-risk of leakage. Tidal oscillations enable fixed platforms to derive dynamic baselines when positioned appropriately. Low operational costs once deployed, and can remain in situ for many months, covering full tidal cycles.	Sensor detection capabilities dependent on magnitude of any leak relative to background variability. Data transfer: frequency of data transfer limited when not using seafloor cables. Deployment durations may be limited by reagent usage and/or biofouling over time that can impair data quality.	Seafloor landers represent the most cost-effective approach for monitoring areas at relatively higher risk of leakage, which prior to the start of injection are the pre-existing wells. Additional landers should be deployed to assess any other features of interest or potential sites of leakage identified during future geophysical and/or mobile surveys.	Seafloor landers represent the most cost-effective approach for monitoring Formation Water. Only CTD and DO sensors are required for long-term Formation Water monitoring.

2.3 Drilling

2.3.1 Selection of Drill Rig

As the water depth at Endurance is 60 m, a jackup rig has been assumed for all drilling and completion activity. A typical North Sea jackup will be capable of drilling and completing the wells given the shallow water depth and proposed design of the wells. The rig that is selected will meet requirements which include:

- Operates in 60 m water depth;
- Can drill to 2,400 m below the rotary table[49];
- Can drill with water andlow toxicity oil based muds (LTOBM));
- Has equipment to skip and ship LTOBM back to shore for treatment and or disposal;
- Has space for a ROV; and
- Can install subsea trees[50].

Use of a jackup rig eliminates the need for anchoring or dynamic positioning typically associated with drilling and completion activity from a semi-submersible drill rig, thereby reducing emissions released to atmosphere relative to a dynamically positioned (DP) rig. While a specific rig has not yet been selected, the specifications of the VALARIS 76 MLT Super 116-C Jackup have been used as an analogue for the purposes of the EIA.

2.3.2 Number of Injection Wells

Average injection rates of up to 4.0 MtPAa (with peak rates up to 6 MtPAi) require six wells to be drilled, five CO_2 injection wells and one monitoring well. The wells will be located over the Store to optimise movement, distribution and monitoring of CO_2 throughout the Store.

Drilling fewer than five injection wells was evaluated but would increase the risk of not achieving the required injection capacity. Lower rates of injectivity on any one well (e.g. resulting from lower than expected well efficiency) may result in an inability to inject all CO_2 at peak rates.

2.3.3 Drilling Fluids and Cuttings Disposal

Drilling fluids (‘muds’) have a number of functions as drilling progresses from wider diameter to smaller diameter sections of the well, including:

- Maintenance of downhole pressure to avoid formation fluids flowing into the wellbore (also called “a kick”);
- Wellbore stability;
- Removal of drill cuttings from the drill bit to permit further drilling and transporting cuttings to the surface cuttings handling equipment;
- Lubricating and cooling the drill bit, bottom hole assembly and drilling string; and
- Deposition of a mudcake on the walls of the well bore, which seals and stabilises the open-hole formations.

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[49] The rotary table is commonly used as a reference location on a rig from which to measure distance to the bottom of a well.
[50] Subsea/wellhead trees are structures above a well that are used in well monitoring and control.

Different mud formulations are required at different stages in the drilling operation because of variations in pressure, temperature and the physical characteristics of the rock being drilled.

Of the four sections of each well, two will be drilled riserless with water based mud (WBM) that will be discharged at the seabed. It is not possible to return mud and cuttings to the rig without a riser, which can only be put in place after the top sections of a well have been drilled. Riserless drilling of tophole sections and discharge of cuttings and WBM to sea will be done under the terms of a Chemical Permit, as is standard practice across the UK Continental Shelf. WBM is a substance which is considered to Pose Little or No Risk to the environment (PLONOR[51]). This means that discharge to sea reduces vessel activity and emissions associated with the transport of the cuttings to shore and also reduces onshore treatment and waste handling. Of the two sections to be drilled with low toxicity oil based mud (LTOBM), cuttings will be returned to the rig and skipped and shipped back to shore for treatment and subsequent disposal. The cuttings will be transferred and treated or disposed of by licensed contractors at licensed sites with all the necessary permits, licences and consents. Throughout these activities duty of care will be exercised through an appropriate assurance process. The LTOBM will be recycled and reused in the drilling process. Offshore treatment of cuttings i.e. thermal treatment, was not deemed feasible due to low quantity of feedstock, i.e. quantity of LTOBM.

2.3.4 Drilling Strategy and Well Design

The selected layout of the injection wells influences the volume of the Store into which CO_2 can be injected, the design of the wells and the number of moves the jackup rig is required to make over the six well drilling campaign. The layout of the wells could either be clustered (i.e. drilling commences from one or two locations and the well design is such that the well deviates from vertical under the seabed until reaching the target location in the vicinity of the aquifer) or distributed (i.e. when wells are drilled near-vertically above each target location).

Distributed wells require the jackup rig to move between the drilling of each well, however clustered wells with more complex drilling trajectories are not technically suitable and are deemed higher risk due to:

- Higher drilling angles which increase complexity, water wash volumes and the potential for halite deposition; and
- Need for low drilling angles to ensure robust cement jobs which are required for long-term well integrity.

Injecting CO_2 over a greater volume of the aquifer (distributed wells) minimises the risk of poor CO_2 migration due to compartmentalisation in the aquifer[52] and increases understanding of the aquifer over a greater volume (relative to clustered wells). Monitoring of the CO_2 migration in the aquifer is simplified in a distributed well configuration as in-well monitors (e.g. downhole pressure-temperature gauges) are more widely distributed across the aquifer.

Distributed wells, drilled near vertically are lower cost and simpler in terms of well cementing. Simplicity in well cementing maximises the long-term capability of the wells to deal with the fatigue effects from anticipated cyclic stresses. These stresses may result due to variations in the CO_2 feed

[51] There are a number of additives that are required which may not be PLONOR.

[52] CO_2 migration from the injection location is necessary to allow injection of additional CO_2.

from dispatchable flows from the CCGT power plant, necessitating the wells to be shut in once or twice a week. Vertical wells also allow ease of intervention, water wash operations and data acquisition (facilitating higher quality and reliability of monitoring activities).

For these reasons, a distributed well layout of vertical wells was selected.

2.4 Injection Infrastructure

To identify the optimal facilities and layout for injection infrastructure, a number of cases have been evaluated against the criteria provided in Table 2-1. Reuse of existing infrastructure was evaluated but not considered feasible at this time (Section 2.2). The cases evaluated are as follows:

- ***Daisy chain distributed subsea option***: Co-mingling manifold[53] and one standard four-slot manifold. Six rig locations are used to drill the wells which requires rig moves between drilling activities and vessel/rig moves for water washing during the operate phase. In this option, five injection wells, plus the monitoring well are located, installed and connected in a distributed manner. This will enable optimisation of well locations, deliverability and maximise the benefits of dynamic appraisal. Additional lengths of infield flowlines and cables would be required to connect the manifolds and wells relative to the subsea dual cluster option and, if each well and manifold is associated with a safety zone (Section 2.6), other sea users may be excluded from a larger area of sea;
- ***Subsea dual cluster***: Co-mingling manifold and two standard four-slot manifolds. Two rig locations are used to drill the wells which results in fewer rig moves during drilling activities and fewer vessel/rig moves for water washing during the operate phase. However, the potential cost saving is offset by the requirement for deviated wells, i.e. wells are longer and angled to reach greater distances and are associated with more complex cementing. The increased length of well increases the number of drilling days required. An increased drilling campaign duration increases disruption to fisheries, navigational risk and atmospheric emissions;
- ***Normally Unmanned Installation (NUI) linked to subsea manifold***: Minimally equipped topsides (estimated weight < 600 te) attached to substructure (estimated weight ~1060 te) and linked to a four-slot manifold and a co-mingling manifold. A NUI allows for the removal and management of Store Formation Water, unlike fully subsea solutions. All wells are anticipated to be deviated except the monitoring well which may be vertical to enable better quality data acquisition. The NUI is equipped with solar panels and wind turbines with an installed generation capacity and back-up batteries to support power demand (estimated as 4 kW). No cable from shore is required, but the infrastructure has a presence on the sea surface potentially affecting other sea users, including shipping activity. The NUI has a higher embodied carbon content[54] than the subsea concepts due to the material quantities required to construct the installation; and
- ***Dual NUI***: Two NUIs, each as described above, are both self-powered by renewables. A co-mingling manifold is required. A NUI allows for the removal and management of the Store Formation Water, unlike fully subsea solutions. No cable from shore is required but the

[53] Subsea structure which combines CO_2 from the Teesside and Humber Pipelines and re-distributes to injection wells or second manifold.
[54] Embodied carbon content refers to the CO_2 equivalent emissions resulting from the production of materials (mining raw materials, refining, forming, transportation) associated with the infrastructure.

infrastructure has a presence on the sea surface potentially affecting shipping lanes. The dual NUI has the highest embodied carbon content due to the material quantities required to construct the installations.

The subsea concept was selected for versatility. Further, these concepts do not require surface facilities at the Endurance Store, eliminating risk associated with platform visits for maintenance and therefore being the more inherently safe option. The absence of surface facilities avoids impact to navigational risk, seabed footprint associated with jacket legs and emissions associated with vessel/helicopter flights.

Clustered vs. distributed subsea options were evaluated, with the daisy-chain distributed option being selected given that distribution of the wells improves appraisal of the Store while also being more robust against any field compartmentalisation. The distributed option enables flexibility in well placement and uses standardised equipment, thereby providing higher execution predictability and greater inherent safety, maximising separation between wells. The single wells in the distributed layout minimise the potential for cuttings discharged from multiple wells to accumulate in one location.

2.4.1 Control and Communications for Subsea Infrastructure at the Store

Following the decision to select a subsea concept, two options of control and communication for the subsea infrastructure were evaluated against the criteria provided in Table 2-1:

- An electro-hydraulic system, wherein the valves in the subsea infrastructure are operated using hydraulic actuators[55], with the hydraulic fluid delivered from onshore; and
- An all-electric system, wherein valves in the subsea infrastructure are operated electrically, with the electricity delivered from onshore.

Following evaluation, the all-electric system was selected. This selection is based on the following key conclusions:

- There are no hydraulic fluid discharges or potential fluid leaks to the environment from an all-electric system whereas existing electro-hydraulic technology would require storage of control fluid offshore to reliably operate the valves;
- The cost of the all-electric system is lower with the elimination of the need for hydraulic tubing and hydraulic fluid throughout the duration of the Development; and
- Although all-electric systems are typically at a lower technology readiness level than electro-hydraulic systems, all-electric actuators have been deployed for over 20 years and joint industry projects are being run to deliver next generation all-electric systems.

As there are currently no low-temperature rated all-electric valves, the valve within each injection well which isolates the well from the surface in an emergency, i.e. the surface-controlled subsurface safety valve (SCSSV), will operate using an electric powered, hydraulic power unit (HPU).

[55] *A device which uses pressurised hydraulic fluid to convert a control signal into mechanical motion*

2.4.2 Infield Pipeline, Flowlines, and Cables

While the routing of infield flowlines, pipeline and cables remains to be finalised, the criteria applied to determine the routing incorporates the criteria provided in Table 2-1 and includes:

- Required flowline, pipeline and cable line sizes;
- Protection and stability requirements for life of the flowlines, infield pipeline and cables;
- Physical seabed characteristics;
  - Topography, water depth and sediment conditions;
  - Known locations of seabed features, e.g. gullies, undulations, pockmarks, wrecks, debris, boulders, shifting sands, sandwaves;
- Minimisation of flowlines, infield pipeline and cable lengths and lay corridors;
- Seabed disturbance and impact to marine life;
- Impact to other users of the sea, e.g. fishing and shipping activities;
- Ability to install and decommission the flowlines and infield pipeline;
- Unexploded Ordnances (UXO); and
- Shallow hazards below the surface of the seabed e.g. gas pockets.

Different installation and protection measures are being considered and the final installation concept will be determined during the detailed design phase. The base case option used for assessment in the ES is described in Section 2.5.3.

2.5 CO_2 Transportation

The two CO_2 transport alternatives evaluated against the criteria provided in Table 2-1 were pipeline and shipping.

CO_2 has been transported by pipeline for many years. CO_2 is transported in dense phase due to its unique properties in this phase, i.e. it has a higher density and no liquids form in the pipeline, thereby reducing the likelihood of corrosion and associated pipeline integrity risk. There are over eighty CO_2 pipeline facilities/projects around the world, the majority of which have been developed onshore in the United States for enhanced oil recovery (GCCS Institute, 2021). The only operational offshore CO_2 transport pipeline at commercial scale is the 200 mm (8”), 153 km Snøhvit pipeline[56], transporting 0.7 MtPA of CO_2 at 100 bar from Hammerfest to the subsea injection well at the Snøhvit field in the Barents Sea. The limited number of offshore CO_2 pipelines is due not to technical challenges but to a lack of demand.

Studies have considered the potential benefits of large scale ship transportation of CO_2, however none has yet been implemented. Longship[57] is a project supported by Gassnova and the government of Norway which aims to develop a hybrid (shipping from industrial emitters to an onshore terminal and pipeline transportation to an offshore sink) CCS configuration. CO_2 can be efficiently transported by ship in the liquid phase and at medium pressure. The Ethylene and liquefied petroleum gas (LPG) shipping industry, which are matured with well-established design standards, operate under transportation conditions similar to those proposed for CO_2. Existing CO_2 carriers are designed

[56] *https://www.equinor.com/en/what-we-do/norwegian-continental-shelf-platforms/snohvit.html*
[57] *https://ccsnorway.com/*

according to the same standard, the International Gas Carrier Code, and future designs of large CO_2 carriers are expected to draw heavily on this experience.

Advantages of a shipping concept over a pipeline solution include the ability to reuse ships for other services, matching of CO_2 sources and sink, and the possibility of phased development. However, there are also safety and technical challenges associated with the offshore cargo CO_2 transfer system and the use of ships for transporting CO_2 is currently limited to a fleet of small ships in the European trade of CO_2 for industrial uses. A study commissioned by BEIS (now DESNZ) (elementenergy, 2018) found that shipping is more favourable relative to pipelines for projects for which flow rates of CO_2 are less than 5 MtPA, which have durations of less than 20 years, and which entail transport distances of greater than 500 km.

As the Development does not fulfil these criteria, on the basis of cost, and maturation of technology available within the timeframe of the Development, the pipeline option was selected.

2.5.1 Pipeline Design

The decision relating to sizing of the Teesside and Humber Pipelines was based on the criteria included within Table 2-1, as well as pipeline-specific criteria (Table 2-4), and specifically the injection profile required. Uncertainties that influenced the decision making process (bp, 2021c) included the level of demand for CO_2 storage from onshore industry, available CO_2 storage volumes in the Endurance Store, and the development of future phases of offshore CO_2 storage (beyond the scope of this ES).

Multiple options and combinations of options were evaluated, including pipeline diameters from 14” to 30”. The Development, within the wider ECC (Section 1.4) seeks to support and expand on the UK Government ambition to establish at least one low-carbon industrial cluster by 2030 and the world’s first net zero carbon industrial cluster by 2040. Therefore, pipeline sizing was evaluated with a view towards facilitating future decarbonisation of industries in both regions. It was decided to size the Teesside Pipeline for 10 MtPAi and the Humber Pipeline up to 17 MtPAi, i.e. with a diameter of 28” and a design pressure of 235 barg. This results in lower overall environmental and social impact as future additional pipelines will not be required. Survey, installation and commissioning disturbance over the life of the Development will therefore be minimised.

Table 2-4 - Decision criteria relating to pipeline sizing

Criteria	Description
Technical feasibility	Selected sizes are within capabilities of pipeline suppliers and installation contractors. Readiness of any technology. Impact to onshore design. Required pressure drop to convey the design CO_2 flowrate to the offshore storage site
Strategic alignment	Highest throughput at the lowest unit cost.
Faster demand	Speed and ease with which the system could be expanded to accommodate faster demand from capture projects.
Reduced or slower demand	Robustness to reduced or slower demand from capture projects and impact on unit cost.
Reduced storage capacity	Robustness to reduced aquifer storage volumes.
Operations	Pipeline operability at different rates and different transient conditions. Impact on OPEX.

Two different pipeline material options were considered, carbon steel with 6 mm corrosion allowance and carbon steel mechanically lined with stainless steel (AISI 316L). Carbon steel with 6 mm corrosion allowance was selected given that:

- Carbon steel is technically acceptable, assuming the CO_2 within the pipeline is maintained within the defined entry specification. The entry specification requires a water content in the gas that is an order of magnitude below that where free water (which exacerbates corrosion) will occur;
- Carbon steel is significantly lower cost than mechanically lined pipe;
- Carbon steel is commonly used in offshore pipelines and is widely available from multiple line pipe suppliers; and
- Carbon steel has been selected elsewhere in the industry to transport dense phase CO_2 gas (e.g. Petra Nova, Porthos, Alberta, Northern Lights).

During normal operation i.e. dry CO_2 within entry specification, conditions are not considered corrosive for carbon steel and therefore there is no plan to use corrosion inhibitor over the lifetime of Development.

To facilitate pipeline inspection and the response to detection of off-specification contents in the CO_2 pipelines (e.g. high water content), consideration was given to the use of permanent or temporary pig receivers[58] at the two manifold locations (Section 2.4). A rapid response to detection of off-spec conditions is required to return pipeline contents to within specification, minimising flow and corrosion risks within the pipeline and mitigating potential well injectivity issues. A permanent pig receiver enables this rapid response and was therefore selected for the Development.

2.5.2 SSIV

Pre-Front End Engineering and Design (FEED) pipeline engineering assessed the risk reduction achieved by the installation of a Subsea Safety Isolation Valve[59] in the nearshore (< 10 km) sections of the Teesside and Humber Pipelines. In the highly unlikely event of a CO_2 release from a pipeline, assessment has been conducted for nearshore pipeline sections to assess the speed of dispersal of CO_2 and the distance at which the CO_2 could present a hazard to personnel (bp, 2022a).

For the Humber Pipeline, the pre-FEED assessment concluded that the risk to personnel was sufficiently low without an SSIV, given the topography of the area. In the unlikely event that a pipeline CO_2 release occurred in the vicinity of the Humber landfall, and the CO_2 reached shore, the presence of cliffs forms a physical barrier than should ensure any CO_2 released travels along the beach. Assessment demonstrated that CO_2 would not travel inland where there are more densely (albeit still sparsely) populated areas. Further, the Development seeks to minimise the footprint in protected areas, namely the Holderness Inshore and Offshore MCZs. Consequently, there are limited locations in which the SSIV module could be installed on the seabed and in these locations, water depths are relatively shallow. It was therefore concluded it was not necessary to install an SSIV on the Humber Pipeline.

For the Teesside Pipeline, pre-FEED assessment concluded that further work would be required to assess the need for SSIV installation with further studies, pipeline failure frequency assessment, refinements in cost estimates and consultee engagement to be conducted. For the purposes of the ES therefore, and to ensure assessment of maximum design envelope, it will be assumed that an SSIV will be installed on the Teesside Pipeline between KP6 and KP8. This is further described in the Project Description (Section 3.2.1).

2.5.3 Pipeline Route Selection

Pipeline route selection requires holistic consideration of offshore, nearshore and landfall options, including connection locations to the onshore pipeline or infrastructure, applying evaluation criteria provided in Table 2-1. Studies conducted during early engineering of the Development are summarised in the following section.

The Endurance Store lies within the SNS SAC. The Teesside Pipeline route will pass through the Teesmouth and Cleveland Coast SPA and in close proximity to the Runswick Bay MCZ. The Humber Pipeline route will pass through the Holderness Offshore MCZ, the Holderness Inshore MCZ and the Greater Wash SPA. During design of the Development, environmental and social concerns have been discussed extensively with key stakeholders. The concerns raised have been incorporated into the Development and the routes and installation methods are being designed to minimise disruption to

[58] A structure that receives and holds the pipeline inspection gauge or tool (pig) following transit of the pig along the length of the pipeline. Pigging forms part of the inspection and maintenance programme of a pipeline

[59] A valve that will close and isolate a particular pipeline or process in an emergency.

protected areas and stakeholders, including fisheries. Coastal erosion and sediment transport processes that occur along the Holderness coastline are also considered in the design and installation methodology of the Humber Pipeline, to minimise impacts on MCZs, SPAs and SACs in the vicinity.

2.5.3.1 Onshore

Teesside

The site selection process for the onshore NZT Power development, which represents the first confirmed emitter contributing to the Development, is presented in the DCO (NZT Power DCO, 2021). The onshore transportation and storage infrastructure is associated with the construction of the NZT Power facility and is briefly summarised here given the influence on the landfall location for the Teesside Pipeline.

A number of key criteria were applied as part of the NZT Power site selection process:

- East coast site – due to its proximity to a number of potential offshore CO_2 storage sites in the North Sea that have already been characterised for their storage potential;
- Dimensionality – ensuring there is sufficient space for the NZT Power development and its constructability and expansion potential;
- Utilisation of brownfield land where reasonably practical;
- Proximity to industrial sources that could connect into the CO_2 Gathering Network;
- Proximity to the coast to enable high pressure CO_2 export to be quickly directed offshore and to separate high pressure systems from residential areas;
- Proximity to necessary connections including gas network, electricity transmission network, water supply; and
- Minimising environmental and social effects or risks.

Prior to the formation of NEP, the concept was initiated and developed by the ETI and other parties. This led to a number of sites being shortlisted including:

- The former Redcar steelworks site (now known as the South Tees Development Corporation (STDC) site or Teeswork site), which encompasses an area of over 2,000 hectares (ha);
- A brownfield plot on the Wilton International site near to Lazenby; and
- Various sites within the Seal Sands area.

These sites were ranked based on a series of criteria including site area, use of brownfield land, proximity to the coast for the export pipeline, access to natural gas supply, the electricity transmission system and a source of water, and potential for minimising environmental effects.

Through this process, a preferred site was identified as being most suitable for the proposed development location – the Teeswork site. This location also enabled linking to the Tees Valley Combined Authority work, to develop the Teesside industrial cluster. This preferred site is a brownfield site that is relatively distant from residential areas and is of sufficient area to enable construction. Further, the site has proximity to the necessary connections, is close to the North Sea coastline for offshore export of CO_2 and is accessible for construction – including from port and jetty facilities.

Within the Teesworks site, four main locations were considered, taking into account the strategic plan for the site redevelopment at that time, proximity to the North Sea, proximity to residential receptors, access, ground conditions, presence of existing structures and minimising land take adjacent to the river that was considered to be of higher redevelopment potential. A plot of land to the east of the former blast furnace was identified as the most suitable. The red line boundary for the NZT Project DCO site is shown in Figure 2-3.

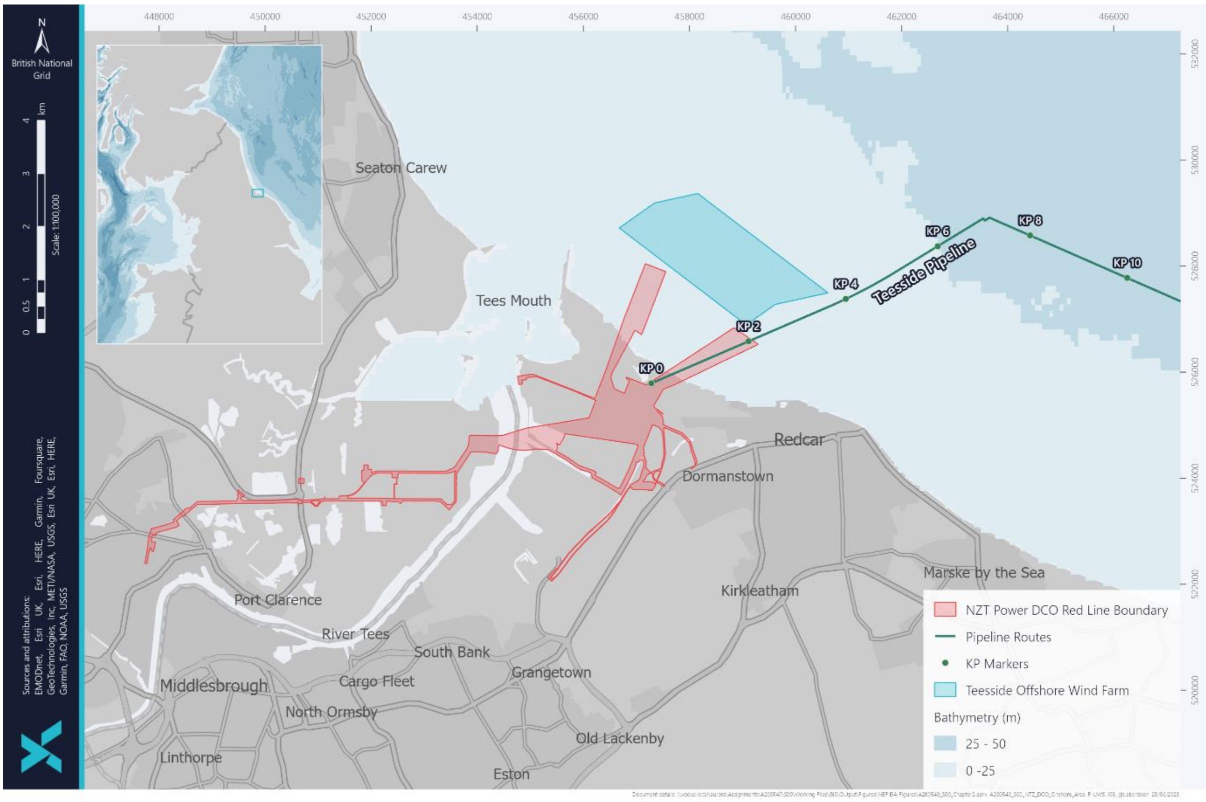

Figure 2-3 - NZT Project DCO red line boundary

Humber

Initial information relating to the site selection process for Onshore Humber (HLCP, 2022) is briefly summarised here given the influence of the process on the landfall location for the Humber Pipeline. As the work undertaken to date by NGV in relation to Onshore Humber forms the basis for NEP partner progression of this NSIP, reference is made to it within this ES.

Onshore Humber is anticipated to comprise the construction of dual pipelines and above ground installations (AGI) to transport CO_2 between potential emitters (at Drax, Keadby, Killingholme and Saltend) in North Yorkshire and a landfall point on the Holderness coast in East Riding of Yorkshire. Option appraisal assessed potential route corridors and AGI siting options to develop a preferred end-to-end solution for the pump facility, landfalls, pipeline inspection gauge (PIG) trap sites and main route corridors[60].

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[60] *Pipelines providing connections between potential emitters.*

Appraisal identified potential physical and environmental and community/social features and receptors that could be affected by and may influence the routing and siting options for Onshore Humber including: biological environment, landscape, historic, land use and planning, infrastructure, physical environment, settlement and population, and tourism and recreation.

1 km wide route corridor options were identified linking emitters in the Humber region to potential landfall points for onward transportation (of CO_2 only) to the Endurance Store. Also identified were sites for a pump facility as well as other AGIs (e.g. for pig traps installations).

Corridors were identified that could connect emitter groups together, rather than each having a separate route corridor connecting back to the landfall location. Routes were identified by working from the coastal landfall locations back towards the closest emitter.

When developing routing options, key constraints were avoided wherever feasible e.g. the Humber Estuary, which is designated as an SAC, an SPA and a Ramsar site, and the routes devised were towards less constrained areas. However, this was balanced with an overarching need to keep pipeline route corridors as short as practicable as smaller scale infrastructure projects are generally likely to have lower environmental, safety, sustainability, and cost implications (for comparable technology options).

Pipeline route corridor options from three landfall options (see Section 2.5.3.2) to the main route corridor options were evaluated with a view towards selecting a route corridor that avoids environmental and physical features and receptors as far as reasonably practical. Six main route corridors were evaluated within two configurations:

- Configuration A: Most of the route corridor lies south of the Humber Estuary with the crossing of the estuary via a bored tunnel immediately north of Killingholme power station and south of the Saltend chemicals park; and
- Configuration B: A longer route with emitters south of the Humber being connected via a route which crosses the River Ouse.

Appraisal selected the route of a shorter total length within Configuration A. The selected route option is shown in Figure 2-4. This was selected to avoid larger settlements and facilitate connections to a greater number of potential emitters (HLCP, 2022).

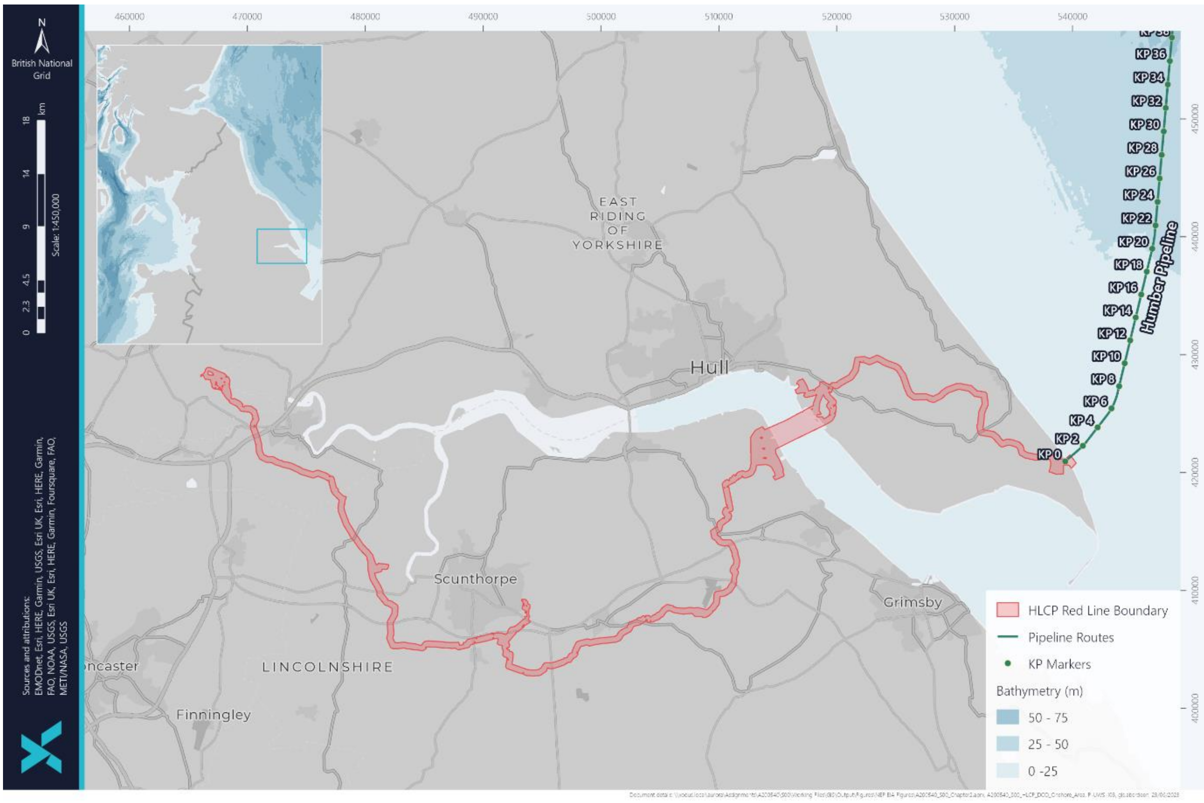

Figure 2-4 - Onshore Humber scoping route corridor (HLCP, 2022)

2.5.3.2 Landfall Location and Methodology

At this stage of design, a number of options are being evaluated for the landfall methodology at Teesside and Humber (Table 2-5), as discussed further in the following sections. NEP will continue to complete option decisions based on the criteria provided in Table 2-1 throughout detailed engineering design.

Table 2-5 - Landfall methodologies under consideration at Teesside and Humber

Option	Summary of approach	Under consideration	
		Teesside	Humber
Horizontal directional drilling (HDD)	A pilot hole is drilled along a proposed route and subsequently enlarged to the target diameter via the use of a tool termed a reamer. Reaming is followed by "pullback" whereby the reamer is withdrawn to the entry point and the pipeline simultaneously installed.	Yes	Yes
Microtunnel	The MicroTunnel Machine (MTM) is launched from the base of a vertical shaft. As the MTM cuts the ground, the assembly is jacked forwards by hydraulic rams located within the shaft with pre-cast segmental concrete pipe attached and jacked in behind as the tunnel progresses.	Yes	Yes
Direct pipe	A combination of HDD and microtunnelling with simultaneous excavation of the tunnel and installation of the pipe duct.	Yes	Yes
Microtunnel and cofferdam	Microtunnel with cofferdam and open cut.	No	Yes

Teesside Landfall Location

Onshore routing of the CO_2 export pipeline from the selected site (Section 2.5.3.1) to MLWS sought to enable maximisation of the distance between the pipeline route and the Teesside Offshore Windfarm (OWF) (Figure 2-3).

Teesside Landfall Methodology

Installation of the pipeline above MLWS will utilise trenchless construction[61] to minimise the potential for impacts on Coatham Dunes and Sands and on the habitats and species at the Teesside and Cleveland Coast Site of Special Scientific Interest (SSSI)/SPA/Ramsar site. Furthermore, a cofferdam is not considered an option due to the long distance from shore before the water is deep enough for a pipelay vessel to moor and the resultant length of the cofferdam which would be required.

One of three options (Table 2-5) will be utilised to fulfil the Development requirement of seeking a safe solution which minimises environmental impact: direct pipe, microtunnelling or HDD. Further

[61] Installation methods whereby the pipeline is installed under an area without breaking open the ground and digging a trench. Onshore, tunnelling commences at the location termed "entry pit" and offshore, the pipeline emerges at the point termed "punch-out location".

engineering is required to select the optimum solution for the Teesside landfall and therefore, for the purposes of the ES, all possible options will be described in Section 3.2.1.1 and the design envelope parameters which are predicted to result in the greatest environmental impact assessed in individual impact assessment chapters. For example, if shown that microtunnelling would be associated with the highest vessel emissions, this option would be considered in the atmospheric emissions impact assessment, and if shown that direct pipe would be associated with the greatest seabed footprint, this option would be considered in the seabed disturbance impact assessment.

Humber Landfall Location

A review was carried out (Hartley Anderson Ltd, 2020), to identify the physical, environmental and socio-economic constraints and their relative influence on pipeline routing between the Endurance Store area and the Yorkshire, Humber and Lincolnshire coasts. The study identified seven potential landfall locations from Theddlethorpe in the south to Barmston in the north. Three of these landfall zones were south of the Humber Estuary and four were north of the Humber Estuary, on the Holderness coast (Figure 2-6).

Table 2-6 - Possible landfall locations for the Humber Pipeline

Option ID	Landfall name	Nearshore route corridor option
1	Theddlethorpe	3 – Southern Spur
2	Tetney Haven to Horseshoe Point	3- Central
3	East of Immingham Dock	3 – Humber
4	Holmpton to Spurn (Easingston)	2 – Southern Spur
5	South Cliff to Tunstall (Aldbrough)	2
6	Moor Hill to Double Gates (Atwick)	1 – Southern Spur
7	Ulrome Sands to Fraisthorpe Sands (Barmston)	1

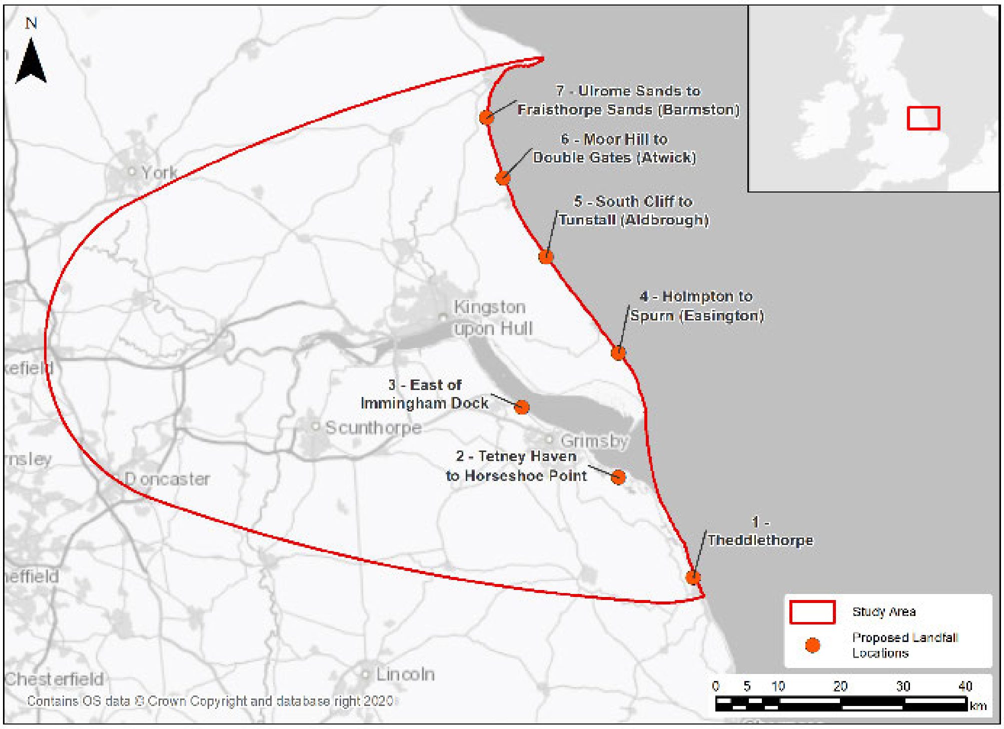

Figure 2-5 - Humber landfall location options evaluated

The Holderness coast is associated with rapid rates of coastal erosion. With the exception of certain existing shoreline defences (e.g. at Bridlington, Mappleton, Easington and around the mouth of the Humber), a shoreline management policy of no active intervention (NAI) is in place (Humber Estuary Coastal Authorities Group, 2010a). The likely evolution of the coast needs to be considered for any landfall in these areas so that defence works additional to those currently present are not required through the life of the Development.

Following evaluation and scoring based on environmental and socio-economic, permitting and constructability constraints, landfall locations to the south of the Humber Estuary scored least favourably – requiring longer offshore pipelines and a much greater number of crossings of existing and proposed pipeline and cable routes. Additionally, the extensive sandflats, saltmarsh and dune systems to the south of the Humber are important habitats to take account of in landfall selection. Assessment concluded that:

- Option 1 (Theddlethorpe) and Option 2 (Tetney Haven to Horseshoe Point) were discounted as landfall locations due to the lack of availability of viable, short onshore routing alternatives;
- Option 3 (East of Immingham Dock) scored least favourably overall and was discounted due to constructability challenges including the crossing of multiple constraints within the harbour area, near shore sandwaves, high number of nearshore coastal protected areas and high interaction with other sea users;
- Option 7 (Barmston) was discounted as a landfall location due to the lack of availability of viable, much shorter onshore routing alternatives. Option 7 was also discounted as it is proposed as the landfall location for Hornsea Project Four resulting in potential overlap between the DCO order limits of the Hornsea Project Four and Onshore Humber projects. The area to the south of Barmston is covered by the offshore cable agreement area for the Dogger

Bank OWFs, which represents a corridor within which the cables could be installed. The potential exists for cumulative effects and additional permitting/liaison complexities that could impact the timeline for execution of the Development;

- Landfall option 4 (Easington[62]) and 5 (Aldbrough) were similarly ranked. Option 6 (Atwick) scored most favourably on ease of constructability at the landfall, the number of coastal protected areas in the vicinity, and fewer consenting issues;
- From an onshore perspective, options 4, 5 and 6 were considered further, including refinement of route corridors connecting the landfall zones to the main route corridors. Assessment criteria included proximity to receptors (e.g. populated areas), crossings, topography, ground conditions, access, reduced construction working area, testing suitability, schedule and cost. Option 6 was discounted during initial assessment, requiring substantially longer route corridors than routes associated with option 4 or option 5. As a longer route, there is greater potential to result in environmental effects to a greater number of potentially sensitive receptors and in higher costs. Option 6 is relatively close to the population of Hornsea; and
- Options 5 and 6 would both require a new industrial development (Hydrogen plant and CO_2 pumping station) while Options 5 and 6 are both in close proximity to holiday accommodation.

Prior to making a final decision on the landfall location, the Development required a landfall location assumption for the reference case. Based on the information available at the time, Easington was assumed as the reference landfall location due to the number of existing landfalls at Easington and therefore the significantly higher confidence in deliverability versus Aldbrough where no previous pipeline landfalls have been made. This reference case was included in successful bids to UK Research and Innovation (UKRI) for the Industrial Strategy Challenge Fund (ISCF) and Phase-1 of the BEIS (now DESNZ) CCS cluster sequencing process, and for the EIA Scoping Report (bp, 2020b).

Options 4 (Easington) and 5 (Aldbrough) were carried into non-statutory consultation[63] and considered further (as summarised in Table 2-9 to Table 2-11; NEP, 2022).

[62] *Easington refers to the location originally approved for the Tolmount pipeline landfall, prior to its re-routing and subsequent landfall further south.*
[63] *Part of the NGV Humber Low Carbon Pipeline DCO process, Section 1.4*

Table 2-7 - Scoring matrix (Genesis, 2021b)

Constraint	Scores		
	1 (most preferred)	2	3 (least preferred)
Environmental constraint			
Offshore conservation sites (no.)	Offshore pipeline corridor interacts with 1 to 2 protected sites.	Offshore pipeline corridor interacts with 3 to 4 protected sites.	Offshore pipeline corridor interacts with 5 or more protected sites.
Coastal protected areas	Landfall corridor does not interact with any protected sites.	Landfall corridor interacts with 1 protected site.	Landfall corridor interacts with 2 or more protected sites.
Important species	Potential effects of project activities managed through seasonal timing of activities to reduce interactions.	Potential to use seasonal timing to manage potential effects of activities is possible but limited given construction activities.	Potential effects of activities could not be managed through seasonal timing of activities to reduce interactions.
Important habitats	Habitats present do not have the potential to be impacted from project activities.	Habitats present have potential to be impacted from project activities. Standard mitigation measures can be applied to reduce the level of impact to acceptable levels.	Habitats present have potential to be impacted from project activities. Significant mitigation measures to reduce level of impact to acceptable levels.
Nearshore sandbanks/ waves	Nearshore pipeline corridor avoids sandbank or sandwave features.	Potential for sandbank or sandwave features within the nearshore pipeline corridor.	High potential for sandbank and sandwave features within the nearshore pipeline corridor.
Coastal erosion (shoreline management)	Less than 200 m of cliff loss over 50-100 years, or landfall is in a 'hold the line' coastal defence area.	Between 200 -500 m of cliff loss over 50-100 years, with no active coastal intervention in place.	Substantial cliff erosion losses (~500 m of cliff loss over 50 – 100 years).
Socio-economic constraints			
OWF area overlap	The landfall pipeline corridor and the nearshore pipeline corridor do not overlap with any OWF areas.	Either the landfall pipeline corridor or the nearshore pipeline corridor overlaps with a OWF area.	Both the landfall pipeline corridor and the nearshore pipeline corridor overlaps with OWF areas.
Agreement for lease*	The landfall pipeline corridor and the nearshore pipeline corridor do not overlap with any OWF areas.	Either the landfall pipeline corridor or the nearshore pipeline corridor overlaps with a OWF area.	Both the landfall pipeline corridor and the nearshore pipeline corridor overlaps with OWF areas.
Navigation density	Low, one navigation route crossed.	Moderate, several navigation routes crossed.	High, several navigation routes are crossed & presence of anchorage locations.
Ministry of Defence (MoD) Danger Area	Pipeline corridor does not cross an MoD Danger Area.	Pipeline corridor is located in close proximity to an MoD Danger Area.	Pipeline corridor crosses an MoD Danger Area.
Wrecks / UXO	No presence of wrecks or UXO.	Wrecks or UXO present.	High-density of wrecks or UXO present.
Other marine users	Oil and Gas infrastructure not present. Fishing effort is considered to be low. No dredging.	Oil and Gas/power station infrastructure present, but easily avoided. Moderate fishing effort. Some dredging.	Oil and Gas/power station infrastructure present which cannot be easily avoided. High fishing effort. More extensive dredging.
Regulatory constraints			
Consenting risk	Low. Project activities are readily mitigated through avoidance or minimising impact, or mitigation may not be required. Assessments would still be required through EIA, and potentially HRA. Stakeholder and legal liaison/ agreement is not considered significant.	Moderate. Mitigation measures (e.g. seasonal timing, project design or dialogue on co-location issues) likely required to significantly reduce level of constraint so that project activities acceptable. Assessments required through EIA, and likely through HRA. Stakeholder and legal liaison/ agreement required, but not expected to unduly affect project timings/ present significant obstacle.	High. Project activities would require significant levels of mitigation. Assessments would still be required through EIA, and likely through HRA. Significant stakeholder and legal liaison/agreement is considered to be required and has the potential to impact on project timings or present a significant obstacle to the Development.
Constructability constraints			
Crossings	1 to 5 pipeline/cable crossings	6 to 10 pipeline/cable crossings	Over 10 pipeline/cable crossings
Onshore constructability*	Score of 1-3	Score of 4-6	Score of 7-9

* Considers factors including erosion rates, pre-cut trench lengths required, other user constraints

Table 2-8 - Consideration of alternatives for landfall options of the Humber Pipeline. ID numbers correspond to those in Table 2-6 (Genesis, 2021a).

ID	Environmental constraints						Socio-economic constraints						Regulatory constraints	Constructability constraints		Total score
	Offshore Conservation sites (no.)	Coastal Protected Areas	Important Species	Important Habitats	Nearshore Sandbanks/ waves	Coastal erosion (shoreline management)	Windfarm area overlap	Agreement for lease*	Navigation Density	MoD Danger Area	Potential for wrecks/ UXO	Other Marine users	Consenting Risk	Pipeline/ cable crossing (no.)	Onshore	
1	2	2	3	3	2	1	2	2	2	2	3	1	2	3	5	**35**
2	2	3	2	2	3	1	2	2	3	3	3	2	2	3	8	**41**
3	2	3	2	2	3	1	2	2	3	3	3	3	3	3	8	**43**
4	2	2	2	2	1	1	2	1	2	1	2	1	2	1	3	**25**
5	2	1	2	2	2	3	1	2	1	1	2	2	2	1	2	**26**
6	2	1	2	2	1	2	1	1	1	1	2	1	1	1	1	**20**
7	1	1	3	2	1	2	1	3	1	1	2	1	2	1	4	**26**

* for OWF (pre-consent) and lease areas (consented) the design of which has not been finalised

Table 2-9 - Constraints for which Aldbrough and Easington options are broadly comparable (NEP, 2022)

Offshore		Onshore	
Environmental constraint			
Important species	Presence of wintering bird species; 35-40% UK breeding sandwich tern & little tern; Harbour porpoise SNS SAC.	Geo-environmental	There are no Historic or Authorised Landfill Site or Mineral Safe guarding Zones.
Important habitats	Intertidal sand and muddy sand, moderate and high energy circalittoral rock, a range of other sediments from mud to coarse sediment Broadscale features including subtidal mixed and coarse sediments Possible presence of Annex I habitats.	Landscape and visual	No local, national or international designations.
Socio-economic constraint			
OWF area overlap	The landfall corridor does not overlap OWF areas.	Settlement & population	No education facilities, medical facilities or emergency services. No urban settlements.
Agreement for lease	The landfall corridor does not overlap with proposed OWF areas. Offshore pipeline route crosses proposed Hornsea Project Four cable route.		
Navigation density	Crosses one important navigation route.		
MoD danger area	The landfall corridor does not overlap MoD danger areas.		
Potential wrecks/UXO	The landfall corridor has the potential for wrecks and UXO.		
Other marine users	Passive fishing effort is considered generally high in the nearshore. Pelagic, demersal, dredging and seine fishing effort is low. No oil and gas or dredging constraints noted.		
Legal/regulatory constraints			
Consenting risk[64]	Landfall require HRA and MCZ assessments. Liaison required: navigation routes, pipeline crossings and temporary fisheries exclusion.		
Technical/constructability constraint			
Pipeline/cable crossings	Two crossings (Langeled Pipeline and Hornsea Project Four power cable) plus one proposed pipeline (Whittle to Cleeton Pipeline).	Road and other crossings	Similar number of crossings of A, B and unclassified roads. There is potential to auger bore all of the roads during the construction phase and this this is unlikely to be a constraint
Major accident risks (MAR)	MAR analysis concluded acceptable risk in the unlikely event of a pipeline failure. Individual and societal risks likely to be acceptable.	Access	Reasonably well serviced with minor roads

[64] *Risk of non-approval or significant delays in obtaining regulatory approval.*

Table 2-10 - Offshore constraints for which a preferred (green shading) and a least preferred (light green shading) option were identified (NEP, 2022)

Constraint	Aldbrough	Easington
Environmental constraint		
Offshore conservation sites	Intersects four offshore conservation sites. Shallow beach profile will require pre-cut trench of 7 m deep, 15 m wide and 1.5 km length.	Intersects four offshore conservation sites. Consenting precedent (Tolmount).
Coastal protected areas	No coastal protected areas intersected.	Dimlington Cliffs SSSI (geological feature). Consenting precedent (Tolmount).
Nearshore sandbanks/ waves	Potential for nearshore sandwaves.	Pipeline corridor avoids sandbank/sandwave features.
Coastal erosion	Substantial cliff erosion loss [200 – 500 m cliff loss over 50 – 100 years].	Variations in cliff erosion [70 – 180 m cliff loss over 50-100 years].
Technical/constructability constraint		
Landfall execution	1.5 km pre-cut trench required. No landfall precedent; unknown geology with schedule implications to obtain requisite data.	Numerous trenchless landfall construction techniques feasible. Multiple landfall precedents. Large number of geotechnical site investigations conducted providing high level of certainty of the geology that will be encountered and predictability of landfall construction and cost.
Offshore execution	Pipe-lay vessel anchors 3 km from shore: shallower slope of seabed If onshore pull-in required, larger winch and foundation required due to doubling of length of pipeline pulled-in.	Pipe-lay vessel anchors 1.5 km from shore Proximity of pipelay vessel anchors to numerous pipelines in the area: detailed design and management during installation works.
Schedule	Geological and execution uncertainty.	Greatest execution predictability.
Cost	Shorter length of Humber Pipeline. Additional open cut trenching. High landfall execution uncertainty.	Longer length of Humber Pipeline. High landfall execution predictability.

Table 2-11 - Onshore constraints for which a preferred (green shading) and a least preferred (light green shading) option were identified (NEP, 2022)

Constraint	Aldbrough	Easington
Environmental constraint		
Priority habitats	Three areas of deciduous woodland. Expected to be avoidable with micro-siting.	Four areas of deciduous woodland, three areas of semi-improved grassland and three areas of coastal and floodplain grazing marsh. Expected to be avoidable with micro-siting.
Listed buildings	Three Grade II Listed buildings. Temporary settings impact during construction.	One Grade II Listed building. Temporary settings impact during construction.
Watercourses	Three water courses within landfall corridor route. All crossings are likely to be open cut trenches with no trenchless techniques required.	Seven water courses within landfall corridor route. All crossings are likely to be open cut trenches with no trenchless techniques required.
Flood risk	Small, interspersed areas of Flood Zone 2 and 3.	Four large areas of Flood Zone 2 and 3.
Agriculture and soils	Temporary loss of approx. 13.75 km^2 of best and most versatile (BMV) agricultural land. Land will return to BMV.	Temporary loss of approx. 25 km^2 of BMV agricultural land. Land will return to BMV.
Socio-economic constraint		
Tourism & recreation	Caravan park at northern extent of corridor. No cultural facilities, historic landmarks, supports and leisure centres, sports clubs or National Trust land.	No hotels, B&Bs, caravan or holiday parks or other accommodation facilities. No cultural facilities, historic landmarks, supports and leisure centres, sports clubs or National Trust land.
Public right of way (ProW)	Approx 10 ProW. Appropriate diversions will be implemented for any ProW obstructed during construction to minimise effects on accessibility.	Approx 14 ProW. Appropriate diversions will be implemented for any ProW obstructed during construction to minimise effects on accessibility.
Technical/constructability constraint		
Strategic	Potential incorporation into planned hydrogen storage. Potential CO_2 emitter at Aldbrough.	Easington has become nationally important hub. Nine existing offshore pipeline connections make it well positioned to support the NSTA Strategy and Stewardship expectation 11 (Net Zero) relating to CCS re-use opportunities. Options for hydrogen at Easington also exist.
Cost	Shorter pipeline route: lower pipeline cost.	Longer pipeline route: higher pipeline cost.

Easington was therefore selected as the landfall location. In summary, this was due to:

- Constructability – The proposed route has two crossings (one pipeline and one proposed cable) which is a considerably lower number than the crossings required for options south of the river which have 13 – 14 crossings each. In addition, the landfall constructability for large diameter gas pipeline is proven and known based on previously approved pipelines e.g. Langeled, York and Tolmount. The site is at an existing industrial location and therefore does not introduce the risks associated with greenfield developments;
- Seabed slope – The shallower seabed slope reduces the length of pre-cut trench required within the Holderness Inshore MCZ for landfall installation, reducing potential impacts on the designated site;
- Existing onshore development and pipeline installation sets a precedence for approval of the installation of the pipeline and hazardous facilities, increasing confidence in deliverability. Aldbrough would require the construction of new sea defences, which conflicts with the East Riding of Yorkshire Council Shoreline Management Plan (SMP)[65] policy of "no active intervention" or a significant standoff distance from the coastline to avoid coastal erosion; and
- Onshore pipeline routing and facilities – This location minimises the length of the proposed onshore Humber CO_2 pipeline. As a shorter route, there is less potential to result in environmental effects to potentially sensitive receptors.

While the Easington landfall crosses the Dimlington Cliff SSSI which is designated for geological features, the SSSI will be crossed by a trenchless construction method.

Humber Landfall Methodology

One of four options (Table 2-5) will be utilised to fulfil the project requirement of achieving a safe solution which minimises environmental impact: direct pipe, HDD, microtunnel, and microtunnel and cofferdam. Further engineering is required to select the optimum solution for the Humber landfall and therefore, for the purposes of the ES, all possible options will be described and the design envelope parameters which are predicted to result in the greatest environmental impact, described and assessed in individual impact assessment chapters. For example, hypothetically, HDD may be associated with the greatest vessel emissions and therefore would be assessed in the atmospheric emissions impact assessment, however microtunnel and cofferdam may be associated with the greatest effect on coastal processes and therefore assessed in the seabed disturbance impact assessment.

2.5.3.3 Offshore

Surveys of the pipeline routes consist of geotechnical, geophysical and environmental elements (further details provided in Section 4.2) have been conducted to allow detailed engineering. This survey data supplements previous datasets collected in 2020 (further details provided in Section 4.2). These surveys allow modification of the pipeline route to reduce impact on sensitive habitats that may

[65] *https://www.eastriding.gov.uk/environment/sustainable-environment/looking-after-our-coastline/defending-the-east-riding-coastline/*

be encountered, as far as reasonably practical. Further, consideration of other sea users and features of conservation interest (FOCI) for the Holderness Offshore MCZ and the Holderness Inshore MCZ will be taken into account during pipeline micro-routing to avoid these as far as reasonably practicable.

Pipeline installation methodology will undergo optimisation during FEED. The currently proposed methodology (as discussed in Section 3.2) was selected based on water depth, soil type and hydrodynamic conditions. The methodology involves pre-cut trenching nearshore using a Backhoe Dredger (BHD) with a Cutter Suction Dredger (CSD) also available for use as a contingency in the event stiffer soils are encountered. A Trailing Suction Hopper Dredger (TSHD) will be used to maintain the pre-cut trench, as required.

For the offshore pipeline routing assessment, the following criteria were considered:

- Minimising the pipeline route length and route bends while still satisfying other route criteria (i.e. those contained within this list);
- Construction vessel limitations and pipeline installation methods including initiation lay radius and crossing requirements;
- Minimising the environmental impact and seabed disturbance due to pipeline installation and operation activities;
- Maintaining a minimum clearance of 50 m distance from any (isolated) abandoned / suspended well;
- Maintaining, unless where crossing required, a minimum of 30 m distance from any existing flowline, cable, umbilical or subsea structure;
- Avoiding, where reasonably practical, any seabed obstructions or features (e.g. boulders, debris, wrecks, sandwaves, mega ripples, rocky outcrops, unstable slopes, ridges, depressions, debris, pockmarks and coral);
- Minimise the number of crossings of other pipelines and cables. Where required, crossings are to be as close to perpendicular as possible;
- Physical seabed characteristics e.g. seabed bathymetry and sediment conditions; and
- Avoidance of:
    - Exclusion zones;
    - Existing subsea infrastructure;
    - Anchorage areas;
    - Shipping lanes;
    - Military exercise areas; and
    - UXO.

The assessment identified pipeline route corridors of 2 km width which have been surveyed and within which, during subsequent design, further mico-siting of the pipelines will occur. For both pipelines, there is a relatively high potential for UXO to be present along the coast and in the offshore area, which will be located via route specific surveys. Based on an initial assessment it is anticipated that it will be possible to avoid any UXO encountered. Should clearance or detonation be required, this would be subject to separate assessment and applications.

Teesside

From the onshore and landfall locations identified (Section 3.2.1.1), the most direct route to the Endurance Store was selected, cognisant of the following constraints:

- An existing OWF (Teesside OWF) to the north of the pipeline route;
- Two pipelines to the south (Central Area Transmission System (CATS) trunkline and the Breagh infrastructure: a 20" gas pipeline, a 3" MEG pipeline and a fibre optic cable); and
- Rock outcrops south of the existing pipelines.

The shore approach route is constrained by these features, and as such a central corridor has been selected between them. The proposed corridor centreline lies approximately 100 m from the existing pipelines and approximately 100 m from the incoming cable corridor associated with Teesside OWF. Final routing shall be informed by detailed bathymetry and identification of existing pipelines / cables within the shore approach area. There are no designated anchoring areas within the shore approach area. Key designated anchoring areas are located further north.

The Teesside Pipeline runs from MLWS in northeast bearing up to approximately kilometre point (KP) 7 where it changes to a due southeast bearing for the remaining distance (135 km approximately) to the location of the Endurance Store (Section 3.2.1.1). Between KP7 and KP50 the pipeline route crosses the leased areas of the Boulby and Hundale potash mines (Section 4.6.6). Consultation with the licence area operators will be conducted prior to The Crown Estate (TCE) granting the rights to install the pipeline on the seabed[66]. At approximately KP115 the Teesside Pipeline crosses the 44" Langeled gas pipeline. Engagement will be conducted with all relevant stakeholders to enter the necessary crossing or proximity agreements.

The Teesside Pipeline routing was modified to specifically avoid routing of the pipeline through the protected area, Runswick Bay MCZ. Interactions with the 'summer' area of the SNS SAC (a conservation site for harbour porpoise) are unavoidable due to the location of the Store.

Offshore surveys of the 1 km corridor of the proposed centreline confirmed the presence of sandwaves along the Teesside Pipeline route from KP115 which may require pre-lay smoothing (Gardline, 2021a). Wrecks are known to occur along the route. Siting of the pipeline within the surveyed corridor will avoid any wrecks and minimise the requirement for boulder removal.

Humber

A review was carried out (Hartley Anderson Ltd, 2020), to identify the physical, environmental and socio-economic constraints and their relative influence on pipeline routing between the Endurance Store area and the Yorkshire, Humber and Lincolnshire coasts. The study identified three main broad route corridors with multiple offshore and nearshore corridor options (Figure 2-6), matched to seven potential landfall areas on the Holderness coast and to the south of the Humber Estuary.

The Hills sandbanks provide a significant topographical constraint to routing near the Endurance Store area, constraining most routes to exit either to the northwest or southeast in parallel to the

[66] *Consultation to date has occurred in support of survey work completed along the pipeline corridor during The Crown Estate seabed survey licensing process.*

orientation of the banks. There have been significant hydrocarbon developments, and more recently, offshore wind development in the area. As a result, pipeline and cable crossings will be unavoidable. However, fewer crossings would be required for the northerly route corridor.

Wrecks are widespread along all the route corridors identified; route specific surveys have been conducted to inform more precise route selection of the selected route (Section 4.6.5). Siting of the pipeline within the 1 km corridor of the proposed centreline will avoid any wrecks and minimise the requirement for boulder removal.

Interactions with the 'summer' area of the SNS SAC (a conservation site for harbour porpoise) are unavoidable, with only the southern spur of route corridor 2 crossing both a 'winter' and 'summer' area of the site.

Routing to the south of the Humber is constrained by a number of features including aggregate extraction areas, anchorages and vessel routing measures, such that there are more limited options for routing in this area. Anchorages and routing measures were considered to be hard constraints, e.g. due to potential physical interactions with the pipeline from anchor laying, and potential challenges in pipelay within heavily used channels. However, across the rest of the study area, shipping activity is not considered to be a significant constraint.

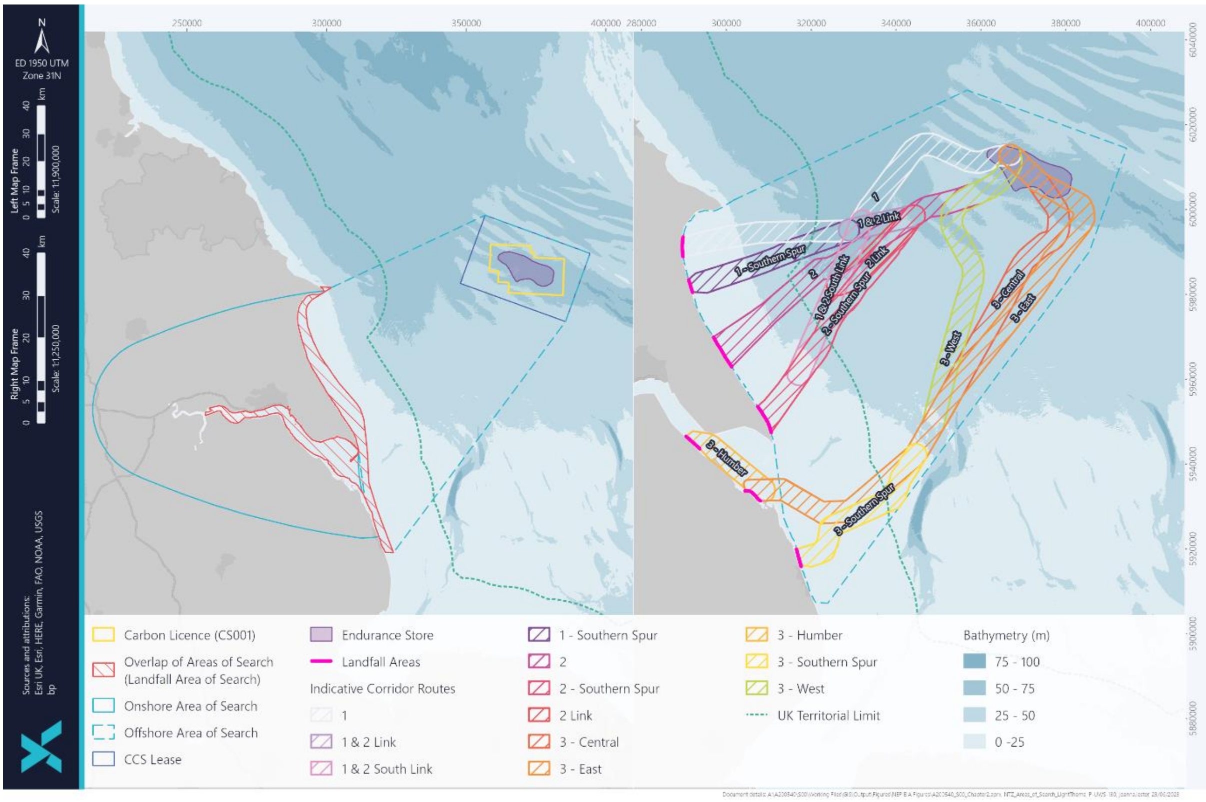

Figure 2-6 - Humber Pipeline route corridor options (after Hartley Anderson, 2020)

The base case pipeline routing therefore selected is from the Endurance Store to Easington, to the north of all the existing pipelines. This location was selected to avoid near shore crossings at the congested location to the south. From MLWS, the pipeline initially follows the existing Cleeton pipeline corridor, then after the Langeled pipeline, crosses the Cleeton pipeline, following the existing Langeled pipeline corridor. To facilitate a crossing over the Langeled pipeline, the proposed pipeline routing then deviates from the Langeled pipeline corridor and heads north. After the crossing, the pipeline is routed to the west of the Woolaton field and then follows a previous pipeline design from a FEED project routed to the same region as the Endurance Store. The proposed pipeline route passes a number of abandoned and operating wells in the region of the crossing over Langeled and the route to Endurance. However, a minimum of 100 m clearance is intended to be maintained between the proposed pipeline and existing wells.

As set out in Table 2-12, a number of routing options for the proposed pipeline between Easington and Endurance have been considered (Genesis, 2021b) including:

- Variations in the crossing angle[67] and location of the proposed pipeline over the Langeled Pipeline;
- A more direct route to Endurance after the proposed pipeline crossing over the Langeled Pipeline; and
- A hybrid option combining the above.

Table 2-12 - Humber Pipeline routing option assessment summary, varying crossing angle of Langeled Pipeline (Genesis, 2021b)

Route option	Route length (km)	Crossing angle (°)	Advantages	Disadvantages
Base Case	102.0	70	Optimum pipeline design approach.	Longest pipeline length
Option 1	98.7	30	3.3 km reduction in pipeline length.	30° Crossing Angle
Option 2	97.4	19	4.6 km reduction in pipeline length.	Crossing angle less than 30°
Option 3 Near shore crossing	96.3	23	5.7 km reduction in pipeline length.	Crossing angle less than 30°. Additional crossings. Congested approach to Easington.
Option 4 Direct approach, Endurance	94	70	8 km reduction in pipeline length.	Route would pass directly over known sandwave features.
Option 5 Shortest route	90	23	12 km reduction in pipeline length.	As per Options 3 and 4

The assessment concluded the following:

[67] Crossings are to be as close to perpendicular as possible with trade-offs to be made with other constraints.

- For Options 1 and 2, reductions in overall route length of less than 5% are achieved by reducing the crossing angle over the Langeled pipeline;
- For Option 3, reductions in overall route length of less than 5% are achieved by reducing the crossing angle over the Langeled pipeline. This option also has a more congested approach into Easington and additional crossings over the Woolaston pipeline and umbilical (although these would not be as complex as the crossing over Langeled).
- For Option 4, reductions in overall route length of less than 7% are achieved by routing the pipeline directly over the known sandwave features which the Development is seeking to avoid. This option also has an additional crossing over the Woolaston pipeline and umbilical (although these would not be as complex as the crossing over Langeled); and
- Option 5 offers the largest reduction in pipeline length (~10%) but has the issues associated with Options 3 and 4.

The base case route option was selected for the Development as the majority of other options considered offered small reductions in pipeline length while involving reductions in the crossing angle over the Langeled pipeline, a greater number of crossings and/or a more congested route into Easington.

As a 28” pipeline (Section 2.5.1) has inherent stiffness necessitating long bend radii, it is not possible to avoid all the areas containing stony reefs or clay ridges. Where feature crossings are unavoidable, reasonable endeavours will be made to cross raised features such as clay ridges at their lowest point, and other feature types at points where impacts are minimised as far as reasonably practical. The route will be optimised within the survey corridor to minimise impact on these areas and ridges.

2.5.3.4 Pipeline Lay

The decision to concrete coat the 28” pipelines influenced subsequent decisions around pipeline lay given protection and stability requirements. Rock is the least preferred method of pipeline protection and design aims to avoid the requirement for rock protection e.g. via trenching. At this stage of design, contingency is required to mitigate scenarios which will be considered further during detailed design, reducing the worst case quantities of rock presented in this ES.

In the shallower, nearshore sections of the Teesside and the Humber pipelines, burial is required to mitigate high hydrodynamic loading and provide additional protection from vessel activity associated with other sea users. The Humber Pipeline will be laid into a deeper pre-cut trench to provide the necessary mitigation while accounting for coastal erosion and seabed lowering.

Sections of the Teesside Pipeline route cross a rocky section of seabed which has a very thin and intermittent sand layer. In these sections, as it is not practical to trench the pipeline and no pipeline embedment will occur, the pipeline will be surface laid and protected by rock (Section 3.2.5).

The remaining sections of the pipelines will be surface laid, except where partial trenching may be required to mitigate scour (Section 3.2.3.3) and prevent excessive exposure or burial during the operational phase of the Development.

2.6 Safety Zones

For oil and gas installations, under the Petroleum Act 1987 ('the 1987 Act') Section 21, safety zones are established automatically around all installations which project above the sea at any state of the tide. Under the Petroleum Act 1987 Section 22, the SoS may, by order, establish a 500 m safety zone around a subsea installation within designated waters.

Assuming that Health Safety and Environment (HSE) Operations Notice 54, Establishment of permanent safety zones for subsea installations applies to CCS activities, safety zones will be applied for under The Petroleum Act 1987 at the wellheads, manifolds and the SSIV locations. Any applications would be subject to consultation with interested parties[68].

A safety zone of 500 m will be in place around the jackup drill rig during drilling operations. Advisory safe passing distances will be in place around each installation and pipelay vessel during installation works.

2.7 Conclusion

The Development is part of a FOAK power and industrial CCS scheme and contributes to the abatement of carbon emissions from industrial sources on Teesside and Humber, which constitute almost 50% of the UK's industrial cluster CO_2 emissions (BEIS, 2019). Further, the Development provides a CO_2 transportation and storage to support the development of dispatchable power with carbon capture, to support the decarbonisation of the UK grid in tandem with increased electricity generation from renewable energy sources.

Following a store selection process (Section 2.2.1), the Endurance Store was selected based on available storage capacity, relatively low development costs, lower power demands and accrued industry experience of CO_2 injection into saline aquifers. The Store fulfils the attributes required for CO_2 geological storage in line with the CCS Directive enacted into UK law by the Energy Act 2008.

The options selected for the Development were arrived at through a holistic, documented technical and commercial concept selection process which sought to mitigate any potential impacts on sensitive receptors as much as practicable and did not result in a significant impact. A gated project development process, conformant with the applicable bp guidelines and standards, has been used during this process. As a result of the process, and as illustrated in Figure 2-8, the proposed Development infrastructure is intended to comprise:

- Two 28" CO_2 Export Pipelines from Teesside and Humber to the Endurance Store;
- A crossover co-mingling subsea manifold which combines the flows from the Teesside and Humber Pipelines and distributes it for injection into two wells at the Endurance Store;
- A four-slot subsea manifold which distributes CO_2 for injection into three wells at the Endurance Store;

[68] *bp intend to apply for safety zones at the wellheads, manifolds and SSIV locations. Engagement is ongoing with the Health and Safety Executive to confirm the application of the Petroleum Act 1987 to safety zones for subsea installations associated with CO_2 transportation and storage. To ensure assessment of the potential worst case within the ES, both scenarios are considered, i.e. safety zones in place, and safety zones not in place at the wellheads, manifolds and SSIV locations.*

- A subsea pig receiver[69] per manifold at the Endurance Store;
- One infield pipeline, up to 28" in diameter which runs between the two manifolds. This will be a maximum of 6 km in length;
- Five infield flowlines, up to 8" in diameter, which run from the manifolds to the injection wells. Each flowline will be a maximum of 3 km in length;
- Five CO_2 injection wells and one monitoring well;
- Six subsea trees, i.e. structures above each well that are used in well monitoring and control; and
- Control and communication cables;
    - One electric power and fibre-optic communications control cable running from Teesside to the subsea infrastructure at the Endurance Store; and
    - One electric power and fibre-optic communications control cable between the two manifolds and six cables from the manifolds to each of the six wells.

As presented in this chapter, there are outstanding decisions to be made. These include:

- Landfall installation methodology;
    - Teesside: HDD or direct pipe or microtunnel; and
    - Humber: HDD or direct pipe or microtunnel or microtunnel and cofferdam.
- Pipeline installation using anchored or DP vessel;
- Requirement for SSIV and (if required) the distance of the SSIV from shore, i.e. between 6 and 8 km from KP0. For the purposes of the ES, it is assumed that an SSIV will be installed on the Teesside Pipeline;
- Requirement for one power, control and hydraulics umbilical running from Teesside to the SSIV (the Teesside – SSIV cable).

These options will be taken forward as the Development moves into FEED and further design work is undertaken. This assessment adopts a precautionary approach and considers the design envelope parameters which are predicted to result in the greatest environmental impact, i.e. the 'realistic worst case scenario'. Given that the realistic worst case environmental impact scenario is based on the design option (or combination of options) that represents the greatest potential for change, confidence can be held that development of any alternative options within the design parameters will give rise to no worse effects than assessed in this impact assessment.

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[69] A structure that receives and holds the pipeline inspection gauge or tool (pig) following transit of the pig along the length of the pipeline. Pigging forms part of the inspection and maintenance programme of a pipeline

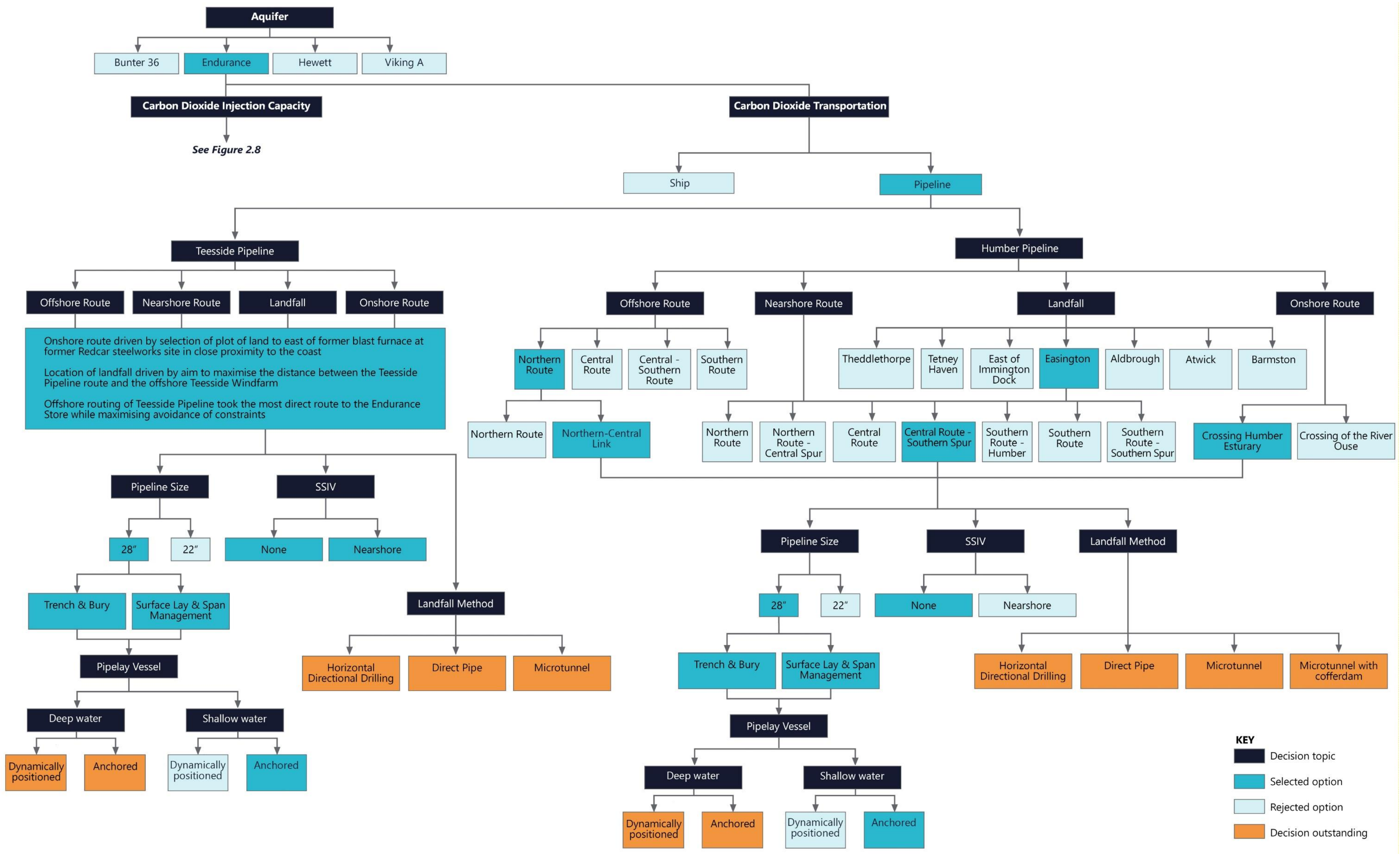

Figure 2-7 - Consideration of alternatives: Aquifer and CO_2 transportation

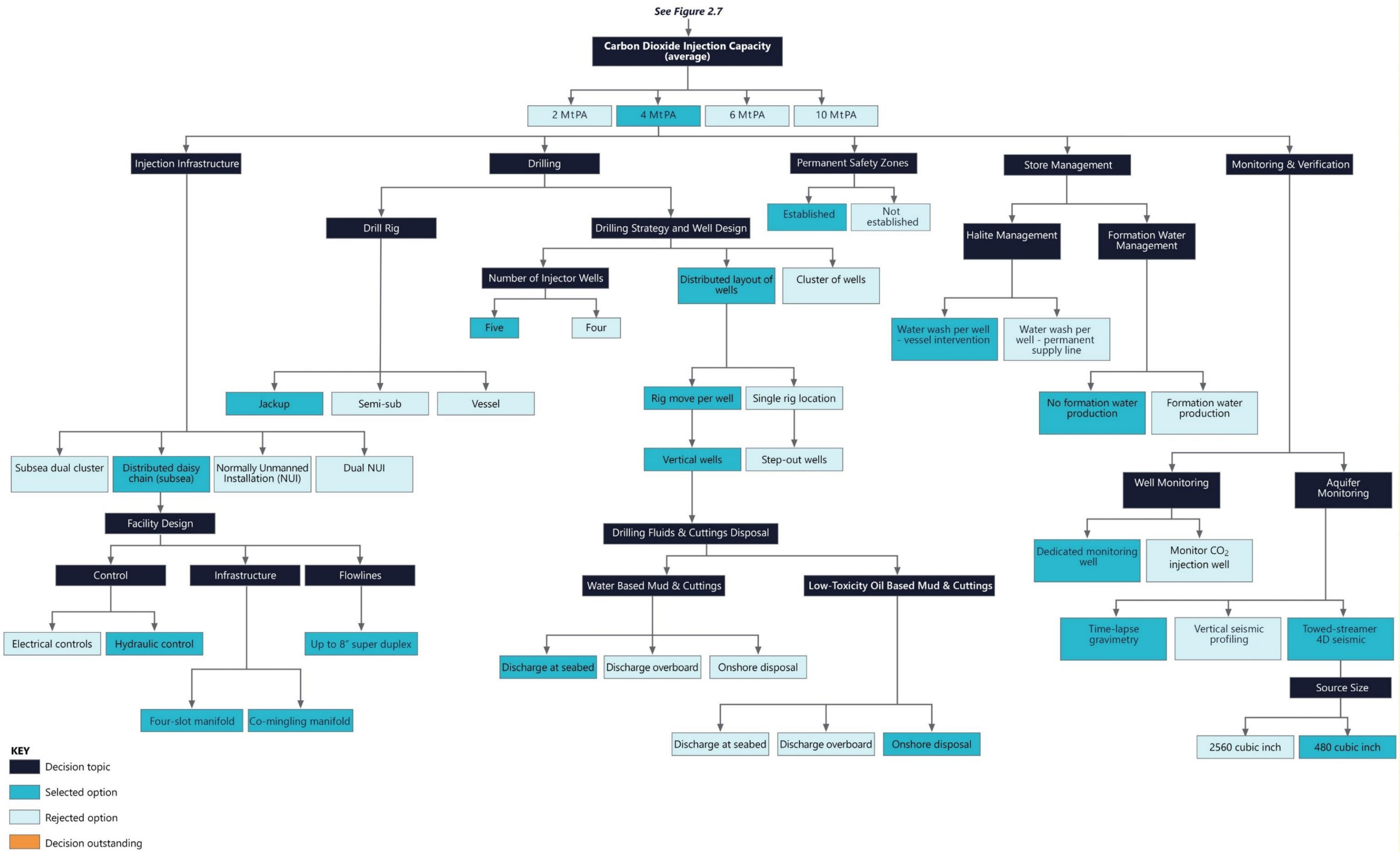

Figure 2-8 - Consideration of alternatives: CO_2 injection

3 PROJECT DESCRIPTION

3.1 Introduction

This Section presents an overview of the Development, one component of the proposed ECC strategic initiative that aims to deliver the UK's first zero carbon industrial cluster (Section 1.4). The ECC is intended to consist of a diverse mix of low-carbon projects including industrial carbon capture, low-carbon hydrogen production, negative emissions power, and power with carbon capture.

This ES encompasses offshore activity associated with the Development that is seaward of the MLWS boundary (Section 2.5.3.1). While the ES will focus on the impacts up to MLWS, it is good practice to reflect impacts up to Mean High Water Springs (MHWS) and therefore this ES includes discussion of relevant impacts up to MHWS. All work will be conducted in accordance with scope-specific permits obtained prior to activity commencing.

Conditioned and compressed CO_2 will be transported offshore via two new, concrete-coated CO_2 Export Pipelines of approximately 28" diameter that will direct the dense phase fluid[70] to the Endurance Store. These pipelines are referred to as the Teesside Pipeline and the Humber Pipeline respectively. The Endurance Store is a large and well-understood saline aquifer suitable for CO_2 storage, that was selected following consideration of several store options (Section 2.2.1). CO_2 from both pipelines will be combined and distributed for injection into the Store via well injection facilities on the seabed. Monitoring is planned of the injected CO_2, as will be outlined in the MP for the Endurance Store which is to be developed and agreed with the NSTA as part of the storage permitting process.

The proposed Development infrastructure is therefore intended to comprise:

- Two 28" CO_2 Export Pipelines from Teesside and Humber to the Endurance Store;
- A crossover co-mingling subsea manifold which combines the flows from the Teesside and Humber Pipelines and distributes it for injection into two wells at the Endurance Store;
- A four-slot subsea manifold which distributes CO_2 for injection into three wells at the Endurance Store;
- A subsea pig receiver[71] per manifold at the Endurance Store;
- One infield pipeline, up to 28" in diameter which runs between the two manifolds. This will be a maximum of 6 km in length;
- Five infield flowlines, up to 8" in diameter, which run from the manifolds to the injection wells. Each flowline will be a maximum of 3 km in length;
- Five CO_2 injection wells and one monitoring well;
- Six subsea trees, i.e. structures above each well that are used in well monitoring and control;

[70] *Dense phase means the CO_2 demonstrates properties of both liquid and gas. The dense phase has a viscosity similar to that of a gas, but a density closer to that of a liquid. The unique properties of this phase, are favourable for the transportation of CO_2 over long distances.*

[71] *A structure that receives and holds the pipeline inspection gauge or tool (pig) following transit of the pig along the length of the pipeline. Pigging forms part of the inspection and maintenance programme of a pipeline*

- An SSIV[72] on the Teesside Pipeline between 6 and 8 km of KP0 (assumed to be installed for the purposes of the ES); and
- Control and communication cables:
  - One electric power and fibre-optic communications control cable running from Teesside to the subsea infrastructure at the Endurance Store;
  - One electric power and fibre-optic communications control cable between the two manifolds and six cables from the manifolds to each of the six wells; and
  - One power, control and hydraulics umbilical running from Teesside to the SSIV (the Teesside - SSIV cable).

The subsea infrastructure allows for connection of up to two future injection wells however, any further development of the Store will be the subject of a separate impact assessment and ES.

3.1.1 Injection Profile and Pipeline Entry Specification

Based on the expected availability of the offshore and onshore systems and the volumes of CO_2 expected to be captured, the average injection rates[73] into the Endurance Store are expected to peak, and largely plateau from 2028 at around 5,881,000 m^3 per day (approximately 11,000 t per day and 4 MtPAa).

Each of the five CO_2 injector wells (EC01, EC02, EC03, EC04 and EC05) will inject at an average rate of 0.8 MtPAa for 25 years. It is expected that each injector will be capable to inject up to 1.5 MtPAi over the life of the store. For a peak instantaneous rate, it is assumed that four out of the five wells will inject up to 1.5 MtPAi, with one well spare (i.e. installed injection capacity of 6 MtPAi assuming one spare well).

Over the 25 years during which CO_2 is expected to be transported to and injected into the Endurance Store, Figure 3-1 and Table 3-1 show the predicted average rates. The Carbon Storage Development Plan submitted to the NSTA as part of the Storage Permit Application is consistent with the data in this ES, seeking to obtain consent for a total of 100 Mt CO_2 to be injected over the 25 years of operation.

[72] A valve that will close and isolate a particular pipeline or process in an emergency.

[73] Corresponds to the CO_2 volumes for expected captured volumes. Volumes are equal to a P90 storage capacity value, i.e. there is a 90% chance that the storage capacity is greater than 100 Mt (bp, 2021d).

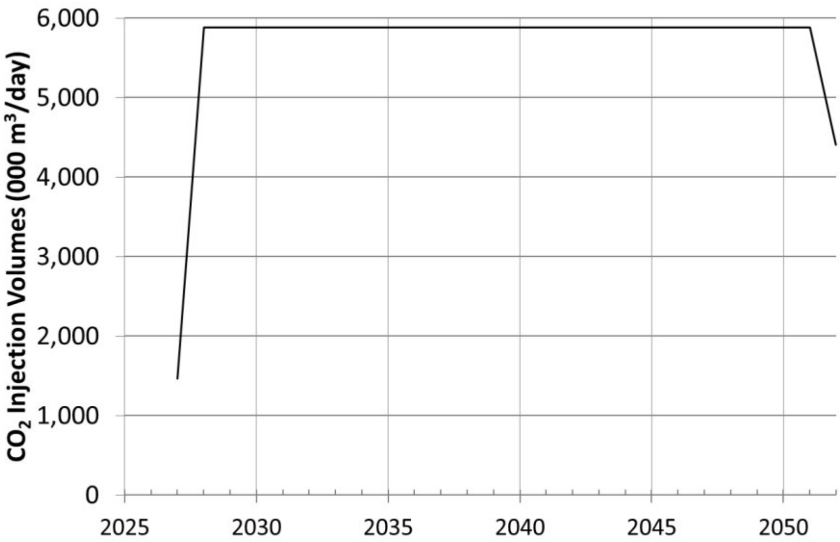

Figure 3-1 - Annual average injection rates

Table 3-1 - Annual average injection rate

Year	Annual average injection rate (1,000 m^3/day)[74]	Annual average injection rate (t/day)[75]
2027	1,470	2,740
2028	5,881	10,959
2029	5,881	10,959
2030	5,881	10,959
2031	5,881	10,959
2032	5,881	10,959
2033	5,881	10,959
2034	5,881	10,959
2035	5,881	10,959
2036	5,881	10,959
2037	5,881	10,959
2038	5,881	10,959
2039	5,881	10,959
2040	5,881	10,959
2041	5,881	10,959
2042	5,881	10,959
2043	5,881	10,959
2044	5,881	10,959
2045	5,881	10,959
2046	5,881	10,959
2047	5,881	10,959
2048	5,881	10,959
2049	5,881	10,959
2050	5,881	10,959
2051	5,881	10,959
2052	4,410	8,219

The CO_2 pipeline entry specification is presented in Table 3-1.

[74] *Conversion from million standard cubic feet (MMscf) to 1,000 m^3 used the calculation: (MMscf x 0.028316579) x 1,000.*
[75] *1 MtPA is equal to 51.918 million standard cubic feet per day (MMscfd).*

Table 3-2 - CO_2 pipeline entry specification

Component	Limit
Carbon Dioxide CO_2	≥ 96 mol%
Water H_2O	≤ 50 ppm mol
Hydrogen Sulphide H_2S	≤ 5 ppm mol
Carbon Monoxide CO	≤ 1000 ppm mol
Oxides of Nitrogen NOx	≤ 10 ppm mol
Oxides of Sulphur SOx	≤ 20 ppm mol
Combined non-condensables and light HCs (N_2, Ar, CH_4, C_2H_6)	≤ 4 mol%
Oxygen O_2	≤ 10 ppm mol
Hydrogen H_2	≤ 0.75 mol%
Glycols	≤1 ppm mol
Amines	≤ 1 ppm mol
Ammonia	≤ 10 ppm mol
Formaldehyde	≤ 20 ppm mol
Acetaldehyde	≤ 20 ppm mol
Mercury Hg	≤ 0.0025 ppm mol
Cadmium	≤ 0.005 ppm mol
Thalium	≤ 0.012 ppm mol
Methanol / cumulative methanol + ethanol	≤ 500 ppm mol
Ethanol	≤ 200 ppm mol
Particulates (particle size < 5 micron)	≤ 1 mg/Nm3
Heavy Hydrocarbon	Quantity which does not shift dew point below pure CO_2

3.1.2 Development Schedule

FEED[76] for the Development commenced in March 2022 and detailed design[77] is scheduled to commence Q2 2024.

A final investment decision for the Development is targeted for 2024. Subject to that decision, based on current schedule estimates, bp as operator of NEP, plans that preparatory works and landfall construction will commence in 2025 with installation of the pipelines and subsea infrastructure

[76] FEED typically describes the engineering required to support the investment decision to sanction a project and involves the production of process and engineering documentation that define the project requirements for subsequent detailed engineering, procurement and construction.

[77] Detailed design typically describes the engineering phase during which 2 and 3 dimensional models are produced, as are process diagrams and more refined cost estimates.

(including manifolds) and drilling of the wells into the Endurance Store expected to commence in 2026. CO_2 injection is anticipated from Q4 2027 and the operate phase is assumed to last for 25 years.

The preliminary, high-level schedule for execution of the Development is illustrated in Figure 3-2. This programme may change subject to revisions in DESNZ cluster sequencing timelines, detailed scheduling, fabrication times associated with key pieces of equipment and the availability of construction vessels.

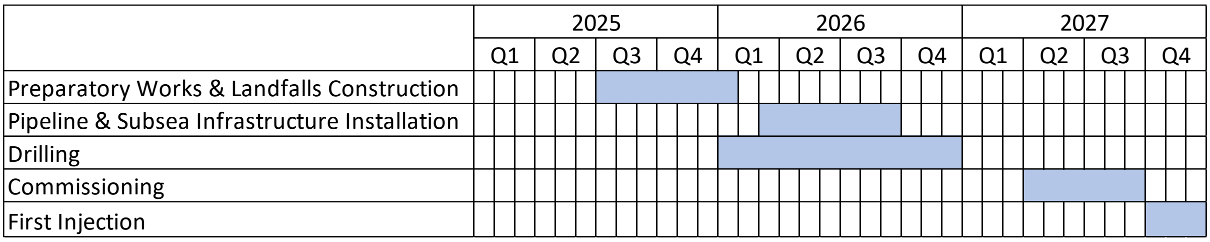

Figure 3-2 - Overview of Development's preliminary schedule

3.2 Pipelines, Flowlines, Cables and Subsea Infrastructure

The Teesside Pipeline will be approximately 143 km in length and the Humber Pipeline approximately 101 km in length[78]. Both will be coated with either Fusion Bonded Epoxy or 3-layer polyethylene/polypropylene and between 40 and 150 mm of concrete weight coating. Pipeline design pressure will be 236 bara[79] and the design temperature, 50°C. KP0 is located at the landfall tunnel entry point, i.e. above MLWS. MLWS occurs at KP0.9 on the Teesside Pipeline and KP0.4 on the Humber Pipeline, i.e. from MLWS, the Teesside Pipeline is approximately 142 km in length and the Humber Pipeline is approximately 100 km in length.

A pipeline protection study has been performed during the FEED stage of the design process and will be revisited during detailed design. The study assesses the proposed protection requirements of the new pipelines and associated tie-in spool pieces[80] against the risk of impact from dropped objects and fishing gear interaction. The study will be performed in accordance with DNV-RP-F107 for the dropped object impact assessment, and in accordance with DNV-RP-F111 for the fishing gear impact assessment.

This section provides an overview of the details of construction, installation, commissioning and operations of the pipelines and subsea infrastructure. It is structured to minimise duplication as follows:

- Teesside Pipeline: landfall and nearshore construction and installation;
- Humber Pipeline: landfall and nearshore construction and installation;
- Teesside and Humber Pipeline: seabed preparation, offshore pipeline lay, post-lay trenching, pipeline protection & pre-commissioning; and
- Subsea Infrastructure: installation and pre-commissioning of the manifolds, infield flowlines, pipeline and wellheads.

[78] From KP0.

[79] Bar-absolute, i.e. bars above atmospheric pressure + atmospheric pressure.

[80] Relatively short lengths of pipe that connect e.g. the pipeline to the subsea infrastructure.

The onshore (landward of MLWS) construction associated with the pipeline landfall construction methodology is assessed in detail within the NZT Project DCO and will be assessed within the Onshore Humber application (to be developed). Where necessary for completeness, a brief overview of the onshore activity associated with each landfall option is presented in the following sections.

3.2.1 Teesside Pipeline, Landfall and Nearshore

The Teesside Pipeline landfall is at Coatham Sands, to the southeast of the mouth of the River Tees.

3.2.1.1 Landfall

To install the landfall, there are three main potential options which will help the Development achieve a balance of safety, technical, environmental and commercial criteria. Options for the landfall include microtunnel, HDD or direct pipe (Figure 3-3), each of which is described below. Further engineering is required to select the optimum solution for the Teesside landfall. For the purposes of the ES, all options are presented and the worst case, from an environmental impact perspective, described and assessed in individual impact assessment chapters. For each option, worst case assumptions are made which will be refined, and reduced, during subsequent design.

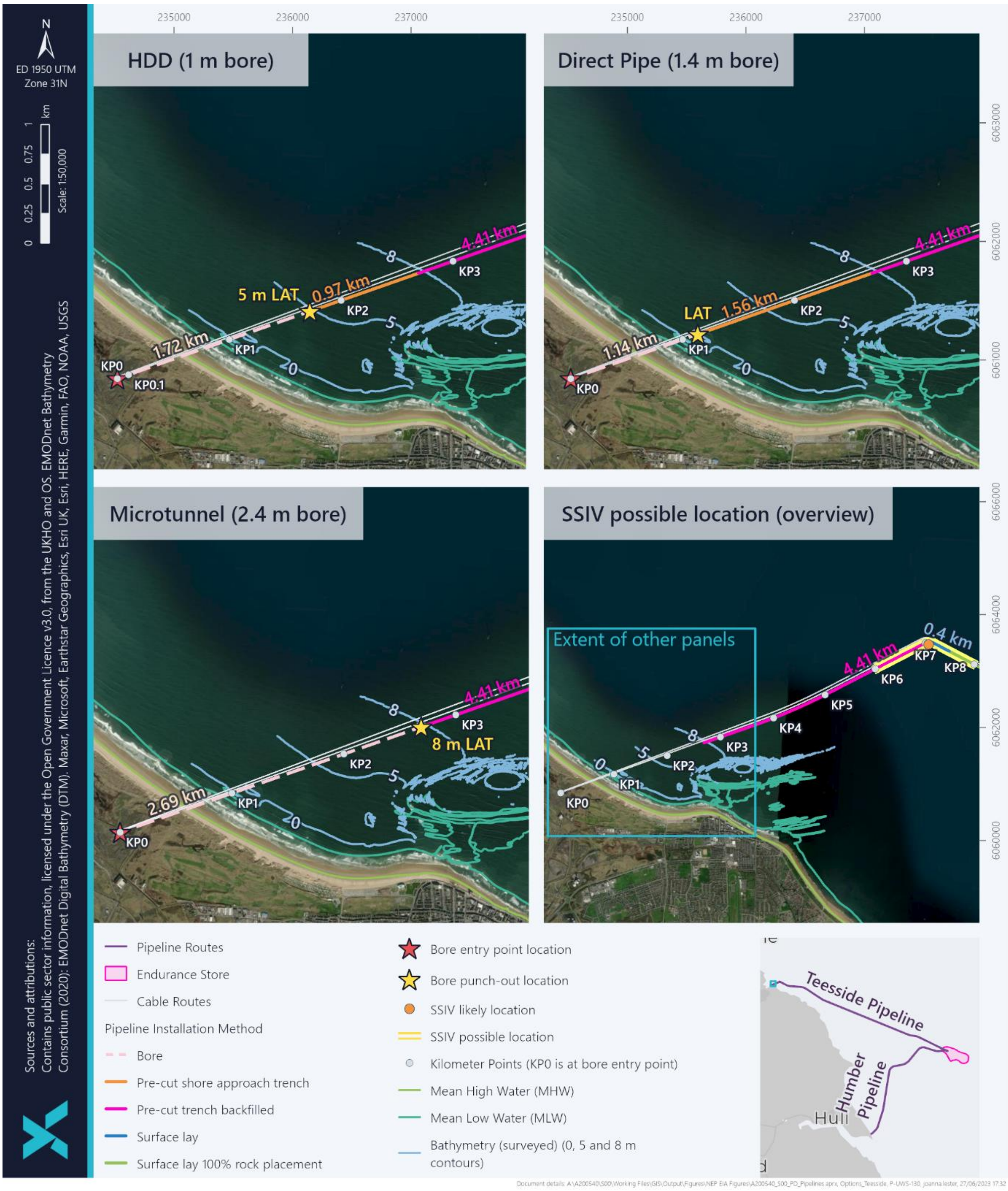

Figure 3-3 - Overview of three potential landfall options at Teesside and possible location of SSIV

In advance of executing the selected landfall option, surveying will be required to assess the as-found status of the landfall area (Section 3.2.6). The vessel requirements associated with these surveys are included in Table 3-22. Any boulders encountered would require to be moved in advance of landfall construction.

The jackup barge utilised in each option will typically be positioned on location using anchor handling vessels. The barge may have up to four legs penetrating the seabed, each of up to 1.8 m diameter. A support vessel will be in attendance for the duration the jackup barge is on location at the landfall, to provide safety and security support.

1. HDD entails drilling of a pilot hole along the proposed route. The pilot hole is subsequently enlarged to the target diameter via the use of a tool termed a reamer. Reaming is followed by “pullback” whereby the reamer is withdrawn to the entry point and the pipeline simultaneously installed (Figure 3-4). The process requires:

a) The following equipment:

- Drilling rig: up to two rigs may be utilised, located at both the entry point (onshore) and the punch-out location (offshore), i.e. the seabed exit location. The rigs drill simultaneously with gyroscopic and magnetic guidance systems used to align the two pilot holes (termed ‘intersect drill’);
- Jackup barge: vessel which supports the HDD drilling rig and counteract the HDD rigs forces for the diameter and length of pipe required. The jackup is likely to be in the order of 12 m above sea level to take account of deck thickness, maximum tides and maximum waves;
- Trestle structure and casing pipe: the trestles form a temporary structure to support the casing pipe (approximately 200 m long and 1.6 m diameter) between the seabed and the jackup barge (Figure 3-4). The casing pipe, a temporary structure installed using a piling hammer situated on the jackup barge, is used to support the hole during construction and help mitigate drilling fluid loss. Up to two rows of four piles may be required to form the trestle structure, with 10 m separation between the rows and 50 m separation between piles within a row. Each of the up to eight piles are anticipated to be up to 24 m long and up to 1.2 m in diameter with a required penetration depth of up to 8 m. Pile driving may take up to four hours per pile and up to eight hours for the casing pipe and is anticipated to be delivered via jackup barge, or similar equivalent method. The casing pipe is secured to the trestle structure.

b) Onshore, for a typical HDD application, a secure fenced compound of a minimum 50 m x 50 m will be required with level and stable terrain. The compound is required for welfare, offices, storage, mud labs, mud mixing, separation plant (including mud recycling units), HDD rig and workshops.

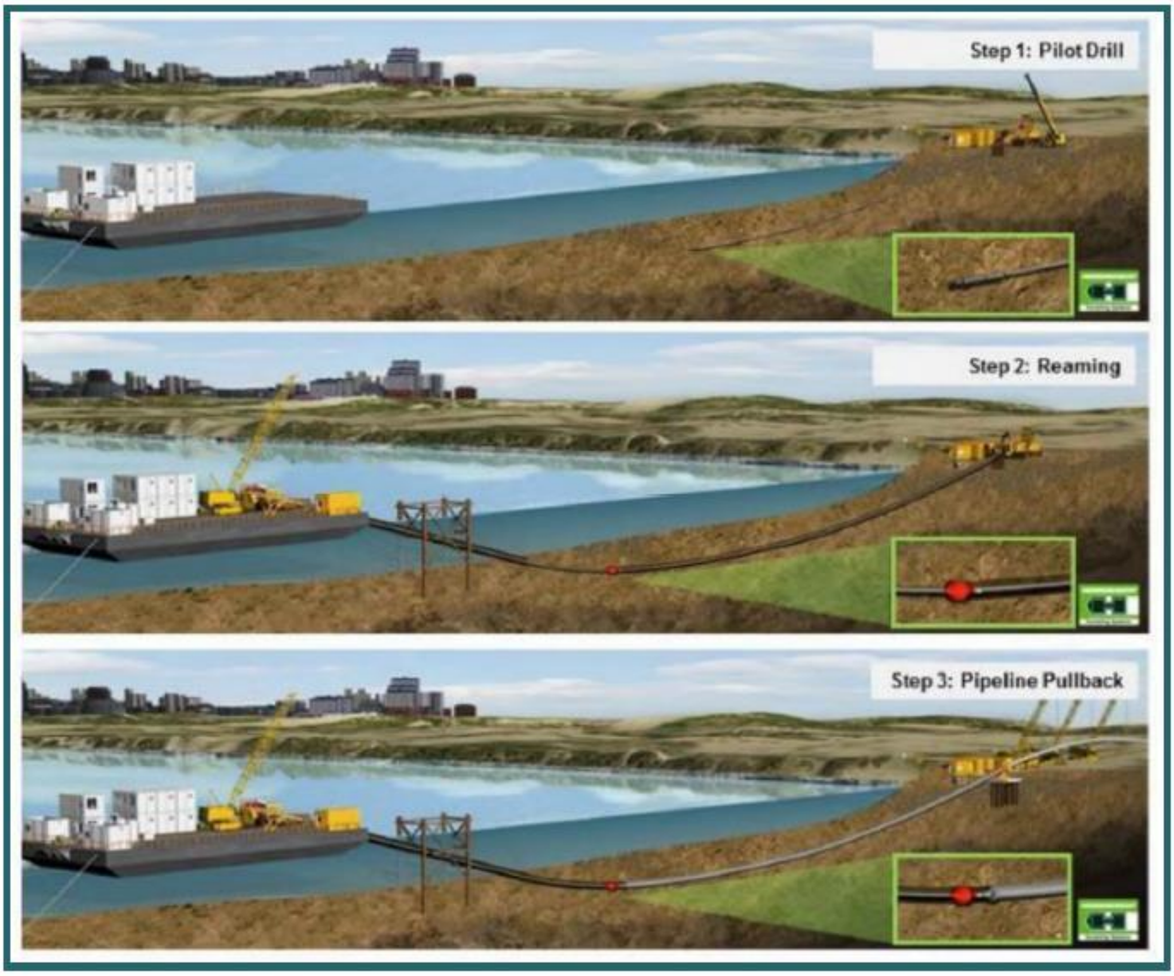

Figure 3-4 - HDD schematic showing the phases of pilot drill, reaming and pipeline and the temporary trestle structure required to support the casing pipe during reaming and pipeline pullback (image courtesy of Herrenknecht and SDL)

2. Microtunnel entails concrete segmental rings being driven through the geology by a jacking rig while controlled excavation using a micro Tunnel Boring Machine (mTBM) is undertaken at the face of the tunnel. The jacking rig is typically located within a shaft. The process requires:

a) The following equipment:

- Shafts: microtunnels are typically launched and received from shafts with the size of the shaft influenced by the size of the jacking rig;
- Jacking rig and mTBM;
- Jackup barge: used to retrieve the mTBM offshore, at the punch-out location. This involves works on the seabed, typically the construction of a reception pit; and
- Reception pit: located at the punch-out location to enable tie-in of the pipeline. May require temporary structural works.

b) onshore: mTBM are typically launched and received from temporary pits or shafts. A separation plant is required to remove the excavated material, such as clay and sand, from the bentonite slurry to allow the soil to be dried and the slurry to be used again in excavation during the construction process. An area of ground is also required for temporary spoil storage.

Figure 3-5 - Microtunnelling schematic showing shaft and microtunnel boring machine (image courtesy of Herrenknecht and SDL)

3. Direct pipe is a combination of HDD and microtunnelling with simultaneous excavation of the tunnel and installation of the pipeline. The process requires:

a) The following equipment:

- Launch pit: a temporary excavation which may require temporary works/sheet piles or similar, dependant upon depth and geology. Usually, the floor of the excavation is graded to provide the correct entry angle for a mTBM, and to allow for insertion of pipe string, which can be of varying length, dependent upon site space constraints. The mTBM is typically launched from this pit onshore;
- mTBM: typically launched from onshore launch pit;
- Pipe thruster: located within the launch pit, consists of hydraulically operated pipe clamp. The clamp grips the pipe and hydraulic rams push the pipe forward at the same time that the mTBM is excavating at the head of the casing pipe string. The casing forms the permanent ducting through which the pipeline is installed at a later date, with the annulus between the casing and product pipe grouted up;
- Jackup barge: Retrieval of the mTBM at the punch-out location after it is detached from the pipeline. This involves works on the seabed; and

The mTBM would punch-out on to the seabed before being recovered by a barge mounted crane. The direct pipe would then be sealed by a bespoke flange plate before the direct pipe is retracted back to the target level for the permanent installation.

b) Onshore: A compound, typically approximately 100 m by 100 m in size, is required to site a variety of units and containers which contains welfare, offices, storage, mud labs, mud mixing, mud recycling units, control unit and workshops. The drilling fluids and cuttings are pumped back along the casing through pipework with cleaned water pumped to the cutting head and the cuttings removed in the return flow and then processed through shakers and screeners located at the shaft head.

Independent of the landfall solution utilised, drilling is undertaken using a viscous drilling fluid that is typically a mixture of water and bentonite. Bentonite is a non-toxic clay that is routinely used in farming practices and is a PLONOR[81] substance. The drilling fluid is continuously pumped to the cutting head or drill bit to facilitate the removal of rock cuttings, stabilise the tunnel, cool the cutting head, and lubricate the passage of the pipeline/lining through the well bore. Drilling fluid will be recycled as far as reasonably practical by separating the drill cuttings which the drilling fluid recovers from the cutting head, allowing the cleaned drilling fluid to be reused in a closed drilling fluid cycle. This reduces the use of raw materials (in particular water and bentonite) and reduces the time taken for the drilling process to be completed. Drilling fluids are not discharged offshore. In relation to the Direct pipe solution, as the cutter head approaches the exit point, the drilling fluid is replaced with clean water to eliminate drilling fluid releases. As noted above, HDD activities offshore will require a carrier pipe to be installed between the exit point on the seabed and the offshore drill rig positioned on the jackup barge. The drill and fluids are controlled by a continuous casing from the jackup barge to a depth within the seabed that shall be designed to mitigate the risk of loss of fluid.

For operations involving drilling fluid, there is a risk that soils of higher permeability can pose an increased risk of drill fluid release out of the bore (fluid loss to the rock formation) and pathways to the surface (break-out). Microtunnel and direct pipe techniques are less susceptible to break-out events due to the lower pressure of drilling fluid. In the case of an intersection HDD drill there should be no surface breakout of fluid, and assuming the intersection point is close to the middle of the crossing, there should be limited volumes of drilling fluid lost to the formation.

Key parameters of each option are summarised in Table 3-2 and considered further in each impact assessment chapter.

[81] PLONOR chemicals are those which pose little or no risk to the environment according to OSPAR, i.e. the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North East Atlantic.

Table 3-3 - Teesside landfall solutions key parameters

Trenchless parameters	Vessel requirements	Seabed footprint
(1) HDD		
Length of bore: 1,720 m Bore diameter: 1.0 m Punch-out location: 5 m LAT[82], KP1.8	Jackup Barge: anchored up to 12 months Support Vessel: up to 12 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Pre- cut trench: punch-out to 8 m Lowest Astronomical Tide (LAT) (KP2.7, distance of 970 m) Within area of up to 800 m x 800 m • Trestle structure (8 piles x 1.2 m diameter) • Over-excavated trench 10 x 25 m • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
(2) Microtunnel		
Length of bore: 2,690 m Bore diameter: 2.4 m Punch-out location: 8 m LAT, KP2.7	Jackup Barge: anchored up to 12 months Support Vessel: up to 12 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Within area of up to 800 m x 800 m • Over-excavated trench: 10 x 25 m • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
(3) Direct pipe		
Length of bore: 1,135 m Bore diameter: 1.4 m Punch-out location: LAT, KP1.1	Jackup Barge: anchored up to 3 months Support Vessel: up to 3 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Pre- cut trench: punch-out to 8 m LAT (KP2.7, distance of 1,560 m) Within area of up to 800 m x 800 m • Over-excavated trench 10 x 25 m • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method

[82] *At Teesside: MLWS @ -2.7 m ODN, LAT @ -3.6 m ODN. Throughout this document, LAT values seaward of LAT are quoted as positive.*

Each solution would 'punch-out' at the locations indicated in Table 3-2. Independent of the landfall solution utilised, there will need to be a smooth transition profile at the seabed for the pipeline emerging from the tunnel. This will be achieved via the use of an over-excavated trench (taking more seabed than needed for the pipeline). The dimensions and location of this trench will be determined in detailed design following selection of the landfall solution.

Following punch-out, up to 15 x 2 t rock bags[83] may be required to temporarily protect the punch-out location. These would be recovered and returned onshore following pipeline installation.

Installation of the pipeline between onshore and the punch-out may be from sea to land or land to sea. If from sea to land, this would involve a "pulled" installation technique in which the length of pipeline to be installed would be floated out to sea in full or installed in sections from the pipelay vessel or jackup barge. If from land to sea, this would involve a "pushed" installation technique in which the length of pipeline to be installed would be pushed from land until it reaches the punch-out location. The final option will be selected following detailed engineering.

For the direct pipe and HDD options, prior to shallow water pipelay, a pre-cut shore approach trench would be constructed from the punch-out location to 8 m LAT (KP2.7). Microtunnel punch-out occurs at 8 m LAT and therefore would not require this. The trench dimensions in the landfall region take into account the erosion of the seabed that will occur in the area over the design life of the pipeline and minimise any risk that the pipeline will be uncovered in the long-term.

The pre-cut shore approach trench would be constructed from the jackup barge using a BHD or equivalent (Figure 3-6). Due to the large potential cutting force of the BHD it is capable of excavating/dredging a wide range of materials. In the event that the BHD or equivalent cannot create a pre-lay trench due to the water depth or soils, some of the nearshore pipeline may be post-lay trenched using a plough.

Figure 3-6 - Backhoe dredger

[83] Similar to gabions but constrained by a rope basket rather than a wire cage, thus being more compliant to the substrate.

The dimensions of the pre-cut shore approach trench will vary with the sediments encountered; indicative trench dimensions are as follows (Figure 3-7):

- Trench width (bottom): 4.0 m;
- Trench depth: 3 m; and
- Trench width (top): 22 m.

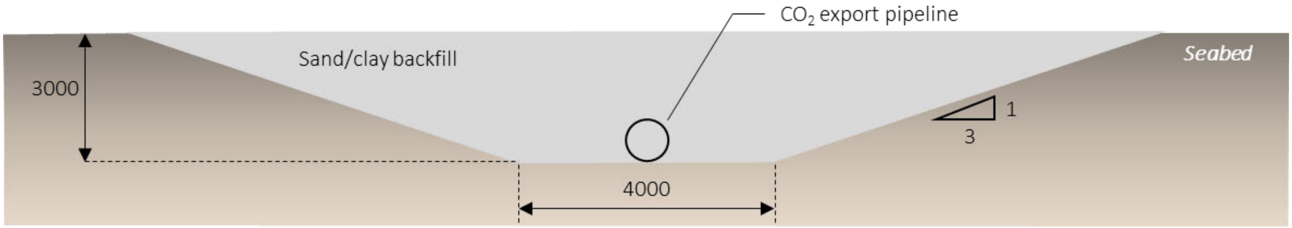

Figure 3-7 - Illustration of likely pre-cut trench (in mm)

Installation of the pipeline in the region between the trenchless exit point and 8 m LAT (KP2.7), may be undertaken by the pipelay vessel, with the pipe floated into position in shallower water.

3.2.1.2 Nearshore Region

There is an existing OWF (Teesside OWF) to the northwest of the pipeline route and pipelines to the south (CATS trunkline and the Breagh pipelines and cable, Table 3-5). There are also rock outcrops south of the existing pipelines. The shore approach route is constrained between these facilities and features, and as such a central corridor has been selected between them. The proposed corridor centreline lies approximately 100 m from the existing pipelines and approximately 100 m from the export cable corridor associated with Teesside OWF. Final routeing shall be informed by a range of technical, engineering, commercial and environmental factors, including detailed bathymetry and identification of existing pipelines/cables within the shore approach area. Engagement with 3rd party asset owners is underway already and proximity agreements (and where required crossing agreements) will be sought with relevant parties.

In the nearshore section, from 8 m LAT (KP2.7) to KP7.1, the pipeline will not be stable in the temporary installed condition due to hydrodynamic forces and seabed conditions, so it is proposed to install the pipelines in a pre-cut trench. Pipeline burial is required to mitigate high hydrodynamic loading and provide additional protection from vessel activity associated with other sea users.

The trench will be excavated using a BHD, CSD or a TSHD, or equivalent (Figure 3-8). A TSHD will also be used to maintain the pre-cut trench, as required. Both the TSHD and the CSD will be DP vessels and will not require planned anchoring during the routine completion of these activities. Should post lay trenching be required, a plough and backfill will be utilised.

(a) (b)

Figure 3-8 - (a) Cutter suction dredger (b) Trailing suction hopper dredger

The dimensions of the pre-cut trench will vary with the sediments encountered; indicative dimensions to reach a target burial depth of 1.5 m are as shown in Figure 3-7. It is expected that the pre-cut trench will immediately start to backfill with loose material (sand) transported by wave/current action; the speed of infill will be monitored throughout the operations prior to laying the pipeline. Maintenance of trench integrity e.g. depth and sides will be required immediately prior to pipeline installation. This will be achieved by use of the TSHD.

Once the nearshore section of the pipeline has been laid, surveyed and approved for backfill (Section 3.2.4), the BHD will move stored spoil to infill the trench. In the event of sediment erosion leading to a shortfall in backfill material, the TSHD will collect any shortfall from a licenced dredging site. As the nearshore section will be the first section to be backfilled and the soils will be clays, it is anticipated that there will be limited spoil loss prior to backfilling.

3.2.1.3 SSIV

For purposes of this ES, it is assumed an SSIV will be installed on the Teesside Pipeline to enable targeted isolation of the onshore/nearshore section of the pipeline in the unlikely event of a significant release of CO_2 from the pipeline. The SSIV will require a protective structure and will be fishing friendly. The design and location of the SSIV and associated protective structure are yet to be finalised, however a preliminary estimate of the SSIV structure dimensions are 16 m long x 8 m high[84] x 9 m width to be located within 6 and 8 km of KP0. The SSIV has a preliminary estimated weight in air of 350 t. The pipeline will be connected to the SSIV by flanged spool-pieces installed by divers from a dive support vessel (DSV) or by a Remotely Operated Vehicle (ROV) (see Section 3.2.9 for Control and Communication).

SSIV installation will occur from a lift barge. The SSIV and associated protective structure may be installed using the routine installation method of piling. Four piles will be used to anchor each structure. The piles are anticipated to be 610 mm in diameter and 28 m long, with a penetration depth of 21 m. Pile driving is expected to take one hour per pile and is anticipated to be delivered via jackup

[84] *The SSIV is likely to be 6.5 m high but to ensure a "worst case" assessment, a maximum height of up to 8 m is assumed.*

barge, or similar method. Two mudmats may be required for stability of the structure, each of 8 m length x 6.5 m width.

A high risk of scour along with considerable magnitude of scour depths has been predicted for the SSIV. For the purposes of the ES, it is assumed that rock placement will be required to mitigate scour risk with geotextile laid beneath the rock to separate the rock from the seabed sediment. The estimated rock requirement is 786 t (328 m^3). The geotextile will extend 7 m from each edge of the SSIV.

Figure 3-9 shows a typical SSIV structure.

Figure 3-9 - Typical SSIV structure, analogous to that to be installed on the Teesside Pipeline

3.2.2 Humber Pipeline, Landfall and Nearshore

The Humber Pipeline landfall is in the Easington area, north of the Perenco Dimlington terminal. This is the location originally approved for the Tolmount pipeline landfall prior to its re-routeing and subsequent landfall further south into Easington terminal. The Tolmount pipeline was installed in 2020 to transport gas from Harbour Energy's Humber Gathering System (HGS) Tolmount platform to the Easington terminal.

3.2.2.1 Landfall

The proposed seaward extent of the landfall area lies approximately 650 m offshore from MLWS in a water depth of minimum 8 m LAT[85] (KP1.0). Evidence, based on previous works in this area, indicates that seabed sediments are highly mobile (ERYC, 2019). The landfall is in an area of active coastal regression and associated seabed lowering. The erosion of the coastline is not a gradual process and is generally controlled by meteorological and oceanographic processes which result in changes to the cliffs, beach and seabed. The cliffs are indicated to be retreating at around 1.5 m to 3.0 m/year. The clay seabed at the beach and nearshore is lowering at a rate of between 0.03 m and 0.21 m/year.

One of four options (Figure 3-10) will be utilised to fulfil the project requirement of achieving a safe solution which minimises environmental impact. These include HDD, direct pipe, microtunnel or microtunnel and cofferdam. Table 3-4 provides a summary of the landfall options under consideration

[85] This depth has been chosen to maximise the choice of potential Engineering, Procurement, Construction and Installation vessels that can perform the pipe insertion.

at Humber: otherwise this section only presents information where the proposed Humber landfall options differs from those presented for the Teesside landfall in Section 3.2.1.1.

Figure 3-10 - Overview of four potential landfall options at Humber

1. HDD: The solution is as described for the Teesside landfall but with a requirement for the top of the pipeline tunnel to be terminated at a depth of at least 6 m below seabed to protect the pipeline from seabed erosional forces and long-term seabed lowering. FEED studies have identified tunnel stability as a potential issue associated with the HDD solution at Humber and therefore the other solutions presented below continue to be developed in parallel with HDD.

2. Direct pipe: The solution is as described for the Teesside landfall

3. Microtunnel: The mTBM is launched from the base of a vertical shaft to drill a tunnel beneath the cliffs. As the mTBM cuts the ground, the whole assembly is jacked forwards by hydraulic rams located within the shaft with pre-cast segmental concrete pipe attached and jacked in behind as the tunnel progresses. The arisings generated by the mTBM are then passed through a crushing cone and removed to the surface through a closed slurry circuit within the tunnel. Clean water is pumped to the face and the rock cuttings pumped back to the surface and processed through shakers and screeners located at the surface prior to the cleaned water being pumped back to the cutting head. The casing forms the permanent ducting through which the pipeline will be installed, with grout taking up the annulus between the casing and pipeline.

The offshore exit point (over-excavated trench) will be into a pre-cut trench that is maintained to keep it free of silt and sand accumulations. To protect the pipeline from seabed erosional forces and long-term seabed lowering the top of the pipeline tunnel must be terminated at a depth of 5.70 m below seabed (30-year design life) to top of casing.

The offshore pit will allow recovery of the mTBM, which would be by crane from a barge and assisted by divers.

Onshore: The compound is required to site a variety of units and containers which contain welfare, offices, storage, mud recycling units, control unit and workshops as well as a suitable area for a concrete pipe laydown. To launch the mTBM, a vertical precast caisson shaft would need to be excavated through very stiff to hard clay behind the cliff-line by combination of excavation and jacking. The shaft will house the mTBM jacking frame and its final diameter will depend on the design diameter of the tunnel to allow the running of slurry and water pipes as well as allow the installation of a suitably sized mTBM and jacking frame.

4. Microtunnel with cofferdam: This method, which has been adopted by other pipeline projects that have made landfall along the Dimlington/Easington coast, is an option being maintained by the Development while further design is undertaken.

A vertical shaft and tunnel is required, as described for the microtunnel option. The pipeline is routed across the beach in a trench, construction of which would require vehicle access to the foreshore, necessitating works to create a temporary roadway from the existing public road network to the foreshore.

The exit point of mTBM would be a cofferdam sheet pile reception pit located on the foreshore at approximately the MHWS boundary. This would allow for recovery of the mTBM from the foreshore. A combination of cofferdam trenching across the intertidal beach area, and winched plough, mounted on a working platform on the beach, with a subsequent pre-cut trench would be used to form a trenched installation out to 8 m LAT (KP1.0, Figure 3-11).

The cofferdam comprises two rows of sheet piles, approximately 7 m apart, from the low water mark to the seaward end of the work platform, a distance of approximately 100 m. The steel sheet piles of the cofferdams will be driven using one or more conventional pile driving rigs (a hydraulic vibratory hammer mounted on a tracked crawler vehicle) as tides permit. It is anticipated that due to the high undrained shear strength of the clay present, pre-augering to loosen the ground over the full pile depth may be required prior to main pile driving operations. Pre-augering will be undertaken using a continuous flight auger rig. Following on from pre-augering at each location, the main pile driving operations will be undertaken with hydraulic vibratory piling hammers.

Upon completion of the piling works the area inside of the working platform will be built up to approximately +4.0 m Ordnance Datum Newlyn (ODN) by re-using the sands and gravels excavated during cofferdam construction.

After the pipeline has been installed, it will be buried using the excavated material and the beach will be reinstated to pre-construction condition as far as reasonably practical.

Onshore: Infrastructure above, and set back from, the cliff would be as per the microtunnel, described above. Infrastructure on the beach would include a number of cabins and stores containers to support personnel working on the beach, plus storage of piles and plant. The beach works site will be cordoned off from the general public for health and safety grounds. A passage will be maintained to allow members of public access along the length of the beach during construction works for as much of the construction period as reasonably practical.

A temporary access road from the top of the cliffs down to the beach will be required for this option to allow equipment to be transported to the beach area. The cliffs will be reinstated as far as reasonably practical on completion.

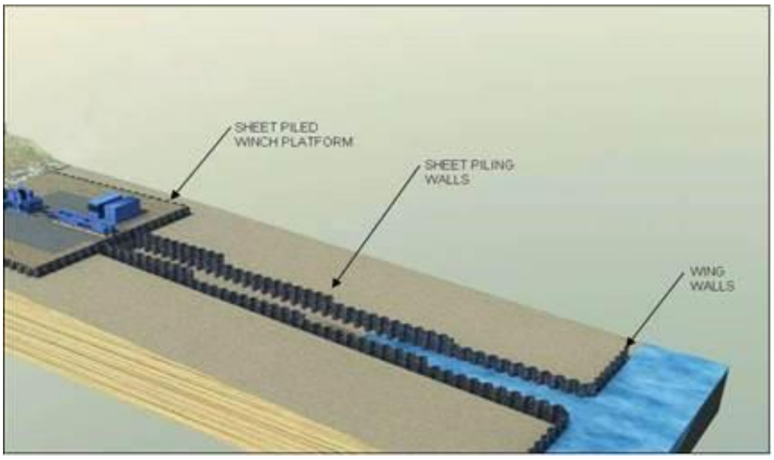

Figure 3-11 - Example of beach crossing cofferdam and working platform

The HDD punch-out location occurs at 8 m LAT (KP1.0) and therefore would not require a pre-cut shore approach trench. For the other landfall options, prior to shallow water pipelay, a pre-cut shore approach trench would be constructed to 8 m LAT.

The dimensions of the pre-cut shore approach trench will vary with the sediments encountered along the route. Further, as the Humber coast is highly dynamic, sediment levels can vary significantly from year to year. Before works commence, surveys will be conducted to assess sediment depths. It is anticipated the pre-cut shore approach trench bottom will be 4.0 m wide and the trench depth up to 8 m depth, resulting in a top of trench width of 52 m.

Key parameters of each option are summarised in Table 3-4 and considered further in each impact assessment chapter.

Table 3-4 - Humber landfall options key parameters

Trenchless parameters	Vessel requirements	Seabed footprint
(1) HDD		
Length of bore: 1,000 m Bore diameter: 1.0 m Punch-out location: 8 m LAT[86] (KP1.0)	Jackup Barge: anchored up to 12 months Support Vessel: up to 12 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Within area of up to 800 m x 800 m: • Trestles (8 piles x 1.2 m diameter). • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
(2) Direct pipe		
Length of bore: 690 m Bore diameter: 1.4 m Punch-out location: 4 m LAT (KP0.7)	Jackup Barge: anchored up to 6 months Support Vessel: up to 6 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Pre- cut trench: punch-out to 8 m LAT (300 m) Within area of up to 800 m x 800 m: • Over-excavated trench 10 x 25 m • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
(3) Microtunnel		
Length of bore: 280 m Bore diameter: 1.8 m* Vertical shaft diameter: 7 m** Punch-out location: LAT (KP0.4)	Jackup Barge: anchored up to 6 months Support Vessel: up to 6 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Pre-cut trench: punch-out to 8 m LAT (610 m) Within area of up to 800 m x 800 m: • Over-excavated trench 10 x 25 m • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
(4) Microtunnel with cofferdam		
Length of bore: 160 m Bore diameter: 1.5 m* Vertical shaft diameter: 7 m** Punch-out location: MHWS (KP0.2)	Jackup Barge: anchored up to 6 months Support Vessel: up to 6 months Pipelay Vessel: up to 3 months Dive Support Vessel: up to 3 months	Beach access route: 6 x 400 m Work platform: 40 x 25 m Cofferdam: 100 m x 7 m Pre-cut trench: cofferdam to 8 m LAT (730 m) Within area of up to 800 m x 800 m: • Jackup Barge legs • Pipelay Vessel anchor spread • Rock bags (temporary protection) or similar equivalent method
* tunnel; ** vertical precast caisson shaft of up to 39 m depth required to enable launch of machine onshore		

[86] *At Humber: MLWS @ -1.95m ODN; LAT @ -3.6m ODN.*

3.2.2.2 Nearshore Region

This section only presents information where the proposed activity in the Humber nearshore region differs from that presented for the Teesside nearshore region in Section 3.2.1.2.

From 8 m LAT (KP1.0) to KP16.3, the pipeline will not be stable in the temporary installed condition due to hydrodynamic forces and seabed conditions, so it is proposed to install the pipeline in a pre-cut trench which would be backfilled.

Subject to pre-construction survey works to assess sediment depths, it is anticipated that the trench between 8 m LAT (KP1.0) and KP2 will be 8 m deep with a trench bottom of 4 m width and top of trench width of 52 m. From KP2 to KP16.3, it is anticipated that the trench will be 3 m deep with a trench bottom width of 4 m and top of trench width of 22 m.

3.2.3 Seabed Preparation

To prepare for pipeline installation, a range of activity is required.

3.2.3.1 UXO Clearance

A UXO survey will be undertaken to identify any UXO that may need to be avoided by minor re-routeing of the pipelines. Based on an initial desk based UXO assessment it is assumed that it will be possible to avoid any UXO encountered. Should any further mitigation be required, such as clearance or detonation, this would be subject to separate assessment and applications.

3.2.3.2 Boulder Clearance

Boulders along each pipeline route that are large enough to hinder pipeline installation must be moved a sufficient distance in advance of construction activities and out of the installation corridor. A SCAR plough (Figure 3-12) is likely to be used, although this will be further assessed by the installation contractor. The maximum width of the corridor created by the SCAR plough is likely to be 30 m and the boulders moved by the plough are anticipated to end up within a 5 m wide strip either side of the 30 m corridor.

Figure 3-12 - SCAR plough

3.2.3.3 Seabed Sweeping and Trenching for Scour Protection

As is routine for pipelay operations in areas of seabed waves and ridges underlain by stiff clay, the seabed will require some sweeping prior to installation of each pipeline. This provides the relatively flat seabed surface that is typically required for installation and mitigate against sandwave migration which may otherwise lead to pipeline exposure and/or free spans, causing stresses and compromising pipeline integrity. Detailed design will specifically identify the areas requiring sweeping, while seeking to minimise this activity as far as reasonably practicable. For the purposes of the ES it is conservatively assumed that sweeping of a 30 m corridor will be required in the following locations prior to pipelay (for control and communication see Section 3.2.9):

- From KP115 to the co-mingling manifold on Teesside Pipeline;
- From KP60 to the co-mingling manifold on Humber Pipeline;
- Along the infield pipeline; and
- Along the infield flowlines.

Scour, a widely occurring phenomenon, results when sediment moves from around an installed pipeline as a result of wave or current action. Scour carves out gaps between the pipeline and the seabed and may generate free spans, compromising pipeline integrity.

A shallow trench up to 1 m deep with a 4 m wide base and 1:3 side slope may be required to mitigate scour:

- From KP90 to the co-mingling manifold on the Teesside Pipeline;
- From KP60 to the co-mingling manifold on the Humber Pipeline; and
- Along the infield pipeline, a length of 6 km.

Trenching for scour mitigation may be conducted pre-lay or post-lay. No trench backfilling is required for scour mitigation.

A CSD, BHD, Grab Dredger, or similar, will be used for sweeping and trenching operations to cut through ridges with predicted stiff clays whereas for softer soils, a mass flow excavator (MFE) or a TSHD (Figure 3-8) will be capable of levelling the seabed and creating a trench. As sandwaves are likely to reform, either the operation will be carried out shortly before the pipelay operations or maintenance sweeping by the TSHD will be required to maintain the corridor required for pipeline installation.

Spoil generated may be transferred into split hopper barges positioned alongside the CSD and transported to offshore storage sites licenced for the Development. If sweeping is conducted by the TSHD, once the hopper is full, the vessel must halt operations and empty it at the licenced storage site. If the work is conducted by a MFE the spoil will disperse locally.

Both the TSHD and the CSD will be DP vessels and will not require anchoring during seabed sweeping.

Storage sites have not yet been identified and their exact location will be confirmed during detailed design. It is planned that the storage sites will be as close to the pipeline route as reasonably practical, that they will be outwith Runswick Bay MCZ (Teesside Pipeline) and the Holderness Offshore and Inshore MCZs (Humber Pipeline), and that – where reasonably practical – the sites will be in an area that has previously been subjected to construction disruption. Identification and use of the sites will be subject to future stakeholder consultation under the relevant regulatory regime.

3.2.3.4 Pipeline Crossings

The Teesside Pipeline (and the Teesside – Store cable, Section 3.2.9) will cross the infrastructure listed within Table 3-5. The Humber Pipeline route will cross the infrastructure listed within Table 3-6. A combination of concrete mattresses and/or rock will be installed at the crossing locations prior to laying activities with a view towards achieving minimum separation to the existing infrastructure and to avoid point loads[87]. This will be covered by protection material (rock) following lay and therefore the total footprint of mattresses at crossings are not included within the seabed footprint of the Development[88]. According to preliminary information and surveys, all crossed pipelines and cables are buried with the exception of the Langeled pipeline which is surface laid. It is noted that some pipelines (Breagh) appear buried on bathymetry survey at proposed crossing location, although areas of intermittent exposure are visible nearby.

[87] *Load applied at a specific point rather than being distributed along a section of e.g. pipeline.*

[88] *A conservative estimate has been made of the seabed footprint of concrete mattresses which may protrude beyond the post-lay rock.*

Table 3-5 - Teesside Pipeline and Teesside – Store cable crossings

	Diameter	Service
Everest	36″	Gas
Breagh	20″	Gas
Breagh	3″	MEG
Breagh	Unknown	Fibre Optic Cable
Fikspos/Cantat	Unknown	Disused cable
Pangea North	Unknown	Active cable
Dogger Bank C, Sofia Offshore Windfarm	Unknown	Windfarm power export cable (future)
Dogger Bank A, Dogger Bank B	Unknown	Windfarm power export cable (future)
UK-Denmark 4	Unknown	Disused cable
Eastern Green Link 2	Unknown	High Voltage Direct Current (HVDC) transmission cable (future)
TATA North Europe 1	Unknown	Active cable
UK-Germany 6	Unknown	Disused cable
Langeled	44″	Gas

Table 3-6 - Humber Pipeline crossings

	Diameter	Service
Langeled	44″	Gas
Hornsea Project Four	Unknown	Windfarm export cable (future)

Per crossing, it is assumed that the materials and dimensions detailed in Table 3-7 will be utilised in an arrangement schematically depicted in Figure 3-13 and Figure 3-14. Each crossing will be individually designed with a view to minimizing any impacts on the integrity of the existing infrastructure, in accordance with any specific requirements of the crossed pipeline/cable owner(s). The dimensions and quantities estimated are a worst case envelope and will be minimised as far as reasonably practical during detailed design.

Table 3-7 - Crossing approximate dimensions and cover requirements[89]

		Surface infrastructure (Langeled pipeline)	Buried infrastructure
Width of Base of Post-Lay Gravel/Rock Berm		up to 19 m	up to 15 m
Length of Post-Lay Gravel/Rock Berm		up to 716 m	up to 519 m
Height of Post-Lay Gravel/Rock Berm		up to 2.9 m	up to 2.4 m
Side Slope of Gravel/Rock Berm		1:3	1:3
Number of Crossings	Teesside Pipeline	1	10
	Humber Pipeline	1	1
Per Crossing	Protruding concrete mattress[90]	N/A	12 mattresses
	Mass (and Volume) of Rock[91]	40,082 t (16,701 m^3)	26,721 t (11,134 m^3)
Total Mass (and Volume) of Rock		374,095 t (155,876 m^3)	

The method used for crossing abandoned or disused cables depends on the status of the cable, exposed or buried, and if the crossed line will rest on the seabed or be lowered.

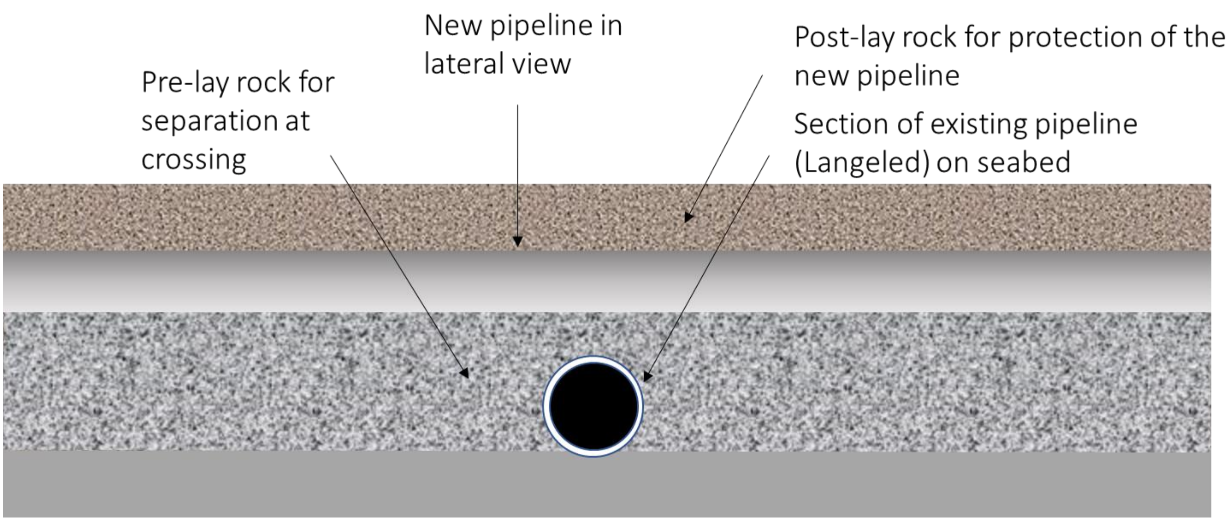

Figure 3-13 - Typical crossing of surface infrastructure (Langeled pipeline)

[89] The berms will have an oval footprint, widths presented are the maximum berm width. Top of berm width of up to 2 m
[90] Each with an approximate footprint of 6 m x 3 m
[91] Density assumed to be 2.4 t/m^3

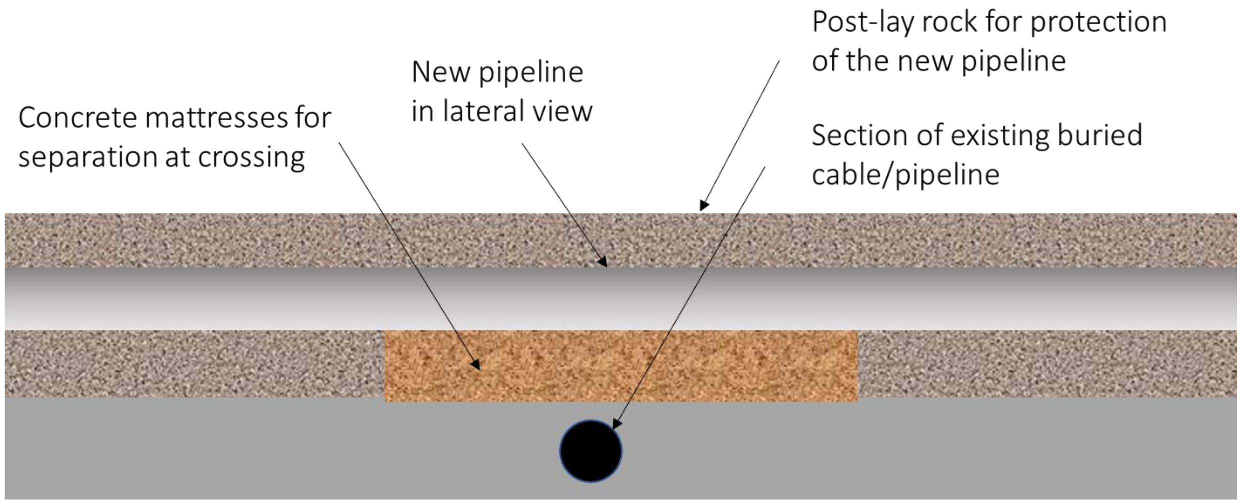

Figure 3-14 - Typical crossing of buried infrastructure

3.2.4 Pipeline Lay

Figure 3-15 provides a summary of pipeline installation methodology for the Teesside and Humber Pipelines.

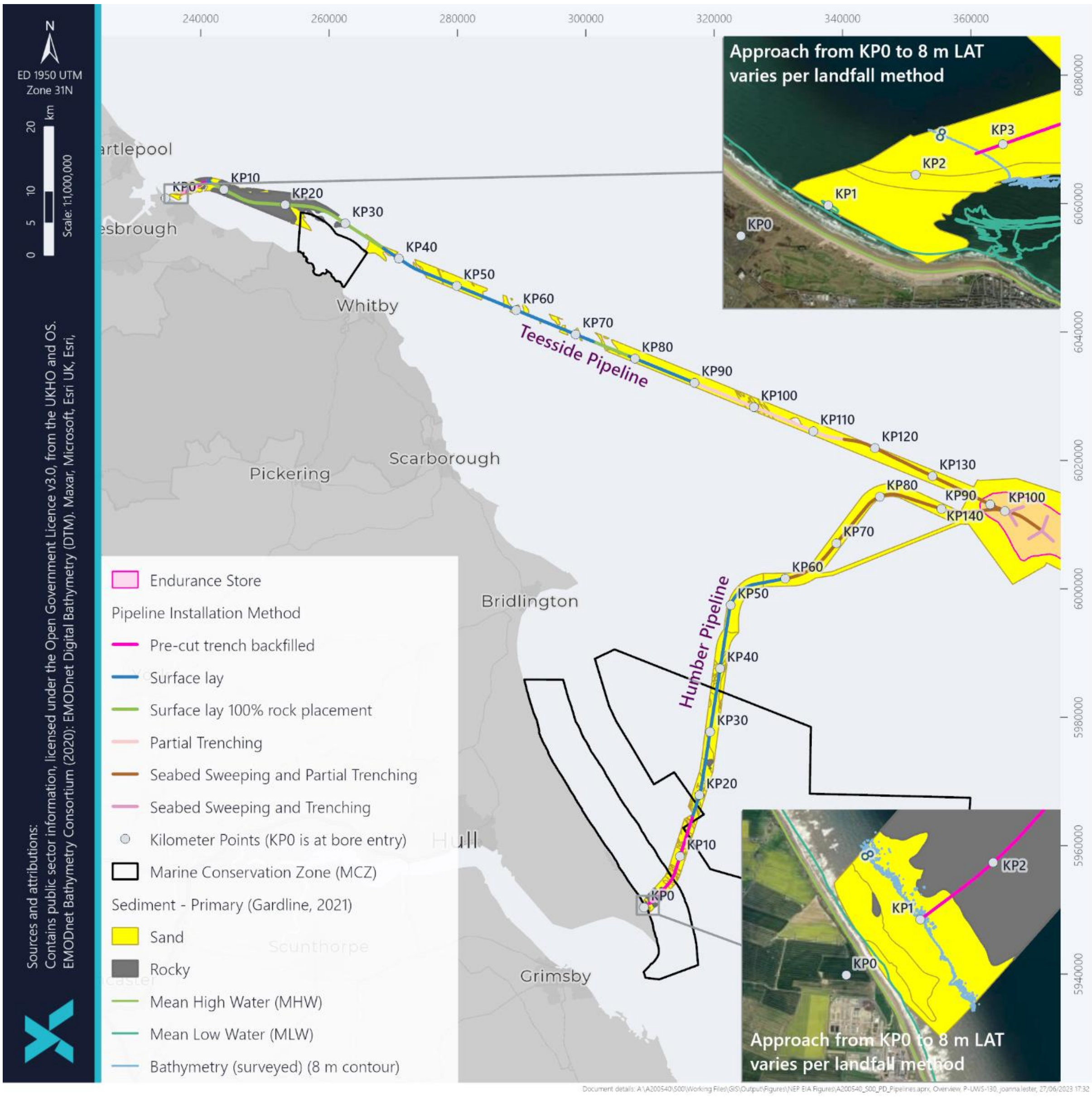

Figure 3-15 - Proposed installation methodology along the Teesside and the Humber Pipeline routes

An “S” lay pipelay vessel will carry out pipeline installation (for infield flowline installation, see Section 3.2.8.2). A survey vessel with an ROV will provide pipeline touchdown monitoring survey support as required.

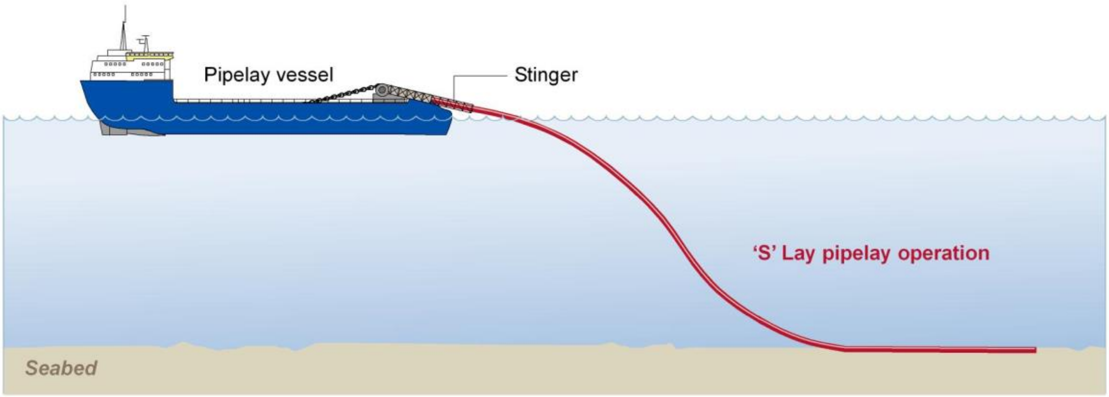

Figure 3-16 - Typical ‘S’ lay installation

For shallow water pipelay (< 20 m water depth), the vessel will be held in position by anchors, which control and restrict movement of the vessel to minimise the risk of incorrect positioning of the pipeline and to avoid undue stress on the pipeline as it is being laid. The anchored pipelay vessel will install the pipeline section out to a water depth suitable for deep water vessels and laydown the section installed from landfall.

While there is a preference for DP for the deep water pipelay, an anchored vessel may be required and this is assessed within the impact assessment as the worst case[92]. The deep water pipelay vessel would initiate pipeline installation against a fixed strong point such as a drag anchor. Initiation rigging would be attached to the start-up head. Initiation and lay away will be required at the transition between shallow and deep water pipelay on both the Teesside and the Humber Pipelines and to lay the infield pipeline between the manifolds (Section 3.2.8.1). Appropriate protection e.g. a guard vessel, will be in place should deep water lay not immediately follow shallow water lay.

The pipelay barge would construct sections of the pipeline on the barge and lower each section in turn onto the seabed as part of the continuous pipeline The pipeline is tensioned by grippers on the barge to secure the pipeline and control the “S” configuration as it is laid out along the stinger to the rear of the vessel.

Anchored vessels typically use 12 anchors, with each one typically being a 20 t or 22.5 t anchor. It is estimated that each anchor will need to be re-positioned approximately every 400 m along the pipeline route. The maximum length of any of the anchor lines will be 1.2 km with up to 400 m on the seabed. There is no anticipated laydown of the pipelines during offshore installation, this option is held as contingency in the event of deteriorating weather conditions, equipment failure or other unseen events.

[92] *Due to the longer duration required for anchored pipelay, this represents worst case in terms of seabed disturbance, physical presence and atmospheric emissions.*

Supporting the pipelay vessel will be pipe carrier vessels, guard vessels, a survey support vessel and anchor handling tugs (if the pipelay vessel is anchor moored). When the pipelay vessel reaches the termination target box[93], the vessel will lay down the pipeline on the seabed.

3.2.4.1 Spool Pieces

Any pipeline or flowline connection to a subsea structure (SSIV, manifold or wellhead trees) will be achieved via a flanged spool up to 100 m long, installed by divers from a DSV or by an ROV.

Table 3-15 provides a summary of the tie-in spools to be installed.

Table 3-8 - Spool details

	Maximum length (each)	Number
SSIV	100	2
Co-mingling manifold	90 m	5
Four-slot manifold	90 m	4
Five injection wells	50 m	5
TOTAL		**16**

Dye sticks will be inserted at the flange connections during spool-piece tie-in to enable leak detection; dye will only be used where a leak is most likely to occur (i.e. at the flange connections), and total quantity of dye used will be minimised as far as reasonably practicable. Corrosion inhibitor, oxygen scavenger and biocide sticks may also be inserted during tie in to further reduce the risk of corrosion.

3.2.5 Pipeline Protection and Stabilisation[94]

The base case is for no rock placement along the route of the pipelines. While design aims to minimise the requirement for rock placement, contingency is required to address scenarios which will be considered further during detailed design. Graded rock/gravel could be required:

- At each crossing (detailed in Section 3.2.3.4);
- For freespan correction;
- For upheaval buckling mitigation[95];
- For additional protection in specific section if/where required e.g. where required trenching depth cannot be achieved;

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[93] *Location where pipeline ends and from where spools will be used to connect the pipeline to the subsea infrastructure.*
[94] *Excludes use of temporary 15 x 2 t bags which may be used at the landfall punch-out location.*
[95] *Unlike oil and gas pipelines, the contents of which are warmer at the offshore location and cooler towards landfall, the temperature of CO_2 in the Teesside and Humber Pipelines is higher at landfall and cooler offshore. This may increase rock requirements to mitigate upheaval buckling nearshore. Worst case assumptions are contained within the ES.*

- To stabilise the pipeline where a rocky seabed prevents embedment and where the maximum practical concrete thickness (150 mm) is not sufficient for stability; and
- At the ends of the flowlines.

Rock will be deposited by a fall pipe vessel to support accurate positioning of the rock. In shallow water depths, where a vessel with a fallpipe cannot operate, a side-dump vessel will be utilised, implementing the contractor's standard operating procedures to minimise the footprint. To support long-term stability, the side slopes of the fishing friendly rock berms will be no steeper than 1 in 3 .

To ensure assessment of a worst case scenario, from an environmental impact perspective, the assumptions detailed below are adopted for this ES in relation to rock requirements.

In the nearshore region at Humber, it is expected to become more difficult to achieve the required burial depth due to the veneer of mobile sediment on the seabed becoming thinner, and the underlying stiff clays approaching closer to the surface of the seabed. In the event that it is not possible to reach the required burial depth with trenching, it will be necessary to cover the affected sections of the pipeline with a rock armour berm. Rock armour has well understood properties that will reliably prevent pipeline exposure and fishing gear snagging.

The realistic worst case rock placement scenario assessed for the Humber Pipeline route within the Holderness Inshore MCZ is 7.5% coverage of the pipeline and within the Holderness Offshore MCZ is 5% coverage of the pipeline. Rock will not be placed landward of 10 m LAT (KP1.2). The length of pipeline within the Holderness Inshore MCZ is 6.1 km from MHWS, 6.0 km from MLWS[96] and 5.2 km from 10 m LAT, therefore 391 m of pipeline within the MCZ may be covered by rock. The length of pipeline within the Holderness Offshore MCZ is 19.82 km and so 991 m may be covered by rock. While it is likely that this rock will be placed as discontinuous spot rock, the worst case with regards to impacts to the MCZs is that the rock will be placed as a single long berm.

It should be noted that the Tolmount HGS pipeline was installed in 2020 with requirement for 11,278 t of rock armour within the Holderness Inshore MCZ and that the York pipeline was installed in 2011 – 2012 without any rock armour requiring to be placed within the Holderness Inshore MCZ. Rock placement within the Holderness Inshore MCZ was required on the Tolmount HGS pipeline to achieve sufficient depth of cover for protection from other marine activities. A berm was required in two locations where insufficient burial depth was achieved and in a number of locations where the pipeline was at the requisite depth within a trench but where natural backfill material was not available to provide sufficient protection within the necessary timescales.

Geophysical surveys of the Teesside Pipeline route corridor, which was selected as described in Section 4.2, indicate that due to the rocky nature of the seabed which has a very thin and intermittent sand layer it will not be possible to stabilise the pipeline via trench and bury between KP7.5 – KP37.1 and KP72.0 – KP79.0. As no pipeline embedment will occur, it is assumed that 100% rock placement will be required over these sections of the pipeline route.

In the remaining sections of the Teesside Pipeline (Table 3-9) and from KP16.3 on the Humber Pipeline to the Endurance Store, the pipelines will be surface laid (with the exception of partial trenching for scour protection, Section 3.2.3.3). There may however be a requirement for additional rock once each

[96] *OPRED consenting boundary*

pipeline has been laid on the seabed. As these exact locations are not known at this stage of pipeline engineering, it has been assumed that rock placement will be required for 5% of the pipeline length.

The infield pipeline will be surface laid however there may be a requirement for additional rock once the pipeline has been laid on the seabed. It has been assumed that rock placement may be required for 10% of the pipeline length.

The flowlines are assumed to be trenched and buried (Section 2.4.2), albeit there may be sections where it is not possible to achieve the required burial depth and additional rock cover is needed. As these exact locations are not known at this stage of pipeline engineering, it has been assumed that rock placement will be required for 10% of the flowline length. Additionally, rock placement will be required at the flowline ends (transition zone) at the Endurance Store to provide protection to otherwise exposed sections of the flowlines. Rock placement will also be required along transitions[97] on the Teesside Pipeline (three) and Humber Pipeline (one). An estimated amount for this eventuality is provided in Table 3-9.

Table 3-9 - Rock placement assumptions: pipelines and flowlines[98] (rock requirements for crossings contained in Table 3-7)

	Rock placement length	Width[99] (m)	Height (m)	Volume (m^3)	Weight [100](t)
Teesside Pipeline route	Total of 40.9 km length, i.e. a) 5% of 106.5 km length: • KP0.9– KP7.5 • KP37.1 – KP73.0 • KP79.0 – KP143.0 b) 100% of 35.6 km length: • KP7.5 – KP37.1 • KP73.0 – KP79.0	13 (to KP7.5) 10 (from KP7.5)	2 (to KP7.5) 1.5 (from KP7.5)	497,924	1,195,019
Humber Pipeline route	Total of 5.1 km length, i.e. a) 7.5% of 4.8 km length: • KP1.2-KP6.0 b) 5% of 95 km length • KP6.0 – KP101.0	13 (to KP6) 10 (from KP6)	2 (to KP6) 1.5 (from KP6)	65,156	156,374

[97] *i.e. where the pipeline changes from being buried to surface laid or where the Teesside Pipeline connects to the SSIV.*
[98] *The volume of rock was calculated according to the sum: Area of vertical cross section (m^2) x Total berm length (m) x Factor to ensure minimum rock cover requirements are reached and to account for settlement of the rock berm.*
[99] *Widths presented are the maximum berm width as the berms will have an oval footprint. Width is calculated according to the following sum: Width of top of berm (1 m) + [two side slopes of 1:3 gradient (i.e. 6) * (Depth of rock cover required above pipeline or cable (m) + Height to top of pipeline or cable (m))].*
[100] *Weight = Volume (m^3) x Rock density (assumed to be 2400 kg/m^3).*

	Rock placement length	Width[99] (m)	Height (m)	Volume (m^3)	Weight [100](t)
Trench transitions	200 m per transition, total 14: • Teesside Pipeline: 3 • Humber Pipeline: 1 • 5 flowlines x 2	7	1	17,920	43,008
Infield Pipeline	10% of 6 km length, i.e. 600 m	10	1.5	7,255	17,413
Flowlines	10% of 5 x 3 km i.e. 1.5 km	7	1	9,600	23,040
Total				**597,855**	**1,434,853**

Concrete mattresses, rock placement or purpose built structures provide protection for exposed spool-pieces (Section 3.2.3.4; e.g. from dropped objects) and sections of un-trenched cable in the vicinity of subsea infrastructure. Initial design has estimated the mattress requirements (each with an approximate footprint of 6 m x 3 m) as outlined in Table 3-10.

Table 3-10 - Concrete mattress assumptions[101]

	Connecting infrastructure	Number of mattresses
SSIV	Teesside Pipeline Cable	50
Co-mingling manifold	Teesside Pipeline Humber Pipeline Infield Pipeline Flowlines x 2 Cable	200
Four-slot manifold	Infield Pipeline Flowlines x 3 Cable	150
Five injection wells	Each connecting to • Flowline • Cable	250
Monitoring well	Cable	30
Total		**680**

[101] *Grout bags are not used for stabilisation of the pipelines. Grout bags may be used to support spool pieces and/provide protection for infield umbilicals. The footprint occupied by the grout bags will not lie outwith that calculated for concrete mattresses or rock placement.*

3.2.6 Survey Support

Survey vessels will be active prior to and throughout installation activities, carrying out a variety of tasks with a range of sensors and instrumentation (see Section 3.5 for details on vessel durations). Sidescan sonar (SSS) and AUVs may be utilised during survey activity which includes the following:

- Seabed Preparation Survey – surveys carried out during the seabed preparation works including pre-trench survey which includes UXO survey;
- Pre-lay Survey - Pre-lay surveys will be required, across the area over which pipelines, cables and subsea infrastructure are to be installed. These will include a UXO survey;
- Pipelay Support – ROV surveys providing:
    - Initiation and laydown support, i.e. monitoring the starting location of pipelay;
    - Touch down monitoring, i.e. monitoring the pipeline profile between the pipelay vessel and the seabed;
    - Real time route plotting;
    - As-laid survey, i.e. recording actual location of the installed pipelines;
- Trenching Support – ROV surveys covering:
    - Plough set down onto pipeline support;
    - Plough recovery support;
    - As-trenched survey;
    - As-backfilled/OOS survey;
    - As-built survey once all construction activities are completed; and
- Rock placement survey – to be carried out by the rock placement vessel.

3.2.7 Pipeline Pre-Commissioning

To reduce corrosion risk once installed, each pipeline will be sealed at both ends, flooded with filtered, chemically treated seawater and subsequently hydrotested to verify system integrity. A routine activity during pipeline installation, hydrotesting involves inhibited water being pumped into the pipeline (approximately 120% of line volume). The pressure of the system is increased until the pressure has been established and a successful hold time and stabilisation period achieved. Test pressure will be held for 24 hours before the lines are depressurised, by discharging the extra volume of water to sea in the Endurance Store area[102], at predetermined rates. Hydrotesting may be repeated to verify the pipeline integrity at intermediate steps, or in case of failure.

After hydrotesting, spool-pieces will be installed to tie each pipeline into the subsea structures (manifold and SSIV).

Once tied-in each connection will be leak-tested, following a similar procedure as hydrotesting, using filtered, chemically treated seawater. Additional quantities of inhibited seawater pumped into each pipeline to establish leak test pressures will be discharged to sea. Once fully installed and tested, the remaining volumes of inhibited seawater will be flushed out of each pipeline at the manifold locations, in a process known as dewatering.

Any chemical requirements (typically oxygen scavenger, corrosion inhibitor, biocide and dye are used during pipeline commissioning operations) that fall under the Convention for the Protection of the

[102] *Testing of the nearshore section of the Teesside Pipeline may involve discharge at the SSIV location.*

Marine Environment of the North-East Atlantic (OSPAR Convention) and OCR 2002 (as amended) will be included on relevant pipeline chemical permits prior to operations commencing. The permit applications fully risk assess the use and discharge of the exact chemicals, dose and dispersion rates, and any impact to the marine environment is determined. An initial assessment using indicative chemicals is included within this ES (Section 8.3.1).

Alternatively, pipelines could be hydrotested after the spool-pieces have been installed in a combined hydro/leak test which would reduce the total volume of water and chemicals discharged to the environment.

The pipelines will be dewatered using super dry air or nitrogen which will drive a dewatering pig train[103] through the pipelines. The train may include one or more batches of MEG to maximise the amount of water removed. The MEG, a PLONOR[104] substance will be discharged out of each pipeline upstream of the co-mingling manifold once it has travelled along the length of a pipeline. An initial assessment is included within this ES (Section 8.4.3). Following MEG discharge, dry nitrogen will be used to dry the pipeline to mitigate risk of corrosion, hydrates or loss of CO_2 injectivity which could result from the reaction of CO_2 with residual water in the pipelines. Therefore the pipelines will be full of nitrogen gas after the MEG has been discharged. Depending on execution schedules, a period of time may elapse following dewatering and drying, in advance of CO_2 injection commencing.

To allow for pig retrieval at the Store, a temporary pig receiver will be located at each manifold on the seabed for the duration of pre-commissioning. The footprint of the temporary pig receiver is estimated to be 13 m x 4 m with an estimated height of 3 m. The pig receiver will be removed from the seabed following completion of pre-commissioning activities.

3.2.8 Subsea Infrastructure at the Endurance Store

There will be no permanent structures above sea level associated with the Development at the Endurance Store area. Figure 3-17 shows the distributed configuration of subsea infrastructure at the Store which is intended to be installed and which is required to inject CO_2 into the Store.

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[103] A pig train consists of a series of pigs separated by a liquid batch in a gas pipeline.
[104] PLONOR chemicals are those which pose little or no risk to the environment according to OSPAR, i.e. the mechanism by which 15 Governments & the EU cooperate to protect the marine environment of the North East Atlantic.

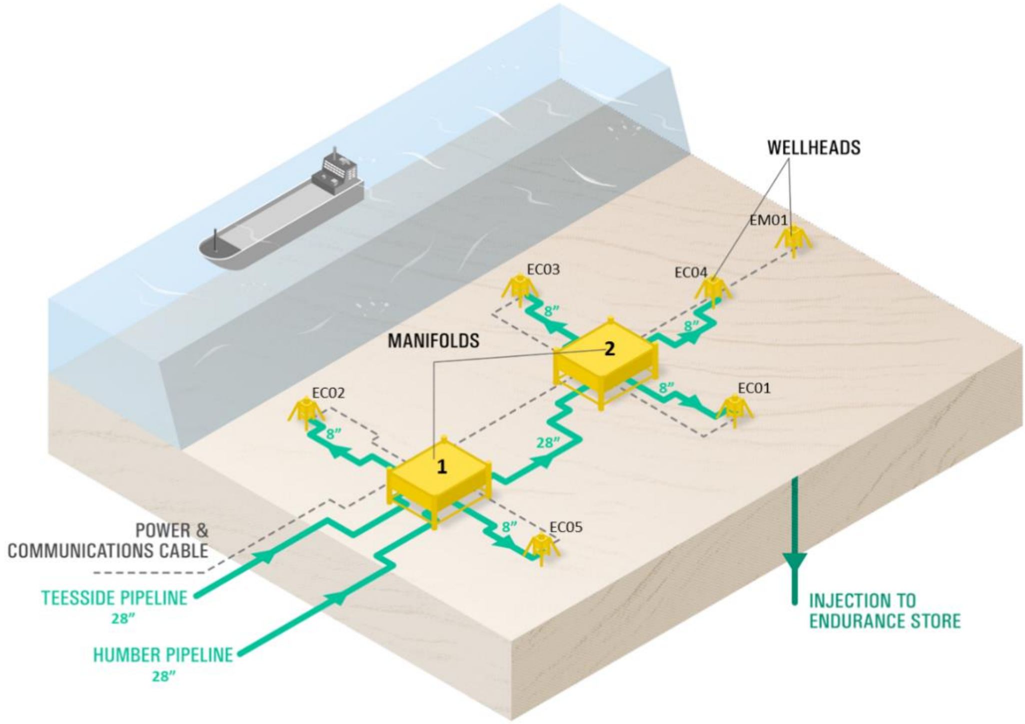

Figure 3-17 - Schematic of the subsea infrastructure at the Endurance Store area (not to scale) showing the crossover co-mingling manifold (1) and the four-slot manifold (2)

3.2.8.1 Manifolds, Infield Pipeline, Flowlines and Trees

Subsea infrastructure at the Endurance Store will be electrically powered via a power and fibre-optic communications control cable from Teesside. Two manifolds[105] will be connected by a surface laid 28" infield pipeline of approximately 6 km length and an electric power and fibre-optic communications control cable (Figure 3-17). The manifolds connect to five injection wells and a monitoring well via 8" flowlines (five injection wells) and power and fibre-optic communications control cables (all six wells).

The two manifolds are:

- A crossover co-mingling manifold to combine the flows from the Teesside and Humber Pipelines and distribute it for injection into two wells and to the four-slot manifold. Provides power and communication connection to injection wells and the four-slot manifold; and
- A four-slot manifold at the Endurance Store connected to the other three injection wells, with the potential to support a further tie-in point. Provides power and communication connection to injection wells and the monitoring well.

The footprint of the co-mingling manifold (subject to detailed design) is 16 m x 20 m with an estimated height of 6 m and an estimated weight in air of 570 t while the footprint of the four-slot manifold (subject to detailed design) is 24 m x 10 m with an estimated weight in air of 400 t. The manifolds will

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105 *Arrangement of piping and/or valves designed to combine, distribute, control, and often monitor flow.*

be installed by a Heavy Construction Vessel or by an S-lay vessel (to be confirmed during detailed design).

As is routine in the installation of subsea infrastructure, four piles may be used to anchor each manifold. The piles are anticipated to be 610 mm in diameter and 28 m long, with a penetration depth into the seabed of 21 m. Pile driving is expected to take one hour per pile. Appropriate permits will be obtained. Two mudmats may be required for stability of each manifold, the mudmats associated with the co-mingling manifold are each of 12 m length x 8.5 m width and the mudmats associated with the four-slot manifold each of 10 m length x 6 m width.

To facilitate intelligent inspection pigging or responsive operational pigging[106] of the pipelines, one subsea pig receiver will be installed as an extension to each subsea manifold. The footprint of the pig receiver is estimated to be 10 m x 4 m with an estimated height of 3 m and an estimated weight in air of 40 t. The pig receiver is expected to remain on the seabed over the life of the Development, being designed to be recovered post pigging to retrieve the pig and subsequently re-installed on the seabed.

The two manifolds will be connected by an infield pipeline, up to 28” in diameter. This will be surface laid except where partial trenching may be required to mitigate scour (Section 3.2.3.3). The infield pipeline be a maximum of 6 km in length.

The wellhead trees will each be 5 m x 5 m x 4 m high and installed by either a jackup rig[107] or a construction vessel (to be confirmed during detailed design).

The up to 8” infield flowlines[108] which run from the manifolds to the five injection wells will each be a maximum 3 km in length. Power and communications are provided to each of the six wells, including the monitoring well (Section 3.2.9).

All installed structures will be designed to be fishing friendly with no snaggable protrusions.

A high risk of scour along with considerable magnitude of scour depths has been predicted for both manifolds. For the purposes of the ES, it is assumed that rock placement will be required to mitigate scour risk with geotextile[109] laid beneath the rock to separate the rock from the seabed sediment. The estimated rock requirement is 829 t (346 m^3) for the co-mingling manifold and 795 t (331 m^3) for the four-slot manifold. The geotextile will extend 6 m from each edge of the manifold.

3.2.8.2 Flowline Installation and Pre-Commissioning

The infield flowlines will be trenched and backfilled for protection. The only sections not trenched are locations in close proximity to the manifolds and wellheads. Installation, burial and commissioning of the infield flowlines typically follows the below process – the process of flooding, hydrotesting, leak-

[106] i.e. pigging required in response to detection of off-spec contents of the pipeline e.g. high water
[107] Mobile offshore drilling unit that rests on the seafloor, i.e. the legs are on the seabed and the drilling equipment is jacked up above sea level
[108] Assumed to be super duplex stainless steel but material selection subject to further design engineering. The diameter of the flowline may be up to 10” if the selected material is not super duplex stainless steel. As the flowlines are trenched and buried, any change in diameter will not have a discernible effect on the impact assessment
[109] Geotextile are flexible, permeable textile materials used widely in construction.

testing and dewatering follows that which has been described for the pipelines (e.g. Section 3.2.7) and is not repeated here:

- Seabed sweeping;
- Lay on seabed;
- Trench into seabed;
- Flood with chemically inhibited potable water;
- Backfill trench;
- Hydrotest;
- Tie-in flowlines at both ends;
- Leak-test; and
- Dewatering and commissioning.

It is currently anticipated that the infield flowlines will be laid using a DP vessel however this is subject to change and therefore, for the purposes of seabed impact assessment it is assumed that an anchored pipelay vessel will be used, utilising the assumptions detailed in Section 3.2.4. Survey requirements are addressed in Section 3.2.6.

Once laid on the seabed, the infield flowlines will be trenched using a displacement plough or jet trencher. The plough is towed behind a plough vessel, creating an open v-shaped trench into which it guides or directs the flowline. Spoil from the trench is deposited on either side of the trench in shallow berms. Trenches are likely to be between 2.5 m and 6 m wide depending on the plough used and the configuration of the plough, with spoil heaps up to 3 m wide and 2 m high on either side. In total, up to a 12 m wide strip of seabed will be affected along each flowline route, although this may vary depending on the equipment used. The target depth for each trench of 1.5 m will allow for a 1.0 m cover from the top of the flowline to mean seabed level.

Each trench will be terminated approximately 200 m from the wellhead or manifold.

A separate backfill plough will then be towed along each route to return the spoil into the trench. After backfill the final seabed profile will be a shallow depression over each route due to the loss of finer sediments from displaced material. Small residual berms may be present along the route. A post-lay survey will be conducted to determine the as-laid position of the flowlines and evaluate the cover that has been achieved.

The spool-pieces between the trench transition location and the manifold or wellhead (Table 3-10) will be protected with rock, concrete mattresses or purpose-built structures. It is estimated that up to four spool-pieces will be required per flowline, two at each end. It is assumed that 10% of each flowline length will require rock placement, where the necessary burial depth has not been achieved or where the potential for upheaval buckling is identified (Table 3-9).

3.2.9 Controls and Communication

A 57 kilo volt-ampere (kVA) electric power and fibre-optic communications control cable will be installed from Teesside to the subsea infrastructure (connecting to both manifolds, the five injection wells and the monitoring well) at the Endurance Store (Teesside – Store cable). From Teesside to just before the co-mingling manifold, the cable runs parallel to the Teesside Pipeline. Branches, made via a y-splice will run to both manifolds (Figure 1-1).

A power, control and hydraulics control umbilical of up to 7 km length from MLWS, will be laid and post-lay trenched or post trench backfilled from Teesside to the SSIV (Teesside – SSIV cable). While the cable may be laid within the pipeline trench, installation via a separate pre-cut trench has been assumed for the purposes of the ES. An anchored lay vessel will be used to install the Teesside – SSIV cable.

Up to two cable landfalls may be required, one for the Teesside – Store cable and one for the Teesside – SSIV cable. HDD will be utilised to drill each pilot hole, from onshore to offshore. Pull heads will be attached to the ends of the cables and used to pull the cables in. The onshore (landward of MLWS) construction associated with the landfall construction methodology at Teesside is assessed in detail within the NZT Project DCO. The seabed footprint of the cable landfalls, i.e. the over-excavated trench into which the cables will be laid on emergence at the seabed, are within the footprint outlined in Table 3-2. Similarly, vessel requirements are contained within vessel numbers outlined in Table 3-21.

While all of the above cables may be laid within the pipeline trenches or within the flowline trenches, installation via a separate trench has been assumed for the purposes of the ES.

As described for the pipelines and flowlines in Section 3.2.3.3, seabed sweeping is assumed to be required for the electric power and fibre-optic communications control cable:

- From KP115 to the co-mingling manifold on the Teesside – Store cable;
- Along the cable between the co-mingling manifold and the four-slot manifold; and
- Along the infield cables.

Following installation of the Teesside Pipeline, the Teesside – Store cable will be laid. It is anticipated that, as is routine in marine cable lay activities, the Teesside – Store cable will be installed using a standard DP cable lay vessel (CLV) equipped with a cable carousel[110] from approximately 20 m water depth. Up to 20 m water depth, an anchored lay vessel will be used and the cable installed into a pre-cut trench as described for the Teesside Pipeline route (Section 3.2.1.2).

In water depths > 20 m, post-lay burial will be conducted using burial equipment such as ploughs, jet sledges, trenchers or mechanical cutters (or equivalent). As seabed conditions change along the route, more than one tool may be required to achieve target burial depth. This target depth will be determined via a Cable Burial Risk Assessment which will be completed during subsequent design. For the purposes of this ES, it is assumed that a minimum burial depth of 1.5 m will be required. During trenching, a corridor up to 15 m wide along the cable route may be disturbed. This represents a worst case as it is likely that the width disturbed during cable installation will overlap with the width disturbed during pipeline installation but for the purposes of the assessment, no overlap has been assumed.

The final methodology will be developed by the cable manufacturer in conjunction with the offshore cable installation contractor taking the vessels, materials, burial equipment and environmental impact into consideration.

It is likely that there will be locations along each cable route where, due to extremely stiff clays and/or underlying boulders, the achieved depth of burial is not sufficient and subsequent backfilling is

[110] A structure which may be static or rotating that is used to store and handle cable.

therefore not adequate to keep the cable buried throughout the design life. Where it is established that rock placement is needed, this would be applied above the cable by installation of an engineered berm of crushed rock, achieving a minimum depth of cover of 0.5 m. The quantities and locations for this spot placement of rock will not be known until the as-trenched survey along the cable has been completed, and therefore, to ensure assessment of a worst case scenario, from an environmental impact perspective, for this ES it assumed that up to 5% of the Teesside – Store cable route will require rock placement. In addition, 100% rock placement between KP7.5 and KP37.1 and KP73.0 and KP79.0 is assumed for the Teesside – Store cable due to seabed conditions. Separate Teesside – Store cable crossings have also been assumed for the infrastructure listed in Table 3-5. Associated rock requirements are presented within Table 3-11.

Guard vessels may be deployed in areas where cable is exposed on the seabed prior to external rock placement.

Table 3-11 - Rock placement assumptions: cables[111]

	Length (m)	Width[112] (m)	Height (m)	Volume (m^3)	Weight (t)
Teesside – Store cable	Total of 40.9 km length, i.e. a) 5% of 106.5 km length • KP0.9 – KP7.5 • KP37.1 – KP73.0 • KP79.0 – KP143.0 b) 100% of 35.6 km length • KP7.5 – KP37.1 • KP73.0 – KP79.0	5	0.6	109,492	262,781
Teesside – SSIV cable	Total of 700 m length, i.e. 10% of 7 km	5	0.6	1,873	4,495
Infield cables	Total of 3 km length, i.e. 10% of 5 x 3 km 10% of 1 x 8 km 10% of 1 x 7 km	5	0.6	7,759	18,621
Total				**119,124**	**285,897**

[111] The volume of rock was calculated using a 1 m top of berm width. A slope of 1:3 was assumed
[112] The berms will have an oval footprint, widths presented are the maximum berm width

Table 3-12 - Crossing approximate dimensions and rock requirements: Teesside – Store cable[113]

		Surface infrastructure (Langeled pipeline)	Buried infrastructure
Width of Base of Post-Lay Gravel/Rock Berm		up to 15 m	up to 12 m
Length of Post-Lay Gravel/Rock Berm		up to 242 m	up to 246 m
Height of Post-Lay Gravel/Rock Berm		up to 2.1 m	up to 1.6 m
Side Slope of Gravel/Rock Berm		1:3	1:3
Number of Crossings	Teesside Pipeline	1	10
Per Crossing	Protruding concrete mattress[114]	N/A	12 mattresses
	Mass (and Volume) of Rock[115]	5,591 t (2,330 m^3)	5,243 t (2,185 m^3)
Total Mass (and Volume) of Rock		58,021 t (24,180 m^3)	

3.2.10 Summary

Table 3-13 provides a summary of the pipelines and flowlines to be installed.

Table 3-13 - Pipeline and flowline details

	Teesside Pipeline	Humber Pipeline	Infield pipeline	Flowlines
Length (below MLWS)	1 x 142 km	1 x 100 km	1 x 6 km	5 x 3 km
Construction material	Carbon steel Concrete coating of variable thickness (40-150 mm) Corrosion coating of Fusion Bonded Epoxy or 3-layer polyethylene/polypropylene			Corrosion resistant alloy rigid pipe[116] 3-Layer Polypropylene

[113] The berms will have an oval footprint, widths presented are the maximum berm width.
[114] Each with an approximate footprint of 6 m x 3 m
[115] Density assumed to be 2.4 t/m^3
[116] Assumed to be super duplex stainless steel but material selection subject to further design engineering. The diameter of the flowline may be up to 10" if the selected material is not super duplex stainless steel. As the flowlines are trenched and buried, any change in diameter will not have a discernible effect on the impact assessment

	Teesside Pipeline	Humber Pipeline	Infield pipeline	Flowlines
Outer diameter (")	28			8
Lay[117]	Surface laid with nearshore trench and bury Partial trenching for scour protection			Trenched and buried
Protective deposits	Rock placement (Table 3-9) Concrete mattresses (Table 3-10)			

Table 3-14 provides a summary of the subsea structures to be installed.

Table 3-14 - Subsea structure details

	SSIV	Co-mingling manifold	Four-slot manifold	Wellhead trees
Dimensions	One of 16 m x 9 m x 8 m high	One of 16 m x 20 m x 6 m high	One of 24 m x 10 m x 6 m high	Six of 5 m x 5 m x 4 m high
Scour protection	Armour rock over a non-woven geotextile laid on seabed Rock requirement: 210 m^3 or 550 kt Geotextile adds 14 m to length and width of seabed footprint	Single layer of armour rock over a non-woven geotextile laid on seabed Rock requirement: 115 m^3 or 305 kt per manifold Per manifold, geotextile adds 12 m to length and width of seabed footprint		Not required

Table 3-15 provides a summary of the cables to be installed.

[117] *Seabed sweeping is required per Section 3.2.3.3*

Table 3-15 - Cable details

	Teesside – Store cable	Teesside – SSIV cable	Infield cables
Length (below MLWS)	1 x 142 km	1 x 7 km	1 x 8 km 1 x 7 km 5 x 3 km
Function	Power and communications cable running from Teesside to the co-mingling manifold at the Endurance Store	Power, control and hydraulics umbilical running from shore to the SSIV to supply electrical power and communications	Power and communication cables between the two manifolds and from the manifolds to each of the six wells
Lay[117]	Trenched and buried		
Protective deposits	Rock placement (Table 3-11) Concrete mattresses (Table 3-10)		

Table 3-16 provides a summary of the estimated total quantity of rock required for the Development.

Table 3-16 - Total rock placement requirements

	Cross-reference	Volume (m^3)	Weight (t)
Crossings – Humber and Teesside Pipelines	Table 3-7	155,876	374,095
Placement - Pipelines and flowlines	Table 3-9	597,855	1,434,853
Scour Protection: Subsea Structures	Section 3.2.1.3, 3.2.8.1	1,004	2,411
Placement - Cables	Table 3-11	119,124	285,897
Crossings - Teesside – Store cable	Table 3-11	24,180	58,021
TOTAL		**898,040**	**2,155,276**

3.2.11 Pipeline Operation and Maintenance

During their operational lifetime, the pipelines and flowlines may be subject to inspections (called in-line inspections) to examine integrity as part of the pipeline integrity management strategy. Intelligent pigging[118] operations are likely to be performed on an as-required basis only. External inspection of the pipelines will take place through a combination of ROV/AUVs and towed sonar, or sensor instrumentation external to pipelines. The frequency of such maintenance will be determined by integrity management strategy and risk based inspection program.

Installation of instruments will be considered during subsequent engineering studies to enable mass balance measurements through pressure, flow and temperature transmitters as leak detection techniques.

The minimum pipeline operating pressure is established to maintain CO_2 in dense phase throughout the length of the pipelines. The operating pressure within the dense phase export pipeline network will range from about 110 bara to about 195 bara (the maximum operating pressure throughout the life of field corresponds to late life when the system is operating at maximum capacity). The operating temperature within the dense phase export pipeline network will range from 40 °C at the onshore inlets, to the equivalent of seawater ambient temperature (4°C to 16°C) offshore.

3.3 Wells and Drilling

3.3.1 Drilling Strategy

Six wells are planned to be drilled, comprising five CO_2 injection wells (EC01 – EC05) and one monitoring well (EM01), per schedule in Section 3.1.2. The rig used to drill the wells will be re-located between the drilling of each well. The six wells are of identical design and it is anticipated that it will take approximately 63 days to drill each well.

3.3.2 Drilling Rig

Although the rig contract has not been finalised, given the relatively shallow water depth, a jackup rig is expected to be used, such as the Valaris 76 which is a Marathon Le Tourneau Super 116-C Jackup.

A jackup rig is a mobile self-elevating drilling platform that consists of a buoyant hull fitted with three movable legs. The buoyant hull enables transportation of the unit between locations. Once on location the hull can be raised to the required elevation above the sea surface by jacking itself up on its legs. The legs of such units are typically fitted with enlarged footings (termed spud cans) to provide stable support and to limit penetration into the seabed as the hull is jacked up. Jackup rigs are generally not self-propelled and rely on tugs and anchor handlers for transportation to the drilling location.

Positioning of the jackup rig typically involves anchor handlers however, because open water jackup rig operations are planned, no anchor handling is envisioned for positioning and final approach of the jackup rig. There is no expectation for operations which require anchor handling, such as jackup rig stomping operations to enhance foundation stability at the legs. No anchoring is required during the duration of the drilling campaign when the jackup rig legs are pinned to seabed and the jackup rig is in final position with hull jacked up out of the water and the drilling package skidded to the final position over the well location.

On completion of drilling operations, the jackup rig will jack down and the tow vessels will tow the jackup rig to the next well location.

[118] *internal inspections of the pipeline.*

3.3.3 Well Design

The overall target depth for each well is between 1,300 and 1,500 m True Vertical Depth Sub Sea (TVDss). Drilling mud will be used to lubricate the drill mechanism and bring rock cuttings to the surface. The first two sections of each well (36” and 17 ½”) will be drilled using WBM fluids with the fluids and cuttings being discharged at the seabed as there is no riser (see below). A steel casing will be installed in each section to provide structural strength and to isolate varying down-hole pressure regimes. Each steel casing will be cemented into place to provide a structural bond between the casing and surrounding formation. The casing design has been optimised to consist of three casing strings (for the sections with diameter of 36”, 17 ½”, and 12 ¼”) and a cemented liner for the 8 ½” diameter section to provide long-term integrity and robustness during operation.

After the casing has been installed in the 17 ½” section, a wellhead and a riser will be installed to connect the jackup rig’s drilling equipment to the well and through which the mixture of cuttings and SBM returning back up the well bore can be pumped up to the rig. This enables cleaning and separation of the mud and cuttings mixture to take place, so that the drilling mud can be recycled and used again, and the cuttings retained for onshore disposal.

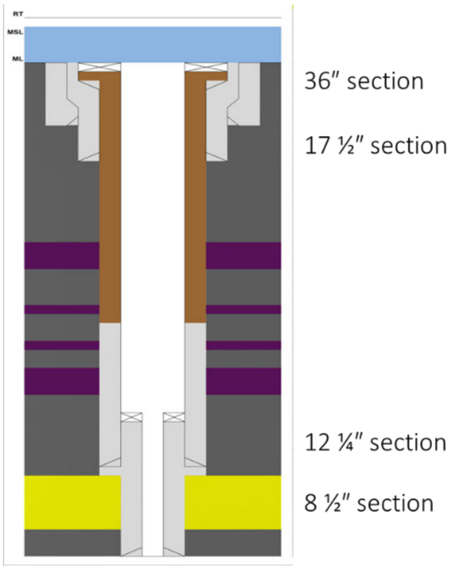

Figure 3-18 - Development well schematic

3.3.4 Mud System and Cuttings

Drilling fluids (‘muds’) have a number of functions as drilling progresses from wider diameter to smaller diameter sections of the well, including:

- Maintenance of downhole pressure to avoid formation fluids flowing into the wellbore (also called “a kick”);
- Wellbore stability;
- Removal of drill cuttings from the drill bit to permit further drilling and transporting cuttings to the surface cuttings handling equipment;
- Lubricating and cooling the drill bit, bottom hole assembly and drilling string; and
- Deposition of a mudcake on the walls of the well bore, which seals and stabilises the open hole formations.

Drilling fluids can consist of various materials including weighting agents and other chemicals to achieve the required weight, viscosity, gel strength, fluid loss control and other characteristics to meet the technical requirements of drilling and completing a well. Various chemicals can be added to the drilling fluid system to achieve specific functions, which are mainly driven by geological characteristics.

The WBM and cuttings will be discharged at the seabed (under the terms of a Chemical Permit), as is standard practice across the UK Continental Shelf. WBM drilling fluids contain bentonite and barite, both of which are included on the OSPAR List of Substances Used and Discharged Offshore and which are considered to be PLONOR[119] (OSPAR, 2019). To reduce the likelihood of the drilling equipment getting stuck and to provide sufficient lubrication between the equipment and the borehole, lower sections of each well will be drilled using LTOBM drilling fluids. LTOBM and associated cuttings will be returned to the jackup rig and the cuttings separated from the LTOBM fluid using shale shakers. In line with established processes and standard practice, the cuttings will be contained and shipped to shore for further treatment and ultimately disposal. The recovered LTOBM fluid will be treated and recycled back to the LTOBM system for re-use. No discharges of drill cuttings to sea during drilling of the 12 ¼" and the 8 ½" sections are anticipated.

Table 3-17 details the drilling mud requirements for each well.

Table 3-17 - Tonnage of drilling mud components per well

Component	36" section	17 ½" section	12 ¼" section	8 ½" section
Diameter (in)	36	17.5	12.25	8.5
Length (m)	72	418	607	407
Mud type	WBM	WBM	LTOBM	LTOBM
Fate of mud/fluid/cuttings	Discharged at seabed	Discharged at seabed	Zero discharge Skipped & shipped to shore for disposal	Zero discharge Skipped & shipped to shore for disposal
Non-PLONOR chemical additives (t)	-	5	61	50
Estimated weight of cuttings (t)	293	203	126	40

3.3.5 Cementing and Other Chemicals

Each steel casing is cemented into place to provide a structural bond between the casing and surrounding formation. The conductor and casing for the 36" and 17 ½" sections will be cemented in place with limited cement returns occurring to the seabed. It is anticipated that the majority of the

[119] *There are a number of additives that are required which may not be PLONOR.*

cementing material will remain downhole. Small operational discharges to the environment will only occurring when the cement unit is cleaned between each cementing operation, prior to solidifying. Table 3-18 provides the reasonable worst case volumes of mixed cement that may be discharged at the seabed during drilling of each well section.

Table 3-18 - Estimated mixed cement discharges per section, per well

Cement discharged	36” section	17 ½” section	12 ¼” section	8 ½” section
Barrels	50	60	20	20
m^3	8	9.6	3.2	3.2

These routine cement discharges will be presented and assessed for environmental impact in the drilling chemical permit which will be applied for at the time of drilling, in sufficient time to allow permitting. The cement discharges are fine materials which are expected to be widely dispersed with negligible seabed impacts. This discharge is therefore not included in the seabed impact assessment. Significant cement patio on the seabed is not expected as the majority of cement will remain within the formation. Cement returns to the seabed will be closely monitored using a pH meter and fluorescent dye to assist in reducing the amount of cement used. Any cement patio[120] will be further reduced by jetting from the ROV to dissipate excess cement fluid post cementation, prior to setting. With these measures in place the area of cement will be kept to the immediate vicinity of the well within the footprint of the cuttings, and is not expected to contribute an additional footprint beyond that quantified in Chapter 6: Seabed Disturbance.

All chemicals to be used within the cement will be selected based on their technical specifications and environmental performance. Chemicals with substitution warnings (those chemicals that contain substances hazardous to the marine environment and their use and/or discharge selected for phase-out) will be avoided where technically possible. The cementing chemicals to be used have not yet been determined but will be selected in compliance with OSPAR and the UK OCR (2002).

3.3.6 Well Completion, Clean-up and Testing

During completion operations, when the well is made ready for injection to commence, it is expected that completion fluids will be used to displace the drill mud remaining in the well. The completion fluids will be recovered to the rig, retained in skips and shipped to shore for treatment and disposal. There will be no discharge to the marine environment.

Immediately before CO_2 injection commences for the first time, up to 6,000 barrels (bbl) (954 m^3) of inhibited[121], 2,000 parts per million (ppm) potassium chloride brine or equivalent will be injected per well to mitigate against the loss of CO_2 injectivity which can occur when CO_2 contacts the Store Formation Water and salt can be precipitated. The water will dilute the Formation Water and

[120] Routine activity for drilling any seabed wells.

[121] Inhibition via use of biocide, not corrosion inhibitor. The inhibited brine will not be discharged into the marine environment but will be injected into the well.

eliminate the potential for halite formation near the injection well. N_2 will also be injected before and after each washing to mitigate the risk of hydrate[122] blockages when water comes into contact with CO_2.

3.3.7 Well Operation

During well operations, activity primarily constitutes monitoring. It is expected that a constant minimum base-load injection rate will be maintained for the first few years of operation, which will allow brine to be swept away from the well bore and reduce the requirement for water washing (see Section 3.3.8).

Monitoring activity during well operations is described in Section 3.4.7. Valves are in place on each wellhead and within each well (subsurface safety valve) to allow isolation of the well for maintenance and in the unlikely event of an emergency. The valves will undergo testing at a frequency and using a methodology that is to be confirmed during subsequent engineering.

3.3.8 Well Intervention

During operations, it is likely that water washing of each well borehole may be required on an annual basis to avoid the loss of CO_2 injectivity which can occur when CO_2 contacts the Store Formation Water.

It is anticipated that washing will occur once per well per year with 2,000 bbl (318 m^3) of inhibited, low salinity brine of up to 2,000 ppm potassium chloride (with options for a biocide and possible a scale inhibitor) per well. This will be done from a vessel set up to connect to either the tree or manifold. This frequency may be conservative and will be refined based upon well performance.

No planned discharges to sea will occur during water washing because the wash will be going into the Store with no return.

3.4 Endurance Store

To address OPRED comments, Section 3.4 is provided to detail Store characterisation, any penetrations through the aquifer, the seal status and the assurance process undertaken.

3.4.1 Geological Characterisation

The Endurance Store structure that forms the CO_2 store, is a four-way dip closure, meaning that the structure dips away in all four possible directions. As a result, and given the difference in density between CO_2 and brine, injected CO_2 will be prevented from migrating laterally. The structure is described as a closure because the overlying stratigraphy acts as a sealing stratum, meaning any CO_2 injected into the Store will be trapped by this feature (preventing vertical migration of CO_2).

Discovered in 1970, Endurance is the best appraised CO_2 store in the SNS containing two plugged[123] exploration wells (42/25-1 and 43/21-1) and one recent appraisal well from the National Grid-led White Rose CCS development in 2013 (42/25d-3, plugged). In addition, thirteen additional well penetrations are present in the near field of the structure (Figure 3-19), from which information has

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[122] *Hydrates are ice-like solids which form when free water and gas combine at high pressure and relatively low temperature.*
[123] *Made incapable of flowing and no longer in use, industry term typically applied to wells of this status being "plugged and abandoned".*

been obtained about the reservoir characterisation in the area (bp, 2021d). These wells are termed legacy wells and are discussed further in Section 3.4.5.

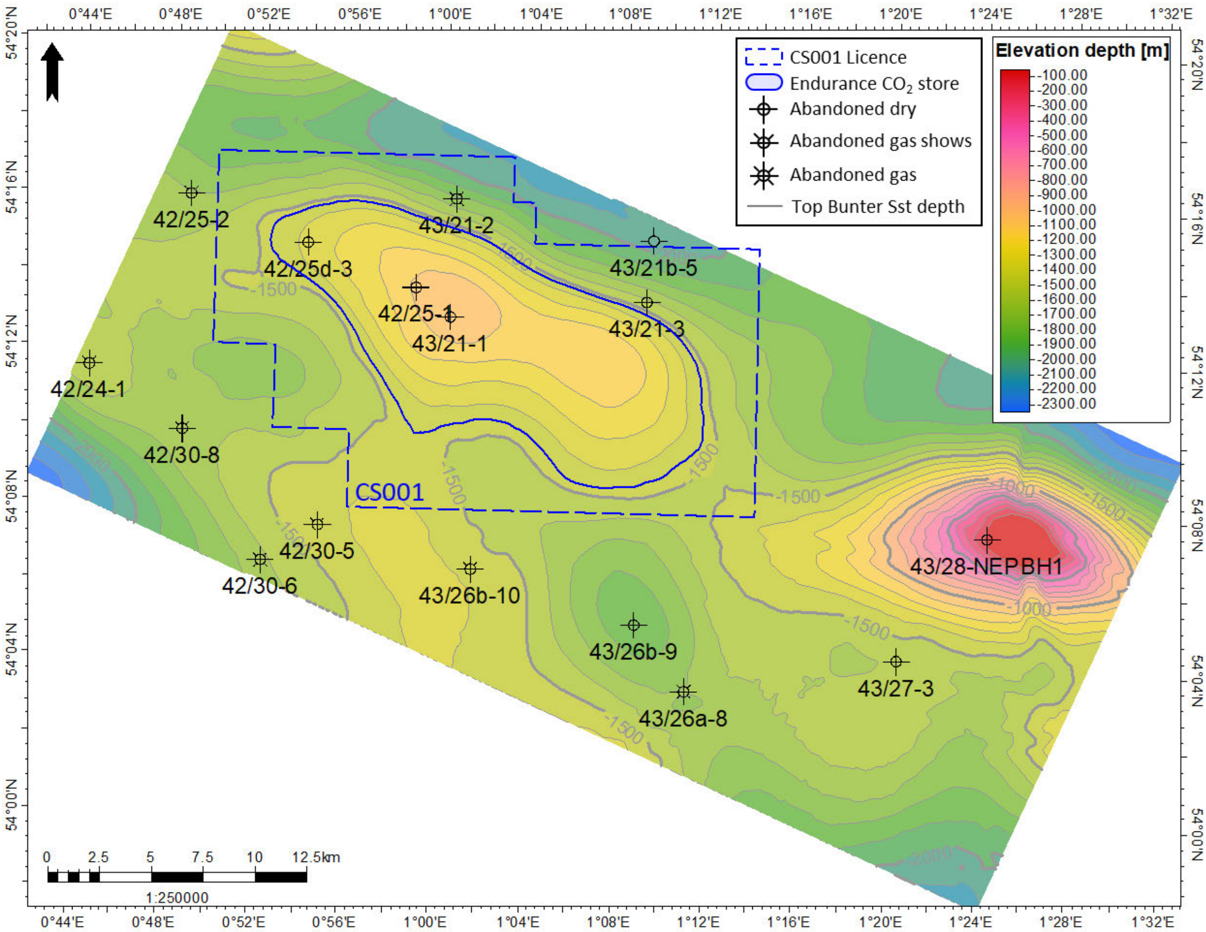


Figure 3-19 - Top Bunter structural map of the vicinity of the Endurance structure

The Endurance Store structure is approximately 25 km in length, 8 km wide and over 250 m thick, presenting circa 26 Giga barrels of pore space available for CO_2 storage above the spill point[124] (the CO_2 volumes planned to be injected during the life of the Development represent in total approximately 100 Mt, accounting only for 3 – 4% of that space). The crest of the Store is at a depth of approximately 1,020 m. The CO_2 storage site is a saline aquifer known as the Bunter Sandstone Formation which contains highly saline water (approximately 250,000 milligrams per kilogram (kg)). The formation has good reservoir properties, including porosity[125] (16 – 24%) and permeability[126] making it highly suitable for the injection and storage of CO_2 (Figure 3-20).

Geochemical modelling [127](bp, 2021f) predicts that, on injection into the saline aquifer, CO_2 will react with highly saline water in the near well zone causing precipitation of salts within the pore spaces. Precipitation is likely to occur within the first few metres of each injection well and could impact the

[124] The structurally deepest point in the reservoir that can retain (i.e. trap) CO_2.

[125] Porosity is defined as the ratio of the volume of pores to the volume of bulk rock and is usually expressed as a percentage.

[126] Permeability refers to how connected pore spaces are to one another.

[127] Process used to simulate potential interactions between CO_2, highly saline water, and the overlying seal

ability to keep injecting CO_2. This risk will be mitigated by flushing each well with low-salinity water (Section 2.2.3.1) and via maintenance of a minimum CO_2 injection rate.

Modelling (bp, 2021f) also predicts that dissolution of CO_2 into the highly saline water will causes a pH drop. This drop is mitigated (buffered) by interaction with carbonate minerals which means that no significant damage to the aquifer or seal will occur as a result of CO_2 injection.

3.4.2 Seal Description

Overlying the Bunter Sandstone Formation are the 100 m-thick Rot series of clay and halite formations. The Rot series acts as the primary seal, trapping CO_2 underneath due to the extremely low porosity and permeability of the clay and halite formations. The primary seal is also an impermeable barrier. Above the primary seal of the Rot clay and halite formations, further layers of halite and mudstone formations (circa 900 m of overburden rocks), also of extremely low porosity and permeability, are present and provide additional secondary sealing capability.

The fracture closure pressure of the Rot clay, a measure of sealing potential, measured 264 bars (equivalent to 3,830 pounds per square inch (psi)) at 1,353 m TVDss. This indicates that the formation is geomechanically strong and therefore capable of withstanding any significant changes in differential pressure due to CO_2 injection. This makes it highly suitable as a primary seal to trap CO_2 (Figure 3-20).

3.4.3 Faulting in the Overburden

There is no clear evidence of faults in the overburden (i.e. overlying rock layers) extending into the Bunter Sandstone Formation within the Endurance Store structure area. Faults present in overlying mudstone and halite formations decrease in offset (i.e. displacement in formation on either side of a fault) to zero with increasing depth towards the primary seal (Rot series).

3D geomechanics modelling (bp, 2021d) indicates the Endurance Store structure can withstand pressures encountered during CO_2 injection without failure of the primary seal (i.e. Rot series) or fault reactivation in the overburden above the Endurance Store structure.

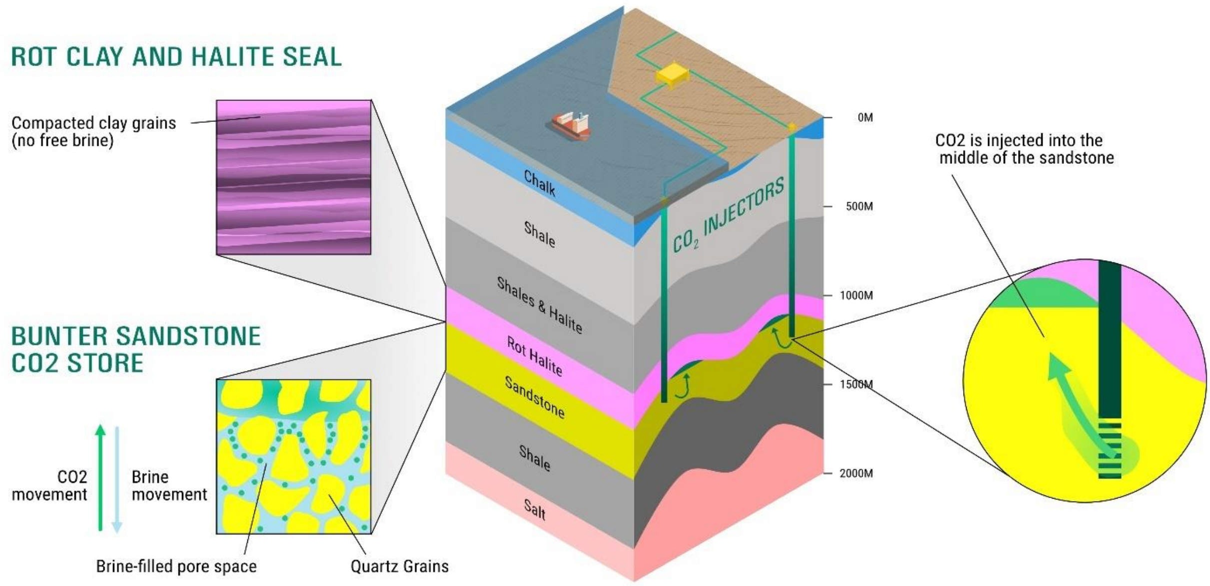


Figure 3-20 - Endurance Store cross-section and Development overview

3.4.4 Bunter Sandstone Outcrop East of the Endurance Store Structure

The Bunter Sandstone Formation forms an outcrop at the seabed ~25 km east of the Endurance Store structure (Figure 1-3; Figure 3-21; Figure 3-22). The exposed outcrop covers an area of between 1 and 2 km^2, with overlying Quaternary sediments in places. As CO_2 is injected into the Endurance Store it will increase the pressure within the Bunter Sandstone Formation. As described above, the seal rocks directly above the Bunter Sandstone Formation which act as the primary seal, are geomechanically strong and able to withstand changes in pressure, meaning injected CO_2 remains trapped within the Endurance Store. Subsequently pressure increases within the Bunter Sandstone Formation will dissipate throughout the formation in the surrounding area, including to the outcrop. Dynamic simulation modelling based on seismic and well data for the area indicates that pressure effects will reach the outcrop approximately four years after first injection of CO_2 into the Endurance Store. The increase in pressure at the outcrop is likely to lead to the displacement of Formation Water in the upper 140 m of the Bunter Sandstone Formation at the outcrop. The maximum displacement of Outcrop Formation Water will be < 1,600 m^3/day. Based on analysis of cores obtained from the Bunter Sandstone Outcrop, there is known to be high permeability and porosity of the Bunter Sandstone Formation and therefore it is expected that displacement will occur diffusely across the outcrop area. The occurrence of a point source displacement is considered to be of extremely low probability.

The Formation Water column in the outcrop area (subject to potential displacement) was appraised by a shallow borehole (43/28-NEPBH1) in June 2022 with core, reservoir pressure, and fluid samples taken from depths down to 290 m TVDss.

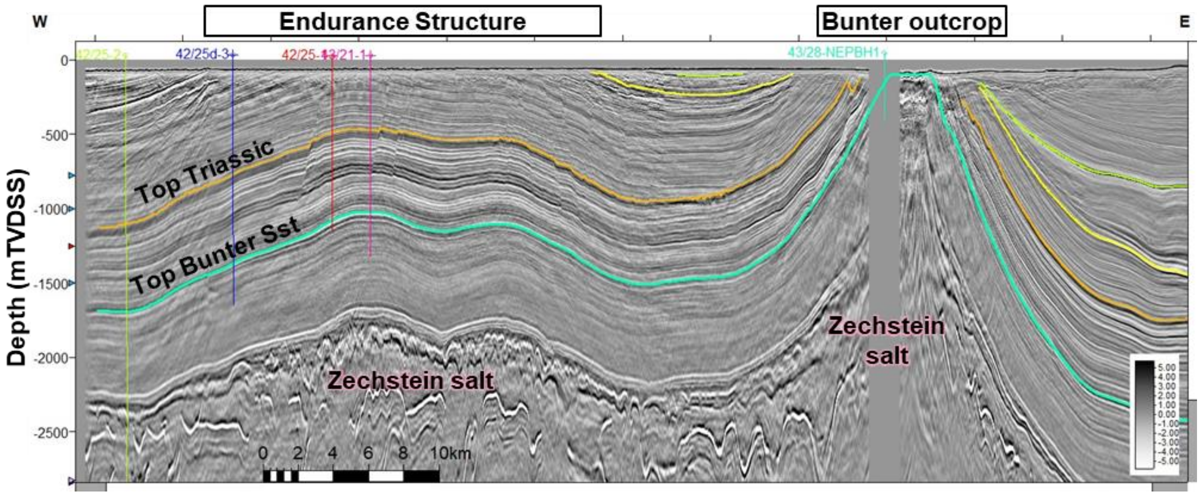


Figure 3-21 - Cross-section from Endurance Store structure to outcrop area, from seismic imagery

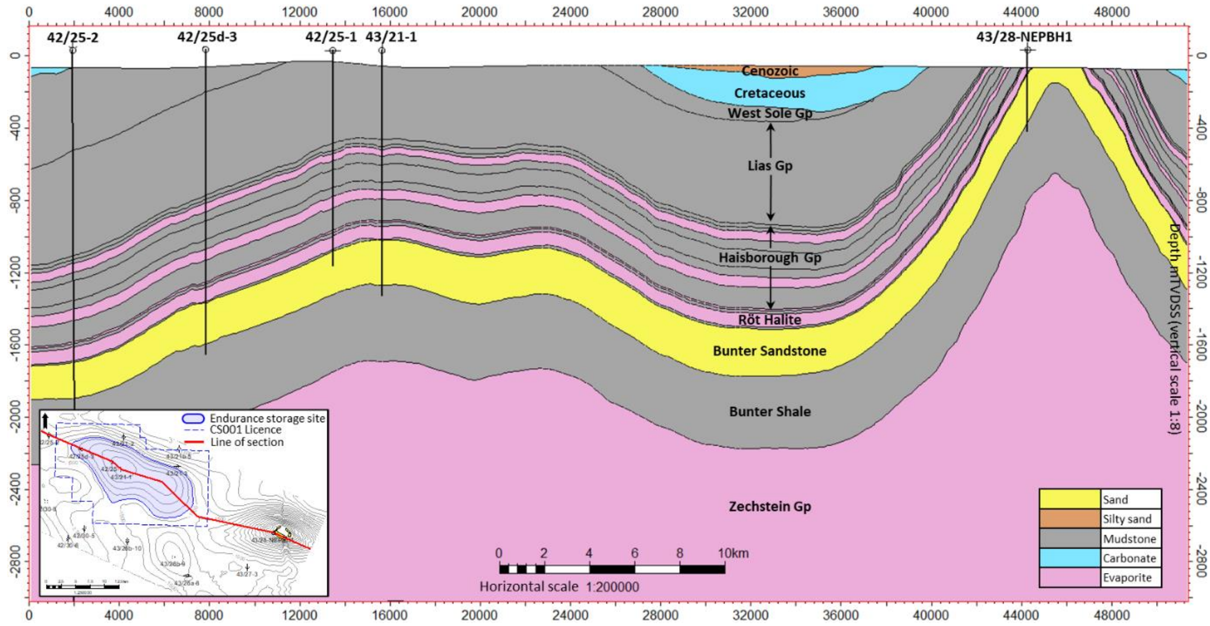


Figure 3-22 - Cross-section through Endurance Store structure showing Bunter Sandstone Formation occurring at the seabed and the relative location of previous (legacy) wells

3.4.5 Legacy Wells

There are three on-structure legacy wells, i.e. wells that were drilled previously and which penetrate the aquifer (Figure 3-19). The three wells were drilled by Mobil in 1970 (43/21-1), BP in 1990 (42/25-1) and National Grid (NG) in 2013 (42/25d-3) and have been assessed for existing integrity, risk of CO_2 leakage, quantification of the risked leak rate and potential remedial actions (bp, 2021e).

The initial fluid in the Store is a salt-saturated brine. Even if left un-isolated, it will not flow to the seabed as the aquifer is normally-pressured and the fluid denser than seawater. The injection of CO_2 will raise the pressure, and additional work has been done to demonstrate that the risk of leakage through existing well barriers and isolations is low, particularly in the oldest of the three wells.

National Grid well 42/25d-3 is the most recent well, drilled specifically to appraise the field for CO_2 storage, and has been plugged in line with current industry and regulatory guidelines with a combination (2-barrier) cement isolation of the Bunter sand. BP well 42/25-1 and Mobil well 43/21-1 were plugged in line with regulatory and industry guidance at the time, but records of verification of barrier integrity were less detailed than required today. The primary barrier in both wells is a cement plug set above the Bunter sand, which is considered sufficient to withstand the maximum anticipated CO_2 pressure at cessation of injection. The overlying Rot Halite salt layer is predicted to “creep” over time (i.e. close in and form a seal) above the primary barriers and provide additional confidence in CO_2 isolation, effectively re-instating the natural cap rock. This will already have occurred in the time since well 43/21-1 was abandoned, and will have occurred in well 42/25-1 approximately five to 10 years after injection commences.

The risk of CO_2 leakage via a leak path associated with a legacy well is primarily a risk for the on-structure wells as it is unlikely the off-structure wells[128] would see any CO_2 assuming the plume does not migrate beyond the spill point. The off-structure wells will however experience an increase in pressure within the Bunter Sandstone due to displacement of fluid by CO_2 from Endurance into the regional aquifer. Assessment of off-structure wells which could potentially leak brine if the cement casing of these wells came into contact with the aquifer fluid, demonstrated that the probability of leakage was also very low (bp, 2021e).

3.4.6 Summary

Containment within a store is the primary purpose of a CCS project. The Endurance Store and associated overburden (the rock layers above the Store) has (bp, 2021d):

- Excellent trapping mechanism: the rock architecture of the Store and overlying material provides storage security;
- Seal competence: the impermeable overburden provides storage security, primarily consisting of sealing lithologies such as clay, shales, anhydrites and halite (the minerally occurring form of sodium chloride, or table salt);
- Capacity: the Endurance Store has significant store capacity of about 450 Mt CO_2 due to the size of the Bunter Sandstone Formation ‘dome-like’ structure; and

[128] *Wells which were drilled previously and which do not penetrate the aquifer.*

- Injectivity: the structure contains pore spaces between sand grains that are filled with saltwater. These pores are large enough (porosity) and connected enough (suitable rock permeability) to allow CO_2 to move through and be stored.

The Store also has a limited number of on-structure legacy wells which have been evaluated to present a low risk of CO_2 leakage (bp, 2021e).

In addition to the dissolution of CO_2 into Formation Water[129], geochemical processes operating over tens of thousands of years result in the precipitation of CO_2 into mineral form and/or it being held by, for example, clay minerals. This means that, over time, CO_2 storage security increases.

100 Mt of CO_2 are planned to be stored over the anticipated 25-year operational period of the Development[130]. The target CO_2 injection rate is 1 MtPA per well on average and 1.5 MtPA per well maximum. Due to temperatures and depth pressures in the Endurance Store, CO_2 will be in dense phase form.

3.4.7 Measurement, Monitoring and Verification

The Energy Act 2008 provides for a licensing regime that governs the offshore storage of CO_2. It forms part of the transposition into UK law of EU Directive 2009/31/EC on the geological storage of CO_2. Regulations state "Monitoring is essential to assess whether injected CO_2 is behaving as expected, whether any migration or leakage occurs, and whether any identified leakage is damaging the environment or human health". OSPAR Decision 2007/2 on the Storage of Carbon Dioxide Streams in Geological Formations (OSPAR, 2007a) and associated guidelines (OSPAR, 2007b) require that any permit or approval issued shall contain a risk management plan that includes monitoring requirements.

Accordingly, a MP (bp, 2023a) for the Endurance Store is being developed and agreed with the NSTA as part of the storage permitting process. Although risk mitigation barriers and monitoring controls make it extremely unlikely that CO_2 leakage will occur from the Store, effective monitoring of the shallow sub-surface, seabed and overlying water column is required to detect, attribute and quantify any CO_2 leakage above the natural temporal and spatial variations that occur in marine environments.

The MP describes the monitoring that is designed to demonstrate conformance and verify containment, and to detect and measure any significant irregularity or leakage event, at the Endurance Store. The MP is designed to identify indications of any risk events set out in the Containment Risk Assessment (bp, 2023b), and directly informs the Corrective Measures Plan (bp, 2023c) and the Provisional Post-Closure Plan (bp, 2023c). It is based on the characterisation of the storage complex described in the Storage Site and Complex Characterisation (bp, 2023d).

The activities described in the MP encompass the following domains:

- Endurance Store and identified potential CO_2 leakage pathways;
- CO_2 injection facilities including wells and subsea infrastructure (manifolds etc.), all of which are enclosed within the footprint of the Endurance Store at seabed;
- Bunter Sandstone Outcrop; and

[129] Formation water is water that occurs naturally within the pores of rocks.

[130] Volumes consistent with those which will be contained within the Store development plan to be submitted to the NSTA.

- CO_2 pipeline routes offshore to the Endurance Store from Teesside and Humber.

The objectives of the MP are to

- Verify containment of CO_2. The key risks to containment relate to (Section 10.5.3):
  - Geological CO_2 leakage (vertical and lateral);
  - Well-related CO_2 leakage (injection, observation & legacy); and
  - Leakage from pipelines and subsea injection infrastructure.
- Monitor conformance of injected CO_2 and Store behaviour;
- Monitor for environmental impact;
- Provide early warning of risk evolution and inform appropriate response;
- Verify injected CO_2 quantity and composition; and
- Demonstrate competent, safe operation of the CO_2 store to stakeholders.

Monitoring will be split into a series of phases across the Development:

- Baseline characterisation (pre-injection): Before injection of CO_2 into the reservoir commences, there will be comprehensive baseline data acquisition for technical assessment and for future comparison.
- Operational phase (injection): During the 25-year CO_2 injection period, data acquired will be monitored to assess CO_2 movement within the aquifer; and
- Closure/post-closure/pre-transfer phase (post-injection): Site closure is anticipated to be performed from 2052 onwards. Post-closure period and obligations are to be defined during dialogue with authorities and will be documented in a post-closure plan.

Candidate technologies were screened (Chapter 2: Consideration of Alternatives) to select technologies for monitoring. Those selected are described fully in the MP and summarised in Table 3-20. Technologies assessed in the impact assessment chapters are discussed in further detail here. These technologies include:

- 4D seismic;
- 4D gravity & seabed deformation; and
- Seabed landers.

Movement of CO_2 within the aquifer will be imaged seismically utilising ***4D seismic***, i.e. 3D seismic data acquired at different times over the same area to assess changes in the Store. The source size is likely to be 300-400 cubic inches (cu in), i.e. 3-56pprox.. 10-20% the size of a typical seismic source. For the purposes of the ES, it is assumed that, following baseline establishment, there will be a maximum of six surveys undertaken during O&M. These surveys will only be conducted over the area that is being developed and not the whole area of the structure. For modelling propagation of the underwater sound generated by the seismic survey (Section 7.4.2), a worst case size of 480 cu in has been utilised.

4D gravity and seabed deformation uses time-lapse gravity to directly measure density changes beneath the seabed. It is particularly effective when a strong density contrast occurs e.g. between CO_2 and brine. The method is highly sensitive to changes in the vertical position of the gravimeter[131],

[131] *Device for measuring variations in the Earth's gravitational field at specific locations*

therefore seabed deformation is also measured using a hydrophone and corrected for as part of the survey procedure. To enable the measurements, up to 50 concrete plinths are placed on the seabed above the aquifer. The plinths are truncated cones of 3-57pprox.. 80 cm diameter at the top, 3-57pprox.. 1.6 m diameter at the base and height of approximately 0.35 m (i.e. seabed footprint per plinth of 2 m^2). For the purposes of the ES, it is assumed that the plinths are permanently deployed during the lifetime of the Development. The conical design is fishing-friendly. A survey of the Endurance Store would involve the placing of a single instrument module on each of the concrete plinths sequentially to obtain a measurement. The survey duration would be of up to two weeks.

The Development is planning to utilise fixed ***seabed landers*** to monitor areas around legacy wells (Section 3.4.5) and at the Bunter Sandstone Outcrop. The landers will be designed to industry standards which may include NORSOK U001/ISO 13628-1 trawl load standards. Sensors are likely to include active sonar landers, which can detect CO_2 releases as low as 1 litre per minute over an area of several square kilometres around the lander position, and passive/chemical landers, which utilise passive sonar to detect CO_2 releases with detection limits of 10 litres/min (passive sonar) and 100 litres/min (chemical sensors) with ranges depending on flux rates. All lander types detect high flux rates. The landers will be capable of deployment and operation for 12 months between servicing. For the purposes of the ES, it is assumed that they are permanently deployed during the lifetime of the Development. It is anticipated that acoustic detections and the chemical sensor data will be transferred by acoustic communications to a Surface Communications Unit – either an Autonomous Surface Vehicle (ASV) or a Gateway Buoy, which will relay the data to a Shore Analysis Facility via satellite communications.

Table 3-19 - Lander parameters

	Equipment	Comment	Dimensions
Active Sonar Lander	Automatic Leak Detection Sonar (ALDS)	Active sonar operating at 70 kHz for long range (>200 m) automatic detection of CO_2 leaks.	Subsea basket 3 m by 2.4 m by up to 2 m high
	Acoustic Modem	To transmit data to the surface.	
	Battery Pack	To power all integrated devices to remain operational for a deployment of up to 12 months.	
	Lander Hub	Central data scheduling, logging and acoustic offloading unit for all integrated devices.	
Chemical/Passive Sonar Lander	Passive Sonar	Operating bandwidth 10 Hz to 200 kHz, dynamic range 118 dB with sensitivity of -170 decibels (dB re µPa).	Subsea basket 3 m by 2.4 m by up to 2 m high
	Chemical Sensors	Measurement of phosphate, nitrate, pH (slow response), pH (fast response), DO concentration, conductivity, temperature and depth at prescribed accuracy and precision.	
	Acoustic Modem	To transmit data to the surface.	
	Battery Pack	To power all integrated devices to remain operational for a deployment of up to 12 months.	
	Lander Hub	Central data hub to allow independent scheduling, time stamping, recording and acoustic offloading unit for all connected chemical sensors and devices.	

Figure 3-23 - Examples of seafloor lander designs deployed during the Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEMM-CCS) project (NOC, 2022)

It is planned to utilise an AUV for surveys over the wider Endurance Store and Bunter Sandstone Outcrop area. The vehicle will carry bathymetric side scan sonar, plus the same suite of chemical sensors as the seabed landers. The AUV's side scan sonar will be the primary sensor for initial detection of very low (0.1 litres/min) to high leakage fluxes. The onboard chemical sensors will detect moderate to high fluxes. The vehicle will conduct a pre-search of the entire area (including legacy and injection wells) and identify any potential leak sites. On completion, it will then return to the possible leaks and conduct a fine-scale search using the sonar and the chemical sensors, to confirm and classify the detections as CO_2 leaks.

The MP will be updated within no more than five years of approval to take account of any changes in risk assessment, advances in technology or understanding, and an assessment of the efficacy of the monitoring technologies applied and monitoring data acquired to date.

In addition to the MP, a ***Corrective Measures Plan*** will be agreed with the authorities to address identified risks associated with CO_2 injection and storage. Corrective measures are intended to mitigate any risks associated with geological storage and can be both preventative and remedial measures. Corrective measures are part of the overall risk management process that is intended to manage the risks from leakage during the life cycle of the Development and support safe geological storage.

The plan is site specific; it is risk based and linked to identified risks from site characterisation, risk assessment and MP and subject to the limitations of available technologies.

The priorities for the corrective measures plan are ranked in the following order:

- Prevention of risks to human health;
- Prevention of risks to the environment; and
- Prevention of leakage from the storage complex.

The plan will address Article 18, Point 1 of 2009/31/EC CCS Directive by:

- Providing evidence that the projected volumes of CO_2 to be injected will be stored safely and completely and permanently contained; and
- Stating risks to complete and permanent containment (as a basis for developing monitoring and mitigation plans), including risks of exceeding any pressure limits and thereby threatening the maintenance of site integrity.

Table 3-20 - Overview of Endurance Monitoring Plan

Monitoring domain	Technology	Pre-injection	During injection	Closure	Post-closure
CO_2 distribution and migration in the subsurface	4D seismic (3D TS)	Baseline 3DHR survey	Repeat surveys at 3-5 year intervals, total of 6 during injection phase	1 repeat survey within ~1 year after cessation of injection	1 repeat survey 5+ years after Closure survey
	4D gravity (seabed array) (subject to feasibility study)	Baseline survey	1-5 repeat surveys (may displace later seismic surveys)	1 repeat survey coincident with seismic survey (as close as possible)	Contingent repeat survey 5+ years after Closure survey
	Seabed deformation (seabed array) (subject to feasibility study)	Required as part of 4D gravity surveys – always acquired contemporaneously			
	Monitoring well	Drilled on eastern crest.	(See below for in-well)	Plugged and abandoned	Provisional: pressure/ temperature monitoring may be utilised with wireless gauges for life of battery
In-well	Downhole and wellhead PTGs	Baseline PT at 5 injectors + monitoring well	Continuous (injection + monitoring wells) Regular Pressure Transient Analysis at injectors during shut-ins.	Wells to remain instrumented between cessation of injection and P&A	Provisional: pressure/ temperature monitoring may be utilised with wireless gauges for life of battery
	Saturation logging (Pulsed Neutron Logging)	Baseline Saturation Logging Tool (SLT) run at 5 injectors + monitoring well	SLT after ~1 year at injection wells, then contingent repeats every 5 years, up to 5 in total. Contingent SLTs at monitoring well at same time, only if CO_2 plume thought to have reached it.	SLT on closure at monitoring well only	-
	Injection Logging Test (ILT)	-	ILT surveys done at same times as SLT above (injection wells only)	-	-
	Downhole fluid sampling (cased hole sampling)	Store Formation Water sampling at injector(s) and monitoring well	Provisional: Store Formation Water sampling at monitoring well at same times as ILT/SLT campaigns above, except for first survey (after ~1 year)	Store Formation Water sampling at monitoring well	-
	Tracers	-	Gas/water tracers injected with early CO_2 injection/initial pre-flush	-	-
CO_2 or Formation Water detection and monitoring in	Fixed landers on-structure legacy wells	Baseline water chemistry, pH, salinity, natural CO_2/gas seepage for minimum 12-month continuous period.	Ongoing continuous monitoring	Landers decommissioned with subsea infrastructure	Legacy wells covered by AUV survey(s)

Monitoring domain	Technology	Pre-injection	During injection	Closure	Post-closure
the marine environment	Integrated mobile (e.g. surface vessels and/or AUVs) and fixed platform surveys at Bunter Sandstone Outcrop	Baseline water chemistry, pH, salinity, natural CO_2/gas seepage for minimum 12-month continuous period.	Periodic integrated mobile platform (e.g. surface vessels or AUVs) and fixed platform surveys (every 6 – 10 years and should a specific area of interest be identified, i.e., anomaly).	Mobile platform survey platform (e.g. surface vessels or AUVs)	Bunter Sandstone Outcrop covered by mobile platform survey(s) (provisionally at Year 1 and every 6 – 10 years until handover)
	Mobile platform (e.g. surface vessels or AUVs) surveys of seabed above storage complex	High-res bathymetry, and water quality baseline	Periodic mobile platform (e.g. surface vessels or AUV's) surveys (every 6 – 10 years)) for acoustic and water quality monitoring	Mobile platform survey platform (e.g. surface vessels or AUVs)	Mobile platform survey (provisionally at Year 1 and every 6 – 10 years until handover)
	Mobile platform surveys around legacy wells off-structure (i.e. 43/21-2 and 43/21-3)	As for storage complex above	Periodic mobile platform (e.g. surface vessels or AUV's) surveys (every 6 – 10 years) for water chemistry, salinity, pH, habitat monitoring, evidence of Formation Water displacement	Mobile platform survey platform (e.g. surface vessels or AUVs)	Mobile platform survey (provisionally at Year 1 and every 6 – 10 years until handover)
Environmental monitoring	Geophysical assessment	See section on mobile platform surveys of seabed above storage complex			
	Visual assessment	Baseline video and still camera imagery at environmental sample stations (Endurance Store, Bunter Sandstone Outcrop and on-structure legacy wells)	Periodic sampling following a risk-based approach (provisionally every 6- 10 years)		Full environmental survey (estimated at Year 1 after cessation) with periodic sampling following a risk-based approach to handover (Provisionally every 6 -10 years)
	Benthic assessment	Baseline grab sampling for physiochemical and macro faunal analysis at environmental sample stations (Endurance Store, Bunter Sandstone Outcrop and on-structure legacy wells)			
Natural & induced seismicity	BGS UK onshore national network (subject to agreement)	Historic long-term baseline (high detection threshold, high uncertainty on event locations and magnitude estimates)	Continuous operation assumed with public catalogue. Only for larger events of magnitude (M) on the Richter scale >2-3; close to real-time data may be possible (subject to BGS agreement)	Continuous operation assumed with public catalogue. Only for larger events (M>2-2.5).	Continuous operation assumed with public catalogue. Only for larger events (M>2-2.5).
	Onshore targeted array (subject to feasibility)	1-2 focussed surface or shallow borehole compact arrays, subject to feasibility and agreement with academia/third-party operator. Minimum 6-12 months baseline data.	Subject to feasibility/value assessment, 1-2 targeted onshore arrays.	Decommissioned after cessation of injection	

Monitoring domain	Technology	Pre-injection	During injection	Closure	Post-closure
	Offshore seabed/shallow borehole sensors (subject to feasibility)	Subject to feasibility, 3-component seismometers deployed with landers and/or elsewhere on seabed. To coincide with focused onshore array for calibration.	Subject to feasibility/value assessment, 3-component seismometers deployed with landers and/or elsewhere on seabed	Seabed seismometers decommissioned with subsea infrastructure	-
Offshore pipeline and flowline integrity	Corrosion monitoring		Offline modelling		
	Real-time transient analysis		Virtual modelling (can be real-time or offline using field data) to detect deviations		
	Visual assessment		Periodic AUV surveys will be used for visual inspection of in-field infrastructure (flowlines, manifolds, wellheads for injectors)	AUV survey	
CO_2 injected quantity and composition	Physical wellhead flowmeters		Continuous, real-time, all injection wells		
	Physical flowmeter & online analyser before entry to Teesside and Humber pipelines		Continuous flow and analyser for bulk composition (CO_2, water (H_2O), NO_x, SO_x, O_2)		
	Fluid sampling and offline chemical analysis		Periodic, before entry to offshore pipeline		
	Online analysers & flowmeters at all emitters		Continuous		

3.5 Vessel Requirements

Table 3-21 and Table 3-22 outlines the anticipated vessel requirements for the installation of the Development at this stage of engineering. These durations do not include mobilisation, demobilisation or transit times, and also do not include allowance for weather, tide and current delays. The number of vessel days required could be reduced during detailed design as a result of amendments to the Development and input from the installation contractor. The vessel days presented here are considered to be a worst case estimate.

Table 3-21 - Predicted vessel requirements for the Development: landfall options

Activity	Vessel type	No. vessels	Days per vessel
Teesside Landfall			
Option: HDD or Microtunnel	Jackup Barge	1	360
	Support Vessel	1	360
	Pipelay Vessel	1	90
	Dive Support Vessel	1	90
Option: Direct pipe	Jackup Barge	1	180
	Support Vessel	1	180
	Pipelay Vessel	1	90
	Dive Support Vessel	1	90
Humber Landfall			
Option: HDD	Jackup Barge	1	360
	Support Vessel	1	360
	Pipelay Vessel	1	90
	Dive Support Vessel	1	90
Option: Direct pipe or Microtunnel or Microtunnel & cofferdam	Jackup Barge	1	180
	Support Vessel	1	180
	Pipelay Vessel	1	90
	Dive Support Vessel	1	90

Table 3-22 - Predicted vessel requirements for the Development (excluding landfall options)

Activity	Vessel type	No. vessels	Days per vessel
Pipeline Installation			
Nearshore pipeline surveys	Nearshore Survey Vessel	2	14
Dredge nearshore trenches prior to pipelay	BHD	4	50
	Support tug to tow BHD to/from site	4	50
	CSD	2	14
	Split Hopper Barge	2	14
Maintenance of dredged trenches and pre-sweeping	TSHD	2	14
Backfill nearshore trenches following nearshore pipelay	BHD	2	50
	TSHD	2	14
Offshore pipeline surveys (pre-lay, as-laid, as trenched, as-built, metrology), boulder clearance, crossing preparation	ROV Support Vessel	1	180
Sweep seabed and boulder clearance as required along offshore pipeline route	SCAR Plough/TSHD/Grab Dredger	1	110
Pipelay[132]	Lay Barge – shallow water	1	135
	Lay Barge – deep water	1	355
	Anchor Handling Vessel	3	490
	Pipe Carrier	6	30
Protection - pipeline ends over winter - cable prior to trenching - infield flowline ends during installation	Guard Vessel	4	360

[132] *Shallow water pipelay will be performed by an anchored barge. Deep water installation preference for dynamic positioning which would take approximately 135 days. Anchored barge duration would be considerably longer (355 days). Activity includes installation of infield pipeline between the two manifolds.*

Activity	Vessel type	No. vessels	Days per vessel
Offshore pipeline trenching	Towed Plough	1	30
Rock placement	DP Fallpipe Vessel	2	30
	Side Stone Installation Vessel	2	30
Installation and protection of tie-in spool pieces between pipelines and subsea infrastructure	DSV/ROV Support Vessel	1	210
Power & communications cable SSIV umbilical lay & trench	Shallow Water vessel	1	20
	Cable Lay Vessel	1	35
Supply of equipment and material	Supply Vessel	1	150
Subsea Infrastructure Installation			
Seabed surveys	ROV Support Vessel	1	12
Install SSIV and manifolds, pile SSIV and manifolds	Heavy Construction Vessel	1	18
	Safety Standby Vessel	1	18
Install infield flowlines and tie-in spool-pieces	Lay Barge	1	30
	Anchor handling Vessel	3	30
	Trench/backfilling Vessel	1	30
	Support Vessel	1	30
Drilling			
Rig move	Anchor Handling Vessel	2	36
	Tow Vessel	1	36
Drilling	Drilling Rig	1	370
	Safety Standby Vessel	1	370
	Supply Vessel	1	106
	Spot Hire Vessel	1	74

Activity	Vessel type	No. vessels	Days per vessel
Helicopter flights	S-92 helicopter	1	370
Seabed survey	ROV Support Vessel	1	1
Commissioning			
Wellheads & subsea infrastructure	ROV Support Vessel	1	50
Pipeline	ROV Support Vessel	1	100
	DSV	1	21
Operations[133]			
Well water washing	ROV Support Vessel	1	14 x 25
	Safety Standby Vessel	1	14 x 25
Retrieval and maintenance of landers	ROV Support Vessel	1	3 x 25
Store monitoring: seismic (6 surveys of 8 weeks over 25 years of operation)	Seismic Survey Vessel	1	56 x 6
	ROV Support Vessel	1	56 x 6
Store monitoring: 4D gravity (baseline survey: 28 days; up to 5 surveys of 14 days over 25 years of operation)	ROV Support Vessel	1	28 + 5 x 14
Pipeline integrity and inspection surveys (5 days every 5 years over 25 years of operation)	ROV Support Vessel	2	5 x 5
Internal pipeline integrity and inspection operations (14 days every 7 years over 25 years of operation)	Dive Support Vessel	2	14 x 4

3.6 Decommissioning

To cease CO_2 injection into the Endurance Store and commence decommissioning of the infrastructure, permission will be sought from the NSTA. Decommissioning of CCS facilities in the UK

[133] *Environmental sampling and survey are assumed to utilise ROV Support Vessels undertaking other inspection activity*

is regulated under the Petroleum Act 1998, as amended subsequent Energy Bills. The UK's international obligations on decommissioning are governed principally by the OSPAR Convention.

The OSPAR provisions do not apply to pipelines; however, current guidance (BEIS, 2018) sets out UK policy on pipeline decommissioning and shows the process leading to approval of a decommissioning programme supported by a focused environmental process that culminates in a streamlined Environmental Appraisal (EA) report. This has informed the current decommissioning philosophy for the pipelines and flowlines which has been produced as part of FEED. During detailed design, decommissioning including enabling removal will be assessed. The size of the pipelines are governed by the required pressure drop to convey the design CO_2 flowrate to the offshore storage site. The ultimate intention is to leave the seabed in the area of the Development in a condition which will pose no risk to the marine environment or to navigation and other sea users. The decommissioning strategy for the pipelines and flowlines will depend on a number of factors including any potential re-use or repurposing opportunities, the availability of suitable technology and knowledge, and the potential environmental, safety and cost implications of decommissioning methods at the end of field life.

Decommissioning will be undertaken according to recognised industry standard environmental practice, in line with the legislation and guidance in place at the time. Discussions on what may be required will be held with the Regulator as early as possible before decommissioning commences.

Prior to the decommissioning process, re-use and recycling alternatives will be considered where feasible to reduce the potential for materials having to go to landfill. In advance of the decommissioning process an inventory of equipment will be made and the potential for further reuse will be investigated. As an integral component of the decommissioning process, bp will undertake a study to comparatively assess the technical, financial, health, safety and environmental aspects of decommissioning options, for which a further EIA may be required at that time.

Wells will be plugged[134] in line with NSTA requirements[135] and industry guidance, following cessation of injection. Site monitoring will be conducted following cessation of injection, i.e. during the closure and post-closure periods. The duration and type of monitoring during these periods, and any other monitoring that may be determined necessary, will be agreed with the relevant regulators as part of the post-closure plan (Section 3.4.7).

[134] *Made incapable of flowing.*

[135] *Current guidance being OEUK Well Decommissioning for CO_2 Storage Guidelines, Issue 1, Nov 2022. The requirements in place at the time of decommissioning will be referenced.*

4 ENVIRONMENTAL DESCRIPTION

4.1 Introduction

This section describes the environment in and around the Development area. This area extends from the Endurance Store, encompassing the offshore extent of the proposed pipelines ending at the mean low water (MLW) mark at Teesside and Easington respectively. Environmental receptors that are potentially sensitive to disturbance are highlighted.

This section draws on published papers, strategic environmental assessments (SEAs), primarily the Offshore Energy SEA 3 (DECC, 2016), site surveys and studies, the East Inshore and East Offshore Marine Plans, and the North East Inshore and North East Offshore Marine Plans.

As this environmental description covers a large area, which can be broadly split into the offshore Endurance Store, the Teesside Pipeline and the Humber Pipeline routes, the format of the environmental description varies between the receptors as required. In some instances, the granularity of data available does not warrant geographic differentiation. However, in other instances the level of detail pertaining to a receptor is such that each of these areas (Endurance Store, Teesside Pipeline and Humber Pipeline) are separately addressed.

4.2 Site-specific Surveys and Information

The main source of environmental, geophysical and geotechnical information in this chapter is taken from survey reports produced as part of the Gardline survey effort at the Endurance Store, conducted in October – November 2020 (Gardline, 2021a, 2021b) and more recent survey effort along the Teesside and Humber Pipeline routes, conducted in July – October 2021 (Gardline, 2022a, 2022b).

These surveys focussed on geophysical data acquisition, shallow geotechnical testing, including sediment characterisation and ground truthing of acquired geophysical data, and collection of environmental baseline information for the Endurance Store area, including the Bunter Sandstone Outcrop and the Teesside Pipeline and Humber Pipeline routes.

Site-specific survey reports referenced in this environmental description are listed below:

- Gardline (2020) NetZero Teesside Integrated Site Survey Marine Mammal Observation and Passive Acoustic Monitoring Report (December 2020);
- Gardline (2021a) NetZero Teesside Integrated Site Survey, Environmental Baseline Report (May 2021);
- Gardline (2021b) NetZero Teesside Integrated Site Survey, Environmental Habitat Assessment Report (April 2021);
- Gardline (2022a) Northern Endurance Partnership Integrated Site Survey – 2021 Environmental Baseline Report (March 2022); and
- Gardline (2022b) Northern Endurance Partnership Integrated Site Survey – 2021 Environmental Survey Habitat Assessment (April 2022).

Please note, the KP reference system utilised by Gardline at the time of survey completion (KP0=MLWS) differs to that which forms the basis of the most recent detailed engineering design (KP0= landfall tunnel entry). The engineering KP reference system is referred to throughout as 'KP'.

For the purposes of this section, 'KPS', is used to denote where the KP referenced corresponds to those which align with the survey. There is a minor misalignment between the two KP systems (of less than 1 km along the Teesside Pipeline and less than 0.5 km along the Humber Pipeline). This misalignment has been fully accounted for in the environmental description and throughout the EIA.

As part of the environmental survey scopes, geophysical data from MBES, SSS, magnetometer and 2D Underwater High Resolution (2DUHR) imagery was acquired over the Endurance Store area and Bunter Sandstone Outcrop. Seismic, sub-bottom profiler and seismic data were also acquired; this aligned with the bathymetry and SSS data and aided the characterisation of the seabed sediments in the area.

A total of 22 environmental stations were investigated across the whole survey area, including 17 sample locations at Bunter Sandstone Outcrop and a further five at the Endurance Store. The sample locations were investigated with a digital stills camera/CTD profiling as part of the habitat assessment. Water samples taken close to the seabed and grab samples of seabed sediments were also taken. The 17 Bunter Sandstone Outcrop stations (ENV01-ENV17) were taken at increasing distances (250 m, 500 m, 1,000 m and 2,000 m) along four transects which radiated from a defined central point (ENV01). The Endurance Store stations (ENV18-ENV22) were distributed in a grid pattern. An additional camera and CTD station (CAM01) was also included.

The most recent survey scopes involved an integrated survey approach encompassing the two pipeline routes that run from the Endurance Store area in the SNS, towards land. Consequently, they covered both the Endurance Store, in addition to the area around the offshore ends of the two pipelines which were more densely sampled. This survey effort utilised MBES, SSS, magnetometer, pinger, vibrocoring, cone penetrometer test with pore water pressure measurement (CPTU) and environmental camera/grab equipment. In total 154 stations were investigated using a drop-down camera, with 125 of these also sampled either directly (in the intertidal zone) or using a Day grab (offshore) or mini-Hamon grab (nearshore). Each of these 125 stations were analysed for DNA, 122 for particle size analysis (PSA), 112 for total organic matter (TOM), total organic carbon (TOC) and hydrocarbons, 106 for metals following aqua regia (AR) digest, organotins, polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs), 109 for macrofauna and 6 for other elements and pH.

The complete survey effort to date across the Development area is shown in Figure 4-1 and Figure 4-2. Inset five of Figure 4-1 shows survey effort at the location of the Bunter Sandstone Outcrop.

A later review of the geophysical data acquired by Gardline during the 2021 survey effort (Gardline, 2022a, 2022b) was commissioned in response to stakeholder queries regarding seabed features within the nearshore area along the Humber Pipeline. The review was undertaken by Xodus Geohzard/Ocean Geo Solutions Inc (XOGS). This review re-interpreted the geophysical survey data along the nearshore section of the pipeline route with the aim of determining the presence of absence of clay outcropping features, particularly in relation to the Holderness Inshore MCZ and Holderness Offshore MCZ (XOGS, 2023). The review was additionally supplemented by other survey work undertaken in the area, for nearby developments (Tolmount and Humber Gateway OWF). During consultation with NE, it was suggested that such features are characteristic of the Holderness coastline (where Humber Pipeline landfall will be achieved). The results of this secondary review are referred to throughout Sections 4.3.3.3 and 4.4.2.3.1, as appropriate.

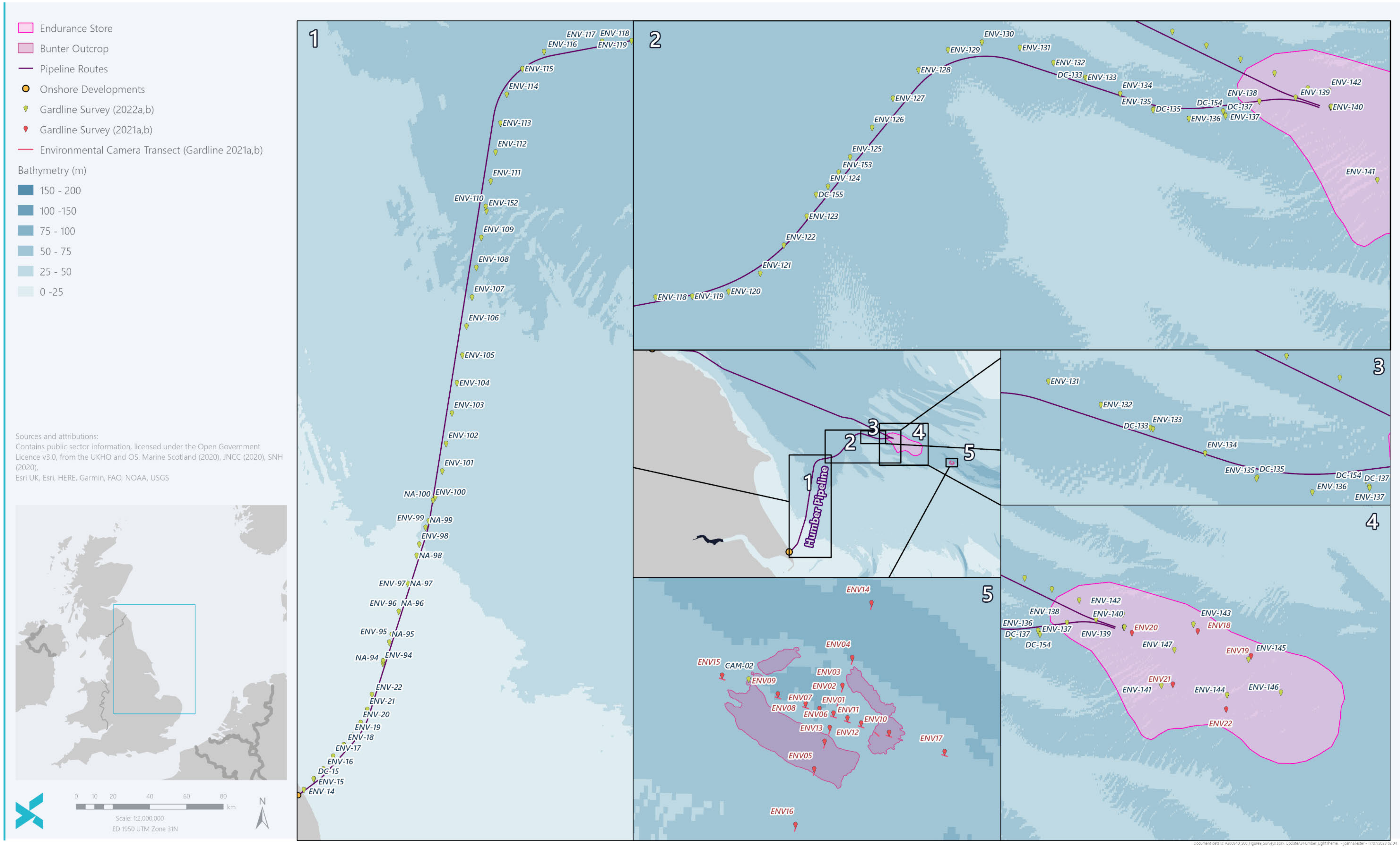


Figure 4-1 - Survey sample locations across the Endurance Store (inset 4), Bunter Sandstone Outcrop (inset 5) and along the Humber Pipeline route

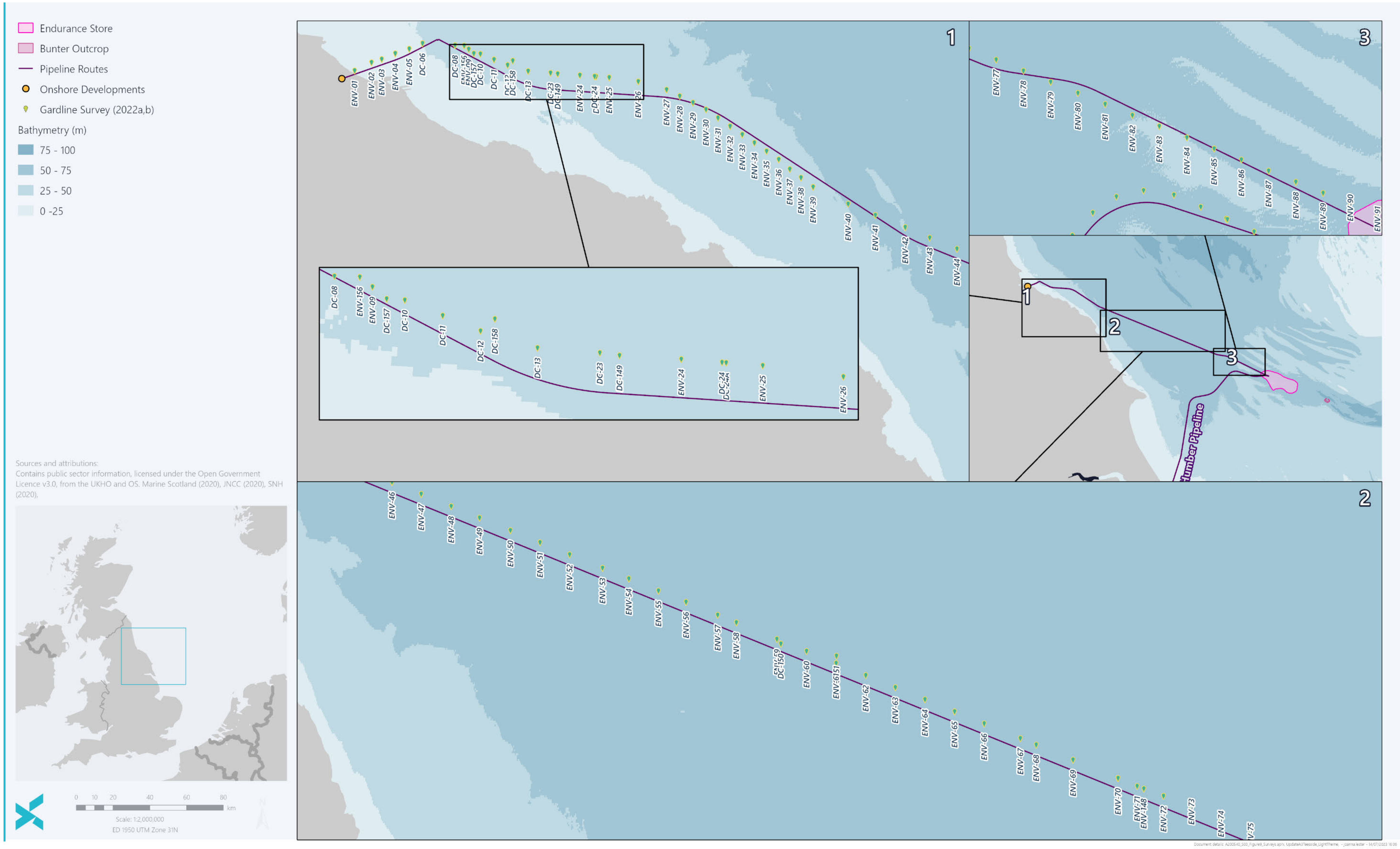


Figure 4-2 - Survey sample locations along the Teesside Pipeline route

4.3 Physical Environment

4.3.1 Weather and Water

The east coast of the UK is relatively sheltered compared to the west. Mean wind speed at the coast is 5-8 metres per second (m/s) during winter and 4-5 m/s during summer (DECC, 2016). Offshore, in Regional Sea 2 where the Endurance Store is located, winds are predominantly from the south and northwest. Wind speeds are typically between 1-11 m/s in summer. In winter there is an increased probability of high winds; In January wind speed exceeds 14 m/s 20% of the time, while in July these speeds occur only 2-4% of the time (DECC, 2016).

This region of the North Sea is dynamic, characterised by shallow, well-mixed waters, which undergo large seasonal temperature variations. The SNS receives significant freshwater input from the surrounding land masses, making it less saline than other parts of the North Sea and subject to nutrient-rich inputs (DECC, 2009; 2011). Currents in the North Sea circulate in an anti-clockwise direction, driven by inflows from the North Atlantic which travel down the east coast of the UK, and from the English Channel, with outflow northwards along the Norwegian coast (Figure 4-3).

The dynamic nature of the marine environment in the Development area is indicated by a study of seabed habitats around the UK that assessed combined peak kinetic energy at the seabed due to both wave and current action (McBreen *et al.*, 2011). This classified the peak combined kinetic energy from waves and currents at the seabed as moderate over most the SNS, increasing to high in areas along the coast.

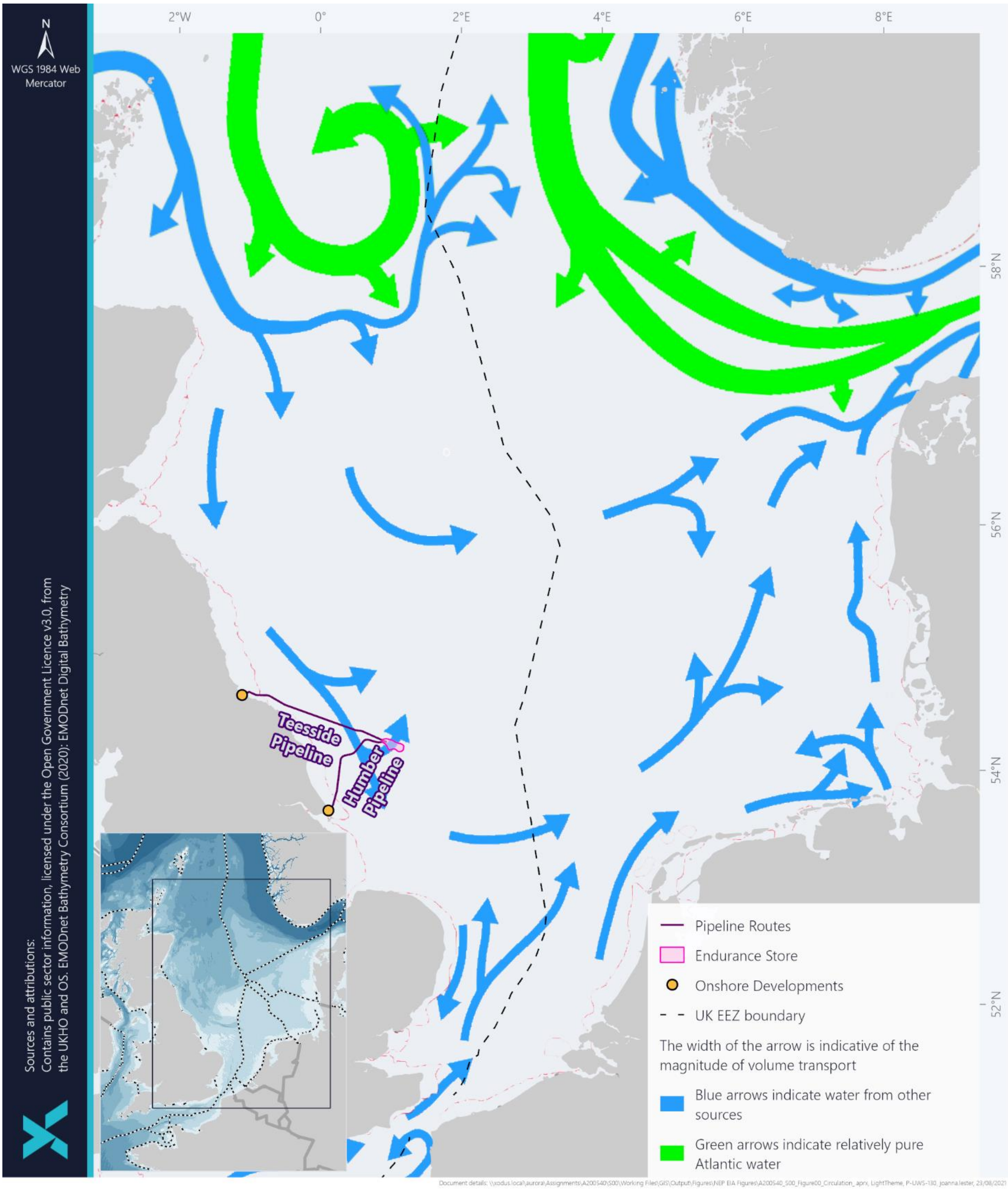


Figure 4-3 - Circulation patterns in the North Sea

4.3.1.1 Endurance Store Area

A preliminary assessment of metocean conditions for the Endurance Store area and Teesside Pipeline route was undertaken in 2020. Figure 4-4 shows the annual wind direction modelled for the Endurance Store. Winds occur from all directions but winds from the southwest and west predominate. The maximum annual wind speed is 25 m/s (bp, 2020c).

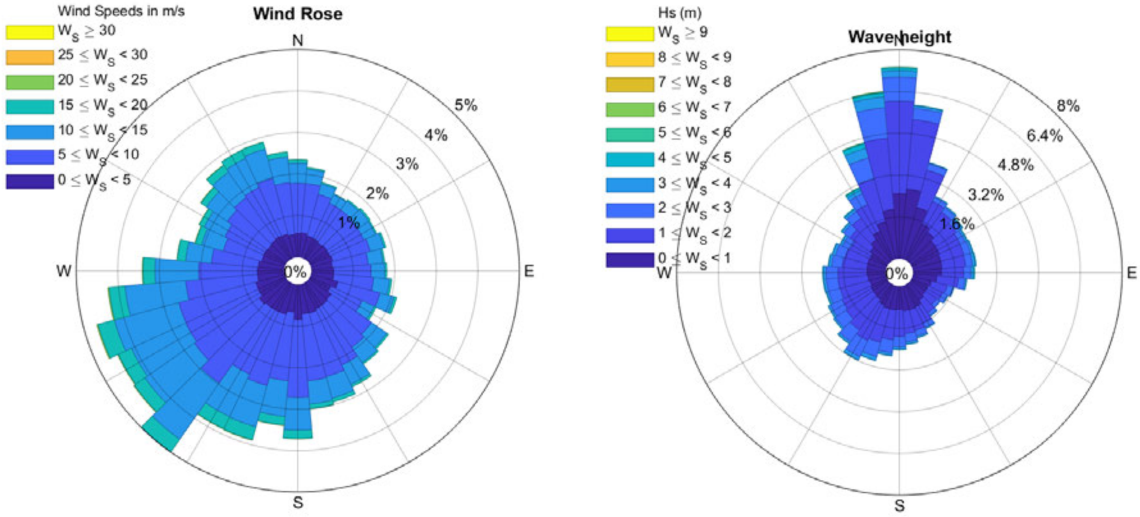


Figure 4-4 - Mean wind direction and speed and mean significant wave height and direction (coming from) at the Endurance Store area (bp, 2020c)

Figure 4-4 also shows the mean significant wave height and direction at the Endurance Store. The majority of waves come from the north and reach a maximum significant height of 7 m. The most frequently occurring waves (based on modelled information), are between 0.5 and 1 m in height, followed by slightly larger waves between 1 and 1.5 m in height (bp, 2020c).

Surface currents are typically between 0.4 and 1 m/s. Near-bed currents are typically lower, at about 0.2 to 0.8 m/s (Figure 4-5). Currents in the Development area flow northwest/southeast.

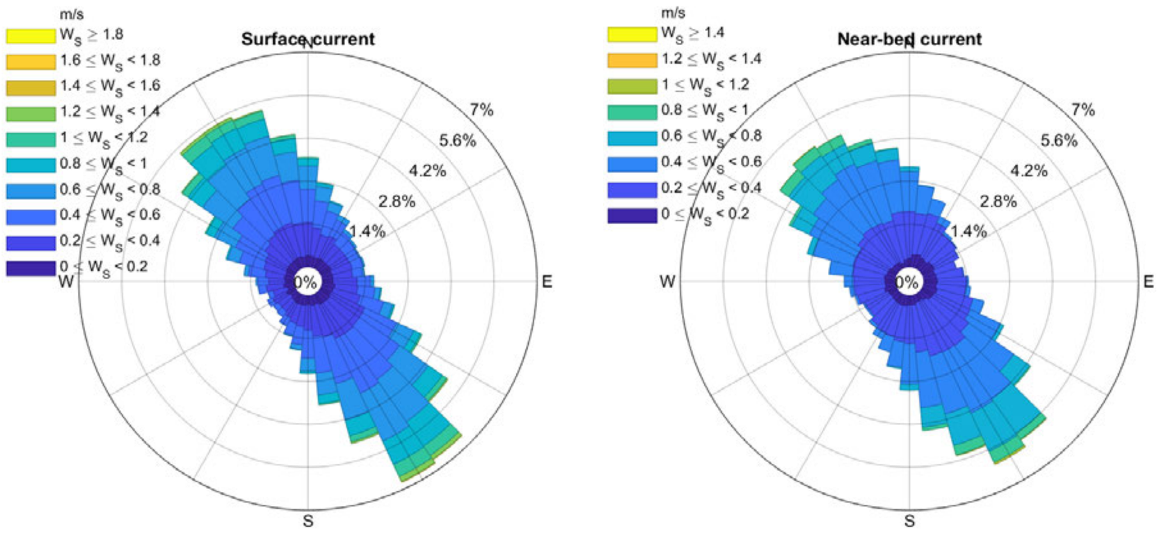


Figure 4-5 - Surface and near-bed annual current speeds at the Endurance Store (going towards) (bp, 2020c)

4.3.1.2 Teesside Pipeline

The spring tidal range at the shore close to the point of landfall for the pipeline is approximately 4.34 m with an associated tidal power of up to 0.03 kW/m^2. The neap tidal range is approximately 2.22 m (ABPmer, 2008).

Modelled surface currents under operational conditions along the Teesside Pipeline route increase with distance from shore. In terms of frequency of occurrence, currents at the shore are most likely to be between 0.1 and 0.4 m/s, compared to speeds of 0.3-0.5 m/s nearer the Store (bp, 2020c). Figure 4-6 shows the near-bed currents at three points along the Teesside Pipeline route, with Figure 4-6a being representative of a point furthest offshore, Figure 4-6b being a mid-point along the pipeline route and Figure 4-6c showing currents at the point of landfall. Near-bed current directions are predominantly southeast and northwest along the pipeline route.

Modelled sea-surface temperatures (SSTs) along the pipeline route range from approximately 8 to 15°C and near-bed temperatures range between approximately 6 to 13°C (bp, 2020c).

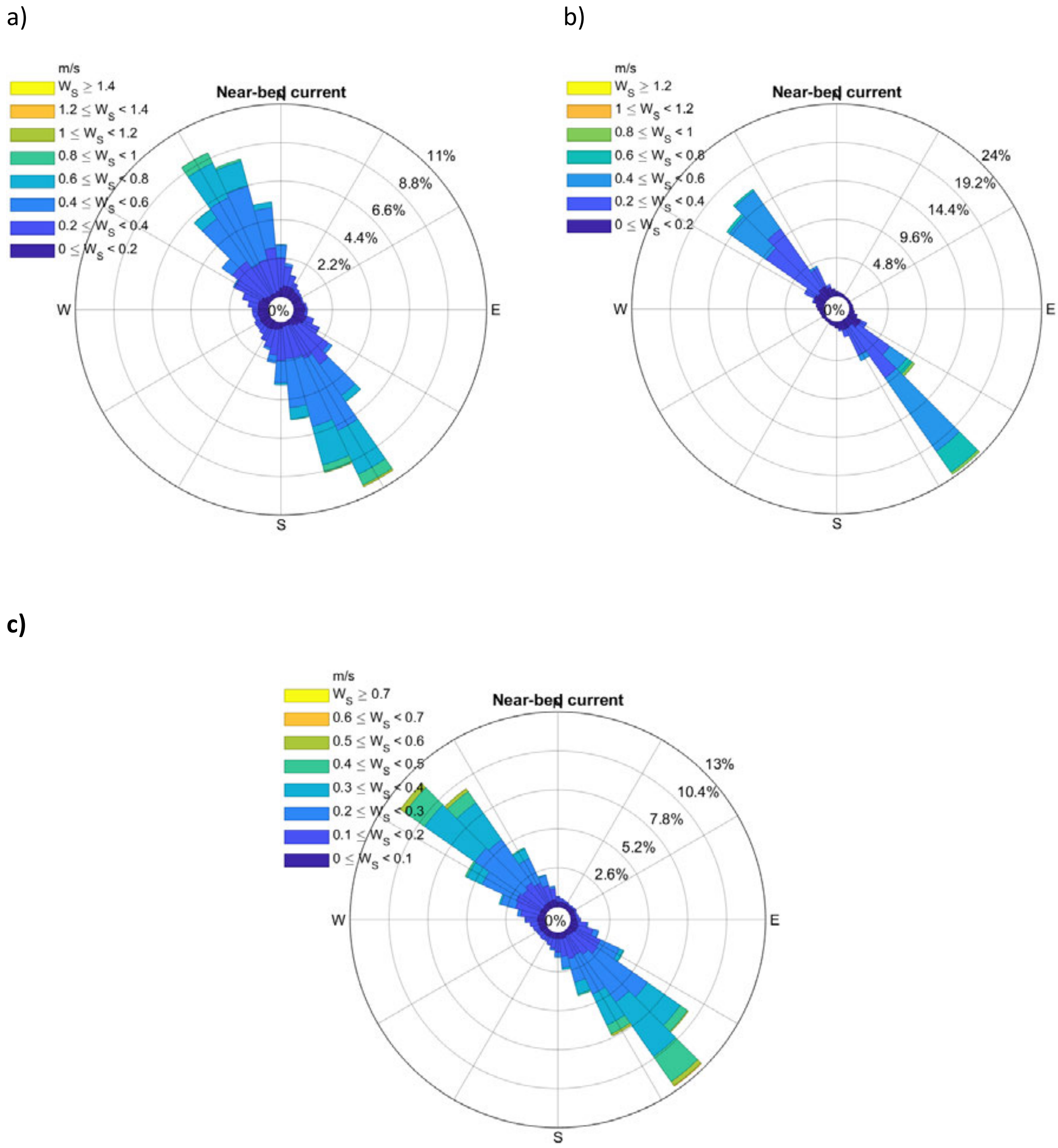


Figure 4-6 - Near-bed annual current speeds (going towards) along the Teesside Pipeline route (a) close to the Endurance Store (b) at a mid-point along the pipeline and (c) close to shore (bp, 2020c)

The wave buoy at Whitby, located 2 km from shore, and the Tyne/Tees wave buoy, 70 km from shore, are situated within 10 km and 50 km from the Teesside Pipeline route respectively. Being further offshore, the significant wave height recorded by the Tyne/Tees wave buoy over the past five years reaches greater heights than recorded closer to shore by the Whitby buoy. The annual mean significant wave height at the point of landfall for the Teesside Pipeline is 1 m which increases with distance from shore to a maximum of approximately 1.66 m near the Endurance Store (ABPmer, 2008).

The Tyne/Tees wave buoy has recorded long period swell waves with heights of 0.5 to 1.5 m and periods over 20 seconds (s). Analysis of the 2020/21 data found the largest significant wave height recorded was 6.6 m (with an associated zero crossing period of 8.2 s) which occurred on 25th September 2020 (Scarborough Borough Council, 2021a).

Though waves come from all directions throughout the year, the majority of the waves approach from the north to north-northeast sector (0-30°; Scarborough Borough Council, 2021a). Compared to other buoys along the northeast coast of England, the Tyne/Tees buoy typically experiences the highest storm wave heights due to its deeper water deployment further offshore (60 m; Scarborough Borough Council, 2021a).

The Whitby buoy, which is closer to both the coast and Teesside Pipeline route, has been recording metocean data since 2010. The largest measured significant wave height to date was 6.7 m and was recorded over the 2015/16 data period. This wave had an associated zero crossing wave period of 8.3 s (Scarborough Borough Council, 2021a).

Waves predominantly approach the coastline at Whitby from the north or northeast direction. In the most recent data year (2020/21), a larger than usual proportion of waves originated from the southeast (Scarborough Borough Council, 2021a).

4.3.1.3 Humber Pipeline

The tide along the Holderness coast floods southwards and ebbs northwards. At Bridlington, just south of Flamborough and Spurn Head, the mean ranges of the spring tide are 5.0 m and 5.7 m respectively, mean neap tidal ranges are 2.4 m and 2.8 m (HR Wallingford *et al.*, 2002). The spring tidal range at the shore within 1 km of pipeline landfall is approximately 5.27 m with an associated tidal power of 0.89 kW/m^2. The tidal power is particularly strong at the entrance to the Humber Estuary and peaks just off the coast of Spurn Head, south of the pipeline landfall. The neap tidal range is approximately 2.34 m (ABPmer, 2008).

Close to the Holderness coast, mean spring near-surface tidal currents range between 0.75 and 1.25 m/s. Near-bottom velocities are lower than those at the surface but only by a small amount due to the relatively shallow water depths (Tappin *et al.*, 2011). The maximum flood flow velocity is generally equal to or higher than the maximum ebb flow and also lasts longer, resulting in a net residual water movement to the south (DTI, 2001).

The Hornsea wave buoy, situated 5 km off Hornsea, is located approximately 10 km from the Humber Pipeline route, therefore provides wave data analogous with the wave climate along much of the route.

Most waves are below 2 m in height with occasional storm events generating waves of up to or greater than 4 m (Cefas, 2021). The mean wave field from 2008 to 2016 for the months of January, April, July and October showed the most frequent wave direction in all months is north-northeast, followed by northeast then east-northeast in all months but July (Premier Oil, 2018).

4.3.2 Bathymetry

4.3.2.1 Endurance Store Area

Across the Endurance Store, water depth varies from 40.1 m below LAT to 63.8 m LAT in a depression in the north of the survey area (Gardline, 2021a).

The seabed was mostly flat (gradients of less than 1°), with the exception of prominent sandwaves which were abundant across the site. The sandwaves were oriented northeast to southwest and were up to 8 m high in places. The flanks of the sandwaves had gradients of up to 11°. Megaripples on the sandwaves were typically less than 0.5 m in height and megaripple features were absent from within the troughs between sandwaves (Gardline, 2021a).

The Bunter Sandstone Outcrop is located approximately 25 km east of the Store. Across the Bunter Sandstone Outcrop survey area water depth varied from 47.8 m LAT atop a shoal in the southwest, to 86.8 m LAT within a large depression in the northeast. The seabed topography is highly irregular across the Bunter Sandstone Outcrop (Gardline, 2021a).

Within the centre of the Bunter Sandstone Outcrop area lies a section of exposed sandstone bedrock which stands up to 15 m from the surrounding seabed and is between 0.05 to 2.5 km in length. Seabed gradients across the area surveyed were generally less than 3°, although localised gradients up to 20° were observed around the central outcrop of bedrock (Gardline, 2021a).

Some sandwaves were observed at the Bunter Sandstone Outcrop, particularly in the south of the site, but were absent where the bedrock was exposed. The sandwaves were oriented in a north-south direction and were up to 3 m in height with gradients up to 7°. Megaripples were superimposed on the sandwaves and rarely exceeded 0.5 m in height (Gardline, 2021a). Sandwaves are common seabed features in areas with sandy seabed which are located in relatively mobile regions, such as the SNS. No sandbanks were identified in the area and therefore these sandwaves are likely isolated features and not part of a more widespread sandbank system.

4.3.2.2 Teesside Pipeline

The water depth along the Teesside Pipeline route varies from -1.2 m LAT at KPS0 to 67.1 m LAT at the offshore end of the route (KPS131.64). Seabed gradients along the Teesside Pipeline route are generally < 1°. However, on the flanks of bedrock outcrops, localised gradients can approach 40° (Gardline, 2022b).

Much of the route is featureless with some areas of irregular seabed due to erosional exposed underlying rock. Along the route, the geophysical survey detected 3951 seafloor contacts which were interpreted to be boulders which measured hights above the seabed of up to 1.5 m. Most of these boulders are found in areas where the underlying bedrock it outcropping and exposed (Gardline, 2022b).

Due to the mobile nature of sediments in the area, sandwaves and megaripples occur frequently along the route. These features occur during the latter half of the route, approximately from KPS42 onwards. The features are of a height of typically 1 to 2 m above the seabed, with the exception of some larger sandwaves offshore. Lower amplitude bedforms are also commonly superimposed on high amplitude bedforms. From KPS111.24 to KPS140.67 the depth of sediment below the seabed is > 10 m in height which forms a thick bank of sand overlying the bedrock (Gardline, 2022b).

4.3.2.3 Humber Pipeline

The water depth along the Humber Pipeline route varies from 10.9 m LAT at KPS0 to 60.9 m LAT at KPS83.18. Seabed gradients along the Humber Pipeline route are generally < 1°, however, on the flanks of bedforms localised gradients can approach 16° (Gardline, 2022b).

Comparatively, far fewer seabed contact points were distinguished along the Humber Pipeline. Of these contact points, 72 were thought to represent boulders with measured heights of up to 5.2 m (Gardline, 2022b).

Megaripples, up to 1 m in height, are found along the initial part of the route from KPS35.41 to KPS38.13. Past this point the features are slightly larger, with a depth of sediment of up to 4 m. From KPS56.81 to KPS100.84, the depth of sediment is > 10 m which forms a bank of sediment covering the underlying geology which is superimposed with megaripples and sandwaves (Gardline, 2022b).

In the nearshore along the Humber Pipeline route, clay outcrop features have been identified (XOGS, 2023). These are described in full in Section 4.3.3.3.

4.3.3 Seabed Sediments and Features

The benthic environment in the SNS is largely sedimentary, consisting mostly of sand or muddy sand with significant areas of coarse sediment and occasional outcropping bedrock closer to shore (DECC, 2009; EMODnet, 2019). Seabed features in the SNS include active sandbanks and sandwaves (DTI, 2001), which are maintained by the tidal and the current regime described in Section 4.3.1. Examples of such features include the North Norfolk Sandbanks, active systems that are thought to be progressively elongating in a northeasterly direction and which are maintained and developed by sediment transported offshore, and the less active Dogger Bank, a large sublittoral sandbank formed by glacial processes before being submerged through sea level rise (DECC, 2009).

4.3.3.1 Endurance Store Area

Ground truthing at the Endurance Store indicated the sediments consist of predominantly loose to medium dense sand. Coarser sediment lies in the troughs between sandwaves (Gardline, 2021a). The uppermost sediment layer within the Endurance Store area becomes more gravelly at the base where it sits atop older deposits.

Mean particle diameter at the Store varied from 270 micrometres (µm) (ENV21) to 419 µm (ENV22); classed as medium sand on the Wentworth scale (Wentworth, 1922). Fines (particles of a size less than 63 µm) content was low, (0% to 7.6%) as was gravel (greater than 2 millimetres (mm)) content (0.3% to 9.9%) (Gardline, 2021a).

PSA of samples taken within the Endurance Store area identified two broad sediment groups within the context of the seabed morphology across the survey area:

- Megarippled seabed near the crests of sandwaves across the Endurance Store exhibited moderately well sorted sand or slightly gravelly sand. Gravels and fines content was minimal, with each contributing to less than 2% of the sediment composition; and

- Seabed between the sandwaves, or where megaripples were less well defined/absent, was poorly to moderately sorted. Gravel content was higher (<1% to 10). These areas of increased gravel are thought to represent coarse lag deposits where the top layer of Holocene deposits have thinned between sandwaves.

Surface sediments at the Store were relatively homogenous in comparison to those at the Bunter Sandstone Outcrop. However, it is worth noting that the Bunter Sandstone Outcrop is located approximately 25 km from the Store and is likely to present differing characteristics to the rest of the Endurance Store area. The seabed at the Bunter Sandstone Outcrop is predominantly medium to coarse silty sand with areas of coarser gravelly sands, additionally characterised by an absence of sandwaves. The sediment layer was at its thickest in the centre of the survey area among the sandstone outcrops. This uppermost sediment layer was up to 18 m thick in places, however, was typically between 1 and 8 m thick in the north of the site but present as only a thin veneer in the south (Gardline, 2021a).

PSA identified varied grain size and contribution of fines and gravel. Mean particle diameter across the Bunter Sandstone Outcrop area varies from 164 µm (ENV09) to 604 µm (ENV06). PSA identified three distinct sediment groups at the Bunter Sandstone Outcrop (Gardline, 2021a):

- Four stations (ENV01, ENV05, ENV06 and ENV07) considered to be moderately well/moderately sorted medium sand. These stations had low fines content (less than 2%) and negligible gravel content (less than 1%), therefore were largely sand;
- Six stations (ENV04, ENV09, ENV12, ENV14, ENV16 and ENV17) had increased fines content (6% to 23%) but low gravel content (less than 3%). These sediments were considered poorly sorted and were classed as sand, muddy sand or slightly gravelly muddy sand; and
- Seven stations (ENV02, ENV03, ENV08, ENV10, ENV11, ENV13 and ENV15) were classed as poorly sorted gravelly muddy sand, with fines 11% to 17% and gravel 7% to 19%. All but one station was classed as medium sand. ENV13 was considered coarse sand.

A number of boulders and debris items populate the seabed within the Endurance Store area. Magnetic anomalies indicated the presence of either Offset Wells 42/25-1 or 43/21-1 (Gardline, 2021a). SSS identified numerous points with raised profiles identified as boulders across the Bunter Sandstone Outcrop area (Gardline, 2021a). The PL1570 pipeline from Shearwater to Bacton Terminal was also identified during SSS surveys; the pipeline passes through the Bunter Sandstone Outcrop area from north to south across the centre of the survey area. The pipeline appears to be trenched and backfilled and stands 0.5 to 1 m above the seabed. At one point the pipeline is almost 2 m above the seabed – this location is thought to represent an area of localised gravel placement. Though not identified during the SSS survey, magnetic anomalies confirmed the presence of a known legacy well (Offset Well 43/28a-3), in addition to three remnant spudcan depressions each of approximately 30 m diameter (Gardline, 2021a).

Chemical analysis of the sediments was also conducted as part of the survey workscope. Hydrocarbon concentrations (Total Hydrocarbons (THC), total n-alkenes, and polyaromatic hydrocarbons (PAHs)) showed positive correlations with TOC and were consistent with background data. Sediment concentrations of THC across the whole survey area ranged from 2.9 µg/g at station ENV19 to 5.2 µg/g at station ENV21 (Gardline, 2021a). Putting this in a wider context, 4.34 µg/g is the mean THC concentration for stations over 5 km from existing infrastructure in the SNS. While station ENV21 showed THC levels higher than this mean, THC concentrations at all sites across the Endurance Store and Bunter Sandstone Outcrop were below the THC 95th percentile (11.39 µg/g; Gardline, 2021a). All THC concentrations were well below levels considered to generate adverse effects on benthic macrofauna.

TOC and TOM were relatively uniform across the Endurance Store samples, with an average TOC of 0.4% and TOM of 2.4%. Greater variation was observed at the Bunter Sandstone Outcrop. Generally, increased TOC values are expected with fine sediment, as it adsorbs to the increased surface area provided by smaller particles; this relationship was observed in the survey samples. TOM content at the Endurance Store was consistent with expected background values. Conversely, TOM at eight stations at the Bunter Sandstone Outcrop exceeded the 95th percentile value (Gardline, 2021a).

Concentrations of aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium (Li), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), strontium (Sr), titanium (Ti), vanadium (V) and zinc (Zn) were determined in the sediment samples. Most metals concentrations were below their respective Effects Range Low (ERL) levels across the Store and Bunter Sandstone Outcrop samples, suggesting toxic effects on biota would rarely be observed (Gardline, 2021a). ERL is a measure of toxicity in marine sediments. Below the ERL threshold toxic effects are scarcely observed or predicted. Above the Effects Range Median (ERM), effects are generally or always observed. Concentrations between ERL and ERM are those in which harmful effects would occasionally occur. The concentration of As at one station (18 µg/g) exceeded the ERL for As (8.2 µg/g) but fell far below the ERM (70 µg/g).

The Centre for Environment, Fisheries and Aquaculture Science (Cefas) currently has Action Level limits for contaminants such as trace elements and PCBs in dredged material for possible disposal to sea. The Action Levels are not statutory limits but are used as guidelines on the disposal of dredged material to sea. Generally, contamination below Action Level 1 is of no concern. Material with contaminant levels above Action Level 2 is generally considered unsuitable for sea disposal. The most recent survey effort within the Endurance Store area had a focus on the western-most half of the Store, where the two pipeline routes will terminate. During this survey effort, Mn, Se and V exceeded apparent effects thresholds (AETs) at most stations in the west of the Store area, while As and Cd exceeded Cefas Action Level 1. AETs are concentrations of a contaminants in sediments above which adverse biological effects have been observed consistently. These concentrations as reported by Gardline (2022a) indicate that low-level toxicological impacts to biota associated with these metal concentrations may occur within the Endurance Store area where the two pipeline routes start.

Ba presence can be important in the detection of localised anthropogenic sediment pollution as it is often used in drilling fluids. Ba levels recorded in the survey samples were notably higher when compared against previous surveys in the area, exceeding the mean of 218 µg/g for samples taken in the SNS over 5 km from infrastructure (Gardline, 2021a). These elevated levels were suggested to be due to increased local infrastructure development. Other metals were most elevated in gravelly muddy sandy sediments and overall suggests that concentrations were linked with natural variation or from some wider diffuse input, rather than from any point source contamination (Gardline, 2021a).

During the more recent survey (Gardline, 2022a), concentrations of Ba, which ranged from 151 µg/g to 234 µg/g, were significantly lower than the previous (Gardline, 2021a) survey, but were consistent with older surveys in the area (from 2012) indicating a possible short-term influence on Ba concentrations relating to the appraisal Well 42/25d-3 that was drilled in 2013 (Gardline, 2022a).

4.3.3.2 Teesside Pipeline

Sediments at the majority of the 66 stations along the proposed Teesside Pipeline route were similar to those at the Endurance Store and were dominated by sand. However, there were notable exceptions at Stations ENV-36, ENV-38 to ENV-39 and ENV-41, which are located between KPS31 and KPS38.6; these sample stations recorded 37-60% gravel and were described as muddy sandy gravel. PSA was not conducted between Stations ENV-05 (KPS4) and ENV-26 (KPS20) due to the dominance of coarse sediments at these locations (Gardline, 2022a).

As expected, there was a significant correlation between depth and particle size along the Teesside Pipeline route, with the coarsest sediments recorded in shallower water (< 30 m LAT). Very poorly sorted sediments dominated in water depths < 51 m LAT, while in deeper water, sediments were more consistently sandy (Gardline, 2022a).

TOM in samples ranged from 1.3% to 8.5% across the 63 stations along the proposed Teesside Route. Though there were no outliers, 48% of stations exceeded the UK Offshore Operators Association (UKOOA) (2001) 95th percentile of 4.5%. This indicates these samples are organically rich relative to background sediments in the North Sea (Gardline, 2022a). TOC concentrations were most variable and generally highest in areas consistent with the higher TOM content and corresponding to areas of mixed sediments with notable fines and/or gravel content (Gardline, 2022a).

Stations (ENV-29 to ENV-39) exhibited elevated levels of THC, which could have adverse effects on biota (Gardline, 2022a). The maximum THC of 48.9 µg/g was recorded at Station ENV-39 (KPS34), exceeding the UKOOA (2001) 95th percentile and representing a significant high outlier within the Teesside Route data set. This station was > 19 km from any existing well.

Metals were analysed at 63 stations along the Teesside Pipeline route and greatest concentrations were generally recorded at the 20 stations between KPS20 and KPS60.7 (Stations ENV-26 to ENV-52). In particular, elevated levels of several metals were recorded in the shallowest third of the route, especially regarding As. Concentrations of As at stations ENV-29 to ENV-39 (between KPS20 and KPS60.7) were above Cefas Action Level 1 and additionally exceeded Cefas Action Level 2 and/or ERM values from Long *et al.* (1995; cited in Gardline, 2022a). At Station ENV-31, the concentration of As reached a peak of 187.8 µg/g, considerably exceeding the Cefas Action Level 2 threshold of 100 µg/g. These high concentrations of As corresponded to the elevated THC levels observed along this section of pipeline. In addition, Cu, Ni, Pb and Zn concentrations were above Cefas Action Level 1 at several stations within this section of the route. These elevated levels may have low-level toxicological effects on local biota (Gardline, 2022a). Comparatively, along the rest of the pipeline route, metal concentrations fell below respective limits and thresholds.

PCBs are present in the environment as a result of widespread historical use of these products. Although the ban on new uses of PCBs was put in place in 1981, these compounds are very persistent in the environment (Defra, 2012). PCB concentrations were below the limit of detection (LOD)v along the Teesside Pipeline route with the exception of nine sample locations which were located between KPS20 (ENV-26) and KPS34 (ENV-39). At Station ENV-26 (KPS20) the total PCB concentrations of 342 nanograms per gram (ng/g) exceeded the Cefas Action Level 2 threshold (200 ng/g). The

Department for Environment, Food and Rural Affairs (Defra) (2012) widescale report on monitoring of the quality of the marine environment, found that in the Tyne/Teesside area, the highest concentrations of chlorobiphenyls (a type of PCB) were identified in stations closest to the mouths of the Rivers Tyne and Tees.

4.3.3.3 Humber Pipeline

The XOGS (2023) review of the Gardline geophysical data determined the seabed consisted of low relief widespread deposits of gravels, pebbles, cobbles and boulders (cobble pavement). In the very nearshore, until KPS1, the cobble pavement is interspersed with frequent protruding clay mounds and ridges up to 1.5 m in height. From KPS3 to KPS16, these features are generally trending northwest-southeast and are up to 4 m high. Beyond KPS22, sandy seabed sediments become more frequent. The underlying deposits are expected to be part of the Boulders Bank Formation, which is exposed in areas as clay protrusions (XOGS, 2023). The clay exposures are shown in Figure 4-7.

While both mounds and ridges can be locally elevated up to 1.5 m above the seabed, the shape of the features differs. The mounds are up to 15 m across, and the ridges are elongated, varying from 20 m to 70 m in length and up to 15 m wide. These features are also oriented roughly perpendicular to the coastline (XOGS, 2023). The ridges are stationary, covered in gravel, pebbles and cobbles, and likely have persisted since the last glacial retreat. Overall, 17 ridges will be crossed by the proposed Humber Pipeline route. Two ridges are within the Holderness Inshore MCZ and two ridges are within the Holderness Offshore MCZ (XOGS, 2023). These features are discussed further in Section 4.4.2.3.1 with respect to the habitats they support.

a) b)

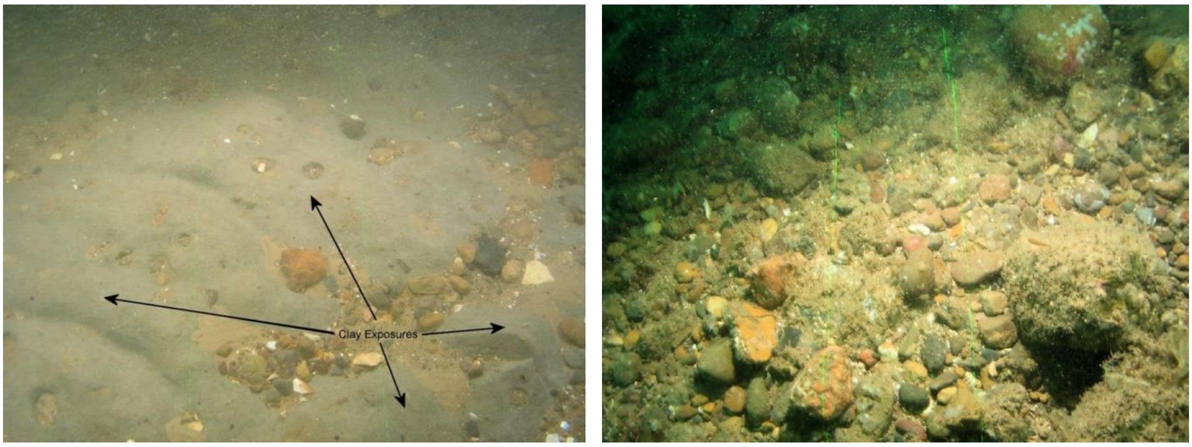


Figure 4-7 - (a) Clay exposures at ENV-15 and (b) typical cobble pavement proximal to a clay ridge feature (XOGS, 2023)

PSA results indicated sediments at the majority of the 49 stations along the proposed Humber Route were dominated by sand, other than between KPS1 (ENV-15) and KPS22 (ENV-100) where gravel and/or silt and clay were dominant in the shallower water. Otherwise, sediments were in-keeping with those across the Endurance Store area (Gardline, 2022a). As was found along the Teesside Pipeline route, sediments became more sorted with depth, with coarser sediments typical of shallower water (Gardline, 2022a).

TOM was highest between KPS71 (ENV-153) and KPS98 (ENV-138) along the Humber Route, corresponding with where the sediment was sand or muddy sand. TOM ranged from 1.7% to 9.3% along the proposed Humber Pipeline route. As at the Teesside Pipeline route, 71% exceeded the UKOOA (2001) 95th percentile of 4.5% indicating these samples were organically rich relative to background levels (Gardline, 2022a). As expected, there was also a significant correlation between depth and TOC along the Humber Pipeline route: generally, TOC was found in higher concentrations in shallower water, attributed to the coarser sediments associated with shallower depths (Gardline, 2022a).

Relatively high THC levels were recorded at various points along the route; the highest concentration (40.8 µg/g) was at station ENV-111 (KPS44) which may have possibly been related to historic drilling activity nearby. While this level does exceed the UKOOA (2001) 95th percentile of 40.1 µg/g for background sediments in the North Sea, this station did represent a significant outlier within the Humber Pipeline route data set. THC levels correlated to areas of increased TOC (Gardline, 2022a).

Concentrations of metals were generally highest between KPS1 (ENV-15) and KPS56 (ENV-117) along the Humber Pipeline route. Within this section of the route, As concentrations were above Cefas Action Level 1 from KPS20.5 (Station ENV-99), while Cd, Ni and Pb concentrations exceeded Cefas Action Level 1 at Station ENV-15 (K P1). Furthermore, Pb and Zn concentrations were above UKOOA SNS and SNS 95th percentiles at several stations within this section of the route. These higher concentrations were consistent with TOC results and generally corresponded to areas of more mixed sediments with higher percentages of fines and/or gravels (Gardline, 2022a).

4.3.4 Sediment Transport

4.3.4.1 Endurance Store Area

Studies completed across the wider SNS region indicate a north to northwest directed sediment transport pathway across the offshore locations covered by the Endurance Store area.

The seabed across the Endurance Store area comprises sandwave and megaripple features, with heights of up to 8 m and gradients that would indicate active movement of these features (Gardline, 2021a). The orientation of these sandwave features varying between north – south and northeast – southwest across the Store area (Section 4.3.3) further highlights the dynamic and variable patterns of sediment movement across this offshore location.

4.3.4.2 Teesside Pipeline

The Teesside Pipeline landfall is located within Coastal Cell 1, as defined within a region-wide coastal monitoring programme which collates information on coastal change and which extends between St Abb's Head, Scotland and Flamborough Head. The coastline and nearshore seabed in this area are predominantly controlled by the underlying geological structure, which creates a series of typically sandy bays between harder rock headlands. Sediment transport processes along the frontage are through longshore transport processes in the nearshore, with cross-shore sediment movement particularly in relation to seasonal environmental patterns. Where individual bays exist, longshore transport is generally well-confined within these along the coastal cell frontage (Scarborough Borough Council, 2014).

Elsewhere along the more open coast that characterises the Teesside Pipeline landfall, sediment transport is predominantly to the south, where drift rates are relatively low and temporary drift reversals can occur along frontages under short-duration storm events from different directions. Sediment transport is also strongly influenced by changes in orientation of the shore profile and the angle of the shore relative to the approach directions that characterise the nearshore wave climate. There are complex physical process effects in the lee of major headlands (e.g. Hartlepool Headland, Scarborough Castle Headland) and significant shore-perpendicular structures (e.g. North and South Gare Breakwaters, Whitby Harbour Piers) which have localised effects on sediment transport directions and rates. Cross-shore sediment exchange is also of great importance to the frontage along the coastal cell, with many beaches experiencing significant onshore-offshore transport during storm events. During periods of energetic storm events, material is drawn down the beach to the lower foreshore and nearshore zone, where it can become entrained by tidal currents and advected along the coast, generally in a southerly direction in line with the dominant sediment transport direction (Scarborough Borough Council, 2014).

In general, beach sediment slowly and progressively returns to the upper foreshore as conditions become calmer, leading to beach recovery. Therefore, it is wave-generated forces that dominate longshore transport in this region, with tidal currents having little effect in the mobilisation of sediments. Generally, sediment volumes involved in such short-term cross-shore transport can be greater – in many cases orders of magnitude greater – than the net alongshore sediment transport potential. It is likely that during storms sediment is removed from the beaches as a cross-shore process and then transported alongshore (predominantly to the south) in the shallow nearshore zone. After the stormier wave climate has passed, the sediment then progressively returns to the beaches as a cross-shore process (either within the same bay or further south along the coast after bypassing a headland) during calmer wave conditions (Scarborough Borough Council, 2014).

4.3.4.3 Humber Pipeline

The Humber Pipeline landfall is located within Coastal Cell 2, which extends between Flamborough Head to Gibraltar Point at the mouth of The Wash. The Holderness coast is one of Europe's fastest eroding coastlines, receding landwards at a rate of between 1.5 and 2 m/year (ERYC, 2017a). Persistent wave and tidal energy from the North Sea drives the erosion of both the soft glacially deposited boulder clay cliffs backing the beach, and the cohesive shore platform (clay substrate) and overlying beach sediments on the foreshore.

Cliff erosion liberates up to 1,000,000 m^3 of sediment annually, while erosion of the clay foreshore produces up to a further 2,000,000 m^3/year (ERYC, 2017b). The estimated proportions of eroded sediment types are: 79% clays (2,370,000 m^3/year), 12.5% fine sands (375,000 m^3/year), 7.5% sands and shingle (225,000 m^3/year) and 1% cobbles and boulders (30,000 m^3/year).

Once the eroded cliff and beach sediments are entrained by the sea, they are transported away by wave and tidal forces. In the nearshore, the dominant northeasterly wave propagation direction drives transport, moving sediment to the south as demonstrated in Figure 4-8a. In deeper water, tidal currents take over, with the flood ebb inequality likewise producing a net movement to the south as illustrated in Figure 4-8b.

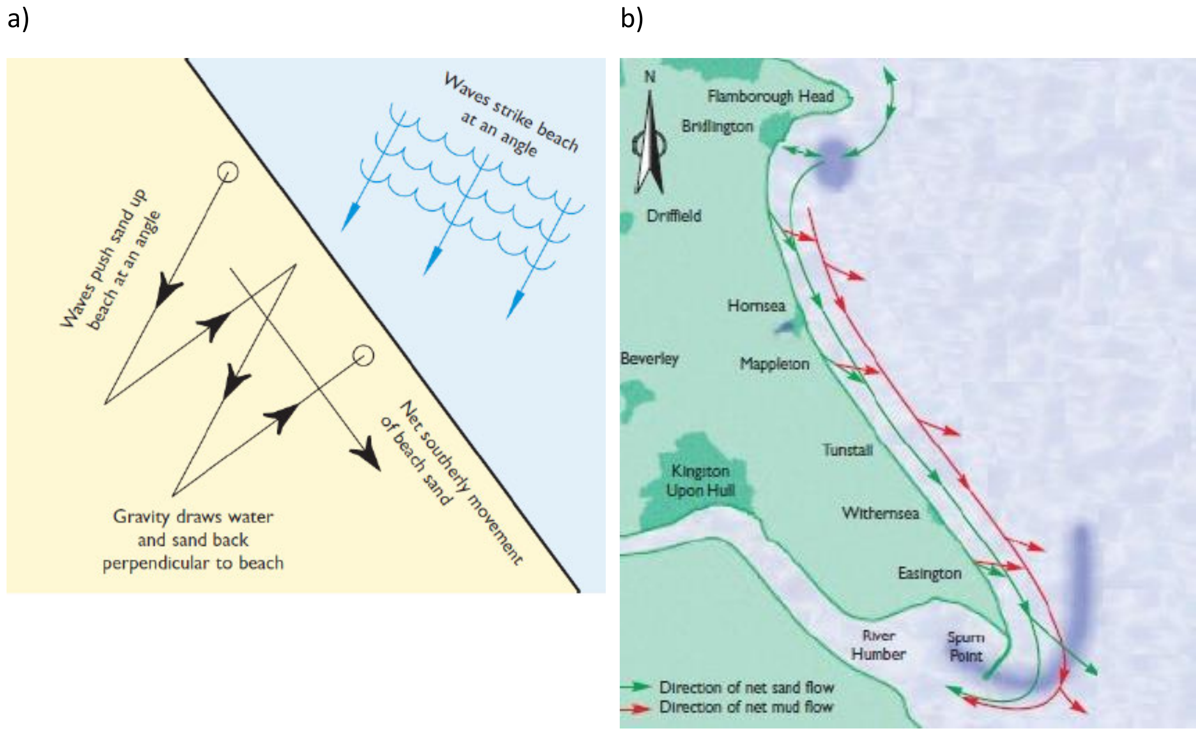


Figure 4-8 - Sediment transport figures demonstrating (a) dominant northeasterly wave direction which leads to net southerly movement of beach sand and (b) dominant offshore transport of eroded clay cliffs, bed strata bed strata and sand in suspension (ERYC, 2017a)

A comprehensive study of the sediment transport of the SNS was undertaken, including numerical modelling and field campaigns to better characterise offshore sediment transport for regions such as the Holderness coast (HR Wallingford *et al.*, 2002). The study culminated in estimates of sediment transport volumes and major transport pathways. The offshore sediment transport schematic derived through an analysis of seabed features is presented in Figure 4-9.

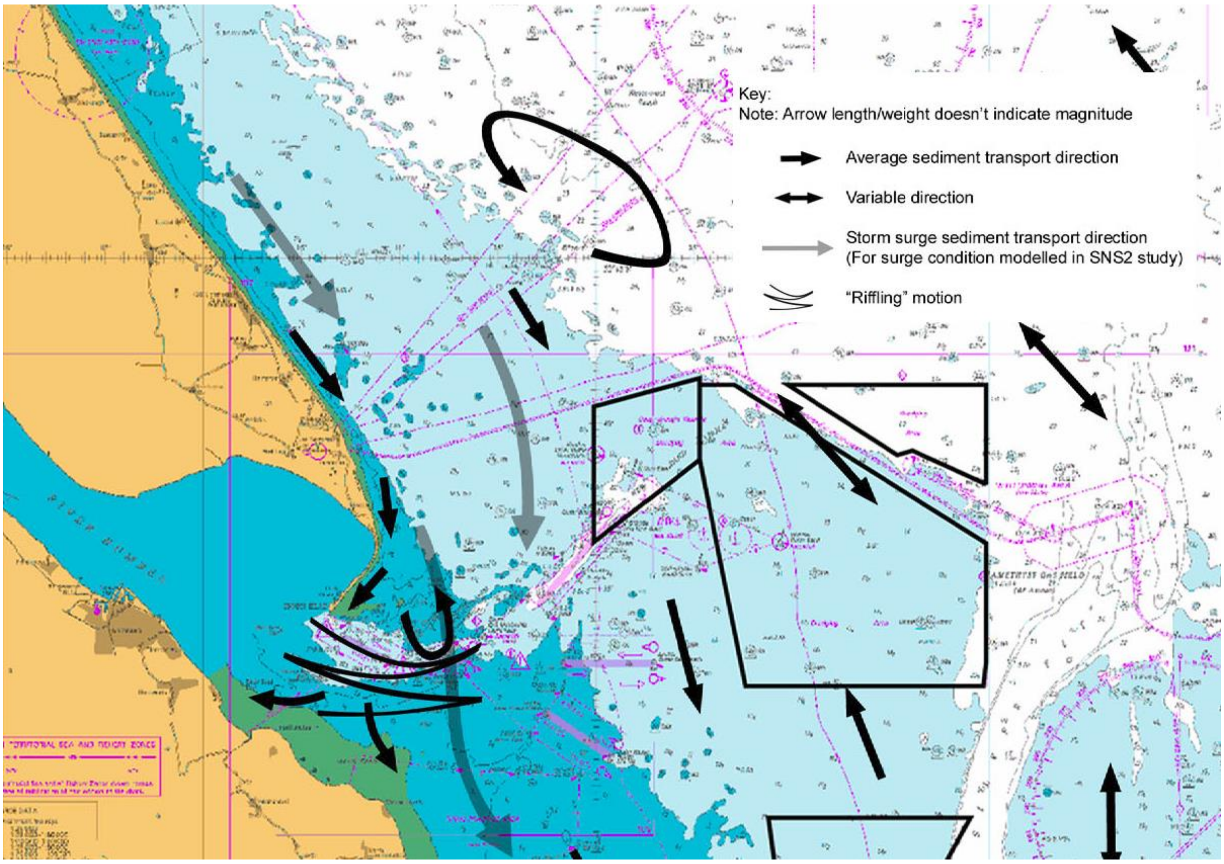


Figure 4-9 - Schematic sediment transport pathways for South Holderness, the entrance to the Humber and North Lincolnshire (the black boxes show licensed aggregate dredging areas) (HR Wallingford *et al.*, 2002)

The potential longshore sediment transport rate for sand was calculated at between 200,000 and 350,000 m^3/year. Transport rates are highest during major storm events, and within about 2 km of the shore (HR Wallingford *et al.*, 2002).

4.3.5 Coastal Properties

4.3.5.1 Teesside Pipeline

The coastal properties along Coastal Cell 1 comprise a series of geologically controlled embayments with sections of open coast. In proximity to the Teesside Pipeline landfall at Coatham Sands, long-term trends in the beach profile show that along the upper beach, dune systems are prevalent, much of which are stable or even accreting seawards (Natural England, 2018c). Accretion is particularly prominent in the west of the Coatham area (Redcar and Cleveland Council, 2021). Overall, beach levels at Coatham Sands remain high in 2021 compared to the range recorded in previous surveys (Redcar and Cleveland Council, 2021). The dunes at Coatham have been influenced by historic slag deposition from local industrial works (Scarborough Borough Council, 2018).

Currently, the SMP covering Coatham Sands proposes NAI as part of future management. At Coatham East, hold the line (HTL) defence is proposed at the Redcar frontage. This may lead to losses of sand at the foreshore which may in turn have a possible ecological consequence on the terrestrial coastal habitats and species (Scarborough Borough Council, 2017).

4.3.5.2 Humber Pipeline

Based on the SMP for the Coastal Cell 2 (Humber Estuary Coastal Authorities Group, 2010a), the coastal properties along Cell 2 comprise five main components:

- Chalk cliffs (Flamborough Head to Sewerby);
- Holderness cliffs (Sewerby to Kilnsea);
- Spurn Head;
- Outer Humber; and
- Lincolnshire coast (Donna Nook to Gibraltar Point).

The Humber landfall intersects with the Holderness Cliffs and is in proximity to Spurn Head. Based on the SMP for this stretch of coast, the level of coastal defence and intervention is variable according to the level and type of local land use and coastal processes exhibited in the area. The cliffs along the Holderness coastline are actively eroding with cliff collapse and recession frequently recorded. These 'soft' cliffs are eroding rapidly at a rate of approximately 1.8 m per year; a process which has been ongoing since the end of the last ice age. This erosion occurs through repeated landslide activity (Humber Estuary Coastal Authorities Group, 2010a). The rapid erosion is attributed to wave activity coming from the northeast, which is also the direction of the longest fetch. This, combined with the geology of the cliffs, is responsible for the differential rate of erosion along the Holderness coast in comparison to the harder chalk headland of Flamborough Head to the north (Curriculum Press, 2003). The cliffs are primarily comprised of mud (up to 67%) and are a main source of suspended sediment regionally. As discussed in Section 4.3.4, this sediment is transported south by longshore drift (Humber Estuary Coastal Authorities Group, 2010a; Tappin *et al.*, 2011). While finer sediments are likely to travel down to the Lincolnshire coast, larger sediment sizes, such as gravels, are unlikely to cross the Humber mouth.

At certain locations along the coastline coastal defences protect the cliffs, such as at Easington (Humber Estuary Coastal Authorities Group, 2010a). There is an HTL for current defences along the Cell 2 frontage, while a NAI is in place everywhere else, with the exception of Spurn Head, which has managed realignment (MA) in the short-term and MA/NAI in the medium to long-term. In proximity to the Humber landfall at Easington, there is an HTL in place. However, this is due to be reviewed in 2025 (Humber Estuary Coastal Authorities Group, 2010a).

4.3.6 Water Quality

4.3.6.1 Endurance Store Area

Survey and analysis of water quality at the Endurance Store area was completed as part of the integrated site survey. The work included analyses of TOC, total inorganic carbon (TIC), nutrients, suspended solids, THC, PAH, phenols and metals (Gardline, 2021a).

Concentrations of TOC, nitrate and total suspended solids (TSS) were generally below their respective LOD. The few exceptions were at low levels. Mean concentrations of TOC were 3.8 milligrams per litre (mg/L) and 3.3 mg/L at the Bunter Sandstone Outcrop and Endurance Store respectively.

Concentrations of THC were generally below 6.4 µg/L, with a few exceptions. All concentrations of PAHs and 16 priority concentrations were below the LOD at < 1 µg/L for each target compound, indicating PAH levels were negligible and therefore not expected to have deleterious or detrimental environmental effects. All phenols were below their respective LOD.

Concentrations of most of the tested metals were below their respective LOD. This included Hg, Ni, tin (Sn), Al, Be, Cu, Fe, Pb and Zn. Levels of As, Ba, Cd, Cr, Co, Li, magnesium (Mg), Mn, Se, Sr and V were all detected, although these were at low levels. This suggests that the concentrations are not noticeable above background levels therefore the water quality in the area is not significantly compromised by any local contamination.

4.3.6.2 Teesside Pipeline

The Teesside Pipeline route passes through the Tees Coastal water body (GB650301500005), which is designated under the Water Framework Directive (WFD) and is defined as a body of water between the coastline and 3 NM offshore (approximately 5.6 km), running from just north of Hartlepool in the north to west of Runswick Bay. Tees Coastal is classified as being a heavily modified water body (HMWB), since it supports coastal protection, flood protection and navigation, ports and harbours. The water body has a 'Moderate' overall status with a 'Good' performance against chemical standards but a 'Moderate' status against ecological standards (Environment Agency, 2021). The classification status system is made up of many different tiers of data including alien species, pollutants, water chemistry and biological conditions. The water body aims to achieve a target status of 'Good' by 2027. The water body is not monitored for harmful algae and it does not have a phytoplankton classification. There are no WFD mitigation measures currently in place (Environment Agency, 2021).

4.3.6.3 Humber Pipeline

The Humber Pipeline route runs through the Yorkshire South coastal WFD water body (GB640402491000) prior to landfall. The water body runs from Flamborough Head in the north to Spurn Point in the south. Yorkshire South is also considered an HMWB, since it supports coastal protection, flood protection and navigation, ports and harbours. It is currently classified as having a 'Moderate' overall status with a 'Good' performance against chemical standards but a 'Moderate' status against ecological standards (Environment Agency, 2021). The target water body status aimed for in 2027 is 'Good'. The water quality phytoplankton and harmful algae classification is 'High', but the water body is not monitored so there is no known history of harmful algae. There are no WFD mitigation measures currently in place (Environment Agency, 2021).

4.3.7 Endurance Store and Bunter Sandstone Outcrop Fluid Composition

As described in Section 3.4**,** fluids are contained within both the Endurance Store structure and the Bunter Sandstone Formation, which forms the Bunter Sandstone Outcrop, at the seabed ~25 km east of the Endurance Store structure. The composition of the fluids at multiple locations (Figure 4-10) has been analysed (Section 3.4.4) and is presented in Table 4-1.

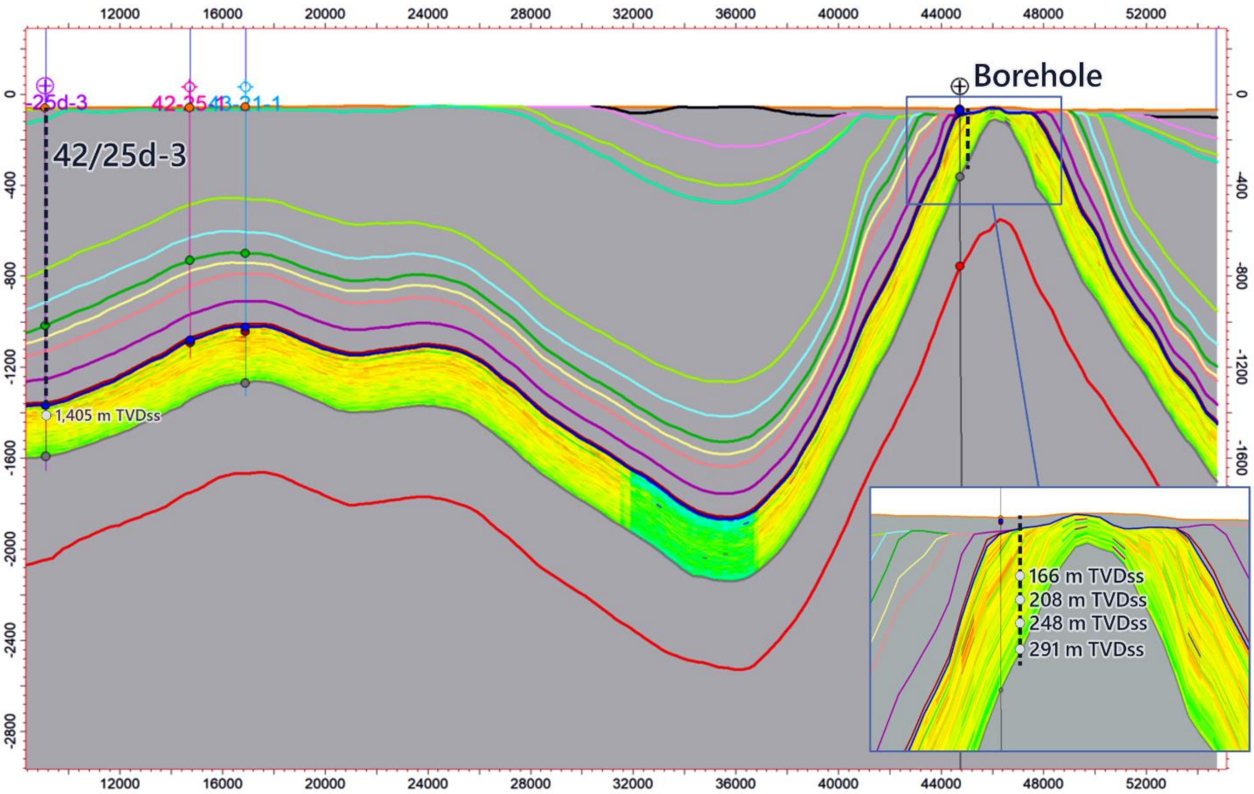


Figure 4-10 - Locations where Store and Outcrop Formation Water samples were obtained from the Bunter Sandstone Formation (True Vertical Depth subsurface, TVDss). Yellow and green shading represents Formation Water. Coloured lines represent boundaries of different subsurface layers.

Table 4-1 - Fluid composition in the Endurance Store structure (sample from well 42/25d-3) and the Bunter Sandstone Outcrop with typical composition of seawater included for comparison (mg/L unless otherwise stated; depths TVDss)

	Store structure[136] 1,405 m	Bunter Sandstone Outcrop[137]				Seawater [138]
		291 m	248 m	208 m	166 m	
pH	5.25	7.2	7.4	7.4	7.6	7.9
Specific gravity @ 15°C (kg/L)	1.188	1.0614	1.0489	1.0404	1.0328	
Conductivity @ 25.0°C (mS/cm)		106	86	72	60	
Resistivity @ 25.0°C (ohm.m)	0.047	0.094	0.116	0.139	0.166	
Total dissolved solids (TDS)	247,659	87,050	67,857	55,594	45,003	34,483
Anionic species (soluble)[139]						
Chloride	148,780	47,601	36,459	29,468	23,910	18,980
Bromide	460	289	227	208	177	65
Iodide	<4	0.40	0.37	0.36	0.29	<1
Nitrate	<4	<0.027	<0.027	<0.027	0.051	<1
Phosphate	<20	0.20	0.23	0.59	0.56	<1
Sulphate	359	6,022	5,583	5,017	3,998	2,649
Bicarbonate	37	148	217	208	226	140
Cationic species (soluble)[140]						
Lithium	8	0.43	0.34	0.19	0.15	0.17
Sodium	79,664	28,537	21,537	17,403	13,989	10,800
Potassium	1,469	1,150	800	586	451	392
Magnesium	3,014	1,535	1,372	1,212	1,143	1,262
Calcium	8,640	1,753	1,629	1,484	1,071	411
Strontium	111	8.1	5.4	3.5	1.5	8.1

[136] *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/531045/K40_Subsurface_Geoscience_and_Production_Chemistry.pdf*
[137] *Expro (2022).*
[138] *Turekian (1968) and Lenntech (2023).*
[139] *Atom or group of atoms having a negative charge.*
[140] *Atom or group of atoms having a positive charge.*

	Store structure[136] 1,405 m	Bunter Sandstone Outcrop[137]				Seawater [138]
		291 m	248 m	208 m	166 m	
Barium	1	<0.1	<0.1	<0.1	<0.1	<0.1
Vanadium	0.07	0.000116	0.000412	0.0000893	<0.00005	0.0003
Chromium	0.4	0.002160	0.001700	0.000764	0.00112	0.0019
Manganese	1.6	<0.5	<0.5	<0.5	<0.2	0.0004
Iron	<1	<1	<1	<1	0.567	0.0034
Copper	1.7	0.47	0.0537	0.122	0.132	0.001
Zinc	8.5	0.155	0.158	0.179	0.139	0.01
Cadmium	0.2	0.000406	0.000319	0.000338	0.000154	0.00005
Aluminium	0.00001	<10	<10	<10	<4.0	0.0009
Lead	1.3	0.00361	0.00647	0.000948	0.000274	0.00003
Elemental species (soluble)						
Boron	10	5.47	5.42	4.78	4.36	4.45
Silicon	3	3.66	5.27	3.94	4.19	2.9
Phosphorus	<6	<10	<10	<10	<4.0	0.088
Arsenic	1.3	0.0033	0.00544	0.0033	0.00093	0.0026
Nickel	1.8	0.0751	0.0962	0.0383	0.0739	0.0066
Cobalt	0.16	<1.0	<1.0	<1.0	<0.4	0.00039
Sulphur		1,950	1,810	1,620	1,310	1,290
Total equivalent						
Cl-	149,271	52,264	40,825	33,387	27,093	
Na+	96,204	34,134	26,475	21,745	17,647	
NaCl	245,474	86,398	67,300	55,132	44,740	

4.4 Biological Environment

4.4.1 Plankton

Plankton consists of the plants (phytoplankton) and animals (zooplankton) that drift with the tides and currents during a transitional stage of life where over time, they will grow and achieve independent mobility. Plankton exist in a range of sizes, from small to microscopic. Phytoplankton forms the basis of most marine ecosystem food webs, and phytoplankton-rich areas provide important feeding grounds for other marine fauna including zooplankton, cephalopods, pelagic fish, seabirds and cetaceans (Johns and Reid, 2001). The distribution of plankton therefore directly influences the distribution and behaviour of other marine species.

The majority of plankton occurs in the photic zone, the upper part of the water column which receives enough light for photosynthesis. This extends to approximately 20 m depth in temperate latitudes (Johns and Reid, 2001), although it varies locally depending on water clarity.

Plankton production generally shows two peaks in the year. The first occurs in spring when increased sunlight allows exploitation of the nutrient rich water generated over winter, and the second occurs in autumn, when the onset of mixing delivers additional nutrients while there is still sufficient energy from sunlight to power photosynthesis.

Phytoplankton abundance in the SNS fluctuates less than in the CNS and Northern North Sea (NNS) due to there being relatively little stratification throughout the year and considerable nutrient rich run-off year-round. The phytoplankton community is dominated by the dinoflagellate genus *Ceratium* (*C. fusus*, *C. furca*, C. *lineatum*), along with higher numbers of the diatom, *Chaetoceros* (subgenera *Hyalochaete* and *Phaeoceros*) than are typically found in the NNS. The zooplankton community predominantly comprises *Calanus helgolandicus* and *C. finmarchicus* (DECC, 2016).

4.4.2 Benthos

The biota living near, on or in the seabed is collectively termed benthos. The diversity and biomass of the benthos is dependent on a number of factors including substrate type (e.g. sediment, rock), water depth, salinity, local hydrodynamics and nutrient availability. The species composition and diversity of the benthos is commonly used as a biological indicator of sediment disturbance or contamination.

4.4.2.1 Endurance Store Area

4.4.2.1.1 Epifauna and Habitats

Faunal abundance and diversity across the Endurance Store area was relatively low, consisting mainly of annelid worms (Polychaeta), prawns (Paguridae), starfish (Asteroidea), bivalves (Pectinidae), fish (Callionymidae, Pleuronectiformes) and sponges (Gardline, 2021a). Comparatively, heterogenous areas of seabed, as at the Bunter Sandstone Outcrop, which consisted of gravelly sand with cobbles and boulders were characterised by higher faunal density, notably Hydrozoa and *Alcyonium digitatum*. Other fauna observed consisted of the following: annelid worms (Polychaeta, *Sabellaria sp.* Tubes); crabs and shrimp (Brachyura, Caridea, Paguroidea); fish (Actinopterygii, *Ammodytes sp.*, Pleuronectiformes); cnidaria (Alcyonidae); urchins, brittle stars and starfish (Asteroidea, Echinoidea, Ophiuroidea) and bivalves (Pectinidae) (Gardline, 2021a). Filter feeding species in particular, were prevalent on the Bunter Sandstone Outcrop.

Much of the Endurance Store surveyed area was considered to be representative of European Nature Information System (EUNIS) biotope habitat A5.27 'deep circalittoral sand' (Gardline, 2021b). A few locations were the exception with coarser sediments and were instead classified as biotope A5.44 'circalittoral mixed sediments'. Figure 4-11 shows the predicted EUNIS classification of sediments within the Development area; the predicted biotopes largely correspond to the most recent survey results (Gardline, 2022b). The EUNIS habitats at sample station locations within the Endurance Store area (and along the Humber Pipeline route) are shown in Figure 4-12. Images of the seabed at the Endurance Store and Bunter Sandstone Outcrop are shown in Figure 4-13.

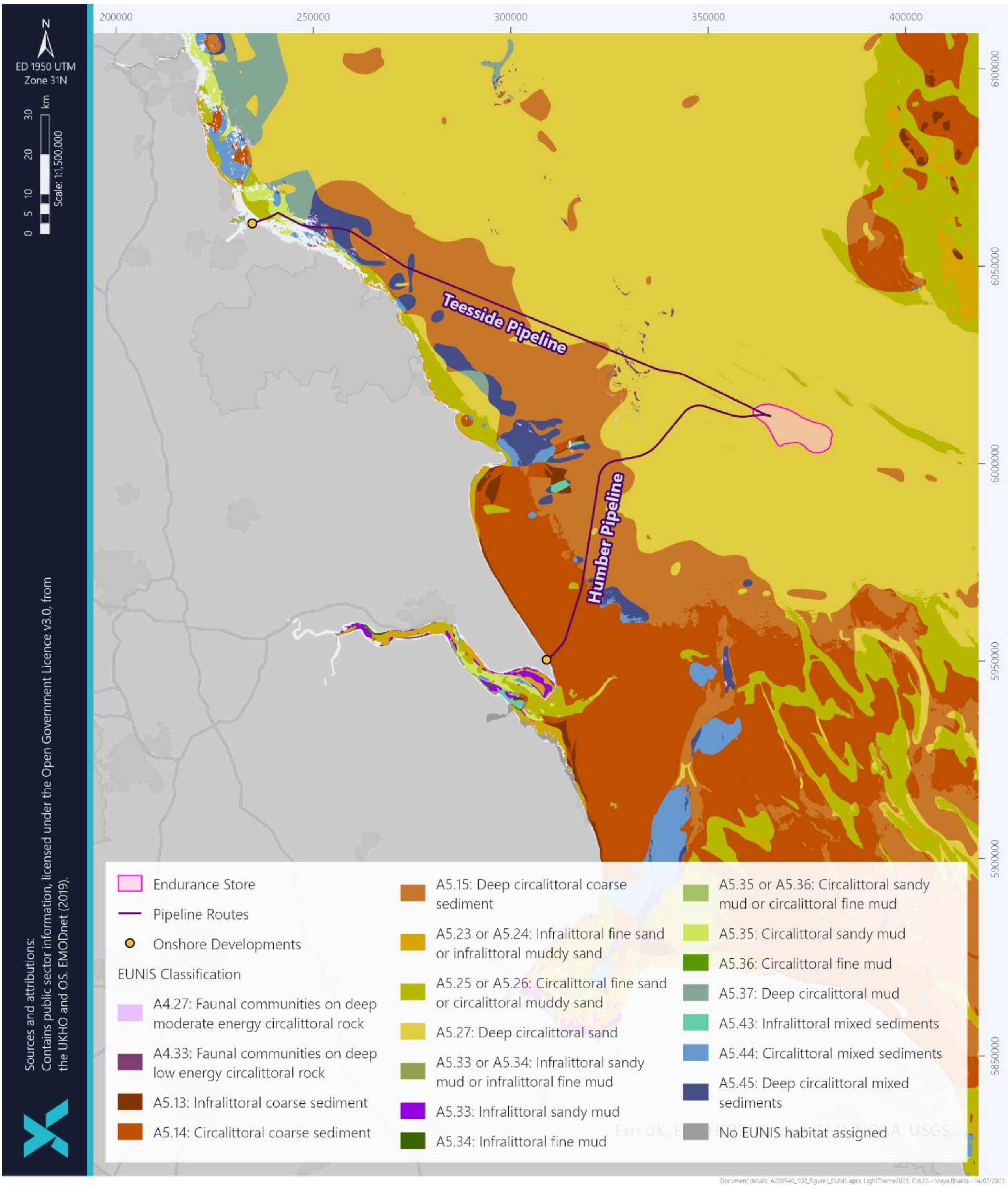


Figure 4-11 - EUNIS habitats across the Development area

During the 2021 survey, at sample locations ENV05 and ENV13 (see Figure 4-13) high densities of brittle stars (Ophuiroidea) were observed covering the seabed. The prevalence of brittle stars at these locations led to their classification as biotope A5.445 '*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment' (see Figure 4-13; Gardline, 2021a).

The most recent survey of the Endurance Store area identified two locations which represented distinctly different habitats. At station ENV-147 EUNIS habitat complex A4.22 '*Sabellaria* reefs on circalittoral rock' was identified. Aggregations of *Sabellaria spinulosa* debris were also noted in grabs recovered from this station (Gardline, 2022b). *S. spinulosa* aggregations are discussed in more detail below.

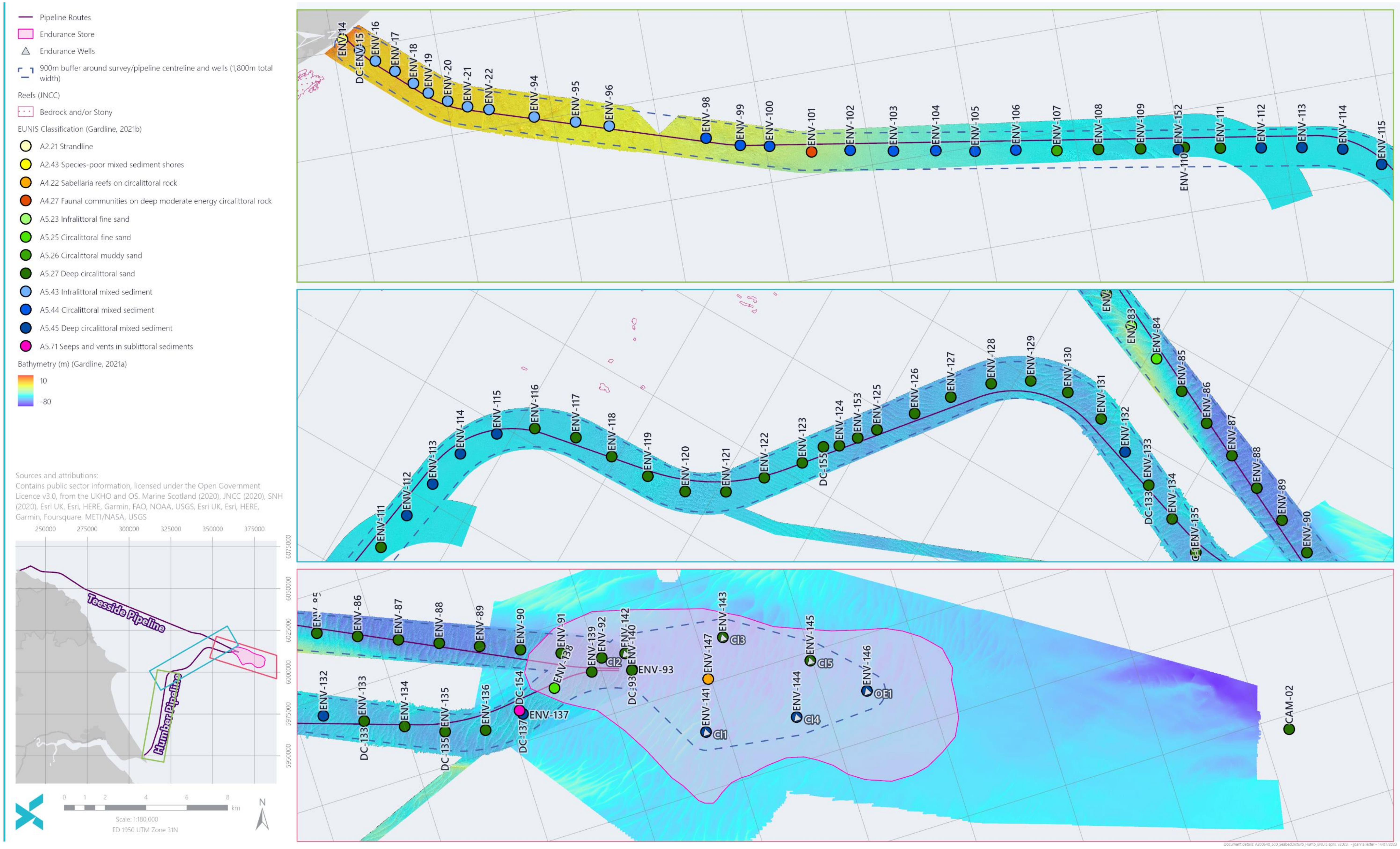


Figure 4-12 - EUNIS habitats at the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

Ocean quahog

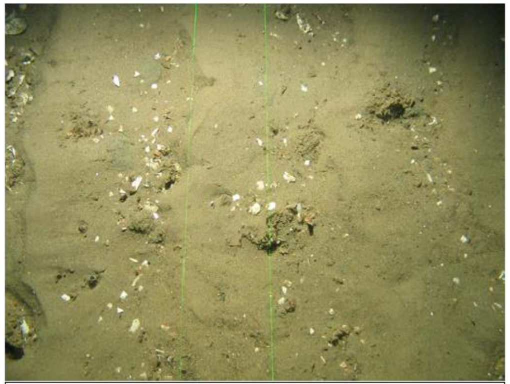
Bivalve shells which resembled the long-lived ocean quahog (*Arctica islandica*), although not confirmed, were seen at stations ENV13 and ENV15 (Gardline, 2021a). *A. islandica* is a long-lived bivalve mollusc which has a very slow growth rate. It is featured on the OSPAR (2008) list of threatened and/or declining species. However, it is commonly found throughout much of the North Sea.

Sabellaria reef

The Ross worm (*S. spinulosa*) is a tube-dwelling polychaete which can form dense aggregations creating a reef structure. Reefs formed from *S. spinulosa* are protected as 'biogenic reefs' under Annex I of the Habitats Directive. *S. spinulosa* was observed at ENV18 and ENV19, in the north of the Endurance Store area (see Figure 4-13) however it was determined that there was no resemblance to biogenic reef (Gardline, 2021b). Figure 4-13 shows some isolated patches of *S. spinulosa*. Small, isolated patches of possible *Sabellaria sp.* Tubes were also observed on still images taken at the Bunter Sandstone Outcrop. Pieces of polychaete casts (possibly belonging to *Sabellaria sp*. Were found in three grab samples (ENV10, ENV11, ENV15, Gardline, 2021a).

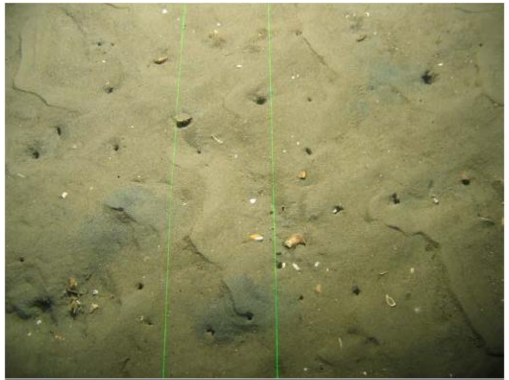
Observational evidence suggests that there is potential for *Sabellaria sp.* And Annex I stony reef habitats to be present on the seabed at the Bunter Sandstone Outcrop. Stations ENV10 and ENV13 were identified as having low resemblance (less than 10% coverage) to Annex I stony reef due to elevation and composition of biota. Similarly, stations ENV11, ENV13 and ENV15 showed low resemblance, at best, to *S. spinulosa* reef (Gardline, 2021b).

ENV18



Fix: 717 **E:** 371464 **N:** 6011486 **Depth:** 58m

ENV21



Fix: 879 **E:** 369768 **N:** 6007881 **Depth:** 59m

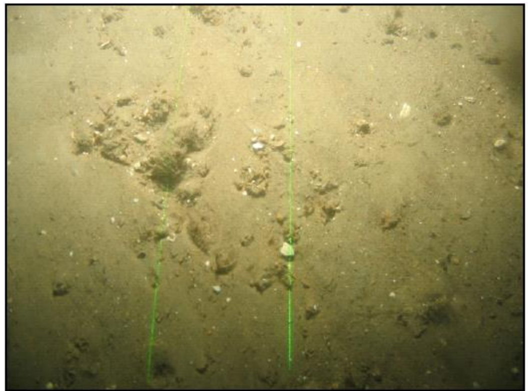
ENV05

Fix: 537 **E:** 397380 **N:** 5997830 **Depth:** 72m

ENV10

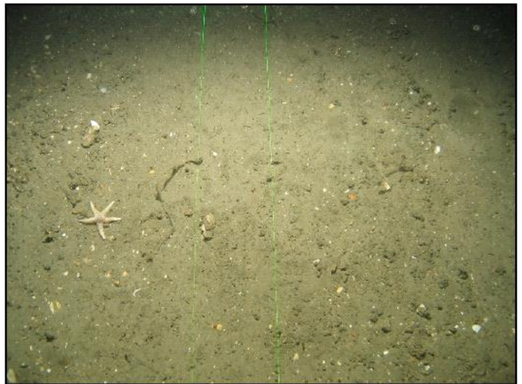
Station: ENV10 **Fix:** 79 **E:** 398672 **N:** 5998405 **Depth:** 61m

ENV12



Station: ENV12 **Fix:**186 **E:** 397999 **N:** 5998634 **Depth:** 72m

ENV15



Station: ENV15 **Fix:** 599 **E:** 395831 **N:** 5999379 **Depth:**67m

Figure 4-13 - Images of the seabed at the Endurance Store (ENV18, ENV21) and Bunter Sandstone Outcrop (ENV05, ENV10, ENV12, ENV15) (Gardline, 2021b)

Seapens and burrowing megafauna

The prominent presence of burrows is necessary in the determination of 'seapen and burrowing megafauna communities', an OSPAR (2008) listed threatened and/or declining habitat. Conversely, the presence of seapens is not the main designatory feature of this OSPAR habitat.

The density of burrows at the Endurance Store ranged from 0.05 burrows/m^2 at ENV22 to a maximum of 10.46 burrows/m^2 at ENV21. Station ENV21 had the highest density of burrows, classified as 'frequent' on the SACFOR scale[141] (see Figure 4-13). However, burrowing fauna were rarely sighted and burrow diameter was small. As such, the burrows could not be attributed to any of the classified 'megafauna' species within the 'seapen and burrowing megafauna communities' habitat. Therefore, it was determined that the seabed across the Endurance Store showed overall low similarity to the 'seapen and burrowing megafauna communities' habitat (Gardline, 2021b).

Frequent or greater faunal burrow densities were observed at the Bunter Sandstone Outcrop (at ENV02, ENV09, ENV11, ENV13 and ENV15). This, combined with the occasional observed presence of bivalve siphons, showed some similarity to the 'seapen and burrowing megafauna communities' OSPAR habitat. However, no visually conspicuous fauna were identified as responsible for the burrows.

Only one seapen (*Pennulata phosphorea*) was identified at ENV15 at the Bunter Sandstone Outcrop. However, burrows were frequently observed at the Bunter Sandstone Outcrop. The density of burrows ranged from 0.04 burrows/m^2 to a maximum of 4.98 burrows/m^2. The highest density of burrows was observed at ENV15 where their presence was categorised as 'occasional' to 'common' (Gardline, 2021b). For the 'seapen and burrowing megafauna communities' to be present, burrows must be at a 'frequent' or higher density. This requirement was met at multiple survey points however, as at the Endurance Store, it was not possible to determine the species which were responsible for the burrows, therefore the seabed at the Bunter Sandstone Outcrop was again considered to show, at best, low similarity to the 'seapen and burrowing megafauna communities' habitat (Gardline, 2021b).

Sponge communities

While sponges (Porifera) were observed at some of the survey sample locations at the Bunter Sandstone Outcrop (CAM01, ENV10 and ENV13, see Figure 4-13), in all instances they covered less than 5% of the photographs. Only images with over 10% sponge coverage for hard substrate areas are deemed to constitute deep water sponge aggregations. Therefore, it is unlikely that a significant sponge aggregation habitat is present at the Bunter Sandstone Outcrop (Gardline, 2021b). As at the Bunter Sandstone Outcrop, sponges were observed at ENV20 and ENV21 at the Endurance Store and they also did not constitute a significant sponge aggregation (Gardline, 2021b). No other habitats of concern were identified during the survey across the Endurance Store and Bunter Sandstone Outcrop (Gardline, 2021b).

[141] *An abundance scale from super-abundant, abundant, common, frequent, occasional, rare, to present.*

4.4.2.1.2 Infauna

Annelid worms (Polychaeta; n=6,134) was the most abundant taxonomic group at the Bunter Sandstone Outcrop, making up 50% of sampled individuals and 43% of the taxa. This community composition was comparable to past surveys of the area. Polychaete dominance is typical for most soft bottom benthos communities. Echinodermata (n=2,835) was the second most abundant taxonomic group however, only made up 5% of adult taxa which proportionately means the group was relatively lacking in diversity. This was followed by Mollusca (n=1,645) and Arthropoda (n=972). Arthropoda were comparatively a diverse group, making up 29% of all adult taxa. Of juveniles counted (n=1,980), 98% were Echinodermata. Between stations, abundance also varied considerably with some stations containing twice the number of individuals as others.

Of the adult species, the most common Annelida were *Lumbrineris aniara*, *Pholoe sp.* (including *Pholoe baltica*) and *S. spinulosa*. Of the Echinodermata, the brittle star (*Amphiura filiformis*) was particularly abundant. The species favour fine or muddy sediments and can tolerate some level of smothering. Of the populous juvenile Echinodermata, all were considered to be brittle stars (*Ophiuroidea sp.)* (Gardline, 2021a).

The faunal composition at the Endurance Store was dominated by Annelida (Polychaeta; n=1,084), which accounted for 39% of individuals and 40% of taxa. Compared to the Bunter Sandstone Outcrop, the Endurance survey area reported a higher dominance of Arthropoda (n=563), which made up 20% of individuals and 29% of taxa. Mollusca (n=523) were similarly proportioned to Arthropoda at 19% of individuals and 23% of taxa. However, the prevalence of Echinodermata was much reduced from the findings at the Bunter Sandstone Outcrop (n=364, 13% of taxa); this could be due to fewer samples taken at the Endurance or due to regional differences in community composition. However, of the 2,412 juveniles at the Endurance Store, 99% were Echinodermata.

The composition of Echinodermata species at Endurance was the same as at the Bunter Sandstone Outcrop; dominated by brittle stars *A. filiformis* (which were identified at every station) and *Ophuroidea sp*. Juveniles. Of the Arthropoda, the amphipods *Urothoe elegans* and *Guernea (Guernea) coalita* were ranked within the top ten species, according to abundance. The most common polychaete worm species were *Pholoe sp.*, with *P. baltica* making up a significant portion of individuals and was identified in every station within the Endurance area.

In terms of species of conservation importance, two juvenile *A. islandica* individuals were recorded in two samples at the Bunter Sandstone Outcrop (ENV02 and ENV10; Gardline, 2021a). Additionally, a number of juvenile bivalves, possibly *A. islandica* juveniles, were found in a number of grabs at ENV14 and ENV19 (Gardline, 2021a).

Metabarcoding analysis was conducted for the most recent site survey. This was achieved using environmental DNA (eDNA) obtained in sediment samples and revealed evidence of a large, diverse number of species across the surveyed areas. The eDNA was largely attributed to species of bacterial origin, with meiofauna and macrofauna responsible for the remaining proportion. There was no clear distinction between the results for the Endurance Store and the two pipeline routes (Gardline, 2022a).

4.4.2.2 Teesside Pipeline

4.4.2.2.1 Epifauna and Habitats

At the offshore end of the Teesside Pipeline route, the seabed was classed as EUNIS habitat A5.27 'Deep circalittoral sand', much the same as the rest of the offshore Development area. Two samples (ENV-83 and ENV-84) which coincide with an area of shallower seabed were considered A5.23 'Infralittoral fine sand'. Closer to shore sediments were more mixed and largely fell into the complex A5.44 'Circalittoral mixed sediment'. Some individual station locations were identified as A4.22 'Sabellaria reefs on circalittoral rock' and A4.27 'Faunal communities on deep moderate energy circalittoral rock'. The full classification of samples along the Teesside Pipeline route are shown in Figure 4-15. Images of the seabed from the pipeline route can be seen in Figure 4-14.

The sandy stations at the nearshore end of the Teesside Pipeline route out to Station ENV-08 (KPS7.2) were notably sparse, with very few visible fauna or features. The variable sediment type along the majority of the route mostly supported Annelida (*Serpulidae*), Arthropoda (*Caridea* and *Galatheidae*), Bryozoa (*Alcyonidium diaphanum* and *Flustridae*), Mollusca (*Pectinidae*), Cnidaria (*Alcyonium digitatum* and *Tubularia*) and faunal turf. However, from ENV-85 (KPS126.7) to the end of the route, Bryozoa (*A. diaphanum*), Echinodermata (*Luidia sarsii*), Chordata (*Limanda limanda*), bivalve siphons and animalia tubes became more prominent (Gardline, 2022b).

Sandbanks

'Sandbanks, which are slightly covered by seawater all of the time' are listed under Annex I of the Habitats Directive (1992). The predominantly sandy shallow section of the Teesside Pipeline route was relatively sparse with only occasional fish observed (e.g. Trachinidae); therefore, this area was not thought to represent a sandbank habitat as defined by the JNCC (2020b) (Gardline, 2022b).

Rocky reef

Reefs are one of the habitats of conservation significance listed under Annex I of the Habitats Directive (1992) for protection within SACs. Using a multi-criteria scoring system, the characteristics of the potential rocky reefs was assessed as having low, moderate, or high resemblance based on the spatial extent, substratum composition (% cover), and elevation. Across the whole survey area 45 stations were found to resemble rocky reefs, 39 with low resemblance, and 6 with moderate resemblance. The majority of these were identified inshore along the Teesside Pipeline route from KPS9 (DC-10) to KPS40.8 (ENV-42) and KPS68.5 (ENV-56) to KPS78.7 (ENV-61) and broadly corresponded with areas of known bedrock and rocky reef (Gardline, 2022b). Figure 4-16 shows the rock reef resemblance of each station along the pipeline route. The areas closer to shore which exhibited higher rocky reef resemblance correspond to JNCC areas of known reef.

Peat and clay outcrops

Peat and clay exposures are a marine habitat of principal importance in England (JNCC and Defra, 2012) and a UK Biodiversity Action Plan (UKBAP) priority habitat (JNCC, 2008b). Clay/chalk outcrops were recorded at two stations, one in the nearshore area (DC-24, KPS17.1) and one in the deepest offshore section of the route (ENV-72, KPS100.7). The shallower-water example has indications of boring by piddocks and could be part of a UKBAP priority habitat (Gardline, 2022b); an image from this location is shown in Figure 4-14. The offshore clay outcrop largely corresponded with *S. spinulosa* presence. This indicates that these relatively soft and stable clay outcrop features provide an anchor point from which *S. spinulosa* reef can establish. It was also assumed that at least some of the *S. spinulosa* cover obscured the full extent of clay outcrops along the Teesside Pipeline route (Gardline, 2022b).

Sabellaria reef

Biogenic reefs formed by the tube-dwelling *S. spinulosa* (Graham *et al.*, 2001), are listed under Annex I of the Habitats Directive (1992). Whilst *Sabellaria* was found in all areas of the survey, it was the most widespread along the Teesside Pipeline route; the presence of biogenic reef is shown in Figure 4-17. Reef outcrops were located at in the offshore region, at stations KPS86.7 (ENV-65), KPS97.7 (DC-70) to KPS100.7 (ENV-72) and KPS104.7 (ENV-74). The wider prevalence of *Sabellaria* (if not always as a reef, and thus Annex I habitat) in this section of the pipeline route indicates that this is a suitable environment for *Sabellaria* settlement and that other reef outcroppings may be present in the wider area that have not been identified (Gardline, 2022b). Examples of *S. spinulosa* reef encountered along the Teesside Pipeline route are shown In Figure 4-14.

Seapens and burrowing megafauna

The 'seapen and burrowing megafauna communities' habitat is classified as a threatened and/or declining habitat (OSPAR, 2008a). Burrows were recorded across the whole survey area; however, they were predominantly classified as 'Rare' or 'Absent' on the SACFOR scale. Only three stations along the Teesside Pipeline route reached 'Occasional' densities. During image analysis burrowing fauna not associated with the 'seapen and burrowing megafauna communities' habitat were observed across the survey area including *Ceriantharia, a tube-dwelling anemone*. Therefore, it is highly unlikely the survey area will constitute anything other than a low resemblance to the protected 'seapen and burrowing megafauna communities' habitat (Gardline, 2022b).

Sponge communities

Fragile sponge and anthozoan communities on subtidal rocky habitats are listed on the UKBAP as a priority species (JNCC, 2011a). The Teesside Pipeline route contained only a single image with >10% coverage by sponges at Station ENV-37 (KPS32) at a depth of approximately 46 m LAT; no sponge habitats were identified along the route (Gardline, 2022b). A photo taken from Station ENV-37 is shown in Figure 4-14.

Ocean quahog

Seabed imagery along the Teesside Pipeline route indicated the possible presence of the OSPAR list of threatened and/or declining species and habitats listed species ocean quahog, *A. islandica*, at 17 stations spread intermittently along the route (Gardline, 2022b).

Station: NEP21-ENV-DC-01
Fix: 40 **E:** 235531 **N:** 6060854 **Depth (m):** NA

Sediment Description:
Area adjacent to exposed pipe/outfall, high coverage of stranded algae, coarse black sand, shell fragments and sparse gravels

Faunal Description:
No visible fauna

Station: NEP21-ENV-DC-08
Fix: 1070 **E:** 242220 **N:** 6062861 **Depth (m):** NA

Sediment Description:
Not Yet Analysed

Faunal Description:
Brachyura

Station: NEP21-ENV-DC-24
Fix: 5866 **E:** 251701 **N:** 6060772 **Depth (m):** 82

Sediment Description:
Hard substrate covered with a veneer of sand cobbles and boulders. Piddock

Faunal Description:
Annelida (Serpulidae), Arthropoda (Caridea, *Munida rugosa*), Bryozoa (Flustridae, *A. diaphanum*), Cnidaria (*A. digitatum*), Echinodermata (Asteroidea 01, *Echinus esculentus*, Ophiuroidea) Faunal turf

Station: NEP21-ENV-DC-37
Fix: 5587 **E:** 264962 **N:** 6054432 **Depth (m):** 48

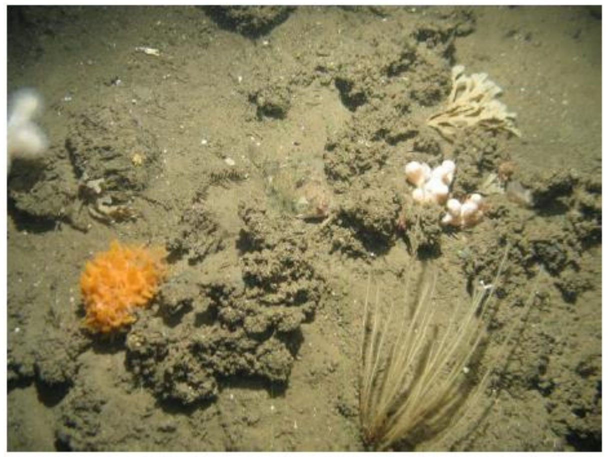
Sediment Description:
Sand with shell hash, gravel and cobbles. Underlying hard substrate. Large boulder in centre of image.

Faunal Description:
Annelida (Serpulidae), Arthropoda (Galatheidae), Bryozoa (Flustridae), Chordata (*Microstomus kitt*), Cnidaria - Hydrozoa 02, *Tubularia sp*), Echinodermata (Asteroidea 01, *Echinoidea sp*), Faunal turf

Station: NEP21-ENV-DC-86
Fix: 1525 **E:** 354137 **N:** 6017368 **Depth (m):** 67

Sediment Description:
Rippled sand with shell fragments

Faunal Description:
Animalia tube, Echinodermata (*A. rubens*)



Station: NEP21-ENV-DC-150
Fix: 4501 **E:** 304396 **N:** 6037454 **Depth (m):** 58

Sediment Description:
Sand with cobbles/underlying hard substrate, shell hash and fragments

Faunal Description:
Annelida (Serpulidae), Arthropoda (Caridea, Galatheidae), Bryozoa (Flustridae), Chordata (Ascidiacea 02, *M. kitt*), Cnidaria (*A. digitatum*, Nemertesia 01), Echinodermata (Ophiuroidea), Mollusca (Nudibranchia 02)

Figure 4-14 - Images of the seabed along the Teesside Pipeline route (Gardline, 2022b)

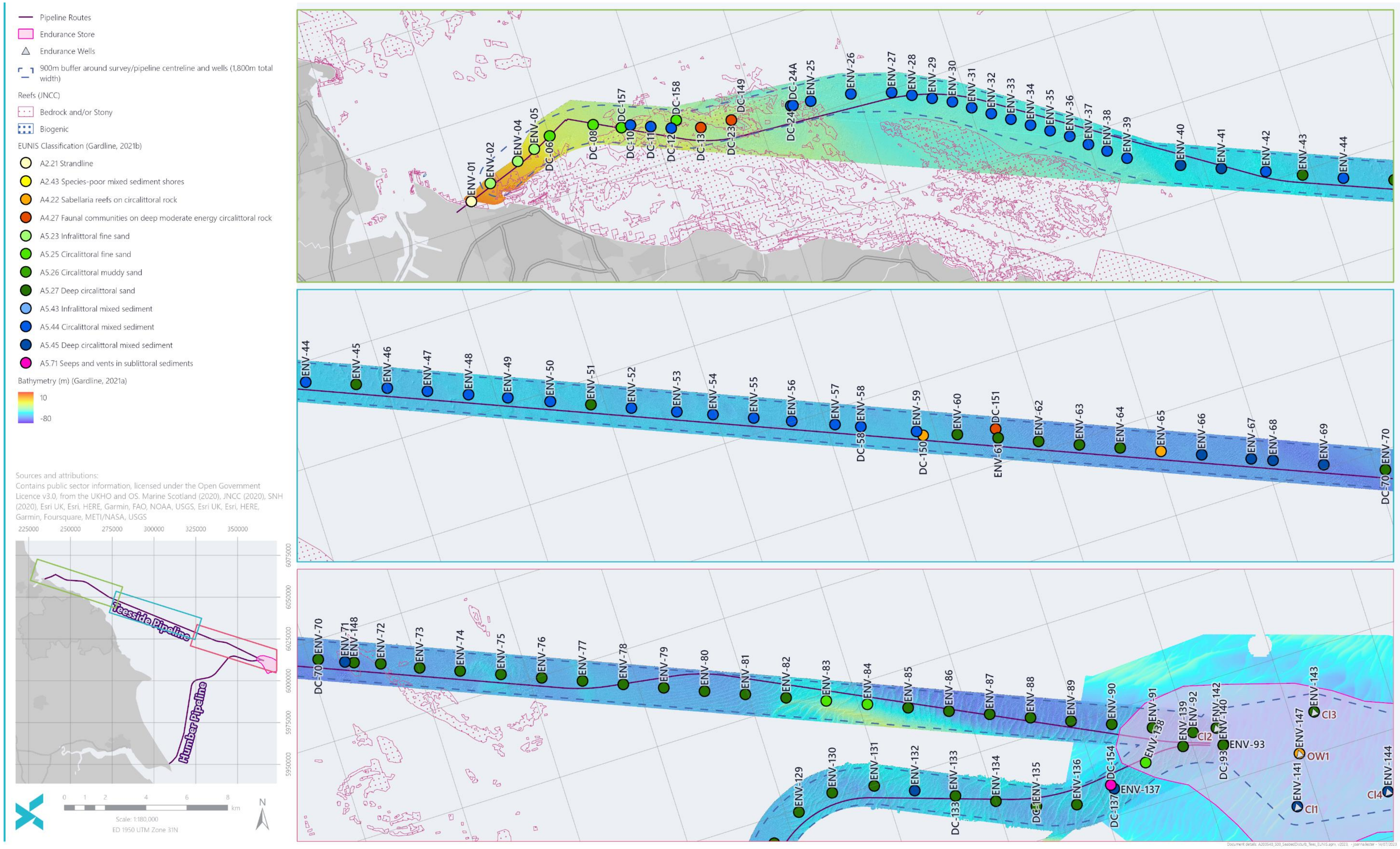


Figure 4-15 - EUNIS habitats along the Teesside Pipeline route (Gardline, 2022b)

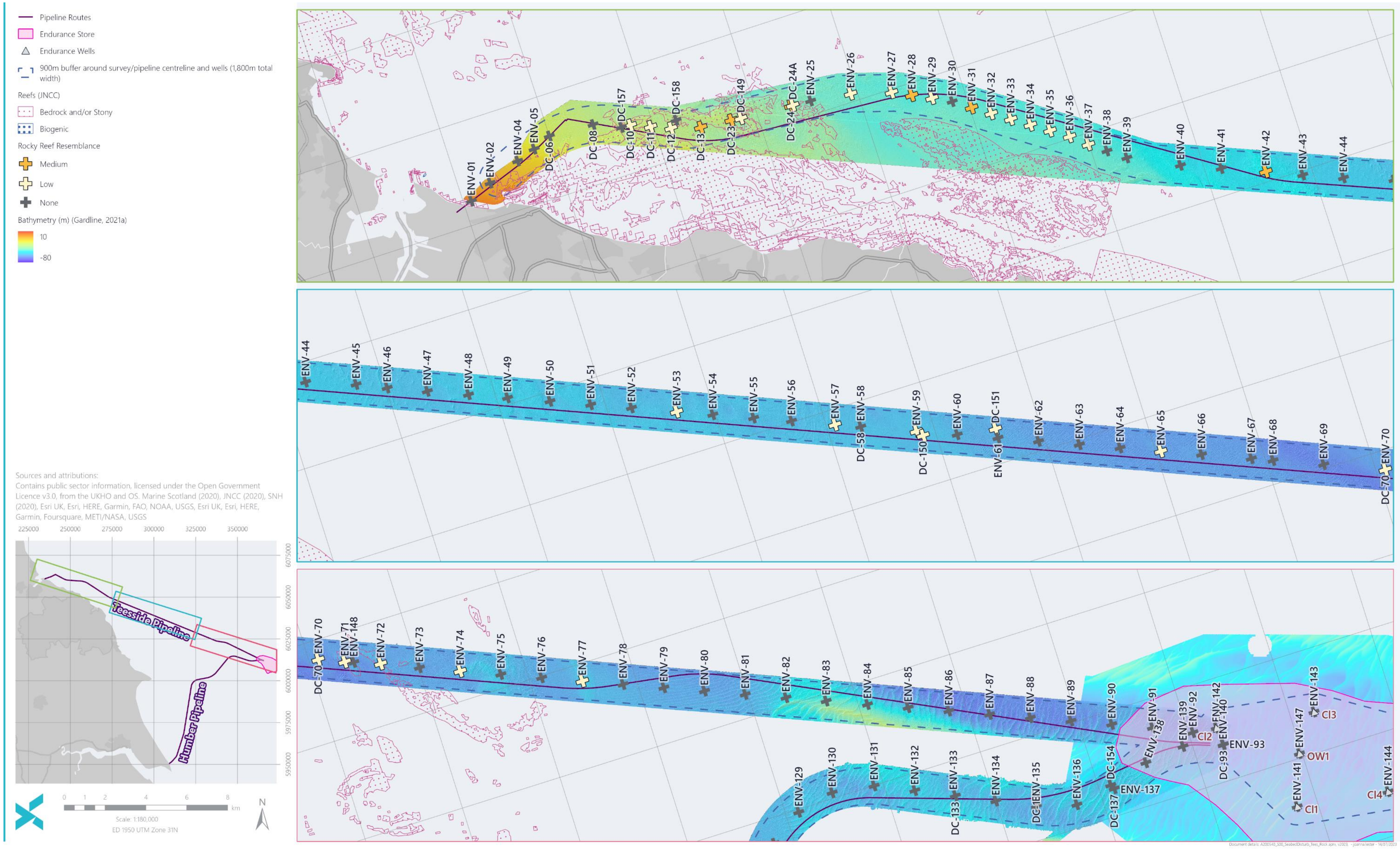


Figure 4-16 - Rocky reef presence and resemblance along the Teesside Pipeline route (Gardline, 2022b)

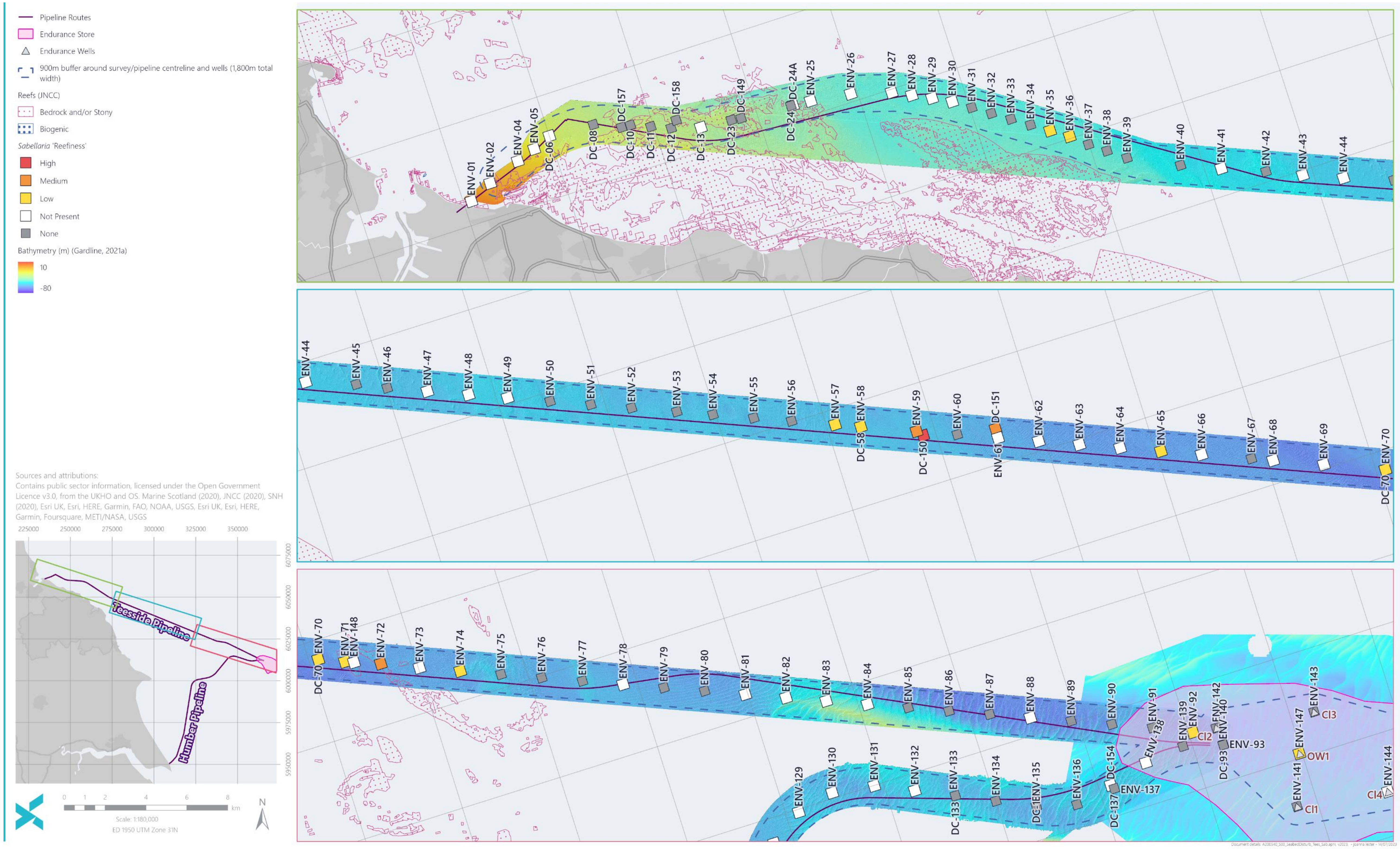


Figure 4-17 - Sabellaria reefiness along the Teesside Pipeline route (Gardline, 2022b)

4.4.2.2.2 Infauna

The adult faunal data set for Teesside Pipeline route was dominated by Annelida (Polychaeta; 53%). The dominance of Annelida is consistent with the findings of Gage (2001) and therefore can be considered typical for the region (Gardline, 2022a). The relatively high numbers of both widespread taxa and single or low abundance taxa across the survey areas suggested a reasonably diverse community that has been subjected to relatively little disturbance or contamination (Gardline, 2022a).

Along the Teesside Route, *S. spinulosa* was the most abundant adult taxon and second most abundant when including juveniles. The abundance of *S. spinulosa* was not consistent along the full length of the pipeline route, however, with the Echinodermata Amphiuridae (brittle stars), dominant at more stations overall. *S. spinulosa* is a suspension feeder typically found attached to bedrock, boulders or cobbles, which explains its variable distribution along the pipeline route. The species was mostly found between KPS20 and KPS74.7 along the Teesside Pipeline route (Stations ENV-26 to ENV-59, n=2,061, 62% of all *S. spinulosa* identified across the whole survey area; Gardline, 2022a).

Additionally, there was an apparent correlation between *S. spinulosa* abundance and species richness (Gardline, 2022a), evidenced in both the prevalence of *S. spinulosa* and increased faunal diversity along the Teesside route relative to the Humber. Densities of *S. spinulosa* reached a maximum of 6,300 individuals per square metre (m2) at Station ENV-48 at KPS52.7 along the route, however, there was no evidence of biogenic reef in seabed imagery at this station (Gardline, 2022a).

One adult *A. islandica* was recorded at Station ENV-57 along the Teesside Pipeline route and a total of 78 juveniles were recorded. The majority of these juveniles were recorded across 26 of the stations along the pipeline route (Gardline, 2022a).

4.4.2.3 Humber Pipeline

4.4.2.3.1 Epifauna and Habitats

At the offshore end of the Humber Pipeline, and along the majority of the pipeline route, the seabed was mostly categorised as EUNIS habitat complex A5.27 ‘Deep circalittoral sediment’, as seen in Figure 4-11 and the middle and bottom panels of Figure 4-12. A few notable exceptions in the offshore region are discussed in the following paragraphs. Closer to shore, the seabed was mostly classified as A5.43 ‘Infralittoral mixed sediment (the top panel of Figure 4-12), visible in the images taken along the Humber Pipeline route in Figure 4-18.

Along the Humber Pipeline route, the coarser sediments of the nearshore stations were characterised by Annelida (*Serpulidae*), Arthropoda (*Cirripedia*), Bryozoa (*Flustridae*), Chordata (*Ascidiacea*), Cnidaria (*Hydrozoa* and *Tubularia*) as well as Animalia tubes and burrows and faunal turf (Gardline, 2022b). Beyond this, within the mixed sediment between ENV-101 (KPS24) and ENV-117 (KPS56), these species largely remained characteristic together with the addition of Cnidaria (*A. digitatum*) and Echinodermata (*Asterias rubens*). In the predominantly sandy sediments between ENV-118 (KPS58) and ENV-132 (KPS86), visible fauna was relatively sparse and mainly included Echinodermata (*A. rubens* and *Astropecten irregularis*) together with animal tubes and burrows and faunal turf (Gardline, 2022b).

Sandbanks

The seabed landward of station ENV-97 (KPS16) reached depths of <20 m LAT. The visible faunal community along this mixed and gravelly section of the Humber Route was characterised by a community broadly consistent with a gravelly sandbank, as described by JNCC (2020a) which is characterised by foliose seaweeds, hydroids, bryozoans and ascidians (Gardline, 2022b).

Rocky reef

Thirteen inshore stations with a low resemblance to a rocky reef were found on the Humber Pipeline route at KPS1 (DC-15) then continuously between KPS4.1 (ENV-18) and KPS24 (ENV-101), as shown in Figure 4-19. At these locations, the EUNIS biotope A4.27 'Faunal communities on deep moderate energy circalittoral rock' was identified; however, it was only at station ENV-101 where this was the dominant habitat, as seen in the top panel of Figure 4-12 (Gardline, 2022b). The seabed at ENV-101 is also shown in Figure 4-18. This low resemblance rocky reef was consistent across samples located within the Holderness Inshore MCZ (through which pipeline route will pass) – a protected site designated for moderate and high energy circalittoral rock, amongst other features. A full discussion of conservation sites and features across the Development area is presented in Section 4.5.

Clay ridges

As described in Section 4.3.3.3, clay ridge and mound features have been identified along the coast where the Humber Pipeline will reach landfall (XOGS, 2023). These features are characterised in the coarse sediment which can be seen in Figure 4-7 and Figure 4-18. It is possible that the clay ridges, owing to their coarse overlying sediment, have been categorised as rocky reef (described above) during the environmental survey effort (Gardline, 2022b). However, these two benthic features are not necessarily mutually exclusive. Rocky reef is an ecological description and these discrete reef locations may be underpinned by clay outcrops which are better described as a seabed/geological feature.

Sabellaria reef

S. spinulosa was identified at almost half the stations (n=53) along the Humber Route, with the majority of individuals recorded between KPS1.9 and KPS56 (Stations ENV-16 to ENV-117, n=475); this spatial pattern of distribution broadly corresponds with the areas of gravelly or mixed sediments (Gardline, 2022a). The overall abundance of *S. spinulosa* was lower along the Humber Pipeline route compared to the Teesside Pipeline route.

With regards to biogenic reef, only one station along the Humber Pipeline route (ENV-16) was considered to show low resemblance to *S. spinulosa* reef. The presence of *Sabellaria* reef along the whole pipeline route is shown in Figure 4-20.

Methane-derived authigenic carbonate

The European Commission (EC) Habitats Directive includes 'submarine structures made by leaking gases', often observed as methane-derived authigenic carbonate (MDAC) structures within pockmarks, is a protected habitat or feature on Annex I of the Directive (1992). From ENV-133 (KPS88) to the end of the route at ENV-140 (KPS102), the community was similar to the rest of the route except bivalve siphons and animal tubes became more prominent. Along this stretch of the pipeline route, Station DC-154 (KPS96) was distinct and classified as EUNIS habitat complex A5.71 'Seeps and vents in sublittoral sediments' (Figure 4-12). At this location, a structure that appeared to be composed of MDAC, or a substance closely resembling it, was observed (Figure 4-18). Fauna characteristic of harder substrates were observed as well as evidence of bacterial mats which are often associated with leaking gas. However, this feature was isolated and not associated within a depression, therefore does not look like a pockmark that is characteristic of protected MDAC structures described by the JNCC (2021; cited in Gardline, 2022b). Geophysical data indicated that the structure contained metallic objects and imagery of the area showed various anthropogenic debris items, some of which were partially buried in the potential MDAC. This is potential evidence of a small wreck, dumped refuse or lost equipment. Archaeological study of the area identified a wreck, the location of which appears to coincide with the MDAC station (Wessex Archaeology, 2023). Plastic strips, glass bottles and metallic items were identified among the debris. Consequently, it is likely that this area of differing habitat has been influenced by the presence of anthropogenic substances. The feature has likely been caused by leaking hydrocarbons or other chemical enrichment from the debris as it decomposes and leaches into the environment (Gardline, 2022b). This, in addition to the location of the Development, suggests the likelihood of MDAC presence is low.

Seapens and burrowing megafauna

Burrows were recorded at numerous sample stations along the Humber Pipeline route; however, they were considered more than 'Rare' on the SACFOR scale at all but three locations; at ENV-19, ENV-20 and ENV-102 burrows were considered 'Occasional'. No seapens were observed in the seabed imagery. However, during imagery analysis burrowing fauna not associated with the 'seapen and burrowing megafauna communities' habitat were observed across the survey area including *Ceriantharia*. As such, it is highly unlikely the survey area will constitute anything other than a low resemblance to the 'seapen and burrowing megafauna communities' habitat.

Sponge communities

Along the Humber Pipeline route five stations between KPS4.1 (ENV-18) and KPS9.8 (ENV-94) contained a total of 11 images with > 10% sponge coverage (including Station DC-21, which is shown in Figure 4-18). These stations all lay within a depth range of 13-17 m LAT. This area coincides with a raised outcrop interpreted as exposed underlying sediment and is coincident with stations assessed as having resemblance to rocky reefs (Gardline, 2022b). Though several of the species of sponge and other non-sponge species (*Nemertesia sp*.) were present that are listed within the 'fragile sponge and anthozoan communities on rocky habitats', they are at very low abundances so are not thought to represent this habitat (Gardline, 2022b).

Ocean quahog

Evidence of adult ocean quahog through seabed imagery was only found at one station along the pipeline route (ENV-119, KPS60; Gardline, 2022b). No adult ocean quahog were observed in any of the images taken within the boundaries of the Holderness Offshore MCZ, which is partly designated for the species.

Station: NEP21-ENV-DC-14
Fix: 16 **E:** 309347 **N:** 5950469 **Depth (m):** NA

Sediment Description:
Sandy gravel with cobbles, with tidal/erosional channels. Image showing the boundary zone

Faunal Description:
None noted

Station: NEP21-ENV-DC-18
Fix: 312 **E:** 312160 **N:** 5953584 **Depth (m):** NA

Sediment Description:
Not Yet Analysed

Faunal Description:
Arthropoda (Galatheidae), Annelida (Polychaeta)

Station: NEP21-ENV-DC-19
Fix: 310 **E:** 312785 **N:** 5954209 **Depth (m):** NA

Sediment Description:
Not Yet Analysed

Faunal Description:
Annelida (Polychaeta) Echinodermata (Ophiuroidea)

Station: NEP21-ENV-DC-21
Fix: 242 **E:** 313767 **N:** 5955956 **Depth (m):** NA

Sediment Description:
Not Yet Analysed

Faunal Description:
Arthropoda (Galatheidae), Annelida (Polychaeta)

Station: NEP21-ENV-DC-95
Fix: 124 **E:** 315424 **N:** 5961051 **Depth (m):** NA

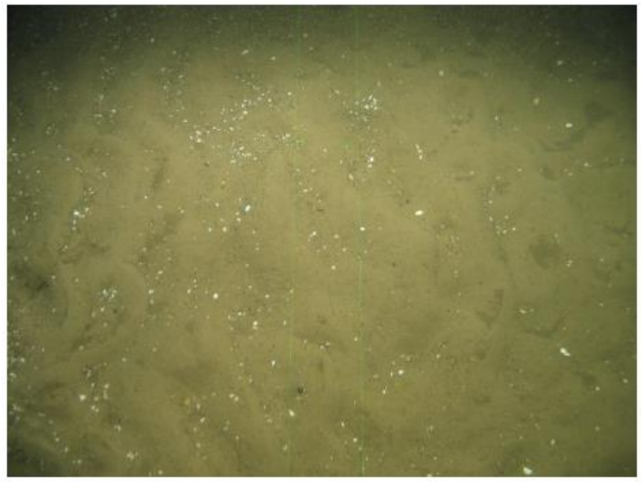
Sediment Description:
Not Yet Analysed

Faunal Description:
Arthropoda (Galatheidae), Annelida (Polychaeta)

Station: NEP21-ENV-DC-101
Fix: 2535 **E:** 318877 **N:** 5972167 **Depth (m):** 34

Sediment Description:
Smaller cobbles and some sand patches with some faunal turf. Potential rocky reef resemblance

Faunal Description:
Annelida (Serpulidae), Arthropoda (*L. depurator*), Bryozoa (Flustridae), Cnidaria - (Actiniaria 01, *A. digitatum*, Cerianthiidae 01, Nemertesia 02), Echinodermata (*E. esculentus*), Faunal turf



Station: NEP21-ENV-DC-123
Fix: 3006 **E:** 337961 **N:** 6005797 **Depth (m):** 54

Sediment Description:
Rippled sand with shell hash

Faunal Description:
No visible fauna

Station: NEP21-ENV-DC-154
Fix: 3986 **E:** 360601 **N:** 6011534 **Depth (m):** 55

Sediment Description:
Possible MDAC with sand, shell hash and fragments

Faunal Description:
Arthropoda (*C. pagurus*, *L. depurator*), Bryozoa (*A. diaphanum*, Flustridae), Cnidaria (*A. digitatum*, *Tubularia sp*), Echinodermata (*A. rubens*, *O. fragilis*), Faunal turf

Figure 4-18 - Images of the seabed along the Humber Pipeline route (Gardline, 2022b)

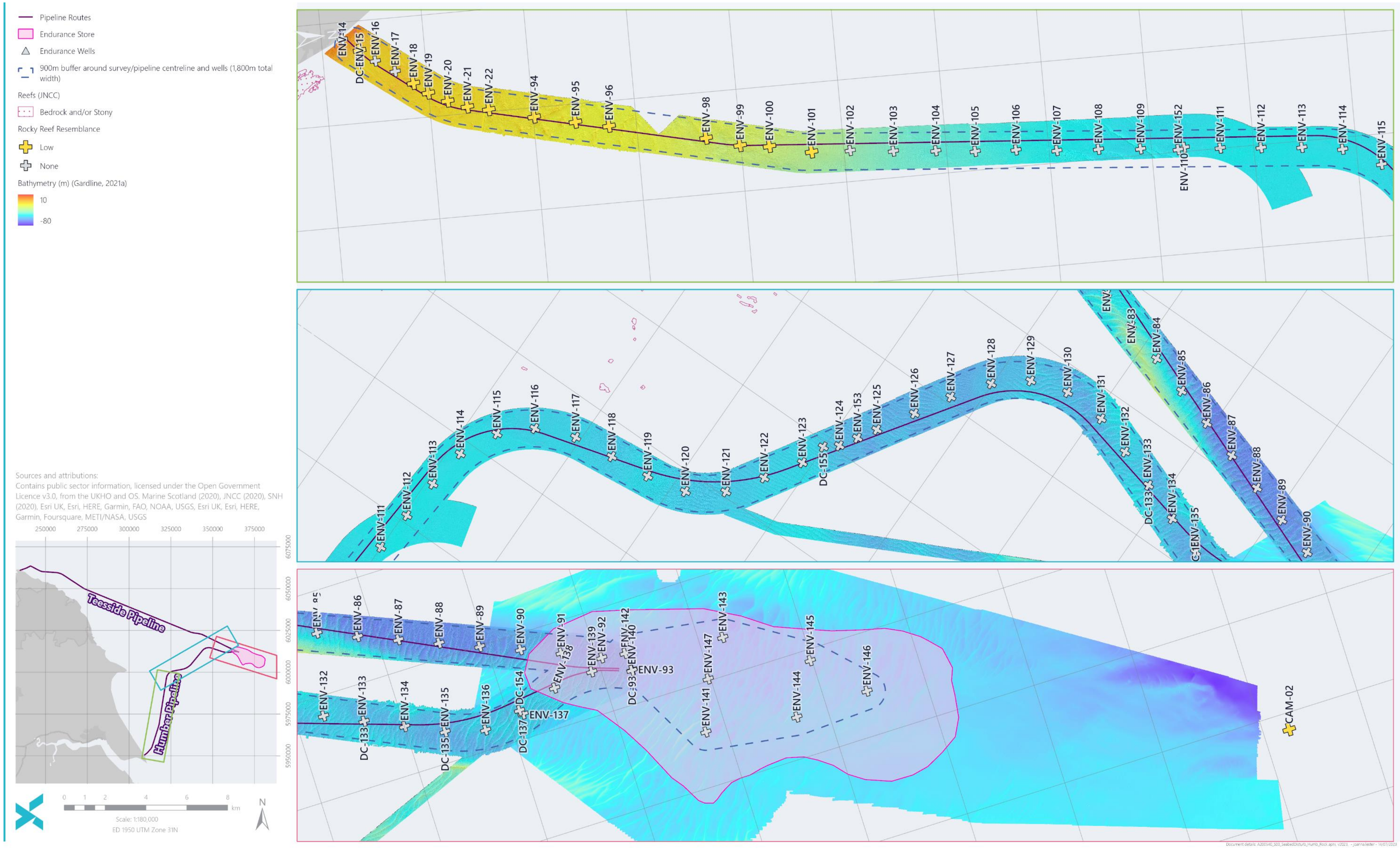


Figure 4-19 - Rocky reef presence and resemblance along the Humber Pipeline route (Gardline, 2022b)

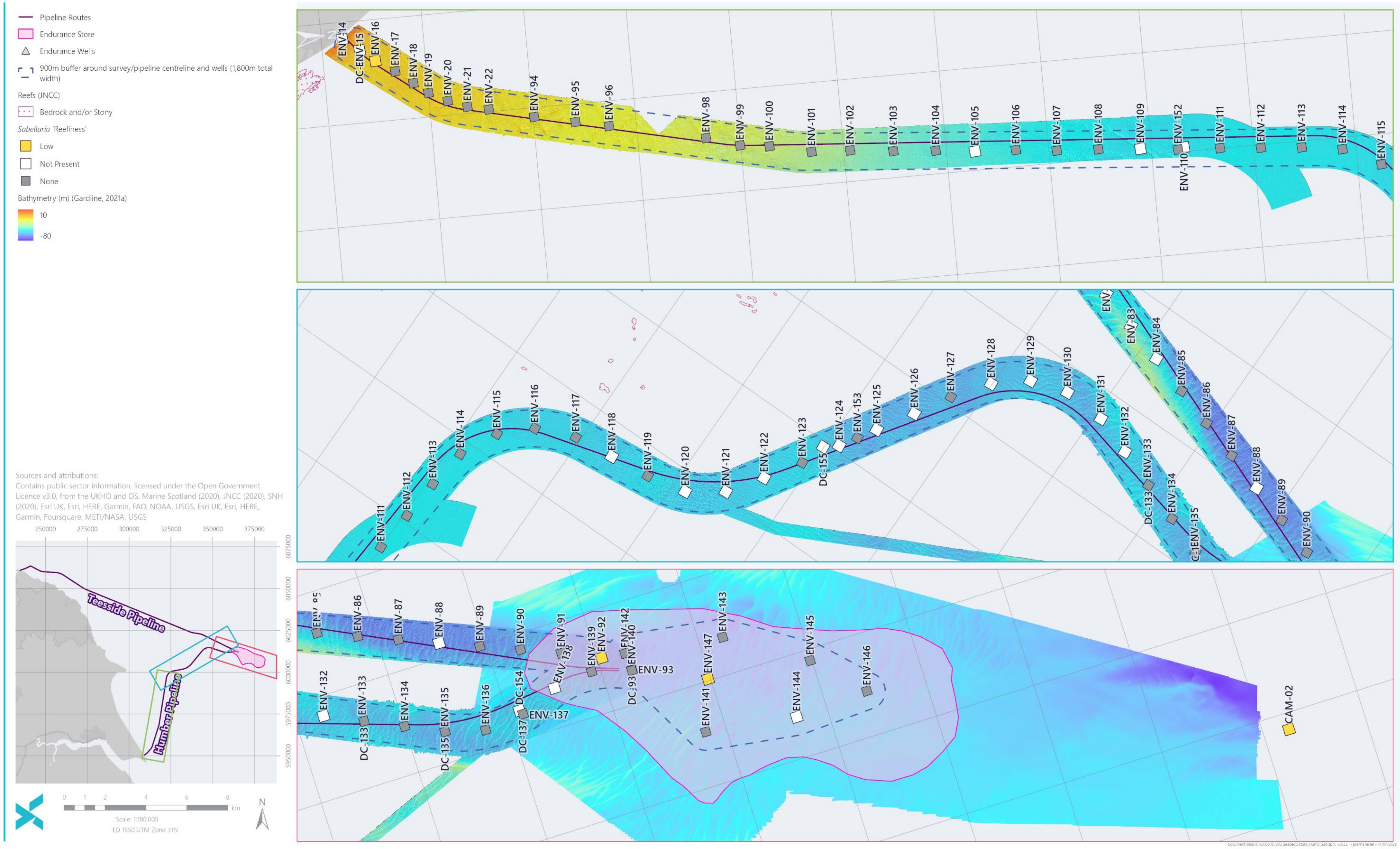


Figure 4-20 - Sabellaria reefiness along the Humber Pipeline route (Gardline, 2022b)

4.4.2.3.2 Infauna

Along the Humber Pipeline route, the Annelida *Spiophanes bombyx* was the most abundant taxa in the adult only data set. Polychaetes generally dominated the infaunal findings, with Annelida accounting for 51% to 53% of the sampled individuals and 41% to 42% of all taxa. As with the Teesside Pipeline route, these findings are typical of this area of the North Sea. A relatively patchy distribution of the most dominant taxa is expected along such a long and varied route corridor as it relates to the sediment and topographic heterogeneity observed along the pipeline route. The shallowest stations exhibited relatively impoverished communities With Station ENV-14 (at KPS0) being particularly impoverished, how this may in part be linked to relatively low sample volume (≤ 25%). The abundance of adult individuals, taxa and the diversity of the infaunal community tended to be higher in areas of mixed sediment (i.e. poorer sediment sorting with more gravel and/or fines; Gardline, 2022a).

There was no evidence of a significant anthropogenic influence on the faunal communities relating to elevated chemical concentrations (Gardline, 2022a).

Only ten individual juvenile *A. islandica* were recorded within samples taken across eight stations along the Humber Pipeline route (Gardline, 2022a).

4.4.3 Fish and Shellfish

4.4.3.1 Endurance Store Area

A number of commercially important fish species occur in the vicinity of the Development. The Endurance Store is located in high intensity nursery areas for cod (*Gadus morhua*) and whiting (*Merlangius merlangus),* and low or undetermined intensity nursery areas for herring (*Clupea harengus*), lemon sole (*Microstomus kitt*), sandeel (*Ammodytes marinus*), sprat (*Sprattus sprattus*), anglerfish (*Lophius piscatorius*), blue whiting (*Micromesistius poutassou*), mackerel (*Scomber scombrus*), European hake (*Merluccius merluccius*), and spurdog (*Squalus acanthias*) (Table 4-2; Coull *et al.*, 1998; Ellis *et al.*, 2012b). According to González-Irusta and Wright (2016), the Endurance Store is located in an area of seabed which is occasionally used by cod for spawning.

Of the species which may be present in the Endurance Store area, cod and spurdog are on the OSPAR (2008) list of threatened and/or declining species and habitats. Spurdog is additionally globally classed as vulnerable under the International Union for Conservation of Nature (IUCN) Red list. Cod are particularly vulnerable to anthropogenic impacts due to their seasonal site fidelity, and their territorial lekking-type behaviour which leads to aggregations on specific grounds to spawn (González-Irusta and Wright, 2016).

Spawning grounds are generally regarded as having higher sensitivity than nursery areas. The Endurance Store is located within spawning grounds for cod, lemon sole, sprat and whiting. The Endurance Store also overlaps a high intensity spawning location for plaice *Pleuronectes platessa* and sandeel. Spawning periods of plaice, cod and sprat are driven by environmental cues; Peak spawning for plaice occurs from January to February. For cod, peak spawning is between January and March, preferring water temperatures of 5-7°C (González-Irusta and Wright, 2016), and peak spawning for sprat is from May to June. For sandeels, peak spawning is between November and February (Table 4-2; Coull *et al.*, 1998; Ellis *et al.*, 2012b). A study undertaken by Langton *et al.* (2021) modelled the probability of presence of buried sandeel and their predicted density. The Development area contains habitat that is highly suitable for sandeels, with high densities predicted particularly near the

Endurance Store area. The model has depth biases and may underestimate probabilities in areas deeper than 70 m.

The spatial distribution of species' spawning and nursery grounds in relation to the wider Development area is shown in Figure 4-21 and Figure 4-22.

During the most recent surveys of the Endurance Store area a sandeel spawning assessment was conducted (Gardline, 2022b), the results of which are shown in Figure 4-27. In order to be classified as 'Prime' or 'Sub-Prime' for sandeel spawning, the sediment must be composed of >85% or >70% sand (≥63 µm, <2 mm), respectively, with little mud (<1% or 4%; <63 µm; Gardline, 2022b). the western end of the Endurance Store area exhibits some suitability for sandeel spawning (Gardline, 2022b). A herring spawning assessment found that none of the habitat within the Endurance Store area was suitable for the species (Figure 4-26; Gardline, 2022b).

A number of fish were observed in the recent survey footage; some of which were ubiquitous across the Development area belonging to the class Actinoptrygii of ray-finned fishes, including solenette (*Buglossidium luteum*), common dragonet (*Callionymus lyra*), and common dab (*Limanda limanda*) (Gardline, 2022b).

Table 4-2 - Fisheries sensitivities within the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Anglerfish	N	N	N	N	N	N	N	N	N	N	N	N
Blue Whiting	N	N	N	N	N	N	N	N	N	N	N	N
Cod	S/N	S*/N	S*/N	S/N	N	N	N	N	N	N	N	N
Herring	N	N	N	N	N	N	N	S/N	S/N	S/N	N	N
Ling	N	N	N	N	N	N	N	N	N	N	N	N
Lemon Sole	N	N	N	S/N	S/N	S/N	S/N	S/N	S/N	N	N	N
Mackerel	N	N	N	N	N	N	N	N	N	N	N	N
Plaice	S*/N	S*/N	S/N	N	N	N	N	N	N	N	N	S/N
Sandeels	S/N	S/N	N	N	N	N	N	N	N	N	S/N	S/N
Sole	N	S/N	S*/N	S/N	N	N	N	N	N	N	N	N
Sprat	N	N	N	N	S*/N	S*/N	S/N	S/N	N	N	N	N
Spurdog	N	N	N	N	N	N	N	N	N	N	N	N
Thornback ray	N	N	N	N	N	N	N	N	N	N	N	N
Whiting	N	N	N	N	N	N	N	N	N	N	N	N

S = Spawning, N = Nursery, S/N = Spawning and Nursery, * = peak spawning, Shading = High nursery intensity as per Ellis *et al.* (2012b), Shading = High intensity spawning as per Ellis *et al.* (2012b)

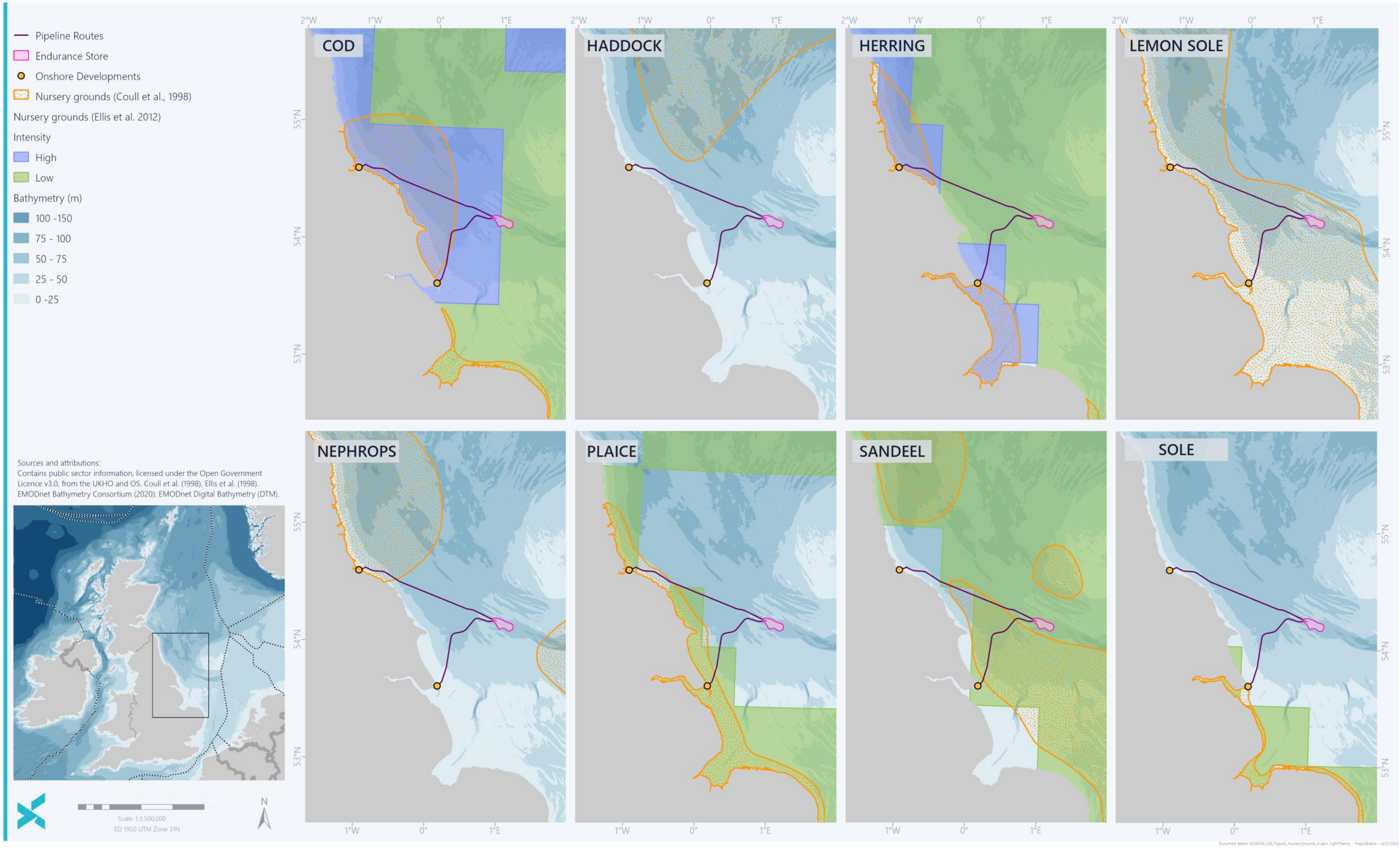


Figure 4-21 - Nursery grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b) (1 of 2)

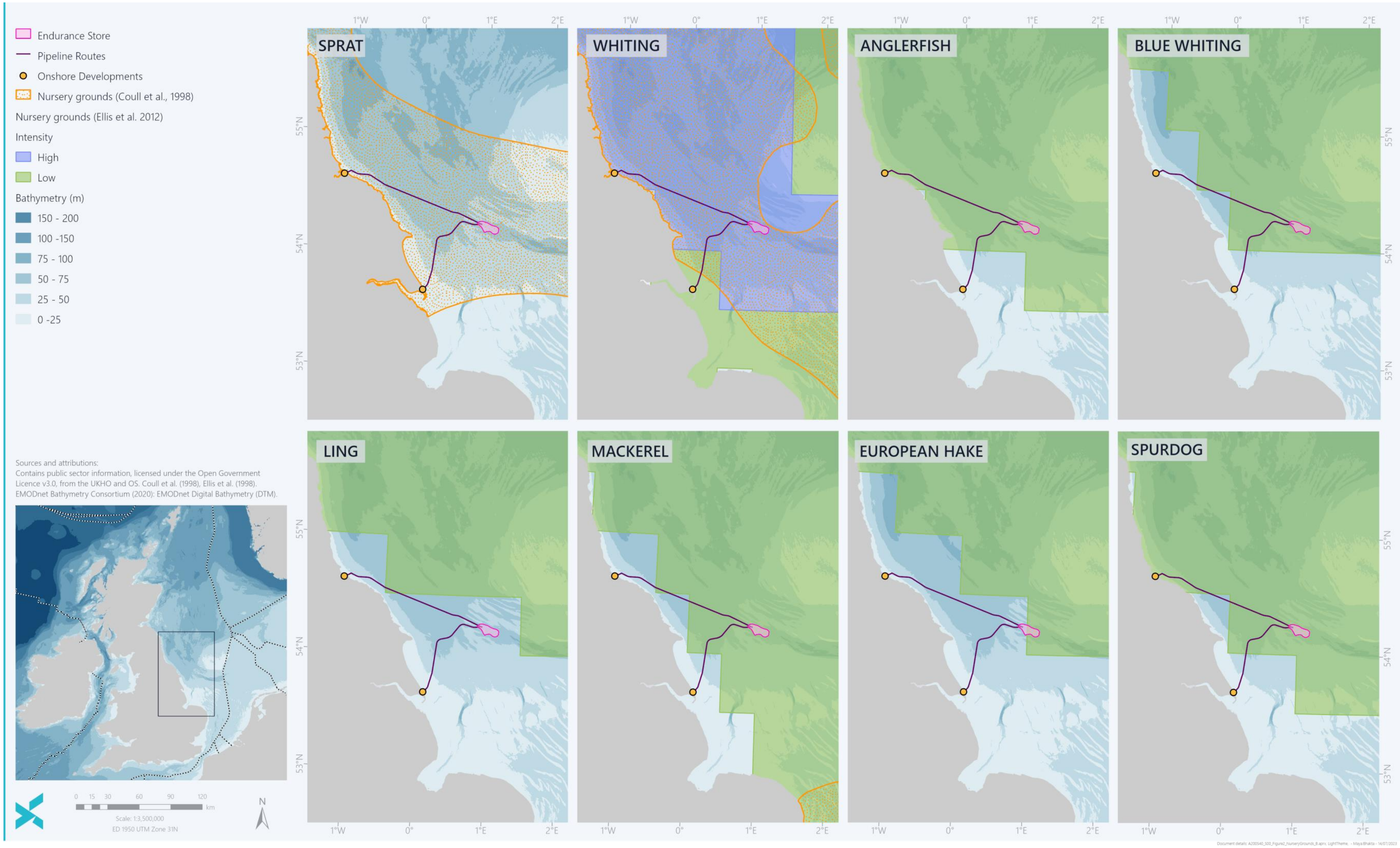


Figure 4-22 - Nursery grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b) (2 of 2)

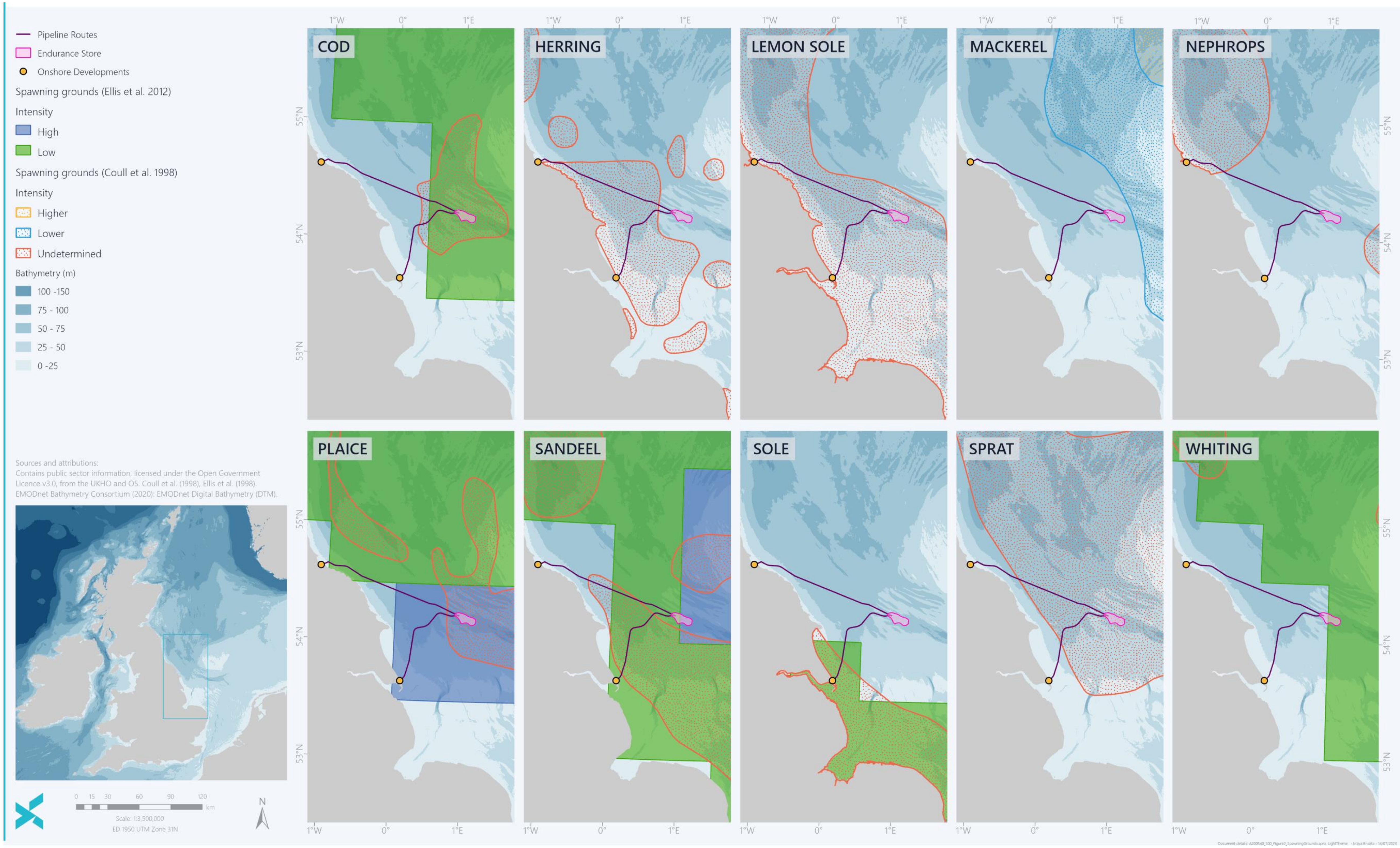


Figure 4-23 - Spawning grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b)

Commercial fisheries landings in the vicinity of the Development are mostly dependent on shellfish species however, plaice also significantly contribute to the value of catch in parts of the Development area (see Section 4.6.1). In addition, sprat and herring play an important ecological role as principal prey items for several larger fish species, marine birds and mammals. Although there is fish spawning and nursery activity in the vicinity at certain times of the year, the spawning and nursery areas are part of larger offshore regions and exact spawning locations may vary spatially and temporally from year to year (Coull *et al.*, 1998, Ellis *et al.*, 2012b).

A review of available data on juvenile fish was undertaken by Aires *et al.* (2014), taking into account the findings of Ellis *et al.* (2012b) and Coull *et al.* (1998) together with findings from the National and International Bottom Trawl Surveys, the Beam Trawl Survey, International Herring Larval Surveys and other standalone surveys. The findings summarise the probability of aggregations of fish in the first year of their lives around the UKCS. Within the Development area and surroundings, there is a low probability of juvenile plaice, sole, whiting, haddock, cod, sprat, herring, hake, angler fish, mackerel, horse mackerel, Norway pout and blue whiting (Aires *et al.*, 2014).

Environmental surveys in the Development area recorded occasional fish, including errant scavenger species such as flatfish (Gardline, 2021a). Individual sandeels were identified within sediment samples taken at the Bunter Sandstone Outcrop. They were also observed along the transect CAM01 (Gardline, 2021a). Sandeel species are listed as FOCI in relation to the UK's MCZ network.

Other species commonly recorded in the commercial catch within the Development area include haddock, red mullet, gurnards, dab, sole, brill and turbot (MMO, 2022). Several species of shellfish also occur in the region and some are caught commercially including clams, common octopus (*Octopus vulgaris*), common prawns, crawfish, cuttlefish (*Sepia officinalis*), lobster (*Homarus gammarus*), scallops (*Pecten maximus*), squid and octopus (various species), various crab species (including spider crab (*Maja squinado*) and brown crab (*Cancer pagurus*)), Norway lobster (*Nephrops norvegicus*), mussels (*Mytilus edulis*), sea urchins, whelks and brown shrimp (*Crangon crangon*) (MMO, 2022).

The basking shark (*Cetorhinus maximus*) is classed as vulnerable on the IUCN Red List and is protected under the Wildlife and Countryside Act 1981 (as amended). Basking sharks are seasonal visitors to British waters and are predominantly sighted off the west coast of the UK (Basking Shark Trust, 2021). Despite the relative suitability of the habitat in the Development area (Austin *et al.*, 2019), mean annual sighting density from 1998 to 2008, is low in the region (Witt *et al.*, 2012). On the whole, research into basking sharks is limited and, in the context of the UK, is focussed on the west coast.

The MMO and Passive Acoustic Monitoring (PAM) report produced following the 3D seismic survey scan of the Store area, which took place in the spring of 2022, did record a single basking shark sighting (Hydenlyne, 2022). However, on the whole basking sharks are less common in the North Sea compared to the west coast. As such, the Development area is considered to be of low importance for basking sharks.

4.4.3.2 Teesside Pipeline

Along the Teesside Pipeline route, the species using the area as nursery grounds and for spawning are much the same as those at the Endurance Store area (Table 4-2), with a few exceptions. European hake are exclusively found further offshore therefore, while they are found at the Endurance Store area, they are not noted as using the area along the Teesside Pipeline route for spawning or as nursery grounds (Coull *et al.*, 1998; Ellis *et al.*, 2012b). Additional to the other species present at the Endurance Store, *Nephrops*, plaice and ling (*Molva molva*) may be present at points along the pipeline route using the area as nursery grounds. *Nephrops* also use the area for spawning grounds further north, overlapping with the Teesside Pipeline route close to landfall (Coull *et al.*, 1998; Ellis *et al.*, 2012b). *Nephrops* spawn all year round but peak between April and June (Coull *et al.*, 1998). The majority of the Teesside Pipeline route passes through areas which are either rarely or occasionally utilised by cod for spawning (González-Irusta and Wright, 2016).

During the most recent survey effort, the sediments along both pipeline routes were assessed for their suitability for herring spawning. Herring typically spawn within the 15-40 m depth range (Gardline, 2022b) In order to be classified as 'Prime' or 'Sub-Prime' under the habitat sediment preference criteria for herring spawning, the sediment must be composed of >50% or >25% gravel (>2 mm) respectively, with little (<5%) mud (<63 µm, silt and clay) (Gardline, 2022b). The classification of sediments along the pipeline route according to these criteria are shown in Figure 4-24. In total, 17 stations along the Teesside Pipeline route fell within the depth and sediment criteria suitable for herring spawning, although 'Preferred' herring spawning potential was noted at four locations only, one in the nearshore area and three offshore. None of the stations met the full criteria for suitable herring spawning areas (Gardline, 2022b).

Sediment suitability for sandeel spawning differs from herring requirements as sandeel prefer sandier substrates. Seabed was assessed as being 'Prime', 'Sub-Prime' or 'Suitable' for sandeel spawning at several stations distributed along the route, most consistently between ENV-77 (KPS110.7) to ENV-84 (KPS124.7; Gardline, 2022b). Figure 4-25 shows the habitat suitability for sandeel spawning along the Teesside Pipeline route.

Two species of sandeel belonging to the genus *Ammodytes* occur in UK waters, members of the *Ammodytes* genus (specifically *A. marinus*) are listed as priority species under UK Post 2010 Biodiversity Framework and as FOCI defined in relation to the MCZ network (Gardline, 2022b). *Ammodytes tobianus* were present in grab samples acquired at three stations along the Teesside Route (>KPS99) corresponding with areas of predominantly sandy sediment. Langton *et al.* (2021) determined the probability of presence of buried sandeel to be low along the majority of the Teesside Pipeline, with marginally higher probabilities further offshore. Therefore, the predicted density of buried individuals is also expected to be low.

Other observed fauna along the Teesside and Humber Pipeline routes included a number of commercially important fish and shellfish species (Gardline, 2022b). Appendix F details all the fauna observed during the surveys along the two pipeline routes. The observational information was obtained through use of an ROV/visual imagery along the proposed routes. Owing to the non-specific nature of the survey methodology, there are caveats to this data as certain species will be more visually apparent than others, which is not necessarily indicative of overall abundance.

4.4.3.3 Humber Pipeline

The same species are present along the Humber Pipeline route as at the Endurance Store, with the exception again of European hake which is absent from the pipeline route. Plaice use the area for nursery grounds, common to both export pipeline routes and absent from the Endurance Store area (Coull *et al.*, 1998; Ellis *et al.*, 2012b). With regards to species which may use the area for spawning (Table 4-2), sole (*Solea solea*) are unique to the Humber Pipeline route and confined to the nearshore area. They are recorded as being present along the coast south of Flamborough and peak spawning effort occurs in April (Coull *et al.*, 1998; Ellis *et al.*, 2012b). The majority of the Humber Pipeline route passes through areas of seabed which is occasionally utilised by cod for spawning (González-Irusta and Wright, 2016).

According to the Gardline (2022b) herring spawning assessment, five stations along the Humber Route (ENV-19 (KPS5), ENV-20 (KPS6), ENV-94 (KPS10.3), ENV-99 (KPS20.5) and ENV-100 (KPS22.2) contained proportions of fines and gravels indicating potential prime herring spawning ground. The sediment at only three stations (ENV-19, ENV-20 and ENV-94), was categorised as both 'Prime' (sediment preference) and 'Preferred' (sediment classification), as seen in Figure 4-26 (Gardline, 2022b). However, while these five stations may offer the best herring spawning suitability of the sampled stations, none of them reach the full criteria to be considered as acceptable spawning ground and none fall on a seabed consisting of current-sculpted coarse sand and gravel as evidenced by the geophysical data (Gardline, 2022b).

The suitability of the habitat along the Humber Pipeline route for sandeel spawning is shown in Figure 4-27. Good potential for sandeel spawning, consisting of ‘Preferred’ and ‘Suitable’ habitats were notable along the mid-section of the pipeline route (shown in the blue panel in Figure 4-27). One station (ENV-122) was classified as ‘Preferred’ and ‘Sub-Prime’ therefore has the highest suitability along the route (Gardline, 2022b). *A. tobianus* were present in grab samples acquired at four stations along the Humber Route (mostly ≥KPS90) which corresponds to areas of predominantly sandy substrate (Gardline, 2022b). The probability of presence of buried sandeel and predicted density is marginally higher along the Humber Pipeline route than further north along the Teesside Pipeline. However, ultimately this still constitutes a low probability of presence and a density of up to approximately 90 individuals per m^2 in highly localised areas (Langton *et al.*, 2021).

The Humber Pipeline route is located 2.74 km from the Humber Estuary SAC which is noted for the presence of river lamprey (*Lampetra fluviatilis*) and sea lamprey (*Petromyzon marinus*) which breed in the River Derwent, a tributary of the River Ouse. These species are both Annex II listed and UK populations of river lamprey in particular are considered important to the European population as a whole.

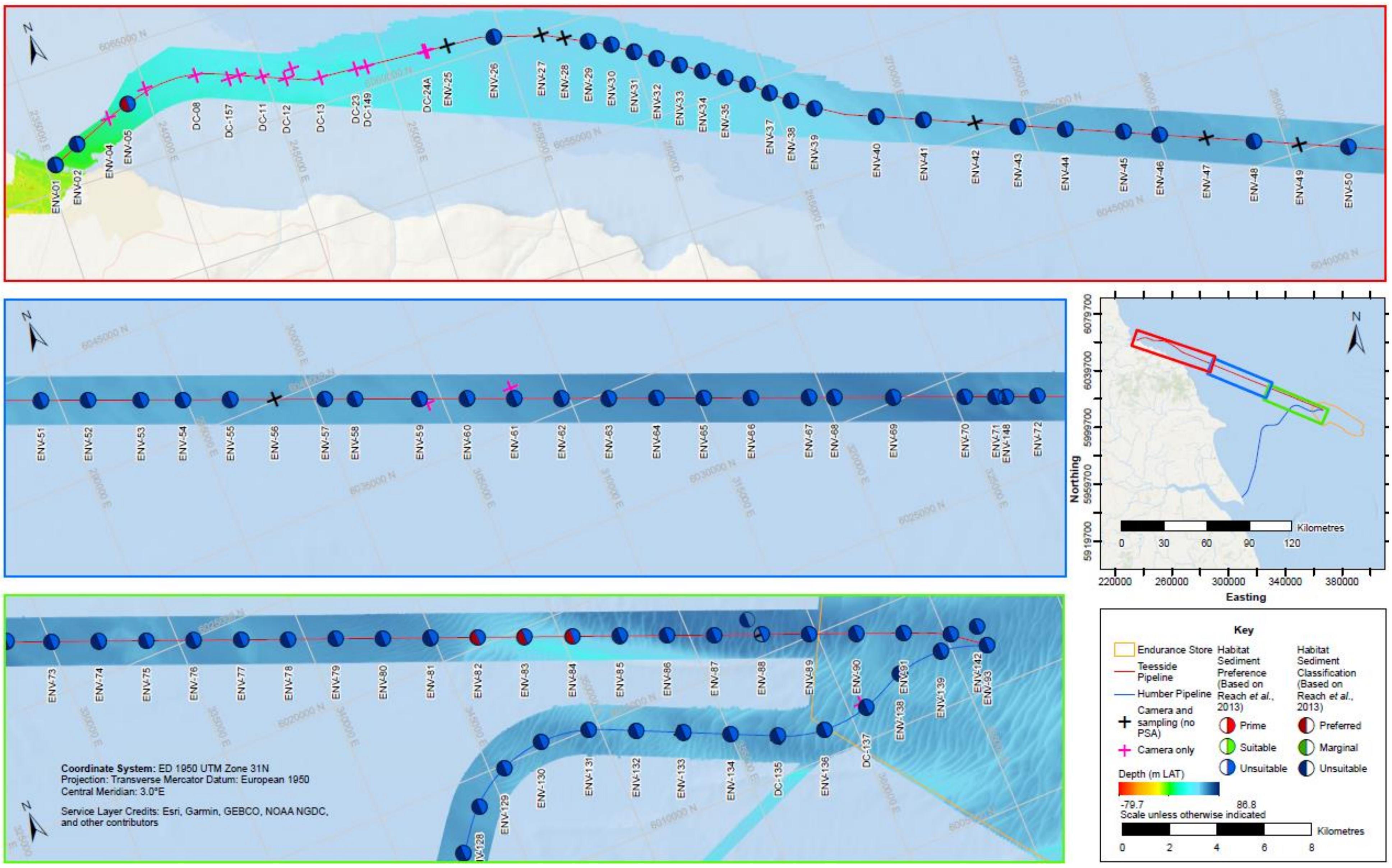


Figure 4-24 - Herring spawning ground potential along the Teesside Pipeline route (Gardline, 2022b)

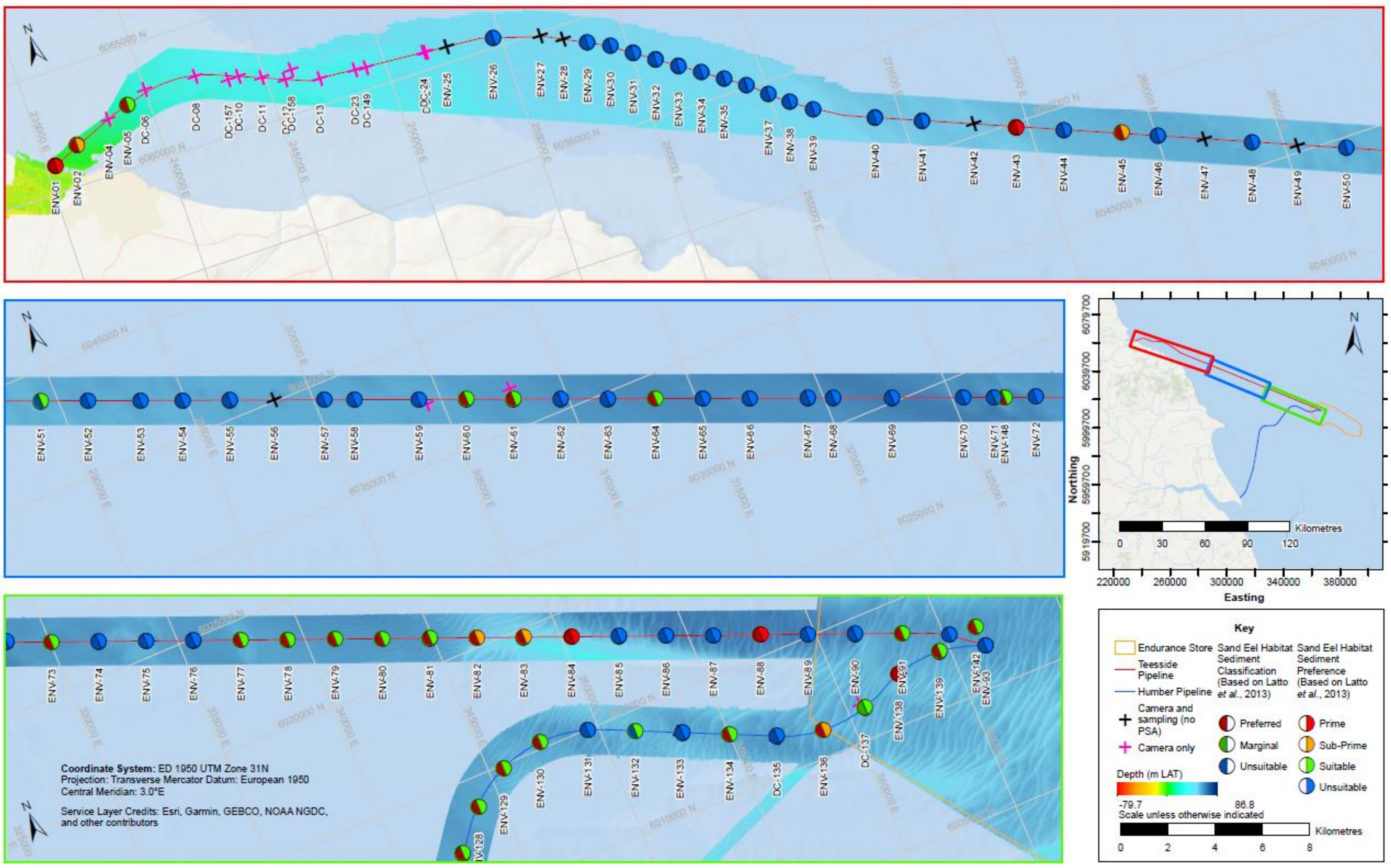


Figure 4-25 - Sandeel spawning group potential along the Teesside Pipeline route (Gardline, 2022b)

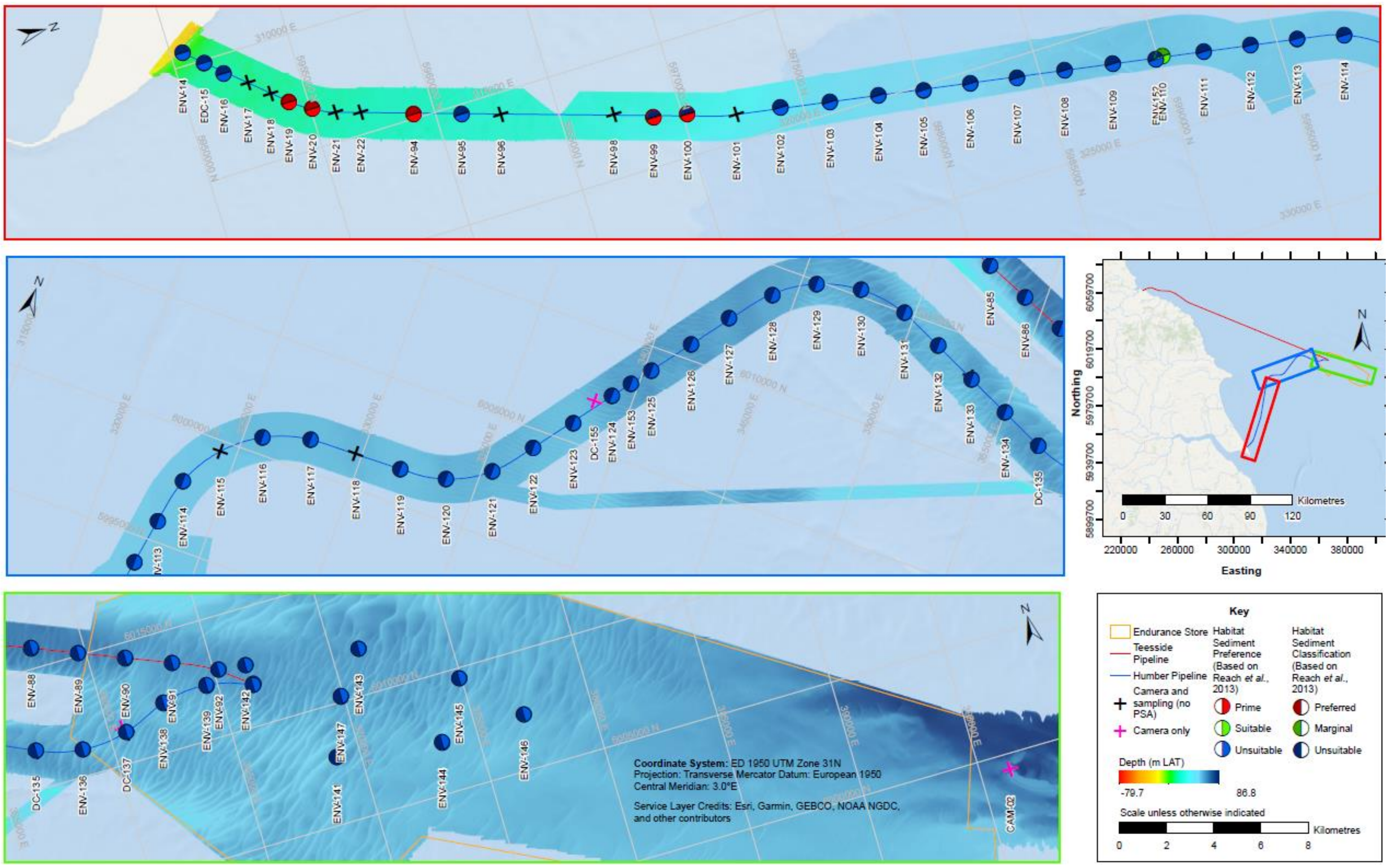


Figure 4-26 - Herring spawning ground potential within the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

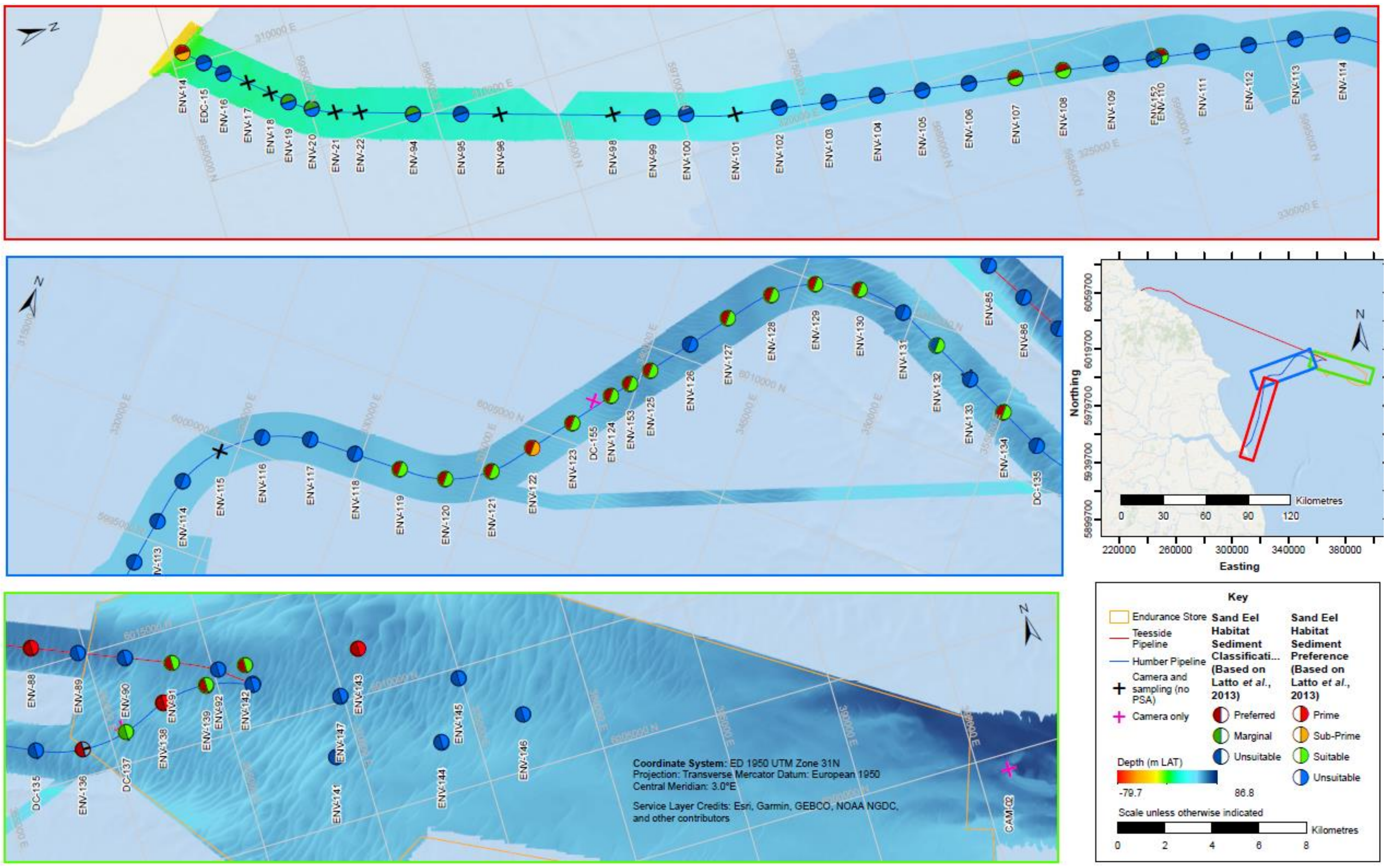


Figure 4-27 - Sandeel spawning ground potential within the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

4.4.4 Marine Reptiles

Of the seven species of marine turtle which occur globally, five have been recorded in UK waters: leatherback turtle (*Dermochelys coriacea*), loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), green turtle (*Chelonia mydas*) and hawksbill turtle (*Eretmochelys imbricata*). The majority of records in UK waters are for leatherback turtle (DECC, 2016). Most sightings occur around the west and south coasts of Ireland, southwest England, northwest Wales and the Irish Sea (National Biodiversity Network Atlas, 2021; Reeds, 2004). Penrose *et al.* (2021) indicates there was a single sighting or stranding event between 2010 and 2020 along the northeast coast of England, approximately 40 km south of Teesside. It is therefore considered unlikely that turtles will be observed in the vicinity of the Development. No other species of marine reptile are recorded in the North Sea.

4.4.5 Birds

Of the seabird species which breed regularly in Britain and Ireland, fulmar (*Fulmar glacialis*), cormorant (*Phalacrocorax carbo*), shag (*Phalacrocorax aristotelis*), gannet (*Morus bassanus*), three species of auk, six species of gull and five species of tern breed around the North Sea coast of England (DTI, 2001). Seabird colonies support nationally and internationally important populations at the Farne Islands, Coquet Island, the coastline from Scremerston near Berwick-Upon-Tweed in the north to Blyth in the south and at Flamborough Head and Bempton Cliffs. An Ornithological Technical Report has been completed with the aim of providing a characterisation of ornithological conditions in the Development area (NIRAS, 2023). A number of sources have been used to identify the importance of the Development area for seabirds. In the first instance the density layers associated with Waggitt *et al.* (2019) have been used. Where a species is absent from this dataset, data from Bradbury *et al.* (2014) have been used, followed by Kober *et al.* (2010). Where data on a particular species is not available from the previous three sources, then an older source, Stone *et al.* (1995), has been used. In using Stone *et al.* (1995), consideration has been given to any potential changes in the distribution of relevant species which may have occurred since publication.

The Development area may be of importance for the following species throughout the year: black-legged kittiwake (*Rissa tridactyla*), great black-backed gull (*Larus marinus*), herring gull (*Larus argentatus*), lesser black-backed gull (*Larus fuscus*), and cormorant (*Phalacrocorax carbo*). Razorbill (*Alca torda*), puffin (*Fratercula arctica*), red-throated diver (*Gavia stellata*), and shag (*Phalcrocorax aristotelis*) may all be present during their respective non-breeding seasons. During the breeding season, common tern (*Sterna hirundo*) may be found in the Development area. Little gull (*Hydrocoloeus minutus*) are also documented as using the Development area during their breeding season, although they do not breed in the UK and their distribution may reflect passage movements. Similarly, Sandwich tern (*Thalasseus sandvicensis*) and Arctic tern (*Sterna paradisaea*) may be present during their respective breeding seasons, although both species' density layers likely represent migratory movements. Guillemot (*Uria aalge*) may use the area during the non-breeding season.

The maps presented in Cleasby *et al.* (2020) also suggest the Development area may be of importance for guillemot and razorbill during the breeding season. The density layers associated with Wakefield *et al.* (2013) indicate that the Development area is of importance for gannet in the breeding season. Using information on the conservation status and vulnerability of species to the impacts associated with the Development, Valued Ornithological Receptors (VORs) were identified. This information is summarised in Table 4-3 for each species.

Table 4-3 - Conservation status and vulnerability of species which may be impacted by the Development

Species	Status/relation to protected sites	Occurrence	Vulnerability
Kittiwake (*Rissa tridactyla*)	Kittiwake is currently red-listed on the UK Birds of Conservation Concern (BOCC) (Eaton *et al.*, 2015). The species is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). There is connectivity between the Development and kittiwakes from the Flamborough and Filey Coast SPA. Kittiwake is identified as a VOR with an International conservation value.	The offshore sea areas through which both pipelines pass are of importance for kittiwake throughout the year (Waggitt *et al.,* 2019). The sea area in which the Endurance Store is located is of importance in the non-breeding season. Cleasby *et al.* (2020) also suggests that the Development will pass through sea areas within the utilisation distribution of breeding kittiwake from Flamborough and Filey Coast SPA in the breeding season.	Kittiwakes are not considered vulnerable to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species is also considered to have a moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).
Great black-backed gull (*Larus marinus*)	Great black-backed gull is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). The species is currently amber-listed on the UK BOCC (Eaton *et al.*, 2015). There are no SPAs at which great black-backed gull is a feature within 100 km of the Development. Great black-backed gull is identified as a VOR with a Local conservation value.	The sea areas through which both Development pipelines will pass and the area in which the Endurance Store is located are of importance for great black-backed gull in the non-breeding season (Bradbury *et al.,* 2014). In addition, the sea areas through which both pipelines will pass are of importance in the breeding season, although there are no breeding colonies within foraging range of the Development with birds present therefore likely to be non-breeding or immature individuals.	Great black-backed gulls are not considered vulnerable to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species has moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).
Sandwich tern (*Thalasseus sandvicensis*)	Sandwich tern is listed on Annex I of the EU Birds Directive (2009/147/EEC) and the species is currently amber-listed on the UK BOCC list (Eaton *et al.*, 2015). There is no connectivity between the Development and any SPAs at which Sandwich tern is a designated feature. Sandwich tern is identified as a VOR with a National conservation value.	The inshore sea areas through which the Teesside Pipeline will pass appear to be of importance for Sandwich tern in the breeding season based on the density layers associated with Waggitt *et al.* (2019) however foraging range data suggests no connectivity between these sea areas and Sandwich tern breeding colonies (Woodward *et al.,* 2019). It is likely that these apparent areas of high-density represent movements of birds during the pre- or post-breeding seasons.	Sandwich terns are not considered vulnerable to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species has moderate vulnerability to accidental contamination events (Williams *et al.,* 1995).
Little tern (*Sterna albifrons*)	Little tern is listed on both Annex I of the EU Birds Directive (2009/147/EEC) and Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). The species is also amber-listed on the UK BOCC (Eaton *et al.* 2015). There is connectivity between little tern from the Humber Estuary SPA and the Development. Little tern is identified as a VOR with an International conservation value.	The sea areas in which the Development will be located do not appear to be of importance for little tern in the breeding or non-breeding seasons (Bradbury *et al.,* 2014). Both pipelines are however located close to little tern breeding colonies. Site-specific foraging range data suggests connectivity between the Humber pipeline and little tern from the Humber Estuary SPA but not between the Teesside pipeline and birds from the Teesmouth and Cleveland Coast SPA.	Little terns are not considered vulnerable to disturbance but have a low habitat flexibility (Wade *et al.*, 2016). The species is also considered to have a moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).
Common tern (*Sterna hirundo*)	Common tern is listed on Annex I of the EU Birds Directive, and the species is currently amber-listed on the UK BOCC (Eaton *et al.*, 2015). There is connectivity between common tern from the Teesmouth and Cleveland Coast SPA and the Development.	The offshore sea areas through which the Humber pipeline will pass are of importance for common tern in the breeding season (Bradbury *et al.,* 2014). The closest breeding colonies to the two pipelines are at the Teesmouth and Cleveland Coast SPA (Teesside Pipeline) and at the	Common terns are not considered vulnerable to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species has moderate vulnerability to accidental contamination events (Webb *et al.*, 2016).

Species	Status/relation to protected sites	Occurrence	Vulnerability
	Common tern is identified as a VOR with an International conservation value.	Humber Estuary (Humber Pipeline). The generic mean-maximum foraging range of common tern (Woodward *et al.*, 2019) (18 km) suggests connectivity between the Teesmouth and Cleveland Coast SPA and the Development.	
Arctic tern (*Sterna paradisaea*)	Arctic tern is listed on Annex I of the EU Birds Directive, and the species is currently amber-listed on the UK BOCC list (Eaton *et al.*, 2015). There is no connectivity between the Development and any SPAs at which Arctic tern is a designated feature. Arctic tern is identified as a VOR with a National conservation value.	The offshore sea areas through which the two pipelines will pass are of importance for Arctic tern during the breeding season (Bradbury *et al.,* 2014). The Development is, however, not within the foraging range of Arctic tern from any breeding colonies for the species (Woodward *et al.,* 2019). It is likely that these apparent areas of high-density represent movements of birds during the pre- or post-breeding seasons.	Arctic terns are not considered vulnerable to disturbance and are considered to have a moderate habitat flexibility (Wade *et al.*, 2016). The species is also considered to have a moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).
Common guillemot (*Uria aalge*)	Common guillemot is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). The species is currently amber-listed on the UK BOCC (Eaton *et al.*, 2015). There is connectivity between the Development and guillemots from the Flamborough and Filey Coast SPA. Common guillemot is identified as a VOR with an International conservation value.	The sea areas through which both Development pipelines will pass and the area in which the Endurance Store is located are of importance for common guillemot outside of the breeding season (Waggitt *et al.,* 2019). Cleasby *et al.* (2020) also suggests that the Development will pass through sea areas within the utilisation distribution of common guillemot from Flamborough and Filey Coast SPA in the breeding season.	Common guillemots are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species is considered to have a high vulnerability to accidental contamination events (Webb *et al.,* 2016).
Razorbill (*Alca torda*)	Razorbill is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). The species is currently amber-listed on the UK BOCC (Eaton *et al.*, 2015). There is connectivity between the Development and razorbills from the Flamborough and Filey Coast SPA. Razorbill is identified as a VOR with an International conservation value.	Inshore sea areas through which both Development pipelines will pass and the sea area in which the Endurance Store is located are of importance for razorbill outside of the breeding season (Waggitt *et al.,* 2019). Cleasby *et al.* (2020) also suggests that the Development will pass through sea areas within the utilisation distribution of razorbill from Flamborough and Filey Coast SPA in the breeding season.	Razorbills are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species is considered to have a high vulnerability to accidental contamination events (Webb *et al.,* 2016).
Puffin (*Fratercula arctica*)	Puffin is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Country-side Act 1981 (as amended). The species is red-listed on the UK BOCC (Eaton *et al.*, 2015). There is connectivity between the Development and puffins from the Farne Islands SPA. Puffin is identified as a VOR with an International conservation value.	Inshore sea areas through which the Teesside Pipeline will pass are of importance for puffin outside of the breeding season (Waggitt *et al.,* 2019). There is no evidence to suggest that the sea areas in which the Development will be located is of importance for puffin in the breeding season.	Puffins are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility (Wade *et al.,* 2016). The species is considered to have a high vulnerability to accidental contamination events (Webb *et al.,* 2016).
Red-throated diver (*Gavia stellata*)	Red-throated diver is listed on Annex I of the EU Birds Directive (2009/147/EEC) and Schedule 1 of the Wildlife and Countryside Act 1981 (as amended).	Inshore sea areas through which Humber Pipeline will pass are of importance for red-throated diver in the non-breeding season (Bradbury *et al.,* 2014) with these areas corresponding with the boundary of the Greater Wash SPA at which red-throated diver is a	Red-throated divers are considered to have a high vulnerability to disturbance and have a low habitat flexibility (Wade *et al.*, 2016). The species

Species	Status/relation to protected sites	Occurrence	Vulnerability
	Red-throated diver is a non-breeding feature at the Greater Wash SPA through which the Humber pipeline passes. The species is therefore identified as a VOR of International conservation value. Red-throated diver is identified as a VOR with an International conservation value.	designated feature. Lawson *et al.* (2016) suggests that the area through which the Humber pipeline will pass supports moderate densities of red-throated diver in the non-breeding season.	is also considered highly vulnerable to accidental contamination events (Webb *et al.,* 2016).
Gannet (*Morus bassanus*)	Gannet is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Country-side Act 1981 (as amended). Gannet is currently amber-listed on the UK BOCC (Eaton *et al.*, 2015). There is connectivity between the Development and gannets from the Flamborough and Filey Coast SPA. Gannet is identified as a VOR with an International conservation value.	The sea areas through which both Development pipelines will pass and the area in which the Endurance Store is located are not of importance for gannet throughout the year based on the density layers associated with Waggitt *et al.* (2019), despite the presence of breeding birds at the Flamborough and Filey Coast SPA in close proximity to the Development. However, tracking data presented in Wakefield *et al.* (2013) suggests connectivity between birds from the Flamborough and Filey Coast SPA and the sea areas in which the Development will be located.	Gannets are not considered vulnerable to disturbance and have a high habitat flexibility (Wade *et al.,* 2016). The species is considered to have a high to moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).
Shag (*Phalacrocorax aristotelis*)	Shag is listed on Annex I of the EU Birds Directive (2009/147/EEC) and the species is currently red-listed on the UK BOCC list (Eaton *et al.*, 2015). There is no connectivity between the Development and any SPAs at which shag is a designated feature. Shag is identified as a VOR with a National conservation value.	Inshore sea areas through which the Teesside Pipeline will pass are of importance for shag in the non-breeding season (Waggitt *et al.,* 2019). There is no evidence to suggest that the sea areas in which the Development will be located is of importance for shag in the breeding season with no breeding colonies within foraging range (Woodward *et al.,* 2019).	Shags are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species is also considered highly vulnerable to accidental contamination events (Webb *et al.,* 2016).
Cormorant (*Phalacrocorax carbo*)	Cormorant is not listed under Annex I of the EU Birds Directive (2009/147/EEC) or Schedule 1 of the Wildlife and Countryside Act 1981 (as amended). The species is currently green-listed on the UK BOCC list (Eaton *et al.*, 2015). There is no connectivity between the Development and any SPAs at which shag is a designated feature. Cormorant is identified as a VOR with a Negligible conservation value.	Inshore sea areas through which both Development pipelines will pass are of high importance to cormorant in the breeding season with the inshore areas associated with the Teesside Pipeline of importance in the non-breeding season (Waggitt *et al.,* 2019). There are however, no breeding colonies within foraging range of the Development.	Cormorants are not considered vulnerable to disturbance and have a moderate habitat flexibility (Wade *et al.*, 2016). The species is considered to have a moderate vulnerability to accidental contamination events (Webb *et al.,* 2016).

The JNCC monitors the population trends of a number of seabird species. Between 2000 and 2019, five species which have been recorded in the Development area showed a decrease in population size across the UK: Arctic skua (70%), northern fulmar (33%), black-legged kittiwake (29%), great black-backed gull (23%), and common tern (3%), with such declines often linked to changes in food availability. However, of the colonies which may interact with the Development area, populations of black-legged kittiwake have shown increases in recent years (JNCC, 2021b). A further three species have also seen an increase in population size at a UK level: common guillemot (+60%), razorbill (+37%), and northern gannet (+34%), (JNCC, 2021b). These trends are also reflected at a regional level in those colonies close to the Development area, albeit at a lesser magnitude than exhibited nationally.

The Seabird Oil Sensitivity Index (SOSI) (Webb *et al.*, 2016) identifies regions where seabirds are likely to be most sensitive to oil pollution. It is an updated version of the Oil Vulnerability Index (JNCC, 1999) which uses survey data collected between 1995 and 2015 and covers the UKCS and beyond. The SOSI also includes an improved method to calculate a single measure of seabird sensitivity to oil pollution. These data were combined with individual species sensitivity index values and summed at each location to create a single measure of seabird sensitivity to oil pollution (Webb *et al.*, 2016).

Seabird sensitivity to oil pollution in the region of the Development is variable throughout the course of the year and between the Endurance Store and pipeline routes. Although the Development area on the whole experiences quite high seabird sensitivities throughout the year, extremely high SOSI is experienced along the Teesside Pipeline route in February, March, May through August and December. The Humber Pipeline route experiences extremely high sensitivity in February, March, May, June, September and October. Comparatively, extremely high SOSI scores are identified at the Endurance Store in the months of June, September, and December (Webb *et al.*, 2016; Figure 4-28 and Figure 4-29).

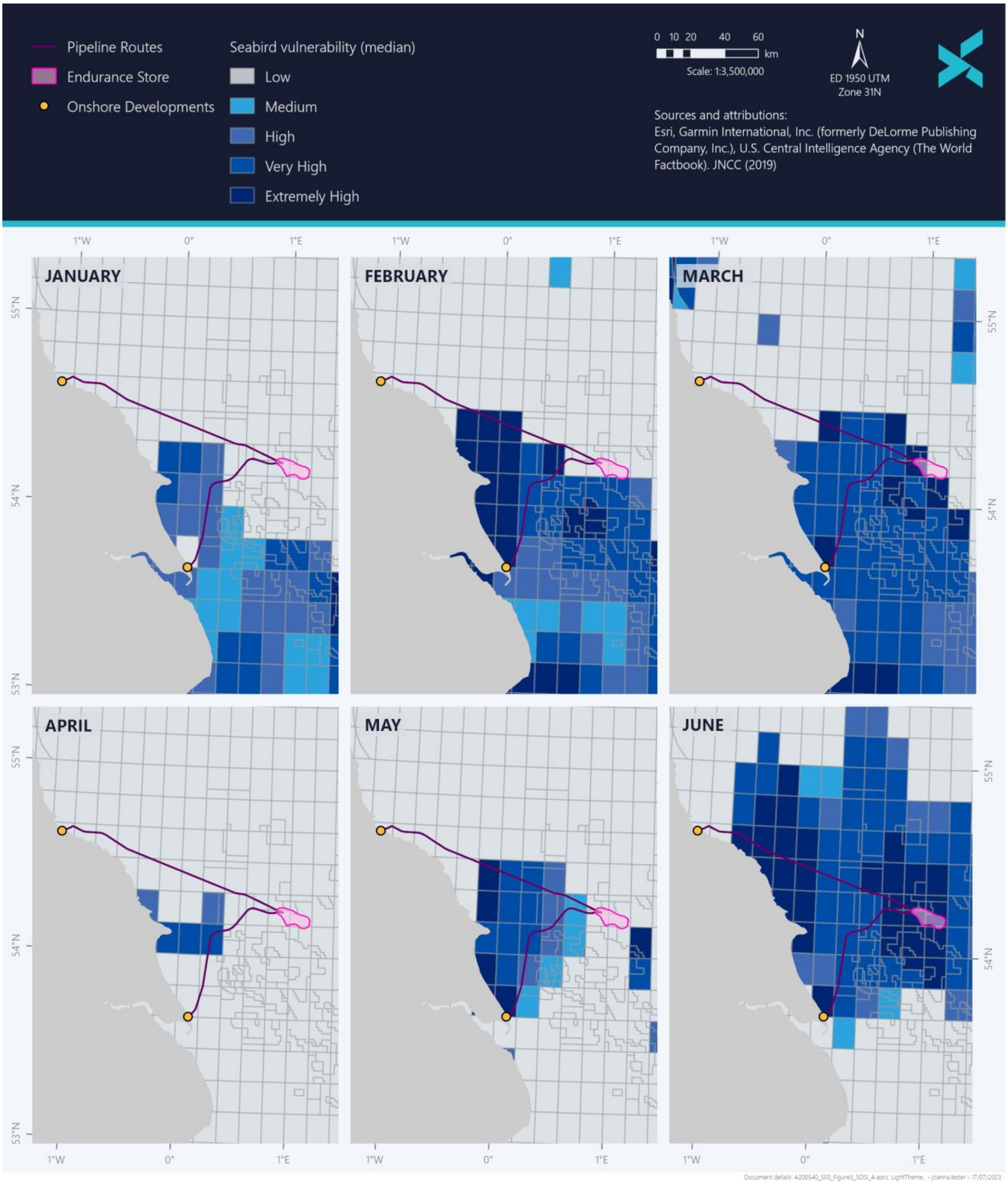


Figure 4-28 - SOSI across the Development area (Webb *et al.*, 2016) (1 of 2)

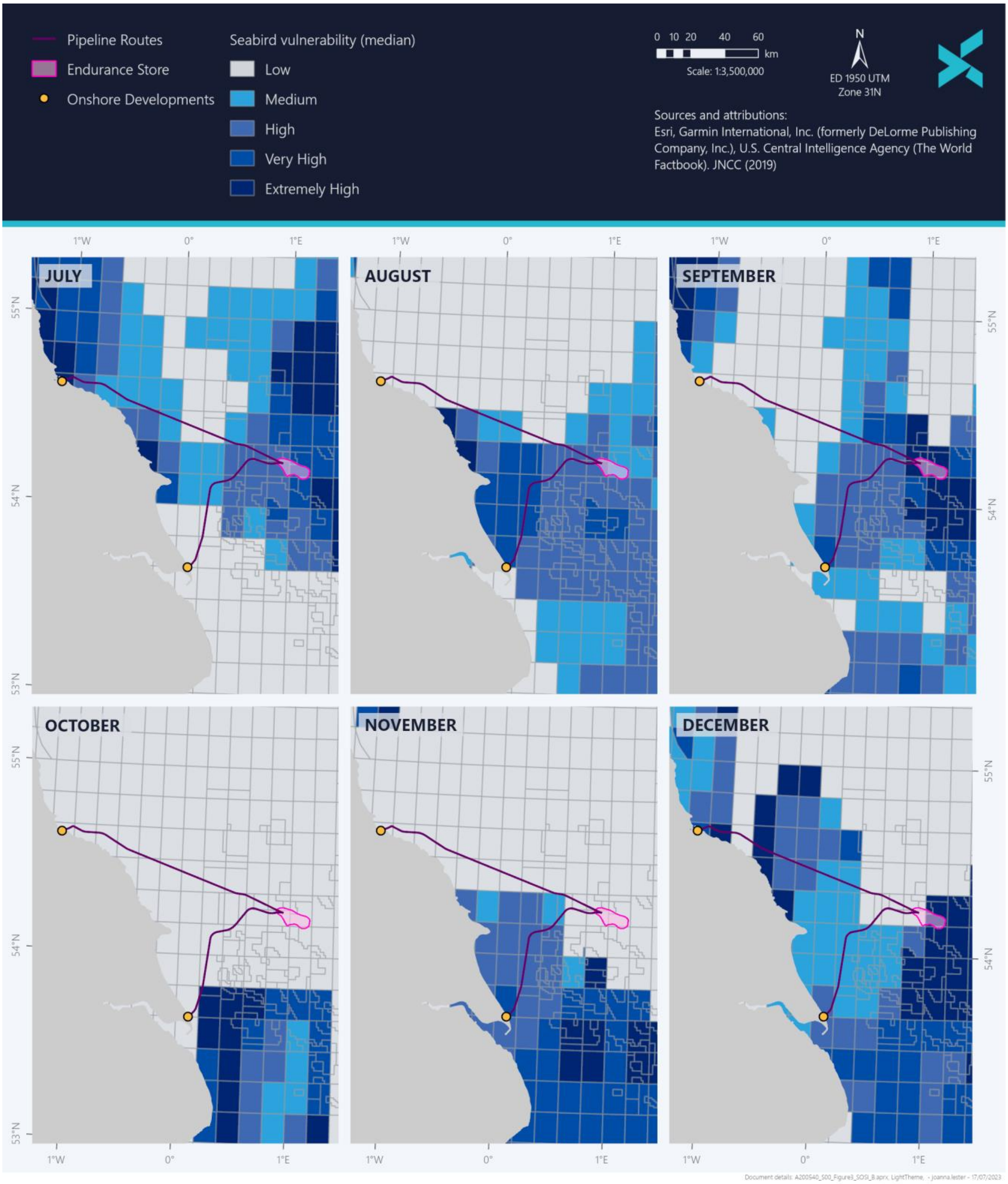


Figure 4-29 - SOSI across the Development area (Webb *et al.*, 2016) (2 of 2)

4.4.6 Marine Mammals

4.4.6.1 Pinnipeds

Both grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*) are resident in UK waters and are found on the east coast of England. Out to 12 NM, grey and harbour seals are protected under The Conservation of Seals Act 1970, the Wildlife and Countryside Act 1981 and the Conservation of Habitats and Species Regulations 2017. Beyond 12 NM they are protected under the Conservation of Offshore Marine Habitats and Species Regulations 2017. Both species feed both inshore and offshore depending on the distribution of their prey, which varies seasonally and annually. Both species tend to be concentrated close to shore, particularly during the pupping and moulting season.

The UK supports approximately 30% of the European harbour seal population, down from approximately 40% in 2002 due to various localised declines in English and Scottish populations. The population of the English east coast was reduced by approximately 52% following a viral epidemic in 1988, and a further 22% following a second outbreak in 2002. The population in The Wash recovered rapidly between 2006 and 2012; since 2012 it has been increasing by an average of 1% per year and is now above its pre-2002 level (SCOS, 2016). The population of harbour seals in England is currently estimated to be approximately 5,400 individuals, equating to 12% of the UK population (approximately 44,000 individuals; SCOS, 2020). Seal counts within the Southeast England Seal Management Unit (SMU), within which the Development is located, between 2016 and 2019 totalled 3,752 observations (SCOS, 2020).

Harbour seals haul out every few days on tidally exposed areas of rock, sandbanks or mud. Pupping and moulting seasons occur from May to August, during which time seals will come ashore more often. Generally, harbour seals forage around their haul out sites throughout the year and are not normally recorded more than 60 km from shore, although tagging studies have shown that they may occasionally forage at much greater distances. Foraging density maps published by the Sea Mammal Research Unit (SMRU) report the presence of harbour seals at the Endurance Store to be <1 individual per 25 km^2 (Russell *et al.*, 2017; Carter *et al.*, 2020). Along the Teesside and Humber Pipeline routes there is a marginally higher probability of encountering a harbour seal (5-10 individuals per 25 km^2; Carter *et al.*, 2020). Figure 4-30 shows the estimated density of harbour seals at sea in the Development area.

Approximately 38% of the world's grey seal population breeds in the UK, however the majority of these breed in Scotland. Donna Nook, Blakeney Point and Horsey are the three best established breeding colonies on the east coast of England. Pup production has consistently increased across the UK since 2014, though much of the growth in the North Sea is attributed to newly established colonies (SCOS, 2020). Donna Nook, a well-established breeding colony, is located approximately 17 km south of the Humber Pipeline landfall. The site is a National Nature Reserve (NNR) covering approximately 10 km of coastline. The seals at Donna Nook have apparently become acclimatised to human presence; over 70,000 people visit the colony during the breeding season with no discernible impact on breeding success (SCOS, 2020). Pupping for the east coast population occurs between early November and mid-December (SCOS, 2020). Based on pup production, the 2019 population of grey seals in England was estimated to be approximately 28,400. This equates to 19% of the total UK population (approximately 149,700 individuals, SCOS, 2020).

Most grey seals forage within 100 km of haul out sites, although they are capable of travelling many hundreds of kilometres. Distribution data on grey seals suggests it is likely for grey seals to be present in the Development area. Grey seal density maps published by the SMRU report the presence of grey seals at the Endurance Store to be 0.04 individuals per 25 km^2. At other locations in the Development area the seal density was as high as 101-200 individuals per 25 km^2 (Russell *et al.*, 2017); mostly associated with the coast. Recent data suggests 10-25 grey seals (per 25 km^2) could be in the Store area at any given time (Carter *et al.*, 2020). Figure 4-30 shows the estimated density of grey seals at sea in the Development area.

For grey seals, the potential for a seal encounter increase with proximity to shore, in particular along the Humber Pipeline route. At the point of landfall for this pipeline, up to 50-75 individuals (per 25 km^2) could be in the area at any given time (Carter *et al.*, 2020). Where the Teesside Pipeline route comes close to the coast the seal at-sea density also increases but at landfall is consistent with densities expected offshore at the Endurance Store.

During the 2022 3D seismic survey of the wider Store area, a number of marine mammal observations were made, including several seal sightings. 51 observations of grey seals were recorded over a reporting period of two months; these observations were thought to represent a minimum number of 179 individuals. A further ten sightings of unidentified seal species were made, each representing a single individual. By comparison, there were no confirmed sightings of harbour seals (Hydenlyne, 2022). The distribution of seal sightings was relatively uniform across the Store area; however, the highest densities were recorded in areas consistent with steep slopes and a sandy seabed (Hydenlyne, 2022).

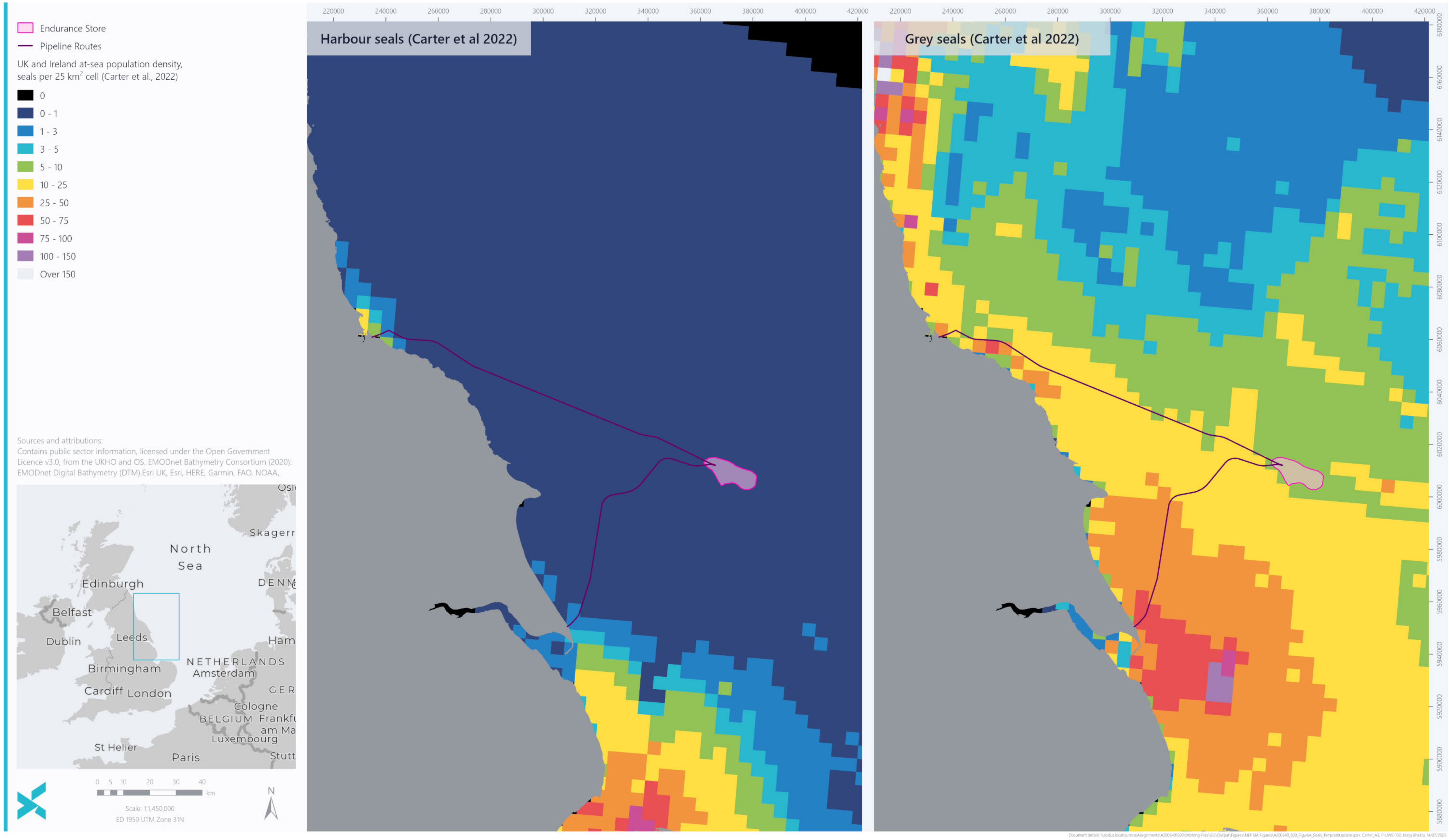


Figure 4-30 - Seal at sea density across the Development area (Russel *et al.*, 2017, Carter *et al.*, 2020)

4.4.6.2 Cetaceans

A total of 19 species of cetacean have been recorded in UK waters (Reid *et al.*, 2003). Cetaceans regularly recorded in the North Sea include harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), minke whale (*Balaenoptera acutorostrata*), killer whale (*Orcinus orca*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*) and white-beaked dolphin (*Lagenorhynchus albirostris*). Rarer species include fin whale (*Balaenoptera physalus*), long-finned pilot whale (*Globicephala melas*), Risso's dolphin (*Grampus griseus*) and the short beaked common dolphin (*Delphinus delphis*) (Reid *et al.*, 2003). With the exception of harbour porpoise, the SNS typically has a lower density of cetaceans than the NNS and CNS.

In the Development area, bottlenose dolphin, harbour porpoise, white-sided dolphin, pilot whale, minke whale, white-beaked dolphin, bottlenose dolphin and common dolphin have all been observed at various times of year in differing numbers (Table 4-4).

Table 4-4 - Cetacean observations in the Development area (Reid *et al.*, 2003)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Endurance Store												
Bottlenose dolphin							1	1				
Harbour porpoise	2	1	1		2	2	2	2	2	3	1	3
Pilot whale								3				
Minke whale							2	2	2	2		
White beaked dolphin			2		3	1	2	2	2	2	2	
Teesside Pipeline												
White sided dolphin						2			2			3
Harbour porpoise	2	1	1		1	2	2	2	2		3	3
Minke whale						2	2	2	2	2		
White beaked dolphin			1		2	1	2	2	2	2	2	3
Humber Pipeline												
White sided dolphin									2			
Bottlenose dolphin							1	1				
Common dolphin									2			
Harbour porpoise	2	2	1	2	2	2	2	2	2	3	3	3
Minke whale									3			
White beaked dolphin					3	1		2	2	2		

1 = High-density, 2 = Moderate Density, 3 = Low-density, Blank = No data

Surveys undertaken for the Small Cetaceans in the European Atlantic and North Sea (SCANS-III) were used to determine cetacean abundance and predict density estimates throughout the UKCS. The Development area is located within region 'O' of the SCANS-III study. SCANS-III identified harbour porpoise as the most abundant cetacean species in the regional area (supporting approximately 53,500 individuals), followed by minke whale (approximately 600 individuals) and white-beaked dolphin (approximately 150 individuals) (Hammond *et al.*, 2021).

The Joint Cetacean Protocol (JCP) has been set up with the aim of delivering information on the distribution, abundance and population trends of cetacean species occurring in the North Sea and adjacent sea regions. Effort-linked sightings data contained within the JCP data resource were used to estimate spatio-temporal patterns of abundance for seven species of cetacean over a 17 year period from 1994 – 2010. In 2017 the JCP Phase III density calculations were scaled to earlier SCANS-II abundance estimates (Paxton *et al.*, 2016). The results for the Development area are presented in Table 4-5 below, along with the estimated cetacean densities of some species from the SCANS-III study.

Table 4-5 - Estimated cetacean densities in the vicinity of the Development (Paxton *et al.*, 2016; Hammond *et al.*, 2021)

Species	Density (animals/km^2)	
	SCANS-III Hammond *et al.* (2021)	JCP Paxton *et al.* (2016)
Bottlenose dolphin	-	0-0.001
Harbour porpoise	0.888	0.011-0.5
White-sided dolphin	-	0-0.001
Pilot whale	-	-
Minke whale	0.01	0-0.002
White-beaked dolphin	0.002	0-0.004
Common dolphin	-	0-0.002
'-' For some species, density estimates are unavailable due to limited observational information		

A report by Heinänen and Skov (2015), used in support of the designation of the SNS SAC, identified seasonal changes in harbour porpoise density within the North Sea. General trends indicate a more widespread distribution of harbour porpoise in summer months (> 3 individuals per km^2) across the SNS area, however winter distributions were also modelled in the region of the Development area. Comparatively, in winter the distribution of harbour porpoise is concentrated further south, therefore less likely to be observed along the Teesside Pipeline route.

During initial geophysical surveys at the Endurance Store, a single pod (of approximately seven individuals) of an unidentified dolphin species was observed over a 27 day period (Gardline, 2020).

More recent observational data (Hydenlyne, 2022) recorded 51 observations of mink whale (equating to 64 individuals), 17 observations of harbour porpoise (equating to 22 individuals), three observations of unidentified dolphin species (equating to 63 individuals), and a single observation of an unidentified baleen whale species (representing one individual).

Most minke whale sightings were of solitary individuals and were occasionally associated with feeding seabirds. Harbour porpoise were also mostly solitary, however on three occasions they were sighted in groups of up to 3 individuals (Hydenlyne, 2022).

4.5 Conservation

The Endurance Store and Teesside and Humber Pipeline routes intersect with a number of protected sites, including SPAs, SACs and MCZs. Designated sites proximal to the Development are shown in Figure 4-31. Table 4-6 lists the sites which directly intersect with the Development and provide a detailed description of the site and the Conservation Objectives associated with the qualifying features of the site.

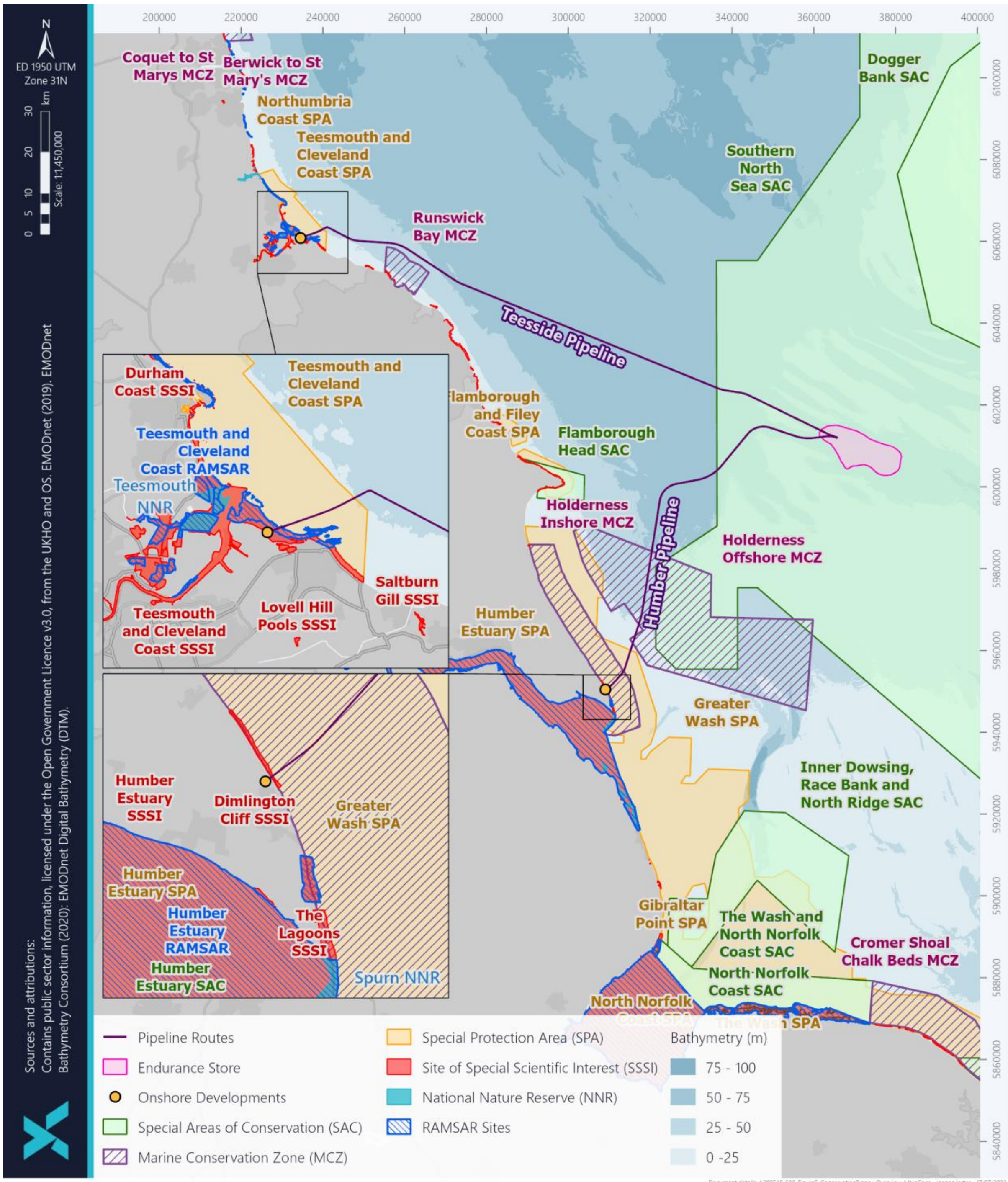


Figure 4-31 - Location of designated sites in the vicinity of the Development

Table 4-6 - Designated sites which intersect with the Development

Designated site	Description and qualifying features	Conservation objectives	Intersecting area
SNS SAC	The SNS SAC has been designated due to its importance as habitat for harbour porpoise during both the summer and winter months (JNCC, 2019). The Endurance Store, and both pipeline routes are partly located within the summer habitat for the species. Additionally, the Humber Pipeline route also passes adjacent to an area of harbour porpoise winter habitat prior to its landfall.	To ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining Favourable Conservation Status (FCS) for Harbour Porpoise in UK waters. In the context of natural change, this will be achieved by ensuring that: 1. Harbour porpoise is a viable component of the site; 2. There is no significant disturbance of the species; and 3. The condition of supporting habitats and processes, and the availability of prey is maintained (JNCC, 2019).	Endurance Store located within site
Teesmouth and Cleveland Coast SPA	The Teesmouth and Cleveland Coast SPA contains significant areas of intertidal sand and mudflat, saltmarsh and freshwater grazing marsh, saline lagoon, sand dune, shingle, rocky shore and shallow coastal waters. The site was first classified for a number of breeding bird species, but in 2020 the list was extended resulting in the site being designated for the following: breeding little tern, passage Sandwich tern, wintering red knot and passage common redshank. The 2020 extension to the site includes additional areas of coastal and wetland habitats, the River Tees channel and the shallow coastal waters of Tees Bay (Natural England, 2020).	The site objectives are to ensure that, subject to natural change, the integrity of the site is maintained or restored as appropriate, and that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring: - the extent and distribution of the habitats of the qualifying features; - the structure and function of the habitats of the qualifying features; - the supporting processes on which the habitats of the qualifying features rely; - the populations of each of the qualifying features; - the distribution of qualifying features within the site (Natural England, 2020).	Teesside Pipeline route intersects site
Greater Wash SPA	The Greater Wash SPA is a very extensive site, stretching from Bridlington Bay in the north to the Outer Thames Estuary in the south and extends from shore beyond 12 NM. Habitats present across the site include areas of coarse sediment, sand, mud and mixed sediments, subtidal sandbanks and occasional Annex I reefs. The site qualifies for designation by regularly supporting nationally important populations of red-throated diver, little gull, sandwich tern, common tern and little tern, as well as an internationally important population of the migratory common scoter (JNCC, 2020b).	The site objectives are to ensure that, subject to natural change, the integrity of the site is maintained or restored as appropriate, and that the site contributes to achieving the aims of the Wild Birds Directive, by maintaining or restoring: - the extent and distribution of the habitats of the qualifying features; - the structure and function of the habitats of the qualifying features; - the supporting processes on which the habitats of the qualifying features rely; - the populations of each of the qualifying features; - the distribution of qualifying features within the site (Natural England, 2019).	Humber Pipeline route intersects site
Holderness Offshore MCZ	The seabed is designated for subtidal coarse sediment, subtidal sand, subtidal mixed sediments, part of a North Sea glacial tunnel valley and ocean quahog. The diverse seabed allows for a wide variety of species which live both in and on the sediment such as crustaceans, starfish and sponges. This site is also a spawning and nursing ground for a range of fish species including lemon sole, plaice and European sprat. (JNCC, 2020c).	The Conservation Objective for the Holderness Offshore MCZ is that the protected features: - so far as already in favourable condition, remain in such condition; and - so far as not already in favourable condition, be brought into such condition, and remain in such condition. With respect to Subtidal coarse sediment, Subtidal sand and Subtidal mixed sediments within the Zone, this means that: i. its extent is stable or increasing; and ii. its structures and functions, its quality, and the composition of its characteristic biological communities (which includes a reference to the diversity and abundance of species forming part of or	Humber Pipeline route intersects site

Designated site	Description and qualifying features	Conservation objectives	Intersecting area
		inhabiting that habitat) are such as to ensure that it remains in a condition which is healthy and not deteriorating. With respect to the ocean quahog (*A. islandica*) within the Zone, this means that the quality and quantity of its habitat and the composition of its population in terms of number, age and sex ratio are such as to ensure that the population is maintained in numbers which enable it to thrive. With respect to the North Sea glacial tunnel valleys within the Zone, this means that: i. its extent, component elements and integrity are maintained; ii. its structure and functioning are unimpaired; and iii. its surface remains sufficiently unobscured for the purposes of determining whether the conditions in paragraphs (i) and (ii) are satisfied (JNCC, 2021c).	
Holderness Inshore MCZ	The mosaic of habitats within the Holderness Inshore MCZ supports a diverse range of organisms including red algae, sponges and other encrusting fauna. The site also supports fish species such as European eel, dab and wrasse, and commercially important crustaceans such as edible and velvet swimming crabs and lobster. The site also protects a geological feature, Spurn Head, located at the southern end of the MCZ. This is a unique example of an active spit system, extending across the mouth of the Humber Estuary (Defra, 2016b). The site is designated for Intertidal sand and muddy sand; Moderate energy and High energy circalittoral rock; Subtidal coarse sediment; Subtidal mixed sediments; Subtidal sand and Subtidal mud (Defra, 2016b).	The general management approach for the features is to maintain them in favourable condition (Defra, 2016b).	Humber Pipeline route intersects site

The following sites are within 50 km of the Development but do not intersect directly with any Development infrastructure:

- Runswick Bay MCZ (1 km south-southwest of the Teesside Pipeline route);
  - Designated for a number of intertidal benthic habitats and ocean quahog;
- Humber Estuary SPA (3 km south-southeast of the Humber Pipeline route);
  - Designated for numerous breeding and non-breeding bird species and waterbird assemblages;
- Humber Estuary SAC (4 km south-southwest of the Humber Pipeline route);
  - Designated for a number of Annex I habitats including 'Sandbanks which are slightly covered by seawater all the time', a number of terrestrial habitats, grey seal, sea lamprey and river lamprey;
- Northumbria Coast SPA (15 km north-northwest of the Teesside Pipeline route);
  - Designated for breeding Arctic tern and little tern and non-breeding purple sandpiper and turnstone;
- Flamborough Head SAC (19 km west-northwest of the Humber Pipeline route);
  - Designated for Annex I 'Reefs', vegetated sea cliffs and sea caves;
- Dogger Bank SAC (21 km north-northeast of the Endurance Store);
  - Designated for 'Sandbanks which are slightly covered by seawater all the time';
- Flamborough Head and Filey Coast SPA (22 km west-northwest of the Humber Pipeline route);
  - Designated for breeding gannet, guillemot, kittiwake, razorbill and general seabird assemblages;
- Inner Dowsing, Race Bank and North Ridge SAC (45 km east-southeast of the Humber Pipeline route);
  - Designated for Annex I 'Sandbanks which are slightly covered by seawater all the time' and 'Reefs'.

In addition to sites of conservation importance, numerous species found in the offshore area are listed as species of conservation importance. These species have been highlighted as required in the previous sections.

Ramsar sites are wetlands of international importance designated under the Ramsar Convention. The following sites are located close to the Development:

- Teesmouth and Cleveland Coast Ramsar site (situated onshore of the Teesside Pipeline landfall location). The site includes a range of coastal habitats, including sand-flats and mud-flats, rocky shore, saltmarsh, freshwater marsh and sand dunes which are situated in and around an estuary which has been considerably modified by human activities. The Teesmouth and Cleveland Coast site is designated for assemblages of international importance and the presence of populations of common (representing an average of 0.7% of the British population) and wintering red knot (representing an average of 0.9% of the British population; JNCC, 2008a);
- Humber Estuary Ramsar site (approximately 3 km south of the Humber Pipeline route). Being the largest macro-tidal estuary on the British North Sea coast, the Humber Estuary is the site of the single largest input of freshwater from Britain into the North Sea. The inner estuary supports extensive areas of reedbeds and saltmarsh. At other places within the estuary the saltmarsh is backed by sand dunes and marshy slacks. This varied habitat supports

internationally important populations of waterfowl in winter and nationally important breeding populations in summer. Species of particular interest, and contributing to the designation of the site are: Eurasian golden plover (*Pluvialis apricaria*); red knot; dunlin (*Calidris alpina*); black-tailed godwit (*Limosa limosa*); common redshank (*Tringa totanus*); common shelduck (*Tadorna tadorna*); bar-tailed godwit (*Limosa lapponica*) (JNCC, 2008b).

A number of coastal SSSIs are situated onshore of the landfall locations (Figure 4-31). The Teesside Pipeline landfall is seaward of the Teesmouth and Cleveland SSSI and the Humber Pipeline landfall is seaward of the Dimlington Cliff SSSI, designated for geological features (Natural England, 1990a; Natural England, 2018b). The Teesmouth and Cleveland SSSI is designated for both geological and biological features, including sand dune and saltmarshes habitats, breeding harbour seals, breeding bird species and an assemblage of more than 20,000 waterfowl during the non-breeding season (Natural England, 2018c). The Lagoons SSSI, 3 km west-southwest of the Humber Pipeline route, comprises a variety of coastal habitats including saltmarsh, shingle, sand dune, swamp and most significantly, saline lagoons and pools which represent the only extant example in North Humberside of this nationally rare habitat (Natural England, 1990b).

4.6 Other Sea Users

A broad overview of other infrastructure in the vicinity of the Development is shown in Figure 4-32. Other sea users are discussed in detail in the following sections.

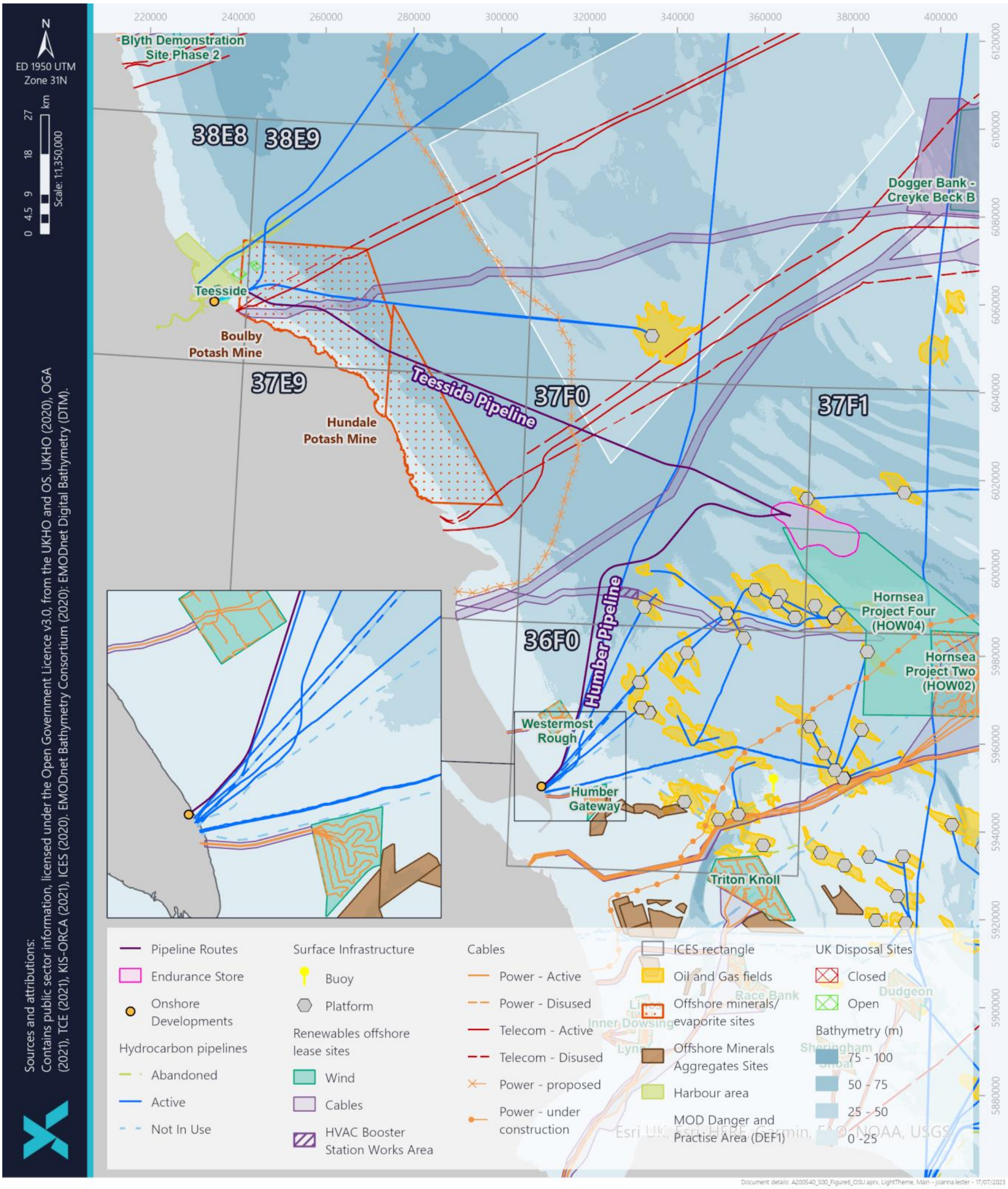


Figure 4-32 - Summary of other infrastructure in the Development area

4.6.1 Commercial Fisheries

4.6.1.1 Live weight, catch value and composition

The North Sea has important fishing grounds and is fished throughout by both UK and international fishing fleets, targeting demersal, pelagic and shellfish fish stocks. Commercial fisheries statistical data utilised throughout this Section originates from the MMO (2022) and the Scottish Government (2022).

The seas in the northeast Atlantic region have been divided into a series of administrative rectangles by the International Council for the Exploration of the Seas (ICES). These are known as ICES statistical rectangles and measure 30 minutes latitude by 1 degree longitude in size, which covers approximately 30 NM^2 and are used as a basis for carrying out statistical analysis of sea areas (MMO, 2022). The Development is located within a number of ICES rectangles. The Endurance Store is located in rectangles 37F0 and 37F1, the Humber Pipeline route crosses rectangles 37F0 and 36F0, and the Teesside Pipeline route crosses rectangles 37F0, 37E9, 38E8 and 38E9 in addition to extending almost the length of 37F0 (Figure 4-32).

From 2017 to 2018 shellfish typically dominated both the landings value and live-weight tonnage from ICES rectangle 37F0, accounting for over 90% of the landings value and 90% of the landings weight. In 2019 there was an increase in pelagic catch and this was repeated in 2020 when pelagic catch contributed almost 50% of annual catch by weight, and finally in 2021 where it contributed more than 90% of annual catch by weight, rivalling that of shellfish. Comparatively though, the value of catch was still predominantly attributed to shellfish apart from 2021 where pelagic catch accounted for 75% of value, indicating the inflated value of shellfish in comparison to other species. Demersal catch remains consistently low year on year in this area (Table 4-7).

Data for rectangle 37F1 shows much the same trend with shellfish making up most of the annual landings and catch, although to a lesser extent. However, demersal species have historically made up a proportion of catch and landings value often almost equal to shellfish, until 2019 when shellfish made up over 80% of landings by weight and value. Of all the rectangles across which the Development area spans, 37F1 produced the lowest tonnage of landings in 2021 (approximately 310 Mt; Table 4-7), almost an order of magnitude lower than all other rectangles.

Table 4-7 - Fisheries landed weight and landings value ICES rectangles 36F0, 37E9, 37F0, 37F1, 38E8 and 38E9 in 2017-2021 (MMO, 2022)

Species type	2021		2020		2019		2018		2017	
	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)
ICES rectangle 36F0										
Demersal	30.98	23,821	15.68	18,236.38	15.33	15,582	9.07	10,372	5.79	9,865.97
Pelagic	5.2	4,024.7	2.68	2,732.4	0	-	161.57	87,222	<1	165.2
Shellfish	3,971.30	15,750,561	3,130.11	8,991,575	3,436.43	10,910,307	3,678.11	11,022,652	3,857.70	11,129,784
Total	4,007.50	15,778,406	3,148.47	9,012,544	3,451.76	10,925,889	3,848.75	11,120,246	3,863.68	11,139,815
ICES rectangle 37F0										
Demersal	205.26	172,783	149.29	176,064	28.98	56,338	10.01	14,523	79.18	106,998
Pelagic	14,723	8,955,350	914.96	583,095	1,547.93	1,130,215	0.40	164.17	11.52	19,099
Shellfish	1,072.74	2,788,577	830.63	2,395,328	1,544.01	3,951,575	1,916.82	4,611,760	1,373.96	3,308,248
Total	16,001	11,916,711	1,894.88	3,154,487	3,120.93	5,138,128	1,927.22	4,626,447	1,464.66	3,434,345
ICES rectangle 37F1										
Demersal	21.04	21,067	27.55	39,372	48.46	69,389	134.67	276,773	226.75	339,690

Species type	2021		2020		2019		2018		2017	
	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)
Pelagic	1.65	1,815.75	<1	70.5	<1	1,336.60	<1	77.82	<1	37.10
Shellfish	287.42	515,617	205.78	386,456	287.23	595,779	256.30	630,487.30	254.30	534,461.27
Total	310.10	538,500	233.4	425,898	336.26	666,505	391.05	907,338	481.09	874,188
ICES rectangle 37E9										
Demersal	10.36	37,432.3	16.85	29,305	15.99	22,887	66.83	84,174	67.26	103,840
Pelagic	1,082.50	663,905	0.27	534.35	1,225.37	894,551	1.45	2,861.86	1.68	2,465.21
Shellfish	1,657.51	6,340,499	1,037.32	3,954,047	2,090.63	7,405,973	2,301.67	7,984,662	1,989.04	6,911,949
Total	2,750.37	7,041,836	1,054.43	3,983,887	3,331.99	8,323,411	2,369.95	8,071,698	2,057.98	7,018,255
ICES rectangle 38E8										
Demersal	115.71	206,501	131.69	198,682	241.84	297,610	227.57	267,558	332.11	509,070
Pelagic	6.83	6,649.62	4.58	5,912.82	9.27	14,003	14.38	18,984	21.86	23,195
Shellfish	600.78	2,310,008	734.74	2,528,607	1,165.23	4,582,584	859.53	3,877,031	723.98	3,020,741
Total	723.31	2,523,159	871	2,733,201	1,416.34	4,894,197	1,101.47	4,163,573	1,077.95	3,553,005

Species type	2021		2020		2019		2018		2017	
	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)	Liveweight (Mt)	Value (£)
ICES rectangle 38E9										
Demersal	25.16	43,035	30.26	36,014	20.21	23,533	53.28	55,229	88.60	104,171
Pelagic	<1	240.93	<1	229.73	<1	169.31	2.08	2,754.94	3.99	3,823.20
Shellfish	1,128.61	3,203,577	381.78	1,291,059	860.78	2,843,607	808.56	3,017,746	1,091.48	3,194,166
Total	1,153.96	3,246,853	412.18	1,327,302	881.05	2,867,309	863.93	3,075,730	1,184.07	3,302,160
Whole UKCS										
Demersal	139,936	290,289,755	147,641	287,079,709	164,132	346,770,370	176,398	355,154,721	182,261	354,738,644
Pelagic	400,018	319,252,767	354,526	281,721,093	310,952	247,198,518	385,2867	272,720,317	394,851	257,259,889
Shellfish	131,517	332,403,844	121,078	262,031,325	146,802	392,834,212	138,305.2	374,801,843	149,598	375,619,502
Total	671,471	941,946,366	623,246	830,832,127	621,886	986,803,100	699,989	1,002,676,881	726,709	987,618,034

The Teesside Pipeline route, at approximately 145 km long, falls within ICES rectangles 37E9, 38E8 and 38E9. Across these rectangles catch composition varies, though shellfish make up the greatest proportion of catch according to landings weight and value almost every year. However, in rectangle 37E9 in 2019 and 2021 has pelagic catch contributed a noticeable amount (over 20%) to the weight of landings. This was also the case in rectangle 38E8 in 2017. Shellfish remain the most profitable species group however.

The Humber pipeline route travels southwest from the Endurance Store through ICES rectangle 36F0. The contribution of shellfish here is the highest across any other rectangles covering the Development area at 95% every year, both in terms of landings weight and catch value. In 2021, this rectangle produced approximately 4,008 t (tonnes) of landed catch. While this is roughly in keeping with the other Development rectangles (discussed in the Sections above), catch in rectangle 36F0 was valued at just under £12 million, considerably higher than in any other rectangle within the Development area (MMO, 2022). To put this into the wider context, a total of 671,471 t with a value of approximately £942 million was landed in the UK in 2021 (MMO, 2022). Overall, this rectangle alone contributed 0.60% of the UKCS total landings by weight and 1.68% of the annual value (MMO, 2022), making this one of the most productive rectangles in the Development area.

Shellfish waters are designated under the WFD to protect shellfish growth and contribute to a high quality product for human consumption. To the north, the nearest such site is Holy Island – approximately 121 km north of the Teesside Pipeline. Native and Pacific oyster shellfish production areas coincide with these shellfish waters. The nearest designated shellfish waters site to the overall Development is approximately 76 km south of the Humber Pipeline (the West Wash) (Defra, 2023).

A bivalve classification area is located at Horseshoe Point on the south side of the Humber Estuary, approximately 19 km south of the Humber Pipeline landfall. Classification areas indicate the level of sampling required within the area prior to commercial distribution of shellfish harvested from that area. The Horseshoe Point area is designated for common cockle. Another bivalve classification area coincides with the West Wash shellfish waters. The area is designated for mussel species. Additionally, some blue mussel and native oyster shellfish production occurs within the Wash (MMO, 2023). No other aquaculture activity occurs along this coastline.

4.6.1.2 Key commercial species

As described above, shellfish are a very important commercial group which are responsible for much of the commercial fishing value in the ICES rectangles across the Development area. Table 4-8 lists all commercially important shellfish species which are caught across the Development area. The top three species in almost all ICES rectangles are shellfish, particularly brown crabs, lobsters, scallops and Norway lobster. The landed weight and value of these species is shown in Table 4-8, along with the percentage contribution of the weight/value of each of the top four key species in the context of the whole ICES rectangle. Blank cells in the table indicate that the species does not contribute to the catch in that ICES rectangle. The totals in Table 4-8 indicate the importance of shellfish overall across much of the Development area. As detailed in Section 4.4.3, a number of shellfish species were observed across the Development area, including the commercially important brown crab (*C. pagurus)*, lobster (*H. gammarus*) and velvet swimming crab (*N. puber*); these species were typically found in low numbers sporadically along the pipeline routes, with a total of 17 *C. pagurus*, three *H. gammarus* and 11 *N. puber* observed (Gardline, 2022b).

Only rectangle 37F0 (offshore at the Endurance Store) has a fish in its top three most valuable species: the pelagic species herring. This corresponds to the increased contribution of pelagic species to the catch in this rectangle compared to others (Table 4-7, Table 4-8).

Table 4-8 - Value and live weight tonnage for shellfish species landed from ICES rectangles 36F0, 37E9, 37F0, 37F1, 38E8 and 38E9 in 2021 (MMO, 2022)

Shellfish species	36F0		37E9		37F0		37F1		38E8		38E9	
	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)	Landed weight (t) (% of the total shellfish landed weight)	Value (£) (% of the total shellfish value)
Lobsters	523.5 (13.2%)	8,687,267.3 (55.2%)	203.2 (12.4%)	3,335,604.2 (52.6%)	46.3 (4.3%)	830,288.4 (29.8%)	2.6 (<1%)	40,737.2 (7.9%)	64.8 (13.8%)	941,224.3 (40.7%)	60.6 (5.5%)	987,147.7 (30.8%)
Crabs (brown crab)	3036.7 (76.5%)	6,439,163.0 (40.9%)	538.0 (32.8%)	1,185,833.2 (18.7%)	396.8 (37.0%)	863,622.0 (31.0%)	92.9 (32.5%)	232,722.7 (45.1%)	103.2 (22.0%)	216,997.4 (9.4%)	312.8 (28.1%)	776,626.9 (24.2%)
Scallops	244.4 (6.2%)	445,588.0 (2.8%)	876.4 (53.4%)	1,785,730.4 (28.2%)	555.1 (51.7%)	974,546.5 (34.9%)	10.2 (3.6%)	17,852.2 (3.5%)	5.9 (1.3%)	10,951.4 (<1%)	700.8 (63.0%)	1,286,764.8 (40.2%)
Nephrops (Norway lobster)	-	-	3.1 (<1%)	11,377.7 (<1%)	-	-	3.7 (1.3%)	15,284.0 (3.0%)	283.4 (60.4%)	1,101,253.0 (47.7%)	36.5 (3.3%)	150,001.1 (4.7%)
Whelks	147.3 (3.7%)	157,528.7 (1%)	17.8 (1.1%)	17,934.6 (<1%)	<1	957.8	172.6 (60.5%)	206,364.6 (40.0%)	1.1	1,022.8	<1	27.0
Squid	10.9	11,095.1	0.2	836.6	73.1 (6.8%)	117,884.2 (4.2%)	3.4	2,488.5	6.6 (1.4%)	32,819.7 (1.4%)	<1	2,264.7
Crabs (velvet swimming)	5.6	9,918.7	1.5	2,510.8	<1	845.6	<1	134.8	2.5	4,213.4	<1	4.5
Octopus	-	-	-	-	-	-	-	-	<1	1,721.9	<1	24.1
Mixed squid and octopi	-	-	<1	258.1	<1	326.2	-	-	<1	16.4	<1	38.5
Shortfin squids	-	-	-	-	-	-	<1	32.9	<1	16.4	<1	312.4
Spider crabs	-	-	-	-	-	-	-	-	<1	44.0	<1	316.9
Cuttlefish	-	-	-	-	<1	105.4	-	-	-	-	-	-
European flying squid	-	-	-	-	-	-	-	-	<1	38.3	<1	4.1
Common octopus	-	-	-	-	<1	<1	-	-	<1	2.6	<1	39.1

Shellfish species	36F0		37E9		37F0		37F1		38E8		38E9	
	Landed weight (t) (% of the total shellfish landed weight)	**Value (£) (% of the total shellfish value)**	**Landed weight (t) (% of the total shellfish landed weight)**	**Value (£) (% of the total shellfish value)**	**Landed weight (t) (% of the total shellfish landed weight)**	**Value (£) (% of the total shellfish value)**	**Landed weight (t) (% of the total shellfish landed weight)**	**Value (£) (% of the total shellfish value)**	**Landed weight (t) (% of the total shellfish landed weight)**	**Value (£) (% of the total shellfish value)**	**Landed weight (t) (% of the total shellfish landed weight)**	**Value (£) (% of the total shellfish value)**
Common prawns	-	-	-	-	-	-	-	-	-	-	<1	5.0
Mixed crabs	-	-	-	-	-	-	-	-	-	-	-	-
Queen scallops	-	-	-	-	-	-	-	-	-	-	-	-
Brown shrimps	-	-	-	-	-	-	-	-	-	-	-	-
Crawfish	-	-	-	-	-	-	-	-	-	-	-	-
Total (% of overall catch)[142]	3,968.4 (99.0%)	15,750,560.8 (99.8%)	1,640.5 (59.6%)	6,340,498.6 (90.0%)	1,072.7 (6.7%)	2,788,577.0 (23.4%)	285.6 (92.1%)	515,616.9 (95.8%)	469.0 (64.8%)	2,310,008.1 (91.6%)	1,111.6 (96.3%)	3,203,576.7 (98.7%)

[142] *See Table 4-7 for a breakdown of the overall catch per ICES rectangle.*

4.6.1.3 Fishing effort

Fishing activity in the Development area occurs throughout the year as detailed in Table 4-9.

Effort is lowest in rectangle 37F1 which is within the Endurance Store area. For many months effort is recorded as disclosive in this rectangle meaning fewer than five vessels (>10 m) spent time fishing that month and thus detailed records are not published for reasons of commercial confidentiality.

In comparison, effort is highest in rectangle 36F0 close to shore through which the Humber Pipeline route passes. Typically, effort is consistently high, with highest fishing effort often exceeding 300 days in the summer. In 2017 there was a peak in effort considerably larger than in any other year, reaching 423 days in August (Table 4-9; Scottish Government, 2022). However, in 2019 overall effort was the lowest compared to preceding years, although, at 2,344 days of effort, it was still significantly higher than across all other Development ICES rectangles. Effort has since increased considerably in 2020 and 2021 during July to October, reaching 3,211 days of effort in 2021, twofold higher than any other ICES rectangles (Scottish Government, 2022).

The most common gear types in the Development area close to shore are pots and traps, and gears using hooks. Further offshore, demersal trawls/seines, beam trawls, and dredges dominate. There was two instances of drift and fixed nets being used in rectangle 38E8 in 2017 and 2019 (Scottish Government, 2022).

Average distribution of landings value and effort between 2013 and 2017 (MMO, 2019) is shown for passive and mobile gear types in Figure 4-33 and Figure 4-34. The figures show that fishing effort in the vicinity of the Development using passive gear is moderate for limited extents of the offshore region of the Teesside Pipeline route and along much of the mid and shoreward sections of Humber Pipeline route.

For mobile gear, effort and landings in the vicinity of the route are low to moderate along both pipeline routes, with the majority of activity in the Development area focused in an area which follows the coast where levels of effort and value are moderate-high. Overall, moderate levels of passive landings and effort are associated with the Humber Pipeline route and mobile landings and effort and more extensive along the Teesside Pipeline route. Effort is comparatively low further offshore at the Endurance Store area.

Table 4-9 - Days fished (all gears) in ICES rectangles 36F0, 37E9, 37F0, 37F1, 38E8 and 38E9 between 2017-2021 (Scottish Government, 2022)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
ICES rectangle 36F0													
2017	167	141	211	230	260	274	306	423	252	258	241	159	2,922
2018	136	116	207	248	238	210	285	380	283	246	162	137	2,645
2019	142	149	124	173	227	165	277	291	269	243	152	131	2,344
2020	135	91	129	76	221	218	306	309	352	287	242	186	2,552
2021	292	126	209	235	281	230	345	354	343	319	263	215	3,211
ICES rectangle 37E9													
2017	62	80	252	239	83	64	86	105	74	44	66	99	1,255
2018	80	156	298	281	114	197	100	248	96	166	69	169	1,973
2019	168	149	190	187	140	87	90	239	110	96	112	79	1,648
2020	66	64	138	27	42	50	104	83	93	70	82	62	882
2021	58	172	200	105	135	80	70	58	67	46	56	53	1,099
ICES rectangle 37F0													
2017	49	42	150	162	66	78	61	76	64	75	72	95	989
2018	52	59	95	106	160	64	91	150	129	122	92	98	1,218
2019	78	85	120	115	156	98	88	88	220	88	73	54	1,264
2020	23	19	67	23	63	37	62	61	136	95	58	47	692
2021	28	58	144	88	100	41	45	40	104	88	55	39	829
ICES rectangle 37F1													
2017	D	D	7	D	10	56	41	36	17	D	D	D	189
2018	D	D	D	D	D	14	16	39	20	14	D	D	135
2019	-	D	D	D	25	D	17	18	18	0	D	D	145
2020	D	D	D	D	13	11	D	D	D	17	D	D	41
2021	D	D	D	20	27	16	D	10	D	D	D	D	72
ICES rectangle 38E8													
2017	114	64	173	98	54	41	167	140	61	120	151	78	1,260
2018	125	91	74	79	38	57	84	143	80	90	126	123	1,108
2019	130	144	126	98	83	59	123	133	133	192	167	157	1,546
2020	154	98	119	22	37	61	129	79	125	143	137	86	1,190
2021	93	71	132	84	52	59	70	81	94	116	176	155	1,181
ICES rectangle 38E9													
2017	77	84	226	152	123	169	138	121	84	57	49	35	1,314
2018	87	70	73	79	124	94	129	105	80	79	73	96	1,090
2019	118	130	132	143	136	111	77	78	65	80	58	66	1,195
2020	56	69	86	D	51	56	62	49	57	65	66	44	660
2021	55	111	194	146	102	72	77	65	79	77	87	93	1,158

Key: green: 0–100 days; yellow: 101–200 days; orange: 201–300 days; red: ≥301 days; D: Disclosive data[143]; - no data.

[143] *Disclosive data are provided for rectangles in which the records are from fewer than five vessels (>10 m); detailed records are not published for reasons of commercial confidentiality.*

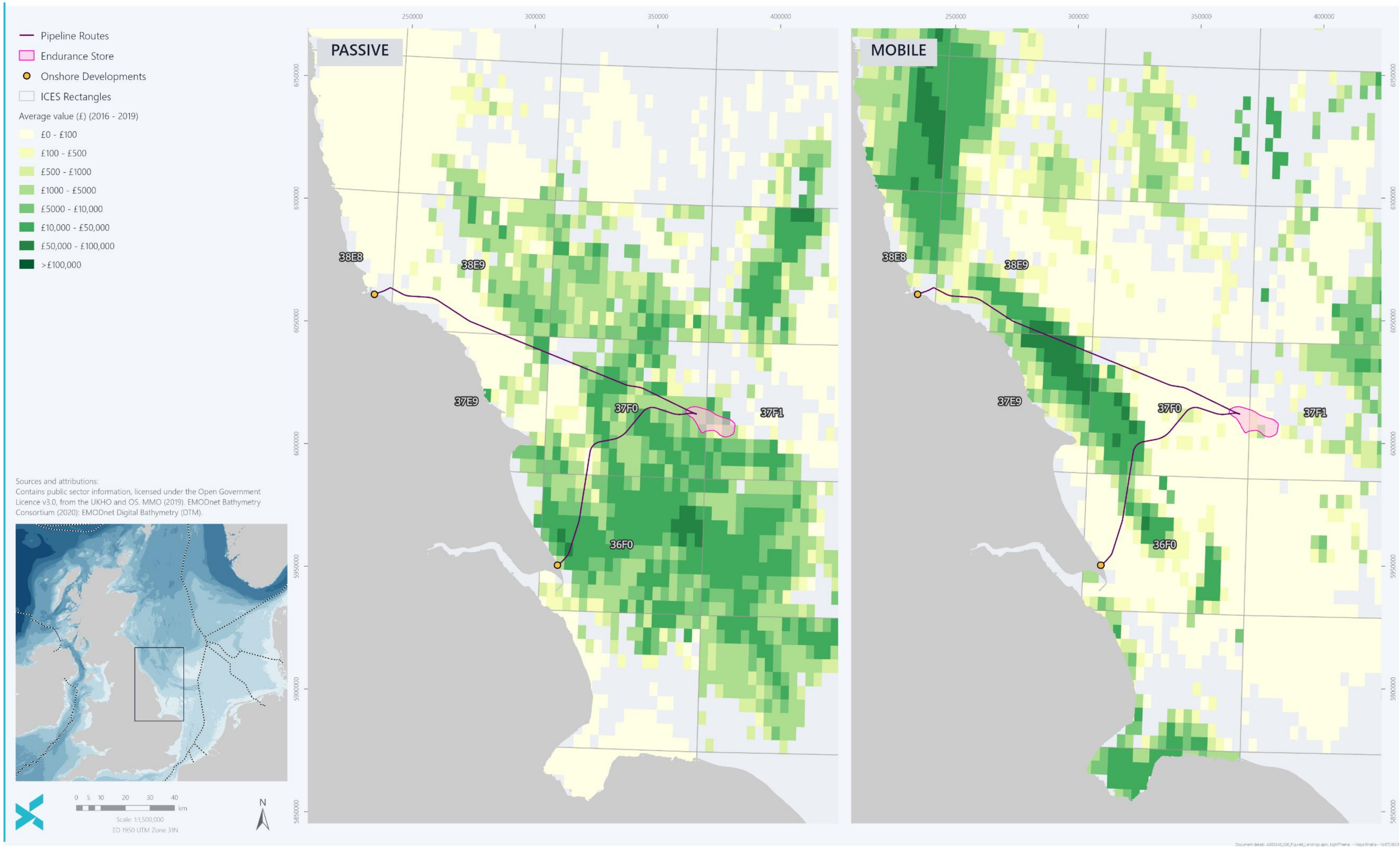


Figure 4-33 - Average value of catch in the Development area according to gear type 2016-2019

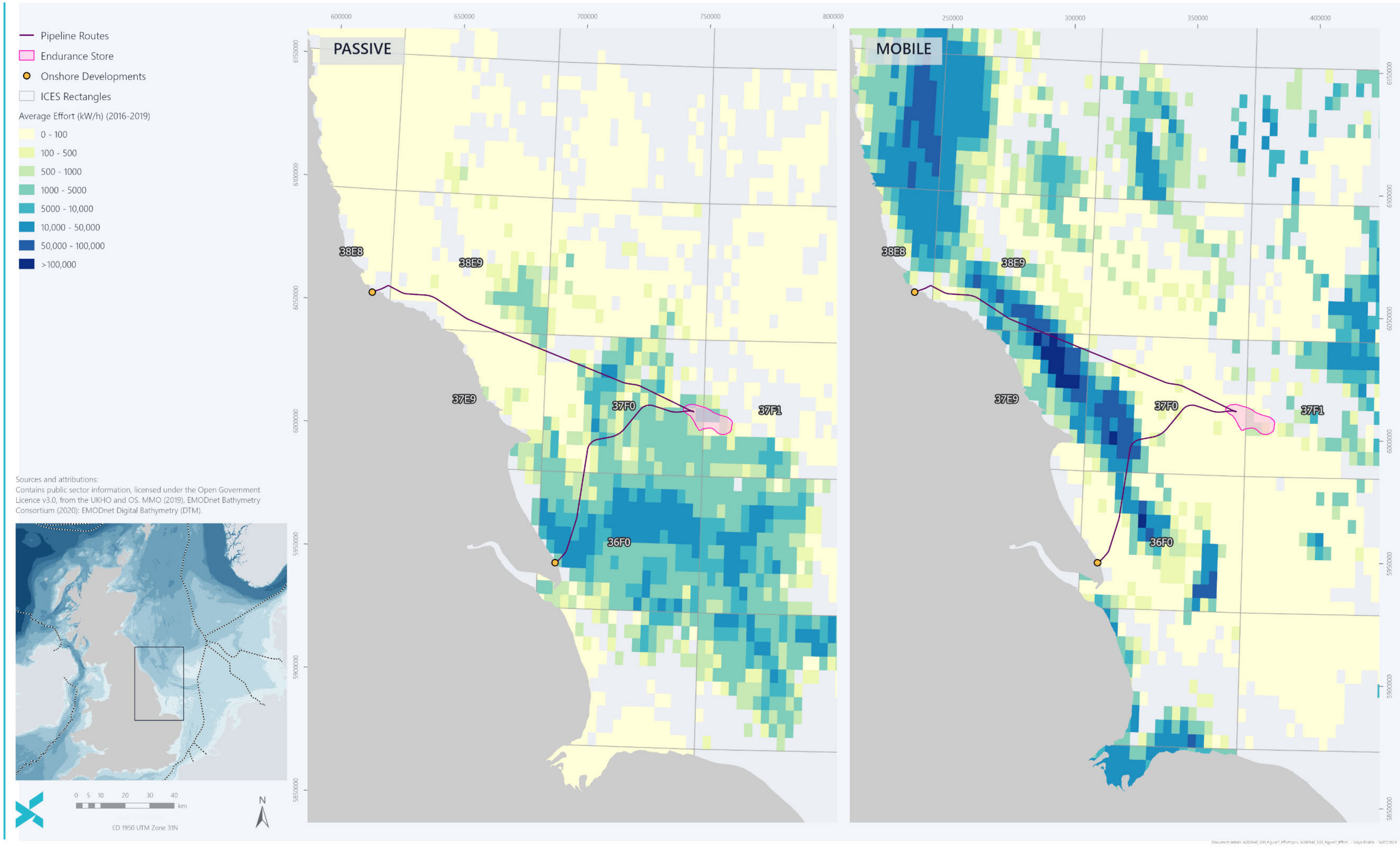


Figure 4-34 - Average fishing effort in the Development area according to gear type 2016-2019

4.6.2 Offshore Infrastructure

4.6.2.1 Oil and Gas Activity

The Development is located in an area of oil and gas exploration and production. Accordingly, there are numerous wells, pipelines and platforms in the region. The closest platform is the Garrow NUI, 2 km north northeast of the Endurance Store and owned and operated by Perenco. There are an additional 16 other platforms located within 40 km of the Endurance Store. Oil and gas surface installations within a 40 km radius of the Development are detailed in Table 4-10.

Table 4-10 - Offshore oil and gas surface installations within 40 km of the Development

Name	Operator	Distance and direction from closest point of Development
Garrow	Perenco	2 km NNE (Endurance)
HGS Tolmount	Harbour Energy	10 km ESE (Humber)
York	Spirit Energy	12 km ESE (Humber)
Ravenspurn North ST3	Perenco	12 km SSW (Endurance)
Ravenspurn North ST2	Perenco	13 km SSW (Endurance)
Ravenspurn South B	Perenco	13 km SSW (Endurance)
Rough BD	Centrica	13 km ESE (Humber)
Rough BP	Centrica	13 km ESE (Humber)
Rough CD	Centrica	13 km ESE (Humber)
Ravenspurn South C	Perenco	14 km SSW (Endurance)
Kilmar	Perenco	14 km NNE (Endurance)
Ravenspurn North CCW	Perenco	14 km SSE (Endurance)
Ravenspurn North CC	Perenco	14 km SSW (Endurance)
Rough AD	Centrica	15 km ESE (Humber)
Rough AP	Centrica	15 km ESE (Humber)
Ravenspurn South A	Perenco	16 km SSW (Endurance)
Breagh Alpha	INEOS SNS UK	17 km NNE (Teesside)
Cleeton CC	Perenco	20 km ESE (Humber)

Name	Operator	Distance and direction from closest point of Development
Cleeton WLTR	Perenco	20 km ESE (Humber)
Cleeton PQ	Perenco	20 km ESE (Humber)
Babbage	Spirit Energy	22 km SSE (Endurance)
Minerva	Perenco	22 km ESE (Humber)
Neptune	Perenco	24 km SSW (Endurance)
Amethyst C1D	Perenco	29 km ESE (Humber)
Trent	Perenco	33 km ENE (Endurance)
Amethyst A1D	Perenco	38 km ESE (Humber)
Hyde	Perenco	39 km SSW (Endurance)
Hoton	Perenco	40 km SSE (Endurance)

Construction and decommissioning of nearby oil and gas installations could potentially increase interactions with the Development due to increased vessel presence and activities in the surrounding waters. The Cavendish surface installation and associated pipelines (approximately 48 km from the Endurance Store) have been approved for decommissioning which is expected to be ongoing from Q2 2019 until Q4 2023 (INEOS UK SNS Ltd, 2020).

The Tolmount field has recently commenced production as of April 2022. Therefore, it is assumed that activities associated with the project will not coincide with the Development timeline. The associated Tolmount-Easington Pipeline lies within one kilometre of the Humber Pipeline landfall.

As shown in Figure 4-32, a number of existing pipelines are located within the vicinity of the Development. Pipelines within 1 km of the Humber and Teesside Pipeline routes are presented in Table 4-11.

Table 4-11 - Pipelines within 1 km of the Humber and Teesside Pipeline routes

Pipeline	Description	Operator	Nearest point to the Development
Humber Pipeline route			
Langeled Pipeline	44" gas pipeline (PL2071)	GASSCO	Crossing
Tolmount Pipeline	20" gas pipeline	Harbour Energy	<1 km SSE
Cleeton CP to Dimlington	36" gas pipeline (PL447)	PERENCO	<1 km ESE
Rough 47/3B Import/Export	36" gas pipeline (PL150)	Centrica Storage	<1 km SSE
Easington to Rough 47/3B	16" gas pipeline (not in use; PL26)	Centrica Storage	<1 km SSE
York Production Pipeline	16" gas pipeline (PL2917)	Spirit Energy	<1 km ESE
York Methanol Pipeline	3" methanol pipeline (PL2918)	Spirit Energy	<1 km ESE
Teesside Pipeline route			
Everest to Teesside CATS	36" gas pipeline (PL774)	CATS	Crossing
Breagh Pipeline	20" gas pipeline (PL2768.2)	INEOS UK SNS	Crossing
Breagh Pipeline	3" MEG pipeline (PL2769.2)	INEOS UK SNS	Crossing

4.6.2.2 Cables

The Teesside Pipeline route will cross two wind cable lease areas. Both cable lease areas are currently in planning and will extend from shore to the proposed OWFs on the Dogger Bank: Dogger Bank A (DBA) (previously known as Creyke Beck A), Dogger Bank B (DBB) (previously known as Creyke Beck B), Dogger Bank C (DBC) (previously known as Teesside A) and Sofia OWF (previously known as Teesside B). Close to landfall of the Teesside Pipeline, the route will pass within 1 km of the Teesside OWF export cable which is currently in operation. No other renewables cable lease areas come within 50 km of the Teesside Pipeline route.

The Teesside Pipeline route will cross the fibre optic cable associated with the Breagh field. The pipeline route will also cross a number of telecom cables:

- UK-Denmark 4 (operated by British Telecom (BT)) disused cable;
- Pangea North (operated by ASN) active cable; and
- TATA North Europe (operated by TATA Communications) active cable.

The UK-Germany (BT) disused cable is located within a kilometre of the Teesside Pipeline route. The proposed Scotland England Green Link 2 (SEGL2) is an HVDC link between Peterhead in Aberdeenshire and Drax in North Yorkshire that is currently in pre-planning phases. Once installed it will cross the Teesside Pipeline route approximately halfway along its length.

Being located close to the Humber Gateway, the Humber Pipeline route will come within 2 km of the associated Humber Gateway Offshore Transmission Owner (OFTO) cable. It will also pass within 5 km from the DBA and DBB cable lease areas. The Humber Pipeline route will pass 6 km from the Westermost Rough OFTO export cable. At present, the Hornsea Project Four proposed export cable corridor reaches landfall south of Bridlington along the Holderness coast. Once installed, the export cable will cross the Humber Pipeline route approximately halfway along its length.

A further three cables, all under construction, are located within 10 km of the Humber Pipeline route, associated with the Hornsea Development Two, Hornsea One and Triton Knoll OWFs.

The chosen export cable route for the Dogger Bank South OWFs (awarded as part of the Leasing Round 4 in England) will cross the Teesside Pipeline and Teesside – Store Cable. Construction is predicted to commence no sooner than 2026 (RWE, 2021a).

The Humber Pipeline route does not come within 20 km of any telecom cables.

4.6.2.3 Renewables

There are a number of OWF licensed areas and OWF projects under development in the vicinity of the Development (Figure 4-32).

The Endurance Store area overlaps with TCE Lease area currently under agreement for the Hornsea Project Four OWF. The OWF application was consented under the DCO process on 12th July 2023 and will be 69 km from the Yorkshire coast, at the closest point, once complete. The OWF could cover up to 492 km^2 and contain up to 180 wind turbines (Ørsted, 2021a). On 17th June 2023, a commercial agreement[144] was reached with Ørsted (the developer of Hornsea Project Four) to avoid construction of Hornsea Project Four infrastructure within the area of overlap with the Endurance Store.

Hornsea Project Four will be adjacent to Hornsea Two which is currently under construction. The Phase 2 (Soundmark) section of Hornsea Two is located closest to the Endurance Store at 25 km east-southeast. Hornsea Two is currently under construction with the intention of becoming fully operational in 2022 (Ørsted, 2021b). The Hornsea One OWF is located 41 km east-southeast of the Endurance Store and became fully operational in 2021. Covering approximately 407 km^2, it is the largest OWF in the world (Ørsted, 2021c). Hornsea One, Hornsea Two and Hornsea Project Four are all operated by Ørsted. No other renewables lease areas, operational or under agreement, are located within 50 km of the Endurance Store.

The Teesside OWF is located within 1 km of the Teesside Pipeline route at the closest point. The OWF is located near Redcar in North Yorkshire. It is located close to the coast, just 1.5 km offshore. The OWF contains 27 turbines and has been operational since 2014. It has a capacity of 62 MW, powering up to 54,000 homes. The OWF is operated by EDF Renewables (EDF Renewables, 2021).

[144] *https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010098/EN010098-002322-EN010098%20-%20Orsted%20-%20SoS%20Consultation%20Response%20-%20HOW04%20DCO%20Objection%20Withdrawal_17-06-23.pdf*

The Westermost Rough OWF is situated 8 km off the Yorkshire Coast, north of Hull and contains 35 turbines of 6 MW capacity, covering a total area of 35 km^2 and providing enough electricity to power around 150,000 UK homes (Ørsted, 2019). The OWF is located less than a kilometre from the Humber Pipeline route at the closest point.

The Humber Gateway OWF is located approximately 8 km from the East Yorkshire coast and 7 km from the Humber Pipeline route. The OWF became fully operational in 2015. The farm is operated by E.ON Energy and consists of 73 turbines producing 219 MW of energy which is enough to power 170,000 homes (E.ON Energy, 2021).

The Triton Knoll OWF is currently under construction and is approximately 41 km from the Humber Pipeline route. As of January 2022, turbine commissioning has been completed. Once complete, the OWF will have a capacity of 857 MW. The project is jointly owned but construction and operation will be done by RWE (RWE, 2021b).

No other renewables lease areas are located within 50 km of either pipeline route.

4.6.3 Military Activity

A number of military Practice and Exercise Areas (PEXAs) overlap with the Development along the two pipeline routes. The Endurance Store is located within PEXA D323C. The PEXAs which overlap with the Development are all designated as Areas of Intense Aerial Activity (AIAA) (Xodus Group, 2023a). The closest onshore training site is located approximately 26 km south of the Humber Pipeline landfall on the coast at Donna Nook (DTE, 2021).

In addition, special consultation conditions are flagged by the MoD in relation to some of the UKCS Blocks in the vicinity of the Development (Blocks 47/2, 47/7, 42/27, 42/17 and 42/18; OGA, 2019). Activity in these blocks or sub-blocks are of concern to the MoD because they lie within training ranges. The following special condition is attached to any Licence covering, wholly or in part, any such block or sub-block: “The MoD must be notified, at least twelve months in advance, of the proposed siting of any installation anywhere within Block(s), whether fixed to the seabed, resting on the seabed or floating, that is intended for drilling for or getting hydrocarbons, or for fluid injection.”

4.6.4 Shipping Activity

The average weekly density of vessels in 2015 in the Development area ranged from 5.1 to 250 transits per 4 km^2. Vessel presence is lowest offshore at the Endurance Store and increases along the export pipeline routes, particularly the Humber Pipeline route; the Humber Estuary is a busy shipping area. Shipping levels within the Development area are high in all Blocks (42/28, 47/7, 42/23, 42/27, 42/17 and 42/18) with the exception of Block 47/2, in which shipping activity is considered very high (OGA, 2016).

The Humber Estuary is a busy shipping area and this area of coastline, from Teesside to Humber is extremely busy with most traffic attributed to cargo vessels and tankers (Figure 4-35); 39.8% of tracks were attributed to cargo/tanker vessels (Xodus Group, 2023a). A distinct increase in local vessel transit density can be attributed to the Westermost Rough OWF close to the coast. Automatic Identification System (AIS) vessel movement tracks associated with various service craft are also concentrated at certain points throughout the SNS, likely corresponding to other offshore assets, including renewables sites and oil and gas infrastructure, as can be seen in Figure 4-35. Number of AIS tracks were higher in the summer months, compared to winter. Fishing vessel movement is also pronounced along the coastline, especially south of Flamborough. Passenger vessel routes are evident coming out of the Humber Estuary and travelling south. No passenger vessel routes depart from Teesside, however an apparent route does extend south from Newcastle upon Tyne, which comes close to the Teesside Pipeline route and the Endurance Store area (Xodus Group, 2023a).

The Development does not directly overlap with any International Maritime Organisation (IMO) routing measures. South of the Humber Pipeline route, Traffic Separation Schemes are present outside the entrance to the River Humber. Approaches to this routing area are approximately 14 km southeast of the Humber Pipeline route (Xodus Group, 2023a).

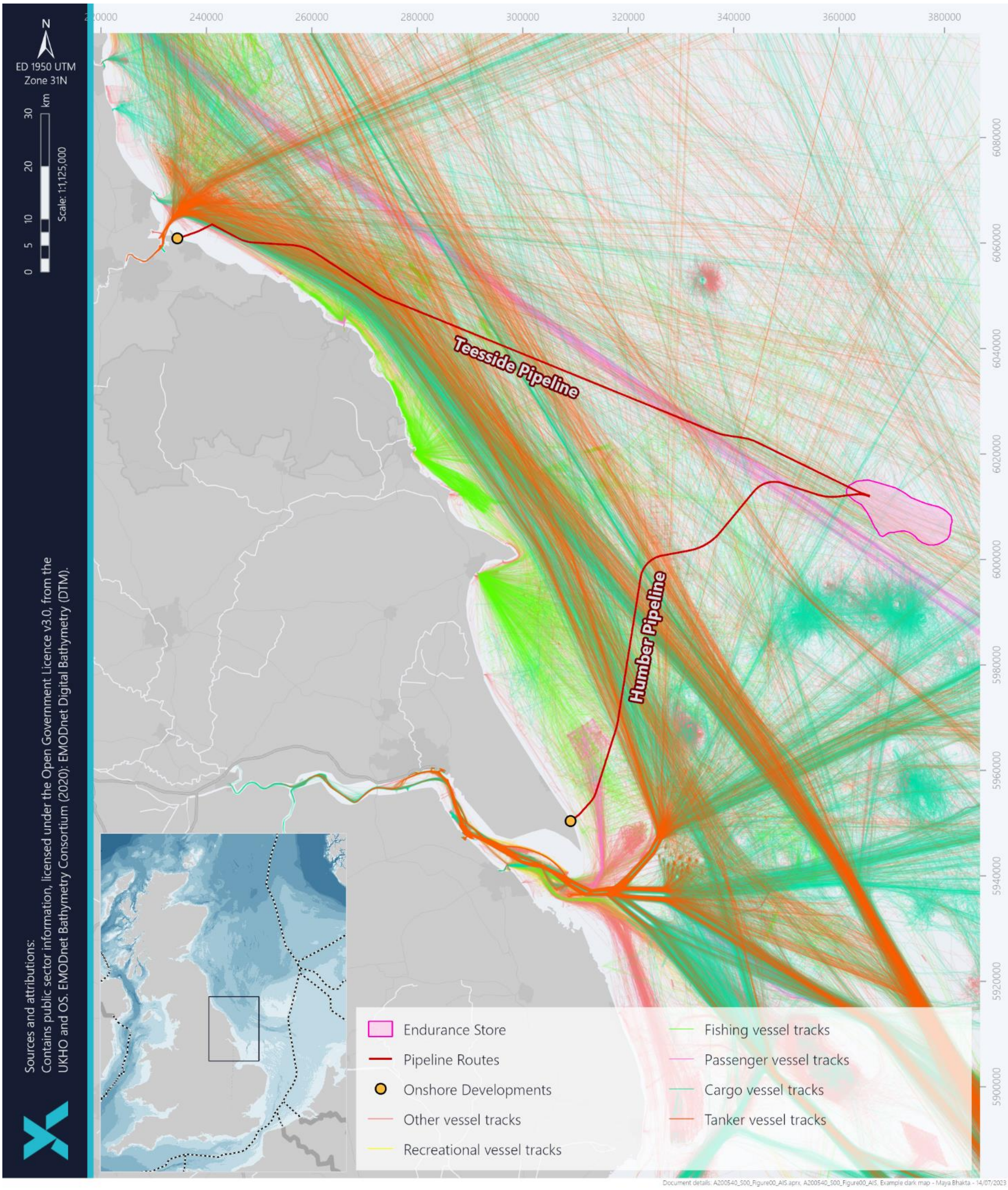


Figure 4-35 - AIS tracks in the Development area

4.6.5 Archaeology

There are 15 records of non-dangerous wrecks within 10 km of the Endurance Store (UKHO, 2020). The closest of these are two un-named wrecks, one (ID 6830) located within the Store area, and another (ID 6832) located 0.6 km north-northeast. Similarly, there are 77 records located within 5 km of the Teesside Pipeline route, of which 59 are classed as non-dangerous wrecks, 13 are classed as dangerous wrecks, one distributed remains of a wreck, and four classed as a wreck showing any portion of hull or superstructure. There are 52 records of wrecks within 5 km of the Humber Pipeline route, of which 30 are non-dangerous, 21 are classed as dangerous and one wreck is listed as a wreck showing any portion of hull or superstructure.

Archaeological interpretation of the geophysical survey data obtained along within the Development area identified two wrecks within the Store area, 11 wrecks along the Teesside Pipeline route, and seven along the Humber Pipeline route, only a handful of which have been previously recorded. A number of smaller anomalies were also recorded which included debris and obstructions (Appendix I). As noted in Section 4.4.2.3, an area of MDAC-like habitat was found at one station along the Humber Pipeline route, which is associated with anthropogenic debris, potentially indicative of a small wreck. Detailed archaeological interpretation of this suggests that it is associated with a wreck (Appendix I).

There are no records of protected wrecks in the vicinity of the Humber Pipeline, or the Teesside Pipeline routes (Historic England, 2021).

The waters in this region contain multiple areas of potential UXO sources. A large offshore Second World War (WWII) British Mine Area extends along much of the UK east coast and both pipeline routes intersect multiple historic UXO source areas including British WWII Military Armament Areas, Frist World War (WWI) German Mine Areas and WWI British Mine Areas (Ordtek, 2021). Despite the prevalence of potential UXO source areas, there is only a low (1-5) density of reported munitions encountered in the Development area, largely limited to the coastal waters of both pipeline routes (OSPAR, 2009).

4.6.6 Aggregate and Mineral Extraction

Each year, 15 to 20 Mt of marine sand and gravel is extracted from the seabed within English and Welsh waters (The Crown Estate, 2018). There are no licenced aggregate extraction sites within the development area, however four are located within 20 km of the Humber Pipeline route as it approaches shore. The Humber region contains, at present, ten licenced production agreement marine aggregation extraction sites. The licences are for the removal of both sand and gravel, principally for use in the construction industry. TCE reports that the Humber region provides an average of 1.96 Mt of aggregate per year, over a ten year period. In 2017, 1.88 Mt of aggregate were produced, the majority of which was shipped for use in the Netherlands. (The Crown Estate, 2018). There are no aggregate extraction areas within 50 km of the Endurance Store or Teesside Pipeline route.

The Teesside Pipeline route, once it comes within approximately 10 km of the coast, will pass through areas of seabed leased for the Boulby and Hundale potash mines. These are amongst the only potash mines in the UK. As such, there are no other areas licensed for mineral extraction close to the Development area.

4.6.7 Dredging and Disposal Sites

Offshore, the closest disposal sites to the Store are those associated with Hornsea One and Hornsea Two. These disposal sites are located within the footprint of the two OWFs and are located approximately 31 km and 44 km respectively from the Store.

There are a number of dredging and disposal sites in the vicinity of the Teesside and Humber Pipeline routes. The Teesside Pipeline passes through a disused disposal area (at approximately KPS2) for 2.3 km. The disposal site was associated with the installation of the CATS pipeline (when it was under operation of Amoco) which runs parallel to the Teesside Pipeline prior to landfall. The Tees Bay A and Tees Bay C disposal sites are located further offshore, approximately 2 km and 3 km from the Teesside Pipeline respectively. These sites are both currently operational. The Tees Bay A site is used for the disposal of maintenance dredging from the River Tees (which is periodically dredged to maintain the channel). Consequently, the dredged material ranges from riverine silt to fine sands. Approximately 1,000,000 m^3 of material is dredged per year (PD Teesport, 2019). The Tees Bay C site is used for disposal of capital dredged material. Use of this site is more infrequent and typically constitutes smaller scale use; some years show no usage at all (PD Teesport, 2019).

The closest disposal site to the Humber Pipeline is located approximately 6 km north of the pipeline landfall. This area was dredged as part of a replacement of an outfall from the Withernsea Wastewater Treatment Works. Works concluded in 2020.

A number of additional smaller disposal sites are located within the Humber so are separated from the Development activities by the presence of Spurn Head.

4.6.8 Recreation and Tourism

A number of recreation and tourist sites and activities occur in the vicinity of the coastal area of the Development. Withernsea beach is located approximately 9 km north from the Humber Pipeline landfall. The bathing waters at Withernsea are also reported as good standard in the 2019 Bathing Waters Compliance Report (Defra, 2019a).

Located in close proximity to the Teesside Pipeline landfall are the Redcar Coatham, Redcar Lifeboat and Redcar Granville designated bathing waters. Redcar Coatham and Redcar Lifeboat are considered to be of an excellent standard, and Redcar Granville is considered to be of a good standard (Defra, 2019a).

A number of marinas and slipways are located within the Humber Estuary and the Humber Pipeline route passes through an area described by Royal Yachting Association (RYA) as a general boating area. The Teesside Pipeline route will also terminate just south of a general boating area which covers much of Teesside. Various places along the Holderness coast are used for surfing, but the nearest noted site is at Withernsea (Magic Seaweed, 2021), to the north of the proposed Humber Pipeline landfall. There are no known designated recreational waters within the Development area. However, there is a British Sub-Aqua Club (BSAC) registered scuba diving group based at South Gare in Teesside, which dive regularly in the local area, and there a number of small BSAC groups based on the south bank of the Humber, near Grimsby.

4.6.9 Coastal Land Use

Despite terrestrial implications associated with the Development being out of scope of this ES, some information on the local coastal land use at the landfall points has been provided here for context.

Land use along the Holderness Natural Character Area (NCA), where the Humber Pipeline route will terminate, is mainly for agricultural purposes with more than 90% of the coast undeveloped and over 71,000 ha used for agriculture purposes (Natural England, 2013a). Of this, arable land for cereal production accounts for over half of this agricultural land (38,997 ha). Only 11% of the farm holdings along the Holderness coast manage livestock (Natural England, 2013a).

Land use within the Tees Lowlands NCA, at the Teesside Pipeline landfall, is also predominantly for arable agriculture. In 2009, there were 63,056 ha within the NCA of which 44% is for cereal production (Natural England, 2013b). 11% of the NCA is urban and much of this industrialised conurbation is centred around Middlesbrough which lies at the estuary of the River Tees (Natural England, 2013b), close to the landfall of the Teesside Pipeline route.

4.7 Future Marine Environment

This section summarises the current evidence and future predictions for marine climate change.

Two key sources of climate projections include the Marine Climate Change Impacts Partnership (MCCIP) and UK Climate Projections 2018 (UKCP18). The MCCIP publishes evidence reviews and summaries on marine climate change, focussed on the UK, including regions such as the North Sea, the Celtic Sea, the Irish Sea, the English Channel and the North Atlantic (MCCIP, 2022). The UKCP18 is a climate analysis tool that forms part of the Met Office Hadley Centre Climate Programme.

The key uncertainties associated with predicting the impact of climate change on the physical, biological and socio-economic environment include:

- Uncertainty in the modelled predictions resulting from the uncertainty around the future emissions scenarios as well as an uncertainties in other model inputs (e.g. current conditions, parameters etc.);
- Uncertainty around the response of the physical, biological and socio-economic environment to changes in climate variables; and
- Difficulties in attributing changes in the physical, biological and socio-economic environment to climate change.

4.7.1 Physical Environment

4.7.1.1 Storms and Waves

Analysis of observed and modelled wind and wave data can be used to identify long-term trends in weather patterns. The frequency and intensity of storms within the north of the Atlantic Ocean is increasing, with a much weaker trend observed in the UKCS. However, there is a low confidence in attributing these changes in weather patterns to climate change and the high degree of variability in the data also creates difficulties in identifying trends over time (Wolf *et al.*, 2020).

Future predictions for storms and waves are uncertain, and it is expected that natural variability will continue to account for trends observed in the frequency and intensity of waves and storms. In addition, the low confidence in attributing past trends in weather patterns to climate change also presents difficulties in adequately predicting future long-term trends. Nevertheless, it is possible that climate change may influence storm tracks with knock-on effects on winds and wave heights. Climate projections, under the Representative Concentration Pathway (RCP) 8.5 (high emissions scenario), indicate that there may be a reduced frequency in storms and a change in storm tracks. It is also predicted that there will be an overall reduction in mean significant wave height, combined with an increase in the mean annual maximum wave height by 0.5 m (i.e. larger waves less frequently) and that wave heights to the north of the UK will increase as a result of a retreating Arctic sea ice (Wolf *et al.*, 2020).

4.7.1.2 Sea Surface and Near-bottom Temperature

Tinker and Howes (2020) analysed the warming of SSTs over ~30 years (1988 – 2017). The analysis indicates that observed increases in SSTs were strongest in the waters to the North of Scotland (north of Caithness and Sutherland) and in the North Sea, where temperatures have increased by up to 0.24°C per decade (Tinker and Howes, 2020).

It is predicted that increases in SST by 2100 in the North Sea may range from 1-4°C (depending on the area and the climate model used; Tinker and Howes, 2020). Tinker *et al.* (2016) simulated changes in temperature between the 1960 – 1989 and 2069 – 2098 periods under a medium emissions scenario (Special Report on Emissions Scenario (SRES) A1B[145]). The predicted increase in SST for the SNS 3.26°C (±0.72°C), and the near-bottom temperature increase is 3.22°C (±0.71°C) (Tinker and Howes, 2020).

There is high confidence in the global rise in SST as SSTs are one of the most measured parameters, and there is high confidence in the long-term future warming trend. However, confidence in the exact rates of warming at regional scales is lower. As such, the confidence in these predictions is medium (Tinker and Howes, 2020).

4.7.1.3 Stratification, Dissolved Oxygen and Salinity

There is some evidence that the timing of thermal stratification has changed over time, with a trend for stratification beginning earlier in the year across the North Sea. At present, there is no indication that this trend will be sustained or that this trend is beyond what would be expected from natural variability (Sharples *et al.*, 2020). However, from modelled climate projections based on the SRES A1B emissions scenario, it is predicted that stratification across the UKCS will occur one week earlier by the end of 2100 and that the breakdown of seasonal stratification will occur 5-10 days later than present, mainly attributed to increases in air temperature. Additionally, when the RCP 8.5 emissions scenario is considered, it is predicted that the UKCS will become more strongly stratified, as a result of changes in seasonal heating cycles, and this could reduce upward mixing of nutrients and therefore lead to reduced primary production (Sharples *et al.*, 2020).

Within the North Sea, declines in DO levels have been documented in late summer, although no hypoxic conditions have been observed. Ocean warming is expected to account for one third of the decrease in DO levels (due to reduced solubility of oxygen), with the remaining declines being attributed to increased biological oxygen consumption. DO concentrations are expected to continue to decline through to the end of the century in the North Sea, by up to 11.5% (Mahaffey *et al.*, 2020).

Salinity has also shown a general decrease in the west of the UKCS in the last five years, although this trend is weaker in other regions of the UKCS, such as the North Sea, where there is no clear long-term trend (Dye *et al.*, 2020). When the SRES A1B emissions scenario is considered, it is predicted that

[145] *Details on the SRES A1B scenario are available here: https://www.ipcc.ch/site/assets/uploads/2018/03/emissions_scenarios-1.pdf. These have now been superseded by RCP emissions scenarios. SRES A1B is an 'on balance' emissions scenario in a world of rapid economic and population growth, where no one energy source is relied on too heavily.*

waters will be less saline in the North Sea by 2100 due to ocean circulation changes driven by climate change (*et al.*, 2020).

The confidence in these predictions is medium for DO and salinity and low for stratification (Sharples *et al.*, 2020; Mahaffey *et al.*, 2020; Dye *et al.*, 2020).

4.7.1.4 Ocean Acidification

Ocean acidification occurs as increases in anthropogenic CO_2 absorbed by the ocean causes a decline in pH. One quarter of atmospheric CO_2 is absorbed by the ocean. When CO_2 is absorbed by the ocean, hydrogen ions are released (which therefore reduces pH) and are available to bond to carbonate ions, which consequently reduces the concentration of carbonate ions available for calcifying organisms. This also reduces the potential for the ocean to absorb and store atmospheric CO_2 in the future.

Atmospheric CO_2 now exceeds 400 ppm (increase of 2.3 ppm per year between 2010-2020). Evidence of ocean acidification has been documented in the Atlantic Ocean which has sustained a decrease in pH at a rate of 0.0013 (± 0.0009) per year between 1995 and 2013. Under RCP 8.5, pH in the UKCS could decrease at a rate of 0.0036 per year (pH in 2100 of 0.366) (Humphreys *et al.*, 2020).

There is very high confidence in the first order expectation that global mean seawater pH and saturation states of carbonate minerals will decrease in response to increasing atmospheric CO_2. However, specific details of regionally resolved decadal trends and changes in interannual and seasonal variability are highly complex and less certain. The confidence in the predictions is therefore low to medium (Humphreys *et al.*, 2020).

4.7.1.5 Sea Level Rise and Coastal Erosion

Sea-level rise and coastal erosion are also a potential impact of climate change. Sea level rise occurs as sea ice continues to decline and due to the expansion of seawater as it warms. The average global sea level rise was reported as 3.2 mm per year between 1993 and 2010 and a long-term increase in the rate of sea-level rise in the 20th century is well-documented (Horsburgh *et al.*, 2020).

The rate of sea-level rise varies by location, in accordance with local conditions. At present, climate change is expected to attribute to 1 – 2 mm increase in the sea level rise per year in the UK. Sea level rise is expected to continue through to 2100. Sea level rise in England is expected to continue to exceed Scotland, and overall, the rise in sea-level in the UK is expected to be slightly lower than the global average (Horsburgh *et al.*, 2020).

Sea level projections are shown for the Teesside landfall (Figure 4-36) and the Humber landfall (Figure 4-37) over the operational phase of the Development, relative to a baseline period of 1981-2000. The projection for the average height of the sea over a year is obtained from multiple models that were used to inform the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Palmer *et al.*, 2018).

At the Teesside landfall, a mean sea level (MSL) rise of 0.11 m is projected by commencement of operations in 2027 and of 0.26 m by cessation of operations in 2052. The range associated with the projection is shown in light blue, i.e. models project that there is 95% likelihood that a MSL rise of more than 0.07 m will occur by 2026 and 5% likelihood that a sea level rise of more than 0.15 m will occur by 2026, similarly models project that there is 95% likelihood that a sea level rise of more than

0.16 m will occur by 2050 and 5% likelihood that a sea level rise of more than 0.35 m will occur by 2050[146].

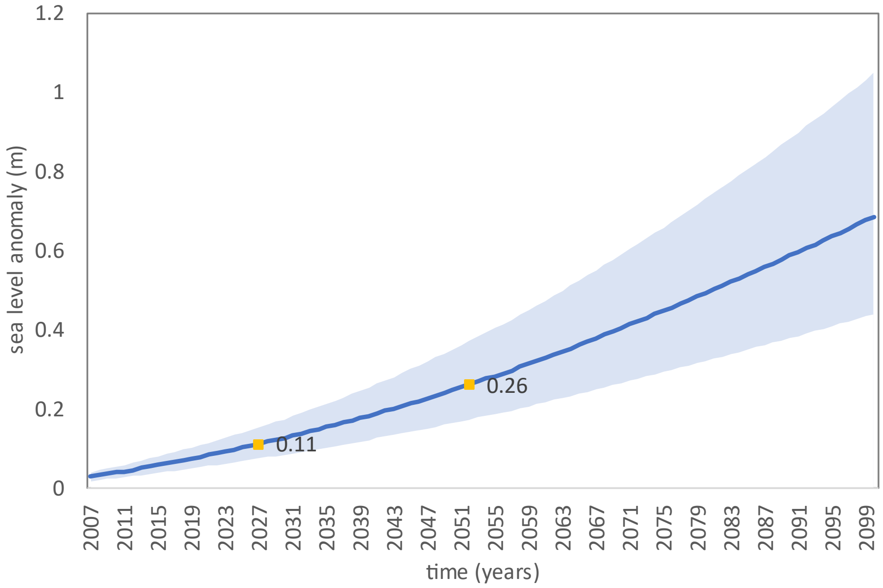


Figure 4-36 - Mean sea level projections for the Teesside landfall, relative to a baseline period of 1981-2000 (RCP8.5). The shaded region represents the projection range (produced using data from Palmer *et al.*, 2018)

At the Humber landfall, a MSL rise of 0.13 m is projected by commencement of operations in 2026 and of 0.30 m by cessation of operations in 2052. The range associated with the projection is shown in light blue, i.e. models project that there is 95% likelihood that a MSL rise of more than 0.09 m will occur by 2026 and 5% likelihood that a sea level rise of more than 0.17 m will occur by 2026, similarly models project that there is 95% likelihood that a sea level rise of more than 0.20 m will occur by 2050 and 5% likelihood that a sea level rise of more than 0.39 m will occur by 2050.

[146] Please note, per UKCP18, there may be a greater than 10% chance that the real-world response lies outside these ranges and this likelihood cannot be accurately quantified.

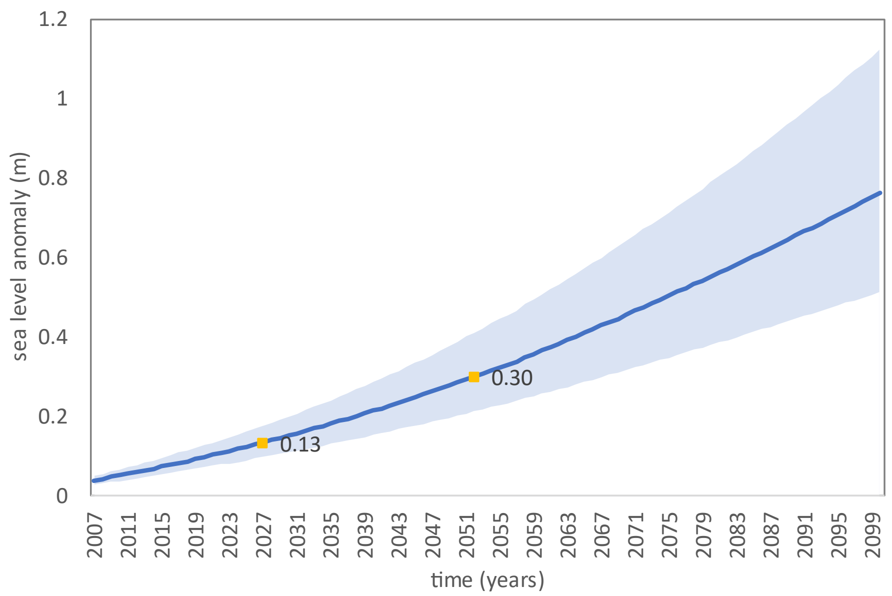


Figure 4-37 - Mean sea level projections for the Humber landfall, relative to a baseline period of 1981-2000 (RCP8.5). The shaded region represents the projection range (produced using data from Palmer *et al.*, 2018)

Sea-level rise is expected to contribute to coastal erosion, and it is estimated that 17% of the UK coastline is currently experiencing erosion. Areas across England and Wales suffer from coastal erosion of more than 10 cm per year. In addition to sea-level rise, coastal erosion results from reduced sediment supply, storms and anthropogenic disturbance (Masselink *et al.*, 2020). Coastal erosion is predicted to increase due to the predicted increases in sea-level rise (Horsburgh *et al.*, 2020).

4.7.2 Biological Environment

The biological environment may be affected by changes in the physical environment, including temperature increases driving changes in species distributions and changes in storm frequencies. Indirect impacts of climate change may also arise through changes in habitat provision, species distribution, predator-prey relationships, physiological responses, amongst others.

Changes in community composition have been documented and may be linked to the thermal affinities of species (e.g. cold or warm-water species). Physiological impacts as a result of increased temperatures and reduced oxygen levels may also reduce fish growth as a result of increased metabolic costs (Wright *et al.*, 2020). The impacts on plankton and fish may indirectly affect predator species, such as seabirds and marine mammals (Mitchell *et al.*, 2020). Additionally, shifts in marine mammal distributions have also been observed with northward shifts of warm-water species such as short-beaked common dolphin (*Delphinus delphis*) (Evans and Waggitt, 2020).

The following features of conservation interest present across the Development are addressed in turn in the following sections:

- Harbour porpoise (qualifying feature of the SNS SAC) (Section 4.7.2.1);
- Ocean quahog (qualifying feature of the Holderness Offshore MCZ) (Section 4.7.2.2);
- *S. spinulosa* and Sabellaria biogenic reef (Section 4.7.2.3);
- Sandbanks (specifically gravelly sandbanks) (Section 4.7.2.4); and

- Rocky reef (Section 4.7.2.5).

4.7.2.1 Harbour porpoise

At a global scale, the main observed effects of climate change on marine mammals have been geographical range shifts and loss of habitat, changes to the food web, increased exposure to algal toxins and susceptibility to disease (Evans and Waggitt, 2019).

Generally speaking, in mid-latitudes in the Northern Hemisphere such as around the British Isles, geographical range shifts have been observed across a number of marine mammal species, with northward extensions of the range of warmer water species (Evans and Waggitt, 2019). Inevitably, as a result of this lateral shift, colder water species will face greater pressure from global warming as they have reduced areas into which to move (Evans and Waggitt, 2019).

A documented shift in porpoise abundance from the NNS to the SNS between the 1990s and 2000s resulted in an increase in abundance in this region (Evans and Waggitt, 2019); it has been theorised that the shift was due to a shortage of sandeels, a known prey item (Evans and Bjørge, 2013). Numbers appear to have remained stable since this shift; however, changes in climate could result in mismatches in synchrony between predator and prey, either spatially or temporally (Evans and Bjørge, 2013).

In addition to possible changes in the food web structure as a result of climate change influences, subtle effects of pollutants (e.g. disruption of the immune, reproductive or endocrine systems) on marine mammals could also be exacerbated by nutritional stress brought on by reduced food availability (Evans and Waggitt, 2019).

Warming seas may also lead to the spread of infectious diseases into new areas, with novel pathogens able to survive in a different warmer climate. Marine mammals may find themselves more susceptible to disease due to being unaccustomed to these pathogens, thereby potentially resulting in unusually high mortality events (Evans and Waggitt, 2019).

Future changes to the climate are likely to be highly complex in nature therefore it is not possible to definitively predict harbour porpoise sensitivity to climate change or outline any future changes in the abundance of the species across UK waters.

4.7.2.2 Ocean quahog

The sensitivity of ocean quahog, mainly found in northerly latitudes, to increased temperature is considered ‘medium’. Increased temperatures may affect ocean quahog recruitment. It is expected that larvae and juveniles are tolerant to temperatures up to 20°C and adults are tolerant of temperatures up to 16°C. Long-term increases in temperature may result in increased mortality in the summer months (Tyler-Walters and Sabatini, 2017). The approximate near-bottom temperature at the Endurance Store fluctuates between 6-13°C across the year and, with an expected 2.8°C increase in temperatures in the North Sea for the 2069-2098 period when compared to 1960-1989 (see Section 4.7.1.2), the near-bottom temperature is still expected to be below 16°C by the end of the century.

The near-bed temperature along the Teesside Pipeline route ranges from approximately 6 to 13°C (bp, 2020c), and is likely to be similar along the Humber Pipeline route, indicating that, despite their patchy presence in low numbers along both pipeline surveys (Gardline, 2022a, b), the pipeline routes are suitable for the species and will continue to be so throughout the Development lifespan.

The species are not considered to be sensitive to decreases in salinity and de-oxygenation (Tyler-Walters and Sabatini, 2017).

4.7.2.3 S. spinulosa and Sabellaria biogenic reef

S. spinulosa are typically most sensitive to physical pressures, such as abrasion. Thus, they are often affected by anthropogenic activities which interact with the seabed directly, such as aggregate dredging and trawling (OSPAR, 2010). As it is currently understood, *S. spinulosa* have 'low' sensitivity to increased temperature, decreased salinity and de-oxygenation, all of which are predicted to arise as a result of climate change.

The distribution and extent of *S. spinulosa* reef is driven primarily by variation in abiotic conditions. In particular, storms may generate conditions which disturb reef features and result in localised mortality (OSPAR, 2010). Increased wave action may mobilise the typically mixed sediments on which *S. spinulosa* often occurs; such sediments having been identified across the Development area and aligning with biogenic reef presence (Figure 4-17 and Figure 4-20). An increase in wave action may result in increased abrasion and mortality.

As described in Section 4.7.1.1, the full effects of climate change on the frequency and magnitude of storm events is not possible to predict with accuracy. It is possible that, in the future, *S. spinulosa* will be exposed to altered wave conditions, resulting in either more or less physical disturbance. However, high levels of recruitment mean that recovery in the wake of a storm event could be quite rapid, even within a year, but timescales for the re-establishment of reefs are not clear (Jackson, and Hiscock, 2008; OSPAR, 2010).

4.7.2.4 Sandbanks (specifically gravelly sandbanks)

As described in Section 4.4.2.3, the survey along the Humber Pipeline route identified a habitat consistent with Annex I habitat 'Sandbanks which are slightly covered by sea water all the time', specifically gravelly sandbanks. While these habitats may be colonised by species which form distinctive communities, they are generally characterised by foliose seaweeds, hydroids, bryozoans and ascidians. These species will be exposed to changes in climate and are likely to be affected in a number of ways, as outlined throughout Section 4.7.2; including changes in distribution or range shifts due to exposure to increased temperatures, and changes in other physical environmental factors.

Sandbanks as a physical feature may be influenced by changes in the local metocean climate (including waves, tidal currents and storms). However, these are largely fixed in their distribution throughout the North Sea. On the other hand, benthic communities associated with these habitats may undergo changes in response to, or as a consequence of, climate change. For example, evidence exists to suggest that North Sea infaunal species have shifted their distributions in response to changing sea temperature. However, most species have not been able to keep pace with shifting temperatures meaning that they are subjected to warmer conditions which may be unfavourable (Moore and Smale, 2020). Additional evidence suggests that in the SNS, soft sediment benthos have experienced a reduction in density and species richness due to warm winter temperatures (Birchenough *et al.*, 2013).

Overall, benthic community level responses are dependant on species life-history traits (Moore and Smale, 2020).

4.7.2.5 Rocky reef

Rocky reefs, like sandbanks, are physical features/habitats which are unlikely to be as readily physically influenced by changes in the climate as the species associated with them. However, as described above, benthic communities associated with these habitats may undergo changes in response to, or as a consequence of, climate change. The fauna associated with rocky habitats are highly varied and are affected mainly by local wave action, tidal stream strength, salinity, turbidity, the degree of scouring and rock topography (European Environment Agency, 2019) and thus may be influenced by changes in the local metocean climate. Likewise, epifaunal communities may change in their composition as a result of range shifts. As this habitat is so heavily influenced by physical conditions and metocean properties, any changes in these features due to climate change will likely have an impact on rocky reef communities.

4.7.3 Other Sea Users

Impacts on the physical and biological environment may also affect human activities in the marine environment. For instance, any impacts on fish stocks will indirectly impact commercial fishing activity, potentially reducing the abundance of species or altering species composition. However, determining the causal factors for these changes is difficult when other factors also influence fish stocks (Pinnegar *et al.*, 2020). Additional consequences of climate change may generate impacts on cultural heritage through exacerbated rates of degradation attributed to changing metocean conditions (Harkin *et al.*, 2020). Tourism and recreation may also be variably affected by climate change processes due to the knock-on effects of changes in weather conditions, as experienced by tourists making use of coastal and marine areas (Coles, 2020). Climate change may also have a fundamental impact on human health, through predicted increases in phytoplankton, pathogenic Vibrio species (bacteria) and noroviruses (Bresnan *et al.*, 2020).

Ultimately, many of these socio-economic factors will be affected as a consequence of changes to the physical and biological environment as a result of climate change. Further evaluation has not been conducted of potential climate-related socio-economic effects due to uncertainty in how the physical/biological environment will respond to climate change and the associated complexity of teasing out the impacts of climate change amongst other factors that influence the physical/biological environment and related socio-economic receptors.

5 EIA METHODOLOGY

This section provides detail on how the process of EIA has been applied to this Development and describes the key components that have fed into the assessment. Figure 5-1 below presents an overview flow diagram of the EIA process used for this ES.

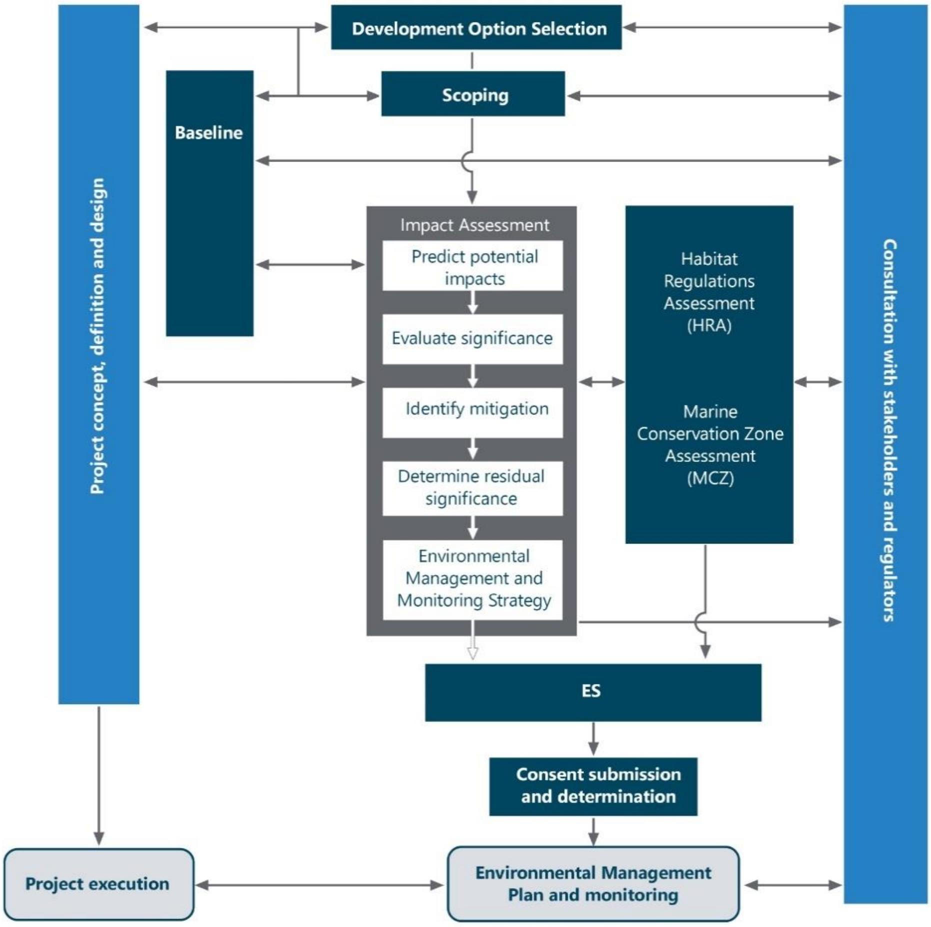


Figure 5-1 - The EIA process

5.1 Environmental Issues Identification

The main objective of the ENVID process is to identify the key potential environmental issues requiring discussion and assessment, and to agree practicable measures (mitigation) to eliminate or minimise harm to the environment.

ENVID has taken place based on:

- Known potential environmental issues specifically related to the Development;
- ENVID Workshop which brings together expert judgement from environmental practitioners and project engineers; and
- Stakeholder engagement through consultation meetings.

As understanding of the Development increased and as consultation continued, The ENVID process was kept under review and mitigation revised. The key issues that were assessed in this ES are therefore a combination of issues identified as significant during the early ENVIDprocess (including ENVID workshop, the output of which is detailed in Appendix A), issues of importance raised by consultees (the output of which is detailed in Appendix B), and issues that have become clearer during design evolution of the Development. The key issues identified are listed below and described in more detail in Section 5.4:

- Seabed disturbance;
- Underwater sound;
- Discharges to sea and Outcrop Formation Water displacement;
- Atmospheric emissions;
- Physical presence interactions with ornithological features, marine mammals and other sea users; and
- Accidental events.

5.2 Stakeholder Engagement and Consultation

The scope of work required during the EIA was established early in the process with the intention of capturing all potential issues. A consultation meeting was held in the early stages of the Development with OPRED and further meetings held between 2020 and 2023. Meetings have been held with fisheries, the Maritime and Coastguard Agency (MCA), Trinity House, Humber and Teesside Port Authorities, NE, the JNCC and Historic England over the course of the Development to date.

A document to support informal scoping was issued by bp as operator of the Development, on 21st September 2021. The document provided an overview of the Development, a summary description of the environment and identified potential environmental issues for further consideration in the EIA process. The document was issued to a range of statutory and non-statutory consultees and was also made available on the ECC website (https://eastcoastcluster.co.uk/) until the 18th October 2021.

The consultees provided robust feedback on the proposed approach to the EIA, the key environmental issues and potential impacts identified for assessment, and the supporting studies proposed to facilitate assessment. The issues raised through this process have been considered and addressed via the EIA; the key concerns are summarised below and details of how each issue has been addressed are provided in Appendix B.

- Potential direct and indirect impacts on features of nationally and internationally designated sites within which the Development lies and to which the Development is adjacent;
- Potential direct and indirect impacts of the Development on protected species and habitats;
- Avoidance of areas of *S. spinulosa* and stony reef habitat as far as reasonably practicable;
- Potential impact of protective materials associated with the pipelines and the introduction of hard substrate;
- Presentation of a realistic worst case scenario to enable a meaningful assessment of the full environmental impacts of the Development;
- Provision of information relating to the landfall and intertidal infrastructure;
- Potential impacts to shipping and navigation which require to be addressed via navigational risk assessment (NRA), associated consultation and underkeel clearance assessment;

- Potential impacts to fish and shellfish ecology including herring, cod and sandeel spawning and nursery grounds and potential impacts on brown crab;
- Potential impacts of underwater sound generation on marine mammals and fish;
- Potential impacts on the marine environment of CCS including but not limited to disposal of spoils, impact of leaks of chemicals during construction of wells, any leaks during transport and storage of CO_2 during operation, predicted Formation Water seepage at the Bunter Sandstone Outcrop;
- Detail of the Store characterisation, penetrations through the aquifer, the seal status and assurance process undertaken.
- Purpose of the Monitoring well, including the data likely to be available and the intended purpose of the data;
- Provision of information on the MP, Corrective Measures Plan and Post-Closure Plan;
- Ensuring that infrastructure is "fishing friendly", managing disruption to fisheries, applying good practice to pipeline burial and appropriate management of residual seabed marine hazards that remain post installation;
- Consideration of sediment quality both at the proposed landfall locations and throughout the proposed cable routes; and
- Cumulative impact of the Development, including full consideration of the whole scheme which is being consented by different regulatory bodies, and all supporting infrastructure.

5.3 Environmental Significance

5.3.1 Overview

The decision process related to defining whether or not a project is likely to have significant impacts on the environment is the core principle of the EIA process and the methods used for identifying and assessing potential impacts should be transparent and verifiable.

The method presented here has been developed by reference to the Chartered Institute of Ecology and Environmental Management (CIEEM) Guidelines for Ecological Impact Assessment (CIEEM, 2022), the Marine Life Information Network (MarLIN) species and ecosystem sensitivities guidelines (Tyler-Walters *et al.*, 2001) and guidance provided by the Institute of Environmental Management and Assessment (IEMA) (IEMA, 2016).

The terms impact and effect have different definitions in an EIA and one drives the other. An impact is considered to result in an effect if a pathway to a receptor exists.

Impact – Measurable, physical changes in the receiving environment (e.g. volume, time, area) arising from project activities.

Effect – Considers the response of a receptor to an impact.

The relationship between impacts and effects is not always straightforward; for example, a secondary effect may result in both a direct and indirect impact on a single receptor. There may also be circumstances where a receptor is not sensitive to a particular impact and thus there will be no significant effects/consequences.

The assessment identifies a receptor's sensitivity and vulnerability to an impact and implements a systematic approach to understand the significance of the effect on the receptor. The process considers the following:

- Identification of receptor and impact (including duration, timing and nature of impact);
- Definition of sensitivity, vulnerability and value of receptor;
- Definition of magnitude and likelihood of impact; and
- Assessment of the significance of potential effects on the receptor, considering the magnitude of the impact and the sensitivity/vulnerability/value of the receptor.

Once the significance of potential effects has been assessed, it is possible to identify additional measures that can be taken to mitigate impacts through design or operational measures. This process also identifies aspects of the Development that may require monitoring.

For some environmental impacts, significance criteria are standard or numerically based. For others, for which no applicable limits, standards or guideline values exist, a more qualitative approach is required. This involves assessing significance using professional judgement.

Despite the assessment of effects significance being a subjective process, a defined methodology has been used to make the assessment as objective as possible and consistent across different topics. The assessment process is summarised below. The terms and criteria associated with the assessment process are described and defined; details on how these are combined to assess the significance of the effects are then provided.

5.3.2 Baseline Characterisation and Receptor Identification

Characterisation (a description) of the existing environment was undertaken to determine the baseline conditions in the area covered by the Development and relevant surrounding study areas. The baseline environment has been described in Chapter 4: Environmental Description and is based on regional studies combined with site-specific surveys.

Where data gaps and uncertainties remained (e.g. where there were no suitable options for filling data gaps), as part of the EIA process these have been documented.

The EIA process requires identification of the potential receptors that could be affected by the Development (e.g. marine mammals, seabed species and habitats). High level receptors are identified within each topic chapter.

5.3.3 Impact Definition

The assessment uses the conceptual 'source-pathway-receptor' model. This model identifies potential impacts resulting from the proposed activities on the environment and sensitive receptors within it. This process provides an easy to follow assessment route between impact sources and potentially sensitive receptors ensuring a transparent impact assessment. The aspects of this model are defined as follows:

- Source – the origin of a potential impact (i.e. an activity such as pipeline trenching and a resultant effect e.g. re-suspension of sediments);
- Pathway – the means by which the effect of the activity could impact a receptor (e.g. for the example above, re-suspended sediment could settle and smother sea bed); and

- Receptor – the element of the receiving environment that is impacted (this could either be a component of the physical, ecological or human environment such as water quality or benthic habitat, e.g. for the above example, species living on or in the sea bed).

In general, the impact assessment for each topic will use this model when considering the potential impacts arising during the construction, O&M and decommissioning phases of the proposed Development. In some cases, it is appropriate to use other models for assessment, for example where a risk assessment approach is required instead.

5.3.3.1 Impact Magnitude

Determination of impact magnitude requires identification, and then description of specific aspects of the impact in terms of the following key criteria:

- Nature of impact, whether it will be beneficial or adverse;
- Type of impact, is it direct or indirect;
- Size and scale of impact, i.e. the geographical area;
- Duration over which the impact is likely to occur, i.e. days, weeks;
- Seasonality of impact, i.e. is the impact expected to occur at any time of year or during specific times of the year e.g. spring or summer; and
- Frequency of impact i.e. how often is the impact expected to occur.

Each of these variables are expanded upon in the tables below to provide consistent definitions across all EIA topics. In each impact assessment, these terms are used in the assessment summary table and are enlarged upon as necessary in any supporting text. With respect to the nature of the impact (Table 5-1) it should be noted that all impacts discussed in this ES are adverse, unless explicitly stated otherwise.

The maximum potential impact of the Development is assessed, based on the worst case parameters as defined by the Development design envelope. Further detail on specific design envelope parameters identified per EIA topic are provided in each of the relevant ES chapters.

Table 5-1 - Nature of impact

Nature of impact	Definition
Beneficial	Advantageous or positive effect to a receptor (i.e. an improvement).
Adverse	Detrimental or negative effect to a receptor.

Table 5-2 - Type of Impact

Type of impact	Definition
Direct	Impacts that result from a direct interaction between the Development and the receptor. Impacts that are caused by the introduction of the Development activities into the receiving environment, e.g. the direct loss of benthic habitat.
Indirect	Reasonably foreseeable impacts that are caused by the interactions of the Development, but which occur later in time than the original, or at a further distance from the Development location. Indirect impacts include impacts that may be referred to as 'secondary', 'related' or 'induced' (e.g. the direct loss of benthic habitat could have an indirect or secondary impact on by-catch of non-target species due to displacement of these species caused by loss of habitat).

Table 5-3 - Duration of impact

Duration	Definition
Temporary	Impacts that are predicted to be of short duration (e.g. less than one year) and are temporary or intermittent in nature.
Short-term	Impacts that are predicted to last for a limited period of time (e.g. between 1 and 5 years) and will cease on completion of the development activities (e.g. installation / construction) or as a result of planned mitigation, reinstatement or natural recovery.
Medium-term	Impacts that are predicted to last more than a few years (e.g. between 5 and 10 ye–rs – depending on overall lifetime of the Development). For example, impacts that might occur during construction and installation (e.g. over a couple of years) but may last longer than this until mitigation, reinstatement or natural recovery has taken effect.
Long-term	Impacts that may, but not necessarily, commence during construction / installation or during operation / decommissioning and are expected to continue for the duration of the Development, or in some cases beyond the lifetime of the Development, before eventually ceasing. These include ongoing intermittent or repeated activities e.g. maintenance or seasonal events that are required to take place for the lifetime of the Development.
Permanent	Impacts that are predicted to cause a permanent irreversible change and to continue well beyond the planned lifetime of the Development.

Table 5-4 - Geographical extent of impact

Geographical extent of impact	Definition
Local	Impacts that are limited to the area surrounding the Development footprint and associated working areas. Alternatively, where appropriate, impacts that are restricted to a single habitat or biotope or community.
Regional	Impacts that are experienced beyond the local area to the wider region, as determined by habitat/ecosystem extent.
National	Impacts that affect nationally important receptors or protected areas, or which have consequences at a national level. This extent may refer to either England or the UK depending on the context.
Transboundary	Impacts that could be experienced by neighbouring national administrative areas.
International	Impacts that affect areas protected by international conventions, European and internationally designated areas or internationally important populations of key receptors (e.g. birds, marine mammals).

Table 5-5 - Frequency of impact

Frequency of impact	Definition
Continuous	Impacts that occur continuously or frequently.
Intermittent	Impacts that are occasional or occur only under a specific set of circumstances which occurs several times during the course of the Development. This definition also covers such impacts that occur on a planned or unplanned basis, and those that may be described as 'periodic' impacts.

5.3.3.2 Impact Magnitude Criteria

Overall impact magnitude requires consideration of all impact parameters described above. Based on these parameters, magnitude can be assigned following the criteria outlined in Table 5-6. The resulting effect on the receptor is considered under vulnerability and is an evaluation based on professional judgement.

Table 5-6 - Impact magnitude criteria

	Definition
High	**Extent of change**: Impact occurs over a large scale or spatial geographical extent and /or is long-term or permanent in nature. **Frequency/ intensity of impact**: high frequency (occurring repeatedly or continuously for a long period of time) and/or at high intensity.
Medium	**Extent of change**: Impact occurs over a local to medium scale/spatial extent and/or has a short to medium-term duration. **Frequency/intensity of impact**: medium to high frequency (occurring repeatedly or continuously for a moderate length of time) and/or at moderate intensity or occurring occasionally/intermittently for short periods of time but at a moderate to high intensity.
Low	**Extent of change**: Impact occurs over a local to medium scale/spatial extent and/or has a short to medium-term duration.
Negligible	**Extent of change**: Impact is highly localised and very short-term in nature (e.g. days/few weeks only).
Positive	An enhancement of some ecosystem or population parameter.
Note: Magnitude of an impact is based on a variety of parameters. Definitions provided above are for guidance only and may not be appropriate for all impacts. For example, an impact may occur in a very localised area (minor to moderate) but at very high frequency/ intensity for a long period of time (major). In such cases expert judgement is used to determine the most appropriate magnitude ranking and this is explained through the narrative of the assessment.	

5.3.3.3 Impact Likelihood (for Unplanned and Accidental Events only)

The likelihood of an impact occurring for unplanned/ accidental events is another factor that is considered in this impact assessment. This captures the probability that the impact will occur. For some types of incident there are historical data available that allows a quantitative estimate of incident likelihood to be calculated; for other impacts, professional judgement must be used to present a qualitative estimate. The quantitative and qualitative terms used to describe impact likelihood in the impact assessment chapters are defined in Table 5-7. Consideration of likelihood is described in the impact characterisation text and used to provide context to the specific impact being assessed.

Table 5-7 - Likelihood for unplanned and accidental events

Likelihood	Quantitative definition	Qualitative definition
Likely	More than once per year	Event likely to occur more than once on the facility
Possible	Once in 10 years	Could occur within the lifetime of the development
Unlikely	Once in 100 years	Event could occur within lifetime of 10 equivalent developments. Has occurred at equivalent facilities.
Remote	Once in 1,000 years	Similar event has occurred somewhere in equivalent industry but not likely to occur with current practices and procedures.
Extremely remote	Once in 10,000 years	Has never occurred within equivalent industry but theoretically possible.

5.3.4 Receptor Definition

5.3.4.1 Overview

As part of the assessment of the significance of effects, it is necessary to differentiate between receptor sensitivity, vulnerability and value.

In each ES topic chapter, justification is made for the criteria assigned to sensitivity / vulnerability / value to provide transparency in how each variable has been assigned and a summary of the justification is provided in tabular format.

It is important to note that the following approaches to assessing sensitivity / vulnerability are not appropriate in all circumstances and in some instances professional judgement has been used in determining sensitivity. In some instances it has also been necessary to take a precautionary approach where stakeholder concern exists with regard to a particular receptor. Where this is the case, this is detailed in the relevant impact assessment chapter.

5.3.4.2 Receptor Sensitivity

The sensitivity of a receptor is defined as 'the degree to which a receptor is affected by an impact'.

The ability of a receptor to adapt to change, tolerate, and/or recover from potential impacts is key in assessing its sensitivity to the impact under consideration. For ecological receptors, tolerance could relate to short-term changes in the physical environment; for human environment receptors, tolerance could relate to impacts upon socio-economics or safety. The time required for recovery is an important consideration in determining receptor sensitivity.

The overall receptor sensitivity is determined by considering a combination of value, adaptability, tolerance and recoverability. This is achieved through applying known research and information on the status and sensitivity of the receptor, coupled with professional judgement and past experience.

Example definitions for assessing the sensitivity of a receptor are provided in Table 5-8.

Table 5-8 - Sensitivity of receptor

Receptor sensitivity	Definition
Very high	Receptor with no capacity to accommodate a particular effect and no ability to recover or adapt.
High	Receptor with very low capacity to accommodate a particular effect with low ability to recover or adapt.
Medium	Receptor with low capacity to accommodate a particular effect with low ability to recover or adapt.
Low	Receptor has some tolerance to accommodate a particular effect or will be able to recover or adapt.
Negligible	Receptor is generally tolerant and can accommodate a particular effect without the need to recover or adapt.

5.3.4.3 Receptor Vulnerability

Receptor vulnerability, defined as 'the degree to which a receptor can or cannot cope with an adverse impact' is based on professional judgement taking into account a number of factors, including the previously assigned receptor sensitivity and impact magnitude, as well as other factors such as known population status or condition, distribution and abundance. These criteria are used to define receptor vulnerability as per Table 5-9.

Table 5-9 - Vulnerability of receptor

Receptor vulnerability	Definition
Very high	The impact will have a permanent effect on the behaviour or condition of a receptor such that the character, composition or attributes of the baseline, receptor population or functioning of a system will be permanently changed.
High	The impact will have a prolonged or extensive temporary effect on the behaviour or condition of a receptor resulting in long-term or prolonged alteration in the character, composition or attributes of the baseline, receptor population or functioning of a system.
Medium	The impact will have a temporary effect on the behaviour or condition of a receptor such that the character, composition, or attributes of the baseline, receptor population or functioning of a system will either be partially changed post Development or experience extensive temporary change.
Low	Impact is not likely to affect long-term function of system or status of population. There will be no noticeable long-term effects above the level of natural variation experienced in the area.
Negligible	Changes to baseline conditions, receptor population or functioning of a system will be imperceptible.

5.3.4.4 Receptor Value

The value or importance of a receptor depends on a pre-defined judgement based on legislative requirements, guidance or policy. In the absence of specific legislation, it is necessary to make an expert judgement on receptor value based on the perceived views of key stakeholders, experts and specialists. Examples of receptor value definitions are provided in Table 5-10.

Table 5-10 - Value of receptor

Receptor value	Receptor type	Definition (example only – does not cover all receptors)
Very high	Environmental receptors	Receptor of very high importance or rarity, e.g. species that are globally threatened e.g. IUCN Red List of Threatened Species ('Red List') including those listed as endangered or critically endangered and/ or a significant proportion of the international population (> 1%) is found within the Development site.
	Cultural and socio-economic receptors	Receptor has no alternative to utilise an alternative area.
High	Environmental receptors	Receptor of high importance or rarity, such as species listed as near-threatened or vulnerable on the IUCN Red List. Habitats and species protected under the EC Habitats Directive. Bird species protected under the EC Birds Directive. Habitats and species (including birds) that are a qualifying interest of a SAC, SPA or Ramsar site and a significant proportion of the national population (> 1%) is found within the Development site. Conservation interests (habitats and species) of MPAs, Heritage MPAs and MCZs.
	Cultural and socio-economic receptors	Receptors and sites of international cultural importance (e.g. United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage Sites (WHSs). Receptor has little flexibility to utilise an alternative area. Receptor generates the majority of income from the Development area. Receptor is an above average example and/or has high potential to contribute to knowledge and understanding and/or outreach.
Medium	Environmental receptors	Receptor of least concern on the IUCN Red List, listed as a breeding species on Schedule 1 of the Wildlife and Countryside Act 1981, form a cited interest of a SSSI, are listed in the UKBAP or on the BOCC 'Red list' and a significant proportion of the regional population (> 1%) is found within the Development site.
	Cultural and socio-economic receptors	Receptor has some flexibility to utilise an alternative area. Receptor is active in the Development area and utilises it for up to half of its annual income/activities. Receptor is average example and/or has moderate potential to contribute to knowledge and understanding and/or outreach.
Low	Environmental receptors	Any other species of conservation interest (e.g. BOCC Amber listed species).
	Cultural and socio-economic receptors	Receptor has high flexibility to utilise an alternative area. Receptor is active in the Development area and other areas and is reliant on Development area for some income/activities. Receptor is below average example and/or has low potential to contribute to knowledge and understanding and/or outreach.
Negligible	Environmental receptors	Receptor of very low importance, such as those which are generally abundant around the UK and Ireland with no specific value or conservation concern.
	Cultural and socio-economic receptors	Receptor is very active in other areas and not typically present in the Development area. Receptor does not generate any income/activities from the Development area. Receptor is poor example and/or has no potential to contribute to knowledge and understanding and/or outreach.

5.3.5 Evaluation to Determine Significance

Overall significance of an impact is determined by correlating the magnitude of the impact and the sensitivity of receptor. To support a transparent and consistent approach throughout the ES, a matrix approach has been adopted as a guide (see Table 5-11). There is however latitude for professional assessment where deemed appropriate in the application of the matrix.

Table 5-11 - Consequence matrix

Receptor sensitivity	Magnitude of impact				
	No Change	Negligible	Low	Moderate	High
Negligible	Negligible	Negligible	Negligible/ Minor	Negligible/ Minor	Minor
Low	Negligible	Negligible/ Minor	Negligible/ Minor	Minor	Minor/ Moderate
Medium	Negligible	Negligible/ Minor	Minor	Moderate	Moderate/ Major
High	Negligible	Minor	Minor/ Moderate	Moderate/ Major	Major
Very high	Negligible	Minor	Moderate/ Major	Major	Major

The definitions of the categories are described in Table 5-12. In general, any consequence of moderate or greater is considered 'significant' in EIA terms. For each topic specific chapter, what is considered 'significant' will be clearly defined. Where further mitigation is not possible a residual significant impact may remain.

Table 5-12 - Assessment of consequence

Assessment consequence	Description (Consideration of receptor sensitivity and value and impact magnitude)	Impact significance (EIA Regulations)
Major	Impacts are likely to be highly noticeable and have long-term effects, or permanently alter the character of the baseline and are likely to disrupt the function and status/value of the receptor population. They may have broader systemic consequences (e.g. to the wider ecosystem or industry). These impacts are a priority for mitigation in order to avoid or reduce the anticipated effects of the impact.	Significant
Moderate	Impacts are likely to be noticeable and result in lasting changes to the character of the baseline and may cause hardship to, or degradation of, the receptor population, although the overall function and value of the baseline/receptor population is not disrupted. Such impacts are a priority for mitigation in order to avoid or reduce the anticipated effects of the impact.	Significant
Minor	Impacts are expected to comprise noticeable changes to baseline conditions, beyond natural variation, but are not expected to cause long-term degradation, hardship, or impair the function and value of the receptor. However, such impacts may be of interest to stakeholders and/or represent a contentious issue during the decision-making process and should therefore be avoided or mitigated as far as reasonably practical.	Not significant
Negligible	Impacts are expected to be either indistinguishable from the baseline or within the natural level of variation. These impacts do not require additional mitigation to reduce impact and are not anticipated to be a stakeholder concern and/or a potentially contentious issue in the decision-making process.	Not significant
Positive	Impacts are expected to have a positive benefit or enhancement. These impacts do not require mitigation and are not anticipated to be a stakeholder concern and/or a potentially contentious issue in the decision-making process.	Not significant

5.3.5.1 Mitigation

Where an impact assessment identifies that an aspect of the development is likely to give rise to significant effects, mitigation measures must be considered. The intention is that such measures should remove, reduce or manage the impacts to a point where the resulting residual significance is at an acceptable or insignificant level. Section 5.3.5 provides detail on these commitments and how any mitigation measures identified during the impact assessment will be managed. Notwithstanding any other statements in this ES, the definitive list of those mitigation measures is set out in the Commitments Register at Appendix C.

For the purposes of the EIA, two types of mitigation have been defined:

- Embedded mitigation: consisting of mitigation measures that are identified and adopted as part of the evolution of the Development's design, and are included and assessed in the EIA; and
- Additional mitigation: consisting of mitigation measures that are identified during the EIA process specifically to reduce or eliminate any predicted significant effects. Additional mitigation is therefore subsequently adopted as a commitment by inclusion in the Commitment Register at Appendix C.

5.3.5.2 Residual Impacts

Residual impacts are those that remain once all options for removing, reducing or managing potentially significant impacts (i.e. all mitigation) have been taken into account.

5.4 Issues Scoped In

The ENVID process, consultation and technical review phases resulted in the following issues being considered and agreed for assessment in the EIA:

- Seabed Disturbance (Chapter 6);
  - Direct loss of benthic species;
  - Direct loss of existing seabed habitat;
  - Introduction of new habitat;
  - Direct loss of marine archaeological remains;
  - Direct loss of existing seabed habitat used by diving birds;
  - Wider indirect disturbance to the benthic environment through the suspension and re-settlement of sediments through possible rig anchoring, drilling and cuttings, mud and cement discharges; and
  - Wider indirect disturbance to coastal processes and sediment transport through pipeline installation activities.
- Underwater Sound (Chapter 7);
  - Injury and disturbance to marine mammals and fish through sound from piling, seismic surveys, drilling, vessels and clearance of UXO (if required) across the Development area;
- Discharges to Sea and Formation Water Displacement (Chapter 8);
  - Discharge of WBMs, drill cuttings, cementing and completion chemicals from drilling operations into the water column and onto the seabed, resulting in changes in water

quality, localised and temporarily increased suspended solid concentrations, and possible impacts to organisms in the water column and on the seabed;
  - Discharge of treated water from pipeline testing activities; and
  - Displacement of Formation Water at the Bunter Sandstone Outcrop due to the injection of CO_2 into the Endurance Store, resulting in potential changes in water quality and possible impacts to organisms in the water column and on the seabed.
- Physical Presence Interactions (Chapter 9);
  - Disturbance to ornithological features from increased vessel movements;
  - Interference with shipping and fishing activities that may occur in the area;
  - Loss of access to the area for other vessels on a temporary or permanent basis; and
  - Increased risk of vessel collisions through the presence of the drilling rig and other vessels during drilling and installation activities.
- Accidental Events (Chapter 10);
  - Possible toxicity and smothering impacts to birds, other marine species (e.g. marine mammals) and habitats through the release of diesel and chemicals from a loss of inventory from the drilling rig or vessels associated with pipeline installation;
  - Possible impacts through the leakage of CO_2 from the pipelines, wells or the Endurance Store; and
  - Possible impacts through the leakage of brine from wells previously drilled in the vicinity of the Endurance Store.
- Atmospheric Emissions (Chapter 11);
  - Climate change assessment including inventory of emissions of GHGs associated with the Development, climate change resilience review and in-combination climate impact (ICCI) assessment; and
  - Generation of acid rain from oxides of nitrogen (NO_x) and sulphur (SO_x).

The key environmental issues outlined above were reviewed and ranked against a series of significance criteria, the detailed methodology for which is provided in Section 5.3.

5.5 Issues Scoped Out

During the ENVID workshop and as the EIA developed, the following issues were reviewed but it was considered that they would be scoped out of further assessment in the EIA if there was:

- Lack of linkage between receptor and impact with potential impacts being so small that they were likely to be insignificant; and/or
- Existence of legislation and established management processes and procedures that control the activity or impact to the extent there is no plausible route to significant impact.

The following issues were scoped out of further assessment in the EIA:

- Seabed Disturbance;
  - WFD assessment: Communication with NE, OPRED and the EA concluded that as the NZT Project DCO includes (and the Onshore Humber application will include) WFD assessment for the CO_2 export pipeline corridor out to 1 NM, no additional WFD assessment would be included for the Development. A commitment is made within the Commitments Register (Appendix C) that such an assessment will be conducted for Onshore Humber.

- Underwater Sound;
  - Impacts on seabirds from underwater sound given that the seabirds in the Development area are not expected to rely heavily on underwater hearing for the majority of their behaviours (Popper and Hawkins, 2012).
- Discharges to Sea;
  a. Routine blackwater production (i.e. sewage), grey water (i.e. from showers and laundry) and food waste (macerated) disposal (from vessels and jackup rig). Existing, effective management controls are in place for such discharges which are also regulated under International Convention for the Prevention of Pollution from Ships (MARPOL);
  b. Ballast water management. Existing, effective management controls are in place. Regulated under Merchant Shipping regulation; and
  c. Routine seawater usage for cooling (e.g. engine cooling) due to the highly limited temporal and spatial extent of such discharges.
- Physical Presence;
  d. Seascape, Landscape and Visual Impact Assessment: During a meeting held with NE in February 2022, it was discussed that the boundary of the ES is activity seaward of MLWS, activity landward of the MLWS is permitted under the DCO process. It was noted that seaward of the MLWS, there will be no permanent infrastructure above the sea surface and no change to the current landscape or seascape. During the temporary and localised installation phase, construction vessels will be used to install the Teesside and Humber Pipelines.
- Accidental Events;
  - The accidental deposit of materials on the seabed (e.g. dropped objects). Existing, effective management controls are in place.
- Atmospheric Emissions;
  - Fugitive emissions (e.g. from seals, welds, valves, flanges etc.) are expected to be at extremely low levels that, even cumulatively, would not contribute to any potential impact; and
  - Release of CO_2 into water column from wireline work (intervention), testing subsea tree valves and choke changeouts – subsea interventions.
- Waste;
  - Routine generation and disposal of non-hazardous waste streams. bp, as operator of the Development, has existing, effective management controls are in place to comply with regulatory requirements and conform to industry good practice; and
  - Routine generation and disposal of special/ hazardous wastes, e.g. oil/grease/chemical cans/drums/sacks, and contaminated cuttings. Bp, as operator of the Development, has existing, effective management controls are in place to comply with regulatory requirements and conform to industry good practice.

5.6 Cumulative and In-Combination Impact Assessment

Cumulative impacts act together with other impacts (including those from any concurrent or planned future third-party activities) to cause environmental effects to the same receptors as the proposed Development. In relation to HRA, assessment is required of whether the impacts of a development alone, or 'in-combination' with other projects or plans will result in Likely Significant Effects (LSEs).

The EC has defined cumulative impact as being those resulting "from incremental changes caused by other past, present or reasonably foreseeable actions together with the project" (European Commission, 1999). As outlined in studies by the EC (1999) and the United States Council on Environmental Quality (1997), identifying the cumulative impacts of a project involves:

- Considering the activities associated with the project;
- Identifying potentially sensitive receptors/resources;
- Identifying the geographic and time boundaries of the cumulative impact assessment;
- Identifying past, present and future actions which may also impact the sensitive receptors/resources;
- Identifying impacts arising from the proposed activities; and
- Identifying which impacts on these resources are important from a cumulative impacts' perspective.

The requirement for assessment in relation to the HRA of whether the impacts of a development alone, or 'in-combination' with other projects or plans will result in LSEs is codified within The Conservation of Habitats and Species Regulations 2017 (Regulation 63) and, beyond UK territorial waters (12 NM), in The Conservation of Offshore Marine Habitats and Species Regulations 2017 (Regulation 28). In practice, such an 'in-combination' assessment is of greatest relevance when an impact pathway relating to a project would otherwise be screened out because it is considered not to result in LSEs.

To assist the assessment of cumulative and in-combination impacts, a review of existing and planned future developments (including oil and gas, cables and renewables) that could have the potential to interact with the Development was undertaken and refined through consultation with JNCC, NE, the MMO and OPRED. These projects and associated project details are provided in Appendix D. The location of these projects is shown Appendix D. The impact assessment has considered these projects when defining the potential for cumulative impact (Chapters 6: Seabed Disturbance to 11: Atmospheric Emissions).

The following types of projects are Ied in the assessment (subject to available information[147]):

- Existing completed projects;
- Approved but uncompleted projects;
- Ongoing activities;
- Plans or projects for which an application has been made and which are under consideration by the consenting authorities; and
- Plans and projects which are reasonably foreseeable, i.e. projects for which an application has not yet been submitted, but which are likely to progress before completion of the development and for which sufficient information is available to assess the likelihood of cumulative and in-combination effects.

It is noted that the level of detail that is available varies from project to project. Taking this into account, the assessment of cumulative impacts usually can only be carried out on a qualitative basis, using expert judgement to identify and determine the significance of any potential impacts. Details of

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[147] *ES submission to OPRED is targeting the end of July 2023 therefore the assessment considers projects which fulfil the criteria up to the end of April 2023. The list of projects and their status is up to date as of the end of April 2023.*

the projects to be considered for the cumulative impact assessment were provided to all EIA study leads. The study leads then considered which of these projects could result in potential cumulative impacts with the Development. This decision was based on the results of the specific impact assessment together with the expert judgement of the specialist consultant undertaking the impact assessment.

5.6.1 Whole Scheme Assessment

The Development and onshore works (NZT Power and Onshore Humber) are being progressed by separate applicants and will be consented under separate regimes. To fully assess the complete effects arising from both the onshore and offshore works, Chapter 6: Seabed Disturbance considers the potential for shared receptors to be affected by both the onshore and offshore works and draws a conclusion as to whether any additional significant impacts will arise.

5.7 Transboundary Impact Assessment

Transboundary effects arise when impacts from the proposed Development within one state affects the environment under the jurisdiction of another state(s). The need to consider such transboundary effects has been embodied by the United Nations Economic Commission for Europe Convention on EIA in a Transboundary Context (commonly referred to as the 'Espoo Convention'). The Convention requires that assessments are extended across borders between Parties of the Convention when a planned activity may cause significant adverse transboundary impacts.

The impact assessment presented in Chapters 6: Seabed Disturbance to 11: Atmospheric Emissions contains sections which identify the potential for, and where appropriate, assessment of transboundary impacts. For the Development, the UK/Netherlands median lies approximately 105 km away from the nearest part of the Development, which is the Endurance Store.

5.8 Habitat Regulations Assessment and Marine Conservation Zone Assessment

It is the responsibility of the Competent Authority (Offshore Petroleum Regulator for Environment & Decommissioning, OPRED) to make an AA of the implications of a plan, programme or in this case project, alone or in combination, on a SAC or SPA in view of the site's conservation objectives and the overall integrity of the site.

As part of the assessment of impacts on key receptors, for those receptors that are a qualifying feature of a site, relevant information on SACs or SPAs has also been provided. This information will then be used by the Competent Authority to determine the need for, and subsequently carry out (if required), an AA of the Development.

In accordance with the Conservation of Offshore Marine Habitats and Species Regulations 2017 (for offshore areas, 12 – 200 NM) and the Conservation of Habitats and Species Regulations 2017 (less than 12 NM), the impacts of a project on the integrity of a UK site network site are assessed and evaluated as part of the HRA process. In an analogous process, the MCAA require assessment of the potential for significant risk to achievement of the conservation objectives of MCZs.

The requirement to undertake the assessment lies with OPRED but the ES provides both qualitative and quantitative information to inform the assessment process and enable OPRED to determine whether a significant effect is likely and whether the proposed activities would have an adverse effect on the integrity of the relevant site.

5.9 Site Surveys and Studies

The North Sea has been extensively studied, meaning that this EIA has been able to draw on a significant volume of published data. This bank of published data has been supplemented by a site survey programme and studies undertaken on behalf of bp to collect environmental data specific to the Development, ensuring a robust baseline is available against which to assess impact. Where appropriate, studies have been commissioned to inform the impact assessment.

When evaluating and characterising potential impacts that could be associated with the Development, a variety of inputs are used, including baseline environmental data, modelling results, estimation of emissions and the footprint of the Development. These inputs carry varying levels of uncertainty and conservatism and although potential impacts may occur, they are not certain to occur (for example, there is some uncertainty in marine mammal response to certain sound emissions at a population level). To account for this uncertainty, worst case assumptions have been made, and where key uncertainties exist they have been outlined within the impact assessment chapters.

6 SEABED DISTURBANCE

6.1 Introduction

This chapter assesses the potential impacts from seabed disturbance associated with the Development. The focus of the assessment is on subtidal areas (seaward of MLWS). In line with good practice, consideration has also been given to the potential impacts from disturbance of the seabed in intertidal areas (between MLWS and MHWS); any impacts identified in this zone are summarised, and relevant interactions discussed.

The following specialists have contributed to this assessment:

- Gardline Limited – environmental and geophysical surveys, environmental baseline survey reporting, habitat assessment reporting;
- NIRAS Limited – ornithological technical report, baseline description and impact assessment for birds;
- Wessex Archaeology – marine archaeological baseline description, technical study and impact assessment; and
- Xodus Group – baseline description, coastal processes study, MCZ assessment, impact assessment and ES section write up.

Table 6-1 provides a list of all the supporting studies which relate to the seabed disturbance impact assessment.

Table 6-1 - Supporting studies

Details of study
Environmental Baseline Report (Gardline, 2022a)
Environmental Survey Habitat Assessment (Gardline, 2022b)
Ornithological Technical Report (NIRAS, 2023)
Marine Archaeology Technical Report (Wessex Archaeology, 2023)
Coastal Processes Baseline and Impact Assessment Methodology (Xodus Group, 2023c)

The key aspects of the Development that may interact with the seabed are:

- Construction of the pipeline landfalls at Teesside and Humber;
- Seabed preparation, trenching, installation, burial and protection (as required) of the Teesside and Humber Pipelines, the Teesside – Store cable and the Teesside – SSIV cable;
- Installation of subsea infrastructure at the Endurance Store and the SSIV nearshore on the Teesside Pipeline;
- Seabed preparation, trenching, installation, burial and protection (as required) of the infield pipeline, flowlines and cables; and
- Physical presence of the surface-laid pipelines, subsea infrastructure and protection structures for the lifetime of the Development.

The above activities may lead to the following potential impacts:

- Temporary direct and/or indirect disturbance or localised damage to seabed habitats and the biota that depend on them (including benthos, fish and birds);
- Localised loss/change of seabed substratum;
- Direct and indirect disturbance or damage to cultural heritage (marine archaeology); and
- Effects on coastal sediment transport processes.

6.2 Regulatory Controls

In addition to the EIA regulations detailed in Section 1.5, there are other requirements of UK legislation, international treaties and agreements and local management plans relevant to the assessment of impacts from seabed disturbance. The following legislation is key in relation to potential seabed disturbance impacts from the Development on benthic habitats, biota, marine cultural heritage and coastal processes:

- *Petroleum Act 1998* regulates the placement of pipelines and other permanent subsea infrastructure onto the seabed;
- *Marine and Coastal Access Act 2009* (MCAA) is the primary legislation relevant to marine development within English territorial waters. The MCAA introduced a new marine planning system and provided for the designation of MCZs;
- *The Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001*, as amended set down the obligations for the assessment of the impact of offshore oil and gas activities (including gas and carbon dioxide unloading and storage activities) on habitats and species protected under Council Directive 92/43/EEC (the Habitats Directive); the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019) transferred the functions from the European Commission to the appropriate authorities in England and Wales;
- *The Conservation of Habitats and Species Regulations 2017*, as amended, and The Conservation of Offshore Marine Habitats and Species Regulations 2017, as amended, transposed (prior to the UK's departure from the European Union) the EU Habitats Directive (Council Directive 92/43/EEC) and certain elements of the EU Wild Birds Directive (Directive 2009/147/EC) into UK law for inshore waters (up to 12 nautical miles from shore) and offshore waters (over 12 nautical miles from shore) respectively, and included provisions for the designation and protection of areas that host important habitats and species; the 2019 amendments (The Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019) transferred the functions from the European Commission to the appropriate authorities in England and Wales, but all other processes and terms in the 2017 Regulations remain unchanged and existing guidance is still relevant;
- *The Convention for the Protection of the Marine Environment of the North-East Atlantic* (The OSPAR Convention) has developed the OSPAR List of Threatened and/or Declining Species and Habitats with the aim of identifying species and habitats in need of protection;
- *The Convention on Biological Diversity* has prepared the first draft of the post-2020 Global Biodiversity Framework (Convention on Biological Diversity, 2021);
- *The Convention on the Conservation of European Wildlife and Natural Habitats* (Bern Convention) is a binding international legal instrument for nature conservation that aims to ensure the conservation and protection of wild plant and animal species and their natural habitats, as listed in Appendices I and II of the Convention;

- Protection of Wrecks Act 1973 and Ancient Monuments and Archaeological Areas Act 1979 designate marine cultural heritage receptors;
- *Protection of Military Remains Act 1986* protects military wrecks and aircraft remains; and
- *Merchant Shipping Act 1995* is used to determine the ownership of any wreck remains.

The East Inshore and East Offshore Marine Plans (Defra, 2014) and the North East Inshore and North East Offshore Marine Plan (Defra, 2021) aim to help ensure sustainable development of the marine area through informing and guiding regulation, management, use and protection of the area. Appendix C shows how these policies are addressed by the EIA.

SMPs are in place for the entire length of the coastline of England and Wales (Environment Agency, 2022a). Their purpose is to develop a sustainable management approach for the shoreline that takes account of issues such as coastal erosion and water quality, and to achieve the best possible balance of all the values and features that occur around the shoreline for the longer term (currently 2105). The following SMPs are relevant to the Development area (further details provided in Appendix G):

- The Teesside Pipeline landfall lies within Coastal Cell 1, covered by the River Tyne to Flamborough Head SMP managed by Scarborough Borough Council (North East Coastal Authorities Group, 2007);
- The Humber Pipeline landfall lies within Coastal Cell 2, covered by the Flamborough Head to Gibraltar Point SMP managed by the East Riding of Yorkshire Council (Humber Estuary Coastal Authorities Group, 2010a).

6.3 Assumptions and Data Gaps

6.3.1 Assumptions

The impact assessments in Section 6.4.2 for benthic ecology, fish, birds, marine archaeology and coastal processes each address the worst case parameters for the receptor group concerned; the worst case, particularly in relation to options for the pipeline landfalls at Teesside and Humber, is not the same for each receptor but is defined in each impact assessment.

Three main options are under consideration for the landfall at Teesside (microtunnel, HDD and direct pipe; Section 3.2.1.1), while four options are under consideration for the Humber Pipeline landfall (HDD, direct pipe, microtunnel alone and microtunnel with cofferdam (Section 3.2.2.1). Further engineering is required to select the optimum solution for landfall installation. The worst case options used in the assessment of impacts associated with the landfall are summarised in Table 6-2.

Table 6-2 - Worst case landfall installation options for seabed disturbance

Receptor group	Worst case landfall scenario	Justification
Benthos, fish and marine archaeology	**Teesside** Direct pipe **Humber** Microtunnel with cofferdam	At Teesside, direct pipe installation would have the largest seabed footprint due to the greater requirement for pre-cut trenching between the punch-out location (at LAT) seaward to 8 m LAT (see Figure 3-3 and Table 3-3). At Humber, both the microtunnel and the microtunnel with cofferdam options would require additional pre-cut trenching from LAT to 8 m LAT, but the microtunnel with cofferdam is the worst case as it also involves the use of a cofferdam on the beach seaward from MHWS (see Figure 3-10 and Table 3-3). No localised differences in sensitivities in the receptor groups have been identified for either landfall, and therefore these options are considered to represent the worst case for all receptors sensitive to the overall seabed footprint of the Development.
Birds	**Teesside** Microtunnel or HDD **Humber** HDD (red-throated diver) or microtunnel with cofferdam (for little tern)	Little tern and red-throated diver were assessed as being the most sensitive species to habitat loss impacts associated with the Development (Section 6.4.2.1.4). As neither of these species are of key importance at the Teesside landfall, the worst case scenario is that which involves the longest period of disturbance. This will be either microtunnelling or HDD, which require the presence of a jackup barge for 180 days. At the Humber landfall, HDD is considered the worst case option for red-throated diver due to the period of use of a jackup barge of up to 12 months, while microtunnel with cofferdam has the largest potential to impact the foraging area of little tern.
Coastal processes	**Teesside** Direct pipe **Humber** Microtunnel with cofferdam	At the Teesside Pipeline landfall, the direct pipe option has the shallowest punch-out location (LAT), and thus stands to be most impactful in the nearshore than the other options. At the Humber Pipeline landfall, the microtunnel with cofferdam option has the largest bore diameter under consideration, and the cofferdam will cover the greatest area of seabed.

With respect to the quantification of the worst case seabed footprint of the Development as presented in Section 6.4.1, the greatest numbers and dimensions of structures and activities have been assumed as described in Chapter 3: Project Description. The assumptions made include the following, with further details shown in Table 6-3, Table 6-4 and Table 6-5:

- The pipelay vessel(s) may have up to 12 anchors of approximately 5.7 x 4.5 m, which will require repositioning every 400 m along each pipeline route;
- The anchor spread will be 1-2 km with up to 400 m of each anchor line interacting with the seabed;
- Sections of pipelines and flowlines will be either surface-laid or trenched and buried depending on the specific requirements and seabed conditions along the routes, as summarised in Table 6-3, Table 6-4 and Table 6-5;
- All cables will be trenched and buried;
- Worst case rock protection requirements for pipelines, cables and flowlines are as detailed in Table 6-3, Table 6-4 and Table 6-5;
- Rock placement will also be required at 11 crossings each for the Teesside Pipeline and the Teesside – Store cable, at two crossings for the Humber Pipeline, at three trench transitions on the Teesside Pipeline, at one trench transition on the Humber Pipeline and at ten trench transitions for the infield flowlines;
- Maximum likely rock berm dimensions have been assumed, with future design work expected to reduce these where reasonably practical;
- Concrete mattresses (each 6 m x 3 m) are required to protect exposed spool-pieces and sections of untrenched cable in the vicinity of the SSIV (50 mattresses), and infield at the approaches to the manifolds and wells (630 mattresses);
- Concrete mattresses will also be used at crossings with buried infrastructure, some of which will have a footprint extending beyond the rock berm at the crossing;
- The jackup rig for drilling the injection wells will have three spud cans (feet) each of 18 m diameter;
- There will be a single SSIV, located on the Teesside Pipeline, with an associated protective structure and scour protection;
- The infield infrastructure at the Endurance Store will be as listed in Table 6-5 and includes three seabed landers to be deployed as part of the MP; a further lander will be deployed in the Bunter Sandstone Outcrop area.

6.3.2 Data Gaps

There are considered to be no major data gaps in the baseline information which would affect the assessment of impact on benthic ecological features or their use by fish or birds, on coastal processes.

With regards to assessment of archaeological features, it is noted that the records reviewed in the archaeological study are not a record of all surviving cultural heritage assets, rather a record of the discovery of a wide range of archaeological and historical components of the marine historic environment. The information presented may not be complete and does not preclude the subsequent discovery of further elements of the historic environment that are, at present, unknown. In particular, this relates to sub-surface archaeological features. Detailed interpretation of geophysical survey data from all parts of the marine Development area has been undertaken to reduce the risk of any undiscovered features of archaeological interest being encountered during implementation of the Development.

6.4 Description and Quantification of Potential Impacts

This section describes the potential impacts that may result from seabed disturbance associated with the Development and indicates the level of risk to each of the relevant receptors identified in Chapter 4: Environment Description.

The area within which these potential impacts may occur is shown in Figure 6-1 and Figure 6-2. These figures also show the seabed habitat types, protected sites and records for species of conservation interest in the area.

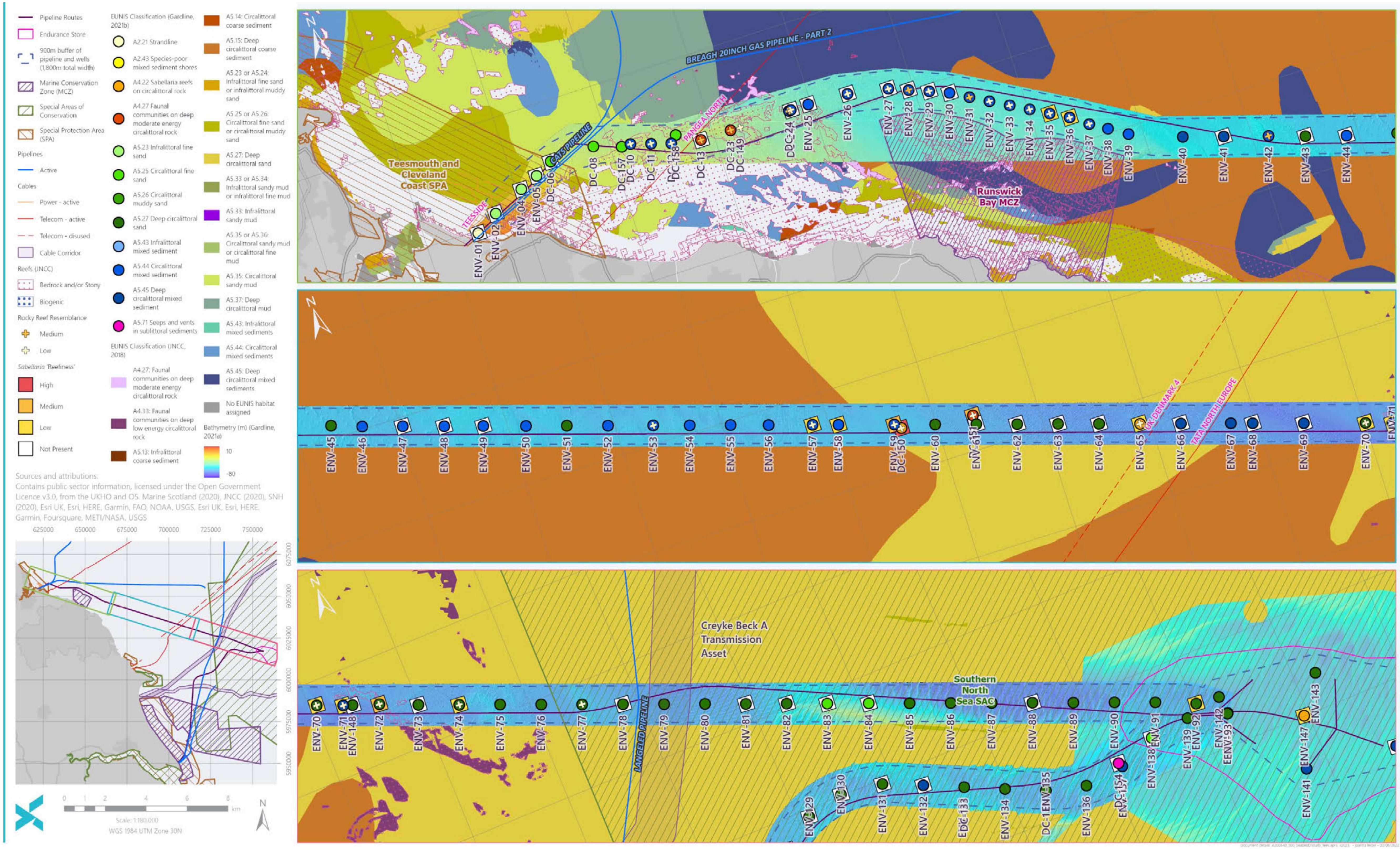


Figure 6-1 - Development activity boundaries for the Teesside Pipeline

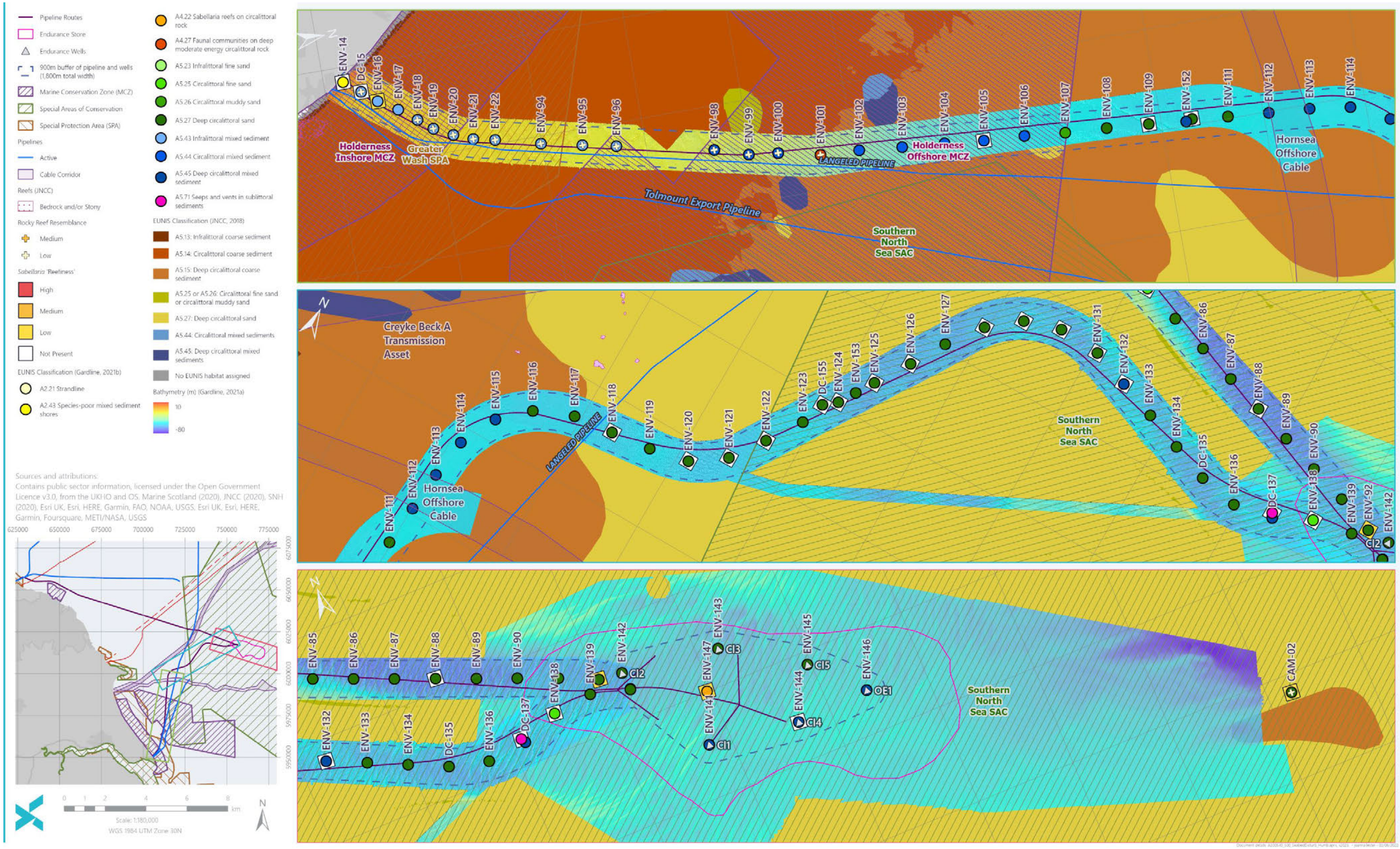


Figure 6-2 - Development activity boundaries for the Humber Pipeline and Endurance Store area

6.4.1 Quantification of Seabed Disturbance Areas

The activities expected to result in seabed disturbance are described in Chapter 3 Project Description. Sections 6.4.1.1 to 6.4.1.3 present the areas of direct and indirect seabed disturbance associated with these activities for each pipeline and for the Endurance Store and Bunter Sandstone Outcrop areas.

Direct impacts may occur where the seabed is directly disturbed or manipulated in some way during Development activities; this includes deliberate activities such as dredging or the placement of rock protection, as well as incidental disturbance such as abrasion of the seabed by dragging anchor lines. The areas of direct disturbance have been calculated by summing the expected footprints of all the relevant Development activities. Where activities overlap (for example boulder clearance by SCAR plough, seabed sweeping and subsequent trenching; or the placement of concrete mattresses and rock berms in the same area), the activity covering the bigger footprint has been used to calculate the area affected in order to avoid double-counting.

The sites that will be utilised for spoil deposit from the seabed sweeping activities have not yet been determined and therefore the areas of impact are not quantified below. They will be selected to be as close to the pipeline and flowline routes as reasonably practical, they will be outwith Runswick Bay MCZ (Teesside Pipeline) and the Holderness Offshore and Inshore MCZs (Humber Pipeline), and – where reasonably practical – the sites will be in an area that has previously been subjected to construction disruption. Identification and use of the sites will be subject to future stakeholder consultation under the relevant regulatory regime.

Many of the direct seabed impacts occur only during the installation phase of the Development and are temporary and short-term. Where structures such as rock berms and subsea infrastructure will remain on the surface of the seabed permanently (or at least for the lifetime of the Development), their presence represents a very localised but long-term change to the seabed environment.

The areas of indirect impact presented in Table 6-3, Table 6-4 and Table 6-5 are those areas of seabed that may be affected by sediment re-settling following re-suspension due to Development activities. The indirect area is assumed to be twice the calculated temporary and permanent direct impact areas. This assumption is informed by the review of BERR (2008) which summarises modelled and observed indirect impact extents from sediment re-settlement following cable trenching operations in the SNS. BERR (2008) suggests a possible impact range of 20 m to 200 m, assuming conservatively that all excavated material becomes suspended (which is not expected to happen). An indirect impact area of twice the direct area would fall within the range indicated by BERR (2008) and is reasonable considering the natural suspended sediment level is high as described in Section 6.4.2.2.

Wider potential indirect impacts, for example on the sediment transport regime or on seabird feeding at protected sites outside of the Development area, are discussed in Sections 6.4.2.2 and 6.9.

6.4.1.1 Teesside Pipeline, Teesside – Store Cable, Teesside – SSIV Cable

The area of direct and indirect disturbance associated with each activity along the Teesside Pipeline and cable routes is presented in Table 6-3, which also signposts the relevant part of Chapter 3: Project Description where the information is presented.

As discussed in Section 3.2.1.1, three main options are under consideration for the landfall at Teesside: microtunnel; HDD; and Direct pipe. Direct pipe installation would have the largest seabed footprint due to the requirement for additional pre-cut trenching from the punch-out location at LAT seaward to a water depth of 8 m LAT compared to other options which can punch-out at 5 m or 8 m LAT (see Table 3-3). This option is therefore considered to represent the worst case with respect to the seabed footprint for disturbance and has been used in this assessment.

As discussed in Section 3.2.9, although the Teesside – Store cable and the Teesside – SSIV cable may may be laid within the adjacent pipeline or flowline trenches, installation via separate trenches has been assumed for the purposes of the ES. This represents the worst case as it is likely that the width actually disturbed during cable installation will overlap with that disturbed during pipeline installation.

Table 6-3 - Short and long-term direct and indirect seabed impact areas on the Teesside Pipeline route[148]

Parameter	Seabed footprint/ Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Landfall[149] area					
Pre-cut shore approach trench from punch-out location at LAT to 8 m LAT	1.6- km x 22 m	Section 3.2.1.1, Table 3.2.	0.0343	0.0686	None
Working area: trestle structure, over-excavated trench, jackup barge legs, pipelay vessel anchor spread, temporary protection	800 x 800 m	Table 3-2	0.6400	1.2800	None
Nearshore[150] and offshore[151] areas					
Nearshore section boulder clearance area for the pipeline from 8 m LAT to KP7.1	4.4 km x 30 m	Section 3.2.3.2	No increase to impact area: accounted for via pipeline pre-cut trench and temporary storage of dredge spoil	No increase to impact area: accounted for via pipeline pre-cut trench and temporary storage of dredge spoil	None[152]
Nearshore section boulder deposition area 5 m either side of clearance area for the pipeline from 8 m LAT to KP7.1	4.4 km x 10 m	Section 3.2.3.2	Accounted for in permanent direct impact area	No increase to indirect impact area: accounted for via pipeline trenching	0.0441[153]
Nearshore section boulder clearance area for Teesside – Store cable from 8 m LAT to KP7.1	4.4 km x 30 m	Section 3.2.3.2	No increase to impact area: accounted for via cable trenching	No increase to indirect impact area: accounted for via cable trenching	None[152]
Nearshore section boulder deposition area 5 m either side of clearance area for Teesside – Store cable 8 m LAT to KP7.1	4.4 km x 10 m	Section 3.2.3.2	Accounted for in permanent direct impact area	No increase to indirect impact area: accounted for via pipeline trenching	0.0441
Pipeline pre-cut trench (backfilled) from 8 m LAT to KP7.1	4.4 km x 22 m	Section 3.2.1.2	0.0970	0.1940	None
Temporary storage of dredge spoil from pipeline pre-cut trench backfilled from 8 m LAT to KP7.1	4.4 km x 30 m	Section 3.2.1.2	0.1323	0.2645	None
Trench for Teesside – Store cable	106.6 km x 15 m	Section 3.1, Section 3.2.9	1.5984	3.1969	None

[148] Concrete mattresses to protect pipeline tie-in spools and the Teesside – Store Cable on approaches to crossover manifold are included in Table 6-5.
[149] The proposed seaward extent of the landfall area lies approximately 650 m offshore (from MLWS) in a water depth of minimum 8 m LAT Works above MLWS (KP0.9) are outwith the consenting boundary but included here for completeness.
[150] Used here to refer to the area seaward from the landfall area, which requires a pre-cut trench for pipelay (approximately 6.1 km seaward of 8 m LAT):
[151] The area where the pipeline will be surface laid, extending offshore from the end of the pre-cut back-filled trench to the end of the pipeline
[152] There will be permanent impact in the sense that boulders are removed from this area and not replaced. However, the areas involved will be limited to the actual areas previously occupied by any individual boulders and very small, and the boulders themselves (providing a diversity of benthic habitat) will still be present, albeit a few metres away in the deposition area.
[153] This is a highly precautionary approach since the actual amount of boulder deposition depends on the presence of boulders in the clearance area. No additional boulders are being added but they are being moved a short distance from their original positions.

Parameter	Seabed footprint/ Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Trench for Teesside – SSIV cable	7.1 km x 15 m	Section 3.1, Section 3.2.9	0.1063	0.2125	None
SSIV scour protection[154]	30 m x 23 m	Section 3.2.1.3	Accounted for in permanent direct impact area	No increase in indirect impact area accounted for	0.0007
Offshore section boulder clearance area for pipeline, KP7.1 to co-mingling manifold (includes area of seabed sweeping from KP115 to co-mingling manifold and of partial trenching from KP90 to co-mingling manifold)	136.1 km x 30 m	Section 3.2.3.2, Section 3.2.3.3	4.0820	8.1640	None[152]
Offshore section boulder laydown area for pipeline, 5 m wide either side of boulder clearance area	136.1 km x 10 m	Section 3.2.3.2	Accounted for in permanent direct impact area	2.7213	1.3607[6]
Offshore section boulder clearance area for Teesside – Store cable, KP7.1 to co-mingling manifold (assumed to include seabed sweeping from KP115 to co-mingling manifold)	136.1 km x 30 m	Section 3.2.9	4.0820	8.1640	None[152]
Offshore section boulder laydown area for Teesside – Store cable, 5 m wide either side of boulder clearance area	136.1 km x 10 m	Section 3.2.9	Accounted for in permanent direct impact area	2.7213	1.3607[6]
Pipelay vessel anchor placements[155]	4,268 anchor placements x 5.65 m x 4.52 m	Section 3.5[156]	0.1090	0.2180	None
Pipelay vessel anchor line abrasion corridors[157]	4,268 anchor placements x 400 m x 10 m	Section 3.5[9]	17.0700	34.1400	None
Cable lay vessel anchor placements up to 20 m water depth for Teesside – Store cable[155]	129 anchor placements x 5.65 m x 4.52 m	Section 3.2.9	0.0033	0.0066	None
Cable lay vessel anchor line abrasion corridors up to 20 m water depth for Teesside – Store cable[157]	129 anchor placements x 400 m x 10 m	Section 3.2.9	0.5150	1.0301	None
Cable lay vessel anchor placements for Teesside – SSIV cable[155]	213 anchor placements x 5.65 m x 4.52 m	Section 3.2.9	0.0054	0.0109	None
Cable lay vessel anchor line abrasion corridors for Teesside – SSIV cable[157]	213 anchor placements x 400 m x 10 m	Section 3.2.9	0.8500	1.7000	None

[154] *The footprint of the SSIV and its protective structure are not included as they lie within the larger footprint of the SSIV scour protection.*
[155] *Assumes 12 anchors of 5.65 x 4.52 m, repositioned every 400 m along route.*
[156] *Assumes worst case of anchored lay vessels for entire length.*
[157] *Assumes 12 anchor lines of maximum length 1,200 m of which 400 m rests on seabed with lateral movement of up to 10 m.*

Parameter	Seabed footprint/ Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Rock placement for pipeline at ten buried infrastructure crossings	Ten post-lay gravel berms up to 519 m x 15.3 m, total footprint of 61,650 m²	Section 3.2.3.4	Accounted for in permanent direct impact	0.1233	0.0617
Mattresses protruding at ten buried infrastructure crossings for pipeline	Twelve per crossing, each approximately 3 x 6 m	Section 3.2.3.4; Table 3-6	Accounted for in permanent direct impact	No increase to indirect impact area, already accounted for	0.0021
Rock placement for pipeline at one surface crossing	Post-lay gravel berm up to 716 m long and 19 m wide, total footprint of 7,168 m²	Section 3.2.3.4	Accounted for in permanent direct impact	0.0143	0.0072
Rock placement for Teesside – Store cable at ten buried infrastructure crossings	Ten post-lay gravel berms up to 246 m long and 12 m wide, total footprint of 20,440 m²	Section 3.2.9	Accounted for in permanent direct impact	0.0409	0.0204
Mattresses protruding at ten buried infrastructure crossings for Teesside – Store cable	Eight per crossing, each approximately 6 x 3 m	Section 3.2.9; Table 3-10	Accounted for in permanent direct impact	No increase to indirect impact area already accounted for	0.0014
Rock placement for Teesside – Store cable at one surface crossing	Post-lay gravel berm up to 242 m x 15 m, total footprint of 2,123 m²	Section 3.2.9	Accounted for in permanent direct impact	0.0042	0.0021
Surface-laid portions of pipeline with no rock protection (includes spool pieces) from KP7.1 to Store	94.5 km x 0.7 m	Section 3.2.4; Figure 3-15	No increase to temp. impact area already accounted for	No increase to temp. impact area already accounted for	0.0672
Rock placement at three pipeline trench transitions	200 m x 7 m	Section 3.2.5; Table 3-7	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0042
Rock placement to protect pipeline and mitigate insufficient pipeline burial	Worst case of 5% of 106.5 km length and 100% of 35.6 km length (40.9 km x 9 m)	Section 3.2.5; Table 3-7	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.4129
Rock placement to protect Teesside – Store cable	Worst case of 5% of 106.5 km length and 100% of 35.6 km length (40.9 km x 5 m)	Section 3.2.9; Table 3-9	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.1882
Rock placement to protect Teesside – SSIV cable	10% of total cable length of 7.1 km (710 m x 3 m)	Section 3.2.9; Table 3-9	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0032
Concrete mattresses to protect exposed spool-pieces and sections of untrenched cable in vicinity of SSIV	50 mattresses, each 6 m x 3 m	Section 3.2.5, Table 3-8.	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0009
Total area of short-term direct disturbance (km²)			**29.2907**		
Total area of short-term indirect disturbance (km²)				**64.2069**	
Total area of long-term impact (km²)					**3.5818**

6.4.1.2 Humber Pipeline

The area of direct and indirect disturbance associated with each activity along the Humber Pipeline is presented in Table 6-4.

As discussed in Section 3.2.2.1, four options are under consideration for the Humber Pipeline landfall:

- HDD;
- Direct pipe;
- Microtunnel; and
- Microtunnel with cofferdam.

The microtunnel and microtunnel with cofferdam options would have the largest subtidal seabed footprint due to the requirement for greater additional pre-cut trenching from the punch-out location seaward to a water depth of 8 m LAT compared to other options which either punch-out at 8 m LAT (HDD option) or require a shorter pre-cut trench. In addition, the microtunnel with cofferdam option has a larger intertidal footprint due to the requirement for a beach access route, work platform and cofferdam (see Table 3-4). This option is, therefore, considered to represent the worst case with respect to potential impacts from seabed disturbance and has been used in this assessment, noting that works above MLWS are outwith the offshore consenting boundary.

Table 6-4 - Short and long-term direct and indirect seabed impact areas on the Humber Pipeline route[158]

Parameter	Seabed footprint / Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Landfall[159] areas					
Beach access route (vehicular access to cofferdam)	400 m x 6 m	Table 3-3	0.0024	0.0048	None
Beach working platform	40 m x 25 m	Table 3-3	0.0010	0.0020	None
Cofferdam	100 m x 7 m	Table 3-3	0.0007	0.0014	None
Pre-cut shore approach trench: end of cofferdam to 8 m LAT (KP1.0)	700 m x 52 m	Section 3.2.2.2; Table 3-3	0.0364	0.0728	None
Landfall working area including jackup barge legs, pipelay vessel anchor spread, temporary protection	800 m x 800 m	Table 3-3	0.6400	1.2800	None
Nearshore[160] and offshore[161] areas					
Nearshore section boulder clearance area (8 m LAT (KP1.0) to KP2)	1 km x 60 m	Section 3.2.3.2	No increase to impact area accounted for via pipeline trenching and temporary storage of dredge spoil	No increase to impact area accounted for via pipeline trenching and temporary storage of dredge spoil	None[162]
Nearshore section boulder clearance area (KP2 to KP16.3)	14.3 km x 30 m	Section 3.2.3.2	No increase to impact area accounted for via pipeline trenching and temporary storage of dredge spoil	No increase to impact area accounted for via pipeline trenching and temporary storage of dredge spoil	None[15]
Nearshore section boulder deposition area 5 m either side of clearance area (8 m LAT (KP1.0) to KP16.3)	15.3 km x 10 m	Section 3.2.3.2	Accounted for in permanent direct impact area	No increase to impact area accounted for via pipeline trenching	0.1530[163]
Pipeline pre-cut backfilled trench from 8 m LAT (KP1.0) to KP2	1 km x 52 m	Section 3.2.2.2	0.0526	0.1051	None
Pipeline pre-cut backfilled trench from KP2 to KP16.3	14.3 km x 22 m	Section 3.2.2.2	0.3146	0.6292	None
Temporary storage of dredge spoil from pipeline pre-cut backfilled trench from 8 m LAT (KP1.0) to KP16.3	15.3 km x 30 m	Section 3.2.2.2	0.4590	0.9180	None
Offshore section boulder clearance area from KP16.3 to co-mingling manifold (includes area of seabed sweeping and partial trenching from KP60 to co-mingling manifold)	84.4 km x 30 m	Section 3.2.3.2	2.5309	5.062	None[15]

[158] Concrete mattresses to protect pipeline on approaches to crossover manifold are included in Table 6-5.
[159] The proposed seaward extent of the landfall area lies approximately 650 m offshore (from MLWS) in a water depth of minimum 8 m LAT. Works above MLWS (KP0.4) are outwith the consenting boundary but included here for completeness.
[160] Used here to refer to the area seaward from the landfall area, which requires a pre-cut trench for pipelay.
[161] The area where the pipeline will be surface laid and/or partially trenched, extending offshore from the end of the pre-cut trench to the end of the pipeline.
[162] There will be permanent impact in the sense that boulders are removed from this area and not replaced. However, the areas involved will be limited to the actual areas previously occupied by individual boulders and very small, and the boulders themselves (providing a diversity of benthic habitat) will still be present, albeit a few metres away in the deposition area.
[163] This is a highly precautionary approach since the actual amount of boulder deposition depends on the presence of boulders in the clearance area. No additional boulders are being added but they are being moved a short distance from their original positions.

Parameter	Seabed footprint / Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Offshore section boulder deposition area (5 m wide either side of boulder clearance area)	84.4 km x 10 m	Section 3.2.3.2	Accounted for in permanent direct impact area	1.6873	0.8436[16]
Pipelay vessel anchor placements[164]	3,009 anchor placements x 5.65 m x 4.52 m	Section 3.2.4	0.0768	0.1537	None
Pipelay vessel anchor line abrasion corridors[165].	3,009 anchor placements x 400 m x 10 m	Section 3.2.4	12.0360	24.0720	None
Rock placement at two crossings	Two post-lay gravel berms, one up to 519 m x 15.3 m, one up to 716 m x 19 m, total footprint of 13,333 m^2	Section 3.2.3.4; Table 3-5; Table 3-6	Accounted for in permanent direct impact	0.0267	0.0133
Mattresses protruding at one buried infrastructure crossing	Twelve mattresses, each approximately 3 x 6 m	Section 3.2.3.4; Table 3-6	Accounted for in permanent direct impact	0.0004	0.0002
Surface-laid portions of pipeline (includes spool pieces) between KP16.3 and co-mingling manifold	84.4 km x 0.7 m	Section 3.2.4; Figure 3-15	No increase to temp. impact area already accounted for	No increase to temp. impact area already accounted for	0.0600
Rock placement at one pipeline trench transition	200 m x 7 m	Section 3.2.5; Table 3-7	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0014
Nearshore (10 m LAT (KP1.2) to KP6) rock placement to protect pipeline and mitigate insufficient burial (worst case of 7.5% of this portion)	0.4 km x 13 m	Section 3.2.5; Table 3-7	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0047
Rest of route (KP6 to co-mingling manifold) rock placement (5%)	4.8 km x 10 m	Section 3.2.5; Table 3-7	Accounted for in permanent direct impact	No increase to temp. impact area already accounted for	0.0478
Total area of short-term direct disturbance (km²)			**16.1504**		
Total area of short-term indirect disturbance (km²)				**34.0152**	
Total area of long-term impact (km²)					**1.1241**

[164] *Assumes 12 anchors of 5.65 x 4.52 m, repositioned every 400 m along route.*
[165] *Assumes 12 anchor lines of maximum length 1,200 m of which 400 m rests on seabed with lateral movement of up to 10 m*

6.4.1.3 Endurance Store Area

The area of direct and indirect disturbance associated with each activity in the Endurance Store area is presented in Table 6-5.

At the Bunter Sandstone Outcrop area, the only source of seabed disturbance will be the possible deployment of a seabed lander as part of the MP described in Section 3.4.6. To assess the worst case seabed disturbance impact, it is assumed that a lander will be permanently deployed in the Bunter Sandstone Outcrop area for the lifetime of the Development. It would occupy an area of seabed of 3 m by 2.4 m, resulting in a permanent area of direct disturbance of 7.2 m^2 (0.000007 km^2). A temporary area of indirect seabed disturbance may occur during initial deployment and any subsequent removals/redeployments of 14.4 m^2 (0.000014 km^2).

Table 6-5 - Short and long-term direct and indirect seabed impact areas in the Endurance Store area

Parameter	Seabed footprint / Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km^2)
			Direct area (km^2)	Indirect area (km^2)	
Placement and removal of jackup rig legs at each of six wells	Three spud cans each 18 m diameter	Section 3.3.2	0.0046	0.0092	None
Seabed sweeping along 6 km infield pipeline, the five 3 km flowlines and infield cables[166]	Total of 51 km x 30 m	Section 3.2.8.2; Section 3.2.9,	1.5300	3.0600	None
Trenching of five infield flowlines	5 x 2.6 km x 12 m	Section 3.2.8.2	No increase to impact area accounted for via seabed sweeping	No increase to impact area accounted for via seabed sweeping	None
Trenching of infield cables between manifolds (8 km), between wells & manifolds (5 x 3 km), to monitoring well (7 km)	Total of 30 km x 15 m	Section 3.2.8.2; Table 3-12	No increase to impact area accounted for via seabed sweeping	No increase to impact area accounted for via seabed sweeping	None
Offshore pipelay vessel anchor placements[167]	630 anchor placements x 5.65 m x 4.52 m	Section 3.2.8.2	0.0161	0.0322	None
Offshore pipelay vessel anchor line abrasion corridors[168]	630 anchor placements x 400 m x 10 m	Section 3.2.8.2	2.5200	5.0400	None
Co-mingling manifold including scour mitigation	32 m x 28 m	Section 3.2.8.1	Accounted for in permanent direct impact area	0.0018	0.0009
Four-slot manifold and scour mitigation	36 m x 22 m	Section 3.2.8.1	Accounted for in permanent direct impact area	0.0016	0.0008
Pig receiver at each of the two manifolds	2 x 10 m x 4 m	Section 3.2.8.1	Accounted for in permanent direct impact area	0.0002	0.0001
Three seabed landers as part of MP	Each 3 m x 2.4 m	Section 3.4.7	Accounted for in permanent direct impact area	<0.0001	<0.0001[169]
Up to fifty concrete plinths for 4D gravimetry	Each 2 m^2	Section 3.4.7	Accounted for in permanent direct impact area	0.0002	0.0001
Surface-laid infield pipeline connecting the manifolds (includes spool pieces)	6 km x 0.7 m	Section 3.2.8.1	Accounted for in permanent direct impact area	No increase to temp. impact area already accounted for	0.0043
Six wellhead trees	Each 5 m x 5 m	Section 3.2.8.1; Table 3-12	Accounted for in permanent direct impact area	0.0003	0.0002

[166] *Includes area of partial trenching of infield pipeline, which is therefore not shown separately*
[167] *Assumes 12 anchors of 5.65 x 4.52 m, repositioned every 400 m along routes.*
[168] *Assumes 12 anchor lines of maximum length 1,200 m of which 400 m rests on seabed with lateral movement of up to 10 m*
[169] *Areas of less than 0.0001 km^2 are not shown here but are included in total impact area.*

Parameter	Seabed footprint / Assumptions	Information source	Temporary impact during construction		Permanent direct impact area (presence) during operation (km²)
			Direct area (km²)	Indirect area (km²)	
Concrete mattresses at approaches to manifolds and wells	630 mattresses, each 6 m x 3 m	Section 3.2.8.2	Accounted for in permanent direct impact area	0.0227	0.0113
Rock placement at ten trench transitions (two per infield flowline)	Ten rock berms each 200 m x 7 m	Table 3-7	Accounted for in permanent direct impact area	0.0280	0.0140
Rock placement along five infield flowlines (maximum of 10% of each 3 km flowline with berm width of 7 m)	1.5 km x 7 m	Table 3-7	Accounted for in permanent direct impact area	No increase to temp. impact area already accounted for	0.0105
Rock placement along infield pipeline (maximum of 10% of 6 km pipeline)	0.6 km x 10 m	Section 3.2.8.2	Accounted for in permanent direct impact area	No increase to temp. impact area already accounted for	0.0060
Rock placement along infield cables (maximum of 10% of 30 km)	3 km x 7 m	Table 3-9	Accounted for in permanent direct impact area	Does not increase area of impact already accounted for	0.0133
Total area of short-term direct disturbance (km²)			**4.0707**		
Total area of short-term indirect disturbance (km²)				**8.1961**	
Total area of long-term impact (km²)					**0.0615**

6.4.2 Description of Potential Impacts

Direct impacts generally occur immediately upon an action being taken, while indirect impacts may occur after a delay since they result from a causal chain of events leading back to the initial action. Potential direct impacts associated with the Development are discussed in Section 6.4.2.1 and indirect impacts are discussed in Section 6.4.2.2. In addition, the carbon sequestration potential of seabed habitats in the Development area is discussed in Section 6.7.

Consideration is given to installation activities (including seabed preparation) and to normal O&M. Decommissioning activities are discussed in Section 6.8.

The management and mitigation measures applicable to this assessment are presented in Section 6.5 and included in the overall commitments register (Appendix C).

Potential transboundary and cumulative impacts and impacts on protected sites could occur as a result of the Development activities; these are discussed in Sections 6.6 and 6.9 respectively.

6.4.2.1 Potential Direct Impacts

6.4.2.1.1 Summary of direct impacts

Direct impacts may result from the removal or disturbance of seabed[170] sediments or boulders and from the deposition or placement of material on the seabed. Direct impacts may be temporary, for example from pipeline and cable trenching, deposition of dredge spoil or use of anchors and jackup drilling rigs during the installation stage; or long-term/permanent in the case of placement of rock armour, surface-laid pipelines or subsea infrastructure such as manifolds.

Depending on the precise nature of the installation activity, benthic fauna (epifauna and infauna) within the seabed footprint of these activities may be disturbed, damaged or crushed, displaced into the water column or displaced into spoil heaps. The species and habitats affected may be of conservation importance or features of protected sites (the latter are assessed in detail in Section 6.9). Direct impacts may also include disturbance of habitats important for fish, such as spawning grounds, or for seabird feeding activity. All of these kinds of impact are considered as temporary, since the impact mechanism is short-term, and the potential and timescales for recovery are considered in the assessments below. In contrast, there is potential for damage to marine archaeological features within the footprint of the activities which, should it occur, would be regarded as permanent.

The long-term or permanent presence of rock protection, surface-laid pipeline and infrastructure on the seabed will introduce additional areas of hard substrate. Boulder clearance activities will result in increased concentrations of rocks and boulders to the sides of the pipeline corridor. These areas may provide suitable habitat for reef biota, encouraging the development of new reef habitat. Conversely, boulder clearance and ridge flattening will remove any potential reef habitat from within the trenching corridor.

The installation activities, and topographical changes due to the presence of structures on the seabed, also have the potential to cause direct impacts on the local hydrodynamic regime. The potential for such impacts to lead to changes in seabed habitats or to affect wider-scale coastal processes is considered in 6.4.2.2.

[170] *Seabed refers to both intertidal and subtidal areas.*

6.4.2.1.2 Consequences to benthic ecology

During the installation of the pipelines and cables and the subsea infrastructure at the Endurance Store area, the benthos will be exposed to short-term direct impacts associated with disturbance of sediment and boulders and the placement of infrastructure on the seabed. This disturbance will include sporadic clearance of boulders, smoothing of the seabed profile, displacement of sediment and overturning of sediment layers. In addition, along the pipeline, cable and flowline routes, pipelay and cable lay vessel anchors will penetrate the sediment, and anchor chains and wires will be dragged across the seabed, abrading the surface layers. The spud cans of the jackup rig will penetrate the seabed during drilling of the injection wells. Within the affected areas, epifauna and infauna will be disturbed to a greater or lesser degree. Mobile epifauna may leave the area, while sessile fauna will be vulnerable to the various activities described above.

In the longer term, the presence of the infrastructure that remains on the seabed surface, such as rock protection, surface-laid portions of the pipelines, the SSIV and the subsea infrastructure in the Endurance Store area, will represent highly localised changes to the seabed habitat, where sandy and mixed sediment types are overlain with hard substratum.

Quantification of the maximum areas that could be affected along the pipeline and cable routes and in the Endurance Store area, temporarily or permanently, is provided in Table 6-3, Table 6-4 and Table 6-5.

With respect to temporary disturbance, seabed preparation and trenching, temporary storage of dredge spoil and backfilling activities along the pipeline and cable routes will disturb a corridor of maximum 85 m width in the nearshore parts of the Teesside Pipeline (Table 6-3), under the worst case scenario in which the Teesside – SSIV and Teesside – Store cables are installed in completely separate trenches from the pipeline. For the Humber Pipeline, the combined pipeline trenching activities will disturb a corridor 83 m wide as far as KP2, after which the corridor reduces to a maximum of 52 m (Table 6-4). Outside of the immediate pipeline and cable corridors, further sporadic disturbance will be caused by the placement and removal of anchors and the lateral movement of the anchor chains and wires across the seabed as the pipelay barge is pulled forward. Total areas of approximately 18.6 km^2 (Teesside Pipeline, Teesside – SSIV cable and Teesside – Store cable) and 12.1 km^2 (Humber Pipeline) may be directly disturbed by pipelay barge anchoring activities, i.e. the single biggest area of temporary impact from Development activities.

With respect to the permanent presence of structures on the seabed, rock-armour or concrete mattressing installed for pipeline protection at transitions and crossings, and as mitigation against scour and areas of unexpected upheaval buckling (using worst case assumptions), and the surface-laid portions of the pipelines not protected by rock will introduce a total of approximately 3.58 km^2 of new hard substrate along the Teesside Pipeline route (Table 6-3) and 1.12 km^2. Along the Humber Pipeline route (Table 6-4). The areas covered by new hard substrate will fall within areas already disturbed by boulder clearance, trenching and pipelay activities, or by previous industry activity (the cable and pipeline crossings).

At the Endurance Store area, the subsea infrastructure required to receive, inject and monitor CO_2 (infield pipeline, well-head trees, manifolds, flowlines and landers) and their required protection structures will introduce a total of approximately 0.06 km^2 of new hard substrate (Table 6-5). Much of the area covered will already have been disturbed during installation activities as described above, and by the drilling of the wells (Section 8.4.1).

Several habitat types are present in the Development area as described in Section 4.4.2 and summarised below for the Teesside Pipeline, Humber Pipeline and Endurance Store and Bunter Sandstone Outcrop areas.

- **Teesside Pipeline route**: The intertidal area landward of the Teesside landfall was categorised by Gardline (2022b) as EUNIS habitats A2.21 'Strandline' and A2.22 'Barren or amphipod-dominated mobile sand shores'. The sandy subtidal stations at the nearshore end of the Teesside Pipeline route out to Station ENV-08 (KPS7.2) were notably sparse, with very few visible fauna or features. EUNIS habitat A5.23 'Infralittoral fine sand' was assigned for those nearshore stations where water depths were <20 m LAT, from ENV-02 (KPS1.3) to ENV-05 (KPS4). The rest of the nearshore area, and the offshore area up to depths of 50 m LAT, consisted predominantly of mixed sediments categorised as A5.44 'Circalittoral mixed sediment'. Some areas contained more rocky substratum, with individual sampling stations identified as A4.22 'Sabellaria reefs on circalittoral rock' (see further discussion below) and A4.27 'Faunal communities on deep moderate energy circalittoral rock'. At the offshore end of the pipeline route, where water depths generally exceeded 50 m, the seabed was classed as A5.27 'Deep circalittoral sand', although two stations (ENV-83 and ENV-84) which coincided with an area of shallower seabed in this region were categorised as A5.25 'Circalittoral fine sand'.
- **Humber Pipeline route:** The sandy intertidal areas landward of the Humber landfall were categorised as A2.21 'Strandline' and A2.22 'Barren or amphipod-dominated mobile sand shores', while the more gravelly intertidal areas were categorised as A2.11 'Shingle (pebble) and gravel shores' or A2.43 'Species-poor mixed sediment shores'. At the shallowest subtidal stations close to shore, the seabed habitat was mostly classified as A5.43 'Infralittoral mixed sediment'. Seaward of this, the seabed was mostly A5.44 'Circalittoral mixed sediment', with A4.27 'Faunal communities on deep moderate energy circalittoral rock' recorded at one station. The deeper parts of the pipeline route were A5.45 Deep circalittoral mixed sediment and A5.27 'Deep circalittoral sand', with A5.25 'Circalittoral fine sand' recorded where the offshore water shallows to < 50 m.
- **Endurance Store area:** Much of the Endurance Store surveyed area was considered to be representative of A5.27 'Deep circalittoral sand'. A few stations were slightly shallower, with coarser sediments, and classified as A5.44 'Circalittoral mixed sediments'. The habitat at one station was categorised as A4.22 'Sabellaria reefs on circalittoral rock'. This is discussed further below. As discussed in Section 4.4.2.1, relatively low faunal abundance and diversity was recorded across the predominantly sandy seabed in the Endurance Store area. In contrast, the more heterogeneous seabed in the Bunter Sandstone Outcrop area (gravelly sand with cobbles and boulders) supported a more abundant fauna including a variety of epifaunal filter-feeding species.

The site-specific surveys also provide detailed information on the occurrence of species and habitats of conservation interest within the Development area as described in Section 4.4.2. The key findings are summarised below.

- **Sandbanks:** 'Sandbanks, which are slightly covered by seawater all of the time' are listed under Annex I of the Habitats Directive (1992). The mixed and gravelly shallow subtidal parts of the Humber Pipeline route closest to shore (landward of station ENV-97; KPS16) reached depths of <20 m LAT. The fauna community observed in this area was broadly consistent with a gravelly sandbank, as described by JNCC (2020b) which is characterised by foliose seaweeds, hydroids, bryozoans and ascidians. No other potential sandbanks were observed in the Development area.

- **Sabellaria reef:** Reefs formed from *Sabellaria spinulosa* are protected as 'biogenic reefs' under Annex I of the Habitats Directive. As discussed in Section 4.4.2, *S. spinulosa* was found in all of the survey areas (though not always as a reef, and thus Annex I habitat), and was most widespread along the Teesside Pipeline route on areas of circalittoral mixed or rocky seabed. Of the reef outcrops identified in the offshore part of the Teesside Pipeline route, most were assessed as having low resemblance to biogenic reef. One station (DC-150) was assessed as having 'high' resemblance to a biogenic reef, while those at three other stations were assessed as being of 'medium' reefiness. One station on the Humber Pipeline route, and two at the Endurance Store area, were considered to show low resemblance to biogenic reef, while occurrences of *S. spinulosa* at the Bunter Sandstone Outcrop area showed low resemblance to biogenic reef.
- **Rocky reef:** Reefs are a habitat of conservation significance listed under Annex I of the Habitats Directive (1992) for protection within SACs. Across the whole survey area, 45 stations were found to resemble rocky reefs, 39 with low resemblance, and 6 with moderate resemblance; none were found with high resemblance. The majority of the potential reef areas were on the inshore part of the Teesside Pipeline route from sampling stations DC-10 to ENV-42 (KPS9 to KPS40.8) and broadly corresponded with areas of known bedrock and rocky reef. Thirteen inshore stations with a low resemblance to rocky reef were found on inshore parts of the Humber Pipeline. This low resemblance rocky reef was consistent across samples located within the Holderness Inshore MCZ. A full assessment of the potential for impacts in the MCZ is included in Section 6.8. As described in Section 4.3.3.3, XOGS (2023) re-examined the geophysical data and seabed photography obtained during the site-specific surveys in order to provide further definition of linear ridges observed in the bathymetric data. The study reported a series of elongated ridges, 20 – 70 m long, up to 15 m wide and up to 4 m high, oriented roughly parallel to the coastline. Although interpreted as likely clay-cored ridges associated with the Bolders Bank Formation as described below, they are covered in gravel, pebbles and cobbles. The portion of the pipeline that passes through the ridges (KPS3 to KPS16) coincides with the general area within which Gardline (2022b) recorded low resemblance rocky reef (although no samples were taken at the tops of the ridges themselves).
- **Peat and clay outcrops:** Peat and clay exposures are a marine habitat of principal importance in England (Defra and Natural England, 2022) and a UK Biodiversity Action Plan (UKBAP) priority habitat (JNCC, 2008b). Section 4.4.2.2 describes the records of clay/chalk outcrops at two stations along the Teesside Pipeline route. EUNIS habitats A4.23 'Communities on soft circalittoral rock' and A4.231 'Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay' were not used due to limited evidence of piddocks in the survey images; there were isolated images of clay where piddocks were seen but there was insufficient evidence to classify any stations within this category. During reanalysis of the site-specific survey data for the Humber Pipeline route, XOGS (2023) identified the presence of frequent protruding clay mounds and ridges, up to 1.5 m high, in the shallow nearshore area up to KPS1. Between KPS3 and KPS16, a series of larger, linear ridges were described, lying approximately parallel to the coastline and reaching up to 4 m high. The underlying deposits in for both kinds of mounds/ridges are expected to be part of the Bolders Bank Formation, which is exposed in areas as clay protrusions (XOGS, 2023).

- **Ocean quahog:** The ocean quahog *Arctica islandica* is a long-lived bivalve mollusc which is featured on the OSPAR (2008) list of threatened and/or declining species and found throughout much of the North Sea. It was observed in seabed imagery at 17 stations along the Teesside Pipeline route, one station on the Humber Pipeline route and two stations in the Bunter Sandstone Outcrop area. Grab samples from the Teesside Pipeline route also contained several juvenile and one adult *A. islandica*. Some juveniles were also recorded from the Humber Pipeline route and Bunter Sandstone Outcrop area, but in lower numbers.

Figure 6-1 and Figure 6-2 show the EUNIS habitat types identified and the findings of the reefiness assessments within the Development area, together with the maximum zone of impact for temporary (short-term during installation) direct disturbance. To present the worst case, this has been considered as the maximum areas (up to 900 m each side of pipelines and flowlines) within which pipelay vessel anchors may be deployed. Impacts will not occur throughout the whole of this area and will be dependent on actual anchoring locations. Note that thickness of the pipelines as shown on these maps approximates to the width of the boulder clearance and deposition corridor (20 m either side of the pipelines).

Broad scale habitat mapping (EMODnet, 2019) suggests that the dominant habitat complexes present in the Development area are widespread in the region (Figure 6-1 and Figure 6-2). Table 6-6 describes the sensitivity of these habitats to abrasion or disturbance of the seabed, as would be experienced during temporary direct impacts from the Development.

Table 6-6 - Summary of resistance, resilience and sensitivity of habitat complexes in the Development area to abrasion/disturbance of the seabed (Source: MARLIN (2022) and selected supporting publications as listed)

EUNIS level 4 biotope complex	Resistance, resilience and sensitivity to abrasion/disturbance of the surface of the seabed[171]
A4.22 Sabellaria reefs on circalittoral rock A4.27 Faunal communities on deep moderate-energy circalittoral rock[172]	A4.27 was used to denote rocky areas where Sabellaria reef had been identified through imagery, while A4.22 was used to denote rocky areas in the images with no Sabellaria present. Limited information is available for A4.27, which is not included on the MarLIN website. These communities populate hard substrata with low hydrodynamics and strong sedimentation. Empirical evidence to assess the likely recovery rate of *S. spinulosa* reefs from impacts is limited (Gibb *et al.,* 2014). Where reefs are extensively damaged or removed, recovery will rely on larval recolonisation. In naturally disturbed areas, reefs may undergo annual cycles of erosion and recolonisation. Surveys on the North Yorkshire and Northumberland coasts found that areas where *S. spinulosa* had been lost due to winter storms appeared to be recolonised up to the maximum observed thickness (2.4 cm) during the following summer (Holt *et al.,* 1998). Resistance is low, resilience is medium and **sensitivity is medium**.
A5.23 Infralittoral fine sand	A5.231 Infralittoral mobile clean sand with sparse fauna. The species inhabiting this biotope are characteristic of mobile sediments and adapted to high levels of disturbance. Even following severe disturbance, recovery would be expected to occur within a year. Although resistance is low, resilience is nonetheless high and overall **sensitivity is low** (Fish, 1970; Jones, 1970; MES, 2010).
A5.25 Circalittoral fine sand	A5.251 *Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand A5.252 *Abra prismatica, Bathyporeia elegans* and polychaetes in circalittoral fine sand These biotopes may recover from impacts via in situ repair of damaged individuals, migration of adults of mobile species, and recolonisation by pelagic larvae. Adults may also be transported in the water column following washout from sediments. Resistance is medium, resilience is high and overall **sensitivity is low** (Boyd *et al.,* 2005; Gilkinson *et al.,* 2005; Le Bot *et al.,* 2010).
A5.27 deep circalittoral sand	A5.271 Maldanid polychaetes and *Eudorellopsis deformis* in deep circalittoral sand or muddy sand

[171] *Presented for the specific EUNIS Level 5 biotope recorded in the Development area, where this is provided by Gardline (2022b)*
[172] *Recorded by Gardline (2022a) but no sensitivity information is available from MARLIN; sensivity assessments are based on the relevant EUNIS Level 4 and 5 biotopes recorded.*

EUNIS level 4 biotope complex	Resistance, resilience and sensitivity to abrasion/disturbance of the surface of the seabed[171]
	A5.272 *Owenia fusiformis* and *Amphiura filiformis* in deep circalittoral sand or muddy sand The characteristic species require sand or muddy sand substratum, due to substratum or feeding preferences (e.g. for burial; deposit or suspension feeding). Minor damage to individual echinoderms is likely to be repaired, and recovery from impacts with a small spatial footprint may occur through migration of adults. Where populations are significantly reduced over large areas, recovery will be through recruitment of juveniles, which may occur within 2 years. The *Amphiura* component may recover in 2-10 years following significant disturbance, but recoverability is dependent on the frequency and intensity of disturbance. Resistance is low or medium, resilience is medium and **sensitivity is medium** (MES, 2010; Gilkinson *et al.,* 2005).
A5.43 Infralittoral mixed sediment	The mixed sediments in this biotope complex is an important structural component, providing the complexity required by the associated communities. Epifauna and algae are attached to gravel and pebbles and infauna burrow in the soft underlying sediment. The majority of species in these biotopes are likely to have high recoverability. Resistance is low-medium, resilience is medium-high and **sensitivity is low-medium**.
A5.44 Circalittoral mixed sediment and A5.45 Deep circalittoral mixed sediment	At least some of these habitats were defined by Gardline (2022a) as biotope A5.445 '*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment, which is considered here alongside other circalittoral mixed sediment biotopes. Minor damage to individual brittlestars is likely to be repaired (Tillin and Tyler-Walters, 2014), and recovery from impacts with a small spatial footprint may occur through migration of adults (Groenwold and Fonds, 2000). Resistance is low, resilience is medium and **sensitivity is medium**.

A4.23 Communities on soft circalittoral rock, and A4.231 Piddocks with a sparce associated fauna, are not included in Table 6-6 since there was insufficient evidence to classify any stations within these categories. However, it is known that the occurrence of piddock biotopes is highly dependent on the presence of suitable substratum (sublittoral very soft chalk or clay), which has a restricted distribution (Connor *et al.*, 2004). As recovery of piddocks depends on recolonisation and subsequent growth to adult size (2-10 years), resistance is medium, resilience is very low and sensitivity is medium.

It is expected that the sediment infauna and epifauna within the areas of temporary direct impact will recover in the short to medium term (one to ten years), as will the epifauna that is damaged or disturbed during boulder clearance. As such, boulder clearance is not recorded as a permanent impact in Table 6-3 and Table 6-4. Sediments in much of the Development area are mobile and continuously reworked by wave and current action. Analysis of samples taken from the sediment above the trenched Corvette to Leman pipeline in the SNS indicated no significant differences from samples collected away from the pipeline route, suggesting full recovery of the benthic community had occurred (Centrica, 2010). The Corvette field was brought into production in 1999 and a survey report published in 2003 indicated that recovery had occurred within five years.

Ocean quahog is highly sensitive to abrasion/disturbance of seabed, with low resistance, very low resilience and a sensitivity ranked as high (MARLIN, 2022). Tyler-Walters and Sabatini (2017) report mortality of circa 11% with a single pass of a beam trawl, indicating pipeline trenching and anchor placements will be sufficient to cause some mortality. Conversely, this species is not sensitive to smothering or changes in water clarity making indirect impacts unlikely. Recovery from disturbance is slow, and has been estimated at between 10 and 100 years for populations heavily depleted by targeted fishing (Tyler-Walters and Sabatini, 2017). Individuals in the path of trenching activity or anchor abrasion may be killed, although mortality is not expected to be total. Individuals covered with spoil are likely to survive, as this species has been recorded burrowing to the surface through up to 41 cm of cover.

In relation to the sensitivities of habitats to permanent direct impacts (physical change to another seabed type), all habitats present have no resistance to such changes, very low resilience and consequently high sensitivity. It is important to note that the structures planned to be placed on the seabed will add small amounts of hard substratum to areas of naturally sandy or mixed sediments or rocky seabed. The loss of soft sediment in this context is insignificant. The invertebrate species inhabiting the sediments are largely populated through the settlement of post-larval stages from the planktonic stage of the life-cycle, and therefore additional hard structures such as this will not interfere with the functioning of the surrounding soft-sediment communities. The structures will introduce additional hard substrate which is expected to become colonised in the medium term (within 10 years) by encrusting fauna already colonising rocks and boulders in the area. The seabed area covered by this new hard substratum will be small (approximately 3 km^2) in the context of the available similar habitat. There will also be a change to the distribution of boulders on the seabed along the disturbance corridor; however, this is not expected to exert a significant negative impact on the diversity or health of the benthos in the area.

It is not expected that there will be any disturbance to the intertidal zone at Teesside as the landfall installation in this area will be trenchless. In the intertidal zone of the Humber Pipeline, a worst case area of approximately 0.0041 km^2 will be exposed to direct disturbance due to the construction and use of the beach access route, beach working platform and cofferdam, should the microtunnel and cofferdam landfall option be selected. Four biotopes are expected to be subject to disturbance: A2.21 ‘Strandline’ at the upper shore, A2.22 ‘Barren or amphipod-dominated mobile sand shores’ on the mid/lower shore together with areas of A2.11 ‘Shingle (pebble) and gravel shores’ and A2.43 ‘Species-poor mixed sediment shores’.

It is anticipated that any disturbance to the beach at Humber will be temporary and it is anticipated that the beach will be fully reinstated following completion of installation operations.

The potentially impacted intertidal biotopes are naturally subject to frequent extensive disturbance by wave action.

Most mobile sand shores support a limited range of species. Bands of gravel and shingle may be present on the upper shore of exposed beaches. A strandline of talitrid amphipods typically develops at the top of the shore where decaying seaweed accumulates. Mobile sand shores may show significant seasonal changes, with sediment accretion during calm summer periods and beach erosion during more stormy winter months (Tillin, 2018). All of the intertidal biotopes recorded in the Development area have low sensitivity to abrasion or disturbance of the substratum or seabed and to penetration or disturbance of the substratum subsurface (Tillin and Budd, 2004; Tillin *et al.,* 2019; Tillin and Hill, 2016a, b). Given the low sensitivity of the biotopes present in the intertidal zones, the small physical footprint and the temporary nature of the disturbance, there are not expected to be significant impacts on intertidal ecology.

6.4.2.1.3 Consequences to fish and shellfish

Direct seabed impacts to adult and sub-adult fish (Section 4.4.3) are anticipated to be limited to disturbance or mortality from crushing or smothering during trenching and backfilling activities. Fish are generally highly mobile and sensitive to pressure changes and visual stimuli and it is therefore expected that the majority of fish in the path of the proposed operations will avoid physical damage. Given the wide area of similar habitat available and the temporary nature of the operations it is expected that fish will move outside the area of disturbance while installation activities are ongoing, and the Development area will be rapidly re-colonised following the cessation of installation activities.

The shellfish identified as being present in the area are also generally mobile, although brown crab, lobster and scallops are less capable of moving rapidly away from disturbance and may therefore tend to be subject to crushing or smothering. Individuals that are unearthed from the sediment or buried under sediment are likely to survive and re-establish themselves. Given the wide area of similar habitat available and the ongoing fishery activities in the area (which in themselves suggest reasonable rates of recovery), the proposed operations are not expected to have a significant direct impact on fish or shellfish populations.

Given that offshore installation is expected to take place between March and September, the works may coincide with spawning periods for herring, lemon sole, sprat, plaice, whiting, sole (nearshore part of Humber Pipeline route only) and *Nephrops* (nearshore part of Teesside Pipeline route only; Coull *et al.*, 1998). The majority of these species spawn in the water column over large areas, therefore the proposed operations are expected to affect only a small proportion of the spawning adults, spawn and juveniles of each affected species.

Sandeel and herring spawning are considered more vulnerable to seabed disturbance because these species spawn on the seabed and have very specific and limiting benthic habitat requirements. As described in Sections 4.4.3.2 and 4.4.3.3, ‘Preferred’ herring spawning potential was noted at only four locations on the Teesside Pipeline route and three stations on the Humber Pipeline route, with no stations meeting the full criteria for suitable herring spawning areas (Gardline, 2022b).

Pipeline installation activity, including nearshore trench backfill, offshore pipelay and rock placement, all of which require calmer summer weather, is expected to occur between April and September. This overlaps with the expected herring spawning period of August to October. Given the low potential for herring spawning in the Development area and, the small area of potential herring spawning ground that would be affected compared to the area available, it is considered unlikely that the Development will have a significant direct impact on herring spawning.

With the exception of stations ENV-142 ('Suitable') and ENV-143 ('Prime'), the Endurance Store was unsuitable for sandeel spawning. The seabed was assessed as being 'Prime', 'Sub-Prime' or 'Suitable' for sandeel spawning at several stations distributed along the Teesside Pipeline route, most consistently between ENV-77 (KPS110.7) to ENV-84 (KPS124.7). Good potential for sandeel spawning, consisting of 'Preferred' and 'Suitable' habitats was recorded along the mid-section of the Humber Pipeline route. One station (ENV-122) was classified as 'Preferred' and 'Sub-Prime' therefore has the highest suitability along the route. Sandeel were present in grab samples acquired at four stations along the Humber Pipeline route (mostly ≥KPS90) which corresponded to areas of predominantly sandy substrate (Gardline, 2022b). Although use of some part of the Development area by sandeel is apparent, sandeel spawn during the winter months (MacDonald *et al.,* 2019) and therefore it is unlikely that installation activities will have any direct impact on sandeel spawning and recruitment.

The Development is not likely to cause disturbance to fish spawning or recruitment at the population level and is therefore not expected to result in significant direct impacts.

6.4.2.1.4 Consequences to birds

Habitat loss may result in the removal or fragmentation of habitat supporting the prey species of foraging seabirds. Long-term habitat loss associated with pipeline and drilling projects is generally relatively small in spatial extent, amounting to the area lost to installed infrastructure. Short-term habitat loss associated with construction processes such as pipeline trenching will be larger. Habitat loss can be direct (removal of benthic substrate) or indirect (loss of prey species due to reductions, through suspended sediment or smothering, in benthic organisms upon which prey species may feed). In general, habitat loss impacts are likely to be temporary, local, occurring during construction and not in operation. Habitat loss may occur during construction of all aspects of the Development.

Current schedule estimates for the Development are presented in Section 3.1.2.

The sensitivity of birds to habitat loss varies with species. Those species and species groups that are less sensitive to habitat loss include fulmar, gannet, shearwaters, petrels and gulls: species that have large foraging ranges and are able to exploit a variety of different habitats. Species that are sensitive to habitat loss generally have smaller foraging ranges and/or utilise fewer specific habitats.

The Ornithological Technical Report (NIRAS, 2023) identified Valued Ornithological Receptors (VORs) based on the distribution and conservation of species in the SNS and their species-specific sensitivity to impacts associated with the Development, using the sensitivity scores presented in Wade *et al.* (2016)[173] and Bradbury *et al.* (2014). To determine which species require consideration in this assessment, the sensitivity of each species to habitat loss and the species' habitat flexibility is presented in Table 6-7. Those species which are largely restricted to foraging in shallower, nearshore waters (e.g. little tern and red-throated diver) are more likely to be sensitive to the impacts on habitats that support their prey species on the basis they are unable to utilise alternative foraging areas further offshore. Fulmar, gannet, guillemot, razorbill and puffin are not restricted to foraging in shallow, nearshore waters and therefore have negligible sensitivity impacts on the seabed (Snow and Perrins, 2008).

[173] *Sensitivity scores presented in Wade et al. (2016) are for impacts relating to OWFs. Therefore, this is considered to be conservative when compared to the impacts associated with the Development.*

Table 6-7 - Summary of the sensitivity of Valued Ornithological Receptors (VORs) Identified for the Development to habitat loss (Niras, 2023)

Species	Sensitivity
Kittiwake (*Rissa tridactyla*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Great black-back gull (*Larus marinus*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Sandwich tern (*Thalasseus sandvicensis*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Little tern (*Sternula albifrons*)	- High sensitivity to habitat loss - Low habitat flexibility.
Common tern (*Sterna hirundo*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Artic tern (*Sterna paradisaea*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Common guillemot (*Uria aalge*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Razorbill (*Alca torda*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Puffin (*Fratercula arctica*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Red-throated diver (*Gavia stellata*)	- High sensitivity to habitat loss - Low habitat flexibility.
Gannet (*Morus bassanus*)	- Low sensitivity to habitat loss - High habitat flexibility.
Shag (*Phalacrocorax aristotelis*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.
Cormorant (*Phalacrocorax carbo*)	- Moderate sensitivity to habitat loss - Moderate habitat flexibility.

Based on the scores presented in Table 6-7, the following species are therefore considered in relation to habitat loss impacts associated with the development:

- Red-throated diver; and
- Little tern.

Both of these species have low habitat flexibilities whilst also being highly sensitive to the likely impacts associated with the Development. Although other species are also highly or moderately sensitivity to habitat loss, these species are able to exploit a large area and/or a wider range of habitats and are therefore discounted from further assessment. The impact of seabed habitat loss to opportunistic, kleptoparasitic and surface-feeding seabirds such as kittiwake and great black-backed gull will be negligible and therefore these species are not considered further.

Red-throated diver and little tern, as they occur in relation to the Development, are designated features of SPAs: red-throated diver as a non-breeding feature at the Greater Wash SPA and little tern as a breeding feature at the Humber Estuary SPA. The Humber Pipeline passes through the Greater Wash SPA and is located approximately 3 km to the north of Easington Lagoons, where the breeding colony for little tern within the Humber Estuary SPA is located. Site-specific tracking data suggest that little tern from the breeding colony may utilise the area in which the pipeline will be installed for foraging purposes. There are no further populations of concern, meaning activities associated with the Teesside Pipeline and the Endurance Store are not considered further in the assessment.

Construction activities associated with the Humber Pipeline landfall may occur during the period July 2025 to January 2026 and therefore could overlap with the periods during which both red-throated diver and little tern will be present in their respective SPAs. The installation of the nearshore part of the Humber Pipeline may occur between March and September 2026 and therefore could overlap with the period during which red-throated divers will be present in the SNS.

Red-throated diver

Red-throated divers are considered to have a high sensitivity to habitat loss and low habitat flexibility, meaning they are restricted in terms of the habitats they are able to exploit. The nearshore section of the Humber Pipeline will pass through the Greater Wash SPA which is designated for red-throated diver in the non-breeding season (October to March). Lawson *et al.* (2016) suggests that the area through which the Humber Pipeline will pass supports moderate densities of the species. There are unlikely to be significant numbers of red-throated diver in other sea areas through which the Humber Pipeline or Teesside Pipeline will pass or at the Endurance Store area. As construction activities at the Humber landfall may take place between July 2025 and January 2026, they may interact with red-throated divers. Pipelay activities in the nearshore may occur between March and September 2026, and therefore impacts could occur whilst red-throated divers are present in March.

Regardless of the option chosen for landfall construction (HDD, direct pipe, microtunnel or microtunnel and cofferdam), all will require the presence of a jackup barge located in the landfall area. The development schedule indicates that the jackup barge will be present in the nearshore for up to 12 months if the landfall is constructed using HDD. This option is therefore identified as the worst case for habitat loss impacts on red-throated diver and it is assumed that the jackup barge will be present within the key period for red-throated diver. The remaining details of these four methods for the purposes of assessing habitat loss impacts on red-throated diver are considered to be broadly comparable.

The nearshore section of the Humber pipeline, specifically the 11.4 km of the pipeline that passes through the Greater Wash SPA (see Figure 4-31), is the key area for red-throated divers for the purposes of this assessment, although birds do occur outside of the SPA. The density layers associated with the designation of the SPA (Lawson *et al.,* 2016) indicate that densities of red-throated diver are above 0.05 birds/km^2 up to the 20 km point of the pipeline. It is therefore considered that beyond 20 km any effect upon red-throated divers is likely to be insignificant.

As presented in Table 6-4, along the nearshore length of the pipeline where red-throated divers are expected to be present (i.e. to approximately KP19), the total seabed area directly affected during construction would be approximately 0.83 km^2.

The area of seabed directly affected by the presence of the jackup barge required for landfall construction activities and other associated infrastructure is 800 m x 800 m with the barge being a static feature for most of the construction period. The Zone of Influence (ZoI) associated with the landfall construction would therefore be 0.64 km^2. The total affected area of seabed would therefore be 1.47 km^2. This represents approximately 0.04% of the total Greater Wash SPA area or an even smaller proportion of the total area of the SNS used by red-throated divers.

The average density in the area affected is 0.25 birds/km^2. When multiplied by the area potentially affected (1.47 km^2), this provides an affected population of less than one bird. The regional population of red-throated diver in the SNS is 10,177 birds (Furness, 2015). An affected population of less than one bird therefore represents less than 0.01% of the regional population.

Mortality rates associated with the loss of habitat due to construction activities are unknown, with no evidence that loss of habitat will result in direct mortality of individual birds. Mortality as a consequence of displacement is more likely to occur as a result of increased densities outside of the impacted area, which may lead to increased competition for resources. Displacement of birds from low density areas (e.g. the area associated with the pipeline routes) is less likely to result in mortality as these low density areas are likely to be of lower habitat quality. As such, the use of a 1% mortality rate is considered appropriate for this assessment[174].

Applying a 1% mortality rate results in a displacement mortality of less than one bird. This level of impact is considered to be of an insignificant magnitude in relation to the regional population of red-throated diver (10,177 birds). Such a low level of displacement mortality represents less than 0.001% of the regional population of red-throated diver.

The impact is predicted to be adverse in nature, direct, intermittent and affecting an International geographic extent due to the presence of red-throated divers from an SPA within the affected area; however, the actual area affected will be limited when considered against the area available to red-throated divers for foraging and other behaviours. According to the current schedule, construction activities which may affect important areas for red-throated divers may occur between July 2025 and January 2026 and between March and September 2026 (although precise timings within these periods are unknown) and are therefore considered to be short-term. Taking these characteristics into account, the impact is considered to be of negligible magnitude.

Red-throated diver is considered to have a high sensitivity to impacts associated with seabed disturbance (Wade *et al.,* 2016). Red-throated diver is considered to have a low vulnerability to impacts associated with seabed disturbance as it is considered highly unlikely that any impact will affect the long-term status of relevant populations or result in noticeable long-term effects. Red-throated diver is considered to be of high conservation value due to the species being a qualifying feature at the Greater Wash SPA through which the Humber pipeline will pass. The effect of impacts

[174] *A 1% mortality rate is consistent with the rate applied in previous assessments, including those for telecommunications and OWF export cables on the east coast of England.*

associated with seabed disturbance on red-throated diver is therefore considered to be of minor significance.

Little tern

Little tern are considered to be highly sensitive to habitat loss having a low habitat flexibility. The Humber Pipeline makes landfall 3 km to the north of Easington Lagoon, passing through areas potentially used by little terns for foraging. There are a number of construction techniques under consideration for the Humber landfall including HDD, direct pipe, microtunnel or microtunnel and cofferdam. Of these, the option with the largest potential to impact the foraging area of little tern is microtunnel and cofferdam. The cofferdam will be constructed on the foreshore above MLWS with trenching across the intertidal beach area into the subtidal. The cofferdam would be composed of two rows of sheet piles, approximately 7 m apart, from the low mark to the seaward end of the work platform, a length of approximately 100 m. This landfall option also involves a beach access route of 6 x 400 m and beach work platform of 40 x 25 m, resulting in a total area of potential habitat loss on the beach of 0.004 km^2.

In addition, this landfall option would involve a pre-cut shore approach trench from the end of the cofferdam to 8 m LAT (700 x 52 m), potentially disturbing an area of 0.036 km^2. The presence of a jackup barge could also result in habitat loss, depending on how far offshore the barge is located. It is anticipated that the area affected by the jackup barge and associated activities in the landfall working area will be 800 m x 800 m representing an area of 0.64 km^2 (Table 6-4). The overall worst case loss of habitat to little tern would therefore be approximately 0.68 km^2.

Site-specific foraging range data for little tern suggests that little terns from the Easington Lagoons colony will forage up to 5 km along the shore. In addition, birds will forage up to 3 km seaward from the colony. This could therefore represent an area of up to 30 km^2, assuming a foraging rectangle extending 5 km north and south from the colony and 3 km seaward. The affected seabed area (0.68 km^2) would therefore represent less than 2.3% of this area.

Little terns are not considered sensitive to disturbance and are likely therefore to forage around any construction activity, reducing the potential impacted area and therefore the area lost for foraging. Previous studies have indicated that works comparable to those proposed for the Development have not impacted the productivity of little tern at the Easington Lagoons colony. Little tern productivity was recorded to be above the five-year average in each of the two years following the construction of the York pipeline in 2012 (Austin, 2014), indicating that little tern productivity has not previously been adversely affected by pipeline construction in nearby, similar habitat.

The impact is predicted to be adverse in nature, direct, intermittent and affecting an International geographic extent due to the presence of little tern from an SPA within the affected area; however, the actual area affected is likely to be limited when considered against the area available to little tern for foraging and other behaviours. Construction activities which may affect important areas for little terns are scheduled to occur between July 2025 and January 2026 and are therefore considered to be short-term. In addition, bp has confirmed that no rock placement will take place in water depths of <10 m LAT along the Humber pipeline route. Taking these characteristics into account, the impact is considered to be of Negligible magnitude.

Little tern is considered to have a high sensitivity to impacts associated with seabed disturbance (Wade *et al.*, 2016). Little tern is considered to have a low vulnerability to impacts associated with seabed disturbance as it is considered highly unlikely that any impact will affect the long-term status of relevant populations or result in noticeable long-term effects. Little tern is considered to be of high conservation value due to the species being a qualifying feature at the Humber Estuary SPA. The effect of impacts associated with seabed disturbance on little tern is therefore considered to be of minor significance.

Given the relatively small temporary footprint of the Development (0.68 km^2) relative to the total seabed area available for foraging and the evidence from other developments that comparable works have not adversely impacted the little tern population at Easington Lagoons, it is reasonably foreseeable that the impact of direct loss of seabed habitat used by little tern associated with the Humber Estuary SPA is not likely to be significant.

6.4.2.1.5 Consequences to marine archaeology

Methods of potential impact

The direct impacts on maritime heritage receptors from the Development will primarily arise through installation and commissioning activities such as trenching and backfill works, the laying of the pipelines and construction of the seabed manifold and well injection infrastructure. Impacts will also arise through seabed preparation such as boulder clearance and dredging along the pipeline route. Furthermore, seabed contact by legs of jackup vessels and/or anchors on vessels during installation, scheduled and unplanned maintenance works and decommissioning works might cause localised damage or destruction to receptors lying on the seafloor and buried within the seabed sediments.

Impacts on the known and potential maritime heritage receptors are likely to be detrimental as they will damage the condition and integrity of the receptor. The geographical extent of the impacts is anticipated to be limited to those within the Development and therefore are expected to be local. As archaeological and cultural heritage assets cannot typically adapt, tolerate or recover from physical impacts, the duration of the impact will be permanent. As any such impacts would be detrimental and permanent, the magnitude of the impacts is assessed as high.

The nature of features of interest in the Development area

The themes relevant to marine archaeological baseline as assessed in this report are:

- Seabed prehistory (for example, palaeochannels and other features that contain prehistoric sediment, and derived Palaeolithic artefacts e.g. handaxes); and
- Seabed features, including maritime sites (such as shipwrecks and associated material including cargo, obstructions and fishermen's fasteners) and aviation sites (aircraft crash sites and associated debris).

To provide baseline context for the impact assessment, an area defined as the Archaeological Study Area (ASA) comprising the Development area and a further 250 m buffer was considered. Separate Geophysical Study Areas (GSAs) cover the areas around the Humber Pipeline, Teesside Pipeline and Endurance Store which were subject to geophysical survey. The Humber Pipeline and Teesside Pipeline GSAs are defined by a 2 km corridor centred around the two pipeline routes, and the Endurance Store GSA is defined by the SBP data extents. Details are illustrated in the Marine Archaeology Technical Report (Appendix I).

From the currently available data, there are a total of 542 known marine and potential marine archaeological receptors within the GSA. There are no designated maritime or aviation sites that have been identified from the assessment. Furthermore, there are no known seabed prehistory sites or aviation sites identified.

Within the Endurance Store GSA, a total of 21 anomalies were identified. Two anomalies have been discriminated as A1 receptors (i.e. anthropogenic origin of archaeological interest) consisting of wrecks 7536 and 7541. The remaining 19 features within the Endurance Store GSA have all been discriminated as A2_h (i.e. anomaly of likely anthropogenic origin but of unknown date; may be of archaeological interest or a modern feature) and A2_l (i.e. anomaly of possible anthropogenic origin but interpretation is uncertain; may be anthropogenic or a natural feature) during this assessment. Full details are provided in section 5.3 of the Marine Archaeology Technical Report.

Within the Teesside Pipeline GSA, a total of 324 anomalies were identified. Sixteen anomalies have been discriminated as A1 receptors. These consists of eleven wrecks: 7210, 7217, 7253, 7260, 7262, 7263, 7264, 7270, 7308, 7319, and 7339; two associated debris fields: 7265 and 7306; two associated items of debris: 7035 and 7307; and one magnetic anomaly 7503. Five anomalies have been discriminated as A3 receptors (i.e. historic record of possible archaeological interest with no corresponding geophysical anomaly). These consist of recorded wrecks 7197, 7208 and 7323, and recorded obstructions 7205 and 7209. The remaining 303 features within the Teesside Pipeline GSA have all been discriminated as A2_h or A2_l during this assessment. Full details are provided in section 5.3 of the Marine Archaeology Technical Report.

Within the Humber Pipeline GSA, a total of 197 anomalies were identified from the archaeological assessment of geophysical datasets. Seven anomalies have been discriminated as A1 receptors. These consist of wrecks 7007, 7040, 7063, 7066, 7072, 7078, and 7188. Two anomalies have been discriminated as A3 receptors. These consist of recorded wreck 7036 and recorded obstruction 7059. The remaining 188 features within the Humber Pipeline GSA have all been discriminated as A2_h or A2_l during this assessment. Full details are provided in Section 5.3 of the Marine Archaeology Technical Report.

There are a further 93 records consisting of marine recorded losses. These are records for which although a vessel (or vessels) is known to have been lost in the general area, no material has been encountered on the seabed at the recorded location. The gazetteer presented in the Marine Archaeology Technical Report does not include these records due to the inherent inaccuracy of the positional data. The majority of these are from the 19th century and highlight the potential for further unknown wreck material to be located within the Development area.

The nature of the marine archaeological resource is such that there is often a high level of uncertainty regarding the presence/absence, distribution, extent and nature of archaeological receptors on the seafloor. As such, the precautionary principle is applied to the marine archaeological environment.

Sensitivity of features

The sensitivity of a receptor is defined as ‘the degree to which a receptor is affected by an impact’. The capability of an asset to accommodate change and its ability to recover if affected is a function of its sensitivity. Asset sensitivity is typically assessed via the following factors:

- Adaptability – the degree to which an asset can avoid or adapt to an effect;

- Tolerance – the ability of an asset to accommodate temporary or permanent change without significant adverse impact; and
- Recoverability – the temporal scale over and extent to which an asset will recover following an effect.

Archaeological and cultural heritage assets cannot typically adapt, tolerate or recover from physical impacts resulting in material damage or loss caused by development. Consequently, the sensitivity of each asset is therefore assessed as very high.

Vulnerability of features

Receptor vulnerability is defined as 'the degree to which a receptor can or cannot cope with an adverse impact' and takes into account a number of factors, including the previously assigned receptor sensitivity and impact magnitude.

Archaeological features have no adaptability, tolerance or recoverability, and, subsequently, any physical damage will be permanent and irreversible. As such, all archaeological receptors have a very high vulnerability to impacts.

Value of features

The value of known archaeological and cultural heritage assets is assessed on a five-point scale using professional judgement informed by criteria provided in Table 6-8.

Table 6-8 - Criteria to assess the archaeological value of marine assets

Value	Definition
High	- Best known, only example or above average example and / or significant or high potential to contribute to knowledge and understanding and / or outreach. Assets with a demonstrable international or national dimension to their importance are likely to fall within this category; - Wrecked ships and aircraft that are protected under the Protection of Wrecks Act 1973, Ancient Monuments and Archaeological Areas Act 1979 or Protection of Military Remains Act 1986 with an international dimension to their importance, plus as-yet undesignated sites that are demonstrably of equivalent archaeological value; and - Known submerged prehistoric sites and landscapes with the confirmed presence of largely in situ artefactual material or palaeogeographic features with demonstrable potential to include artefactual and/or palaeoenvironmental material, possibly as part of a prehistoric site or landscape.
Medium	- Average example and / or moderate potential to contribute to knowledge and understanding and / or outreach; - Includes wrecks of ships and aircraft that do not have statutory protection or equivalent significance, but have moderate potential based on a formal assessment of their importance in terms of build, use, loss, survival and investigation; and - Prehistoric deposits with moderate potential to contribute to an understanding of the palaeoenvironment.
Low	- Below average example and / or low potential to contribute to knowledge and understanding and / or outreach; - Includes wrecks of ships and aircraft that do not have statutory protection or equivalent significance, but have low potential based on a formal assessment of their importance in terms of build, use, loss, survival and investigation; and - Prehistoric deposits with low potential to contribute to an understanding of the palaeoenvironment.
Negligible	- Poor example and / or little or no potential to contribute to knowledge and understanding and / or outreach. Assets with little or no surviving archaeological interest.
Unknown	- There is not presently enough information available about the site to assess its value.

At this stage, using the precautionary principle, all maritime archaeological receptors should be assumed to have a high value until further investigation is undertaken.

Prehistoric receptors

There are no known prehistoric receptors within the ASA. However, features such as these have been previously identified within the vicinity of the Development, and a number of studies have been undertaken surrounding the Development that have provided an insight into the palaeogeography of the region, specifically relating to the terrestrial landscape that would have existed between the Last Glacial Maximum (LGM) and the Holocene transgression (Bicket and Tizzard, 2015). There is therefore the general potential for the presence of a preserved, post-LGM palaeolandscape along the proposed pipeline routes of the Development.

In general, on the basis of their age and rarity in a marine context, all in situ Palaeolithic and Mesolithic material are likely to be of high archaeological value and of national / international importance. Sites containing certain forms of Palaeolithic material are so rare in Britain that they should, whenever possible, remain undisturbed. In the event that prehistoric archaeological material discovered offshore is found in situ it should be considered of particularly high archaeological importance. As such, the features and deposits which have the potential to contain within them in situ material should be considered as high value assets.

Prehistoric archaeological material discovered within secondary contexts also has the potential to provide valuable information on patterns of human land use and demography in a field of study which is still little understood and rapidly evolving. They are, however, by their very nature derived and, as such, isolated prehistoric finds should be regarded as medium value assets. Palaeoenvironmental evidence in the context of an in situ prehistoric site (if found) will be of high value.

Maritime sites

There are a total of 542 known maritime sites within the ASA. There is further general potential for discoveries of maritime craft from the Mesolithic to the modern period. Post-medieval and modern wrecks, as they were typically made of more substantial material, are more likely to have been discovered through surveys undertaken by UKHO and others, and thus recorded in the archaeological record. However, there is still potential for discovery of previously unrecorded wreck sites, particularly of wooden wrecks, broken up wrecks or partially buried wrecks that are more difficult to detect through geophysical survey.

The value assigned to an individual wreck site is, to a large degree, site specific. A vessel may be considered of special interest on the basis of any number of interrelating integral and relative factors. Those regarded as being of special interest may further be designated under the PWA (1973) or the PMRA (1986). No designated wreck sites are present within the ASA.

Within this work, wrecks which have been identified with a known vessel and are currently undesignated have been ascribed a medium value and are judged to reflect the criteria of average examples of their types.

For all unknown wrecks, there is insufficient data to assess the value of each individual wreck. As such, all such wreck sites must be considered to have archaeological value, to a greater or lesser degree and, in accordance with the precautionary approach, must be considered as high value assets. Similarly, as the value of potential wrecks cannot be evaluated until they are discovered, potential wrecks of all periods should be expected to be of high value.

Derived artefacts are likely to be of limited archaeological interest as individual discoveries. However, a concentration of seemingly isolated finds within an area may signify the presence of a wreck site, historical shipping routes or maritime battlegrounds.

Aircraft crash sites

There are no known aircraft remains charted within the ASA. However, there is relatively high potential for the discovery of previously unknown aviation material dating from the early 1900s to the present day around the British Isles – especially for Second World War military aircraft (Wessex Archaeology, 2008). Under the PMRA 1986, all British aircraft that crashed while in military service are automatically legally protected.

6.4.2.1.6 Consequences to coastal processes

The findings of the coastal processes impact assessment are presented in Section 6.4.2.2.6.

6.4.2.2 Potential Indirect Impacts

6.4.2.2.1 Summary of indirect impacts

Increased sediment load in the water column due to the re-suspension of sediment from trenching, pipelay and seabed installation activities may affect the feeding behaviour of benthic epifauna, fish and seabirds, both within the Development area and down-current as far as the increased sediment load is present. Subsequent re-settling of suspended sediment may cause smothering of benthic epifauna and infauna. These indirect impacts are likely to be temporary in nature, during the various construction and installation activities.

In addition, the construction of the landfalls during the installation phase, and the presence of infrastructure on the seabed in the nearshore and intertidal areas during the operational phase of the Development, have the potential to result in longer-term impacts including localised scouring and interruption of sediment transport processes. The potential impacts on coastal processes have been assessed in detail by Xodus Group (2023c; included in full in Appendix G) with the findings presented below in Section 6.4.2.2.6.

6.4.2.2.2 Consequences to benthic ecology

Re-suspension and re-settling of sediment resulting from Development activities has been assumed to affect an area twice that of the direct impact area and equating to approximately 106.42 km^2. It should be noted that this is the total area that could be impacted over the course of the entire landfall construction and pipeline and subsea infrastructure installation period, which may extend over 15 months; the area impacted at any one time is likely to be much smaller.

Increased concentrations of suspended particles in the water near the seabed may impair respiratory and feeding processes, inducing metabolic stress and reducing growth and survival rates. Larger animals are more resistant to elevated levels of suspended solids in the water column, but some species are likely to be more sensitive than others. The re-settlement of sediments may result in the smothering of epifaunal species (see Gubbay, 2003 for a review), with the degree of impact related to their ability to clear particles from their feeding and respiratory surfaces (e.g. Rogers, 1990). Depending on the sedimentation rates, infaunal species and communities can work their way back to the seabed surface through blanket smothering (Neal and Avant, 2008).

Defra (2010) states that impacts arising from sediment re-suspension are short-term (generally over a period of a few days to a few weeks). Sediment re-suspension and prolonged turbidity is only likely to persist in low energy areas with a high percentage of fine sediments (e.g. Hitchcock *et al.*, 1996, in Gubbay, 2003). Sediments in the Development area are predominantly gravelly sands with varying but generally low mud content. The shallow water depth and high current speeds suggests that the water column would frequently become turbid naturally, especially during storm events, which would create disturbance on a much larger scale than the proposed Development activities. As such, it is likely that the epifauna and infauna in the Development area is tolerant to occasional changes in water clarity and periodic smothering. The biotopes found in the Development area are generally not sensitive or have low sensitivity to changes in suspended sediment and smothering, especially where the current regime is expected to remove any additional overburden rapidly.

The sediment sampling conducted during the environmental baseline surveys showed that surficial sediments in the Development area were generally uncontaminated, with levels of hydrocarbons, heavy metals and PCBs at background levels at most stations (see Section 4.3.3). Slightly elevated levels of certain metals at a few stations along the Teesside Pipeline route and in the Endurance Store area were attributed to historical drilling activities nearby and may possibly be having low-level toxicological impacts on benthic biota, although diverse infaunal communities were recorded. The disturbance of surficial sediments during the installation activities will not alter the overall distribution of contaminants in this part of the North Sea. Landfall construction will involve the excavation of deeper sediments. bp has obtained sediment cores at the Teesside landfall area which are being analysed at the time of writing.

Given the temporary nature of the disturbance, the small scale compared to the natural disturbance expected in the area and the low sensitivity of the biotopes present, it is not expected that indirect impacts associated with seabed disturbance will be significant.

6.4.2.2.3 Consequences to fish and shellfish

During installation of the pipelines and subsea infrastructure, it is anticipated that there may be local increases in suspended sediment concentrations. This may cause indirect impacts on fish and shellfish through smothering.

As per direct disturbance, adult and sub-adult fish and shellfish are expected to move away from disturbance and re-colonise the Development area once the disturbance from installation activities has ceased. Studies on pipeline dredging works off the Holderness coast have indicated that approximately ten percent of suspended sediment would remain in the region after 24 hours with the coarser sediments settling out and the finer materials being transported outside the development area by the currents (BP Amoco Exploration, 1999). Recovery of adult and sub-adult populations is therefore expected to be rapid.

Fish eggs, particularly of those species that lay eggs on the sediment, are expected to be vulnerable to smothering. This is because smothering due to re-settlement of sediment on existing eggs may result in the poor incubation of spawn by decreasing the oxygen supply. The installation of the pipelines is expected to occur between April and September, which overlaps with the expected herring spawning period of August to October. Sediment re-suspension and prolonged turbidity is only likely to persist in low energy areas with a high percentage of fine sediments (e.g. Hitchcock *et al.*, 1996, in Gubbay, 2003). Defra (2010) states that impacts arising from sediment re-suspension are short-term (generally over a period of a few days to a few weeks). Given the small area of potential herring spawning ground and spawning grounds of other species that may be affected, and the expected short-term nature of the disturbance, it is considered unlikely that the Development will have a significant impact on herring spawning or the spawning of other species at the population level.

6.4.2.2.4 Consequences to birds

Indirect effects on seabirds may occur either through settlement of additional sediment on the seabed causing smothering of benthic prey items or through the suspension of sediment in the water column reducing visibility and the ability of birds to find food. Any indirect impacts on birds through this pathway will be temporary. As indicated in Section 6.4.2.1.4, species of relevance to this assessment are red-throated diver and little tern only.

The zones of impact from the suspension of settlement and resulting re-settlement of this sediment within the areas used by either red-throated diver or little tern are estimated to be approximately double those areas of direct impact as described above in Section 6.4.1.1.4. The amount of suspended sediment is also considered unlikely to be significant with the majority of displaced sediment to be used to refill trenches once pipelay has been completed. The assessments presented for little tern and red-throated diver and the resulting conclusions are therefore also considered to be applicable to the potential indirect impacts from seabed disturbance that may arise from the Development.

6.4.2.2.5 Consequences to marine archaeology

The proposed activities may also lead to indirect impacts upon known and unknown cultural heritage deriving from machinery involved during construction, which might change the hydrodynamic and sedimentary regimes whilst carrying out spoil removal and distribution during trenching operations and installation. Further impacts might derive from potential scour and plume effects resulting in increased protection to, or deterioration of assets in the vicinity.

Indirect impacts may affect marine archaeological baseline conditions where they result in the increased exposure or burial of marine archaeological assets. The increased exposure of marine archaeological assets has the potential to cause erosion and deterioration to the assets. Conversely, should assets be subject to increased sedimentation and burial, they may, in turn, benefit from conditions which afford higher levels of preservation.

6.4.2.2.6 Consequences to coastal processes

Teesside – Increased suspended sediments as a result of direct pipe tunnelling activities (including disturbance to Teesmouth and Cleveland Coast SSSI, Ramsar and SPA)

The direct pipe method of installing the Teesside Pipeline landfall is intended to involve tunnelling under the seabed before reaching punch-out location (LAT). A jackup barge is intended to be used to retrieve the mTBM, at the punch-out location. This activity involves works on the seabed, so there will be disturbance which will generate increased suspended sediments, and could potentially impact Teesmouth and Cleveland Coast SSSI and Ramsar sites.

Considering the relatively shallow punch-out location, this is likely to occur within a highly active area of the seabed which is continuously exposed to, and influenced by, wave action. The surficial sediment in the nearshore area comprises mainly sand, specifically classed as fine or medium sand (AECOM, 2021a; Scarborough Borough Council, 2021b); finer sediment sizes are inherently more mobile. Therefore, sediments in the nearshore are likely to be continuously mobile. Ultimately, due to relatively low tidal flows in Tees Bay (between 0.1 and 0.4 m/s close to shore; bp, 2020c), net sediment drift is limited in scale. Consequently, any highly localised increase in sediment attributed to the direct pipe tunnelling punch-out location is likely to be reincorporated into the local sediment regime. By tunnelling under the protected sites, and any effects from punch-out being minimal, impacts to Teesmouth and Cleveland Coast SSSI, Ramsar and SPA are anticipated to be not significant.

Teesside – Increased sediment transport during installation of SSIV

The SSIV is intended to be installed along the Teesside Pipeline between 6 and 8 km from KP0. It will require a protective structure the dimensions of which will be up to 16 x 9 m with a height of up to 8 m. The SSIV and associated structure is intended to be piled.

The Teesside OWF ES undertook analysis of scour at wind turbine generator (WTG) foundations, which are also piled. The SSIV is intended to be located between approximately 500 m and 3.5 km from the Teesside OWF. The findings indicated that sediment plume generated during installation was transported predominantly to the southeast (EDF Energy, 2004), in line with the general understanding of transport dynamics in Tees Bay. Concentrations of additional sediment were increased although well within the range of background levels expected to be observed under a 1 in 10-year return period wave event, placing it within levels of natural variability.

This analysis was conducted assuming an OWF of up to 30 turbines. While the SSIV is intended to be located in depths equivalent to those across the OWF, the scale of impact associated with the SSIV as compared to the OWF turbines is likely to be much smaller. Consequently, it is anticipated that the impact cause by the presence of the SSIV on local sediment transport processes will be not significant.

Teesside – Increases in suspended sediment concentrations and deposition of disturbed sediments during pipeline and cable installation

The excavation, storage and backfilling of material during pipeline and cable installation, has the potential to increase sediment transport and increase local suspended sediment concentrations. This can happen both through losses and suspension of sediments into the water column during trenching, and erosion of temporarily stored material by wave and tide action.

The dimensions of the pre-cut shore approach trench will vary with the sediments encountered along the route. However, based on the indicative dimensions of the trench, it is estimated that the volume of spoil excavated by the backhoe dredger will be around 60,600 m^3, which will then be stored along the south side of the trench on the seabed. Works for the backfilled pre-cut trench section will include the excavation of material by a CSD/TSHD from 8 m LAT out to KP7.1, covering a distance of approximately 4.4 km, making a potential volume sediment of around 120,400 m^3. The conservative assumption is also made that two further trenches are made alongside the pipeline trench to house the Teesside to Endurance Store and Teesside to SSIV cables. These would respectively have trenched lengths of 107 km and 7 km, and would require the movement of 1,197,000 m^3 and 79,000 m^3 of sediment. Finally, pipeline scour protection from KP90 to the co-mingling manifold may require trenching to 1 m depth, which could require the movement of up to 366,000 m^3 of sediment. It may be assumed that up to 10% of this total sediment will be released into the water column (following the method of the Langeled pipeline ES; Metoc, 2004) over the construction period, which would amount to 182,000 m^3 (note that since the quantity of interest is the amount of excavated sediment dispersing into the water column, sediment bulking is not relevant here). The spoil may remain on the seabed, prior to its return to the trench, for around two months.

An estimated 1,000,000 m^3 of material is dredged from the Tees River and deposited at the Tees Bay A dredge disposal site every year, which sits approximately 2 km from the Teesside pipeline. This makes the 182,000 m^3 which may be added to the environment through pipeline and cable installation, distributed along the 142 km route over the period of construction, fairly negligible at around 18% of the dredge material deposited annually. All excavated material still present on the seabed will be used to backfill the trench; any shortfall will be replaced with material from a licensed dredge site. The impact of increased sediment transport during pipeline and cable installation is therefore anticipated to be not significant, since it is temporary, and expected to be within the limits of natural variability.

Teesside – Increased suspended sediments from pre-sweeping / boulder clearance / ploughing / dredging

The seabed is expected to require some sweeping and/or dredging prior to installation of each pipeline due to the presence of sediment waves and, if present, ridges underlain by stiff clay. Efforts will be made to minimise the requirement for this activity as far as reasonably practicable. As sandwaves are likely to reform, to ensure the continued suitability of the seabed for installation, either sweeping will be carried out shortly before the pipelay operations or maintenance sweeping will be required to maintain a clear corridor.

Using the same conservative assumption previously stated, up to 10% of this sediment is likely be released into the water column (following the method of the Langeled pipeline ES; Metoc, 2004) over the two month construction period. Finer sand and silt will likely be stirred into suspension and is expected to settle back out to the seabed naturally over the course of hours or days (Defra, 2010). Gravel and coarser sand is expected to re-settle quickly (mostly within seconds) to form spoil ridges at either side of the trench.

The movement of boulders to the sides of the trenching corridor, out to a width of 40 m, is not expected to have any impacts on sediment transport. Even in the densest regions of boulder coverage, the resulting boulder distribution will be similar to the present situation (see Appendix G, Figure 2-19 and Figure 2-20), where no more than three boulders are found within any 100 m stretch of the 30 m cleared corridor (Appendix G, Figure 2-20). Therefore the impacts on suspended sediments from pre-sweeping/boulder clearance/ploughing/dredging are anticipated to be not significant.

Teesside – Effects of pipelay and landfall drilling activities on water quality

The Teesside Pipeline route will pass through the Tees Coastal water body (GB650301500005) which is defined as a body of water between the coastline and approximately 1 nm offshore (approximately 1.9 km). NZT Power has already undertaken a WFD assessment (NZT Project DCO, 2022). While all trenching methods under consideration have the potential to impact the quality of the water body, such activities are not expected to cause deterioration of the current water body status, neither are they expected to jeopardise the water body achieving target 'Good' status in 2027. The water body currently has 'Moderate' overall status because of issues with ecological status (Environment Agency, 2022c). The activities associated with the installation of the Teesside Pipeline is not expected to affect surface water discharges, since the pipeline will be laid beneath the beach. While concentrations of suspended sediments will be temporarily increased on a localised basis during pipeline installation, these are expected to be within the natural variability of the site. In addition, it is anticipated that drilling fluid will be recycled as far as practicable in a closed cycle and that drilling fluids will not be discharged offshore. Therefore, there is no expected impact associated with drilling fluids on local water quality.

When considering the approximately 1,000,000 m^3 of sediment regularly deposited at the nearby dredge disposal site Tees Bay A every year, the volumes of sediment resuspended during trenching will be negligible. Overall, there is not expected to be any long-term hydromorphological changes, and since suspended sediments are not measured under the WFD assessment criteria, the impact is anticipated to be not significant.

Teesside – Local scour at SSIV

For the purposes of the ES, it is assumed that an SSIV will be installed along the Teesside Pipeline between 6 and 8 km from KP0. It will require a protective structure the dimensions of which will be up to 16 x 9 m with a height of up to 8 m. It is likely scour will occur at the base of the SSIV. This is expected to be similar to scour seen at nearby Teesside OWF during operational monitoring (Bibby HydroMap, 2017), and as seen around boulders scattered in the local area (Figure 2-20). Any scour is therefore determined to be within the levels of natural variability, and the impact is anticipated to be not significant.

Humber – Impedance to longshore sediment transport from beach cofferdam (including disturbance of sediment supply to protected sites down-drift of landfall site including Spurn Head NNR, Humber Estuary SAC, SPA, Ramsar and SSSI)

The beach cofferdam and working platform will be located above MLWS, so do not strictly require assessment in this report but a brief discussion of the impacts and suggested mitigation are presented here for completeness.

Wave and tide conditions along the Holderness coast cause significant erosion to take place at the soft cliffs and beach foreshore (see Appendix G, Section 2.2.7 for further detail). The eroded material is moved in a net southerly direction along the coast by longshore drift, and supplies sediment for the Lagoons SSSI and Spurn Head NNR. Spurn Head is an integral feature to the Humber Estuary, and in turn provides protection for the Humber Estuary SAC, SPA, Ramsar and SSSI. The presence of the cofferdam has the potential to impede net sediment transport to the south (Appendix G, Section 2.2.6), thereby reducing the supply of sediments to these important sites.

Detailed studies have been undertaken in the vicinity of the Humber landfall, to understand the impact of the addition of a cofferdam (Premier Oil, 2018). Premier Oil (2018) provides an estimate of the volume of sediment which could be blocked by the working platform and cofferdam, as summarised in Table 6-9, and the daily average longshore transport rate deduced from field measurements during March 2016 are shown in Figure 6-3. A grab sample collected at the site showed that a median grain diameter of 1.77 m is representative for the local mobile sediment (Premier, 2018). The estimated volume of sediment which could be blocked while the cofferdam and working platform are in place for 6 months is therefore 36,600 m^3, which represents 1.2% of the 3,000,000 m^3 total volume of sediment which is thought to be eroded from the Holderness Coast every year (ERYC, 2017a). Premier (2018) states that the calculated volumes of blocked sediment should not be taken as absolute predictions due to the limitations of the sediment transport modelling software, but that the calculations should be sufficient to plan mitigation measures (Table 6-9).

Table 6-9 - Estimated sediment transport rates and volumes of sediment blocked by the cofferdam for a range of grain sizes (Premier Oil, 2018)

Quantity estimated	Grain size d_{25}=0.5 mm	Grain size d_{25}=1.77 mm	Grain size d_{55}=2.0 mm
Southward sediment transport rate (m^3/day)	420 (m^3/day)	200 (m^3/day)	195 (m^3/day)
Total volume of sediment blocked during modelled 4 month period (m^3)	51,200 (1.7%)	24,400 (0.8%)	23,800 (0.8%)
*Total volume of sediment blocked during modelled 6 month construction period (m^3)	76,900 (2.6%)	36,600 (1.2%)	35,700 (1.2%)

(1) Based on variability in grain size and the actual wave climate during the construction period, the calculated values are conservative and estimated to be within a factor of 1 to 5 of the actual quantity blocked.

(2) Numbers given in brackets are percentages sediment blocked (in m^3) with respect to the total estimated 3,000,000 m^3 annual net sediment transport along the Holderness Coast (ERYC, 2017a).

(3) Values not provided in Premier (2018) report, but estimated using revised project parameters available since publication of erosion study are marked with a *, such as updated project construction periods and the separation of the construction into different phases.

Typical mitigation measures to avoid impacts to longshore sediment transport from the beach cofferdam could include but not be limited to:

- Mechanically moving accreted sediment from the north to the south side of the cofferdam to minimise interference with the sediment transport regime, for the duration of its presence;
- Placement of filter unit rock bags on top of geotextile, with profiles sympathetic to present slopes therefore minimising wave energy to minimise modifications to the wave field;
- A programme of observation and monitoring of beach levels; and
- Reinstate beach to similar conditions as pre installation, but within reason, by maintaining communication with Flood and Coastal Erosion Risk Team at ERYC during the pre-construction beach survey and during beach reinstatement works.

Not all longshore transport of sand occurs in the intertidal zone. The daily average longshore sediment transport rates shown in Figure 6-3 (Premier Oil, 2018) demonstrate that sediment transport occurs beyond MLWS, out to a distance of at least 400 m or more from the cliffs, though the strength of transport for medium and coarse sediments reduces as the water depth increases and the influence of wave energy on the seabed is diminished. Other studies suggest that longshore transport is much reduced in water depths greater than 15 m, as this is approximately the base of wave action (HR Wallingford *et al.*, 2002 [Appendix 11]). All of this means that net longshore drift to the south is expected to still occur, even with a cofferdam present. The transport of fine sediments offshore to the North Sea and Humber is unlikely to be interrupted at all, since their transport occurs in suspension which will be unimpeded.

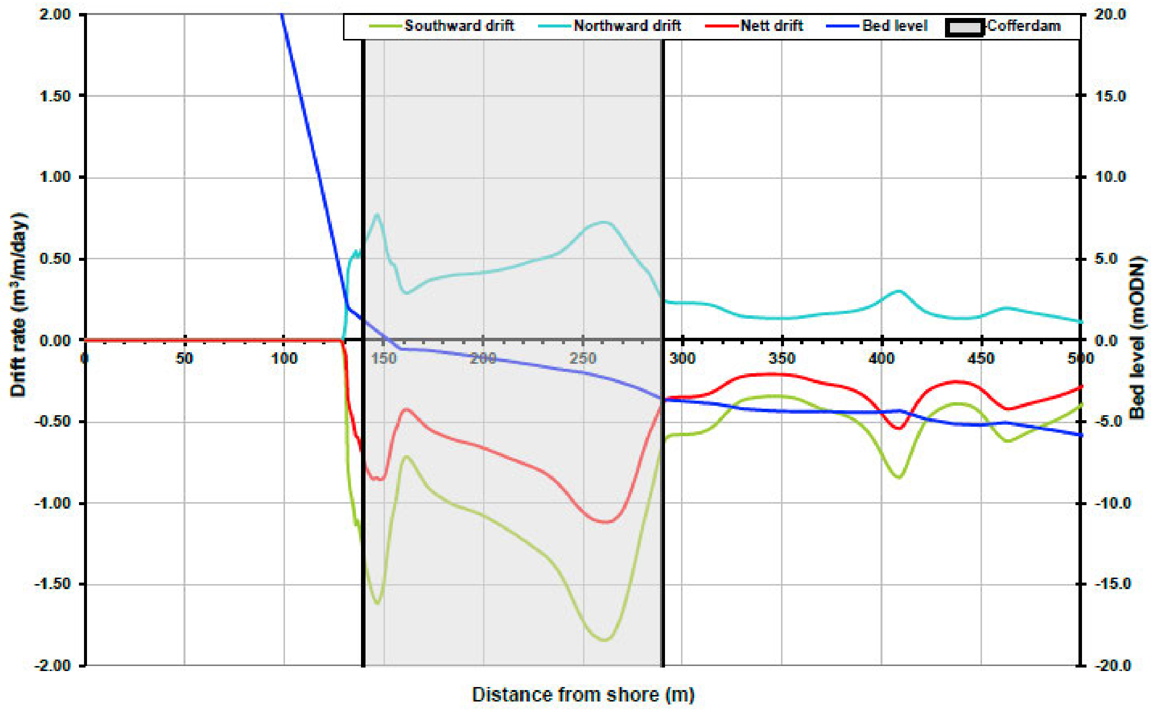


Figure 6-3 - Daily average longshore sediment transport rates during March (Premier, 2018)

A convenient local example serves to support the conclusions drawn above. The Easington gas works facility was opened in 1967, with an intended life span which would not put it at risk from coastal erosion. However, the operational period of the gas works was longer than expected, and in 1999 a rock revetment was constructed in front of the works to protect it from the advancing coastline. Concerns about the impacts of this revetment on local coastal erosion and downstream sediment transport processes triggered the initiation of a now 20-year monitoring campaign, to record the changing coastline and possible impact of the coastal defences. A recent comparison of this monitoring data to historical records, found no evidence of any adverse effects on downdrift frontages from the coastal defences, be that from a supply of sediment south to feed Spurn Head, or from increased erosion around the hard structures (ERYC, 2019).

To summarise, any agreed beach monitoring procedures will effectively mitigate the impact of the presence of the working platform and cofferdam. Any significant accumulation of beach sediments will be mechanically moved to redress any differential in beach level north and south of the working platform and cofferdam. This will allow beach sediments to continue along their dominant transport pathway. It is anticipated that impacts to longshore drift of sediments and natural sediment transport processes will be not significant. This also results in no impact to the downstream sites including Spurn Head NNR, Humber Estuary SAC, SPA, Ramsar and SSSI.

Humber – Disturbance of Dimlington Cliff SSSI

The presence of the beach works structures at the base of Dimlington Cliff SSSI have the potential to cause an increase (through wave funnelling) or decrease (through obstruction) to the natural rates of erosion of the cliff face, which must be preserved as an intrinsic aspect of the SSSI. Further details on the natural cliff erosion rates are presented in Appendix G.

Potential impacts from the Development would be the prevention of the sea reaching the base of the cliffs, thereby altering the natural erosion regime. However, the short period of time that the beach cofferdam and working platform will be in place (6 months), the narrow width and small physical footprint of the working platform (approximately 25 m in width parallel to the beach) and the design of the landfall and onshore pipework, which are intended to be installed well below the exposed base of the cliffs are all anticipated to minimise any impacts during the installation phase. It is also anticipated that potential impacts during the operation phase will be fully mitigated. The Tolmount pipeline placed rock bags on with profiles sympathetic to present slopes, to minimise wave energy and modifications to the wave field (Premier, 2018), which could be considered as a mitigation measure here. As such, any impacts are anticipated to be not significant.

Humber – Disturbance of protected features within the Holderness Inshore MCZ and Holderness Offshore MCZ

Impacts to the disturbance of protected features within the Holderness Inshore MCZ and Holderness Offshore MCZ, including intertidal sands and muddy sands, circalittoral rock, and a range of subtidal sediment types is fully assessed within MCZ assessment (Section 6.9.1).

Humber – Increases in suspended sediment concentrations and deposition of disturbed sediments during pipeline installation

Works for the pre-cut shore approach trench include the excavation, storage and backfilling of material by the backhoe dredger during trenching from shore to 8 m LAT, covering a distance of approximately 700 m. Spoil dug from the trench is intended to be stored on the south side of the trench and replaced post pipelay. Then works for the backfilled pre-cut trench will include the excavation of material by a CSD/TSHD from 8 m LAT out to KP16.3, covering a distance of approximately 15.3 km. These works have the potential to increase sediment transport and increase local suspended sediment concentrations, both through losses and suspension of sediments into the water column during trenching, and erosion of temporarily stored material by wave and tide action.

The dimensions of the pre-cut shore approach trench will vary with the sediments encountered along the route. However, based on the indicative dimensions of the trench, it is estimated that the volume of spoil excavated by the backhoe dredger will be around 117,600 m^3, which will then be stored along the south side of the trench on the seabed. Likewise, based on the indicative dimensions of the backfilled trench the volume of spoil excavated by the CSD/TSHD will be around 78,000 m^3. Finally, pipeline scour protection from KP60 to the co-mingling manifold may require trenching to 1 m depth, which could require the movement of up to 282,000 m^3 of sediment. It may be assumed that up to 10% of this sediment will be released into the water column over the construction period (approximately 2 months), which would amount to 118,000 m^3 (following the method of the Langeled pipeline ES; Metoc, 2004). A 10% loss is expected to be a conservative amount, given the substrate is a stiff clay which is likely to remain in cohesive clumps and not break down significantly over such a short space of time. Finer sand and silt are likely to be stirred into suspension and settle back out to the seabed naturally over the course of hours or days (Defra, 2010). Gravel and coarser sand are expected to re-settle quickly (mostly within seconds) to form spoil ridges at either side of the trench.

An estimated 1,004,755 m^3 of material per year is lost due to cliff erosion alone along the coastline (Boyes, Barnard and Elliott, 2016). Up to 3,000,000 m^3 of material erodes along the Holderness Coast per year when accounting for both the onshore and offshore losses (ERYC, 2017a), of which 60–80% are clays and silts and are transported in suspension and distributed throughout the North Sea (Boyes, Barnard and Elliott, 2016). This makes the 118,000 m^3 which may be added to the environment through backhoe dredging fairly negligible at around 4% of the annual transport, likely to be within the limits of natural variation. All excavated material still present on the seabed is intended to be used to backfill the trench; any shortfall is intended to be replaced with material from a licensed dredge site. The impact of increased sediment transport during pipeline installation is therefore anticipated to be not significant, since it is temporary, and expected to be within the limits of natural variability.

Humber – Increased suspended sediments from pre-sweeping / boulder clearance / ploughing / dredging

Boulder clearance, seabed sweeping and post-lay trenching will cause temporary increases in ambient suspended sediments.

It is expected that the open pre-cut trench will immediately start to backfill with loose finer material (sand) transported by wave/current action. While the speed of infill will be monitored throughout the operations prior to laying the pipeline, some maintenance of the trench will be required to confirm that it is in good condition immediately prior to pipeline installation. As sandwaves are likely to reform, either sweeping will be carried out shortly before the pipelay operations or maintenance sweeping will be required to maintain a clear corridor.

Boulders that are large enough to hinder pipeline installation must be moved a sufficient distance in advance of construction activities. The maximum width of the corridor directly created by the plough required to move the boulders is likely to be 30 m. The boulders moved by the plough are anticipated to end up within a 5 m wide strip either side of the 30 m corridor, resulting in a total width of 40 m. The movement of boulders to the sides of the trenching corridor prior is not expected to have any impacts on sediment transport. Even in the densest regions of boulder coverage, the resulting boulder distribution will be similar to the present situation (see Appendix G; Figure 2-7 and Figure 2-8), where no more than three boulders are found within any 100 m stretch of the 40 m cleared corridor (Appendix G; Figure 2-8).

Based on the permanent movement of boulders, and transient movement of gravel and coarse sand, the impact is anticipated to be not significant.

Humber – Effects of pipelay and landfall drilling activities on water quality

All trenching methods under consideration have the potential to impact the quality of the Yorkshire South Coastal Water Framework Directive (WFD) water body (GB640402491000), which the Humber Pipeline route will pass through from the landfall to 1 nm (1.85 km) offshore. However, it is anticipated these activities will not cause deterioration of the current water body status, neither is it anticipated that they will jeopardise the water body achieving target 'Good' status in 2027. The water body currently has 'Moderate' overall status because of issues with ecological status (Environment Agency, 2022b). The installation of the Humber Pipeline is not expected to affect surface water discharges. Concentrations of suspended sediments will be temporarily increased on a localised basis during pipeline installation, but within the natural variability of the site. In addition, drilling fluid used in the drilling of the pipeline landfall is intended to be recycled as far as practicable in a closed cycle and drilling fluids will not be discharged offshore. Therefore, it is anticipated that there will be no impact associated with drilling fluids on local water quality.

Overall, there it is anticipated that there will be no long-term hydromorphological changes, and since suspended sediments are not measured under the WFD assessment criteria, the impact is anticipated to be not significant. The Environment Agency's 'Clearing the Waters For All' guidance (Environment Agency, 2022a) has been reviewed, and all relevant impacts have been considered and mitigated against throughout this EIA.

Teesside & Humber – Localised scour as a result of the temporary placement of the jackup barge and other vessel anchors

Where vessel anchors and jackup barge legs sit on the seabed in areas of soft sediment, it is likely that localised scour will occur, just as is seen around naturally occurring boulders along the pipeline route (see Appendix G for examples). However, given the mobile and naturally irregular nature of the seabed, scour is considered to be within natural levels of variability for the site, and expected to be temporary. In summary, the impact of localised scour caused by the base of the jackup barge legs and other vessel anchors is anticipated to be not significant.

Teesside & Humber – Impedance of sediment transport processes from nearshore spoil ridge

In the nearshore, the spoil dug from the trench is intended to be stored on the south side of the trench and replaced into the trench, post pipelay. Therefore, there is a possibility that the spoil pile on the seabed might hinder southwards longshore sediment transport offshore due to the raised bed level on the south side of the trench. This may be accentuated by the natural longshore sediment drift preferentially filling in the trench while it is exposed. As the spoil ridge is anticipated to be present temporarily (approximately two months), suspended sediment load will not be uninterrupted as it will continue to travel over and around the spoil ridge, and ultimately when the trench is re-dredged prior to pipelay, any sediment accumulated in the trench is expected to be returned to the water column and continue to be transported in the dominant direction. The impacts to downdrift areas south of the landfall are therefore anticipated to be not significant.

Teesside & Humber – Increased suspended sediments during post-lay trenching

Post-lay trenching is expected to cause temporary increases in ambient suspended sediments. The intention is to use a post-lay trenching plough system for as much of the trenching operations as possible as it is faster and creates a narrower trench. This will utilise a pipeline plough and backfill plough, deployed from a trenching support vessel, which creates a 'V' shaped trench in the seabed. Once the trench depth is acceptable, the spoil will be returned to the trench using a towed backfill plough. It is expected that there would not be any flanking spoil ridges left on the seabed, as the backfill plough is expected to draw the sediment back into the trench when it covers the pipeline. As such, the seabed is expected to be left in a flat condition. Tidal currents are expected to rapidly re-establish the superficial pattern of mobile sediment that was present before trenching. Therefore the impacts on suspended sediments from post-lay trenching is anticipated to be not significant.

Teesside & Humber – Local scour, as a result of exposure of the pipeline

The buried pipeline has the potential to become exposed once operational and create local scour if it is not buried deep enough. As described in Chapter 3: Project Description, to mitigate against this there will be a required depth of cover of 1.2 m for the pipeline. This is intended to reduce the likelihood of any further pipeline covering interventions being required during O&M, minimising disturbance to the site. Where intended depth of burial is not achievable, rock placement is expected to be utilised. No impacts are therefore expected as exposure is not anticipated to occur.

Teesside & Humber – Impedance of bedload transport and the migration of seabed features (e.g. sandwaves) by the presence of rock placement and concrete mattressing

Rock placement will be required along sections of the pipeline to protect it from damage and exposure. These additions to the seabed have the potential to impede bedload transport and the migration of seabed features by acting as a physical barrier, and to cause local scour.

The location of rock and concrete mattresses for protection will most likely be discontinuous, so while the bedload transport will be interrupted in the immediate location of the rock/mattress, the large-scale process of bedload transport and migration of seabed features will not be altered, it will divert around the obstacles as it already does around the existing seabed boulder field.

Where rock armour and mattressing are placed on areas of soft sediment, it is likely that localised scour will occur, just as is seen around naturally occurring boulders along the pipeline route (Appendix G Figure 2-3). However, given the irregular nature of the seabed, the overall effect of scour introduced along the pipeline route is considered to be within natural levels of variability.

Rock placement within the Holderness Inshore MCZ and Holderness Offshore MCZ is addressed fully within the MCZ assessment (Section 6.9.1). In summary, the effects of rock placement on coastal processes are anticipated to be not significant.

Teesside, Humber & Endurance Store – Changes to sandwaves within SNS SAC due to seabed sweeping

Seabed sweeping may be required prior to installation of those parts of the pipelines that lie within the Southern North Sea SAC. This has the potential to alter the form and function of the sandwave system.

The Teesside pipeline has been routed to the north, and the Humber pipeline has been routed to the south of a large sand bank feature (the Hills of the Outer Banks). The sandwaves in the trough of these sand banks, through which the pipelines are routed, are up to 8 m in height (see Appendix G, Figure 2-4 and Figure 2-5). The pipeline route is largely perpendicular to the crests of the sandwaves, this means that when the 30 m wide swept channel is made, the smallest possible cross-section of each sandwave is impacted. The more parallel the clearing route is to the sandwave crest, the greater impact the flattening will have on an individual wave, as is seen in some regions along the Teesside Pipeline (KP113 to KP118).

We have some historical evidence of how the sandwaves will recover with time in this region. The Langeled pipeline was installed in approximately 2006, and crosses the same region of sandwaves within the NEP bathy survey corridor (Gardline, 2021). The bathymetry collected in 2021, shows evidence of the sandwaves not yet having fully reformed along the Langeled route 15 years later, so this is likely the same will be true of the Teesside and Humber Pipeline routes.

The sandwaves are considered to be of moderate sensitivity and value, since they are within the SNS SAC but they are not a designated feature. The impact of flattening the sandwaves can be considered low magnitude, since the majority of pipeline installation will occur perpendicular to the sandwaves, thus only impacting the smallest cross-section of each sandwave. The overall character of the sandwave system will be preserved, so in summary, the impacts of seabed sweeping is anticipated to be not significant. However, effort will be made to reduce the extent of seabed sweeping where possible, to minimise impacts.

Endurance Store – Increased sediment transport during infield flowline and cable trenching and seabed sweeping

Seabed preparation at the Endurance Store requires trenching for pipeline burial, trenching for scour protection and seabed sweeping to flatten the sandwaves. Each of these activities have the potential to increase suspended sediments temporarily during the works. The five (8") infield flowlines (cumulative length of 13 km) are anticipated to be buried, generating approximately 40,000 m^3 of trenched spoil which is intended to be stored on either side of the trench in shallow berms. The (28") infield pipeline and cables (cumulative length 36 km) may require a shallow trench to mitigate against scour prior to installation, which is expected to generate approximately 72,000 m^3 of trenched spoil which will again be deposited on either side of the trench. Seabed sweeping of a 30 m corridor is intended to be carried out for the infield pipeline, the infield flowlines, and cables (cumulative length of 51 km), which may require the movement of up to 52,000 m^3 of sediment, which will either be stored near the trench, or transported to a designated disposal site. Together this amounts to 164,000 m^3 of sediment being moved at the Endurance Store within the SNS SAC.

It may be assumed that up to 10% of this sediment will be released into the water column over the construction period (approximately two months), which would amount to 16,400 m^3 (following the method of the Langeled pipeline ES; Metoc, 2004). Ambient suspended sediment concentrations are much lower at the Endurance Store site than in the nearshore region, so the increase in suspended sediments is likely to be measurable. However, finer sand and silt are likely to settle back out to the seabed naturally over the course of hours or days (Defra, 2010), while gravel and coarser sand are expected to re-settle quickly (mostly within seconds). Therefore, due to the temporary nature of the increase in suspended sediments, the impact is anticipated to be not significant.

6.5 Management and Mitigation

6.5.1 General Measures

The following measures have been or are intended to be taken in order to reduce as far as reasonably practicable potential impacts on the environment from the various Development activities:

- Seabed surveys have been undertaken to identify the habitats and species present across the Development area and the potential for herring and sandeel spawning to occur in the vicinity of the Development;
- Pipeline route optimisation will be conducted where reasonably practical to minimise impacts on potential features of conservation interest;
- Pre-installation survey data will be utilised to aid design of an anchor plan for the pipelay vessel, with an objective to avoid potential features of conservation interest, where reasonably practical;
- Stakeholder consultation e.g. with fisheries and statutory nature conservation bodies will continue to be conducted as part of detailed design to identify areas of stakeholder concern and draw on a wide expertise with regard to potential sensitivities;
- The requirement for pre-installation sweeping and dredging will be minimised as far as reasonably practical;
- The nearshore trench spoil ridge will be present for as short a time as reasonably practical in order to minimise sediment losses and impacts on southwards longshore sediment transport at Humber. Post-lay survey will confirm the spoil ridge has dispersed;

- Taking into account relevant engineering considerations for pipeline stability and protection, the volume and placement of rock armour and concrete mattresses will be reviewed during detailed design to reduce the seabed footprint to the extent that is reasonably practical. Studies to be performed within detail design that will further assess and refine rock placement requirements may include:
  - Pipeline installation analysis;
  - On-bottom stability;
  - Shipping Interaction (for assessment of protection requirements and validate burial depth);
  - Free span and On-bottom roughness (these will quantify the free span mitigations);
  - Upheaval buckling (this will quantify type of backfill material – sand or rock – and quantity); and
  - Crossing design.
- It cannot be guaranteed that placement of rock armour will not occur within the MCZs however bp, as operator of NEP, will attempt to minimise this as far as reasonably practical;
- Rock will not be placed landward of 10 m LAT at the Humber landfall;
- The spread of rock armour during placement will be reduced through use of a fall-pipe system as far as reasonably practical. Side stone rock placement vessel may be utilised in shallower water;
- Prior to commencement of works, agreement on requirements will be reached with consultees for any pre-installation onshore beach survey at both of the pipeline landfall sites.
- A Beach Monitoring and Management Plan will be agreed with the Local Authority and relevant consultees, as required;
- Upon completion of construction and installation activities, all landfall installation equipment, including any beach cofferdam, working platform and temporary access route infrastructure at the Humber landfall will be removed and the beach will be reinstated to pre-construction condition, as far as reasonably practical as described in Section 3.2.2.1. These activities will be agreed with relevant parties as part of the Beach Monitoring and Management Plan;
- Prior to commencement of works, agreement on requirements will be reached with consultees for any post-installation surveys required to assess whether the sites have been returned to their pre-installation state, as far as reasonably practical;
- Any spoil generated from seabed sweeping will be deposited at pre-agreed locations outwith the Runswick Bay MCZ, Holderness Inshore MCZ, Holderness Offshore MCZ and Greater Wash SPA;
- Rock armour may be required at certain locations to ensure adequate protection of the pipelines and pipeline stability;
- Pipeline depth of cover in the nearshore and landfall zones will be sufficient to provide protection over the Development lifetime in light of coastal erosion and climate change;
- Wherever possible and as far as reasonably practical, material removed from trenches will be re-used; and
- A decommissioning philosophy has been developed during the FEED phase of the Development and will be revised during detailed design. Decommissioning will be performed in line with regulatory requirements at the time.

6.5.2 Marine Archaeology Mitigation

There is currently no guidance which specifically details best-practice mitigation methods with respect to submerged gas pipelines and the marine archaeological environment. However, in the absence of any industry specific guidance, as the general nature of impacts for submarine pipelines are likely to be similar to export and/or array cabling associated with wind farm development, the mitigation measures recommended here are in accordance with those set out in Historic Environment Guidance for the Offshore Renewable Energy Sector (Wessex Archaeology, 2007).

Typically, adequate and appropriate mitigation is required to ensure that the archaeological value of the baseline within this Chapter is maintained. International best practice and government policy favours preservation in situ of the archaeological resource.

The following measures are designed to mitigate any predicted adverse effects upon seabed assets from direct impacts. The measures are designed to reduce or offset any damage/disturbance occurring as a result of the proposed Development upon known assets, and to establish the presence of unknown sites.

6.5.2.1 Archaeological Exclusion Zones

Avoidance is considered to represent the primary option with regards to mitigating impacts upon the marine archaeological resource. This is typically achieved through the implementation and monitoring of Archaeological Exclusion Zones (AEZs) around known sites or through the micrositing of the scheme design to avoid vulnerable heritage assets.

The Crown Estate document Archaeological Written Schemes of Investigation for OWF Projects (The Crown Estate, 2021) states that AEZs are formed by establishing a buffer around the known extents of sites for which the available evidence suggests that there could be archaeological material present on the seabed. The mitigation will establish appropriately sized AEZs around assets which have been considered to be of high archaeological potential, in consultation with the Archaeological Curators (Historic England). These areas would be out of bounds to construction activities and to anchoring. Monitoring of any AEZs to minimise any risk of disturbance to them will be part of this mitigation.

Although AEZs are fixed, provision should be made for them to be refined or be removed (with agreement of the Archaeological Curators) as the Development progresses, subject to additional archaeological assessment of subsequent surveys that may be required. Surveys could include further geophysical, ROV, or diver surveys. In addition, in order to maximise the potential benefits of any further surveys, archaeological advice should be sought during the planning stages.

The recommended AEZs all have the potential to be amended or removed at a later date, should further information become available that proves their associated features are not of archaeological potential or represent more widely dispersed sites. This report is intended to inform the decision-making process for confirming the final AEZs.

The below Table 6-10 lists all the AEZs recommended within the Development area and illustrated in Figure 6-4 to Figure 6-6. As features of high archaeological potential, it is recommended that AEZs of 100 m are implemented around the 25 A1 features.

There are four charted wrecks (7036, 7197, 7208 and 7323) and three recorded obstructions (7059, 7205 and 7209) located within the Development area. As these features were not identified in the 2021 Pseudo SSS mosaic or MBES data at their recorded location and their position was not directly covered by the SSS or Mag. Datasets, it is not possible to ascertain whether ferrous material is present at these locations. As remains have been previously found at the recorded locations they have been retained as a precaution in this report. It is possible that the sites are currently completely buried, or possibly erroneously positioned. However, as records of potential archaeological interest, a precautionary AEZ of 100 m is recommended.

Table 6-10 - Recommended AEZs within the Development area

ID	Classification / archaeological discrimination		Position (ED50 UTM31N)		Exclusion zone	Study area
			Easting	Northing		
7536	Wreck	A1	376037	6011477	100 m buffer around current feature extent	Endurance Store
7541	Wreck	A1	377671	6005054	100 m buffer around current feature extent	Endurance Store
7197	Recorded Wreck	A3	236310	6060858	100 m around recorded position	Teesside Pipeline
7205	Recorded Obstruction	A3	239580	6062526	100 m around recorded position	Teesside Pipeline
7208	Recorded Wreck	A3	240669	6063095	100 m around recorded position	Teesside Pipeline
7209	Recorded Obstruction	A3	240706	6062879	100 m around recorded position	Teesside Pipeline
7210	Wreck	A1	243520	6063523	100 m buffer around current feature extent	Teesside Pipeline
7217	Wreck	A1	249133	6061305	100 m buffer around current feature extent	Teesside Pipeline
7253	Wreck	A1	258712	6059647	100 m buffer around current feature extent	Teesside Pipeline
7260	Wreck	A1	259927	6056931	100 m buffer around current feature extent	Teesside Pipeline
7262	Wreck	A1	260730	6058476	100 m buffer around current feature extent	Teesside Pipeline
7263	Wreck	A1	261810	6057750	100 m buffer around current feature extent	Teesside Pipeline
7264	Wreck	A1	261883	6056726	100 m buffer around current feature extent	Teesside Pipeline
7265	Debris field	A1	261892	6056699	100 m buffer around current feature extent	Teesside Pipeline

ID	Classification / archaeological discrimination		Position (ED50 UTM31N)		Exclusion zone	Study area
			Easting	Northing		
7270	Wreck	A1	262099	6055310	100 m buffer around current feature extent	Teesside Pipeline
7305	Debris	A1	267609	6052543	100 m buffer around feature position	Teesside Pipeline
7306	Debris field	A1	267608	6052609	100 m buffer around current feature extent	Teesside Pipeline
7307	Debris	A1	267614	6052537	100 m buffer around feature position	Teesside Pipeline
7308	Wreck	A1	267616	6052571	100 m buffer around current feature extent	Teesside Pipeline
7319	Wreck	A1	270387	6050868	100 m buffer around current feature extent	Teesside Pipeline
7323	Recorded Wreck	A3	271454	6050820	100 m around recorded position	Teesside Pipeline
7339	Wreck	A1	278244	6048535	100 m buffer around current feature extent	Teesside Pipeline
7503	Magnetic	A1	352788	6017861	100 m around recorded position	Teesside Pipeline
7007	Wreck	A1	309166	5951536	100 m buffer around current feature extent	Humber Pipeline
7036	Recorded wreck	A3	315924	5959415	100 m around recorded position	Humber Pipeline
7040	Wreck	A1	316112	5960258	100 m buffer around current feature extent	Humber Pipeline
7059	Recorded Obstruction	A3	318987	5974322	100 m around recorded position	Humber Pipeline
7063	Wreck	A1	319425	5974528	100 m buffer around current feature extent	Humber Pipeline
7066	Wreck	A1	320229	5975612	100 m buffer around current feature extent	Humber Pipeline
7072	Wreck	A1	319021	5977560	100 m buffer around current feature extent	Humber Pipeline

ID	Classification / archaeological discrimination		Position (ED50 UTM31N)		Exclusion zone	Study area
			Easting	Northing		
7078	Wreck	A1	319348	5980106	100 m buffer around current feature extent	Humber Pipeline
7188	Wreck	A1	358336	6012230	100 m buffer around current feature extent	Humber Pipeline

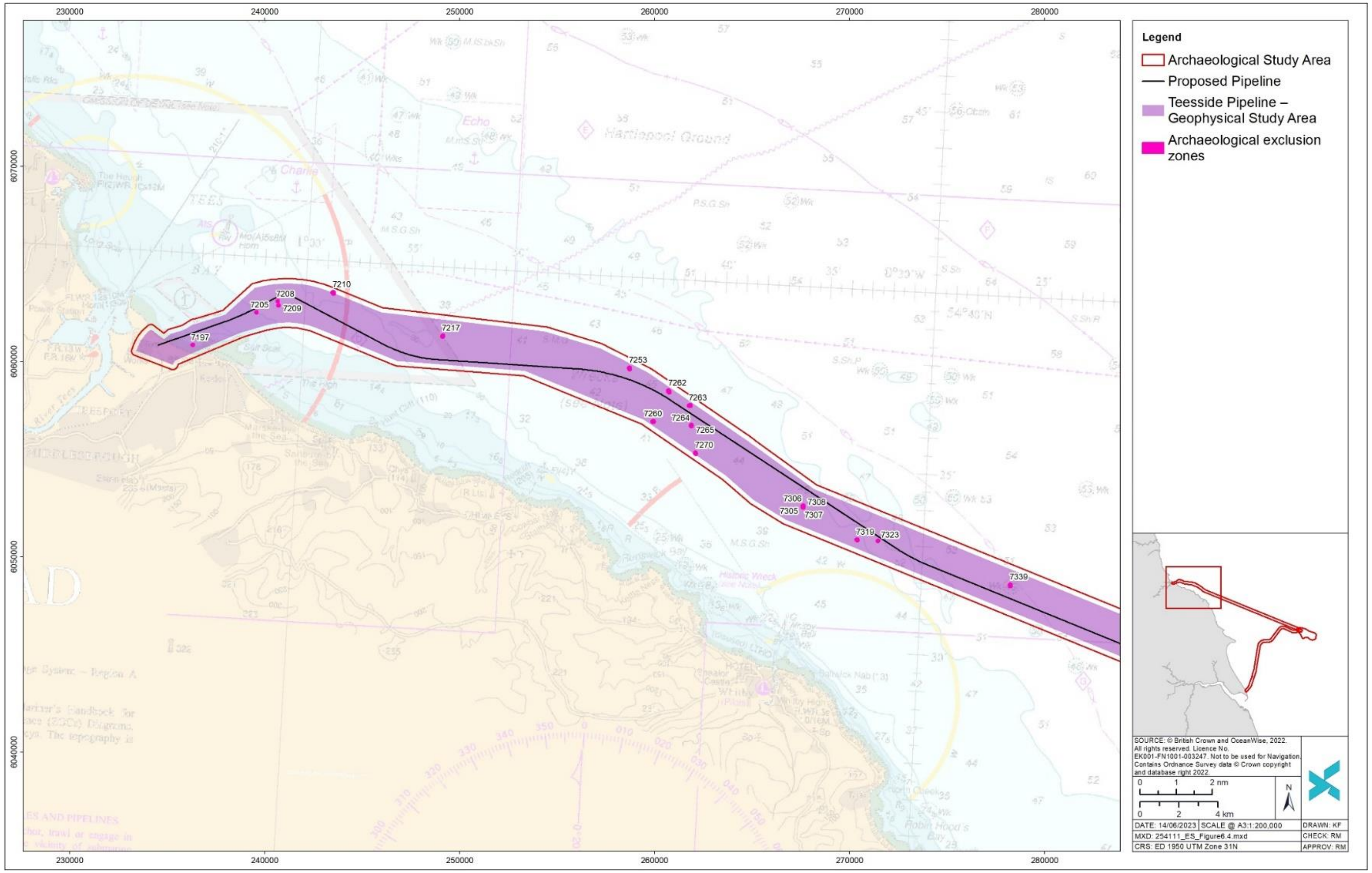


Figure 6-4 - Teesside Pipeline, recommended AEZs

Figure 6-5 - Humber Pipeline, recommended AEZs

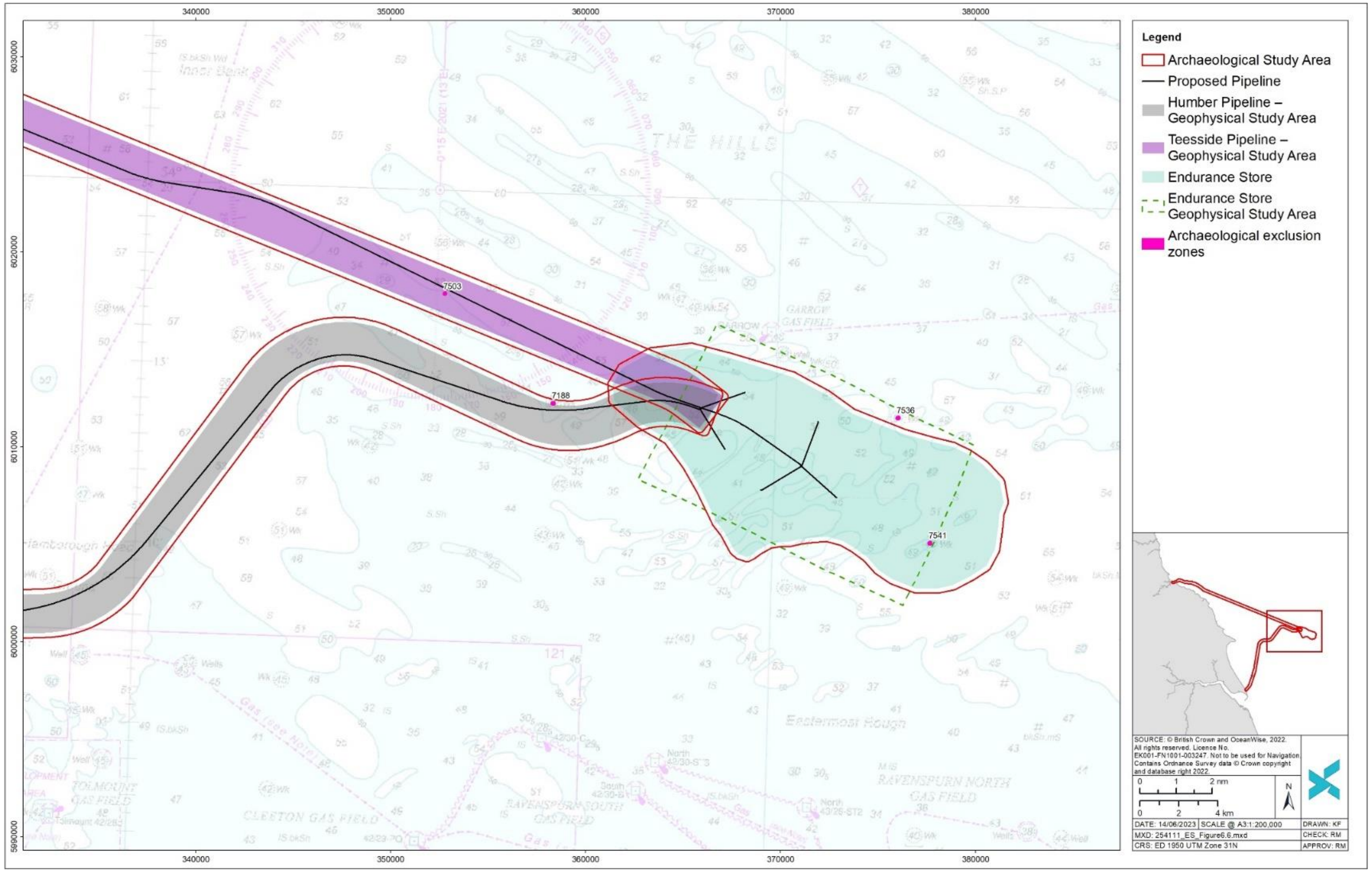


Figure 6-6 - Endurance Store area, recommended AEZs

6.5.2.2 Seabed Features of Archaeological Potential

For features assigned A2 archaeological discrimination rating, no AEZs are recommended at this time. However, avoidance of these features by micro-siting is recommended if they are proposed to be directly impacted by the Development in the future. If micro-siting is not possible, then further appraisal to ascertain the nature of the features may be required.

Reduction of impact can be achieved by means of appropriate mitigation identified through potential opportunities for further investigation of assets (e.g. during pre-installation surveys which may include visual survey methods and UXO assessment). Further investigations mean that anomalies can either have their archaeological value removed, if they prove to be of non-anthropogenic nature or modern, or their value as archaeological assets confirmed. If their value is confirmed, mitigation in the form of either avoidance (which may be enacted by the implementation of an AEZ) or through remedying or offsetting measures as identified through a Written Scheme of Investigation (WSI) which includes a Protocol for Archaeological Discoveries (PAD).

The WSI will detail the agreed mitigation that will be in place during the installation, operation, and decommissioning of the Development. The implementation of a WSI is the mitigation, rather than the document itself. The WSI will be developed in line with standard guidance and The Crown Estate document *Archaeological Written Schemes of Investigation for Offshore Wind Farm Projects* (The Crown Estate, 2021), which sets out agreed archaeological methodologies. The WSI will be set out based on the mitigation measures recommended in this chapter and will be subject to approval by the Archaeological Curators.

In cases where avoidance is either inappropriate or impossible, the damage to archaeological assets should be offset. Any mitigation strategy will be identified through a scheme WSI and any recommended methods will be covered by a specific Method Statement, approved by the Archaeological Curator, should they be implemented.

It is recommended that if further geophysical surveys are undertaken in advance of installation activities, such as UXO survey that requires magnetometer data, that it be assessed by a suitably qualified archaeological contractor. This will allow the identification of any additional ferrous features of archaeological potential within the Development area, as well as to confirm the presence of ferrous material at the location of features identified during this assessment, particularly around identified wreck sites and debris fields.

6.5.2.3 Protocol for Archaeological Discoveries

If previously unknown sites or material are encountered during the different phases of the Development, measures will be taken to reduce the level of impact. In order to provide for these unexpected discoveries a PAD will be adopted. The PAD is a system for reporting and investigating unexpected archaeological discoveries encountered during installation activities, with a Retained Archaeologist providing guidance and advising industry staff on the implementation of the PAD. The PAD also makes provision for the implementation of temporary exclusion zones around areas of possible archaeological interest, for prompt archaeological advice, and, if necessary, for archaeological inspection of important features prior to further activities in the vicinity. The PAD provides a mechanism to comply with the MSA 1995, including notification of the Receiver of Wreck, and accords with the Code of Practice for Seabed Developers (JNAPC, 2006).

6.5.2.4 Remedying and offsetting

In cases where avoidance is either inappropriate or impossible, the damage to archaeological receptors should be offset. In the case of seabed prehistoric receptors, this can be achieved by undertaking a palaeoenvironmental assessment of deposits with High geoarchaeological potential, principally peat deposits. Pollen and macrofossil assessment, supported by radiocarbon dating, will provide information on age and vegetation history of the terrestrial environment, providing a landscape context to any prehistoric activity within the area.

Recovery of artefacts and/or other archaeological receptors should be a final resort, when all other mitigation has failed. Any recovery should be completed under the supervision of an appropriately qualified and experienced marine archaeologist. If required, recovery methods will be identified through a Written Scheme of Investigation.

A final method would include the recording of sites that cannot be preserved.

Due to the vast differences in practice and implementation between these methods, each will be covered by a specific Method Statement agreed in consultation with the Archaeological Curator.

6.6 Cumulative and Transboundary Impacts

In consultation, bp has identified a list of other projects which, together with the Development, may result in potential cumulative or in-combination impacts. The list of these projects including details of their status at the time of the EIA and a map showing their location is provided in Appendix D. Having considered the information presently available in the public domain on the projects for which there is a potential for cumulative or in-combination impacts, Table 6-11 indicates those with the potential to result in cumulative or in-combination impacts from a seabed disturbance perspective. The consideration of which projects could result in potential cumulative or in-combination impacts is based on the results of the project-specific impact assessment together with the expert judgement of the specialist consultants.

Table 6-11 - Summary of cumulative and/or in-combination impacts for seabed disturbance

Project title	Potential for cumulative and/or in combination impacts				
	Benthic ecology	Fish	Birds	Marine archaeology	Coastal processes
Oil and gas field subsea infrastructure					
Tolmount East Development	✓	✓			
Kumatage field	✓	✓			
Pipelines and cables					
Langeled export (PL2071)	✓	✓			✓
Breagh export (PL2769.1, PL2768.1, PL2769.2, PL2768.2)	✓	✓			
CATS export (PL774)	✓	✓			
Amethyst export (PL649)	✓	✓			
OWFs					
Hornsea Project Four	✓	✓	✓	✓	✓
Westermost Rough	✓	✓	✓		
Seabed cables					
Pangea North	✓	✓	✓		
TGN Northern Europe (formerly TATA North Europe)	✓	✓	✓		
Teesside Windfarm cable	✓	✓	✓		
UK-Denmark 4	✓	✓	✓		
UK-Germany 6	✓	✓	✓		
Dogger Bank C Transmission Asset	✓	✓	✓	✓	✓
Dogger Bank A	✓	✓	✓	✓	

Project title	Potential for cumulative and/or in combination impacts				
	Benthic ecology	Fish	Birds	Marine archaeology	Coastal processes
Dogger Bank B Transmission Asset	✓	✓	✓	✓	✓
Sofia Transmission Asset	✓	✓	✓	✓	✓
Breagh Fibre Optic Cable (PL2770)	✓	✓	✓		
Scotland to England Green Link – SEGL2	✓	✓	✓	✓	✓
Hornsea Four Transmission Asset	✓	✓	✓	✓	✓
Aggregate and mineral extraction					
Hundale/Woodsmith Potash Mine	✓	✓	✓	✓	
Humber 1	✓	✓	✓		✓
Humber 2	✓	✓	✓		✓
Other					
York Potash Harbour Facilities Order	✓	✓	✓		
NZT Power	✓	✓	✓	✓	✓
Humber Low Carbon Pipelines	✓	✓	✓	✓	✓
Tees and Hartlepool Maintenance Dredge Disposal	✓	✓	✓		✓
Disposal site – Tees Bay A	✓	✓	✓		✓

6.6.1 Benthos and Fish

The potential impacts discussed in this section are associated with:

- Temporary seabed disturbance and sediment re-suspension during the construction and installation phase of the Development; and

- Long-term changes in seabed habitat due to the presence of structures on the seabed throughout the operational phase (and possibly permanently if structures such as rock berms cannot be removed when the Development is decommissioned).

As demonstrated in Section 6.4.2, the potential impacts on seabed habitats and species are localised and there is little potential for overlapping zones of impact with other plans and projects. To take a conservative approach, consideration has been given to those plans and projects which lie within the tidal excursions of the different parts of the Development area (approximately 5 km for the Teesside Pipeline area and 15 km for the Humber Pipeline and Endurance Store areas) as described below for coastal processes (Section 6.6.4.1). Developments at greater distances have been excluded from specific assessment here. However, it is important to assess the potential cumulative impacts of long-term changes in seabed habitat within protected sites; these impacts are discussed in Section 6.9.

Of the remaining projects, those which are already operational have mostly been excluded because large scale seabed impacts and sediment disturbance will not be occurring and will therefore not interact with the current Development. The exceptions to this are open dredging areas that are expected to generate seabed disturbance and suspended sediment, and existing pipelines and cables which will be crossed by the Development and the presence of which dictate specific seabed disturbance which would not otherwise have been necessary.

6.6.1.1 Construction and installation phase

Seabed disturbance during this phase will be short-term and the majority of the Development area is expected to recover quickly. Rapid recovery by benthic communities following pipeline installation has been recorded at nearby developments, e.g. the Langeled pipeline (Salmon, 2011). Gray and Elliot (2009) report that in UK waters a total area equal to twice the total North Sea seabed is trawled annually. In this context, the temporary disturbance caused by the Development is considered negligible and is not expected to make a significant contribution to cumulative impacts.

Suspended sediment concentrations are expected to be naturally high within the Development area due to the high current speeds and the ample availability of mobile sediment. The quantity of sediment disturbed and mobilised during the proposed operations, even when combined with disturbance from the nearby developments listed above, is expected to be negligible compared to the natural sediment movements in the area, especially those experienced during storm events. There are several studies available indicating that the production of sediment plumes from aggregate dredging is negligible when compared to background suspended sediment concentrations in the area (Hitchcock and Drucker, 1996; Newell *et al.*, 1998; Newell *et al.*, 2002).

6.6.1.2 Operational phase

Along the Teesside Pipeline route, the crossings of the Everest (CATS export), Breach and Langeled gas pipelines and other existing or future cables are expected to generate a requirement for approximately 0.07 km^2 of additional rock armour for pipeline and scour protection purposes. The Teesside – Store cable will make the same crossings, requiring a further 0.02 km^2 of rock protection (Table 6-3). Along the Humber Pipeline route, the crossings of the Langeled gas pipeline and the planned Hornsea Four windfarm export cable are expected to generate a requirement for approximately 0.01 km^2 of additional rock armour. The necessity for these crossings adds small areas of additional long-term habitat changes associated with the proposed Development.

In a more general sense, the total minor long-term impact on habitats and benthic fauna associated with the Development will inevitably have a small cumulative impact in combination with the long-term impacts associated with the many other existing and planned developments in the area. The North Sea Transition Authority (NSTA, 2023) interactive map has been used to identify the presence of approved subsea deposits within the study area for cumulative impacts on benthos and fish, as described above. There are isolated records of rock dump and concrete mattressing to protect pipelines and umbilicals associated with gas production, mainly in the southern part of the Development area in the vicinity of the Humber Pipeline and Endurance Store. In particular, a series of concrete mattresses lie along the Perenco-operated pipeline between Easington Gas Terminal and the West Sole gas field, south of the Humber Pipeline.

While the Development area is relatively heavily exploited compared to the majority of the North Sea, it still supports substantial benthic fishing activity as well as widespread high quality examples of protected seabed features. As such, it is considered unlikely that the small additional seabed area subject to long-term disturbance from the Development will result in cumulative impacts that are significant to the overall condition of seabed habitats or features, or to the structure and abundance of the benthic community and those species dependent on them.

6.6.2 Birds

6.6.2.1 Identification of projects

The screening process used to identify plans and projects that may act cumulatively to affect bird species has identified the following industries that may interact with those birds affected by the Development:

- Oil and gas surface infrastructure;
- Pipelines;
- OWFs;
- Seabed cables;
- Aggregate and mineral extraction; and
- Port developments.

Activities associated with all of these types of project may result in seabed disturbance including during construction or as an ongoing impact through operation if infrastructure remains in the marine environment. The magnitude of an impact for many projects is likely to be greater during construction. This is especially relevant to pipeline and cable projects which, once installed, allow the seabed to return to its original state – except in localised areas if pipelines remain unburied or require rock protection. For other types of project, structures such as platforms and turbines, or activities such as aggregate extraction mean seabed disturbance is permanent across the lifetime of the Development or intermittent as material is removed from the seabed.

For red-throated diver, oil and gas surface infrastructure projects and pipeline projects can be ruled out, with no projects of these types identified that will act cumulatively with the Development to impact red-throated diver. Other project types may act cumulatively and these are considered below For little tern, no projects have been identified that will act cumulatively with the Development.

6.6.2.2 Assessment of cumulative impacts

During construction and operation activities associated with OWFs can result in the loss of seabed habitat for birds. This includes the foundations for turbines and the installation of export cables. There are a number of operational OWF projects located within the Greater Wash SPA that will act cumulatively with the Development to reduce the habitat available to red-throated divers. There are also a number of OWF projects that, although located outside of the area where red-throated diver densities are highest, may cause seabed disturbance through the installation of an export cable (seabed cable projects). There are also a number of aggregate and mineral extraction sites within the Greater Wash SPA that, through ongoing extraction activities, could cause seabed disturbance.

The predicted direct impact associated with the Development represents approximately 0.04% of the total Greater Wash SPA area or an even smaller proportion of the total area of the SNS used by red-throated divers. This small reduction in available foraging habitat for seabirds will not take the foraging habitat available in the wider area below that required to sustain the local seabird populations and there will therefore be no significant cumulative impact with existing projects.

6.6.3 Marine Archaeology

The following section assesses how other plans or projects in the region of the Development may result in cumulative effects to marine archaeology receptors within the Development area.

The potential for cumulative effects has been considered from the list of projects/plans within the vicinity of the proposed Development that have the potential to give rise to cumulative effects for the installation, operation and decommissioning stages of the Development.

It has generally been considered that the potential for cumulative effects will be greatest during the installation phase. Decommissioning is assumed to have similar (or lesser) impacts than installation. In the event that pipelines need to be repaired or maintained, the activities required to undertake the works are considered similar to the effects that may arise during installation although much lower in magnitude due to the considerably reduced scale and shorter duration of works.

Section 5.6 provides details on the assessment. The locations of projects within this list in relation to the proposed Development are illustrated in Appendix D. This includes major projects (OWFs, interconnector cables, oil and gas), aggregate dredging projects, dredging and disposal projects, and coastal projects.

Given the highly localised nature of direct impacts on marine archaeological receptors, the ZoI for cumulative assessment is considered to be the spatial extent of the Development within UK waters.

There is potential for indirect impacts to occur upon known and potential marine archaeology as a result of changes to hydrodynamic and sediment transport regimes, during the installation stage of the proposed Development and / or the decommissioning stages of all considered projects. These effects could lead to increased exposure or coverage of the marine archaeology and cultural heritage resource. Increased exposure could cause receptors to be vulnerable to deterioration, whereas increased coverage could promote preservation. Direct and indirect physical impacts on marine archaeology, due to similar effects from different elements of the proposed Development, or in combination with those from other activities will in most cases be limited by the location and extent of sensitive receptors. Due to proposed mitigation detailed in Section 6.5 such as the implementation of AEZs, reporting protocols and other best-practice elements, it is anticipated that most effects will be avoided, particularly to known receptors identified on/in/beneath the seabed.

The potential for impact increases as the distance between sites decreases, and therefore there is higher potential relating to Hornsea Project Four OWF and Transmission Asset, Dogger Bank C, A and B Transmission Assets, Sofia Transmission Asset, Scotland to England Green Link 2 (SEGL2), Hundale / Woodsmith Potash Mine, Net Zero Teesside and Humber Low Carbon Pipelines. At the time of writing these projects are either consented or in pre-planning stages.

Hornsea Project Four is undergoing EIA, and therefore any significant direct impacts will likely be mitigated against, resulting in negligible adverse significance. However, should direct impact occur, it could range from low to major adverse significance, depending on the value of the receptor being impacted. Indirect impacts, such as scour, are likely to be very localised. Therefore, Hornsea Project Four is unlikely to cause any indirect impacts cumulatively with the Development.

For cable and pipeline projects, any known seabed features should have been avoided during the route development process, as these would constitute engineering hazards. As part of the marine licence consent conditions, a WSI is required for those cable projects which are under construction or operational. As part of the WSI, a PAD is implemented to mitigate against any new discoveries. This is the case for Hornsea Project Four Transmission Asset, Dogger Bank and Sofia Transmission Assets and will likely be the case for SEGL2, Net Zero Teesside and Humber Low Carbon Pipelines, which are currently in pre-planning application stages.

Impacts to buried material in general is likely to be relatively minimal, although over a long distance. The cables would likely have been shallowly buried, or any covering material would have a relatively small footprint. Furthermore, as cables and pipelines are likely to be buried or covered by low-lying material, they are unlikely to cause noticeable changes to hydrodynamic and sediment transport regimes.

Discrete archaeological sites and unknown sites encountered by chance during Installation, will be too small to be subject to impact interactions arising from combined effects of the Development with other developments and activities in the area.

Due to the proposed mitigation detailed above in section 6.5, such as the implementation of AEZs, archaeological reporting protocols and other best-practice elements, most effects will be avoided, particularly to known receptors identified on, in or beneath the seabed. Therefore, any cumulative impacts from direct and indirect impacts from other projects would be negligible which is not significant.

6.6.4 Coastal Processes

6.6.4.1 Teesside Pipeline

No cumulative impacts are anticipated as a result of the Hornsea Project Four windfarm occurring in tandem with the Teesside Pipeline (should the present Hornsea Project Four schedule be met).

A number of subsea cables, mostly to be installed in association with OWFs, will be crossed by the Teesside Pipeline. The transmission assets associated with the Dogger Bank C and Sofia OWFs share the same cable corridor at present. The transmission assets for Dogger Bank A and B also share the same cable corridor (Appendix D). From the proposed project schedules, it is not clear if cable installation would precede the installation of the Teesside Pipeline so it is possible that temporally there may be some overlap. Should this transpire, there could be some spatial overlap at the crossing points. The crossings will occur further offshore and so are likely to coincide with the length of pipeline being surface laid. Dredging of the pipeline and cables are likely to generate similar impacts through increased suspended sediment concentrations. However, crucially the impacts associated with the installation of the Teesside Pipeline and the proposed cables will be temporary in nature. Furthermore, due to the localised nature of impacts anticipated with such activities, any additional sediment released into the water column will be reincorporated into the local sediment regime. Overall, no cumulative impacts are expected as a result of the Teesside Pipeline installation and activities associated with other projects.

The Tees channel is regularly dredged with the spoil deposited offshore on a regular basis, so it is likely, that the dredging will occur at the same time as the proposed Teesside Pipeline works. The proposed dredging activities associated with the Teesside Pipeline will be short-term and exclusive to the construction phase of the Development and so will not require continued maintenance as the Tees channel does. In the context of the channel dredging, the activities associated with the Teesside Pipeline are smaller in scale. The area of impact associated with the proposed pipeline installation will be so localised in scale that it is unlikely that there will be any spatial overlap, should the two activities coincide.

6.6.4.2 Humber Pipeline

The Humber Pipeline will cross the existing Langeled export pipeline (PL2071) and the Hornsea Four Transmission Asset subsea cable, which necessitates rock placement as protection. While the Langeled export pipeline is already installed and any rock placement at crossings will occur in isolation from any activities along the pipeline, installation of the Hornsea Four Transmission Asset may overlap with the installation of the Humber Pipeline. Hornsea Project Four, with which the transmission asset is associated, is also scheduled to begin construction in 2026 (Appendix D). Some of the Hornsea Four project activities may be similar to those associated with the installation of the Humber Pipeline, for example pre-sweeping activities. These activities may generate similar impacts through increasing suspended sediment concentrations, albeit at difference scales. However, the impacts from installation of the Humber Pipeline and the windfarm and associated export cable are all expected to be temporary in nature and will only overlap for the duration of construction (if the present Hornsea Four schedule is met). With regards to installation of rock placement as protection along the Humber Pipeline, or at the Hornsea Four Transmission Asset or within the windfarm array area, the cumulative area of seabed affected by rock placement is unlikely to have a perceptible impact on local hydrodynamic regime; the scale of rock placement within the wider area context is such that it will not pose a barrier to local hydrodynamic conditions. As established throughout Section 6.4.2.2.6 (and Appendix G), the Holderness coast is a highly active environment with sediment transport, so any activity which generates additional suspended sediment in the water column is likely to be quickly reincorporated into the sediment regime and redistributed locally. Consequently, it is not expected that the impacts associated with the installation of the Humber Pipeline and Hornsea Four infrastructure will interact cumulatively on a long-term scale.

The Humber 1 and 2 aggregate extraction areas are located within 15 km of the Humber Pipeline, therefore lie within a tidal excursion ellipsis. The licences are for the removal of both sand and gravel, principally for use in the construction industry. TCE and British Marine Aggregate Producers Association (BMAPA) produced a report on the influence of aggregate dredging on the Humber

Coastline in response to concerns that extraction was contributing to local coastal change. Aggregate is dredged from the seabed and the dredging process typically results in a cut of sediment 0.3 m deep and 2 m wide being removed. The report determined that, over the 15-year period between 1998 and 2012, on average across the dredged area, the seabed was lowered by 0.28 m (TCE and BMAPA, 2015). Therefore, impacts on the local hydrodynamic regime are likely to be minimal due to aggregate activity. When combined with impacts from the Humber Pipeline installation activities, it is not anticipated that changes to the seabed will influence local coastal processes.

Furthermore, the fossil sediments being removed from the dredging areas do not form part of the modern sediment transport system, so they are unrelated to the sediments present along the coast and therefore are not part of the local sediment transport regime (TCE and BMAPA, 2015). Therefore, their removal is not consequential to local sediment transport processes. As the dredged aggregate is drawn up through the dredge pipe, disturbance to the surrounding area through increased suspended sediment in the water column is unlikely to have an impact on sediment transport owing to the mobile nature of the Humber region. In combination with the Humber Pipeline installation which will occur over a short-term period of time, no cumulative impacts are anticipated.

6.6.4.3 Transboundary impacts

Given the focus herein on impacts to physical processes along the east coast of England associated with the installation of the Humber and Teesside pipelines, transboundary impacts will not occur. Using the tidal excursion ellipse extents for the pipelines (per preceding sections), any localised impacts to marine processes are unlikely to extend beyond the tidal excursion distance.

The Endurance Store is located approximately 105 km from the UK/Netherlands median line, and the pipeline landfall locations are further still. Circulation patterns within the North Sea do exist so there is a degree of connectivity between all nations with a North Sea coastline; however, the scale of the proposed impacts associated with the Development are minor within the context of the North Sea region as a whole.

6.7 Blue Carbon

Blue carbon refers to carbon sequestration (the removal of carbon dioxide from the atmosphere) by marine and coastal ecosystems, habitats, and species. Marine sediments are the primary store of biologically derived carbon (Burrows *et al.*, 2014). Carbon stored in organisms can be broadly defined as either 'transient' stores, such as the carbon stored in seagrass beds, kelp and macroalgae; and 'long-term' biological stores, such as biogenic structures (e.g. coral reefs, serpulid reefs, mussel beds).

Carbon may be sequestrated in marine sediments as precipitated carbonates (PCO) or as particulate organic carbon (POC). While sediment accumulation rates tend to be faster nearer to land (e.g. in sea lochs), it is unclear what processes maintain accumulation basins on the shelf, or whether any organic material from phytoplankton in productive shelf waters remains there (Burrows *et al.*, 2014). Threats to long-term carbon burial in sediments include any process that stirs up the sediment, particularly the top few millimetres of sediment. Resuspension of sediment allows rapid consumption of buried carbon by organisms and its subsequent release as carbon dioxide. This significantly reduces the carbon burial rate and the blue carbon inventory.

A mix of sediment types occur across the Development area. Burial rates for organic carbon into finer sediments are higher compared to coarser sediments (Gregg *et al.*, 2021). Average burial rates for sand, which is found across much of the Development area, are low compared to other sediment types (0.2 gC/m^2/yr). Average burial rates for sand/mud/gravel sediments are higher at 7.0 gC/m^2/yr; these mixed sediments can also be found in places along the pipeline routes (Burrows *et al.*, 2014). The overall percentage carbonate in the top 10 cm of superficial sediments across the Development area, interpolated from BGS sediment records, ranges from 10-20% at the Store and along the Humber Pipeline route, to 30-40% close to the Teesside Pipeline landfall (Scottish Government, 2023).

Saltmarsh and seagrass habitats represent the largest sedimentary carbon store of all marine and coastal habitats. When undisturbed, both habitats have the potential to store carbon long-term (Gregg *et al.*, 2021). No saltmarsh or seagrass habitats were observed by surveys of the Development area. The MMO (2019) identified the Humber Estuary area as one suitable for marine habitat restoration. Seagrass meadow restoration efforts are already under way in the lee of Spurn Point, within the Spurn Point Nature Reserve. Oyster beds were not observed in the surveys of the Development area, nor are known to occur close to the proposed Humber Pipeline route.

The physical environment of the Tees estuary suggests the potential for future seagrass (MMO, 2019). The Stronger Shores pilot project aims to provide an innovative approach to tackling flooding and coastal change, through understanding the coastal protection value of kelp, seagrass and oyster reefs along the northeast coast of England between Northumberland and North Yorkshire. At present, there is not likely to be any overlap between the Development and the Teesside Pipeline route and the Development is unlikely to have any impact on the restoration efforts. The Tees Seagrass Project, in partnership between the Tees Rivers Trust and Natural England, has introduced trial patches of seagrass at a number of sites within Teesmouth and Tees Bay, amongst other areas. This project is limited to coastal locations north of the Tees Estuary, therefore will not coincide spatially with the proposed Teesside Pipeline.

No other habitats or species in the Development area are likely to have significant carbon sequestration potential.

There are a number of threats to carbon stocks and sequestration potential in the UKCS but the impact of the offshore energy industry on blue carbon has yet to be assessed and/or quantified. There is little understanding of habitat recovery with regards blue carbon. Activities such as trawling, which physically change the sediment, result in resuspension (which may decrease stocks and create emissions); faunal mortality (which may increase burial) and direct mixing or relocation of carbon (which may increase or decrease stocks/burial; Burrows *et al.*, 2021). Seabed interaction from the Development will be largely temporary and highly localised, with limited opportunity for interaction at the same scale as trawling.

Overall, the sediments in the Development area are considered to have a low-moderate carbonate value. There is, at present, an absence of other key habitats with blue carbon potential (e.g. kelp beds, seagrass beds) in the area. As noted, there may be future seagrass restoration efforts at both Humber and Teesside. The pipeline routes cover a range of habitats with variable blue carbon potential compared to the Endurance Store which has less inherent potential. Overall, the Development area is considered to represent an area of moderate blue carbon potential. Regardless, the activities associated with the Development are unlikely to impact the carbon sequestration potential of the immediate seabed and associated habitats due to their localised nature and largely temporary impact.

6.8 Decommissioning

Decommissioning activities will be subjected to a Decommissioning Environmental Appraisal (EA) at the end of the operational life of the Endurance Store and prior to decommissioning commencing. The significance of any impact will depend on the baseline conditions at the time of the Decommissioning EA and the proposed decommissioning approach. As a worst case, impacts during decommissioning operations are expected to be on a similar scale to those occurring during installation.

As with installation activities, decommissioning activities have the potential to affect archaeological assets either directly or indirectly. If the pipelines are left buried, however, likely significant effects from decommissioning are expected to be avoided. If the pipelines are to be removed at decommissioning this assessment assumes that impacts from decommissioning activities are of a similar nature to installation activities and would be of a similar or lesser scale, and therefore not likely to be significant.

6.9 Protected Sites Assessments

6.9.1 MCZ Assessment

6.9.1.1 Introduction

6.9.1.1.1 Background

Based on the requirements of the Marine and Coastal Access Act (MCAA) (2009) act, an assessment is required on the potential impacts of the pipeline installation, infrastructure and any required rock protection within MCZ boundaries. In line with the guidance provided by the MMO (2013), this assessment addresses the potential for the pipeline and rock berm to significantly hinder the conservation objectives of the designated interest features within the Holderness Inshore MCZ and the Holderness Offshore MCZ.

Runswick Bay MCZ has been scoped out the MCZ assessment, since the Teesside Pipeline has been routed at least 1 km beyond the northern MCZ boundary. No activities (including pipelay vessel anchoring) will take place within the MCZ, and no infrastructure (including rock berms) will be placed within it (Figure 6-1). The only potential impacts within the MCZ are temporary indirect impacts from pipeline installation activities: fine sediments suspended during trenching or backhoe dredging may transit within the MCZ boundary. However, these are unlikely to be detectable above the naturally high levels of suspended matter, therefore any impacts are deemed insignificant.

6.9.1.1.2 Report context

The placement of rock along the Humber Pipeline is the worst case scenario with regards to seabed disturbance and has been assessed as such throughout Chapter 6: Seabed Disturbance. As established throughout the preceding sections, temporary impacts associated with the are not expected to be significant in the context of seabed habitats and benthos. Consequently, this MCZ assessment will focus on permanent impacts associated with the proposed activities, namely the need for rock placement along the Humber Pipeline.

6.9.1.1.3 Consultation

The MCZ assessment methodology presented and applied in this report is informed by the MMO (2013) guidance document. In addition, stakeholders have provided feedback during scoping regarding assessment of features within the MCZ. These stakeholder comments are shown in Table 6-12 and have been addressed throughout this MCZ assessment.

In addition, consultation with NE and JNCC was sought during the EIA process to agree upon the proposed MCZ assessment approach.

Table 6-12 - Stakeholder comments regarding MCZ assessment and impacts on designated interest features

Stakeholder comment	Response
JNCC The Humber Pipeline crosses the Holderness Offshore MCZ, which is designated for subtidal coarse sediment, subtidal sand, subtidal mixed sediments, *Arctica islandica* and North Sea glacial tunnel valleys. All features within this site are currently in an unfavourable status and all have a recover objective, therefore any impacts to this site must be assessed per feature and not as a whole site. We recommend that any introduction of hard substrate (e.g. rock dump) within Holderness Offshore MCZ be avoided.	Direct and indirect impacts on the designated interested features of the Holderness Inshore MCZ and Holderness Offshore MCZ are addressed in Section 6.9.1.4 and Section 6.9.1.5 respectively. Proposed Development impacts are screened in/out against each designated feature individually prior to the Stage 1 MCZ Assessment being conducted; these potential impacts are listed in Section 6.9.1.4.2 and 0 respectively per each MCZ. The conclusions of the assessment take into consideration the conservation objectives of each interest feature. The conservation objectives associated with the Holderness Inshore MCZ and Holderness Offshore MCZ are listed in Section 6.9.1.3.4 and 6.9.1.3.4.2.1 respectively.
Natural England The ES should consider including information on the impacts of this development on MCZ interest features, to inform the assessment of impacts on habitats and species of principle importance for this location. Further information on MCZs is available via the following link: http://publications.naturalengland.org.uk/category/1723382	Direct and indirect impacts on the designated interested features of the Holderness Inshore MCZ and Holderness Offshore MCZ are addressed in Section 6.9.1.4 and Section 6.9.1.5 respectively.
The Wildlife Trust TWT is concerned that the proposed Humber Pipeline intersects with Holderness Inshore MCZ and Holderness Offshore MCZ, particularly regarding the impacts from rock dumping or concrete mattressing. Our position is that cable and pipeline protection should not be permitted in MPAs. This is because protection such as rock dumping or concrete mattressing causes: • Habitat loss, modification and changes in epifauna communities.	A Stage 1 MCZ assessment is completed here for each MCZ to assess for potential impacts on the designated interest features with respect to their respective conservation objectives. Results of the Stage 1 assessment has demonstrated that there is no anticipated impact to the features such that their conservation objectives are hindered. Therefore, it is not anticipated that further assessment is required at this stage.

Stakeholder comment	Response
• Impacts for the lifetime of the Development, placing the conservation objectives of MPAs at risk. In the case of MCZs, this would be contrary to the Marine and Coastal Access Act. • Impacts that can extend beyond the lifetime of the Development, as cable protection can be challenging to decommission. Therefore, it is often left in situ. We request that to avoid habitat loss within the two MCZs and consenting risk, pipeline rerouting should take place to avoid the sites. If the pipeline is not re-routed, we expect the Measures of Equivalent Environmental Benefit (MEEB) will be required. As outlined in draft Defra guidance on marine compensation, MEEB and compensation are to be treated to the same standard. Therefore, it is essential to develop MEEB which would ensure the coherence of the UK MPA network. TWT highlight that MEEB is extremely difficult to deliver for benthic habitats. We would be happy to engage in a further conversation in this area.	
The Wildlife Trust In terms of an MCZ assessment, TWT highlight that it is now standard practice for assessments to be to the same standard as an HRA assessment. This is further supported by Defra draft guidance which states “equal consideration of the effect of proposals should be given to all MPAs, regardless of the legislation they were designated under”.	This MCZ assessment follows the MMO (2013) Marine conservation zones and marine licensing guidance. The first stage of the assessment is the screening process which determines which predicted impacts associated with the Development activities have the potential to impact the MCZ designated features directly or indirectly. Once established what features may be impacted, they are further assessed. The complete assessment takes into consideration of the seabed footprint associated with the pipeline seabed preparation and installation and any required rock protection. The MCZ assessment also includes empirical assessment of the hydrodynamic and sediment transport potential across rock placement within the MCZs. The impacts to each MCZ will be addressed separately with consideration given to the differing interest features and conservation objectives of the sites.

Based on the MMO (2013) guidance and above stakeholder comments, this assessment includes the following:

- A review of the marine processes of the Holderness coastline, which is common to both MCZs, obtained from outputs of local and regional scale studies including:
  - SNS Sediment Transport Study (SNSSTS) (HR Wallingford, 2002);
  - Flamborough Head to Gibraltar Point SMP (Humber Estuary Coastal Authorities Group, 2010a; 2010b);
- Consideration of the seabed footprint associated with the pipeline seabed preparation and installation and any required rock protection; and
- Empirical assessment of the hydrodynamic and sediment transport potential across rock placement within the MCZs – the impacts to each MCZ will be addressed separately with consideration given to the differing interest features and conservation objectives of the sites.

6.9.1.2 Project Description

A full description of the pipelay and trenching operations for the Humber Pipeline and potential rock placement is provided in Chapter 3: Project Description. A summary description of the operations relevant to this assessment is outlined below.

6.9.1.2.1 Description of proposed operations

The pipeline installation methodology is described fully in Section 3.2.4. Within the Holderness Inshore MCZ, the Humber Pipeline will be trenched and buried. Within the Holderness Offshore MCZ the Humber Pipeline will be mostly surface laid, with the exception of a short section being trenched and buried. There will be varying requirements for rock placement along the length of the Humber Pipeline within the two designated sites. A summary of the assumptions for the pipeline and associated rock placement are provided in Table 6-13 below.

If pipeline cover is required, a fall-pipe system would be used to place the rock armour on the seabed as precisely as possible. Rock will not be placed landward of 10 m LAT (KP1.2). A maximum rock berm height of 2 m above the seabed has been assumed for the purposes of this assessment. The flanks of the berm would be no steeper than a 1 in 3 gradient.

The Tolmount HGS pipeline was installed in 2020 with requirement for 11,278 t of rock armour within the Holderness Inshore MCZ. Rock placement was required in two locations where insufficient burial depth was achieved and in a number of locations where the pipeline was at the requisite depth within a trench but where natural backfill material was not available to provide sufficient protection within the necessary timescales. The York pipeline was installed in 2011 – 2012 without any rock armour.

Table 6-13 - Summary information on proposed operations within the MCZs

	Holderness Inshore MCZ	Holderness Offshore MCZ
Pipeline diameter	28" (711.2 mm)	
Pipeline length	6,141 m	19,830 m
Rock placement assumption (worst case)	7.5% of the length within the MCZ	5% of the length within the MCZ
Rock berm width	13	10
Rock berm gradient	1:3	
Rock berm height	2 m (maximum)	
Length of rock placement within site (worst case)[175]	391 m	991 m
Remaining length of surface laid pipeline within site	0 m	18,100 m
Remaining length of trenched and buried pipeline within site	6,141 m	1,725 m
Total rock area within site	5,838 m^2	9,980 m^2

6.9.1.3 Environmental Baseline

6.9.1.3.1 Regional environment description

The Holderness coastline is in a macro tidal setting, with a mean spring tidal range of up to 6 m. Water levels for the closest standard port at Spurn Head are summarised in Table 6-14. Current speeds across the area are twice as fast on a spring tide compared to a neap tide. Current speeds at the tidal diamond (SN017AD) closest to the Humber Pipeline landfall (and within the Holderness Inshore MCZ) reach peak spring rates of 1.34 m/s on the ebb, approximately halfway between high and low water. Peak current speeds of 0.67 m/s are achieved during the ebb of a neap tide (Admiralty TotalTide, 2022). It is generally understood that the area experiences strong flood tides which results in a south-easterly tidal residual and sediment transport in the same direction (Humber Estuary Coastal Authorities Group, 2010a; 2010b; ERYC, 2006).

Further offshore, in the Holderness Offshore MCZ, the mean spring tidal range is 5.0 m. Within the Holderness Offshore MCZ, current speeds are approximately halved compared to rates closer to shore. Current speeds at SN017P and SN017Q reach a peak of 0.72-0.93 m/s on a spring tide (Admiralty TotalTide, 2022). However, these currents may vary within the MCZ area; in particular, hydrodynamic modelling for the Silver Pit, a curvilinear deep partly located within the MCZ, suggests that, within the

[175] *Please note, rock will not be placed landward of 10 m LAT, KP1.2.*

deeps, current velocities are increased (Tappin *et al.*, 2011), although this feature is located far from the Humber Pipeline route.

The dominant wave direction across the whole area is from the northeast, which has a large swell component and is also the direction of the longest fetch. Despite the swell component, the waves that approach the shoreline are predominantly locally generated wind waves. The significant wave height (Hs) associated with the dominant wave regime is between 1 to 1.5 m. The wave regime is the main driver for littoral drift (longshore transport) along the shoreline (Humber Estuary Coastal Authorities Group, 2010a; 2010b; ERYC, 2006). Based on the representative mean significant wave height along this shoreline and wave shoaling effects, the waves would interact with the seabed at water depths of approximately between 8 and 12 m below LAT. This means there is the potential for wave interaction with the seabed and rock placement, should it be located within areas which are shallow during the lowest tidal states. Due to the frequency of MLWS levels, the actual occurrence of wave disturbance directly over and in the vicinity of the berm would be for short periods over the spring neap tidal cycle. At greater water depths (i.e. over 12 m) and further offshore from the shoreline, tidal processes would be the dominant sediment transport mechanism.

Table 6-14 - Water levels for Spurn Head and Bridlington (Admiralty TotalTide, 2022)

Tide levels	Level above CD (m)	
	Spurn Head	Bridlington
Highest Astronomical Tide (HAT)	7.7	6.7
Mean High Water Springs (MHWS)	6.9	6.1
Mean High Water Neaps (MHWN)	5.5	4.7
Mean Sea Level (MSL)	4.08	3.6
Mean Low Water Neaps (MLWN)	2.7	2.3
Mean Low Water Springs (MLWS)	1.2	1.1
Lowest Astronomical Tide	0.3	0.1
Mean Spring Range	5.7	5.0
Mean Neap Range	2.8	2.4

6.9.1.3.2 The shoreline and Spurn Head

The shoreline along the sub-cell frontage is characterised by the Holderness Cliffs with a gentle-sloping subtidal clay platform and the Spurn Head peninsular further south. The platform extends offshore for several kilometres, with a notable change in slope towards a shallower profile at around 10 m LAT, approximately 1 km offshore (Humber Estuary Coastal Authorities Group, 2010a; 2010b). The clay platform is overlain by a thin veneer of mobile sediment comprising sand and gravel. A submerged clay cliff estimated to be around the change in slope marks the boundary between the eroding zone (supratidal cliff and clay platform) and the more stable offshore seabed (ERYC, 2006).

Further south of the Holderness Cliffs is the geomorphological feature of Spurn Head, which comprises a sand and gravel barrier and a continuation of the clay platform from the north. Spurn Head is considered to have developed and been maintained as a result of the combined influences of wave-driven southerly transport of coarse material from the Holderness Cliffs and strong tidal flows from the Humber Estuary (Natural England, 2018d). On the subtidal platform east of Spurn Head are "the Binks" sand and gravel shoals, which dissipate wave energy under certain conditions and therefore shelter Spurn Head during such events (Natural England, 2018d). The Binks have a southwest to northeast orientation and occur at depths of around 10 m LAT, stretching from "Stony Binks", which are east from the tip of Spurn Head, to the "Outer Binks", which are east of the "the Neck" of Spurn Head.

The erosion and retreat of the Holderness Cliffs is an important source of sediment to the beaches to the south, Spurn Head and the Humber Estuary, associated with the southerly wave-driven sediment transport. Over the last 1,000 years, the cliffs have retreated by around 2 km. Approximately 3-4 million m^3 of sediment per year is released into coastal waters by cliff recession and the lowering of the intertidal and subtidal section of the shore platform. Future trends presented in the SMP show that the recession is set to continue for most of this frontage, with recession rates dependent on a range of factors (Humber Estuary Coastal Authorities Group, 2010a; 2010b). The exception to this is the cliff section in front of the Easington gas terminal and adjacent to the HGS pipeline, which is protected at the toe of the cliff by rock revetment.

6.9.1.3.3 Sediment transport regime

The Holderness Cliffs are composed of glacial till, so material released during erosion includes minor fractions of gravel and sand, with the majority comprising silt and clay. Erosion along this stretch of coastline is discussed in Section 6.3.4.3.

The transport of medium and coarse sand and gravel occurs along the beach through littoral transport associated with the dominant wave climate, which predominantly supplies Spurn Head. Also present is an offshore directed sediment transport pathway near Easington, which is considered to provide coarser sediments to the Binks sand and gravel shoals (Natural England, 2018d; ERYC, 2006). The offshore movement of the coarse sediment towards the Binks occurs due to the slight change in the shoreline orientation near Easington (Natural England, 2018d). Due to the grain size of the material that makes up the shoals, and the force required to move such sediment, it is considered that this pathway is most likely initiated during periods of energetic wave and storm surge events.

The transport of finer material (silt and clay) occurs in suspension towards the south and offshore. The erosion of fines from Holderness cliffs has the potential to form a wide plume that extends several kilometres out from the shoreline (Humber Estuary Coastal Authorities Group, 2010a; 2010b), indicating the extent of material in suspension. This finer material is eventually deposited within the estuaries and embayments to the south including the Humber Estuary and The Wash.

6.9.1.3.4 The Holderness Inshore MCZ

The Holderness Inshore MCZ was designated in January 2016. The site covers an area of 309 km^2 extending from MHWS to 6 km offshore, and from Skipsea in the north to the tip of Spurn Head in the south.

6.9.1.3.4.1 Seabed habitat and benthos

The subtidal part of the Holderness Inshore MCZ supports a mosaic of habitats comprised of clay bedrock, cobbles, boulders, gravel, sand, mud and shells. The various habitats support a diverse range of organisms including red algae (*Rhodophyta spp*.), sponges (*Porifera spp*.) and other encrusting fauna. The site also supports fish species such as European eel (*Anguilla anguilla*), dab (*Limanda limanda*) and wrasse, as well as commercially significant crustaceans such as edible crab (*Cancer pagurus*) velvet swimming crab (*Necora puber*) and lobster (*Homarus gammarus*).

EUSeaMap (2021) broad scale habitat mapping shows that much of the seabed across the Holderness Inshore MCZ comprises EUNIS habitat A5.14 'Circalittoral coarse sediment' (Figure 6-7). The Humber Pipeline route corridor through the MCZ has been surveyed by drop-down camera and video in addition to grab sampling where seabed conditions allowed. Survey results are reported in Gardline (2022a, 2022b). The survey concluded that the seabed across much of the MCZ comprised EUNIS habitat A5.43 'Infralittoral mixed sediment', deviating from the EUSeaMap (2021) broad scale mapping. The survey findings are plotted over the top of the broad-scale habitat map in Figure 6-7. The only other habitat within the MCZ boundary identified during the survey is A2.43 'Species poor mixed sediment shores' which corresponds to the shallowest survey station (Gardline, 2022b).

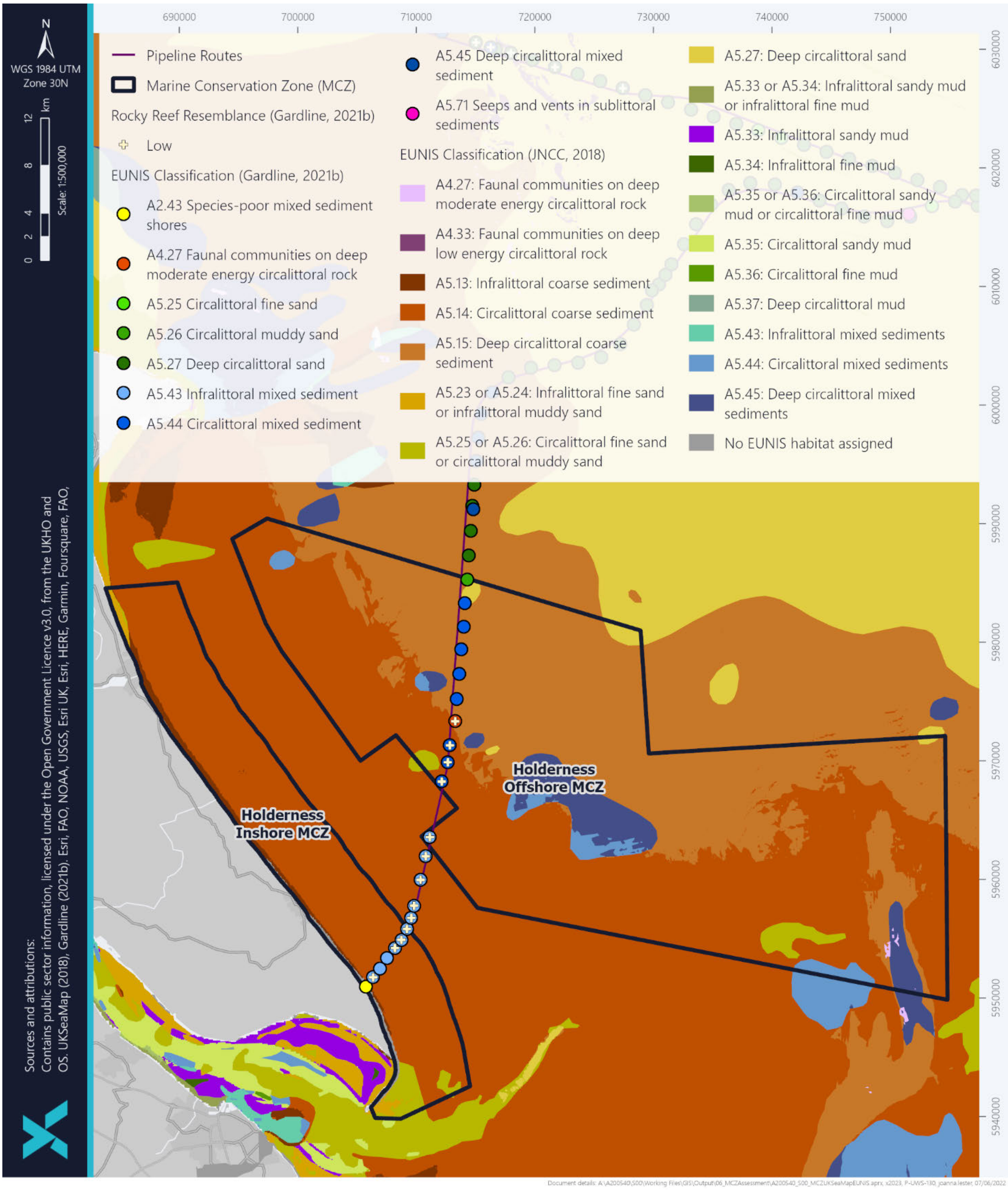
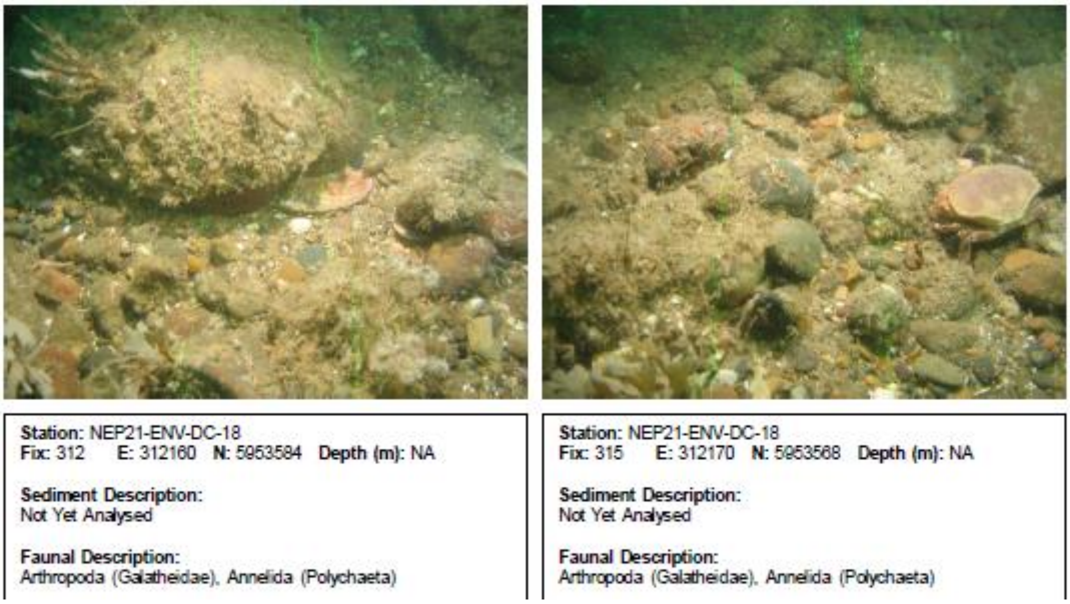


Figure 6-7 - EUNIS habitats across the Development area, overlain with Gardline (2022b) EUNIS classification and rocky reef resemblance data

Figure 6-7 labels survey stations according to the likelihood of being considered rocky reef (presence of crosses). Four of the seven stations sampled within the MCZ boundary are considered 'low' likelihood rocky reef, the remaining stations show no resemblance to this habitat. Figure 6-8 shows seabed photographs of potential 'low' resemblance rocky reef habitat along the Humber Pipeline route, corresponding to the sample locations shown in Figure 6-7 (Gardline, 2022b). These sample stations were classified as EUNIS habitat A5.43 'Infralittoral mixed sediment' (Figure 6-7).

As indicated by the findings of the XOGS (2023) geophysical interpretation report, areas of 'low' resemblance rocky reef may be underpinned by clay outcrops.

ENV-18:



ENV-20:

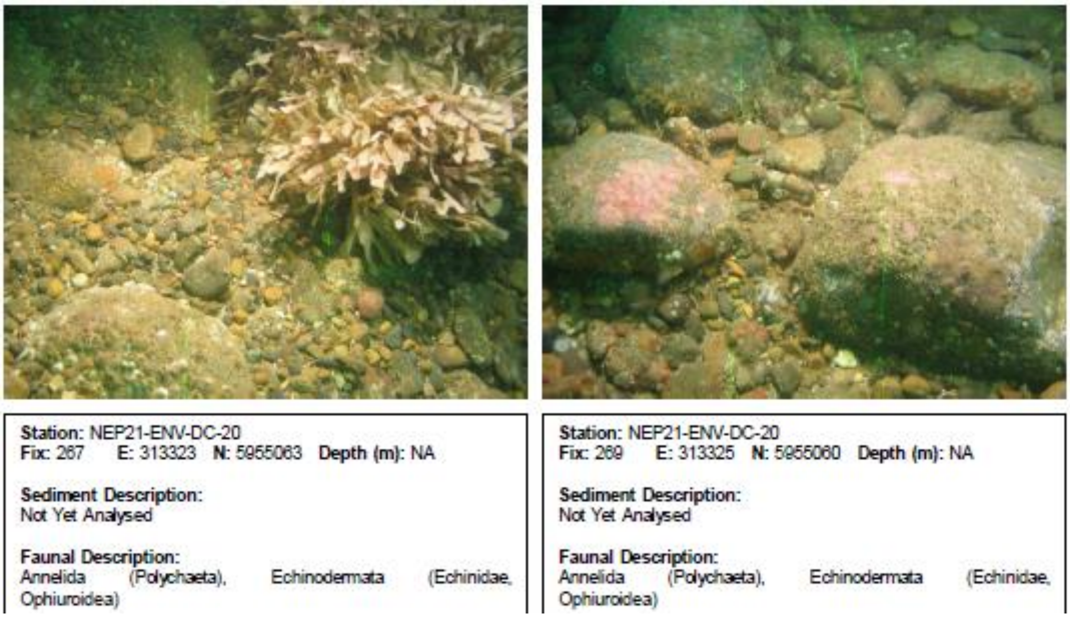


Figure 6-8 - Images of the seabed along the Humber Pipeline route within the Holderness Inshore MCZ considered to potentially be rocky reef habitat (Gardline, 2022b)

6.9.1.3.4.2 Designated interest features

The Holderness Inshore MCZ is designated for seven different habitats and one geomorphological feature. The features for which the MCZ were designated, and their relevant conservation objectives are presented in Table 6-15.

Table 6-15 - Holderness Inshore MCZ interest features and their respective conservation objectives and sensitivity to pressures

DESIGNATED INTEREST FEATURE	CONSERVATION OBJECTIVE, FROM DEFRA (2019)	FEATURE SENSITIVITY TO PRESSURES RELEVANT TO THE DEVELOPMENT ACTIVITIES, FROM NATURAL ENGLAND (2022)				
		Habitat structure changes	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	Physical change to another seabed type	Physical change to another sediment type	Water flow (tidal current) changes, including sediment transport considerations
High energy circalittoral rock	The protected features: 1. Are maintained in favourable condition if they are already in favourable condition 2. Be brought into favourable condition if they are not already in favourable condition	S	NR	S	NR	NS
Intertidal sand and muddy sand		S	S	NR	S	S
Moderate energy circalittoral rock		S	S	S	NR	S
Subtidal coarse sediment		S	S	S	S	NS
Subtidal mixed sediments		S	S	S	S	NS
Subtidal mud		S	S	NR	S	S
Subtidal sand		S	S	S	S	NS
Spurn Head (subtidal) and 'the Binks'		NA				

Pressure sensitivity key: S = Sensitive, NS = Not Sensitive, NA = Not Assessed, NR = Not Relevant (the evidence base suggests that there is no interaction of concern between the pressure and the feature OR the activity and the feature could not interact)

6.9.1.3.4.2.1 Habitats

The habitats within the MCZ create an environment that can support diverse communities of animals including commercially significant crustaceans. For all designated interest features, "favourable condition" means that:

1. Feature extent is stable or increasing; and
2. The structure and functions of the feature, its quality, and the composition of its characteristic biological communities (including diversity and abundance of species forming part of or inhabiting the habitat) are sufficient to ensure that its condition remains healthy and does not deteriorate (Defra, 2019c).

6.9.1.3.4.2.2 Geology

For the Spurn Head (Subtidal) feature, "favourable condition" means that:

1. Its extent, component element and overall integrity are maintained;
2. Its structure and functioning are unimpeded; and
3. The feature remains unobscured so its condition may be determined (Natural England, 2018d).

The sensitivity of this feature to anthropogenic pressures has not been assessed, hence it appears as NA in Table 6-15 (Natural England, 2022).

6.9.1.3.5 The Holderness Offshore MCZ

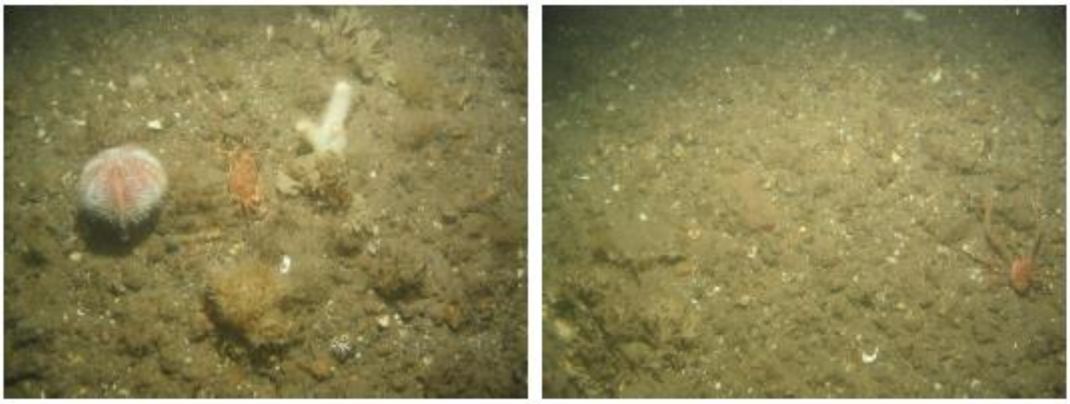
The Holderness Offshore MCZ was designated in May 2019 and lies partly in inshore and partly in offshore waters as it crosses the 12 nm territorial sea limit. The site covers an area of 1,176 km^2 and runs roughly in parallel with the Holderness Inshore MCZ, which lies to the west (Figure 6-7).

6.9.1.3.5.1 Seabed habitat and benthos

The seabed is dominated by 'Subtidal coarse sediment' and hosts 'Subtidal sand' and 'Subtidal mixed sediments'. The varied nature of the seabed means it supports a wide range of species, both on and in the sediment, such as multiple species of worms, mussel beds, sponges, starfish and crustaceans (such as crabs and shrimp). The site is also a spawning and nursery ground for a number of fish species, including lemon sole (*Microstomus kitt)*, plaice (*Pleuronectes platessa*) and European sprat (*Sprattus sprattus)*. In addition, the slow-growing bivalve, ocean quahog (*Arctica islandica*) have been found in the site. The MCZ also contains an area of geological interest: the northern point of the Inner Silver Pit glacial tunnel. The MCZ covers a total area of 1,176 km^2.

Broad scale habitat mapping, shown in Figure 6-7, shows that the seabed across the Holderness Offshore MCZ comprises predominantly EUNIS habitat A5.14 'Circalittoral coarse sediment' and A5.15 'Deep circalittoral coarse sediment'. The Gardline (2022a, 2022b) survey concluded that the seabed across much of the MCZ comprised EUNIS habitat A5.44 'Circalittoral mixed sediment' and A5.27 'Deep circalittoral sand' (Figure 6-7). This is partly in agreement with the Defra (2017) and EUSeaMap (2021) broad scale mapping. Images of the seabed taken at stations within the Holderness Offshore MCZ are shown in Figure 6-9 and correspond to sample station locations shown on Figure 6-7.

The presence of ocean quahog as recorded by Defra (2019) is patchy throughout the MCZ; however, the JNCC advises Moderate confidence in the presence and Low confidence in the extent for ocean quahog within the site (JNCC, 2019). Evidence of adult ocean quahog were identified at one sample station along the Humber Pipeline route however this was located outside of the MCZ boundary (Gardline, 2022b). Overall survey evidence did not identify significant numbers of ocean quahog at any point along the route, including within the MCZ (Section 4.4.2.3). ENV-101:



Station: NEP21-ENV-DC-101
Fix: 2535 **E:** 318877 **N:** 5972167 **Depth (m):** 34

Sediment Description:
Smaller cobbles and some sand patches with some faunal turf. Potential rocky reef resemblance

Faunal Description:
Annelida (Serpulidae), Arthropoda (*L. depurator*), Bryozoa (Flustridae), Cnidaria - (Actiniaria 01, *A. digitatum*, Cerianthiidae 01, Nemertesia 02), Echinodermata (*E. esculentus*), Faunal turf

Station: NEP21-ENV-DC-101
Fix: 2557 **E:** 318857 **N:** 5972208 **Depth (m):** 34

Sediment Description:
Scattered cobbles with sedimentation and sandy patches with shell fragments. Potentially part of rocky reef

Faunal Description:
Annelida (Serpulidae), Arthropoda (*M. rugosa*), Bryozoa (Flustridae), Cnidaria (Nemertesia 02, *Urticina sp*)

ENV-106:

Station: NEP21-ENV-DC-106
Fix: 2384 **E:** 320503 **N:** 5982064 **Depth (m):** 50

Sediment Description:
Sand with some gravel and shell fragments

Faunal Description:
Animalia indet, Bryozoa (Flustridae), Cnidaria (*A. digitatum*, *Urticina sp*), Faunal turf, Mollusca (Bivalvia siphons)

Station: NEP21-ENV-DC-106
Fix: 2417 **E:** 320520 **N:** 5982057 **Depth (m):** 50

Sediment Description:
Gravelly sand with shell fragments

Faunal Description:
Annelida (Serpulidae), Cnidaria (*A. digitatum*, *Urticina sp*)

Figure 6-9 - Images of the seabed along the Humber Pipeline route within the MCZ (Gardline, 2022b)

6.9.1.3.5.2 Designated interest features

The Holderness Offshore MCZ is designated for three broad-scale habitats, one species feature of conservation importance (ocean quahog) and one feature of geological interest (North Sea glacial tunnel valleys). The features for which the MCZ was designated, and their relevant conservation objectives are presented in Table 6-16.

6.9.1.3.5.2.1 Habitats

The 'Subtidal coarse sediment', 'Subtidal sand', and 'Subtidal mixed sediments' habitats within the MCZ create an environment that can support diverse communities of animals including commercially significant crustaceans.

Achieving the conservation objectives for these habitats means that:

i. its extent is stable or increasing; and
ii. its structures and functions, its quality, and the composition of its characteristic biological communities (which includes a reference to the diversity and abundance of species forming part of or inhabiting that habitat) are such as to ensure that it remains in a condition which is healthy and not deteriorating.

Any temporary deterioration in condition is to be disregarded if the habitat is sufficiently healthy and resilient to enable its recovery. Any alteration to that feature brought about entirely by natural processes is to be disregarded (JNCC, 2021c).

6.9.1.3.5.2.2 Ecology

With respect to the ocean quahog within the MCZ, achieving the conservation objectives means that the quality and quantity of its habitat and the composition of its population in terms of number, age and sex ratio are such as to ensure that the population is maintained in numbers which enable it to thrive.

Any temporary reduction of numbers is to be disregarded if the population is sufficiently thriving and resilient to enable its recovery. Any alteration to that feature brought about entirely by natural processes is to be disregarded (JNCC, 2021c).

6.9.1.3.5.2.3 Geology

'North Sea glacial tunnel valleys' are a feature of geological interest within the MCZ. This feature is present only in the southeast area of the MCZ, in relation to Inner Silver Pit.

Achieving the conservation objectives for this feature means that:

i. its extent, component elements and integrity are maintained;
ii. its structure and functioning are unimpaired; and
iii. its surface remains sufficiently unobscured for the purposes of determining whether the conditions in paragraphs (i) and (ii) are satisfied.

Any obscurement of that feature brought about entirely by natural processes is to be disregarded. Any alteration to that feature brought about entirely by natural processes is to be disregarded (JNCC, 2021c).

Table 6-16 - Holderness Offshore MCZ interest features and their respective conservation objectives and sensitivity to pressures

DESIGNATED INTEREST FEATURE	CONSERVATION OBJECTIVE, FROM JNCC (2021C)	FEATURE SENSITIVITY TO PRESSURES RELEVANT TO THE DEVELOPMENT ACTIVITIES, FROM JNCC (2021D)				
		Habitat structure changes	Penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion	Physical change to another seabed type	Physical change to another sediment type	Water flow (tidal current) changes, including sediment transport considerations
Subtidal coarse sediment	The protected features: • so far as already in favourable condition, remain in such condition; and • so far as not already in favourable condition, be brought into such condition, and remain in such condition.	S	S	S	S	NA
Subtidal sand		S	S	S	S	S
Subtidal mixed sediments		S	S	S	S	NS
Ocean quahog		S	S	S	S	NS
North Sea glacial tunnel valleys		Feature sensitivity not documented				

Pressure sensitivity key: S = Sensitive, NS = Not Sensitive, NA = Not Assessed, NR = Not Relevant (the evidence base suggests that there is no interaction of concern between the pressure and the feature OR the activity and the feature could not interact)

6.9.1.4 Holderness Inshore MCZ Assessment of Impacts

6.9.1.4.1 Introduction

This section of the report is concerned with identifying the impacts associated with the placement of the rock along the pipeline and assessing whether each impact, either individually or in combination with other impacts, is likely to significantly hinder the conservation objectives of the designated interest features. The assessment of impacts also includes a high-level review of the supplementary conservation objectives of the designated interest features, by recognising the targets for the relevant feature attributes.

6.9.1.4.2 Identification of impacts

The ES identifies and discusses a range of potential impacts with respect to the seabed preparation and pipeline installation and operation. Section 6.4.2 identified that the potential impacts relevant to the MCZ interest features and requiring further assessment are:

- Direct loss of designated interest features, habitats and benthic communities due to rock placement; and
- Effects on the sediment transport regime as a result of rock placement.

In most cases, where a feature is directly impacted by rock placement, it will also be affected indirectly, through impacts on the local sediment transport regime (hydrodynamic connectivity).

Due to the requirements of the MCZ Assessment, these impacts are assessed with respect to the conservation objectives for the Holderness Inshore MCZ interest features screened in for assessment in Section 6.9.1.4.3.

6.9.1.4.3 Screening

Table 6-17 sets out the interest features for the Holderness Inshore MCZ and the rationale for screening them in or out for a Stage 1 assessment.

Table 6-17 - Screening of the Holderness Inshore MCZ interest features

Designated interest feature	Screening opinion	Screening decision
High energy circalittoral rock	This feature relates to exposed or outcropping quaternary clay largely from the shore platform along the Holderness frontage. It is associated with an energetic environment from waves or strong tidal streams, with current speeds of 1.5 m/s and above. Although the areas of rocky reef identified during the survey along the Humber Pipeline route may relate to the outcropping rock, the dominant current speeds in proximity to the pipeline are on the order of 1.34 m/s (Admiralty TotalTide, 2022). This is less than the specified current speeds of 1.5 m/s characteristic of the high energy circalittoral rock. As the current speeds in proximity to the pipeline are characteristic of a moderate energy environment, and the communities associated with the rocky reef along the pipeline	Out

Designated interest feature	Screening opinion	Screening decision
	route were considered to be representative of A4.27 'Faunal communities on deep moderate energy circalittoral rock' (Gardline, 2022b), it means this designated feature is absent from the immediate vicinity of the proposed works and rock placement. Therefore, the potential for physical (direct) impact on this feature is screened out. Locations with dominant current speeds of 1.5 m/s and higher occur at some distance from the rock; based on information from the SNSSTS such speeds occur in proximity to Flamborough Head (HR Wallingford *et al.*, 2002). These locations are a great distance from the pipeline, beyond any potential impact from any rock placement. As there is no hydrodynamic (indirect) connectivity with this designated interest feature, it is screened out for such impacts.	
Intertidal sand and muddy sand	This feature is located within the intertidal zone and is not located at the point of the Humber Pipeline landfall. This feature is therefore screened out with respect to the potential for a physical (direct) impact. Due to the depth and predicted limited extent of the rock, and the small footprint of the pipeline, there would be no limiting effect on the tidal processes, as it occurs at a much larger scale. However, the sediment transport regime within the intertidal would be mainly driven by littoral drift and as rock placement may be in water depths where wave action is present, there is the potential for hydrodynamic (indirect) connectivity; it is therefore screened in.	In (hydrodynamic connectivity)
Moderate energy circalittoral rock	This feature again relates to the exposed or outcropping quaternary clay largely from the shore platform along the Holderness frontage. This habitat is associated with moderate energy conditions from waves or tidal currents of around 0.5 m/s. The presence of moderate energy circalittoral rock within the MCZ is recorded by Defra in point format (as seen in Figure 6-10). The 11 recorded instances of this feature are not located close to the Humber Pipeline route. The Gardline (2022b) survey identified 'low' likelihood rocky reef at four of the seven sample locations within the boundaries of the MCZ (as seen in Figure 6-7). Based on findings from the XOGS (2023) geophysical interpretation report, these rocky reef sites lie within an area characterised by a series of clay-cored seabed ridges oriented roughly parallel to the coastline that have a variable cover of gravel, cobbles and pebbles and are surrounded by cobble pavement. Furthermore, based on advice	In (physical impact and hydrodynamic connectivity)

Designated interest feature	Screening opinion	Screening decision
	from NE, clay features may be analogous to circalittoral rock. XOGS (2023) concluded two clay ridge features would be crossed by the Humber Pipeline route within the MCZ. Considering the understanding of local flows, outlined above, the two clay ridges that will be intersected by the proposed Humber Pipeline are considered to be representative of moderate energy circalittoral rock. Therefore, the feature is screened in for assessment on the basis of potential for physical (direct) impacts and hydrodynamic (indirect) connectivity.	
Subtidal coarse sediment	This interest feature is estimated to cover approximately 92% of the total subtidal area (i.e. below 0 m LAT) across the MCZ (see Figure 6-10). It therefore occurs over a much larger scale than any rock placement. The feature is also governed by processes that occur at even greater scales, which act to maintain its persistence and functioning. Nonetheless, it is screened in for assessment on the basis that it is a geomorphological feature that has physical (direct) connectivity with the rock footprint.	In (physical impact and hydrodynamic connectivity)
Subtidal mixed sediments	The potential location of this feature from the MAGiC map resource (Defra, 2023) indicates it extends approximately 2 km off the coast. The Gardline (2022b) survey of the pipeline route identified the presence of A5.43 'Infralittoral mixed sediment', which is likely to be representative of this feature. Areas of rock placement may be located within this area; therefore, this feature has the potential to be in physical (direct) connectivity with the footprint of rock placement.	In (physical impact and hydrodynamic connectivity)
Subtidal mud	Surveys completed along the pipeline route do not identify this feature within the Humber Pipeline route footprint within the MCZ. It is however screened in for assessment due to the potential for hydrodynamic (indirect) connectivity, particularly for material carried in suspension.	In (hydrodynamic connectivity)
Subtidal sand	The evidence of this sediment on MAGiC map demonstrates its presence as a thin discontinuous band parallel to the coastline, up to a maximum distance of 0.5 km off the coast. However, the Gardline (2022b) did not identify this habitat at any point along the proposed pipeline route within the MCZ. Owing to the commitment not to place rock in water depths of less than 10 m LAT, this habitat will avoid being affected directly by rock placement activities. However, it is screened in for assessment due to the potential for	In (hydrodynamic connectivity)

Designated interest feature	Screening opinion	Screening decision
	hydrodynamic (indirect) connectivity, particularly for material carried in suspension.	
Spurn Head (Subtidal)	The subtidal element of Spurn Head relates to the Binks sand and gravel shoals, which traps sediment and provides a sheltering effect to Spurn Head. The feature comprises coarse material that is predominantly transported through littoral processes and wave energy. However, due to the change in shoreline orientation in proximity to Easington attributed to the rock berm placement, there is the potential for the coarse sediment to move offshore and feed the Binks geomorphological feature. This feature is therefore screened in due to the potential for hydrodynamic (indirect) connectivity with the rock berm.	In (hydrodynamic connectivity)

In summary, the designated interest features screened in with the potential for a physical (direct) impact are moderate energy circalittoral rock, subtidal coarse sediment and subtidal mixed sediments.

The interest features screened in with the potential for hydrodynamic connectivity (indirect) impacts are intertidal sand and muddy sand, moderate energy circalittoral rock, subtidal coarse sediment, subtidal mixed sediments, subtidal mud, subtidal sand, and Spurn Head (Subtidal).

High energy circalittoral rock is screened out from further assessment.

6.9.1.4.4 Stage 1 MCZ Assessment

6.9.1.4.4.1 Direct loss of designated interest features, habitats and benthic communities

The locations and proportions of sediment and geomorphological features that comprise the interest features across the Holderness Inshore MCZ are not completely known. Instead, Natural England provides information on the likely potential and extents based on the best available evidence and proxy information. A review of information on the MAGiC resource (Defra, 2023) indicate that the rock placement could directly intersect the subtidal coarse sediment, subtidal mixed sediments, and subtidal sand interest features. Additionally, based on findings from XOGS (2023) and advice from NE, clay outcrops and ridges likely correspond to moderate energy circalittoral rock. Consequently, the installation of the Humber Pipeline and associated rock placement will directly interest this feature.

Figure 6-10 shows the Defra understanding of habitats within the MCZ in accordance with the proposed Humber Pipeline route and rocky reef occurrence data, as per recent survey effort (Gardline, 2022b).

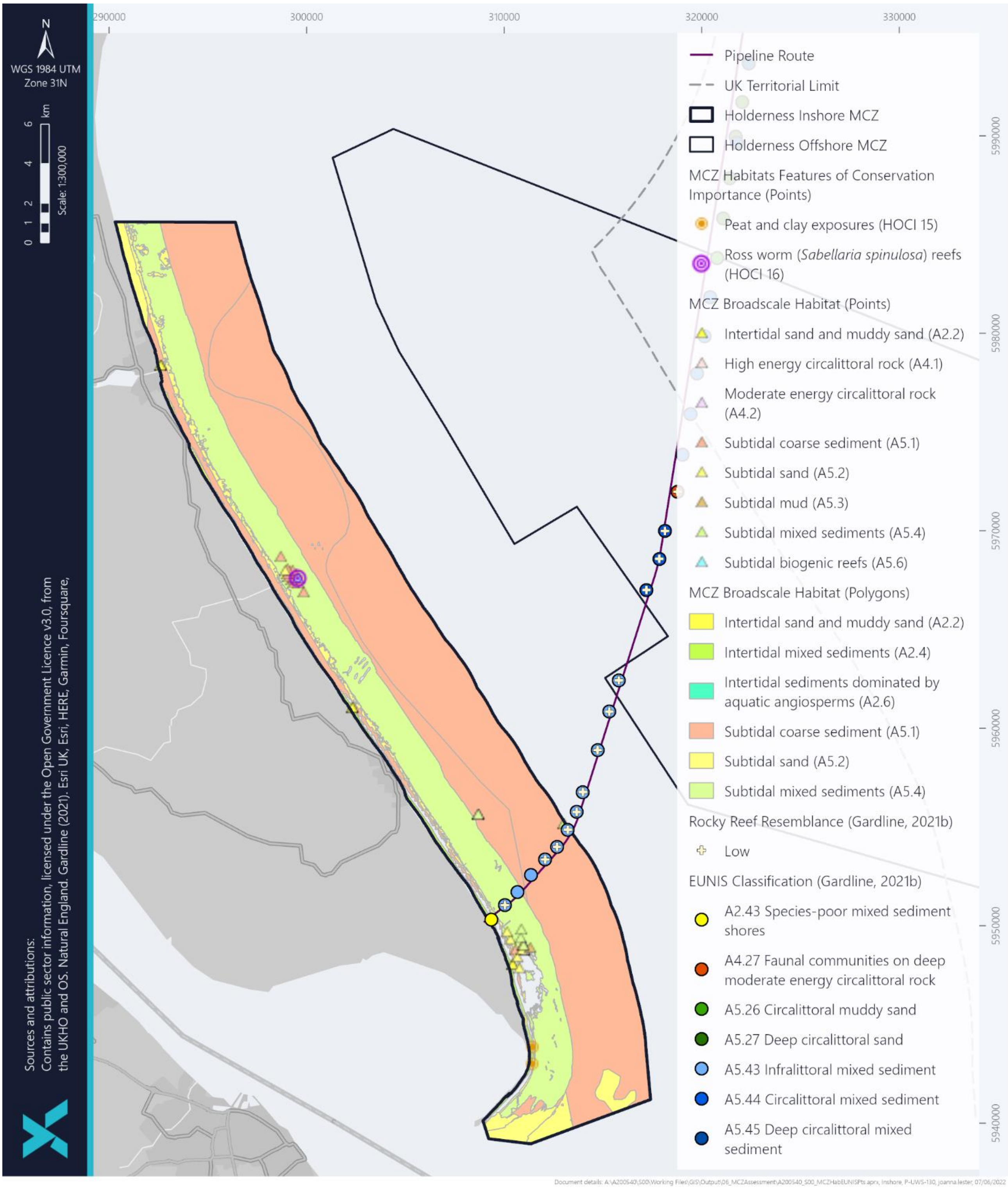


Figure 6-10 - Habitats and features of conservation interest within the Holderness Inshore MCZ (according to Defra, 2016c), overlain with Gardline (2022a, 2022b) survey data of EUNIS habitats and rocky reef occurrence

Natural England's advice on operations within the MCZ, determined the moderate energy circalittoral rock, subtidal coarse sediment, and subtidal mixed sediments are sensitive to the following pressures: habitat structure changes; and penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion. Subtidal coarse sediment and subtidal mixed sediments are also considered sensitive to physical change to another seabed or sediment type (Table 6-15). Of these pressures, the features are considered to be at medium-high risk of being exposed to habitat structure changes and penetration/disturbance of the substratum (Natural England, 2022).

While the presence of rock placement along the pipeline will have a direct (physical) impact on moderate energy circalittoral rock, subtidal coarse sediment, and subtidal mixed sediments features, the actual area of disturbance is minimal with respect to the overall area of the interest features within the surveyed area and MCZ. The total area of the Holderness Inshore MCZ is approximately 309 km^2, although it is important to note that some of this area is not fully subtidal.

The worst case scenario for designated features would be for rock armouring to be placed directly, and only, within a single designated interest feature. For the purposes of the MCZ assessment it has been assumed (per the assumptions in Table 6-13) that 7.5% of the pipeline length within any given habitat will require rock placement, and that the remaining pipeline will be trenched and buried.

The area of impact on the moderate energy circalittoral rock feature cannot be quantified in the same way owing to the area/extent of the feature being unknown within the site. Per the XOGS (2023) findings, two clay ridges (which are thought to correspond to moderate energy circalittoral rock) stand to be directly affected by installation of the Humber Pipeline and associated rock. XOGS (2023) found that the clay ridges could be up to 15 m wide and up to 70 m long. Therefore, based on the disturbance parameters presented in Section 6.4.1.2, the presence of the Humber Pipeline and associated rock placement may result in the loss of a substantial portion of the two individual ridges, or loss of the ridges altogether (depending on their size). Survey findings from the nearby Tolmount development were also used to supplement the XOGS (2023) report; these also reported the frequent presence of clay features. Ultimately, the XOGS (2023) report found that these features were present along much of the coastline within the MCZ, and beyond (the features were present out to KPS16). This suggests that they are relatively numerous within the area. Overall, while the impact on the finite clay ridge/moderate energy rock features represents a permanent loss of this habitat, the scale is very small in the context of the MCZ as a whole.

As was identified by XOGS (2023), the seabed along the proposed Humber Pipeline route within the MCZ mostly constitutes cobble pavement. Additionally, the clay ridges/moderate energy rock features are, as described in Section 4.3.3.3, covered in cobbles and gravel. While not an equivalent substrate, the proposed placement of rock as protection along the pipeline also represents a hard, rocky habitat.

Table 6-18 presents the area of habitat lost with regards to subtidal coarse sediment and subtidal mixed sediment. The area of habitat lost is minimal within the context of the total area of each interest feature in the MCZ; less than 0.01% of each habitat stands to be affected. These interest features cover much of the MCZ and exist on a much larger scale than any introduced hard substrate, and are governed by wave, tide and sediment transport processes that occur at regional scales. Overall, as these percentages are extremely small, the loss is expected to be imperceptible both at the site level and in the context of each designated interest feature. In the context of the MCZ as a whole, approximately 0.0018% of the whole MCZ area will be impacted by the proposed activities.

Ultimately, this is a conservative estimated area of loss as rock coverage along the pipeline will only be used where the required burial depth cannot be achieved, driven by engineering requirements for pipeline safety.

The loss of a small proportion of these interest features will not disrupt their overall structure and functioning across the MCZ. This is because the interest features are not localised to the pipeline route alone; they are driven and maintained in relation to regional tidal and geomorphological properties, which rock placement would not interrupt. Despite the feature sensitivity to pressures associated with pipeline installation, due to ongoing functioning and wider persistence of the interest features across the MCZ, the conservation objectives to "maintain" will also be sustained. Therefore, the burial of the interest features by the potential rock berm is assessed to be insignificant with respect to meeting the conservation objectives of all the designated interest features.

Table 6-18 - Area of designated interest feature present within Holderness Inshore MCZ and the area lost due to Development activities

Designated interest feature	Approximate length of pipeline within feature (m)	Approximate area of habitat inside MCZ (m^2)	Area of habitat lost due to rock placement within MCZ (m^2)	MCZ habitat lost as a % of total habitat present within MCZ
Subtidal coarse sediment	4,031	198,366,355	3,930	0.0013
Subtidal mixed sediments[176]	1,740	80,879,795	1,695	0.0005

6.9.1.4.4.2 Effects on the sediment transport regime as a result of rock placement

This section considers the impact from the potential placement of within the MCZ and onward impacts on local coastal processes and therefore sediment transport. To inform this Stage 1 MCZ assessment a semi-quantitative empirical approach was applied to investigate the potential for any changes to the tidal currents and sediment transport potential, based on the environmental understanding presented in Section 6.9.1.3.

While the exact location of rock has not been determined, rock placement could be required in shallower water where wave action does occur and is a main force with regards to the local sediment transport regime, especially during storms and high-energy wave events. The minimum depth for rock placement along the Humber Pipeline will be 10 m LAT. Typically, rock placement is designed to remain stable on the seabed under the key parameters for its location, including waves and tidal currents, water depth and rock density. Rock placement is engineered to maintain its integrity and protect the pipeline throughout the lifetime of the asset. As described in Section 6.9.1.2, the proposed rock placement will have tapered slopes (typically around 1:3) to provide optimum resistance to wave and current loading. The rock protection will have a filter layer of smaller rock (underneath the armour

[176] *Please note, due to the commitment not to install rock in water depths of less than 10 m LAT, a very short length of pipeline within the subtidal mixed sediment habitat in shallower depths will not qualify for the placement of rock.*

rock layer and directly on top of the pipeline), to reduce the risk of damage to the pipeline during placement. Above this is an upper armour layer between the filter rock layer and the external seawater, which provides the resistance and stability. The sizes of rock for the filter layer and upper rock armour layer will be defined in detailed design to ensure that the rock is hydrodynamically stable and provides pipeline protection during the operational phase of the Development.

The interest features screened in with the potential for indirect impacts associated with hydrodynamic connectivity are moderate energy circalittoral rock, subtidal coarse sediment, subtidal mixed sediments, subtidal sand, intertidal sand and muddy sand, and subtidal mud. Natural England (2022) consider the moderate energy circalittoral rock, intertidal sand and muddy sand and subtidal mud features to be sensitive to changes in water flow (which includes sediment transport considerations) as a result of pipeline installation operations, although they are considered to be at low risk of exposure to this pressure. The remaining three features (subtidal coarse sediment, subtidal mixed sediments, and subtidal sand) are not sensitive to changes in water flow (Table 6-15).

The Spurn Head (Subtidal) interest feature is screened in due to the offshore transport pathway near Easington. Figure 6-10 indicates the distribution of the designated interest features with the MCZ and based on the possibility of installation of rock at any point along the pipeline there is potential for hydrodynamic connectivity associated with the littoral sediment transport pathway providing sediment to the Spurn Head feature (Section 6.9.1.3.2).

In terms of impacts to the coastal processes and sediment dynamics, a continuous rock berm close to the shoreline would represent the worst case situation. Water depths down to approximately 13 m LAT are within the range of wave action, especially during storms. Therefore, should any rock protection be placed in water depths less than 13 m LAT within the MCZ; it will likely interact with local wave forces. Theoretically, the presence of rock could potentially interfere with the natural sediment transport process, including the transport of material carried in suspension or through littoral drift. This could result in both sediment accumulation and scour in the vicinity of the rock placement and the reduction of sediment further away from the structure. As a worst case assumption, for the purposes of the assessment, rock placement has been assumed to occur in the nearshore/intertidal zone of the MCZ (at a minimum of 10 m LAT). Potential impacts arising from scour and disruption of the local sediment transport regime are considered in the sections below.

6.9.1.4.4.2.1 Scour potential

Scour is the result of net sediment removal as a result of elevated turbulence levels due to the complex three-dimensional interaction between currents (from tides and or waves) and obstructions on the seabed. The consideration of scour relates to features in the immediate vicinity off the pipeline.

JNCC (2017b) investigated the potential impacts of rock placement to support pipeline decommissioning within the North Norfolk Sandbanks and Saturn Reef SAC. Two examples of 900 – 1,000 t of rock being rapidly buried by mobile sand in the Cygnus field were identified. JNCC (2017b) also noted the potential for severe scour around wind turbine monopiles and jackup rig legs and noted that effectively placed rock was able to prevent observable scour. With regards to scour development around rock berms, the extent of scour scales with the berm height (Roulund *et al.*, 2019). The potential for scour to develop increases in the event an inappropriate design is used (Pidduck *et al.*, 2017). Therefore, in the context of the proposed rock placement, the potential for scour is expected to be minimal, due to the engineered design of the rock protection. The rock protection design will account for wave and current loading, berm permeability and slope angles in order to reduce the turbulence around the structure and, therefore limiting the development of scour. As a result, the potential impact on the designated interest features in the immediate vicinity of the rock berm is likely to be insignificant, with respect to maintaining their conservation objectives.

6.9.1.4.4.2.2 Local sediment accumulation and disruption of sediment transport pathways

Peak current speeds along the Humber Pipeline are on the order of 1.34 m/s and 0.67 m/s on the spring and neap tides respectively, and together occur for approximately half of a tidal cycle (Admiralty TotalTide, 2022). The shear stress or force associated with these current speeds at a water depth of 10 m LAT are summarised in Table 6-19 along with the critical threshold for mobility for the range of representative sediment grain sizes that occur across the MCZ.

Based on the estimated shear stress, sediment including mud, clay, silt and sand would be mobilised under peak spring flows. Coarser sediment including gravel would not be mobilised by the tidal flow; instead, this material would only be moved in relation to more energetic conditions associated with waves, as bedload transport. Under peak neap flows, the finer sediment up to medium sand would be mobilised, while coarse sand and larger sediment grains would not (Table 6-19).

Table 6-19 - Critical threshold for representative grain sizes and the mobility potential for peak spring and neap flow speeds

<table>
<tr><th rowspan="3">Sediment</th><th rowspan="3">Representative grain size (mm)</th><th rowspan="3">Critical threshold</th><th colspan="2">Mobility potential</th></tr>
<tr><th colspan="2">10 m LAT water depth</th></tr>
<tr><th>Spring (peak)</th><th>Neap (peak)</th></tr>
<tr><td>Mud and clay</td><td>0.002</td><td>0.01</td><td rowspan="6">Mobile</td><td rowspan="5">Mobile</td></tr>
<tr><td>Fine silt</td><td>0.0156</td><td>0.05</td></tr>
<tr><td>Coarse silt</td><td>0.0625</td><td>0.12</td></tr>
<tr><td>Fine sand</td><td>0.25</td><td>0.19</td></tr>
<tr><td>Medium sand</td><td>0.5</td><td>0.26</td></tr>
<tr><td>Coarse sand</td><td>2</td><td>1.17</td><td rowspan="2">Not mobile</td></tr>
<tr><td>Gravel</td><td>4</td><td>3.01</td><td>Not mobile</td></tr>
<tr><td colspan="5">The critical threshold for sediment mobility and bed shear stress associated with the flow speeds along the nearshore section of pipeline are calculated using empirical formulae set out in Soulsby (1997). Mobility potential was calculated using current data across a spring and neap tidal cycle from Admiralty TotalTide (ATT) for the tidal diamond closest to the Humber Pipeline route within the MCZ (SN017AD; Admiralty TotalTide, 2022); the mobility here is presented for the peak spring and neap current speeds. Wave data was obtained from the Hornsea wave buoy located approximately 10 km north of the Humber Pipeline route (Channel Coastal Observatory, 2020).</td></tr>
</table>

Table 6-19 shows that only a proportion of the sediment available in the vicinity of the rock would potentially be mobilised in relation to the flow characteristics; with larger sediment grains moving in relation to waves over a much shorter period. Of the amount available for transport, only a proportion could theoretically be trapped with the rock berm in place, where the exact amount would vary in relation to the tidal processes, wave energy and sediment grain size. Should the rock berm be installed at 10 m LAT, tidal processes are the dominant mechanism for sediment transport through suspension at this depth, with wave-driven bedload transport and littoral drift being secondary. Any changes to tidal processes could therefore have a greater effect on the transport regime, so the potential for varying current speeds and any onward effects on suspended sediment transport was investigated. Data on the tidal characteristics from UKHO (2021) and empirical formulae on determining the depth-averaged flow speed above a submerged near-bed structure (Equation 5.227) from the Construction Industry Research and Information Association (CIRIA) rock manual (CIRIA, 2007) were applied. The data used in the calculation included:

- Water depths at a mid-tide state (in line with when peak speeds occur), upstream, downstream and above the proposed rock berm (at 12 m LAT);
- Peak spring and neap speeds from the SN017AD tidal diamond Admiralty TotalTide, 2022);
- Water levels from Spurn Head (Admiralty TotalTide, 2022); and
- A discharge coefficient of one, which is relevant for a vertical closure, subcritical flow (CIRIA, 2007), which is characteristic of the site conditions with the rock berm in place.

As discussed previously, Natural England (2022) considers the designated interested features which are comprised of finer sands, to be sensitive to changes in water flow (Table 6-15), however the results indicate that there would be negligible change to the tidal flow speeds with the berm in place, as there is no change to the water levels downstream of the berm structure. With no variation in tidal flow speeds, the fine sands, silts and muds that comprise the interest features and are transported through tidal process, would remain in suspension. These sediments would not be disrupted by the presence of the rock berm; instead, they would continue to the intertidal sand and muddy sand, subtidal mud, subtidal coarse sediment, subtidal mixed sediment and subtidal sand interest features that occur elsewhere in the MCZ. Consequently, it is not anticipated that the impact of this pressure on the interest features would contravene their individual conservation objectives or affect the feature within the site as a whole.

The shallowest potential placement of rock (i.e. around 10 m LAT), would interact with waves under MLWS condition, potentially moving coarse grained sediment. Due to the infrequency of MLWS levels, the actual amount of time coarse sediment would be moved and disrupted in the vicinity of the rock would be limited. As the length of rock placement would be a porous structure, the material transported as bedload due to waves could potentially be trapped, meaning the structure could initially act as a localised sink for coarser sediments. This effect, however, would only be temporary and in the short-term, on the order of days to weeks, for the section of the rock placement where wave action interacts with the seabed. With time and as the voids within the rock armour fill or colonise with benthic communities, sediment previously deposited locally, would bypass, pass through or over the top of the rock. More dominant littoral drift processes occur at shallower depths than those in which the rock placement would be located, while the influence of waves occurs over a much larger scale. The rock placement structure is therefore unlikely to cause any hindrance to the transport of coarse sediment in the medium to long-term, which means there would be no impact or changes to the sediment transport regime through the MCZ.

It should be noted that rock coverage of the pipeline will only be used where the required burial depth cannot be achieved. The base case will be for zero rock armour in the MCZ, and any use of rock protection will be driven by engineering requirements for pipeline safety.

Overall, the potential for any indirect impacts due to the disruption of the sediment transport regime on the designated interest features is assessed as **not significant**.

With the proposed rock placement, there is no change to the long-term sediment transport potential of sediment that constitute the designated features. The material would still be moved uninterrupted across the wider MCZ as the wave and tide driven transport processes occur at a much larger scale than the rock placement. Therefore, the overall structure and functioning of the interest features would be maintained and the conservation objectives of the interest features would not be hindered.

With respect to the offshore-directed sediment transport pathway of coarse sands and gravels around Easington and towards the Binks, this is only likely to exist during storm events. The coarse nature of the material that makes up the Binks can only be moved under high energy conditions associated with storms. The shape and orientation of the shoreline local to Easington then provides the offshore pathway. During such high energy events, any rock placement along the pipeline would not act as a barrier to the transport of the coarse sand and gravels, as these processes would be occurring at a much larger scale than the rock extent. The assessment completed with respect to the wave-driven transport of coarse material in proximity to the rock berm, demonstrated that there would be no long-term impacts on the transport of this material. The conservation objectives of the Spurn Head (subtidal) interest feature will be maintained, whereby the structure, functioning and integrity of the interest feature would remain unimpeded. The overall potential for an indirect impact on the interest features is therefore assessed as **not significant**.

6.9.1.4.4.3 Cumulative assessment

Although not explicitly required, the MMO guidelines suggest an assessment of hinderance on the conservation objectives should be considered as any act that could, either alone or in combination with other projects. To this end, a brief assessment of cumulative effects on the conservation objectives of the designated interest features has been undertaken here.

6.9.1.4.4.3.1 Infrastructure

The Holderness Inshore MCZ was designated in January 2016 and at that time there were a number of infrastructure items already present which therefore form part of the baseline. The infrastructure present at the time of designation included:

- West Sole to Easington 16” gas line, PL28;
- West Sole to Easington 24” gas line, PL145;
- West Sole to Easington 24” gas line, PL145;
- 30” gas, Amethyst A2D to Easington, PL649;
- Easington to Rough 47/3B 16” gas line, PL26;
- Rough 47/3B import/export 36” gas line, PL150;
- Langeled pipeline 44” gas pipeline, PL2071;
- York methanol pipeline 89 mm, PL2918;
- Cleeton CP to Dimlington 36” gas export line, PL447;
- Humber Gateway OWF export cables; and
- Westermost Rough OWF export cables.

These infrastructure items all remain active, except for the Easington to Rough 47/3B 16” gas line (PL26), which is noted as no longer in use as of 2019, and the Amethyst A2D to Easington 30” gas (PL649), which is in the process of being decommissioned.

In the time since designation, the Tolmount HGS export pipeline to Easington has been constructed and is operational as of 2022.

6.9.1.4.4.3.2 Cumulative impact assessment

The assessment of direct and indirect impacts presented above concludes that there will be no long-term disruption to the sediment transport regime such that the designated features for the MCZ are affected. Potential impacts are localised to the immediate vicinity of any rock placement, and habitat loss constitutes a proportionately very small area within the site.

There is limited public information of the quantity of rock associated with the projects listed above which has already been placed within the MCZ. While exact areas of impact are not known, it is assumed that rock installed as part of other projects will be on a scale proportionate to that which bp are proposing as part of the Development. Information on rock placement is available for the Tolmount HGS export pipeline, however this is limited to what is reported within the ES and MCZ assessment completed as part of the project; this does not represent the actual quantity of rock which was used during construction.

The Tolmount HGS export pipeline has been installed since designation occurred in 2016. According to the MCZ assessment (Premier, 2020) produced for the project, and based on an assumption that 20% of the pipeline within the site would require rock protection, the affected seabed area would be approximately 0.0075 km^2 (equating to 0.002% of the MCZ). This area was predicted to only affect two interest features, namely the subtidal coarse sediment and moderate energy circalittoral rock. An additional 0.0017% of the MCZ as a whole will be affected by rock placement along the proposed Humber Pipeline (as described in above). Therefore, in combination, the area of impact is anticipated to account for approximately 0.004% of the site, which is a small proportion of the available habitat.

At the time of writing information suggests that the Rough gas store is set to cease production in 2023, after which it may be modified as an offshore hydrogen store. It is not certain what this modification would entail, or if any changes would be required along the pipeline. Additionally, there is no proposed timeline for this work. The Rough gas pipeline (PL26) runs to the Easington Gas Terminal and is approximately 1.6 km south-southeast of the proposed Humber Pipeline route at the closest point (approaching landfall). The empirical assessment on potential impacts of the rock placement along the Humber Pipeline on tidal currents highlighted there would be negligible change to the current speeds, as there was no change to the downstream water levels. In the event this condition is satisfied, there would be little or no potential for cumulative impacts associated with the PL26.

The Amethyst field comprises four normally unmanned installations (NUIs) which feed back to the PL649 main 30” export pipeline, which exports gas to Dimlington Gas Terminal. Cessation of Production (COP) was submitted for approval in February 2020 (Perenco, 2020). A Decommissioning Programme (DP) has not yet been submitted for the associated Amethyst pipelines, so schedule is not yet available, nor is the proposed method of decommissioning. However, it is likely that some rock intervention will be required in the case of any exposures resulting, should the pipeline be decommissioned in situ. This will result in an additional physical impact to the designated features of the MCZ. However, in the context of the whole available area within the MCZ, the areas of rock placement are likely to be proportionately very small.

A final point to note is that the environmental processes governing the sediment transport regime across the MCZ occur at much larger scales than the projects and would therefore not be disrupted by the present infrastructure. Therefore, with respect to the proposed rock placement along the

Humber Pipeline, the potential for cumulative impacts, including hinderance on the conservation objectives of the designated interest features, is assessed as **insignificant**.

6.9.1.5 Holderness Offshore MCZ Assessment of Impacts

6.9.1.5.1 Introduction

This section of the report is concerned with identifying the impacts associated with the placement of the rock and assessing whether this impact, either individually or in combination with other impacts, is likely to significantly hinder the conservation objectives of the designated interest features. The assessment of impacts also includes a high-level review of the supplementary conservation objectives of the designated interest features, by recognising the targets for the relevant feature attributes.

6.9.1.5.2 Identification of impacts

The ES identified and discussed a range of potential impacts with respect to the seabed preparation and pipeline installation and operation. The potential impacts relevant to the MCZ interest features and requiring further assessment are:

- Direct loss of designated interest features, habitats and benthic communities due to the placement of the surface laid pipeline and rock, and
- Effects on the sediment transport regime as a result of the presence of the surface pipeline and associated rock placement.

In most cases, where a feature is directly impacted by the pipeline or rock placement, it will also be affected indirectly, through impacts on the local sediment transport regime (hydrodynamic connectivity).

Due to the requirements of the MCZ Assessment, these impacts are assessed with respect to the conservation objectives for the Holderness Offshore MCZ interest features screened in for assessment in Section 6.9.1.5.3.

6.9.1.5.3 Screening

Table 6-20 sets out the interest features for the Holderness Offshore MCZ and the rationale for screening them in or out for a Stage 1 assessment.

Table 6-20 - Screening of the Holderness Offshore MCZ interest features

Designated interest feature	Screening opinion	Screening decision
North Sea glacial tunnel valleys	This feature relates the Inner Silver Pit glacial deep, which is a historic glacial valley feature. The feature is located in the southeastern most corner of the MCZ, far from the proposed Humber Pipeline route. As such, there is no opportunity for direct physical connectivity with the rock placement along the pipeline. In the offshore environment, metocean conditions are more consistent and, with regards to the relative scale of the feature, the placement of rock is unlikely to have an impact on hydrodynamic processes to an extent that they would exert influence over the	Out

Designated interest feature	Screening opinion	Screening decision
	glacial tunnel. Due to the feature being a great distance from the pipeline, and beyond any potential impact from any rock placement, there is no hydrodynamic (indirect) connectivity with this designated interest feature, and it is screened out for such impacts.	
Ocean quahog (*A. islandica*)	Surveys along the Humber Pipeline route did not identify any evidence of adult ocean quahog, nor were any juveniles found in samples taken within the surveyed pipeline corridor in the MCZ. Despite the pipeline route passing through an area in the north of the site known for the presence of the species, these have not been identified in the completed surveys so it is considered unlikely that they will be found in numbers constituting an aggregation in close proximity to the pipeline and any rock placement. Overall, this designated interest feature is screened out of further assessment as this species has been considered within Sections 6.4 to 6.7 in the context of the Development as a whole.	Out
Subtidal coarse sediment	This interest feature is estimated to cover approximately 91% of the Holderness Offshore MCZ (see Figure 6-11). It therefore occurs over a much larger scale than the pipeline and any associated rock placement. The feature is also governed by processes that occur at even greater scales, which act to maintain its persistence and functioning. Nonetheless, it is screened in for assessment on the basis that it is a geomorphological feature that has physical (direct) connectivity with the pipeline and rock footprint.	In (physical impact and hydrodynamic connectivity)
Subtidal mixed sediments	This feature, as shown in the MAGiC map resource (Defra, 2023), occurs in a patchy distribution throughout the MCZ. According to this distribution, the pipeline route does not directly intersect any of these areas, however most of the sample stations within the MCZ were recorded as A5.44 'Circalittoral mixed sediment' (Figure 6-7; Gardline, 2022b), which is synonymous with subtidal mixed sediments. Therefore, it is assumed that the pipeline will pass through areas of this interest feature. Consequently, the features has been scoped in for direct physical impact.	In (physical impact and hydrodynamic connectivity)
Subtidal sand	This feature also has a patchy distribution within the site. The MAGiC map habitat distribution does not appear to coincide with the proposed pipeline route (Defra, 2023). However, per the survey findings, there are sample locations identified as A5.27 'Deep circalittoral sand' along the pipeline within the MCZ boundary	In (physical impact and hydrodynamic connectivity)

Designated interest feature	Screening opinion	Screening decision
	(Figure 6-7; Gardline, 2022b). Therefore, there is the potential for the pipeline and rock placement to impact this feature directly.	

In summary, the designated interest features screened in with the potential for a physical (direct) impact include subtidal coarse sediment, subtidal mixed sediments, and subtidal sand. These three features are screened in for impacts through changes to hydrodynamic connectivity (indirect impact). The North Sea glacial tunnel valleys and ocean quahog interest features are all screened out from further assessment.

6.9.1.5.4 Stage 1 MCZ Assessment

6.9.1.5.4.1 Direct loss of designated interest features, habitats and benthic communities

The locations and proportions of sediment and geomorphological features that comprise the interest features across the Holderness Offshore MCZ are not completely known. Instead, Natural England provides information on the likely potential and extents based on the best available evidence and proxy information. A review of information on the MAGiC resource (Defra, 2023) indicate that the rock placement could directly intersect the subtidal coarse sediment feature, while subtidal mixed sediments and subtidal sand have a patchy distribution are do not coincide directly with the proposed pipeline route. Figure 6-10 shows the Defra (2019) understanding of habitats within the MCZ.

However, as established during screening, the Gardline (2022b) survey of the proposed Humber Pipeline route within the MCZ identified EUNIS habitat A5.44 ‘Circalittoral mixed sediment’ and A5.27 ‘Deep circalittoral sand’ at a number of sample stations within the boundary of the MCZ. These habitats are thought to be analogous to the designated interest features subtidal mixed sediments and subtidal sand, respectively. The survey interpretation of habitats is also shown in Figure 6-10. Consequently, despite the Defra (2019) data indicating otherwise, it has been assumed for the purposes of this assessment that the proposed pipeline activities may directly impact subtidal mixed sediments and subtidal sand.

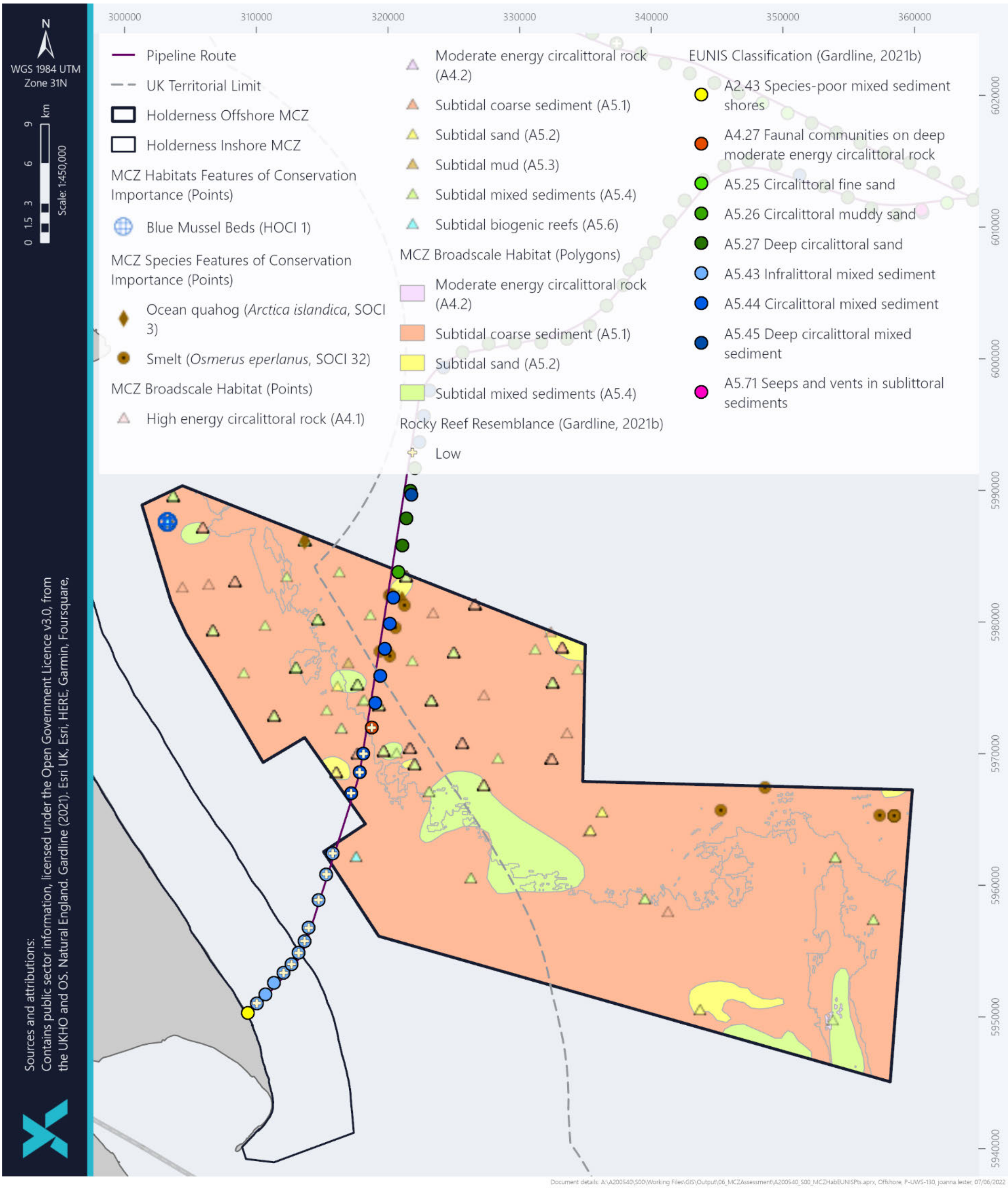


Figure 6-11 - Habitats and features of conservation interest within the Holderness Offshore MCZ (according to Defra, 2019b), overlain with Gardline (2022a, 2022b) survey data of EUNIS habitats and rocky reef occurrence

JNCC Advice on Operations (2021b) consider that subtidal coarse sediment, subtidal mixed sediment and subtidal sand are sensitive to a number of pressures relating energy generation activities, including pipeline construction, operation and maintenance, and decommissioning. They are sensitive to the following pressures: penetration and/or disturbance of the substratum below the surface of the seabed, including abrasion; habitat changes; physical change to another seabed/sediment type; and changes in habitat structure, as would come about by the installation of rock the Humber Pipeline (Table 6-16).

The worst case rock placement scenario for designated features would be for rock to be exclusively placed within a single designated interest feature. For the purposes of the MCZ assessment it has been assumed (per the assumptions in Table 6-13) that 5% of the pipeline length within any given habitat will require rock placement. As stated in Table 6-13, the remaining pipeline will mostly be surface laid, with a short section being trenched and buried. The surface laid sections of pipeline also constitute an area of habitat loss.

Table 6-21 presents the lost area of habitat of subtidal coarse sediment based on the above worst case rock placement and pipeline assumptions. The table demonstrates that the area of habitat loss associated with rock placement on subtidal coarse sediment is minimal, at <0.01% of the total area of the feature.

As the survey evidence supporting the presence of the subtidal mixed sediment and subtidal sand does not translate into an area of habitat, the potential direct impact on these features has not been quantified in the same way. However, it is expected that the proportion of habitat which may be affected by the Development activities will be similarly small in scale given the proportionate availability of the feature within the MCZ as a whole. These interest features cover much of the MCZ and exist on a much larger scale than the presence of pipeline and any associated rock placement. Additionally, these habitats are governed by forcing processes that occur at regional scales. Overall, these percentages are extremely small, and their loss is expected to be imperceptible at the site level.

The disturbance and burial of a small proportion of these interest features will not disrupt their overall structure and functioning across the MCZ. This is because the interest features are not localised to the pipeline route alone; they are driven and maintained in relation to regional tidal and geomorphological properties, which the presence of the pipeline and associated rock placement would not interrupt. Despite the feature sensitivity to pressures associated with pipeline installation, due to ongoing functioning and wider persistence of the interest features across the MCZ, the conservation objectives to “maintain” will also be sustained. Therefore, the loss of the interest features due to the presence of the pipeline and potential associated rock berm is assessed to be **not significant** with respect to meeting the conservation objectives of all the designated interest features.

Table 6-21 - Area of designated interest feature present within Holderness Offshore MCZ and the area lost due to Development activities

Designated interest feature	Approximate length of pipeline within feature	Approximate area of habitat inside MCZ (m^2)	Area of habitat lost due to rock placement within MCZ (m^2)	Area of habitat lost due to pipeline presence within MCZ (m^2)	MCZ habitat lost as a % of total habitat present within MCZ
Subtidal coarse sediment	18,013	1,072,723,390	9,912	12,872	0.0019

6.9.1.5.4.2 Effects on the sediment transport regime as a result of rock placement

To inform this Stage 1 MCZ assessment a semi-quantitative empirical approach was applied to investigate the potential for any changes to the tidal currents and sediment transport potential, based on the environmental understanding presented in Section 6.9.1.3.

6.9.1.5.4.2.1 Scour potential

As described in Section 6.9.1.4.4.2.1, the proposed design of rock placement along the Humber Pipeline is such that the potential for scour generation is minimal. This equally applies within the context of the Holderness Offshore MCZ. The rock berm design accounts for wave and current loading, and the proposed permeability of the berm along with the slope angles all act to reduce the turbulence that would generate scour, therefore limiting the development of scour. Therefore, the potential impact on the designated interest features in the immediate vicinity of the rock berm are assessed to be insignificant, with respect to maintaining their conservation objectives.

6.9.1.5.4.2.2 Local sediment accumulation and disruption of sediment transport pathways

Peak current speeds along the Humber Pipeline route are on the order of 0.72 m/s and 0.41 m/s on the spring and neap tides respectively, and together occur for approximately half of a tidal cycle (Admiralty TotalTide, 2022). The shear stress or force associated with these current speeds are summarised in Table 6-22 along with the critical threshold for mobility for the range of representative grain sizes that occur across the MCZ; these critical thresholds are the same as those within the Holderness Inshore MCZ as the critical threshold varies according to sediment properties alone, irrespective of local metocean conditions (Table 6-19). The shallowest point along the Humber Pipeline route within the Holderness Offshore MCZ lies in a water depth of 28 m LAT. The deepest point along the route within the MCZ is 53 m LAT. Depth has an influence on the metocean conditions therefore two scenarios have been presented in Table 6-22, based on the differing conditions at these two depths.

Based on the estimated shear stress, sediment including mud, clay, silt and medium sand would be mobilised under both peak spring and neap flows. Coarse sand and gravel would not be mobilised by the flow at any point during the tidal cycle. Due to the influence of wave action attenuating with water depth, it is likely that coarser material would only be moved in relation to extreme or storm conditions.

Table 6-22 - Critical threshold for representative grain sizes and the mobility potential for peak spring and neap flow speeds

Sediment	Representative grain size (mm)	Critical threshold	Mobility potential		Mobility potential	
			28 m LAT water depth		53 m LAT water depth	
			Spring (peak)	Neap (peak)	Spring (peak)	Neap (peak)
Mud and clay	0.002	0.01	Mobile	Mobile	Mobile	Mobile
Fine silt	0.0156	0.05				
Coarse silt	0.0625	0.12				
Fine sand	0.25	0.19				
Medium sand	0.5	0.26				
Coarse sand	2	1.17	Not mobile	Not mobile	Not mobile	Not mobile
Gravel	4	3.01				

The critical threshold for sediment mobility and bed shear stress associated with the flow speeds along the nearshore section of pipeline are calculated using empirical formulae set out in Soulsby (1997).

Mobility potential was calculated using current data across a spring and neap tidal cycle from ATT for the tidal diamond closest to the Humber Pipeline route within the MCZ (SN017P; Admiralty TotalTide, 2022); the mobility here is presented for the peak spring and neap current speeds. Wave data was obtained from the Hornsea wave buoy located approximately 10 km north of the Humber Pipeline route (Channel Coastal Observatory, 2020).

Table 6-22 shows that only a proportion of the sediment available in the vicinity of the rock would potentially be mobilised in relation to the flow characteristics; with larger sediment grains moving over a much shorter period and likely under conditions associated with storm events. Of the amount available for transport, only a proportion could theoretically be trapped by the presence of the surface laid pipeline and rock berm, where the exact amount would vary in relation to local metocean conditions and sediment grain size.

At a depth of 28-53 m LAT, tidal currents are the driving force for sediment transport through suspension. The shallowest point along the pipeline and point at which rock could be potentially placed, at approximately 28 m LAT will not interact with, nor influence, the local wave regime. Based on the findings within Table 6-22, only finer sediments will be mobile at any given time during a tidal cycle. With regards to the rock berm specifically, there is little opportunity for the porous rock placement to trap any coarser sediment. Given time, the rock placement will become colonised with benthic fauna, and so the voids within the rock will likely fill. Ultimately, sediment would bypass the rock altogether as the introduced substrate becomes integrated with the local habitat. Similarly, the presence of the pipeline would constitute a new hard substrate for colonisation. The pipeline would present a barrier to sediment transport, and its height above the seabed would initially cause some accumulation of sediment along its length. However, ultimately, given the dynamic nature of the area, once a level of sediment had accumulated, after this point additional sediment would pass over the pipeline uninhibited

With respect to the subtidal coarse sediment, subtidal mixed sediments and subtidal sand designated features which were scoped in due to potential hydrodynamic impacts, only the subtidal sand feature is considered sensitive to changes in water flow (JNCC, 2021c). This is likely due to it being a finer sediment therefore more influenced by water flow. However, as established in Table 6-22, given the conditions in the Holderness Offshore MCZ, subtidal sand is mobile most of the time during a tidal cycle as the area is highly dynamic. Subtidal mixed sediments are not sensitive to this pressure and data is lacking on subtidal coarse sediments to make a determination on their sensitivity to water flow changes (JNCC, 2021c). Based on the information presented in Table 6-22, it is unlikely that coarser sediments are mobile under representative metocean conditions. Consequently, the presence of the pipeline or any rock placement is unlikely to cause any hindrance to the transport of coarse sediment in the medium to long-term, which means there would be no impact or changes to the sediment transport regime through the MCZ. This applies to all depths within the MCZ.

Overall, the potential for any indirect impacts due to the disruption of the sediment transport regime on the designated interest features is assessed **not significant**. With the proposed installation activities, there is no change to the long-term sediment transport potential of sediment that constitute the designated features. The material would still be moved largely uninterrupted across the wider MCZ as the wave and tide driven transport processes occur at a much larger scale than the pipeline and/or rock placement. Therefore, the overall structure and functioning of the interest features would be maintained and the conservation objectives of the interest features would not be hindered.

6.9.1.5.4.3 Cumulative assessment

Although not explicitly required, the MMO guidelines suggest an assessment of hinderance on the conservation objectives should be considered as any act that could, either alone or in combination with other projects. To this end, a brief assessment of cumulative effects on the conservation objectives of the designated interest features has been undertaken here.

6.9.1.5.4.3.1 Infrastructure

The Holderness Offshore MCZ was designated in May 2019 and at that time there were a number of infrastructure items already present which therefore form part of the baseline, much of which also intersects the Holderness Inshore MCZ. The infrastructure present at the time of designation included:

- York platform;
- Rough AD, AP, BD, BP and CD platforms;
- West Sole to Easington 16” gas line, PL28;
- West Sole to Easington 24” gas line, PL145;
- West Sole to Easington 24” gas line, PL145;
- 30” gas, Amethyst A2D to Easington, PL649;
- Easington to Rough 47/3B 16” gas line, PL26;
- Rough 47/3B import/export 36” gas line, PL150;

- Rough 47/8A export 18” gas pipeline, PL151;
- Langeled pipeline 44” gas pipeline, PL2071;
- York methanol pipeline 89 mm, PL2918;
- Cleeton CP to Dimlington 36” gas export pipeline, PL447;
- Helvellyn to A2D gas export line, PL1956;
- Mercury to Neptune 10” gas export line, PL1707;
- Neptune to Mercury 4” condensate umbilical, PL1708;
- Ceres to Mercury 6” gas pipeline, PL2595;
- Mercury to Ceres umbilical, PL2596;
- Mercury to Eris umbilical, PL2598 ;
- Rose to Amethyst A2D 10” gas pipeline, PL1987; and
- Amethyst A2D to Rose 96.5 mm umbilical, PLU1988.

These infrastructure items all remain active, except for the Easington to Rough 47/3B 16” gas line (PL26), which is noted as no longer in use as of 2019. Decommissioning of the Rose to Amethyst A2D 10” gas pipeline (PL1987) and the associated Amethyst A2D to Rose 96.5 mm umbilical (PLU1988) commenced in 2015 and concluded in 2018.

The Tolmount HGS export pipeline to Easington has become operational as of 2022 and travels through the MCZ.

6.9.1.5.4.3.2 Cumulative impact assessment

The assessment of direct and indirect impacts presented above concludes that there will be no long-term disruption to the sediment transport regime such that the designated features for the MCZ are affected. Potential impacts are localised to the immediate vicinity of any rock placement, and habitat loss constitutes a proportionately very small area within the site.

According to a BEIS (now DESNZ) (2021c) review of rock and other protective materials used in offshore oil and gas operations across the UKCS, between 2011 and 2016, an estimated 0.0065 km^2 of seabed deposits were placed within the Holderness Offshore MCZ in association with some of the infrastructure listed above. Some of this rock pre-dates the designation of the site in 2019, but is still included in this total (BEIS, 2021c).

Since the BEIS (now DESNZ) review was conducted, the Tolmount HGS export pipeline has been commissioned, constructed and is now in operation. As outlined in the Tolmount ES (Premier, 2018), the Tolmount HGS export pipeline required rock to be placed at trench transition points and crossings. An additional quantity of rock was required to mitigate against Upheaval Buckling (UHB) and insufficient pipeline burial. It is important to note that not all of this UHB and mitigation rock will have been required within the MCZ, however specific placement locations were not provided. It is also not possible to determine the extent of rock placement within each MCZ interest feature specifically. However, assuming a worst case scenario under which all of this rock would be required within the MCZ, the present calculations estimate that the total area of habitat loss would equate to 0.036 km^2.

The area of habitat loss associated with the installation of the Humber Pipeline, in combination with the rock reported as part of the BEIS (now DESNZ) (2021c) review, and rock installed along the Tolmount HGS export pipeline is shown in Table 6-23.

Table 6-23 - Estimates of habitat loss within the Holderness Offshore MCZ

Source	Area of habitat loss (km^2)	Area as a % of the Holderness Offshore MCZ
NEP Humber Pipeline (see Table 6-13 and Section 6.9.1.4.4)	0.023	0.0019
BEIS (now DESNZ) (2021c) review (captures rock installed between 2011-2016)	0.0065	0.000553
Tolmount HGS export pipeline (assuming the worst case)	0.036	0.003
Total	0.065	0.0055

Per Table 6-23, a cumulative total of 0.06 km^2 of rock could be located within the MCZ. This equates to approximately 0.0055% of the whole site, the majority of which is associated with the Tolmount HGS export pipeline.

The requirement for rock protection in the conversion of the Rough gas store, and associated PL26 pipeline, into an offshore hydrogen store (Section 6.9.1.4.4) is unknown. In the Holderness Offshore MCZ, PL26 is located approximately 13 km southeast of the Humber Pipeline. Given the distance between any required rock placement, there are unlikely to be any cumulative impacts to localised hydrodynamic forces. Any required protection is likely to occur in the form of spot rock placement, on a highly localised scale. Within the context of the wider MCZ; associated loss of habitat will be minimal.

Decommissioning of the Rose to Amethyst A2D 10" gas pipeline (PL1987) and the associated Amethyst A2D to Rose 96.5 mm umbilical (PLU1988) commenced in 2015 and concluded in 2018. The chosen decommissioning options for both pipeline and umbilical were to partially remove the lines, leaving the majority in situ and making safe the ends. Rock remediation at the cut ends was not mentioned in the DP, and instead it was suggested that the ends of the umbilical be trenched and left to backfill naturally (Centrica Energy, 2015). Consequently, it is assumed that no rock was required as part of this decommissioning. Regardless, due to the time frame of the activities, any rock used would likely have been captured in the BEIS (now DESNZ) (2021c) review of protected material use in oil and gas.

The above assessment on potential impacts of the rock placement along the Humber Pipeline on tidal currents in Section 6.9.1.5.4 highlighted there would be negligible change to the current speeds, as there was no change to the downstream water levels. In the event this condition is satisfied, there would be little or no potential for cumulative impacts to the local sediment transport regime associated with any other activities occurring within the MCZ.

Overall, the environmental processes governing the sediment transport regime across the MCZ occur at much larger scales than the projects and would therefore not be disrupted by the present infrastructure. Additionally, the present area of rock placement within the MCZ constitutes a very small area of habitat overall. This would result in a total of 0.0051% of the site being affected when accounting for worst case rock placement along the Humber Pipeline and rock requirements along the Tolmount HGS export pipeline, in addition to overall BEIS (now DESNZ) estimates of rock within the site. The placement of this rock is unlikely to occur in the context of any single designated interest feature alone therefore, the extent of direct impact on each feature will be minimal. With respect to the proposed rock placement, the potential for cumulative impacts, including hinderance on the conservation objectives of the designated interest features, is assessed as **insignificant**.

6.9.1.6 Conclusions

6.9.1.6.1 Holderness Inshore MCZ

The maximum areas of habitat loss predicted through this approach affected <0.01% of the total area of subtidal coarse sediment and subtidal mixed sediments. These potential impact areas are extremely small, and therefore are not considered to be a significant threat to either the extent, functioning or persistence of the designated features.

In terms of the potential for indirect impacts, there should be no long-term disruption to the sediment transport potential and pathways across the MCZ. This is because, there is no expected change to the tidal processes and the fine material transported in suspension. Furthermore, the potential impact on wave-drive bedload transport, would be short-term and highly localised to any rock located within shallower intertidal areas where waves interact with the seabed.

Finally, having assessed the proposed Development activities within the context of wider activities occurring in the MCZ, it has been determined that there is no potential for cumulative impacts associated with rock placement along the Humber Pipeline.

Overall, the worst case scenario for rock placement is not expected to hinder the conservation objectives of the Holderness Inshore MCZ.

6.9.1.6.2 Holderness Offshore MCZ

Habitat loss may affect up to < 0.01% of the total area of each subtidal coarse sediment. While it has not been quantified, it is expected that similarly small areas of subtidal mixed sediments and subtidal sand habitat may be affected by pipeline presence and rock placement. These potential impact areas are extremely small, and therefore are not considered to be a significant threat to either the extent, functioning or persistence of the designated features. The base case is that no rock protection will be required, and therefore there would be no significant disturbance or loss of designated features.

In terms of the potential for indirect impacts, there should be no long-term disruption to the sediment transport potential and pathways across the MCZ. This is because, there is no expected change to the tidal processes and the fine material transported in suspension.

Finally, having assessed the presence of the pipeline and possible associated rock placement within the context of wider activities occurring in the MCZ, it has been determined that there is no potential for cumulative impacts associated with the Humber pipeline and rock placement along its length.

Overall, the proposed activities within the MCZ are not expected to hinder the conservation objectives of the Holderness Offshore MCZ.

6.9.2 Information to Support Screening for Habitats Regulations Assessment

This section provides information on the potential for seabed disturbance associated with the Development (alone or in combination with other plans or projects) to result in LSE on the qualifying interest features of SACs (Section 6.9.2.1) and SPAs (6.9.2.2), to help inform the screening for an Appropriate Assessment. Article 6(2) of the Habitats Directive requires that there should be no deterioration or significant disturbance of the qualifying species or to the habitats upon which they rely. The assessments below identify the potential impacts from seabed disturbance, determine connectivity with designated sites and evaluate the potential for LSE and for any adverse effects as required.

6.9.2.1 SACs

6.9.2.1.1 Screening and connectivity

The impact mechanisms associated with seabed disturbance activities have been identified in Section 6.4.2 and include:

- Temporary direct and indirect impacts on seabed fauna and habitats, including those important for fish; and
- Long-term, localised loss/changes to seabed habitats through the presence of structures on the seabed.

The installation activities, and topographical changes due to the presence of structures on the seabed, also have the potential to cause direct impacts on the local hydrodynamic regime. The potential for such impacts to lead to changes in seabed habitats or to affect wider-scale coastal processes is considered in 6.4.2.2.

The whole of the Endurance Store area and the distal parts of the Teesside and Humber Pipeline routes lie within the SNS SAC (see Figure 4-29), designated to aid the management of harbour porpoise populations in UK waters. Therefore, the connectivity with and likelihood of significant effects on harbour porpoise associated with the SNS SAC are assessed below. Since the potential impacts on benthos and fish arising from the planned construction and installation activities are temporary and not expected to be significant (Section 6.10.1), the assessment focusses on the long-term placement of structures on the seabed.

Stakeholders have provided feedback during scoping regarding the assessment of features within the SAC. These stakeholder comments are shown in Table 6-24 and have been addressed in the assessment.

Table 6-24 - Stakeholder comments regarding the assessment of potential impacts on the SNS SAC

Stakeholder comment	Response
JNCC	
Both pipelines cross, and the Endurance Store area is in, the SNS SAC. Conservation Objective 3 for the SNS SAC, "ensuring that the condition of supporting habitats and processes, and the availability of prey is maintained", should be taken into consideration when assessing seabed impacts on the site. JNCC acknowledge that this may be assessed in terms of any impacts to prey species during a desk-based assessment of potential impacts on fish.	The potential for impacts on the supporting habitats and processes within the SAC, and on the availability of fish prey species, is assessed in Section 6.9.2.1. Consideration is given to the likelihood of significant effects on harbour porpoise using the SAC.

Stakeholder comment	Response
In order to be able to assess the impact on SNS SAC, JNCC request that the operator specifically state how much protection/stabilisation material and area of seabed footprint occurs within the site.	The seabed footprint within the SAC is shown in Section 6.4, with full details provided in Section 6.9.2.1.
Whilst JNCC would encourage the operator to minimise the amount of hard substrate material used, the ES should use the worst case option to enumerate the protection/stabilisation material that will be used, and the area of seabed impacted. Within marine protected areas this should be split by into the feature types impacted.	Chapter 6 identifies and assesses the worst case for rock placement. The worst case area affected is assessed for the SAC in Section 6.9.2.1.
OPRED	
The Scoping Report gives a commitment to assess the potential for impact on the conservation objectives of the SNS SAC but no further information is given on how this will be done. The ES must set-out how BP intend to mitigate any potential impacts on the SNS SAC and the other designated sites impacted. Cumulative impacts must also be considered. The use of rock within the SAC is discussed within Section 4, the impact of this should be assessed paying close attention to the following areas: • killing or injuring harbour porpoise (directly or indirectly); • preventing their use of significant parts of the site (disturbance / displacement); • significantly damaging relevant habitats; or • significantly reducing the availability of prey.	Section 6.9.2.1 considers the potential impacts on the SAC, including cumulative impacts, from the placement and presence of rock protection on the seabed. The assessment focusses on the potential for damage and long-term changes to relevant seabed habitats and on potential changes in the availability of harbour porpoise prey fish species. This has been used to inform and assessment of the likelihood of significant effects on harbour porpoise using the SAC. Chapter 7 Underwater Noise and Chapter 9 Physical Presence consider respectively the potential for underwater noise generated during installation activities to kill or injure harbour porpoise, and the potential for installation activities to interact with harbour porpoise.

Designated in 2019, the overarching conservation objective of the SNS SAC is to ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining FCS for harbour porpoise in UK waters. In view of the potential impact mechanisms from seabed disturbance and the stakeholder comments in Table 6-24, this assessment focusses on Conservation

Objective 3: "*In the context of natural change. The condition of supporting habitats*[177] *and processes*[178], *and the availability of prey is maintained*."

The site covers a very large area of 36,951 km^2 to include key winter and summer habitat for harbour porpoise and stretches from the CNS (north of Dogger Bank) to the Straights of Dover in the south (JNCC, 2020a). The Development overlaps with a small part of the northern section of the site (important for harbour porpoises during the summer season), near its western edge, in water depths of approximately 41 m to 82 m and more than 12 nautical miles from shore (see Figure 4-29). The Development area lies within a relatively deep part of the site, the majority of which is shallower than 40 m, with harbour porpoise thought to prefer water depths of 30 – 50 m (JNCC, 2017c).

6.9.2.1.2 Identification of LSE

A full description of the subsea infrastructure required at the Endurance Store and of the Teesside and Humber Pipelines is provided in Chapter 3 Project Description. A summary of the activities proposed to be undertaken within the SNS SAC is provided here. In line with the rest of the ES, the worst case assumptions have been used in terms of the footprint of seabed impact.

In the Endurance Store area, the required subsea equipment and protection structures that will have a permanent seabed footprint comprises:

- A 28" infield pipeline approximately 6 km long connecting the two manifolds, which will be surface-laid except where partial trenching may be required to mitigate scour;
- Rock placement along the infield pipeline (maximum of 10% of 6 km pipeline);
- A wellhead tree at each of the six wells;
- Rock placement, if needed, along the five trenched infield flowlines (maximum of 10% of each 3 km flowline);
- Rock placement at ten trench transitions (two per infield flowline);
- Rock placement, if needed, along trenched infield cables (as a worst case, the cables are assumed to require rock placement along 10% of their lengths);
- Concrete mattresses at the approaches to the manifolds and wells;
- Up to fifty concrete plinths for 4D gravimetry; and
- Three seabed landers as part of MP. A further lander might be installed on the seabed in the Bunter Sandstone Outcrop area, approximately 20 km east of the Endurance Store area.

In addition, approximately 32.9 km of the Teesside Pipeline and 36.8 km of the Humber Pipeline are expected to lie within the SNS SAC; these sections will be surface-laid. Within the SAC, the Teesside Pipeline route and Teesside – Store cable route cross the Langeled gas pipeline and the cable corridor for the proposed Dogger Bank A transmission asset; these crossings will be covered by protective rock berms. The Humber Pipeline route does not cross any other seabed assets within the SAC area.

The seabed footprint for the structures proposed to be installed on the seabed within the SAC is shown in Table 6-25 and amounts to a worst case of 0.1683 km^2, representing 0.0016% of the overall SAC seabed area.

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[177] *The characteristics of the seabed and water column*
[178] *The movements and physical properties of the habitat*

Table 6-25 - Long-term direct seabed impact areas within the SNS SAC

Parameter	Permanent direct impact during O&M (km^2)
Endurance Store and Bunter Sandstone Outcrop areas	
Co-mingling manifold including scour mitigation (32 m x 28 m)	0.0009
Four-slot manifold including scour mitigation (36 m x 22 m)	0.0008
Pig receiver at each manifold (two, each 10 x 4 m)	0.0001
Surface laid infield pipeline connecting manifolds (6 km x 0.7 m)	0.0043
Rock placement: infield pipeline (10% of 6 km pipeline with berm width of 10 m)	0.0060
Six wellhead trees (each 5 m x 5 m)	0.0002
Concrete mattresses on approach to manifolds & wells (630 total, each 6 m x 3 m)	0.0113
Rock placement: ten trench transitions (two per infield flowline, each 200 m x 7 m)	0.0140
Rock placement: five infield flowlines (10% of each 3 km flowline, berm width 7 m)	0.0105
Rock placement along infield cables (10% of 30 km), total 3 km x 7 m)	0.0133
Up to four seabed landers as part of MP, each 3 m x 2.4 m	<0.0001[1]
Up to 50 concrete plinths for 4D gravimetry	0.0001
Portion of Teesside Pipeline and Teesside-Store cable within the SAC	
Surface laid 28” pipeline (32 km x 0.7 m)	0.0225
Rock placement on pipeline at one buried crossing (Dogger Bank A cable)	0.0062
Rock placement on pipeline at one surface crossing (Langeled Pipeline)	0.0072
Mattresses protruding at one crossing (Pipeline)	0.0021
Rock placement on cable at one buried crossing	0.0020
Rock placement on cable at one surface crossing	0.0021
Mattress protruding at crossing (Cable)	0.0004
Rock placement on pipeline (5% of the 32 km section)	0.016
Rock protection on cable (5% of the 32 km section)	0.0074
Portion of Humber Pipeline within the SAC	
Surface laid portion of 28” pipeline (35 km x 0.7 m)	0.0244
Rock placement on pipeline (5% of the 35 km section)	0.0175
Total area of long-term impact (km^2)	**0.1683**

The majority of substrate types within the SAC as a whole are categorised as sublittoral sand and sublittoral coarse sediment, which aligns with the preference of harbour porpoise for coarser sediments (sand/gravel) rather than fine sediments (mud) (JNCC, 2017c). The predicted EUNIS habitat type within the SAC in the vicinity of the Development Site and surrounding areas is A5.27 Deep circalittoral sand. The site-specific survey recorded mostly A5.27 Deep circalittoral sand in this area, together with some A5.45 Deep circalittoral mixed sediment. Three slightly shallower stations were categorised as A5.25 Circalittoral fine sand and a single station was categorised as A4.22 *Sabellaria* reefs on circalittoral rock (Figures 6.1 and 6.2).

Amongst the key identified pressures on harbour porpoise in UK waters that may affect the achievement of Conservation Objective 3, JNCC (2019) lists the removal of prey species by commercial fisheries. Major dredging and disposal operations, such as navigational dredging, may also lead to physical changes to another habitat type, with the potential for changes in the availability of prey species and habitat loss. In addition, significant installations on the seabed can lead to localised changes in water flow (tidal current) or present a barrier to species movement, potentially resulting in habitat loss or change. Habitat degradation, increased levels of suspended sediments and sedimentation may affect epibenthic and infaunal communities, leading to indirect effects on harbour porpoise through changes in prey availability. However, these effects are not generally considered to present a significant pressure on the conservation objectives, and the relative level of risk to the SAC from these types of impact was assessed as being low. Fisheries bycatch, underwater noise and pollution have been identified as the main threats to harbour porpoise (JNCC, 2019, 2020a; IAMMWG *et al*., 2015). The widescale distribution of harbour porpoise prey species can also be affected by trends associated with climate change (IAMMWG *et al,* 2015).

JNCC (2019) notes that harbour porpoise are thought to be highly dependent on year-round proximity to food sources and that the distribution and condition of the species may strongly reflect the availability and density of its prey. These are in turn influenced by both natural and anthropogenic changes in prey species and their habitats. The maintenance of supporting habitats and processes contributes to ensuring that prey is maintained within the site and is available to harbour porpoises using the site.

Harbour porpoise feed on a wide variety of small fish including benthic and benthopelagic species such as sandeel, goby and whiting, as well as pelagic shoaling fish such as mackerel, herring and sprat (JNCC, 2017c, 2019; IAMMWG *et al.*, 2015). JNCC (2017c) acknowledges that the main prey species of harbour porpoise in the SNS SAC are not known, nor are the features of the habitat that are the most important drivers of the association with prey.

Whiting are benthopelagic migratory species which feed at least in part by scavenging on benthic invertebrates, including polychaetes, crustaceans and molluscs, occurring on mud, sand, gravel and rocky seabeds (Fishbase, 2020). They are expected to be present in the Endurance Store area and may use it as a nursery ground, but the nursery grounds extend over a very large area as described in Section 4.4.3.1. Information presented by Ransijn *et al* (2019) suggests that whiting in this part of the SAC may form an important part of harbour porpoise diet during the winter.

Although feeding predominantly on zooplankton, herring is a demersal spawner and requires coarse, gravelly sediments to spawn. Herring typically spawn within the 15-40 m depth range and are therefore unlikely to spawn in those parts of the Development area within the SAC, which is supported by the findings of a site-specific herring spawning assessment (Gardline, 2022b).

Sandeel are planktivorous, shoaling fish with a close association with sandy substrates, into which they bury themselves for protection from predators and onto which they attach their eggs during spawning. They exhibit a strong association with particular surface sediments, with their distribution possibly being limited by fine particles (JNCC, 2017c, 2022a). Sandeel are vulnerable to various threats including over-fishing, climate change and the physical disruption or removal of their sediment habitat, although very little is known about their recovery in response to these threats (JNCC, 2022a). As described in Section 6.4.2.1.3, several sampling stations in the Endurance Store area and on the deeper parts of both pipeline routes had some degree of suitability for sandeel spawning. In addition, adult sandeel were observed in grab samples from a few sampling stations in the deeper parts of the Humber Pipeline routes.

Although there is some overlap between published sandeel spawning areas and the parts of the Development (short sections of both pipeline routes) lying within the SNS SAC (see Figure 4-23 and Figure 4-31), offshore construction activities are currently scheduled to take place during March to September 2026 and are unlikely to interfere with sandeel spawning which occurs during the winter months (November to February; Section 4.4.3.1). It is unlikely that the localised and temporary direct or indirect impacts from installation activities will have a significant impact on sandeel spawning or adult populations in the SNS SAC. The flattening of sandwaves during seabed sweeping prior to installation of the pipelines and flowlines has the potential to result in localised impacts on any sandeel in the vicinity of this activity, but the sand particles are expected to be redistributed over time under the prevailing bottom current regime. Given that sandeel are adapted to these dynamic conditions, no significant effects are expected.

Seabed sweeping may be required prior to installation of the infield pipeline and flowlines and those parts of the Teesside Pipeline and Humber pipelines that lie within the SAC, although the requirement for this activity will be refined and minimised as far as reasonably practicable during detailed design (see Section 3.2.3.3). It is assumed that sandwaves will be cut to the bottom of the troughs in the route corridors throughout the sandwave areas, so that the linear infrastructure can be trenched below the sand migration layer; conservative assumptions for the areas affected are included in Table 6-3, Table 6-4 and Table 6-5, based in a worst case corridor of disturbance 30 m wide[179].

The site-specific surveys showed the widescale presence of sandwaves in the Endurance Store area, which were up to 8 m high in places, with gradients that would indicate active movement of these features (Gardline, 2021a). Sandwaves are common seabed features in areas with a relatively mobile, sandy seabed, such as the SNS; these sandwaves were interpreted as isolated features and not part of a more widespread sandbank system. The consequences of sandwave flattening on physical processes in the SNS SAC are assessed in Section 6.4.2.2 and considered to be minor. As illustrated in Appendix G, Figure 2-4 and Figure 2-5, the pipeline routes have been selected to avoid nearby large sandbank features and are largely perpendicular to the crests of the sandwaves that are situated in the troughs of the sand banks, particularly so for the Humber Pipeline and the infield pipeline. This means that the smallest possible cross-section of each sandwave is impacted and the overall character of the sandwave system will be preserved.

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[179] The sites that will be utilised for spoil deposit from the seabed sweeping activities have not yet been determined, but they will be selected to be as close to the pipeline and flowline routes, and in areas that have been previously subjected to construction activities, as reasonably practical. Identification and use of the sites will be subject to future stakeholder consultation under the relevant regulatory regime.

Although seabed sweeping has the potential to result in localised impacts on any sandeel in the vicinity of this activity, given the small area affected in the context of the sand waves in this part of the SNS SAC and that sandeel are adapted to dynamic seabed conditions, no significant effects are expected.

As discussed above, the installation of subsea infrastructure and protection structures will introduce additional hard substrata to the predominantly sandy seabed in this area. Given the relatively small areas affected (total of 0.1683 km^2) and the very widespread distribution of similar habitat type within the SAC, no significant negative effects are expected to occur on the supporting habitats or the availability of sandeel or any other harbour porpoise prey species. It is possible that the development of a "reef effect" around the pipelines and subsea infrastructure may result in a positive impact on harbour porpoise (IAMMWG *et al*., 2015), but there is insufficient information available to draw firm conclusions on this.

Overall, the minor changes to the seabed substratum associated with the Development are on a small scale and not likely to have a significant effect on any of the harbour porpoise prey species and will not affect the ability of prey species (especially sandeel) to reproduce. The presence of the structures on the seabed may result in minor changes to benthic epifauna and fish distribution, which could be negative or positive. It is unlikely that the Development would result in any loss of benthic biomass or availability of prey for fish species, or in turn to any reduction in the availability or distribution of harbour porpoise prey species.

6.9.2.1.3 Cumulative impact assessment

Section 6.6.1 considered the potential for cumulative impacts on benthos and fish, associated with both temporary seabed disturbance and sediment re-suspension during the construction and installation phase of the Development, and long-term or permanent changes in seabed habitat due to the presence of structures on the seabed. Given the localised nature of impacts from seabed disturbance, and the low potential for overlapping zones of impact with other plans and projects, consideration was focussed on those plans and projects within the tidal excursions of the different parts of the development area (including 15 km for the Endurance Store area). The key other projects which have the potential to act cumulatively in this way with the parts of the Development within the SNS North Sea SAC include:

- Kumatage gas field, which is currently at the early stage of project engineering;
- Existing Langeled gas export pipeline (to be crossed by the Teesside Pipeline within the SAC);
- Proposed Dogger Bank A transmission asset (to be crossed by the Teesside Pipeline within the SAC); and
- Proposed Hornsea Project Four OWF (construction planned for 2026).

Taking account of these projects, the assessment concluded that no significant cumulative impacts on benthic habitats are anticipated.

The present section considers to what extent the sandy and coarse sediments that cover much of the SNS SAC, and which are thought to be preferred by harbour porpoise due to availability of prey (JNCC, 2019), may be changed by the cumulative effects of multiple plans and projects over a very large area, and whether there is potential for indirect cumulative effects on the conservation objectives.

According to a BEIS (now DESNZ) (2021c) review of rock and other protective materials used in offshore oil and gas operations across the UKCS, seabed deposits resulted in an estimated area of impact of 195,369 m^2 within the SNS SAC between 2011 and 2016, equating to 0.00053% of the total SAC area. The majority of this impact area (136,036 m^2) also falls within other SACs and MCZs designated primarily for their seabed features while 59,333 m^2 is solely within the SNS SAC (equating to 0.0002% of the area of the SAC).

BEIS (now DESNZ) (2021c) also examined the total area impacted in the SNS as a whole by broad habitat type. A range of habitat types are impacted in the SNS, associated with the subtidal sandbanks and reefs found there, with offshore circalittoral sand being most affected being offshore circalittoral sand, circalittoral coarse sand and offshore circalittoral coarse sand. Data for the SNS SAC from 2013-2016 indicate that the predominant deposit material used (having the largest impact) is clean inert rock, followed by gravel and mattresses. The majority of within the SAC are also located within other SACs that have been designated primarily for their seabed features.

The presence of existing deposits within the SNS SAC up to 2016, based on BEIS (now DESNZ) (2021c), of 0.1954 km^2, will be increased by 0.1683 km^2 by the Development, based on the worst case scenario, and could result in a cumulative total of 0.3637 km^2, equating to less than 0.0010% of the total SAC area. This is expected to be increased with the development of additional projects but remains a very small percentage of the available harbour porpoise supporting habitat. Such changes are not expected to have any significant negative effects on the availability or distribution of harbour prey species. With respect to the proposed pipelines, subsea infrastructure and rock protection, the potential for cumulative impacts, including hinderance of the conservation objectives, is assessed as **insignificant.**

6.9.2.1.4 Conclusions

The worst case scenario for permanent impacts from the presence of subsea infrastructure and protection associated with the Development is not expected to hinder the conservation objectives of the SNS SAC through changes to the supporting habitats and availability of prey species. Overall, no likely significant effects on harbour porpoise are reasonably foreseeable as a result of the installation of the Development, alone or in combination with other plans or projects.

6.9.2.2 SPAs

The potential for LSEs on SPA features as a result of activities associated with the Development has firstly been considered based on connectivity between a SPA and the Development. Following this, consideration is given to the pathways through which impacts may occur on the features for which connectivity has been identified. Consideration has been given to all potential SPA features including breeding seabird features (both in the breeding and non-breeding seasons) (e.g. gannet, kittiwake, etc.), wintering water bird features (e.g. red-throated diver, common scoter) and features that utilise either intertidal and/or terrestrial habitats (e.g. ringed plover, turnstone).

6.9.2.2.1 Identification of LSE

Connectivity has been identified between the Development and the SPAs and associated features listed in Table 6-26 based on generic foraging ranges from Woodward *et al.* (2019) and direct overlap between the pipelines/Endurance Store and each SPA. There may be additional SPAs that have connectivity with the Teesside and Humber pipelines and Endurance Store due to either very large foraging ranges of designated features (e.g. fulmar, Manx shearwater, Leach’s petrel and great skua) or the occurrence of a feature in the area in which the pipelines will be installed outside of the breeding season. However, installation activities are intended to occur within a restricted spatial area that is unlikely to represent a significant proportion of the area available to breeding or non-breeding seabirds. It is therefore not anticipated that a LSE will occur for any feature of any other SPA.

The remainder of this section considers each SPA for which generic connectivity has been identified and looks at potential connectivity in more detail including consideration of site-specific foraging data and the distribution of features within SPAs.

Table 6-26 - SPAs and associated features for which connectivity exists with the Teesside Pipeline

SPA	Features	Development component
Flamborough and Filey Coast SPA	Gannet Kittiwake Guillemot Razorbill	Teesside Pipeline Humber Pipeline Endurance Store
Farne Islands	Kittiwake Puffin	Teesside Pipeline
Teesmouth and Cleveland Coast	Common tern Little tern Knot Redshank Sandwich tern Sanderling	Teesside Pipeline
Northumberland Marine	Kittiwake Puffin	Teesside Pipeline
Greater Wash	Red-throated diver Little tern	Humber Pipeline
Humber Estuary	Little tern	Humber Pipeline

As discussed in Section 6.4, of the species that may interact with the Development, as identified in the Technical Report (Appendix H), only little tern and red-throated diver are considered sensitive to impacts associated with habitat loss. This therefore means that only the Greater Wash SPA, the Teesmouth and Cleveland Coast SPA and Humber Estuary SPA, being those SPAs at which red-throated diver and/or little tern are qualifying features, are considered further.

Site-specific tracking data for little tern from the Teesmouth and Cleveland Coast SPA indicate that birds from the SPA exhibit a mean-maximum seaward extent of 3.45 km and a maximum alongshore extent of 5 km to the north and south. The little tern colony within the SPA has been located at Seaton Carew since 2019 having been previously located at Crimdon Dene to the north of Hartlepool. The

Teesside Pipeline is beyond the foraging range of little tern from both breeding locations and therefore an LSE is discounted for little tern.

6.9.2.2.2 Assessment of adverse effects

Greater Wash SPA – Red-throated diver

Red-throated divers are considered to have a high sensitivity to habitat loss and have a low habitat flexibility meaning they are restricted in terms of the habitats they are able to exploit. The nearshore section of the Humber Pipeline will pass through the Greater Wash SPA which is designated for red-throated diver in the non-breeding season (October to March). Lawson *et al.* (2016) suggests that the area through which the Humber Pipeline will pass supports moderate densities of the species.

Humber landfall and nearshore pipelay activities are likely to overlap with the presence of red-throated divers and therefore impacts may occur.

As described in Chapter 4: Environmental Description, the seabed within the Development area is dominated by sandy and mobile sediments. Such seabed sediment types are typically rapidly recolonised by benthic fauna and flora following disturbance, particularly if disturbance is not frequent (National Research Council, 2002; Newell *et al.*, 1998). Evidence of these fast recovery rates of benthic communities was observed and reported by Salmon (2011) following installation of the nearby Langeled pipeline.

Regardless of the option chosen for landfall construction (HDD, direct pipe, microtunnel or microtunnel and cofferdam), all will require the presence of a jackup barge located in the nearshore. The development schedule indicates that the jackup barge will be present in the nearshore for 180 days if the landfall is constructed using HDD or microtunnelling. These two options are therefore identified as the worst case for habitat loss impacts on red-throated diver and it is assumed that the jackup barge will be present for 180 days within the key period for red-throated diver. The remaining details of these two methods for the purposes of assessing habitat loss impacts on red-throated diver are broadly comparable.

The length of the Humber Pipeline that will pass through the Greater Wash SPA is 11.4 km. In the nearshore, from 8 m LAT (KP1) to KP16.3, a pre-cut trench is intended to be created which would be backfilled. The top of the trench is expected to be up to 52 m wide in the section from 8 m LAT to KP2, and 22 m wide in the section from KP2 to KP16.3. The temporary storage of dredge spoil will take place within a corridor up to 30 m wide from 8 m LAT to KP16.3. From KP16.3 onward, the pipeline will be surface laid and up to 10% of the total pipeline length may need to be protected by rock placement. Along the nearshore length of the pipeline where red-throated divers are expected to be present (20 km, i.e. to approximately KP19), the total seabed area directly affected during construction would be approximately 0.83 km^2.

The area of seabed directly affected by the presence of the jackup barge required for landfall construction activities and other associated infrastructure is 800 m x 800 m with the barge being a static feature for the large majority of the construction period. The ZoI associated with the landfall construction will therefore be 0.64 km^2. The total area of seabed which is expected to be affected will therefore be 1.47 km^2. This represents approximately 0.04% of the total Greater Wash SPA area.

The average density in the Greater Wash SPA that is expected to be affected by activities associated with the Development is 0.28 birds/km^2. When multiplied by the area affected (1.47 km^2), this provides a potentially affected population of less than one bird (approximately 0.4 birds). The SPA population of red-throated diver is 1,407 birds. The potentially affected population therefore represents less than 0.03% of the SPA population.

Mortality rates associated with habitat loss due to construction activities are unknown with no evidence that habitat loss will result in direct mortality of individual birds. Mortality as a consequence of displacement is more likely to occur as a result of increased densities outside of the impacted area, which may lead to increased competition for resources. Displacement of birds from low density areas (e.g. the area associated with the pipeline route) is less likely to result in mortality as these areas are likely to be of lower habitat quality. As such, the use of a 1% mortality rate is considered appropriate for this assessment.

Applying a 1% mortality rate results in a displacement mortality of less than one bird. This level of impact is considered to be of an insignificant magnitude in relation to the SPA population of red-throated diver (1,407 birds). Such a low level of displacement mortality represents less than 0.001% of the SPA population of red-throated diver. It is therefore considered that activities associated with construction do not have the potential to cause significant effects.

Given the expected rapid rate of recovery of benthic habitats following pipeline installation and the relatively small footprint of construction activities associated with the Development relative to the total area of the SPA, it is reasonably foreseeable that the impact of direct loss of seabed habitat used by red-throated diver associated with the Greater Wash SPA will not result in an adverse effect on the integrity of the Greater Wash SPA.

There are a number of projects that could act in-combination with the Development on the red-throated diver feature of the Greater Wash SPA, including the presence of OWFs, the installation of transmission infrastructure associated with OWFs and the installation of other subsea cables and aggregate extraction. However, when the spatial separation between projects is considered, the detailed timings associated with each project and the total sea area available for seabird use is taken into account, the in-combination impact is predicted to represent a negligible proportion of the SPA area.

It is unlikely that construction activities associated with these projects will occur at the same time and if they were to do so they would be spatially separated and not affect a significant proportion of the SPA. Any impact is therefore likely to be of a temporary and short-term duration, occurring intermittently for short periods of time and at low intensity. The magnitude of any in-combination impact associated with seabed disturbance is therefore considered to be negligible which is not considered to represent an adverse effect on the integrity of the SPA.

6.9.2.3 SSSIs

The Teesmouth and Cleveland Coast SSSI, situated landward of the Teesside Pipeline landfall, will be intersected by the pipeline and is designated for both geological and biological features, including the sand dunes which front the coast (see Section 4.5). The dunes along the stretch of coastline where the Teesside Pipeline landfall will occur are currently considered stable (Scarborough Borough Council, 2020). For the purposes of this assessment, as established in Section 3.2.1, the punch-out location at the Teesside Pipeline landfall is assumed to be at LAT. Consequently, considering the anticipated minimal disturbance as a result of the pipeline installation, both along its length and in the nearshore, no impacts are anticipated to the Teesmouth and Cleveland Coast SSSI as a result of construction activities. Although out of scope of this assessment, installation of the pipeline above MLWS will utilise trenchless construction to minimise the potential for impacts on Coatham Dunes and Sands and on the habitats and species at the Teesside and Cleveland Coast SSSI and other nearby designated sites.

Long-term, the Teesside Pipeline is not expected to impact the local hydrodynamic regime thus, there would be no opportunity for the pipeline to affect the maintenance regime of the sand dunes for which the site is designated.

The Humber Pipeline landfall is situated close to the Dimlington Cliff SSSI, which is designated to protect the Quaternary stratigraphy, as it provides a record of palaeoenvironmental conditions and a limiting date for the maximum expansion of Late Devensian ice. The cliffs are constantly eroded by the sea, allowing them to yield their valuable geological contents. Potential impacts associated with the presence of the Humber Pipeline would be the prevention of the sea reaching the base of the cliffs, thereby altering the natural erosion regime. However, the short period of time that the beach cofferdam will be in place, the small physical footprint of the cofferdam and the design of the landfall and onshore pipework, which will be buried into the beach well below the exposed base of the cliffs will minimise any impacts during the installation phase and mitigate impacts during the operation phase. As such, no significant impacts on this site are expected.

6.10 Residual Impacts

6.10.1 Benthos and Fish Receptors

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Benthos	Low	Medium	High	Low
Fish	Medium	Low	Medium	Low
Rationale				
The benthic biotopes present in the Development area are expected to have some tolerance to the predicted impacts, with some ability to recover, therefore receptor sensitivity is **low**. Whilst full recovery of the benthic fauna is expected across the majority of the impacted area, there will be permanent impacts over a small area due to the placement of rock armour, surface-laid pipelines, and presence of subsea infrastructure, therefore vulnerability is **medium**. The Development area includes conservation interests of MCZs and therefore the value is considered **high**. While there will be some permanent direct impacts on the benthos across a very small proportion of the total Development area in terms of changes to the available habitat type, it is not expected that these impacts will degrade the function or value of the benthos and therefore impact magnitude is considered to be **low.** The consequence of the impact is therefore assessed as **minor** and **not significant**. Indirect impacts are expected to be temporary and small scale, and when set against the low sensitivity of the biotopes present, are expected to be of negligible significance. As the worst case, the direct impact magnitude has been presented here. Adult and sub-adult fish found in the Development area are expected to be tolerant to the direct and indirect impacts associated with the Development and show rapid recovery following cessation of activities. Eggs and young juveniles, including of benthic spawners such as sandeel and herring,				

Receptor	Sensitivity	Vulnerability	Value	Magnitude
are expected to show low capacity to tolerate disturbance and therefore sensitivity is considered to be **medium**. Impacts are expected to be short-term, with recovery in the season following cessation of Development activities, and it is considered unlikely that there will be long-term effects above the level of natural variation, therefore vulnerability is expected to be **low**. Herring appears on the UKBAP list but none of the stations surveyed met the full criteria for suitable herring spawning grounds. Sandeel species are listed as priority species under UK Post 2010 Biodiversity Framework and as Features of Conservation Importance (FOCI) in relation to the UK's MCZ network. Sandeel were observed during surveys of the pipeline routes and there is some evidence of suitability for sandeel spawning along parts of the pipeline routes. Value is therefore deemed to be **medium**. The impact on sandeel spawning (and by extension, spawning of less sensitive and valuable species) may be noticeable within the Development area, although this is very small in the context of the available area for sandeel spawning, and impacts are expected to be short-term, with recovery in the season following cessation of Development installation activities. Overall impact magnitude is therefore expected to be **low.** The consequence of the impact is therefore assessed as **minor** and **not significant**.				
Consequence			**Impact Significance**	
Minor			Not significant	

6.10.2 Ornithological Receptors

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Seabirds (little tern and red-throated diver)	High	Low	High	Negligible
Rationale				
The sensitivity of seabird species is **high**. The vulnerability of seabird species is **low**. The species of interest are of **high** conservation value. The magnitude of impact, however, is considered **negligible** as the effect on seabirds from seabed disturbance will be of local spatial extent representing a very small proportion of the habitat available to these species, will not occur over a long time period, and will be intermittent and highly reversible. Effects on populations because of seabed disturbance is limited. The consequence of the impact is therefore assessed as **minor** and **not significant**.				
Consequence			**Impact Significance**	
Minor			Not significant	

6.10.3 Marine Archaeology Receptors

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Seabed prehistory – Feature of probable archaeological interest, either because of its palaeogeography or likelihood for producing palaeoenvironmental material	Very High	Very High	High	Positive
Seabed prehistory – Feature of possible archaeological interest	Very High	Very High	Medium	Negligible
Maritime sites – anthropogenic origin of archaeological interest and uncertain origin of possible archaeological interest	Very High	Very High	High	Negligible
Aviation crash sites - anthropogenic origin of archaeological interest and uncertain origin of possible archaeological interest	Very High	Very High	High	Negligible
Rationale				
Cultural heritage receptors are finite and non-renewable, and have no adaptability or tolerance to or recoverability from damage, therefore sensitivity and vulnerability are considered **very high**. Until further determination of value for each receptor can be undertaken, value should be assumed as **high**. Mitigation measures including implementation of AEZs to ensure there is no impact on known archaeological interests, implementation of a PAD and recording or recovery of sites that cannot be preserved will reduce the magnitude and consequence of the expected impacts from medium or high were no measures adopted, to **negligible.** In the case of seabed prehistory receptors, mitigation that includes geotechnical investigations will result in **positive** impacts, as this will increase the limited knowledge of seabed prehistory in the area.				
Consequence		**Impact Significance**		
Positive/Negligible		Not significant		

6.10.4 Coastal Processes Receptors

6.10.4.1 Teesside Pipeline

Project aspect/ receptor	Sensitivity	Vulnerability	Value	Magnitude
Increased suspended sediments as a result of direct pipe tunnelling activities (including disturbance to Teesmouth and Cleveland Coast SSSI, Ramsar and SPA)	Negligible	Low	High	Low
Increased suspended sediments during installation of SSIV	Negligible	Low	Low	Low
Local scour due to presence of vessels and jackup barge	Negligible	Low	Low	Low
Increases in suspended sediment concentrations and deposition of disturbed sediments during pipeline and cable installation	Negligible	Low	Low	Low
Impedance of suspended sediment processes from nearshore spoil ridge	Negligible	Low	Low	Low
Increased suspended sediment from pre-sweeping / boulder clearance / ploughing / dredging	Negligible	Low	Low	Low
Increased suspended sediments during post-lay trenching	Negligible	Low	Low	Low
Short-term impacts to water quality during pipeline and cable installation	Negligible	Low	Low	Low
Local scour at base of SSIV	Negligible	Low	Low	Low

Project aspect/ receptor	Sensitivity	Vulnerability	Value	Magnitude
Local scour as a result of exposure of the pipeline	Negligible	Low	Low	Low
Impedance of bedload transport and the migration of seabed features by the presence of rock placement and concrete mattressing	Negligible	Low	Low	Low
Changes to sandwaves within SNS SAC due to seabed sweeping	Medium	Low	Medium	Low
Increased sediment transport within SNS SAC during infield flowline and cable trenching and seabed sweeping (Endurance Store)	Medium	Low	Medium	Low

Rationale

Tees Bay is a sediment sink and so under calm or normal metocean conditions, sediment is being drawn towards the coast. Therefore, the water is likely to be relatively turbid close to shore. It is therefore expected that the coastal processes regime will be generally tolerant of increased suspended sediment, sediment transport and temporary impedance of sediment transport. Any disturbed sediment will be readily reincorporated into the local sediment regime. Receptor sensitivity is therefore expected to be **negligible**. While there may be a nominal increase in suspended sediments during the proposed operations, this is not expected to be noticeable above natural variation and so the local coastal processes will not be affected in the long-term; therefore, receptor vulnerability is expected to be **low**. By tunnelling underneath Coatham Sands, the Development will mitigate against any impacts to the protected Teesmouth and Cleveland Coast SSSI, Ramsar and SPA sites. Given the temporary and small scale nature of the expected impacts, the magnitude of impacts on all coastal process receptors is expected to be **low**. Therefore, the consequence of impacts on local coastal processes due to the proposed Teesside Pipeline installation and presence is **minor**. Overall, the impact is assessed as being **not significant**.

Consequence	Impact Significance
Minor	Not significant

6.10.4.2 Humber Pipeline

Project aspect/ receptor	Sensitivity	Vulnerability	Value	Magnitude
Impedance to longshore sediment transport from beach cofferdam (including to Spurn Head NNR, Humber Estuary SAC, SPA, Ramsar and SSSI)	Negligible	Low	High	Low
Disturbance of Dimlington Cliff SSSI from increased erosion as a result of presence of the beach works	Medium	Medium	High	Low
Disturbance of protected features within the Holderness Inshore MCZ and Holderness Offshore MCZ	Medium	Low	High	Low
Local scour due to presence of vessels and jackup barge	Negligible	Low	Low	Low
Increases in suspended sediment concentrations and deposition of disturbed sediments during pipeline installation	Negligible	Low	High	Low
Impedance of sediment transport processes from nearshore spoil ridge	Negligible	Low	High	Low
Increased suspended sediment from pre-sweeping / boulder clearance / ploughing / dredging	Negligible	Low	High	Low
Increased suspended sediments during post-lay trenching	Negligible	Low	High	Low

Project aspect/ receptor	Sensitivity	Vulnerability	Value	Magnitude
Effects of pipelay and landfall drilling activities on water quality	Negligible	Low	High	Low
Local scour as a result of pipeline exposure	Negligible	Low	High	Low
Impedance of bedload transport and the migration of seabed features by the presence of rock placement and concrete mattressing	Negligible	Low	High	Low
Changes to sandwaves within SNS SAC due to seabed sweeping	Medium	Low	Medium	Low
Increased sediment transport within SNS SAC during infield flowline and cable trenching and seabed sweeping (Endurance Store)	Medium	Low	Medium	Low
Rationale				
The Holderness coast is influenced by an energetic and changeable current regime. Even when the water is calm it is visibly turbid, especially close to shore. It is therefore expected that the coastal processes regime will be generally tolerant of increases in suspended sediment, sediment transport and temporary impedance of sediment transport. Receptor sensitivity is therefore expected to be **negligible**. While there may be a measurable increase in suspended sediments during the proposed operations, this is not expected to be noticeable above natural variation and so the function of local processes are not expected to be affected in the long-term; therefore, receptor vulnerability is expected to be **low**. Because the coastal processes in the area are key to maintaining Spurn Head, receptor value is interpreted as **high**. Given the temporary and small scale nature of the expected impacts, the magnitude of impacts on all coastal process receptors is expected to be **low**. Therefore, the consequence of impacts on local coastal processes due to the proposed Humber Pipeline installation and presence is **minor**. Overall, the impact is assessed to be **not significant**.				
Consequence		**Impact Significance**		
Minor		Not significant		

7 UNDERWATER SOUND

7.1 Introduction

Underwater sound is generated by natural sources such as rain, breaking waves and marine life, including whales and dolphins (termed ambient sound). Human's use of the marine environment adds additional sound from numerous sources including shipping, oil and gas exploration and production, offshore windfarm (OWF) operation, aircraft and military activity (termed anthropogenic sound). Many species found in the marine environment (including marine mammals) use sound to understand their surroundings, track prey and communicate with members of their own species. Some species, mostly toothed whales, dolphins and porpoise, also use sound to build up an image of their environment and to detect prey and predators through echolocation (Berta *et al.*, 2005).

Exposure to natural sounds in the marine environment may elicit responses in marine species; for example, harbour seals have been shown to respond to the calls of killer whales with anti-predator behaviour (Deecke *et al.*, 2002). In addition to responding to natural sounds, marine species such as marine mammals may also respond to anthropogenic sound. The potential impacts of industrial sound on species may include effects on hearing and displacement of the animals themselves and potential indirect impacts which may include displacement of prey species or stress. In addition to potential behavioural impacts of sound, marine mammals exposed to an adequately high sound source may experience a temporary shift in hearing ability (termed a temporary threshold shift; TTS) (e.g. Finneran *et al.*, 2005). In some cases, the source level may be sufficiently high such that the animal exposed to the sound level might experience physical damage to the hearing apparatus and the shift may not be reversed; in this case there may be a permanent threshold shift (PTS) (Southall *et al.*, 2019).

This Chapter assesses the potential impacts of the Development on marine species, and has been supported by underwater sound modelling, undertaken by Genesis (2022). A summary of the results from the underwater sound modelling has been provided below, with the entire report available in Appendix J.

The following specialists have contributed to this assessment:

- Xodus Group – baseline description, impact assessment and ES section write up; and
- Genesis – underwater sound modelling.

7.2 Regulatory Controls

In addition to the EIA legislation, and the East and North East Inshore and Offshore Marine Plans detailed in Section 1.5, there are other requirements of UK legislation, international treaties and agreements relevant to the assessment of the potential impacts from underwater sound:

- Offshore Petroleum Activities (Conservation Habitats) Regulations 2001 (as amended) – implement the EU Habitats Directive (Directive 92/43/EEC) and EU Wild Birds Directive (Directive 2009/147/EC) in relation to oil and gas and CCS activities on the UKCS. These regulations also establish the HRA process for assessing impacts of oil and gas or CCS proposals on European Sites (formerly known as Natura 2000 sites);
- The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 ('Habitats Regulations') – implement the EU Habitats Directive (Directive 92/43/EEC) and EU Wild Birds Directive (Directive 2009/147/EC).

The Conservation of Habitats and Species Regulations 2017 is relevant to waters out to 12 NM from shore and the Conservation of Offshore Marine Habitats and Species Regulations 2017 is relevant from 12 NM to 200 NM from shore. these 7-2educe7-2rons implement additional measures for the protection of habitats and species to the Offshore Petroleum Activities (Conservation of Habitat) Regulations 2001. This includes establishing measures to protect European Protected Species (EPS);

- The Wildlife & Countryside Act 1981 (as amended) – primarily implements the Birds Directive and the Bern Convention in the UK to establish measures for the protection and conservation of habitats and species;
- The OSPAR Convention – sets out measures for environmental protection of the marine environment, including establishing ecological objectives for the North Sea, developing lists of species and habitats in need of protection, selecting OSPAR marine protected areas and controlling potential sources of impact on the marine environment;
- The Convention on Biological Diversity – establishes three main goals, namely the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from the use of genetic resources; and
- The Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention) – outlines legal commitments for contracting parties on the conservation of engendered and vulnerable species specified in the appendices of the instrument.

In particular, the regulations above make it an offence to:

- Deliberately capture, injure or kill any wild animal of an EPS; or
- Deliberately disturb wild animals of an EPS in such a way as to:
    - Impair their ability to migrate, hibernate, survive, breed, or rear or nurture their young; or
    - Significantly affect the local distribution or abundance of the species to which they belong.

According to the Conservation of Offshore Marine Habitats and Species Regulations 2017, an assessment of the potential to injure and disturb such species must be undertaken for any operations that may emit sound. The assessment should determine:

- The extent to which injury or disturbance may occur (or indeed if it will occur); and
- Whether an EPS licence to conduct the operations is necessary.

7.3 Assumptions and Data Gaps

7.3.1 Assumptions

In order to ensure that the assessment of underwater sound reflects the worst case scenario in relation to underwater sound for the Development, key assumptions have been made regarding the following:

- The thresholds used to understand potential disturbance ranges on marine mammals and fish from the generation of underwater sound are those at which the onset of possible disturbance could occur; in reality, predicted ranges will likely be lower, since not all animals will be disturbed at those larger estimated ranges;

- The manifold and SSIV piling for the Development are expected to be conducted using an impact hammer with maximum energy of 120 kilojoules (kJ), whilst the HDD trestle piling is expected to be conducted with a maximum hammer energy of 235 kJ;
- Four piles will be used to anchor each of the two seabed manifolds and the SSIV. It is assumed that each pile will take four hours to install, so 12 hours per structure, and that up to eight piles will be installed per day;
- The HDD trestles will consist of up to two rows of four piles in each row, so a maximum of eight piles. It is assumed that each pile will take four hours to install and that two piles will be installed per day;
- It is not expected that piling of the different structures (SSIV and manifolds) or of the HDD trestles will occur concurrently;
- As stated in Section 3.2.1, HDD is one of three options for the Teesside Pipeline landfall. Further engineering is required to select the optimum solution for the landfall, therefore the impacts associated with the use of HDD trestles is assessed in this Chapter;
- Survey equipment for pre and post-lay surveys would typically include MBES, SSS, Ultra-Short Baseline (USBL), Long Baseline (LBL), magnetometer and pipe tracker; Sub-Bottom Profiling (SBP) does not form part of typical pipeline pre and post-lay surveys and therefore this is not base case. In the event that SBP is required, this will be assessed during the relevant permit applications and is not assessed below. For these equipment, it is assumed that:
  - The MBES and SSS will be used at frequencies > 200 kilohertz (kHz);
  - The source levels of USBL and LBL will be < 200 dB; and
  - Magnetometers and pipe tracker do not generate underwater sound as part of their normal operations;
- Subsea installation and therefore piling is expected to occur during Q2/Q3 2026. Q2/Q3 2026 have therefore been used for the purpose of this assessment. Piling operations will be subject to the relevant permit applications to the OPRED and will be based on the actual installation date. The impact assessment within the permit applications will be based on the actual installation period;
- An initial desk based UXO assessment was undertaken (see Section 3.2.3.1). Based on the results, it is assumed that it will be possible to avoid any UXO encountered. Therefore, sound associated with UXO clearance is not considered further in this Chapter;
- During the life cycle of the Development, bp, as operator of NEP, plans to undertake monitoring activities at the Endurance Store. Monitoring activities require up to six seismic surveys, each of 75-day duration (including downtime), over 25 years (including a closure survey at the end of the Development). These surveys will only be conducted over the area of the Endurance Store that is being developed and not the whole lease area. These surveys are essential to monitor the Endurance Store during its operational phase;
- The schedules of each of these surveys within the year are currently not known; however, it is likely that these will be undertaken within periods of good weather (i.e. during the spring and summer months) to mitigate any weather related delays;
- bp, as operator of NEP, is committed to a number of embedded mitigation measures, such as the use of soft-start for both piling and seismic surveys. Results from the underwater sound modelling presented in this Chapter include injury ranges before and following the use of soft-start. The benefit of the soft-start is to reduce the ranges at which the thresholds are exceeded. A soft-start procedure reduces initial sound levels, which increase over a period of time, reducing the cumulative sound exposure level (SEL) or giving mammals the opportunity

to swim away from the source before full energy is emitted. Therefore, while results are presented for both before and following the implementation of soft-start, only the results following the implementation of soft-start are discussed. A summary of mitigation measures is provided in Section 7.6;

- The JNCC protocols for piling (JNCC, 2010) and seismic surveys (JNCC, 2017a) will be implemented by bp as operator of NEP.

7.3.2 Data Gaps

Sound propagation models are limited by the available data used to inform the model's metrics. At present, there are no published studies demonstrating PTS in marine mammals (Southall *et al.*, 2007, 2019). Thresholds developed to quantify injury have so far been generally based on measured TTS responses. Data on TTS thresholds have been extrapolated to determine PTS values using auditory weighting functions. There is some discourse within the scientific community as to which extrapolation metric is most appropriate for each hearing group (i.e. high-frequency, mid-frequency, and low-frequency cetaceans, and the true- and eared-seals). However, this remains the best available methodology for determining hearing thresholds in marine mammals given current data limitations.

Data gaps have been identified as follows:

- The installation schedule for the manifolds and SSIV is not currently known. Section 3.1.2 details that subsea installation is expected in Q2/Q3 2026. For the purpose of the assessment, it has been assumed that piling will occur between April and September 2026. As mentioned above, this is an indicative timeline and piling operations will be subject to the relevant permit applications, based on an actual installation date; and
- The time of year at which the seismic surveys will be undertaken is also not known. Due to the requirements to undertake surveys during good weather months, a worst case assumption is made that each survey will occur during the spring or summer months.

As per the Scoping Report, impacts on seabirds from underwater sound have been scoped out of this EIA given that the seabirds in the Development area are not expected to rely heavily on underwater hearing for the majority of their behaviours.

7.4 Description and Modelling of Underwater Sound

7.4.1 Description of Potential Sound Sources

On the basis of the Project Description in Chapter 3: Project Description, the following activities have been identified as key sound sources:

- Piling during installation of:
  - Manifolds in the Endurance Store area;
  - SSIV on the Teesside Pipeline; and
  - HDD trestles at Teesside and Humber landfalls;
- Seismic surveys as part of monitoring activity during the life cycle of the Development;
- Seabed preparation, pre-lay and post-lay surveys during subsea installation;
- Presence of the jackup vessels during drilling of the wells, landfall construction and installation of subsea infrastructure;
- Dredging activities through the use of BHD, grab dredger, trailing head suction dredger, cut suction dredger, plough and jet trencher; and

- Vessels.

Of the activities listed above, only piling activities (manifolds, SSIV and HDD trestles), during installation of the Development, and the use of seismic sources (4D), during the operational phase, are considered to have the potential to impact on the hearing of sensitive marine species as they represent the greatest sound sources in both power (i.e. pressure levels) and in character (i.e. as an impulsive sound). The sound levels emitted by the equipment for the pre and post-lays surveys (i.e. MBES, SSS etc.) will be highly directional, with sound levels transmitted perpendicularly from the beam which are typically 25 to 35 dB lower than sound emitted by airguns (Lurton and DeRuiter, 2011). Therefore, the pre and post-lay surveys are not anticipated to have any adverse effect on the local environment and in particular marine mammals. In addition, based on the frequency of the sound emitted by typical MBES and SSS, it is unlikely fish species will be affected by these surveys. JNCC (2017a) considers that sound emitted by MBES (and SSS) in shallow waters (i.e. < 200 m) typically fall outside of the hearing frequency of cetaceans. The sound produced is likely to attenuate quickly due to the high frequencies of the sounds. For this reason, piling and seismic activities constitute the worst case activities which form the focus of this assessment.

These activities will be undertaken during different periods of the Development and at discrete intervals, i.e. piling will be undertaken during the installation phase, while seismic surveys, will be undertaken during the operational phase of the Development. Seabed preparation and pre/post-lay surveys are planned to occur during the installation phase.

Assumptions have been made in Section 7.3.1 regarding the likely timeline of piling and seismic activities.

7.4.2 Project Scenarios

As detailed in Appendix J, sound modelling for this assessment was undertaken by Genesis (2022). The modelling compares the predicted sound levels at distances from the sound source relative to published injury and disturbance thresholds (NMFS, 2018; further details in Appendix J) to predict potential impact ranges for activities likely to result in impacts (i.e. piling and seismic surveys). Modelling was undertaken at different locations (Teesside Pipeline, Humber Pipeline and Endurance Store area), as shown in Appendix J.

A number of scenarios representing key activities likely to generate underwater sound across different phases of the Development were modelled, as follows:

- Piling operations during subsea installation (manifolds, SSIV and HDD trestles); and
- Seismic survey utilising;
  - 400 cu in[180] airgun; or
  - 480 cu in airgun.

Results from the piling and seismic underwater sound modelling have been presented in Section 7.5. Two sizes of source array which may be utilised in the seismic survey were initially modelled (400 cu in and 480 cu in). The seismic sound modelling results presented in Section 7.5 only detail the 480 cu in airgun, as this is considered to represent the worst case in terms of underwater sound generation, due to its higher capacity.

[180] *cu in are used to described airgun array size.*

7.4.2.1 Sound Modelling Input

Sound modelling input are detailed in Appendix J and are summarised below.

7.4.2.1.1 Piling

The proposed operations include the piling of:

- Two manifolds at the Endurance Store, each with 4 x 0.61 m diameter steel piles;
- One SSIV located between KP6 and KP8 on the Teesside Pipeline, with 4 x 0.61 m diameter steel piles; and
- Two HDD trestles at Humber and Teesside pipeline landfalls, each with 8 x 1.2 m diameter piles.

Parameters used for the piling sound modelling are provided in Table 7-1 and in Appendix J.

Table 7-1 - Modelled piling parameters

Hammer energy (kJ)	Duration (minutes)[181]	Strike rate (blows/minute)	Source level	
			Zero-to-peak sound pressure level (SPL) (dB re 1 µPa-m)	Sound exposure level (SEL) (dB re 1 µPa²s-m)
Manifold Piling				
24	20	44	200.0	226.3
120	100	44	207.2	233.2
SSIV Piling				
24	20	44	200.0	226.3
120	100	44	207.2	233.2
HDD Trestle Piling				
47	20	44	203.2	229.2
235	220	44	210.2	236.2

7.4.2.1.2 Seismic Survey

The assessment initially considered two sizes of source array which may be utilised in the seismic surveys, namely:

- Bolt 1900-LLXT (six array – 480 cu in); and
- Bolt 1900-LLXT (five array – 400 cu in).

[181] *The 20 minutes duration listed in this Table relates to soft-start.*

Source modelling in Appendix J has been conducted for both 400 cu in and 480 cu in arrays. As the predicted sources levels for the 480 cu in array are higher than the corresponding source levels for the 400 cu in array, propagation modelling has only been conducted for the 480 cu in source array (Table 7-2).

Table 7-2 - Modelled seismic equipment parameters

Parameter		480 cu in array
Array elements		Six 1900-LLXT airguns
Total volume		480 cu in.
Source level[1]	Zero-to-peak sound pressure level (SPL)	247.7 dB re 1 µPa-m
	Peak-to-peak SPL	253.2 dB re 1 µPa-m
	SEL	220.6 dB re 1 µPa^{2}s-m
Peak frequency		*c.* 80 Hz
[1] Source levels have been computed using Gundalf array modelling software (Oakwood Computing, 2022) over a frequency range of 0 – 50 kHz.		

7.4.3 Description of Potential Impacts

Underwater sound has the potential to affect marine life in different ways depending on its sound level and characteristics. Richardson *et al.* (1995) defined four zones of sound influence which vary with distance from the source and level. These are:

- The zone of audibility: this is the area within which the animal is able to detect the sound. Audibility itself does not implicitly mean that the sound will have an effect on the marine mammal;
- The zone of responsiveness: this is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, audibility does not necessarily evoke a reaction;
- The zone of masking: This is defined as the area within which sound can interfere with detection of other sounds such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how marine mammals detect sound in relation to masking levels (for example, humans are able to hear tones well below the numeric value of the overall sound level); and
- The zone of hearing loss, discomfort, or injury: this is the area where the sound level is high enough to cause tissue damage to auditory or other systems. This can be classified as either a TTS or PTS. At even closer ranges, and for very high intensity sound sources (e.g. underwater explosions), physical trauma or even death are possible.

There is currently insufficient scientific evidence to evaluate masking. Therefore, the assessment focuses on the ranges from the sound source at which injury (in terms of PTS) or disturbance (i.e. responsiveness) may be experienced by mammals. To determine the potential spatial range of injury and disturbance, a review has been undertaken of available evidence, including international guidance and scientific literature. The relevant PTS, and disturbance thresholds are described in Appendix J.

7.5 Sound Modelling Results and Potential Impacts

7.5.1 Marine Mammals

Marine mammals can be classified into different hearing sensitivity groups (NOAA, 2018, Southall *et al.*, 2019). This is used to determine whether a sound is audible to an individual of a certain hearing capacity, referred to as a 'hearing group'. The hearing sensitivities of identified cetacean hearing groups can be found in Southall *et al.* (2019) and NOAA (2018) and are presented in Table 7-3 below.

Table 7-3 - Auditory bandwidths estimated for marine mammals (Southall *et al.*, 2019; NOAA, 2018)

Cetacean hearing group	Species	Estimated auditory bandwidth
Low Frequency (LF) Cetaceans	Minke whale (*Balaenoptera acutorostrata*)	7 Hz to 35 kHz
Mid Frequency (MF) Cetaceans	White-beaked dolphin (*Lagenorhynchus albirostris*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), bottlenose dolphin (*Tursiops truncatus*), Risso's dolphin (*Grampus griseus*), long-finned pilot whale (*Globicephala melas*), common dolphin (*Delphinus delphis*), killer whale (*Orcinus orca*)	150 Hz to 160 kHz
High Frequency (HF) Cetaceans	Harbour porpoise (*Phocoena phocoena*)	275 Hz to 160 kHz
Phocid pinnipeds	Grey seal (*Halichoerus grypus*), harbour seal (*Phoca vitulina*)	50 Hz to 86 kHz

In the Development area, bottlenose dolphin, harbour porpoise, pilot whale, minke whale and white beaked dolphin have been recorded regularly (see Section 4.4.6). Two species of seals inhabit UK waters: grey seal and harbour seal.

The underwater sound modelling undertaken by Genesis (2022) in Appendix J considered the following:

- Injury (PTS):
  - Zero-to-peak SPL, which provides an "unweighted" result and do not take into consideration the hearing ranges of any marine mammals;
  - Single pulse SEL[182], which provides an auditory-weighted results against the hearing functions of marine mammals (as defined in Table 7-3);
  - Cumulative SEL, which, as per the single pulse SEL, provides auditory-weighted results. In addition, the cumulative SEL results take into consideration the movement of the

[182] *Single pulse SEL is presented in the Appendix J. This metric has not been used for the assessment presented in this Chapter as the thresholds associated with injury relate to cumulative SEL. Comparing a single pulse SEL value to a cumulative SEL threshold value would result in an underestimation of the impact ranges.*

sound source with a marine mammal swimming away from the source (or the seismic survey) or multiple pulses over 24 hours (for piling).

- Disturbance – three threshold levels have been used to assess disturbance to marine mammals:
  - Threshold from the National Oceanic and Atmospheric Administration (NOAA), which is an unweighted root mean square (RMS) SPL;
  - A more conservative threshold from Tougaard (2015), which is assessed as an unweighted SEL threshold. It is noted by Tougaard (2015) that the adoption of this threshold may overestimate behavioural disturbance impacts to marine mammal species other than harbour porpoise; and
  - SCNBs (JNCC, 2020a) developed Effective Deterrence Ranges (EDRs) to assess the range of temporary habitat loss from a number of operations, including an EDR of 15 km for pin-pile activities, 12 km for seismic activities and 5 km for geophysical surveys in the SNS SAC. The EDRs are specific to disturbance on harbour porpoise within the SAC. As discussed in Section 7.3.1, the equipment forming part of the pre and post lay surveys will be used at frequencies and sound levels that are unlikely to disturb marine mammals. Therefore, the EDR for geophysical surveys is not discussed further in this Chapter. An assessment of disturbance on harbour porpoises using the seismic and piling EDRs is provided in Section 7.9.

The distances at which sound levels decrease to below threshold values associated with potential injury for the different modelled scenarios are summarised in Table 7-4 and Table 7-6, based on a comparison of the calculated sound level against the thresholds described in Appendix J. Injury zones are presented relative to the emitting sound source. In particular, the emitted sound is assumed to be highly directional during seismic activities, therefore the distances are presented as the radius of the predicted effected zone.

Estimated ranges for injury (PTS) and disturbance for marine mammals from the scenarios outlined above are presented in Table 7-4 to Table 7-7, both before and after the implementation of the soft-start. It should be noted that Appendix J provides results for all three PTS thresholds (Zero-to-peak SPL, single pulse SEL and cumulative SEL). Table 7-4 below provides the results for injury based on the zero-to-peak SPL and cumulative SEL. Based on the modelling results, the worst case injury range from the piling sources before the implementation of soft-start is 1,400 m (SEL cumulative for Low Frequency (LF) cetaceans at Humber, Table 7-4), which is reduced to 350 m following soft-start. The worst case injury range from piling following implementation of soft-start is 360 m (SEL cumulative for High Frequency (HF) cetaceans at Humber, Table 7-4) from the piling sources. The worst case injury range from the seismic sources is 150 m (zero-to-peak SPL for HF cetaceans, Table 7-6). Zero-to-peak SPL does not take into consideration soft-start. The worst case SEL cumulative injury range from the seismic survey is 1,300 m for LF cetaceans. The threshold for injury is not exceeded following implementation of soft-start. Bp, as operator of NEP, is committed to implement the JNCC protocols for piling and seismic surveys, which both include soft-start. Therefore, the remaining of this Chapter will discuss results of the underwater sound modelling following implementation of the soft-start.

Thresholds for behavioural disturbance to marine mammals are less well defined compared to PTS thresholds (see Appendix J) since different marine mammal species and even different individuals from the same species can exhibit a range of responses to the same sound (Southall *et al.*, 2007, 2021; NMFS, 2018). Furthermore, for many species there is also a lack of evidence to define appropriate thresholds (Southall *et al.*, 2021). Therefore, in this assessment, three different threshold values (as discussed above) have been adopted to assess potential disturbance. The worst case behavioural range from the modelling results is 7.2 km from the piling source (manifold) (Table 7-5) and 8.9 km from the seismic source (Table 7-7), based on the Tougaard (2015) threshold. Disturbance of harbour porpoise within the SNS SAC using the relevant EDR ranges is assessment in Section 7.9.

Table 7-4 - Estimate of injury (SPL zero-to-peak and SEL cumulative before/following implementation of soft-start) ranges from piling activities (Genesis, 2022)

Marine mammal hearing group	PTS thresholds Zero-to-peak SPL (dB re 1 μPa) cumulative SEL (dB re 1 μPa²s)[183]	Maximum distance to threshold (m)			
		Manifold	SSIV	HDD trestle (Teesside)	HDD trestle (Humber)
LF	219 (SPL)	10	10	20	20
	183 (SEL) with no soft-start	640	320	1,400	1,200
	183 (SEL) with soft-start	60	40	350	280
MF	230 (SPL)	10	10	10	10
	185 (SEL) with no soft-start	Not exceeded	Not exceeded	Not exceeded	Not exceeded
	185 (SEL) with soft-start	Not exceeded	Not exceeded	Not exceeded	Not exceeded
HF	202 (SPL)	70	70	160	190
	155 (SEL) with no soft-start	70	150	1,200	1,200
	155 (SEL) with soft-start	Not exceeded	Not exceeded	310	360
Phocid pinnipeds	218 (SPL)	10	10	20	20
	185 (SEL) with no soft-start	Not exceeded	Not exceeded	20	20
	185 (SEL) with soft-start	Not exceeded	Not exceeded	Not exceeded	Not exceeded

[183] *Results for the SEL Cumulative thresholds assume the slowest modelled swim speed for animals (1.5 m/s).*

Table 7-5 - Estimate of modelled disturbance ranges from piling activities (Genesis, 2022)

Method	Behavioural disturbance thresholds	Maximum distance to threshold (km)			
		Manifold	SSIV	HDD trestle (Teesside)	HDD trestle (Humber)
Comparison of modelling results with NOAA 'Level B harassment' threshold for disturbance to marine mammals	Rms SPL: 160 db re 1 µPa SEL: 150 dB re 1 µPa^{2}s	3.8	3.5	3.6	4.3
Comparison of modelling results with Tougaard (2015) threshold for disturbance to marine mammals	SEL: 145 dB re 1 µPa^{2}s	7.2	5.8	6.8	7.1

[1] The NOAA 'Level B Harassment' rms SPL threshold of 160 dB re 1 µPa has been converted to an SEL threshold of 150 dB re 1 µPa^{2}s assuming a conservative integration time of 100 ms.

Table 7-6 - Estimate of injury ranges (zero-to-peak SPL and cumulative SEL before/following implementation of soft-start) from seismic activities (Genesis, 2022)

Marine mammal hearing group	PTS thresholds Zero-to-peak SPL (dB re 1 µPa) Cumulative SEL (dB re 1 µPa²s)[184]	Maximum distance to threshold (m)
LF	219 (SPL)	20
	183 (SEL) with no soft-start	1,300
	183 (SEL) with soft-start	Not exceeded
MF	230 (SPL)	10
	185 (SEL) with no soft-start	Not exceeded
	185 (SEL) with soft-start	Not exceeded
HF	202 (SPL)	150
	155 (SEL) with no soft-start	30
	155 (SEL) with soft-start	Not exceeded
Phocid pinnipeds	218 (SPL)	30
	185 (SEL) with no soft-start	10
	185 (SEL) with soft-start	Not exceeded

Table 7-7 - Estimate of disturbance ranges from seismic activities (Genesis, 2022)

Method	Behavioural disturbance thresholds	Maximum distance to threshold (km)
Comparison of modelling results with NOAA 'Level B harassment' threshold for disturbance to marine mammals	Rms SPL: 160 db re 1 µPa SEL: 150 dB re 1 µPa²s	3.9
Comparison of modelling results with Tougaard (2015) threshold for disturbance to marine mammals	SEL: 145 dB re 1 µPa²s	8.9
[1] The NOAA 'Level B Harassment' rms SPL threshold of 160 dB re 1 µPa has been converted to an SEL threshold of 150 dB re 1 µPa²s assuming a conservative integration time of 100 ms.		

[184] *Results for the SEL Cumulative thresholds assume the slowest modelled swim speed for animals (1.5 m/s).*

7.5.1.1 Consequence of Underwater Sound Generation

7.5.1.1.1 Injury and Disturbance from Piling Operations

Injury

As demonstrated by the sound modelling (results are provided in Table 7-4 and in Appendix j), piling operations have the potential to injure marine mammals. Modelling was undertaken for four piling scenarios, both in the absence of a soft-start and following the implementation of soft-start, with HDD trestle piling at Humber found to produce the worst case injury distances. These distances are reduced for piling of the SSIV at Teesside and for the manifolds in the offshore Store area and any injury, following implementation of mitigation measures, is expected to be very localised (i.e. within less than 100 m from the source).

However, as outlined in Section 7.6, bp, as operator of NEP, expects to adopt mitigation measures that includes both a soft-start (a slow build-up of hammer power), and a monitoring zone of 500 m from the pile location (piling would not commence if marine mammals were observed to be in this zone). With the implementation of these measures, it is assumed that there will be no animals within 500 m of the piling activities at start-up. Given that the maximum injury range for piling with soft-start is 360 m (cumulative SEL with soft-start for the most sensitive species group of HF cetaceans for HDD trestle piling at Humber), the potential for injury of marine mammals from piling is effectively mitigated by the implementation of a 500 m monitoring zone.

Disturbance

To evaluate the impact on mammals that may experience disruption to normal behaviour during piling operations, several factors are considered, including the size and location of the potential disturbance zone (larger areas mean a greater potential to interact with a greater number of animals) and length of time for which the sound source will be present (the longer the period, the greater potential for significant impact). Behavioural changes such as moving away from an area for short periods of time, reduced surfacing time, masking of communication signals or echolocation clicks, vocalisation changes and separation of mothers from offspring for short periods, do not necessarily imply that detrimental effects will result for the animals involved (JNCC, 2010). Temporarily affecting a small proportion of a population would be unlikely to result in population level effects and would be considered as trivial disturbance (i.e. would not be significant disturbance). In contrast, affecting a large proportion may be considered non-trivial disturbance (i.e. could be significant disturbance).

The size of the potential disturbance zone for marine mammals is limited to 4.3 km – 7.1 km for Humber HDD trestle piling, 3.6 km – 6.8 km for Teesside HDD trestle piling, 3.8 – 7.2 km for Endurance Store manifold piling and to 3.5 km – 5.8 km at the Teesside SSIV. Whilst this may not be perceived as a large distance in the context of the available sea in the SNS, and noting that the modelled potential disturbance zone is not necessarily an area from which animals would be excluded, there may be marine mammals present within this zone which could experience some disturbance to normal behaviour.

The Statutory Nature Conservation Bodies (SNCBs) (Hammond *et al.*, 2021; JNCC, 2021a) note that marine mammals of almost all species found in UK waters are part of larger biological populations whose range extends into the waters of other States and/or the High Seas. To obtain the best conservation outcomes for many species, it is necessary to consider the division of populations into smaller management units. This requires an understanding of the geographical range of populations and sub-populations. The output of the SNCB exercise investigating how marine mammal populations may act is the determination of Marine Mammal Management Units (MMMU) for species including harbour porpoise, bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin and minke whale. These MMMUs and associated population estimates can be interpreted in the context of the potential disturbance zones to consider the potential for a significant impact to occur.

As discussed in Section 4.4.6.1, harbour and grey seals may be present with the Development area. Foraging density maps published by the SMRU report the presence of harbour seals at the Endurance Store to be < 1 individual per 25 km^2 (Russell *et al.*, 2017). The most recent seal data indicates that 0-0.001% of the wider at-sea harbour seal population are within the Endurance Store area at any one time, based on known haul out locations, which is considered to be low. Along the Teesside and Humber Pipeline routes there is a similarly low probability of encountering a harbour seal. Grey seal density maps published by the SMRU report the presence of grey seals at the Endurance Store to be 0.04 individuals per 25 km^2. Recent data considers that 0.06-0.08% of the grey seal at-sea population could be in the Development area at any given time. Due to the relatively low densities, the number of individuals likely to be impacted is therefore very limited and there would be no significant effect at the population level. An assessment was therefore not undertaken for seals within the Development area.

To evaluate potential impact, the number of mammals that may experience behavioural disturbance is calculated using local density and population estimates from SCANS-III (detailed in Hammond *et al.*, 2021). For harbour porpoise, Heinänen and Skov (2015) provide a higher density of harbour porpoise than SCANS-III; therefore, the assessment below provides an estimate of population disturbed using both densities. The worst case behavioural change modelled range (7.2 km, see Table 7-5) was used to calculate the number of mammals that may be subject to disturbance from underwater sound generated by piling activities at any one time. This calculated number of mammals which may experience behavioural disturbance was also used to estimate potential impacts at population level, using MMMU population estimates. An assessment on the harbour porpoise population in the SNS SAC using the 15 km EDR is presented in Section 7.9.

Appendix J provided estimated number of individuals and proportion of population likely to be disturbed by the piling operations. Results using the Tougaard (2015) threshold are presented below as the worst case (Table 7-8); further detail is provided in Appendix J.

Table 7-8 - Estimated number of individuals and proportion of population which have the potential to be disturbed by piling operations based on Tougaard (2015) threshold (Genesis, 2022)

Species	Disturbance area (km^2)	Animal density (animals/km^2)[1]	Number of animals disturbed	MMMU population[2]	Percentage of MMMU population disturbed (%)
Manifold piling					
Harbour porpoise (HF cetacean)	163	0.888 – 3	41 – 137	346,601	0.012 – 0.040
White-beaked dolphin (MF cetacean)	163	0.002	1	43,951	0.002
Minke whale (LF cetacean)	163	0.010	1	20,118	0.005
SSIV piling					
Harbour porpoise (HF cetacean)	69	0.888 – 3	62 – 207	346,601	0.018 – 0.060
White-beaked dolphin (MF cetacean)	69	0.002	1	43,951	0.002
Minke whale (LF cetacean)	69	0.010	1	20,118	0.005
HDD trestle piling at Teesside					
Harbour porpoise (HF cetacean)	43	0.888 – 3	39 – 129	346,601	0.011 – 0.037
White-beaked dolphin (MF cetacean)	43	0.002	1	43,951	0.002
Minke whale (LF cetacean)	43	0.010	1	20,118	0.005
HDD trestle piling at Humber					
Harbour porpoise (HF cetacean)	67	0.888 – 3	60 – 201	346,601	0.017 – 0.058
White-beaked dolphin (MF cetacean)	67	0.002	1	43,951	0.002
Minke whale (LF cetacean)	67	0.010	1	20,118	0.005

[1] Marine mammal densities for white-beaked dolphin and minke whale are from SCANS-III data (Hammond *et al.*, 2017). For harbour porpoise, the lower density of 0.888 is from SCANS-III whilst the upper density of 3 is based on Heinänen and Skov (2015).

[2] MMMU populations are from IAMMWG (2021).

Table 7-8 summarises behavioural change at individual and population levels for the different piling scenarios. Disturbance from the piling operations is unlikely to have significant impacts on marine mammal populations in the vicinity of the Development, as < 0.1% of relevant MMMU populations would be disturbed. In particular, disturbance to harbour porpoise is limited. Given the highly restricted period of piling and the temporary and localised disturbance to normal marine mammal behaviour within the maximum distances described in Table 7-5, the piling operations are not likely to result in any significant impact on any marine mammal that might detect the piling sound emissions.

Studies based on impacts associated with sound from piling have indicated that marine mammals return to the area within relatively short periods of time, usually within three days once the activity causing the displacement has ceased (Brandt *et al.*, 2016, 2017, 2018; Carstensen *et al.,* 2006). The manifold piling at the Endurance Store is expected to be completed in two to three days (including downtime). The SSIV piling is expected to be completed in two to three days (including downtime). The HDD trestle piling at Teesside and Humber are each expected to be completed in two to four days depending on ground conditions.

Given the limited zone of potential impact and the short period of piling, the sound would not represent a barrier to wider, regional movements of marine mammals. A change in behaviour may be exhibited by a small number of individual animals for the period that sound is generated by piling (as demonstrated by the very small percentage of population that could potentially be affected, i.e. <0.1% as a worst case using both the NOAA and Tougaard (2015) thresholds). Based on this, it is unlikely that there would be residual impact at population level. Given the small area impacted, the short duration of piling and associated low numbers of marine mammals likely to be impacted, it is considered unlikely that underwater sound generated by piling activities associated with the Development will result in significant impacts to marine mammals.

The Endurance Store (where the manifolds are located) is located within the SNS SAC, which is designated for the presence of Annex II harbour porpoise. The Humber HDD trestle piling location is in close proximity to the SAC (15 km), while the SSIV and Teesside HDD trestle piling locations are located > 90 km from the SAC. Assessment of the impacts on the SNS SAC and its designated features, using the 15 km EDR, are included in Section 7.9.

7.5.1.1.2 Injury and Disturbance during Seismic Activities

Injury

As demonstrated by the sound modelling (Table 7-6 and Appendix J), the seismic activities have the potential to injure marine mammals.

The modelling predicts that the worst case injury range is 150 m for HF cetaceans (zero-to-peak SPL), which is within the nominal 500 m mitigation zone distance employed during seismic surveys (JNCC, 2017a) which will be implemented by bp, as operator of NEP (Section 7.6). bp will also adopt a soft-start as a mitigation measure. The cumulative SEL assessment concluded that implementation of a soft-start procedure resulted in no exceedance of the injury threshold (See Appendix J). The soft-start will allow time for marine mammals to move away from the source to distances where they will not be exposed to sound levels that could cause PTS. Therefore, as a nominal 500 m mitigation zone and associated measures will be implemented during the survey, the probability of sound levels produced by the source arrays causing PTS onset to marine mammals is low and therefore the risk of injury to marine mammals from the seismic surveys is low.

Disturbance

As shown in Table 7-7, the sound modelling considered three behavioural disturbance thresholds (NOAA, Tougaard, 2015 and JNCC, 2020a). The modelling concluded that the seismic activities could result in behavioural changes within 8.9 km from the source (worst case based on Tougaard, 2015). The sound modelling considered both a daily disturbance area of 1,458 km^2 and a disturbance area of 1,810 km^2 over the entire survey duration. As described in Section 3.4.1, seismic surveys of the Store are periodic and would occur on six discrete occasions over the life of the Development. Each survey will occur over a maximum of 75 days (including downtime). It is assumed that seismic surveys will likely occur during the spring or summer. An assessment on the harbour porpoise population in the SNS SAC using the 12 km EDR is presented in Section 7.9.

The same principle, as described above for piling, has been taken into account for assessing disturbance using the percentage of population likely to be affected by the proposed seismic activities. The number of individual marine mammals potentially affected by the seismic operations is detailed in Table 7-8 using the Tougaard (2015) threshold.

Table 7-9 - Estimated number of individuals and proportion of population which have the potential to be disturbed by seismic survey operations (Genesis, 2022)

Species	Disturbance area (km^2)	Animal density (animals/km^2)*	Number of animals disturbed	MMMU population**	Percentage of MMMU population disturbed (%)
Disturbance over 24 hours					
Harbour porpoise (HF cetacean)	1,458	0.888 – 3	1,295 – 4,374	346,601	0.374 – 1.262
White-beaked dolphin (MF cetacean)	1,458	0.002	3	43,951	0.007
Minke whale (LF cetacean)	1,458	0.010	15	20,118	0.075
Disturbance over entire survey duration					
Harbour porpoise (HF cetacean)	1,810	0.888 – 3	1,608 – 5,430	346,601	0.464 – 1.567
White-beaked	1,810	0.002	4	43,951	0.009

Species	Disturbance area (km²)	Animal density (animals/km²)*	Number of animals disturbed	MMMU population**	Percentage of MMMU population disturbed (%)
dolphin (MF cetacean)					
Minke whale (LF cetacean)	1,810	0.010	19	20,118	0.094

* Marine mammal densities for white-beaked dolphin and minke whale are from SCANS-III data (Hammond *et al.*, 2017). For harbour porpoise, the lower density of 0.888 is from SCANS-III whilst the upper density of 3 is based on Heinänen and Skov (2015).

** MMMU populations are from IAMMWG (2021).

Disturbance to marine mammal behaviour may occur within a daily area of 1,458 km² or 1,810 km² over a 75-day survey, including downtime (see Appendix J). It should also be noted that over the course of a day or the survey duration, the survey vessel will be continuously moving at a speed of 2.3 m/s. Therefore, it is unlikely that the seismic survey will be represent a barrier and each survey is not likely to result in any significant impacts on any of the marine mammals that might detect the seismic sound emissions.

The calculation of disturbance at individual and at population level assumes that the entire area (i.e. 1,458 km² over a day and 1,810 km² over the survey duration) is ensonified simultaneously, which is a worst case situation that is unlikely to be representative. Any marine mammals disturbed from the area by the proposed surveys will likely return after cessation of activities (Sarnocińska *et al.*, 2020; Thompson *et al.*, 2013). It was observed by Thompson *et al.* (2013) that harbour porpoise displaced during a seismic survey returned to the survey area within one day after the survey finished. Disturbance from a limited area, even if that occurs over several months, is unlikely to have a significant long-term impact on marine mammal populations levels (Nabe-Nielsen *et al.*, 2018; Nabe-Nielsen, 2020). Any changes to the behaviour of marine mammals from the survey operations are likely to be temporary and limited to the duration of the surveys. The EC guidance on the Habitats Directive recognises "disturbance" as something which "affects the survival chances, the breeding success or the reproductive ability of a protected species or leads to a reduction in the occupied area" (EC, 2021). The short-term duration of activities is unlikely to affect the survival, breeding success, or reproductive ability of animals in the area. Consequently, the definition of "disturbance" per the EC guidance is not met.

Given the limited zone of potential impact and the transitory nature of the seismic survey, the sound would not represent a barrier to wider, regional movements of marine mammals. A change in behaviour that may be exhibited by a small number of individual animals for the period of the seismic survey as demonstrated by the small percentage of population that could potentially be affected, i.e. < 1.3-1.6% of the harbour porpoise population based on a daily and entire survey duration and the Tougaard (2015) threshold and would have no impact at the population level (Thompson *et al.*, 2013). It should be noted that the percentage of population disturbed for other species is < 0.1%.

Given the small area impacted, the intermittent nature of the planned seismic surveys and the associated low numbers of marine mammals likely to be disturbed by an increase in underwater sound generated by the seismic surveys, it is considered unlikely that underwater sound generated by seismic surveys at the Endurance Store will result in significant impact to marine mammals.

For seismic operations using airguns, an EDR of 12 km is recommended to assess potential habitat loss for harbour porpoise within the SNS SAC (Section 7.9).

7.5.2 Fish

The most relevant criteria for the potential impact on fish from seismic airguns and pile driving activities are considered to be those provided in the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al.*, 2014). The criteria for the different types of sources include a number of indices; SEL, RMS and peak SPLs. Where insufficient data exist to determine a quantitative guideline value for disturbance, the risk is categorised in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. in the tens of metres), “intermediate” (i.e. in the hundreds of metres) or “far” (i.e. in the thousands of metres). It should be noted that these qualitative criteria cannot differentiate between exposures to different levels of sound and therefore all sources of sound, independent of source level, would theoretically elicit the same assessment result. In relation to the potential for physical injury or behavioural effects, fish species are grouped into categories defined by a number of factors such as their anatomy for detecting sound pressure and particle motion, the use of sound during navigation or mating and the presence or absence of a swim bladder. Thresholds for fish mortality, injury and disturbance are provided in Appendix J using Popper *et al.* (2014).

7.5.2.1 Modelling Results for Piling Activities

The maximum predicted injury ranges from the manifold piling, SSIV piling, HDD trestle piling at Teesside, and HDD trestle piling at Humber with the hammer operating at maximum energy are presented in Table 7-10. The modelling predicts that sound levels will be below threshold values associated with injury to fish species beyond a maximum distance of 80 m from the piling location (zero-to-peak SPL at HDD trestle piling at Teesside). It is expected that the soft-start of the hammer during piling will likely disperse any mobile fish away from the piling locations to further distances where injury impacts are unlikely to occur. However, fish eggs and larvae that cannot move away from the source array are more susceptible to injury. For static eggs and larvae, injury is estimated within a maximum of 240 m from the piling location (SEL cumulative, HDD trestle piling at Teesside).

Table 7-10 - Predicted maximum distances from piling where the zero-to-peak SPL and cumulative SEL sound levels decrease below thresholds for injury (Genesis, 2022)

Fish group	Injury thresholds Zero-to-peak SPL (dB re 1 μPa) cumulative SEL (dB re 1 μPa²s)[185]	Maximum distance to threshold (m)			
		Manifold	SSIV	HDD trestle (Teesside)	HDD trestle (Humber)
Fish with no swim bladder	213 (SPL)	10	10	40	30
	219 (SEL)	Not exceeded	Not exceeded	Not exceeded	Not exceeded
Fish with swim bladder involved in hearing	207 (SPL)	30	30	80	70
	207 (SEL)	Not exceeded	Not exceeded	Not exceeded	Not exceeded
Fish with swim bladder not involved in hearing	207 (SPL)	30	30	80	70
	210 (SEL)	Not exceeded	Not exceeded	Not exceeded	Not exceeded
Eggs and larvae	207 (SPL)	30	30	80	70
	210 (SEL)	170	130	210	240

The radius of potential injury from the piling source using the Popper *et al.* (2014) criteria is relatively small and range between 10 m and 80 m depending on the type of hearing mechanism of the fish and piling activities. Based on this, it can be concluded that the piling activities will not result in any significant effect on fish populations within the Development area. Any effects will be short-term and highly localised.

As discussed previously, there are no quantitative threshold criteria for assessing behavioural disturbance on fish from sound sources. The qualitative criteria established by Popper *et al.* (2014) suggest that any disturbance to fish species from piling will likely be localised with higher levels of disturbance only occurring in regions near to the piling location (e.g. within a few hundred metres). At further distances from the piling locations (e.g. beyond one kilometre), the risk of behavioural disturbance to fish is likely to be low.

[185] *Results for the SEL Cumulative thresholds assume a swim speed of 0.5 m/s for all fish group, except for eggs and larvae which are static.*

7.5.2.2 Modelling Results for Seismic Activities

The modelling predicts that sound levels will be below threshold values associated with injury to the most sensitive fish beyond a maximum distance of 80 m (zero-to-peak SPL) from the source arrays. Predicted distances are lower for less sensitive fish species. It is expected that the soft -start of the source arrays will likely disperse any mobile fish away from the sound source to distances where injury impacts are unlikely to occur.

Fish eggs and larvae are static, cannot move away from the source array, and are more susceptible to injury. The modelling predicts that fish eggs and larvae that cannot move away from the seismic source may by injured at distances of 400 m from the source (see Appendix J) (Table 7-11).

Table 7-11 - Predicted maximum distances from the source arrays where the zero-to-peak SPL and cumulative SEL sound levels decrease below thresholds for injury (Genesis, 2022)

Fish group	Injury thresholds Zero-to-peak SPL (dB re 1 μPa) cumulative SEL (dB re 1 μPa²s)[186]	Maximum distance to threshold (m)
Fish with no swim bladder	213 (SPL)	40
	219 (SEL)	Not exceeded
Fish with swim bladder involved in hearing	207 (SPL)	80
	207 (SEL)	Not exceeded
Fish with swim bladder not involved in hearing	207 (SPL)	80
	210 (SEL)	Not exceeded
Eggs and larvae	207 (SPL)	80
	210 (SEL)	400

The qualitative criteria established by Popper *et al.* (2014) suggest that any disturbance to fish species will likely be localised with higher levels of disturbance only occurring in areas near to the source (e.g. within a few hundred metres). At further distances from the source (e.g. beyond one kilometre), the risk of behavioural disturbance to fish is likely to be low.

7.5.2.3 Impact Summary

Fish have varying levels of sensitivity to underwater sound: all fishes can detect particle motion, some are also able to detect sound pressure via the swim bladder or other gas-filled structures (Popper *et al.,* 2014). Swim bladders, and their anatomical location within the body, make fish more susceptible

[186] Results for the SEL Cumulative thresholds assume the a swim speed of 0.5 m/s for all fish group, except for eggs and larvae which are static.

to adverse sound impacts than species lacking swim bladders. Additionally, the presence of a swim bladder is also likely to increase the ability of many species of fish to detect sounds over a broader frequency range and at greater distances from the source than fishes without such structures, thereby increasing the range from the source over which sound can have an impact (Popper *et al.*, 2014).

Cartilaginous fish (e.g. spurdog (*Squalus acanthias*)), sandeel (*Ammodytes marinus*), mackerel (*Scomber scombrus*), anglerfish (*Lophius piscatorius*), and flatfish, including lemon sole (*Microstomus kitt*), and plaice (*Pleuronectes platessa*), do not possess a swim bladder nor any other air-filled sac (Popper *et al.*, 2014; FishBase, 2022). Therefore, these species are less susceptible to barotrauma, only detecting sound through particle motion (Popper *et al.,* 2014). Cod (*Gadus morhua*), whiting (*Merlangius merlangus*), herring (*Clupea harengus*), sprat (*Sprattus sprattus*), blue whiting (*Micromesistius poutassou*), European hake (*Merluccius merluccius*) and ling (*Molva molva*) do have a swim bladder and/or other air sac features used for hearing and thus are more sensitive to underwater sound (Hawkins and Pucciulin, 2019; Kaartvedt *et al.*, 2021; Popper *et al.,* 2014).

Adult fish not in the immediate vicinity of sound generating activity are generally able to move away and avoid the likelihood of physical injury. However, larvae are not highly mobile and are therefore more likely to incur injuries from the sound energy, including damage to their hearing, kidneys, hearts and swim bladders. Damage from shock to eggs and developing embryos consist of deformation and compression of the membrane, spiral curling of the embryo, displacement of the embryo, and disruption of the vitelline membrane. Although, such effects are unlikely to happen outside of the immediate vicinity of the sound activities (> 100 m), Popper *et al.* (2014) recognise the need for more data to determine the effects of anthropogenic sound on eggs and larvae.

As described in Section 4.6.1, a number of commercially important fish species are known to utilise the Development area in some capacity throughout their lives. The Endurance Store is located in high intensity nursery areas for cod, whiting, herring, lemon sole, sandeel, sprat, anglerfish, blue whiting, mackerel, European hake, and spurdog (Coull *et al.*, 1998; Ellis *et al.*, 2012b). Plaice and ling are additionally found along both the Teesside and Humber Pipeline routes and sole is found along the Humber Pipeline route. High intensity spawning grounds were also recorded for herring and sandeels (Coull *et al.*, 1998; Ellis *et al.*, 2012b) although site-specific survey (Gardline, 2022b) classed the Endurance Store and the export pipeline routes as an overall unsuitable spawning location for sandeels. Spawning for sandeels (November to February) and peak spawning for plaice (January to February) is outwith the proposed time for piling operations (Q2) or seismic (likely to occur during the summer).

As discussed above, injury to fish species from sound emissions are expected to be highly localised. It is expected that the soft-start of hammer during piling will likely disperse any mobile fish away from the piling locations to areas where injury impacts are unlikely to occur. Once piling operations are complete, fish are expected to be able to move back to the impacted area and no impacts at population level are expected from the small zone of injury, as the impact area is localised. During seismic surveys, injury ranges for fish species are also localised. Due to the transient nature of a survey as the vessel moves, it is unlikely the potential for injury is significant. It is expected that the soft -start of the source arrays will likely disperse any mobile fish away from the sound source to further distances where injury impacts are unlikely to occur. Therefore, injury is mitigated by the soft-start procedures for seismic and piling.

A qualitative assessment has been undertaken for disturbance, as per Popper *et al.* (2014). Disturbance from piling and seismic survey activity will be localised, with higher levels of disturbance expected within close proximity of the sound source. As distances from the sound source increase (and as the vessel moves during seismic survey), the risk for behavioural disturbance reduces and is considered to be low. For eggs and larvae, the risk is moderate close to the centre of activity (tens of metres) and low beyond this point (see Appendix J).

In addition, a number of shellfish species occur, including various crab species (such as spider crab (*Maja squinado*) and brown crab (*Cancer pagurus*)), Norway lobster (*Nephrops norvegicus*), mussels (*Mytilus edulis*). Little is known about how crustacean species are impacted by underwater sound changes (Tidau and Briffa 2016). Unlike fish species, crustaceans do not have an air-filled chamber; therefore, they are unlikely to detect sound pressure but can be sensitive to particle motion (Tidau and Briffa 2016).

Studies by Andriguetto-Filho *et al.* (2005) and Parry and Gason (2006) in Tidau and Briffa (2016) identified a large array of responses to underwater sound pressure, from an increase in behaviour (for example an increase in food intake in lobsters), stress responses, slower or reduced behaviour, change in foraging habitats etc. Current knowledge on how these reactions are displayed is based on a limited range of studies (Tidau and Briffa 2016).

Whilst estimates of fish and shellfish populations are generally not available, it is likely that many millions of individuals make up most species' populations (e.g. Mood & Brooke, 2010). The movement of fish tens or hundreds of metres away from the potential injury or disturbance impact zones would not constitute a large-scale movement by individuals of a species and is unlikely to result in population level impacts.

In summary, using the approach adopted by Popper *et al.* (2014), the area of behavioural change will extend beyond 10 m from the source, but the risk of disturbance will be moderate and is unlikely to be significant beyond 1 km. Given the fact that the survey operations will be constantly moving and the piling activity will be of short duration, no habituation to the sound is likely.

Injury from the piling and seismic operations will be extremely localised. Any changes to the behaviour of fish species will be temporary. Given the small area likely to experience changes, it is considered unlikely that the underwater sound generated by seismic or piling operations associated with the Development will result in significant impact to fish species at population level.

7.6 Management and Mitigation

bp, as operator of NEP, will adhere to the JNCC guidelines as embedded mitigation measures to mitigate the impact of underwater sound on marine species during the different phases of the Development as follows:

- JNCC protocol for minimising the risk of injury to marine mammals from piling sound (JNCC, 2010); and
- JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017a).

It should be noted that JNCC (2017a) do not advise that mitigation is required for MBES in shallow waters (< 200 m).

7.6.1 Marine Mammal Observer (MMO) and PAM

MMOs on board the survey / piling vessel will monitor for the presence of marine mammals, during the pre-start search, soft-start and survey/piling operations. The MMO will recommend delays in the commencement of source activity or pile driving should any marine mammals be detected within the 500 m mitigation zone.

Dedicated PAM operators may also be required to cover the hours of darkness and during periods when day-time conditions are not conducive for visual surveys (e.g. fog or increased sea states). The survey and piling contractor will provide a team to cover 24-hour observations / PAM during the survey.

A dedicated PAM system and operator will be utilised for piling or survey activities if the visibility does not allow for MMO sightings. When visibility is poor (i.e. due to fog or during hours of darkness) and/or during periods when the sea state is greater than Beaufort 3, piling or survey operations shall not be commenced unless a PAM system is deployed to facilitate detection of cetaceans. The PAM operator's primary role is to monitor and detect marine mammals and to potentially recommend a delay in the commencement of piling or survey activity if any marine mammals are detected. In addition, the PAM operatives will be able to advise the crew on the implementation of the procedures set out in the agreed mitigation protocol, to minimise the risk of any non-compliance with those procedures.

7.6.2 Pre-Start Search and Mitigation Zone

All observations (MMO or PAM) will be undertaken during a pre-start search of 30 minutes i.e. prior to the commencement of any use of the seismic sources / pile hammer in waters < 200 m.

The MMO/PAM operative (further details below) will monitor the agreed mitigation zone and advise if any marine mammals are within it. The standard radius of the mitigation zone is 500 m, estimated from the centre of either the airgun array or the pile location.

If marine mammals are detected in the mitigation zone during the pre-start search, then operations must be delayed until their passage, or the transit of the vessel, results in the marine mammals being outside of the mitigation zone. Either way there should be a minimum of a 20-minute delay from the time of the last sighting within the mitigation zone and the commencement of the soft-start and / or start of operations, to allow animals unavailable for detection to leave the area.

7.6.2.1 MMO Search

MMOs will undertake a visual (during daylight hours) search to determine if any marine mammals are present within the 500 m mitigation zone from the centre of the device deployed. MMOs should be equipped with binoculars and a tool to estimate distance i.e. range finding stick or binoculars with reticles. MMOs will be located on a suitable platform on the vessel, enabling the best view of the mitigation zone and ahead of the vessel.

7.6.2.2 PAM Search

PAM will be implemented during hours of darkness or reduced visibility to monitor the presence of marine mammals. PAM systems consist of hydrophones that are deployed into the water column, and the detected sounds are processed using specialised software. PAM operatives are needed to set up and deploy the equipment, and to interpret the detected sounds.

Bp, as operator of NEP, will ensure that the PAM system to be used is suitable for harbour porpoise monitoring, due to the Development being in the SNS SAC. Clicks from harbour porpoise have distinct characteristics and are of high-frequency. To be able to record these clicks during the PAM search, the PAM system must be capable to store and record sound sample at least every 0.003 milliseconds (Wilson *et al.*, 2019).

In addition, in order to maximise potential detection ranges during the pre-start search, it is recommended that background levels are minimised.

7.6.3 Soft-Start

7.6.3.1 Seismic Survey

There will be a soft-start[187] conducted every time prior to survey operations, with the following specified durations:

- From the start of the soft-start until full operational power: minimum of 20 minutes; and
- From the start of the soft-start until the start of the survey line: maximum of 40 minutes.

Where possible power should be built up gradually, in uniform stages from a low energy start-up. Surveys will be planned to avoid unnecessary use of the seismic source at operational power before commencement of an acquisition line and to time operations to commence data collection as soon as possible once full operational power is achieved.

If a marine mammal enters the mitigation zone during the soft-start then, whenever reasonably practical, the activation of the seismic source should cease, or at the least the power should not be further increased until the marine mammal exits the mitigation zone, and there is no further detection for 20 minutes.

If marine mammals are observed within the mitigation zone whilst the airguns are activated, there is no requirement to cease operations or reduce the power.

7.6.3.2 Piling Operations

The piling power will be increased incrementally over a set time period, until full operational power is achieved. The soft-start duration should be a period of not less than 20 minutes. If a marine mammal enters the mitigation zone during the soft-start then, whenever reasonably practical, the piling operation should cease, or at the least the power should not be further increased until the marine mammal exits the mitigation zone, and there is no further detection for 20 minutes.

When piling at full power, there is no requirement to cease piling or reduce the power if a marine mammal is detected in the mitigation zone as they will have been deemed to have entered voluntarily.

[187] *Turning on the airguns at low power and gradually and systematically increasing the output until full power is achieved*

7.6.4 Line Changes – Seismic Survey

In line with the JNCC guidelines, where line turns[188] are expected to take longer than 40 minutes during seismic activities:

- Sound source is to be terminated at the end of the survey line;
- A pre-source start search will be undertaken during the line change;
- The soft-start procedure is to be delayed if marine mammals are sighted within the 500 m mitigation zone during pre-shooting; and
- A full 20-minute soft-start will be undertaken before the start of the next data acquisition line.

7.6.5 Break in Piling Activity

If piling operations pause for a period of greater than 10 minutes, the pre-piling search and soft-start procedure should be repeated before piling recommences. If a watch has been kept during the full duration of the break in piling activity, the MMO or PAM operative may be able to confirm the presence or absence of marine mammals, and the soft-start commenced immediately.

7.6.6 Reporting

All recordings of marine mammals will be made using JNCC Standard Forms. At the end of the survey and piling operations, a monitoring report detailing the marine mammals recorded, methods used to detect them, and details of any problems encountered will be submitted to the JNCC. The report will also include feedback on how successful the mitigation measures were. This requirement will be communicated to the MMO at project start up meetings and at crew change. If the MMO has any queries on the application of the guidelines during the survey they will contact the JNCC for advice.

7.7 Cumulative and Transboundary Impacts

In theory, any project that regularly generates underwater sound has the potential to act cumulatively with the Development to impact marine mammals in the SNS. As operator of NEP, bp has, in consultation, identified a list of other projects which together with the Development may result in potential cumulative or in-combination impacts. The list of these projects including details of their status at the time of the EIA and a map showing their location is provided in Appendix D.

There are a number of oil and gas activities (pipelines and installations) in the vicinity of the Endurance Store. The majority of these installations are already active, as the SNS is a mature basin (DECC, 2016). There is a large number of surface (i.e. platforms) and seabed (i.e. wellheads, manifolds and pipelines) infrastructure within 50 km of the Development, the majority of which are active and therefore unlikely to generate significant underwater sound, other than from vessel movements. There are also several pipelines within 25 km of the Development, along with subsea cables. The most significant sound sources associated with the Development have been determined to be the discrete piling during subsea installation and seismic surveys (up to 6 during the life cycle of the Development). As discussed in Section 3.2.1.1 and Section 3.2.2.1, piling associated with installation is planned in Q2/Q3 2026 and it is expected that each piling activity will be a discrete event lasting up to two-three days. Seismic surveys will be undertaken during the operational phase of the Development. It should be noted that all activities (piling and seismic surveys) will be subject to the relevant permit applications. Therefore,

[188] Seismic data is typically collected along a number of predetermined survey lines. Line change is the term used to describe the activity of turning the survey vessel at the end of the survey line, prior to the commencement of the next survey line (JNCC, 2017a).

the possibility of a cumulative impact from pre-existing oil and gas infrastructure and subsea cables is considered to be negligible.

A number of OWFs have been identified within 50 km of the Development. For the purpose of this assessment, it is considered that operational OWFs will not result in any material increase in underwater sound, other than through the presence of vessels. Instead, OWFs which are either under construction or proposed have been considered.

Cables and interconnectors were identified within 50 km of the Development. For the purpose of this assessment, it is considered that operational cables will not result in an increase in underwater sound, other than through the presence of vessel during potential maintenance. Cables under construction or proposed have been considered further in this assessment.

Table 7-12 provides below an overview of other projects in the vicinity that may results in cumulative impacts, based on findings from a review of other projects (Appendix D).

Table 7-12 - Potential for cumulative impacts

Project and closest distance	High level description	Status	Potential For cumulative impacts	Justification
Oil and Gas				
Kumatage field At closest point, the field is 5 km from the Endurance Store.	The Kumatage gas field comprises UKCS blocks 42/30d and 43/26c. The plan is to develop the gas reservoir either through a platform or subsea development and associated pipeline(s) and umbilical(s) (if required) to tie into existing gas export infrastructure. Final appraisal well location will be subject to seabed survey and detailed design findings. The current timeline of activities is as follows: commitment to appraisal well by 30th September 2022; drilling of appraisal well by 30th September 2024; first gas production by 30th September 2028.	First gas Q4 2028	Negligible	Piling operations for the Development are likely to occur in Q2/Q3 2026. Any sound emitting operations resulting from installation activities at the Kumatage field may occur concurrently with piling at the Endurance Store. However, sound generated by installation activities at the Kumatage field are likely to be continuous only. Piling at the Endurance Store would be of short duration over a limited number of days, as discrete events. There is no potential for cumulative effects with the planned seismic surveys as these would occur once the Kumatage field is operational.
Offshore Windfarms				
Hornsea Project Four The Endurance Store partially overlaps with Hornsea Project Four[189]	The OWF could cover up to 492 km^2 and contain up to 180 wind turbines. This OWF will be adjacent to Hornsea Two. Construction is set to commence in 2026 prior to first power in 2028.	Construction is due to commence in 2026 prior to first power in 2028.	Minor	Based on construction activities starting in 2026 at Hornsea Project Four and subsea installation for the Development planned in Q2/Q3 2026, there is the potential for cumulative impact. Hornsea Project Four considered the maximum potential for cumulative effects from underwater sound with other activities was slight to moderate (for harbour porpoise) (Ørsted, 2021d). Piling of the manifold within the Endurance Store will occur in close proximity to Hornsea Project Four. The assessment in this Chapter considered sound emissions from piling to not be of significance for marine mammals and fish (see Appendix J). Similarly, the assessment undertaken on the conversation objectives of the SNS SAC considered that impacts from the operations will not be significant. Piling would be a series of discrete events, each lasting only a few days. JNCC (2020a) defined that the EDR for monopile is 26 km, which represents an area of 2,124 km^2 (JNCC, 2020a). Ørsted have however committed to sound abatement (Ørsted, 2021e). Therefore, an EDR of 15 km has been used for the purpose of this cumulative assessment (JNCC, 2020a). Based on a 15 km EDR, it is expected that the area impacted by pile driving for a turbine is 707 km^2, which is a reduction from the impact area based on a 26 km EDR. As discussed in JNCC (2020a), the use of sound abatement helps reduce the EDR and therefore allows “piling events or potentially two pairs of adjacent events per day could occur over the whole summer season”. Multiple foundations may be piled during the duration of the piling operations at the Development.

[189] *On 17th June 2023, a commercial agreement was reached with Ørsted (the developer of Hornsea Four) to avoid construction of Hornsea Four infrastructure within the area of overlap with the Endurance Store*

Project and closest distance	High level description	Status	Potential For cumulative impacts	Justification
				Ørsted (2021e) assessed that for the 10% temporal value in the SAC, the anticipated duration of pile driving is within an overall window of 12 months. If concurrent piling is utilised at Hornsea Project Four, or if more than one foundation is installed in a day, the number of days required for piling would fall. Based on these, the maximum seasonal effect of piling in the array in the summer from piling in the array only (assuming the maximum 7.87% per day for every day of the season), would therefore be 7.87%, well within the 10% seasonal threshold. Piling at the Development is considered to represent as a worst case 0.029% of the SNS SAC over a season (for the manifold piling). Based on this and the fact that disturbance of the SAC over the season for piling at the Hornsea Project Four is 7.87%, it is not expected that the 10% seasonal threshold would be exceeded. Therefore the potential for cumulative effects is considered to be minor. bp, as operator of NEP, will monitor activities at Hornsea Project Four to limit the potential for cumulative sound impacts. Seismic surveys at the Endurance Store will be located in the proximity of Hornsea Project Four. In addition, Hornsea Project Four will be operational once seismic surveys will occur during the life cycle of the Development. Therefore, the potential for cumulative effects is considered to be negligible.
Subsea Cables				
Dogger Bank C Transmission Asset The Teesside Pipeline route crosses the Dogger Bank C Transmission Asset. Piling of the HDD trestles at the Teesside landfall may occur in close proximity (i.e. <10 km) from this crossing point.	Export cable connecting the OWF to shore, close to Redcar, North Yorkshire. This transmission asset is shared between Dogger Bank C and Sofia Schedule assumed to be within the OWF timeframe.	In planning	Negligible	Piling of the HDD trestles at the Teesside Pipeline landfall may occur in close proximity to the Transmission Asset. However, construction activities at the Dogger Bank C are expected to be completed by 2025, which is prior to piling activities at the Development in Q2/Q3 2026. Seismic surveys at the Development during its life cycle will occur once the Dogger Bank C OWF is operational. The potential for cumulative impacts is therefore considered to be negligible.
Dogger Bank B Transmission Asset The Teesside Pipeline route crosses the Dogger Bank B Transmission Asset. Piling of the HDD trestles at the Teesside landfall may occur in close proximity (i.e. <10 km) from this crossing point.	Export cable connecting the OWF to shore near Cottingham, East Yorkshire, UK. This transmission asset is shared between Dogger Bank B and A. Schedule assumed to be within the OWF timeframe.	In planning	Negligible	Piling of the HDD trestles at the Teesside Pipeline landfall may occur in close proximity to the Transmission Asset. However, construction activities at the Dogger Bank B are expected to be completed by 2024, which is prior to piling activities at the Development in Q2/Q3 2026. Seismic surveys at the Development during its life cycle will occur once the Dogger Bank B OWF is operational. The potential for cumulative impacts is therefore considered to be negligible.
Sofia Transmission Asset The Teesside Pipeline route crosses the Sofia Transmission Asset. Piling of the HDD trestles at the Teesside	Export cable connecting the OWF to shore, close to Redcar, North Yorkshire. This transmission asset is shared between Sofia and Dogger Bank C. Schedule assumed to be within the OWF timeframe.	In planning	Minor	Construction activities at the Sofia Transmission Asset will include vessel sound, such as rock dumper etc., and would be completed by 2026. Piling (including at the Teesside HDD trestles location) would be a series of discrete events, lasting only a few days. There may be a temporal overlap. However, the potential for cumulative effects is considered to be minor based on results

Project and closest distance	High level description	Status	Potential For cumulative impacts	Justification
landfall may occur in close proximity (i.e. <10 km) from this crossing point.				from the sound modelling results (see Appendix J). bp, as operator of NEP, will monitor activities at Sofia Transmission Asset to limit the potential for cumulative sound impacts. Sofia will be operational once seismic surveys will occur during the life cycle of the Development. Therefore, the potential for cumulative effects is considered to be negligible.
Eastern Green Link 2 (EGL2) The Teesside Pipeline route crosses the Eastern Green Link 2 (EGL2) cable. Piling of the HDD trestles at the Teesside landfall may occur in proximity (i.e. ~50 km) from this crossing point.	The project proposes to construct an HVDC Link from Peterhead in Aberdeenshire to Drax in North Yorkshire. Landfall in England is at Fraisthorpe Sands on the Holderness coast. Construction is currently due to commence in 2024 and be completed in 2029.	Proposed	Minor	Construction activities for a cable will typically, include vessel sound, such as cable lay and rock placement vessels etc., and would be completed by 2029. Piling for the Development would be a series of discrete events, lasting only a few days, of which the manifolds are in the Store area. There may be a temporal overlap as piling operations for the Development are planned in Q2/Q3 2026. It is estimated that the closest piling operation to the EGL2 is the piling of HDD trestles at the Teesside Pipeline landfall (~50 km). However, the potential for cumulative effects is considered to be minor based on results from the sound modelling results (see Appendix J). bp, as operator of NEP, will monitor activities at the Scotland to England Green Link to limit the potential for cumulative sound impacts. The cable will be operational once seismic surveys for will occur during the life cycle of the Development. Therefore, the potential for cumulative effects is considered to be negligible.
Hornsea Project Four Transmission Asset The Humber Pipeline route crosses the Hornsea Project Four Transmission Asset. Piling of the HDD trestles at the Humber Pipeline landfall may occur in proximity (i.e. ~30 km) from this crossing point.	Export cable connecting the OWF to shore, close to Bridlington, East Riding of Yorkshire. The High Voltage Alternating Current (HVAC) Booster Station works area will be located <2 km from the Humber Pipeline. Schedule assumed to be within the OWF timeframe.	In planning	Minor	Based on construction activities starting in 2026 at Hornsea Project Four and subsea installation for the Development planned in Q2/Q3 2026, there may be a temporal overlap. Hornsea Project Four considered the maximum potential for cumulative effects from underwater sound with other activities was slight to moderate (for harbour porpoise) (Ørsted, 2021d). Piling of the HDD trestles at Humber will occur in proximity to the Hornsea Project Four Transmission Asset crossing point (~ 30 km). The assessment in this Chapter considered sound emissions from piling to not be of significance for marine mammals and fish (see Appendix J) and the assessment on the conversation objectives of the SNS SAC. Piling would be a series of discrete events, lasting only a few days. Therefore, the potential for cumulative effects is considered to be minor. bp, as operator of NEP, will monitor activities at Hornsea Project Four to limit the potential for cumulative sound impacts. Seismic surveys at the Endurance Store will not be located in the proximity of the Hornsea Project Four Transmission Asset cable. In addition, Hornsea Project Four will be operational once seismic surveys will occur during the life cycle of the Development. Therefore, the potential for cumulative effects is considered to be negligible.

Subsea installation is due to occur in Q2/Q3 2026, with piling being completed within two to three days for each piling activity (HDD trestle, SSIV and manifolds), which is limited compared to piling associated with wind turbines. Of the projects listed in Table 7-12, the majority of projects are expected to be operational once subsea installation is planned in Q2/Q3 2026. It should be noted that, as discussed in Section 7.3.1, the relevant permit applications to OPRED will consider the potential for cumulative impacts based on the selected and final installation date. This chapter considers the likely option of Q2/Q3 2026. The closest project to the piling operations is the Hornsea Project Four OWF (adjacent to the Endurance Store[190]). bp, as operator of NEP, will monitor activities at the Hornsea Project Four to seek to minimise the potential for cumulative impacts. A number of transmission assets and cables cross the Teesside and Humber Pipeline routes, with piling occurring within 10-50 km from the relevant crossing points. Based on the underwater sound modelling, the potential for cumulative impacts with these cable projects is negligible-minor.

Up to six seismic surveys are planned during the life cycle of the Development (i.e. over 25 years). It is therefore likely that the majority of the surveys will occur after construction of the majority of the OWFs identified within 50 km of the Development. It is unlikely that the planned surveys will occur within the close proximity of any other sound emitting activities (e.g. piling), as the sound generated by other activities could lead to poor data quality for the planned surveys due to signal and sound interference. Therefore, the survey activities associated with the Development are unlikely to be concurrent with any significant sound emitting activities.

Marine mammal and fish populations are free-ranging and long-distance movement is likely to be frequent. Any animal experiencing a significant impact from one project is likely to belong to a much wider ranging population and there is the potential for that same animal to subsequently come into contact with sound from other projects. Potential injury and disturbance impacts resulting from the Development are not expected to be significant, and significant cumulative impact from the unlikely scenario of an animal encountering sound emissions from multiple activities within a short period of time is therefore considered unlikely. As a result, the potential cumulative impact is considered to be not significant.

The Development is located 105 km from the UK / Netherlands boundary line. Since sound emissions capable of potentially causing injury or disturbance to marine mammals or fish will not be received directly by any animals across these boundary lines, direct transboundary impacts are not anticipated. An animal experiencing an impact in UK waters has the potential to belong to a much wider ranging population which may cross boundary lines, such a potential impact could qualify as a transboundary impact. However, since injury is not expected to occur, and any disturbance is expected to be trivial, potential transboundary impacts are considered not significant.

7.8 Decommissioning

Any potential impact that decommissioning operations may have through sound emissions will occur in an area that experienced sound emissions during the operational phase of the Development. In general, activities are likely to be similar in nature to those required for installation (e.g. vessel use) and will generate similar sound emissions. However, should wells be abandoned[191], it is possible that

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[190] bp and Ørsted have reached an agreement with regards to the Hornsea Project Four and NEP Project lease areas. The Endurance Store area will not be developed as part of Hornsea Project Four.

[191] Made incapable of flowing and no longer in use, industry term typically applied to wells of this status being "plugged and abandoned"

wellheads will be cut off below the seabed; these cutting activities would result in sound emissions. Such sound emissions would be of short-term duration only and would be conducted in line with any relevant mitigation measures. Given the residual impact from installation and operation is considered to be not significant, the potential impact from decommissioning is also considered to be not significant.

7.9 Protected Sites

As marine mammals (and fish as their prey) are the key receptors potentially at risk of significant impacts from underwater sound, this Section focuses on protected sites that host marine mammals as designated features.

As described in Section 4.4.6, UK waters host four species of marine mammal which are listed on Annex II of the Habitats Directive, enabling their protection through the designation of protected sites. Of these, the only species that are expected to be present with regularity in the Development area in significant numbers are harbour porpoise from the SNS SAC.

7.9.1 Habitats Regulations Assessment

A HRA is required to determine whether a plan or project has the potential to adversely affect the integrity of a European Sites. Within the Development area, this is required under the Conservation of Habitats and Species Regulations 2017 (as amended), the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended). The HRA process involves first screening protected sites as to whether the potential for LSEs exists, e.g. due to the presence of an impact pathway. Any sites where potential LSEs cannot be ruled out will be subject to an A, conducted by OPRED. The information presented in the Sections below enables OPRED to determine whether the proposed activities may result in LSEs.

7.9.2 HRA Approach

The HRA approach used in this assessment involved an initial screening out of any European Sites where no ecological connectivity between the underwater sound associated with the Development and the qualifying interests of protected sites was identified. Following this, a more in-depth assessment of any sites where ecological connectivity may be possible was undertaken, to determine whether LSEs on European sites could not be ruled out. This more in-depth assessment considered the following:

- The connectivity to a site, either due to proximity to the site or the importance of the Development area as a migratory route or feeding ground for qualifying features;
- The maximum number of individuals expected to be injured and/or disturbed by the underwater sound generated, using the modelling output; and
- The potential impact pathways of activities associated with the Development and the relative sensitivities of the qualifying features against those pathways.

This resulted in an overall conclusion of whether an LSEs on European sites could be excluded to determine whether an AA was deemed necessary, considering the implementation of any appropriate mitigation measures.

7.9.3 Screening of Protected Sites Requiring Further Assessment

Section 4.5 identified a number of protected sites which intersect or are within 50 km the Development. The SNS SAC is the only protected site designated for marine mammals (i.e. harbour porpoise which an Annex II species and EPS) which intersects with the Development. The Holderness Offshore MCZ intersects the Development and the MCZ supports fish spawning habitats. However, fish species are not a qualifying feature of the MCZ and impacts on fish was deemed to be not significant. Sites identified in Section 4.5 are primarily designated for seabed features or seabirds, which are not expected to be significantly impacted by underwater sound emissions.

In addition, the Moray Firth SAC is located approximately 430 km north of the Development. This SAC is designated for its resident population of bottlenose dolphin (JNCC, 2022b). The population at the SAC is estimated at around 130 individuals (JNCC, 2022b); however, this population estimate is based on research from Wilson *et al.* (1999). The East coast bottlenose dolphin population ranges widely from the Moray Firth SAC, with photo-identification suggesting that animals observed within the SAC have been sighted off North East England and the Netherlands (Hoekendijk *et al.*, 2021). A more recent population estimate, utilising data from surveys during the 2015-2019 period within and outside the SAC, is 224 (214-234) individuals (NatureScot, 2021).

Typically, bottlenose dolphin are primarily sighted nearshore, with most observations within 10 km of land (JNCC, 2022c). However, the species has been recorded in the vicinity of the Development (Section 4.4.6.2) over the summer months (July -August) as per Reid *et al.* (2003). Densities recorded were low in the vicinity of the Development, between 0-0.001 animals / km^2 (Paxton *et al.*, 2016). No bottlenose dolphins were observed during SCANS III surveys in the survey block overlapping this Development (Block O) (Hammond *et al.,* 2021), thus no density estimate was generated for this area. Bottlenose dolphin are MF cetaceans. The activity closest to the coast with the greatest potential to have impacts on coastal bottlenose dolphins is the HDD trestle piling. However, the calculated impact ranges for MF cetaceans mean that no LSE on this species or on this protected site (i.e. no impact on the conservation objectives) will occur.

For grey and harbour seals, the generally accepted maximum average foraging range is 200 km and 50 km respectively, which means that the Development is within foraging range from a number of sites designated for grey and harbour seal features (see Section 4.4.6.1). However, the assessment highlighted the low-density of seal in the Development and as such, no LSE on protected sites designated for seals are expected.

Therefore, based on the information from Section 4.4.6, the only site that is caried forward for further assessment is the SNS SAC, in which the Development is located.

7.9.3.1 Southern North Sea SAC

The Development is located within the SNS SAC, which is designated for Annex II harbour porpoise. The habitat within this SAC is highly suitable for key prey species of harbour porpoise (i.e. sandeels), which attract individuals to the area (JNCC, 2019).

The area within this SAC supports harbour porpoise year-round, with harbour porpoise being recorded at higher densities in the south of the site during the winter, and in the north the summer months (JNCC, 2019; JNCC, 2020a). The Development is located within the summer habitat for harbour porpoise (Section 4.4.6.2 However, it is noted that for conservation management purposes, such as assessing impacts to the population associated with the site, the North Sea MMMU (346,601 individuals) should be considered given the highly mobile and non-localised nature of this species (JNCC, 2019). The population, conservation quality and global representation of this site is classed as outstanding. Harbour porpoise are however not isolated to this SAC and are commonly observed in the North Sea (Reid *et al.*, 2003).

One of the most important impact and activity with a high effect on this site has been identified as the exploration and extraction of oil or gas (JNCC, 2019). There is no particular description of impacts associated from CCS operations however activity associated with the Development (piling for manifolds, the SSIV and HDD trestles) and seismic surveys are also typical of oil and gas activities. Any activity with the potential to disturb a significant proportion of the population or to cause temporary habitat loss and which results in long-term population declines or reduces the size of available suitable habitat must be considered in managing sound impacts to harbour porpoise within this SAC (JNCC, 2020a). These activities include: pin-piling, seismic surveys and geophysical surveys (JNCC, 2020a). As discussed in Section 7.3.1, the equipment forming part of the pre and post lay surveys will be used at frequencies and sound levels that are unlikely to disturb marine mammals. Therefore, the EDR for geophysical surveys is not discussed further in this Section.

7.9.3.1.1 Conservation Objectives

The conservation objective for the SNS SAC is to ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining FCS for harbour porpoise in UK waters.

In the context of natural change, this will be achieved by ensuring that:

1. Harbour porpoise is a viable component of the site;
2. There is no significant disturbance of the species; and
3. The condition of supporting habitats and processes, and the availability of prey is maintained (JNCC, 2019).

7.9.3.1.2 Injury Impacts

Sound modelling for piling showed the potential to injure harbour porpoise (HF cetaceans) was limited to a maximum injury range of 360 m (cumulative SEL with soft-start for HDD trestle piling at Humber). The assessment using the cumulative SEL thresholds (available in Appendix J determined that when soft-start was applied, impacts to marine mammals over a 24 hour period were still acceptable as they are limited to within the 500 m monitoring zone.

Similarly, the underwater sound modelling (see Appendix J) determined that the potential injury from seismic surveys is very limited and will be mitigated by the implementation of mitigation measures. The worst case injury range was assessed as 150 m for HF cetaceans (zero-to-peal SPL). This means that the application of mitigations, including a soft-start procedure, and the inclusion of an MMO and PAM for pre-operational and operational monitoring of a 500 m zone will negate the risk of injury to harbour porpoise.

The SCANS-III density for harbour porpoise within the Development area is 0.888 individuals per km^2 (Hammond *et al.*, 2021). Harbour porpoise density estimates from Heinänen and Skov (2015) suggest that densities in the vicinity of the Development could be higher than those from SCANS-III data. Harbour porpoise densities according to Heinänen and Skov (2015) are 3 individuals per km^2. Based on densities reported by Hammond *et al.* (2021), less than one animal is likely to be within encountered within the 500 m monitoring zone at any given time, further decreasing the likelihood of injury impacts to harbour porpoise from the piling or seismic activities associated with the

Development. Using the higher Heinänen and Skov (2015) estimates, 2.3 animals may be within the monitoring zone.

Considering the small number of individuals estimated to be within the injury range and the proposed mitigation measures (see Section 7.6), no injury impacts to harbour porpoise are expected to result in LSE on harbour porpoise at this SAC from either piling or seismic activities. Underwater sound associated with the Development is not expected to lower the reproductive capacity or survivability of harbour porpoise (Thompson *et al.*, 2013; Nabe-Nilsen *et al*., 2018) and as such, are not expected to adversely affect Conservation Objective 1 of the SAC.

7.9.3.1.3 Disturbance Impacts

To manage disturbance impacts on harbour porpoise associated with the SNS SAC, guidance provided by the JNCC (2020a) proposes an assessment of number of individuals disturbed as well as an assessment of temporary habitat loss via sound deterrence. Subsea installation is expected to take place in Q2/Q3 2026 and, as a worst case, seismic surveys are assumed to occur during the summer. As such, potential disturbance is assessed herein for piling and seismic activities (generating impulsive sound to which cetaceans are most sensitive) taking place during the spring/summer months (when highest abundances of harbour porpoise occur) in order to present a worst case scenario.

When considering if any significant disturbance could arise from the piling and seismic activities, constituting as going against Conservation Objective 2 for this site, it is necessary to assess whether the disturbance caused by the piling and seismic activities could result in an exclusion of harbour porpoise from either:

- 20% of the relevant area (summer or winter areas) in any given day; or
- An average of 10% of the relevant area of the site over a season[192].

For the purpose of the assessment below, the potential loss of habitat from the sound emissions have been assessed against the SNS SAC's entire area (36,951 km^2) (JNCC, 2019) and against the SNS SAC's summer area (27,028 km^2) (JNCC, 2020a).

Piling operations are likely to each be completed within two to three days. Each seismic surveys are expected to occur over a period of 75 day (including downtime). Therefore, loss of habitat from piling and seismic activities should be both considered over a day but also over an entire season.

Piling

As discussed previously and in Section 3.2, piling would occur at four locations (manifolds, SSIV, HDD trestle at Humber and Teesside). The SSIV piling location and Teesside HDD trestle piling locations are located approximately 94 km and 100 km from the SNS SAC boundary, respectively. As such they will not impact the SNS SAC and are not considered further in this assessment. However, the manifold piling locations are located within the 'Summer Area' of the SNS SAC and the Humber HDD trestle piling locations are located within 15 km of the 'Winter Area' of the SNS SAC. It should be noted that subsea installation is planned in Q2/Q3 2026. The summer area is defined as April to September (inclusive) and the winter area is from October to March (inclusive) (JNCC, 2020a). As the Humber HDD

[192] *As per JNCC (2020a), the relevant area is defined as that part of the SAC that was designated on the basis of higher persistent densities for that season (summer defined as April to September inclusive, winter as October to March inclusive).*

trestle piling location is located within 15 km of the Winter Area, this means that the harbour porpoise population number is expected to be lower during the subsea installation between Q1 and Q3 2026.

It is recommended that a conservative disturbance range (i.e. EDR) of 15 km be used when considering impacts to harbour porpoise from piling activities in the SNS SAC (Graham *et al.*, 2019; JNCC, 2020a). Within the 15 km EDR, there is the potential for up to 628 – 2,121 and 478 – 1,614 harbour porpoise to be disturbed during manifold piling and HDD trestle piling at Humber respectively, based on measured densities across the Development. When considering the population of the North Sea MMMU (i.e. 346,601 individuals), this equates to a maximum of 0.612% of the MMMU population (Table 7-13).

Table 7-13 - Estimated number of marine mammals disturbed based on a 15 km EDR for disturbance to marine mammals (Genesis, 2022)

Species	Disturbance area (km^2)	Animal density ($animals/km^2$)*	Number of animals disturbed	MMMU population**	Percentage of MMMU population disturbed (%)
Manifold piling					
Harbour porpoise (HF cetacean)	707	0.888 – 3	628 – 2,121	346,601	0181 – 0.612
White-beaked dolphin (MF cetacean)	707	0.002	2	43,951	0.005
Minke whale (LF cetacean)	707	0.010	8	20,118	0.040
HDD trestle piling at Humber					
Harbour porpoise (HF cetacean)	538	0.888 – 3	478 – 1,614	346,601	0.138 – 0.466
White-beaked dolphin (MF cetacean)	538	0.002	2	43,951	0.005

Species	Disturbance area (km²)	Animal density (animals/km²)*	Number of animals disturbed	MMMU population**	Percentage of MMMU population disturbed (%)
Minke whale (LF cetacean)	538	0.010	6	20,118	0.030
* Marine mammal densities for white-beaked dolphin and minke whale are from SCANS-III data (Hammond *et al.*, 2017). For harbour porpoise, the lower density of 0.888 is from SCANS-III whilst the upper density of 3 is based on Heinänen and Skov (2015). ** MMMU populations are from IAMMWG (2021).					

The 15 km EDR is considered highly conservative as only 25% of harbour porpoise were found to be deterred across this radius (Graham *et al.*, 2019). Rather, it is likely that disturbance impacts would be limited to within 3.8 km – 7.2 km from the piling activities (worst case), based on the sound modelling data (Section 7.5). With this disturbance range (as per Tougaard, 2015), a maximum of 201 individuals might experience disturbance at the HDD trestle piling location at Humber, equating to < 0.1% of the North Sea MMMU population.

When taking the conservative 15 km EDR range for the piling activities into account, it is expected that the area of potential disturbance surrounding the manifold piling impact would be 707 km² in a day or 0.2 km² in a day at the HDD trestle piling location at Humber.

For the SNS SAC, the predicted daily percentage impact and the average percentage impact over the season are shown in Table 7-14 for the manifold piling and HDD trestle piling at Humber. The daily and seasonal disturbances have been calculated by comparing the modelling result with the NOAA 'Level B harassment' and Tougaard (2015) threshold for disturbance to marine mammals, as well as using the 15 km EDR suggested by JNCC (2020a). The disturbance associated with the Development's piling operations alone will not exceed the daily and seasonal thresholds for the SAC suggested by JNCC (2020a) (Table 7-14).

Table 7-14 - Predicted areas of SAC impacted by piling operations

Method	Predicted daily disturbance area (km²)	Daily % of SAC impacted	Average % of SAC impacted over the season
Manifold piling			
Comparison of modelling results with NOAA 'Level B harassment' threshold for disturbance to marine mammals	45	0.17	0.002

Method	Predicted daily disturbance area (km^2)	Daily % of SAC impacted	Average % of SAC impacted over the season
Comparison of modelling results with Tougaard (2015) threshold for disturbance to marine mammals	163	0.6	0.007
JNCC (2020a) 15 km EDR	707	2.62	0.029
HDD trestle piling at Humber			
Comparison of modelling results with NOAA 'Level B harassment' threshold for disturbance to marine mammals	0	0	0
Comparison of modelling results with Tougaard (2015) threshold for disturbance to marine mammals	0	0	0
JNCC (2020a) 15 km EDR	0.2	0.002	0.00002

The 15 km EDR would equate to a worst case (i.e. manifold piling as shown above) impact of 2.62% over a day and 0.029% of the overall SAC area over an entire season. This percentage is lower than the maximum loss of habitat threshold for significant disturbance, as established by the JNCC (2020a) and stated above. In addition, based on the timing and character of the piling activities, the potential area of exclusion for harbour porpoise is expected to be considerably lower than this estimate. It is therefore considered that there is no potential for underwater sound associated with the piling activities alone to result in significant disturbance to harbour porpoise, that would result in a LSE to the SAC's designated feature or adversely affect the SAC's Conservation Objectives.

Seismic

It is recommended that a conservative disturbance range (i.e. EDR) of 12 km be used when considering impacts to harbour porpoise from seismic activities in the SNS SAC (Sarnocińska *et al.,* 2020; Thompson *et al.,* 2013; JNCC, 2020a). Within a 12 km EDR for seismic survey at the Endurance Store, and based on the highest measured densities across the Development area, there is the potential for up to 6,375 harbour porpoise to be disturbed (1.839% of the North Sea MMMU) over a day and up to 7,965 individuals (2.298% of the North Sea MMMU) over the entire survey duration, (see Appendix J) (Table 7-15). This is a conservative estimate of potential disturbance impact on individuals and at a population level at it is assumed that the entire area (based on a 12 km EDR, i.e. 2,125 km^2 over a day and 2,655 km^2 over the survey duration) is ensonified simultaneously. Simultaneous ensonification of the entire area is a worst case assumption that will not occur.

Table 7-15 - Estimated number of marine mammals disturbed based on a 12 km EDR for disturbance to marine mammals (Genesis, 2022)

Species	Disturbance area (km^2)	Animal density (animals/km^2)*	Number of animals disturbed	MMMU population**	Percentage of MMMU population disturbed (%)
Disturbance over 24 hours					
Harbour porpoise (HF cetacean)	2,125	0.888 – 3	1,887 – 6,375	346,601	0.544 – 1,839
White-beaked dolphin (MF cetacean)	2,125	0.002	5	43,951	0.011
Minke whale (LF cetacean)	2,125	0.010	22	20,118	0.109
Disturbance over entire survey duration					
Harbour porpoise (HF cetacean)	2,655	0.888 – 3	2,358 – 7.965	346,601	0.680 – 2.298
White-beaked dolphin (MF cetacean)	2,655	0.002	6	43,951	0.014
Minke whale (LF cetacean)	2,655	0.010	27	20,118	0.134

* Marine mammal densities for white-beaked dolphin and minke whale are from SCANS-III data (Hammond *et al.*, 2017). For harbour porpoise, the lower density of 0.888 is from SCANS-III whilst the upper density of 3 is based on Heinänen and Skov (2015).

** MMMU populations are from IAMMWG (2021).

The 12 km EDR has been proposed on findings from Sarnocińska *et al.* (2020) and Thompson *et al.* (2013). Sarnocińska *et al.* (2020) assessed the impacts of a seismic survey using a 3,570 cu in air gun, which is larger than the worst case assessed in the sound modelling study (i.e. 480 cu in). It is therefore considered that the 12 km EDR represents a worst case, in particular in comparison with the disturbance modelled in the underwater sound modelling based on NOAA and Tougaard (2015) thresholds (Table 7-14).

For the SNS SAC, the predicted daily percentage impact and the average percentage impact over the season are shown in Table 7-14 for seismic survey. The daily and seasonal disturbances have been calculated by comparing the modelling result with the NOAA 'Level B harassment' and Tougaard (2015) threshold for disturbance to marine mammals, as well as using the 12 km EDR suggested by JNCC (2020a). It is predicted that the disturbance associated with the Development's survey operations alone will not exceed the daily and seasonal disturbance thresholds for the SAC suggested by JNCC (2020a) (Table 7-16).

Table 7-16 - Predicted areas of SAC impacted by seismic operations

Method	Predicted daily disturbance area (km^2)	Daily % of SAC impacted	Average % of SAC impacted over the season
Comparison of modelling results with NOAA 'Level B harassment' threshold for disturbance to marine mammals	825	3.05	0.93
Comparison of modelling results with Tougaard (2015) threshold for disturbance to marine mammals	1,458	5.39	1.65
JNCC (2020a) 12 km EDR	2,125	7.86	2.41

To estimate potential disturbance to marine mammals over a 24 hour period, the survey vessel has been modelled completing two seismic lines spaced approximately 8 km apart. The two lines were selected to be two of the longest lines in the survey area and will be indicative of the maximum disturbance area that could occur over a 24 hour period. The single-pulse SELs for all source points over the seismic lines were aggregated to predict areas where potential disturbance to marine mammals could occur and are shown in. The single-pulse SELs have also been aggregated over all source points over the entire survey area to demonstrate the cumulative disturbance areas over the entire survey duration and are shown in Figure 7-1 and Figure 7-2.

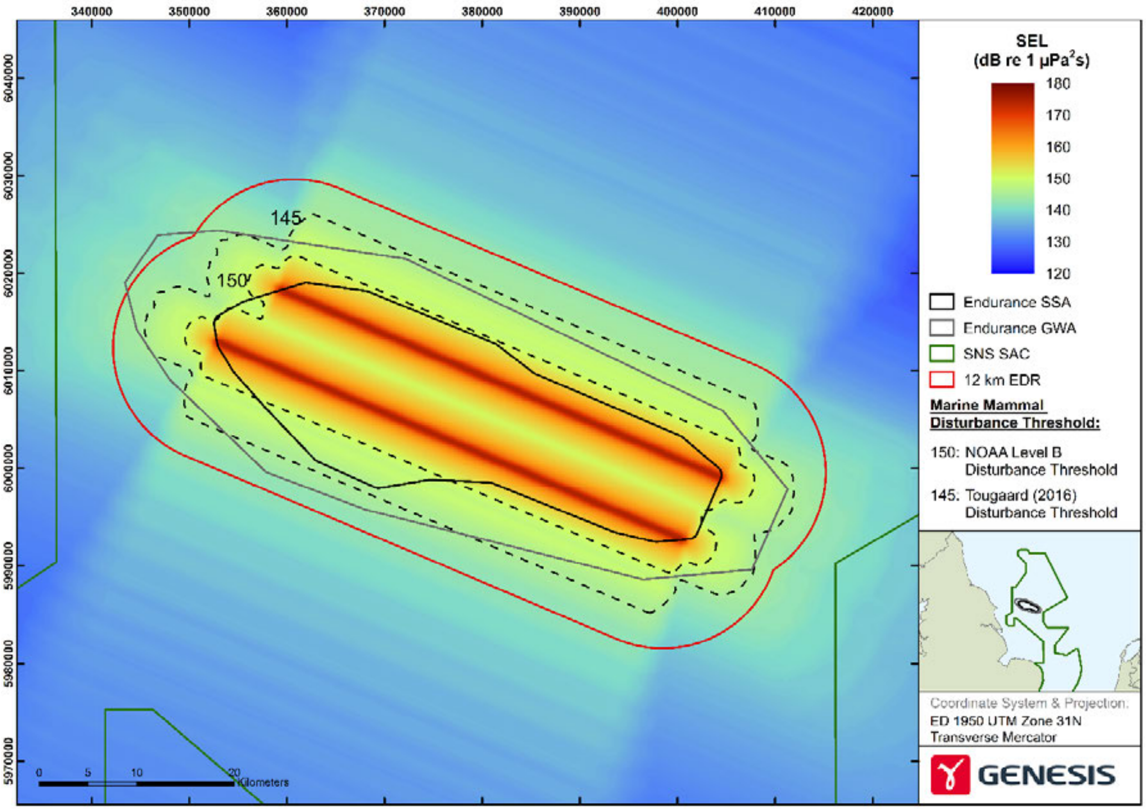

Figure 7-1 - Single pulse SEL over a 24-hour period (Genesis, 2022)

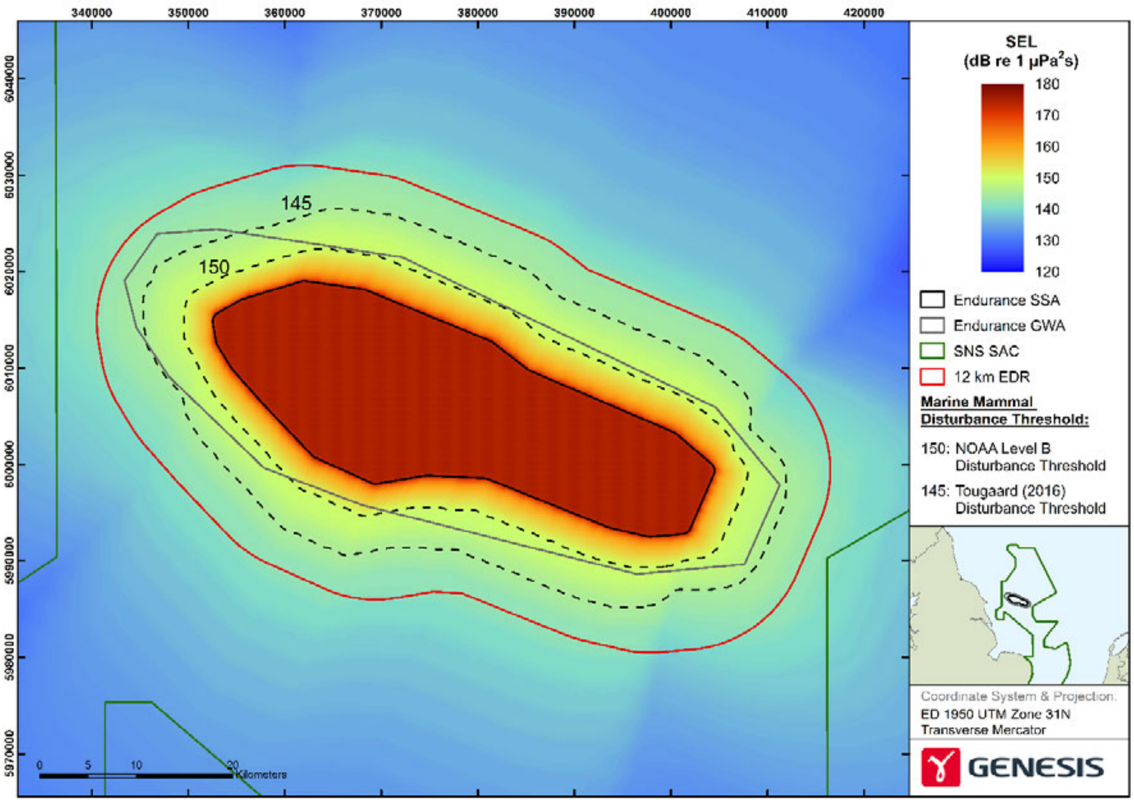

Figure 7-2 - Predicted unweighted single pulse SEL over duration of the survey (Genesis, 2022)

The 12 km EDR would equate to 7.86%[193] of the SAC impacted on a single given day and 2.41%[194] impacted over a season. As the seismic survey will be transient, with the survey vessel covering several kilometres per day at least, it is important to consider the maximum area to be surveyed in a day in association with the EDR, both over a single day and over the season. The area to be surveyed by each survey during the life cycle of the Development is currently not known. However, a review of recent HRAs and AAs conducted by BEIS (now DESNZ) was undertaken to provide a comparison to the surveys planned for the Endurance Store over the Development life cycle.

A recent survey undertaken by bp, as operator of NEP, at the Endurance Store area was the subject of a HRA by BEIS (now DESNZ) (2022b). Similar airguns were used in the survey detailed in BEIS (now DESNZ) (2022b), as modelled in the underwater sound assessment in Appendix J (i.e. 19000 LXT airguns). In addition, the sound pressure (SPL (peak to peak)) quoted in BEIS (now DESNZ) (2022b) is similar to the one assessed in this Chapter (see Section 7.4.1). As the size of the survey area has not yet been defined, it has been assumed, from the purpose of this assessment, that the survey area reported in BEIS (now DESNZ) (2022b) and the findings are applicable to this assessment. BEIS (now DESNZ) (2022b) assessed the area in which harbour porpoise could experience disturbance using the daily and seasonal threshold, with the following assumptions/areas:

- 3 survey lines of 41 to 78 km will be surveyed per day, equating to an area of 2,190 km^2 assuming a 12 km EDR; and
- The survey will last up to 92 days, during which airguns would be used for 64 days.

It was concluded that the maximum area of daily impact from the survey on the seasonal on the daily threshold represented 8.1% of the SAC, with up to 1,945 harbour porpoise potentially experiencing disturbance, so 0.56% of the North Sea MMMU. Based on the seasonal threshold, it was concluded the survey represented between 2.9% and 4.2% of the SAC during the summer period (BEIS, 2022b).

Both the modelling results and the JNCC (2020a) EDR methodology suggest that the seismic surveys associated with the Development on their own will not result in impact areas being above the thresholds suggested by the JNCC (2020a) guidelines. Similarly, the AA assessment undertaken by BEIS (now DESNZ) (2022b) for a recent bp survey at the Store concluded that the operations were not affecting the Conservation Objectives of the SAC and did not result in LSE.

However, the thresholds could potentially be exceeded if other activities occur in the area at the same time as seismic survey. An assessment of cumulative impacts has been undertaken in Section 7.7; projects within 50 km of the Development were considered and the potential for cumulative impacts was considered to be minor. This conclusion is believed to be applicable and similar to each of the six surveys bp, as operator of NEP, is planning to undertake over the life cycle of the Development.

[193] *The percentage of the SNS SAC 'Summer Area' impacted has been calculated based on the predicted disturbance areas for each disturbance threshold and an area of 27,028 km^2 for the SNS SAC 'Summer Area' as per the JNCC (2020a) guidance.*

[194] *The average percentage of the SNS SAC impacted over the season (183 days) has been calculated assuming that the airgun array will be operational for 56 days and the percentage of the SAC impacted will be the same for each day of seismic operation. For example, for the 12 km EDR disturbance threshold, the average percentage of SNS SAC impacted over the season is calculated as 7.86*56/183 = 2.41%.*

Prey availability

Fish species are not a qualifying features of the SNS SAC (JNCC, 2019); however they are the main prey for harbour porpoise and it is therefore important to understand potential impacts to these species to assess potential impacts on the SAC's integrity.

There is the potential for the prey species of harbour porpoise (fish) to be impacted by underwater sound, as considered in the underwater sound modelling study (Section 7.5) and in this Chapter. As discussed in Section 7.5.2, injury impacts on fish species resulting from underwater sound generated by activity associated with the Development are highly localised and will not result in an impact at population level. Piling activities will be of short duration and the seismic survey vessel will be constantly moving. Fish eggs and larvae will not be able to move away from the piling location or the airgun array and will therefore be more susceptible to injury. It is unlikely that fish will be displaced from the Development area during either piling or seismic activities. Given the small predicted areas where fish eggs and larvae may suffer damage, relative to the large spawning areas across the North Sea, it is not expected that the piling or seismic survey will have a significant effect on spawning fish. In addition, BEIS (now DESNZ) (2022b) also concluded that impacts on fish from seismic surveys indicate that the disturbance would be localised and temporary and that any impacts would be inconsequential.

Any impacts on prey availability are therefore considered to be very limited and would not result in a LSE or affect the Conservation Objectives of the SAC.

7.10 European Protected Species

All cetaceans (whales and dolphins) are designated as EPS. According to the Offshore Marine Habitats and Species Regulations 2017 (as amended) and The Conservation of Habitats and Species Regulations 2017, it is an offence to:

- Deliberately capture, injure or kill any wild animal of a EPS; or
- Deliberately disturb wild animals of a EPS in such a way as to:
    - Impair their ability to migrate, hibernate, survive, breed, or rear or nurture their young; or
    - Significantly affect the local distribution or abundance of the species to which they belong.

According to the regulations, an assessment of the potential to injure and disturb such species must be undertaken for impacts relating to physical presence, in order to determine whether a EPS licence to conduct the operations is necessary. Whilst the injury offence is related to acts against one or more animals, the disturbance offence is related to disturbance of a significant group of EPS. An EPS licence is required for any activity that might result in injury to, or disturbance of, an EPS.

As discussed in Sections 7.5 and 7.6, bp, as operator of NEP, will adopt embedded mitigation measures that includes both a soft-start and a monitoring zone of 500 m, whereby piling and operation of airguns would not occur if marine mammals were in such a zone. With the implementation of these measures, there will be no animals within 500 m of the piling and seismic activities at start-up. Given that the maximum injury range for piling with soft-start is 360 m (cumulative SEL with soft-start for HF cetaceans for HDD trestle piling at Humber) and 150 m for seismic activities (zero-to-peak SPL for HF cetaceans), the potential for injury of marine mammals from piling is effectively mitigated by the implementation of a 500 m monitoring zone.

Disturbance from piling and seismic activities has also been assessed in this Chapter. The potential impact zone and short and discrete periods of piling and surveying indicated that these activities would not represent a barrier to wider, regional movements of marine mammals. In addition, only a small number of individual animals (<0.2% of the population for the majority of species) would have the potential to exhibit some form of change in behaviour for the period in which they encounter sound from the different operations and there would be no residual impact at the population level. A slightly higher percentage of harbour porpoise population may be impacted; however, this remains at < 1.5%, even when using the worst case assumption (unlikely to occur) that the entire area is ensonified simultaneously. Consequently, no impacts at population level are expected. The proposed operations are therefore unlikely to significantly affect marine mammal populations or lower their reproductive capacity or survivability.

There is considered to be no potential for significant impact to EPS in terms of injury or disturbance during the Development. As such, it is not considered that an EPS licence will be required for piling operations or seismic operations. Piling operations are discrete events and the conclusion of the assessment presented in this Chapter was that impacts on individuals and at population level would be limited. The assessment conducted for the seismic surveys also concluded that impacts at population level would be limited. However, each survey could last up to 75 days (including downtime) in total. Each seismic survey during the Development life cycle will be subject to a Consent to Undertake a Geophysical Survey Subsidiary Application Template (SAT) submitted to OPRED. Project-specific sound modelling will be undertaken based on the equipment to be used and based on the planned operational duration. Careful consideration will be given at the time of the SAT application to assess potential impacts to the SNS SAC and to EPS in terms of injury and disturbance.

7.11 Residual Impacts

The information below presents the anticipated residual impacts as a result of the underwater sound generated from activities associated with the Development only, following the implementation of the embedded mitigation measures outlined in Section 7.6.

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Harbour porpoise	High	Medium	High	Low
Marine mammals (excluding harbour porpoise)	High	Low	High	Low
Fish	Low	Low	Medium	Low
Rationale				
Considering the information available on the species and species groups that will use the Development area, it is considered that there is some tolerance to accommodate the anticipated underwater sound generated, with an ability to adapt or recover.				

The sound modelling results of piling activity demonstrated that the potential for injury from the Development activities only was limited to a small area and that impacts to marine mammals (at individuals and population levels) would be limited. Mitigation implemented includes a 500 m monitoring zone and a soft-start procedure. Disturbance from piling was also assessed.

A similar assessment was undertaken for seismic surveys as part of the life cycle of the Development, alone. The assessment concluded that injury was unlikely to occur and is anticipated to be mitigated by the implementation of a 500 m monitoring zone. Disturbance was assessed over a day and over the entire survey duration. The assessment concluded that a small percentage of marine mammals will be disturbed by the survey, based on a worst case assumption that the entire zone assessed would be ensonified.

Harbour porpoise are a designated protected feature of the SNS SAC, in which the Development is located. As such, sensitivity and value has been defined as **high** for this species. It is recognised that whilst there may be temporary effects on behaviours (as demonstrated by the underwater sound modelling and subsequent assessment of impact summarised above), there is not expected to be a change as a result of the proposed activities in the long-term functioning or status of any populations to which they belong. As such vulnerability has been listed as **medium** for harbour porpoise. Value is defined as **high** for all marine mammals, on the basis they are designated a degree of protection through the Offshore Petroleum Activities (Conservation Habitats) Regulations 2001 (as amended), Conservation of Offshore Marine Habitats and Species Regulations 2017 (as amended) and The Conservation of Habitats and Species Regulations 2017 (as amended). Following implementation of best practice, it is considered that the magnitude of impact is **low**.

Sound modelling was also undertaken for fish species, which considered that injury would be temporary and highly localised. Disturbance is likely to occur over a slightly greater area range, however this is not likely to impact fish species at population level. Value for fish species is defined as **medium** from an ecological perspective, as some species are the main prey of marine mammals. Finally, as demonstrated by the sound modelling, the extent of change will be localised in scale and time, and in many cases of very limited frequency. Consequently, magnitude is defined as **low** for all fish species.

An assessment was also undertaken for the SNS SAC, in which the Development is located. It was concluded that the disturbance thresholds over a day and over a season as per JNCC (2020a) were not exceeded, meaning that any impacts are not significant and that the operations (piling and seismic survey) are unlikely to result in LSE.ng the assessment undertaken above and the embedded mitigation measures which will be implemented as per JNCC protocols (JNCC, 2010; JNCC, 2017a), the consequence is **minor** and the residual impact of underwater sound generated by the Development is assessed to be **not significant.**

Consequence	Impact significance
Minor	Not Significant

8 DISCHARGES TO SEA AND FORMATION WATER DISPLACEMENT

8.1 Introduction

This Chapter identifies and quantifies the discharges to sea and Outcrop Formation Water displacement associated with the Development. It describes the management and mitigation measures employed to adhere to legislation and achieve bp's environmental standards, as operator of NEP. The potential impacts are assessed for discharges during drilling, installation, commissioning, operation and decommissioning of the Development as well assessing the potential impacts from Outcrop Formation Water[195] displacement.

The following specialists have contributed to this assessment:

- Xodus Group – baseline description, impact assessment and ES chapter

Table 8-1 provides a list of the supporting studies that have been used to inform the discharges to sea and Outcrop Formation Water displacement impact assessment.

Table 8-1 – Supporting studies

Specialist	Details of study
Xodus Group	Pipeline dewatering study to gain an understanding of chemical concentrations being discharged into the environment and to understand what areas of the marine environment the discharge could interact with.
Xodus Group	Drill cuttings dispersion modelling, to assist in predicting the fate and impacts of cuttings discharged to the seabed from the drilling process.
bp	CFD modelling to analyse the dispersion and dilution of displaced Outcrop Formation Water at the seabed and in the water column.
bp	Geochemical modelling to assess the transport and sequestration of certain chemical species during Outcrop Formation Water displacement
bp	Bunter Sandstone Outcrop borehole sampling and analysis campaign (Table 4-1).
Pacific EcoRisk	Chronic Toxicity of NEP Sandstone Outcrop Formation Water to *Skelotonema costatum* and *Cyprinodon variegatus*
EcoAnalysts Inc.	*Americamysis bahia* Acute Toxicity Test
EcoAnalysts Inc.	Oyster (*Crassostrea gigas*) Larval Development Test
EcoAnalysts Inc.	Echinoderm (*Dendraster excentricus*) Larval Development Test

195 *In this chapter, references to Formation Water relate only to the Outcrop Formation Water.*

8.2 Regulatory Controls

In addition to the EIA regulations detailed in Section 1.5, there are other requirements of UK legislation, international treaties and agreements relevant to the assessment of discharges to sea.

The key regulatory controls that relate to the activities described in this section and which will assist in reducing potential impacts are summarised below:

- *Offshore Chemicals Regulations 2002* (as amended): The Oslo and Paris Convention (OSPAR) Decision relating to the Harmonised Mandatory Control System for the use and discharge of offshore chemicals is implemented on the UKCS by the Department under the OCR. Under these Regulations, Operators require permits to use and discharge chemicals;
- *Merchant Shipping (Prevention of Oil Pollution) Regulations 1996* (as amended): The Regulations implement MARPOL Annex 1 in the UK and control oily discharges from any vessel activity including machinery space drainage. The Regulations require all vessels to have in place a UK or International Oil Pollution Prevention Certificate to demonstrate compliance; and
- *The Merchant Shipping (Prevention of Pollution by Sewage and Garbage from Ships) Regulations 2008*: The Regulations implement MARPOL Annex IV in the UK and control sewage discharges from any vessel or ship. The Regulations control sewage treatment and discharge and apply to ships and fixed and floating platforms of 400 gross tonnage and above, and to smaller ships that are certified to carry more than 15 personnel. As such, these Regulations will apply to the majority of vessels associated with the Development.

8.3 Assumptions and Data Gaps

8.3.1 Assumptions

In order to ensure that the assessment of discharges to sea and Outcrop Formation Water displacement reflects the worst case scenario, the following key assumptions have been made:

- Use/discharge volumes of cuttings, cement and other chemical are the likely maximum expected (and will be refined downwards where possible during design);
- The reasonable worst case toxicity values for chemical discharges and the worst case discharge rates have been used in the modelling studies;
- Although specific chemicals have been used for the modelling (i.e. pipeline modelling), final chemical selection will be subject to assessment and appropriate permitting;
- The drill cuttings modelling was conducted during a calculated non-dispersive period using typical metocean data from October 2012. The modelled chemicals in the water column and seabed would be expected to dissipate at the minimum possible rate for the discharge to present the worst case scenario;
- The Development is expected to be operational for 25 years;
- Formation Water displacement:
    - Formation Water displacement will occur at the Bunter Sandstone Outcrop;
    - The Bunter Sandstone Outcrop, approximately 25 km east of where CO_2 injection will occur, is an expanse of up to 1.4 km^2 of bedrock exposed to the seabed. At this location, the Bunter Sandstone Formation has been folded up, over a geological timescale, causing an underlying geological intrusion to occur at the seabed (the Bunter Sandstone Outcrop);

  - The displacement of Formation Water will occur from the upper 140 m of the Bunter Sandstone Formation. It is expected that pressurisation of the Formation Water at the outcrop will first occur four years after first CO_2 injection. The maximum displacement of Formation Water will be a worst case < 1,600 m^3 per day; and
- The following assumptions were made for the supporting studies (see Table 8-1) with regards to Formation Water displacement:
  - Computational Fluid Dynamics (CFD) modelling a displacement of 1,590 m^3 per day. A salinity of 90,000 ppm was used in the model (1.0605 g/cm³ at 15°C) which represents the salinity in the upper section of the sandstone at the Bunter Sandstone Outcrop. The water temperature was assumed to be that of seawater given the assumption that the outcrop is in equilibrium with seawater. The seabed area from which displacement occurs was defined by White Rose (2016).

8.3.2 Data Gaps

The following data gap has been identified:

- The volumes of pipeline chemicals to be discharged have not been confirmed; however, a worst case has been assumed in the modelling.

8.4 Description and Quantification of Potential Impacts

There will be discharges of drilling muds, cuttings, cementing and completion chemicals from the proposed drilling operations. Following installation of the pipeline(s), a number of discharges will occur as part of pre-commissioning testing. In addition, Formation Water is predicted to be displaced at the Bunter Sandstone Outcrop from the Bunter Sandstone Formation from four years after first CO_2 injection. These discharges may lead to potential impacts to the seabed or water column through the following mechanisms:

- Increased suspended solids in the water column;
- Settlement of cuttings and muds on the seabed that may:
  - Alter the seabed topography and habitat due to the introduction of different grain sizes, which can affect oxygen movement within the sediment;
  - Smother the benthic organisms where deposition is high;
  - Impair the feeding and respiratory systems of benthic organisms due to deposition of fine particles and increased concentrations of suspended particles near the seabed;
- Potential toxic impacts from the muds and chemical additives;
- Increase in salinity and temperature following displacement of Formation Water; and
- Potential toxic impacts to the seabed and the water column from the Formation Water displaced.

8.4.1 Drilling Discharges

8.4.1.1 Drilling Programme Overview

As outlined in Section 3.3, the Development will include the drilling of six wells, comprising five CO_2 injection wells (EC0 – EC05) and one monitoring well (EM01). The rig used to drill the wells will be re-located between the drilling of each well. The six wells are of identical design and it is anticipated that it will take about 63 days to drill each well.

The overall target depth for each well is between 1,300 m and 1,500 m TVDss. Drilling mud will be used to lubricate the drill mechanism and bring rock cuttings to the surface. The first two sections of each well (36” and 17½”) will be drilled using WBM fluids with the fluids and cuttings being discharged at the seabed. The deeper sections (12¼” and 8½”) will be drilled with LTOBM with fluid and cuttings skipped and shipped to shore for disposal.

An estimate of the cuttings and WBM that will be generated/used and subsequently discharged to sea is presented in Table 8-2. This table also presents the quantity of LTOBM that will be generated, treated and shipped to shore.

Table 8-2 - Estimate of cuttings generated per well, WBM discharged and LTOBM shipped to shore

Section	Discharge point	Cuttings generated (t)	WBM discharge (bbl)	LTOBM shipped to shore (bbl)
36”	Seabed	293	1,749	0
17½”	Seabed	203	3,561	0
12¼”	Shipped to shore	126	0	3,142
8½”	Shipped to shore	40	0	2,568
Total discharged to sea		496	5,310	0
Total shipped to shore		166	0	5,710
Overall total		662	5,310	5,710

Using the tonnages of drilling mud components and cuttings calculated for a typical well, estimated quantities for all six wells have been calculated and are shown in Table 8-3.

Table 8-3 - Total estimated quantities of cuttings and mud for the six wells

Number of wells	Cuttings Discharged to Sea (t)	Cuttings shipped to shore (t)	WBM discharged (bbl)	LTOBM Shipped to Shore (bbl)
6	2,976	996	31,860	34,260

Drilling chemicals are used to maintain the desired technical composition of the mud to facilitate the drilling of the well. Chemicals for offshore use are approved by Cefas and categorised by applying the Offshore Chemical Notification Scheme (OCNS) ranking scheme based on aquatic and sediment toxicity, biodegradability and bioaccumulation potential. Depending on which method of categorisation has been used, chemicals are assigned a letter (potential for environmental impact ranging from A (highest) to E (lowest) or a colour code (Purple representing the highest threat to the environment and Gold the lowest threat)). The majority of the chemicals likely to be used during drilling activities are categorised as PLONOR, OCNS E rated or Hazard Quotient (HQ) Gold. The detail of the actual chemicals to be used or discharged and their quantities will be the subject of future permit applications.

8.4.1.2 Cementing

Each steel casing is cemented into place to provide a structural bond and an effective seal between the casing and surrounding formation. The conductor and casing for the 36" and 17½" sections will be cemented in place with cement returns occurring to the seabed. It is anticipated that the majority of the cementing material will remain downhole with small operational discharges to the environment only occurring when the cement unit is cleaned between each cementing operation. The likely worst case discharge, from all sections collectively, would be approximately 150 bbl (24 m^3) per well. For all six wells this would mean a worst case discharge of 900 bbl (144 m^3) in total.

All chemicals to be used within the cement will be selected based on their technical specifications and environmental performance. Chemicals with substitution warnings (those chemicals that contain hazardous substances to the marine environment and their use and/or discharge selected for phase-out) will be avoided where technically possible.

8.4.1.3 Completion Chemicals

The wellbore clean-up and completion operations will require large volumes of completion fluid. During completion operations, when the wells are made ready for injection to commence, it is expected completion fluids will be used to displace the LTOBM remaining in the well. This will allow the drill mud remaining in the annulus to be displaced which will be returned to the drilling rig, retained and shipped to shore for treatment and disposal. As well as the drill mud, any LTOBM contaminated completion fluids will also be recovered to the rig, retained and shipped to shore for treatment and disposal.

At the time of completion, up to 6,000 bbl (954 m^3) of inhibited, 2,000 ppm sodium chloride Formation Water or equivalent will be injected per well to mitigate against the loss of CO_2 injectivity which can occur when CO_2 contacts the saline Formation Water, the solution dehydrates, and salt can be precipitated. The water will dilute the Formation Water and eliminate the potential for halite formation near the injection well. N_2 will also be used to mitigate against hydrate precipitation.

8.4.2 Behaviour of Drill Cuttings at Sea

8.4.2.1 Modelling Overview

An assessment of the potential impacts from the drilling of six wells of the same design was conducted to inform this EIA application with the aid of the Norwegian Independent Research Organisation (SINTEF) Dose Related and Effect Assessment Model (DREAM) ParTrack model. The parameters used to undertake the modelling are briefly described here to provide some context to the findings and their relevance to the realistic drilling scenario.

Whilst the results of modelling cannot be directly substituted for observed impacts occurring during an actual drilling situation, modelling is a useful tool to help assess the risk of potential impacts. This modelling represents the worst case potential scenario from the proposed drilling activities.

Modelling was carried out for each of the six wells proposed in order to simulate the sequential aspects of the discharges and how the environmental impacts are likely to change as the six wells are drilled. A single well and 6 well discharge scenarios were modelled whereby the wells consisted of four vertical sections of which 2 were discharged at the seabed and two skipped and shipped to shore. It was assumed all wells were of the same design. Four definitive model runs were conducted as follows:

- Near-field model run of a single well (EC01):
  - Low resolution far-field model run to assess water column impacts and to identify the area for higher resolution modelling (50 m grid cell size, 20 km x 20 km extent);
  - High resolution near-field model to assess mud and cuttings accumulation and sediment impacts close to the discharge location (10 m grid cell size, 2 km x 2 km extent).
- Far-field model run of the six wells (EC01-EC05; EM01):
  - Low resolution far-field model run to assess water column impacts and to identify the area for higher resolution modelling (200 m grid cell size, 130 km x 130 km extent);
  - High resolution near-field model to assess mud and cuttings accumulation and sediment impacts close to the discharge location (50 m grid cell size, 15 km x 15 km extent).

The selection of the model grid size will have an impact on the resolution of the result generated from the model; model grids are therefore selected to provide the output required for the different elements of the study being conducted. The modelled discharge occurred over 1.1 days. However, the model was run for 30 days to monitor the dispersion of chemicals and suspended particles and resultant risk.

For the single well scenario, the lateral extent of the section of the water column that was predicted to have an impact risk on more than 5% of species present extends to a maximum of 5.25 km to the north of the release site, near the seabed. As generally expected with drilling programmes, the water column impact is very transitory, with much of the risk in the water column occurring between days 2 and 5 after drilling begins with rapid dissipation after this until the risk falls below 5% at day 6, there is no risk occurring by day 12.

The modelling of six wells shows the lateral extent of the section of the water column predicted to have an impact risk on more than 5% of species present extends to a maximum of 5.7 km to the north of the release sites and 3.1 km east, near the seabed. The majority of the risk in the water column occurs between days 2 and 7 after drilling begins. The risk is shown to dissipate rapidly after this where the risk falls below 5% at day 9, and after day 19 the risk returns to zero.

Further details are provided in Section 8.4.2.2 below.

8.4.2.2 Environmental Impact Factor (EIF)

EIFs are used to assist in the assessment of potential environmental impact. They are a relative numerical measure of risk to the biota in the marine environment calculated by the ParTrack model. They are calculated using the PEC/PNEC approach (where the predicted environmental concentration (PEC) of a contaminant is divided by the predicted no effect concentration (PNEC): the highest concentration at which no environmental effect is predicted). A ratio of > 1 indicates there may be an environmental effect.

The PNEC values within the ParTrack model are the estimated highest concentrations at which toxic effects are not expected. The PNEC value for each substance is defined by laboratory ecotoxicity tests on a number of species divided by an assessment factor determined by the Regulator in order to produce a value that is considered to be protective of all but the most sensitive 5% of species. This approach is internationally accepted in the regulatory assessment of chemicals. SINTEF has further adapted this methodology by using experimental data to calculate pseudo-PNECs for non-toxic stressors. The stressors are therefore not limited to chemical toxicity, but also include other stressors such as physical changes in sediment particle size, smothering/burial that are correlated with environmental impacts.

The PEC for each contaminant is determined within the model using a number of calculations to simulate the behaviour of contaminants in the water column. Processes including dilution, partitioning, degradation and deposition into the sediment are simulated in order to generate a PEC for each contaminant over time. EIFs for the sediment are more complex, incorporating toxicity of contaminants, but also processes such as oxygen depletion, change in median grain size and burial effects. For drilling discharges, chemical stress and particle stress in the water column are modelled in the water column EIF approach.

The basis for the calculation of the EIF within the model is that the entire water volume in the modelled area is split into compartments measuring 100 m x 100 m x 10 m (0.0001 km^3). Each compartment where the PEC/PNEC ratio is > 1 contributes a value of 1 to the water EIF[196].

Sediment EIFs are calculated based on area rather than volume. The sediment is divided into compartments measuring 100 m x 100 m (1 ha or 0.01 km^2). Each compartment where the PEC/PNEC ratio is >1 contributes a value of 1 to the sediment EIF. Due to the areas of impact modelled, the cuttings piles are not predicted to result in a sediment EIF and therefore no impact is predicted to the seabed by the model as detailed below. A number of stressors are modelled for the sediment EIF, such as chemical stress, oxygen depletion, burial effects and median grain size change.

The EIFs generated for the Development's drilling discharges are discussed in the following sections.

8.4.2.2.1 Potential Seabed Impact

Burial of benthic organisms may result in their mortality depending on the depth of cuttings deposition. Filter feeding organisms (for example hydroids and bryozoans) that rely on suspended particles as a source of food may be more vulnerable to the potential smothering impacts of the drilling discharges than deposit-feeding organisms that rely on the deposition of suspended material. The more mobile species (infauna and epifauna) may be able to avoid unfavourable conditions, and to work their way back through the cuttings to the surface (see review in Trannum *et al.*, 2010).

Effects of WBM cuttings deposited at the seabed on benthos are caused mainly by burial, changes in sediment texture, and low sediment oxygen concentrations caused by microbial degradation of organic matter (Schaanning *et al.*, 2008; Trannum *et al.*, 2010, 2011a, b). WBM cuttings are usually non-toxic, although toxic effects may arise from by-products of organic enrichment.

After deposition, the particulate material would be subject to re-distribution through the action of seabed currents. As discussed in Section 4.3, the sedimentary environment in the vicinity of the Development is relatively dynamic and subject to natural fluctuations in sedimentation rates. Field monitoring studies carried out at single well sites before and after drilling in a range of locations around the world where WBM cuttings have been discharged generally indicate immediate impacts

[196] *As this method converts ratios to probabilities, probability theory may be used to sum the impact of multiple stressors into a final result.*

to sediment and fauna within a radius of approximately 150 m (e.g. reviews by Neff, 2005; Ellis *et al.*, 2012a; IOGP, 2016).

It is anticipated that recovery of the seabed will start immediately following cessation of drilling due to re-colonisation of smothered sediments, as species move back into the disturbed area from adjacent undisturbed sediments and via recruitment from the plankton. Ecological recovery is often well advanced within a year, particularly in energetic environments (e.g. Daan and Mulder, 1996; Currie and Isaacs, 2005; IOGP, 2016). It has also been found that older developments in the SNS typically have little in the way of cuttings accumulations due to the shallow water depths and increased sediment redistribution energy at the seabed (e.g. Breuer *et al.*, 2004).

The roughly oval-shaped cuttings pile resulting from the discharges from all six wells is aligned north-northeast to the southeast. The cuttings pile thickness rapidly decreases with distance from the drill centre. Wider scale deposition of small amounts of finer material is also predicted in the low resolution modelling; however, the amount of material deposited is very small and spread over a very large area, such that it would not be easily detectable or cause significant impact in the marine environment.

This ties in with the published literature discussed above in that the main impact to the seabed is likely to be small and concentrated within a 100 to 150 m radius of the drilling site (refer to Figure 8-4). While significant recovery is expected to take place within a year or so of cessation of drilling (including, potentially the redistribution and disappearance of much of the cuttings' pile), full recovery may take longer.

Modelling scenarios for both a single well and for all six wells is detailed below for information.

Single Well Modelling

The modelled thickness of the deposited drilling mud is presented in Figure 8-1 and Figure 8-2 in both plan and section view, respectively. The modelled cuttings pile at the well is predicted to have a maximum thickness of 1,215 mm rapidly decreasing as the distance from the well increases such that, within 10 m of a wellbore the sediment thickness has decreased to approximately 20 mm and within 50 m it has decreased to less than 1 mm. The thickest area of the mud and cuttings was predicted to be formed to the immediate west of the drilling location. The predicted EIF for the cuttings pile was predicted to be zero.

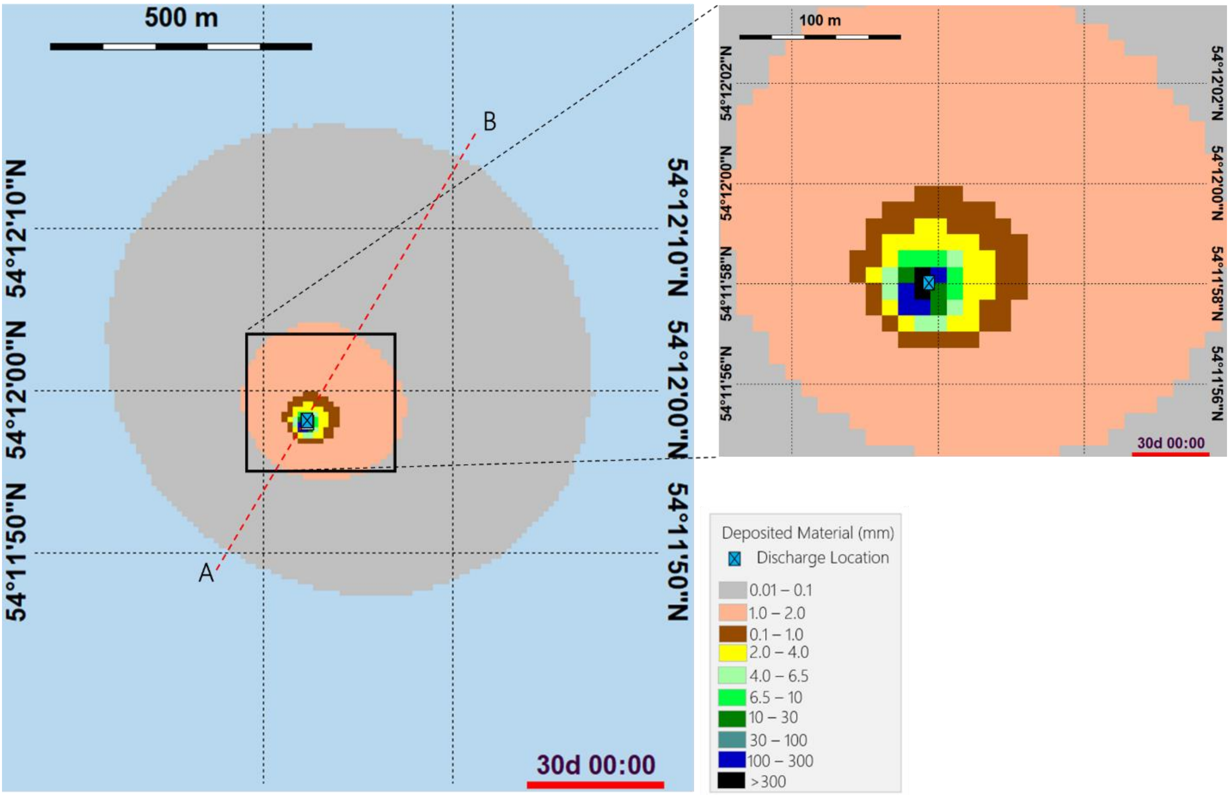

Figure 8-1 - Modelled cuttings accumulation on the seabed from a single well (Well EC01)

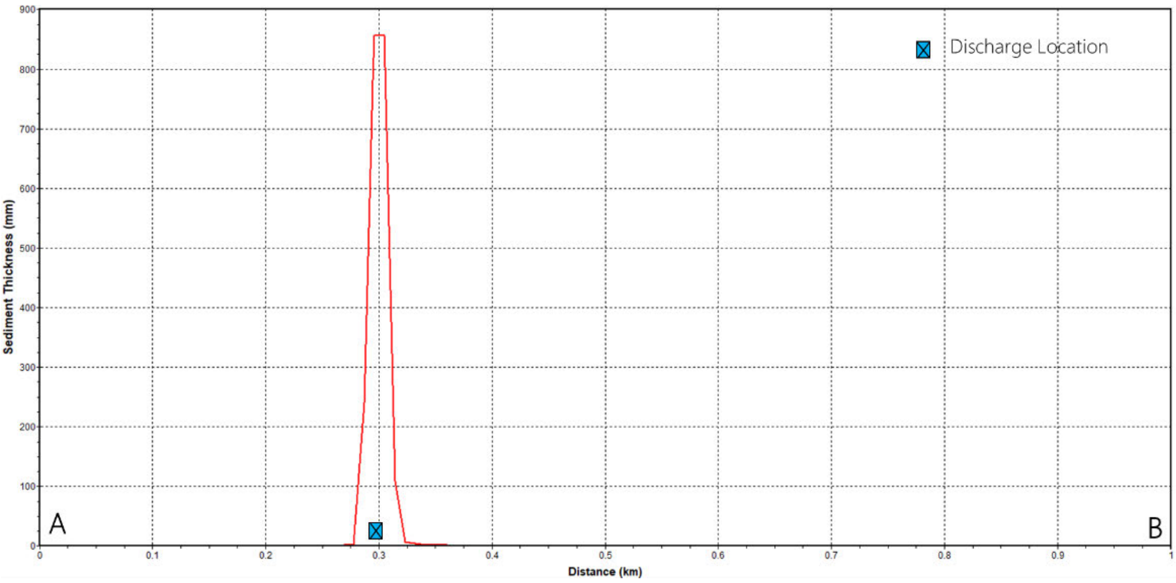

Figure 8-2 - Sediment thickness on the seabed along transect A-B[197]

Six Wells Modelling

The modelled thickness of the deposited drilling mud is presented in Figure 8-3 and Figure 8-4, in both plan and section view. The modelled cuttings pile at the six wells is predicted to have a maximum thickness of 200 mm for any single well of the six wells modelled. This rapidly decreasing as the

[197] *Note: the Transect A-B does not go through the thickest part of the cuttings pile; however it represents a likely transect.*

distance from the well increases such that, within 50 m the thickness decreases to less than 0.6 mm. Maximum depths of the drill mud and cuttings piles for the six wells are as follows: EC011: 114 mm; EC02: 122 mm; EC03: 119 mm; EC04 :117 mm; EC05: 200 mm; EM01: 122 mm. The thickest area of the mud and cuttings pile was predicted to be predominantly formed to the immediate west of each drilling location. There was no overlap predicted for the individual cuttings piles as the drill centre locations are well separated from one another.

It should be noted, as discussed previously, that the DREAM cuttings modelling for the discharge from six wells has been undertaken as a far-field scenario, with a 50 m grid cell size. Modelling for the one well scenario identified that thickness of the cuttings deposit reduced rapidly from 1,215 mm at the well to approximately 20 mm within 10 m. Therefore, the reduced cuttings depth predicted for the six wells scenario is linked to the grid resolution, as the same cuttings thickness behaviour is expected (i.e. a quick reduction within 10 m). Using the worst case thickness modelled during the one well scenario (see Section above) of 1,215 mm, there will still be no overlap between the cuttings piles of the six wells. The direction of the wider-scale deposition of sediment is dominated by prevailing currents to the southwest and west at levels that are not easily detectable in the environment. Therefore, any potential seabed impacts are likely to remain localised.

There was no predicted interaction between the 6 cuttings piles modelled due to the relative positions and distance. Therefore, the model predicts the EIF to be zero immediately after drilling has ceased as the individual wells have an EIF of zero.

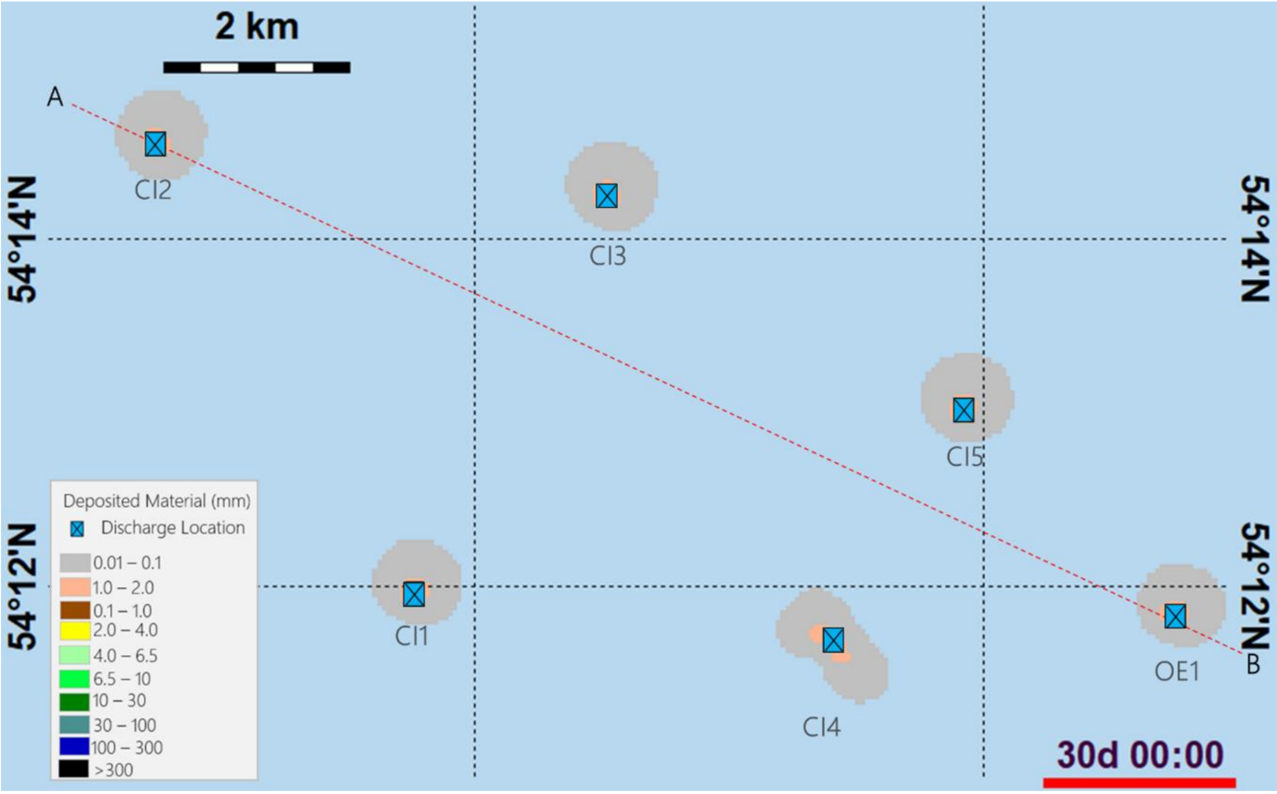

Figure 8-3 - Modelled cuttings accumulation on the seabed from six wells

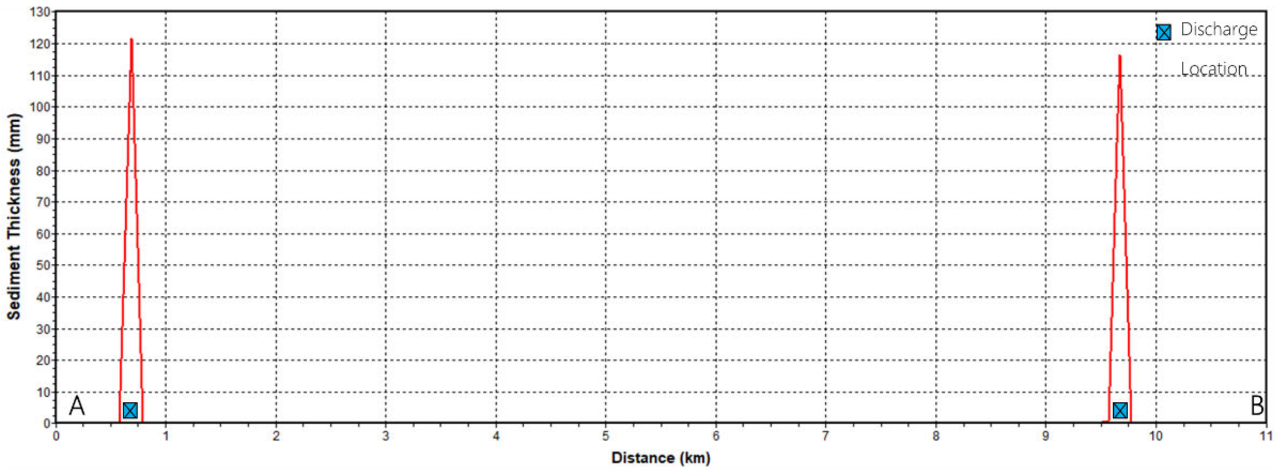

Figure 8-4 - Sediment thickness on the seabed along transect A-B

8.4.2.2.2 Potential Water Column Impact

Both the physical and chemical impacts of drilling discharges in the sea can also result in potential impacts to the water column. Discharges to the water column have the potential to affect fish, planktonic organisms and organisms living at or near the seabed. Organisms affected could experience interference with feeding, respiration and migration due to increased concentrations of suspended particles near the seabed and in the water column.

Increased suspended solids, especially near the seabed, may result in direct irritation to certain types of marine organisms, abrading protective mucous coatings and increasing their susceptibility to parasites and infections, as well as affecting growth, reproduction and feeding.

The development of the water column EIF over time are presented in Figure 8-5 for one well and Figure 8-6 for six wells. These figures shows that the water column impact (EIF) from the drilling is transient, lasting for around five to six days for each well as a worst case (collectively 8 to 9 days).

The one well scenario results predicted that impacts to the water column were predicted on more than 5% of species present within a maximum of 5.25 km to the north of the release site, near the seabed. The impacts were however considered to be very transitory, with much of the risk in the water column occurring between days 2 and 5 after drilling begins with rapid dissipation after this until there the risk falls below 5% at day 6 (left diagram in Figure 8-5). The water column EIF (right diagram in Figure 8-5) peaked on day 3 of the model run at 5,607, returning to 0 after day 6. This highlights that the impacts would be of short-duration.

During the six wells scenario, the lateral extent of the section of the water column predicted to have an impact risk on more than 5% of species present extends to a maximum of 5.7 km to the north of the release sites and 3.1 km east, near the seabed. Most risks were expected to occur between days 2 and 7 after drilling begins, and then falling rapidly to 0 by day 19. The maximum EIF was 31,002 and returns to 0 by day 9. On this multiple wells scenario, the impacts were therefore also transitory.

The high EIF obtained during both scenarios (5,607 and 31,002 for the one and six wells scenarios respectively) is highly linked to the use of biocide in the drilling mud. The right diagram in Figure 8-5 and Figure 8-6 highlights that the contribution of biocide to the EIF was 67% and 60%. Biocides are a common additive of WBM muds as a bactericide. Due to their nature, biocides are inherently toxic, as this is necessary for it to function. While the specific biocide to be used during drilling operations it not currently known and will be subject of the appropriate permit applications, biocides in drilling muds are expected to be biodegradable and to not bioaccumulate. Any biocide within the WBM mix is expected to only represent a small proportion of the chemicals to be discharged as part of WBM drilling, and therefore impacts are expected to be limited. The other components affecting the EIF during drilling operations are bentonite and barite. As discussed in Section 3.3.4, barite and bentonite are PLONOR chemicals. Their contribution to the water column EIF is high, contributing to approximately 33% and 40% of the EIF (combined). Being PLONOR chemicals, this indicates that the predicted impact is predominantly due to particle stress caused by the discharge of fine clay particles in the drilling fluids rather than toxicity from the barite and bentonite. While the overall water column EIF is high for the drilling discharges, it is expected to be of short duration (up to 9 days) and the impacts are expected to be limited.

In the water column the model predicts the usual transitory high EIF that results from chemical and particle stress in the water column from the mud and cuttings components that remain suspended or dissolve in the water column for longer periods. The maximum EIF of 31,002 for the six well scenario predicts the worst case risk for the combined effect of all wells being drilled at the same time. In reality the wells will be drilled sequentially with the maximum EIF equating to that in the single well scenario of 5,607. Thus, there are likely to be six discrete spatial separated transient impacts through the drilling programme. Overall, the model predicts a small short-term impact on the water column, due mainly to particulates (barite and bentonite), that will be undetectable soon after drilling is complete.

Water column residual impacts relate to both the physical and chemical effects predominantly experienced by planktonic species. Considering the relatively limited area over which the water column is predicted to be affected by larger particles, drilling activity, as a result of the Development, is not considered to represent a significant residual impact to the water column. Residual impacts associated with the largest particles are considered to be temporary and short-term. Species are considered of low sensitivity, with recovery likely within 1 year of cessation of drilling activity. It is unlikely that there will be any significant residual impact from drilling discharges on zooplankton feeding, as these will generally be located higher in the water column. Residual mud will likely to be discharged overboard at the sea surface following completion of each well; however, it is expected that the volumes associated will be smaller than modelled and discussed in this Chapter. Residual impact on zooplankton and water column is therefore still considered to be not significant.

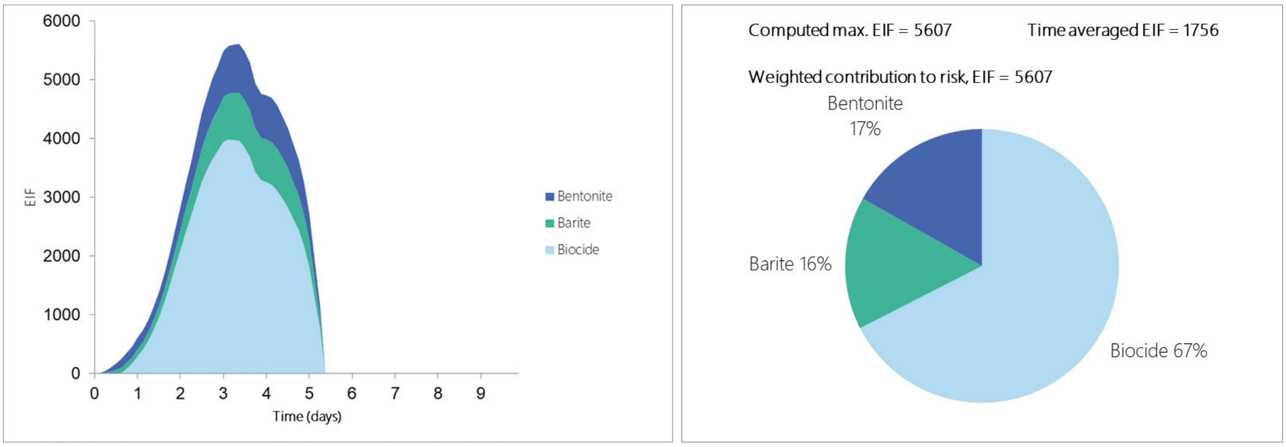

Figure 8-5 - Development of the water column impact in terms of EIF during drilling one well

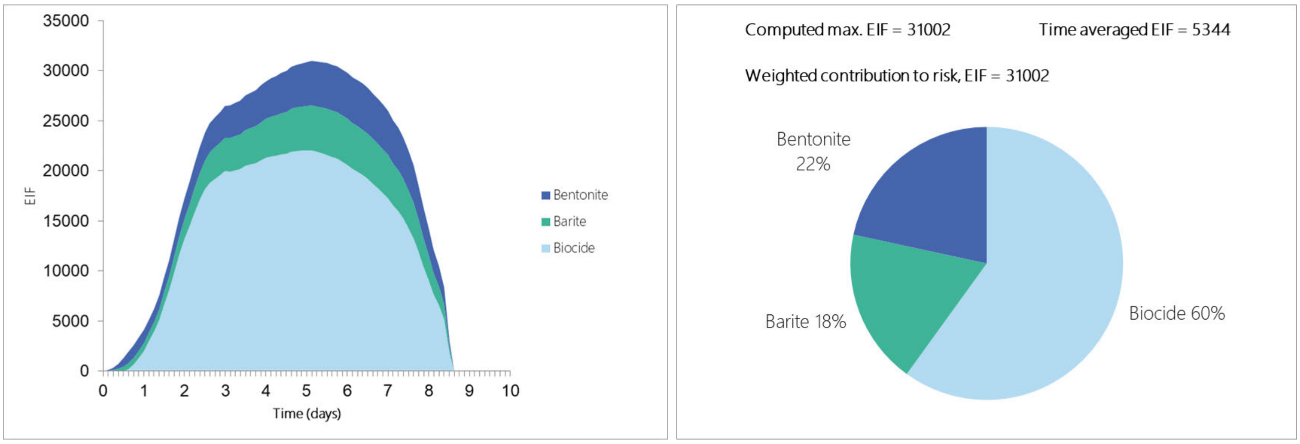

Figure 8-6 - Development of the water column impact in terms of EIF during drilling all six wells

8.4.3 Aqueous Discharges

As outlined in Chapter 3: Project description, conditioned and compressed CO_2 will be transported offshore via two new, concrete coated CO_2 export pipelines of 28" diameter. These two pipelines are referred to as the Teesside Pipeline and Humber Pipeline. The Teesside Pipeline will be approximately 145 km in length and the Humber Pipeline approximately 103 km in length.

After the pipelines have been installed, a series of pre-commissioning operations will be conducted which will result in discharges to the marine environment from the following:

- Flooding;
- Hydrotesting; and
- Dewatering.

Once installed, each pipeline will be flooded with filtered, chemically treated seawater and subsequently hydrotested to verify system integrity. Inhibited water is typically pumped into the pipeline (approximately 120% of line volume). The pressure of the system is then increased until the pressure has been established and a successful hold time and stabilisation period achieved. The test pressure will be held for 24 hours before the lines are depressurised, by discharging the extra volume of water to sea, at predetermined rates.

After hydrotesting, spools will be installed to tie each pipeline into the subsea structures (manifolds and SSIV). Once tied-in, the pipelines will be leak-tested following a similar procedure as hydrotesting, using filtered chemically treated seawater. Additional quantities of inhibited seawater will be pumped into each pipeline to establish leak test pressures and will be subsequently discharged to sea. Once fully installed and tested, the remaining volumes of inhibited seawater will be flushed out of each pipeline upstream of the first co-mingling manifold, in a process known as dewatering. Hydrotesting may be repeated to verify the pipeline integrity.

Alternatively, pipelines could be hydrotested after the spool pieces have been installed in a combined hydro/leak test, which would reduce the total volume of chemicals discharges to the environment (see Section 3.3.5).

The pipelines will be dewatered using MEG which will be driven through the pipeline in multiple slugs between dewatering pigs, driven by nitrogen gas from onshore. This will maximise the amount of water removed. MEG, a PLONOR substance, will be discharged out of each pipeline upstream of the first co-mingling manifold once it has travelled along the length of a pipeline. After the MEG has been discharged, the pipe will be filled with nitrogen gas. The pipelines may be brought into use immediately or there could be a period of preservation before injection of CO_2 commences, depending on the schedules of the contractors executing the scopes.

It should be noted that the subsea/wellhead trees will be hydraulically operated. As such, a small volume of hydraulic fluid will be discharged to sea at the seabed during testing and operations of the valves. In general, approximately 10 L of hydraulic fluid is discharged per valve actuation. As such, small discharges of hydraulic fluids are not considered further as they will be assessed in the relevant Chemical Permit SAT.

All chemicals used as part of the operations will be registered with CEFAS and applied for in the relevant Chemical Permit SAT.

8.4.3.1 Modelling Overview

An assessment of the dispersion of chemicals associated with the Teesside and Humber Pipelines pre-commissioning hydrotesting and dewatering was conducted by modelling the behaviour of the discharge in the environment with CORMIX 8.0 GTS (Mixzone Inc.). The CORMIX model uses the density and flow rate of the effluent and ambient environment, together with the geometry of the discharge port to estimate the movement and dilution of the discharge in the receiving environment. The CORMIX modelling is presented in Appendix L. Modelling was undertaken using current speeds in the range of 0.1 m/s to 1.4 m/s in 0.1 m/s increments.

Assessment of chemical concentrations in the plume from the CORMIX modelling outputs was based on the Chemical Hazard Assessment and Risk Management (CHARM) method of calculating PNEC, since this is the accepted methodology in the UK. Table 8-4 presents the products which were selected as representative products for use in this assessment as they have the same chemical functions as those that will be required during installation. The CORMIX modelling study is only considering the risk (PEC/PNEC) of each chemical separately and does not estimate the aggregated risk of all chemicals in the effluent discharge.

Table 8-4 - CEFAS chemical template data

	Hydrosure HD-5000	RX-5255	RX-5227[198]	RX-9022	MEG
Manufacturer	ChampionX (Champion Technologies Ltd),	Roemex	Roemex	Roemex	Roemex
Function	Biocide	Pipeline Hydrotest Chemical	Corrosion inhibitor	Pipeline Hydrotest Chemical	Pipeline hydrotest/ Pipeline Pigging
Registration number	24858	27896	22982	4579	23517
Template dose rate (ppm)	350	550	1,000	100	1,000,000
Worst case toxicity (mg/l)	0.1349	0.13	3.41	55.8	N/A
Number of aquatic toxicity tests	3	3	3	3	-
OCNS Group	-	-	-	-	E
100% PLONOR	No	No	No	No	Yes
PNEC[199]	0.013	0.013	0.341	5.58	-
Percentage in product	20.31	2.32	44	8.91	100
Log P_{ow}	Not available				
Comments	No sediment re-worker data				

8.4.3.2 Water Column Impact

All discharges will take place in the open water. Water depths used in the CORMIX modelling were 45 m. As discussed in Section 3.2, it may be required to preserve sections of the pipeline in the nearshore area in water depths of approximately 25 m, where flooding, cleaning, gauging and

[198] It is assumed that RX-5227 will be re-certified by Cefas ahead of its use in the operations. If this chemical is not re-certified, bp will use a Cefas registered alternative chemical.
[199] PNEC values were calculated from the data utilising the methodology used in the preparation of UK offshore chemical permits (i.e. CHARM assessment factor of 10 (CHARM Implementation Network (CIN), 2017)).

hydrotesting of the pipeline would be required. Results from the CORMIX modelling provide an overview of chemical behaviour and impact associated with the chemical discharges.

The CORMIX model was used to investigate the potential impacts of chemical discharges on the water column and benthic environment. The chemicals used during hydrotest (Hydrosure HD-5000, RX-5255, RX-5227 and RX-9022) were modelled as single discharge and assessed individually during the post processing of the results. Actual discharges are expected to contain RX-9022 and only one of the other three chemicals. Table 8-5 provides details of the distances at which each hydrotest chemical concentration is predicted to dilute sufficiently to produce centreline PEC/PNECs of less than 1, and therefore be considered to present no environment risk.

Environmental risk has been assessed based on the ratio of a predicted exposure concentration to a predicted no-effect concentration. In this case, the predicted concentration for each chemical discharged in the environment is compared to a predicted concentration threshold for that chemical at which no effect is expected to occur. When the discharge concentration (PEC) is larger than the threshold below which no effect is likely to occur (called the PNEC) (i.e. the ratio is equal to or greater than 1), there may be a risk of toxicity. When the PEC is lower than the PNEC threshold (i.e. the ratio is lower than 1), the risk of toxicity from that single substance is considered to be unlikely.

When assessing an offshore release, the dilution factor at 500 m is the value that is commonly analysed when considering whether a release will cause harm to the environment. The modelling study (Table 8-5) indicated that the dilution required to achieve a PEC/PNEC of less than 1 for the pipeline chemicals is predicted to occur within 334 m (for all chemicals and currents except RX-5255 with a current of 0.1 m/s where the distance was 568 m). When considering the flow weighted average dilution calculations, for a combined release, the dilution factor at 500 m was 1080 (Table 8-6). Therefore, the hydrotest chemical concentration at 500 m would be 0.09% of the concentration discharged.

The assessment conservatively assumed that the concentration of chemicals discharged equalled the application dosage of the chemicals added. As these chemicals react within the pipeline and break down into inert components in a process which protects the pipeline, the discharge concentration of these chemicals is much lower than the concentrations initially added. Consequently, the degree of dilution required to achieve concentrations of any excess chemical in the discharge which pose no risk to the environment is likely to be significantly lower. In addition, the discharge will occur as a small volume during hydrotesting (i.e. the volume of water released equals the volume required to reduce pressure in the pipeline following completion of the test).

Table 8-5 - Predicted distances at which hydrotest chemical concentrations produce PEC/PNECs <1

Run	Current velocity (m/s)	Fraction of current speed occurrence	Predicted distances from source at which centre line PEC/PNECs are less than 1			
			Hydrosure HD-5000	RX-5255	RX-5227	RX-9022
1	0.1	1.61	253	568	3	-
2	0.2	10.37	44	226	4	-
3	0.3	19.68	65	89	5	-
4	0.4	23.85	79	133	5	-
5	0.5	19.23	91	156	6	-
6	0.6	12.57	104	178	6	-
7	0.7	6.85	116	199	6	-
8	0.8	3.25	128	220	6	-
9	0.9	1.68	139	240	7	-
10	1.0	0.73	150	259	7	-
11	1.1	0.17	162	279	7	-
12	1.2	0.01	172	297	8	-
13	1.3	0.005	183	315	8	-
14	1.4	0.002	194	334	9	-

Table 8-6 - Flow weighted average dilution calculations for hydrotest chemical release

Flow weighted average dilution at defined distances from the release point		
Nearfield region	100 m	500 m
887	338	1080

The predicted discharge rate of 0.3 m^3/s for dewatering the pipeline during pipeline commissioning, is the worst case discharge scenario, typically occurring over 8 to 12 hours. Potentially the dewatering will not occur as single discharge, but as several smaller releases due to operational constraints, thus limiting the size of any plume in the far field. This is likely to cause a small and short-lived plume which potentially could contain toxic levels of some of the chemical used during the installation of the pipeline. However, the actual potential for toxic impacts on marine organisms depends on the duration of exposure; i.e. water column organisms would need to be present in the plume and to remain within it for sufficient time to experience acute toxicity (i.e. not move away from the plume).

MEG is a PLONOR chemical under the OSPAR regulations and it is considered to have a very low toxicity. Assessing pelagic ecotoxicity based on the PEC/PNEC ratio is not a relevant concern for MEG. The potential impact from discharges of MEG is through the potential for deoxygenation of the water column due to the ready biodegradation of the MEG. The theoretical oxygen demand (ThOD) of an organic chemical is the amount of oxygen required to completely mineralise (convert it to CO_2 and H_2O) the amount of the chemical present. The ThOD represents a worst case scenario for the oxygen removal capacity of an amount of a chemical. The actual oxygen demand of any compound depends on its biodegradability and the presence of specific organisms to metabolize the compound.

The ThOD for MEG was calculated as 1.289 mg of oxygen per mg of MEG. In each of the MEG discharge scenarios, the centreline concentration at the furthest extent of the chemical plume failed to reduce to below the water degradative capacity (i.e. the potential for oxygen removal), as detailed in Table 8-7, which provides details of the maximum MEG plume extent and the predicted centreline concentrations at those points.

Table 8-7 - Predicted MEG discharge extent and concentration

Run	Current velocity (m/s)	Fraction of current speed occurrence	Predicted centreline concentration at 500 m (mg/L)	Predicted centreline concentration at model extent / 2500 m (mg/l)
1	0.1	1.61	8650	957
2	0.2	10.37	5610	947
3	0.3	19.68	3710	641
4	0.4	23.85	3020	426
5	0.5	19.23	2620	289
6	0.6	12.57	2330	195
7	0.7	6.85	2130	145
8	0.8	3.25	1950	133
9	0.9	1.68	1780	183
10	1.0	0.73	1630	258
11	1.1	0.17	1490	394
12	1.2	0.01	1360	482
13	1.3	0.005	1240	644
14	1.4	0.002	1390	775

Table 8-8 - Flow weighted average dilution calculations for MEG discharge

Flow weighted average dilution at defined distances from the release point		
Nearfield region	100 m	500 m
165	206	344

In each of the MEG discharge scenarios the centreline concentration at the furthest extent of the chemical plume failed to reduce to below the water degradative capacity. Table 8-7 provides details of the predicted centreline concentrations for the MEG plume at 500 m and 2500 m, the furthest extent of the simulation. Table 8-8 presents the results of the flow-weighted average dilution calculation for the MEG discharge. However, in the offshore environment metabolically active micro-organisms would be expected to be present at very low concentrations and therefore whilst the MEG discharge provides a source of carbon and energy for any organisms present, it is unlikely under North Sea environmental conditions that these organisms could increase their numbers sufficiently to cause degradation that would deplete the oxygen in the water column. In addition, MEG is unlikely to reside in a particular location for a prolonged period and therefore there is no potential for a stable community of organisms to develop on this intermittent, short-term point discharge.

The key receptors in the water column are zooplankton since these largely drift in the water currents and are unable to avoid unfavourable conditions. Zooplankton abundance and biomass are likely to be considerably less in the bottom waters of the SNS than they are in the surface waters where primary productivity is highest. However, *C. finmarchicus*, has historically dominated the zooplankton of the North Sea and is used as an indication of zooplankton abundance. The area affected by concentrations of the hydrotest chemicals (including the use of corrosion inhibitor and biocide) high enough to have a potential toxic impact is very small compared to the total area of bottom water available for overwintering *C. finmarchicus*.

Sedentary organisms on the seabed may be exposed to the plume for some hours, during which time mobile benthic and pelagic organisms would be able to move away from the plume. This limited spatial and temporal extent predicted for the plume in the far field will limit any toxicity effects of residual chemicals as exposure time for any organisms is likely to be much less than the exposure of organisms in regulatory toxicity tests used to define acute ecotoxicity. Therefore, there is no anticipated benthic impact resulting from the chemical discharges as part of pre-commissioning. In addition, the turbulent mixing of the discharge chemicals in the environment will result in a rapid dilution of the plume beyond the point where any subsequent mixing could result in toxic concentrations interacting with the seabed.

Considering the modelled behaviour and dilution rate of the plume and the mitigation measures that will be in place with respect to selection and use of chemicals, the consequence of the residual impact is considered, conservatively, to be moderate. The discharge will also be temporary. It should also be noted that, with the exception of biocide and corrosion inhibitor which are designed to provide long-term protection, the actual concentrations of other chemicals discharged during dewatering will be significantly lower than the concentrations at the time of their use as the majority of these chemicals will be used up immediately on being applied to the pipeline; impact predictions herein are therefore worst case. Therefore, the residual impact of the pre-commissioning discharges for the pipeline will be minor and is not considered significant.

8.4.4 Formation Water Displacement

8.4.4.1 Introduction

As discussed in Section 3.4.4, it is anticipated that injection into the Store will indirectly displace Outcrop Formation Water[200] from the upper 140 m of the Bunter Sandstone Formation into the sea at the Bunter Sandstone Outcrop location during the operational phase of the Development.

As CO_2 is injected into the Endurance Store it will increase the pressure within the Bunter Sandstone Formation, which will dissipate into the Greater Bunter Aquifer. As pressure dissipates through the formation, it could ultimately result in an increase in pressure at the Bunter Sandstone Outcrop which lies about 25 km from the Store area (Figure 1-1). The pressure increases in the formation are likely to lead to increased displacement of Outcrop Formation Water into the sea at this location. Such pressure changes at the outcrop will not be instantaneous but will occur gradually over time as

[200] *Formation water is water that occurs naturally within the pores of rocks.*

pressure dissipates through the formation. Geological modelling of the formation and outcrop anticipates pressure changes and associated Formation Water displacement may first occur at the outcrop approximately four years after first injection of CO_2 into the Endurance Store. If 100 Mt CO_2 is injected at Endurance, the increase in pressure is likely to lead to the ultimate displacement of Formation Water from the upper 140 m TVDss of the outcrop formation. This can be thought of as a simple mass balance. The total volume of Formation Water displaced at the outcrop will be equivalent to the pore volume of Store Formation Water displaced within the Endurance Store by the injection of CO_2 (Figure 8-7).

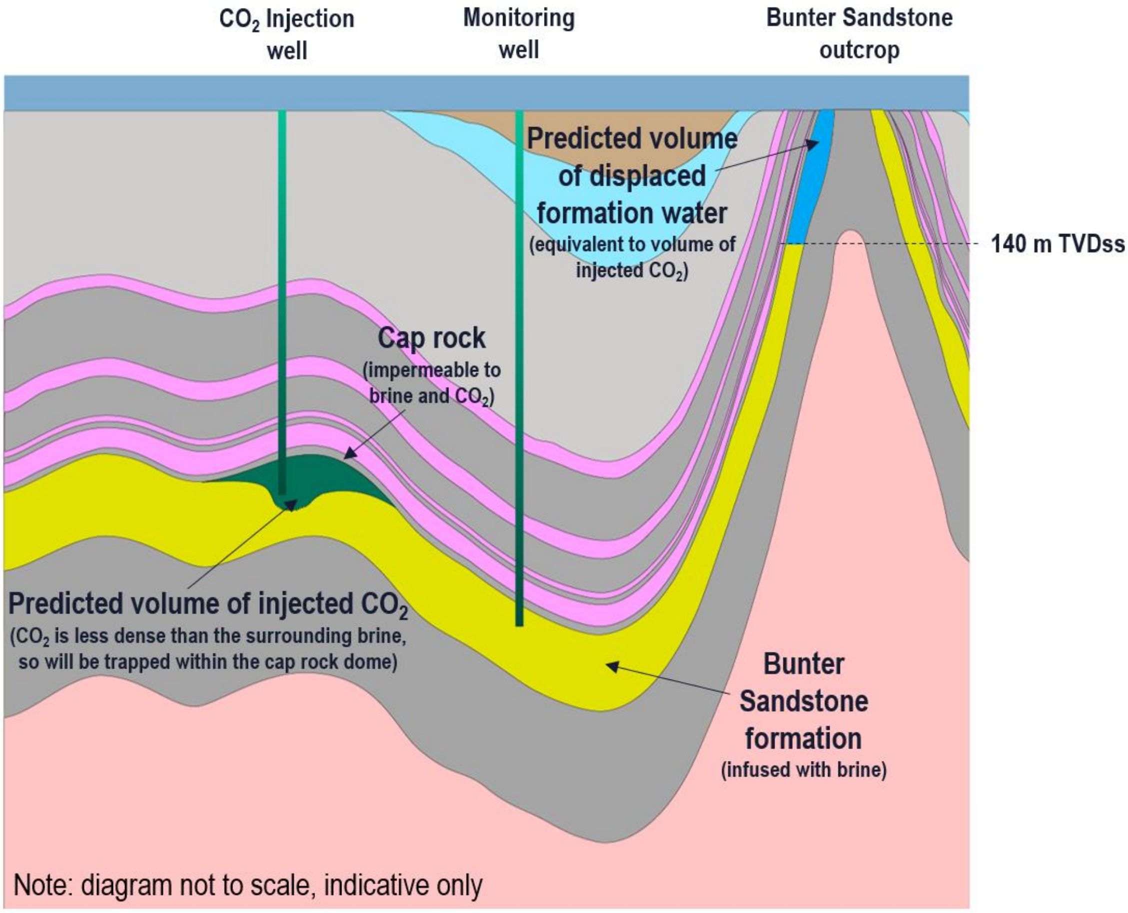

Figure 8-7 - Schematic showing that the volume of injected CO_2 causes a displacement of the equivalent volume of Formation Water at the Bunter Sandstone Outcrop, to a predicted depth of 140 m TVDss

For an exposed area of ~1.4 km^2 and flow rate of 1,590 m^3 per day this equates to a flux of ~1.13 L/d/m^2 across the outcrop area. The characteristics of the Outcrop Formation Water are presented in Section 4.3.6.

Displaced Formation Water will have a salinity of approximately 45,003 ppm (bp, 2022b). This Formation Water may potentially cause detrimental impacts on local water quality, seabed quality and associated marine flora and fauna. Displacement of Formation Water can potentially impact plankton, including the larvae of fish and invertebrates, by causing a drop in osmotic pressure[201] (breaking the osmotic equilibrium between planktonic organisms and seawater), and hence potentially causing negative impacts in primary and secondary production and mortality in larvae (Palomar and Losada, 2011). However, such potential impacts are usually only associated with very large discharges of hypersaline water into coastal areas, e.g. associated with desalination plants. In an offshore environment, such as the Endurance Store, dispersion and dilution of the displaced Formation Water in a well-mixed and dynamic environment (due to currents and bathymetry) reduces potential impacts (Dewar *et al.*, 2022).

To understand potential impacts of the displaced Formation Water on the nearby marine environment, impacts are considered from a near-field perspective. The near-field region is located in the vicinity of the point from which displacement occurs, in this case the Bunter Sandstone Outcrop. The mixing which will initially take place is dependent on the properties and characteristics of the displaced Formation Water against the ambient conditions (Palomar and Losada, 2011). Mixing leads to high dilution rates due to turbulence effects.

8.4.4.2 Borehole Test Results

The Formation Water in the outcrop area was appraised by a shallow borehole (42/28-NEPBH1) in June 2022 with core, reservoir pressure, and fluid samples taken from four depths (166, 208, 248 and 291 m TVDss; Figure 4-10). These data show that Outcrop Formation Water in the upper layer at the outcrop is significantly different to fluids hosted by the Endurance structure.

The results of the sample analyses for the samples are presented in Table 4-1 (Section 4.3.7). Analysis showed that salinity (TDS ppm[202]) increases with depth from 45,003 ppm to 87,050 ppm (166 m to 291 m TVDss). Average seawater TDS is about 34,483 ppm. The composition of the samples becomes increasingly closer to seawater in the shallower horizons, due to quasi-equilibrium[203] between the Outcrop Formation Water and seawater. There is a clear trend that concentrations of all minerals/metals/salts increase with depth. The samples from the shallow subsurface at the outcrop contain much lower concentrations of transition metals and metalloids and have much higher sulphate content and a chloride sulphate ratio of between 6:1 to 8:1 (166 m to 291 m TVDss) which is similar to the ratio for seawater of 7:1.

The concentration of the displaced Outcrop Formation Water at the seabed will be affected by the speed of permeation through the rock. The system within the rock is totally miscible and reactive; the slower the stored water moves, the greater the length of time for mixing and reactions. It is anticipated that piston flow will occur, with the concentrations of anions and cation increasing over

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[201] Osmosis is the physical process in which any solvent moves across a selectively permeable membrane (permeable to the solvent, but not the solute) separating two solutions of different concentrations. Osmotic pressure is the main cause of support in many plants, providing the primary means by which water is transported into and out of cells. When a cell is submerged in water, the water molecules pass through the cell membrane from an area of low solute concentration to high solute concentration.

[202] Salinity (S) is a measure of the quantity of dissolved salts in seawater. It is formally defined as the total amount of dissolved solids in seawater in parts per thousand (‰) by weight when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized. Total dissolved solids (TDS) refers to the amount of minerals, metals, organic material and salts that are dissolved in a certain water volume that is expressed in mg/L. In this instance, as there are no organic components present in the formation water, the term TDS may reasonably be used as a surrogate measure for Salinity. As mg/l is equivalent to ppm, for the purposes of the ES, salinity is expressed in ppm.

[203] In thermodynamics, quasistatic processes are processes that occur at an infinitesimally slow rate. A quasistatic process has all of its states in equilibrium.

time as deeper horizons of water are displaced to the surface. It is anticipated that the chemical analysis of the sample taken at 291 m TVDss represents a conservative worst case for the displaced Formation Water which will be displaced from 140 m TVDss (see Section 8.4.4.1 for the explanation of the origin of this value).

As Formation Water leaves the outcrop and passes through any overlying sediment layer, partitioning and reaction within the sediment will occur. The Formation Water will then be released into the water column and any remaining metals will behave as outlined in Section 8.4.4.3. Arsenic concentrations increase with depth to 1.3 mg/L compared to 0.0018 mg/L in seawater, chromium concentration increase with depth to 0.002 mg/L compared to 0.0002 mg/L in seawater and lead concentration increase with depth to 0.002 mg/L compared to 0.0007 mg/L in seawater. All of the metal concentrations are in line with the values commonly seen in seafloor sediment cover (Section 4.3.7).

8.4.4.3 Toxicity and Chemical Speciation

The Formation Water contains chemicals such as dissolved metals. When the Formation Water is displaced from the Bunter Sandstone Formation at the outcrop, these chemicals will enter the sediment and potentially the water column. In order for a chemical to cause toxicity to an organism, it must first enter its tissues/cells by mean of active transport or passive diffusion, i.e. the chemical species must be bioavailable. The chemical species will have a mode of action at a cellular level and may also be subject to active removal from the organism, because of metabolism by a range of detoxification mechanisms. Therefore, for a substance to be toxic it must be bioavailable such that it enters an organism and achieves a concentration that causes an effect. For many marine organisms it is possible for them to take up and excrete a range of metals at will, without exhibiting any toxicity.

Hazardous elements[204] (i.e. not in compound forms), are present at extremely low concentrations in seawater due to their low thermodynamic stability i.e. existing as pure elements is not energetically favourable. When dissolved in seawater, elements will bind with other atoms in the water to form more energetically favourable (more thermodynamically stable) species. In chemistry, “species” refers to the molecular configuration of atoms of an element or cluster of atoms of different elements. The ability of atoms to form different species is referred to as speciation.

Oxidation states represent the number of electrons an atom gains or loses when bonded with another atom in a molecule. In seawater, arsenic can exist in four oxidation states (V, III, 0 and -III), with Arsenate (V) and Arsenite (As III) being the most predominant. The most abundant forms of inorganic arsenic at the normal pH of marine waters are anionic (negatively charged) for arsenate ($H_2AsO_4^{-1}$ and $HasO_4^{-2}$) and neutral for arsenite (AsOH). Methylarsonic acid (MMA) and di-methylarsinic (DMA) are the two most frequently found organic forms.

Inorganic arsenic is moderately toxic to marine organisms. Arsenite is more bioavailable than arsenate to marine animals so should be more toxic if the cellular mechanisms of their toxicity is similar. Laboratory testing suggest that arsenite and arsenate have similar toxicities to marine organisms; this could be caused by the speciation of arsenite to the more energetically favourable arsenate during the testing. Another possibility is that arsenite may complex with dissolved organic matter which reduces its apparent toxicity (Neff, 1997).

The speciation and bioavailability of copper in seawater is highly dependent on seawater chemistry (e.g. pH, salinity etc.). The speciation is usually dominated by organic ligands, forming relatively stable

[204] *Examples of hazardous elements include arsenic (As), zinc (Zn) and copper (Cu)*

complexes with around 99% of the dissolved Cu. The oxidation state of organic copper is generally implied to be Cu(II). Inorganic copper(I) is unstable in seawater, even though it is stabilised by chloride complexation (i.e. forming CuCl), and is oxidised to copper(II) in a matter of minutes by DO. Cu(II) can form inorganic complexes with carbonates (CO_3^{2-}), hydroxides (OH^-), and chlorides (Cl^-), and organic complexes with organic ligands (L) such as thiols, exopolysaccharides and humic substances (Van Den Berg, 1984; Heller and Croot, 2015; Whitby *et al.,* 2017; Leal *et al.*, 2018).

The European Chemicals Agency (ECHA) presents data on chemical species toxicity. The data shows that the toxicity of common inorganic copper complexes that form in seawater to be like that of elemental copper. However, around 99% of copper in the ocean is complexed by organic ligands, making it less bioavailable and thus less toxic than free Cu(II) (ECHA, 2022).

Lead speciates in a similar way to copper in the ocean. Carbonate and chloride complexes are the most abundant inorganic species, followed by hydroxide complexes. Usually, less than 5% of the inorganic Pb present in seawater is in the form of free ion (Pb(II)). As with copper, a significant percentage of total Pb in coastal seawater can be complexed with organic ligands, vastly decreasing its bioavailability (Lavilla *et al.*, 2011).

Compositional data were collected from a borehole drilled into the subsurface of the Bunter Sandstone Outcrop (Section 8.4.4.2). Sample analyses from a depth of 291 m TVDss were used to constrain geochemical simulations of the mixing of Formation Water with seawater, as a conservative worst case. Two cases were tested to investigate likely geochemical behaviour of the displaced Formation Water (Section 8.4.4.4).

Inorganic ions that naturally occur in marine environments are essential for the health of aquatic organisms (Goodfellow, 2000). Adverse effects can also occur in marine organisms when the normal composition (ratio) of ions is not the same as those normally encountered in marine water. Whilst organism can tolerate a range of ion ratios, outside of this range the organisms become stressed, with mortality as a worst case. The tolerance of organisms to ionic imbalance will be species specific and depend on their ability to internally regulate tissue ion concentrations.

8.4.4.4 Displacement Geochemical Modelling

A study (bp, 2022e) was conducted to assess the transport and sequestration of transition metals and metalloids as the displaced Formation Water mixes with seawater close to the outcrop. A 10% Formation Water 90% seawater mixing cell model was used to evaluate the risk. Fluid composition and mineral precipitation were derived using a combination of equilibrium-speciation-saturation, reaction path and mineral stability models.

Formation Water compositional data was collected from a borehole drilled into the Bunter Sandstone Outcrop. Fluid modelling indicated that Formation Water down to a depth of approximately 140 m would be displaced at the outcrop. The Formation Water at these depths is significantly different to the Store Formation Water within the Endurance Store structure.

A degree of mud filtrate contamination was observed in the samples, and this may have contributed to elevated concentrations of copper and zinc. Overall, the composition results were not materially altered by the presence of 0.5-3% water-based mud in the samples.

As the displaced Formation Water passes up from the outcrop through the overlying sediment veneer and into the water column it moves from a region of no oxygen (i.e. an anaerobic and reducing chemical environment) below the sediment surface layer to an oxygenated layer (i.e. an aerobic and oxidising chemical environment) in the upper 1 cm of the sediment and water column. The different electrochemical environments (i.e. oxidising and reducing) cause the ions present in the Formation Water to react with one another to form stable mineral salts that are insoluble in water and precipitate out of solution and become part of the sediment. This increases the total metal content of some metals in the sediment at the Bunter Sandstone Outcrop, but these metals are chemically bound into to the sediment minerals and are therefore not bioavailable nor toxic to the benthos present in the area. Geochemical modelling was conducted to predict the likely minerals formed from the Formation Water displaced at the Bunter Sandstone Outcrop.

Under oxidising conditions where the displaced Formation Water is significantly diluted by seawater (i.e. 1:9 Formation Water: seawater), the modelling predicted that only cuprite (Cu_2O) and umangite (Cu_3Se_2) are stable (bp, 2022e). Cuprite (Cu_2O) dominates and becomes more prolific as the Formation Water/seawater ratio increases. Umangite (Cu_3Se_2) is stable, because the lack of sulphide limits the capacity for copper to be preferentially partitioned into a competing phase, such as chalcocite (Cu_2S). This is what could be bioavailable and therefore is considered as part of the impact assessment.

Two scenarios were run under increasingly reducing conditions (where the Formation Water is not well diluted by seawater e.g. 9:1 Formation Water : seawater) to represent typical conditions that exist in sediments below the surface layer. The first of these cases resulted in destabilisation of cuprite (Cu_2O), replacement by chalcocite (Cu_2S) and persistence of umangite (Cu_3Se_2). For the case imposing the most reducing conditions, copper is partitioned into three phases. Clausthalite (PbSe) and cadmoselite (CdSe) stabilise and sphalerite ((Zn,Fe)S) becomes the dominant phase. Clausthalite (PbSe), umangite (Cu_3Se_2) and penroseite ($(Ni,Co,Cu)Se_2$) are typically hydrothermal in origin and sphalerite ((Zn,Fe)S) is associated with multiple ore forming processes – these are not the conditions at the Bunter Sandstone Outcrop (Section 4.3). On the basis of paragenesis[205] constraints, cadmoselite (CdSe) and chalcocite (Cu_2S) may precipitate in reducing sediments under low redox alkaline conditions (bp, 2022e). Additionally, any clay minerals and organic material present in the sediment will have a large cation-exchange capacity (CEC) and will absorb metals from the Formation Water effectively binding them to the sediment, removing them from the water phase and reducing their bioavailability.

The modelling conducted implies that while displaced Formation Water contains a wide range of metals derived from the subsurface layers, speciation of these metals and the CEC of the overlying clay is anticipated to reduce the likelihood of metal species reaching the marine environment.

8.4.4.5 Water Column Mixing

A CFD modelling study (bp, 2022b) analysed the dispersion and dilution of the displaced Formation Water at the seabed at the outcrop location. The output of dispersion modelling from the CFD study was used to inform the impact assessment but did not in itself predict impact. The CFD simulations were performed for flow field, turbulence and transport of Formation Water-seawater mixture to predict the extent of localised areas of elevated salinity in the water column (bp, 2022b). The input parameters used are summarised in Table 8-9.

[205] *a set of minerals which were formed together, especially in a rock, or with a specified mineral.*

Table 8-9 - Summary of CFD modelling inputs

Parameter	Value	Reference
Location of displacement	Bunter Sandstone Outcrop, approximately 25 km east from where CO_2 injection will occur	White Rose (2016)
Area over which displacement modelled	700,000 m^2 [206]	White Rose (2016)
Formation water salinity	90,000 ppm	bp (2022b)
Formation & seawater temperature	15°C Assumed to be in equilibrium	
Displacement rate	1,590 m^3 per day	National Grid (2016)
Background salinity	34,500 ppm	bp, 2021d
Hydrodynamic data	Current profile along the water depth for tidal wave in the direction NW-SE	Net Zero Teesside MetOcean Criteria. UE-2020-0147
Bathymetry data	NEP 2020 survey campaign	11545_Bunter_1m_dtm_LAT.xyz

The assumed rate of 1,590 m^3 per day corresponds to the maximum predicted displacement rate associated with CO_2 injection into the Endurance Store during the Development. On commencement of injection, displacement is forecast to gradually increase up to 1,590 m^3 but is not predicted to exceed this rate.

Contour plots of salinity profiles at the seabed in the range of 34,500 ppm to 36,225 ppm (i.e. within 5% of background salinity) were output at regular time intervals. There is no plume as the rate of displacement is very low over a large area and as a result of dilution in the nearfield (Figure 8-8).

According to Dewar *et al.* (2022), a salinity greater than 36,750 ppm (which represents a 5% increase over regional mean salinity) was considered to be a conservative toxicological threshold, based on guidelines related to the permitting of Seawater Reverse Osmosis (desalination) plants (de-la-Ossa-Carretero *et al.*, 2016; Frank *et al.*, 2017; Lykkebo Petersen *et al.,* 2019; Sánchez-Lizaso *et al.,* 2008 in Dewar *et al.* (2022)). The CFD study predicted that, with a 1,590 m^3 per day displacement rate, the increased salinity remains below the 5% threshold within the immediate vicinity of the area from which displacement occurs (Figure 8-8).

The CFD study showed that the increase in salinity will be below the 5% threshold limit. Given the dynamic environment in the Store (Section 4.3), regions of high salinity move back and forth as sea currents change direction from northwest to southeast. Moderate increases in salinity (i.e. below the

[206] The total exposed outcrop area is estimated at ~1,400,000 m^2, but models predict that the area from which displacement is most likely to occur is ~700,000 m^2

5% threshold) were only observable in the immediate vicinity (i.e. less than 150 m) of the displacement location in all modelled scenarios (bp, 2022b).

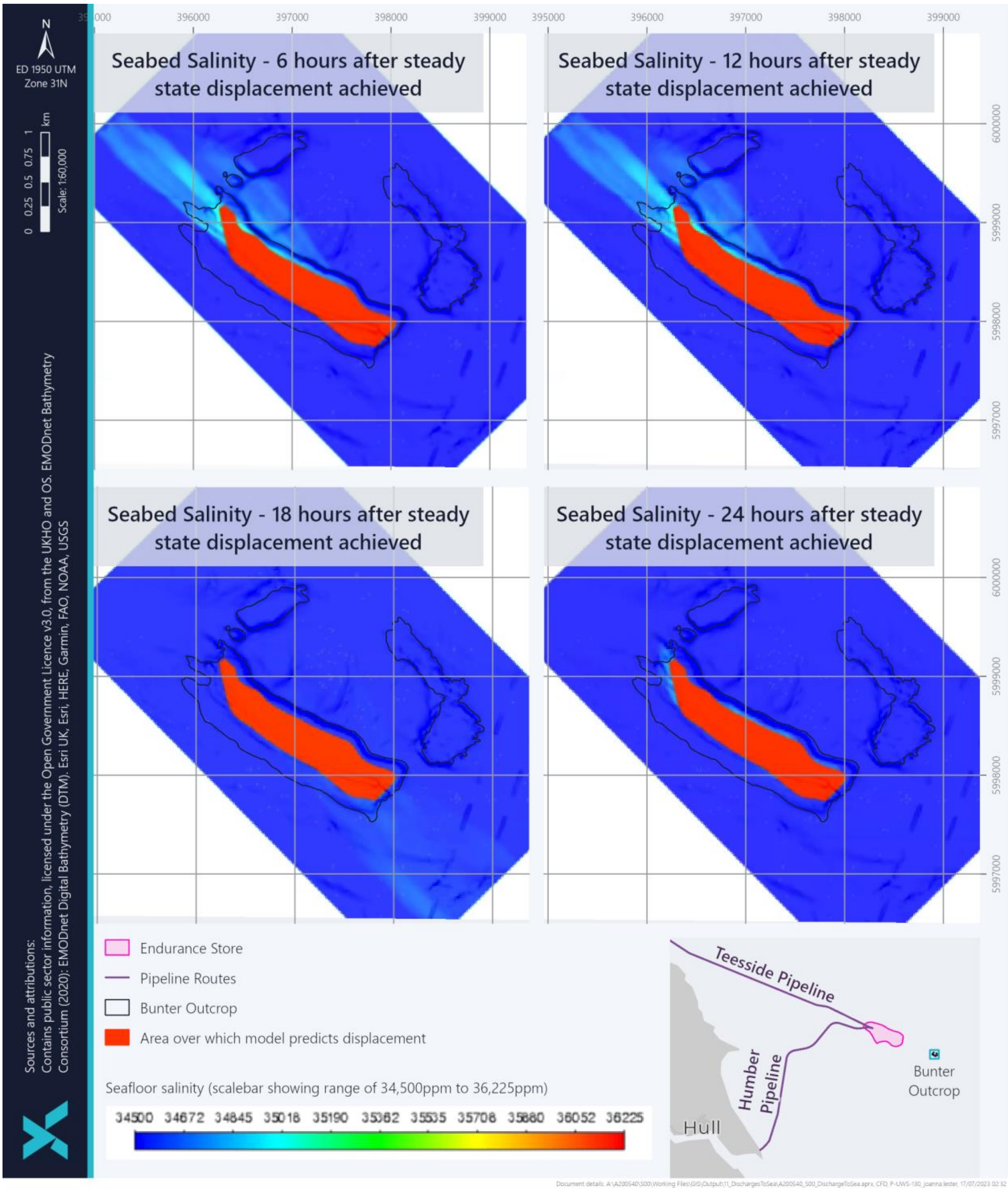

Figure 8-8 - Seafloor salinity profiles (scalebar showing range of 34,500ppm to 36,225ppm) at four different times in a day: displacement from exposed outcrop of 0.7 km² at a rate of 1,590 m³ per day. (bp, 2022b)

8.4.4.6 Potential Benthic Epifaunal and Infaunal Impacts

The modelling undertaken in the CFD studies (Section 8.4.4.5) identified that the plume will primarily interact with the seabed. This is due to a combination of factors, primarily the higher density of the Formation Water compared to ambient seawater (1.061 for the Formation Water compared to 1.026 for seawater).

The seabed at the Bunter Sandstone Outcrop is predominantly medium to coarse silty sand with areas of coarser gravelly sands, and is characterised by an absence of sandwaves which are present in the Endurance Store area (Section 4.3.7).

When considering infauna, annelid worms (Polychaeta; n=6,134) was the most abundant taxonomic group at the Bunter Sandstone Outcrop, making up 50% of sampled individuals and 43% of the taxa. This community composition was comparable to past surveys of the area. Polychaete dominance is typical for most soft bottom benthos communities. Echinodermata (n=2,835) was the second most abundant taxonomic group however, only made up 5% of adult taxa which proportionately means the group was relatively lacking in diversity. This was followed by Mollusca (n=1,645) and Arthropoda (n=972). Arthropoda were comparatively a diverse group, making up 29% of all adult taxa. Of juveniles counted (n=1,980), 98% were Echinodermata. Between stations, abundance also varied considerably with some stations containing twice the number of individuals as others.

Cation exchange capacity is a measure of how many cations can be retained on sediment particle surfaces. Seabed sediments are typically rich in organic matter and clays, which have multiple unoccupied substrate surface sites available for sorption and preferential cation exchange. Therefore, when in contact with mean seawater, they can typically interact with cations (Mg, Ca, Fe, Mn, etc.) that remain in solution. With the exception of H^+, cation exchange affinity favours heavier ions and those with higher valence states. This phenomenon preferentially sequesters ions such as Pb^{2+} and Cd^{2+} over the lighter and lower valence state ions (bp, 2022c). Metals will therefore adsorb to the calys and organic material via electrostatic interactions which become stronger over time. This process results in the metals becoming strongly associated with the sediment and as result not present in the water phase of the sediment (Ditoro and Rosa, 1995; Luoma, 1983). The consequence of this is that the metals are less bioavailable and therefore not toxic to benthic or pelagic organisms. The ability of the seabed sediments to absorb metals, reducing their bioavailability, is a key component in mitigating the risk of the Formation Water impacting the water column.

The existing sediment metal concentrations measured at the Bunter Sandstone Outcrop are presented in Table 8-10 and compared to sediment metal concentrations measured at the Endurance Store and OSPAR Background Assessment Concentration (BAC)[207] values, where these exist (Figure 8-9). Metal concentrations are generally below OSPAR BAC levels, with the exception of lead. Concentrations at the Bunter Sandstone Outcrop are consistently greater than at the Endurance Store.

[207] *Statistical tools defined in relation to the background concentrations which enable testing of whether mean observed concentrations can be considered to be near background concentrations (OSPAR, 2005)*

Table 8-10 - Baseline sediment metal concentrations at the Bunter Sandstone Outcrop and Endurance Store areas (μg g^{-1} dry sediment) (Gardline, 2021a)

	Al	As	Ba	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Sr	Ti	V	Zn
Bunter Sandstone Outcrop																			
Min	10,300	6.0	602	<1.0	0.1	14.5	2.2	5.0	8,110	15.2	7.3	137	<0.01	5.7	<0.5	73	890	25.8	21.4
Max	25,400	24.1	2,090	NQ	0.8	28.1	5.4	9.8	20,100	72.3	22.0	393	0.02	13.8	2.0	211	1,800	60.6	39.6
Mean	**16,835**	**12.6**	**1,198**	**NQ**	**NC**	**19.7**	**3.5**	**6.8**	**13,438**	**40.6**	**11.7**	**258**	**NC**	**9.2**	**NC**	**135**	**1,326**	**41.3**	**31.2**
±SD	3,588	4.9	470	NQ	NC	3.9	0.9	1.0	3,007	17.7	3.4	74	NC	2.4	NC	39	299	8.7	5.2
Endurance Store																			
Min	10,300	5.7	1,150	<1.0	0.1	10.9	1.9	4.6	7,210	14.1	7.1	155	<0.01	4.2	<0.5	79	720	25.4	18.9
Max	13,400	15.5	2,370	NQ	0.2	14.2	2.9	5.7	11,000	37.3	8.7	232	0.00	6.4	0.5	136	800	34.1	22.2
Mean	**11,800**	**10.4**	**1,784**	**NC**	**NC**	**12.2**	**2.3**	**5.2**	**9,336**	**24.3**	**8.0**	**200**	**NC**	**5.5**	**NC**	**109**	**758**	**29.5**	**21.2**
±SD	1,210	4.2	450	NC	NC	1.2	0.4	0.4	1,527	9.5	0.7	30	NC	1.0	NC	21	32	3.9	1.3
OSPAR Background Assessment Concentration																			
	NA	25	NA	NA	0.31	81	NA	27	NA	38	NA	NA	0.07	36	NA	NA	NA	NA	122
NC: Not calculated due to one or more values below the LOD NQ: Not Quantified																			

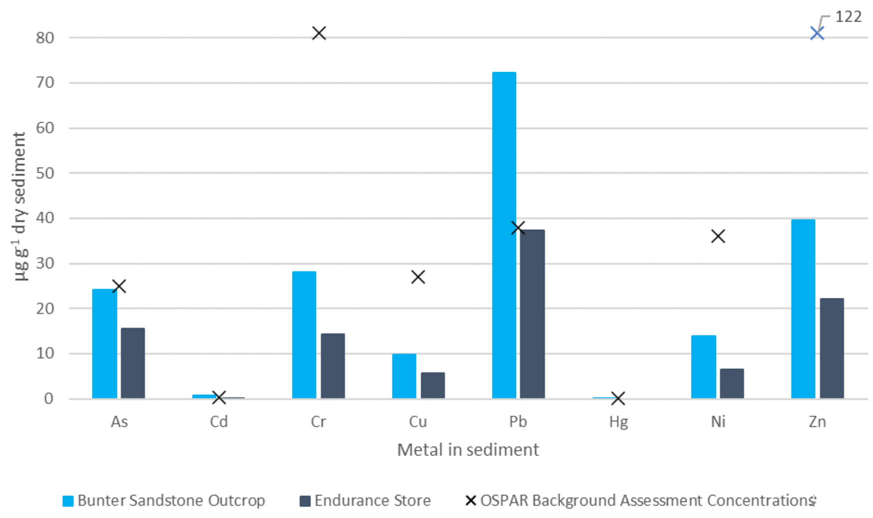

Figure 8-9 - Mean sediment metal concentrations relative to OSPAR Background Assessment Concentrations (OSPAR, 2005)

The thin, unconsolidated shallow seabed sediment veneer commonly consists of a bioturbated upper layer in contact with seawater and a largely undisturbed sublayer of dysoxic[208] to anoxic deposits. The bioturbated[209] zone is subject to seawater circulation, continual macrofaunal disturbance and is dominated by aerobic microbial communities. The sublayer is typically enriched in organic matter. The transition metals reported in the Formation Water are already present in the seafloor sediment sublayer and are adsorbed to the surfaces of clay minerals and organic matter. Most non-ferrous metals are sparingly soluble in water and will readily sorb to available substrates (bp, 2022c).

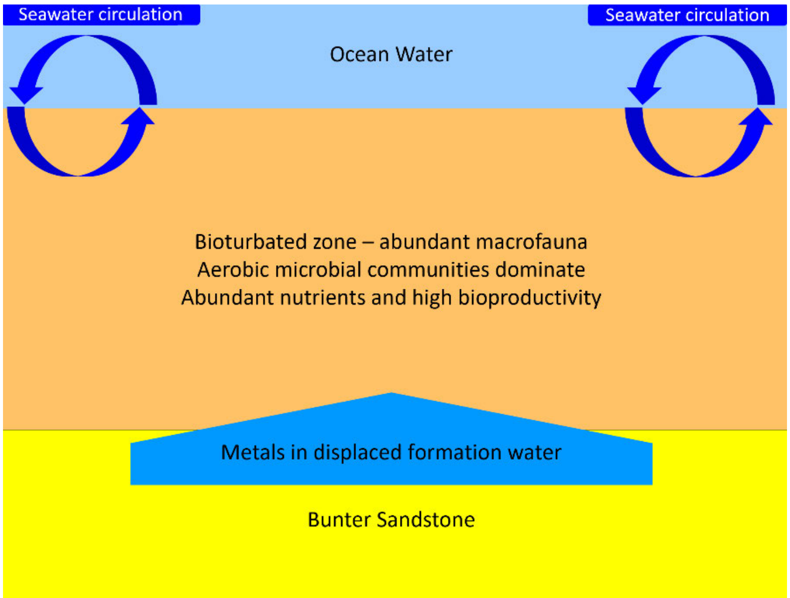

Figure 8-10 - Chemical processes in offshore subsea sediments (bp, 2022c)[210]

The potential for substance accumulations to reach toxic levels is primarily determined by the rate at which the water is displaced though the seabed sediment veneer. In terms of metals, arsenate is the most abundant form of arsenic in oxidized marine sediments, whereas arsenite is the dominant dissolved and solid species in reduced sediment layers (Brannon *et al*., 1987, Masscheleyn and Delauneand, 1991a, 1991b, Riedel *et al*., 1987). Iron oxyhydroxides, which are abundant in oxidized marine sediments, also can catalyse oxidation of arsenite to arsenate (De Vitre *et al.,* 1991). Arsenate is therefore more likely to be present in the sediments than arsenite. Arsenite is more bioavailable than arsenate to marine animals (for example benthos) that may be present in the sediments (Neff, 1997).

Dissolved arsenate can be more toxic to phytoplankton species than to marine invertebrates and fish (Neff, 1997); however, arsenate would be present in the sediments and not within the water column in this case, limiting the potential for impacts.

It is likely that the majority of metals within the Formation Water will be sequestered in the sediments, due to their CEC, and will not be released into the marine environment. In addition, modelling indicated that any metals not retained within the sediments and displaced would be rapidly dispersed.

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[208] Dysoxic refers to having a very low oxygen concentration.

[209] Bioturbation is the disturbance of sediments and sedimentary deposits by living organisms.

[210] This diagram is for illustration purposes. The Endurance Store is a defined area within the Bunter Sandstone Formation.

Sediment reworking by organisms would directly expose the chemical species to the organism's gut, acidifying it, and potentially increasing its bioavailability.

The analysis of metals in sediment at the outcrop (Table 8-10) did not consider the speciation of the metals in the sediment, but rather the total metal content. These metals are present in the sediment either because they are speciated as insoluble mineral salts or they are adsorbed on clay particles and not freely available in the sediment pore water. A higher metals background level in sediment at the outcrop (compared to typical regional levels (OSPAR, 2005)) is to be expected as the outcrop is open to the marine environment and over geological time Formation Water will have exchanged from the outcrop to the marine environment increasing sediment metal concentrations naturally by the processes described earlier in this section. Thus, the higher metal concentrations in the outcrop sediment are not expected to be particularly bioavailable and the benthos extant at the outcrop are unaffected by the presence of elevated sediment concentrations of the various metals. Organisms present in the outcrop area will therefore be tolerant to these increased metal concentrations as demonstrated from the results of the benthic surveys (species variation and abundance) (Section 4.4.2).

WET Testing

Whole Effluent Testing (WET) is an approach commonly used to assess the toxicity of complex effluents and it is the cornerstone of the OSPAR Risk Based Approach to produced water. In a WET laboratory aquatic ecotoxicity testing is conducted to standard test protocols. However rather than exposing the organisms to a series of concentration of a test compound, dilution of the effluent is used instead.

Having developed an understanding of the behaviour of the displaced Formation Water via modelling (Section 8.4.4.4 and Section 8.4.4.5), further information was sought on the potential toxicity of the Formation Water to different trophic levels. Due to the complex nature of the Formation Water and the availability of samples from the outcrop borehole to provide information on the chemical composition, bp, as operator of NEP, commissioned industry standard WET tests for a range of organisms from three separate laboratories. The resultant data was used to inform the impact assessment in relation to the benthic habitat and water column.

To ensure conservative assessment, results of the WET testing of the samples taken at 291 m TVDss are presented below. The dilutions presented in brackets relate to the salinity of the sample taken from this depth. As the salinity of the Formation Water from 140 m TVDss is lower (45,003 ppm at 166 m TVDss relative to 87,050 ppm from 291 m TVDss), less dilution would be required for the lower salinity water displaced at the outcrop.

Laboratory toxicity testing for WET is typically conducted on a series of dilutions of the sample such that the concentrations tested may be represented as a salinity in parts per thousand (‰) or as a concentration of the original sample represented as a percentage (%). The results of the laboratory tests are analysed using statistical methods that fit the data typically to a sigmoidal curve. From this curve the values for No Observed Effect Concentration (NOEC), Effect concentration 10% (EC_{10}: the concentration at which 10% of the population are affected) and effect concentration 50% (EC50: the concentration at which 50% of the population are affected) are determined with their confidence limits. Lowest observed effect concentrations (LOEC) is derived directly from the laboratory data; this is the lowest test concentration at which an effect was observed. In a regulatory context an assessment factor is applied either to the NOEC or EC_{10} value to calculate the PNEC. The assessment factor is determined by regulators and based upon the number and types of tests conducted on the test sample and is intended to take into account the intra and interspecies variation in response to toxicants seen in the extant biota. The PNEC therefore represents a conservative concentration that is considered to be protective of all species present, which accounts for the uncertainty in the experimental data.

The results of the toxicity testing are presented in Table 8-11. A growth rate and yield test (ASTM E1218/ISO10253) was conducted on green alga (*Skeletonema costatum)* which yielded a NOEC of 42.7‰ (sample diluted to 23.2%) and an EC_{10} of 45.1‰ (sample diluted to 27.5%). 7-day (EPA-821-R-02-014) and 4-day (EPA-821-R-02-012, Method 2007.0.) survival tests were carried out on sheepshead minnow (*Cyprinodon variegatus)* and Mysid (*Americamysis bahia)*, respectively. The sheepshead minnow survival test yielded a NOEC of 35‰ (sample diluted to 7.25%) and an EC_{10} of 33.4‰ (sample diluted to 4.69%) and the result of the mysid test was a NOEC of 38‰ (sample diluted to 7.32%) and a LOEC of 43‰ (sample diluted to 15.71%).

Larval development tests were conducted on sand dollar (*Dendraster excentricus)* (EPA/600/R-95-136), and oyster (*Crassostrea gigas)* (EPA/600/R-95-136 Method 1005.0). The sand dollar larval development test yielded a NOEC of <35.1‰ (sample diluted to < 1.79%) and an EC_{10} of 35.4‰ (sample diluted to 2.18%). The oyster larval development test yielded a NOEC of <38‰ (sample diluted to <7.32%) and an EC_{10} of 35.5‰ (sample diluted to 1.28%).

The lowest EC_{10} measured was 33.4‰ (sample diluted to 4.69%) (for *Cyprinodon variegatus*) and as due to the number and types of test conducted, an assessment factor of 10 has been applied to calculate the PNEC (ECHA, 2022). Therefore, the PNEC of the Formation Water would be 3.34‰ (0.469%). This means that the displaced water would need to be diluted about 213-fold in the water column to achieve a deterministic risk quotient of less than 1.

The PNEC for the Formation Water sample is much lower than typical North Sea salinity of 35‰ which indicates that Ionic imbalance is the cause of the adverse effects on the test species rather than particular ion toxicity.

The CFD modelling predicted that there is a small region of low dilution factors in the vicinity of the displacement point, but the dilution factor is above 98% at a distance of 150 m from the displacement point. Therefore, the dilution, required to achieve a PNEC of less than 1, will be achieved within 150 m. This dilution will bring the ion imbalance caused by the displaced Formation Water within the range tolerated by marine organisms and no adverse effect is predicted outside of this range.

Table 8-11 - Toxicity Test Results Summary

Organism	Test type	NOEC[211] (‰)	LOEC[212] (‰)	EC_{10}[213] (‰)
Green Alga (*Skeletonema costatum*)	Growth rate & yield	42.7	-	45.1
Sheepshead minnow (*Cyprinodon variegatus*)	7-d survival	35	-	33.4
Sand dollar (*Dendraster excentricus*)	Larval development	<35.1	35.1	35.4
Mysid (*Americamysis bahia*)	4-d survival	38	43	-
Oyster (*Crassostrea gigas*)	Larval development	<38	38	35.5

8.4.4.7 Water Column Impacts

A series of modelling studies have been undertaken to assess the effects and magnitude of impacts from the displacement of Formation Water. The studies (see Section 8.4.4.5) have indicated that the displaced Formation Water would need to be diluted 213-fold to achieve a concentration that would have no predicted toxic effect on any organisms that encountered it. These tests investigated the effects of dilution of the Formation Water on sensitive life-stages (larval development) or as a result of long-term exposure (greater than 4 days).

Modelling undertaken, in particular the CFD study (bp, 2022b), identified that any noticeable changes will mainly be located within a maximum radius of 150 m from the point at which displacement occurs.

As discussed in Section 8.4.4.6 metals are expected to become trapped in the sediment and not be released into the marine environment, however, to understand the potential for any minerals passing through the superficial sediment to precipitate in the water column and become bioavailable, bp, as operator of NEP, conducted geochemical modelling (bp, 2022e). bp (2022e) identified that of the likely minerals in the Formation Water, chalcocite (Cu_2S) and umangite (Cu_3Se_2) were the two minerals with potential to be above saturation levels[214]. However, it was considered that the likelihood of these minerals precipitating was low, based on their mineral formation mechanics, and therefore their potential bioavailability is limited as they remain in solution. It was considered that other metals would remain within the Formation Water solution, as they are predominantly complexed ion species (bp, 2022c). As discussed previously, minerals and metals that remain within the sediment are less likely to become bioavailable, reducing the risk to the water column.

Based on the dynamic currents in the area (Section 4.3), it is considered that the probability is very low for any transition metals[215] to remain in significant concentrations in the water column as they will be diluted and dispersed (bp, 2022c). The rate at which the Formation Water will be displaced into

211 NOEC = No Observed Effect Concentration.

212 LOEC = Lowest Observed Effect Concentration.

213 EC_{10}/ EC_{20} /EC_{25}/ EC_{50} = Effect Concentration to 10/20/25/50% of test population.

214 Minerals at concentration above the saturation level are more likely to precipitate.

215 Transition metals are a section of the periodic table where metals are typically found.

the marine environment at the Bunter Sandstone Outcrop is the main factor in assessing the potential for metal accumulation. The modelling assessment undertaken assumes worst case of 1,590 m^3 per day being displaced. Metal accumulation would be further reduced if there are any overlying sediments at the Bunter Sandstone Outcrop due to the equilibrium partitioning of the metals within the veneer of sediment material (i.e. species are removed from the pore water to the sediment, reducing the quantity released into the water column).

The CFD modelling predicted that for the single point displacement case, the dilution factor is above 98% at a distance of 150 m from the displacement point. Therefore, the dilution required to achieve a PNEC of less than 1, will be achieved well within 150 m of the point of release from the seabed.

Localised increases in metals in the water column may be detected in the unlikely event that metals in the Formation Water pass through the sediment. However, the bioavailability of these metals will be limited as most will remain in solution. The metals will be diluted and dispersed within 150 m of the displacement point based on the CFD study (bp, 2022c) over the life of the Development.

8.5 Management and Mitigation

As operator of NEP, bp's procedures for chemical management, as well as specific regulatory controls, will be in place to prevent or reduce potential environmental impacts. A number of mitigation measures will be applied to the Development to limit, where practicable, the potential environmental impacts of discharges to sea, including:

- WBM will be recycled as far as reasonably practical to reduce discharges;
- Only WBM will be discharged for the drilling of the riser-less sections. For the sections drilled with riser in place, and with LTOBM, the drilling fluid will be managed within a contained circulation system;
- No discharge of LTOBM or LTOBM contaminated cuttings to sea;
- The use and/or discharge of all chemicals offshore will be subject to environmental risk assessment and permitting under the OCR, with appropriate assessment and identification of relevant measures to reduce risk including chemical selection procedures as part of this process;
- Chemicals posing little or no risk of environmental impact (PLONOR) will be selected wherever practicable. Where practical, alternatives to chemicals carrying substitution notifications will be sought; if a sub-warning chemical is the only option, technical justifications will be provided in chemical permit applications;
- In line with permit requirements, chemical usage and discharge will be recorded and reported; and
- A pre-drilling audit will be conducted to ensure that the drilling rig can comply with all relevant legislation.

Mitigation measures will be applied to the Development to limit, where practicable, the potential environmental impacts of displacement of Formation Water, including:

- A monitoring programme will be developed to include components that monitor Formation Water displacement at the Bunter Sandstone Outcrop and will be submitted as part of the Store Permit Application (details on the MP are provided in Section 3.4.7 and Table 3-20).

8.6 Cumulative and Transboundary Impacts

Modelling predicts that the seabed covered by discharged WBM and cuttings to a thickness of 10 mm will not extend further than 300 m from the drilling location. The seabed around the drilling locations exhibits a good recovery potential due to natural processes such as re-suspension/redistribution and biodegradation. Whilst there is potential for similar oil and gas drilling activity at other locations in the SNS, the impacts from these activities on the benthic environment will be similarly limited both spatially and temporally. These factors, together with the absence of known imminent drilling projects in the close vicinity of the Development, limit the likelihood of benthic impacts from drilling discharges in the area acting additively or synergistically in terms of footprint or persistence.

Pipeline dewatering operations are expected to cause a small and short-lived plume which potentially could contain toxic levels of some of the chemical(s) used during the installation of the Teesside Pipeline and Humber Pipeline. However, considering the behaviour and dilution rate of the plume and the mitigation measures that will be in place with respect to selection and use of chemicals, the consequence of the residual impact is considered to be moderate. Dilution and dispersion of the discharge will minimise exposure of organisms in the water column to toxicity. This will be short-term and spatially limited and negligible impact to the benthic environment is expected.

The limited quantity of chemicals discharged during the life of Development and the use of appropriate management and mitigation measures reduces the likelihood of any measurable cumulative impacts to the benthic environment. Additionally, dilution of discharges during the life of field will likely be rapid and potential impacts transient in nature. Considering this, no significant cumulative impacts are expected with regard to the water column.

Displacement of Formation Water will occur over the Development life and highly localised impacts can be expected. While a medium-term impact, modelling predicted that impacts will be spatially localised. Potential cumulative impacts are expected to be limited due to the nature of this discharge.

Considering that the Development is 105 km from the UK/Netherlands boundary line, no transboundary impacts are expected.

8.7 Decommissioning

There will be limited potential for decommissioning activities to negatively impact the marine environment through discharges to sea. It is possible that there may be some re-suspension of deposited cuttings during the removal of the wells equipment at decommissioning. However, as outlined above, the high-energy marine environment will result in seabed recovery at the Development area to the extent that little or no detectable cuttings pile may remain by the end of field life. If cuttings are still present, then recovery is likely to be rapid following disturbance and any impacts are expected to be far less than during their initial discharge. The Formation Water displacement is not expected to impact decommissioning options. The displacement is likely to continue following cessation of CO_2 injection; however, the monitoring programme would still be in place and regular monitoring would continue.

The mitigation measures described in this chapter with respect to selection and optimisation of chemical use and Formation Water displacement will also apply to the decommissioning process. Chemical risk assessments will be conducted in line with the applicable regulations at the time. Considering the above, the potential impacts from decommissioning are thus likely to be no greater in magnitude to those experienced during drilling, installation, commissioning and operation and thus not significant.

8.8 Protected Sites

The key installation, commissioning and operational discharges and displacement of Formation Water described above may occur within a number of protected sites. Section 4.5 identified a number of protected sites which intersect or are within 50 km the Development. The SNS SAC, the Holderness Offshore MCZ and the Holderness Inshore MCZ are the only protected sites which intersect with the Development. The SNS SAC is designated for the presence of harbour porpoise, which is an Annex II species and EPS. The Holderness Offshore and Inshore Marine MCZs support fish spawning habitats. However, fish species are not a qualifying feature of these MCZs. In addition, in the nearshore area, a number of SPAs are located in close proximity or intersect the pipeline routes. These SPAs are designated for the presence of seabirds, which will not be impacted by the discharges to sea and have therefore been scoped out of the assessment.

8.8.1 Southern North Sea SAC

The Development is located within the SNS SAC, which is designated for Annex II harbour porpoise. The habitat within this SAC is highly suitable for key prey species of harbour porpoise (i.e. sandeels), which attract individuals to the area (JNCC, 2019). Harbour porpoise are not expected to be impacted by discharges to sea (such as drill cuttings, mud and pipeline chemicals) or by the Formation Water displacement. Impact on prey availability is however considered below.

Fish species are not qualifying features of the SNS SAC (JNCC, 2019); however, they are the main prey for harbour porpoise (in particular sandeels) and it is therefore important to understand potential impacts to these species to assess potential impacts on the SAC's integrity.

Individual sandeels were identified within sediment samples taken at the Bunter Sandstone Outcrop and along the transect CAM01 (Gardline, 2021a). Sandeels have a close association with the sandy substrates into which they bury to protect themselves from predators. Once settled, studies have shown that sandeels are mostly resident, rarely travelling more than 20 miles from the areas they reside. In fact, they rarely emerge from the seabed between September and March, except to spawn (NatureScot, 2019). As settled sandeels remain on a sandbank and overwinter for many months without feeding they are sensitive to their local environmental conditions (Heath *et al.*, 2012) and can be threatened by a variety of different factors. For instance, physical disruption or removal of their sediment habitat is a particular threat which can be brought about by offshore developments and activities (such as drilling and WBM contamination). Very little is known about the recovery of sandeel in response to these type of threats however it is estimated that the potential burial of these species from WBM is not expected to significantly impact the species due to their already established characteristic burial methods. Sandeel individuals present within the immediate vicinity of the well may be impacted by smothering. However, the modelling of cuttings and discharges above demonstrate that the maximum spread of thickness of cuttings above 10 mm is restricted to 550 m from the well locations, which represents a minute portion of the SNS SAC. While localised impact to fish species is expected at the well locations from the drill cuttings and mud discharges, it can be concluded that any impacts on prey availability is considered to be very limited and would not result in a LSE or affect the Conservation Objectives of the SNS SAC.

Discharges of pipeline chemicals were assessed in Section 8.4.3. It was concluded that changes to water quality will be localised. In particular, the modelling indicated that the dilution required to achieve a PEC/PNEC of less than 1 for the pipeline chemicals is predicted to be achieved within a maximum of 568 m from the discharge location. With the dynamic environment at the Development, it is therefore unlikely that fish species will be impacted by these discharges. As such, discharges of chemicals during the pipeline dewatering are not expected to affect the designated features of the SAC and no LSE is expected.

Additionally, displacement of formation occur would occur at the Bunter Sandstone Outcrop. Modelling (see Section 8.4.4) was conducted to assess impacts from Formation Water displacement. Section 8.4.4 concluded that a localised increase in metals and salinity may be detected; however, this was limited to 150 m from the displacement location. In addition, the majority of metals were expected to remain in the sediment and any metals passing through the sediment are expected to remain in solution which limits the potential for impacts to fish species via changes to water quality. Formation water displacement is spatially limited and it is believed the majority of metals would be retained within the sediments. Therefore, impacts would be limited to a very small portion of the SNS SAC and are not expected to affect the designated features of the SAC. No LSE is therefore expected.

8.8.2 Holderness Inshore and Offshore MCZs

The only operations likely to impact the Holderness Inshore and Offshore MCZs is the potential interim dewatering of the pipelines. As per above, the modelling concluded (as a worst case) that dilution to achieve a PEC/PNEC of less than 1 would occur within a maximum of 568 m from the discharge location. While localised impacts may occur, these chemical discharges would be quickly diluted and dispersed. Therefore, it can be concluded that any impacts on fish species is considered to be very limited and would not result in a LSE or affect the Conservation Objectives of the Holderness Inshore and Offshore MCZs.

8.9 Residual Impacts

8.9.1 Drilling Discharges

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Benthos	Low	Medium	Negligible	Low
Rationale				
Seabed features in highly mobile environments typically have a good degree of capacity to accommodate change and receptor tolerance is considered high; as such, sensitivity is considered **low**. Where impacts do occur, change is likely to be temporary and thus vulnerability only **medium** and magnitude **low**. As described in Chapter 4: Environmental Description, site-specific survey work around the Development area has identified some features (habitats or species) of conservation concern (such as FOCI sandeels and OSPAR threatened and/or declining ocean quahog *A. islandica* and seapens and burrowing megafauna, cod and spurdog*)* in the vicinity of the Development area. However, these are representative of the wider area and much of the North Sea. Therefore, the value of the receptor is considered **low**. Overall, the impact has been assessed to be **not significant**.				

Consequence	Impact Significance
Minor	Not Significant

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Plankton/Zooplankton	Low	Low	Negligible	Negligible
Rationale				
At a population level this receptor is considered to have a good degree of capacity to accommodate change and receptor tolerance is considered high; as such, sensitivity is considered **low**. Where impacts do occur, change is likely to be imperceptible in relation to natural changes over time and thus vulnerability low and magnitude negligible. As described in Chapter 4: Environmental Description, no species of conservation concern in this respect have been identified and the plankton will form part of very large, widely distributed populations. The value of the receptor is therefore considered **negligible**. Considering the negligible value and low vulnerability of the features, recognising that there will be no impact on protected sites and/or on species, and the short-term duration of the impact mechanism, the residual consequence of discharges to sea due to drilling is ranked as **negligible**. Overall, the impact has been assessed to be **not significant**.				

Consequence	Impact Significance
Negligible	Not Significant

8.9.2 Aqueous Discharges

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Plankton/Zooplankton	Low	Low	Negligible	Negligible
Rationale				
At a population level this receptor is considered to have a good degree of capacity to accommodate change and receptor tolerance is considered high; as such, sensitivity is considered **low**. Where impacts do occur, change is likely to be imperceptible in relation to natural changes over time and thus vulnerability **low** and magnitude **negligible**. As described in Chapter 3: Project Description, no species of conservation concern in this respect have been identified and the plankton will form part of very large, widely distributed populations. The value of the receptor is therefore considered negligible. Considering the negligible value and low vulnerability of the features, recognising that there will be no impact on protected sites and/or on species, and the short-term duration of the				

impact mechanism, the residual consequence of discharges to sea due to drilling is ranked as **negligible**. Overall, the impact has been assessed to be **not significant**.

Consequence	Impact Significance
Negligible	Not Significant

8.9.3 Outcrop Formation Water Displacement

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Water quality / Sediments (and effects on epifauna and infauna)	Medium	Medium	Negligible	Low

Rationale

This receptor is considered to have a good degree of capacity to accommodate change and vulnerability is expected to be **medium** due to the duration of the discharge as such, sensitivity is considered **medium**. No water column species of conservation concern are expected to occur in the proximity of the Bunter Sandstone Outcrop. Additionally, as evidenced by the findings of the benthic surveys in the area, the benthos at the Bunter Sandstone Outcrop are unaffected by the presence of elevated sediment concentrations of the various metals. Therefore, the value of the water column and sediments is considered to be **negligible**. Where impacts do occur, change may be detected in relation to natural changes over time and magnitude is low. Considering the negligible value and medium vulnerability of the features, recognising that there will be no long-term impact on protected sites and/or on species, the residual consequence of Formation Water is considered to be **minor** while acknowledging the long-term duration of the impact mechanism. Overall, the impact has been assessed to be **not significant**.

Consequence	Impact Significance
Minor	Not Significant

9 PHYSICAL PRESENCE

9.1 Introduction

This section assesses the potential effects of the Development on the receiving environment, resulting from the physical presence of vessels and Development infrastructure and equipment. The following specialists have contributed to this assessment:

- Xodus Group – baseline description, impact assessment and ES section write up (with the exception of disturbance to birds); and
- NIRAS – impact assessment and ES section write-up for disturbance to birds.

Table 9-1 provides a list of all the supporting studies which relate to the physical presence impact assessment.

Table 9-1 - Supporting studies

Specialist	Details of study
NIRAS	Ornithological Technical Report (NIRAS, 2023)
Xodus Group	NRA (Xodus Group, 2023a)
Xodus Group	Fishing Intensity Study (Xodus Group, 2023b)

9.2 Regulatory Controls

In addition to the EIA regulations detailed in Section 1.5, there are other requirements of UK legislation, international treaties and agreements relevant to the assessment of physical presence.

The following legislation is key in relation to the physical presence from the Development in terms of potential impacts to environmental receptors offshore:

- *Convention on the Conservation of European Wildlife and Natural Habitats* (the 'Bern Convention') – outlines legal commitments for contracting parties on the conservation of engendered and vulnerable species specified in the appendices of this instrument;
- *Convention on the Conservation of Migratory Species of Wild Animals* (the 'Bonn Convention') – outlines legal commitments for contracting parties on the conservation of endangered migratory species and their habitats;
- *Convention on Wetlands* (the 'Ramsar Convention') – outlines commitments for contracting parties on the conservation of wetland habitats and provides a mechanism for designating wetland habitats of international importance as Ramsar Sites;
- *Convention for the Protection of the Marine Environment of the North-East Atlantic* (the 'OSPAR Convention') – sets out measures for environmental protection of the marine environment, including establishing ecological objectives for the North Sea, developing lists of species and habitats in need of protection, selecting OSPAR marine protected areas and controlling potential sources of impact on the marine environment;
- *Energy Act 2008* – provides for a licensing regime that governs the offshore storage of carbon dioxide. Consents to Locate (CtL) under Part 4A of the Energy Act 2008 will be sought as required. The granting of a CtL ensures that the impact of the Development on navigation has

been considered, such that no significant hazard or risk is anticipated if the Development activities are undertaken in accordance with the consent conditions. The CtL application will be accompanied by supporting information, such as a Vessel Traffic Survey (VTS) report;

- *Marine and Coastal Access Act (MCAA) 2009* – provides for navigational safety and risk management in UK waters. Section 77 of the MCAA 2009 excludes the majority of CCS activities, for which a licence under Part 4 of the Energy Act 2008 is required;
- *Wildlife and Countryside Act 1981 (as amended)* – primarily implements the Birds Directive and the Bern Convention in the UK to establish measures for the protection and conservation of habitats and species. The Act also allows for the designation of Sites of Special Scientific Interest (SSSIs);
- *Natural Environment and Rural Communities (NERC) Act 2006* – provides a list of habitats and species of principle importance on England;
- *The Offshore Petroleum Activities (Conservation of Habitat) Regulations 2001*[216] - implement the EU Habitats Directive (Directive 92/43/EEC) and EU Wild Birds Directive (Directive 2009/147/EC) in relation to oil and gas and CCS activities on the UKCS. These regulations also establish the HRA process for assessing impacts of oil and gas or CCS proposals on European Sites (formerly known as Natura 2000 sites);
- *The Conservation of Habitats and Species Regulations 2017* and the *Conservation of Offshore Marine Habitats and Species Regulations 2017* ('Habitats Regulations')[216] – implement the EU Habitats Directive (Directive 92/43/EEC) and EU Wild Birds Directive (Directive 2009/147/EC) in English waters. The Conservation of Habitats and Species Regulations 2017 is relevant to waters out to 12 NM from shore and the Conservation of Offshore Marine Habitats and Species Regulations 2017 is relevant from 12 NM to 200 NM from shore. These regulations implement additional measures for the protection of habitats and species to the Offshore Petroleum Activities (Conservation of Habitat) Regulations 2001. This includes establishing measures to protect EPS;
- *The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017*[217] – transpose the requirements of the WFD for the sustainable use and protection of water and surface waters and require that all UK waterbodies must achieve a Good Ecological Status (GES) or Good Ecological Potential (GEP) by 2027; and
- *East Inshore and Offshore Marine Plan and the North East Inshore and Offshore Marine Plan* (Section 1.5.1 and Section 1.5.2) – seek to ensure that developments consider and address potential direct or indirect impacts on the marine environment and avoid, minimise or mitigate them accordingly.

9.3 Assumptions and Data Gaps

In order to ensure that the assessment of physical presence reflects the worst case scenario, a number of assumptions have been made regarding Development activities. For example, at this time, the specific pipelay vessel is not known, and the possibility of using either a DP or anchored vessel exists.

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[216] Following the UK's exit from the EU, the Offshore Petroleum Activities (Conservation of Habitat) Regulations 2001, the Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 were amended by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations. Most functions under these regulations have been transferred from the EC to the consenting authorities in England and Wales.

[217] Following the UK's exit from the EU the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 was amended by the Floods and Water (Amendment etc.) (EU Exit) Regulations 2019.

The assessment of physical presence has therefore assumed an anchored vessel since the associated anchoring represents the greatest potential to interfere with other sea users. With regards to physical presence, the Development infrastructure / activities that represent the maximum area, duration and vessel use are considered to reflect the worse-case scenario.

Assuming that HSE Operations Notice 54, Establishment of permanent safety zones for subsea installations applies to CCS activities, safety zones will be applied for under The Petroleum Act 1987 at the wellheads, manifolds and the SSIV locations[218]. Any applications would be subject to consultation with interested parties. The worst case scenario for each impact has been determined, in terms of the potential presence or absence of permanent safety zones and the justifications are described in Table 9-2.

The schedule provided in Section 3.1.2 has been used to inform the assessment of effects. It is acknowledged that this timeline is currently indicative and subject to change. However, relevant permit applications from OPRED will be sought, with supporting environmental information, and will be based on the actual installation period. It should also be noted that the schedule is yet to be confirmed for the installation of the Teesside – Store and Teesside – SSIV cable. Although cable installation may occur alongside pipelay operations, for the purposes of the worst case scenario it has been assumed that this will be a separate operation.

The worst case scenario for the impacts assessed within this chapter are outlined below in Table 9-2, covering both the construction and O&M phase. Decommissioning impacts are considered in Section 9.7.

[218] bp intend to apply for safety zones at the wellheads, manifolds and SSIV locations. Engagement is ongoing with the Health and Safety Executive to confirm the application of the Petroleum Act 1987 to safety zones for subsea installations associated with CO_2 transportation and storage. To ensure assessment of the potential worst case within the ES, both scenarios are considered, i.e. the potential presence or absence of permanent safety zones at the wellheads, manifolds and SSIV locations.

Table 9-2 - Worst case scenario for physical presence

Impact	Worst case scenario	Justification
Increased vessel traffic and collision risk	• Maximum duration of drilling, installation and landfall operations and maximum vessel days (as set out in Section 3.1.2 and Section 3.5); and • No permanent 500 m safety zones at the wellhead, manifold and SSIV locations.	This maximum duration of works and maximum vessel use would result in the greatest potential for interaction with other sea users. The worst case scenario assumes that permanent safety zones at the wellhead, manifold and SSIV locations will not be in place as this represents the greatest potential interaction with other sea users.
Temporary and long-term exclusion	Endurance Store: • Subsea infrastructure in Endurance Store as set out in Section 3.2.8; and • Maximum duration of drilling and installation operations (Section 3.1.2). Pipelines: • Two pipelines (Teesside Pipeline (142 km in length) and Humber Pipeline (100 km in length)) with a maximum working corridor width of 60 m; • SSIV installed on the Teesside Pipeline, between approximately KP6 and KP8, associated with a permanent 500 m safety zone; • Teesside Pipeline route trench, surface lay (Section 3.2.1, 3.2.3 and 3.2.4) and rock placement (Section 3.2.5) worst case assumptions; • Humber Pipeline route trench, surface lay (Section 3.2.2, 3.2.3 and 3.2.4) and rock placement (Section 3.2.5) worst case assumptions; • Landfall works at Teesside by HDD or microtunnelling; • Landfall works at Humber by microtunnel with cofferdam for impacts on beach users; • Landfall works at Humber by HDD for impacts on sea users; and • Maximum duration for installation operations, as set out in Section 3.1.2.	The maximum duration of works, the presence of safety zones and the presence of infrastructure would result in the greatest potential for exclusion. The impacts from HDD or microtunnelling at the Teesside Pipeline route are considered to be equal, as the duration and seabed footprint is the same. These two methods are considered to represent the worst case scenario over direct pipe, which would only take three months to install. The landfall option at Humber of microtunnel with cofferdam is considered to represent the worst case scenario for beach users as this requires the beach to be cordoned off from the general public for potentially up to half a year. The HDD method require the presence of a jackup barge for twice as

Impact	Worst case scenario	Justification
	Cables: • Teesside – Store Cable and Teesside – SSIV Cable installed with associated trenching and rock placement as described in Section 3.2.9; • Up to two landfalls may be required for the cables, installed through HDD. The associated seabed footprint will be within the footprint for the Teesside Pipeline landfall; and • Maximum duration for installation operations, as set out in Section 3.1.2. Safety zones: • A temporary 500 m safety zone placed around the jackup during drilling operations at the Endurance Store; and • No permanent 500 m safety zones at the wellhead, manifold and SSIV locations.	long, and therefore represents the worst case scenario for sea users. It has been assumed that the Teesside – Store and Teesside – SSIV cables will be installed in separate trenches, as this represents the greatest potential area of exclusion. The worst case scenario assumes that permanent 500 m safety zones at the wellhead, manifold and SSIV locations will be in place as this represents the greatest footprint for exclusion of other sea users.
Snagging risk	Endurance Store: • A jackup rig is to be used for the drilling works, with no anchoring required; • Subsea infrastructure in Endurance Store as set out in Section 3.2.8; • Infield pipeline and flowlines route trench, surface lay and rock placement worst case assumptions as set out in Section 3.2.8.1 and Section 3.2.8.2; • The infield cables will be installed with associated trenching and rock placement as described in Section 3.2.9; and • Maximum number of concrete mattresses, as set out in Section 3.2.9. Pipelines: • Two pipelines (Teesside Pipeline (142 km in length) and Humber Pipeline (100 km in length) installed in separate trenches; • Anchored vessel used for installation of pipelines and infield flowlines; • SSIV installed on the Teesside Pipeline, between KP6 and KP8;	The maximum quantity of subsea infrastructure, the maximum area of rock placement and the minimum depth of cover would result in the greatest potential for snagging risk. It has also been assumed that anchored vessels would be used for pipeline installation due to the potential for anchor mounds, which may present a snagging risk. Under the worst case scenario it is also assumed that the cables will be installed in separate trenches (with additional crossings), as this represents the greatest potential area of snagging risk. The worst case scenario assumes that permanent safety zones at the wellhead, manifold and SSIV

Impact	Worst case scenario	Justification
	• Teesside Pipeline route trench, surface lay (Section 3.2.1, 3.2.3 and 3.2.4) and rock placement (Section 3.2.5) worst case assumptions; • Humber Pipeline route trench, surface lay (Section 3.2.2, 3.2.3 and 3.2.4) and rock placement (Section 3.2.5) worst case assumptions; • Rock berm design, as set out in Section 3.2.5; • Potential pipeline / cable crossings for the Teesside Pipeline and the Humber Pipeline as set out in Section 3.2.3.4; and • Maximum number of concrete mattresses as set out in Section 3.2.4. Cables: • Teesside – Store Cable and Teesside – SSIV Cable installed with associated trenching and rock placement as described in Section 3.2.9. Safety zones: • No permanent 500 m safety zones at the wellhead, manifold and SSIV locations.	locations will not be in place as this represents the greatest potential snagging risk.
Dropped objects	• Potential for objects to be accidentally lost overboard during vessel operations over the lifecycle of the Development.	It is assumed that objects could be lost overboard, potentially posing a hazard to other users.
Disturbance and collision risk to marine mammals	• Maximum duration of drilling, installation and landfall operations and maximum vessel days (as set out in Section 3.1.2 and Section 3.5).	The maximum duration of drilling and installation activities and maximum vessel use represent the greatest potential impact for marine mammals.
Disturbance to birds	• Teesside landfall: Presence of jackup barge anchored for up to 12 months; • Humber landfall: Presence of jackup barge for up to 12 months; • 24 / 7 working arrangement; and • Maximum duration of drilling, installation and landfall operations and maximum vessel days (as set out in Section 3.1.2 and Section 3.5).	This maximum duration of works and maximum vessel use would result in the greatest potential for seabird disturbance.

It is considered that the information available to inform this assessment has been sufficient to undertake a thorough and accurate assessment of the potential impacts resulting from the physical presence of the Development.

9.4 Description and Quantification of Potential Impacts

9.4.1 Increased Vessel Traffic and Collision Risk

The temporary physical presence of Development vessels has the potential to interfere with other sea users (in particular fishing and shipping) that may be present in the area, and may increase the risk of vessel collision. A range of vessels will be required to satisfy the installation and operation requirements of the Development.

A detailed breakdown of the types and duration of vessels required is presented in Section 3.5 and the associated schedule in Section 3.1.2.

During installation, a temporary 500 m safety zone may be in place around the drilling rig. Under the worst case scenario for this impact, the assessment has assumed that permanent 500 m safety zones at sub-sea installations will not be in place as this represents the scenario with the greatest potential interaction with other sea users.

As described in the NRA, the Endurance Store is located within an area of low vessel traffic. The southern portion of the Endurance Store overlaps with the Hornsea Project Four lease area (Xodus Group, 2023a). Construction of Hornsea Project Four is expected to commence in 2026, and therefore, may overlap with the Development installation and drilling activities at the Endurance Store. It is possible that the Development vessels may increase the collision risk for construction vessels associated with the Hornsea Project Four.

The Teesside Pipeline route intersects areas of moderate to high vessel density, associated with vessels travelling to and from Teesport, and the Humber Pipeline route intersects areas of moderate vessel traffic densities. The pipelines are also located in a relatively busy region of the North Sea (as shown in Section 4.6.4). There are several navigational features in close proximity to the Teesside and Humber Pipeline routes, including ports and harbours, anchorage areas, disposal sites, military PEXAs and other existing or planned offshore infrastructure. Vessels travelling to or from the Development have the potential to interact with vessels associated with these navigational features (Xodus Group, 2023a).

The NRA assessed the potential vessel collision risk during installation and O&M and the potential for allision with subsea infrastructure due to the reduction in under-keel clearance. The collision risk was assessed as being highest in areas with higher vessel density, including the nearshore area (KP5 to KP80) of the Teesside Pipeline route and between KP20 and KP75 of the Humber Pipeline route.

During the installation phase, the potential for vessel collision with installation vessels and stationary surface hazards (e.g. jackup rig) was assessed. The potential for vessel collision during the installation period was assessed as remote when embedded mitigation measures were considered, such as Notice to Mariners, guard vessel patrol and stakeholder consultation. During the drilling operations, a temporary safety exclusion zone of 500 m will be established around the jackup rig, which will also reduce the potential for vessel collision. Once drilling operations are complete, this safety zone will be removed. However, vessel collision during the O&M phase from recurring activities (e.g. seismic surveys) was also assessed as remote (Xodus Group, 2023a).

The presence of infrastructure potentially reducing under-keel clearance (e.g. presence of the SSIV, wellheads and manifolds and other structures) was also considered within the NRA. The SSIV will be up to 8 m above the seabed between KP6 and KP8. The infrastructure at a number of locations at the Endurance Store will be up to 6 m high. It was concluded that there is sufficient under-keel clearance across the whole identified range of locations for the SSIV (KP6 to KP8). However, it was also concluded that locating the manifolds in the shallowest regions will not provide adequate Under Keel Clearance (UKC). It is recommended that the manifolds are sited, as far as practicable, to maximise water depth, and therefore UKC (Xodus Group, 2023a). In addition, considering that the as-built locations of the SSIV and Endurance Store infrastructure will be added to admiralty charts and communicated to vessel operators through notice to mariners, the likelihood of allision is categorised as remote but potentially of high severity, resulting in a tolerable risk.

9.4.2 Temporary and Long-Term Exclusion

9.4.2.1 Offshore and Nearshore

As outlined above, the establishment of the temporary safety zones around the drilling rig will mean exclusion of other sea users, including shipping and fishing, during drilling operations. For this impact, under the worst case scenario it has been assumed that 500 m safety zones will be established around each wellhead, manifold and the SSIV. No permanent safety zones will be in place around the pipelines and cable infrastructure.

9.4.2.1.1 Shipping

With regards to exclusion of vessels, the area at the Endurance Store, within which 500 m safety zones may be located, experiences low vessel traffic and an estimated seasonal vessel track density of 0 – 150 vessels per 2 km^2 (Xodus Group, 2023a). The temporary safety zone implemented during the drilling phase and the permanent safety zones around wellheads and manifolds may restrict access by other vessels, including those associated with nearby assets and other navigational features, such as the Hornsea Project Four OWF. However, the 500 m safety zones would be implemented in an area of relatively open waters with sufficient sea space for shipping to avoid the Development without significant alterations to routes (Xodus Group, 2023a). Furthermore, given the offshore location of the Endurance Store, any access to other ports or harbours during construction activities is not expected to be reduced. bp, as operator of the Development, will issue relevant notifications (e.g. Notices to Mariners) to inform other users of the planned works and allow for routes to be planned to avoid safety zones.

The pipeline installation works will lead to temporary and very short-term exclusion to vessels from the immediate vicinity of the installation vessels as they travel along the proposed pipeline routes. Any temporary loss of access related to the pipelines will be highest during the installation phase, with limited exclusion impacts expected during operation. The Teesside Pipeline route is proximal to several ports and harbours, including Teesport, Hartlepool and Whitby, and is located within the Teesport Harbour Authority Area. The Humber Pipeline route is also located in close proximity to Grimsby port (Xodus Group, 2023a). Therefore, there is the potential for the installation works to reduce access to these ports. However, vessels will be experienced in navigating around installation vessels and passenger vessels will be aware and prepared to navigate clear of installation vessels with minimal delays expected. Any displacement will be highly localised and occur over a short duration, with an even shorter duration expected for the nearshore area which has the greatest potential to impede access to these ports. As described in the NRA, in most instances, vessels will be able to make minor route diversions around installation vessels. However, delays may be possible for some vessels in the area of the Humber Pipeline route that is immediately adjacent to the Westermost Rough OWF, as the space available for route diversions in this area is more limited (Xodus Group, 2023a). However, considering the temporary and highly localised nature of the displacement, alongside bp's commitment to issue relevant notifications to inform other users of all installation works, no significant reduction in access to these nearby ports is expected.

During the O&M phase, the presence of an SSIV (and potential associated 500 m safety zone) on the Teesside Pipeline, between KP6 and KP8 could also restrict access for vessels, potentially impacting those transiting to and from the ports at Hartlepool and Teesport. However, the SSIV is not expected to present a major subsurface obstacle or hazard given the available UKC. Other vessels should also be familiar with the location of the SSIV, and therefore, any delays are not expected to be significant (Xodus Group, 2023a).

9.4.2.1.2 Commercial fisheries

In terms of fisheries, landings values within the ICES rectangles that overlap with the Development are dominated by pots and traps, scallop dredges and demersal trawls (targeting *Nephrops* and whitefish). As detailed in the Fishing Intensity Study (Xodus Group, 2023b), the highest landings values and fishing effort occur in the coastal ICES rectangles relevant to the Teesside and Humber Pipeline routes, with considerably lower landings values and effort in the Endurance Store area. Pots and traps contribute to the highest proportion of landings values across the Development, with particularly high landings values for this fishing method in ICES rectangle 36F0, relevant to the Humber Pipeline route. The Humber and Teesside Pipeline routes also cross areas associated with high levels of scallop dredging, according to Vessel Monitoring System (VMS) data, and the Teesside Pipeline route is adjacent to areas associated with high demersal trawling effort towards the coast (Xodus Group, 2023b). Shellfish (crabs, lobster and scallops) dominate the landings values across the Development, although landings for some demersal whitefish and herring also occur.

Fishing vessels will be excluded from the 500 m temporary safety zone around the drilling rig within the Endurance Store during drilling operations for a period of 370 days, and from permanent 500 m safety zones that may be in place around wellheads and manifolds during the operational phase. Fishing activity in the Endurance Store is low, and considering the small area encompassed by the safety zones, any exclusion is not expected to have a significant impact.

Areas of higher fishing value and effort occur along the pipeline routes and fishing vessels may experience temporary loss or restricted access to fishing grounds in the immediate vicinity of the installation vessels. Stationary or large slow-moving vessels may be present, that will be restricted in their manoeuvrability, resulting in restricted access to fishing grounds and the re-routing of vessels. However, this will be temporary and most vessels will be present on a transient basis, as they will move along the pipeline and cable routes as installation progresses. Static gear operators (e.g. pots and traps) may also be requested to relocate their fishing gear from the narrow pipeline installation corridors for the duration of construction. However, this is expected to represent a small portion of the available fishing grounds in the area. Therefore, temporary exclusion along the pipeline routes during installation is not expected to have a significant impact on commercial fisheries receptors.

No permanent safety zones are planned along the pipeline and cable routes with the exception of at the SSIV, although it is acknowledged that some fishing vessels, such as scallop dredgers and demersal trawls that tow gear along or close to the seabed, may choose to refrain from deploying their gear along the pipeline and cable routes, due to the potential snagging risks (described further in Section 9.4.3). The portion of the Teesside and Humber Pipeline routes that may be surface laid or partially trenched, which presents the area of greatest potential snagging risk, represents a small extent of the fishing grounds available to fishers and all fishers will be made aware of the location of all infrastructure. Scallop dredging and demersal trawling does occur in the vicinity of the Teesside and Humber pipeline routes and vessels may refrain from fishing over the pipeline due to the potential risks. However, the majority of fishing activity along the routes is undertaken by pots and traps, which are considered to be less susceptible to snagging on pipelines. Rouse *et al. (*2020) report that less than 5% of the claims for damage or loss of gear associated with snagging on oil and gas infrastructure was associated with pots and traps. Therefore, vessels operating pots and traps should be able to continue fishing along the Teesside Pipeline route, Humber Pipeline route and associated cable routes, subject to the discretion of the skipper. It should also be recognised that the worst case scenario of the proportions of the pipeline and cable routes that will be surface laid represent a conservative estimate, and it is likely that a greater proportion of the pipeline and cable routes will be buried to a suitable depth or protected. Overall, the area lost to fishers is considered to represent a relatively small extent of the available grounds in the area, and therefore, limited long-term exclusion is expected from the operation of the SSIV, pipelines or cables.

9.4.2.1.3 Other sea users

As described above, the Endurance Store area overlaps with the lease area currently under agreement for the Hornsea Project Four OWF. As the installation and drilling activities for the Development may overlap with the construction period for Hornsea Project Four, there is the potential for the Development safety zones to restrict access for the construction of Hornsea Project Four infrastructure. During the operational phase, Hornsea Project Four may also obstruct access for O&M activities at the Endurance Store e.g. monitoring (Section 3.4.6). bp, as operator of the Development, has already consulted with Hornsea Project Four and will continue to do so for the duration of the Development to minimise disruption and promote co-existence between the two projects. On 17th June 2023, a commercial agreement[219] was reached with Ørsted (the developer of Hornsea Project Four) to avoid construction of Hornsea Project Four infrastructure within the area of overlap with the Endurance Store. Relevant agreements (e.g. crossing and proximity agreements) between these two developments will also be sought to further minimise disruption.

There are several other nearby users, including other OWFs, such as the Teesside OWF, approximately 1 km from the Teesside Pipeline route, the Westermost Rough OWF, less than 1 km from the Humber Pipeline route and the Humber Gateway OWF, approximately 7 km from the Humber Pipeline route. In addition, there are several oil and gas and cable assets, as well as dredge disposal sites in proximity to the Development (further details are provided in Section 4.6). It is possible that the Development could disrupt access for these other users. However, with adequate promulgation of information to these users, charting of infrastructure, and continued consultation between bp, as operator of the Development, and other relevant parties, any disruption to other sea users is expected to be minimal.

The Teesside Pipeline route and the Teesside – Store cable will cross four existing pipelines, six existing cables and three proposed cables and the Humber Pipeline route will cross an existing pipeline and

[219] *https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010098/EN010098-002322-EN010098%20-%20Orsted%20-%20SoS%20Consultation%20Response%20-%20HOW04%20DCO%20Objection%20Withdrawal_17-06-23.pdf*

one proposed cable. Relevant crossing and proximity agreements will be sought to avoid damage to these assets.

9.4.2.2 Landfall

The worst case scenario for the impact of the landfall works on other users for the landfall option at the Teesside Pipeline is considered to either be HDD or microtunnelling. Both options will involve the presence of an anchored jackup barge and a support vessel at the landfall area for approximately twelve months and the presence of a pipelay and DSV for approximately three months. Due to the nature of HDD and microtunnelling involving minimal impacts to the intertidal zone, there is limited potential for impact to beach users. Beach users will also be notified of the landfall works, as required.

The worst case scenario for the landfall option at the Humber Pipeline route for impacts on sea users is considered to be HDD. This option will involve the presence of an anchored jackup barge and a support vessel at the landfall area for approximately 12 months and the presence of a pipelay and DSV for approximately three months.

The worst case scenario for the landfall option at the Humber Pipeline route for impacts on beach users is considered to be microtunnel with cofferdam. This will involve the presence of an anchored jackup barge for six months, a support vessel for six months, and a pipelay vessel and DSV for up to three months. During the landfall works by microtunnel with cofferdam, access by other sea users at the landfall areas may be restricted. However, this will be on a temporary basis and over a localised area. All other users will be made aware of the works through the promulgation of notifications through standard communication channels. The beach works site at Humber will be cordoned off from the general public for health and safety grounds. A passage will be maintained to allow members of public access along the length of the beach during construction works. Access will be maintained for as much of the construction period as much as reasonably practical.

9.4.3 Snagging Risk

During installation, there is the potential for formation of mounds due to the deployment and recovery of anchors (e.g. for the pipelay vessel). A final decision on the type of vessel which will be utilised to lay the pipelines has not been made, but it may be a vessel which will require anchoring. A 12-point anchoring system may potentially be used for the pipelay vessel, with each anchor being re-positioned every 400 m along the pipeline routes. The maximum length of any of the anchor lines will be 1.2 km. Residual spoil berms may also be present along trenched sections of the pipelines or cables, although the majority of spoil is expected to be used to infill trenches. Overtrawling anchor mounds or spoil berms with fishing gear could result in sediment being retained in fishing nets, with potential damage of nets and equipment and affecting catches, as well as posing a threat to the safety of the vessel. These mounds and berms are most likely to form in areas where sediments at or near the surface contain heavy clay. As discussed in Section 4.3, the seabed sediments in the Development area mostly comprise sand and gravel and the Development location is within a high energy environment. However, stiff clays may be present in some areas. Where sandy sediments are observed in the Development area, the sediment is expected to provide a little resistance to towed gear in contact with the seabed and therefore, the gear is likely to be able to pull through the sediment and wash out. However, in areas with stiff clays, anchor mounds and berms may have the potential to persist for a longer period of time. As described in Section 3.2.11, regular maintenance and pipeline route survey inspections will be carried out during the Development lifetime to determine the condition of the pipeline and reduce any snagging risks.

Fishing gear, such as nets, can also become trapped on subsea infrastructure, resulting in loss of fishing gear or potentially posing a threat to the safety of the fishing vessel and the crew, or damage the asset. Snagging of fishing gear can occur where structures are laid or fixed on the seabed. Fishing methods which are towed along the seabed, including dredges and demersal trawls, are operated within the Endurance Store and along the pipeline routes and these methods are most sensitive to snagging risks.

For the worst case scenario, it has been assumed that no permanent safety zones will be in place along the pipeline routes or within the Endurance Store for the assessment of snagging risk ,and, as such, once the installation and support vessels have moved out of these areas, there will be no statutory restrictions on fishing. Within the Endurance Store, all subsea infrastructure will be designed to be fishing friendly and all infield flowlines will be trenched and back-filled for protection, with the exception of spot locations and at spool-pieces connecting the flowlines to the manifolds and wellheads. This will reduce the snagging risk as far as practicable. The infield pipeline will be surface laid. However, fishers will be made aware of the location of all infrastructure in the Endurance Store, and considering the low effort my demersal trawls and scallop dredgers in this area, the snagging risk is considered low.

As described in Section 9.4.3, snagging risks may be associated with the presence of pipeline and cables, as well as the potential formation of free spans. Areas where the pipelines or cables will be trenched and backfilled are expected to be sufficiently buried to reduce the potential risk of snagging. Where the pipelines or cable are rock protected, berms will be designed to be fishing friendly to also reduce any potential snagging risk. Therefore, the key areas of potential snagging are considered to be associated with areas of the pipelines or cables that are surface laid and unprotected. Areas of free span may also occur along the pipeline routes in areas of hard or uneven seabed, or where strong currents have caused scour beneath the pipelines.

The SSIV on the Teesside Pipeline route also has the potential to interact with fishing gear through the introduction of potential snagging points, which may result in damage or loss of fishing gear or in severe cases, loss of life. However, as the SSIV will be designed to be fishing friendly, the snagging risk is considered low.

Scallop dredging and demersal trawling may occur along the pipeline routes. However, scallop dredging primarily occurs between the 6 and 12 NM limit, representing only a small portion of the pipeline route lengths, and demersal trawling effort is low. Furthermore, Rouse *et al. (*2020) showed that the frequency of snagging events resulting in financial loss, vessel abandonment and/or crew injury or fatality in the North Sea drastically declined (by 98.6%) between 1989 and 2016 and is more likely to occur with older assets. This decline is most likely related to improved Global Positioning Systems (GPS) and communication / data sharing (Rouse *et al.*, 2020).

The location of all infrastructure will be provided to UKHO and the Kingfisher database to enable all fishing vessels to determine the location of such infrastructure. Regular maintenance will also be carried out to identify any potential snagging points (including free spans) and remediate this risk. Considering these mitigation measures, the snagging risk is assessed as low. It is acknowledged that there is a limited potential risk of snagging that remains and that the consequences of this may be severe. However, the risk of snagging has been comprehensively reduced as far as practicable. Measures have also been recommended to reduce the snagging risk in the NRA, such as the distribution of post-lay survey reports to relevant fisheries organisations to increase awareness of the potential the risk of snagging.

9.4.4 Dropped Objects

There is the possibility for objects to be accidentally lost overboard during construction and installation activities and as part of normal O&M. If large enough, such objects can provide an uncharted obstacle that has the potential to damage fishing nets or fishing catch. As described in Section 9.5.4, procedures will be implemented during installation and maintenance activities to reduce the potential for dropped objects and post-installation debris surveys will be undertaken to identify any significant dropped objects for potential removal. Therefore, any potentially effects associated with dropped objects will be minimal. The pipelines will be adequately protected, and thus, minimise the potential for any damage to the pipelines as a result of a dropped object.

9.4.5 Disturbance and Collision Risk to Marine Mammals

9.4.5.1 Collision Risk to Marine Mammals

Increased vessel traffic during installation and construction presents an increased risk of collision with marine mammals. Wilson *et al. (*2007) identifies the main drivers in influencing the number and severity of strikes as a result of shipping as:

- Vessel type and speed;
- High levels of ambient noise resulting in difficulty in detection of approaching vessels;
- Weather conditions and time of navigation affecting the ability of crew to locate marine mammals; and
- Marine mammal behaviour, which is species-specific (but appears to affect juveniles and sick individuals more often than animals in good health as juveniles are inexperienced in how to respond to ship presence and sick animals may be unable to remove themselves from an impact situation and may be less able to recover).

Vessels travelling at 7 m/s or faster are those most likely to cause death or serious injury (Wilson *et al.*, 2007). Vessels involved in the Development are likely to be travelling considerably slower than this, and therefore collision risk is expected to be lower than that posed by commercial shipping activity. The period of greatest vessel presence will be during installation.

9.4.5.2 Disturbance to Marine Mammals

As outlined in Section 4.4.6, harbour porpoise are expected to be the most frequently occurring cetacean in the Development area, followed by minke whale and white-beaked dolphin. Densities of harbour porpoise are expected to be greatest in February, March and November. Densities of minke whale and white-beaked dolphin are expected to be highest in the summer and early autumn months (June to Nov) (Reid *et al.*, 2003). The Endurance Store and part of the Teesside and Humber Pipeline routes overlap with the SNS SAC, designated for harbour porpoise. Specifically, the area that the Development overlaps with represents the area of the SAC which is important for harbour porpoise in the summer, although a portion of the site which is important in winter lies adjacent to the Humber pipeline route. Other regularly occurring cetaceans potentially present in the vicinity of the Development include bottlenose dolphin, Atlantic white-sided dolphin, common dolphin, pilot whale, and killer whale. Harbour porpoise have been shown to be displaced by construction vessels at the

Beatrice and Moray East OWFs but that out to 4 km from the vessel, no response was observed (Benhemma-Le Gall *et al.,* 2021). Minke whale and white-beaked dolphin may also be disturbed by vessel presence. However, it is expected that all species will become habituated to vessel presence and will be able to rapidly recover from any disturbance. Furthermore, vessel presence will be temporary and short-term, slow-moving, and occurring against an already busy shipping background, it is expected that any physical presence impacts are not expected to be significant.

The predicted densities of grey and harbour seal are low in the Endurance Store and increase towards the shore, along the Teesside and Humber Pipeline routes. Harbour seal densities remain low across the Development; however, grey seals reach up to 101 – 200 individuals per 25 km^2 and 0.06 – 0.08% of the grey seal at-sea population at any one time. Harbour seal densities are particularly high along the Humber Pipeline route.

It is possible that the physical presence of vessels associated with the Development could disturb seals hauled out on land. This impact would be most significant for breeding seals hauled out on the coast since adults could exhibit flight reactions which result in them temporarily abandoning their young. In addition, seals that are undertaking the annual moult spend more time out of the water and if they are alarmed to the extent that they move into the water then they may lose condition as a result of additional energetic costs.

Brasseur and Reijnders (1994, in Scottish Executive, 2007) suggest vessels more than 1,500 m from hauled out grey or harbour seals would be unlikely to evoke any reaction in seals but that they could be expected to detect the presence at between 900 and 1,500 m. At closer than 900 m a flight reaction could be expected. These distances are similar to those described by other research (Andersen *et al. (*2011, in Skeate *et al.*, 2012) Jansen *et al.* (2010, in Skeate *et al.*, 2012). The main seal haul-outs in the SNS are located at Donna Nook and Blakeney, both of which are associated with designated sites: Humber Estuary SAC and the Wash and North Norfolk Coast SAC, respectively. Other key haul-outs are located at Horsey and Scroby sands (Russell, 2016). The Humber Pipeline route is 4 km from the Humber Estuary SAC, which contains the Donna Nook seal haul out site, which is the closest haul out to the Development. Considering this distance, no significant disturbance to seals at haul-outs is expected.

As the area of the Development is considered relatively heavily trafficked already it would be fair to assume that any marine mammals which utilise the area, including cetaceans and seals, are already subject to vessel activity on a regular basis and are accustomed to this activity. The Development is therefore unlikely to illicit a disturbance response beyond that which species in the area already experience.

9.4.6 Disturbance to Birds

Disturbance from vessel activity may displace birds from an area of sea, effectively amounting to habitat loss during the period of disturbance (Drewitt and Langston, 2006). Development activities may directly disturb birds leading to displacement from foraging or loafing[220] areas, causing birds to move elsewhere and potentially affecting breeding productivity or survival rates at an individual or population level. A single, localised disturbance event does not have an immediate effect on the

[220] *Loafing is described as behaviour not connected with feeding or breeding. The term includes preening and resting, vital for individual maintenance and ultimately survival.*

survival or productivity of an individual bird. However, repeated disturbance events could lead to displacement affecting the survival and productivity of a bird.

In general, it is considered that any disturbance impact will be direct, but temporary, local and discontinuous during construction becoming less frequent during operation. A detailed summary of vessel types and activity durations is presented in Section 3.5.

The Development is located in an area highly utilised by existing shipping with a total of 49,320 AIS vessel movements recorded across the study area for the NRA between March 2021 and February 2022 (Xodus Group, 2023a). During pipeline installation, the development phase during which the greatest number of vessels will be required is pipelay. At any one time, pipeline installation will occur in discrete sections of the pipelines meaning therefore, that large areas of the pipeline routes will be undisturbed for prolonged periods of time during the overall construction programme.

At the Endurance Store, drilling activities will be undertaken for 370 days and will require the highest number of vessels and the highest number of vessel days although activity will be focused in a relatively small area.

The details associated with each development activity including the number of vessels present, the spatial area affected and the period across which activities occur, will determine the worst case scenario for each species. However, in general, the worst case scenario for the Development, in terms of disturbance impacts, is the use of HDD at both landfalls followed by remaining activities. This would represent the development schedule with the highest number of vessel days.

There are however, details associated with the landfall options that mean that, for certain species, the implementation of another landfall option may represent the worst case scenario. Where this is relevant it will be discussed for individual species in the assessments presented.

The sensitivity of a species to disturbance events varies. Those species and species groups that are less sensitive to vessel movements include fulmar and gulls, opportunistic scavengers that will forage within tens of metres of machinery and moving vessels. Whilst there is evidence to demonstrate that gannet are displaced by structures, evidence suggests they are not disturbed by vessels (Wade *et al.*, 2016). Throughout the lifetime of the Development, birds may return to undisturbed areas when activities are not occurring.

The Ornithological Technical Report (NIRAS, 2023) identified VORs based on the distribution and conservation of species in the SNS and their species-specific vulnerability to impacts associated with the Development, using the vulnerability scores presented in Wade *et al. (*2016)[221] and Bradbury *et al.* (2014). The species identified as VORs and a summary of their vulnerability to disturbance are presented in Table 9-3.

[221] *Vulnerability scores presented in Wade et al., (2016) are for impacts relating to OWFs. Therefore, this is considered to be conservative when compared to the impacts associated with the Development.*

Table 9-3 - Summary of the vulnerability of VORs Identified for the Development to disturbance (NIRAS, 2023)

Species	Vulnerability
Kittiwake *(Rissa tridactyla*)	Not vulnerable to disturbance Moderate habitat flexibility
Great black-back gull (*Larus marinus*)	Not vulnerable to disturbance Moderate habitat flexibility.
Sandwich tern (*Thalasseus sandvicensis*)	Not vulnerable to disturbance Moderate habitat flexibility
Little tern (*Sternula albifrons*)	Not vulnerable to disturbance Low habitat flexibility
Common tern (*Sterna hirundo*)	Not vulnerable to disturbance Moderate habitat flexibility
Artic tern (*Sterna paradisaea*)	Not vulnerable to disturbance Moderate habitat flexibility
Common guillemot (*Uria aalge*)	Moderate vulnerability to disturbance Moderate habitat flexibility
Razorbill (*Alca torda*)	Moderate vulnerability to disturbance Moderate habitat flexibility
Puffin (*Fratercula arctica*)	Moderate vulnerability to disturbance Moderate habitat flexibility
Red-throated diver (*Gavia stellata*)	High vulnerability to disturbance Low habitat flexibility
Gannet (*Morus bassanus*)	Not considered vulnerable to disturbance High habitat flexibility
Shag (*Phalacrocorax aristotelis*)	Moderate vulnerability to disturbance Moderate habitat flexibility
Cormorant (*Phalacrocorax carbo*)	Not vulnerable to disturbance Moderate habitat flexibility

Of the species identified in Table 9-3, the following are vulnerable to disturbance events and are therefore considered further in this section:

- Guillemot;
- Razorbill;
- Puffin;
- Red-throated diver; and

- Shag.

In addition to these species, consideration of the impact of the Development on SPA features (see Section 9.8) has identified a number of non-seabird features that require consideration. These are features of the Teesmouth and Cleveland Coast SPA and may occur in the intertidal area at the landfall for the Teesside Pipeline route. These species are redshank, sanderling and knot.

The timeframes for construction activities (Section 3.1.2) indicate that installation activities may occur when each of the above species is present in UK waters.

9.4.6.1 Guillemot and razorbill

Both guillemots and razorbills are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility meaning they are able to utilise a range of habitats (Wade *et al.*, 2016). The mean-maximum foraging range of guillemot is 55.5 km and for razorbill is 73.8 km (Woodward *et al.,* 2019). The closest breeding location to the Development for both species is within the Flamborough and Filey Coast SPA. Applying the generic foraging range for both species from Woodward *et al.* (2019) suggests birds from the Flamborough and Filey Coast SPA could interact with the areas in which activities associated with both pipelines and the Endurance Store could occur.

The density layers associated with Waggitt *et al. (*2020) suggest limited usage of the Endurance Store area by guillemot and razorbill in those months during which installation activities will occur with the exception of August and September when fledged birds and their accompanying adults are dispersing away from breeding colonies. However, more detailed utilisation data, presented as part of Cleasby *et al. (*2020) does suggest that the pipelines will run through areas of moderate to high usage for both species. The Cleasby *et al. (*2020) data shows no connectivity with the Endurance Store. Disturbance could also occur in the non-breeding season, with a large proportion of the regional population of guillemot remaining in the SNS during that period and a smaller, but still significant proportion of the regional razorbill population also doing so.

The effects of disturbance on auk[222] species during the installation of infrastructure within the marine environment is unclear. During construction surveys at the Lynn and Inner Dowsing OWF there appeared to be no significant patterns of change in guillemot abundance between the OWF and control sites (ECON, 2012). Leopold *et al. (*2010) found indications of disturbance to auks during some surveys at Egmond aan Zee (Netherlands) but numbers were too low to reach statistical significance. Activity at an OWF during construction is significantly greater than that associated with the installation of pipelines, involving many more vessels across much larger spatial and temporal scales and therefore it can be expected that if limited disturbance has been noted during construction of an OWF, then it is highly unlikely that significant disturbance will be noted during the installation of pipelines. Wade *et al. (*2016) report that auks may be disturbed by boats at several hundreds of metres distance although survey vessels have often approached to less than ten of metres before eliciting an evasion response, for example many birds are recorded within fifty metres during boat-based surveys at OWFs.

Installation of the pipelines and cables will involve varying numbers of vessels (Section 3.5). However, the area within which these slow-moving vessels will be located will represent a limited proportion of

[222] *A collective name for species of guillemots, razorbill and puffin in UK waters.*

the total area available to both guillemot and razorbill for foraging purposes and activity in any one area will occur across a limited timeframe. As a result, it is considered unlikely that disturbance events on guillemot and razorbill that may result from activities associated with the Development will result in a significant effect on the regional populations of guillemot or razorbill.

9.4.6.2 Puffin

Puffins are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility meaning they are able to utilise a range of habitats (Wade *et al.,* 2016). The mean-maximum foraging range of the species is 137.1 km (Woodward *et al.,* 2019) with the closest breeding location for the species to both pipelines and the Endurance Store being the small population at Flamborough Head with larger colonies further north (e.g. the Farne Islands SPA). Applying the generic foraging range for puffin from Woodward *et al. (*2019) suggests birds from Flamborough Head and the Farne Islands SPA could interact with the areas in which both pipelines and the Endurance Store would be located. However, as discussed in the Technical Report (NIRAS, 2023), the density layers associated with Waggitt *et al. (*2020) suggests limited usage of the pipeline areas and the Endurance Store by puffin.

Activities throughout the lifetime of the Development across both pipelines and at the Endurance Store could result in disturbance upon puffins. Puffins are present in the SNS in the breeding season, migrating into the Atlantic during the non-breeding season. Only those activities occurring in Q2 and Q3 of any year are therefore likely to impact on meaningful numbers of puffin. As identified above, puffins have a very large foraging range meaning they will be able to exploit a large area if they were to be disturbed by activities associated with the Development. Activities associated with the Development will not occur across the entire Development footprint at any one time with the affected area representing a negligible proportion of the total sea area available to puffins for foraging.

It is therefore considered that there will not be a significant effect on puffins as a result of disturbance events that are caused by activities associated with the Development due to the limited number of birds likely to be present, the species moderate sensitivity to disturbance and the species ability to utilise multiple habitats across a large area.

9.4.6.3 Red-throated diver

Red-throated divers are considered to have a high vulnerability to disturbance and have a low habitat flexibility meaning they are restricted in terms of the habitats they are able to exploit. The nearshore section of the Humber Pipeline route will pass through the Greater Wash SPA which is designated for red-throated diver in the non-breeding season (October to March). Lawson *et al.* (2016) suggests that the area through which the Humber Pipeline route will pass supports moderate densities of the species. There are unlikely to be significant numbers of red-throated diver in other sea areas through which the Teesside Pipeline route or Humber Pipeline route will pass or at the Endurance Store.

Regardless of the option chosen for landfall construction (HDD, direct pipe, microtunnel or microtunnel and cofferdam) all will require the presence of a jackup barge located in the nearshore. Activities on the jackup could cause disturbance to red-throated divers. The Development schedule indicates that the jackup barge will be present in the nearshore for 360 days if the landfall is constructed using HDD or microtunnelling. These two options are therefore identified as the worst case for disturbance impacts on red-throated diver and it is assumed that the jackup barge will be present for 360 days within the non-breeding season (October to March) for red-throated divers. The remaining details of these two methods for the purposes of assessing disturbance impacts on red-throated diver are comparable.

A 2 km buffer is generally used when assessing disturbance impacts from vessels and it is considered appropriate for use in this assessment. If this buffer is applied to the jackup barge the ZoI would cover approximately 12.6 km^2, although note that a proportion of this buffer will occur over land depending on the exact location of the barge. This represents only 0.4% of the total Greater Wash SPA area or an even smaller proportion of the total area of the SNS.

The average density in the area affected within a 2 km buffer around the jackup barge is approximately 0.6 birds/km^2. When multiplied by the area affected (12.6 km^2) provides an affected population of approximately seven birds. The regional population of red-throated diver in the SNS is 10,177 birds (Furness, 2015). An affected population of seven birds therefore represents 0.07% of the regional population.

Mortality rates associated with the disturbance of birds due to construction activities are unknown with no evidence that displacement by vessels will result in direct mortality of individual birds. Mortality as a consequence of displacement is more likely to occur as a result of increased densities outside of the impacted area, which may lead to increased competition for resources. Displacement of birds from low-density areas (e.g. the area associated with the cable route) is less likely to result in mortality as these areas are likely to be of lower habitat quality. As such, the use of a 1% mortality rate is considered appropriate for this assessment[223].

Applying a 1% mortality rate results in a displacement mortality of less than one bird. This level of impact is considered to be of an insignificant magnitude in relation to the regional population of red-throated diver (10,177 birds). Such a low level of displacement mortality represents less than 0.01% of the regional population of red-throated diver. It is therefore considered that activities associated with the landfall installation do not have the potential to cause an effect that would significantly impact red-throated diver.

9.4.6.4 Shag

Shags are considered to have a moderate vulnerability to disturbance and have a moderate habitat flexibility meaning they are able to utilise a range of habitats (Wade *et al.,* 2016). The mean-maximum foraging range of the species is 13.2 km (Woodward *et al.,* 2019) with the closest breeding location for the species to the Humber Pipeline route at Flamborough Head. The Humber Pipeline route and the Endurance Store are, at the closest points, beyond the foraging range of the species from Flamborough Head. The closest breeding location for shag to the Teesside Pipeline route is at ConocoPhillips Jetty in the Tees Estuary which supports 10 Apparently Occupied Nests (AON) (JNCC, 2022d). The Teesside Pipeline route is within the foraging range of shag from this breeding location and therefore the species could experience disturbance due to construction activities occurring at the landfall or in the nearshore.

Construction activities at the landfall and the nearshore are expected to occur during the period in which shag will be present within the estuary. However, these activities are limited in terms of the spatial area that they will occupy and the timeframe across which they will occur. For construction

[223] *A 1% mortality rate is consistent with the rate applied in previous assessments, including those for telecommunications and OWF export cables on the east coast of England.*

activities in the nearshore , these will occur out to 18 km meaning for the large majority of the period during which nearshore activities are occurring they will be outside of the foraging range of shag from the breeding colony.

The Tees Estuary is an area of significant disturbance with the birds nesting on a deep water jetty that is subject to frequent disturbance events, including the docking and loading/unloading of tankers (ships) and visual and noise disturbance events from onshore activities. These birds are therefore likely to already be tolerant of a certain level of disturbance, although could still react to disturbance events that occur in areas where disturbance would not normally occur.

Given the small number of birds, the level of disturbance already being experienced by these birds, the moderate vulnerability of shag to disturbance, the ability of the species to utilise a range of habitats and the limited spatial and temporal scales across which installation will occur it is considered highly unlikely that there will be any significant effects on this species as a result of activities associated with the Development.

9.4.6.5 Redshank, knot and sanderling

The Teesside Pipeline route makes landfall to the west of Redcar at Coatham Sands. The departmental brief accompanying the proposed extension to the Teesmouth and Cleveland Coast SPA (Natural England, 2018a) indicates that knot utilise the Coatham Sands and Redcar Rocks areas during foraging. Sanderling are found on the sandy beaches at Redcar and Coatham Sands with smaller numbers in Hartlepool Bay. Redshank can be found feeding on the intertidal mudflats, saltmarsh areas and intertidal rocky shores within the SPA. When roosting all three species utilise areas away from the proposed landfall location (Ward *et al.,* 2003).

Knot begin to arrive on the coast at Teesside in late July and early August with birds leaving in early March (Ward *et al.,* 2003). Redshank return to the area from early July with the number of birds declining into May. Local breeding redshank remain through May and June. Sanderling begin arriving in the area from mid-July with birds leaving during spring (Ward *et al.,* 2003).

Cutts *et al. (*2013) identify redshank and knot as being highly sensitive to noise disturbance whereas sanderling is considered to have a low sensitivity. Piling may be required for installing trestles associated with HDD landfall methodology, with this likely to take place at high tide. At high tide all three species will be located away from the landfall location and therefore the source of disturbance in the nearshore and it is therefore considered unlikely that disturbance will occur. As a result the likelihood of a significant effect occurring on these species is considered to be highly unlikely.

9.5 Management and Mitigation

9.5.1 Increased Vessel Traffic and Collision Risk

A number of mitigation measures will be employed to minimise the impact of increased vessel traffic and collision risk resulting from the Development:

- CtL will be in place for the drilling operations;
- Standby vessel(s) will operate on site for the duration of drilling operations. Guard vessel(s) will support the pipelay vessels, as required;
- Establishment of temporary 500 m safety zone around the drilling rig during drilling operations;

- In line with the HSE Operations Notice 54, Establishment of safety zones for sub-sea installations, the Development will apply for safety zones under The Petroleum Act 1987 at the wellheads, manifolds and nearshore SSIV locations. Future applications shall be subject to consultation with interested parties.
- As required by subsequent submissions e.g. Pipeline Works Authorisation and Screening Directions, consultation will be undertaken with relevant authorities and organisations, including fisheries;
- Information on the drilling and installation operations will be provided to operators of vessels through standard United Kingdom Hydrographic Office (UKHO) communication channels such as Kingfisher Bulletin, Notice to Mariners and radio navigation warnings;
- Compliance with Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGS);
- Appointment of a Fisheries Liaison Officer (FLO) and development of a fisheries liaison strategy; and
- Vessel Management Plan will be in place.

9.5.2 Temporary and Long-Term Exclusion

bp, as operator of the Development, has reduced the vessel requirements and the number of vessel days as far as practicable. Additionally, to reduce impacts the following measures will be implemented:

- Information on the drilling and installation operations will be provided to operators of vessels through standard UKHO communication channels such as Kingfisher Bulletin, Notice to Mariners and radio navigation warnings;
- Appointment of a FLO and development of a fisheries liaison strategy;
- Rock berms will be designed to be fishing friendly e.g. 1:3 slide slope;
- Subsea infrastructure within the Endurance Store will be designed to industry standards such as NORSOK U001 / ISO 13628-1 trawl load standards; and
- UKHO and the Kingfisher database will be provided with information on all infrastructure.

9.5.3 Snagging Risk

Mitigation measures will be employed to minimise the impact of snagging risk resulting from the Development, including:

- Information on the drilling and installation operations, including the locations of any anchors and associated anchor lines will be communicated through UKHO communication channels as Kingfisher Bulletin, Notice to Mariners and radio navigation warnings;
- Appointment of a FLO and development of a fisheries liaison strategy;
- Rock berms will be designed to be fishing friendly e.g. 1:3 slide slope;
- Subsea infrastructure within the Endurance Store will be designed to industry standards such as NORSOK U001 / ISO 13628-1 trawl load standards;
- Maintenance and pipeline route survey inspections will be carried out during the Development lifetime to determine the condition of the pipelines and minimise any snagging risks. If overtrawl trials are required along pipelines following survey effort, relevant stakeholders will be consulted on the methodology;
- Standby vessel(s) will operate on site for the duration of drilling operations. Guard vessels will be utilised where a risk assessment indicates that they are required to mitigate the risk of

fishing interaction with infrastructure that has been installed but has not yet been protected; and
- UKHO and the Kingfisher database will be provided with information on all infrastructure.

9.5.4 Dropped Objects

The potential for dropped objects will be minimised during drilling, installation and operation through the following measures:

- Potential for dropped objects will be minimised via;
  - Lift planning will be undertaken to manage risk during lifting activities and all lifting equipment will be tested and certified;
  - All deck items will be securely stowed;
  - All equipment and material on vessels will be adequately stowed and seafastened;
  - Transfers of objects will use specialist equipment and consider environmental conditions; and
  - Procedures will be put in place to determine and record the location of any lost material and to support recovery of any significant dropped objects.
- The pipeline spools are to be protected which minimises the possibility of a dropped object causing damage. Concrete mattresses are the base case method of protection, however rock placement or purpose built structures may be utilised;
- In the vicinity of the subsea infrastructure at the Endurance Store, pre- and post-installation surveys will be undertaken. 'As-built' surveys will be performed along the pipelines and cables which will include identification of any significant dropped objects along the routes and at the Endurance Store.

9.5.5 Disturbance and Collision Risk to Marine Mammals

The following measures will be utilised to minimise potential impacts to disturbance and collision risk to marine mammals as a result of the Development:

- Relevant personnel will receive targeted environmental awareness training; and
- Vessel Management Plan will be in place.

9.5.6 Disturbance to Birds

The following measures will be utilised to minimise potential impacts to bird species as a result of the Development:

- Relevant personnel will receive targeted environmental awareness training; and
- Vessel Management Plan will be in place.

9.6 Cumulative, In-combination and Transboundary Impacts

A list of other projects have been identified in consultation with OPRED and other consultees, which together with the Development may result in potential cumulative or in-combination impacts. The list of these projects including details of their status at the time of the EIA and a map showing their location is provided in Appendix D. Having considered the information presently available in the public domain on the Developments for which there is a potential for cumulative or in-combination impacts, Table 9-4 indicates those with the potential to result in cumulative or in-combination impacts from a physical presence perspective.

The consideration of which projects could result in potential cumulative or in-combination impacts is based on the results of the Development specific impact assessment together with the expert judgement of the specialist consultant. The distance at which projects were screened in for other sea users are:

- Commercial fisheries: 50 km;
- Shipping and navigation: 10 NM (18.5 km);
- Other sea users: Projects overlapping with the Development footprint;
- Seabirds: Dependent on mean maximum foraging range; and
- Marine mammals: 50 km.

It is acknowledged that the ZoI for the cumulative impacts on commercial fisheries will depend on the extent of fishing grounds. The Teesside and Humber Pipeline routes and the Teesside – Store cable overlap with scallop grounds and scallop dredgers fish nomadically across the UK coastline. However, considering the short-term nature of any impacts from the Development on commercial fisheries and the wide availability of scallop grounds across the UK, any cumulative impacts are expected to be not significant. Therefore, the cumulative impact assessment focusses on other plans, projects and activities within 50 km of the Development to capture cumulative impacts on fisheries with smaller operating ranges that are more sensitive to the cumulative impacts posed by the Development in-combination with other projects, plans and activities. Operational projects are considered to be part of the existing baseline, with the exception of projects with the potential for ongoing effects.

Table 9-4 - Summary of cumulative and/or in-combination impacts for physical presence

Project title	Relevant receptors				
	Commercial fisheries	Shipping & navigation	Other sea users	Marine mammals	Seabirds
Hornsea Project Four	✓	✓	✓	✓	✓
Dogger Bank C Transmission Asset	✓	✓	✓	✓	✓
Dogger Bank B Transmission Asset	✓	✓	✓	✓	✓
Sofia Transmission Asset	✓	✓	✓	✓	✓
Scotland to England Green Link – SEGL2	✓	✓	✓	✓	✓
Hornsea Project Four Transmission Asset	✓	✓	✓	✓	✓
Amethyst (Oil & gas surface infrastructure)					✓
Kumatage field (Oil & gas surface infrastructure)					✓
Hornsea Project Two					✓
Hornsea Project One					✓
Teesside					✓
Westermost Rough					✓
Humber Gateway					✓
Triton Knoll					✓
Crown Estate Offshore Wind Leasing Round 4 Preferred Project #1					✓
Crown Estate Offshore Wind Leasing Round 4 Preferred Project #2					✓
Crown Estate Offshore Wind Leasing Round 4 Preferred Project #3 (Outer Dowsing)					✓
Hornsea Project Three					✓

Project title	Relevant receptors				
	Commercial fisheries	Shipping & navigation	Other sea users	Marine mammals	Seabirds
Dudgeon					✓
Dudgeon Extension					✓
Sheringham Shoal					✓
Sheringham Shoal Extension					✓
Dogger Bank A					✓
Sofia OWF					✓
Blyth Offshore Demonstrator (phase 1)					✓
Blyth Offshore Demonstrator (phase 2)					✓
Inner Dowsing					✓
Race Bank					✓
Lincs					✓
Lynn					✓
Dogger Bank B					✓
Dogger Bank C					✓
Hornsea 3 Transmission Asset					✓
Humber 1					✓
Humber 2					✓
Humber 3					✓
Humber 4					✓

Given the highly localised nature of impacts relating to dropped objects and snagging risk, all other operators will be under the same safety regulations as the Development and will be required to adopt procedures minimizing the risk that the seabed represents a hazard to fishing and other operations. Therefore, the potential for a cumulative impact to arise is considered to be low and therefore, the cumulative impact associated with snagging risk and dropped objects is not considered further.

9.6.1 Increased Risk of Vessel Collision

A number of projects in the vicinity of the Development (Table 9-4) will utilise vessels which have the potential to act cumulatively in adding to the vessel collision risk posed by the Development. It is considered that already active projects pose a significantly reduced collision risk, as operational phase vessel numbers are generally fewer in comparison to those needed for installation and construction. Therefore, it is considered that the physical presence of the Development will not act cumulatively with any already active projects in terms of increasing collision risk. In terms of projects which are under construction or have recently received consent, there is the likelihood of increased vessel activity which may act cumulatively with vessel activity relating to the Development. This is particularly true for those projects located closest to the Development with overlapping construction timelines, which includes all of the projects listed as relevant to commercial fisheries, shipping and navigation and other sea users in Table 9-4. However, the construction periods of these projects are not planned to all be concurrent and it is unlikely that peak vessel activity or vessel routes for these other projects will overlap with those of the Development. Considering the temporary nature of the impacts from the Development and the fact that notifications will be provided to other sea users, it is considered that such cumulative impacts will not be significant.

It is acknowledged that non-UK vessels will be active in the region, given the offshore location of the Development, and therefore there is the potential for transboundary impacts. However, considering the short duration of the works and the implementation of the mitigations listed in Section 9.5.1, the potential for significant transboundary effects is low.

9.6.2 Temporary and Long-Term Exclusion

A 500 m safety will be implemented at the Endurance Store during the drilling operations. The safety zone associated will amount to an area of 0.8 km^2 from which fishing activity and vessel presence will be prohibited over a period of approximately 370 days. In addition, as described in Section 9.5.2, the presence of installation vessels that are limited in manoeuvrability may also obstruct access for other vessels. If the safety zone and installation activities overlap with those of other projects, there could be a cumulative effect on the amount of area excluded to other sea users, including commercial fisheries, shipping and navigation and other sea users. Projects with construction periods that overlap with the Development have the potential to act cumulatively on other vessels, and this includes all those listed as relevant to commercial fisheries, shipping and navigation and other sea users in Table 9-4. Exclusion zones for installation and construction activities will be temporary and short-term for the Development and for other projects. The presence of operational infrastructure once constructed (e.g. offshore wind turbines) may also act cumulatively with any restricted access for other sea users that occurs during the installation and decommissioning period of the Development. However, given the short-term nature of the construction for the Development, the cumulative impact is considered to be low.

During the operational phase, permanent safety zones around wellheads, manifolds and the SSIV will be applied for, and this has been assumed as the worst case for this impact. However, any obstruction of access will be spatially limited, and therefore, the potential for a cumulative impact to arise is low.

With regards to transboundary effects, it is acknowledged that non-UK vessels could be impacted by the Development, including French, Belgium, Danish, Dutch, German and Swedish fishing vessels. Mostly non-UK fishing effort is concentrated within ICES rectangle 37F0 and 37F1 within which the Endurance Store resides, and comprises pelagic trawling, demersal trawling, beam trawling and demersal seining (Xodus Group, 2023b). The nature of the impact to non-UK vessels is considered to be consistent with those assessed for UK vessels.

9.6.3 Disturbance and Collision Risk to Marine Mammals

Considering the fact that the any collision risk to marine mammals will be highly localised to the vicinity of the Development, there is expected to be a limited potential for cumulative impacts with other projects to arise, when the mitigations listed in Section 9.5.5 are considered. It is expected that projects will implement similar mitigations in order to reduce any potential collision risk or disturbance to marine mammals (e.g. Vessel Management Plan) to reduce any potential collisions with marine mammals.

With regards to disturbance during the drilling and installation works, there is the potential that cumulative impacts could arise with other projects in the vicinity of the Development with overlapping construction timelines. It is expected that vessel routes to and from nearby projects will already be well used, and therefore, there will not be a discernible increase in the potential disturbance caused. Furthermore, construction vessels will likely be moving slowly, reducing the potential impacts to marine mammals. Considering this, in combination with the short-term nature of the disturbance caused, the potential for a significant cumulative impact to arise is low.

With regards to transboundary effects, the potential collision risk and disturbance from vessels associated with the Development are expected to be localised in extent and of a short-term nature. Therefore, the potential for transboundary impacts is considered low.

9.6.4 Disturbance to Birds

The screening process used to identify plans and projects that may act cumulatively to affect bird species has identified the industries that may interact with those birds affected by disturbance associated with vessel activity and the presence of infrastructure associated with the Development in the marine environment. Projects that may interact with a species have been identified using the mean-maximum foraging range of a species (Woodward *et al.,* 2019) from relevant breeding colonies[224].

Impacts with the highest magnitude will occur during the construction or decommissioning phases of oil and gas surface infrastructure with this being the period during which a higher number of vessels are present. Vessels will also be present in the operational phase although it is unlikely that the number of vessels required will be discernible from background shipping levels especially in a heavily transited area such as the SNS. There are only two oil and gas surface infrastructure projects that are

[224] *In the non-breeding season, birds are able to exploit much wider areas due to the cessation of the central place foraging as a result of the necessity to provision chicks and therefore the likelihood of any impact in this season is considered highly unlikely.*

scheduled to be constructed or decommissioned during the construction period for the Development (Table 9-4). There is unlikely to be any interaction between these two projects, landfall construction associated with the Development and red-throated divers or shags however, both lie within the foraging range of guillemots, razorbills and puffins from relevant breeding colonies. These projects are therefore screened in.

The highest number of vessel movements associated with a pipeline project occur during the construction phase with fewer occurring during the operational period. It is however not considered that the number of vessels associated with the operational phase of a pipeline will be discernible from background shipping levels. There are no pipeline projects scheduled for construction during the timeframe of the Development and therefore pipeline projects are screened out.

Although OWFs have a number of impacts on seabirds, only disturbance effects associated with vessel movements are considered in cumulative assessment with the Development. The highest number of vessel movements associated with an OWF occur during the construction and decommissioning phases however, there is still a large number of vessel movements during the operational phase. There are a number of OWF projects that will be constructed or be operational during the timeframes for the Development and these may interact with all of the species considered for disturbance in this chapter. These projects are therefore screened in.

The highest number of vessel movements associated with a subsea cable project occur during the construction phase with few to none during the operational phase. It is considered that the number of vessels associated with the operational phase of a cable will be indiscernible from background shipping levels. There are six subsea cables that may be constructed during the Development timeframes which may interact with guillemot, razorbill, puffin and red-throated diver. These are therefore screened in.

There will be vessel movements associated with the operational phase of an Aggregate and Mineral Extraction project. There are a number of Aggregate and mineral Extraction projects that will be operational during Development timeframes. These may interact with guillemot, razorbill, puffin and red-throated diver. These are therefore screened in.

Port developments may result in disturbance during the operational phase with vessels moving in and out of ports. Shipping from ports utilises well defined shipping routes and therefore it is unlikely that any increase in shipping associated with ports which occurs through defined shipping lanes will lead to any discernible increase in disturbance on seabirds. These projects are therefore screened out.

The assessment of disturbance from increased vessel traffic for the Development alone is predicted to be of negligible consequence for all relevant species. The potential impact of disturbance from increased vessel movement for any other project which may have a cumulative effect is also considered to be of negligible magnitude as the extent of disturbance around vessels is limited, and represents a very small proportion of the habitat available to these species.

Taking into account the spatial separation between projects and the total sea area available for seabird use, the cumulative impact is predicted to be of localised spatial extent. The cumulative impact is likely to be of a temporary and short-term duration, occurring intermittently for short periods of time and at low intensity. The magnitude of any cumulative impact associated with disturbance from vessel movements is therefore considered to be negligible which is not significant in EIA terms.

Given the offshore location of the Development, there is the potential for transboundary impacts. However, the potential for disturbance from vessels associated with the Development are expected to be localised in extent and of a short-term nature. Therefore, the potential for transboundary impacts on seabirds is considered low.

9.7 Decommissioning

Decommissioning will be undertaken according to recognised industry standard environmental practice, in line with the legislation and guidance in place at the time. The most recent guidance (BEIS, 2018) which sets out UK policy on pipeline decommissioning requires that the Decommissioning Programme is supported by a streamlined EA, with the aim of ensuring the seabed of the Development area does not pose a risk to marine environment or to navigation and other users.

It is anticipated that the decommissioning activities associated with the Development will in the main be a reversal of the installation activities and the majority of the potential impacts and the suggested mitigation and management relating to physical presence of the Development will be the same as has been described for installation. Any potential impacts that decommissioning operations may have on other sea users and wildlife interactions will occur in an area that experienced an impact during the installation operations. It is likely that potential impacts will be of a similar or lesser magnitude than the impacts already described in this chapter.

9.8 Protected Sites

As described in Section 4.5 and Section 4.6.9, there are several offshore and coastal designated sites in close proximity to the Development. Non-ornithological sites that are considered to be potentially impacted by the Physical Presence of the Development (excluding any impacts relating to seabed disturbance which is assessed in Chapter 6: Seabed Disturbance) include those that are designated for other mobile species such as marine mammals and birds.

9.8.1 Marine Mammal Designations

The Endurance Store and part of the Teesside and Humber Pipeline routes and the Teesside – Store cable are located within the SNS SAC, designated for harbour porpoise. Specifically, the Development overlaps with the area of the SAC that is more heavily utilised by harbour porpoise in the summer, although a portion of the site utilised in winter lies adjacent to the Humber Pipeline route. Additionally, the Humber Estuary SAC, which contains grey seal as a designated feature is approximately 4 km southeast of the Humber Pipeline route. Grey seals can travel several kilometres from the haul-outs to forage and so there is potential connectivity between grey seals designated within this SAC and the Development.

As described in Section 9.4.5, there is the potential for increased vessel traffic to result in increased collision risk and/or disturbance to marine mammals. However, increases in vessel traffic will be temporary and as the vessels will mostly be travelling slowly, collision risk and disturbance to marine mammals is expected to be low. Considering the area already contains moderate levels of vessel traffic, this is not expected to result in any LSEs on the harbour porpoise population designated in the SNS SAC or the grey seal population of the Humber Estuary SAC.

9.8.2 Ornithological Designations

The potential for LSEs on SPA features as a result of activities associated with the development has firstly been considered based on connectivity between a SPA and the Development. Following this, consideration is given to the pathways through which impacts may occur on the features for which connectivity has been identified. Consideration has been given to all potential SPA features including breeding seabird features (both in the breeding and non-breeding seasons) (e.g. gannet, kittiwake, etc.), wintering water bird features (e.g. red-throated diver, common scoter) and features that utilise either intertidal and/or terrestrial habitats (e.g. ringed plover, turnstone).

9.8.2.1 Identification of Likely Significant Effects

Connectivity has been identified between the Development and the SPAs and associated features listed in Table 9-5 based on generic foraging ranges from Woodward *et al.* (2019) and direct overlap between the pipelines/ Endurance Store and each SPA. There may be additional SPAs that have connectivity with the Teesside and Humber Pipeline routes and Endurance Store due to either very large foraging ranges of designated features (e.g. fulmar, Manx shearwater, Leach's petrel and great skua) or the occurrence of a feature in the area in which the pipelines will be installed outside of the breeding season. However, installation activities will occur within a restricted spatial area that is unlikely to represent a significant proportion of the area available to breeding or non-breeding seabirds. It is therefore considered that a LSE will not occur for any feature of any other SPA.

The remainder of this section considers each SPA for which generic connectivity has been identified and looks at potential connectivity in more detail including consideration of site-specific foraging data and the distribution of features within SPAs.

Table 9-5 - SPAs and associated features for which connectivity exists with the Teesside and Humber Pipelines

SPA	Reason for connectivity	Development component with which connectivity exists	Associated features
Flamborough and Filey Coast	Mean-maximum foraging range	Teesside Pipeline Humber Pipeline Endurance Store	Gannet Kittiwake Guillemot Razorbill
Farne Islands	Mean-maximum foraging range	Teesside Pipeline	Kittiwake Puffin
Teesmouth and Cleveland Coast	Direct overlap / Mean-maximum foraging range	Teesside Pipeline	All features
Forth Islands	Mean-maximum foraging range	Teesside Pipeline Humber Pipeline Endurance Store	Gannet
St Abb's to Fast Castle	Mean-maximum foraging range	Teesside Pipeline	Kittiwake
Northumberland Marine	Mean-maximum foraging range	Teesside Pipeline	Kittiwake
Northumbria Coast	Mean-maximum foraging range	Teesside Pipeline	Arctic tern
Greater Wash	Direct overlap	Humber Pipeline	All features
Humber Estuary	Mean-maximum foraging range	Humber Pipeline	Little tern

As discussed in Section 9.4.6, of the seabird species that may interact with the Development, as identified in the Technical Report (NIRAS, 2023), guillemot, razorbill, puffin, red-throated diver and shag are considered vulnerable to impacts associated with disturbance. This therefore means that only the Flamborough and Filey Coast SPA, the Farne Islands SPA, St Abb's to Fast Castle SPA and Northumberland Marine SPA, being those SPAs at which those features that are vulnerable to disturbance impacts are qualifying features are considered further.

As identified in the Technical Report, the landfall for the Teesside Pipeline route is located within the Teesmouth and Cleveland Coast SPA. The Teesmouth and Cleveland Coast SPA is designated to protect breeding populations of avocet, common tern and little tern, non-breeding populations of knot, redshank, ruff and Sandwich tern and a waterbird assemblage which includes as main components, gadwall, shoveler and sanderling. The assessment presented here considers project activities and associated impacts occurring below MHWS[225]. There is direct overlap between the Teesside Pipeline route and the SPA in addition to areas offshore that may be used by some features for foraging or other purposes. A number of features however do not utilise areas below MHWS (avocet, ruff, gadwall and shoveler) and therefore no connectivity is identified. The potential for LSE is identified for redshank and knot due to these features utilising habitats that may be impacted by the Development through disturbance impacts and the high vulnerability of these two features to noise disturbance impacts.

9.8.2.1.1 Conclusion

Based on the information presented above LSE has been identified for the following SPAs and features in relation to disturbance impacts associated with the Development.

Table 9-6 - SPAs and associated features for which LSE has been identified in relation to disturbance impacts associated with the Development

SPA	Features	Development component
Flamborough and Filey Coast SPA	Guillemot Razorbill	Teesside Pipeline Humber Pipeline Endurance Store
Farne Islands	Puffin	Teesside Pipeline
Teesmouth and Cleveland Coast	Knot Redshank	Teesside Pipeline
Northumberland Marine	Puffin	Teesside Pipeline
Greater Wash	Red-throated diver	Humber Pipeline

9.8.2.2 Assessment of Adverse Effects

9.8.2.2.1 Farne Islands and Northumberland Marine – puffin

The mean-maximum foraging range of puffin is 137.1 km suggesting connectivity with the Teesside Pipeline route, this foraging range, however, incorporates data from puffins on Fair Isle which were recorded during years where reduced prey availability led to unusually long foraging trips. If these data are removed the mean-maximum foraging range for puffin is 119.6 km, which would mean only the nearshore area of the Teesside Pipeline route is within the foraging range of puffin from the Farne Islands SPA. Colonies on the east coast of England generally show high breeding success and have not been affected by dramatic food shortages experienced by populations in Shetland and Orkney. This implies that food supply, and as such foraging opportunities, are good. This would result in foraging breeding adults having to travel shorter distances than those cited in the literature in order to acquire

[225] *As noted in Section 2.5.3.2, while the ES will focus on the impacts up to MLWS, it is good practice to reflect impacts up to MHWS and therefore this ES includes discussion of relevant impacts up to MHWS.*

food and a foraging range of 119.6 km is considered more applicable to the puffin feature of the Farne Islands SPA.

The Northumberland Marine SPA was designated to protect important sea areas utilised by various species that breed at colonies adjacent to or within the SPA. The puffin feature of the SPA incorporates the population of birds at the Farne Islands SPA and therefore any conclusion reached for the puffin feature of the Farne Islands SPA is considered equally applicable to the puffin feature of the Northumberland Marine SPA.

There are few studies that have investigated disturbance/displacement effects on puffins, with the majority having combined all auks together mainly due to limited numbers of each species having been present in relevant study areas. Wade *et al. (*2016) scores puffin the same vulnerability score to disturbance as guillemot and razorbill and therefore the results of studies referencing these species (see below for a summary) are considered applicable to puffin. These studies are associated with effects from OWFs however, with activity at an OWF during construction significantly greater than that associated with the installation of a pipeline, involving many more vessels across much larger spatial and temporal scales. It can therefore be expected that if limited disturbance has been noted during construction of an OWF then it is highly unlikely that significant disturbance will be noted during the installation of a pipeline.

The relative density layers associated with Waggitt *et al. (*2020) suggest that the Teesside Pipeline route is not located in areas of high-density for puffin.

The Development is located in an area highly utilised by existing shipping with a total of 49,320 AIS vessel movements recorded across the study area for the NRA between March 2021 and February 2022 (Xodus Group, 2023a). The total number of vessels to be used during each phase of the development is presented in Table 3-21 and Table 3-22 of Section 3.5. During pipeline installation, the phase during which the greatest number of vessels will be required is pipelay. Pipelay will also require the most vessel days. At any one time, pipeline installation will occur in discrete sections of the pipelines meaning therefore, that large areas of the pipeline routes will be undisturbed for prolonged periods of time during the overall construction programme. The area which may be disturbed represents a negligible proportion of the total sea area available to puffins for foraging. Puffins have a very large foraging range (Woodward *et al.,* 2019) meaning they will be able to exploit a largl area if they were to be disturbed by activities associated with the Development. As a result, it is considered unlikely that disturbance events on puffin that may result from activities associated with the Development will result in an adverse effect on the integrity of the Farne Islands SPA.

The same conclusion Is reached for in-combination impacts. When the spatial separation between projects is considered in-combination and the total sea area available for seabird use is taken into account, the in-combination impact is predicted to represent a negligible proportion of the area available to puffin for foraging. Any impact is likely to be of a temporary and short-term duration, occurring intermittently for short periods of time and at low intensity. The magnitude of any cumulative impact associated with disturbance from vessel movements is therefore considered to be negligible which is not considered to represent an adverse effect on the integrity of the SPA.

9.8.2.2.2 Flamborough and Filey Coast SPA – guillemot and razorbill

The mean-maximum foraging range of guillemot is 73.2 km and for razorbill 88.7 km suggesting connectivity with both pipelines and the Endurance Store for both features. These foraging ranges, however incorporate data from birds on Fair Isle which were recorded during years where reduced prey availability led to unusually long foraging trips. If these data are removed the mean-maximum foraging range for guillemot is 55.5 km and for razorbill 73.8 km, which would mean only certain areas of each pipeline are within foraging range of each feature. Colonies on the east coast of England generally show high breeding success and have not been affected by dramatic food shortages experienced by populations in Shetland and Orkney. Additionally, the populations of guillemot and razorbill at the SPA have shown increasing population trends in recent decades. This implies that food supply, and as such foraging opportunities, are good. This would result in foraging breeding adults having to travel shorter distances than those cited in the literature in order to acquire food and foraging ranges of 55.5 km and 73.8 km are considered more applicable to guillemot and razorbill, respectively at the Flamborough and Filey Coast SPA. This is supported by the data associated with Cleasby *et al. (*2020) which suggests that the pipelines will run through areas of moderate to high usage for both species. The Cleasby *et al. (*2020) data shows no connectivity with the Endurance Store.

The relative density layers associated with Waggitt *et al. (*2020) suggest that the distribution of both guillemot and razorbill from the SPA is focussed around the colony, as would be expected in the breeding season, and comparable general spatial trend as in the utilisation data from Cleasby *et al. (*2020), when birds are restricted due to the need to provision young. Guillemot densities occur in a more restricted area when compared to razorbill, especially between April and July, with much lower densities occurring along the routes of the two pipelines and within the Endurance Store. In August and September, densities in areas further offshore begin to increase representing the movement of fledged birds and accompanying adults away from colonies.

Effects of disturbance during the construction phases of OWFs on guillemots are currently unclear. During construction surveys at the Lynn and Inner Dowsing OWF there appeared to be no significant patterns of change in guillemot abundance between the OWF and control sites (ECON, 2012). Leopold *et al. (*2010) found indications of disturbance to auks during some surveys at Egmond aan Zee, Netherlands, but numbers were too low to reach statistical significance. Activity at an OWF during construction is significantly greater than that associated with the installation of a pipeline, involving many more vessels across much larger spatial and temporal scales and therefore it can be expected that if limited disturbance has been noted during construction of an OWF then it is highly unlikely that significant disturbance will be noted during the installation of a pipeline.

Wade *et al. (*2016) report that auks may be disturbed by boats at several hundreds of metres distance although survey vessels have often approached to less than ten of metres before eliciting an evasion response, for example many birds are recorded within fifty metres during boat-based surveys at OWFs.

The Development is located in an area highly utilised by existing shipping with a total of 49,320 AIS vessel movements recorded across the study area for the NRA between March 2021 and February 2022 (Xodus Group, 2023a). The total number of vessels to be used during each phase of the development is presented in Table 3-21 and Table 3-22 of Section 3.5. However, not all of these vessels will be present at the same time and will be focussed around specific parts of the pipelines at any given time.

During pipeline installation, the phase during which the greatest number of vessels will be required is pipelay. Pipelay will also require the most vessel days. At any one time, pipeline installation will occur in discrete sections of the pipelines meaning therefore, that large areas of the pipeline routes will be undisturbed for prolonged periods of time during the overall construction programme.

Of the activities occurring at the Endurance Store, drilling activities will be undertaken for 370 days and will require the highest number of vessels (four) and the highest number of vessel days (907) although activity will be focused in a small area.

As a result, it is considered unlikely that disturbance events on guillemot and razorbill that may result from activities associated with the Development will result in an adverse effect on the integrity of the Flamborough and Filey Coast SPA.

The same conclusion is reached for in-combination impacts. When the spatial separation between projects considered in-combination and the total sea area available for seabird use is taken into account, the in-combination impact is predicted to represent a negligible proportion of the area available to both guillemot and razorbill for foraging. Any impact is likely to be of a temporary and short-term duration, occurring intermittently for short periods of time and at low intensity. The magnitude of any in-combination impact associated with disturbance from vessel movements is therefore considered to be negligible which is not considered to represent an adverse effect on the integrity of the SPA.

9.8.2.2.3 Teesmouth and Cleveland Coast – knot, redshank

Knot begin to arrive at the SPA in late July and early August with birds leaving in early March (Ward *et al.,* 2003). Redshank return to the SPA from early July with the number of birds declining into May. Local breeding redshank remain through May and June.

The Teesside Pipeline route makes landfall to the west of Redcar at Coatham Sands. The departmental brief accompanying the proposed extension to the SPA indicates that knot utilise the Coatham Sands and Redcar Rocks areas during foraging. When roosting both species utilise areas away from the proposed landfall location (Ward *et al.,* 2003).

Cutts *et al. (*2013) identify both species as being highly sensitive to noise disturbance. Piling may be required when anchoring jackup barges in the nearshore with this likely to take place at high tide. At high tide both species will be located elsewhere within the SPA and it is therefore considered unlikely that disturbance will occur. As a result there is considered to be no adverse effect on the integrity of the Teesmouth and Cleveland Coast SPA due to disturbance impacts on knot or redshank.

There are no projects that will act in-combination with the Development on the knot and redshank features of the Teesmouth and Cleveland Coast SPA

9.8.2.2.4 Greater Wash – red-throated diver

Red-throated divers are considered to have a high vulnerability to disturbance and have a low habitat flexibility meaning they are restricted in terms of the habitats they are able to exploit. The nearshore section of the Humber Pipeline route will pass through the Greater Wash SPA which is designated for red-throated diver in the non-breeding season (October to March). Lawson *et al. (*2016) suggests that the area through which the Humber Pipeline route will pass supports moderate densities of the species. There are unlikely to be significant numbers of red-throated diver in other sea areas through which the Humber Pipeline route or Teesside Pipeline route will pass or at the Endurance Store.

As described in Section 9.4.2.2, works at the landfall will involve the use of a jackup barge which will be located in the nearshore for 360 days and it is assumed for the purposes of this assessment that this will occur during the period when red-throated divers are present in UK waters (i.e. October to March).

A 2 km buffer is generally used when assessing disturbance impacts from vessels and it is considered appropriate for use in this assessment. If this buffer is applied to the jackup barge the ZoI would cover approximately 12.6 km^2, although note that a proportion of this buffer will occur over land depending on the exact location of the barge. This represents only 0.4% of the total Greater Wash SPA area.

The average density in the area affected within a 2 km buffer around the jackup barge is approximately 0.6 birds/km^2. When multiplied by the area affected (12.6 km^2) provides an affected population of approximately seven birds. The SPA population of red-throated diver is 1,407 birds. An affected population of seven birds therefore represents 0.5% of the SPA population.

Mortality rates associated with the disturbance of birds due to construction activities are unknown with no evidence that displacement by vessels will result in direct mortality of individual birds. Mortality as a consequence of displacement is more likely to occur as a result of increased densities outside of the impacted area, which may lead to increased competition for resources. Displacement of birds from low-density areas (e.g. the area associated with the cable route) is less likely to result in mortality as these areas are likely to be of lower habitat quality. As such, the use of a 1% mortality rate is considered appropriate for this assessment.

Applying a 1% mortality rate results in a displacement mortality of less than one bird. This level of impact is considered to be of an insignificant magnitude in relation to the SPA population of red-throated diver. Such a low level of displacement mortality represents less than 0.05% of the SPA population of red-throated diver. It is therefore considered that activities associated with the landfall installation do not have the potential to result in an adverse effect on the integrity of the SPA.

There are a number of projects, including the installation of transmission infrastructure associated with OWFs, operational vessel movements to oil and gas infrastructure and OWFs and vessel movements associated with aggregate extraction that could act in-combination with the Development on the red-throated diver feature of the Greater Wash SPA. However, when the spatial separation between projects is considered, the detailed timings associated with each project and the total sea area available for seabird use is taken into account, the in-combination impact is predicted to represent a negligible proportion of the SPA area.

It is unlikely that vessel movement associated with all of these projects will occur at the same time and if they were to do so they would be spatially separated and not affect a significant proportion of the SPA. The Greater Wash SPA is also regularly transited by a large number of vessels leaving and arriving at ports along the east coast of the UK. Any impact is therefore likely to be of a temporary and short-term duration, occurring intermittently for short periods of time and at low intensity and will likely be indiscernible from current levels of shipping through the SPA. The magnitude of any in-combination impact associated with disturbance from vessel movements is therefore considered to be negligible which is not considered to represent an adverse effect on the integrity of the SPA.

9.9 EPS Risk Assessment

All cetaceans (whales and dolphins) are designated as EPS. According to the Conservation of Offshore Marine Habitats and Species Regulations 2017, it is an offence to:

- Deliberately capture, injure or kill any wild animal of a EPS; or
- Deliberately disturb wild animals of a EPS in such a way as to:
  - Impair their ability to migrate, hibernate, survive, breed, or rear or nurture their young; or

- Significantly affect the local distribution or abundance of the species to which they belong.

According to the regulations, an assessment of the potential to injure and disturb such species must be undertaken for impacts relating to physical presence, in order to determine whether a EPS licence to conduct the operations is necessary. As demonstrated above, injury and significant disturbance to cetaceans is not expected and bp, as operator of the Development, considers there to be no requirement to apply for an EPS licence with regard to potential disturbance or collision risk related to the physical presence of the Development infrastructure.

9.10 Residual Impacts

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Shipping	Low	Low	Medium	Low
Fisheries	Medium	Low	Medium	Low
Other sea users	Medium	Low	High	Low
Beach users	Negligible	Low	Medium	Low
Marine mammals	Low	Low	High	Low
Birds	High	Low	Very High	Negligible
Rationale				

Shipping

Shipping, including in association with nearby assets, is considered to have a **low** sensitivity, as the activity can accommodate a short-term interference. Vulnerability is also considered to be **low**, as no long-term changes will be needed. The value of shipping is considered to be **medium** given the level of activity and number of routes in the area.

This chapter has assessed the potential impact of increased vessel traffic and collision risk and temporary and long-term exclusion on shipping and navigation. The Development area is located in an area of low vessel traffic at the Endurance Store and moderate to high vessel traffic along the Teesside and Humber Pipeline routes. Any increase in vessel traffic will be temporary and any interactions with other vessels or increased vessel collision risk will be mitigated through the measures described in Section 9.5.1, including the presence of a 500 m safety zone around the drilling rig, and adequate communication to other vessels to encourage awareness of Development activities. Exclusion impacts are mainly expected to result from the temporary 500 m safety zone in place around the drilling rig for 370 days as well the presence of installation vessels, localised to the Development area and from any permanent safety zones around wellheads, manifolds and the SSIV. With adequate communication to other users, it is expected that vessels can plan routes to avoid the safety zones with minimal interference. Overall, the magnitude of these impacts is assessed as **low** as the extent will be limited to the vicinity of the Development. Consequence is therefore assessed to be **negligible / minor.**

Fisheries

The fishing effort in area of the Development is considered to be moderate with a range of fishing methods being operated. The sensitivity of fisheries to potential impacts as a result of the physical presence of the Development is considered to be **medium,** as although the fishing industry has some ability to tolerate the impact and is also capable of recover from any short-term exclusion or obstruction of access, some fishing methods in the area have relatively small operational ranges (e.g. pots and traps), which are more limited in terms of where they can fish. The vulnerability is considered to be **low** as there are not expected to be any considerable long-term effects to commercial fishing in the area. The value of the receptor is considered to be **medium** as the effort in the area is considered to be moderate but forms a small part of a much larger area available for fishermen i.e. there is some flexibility to utilise other areas, albeit this will be limited for smaller vessels.

This chapter has assessed the impact of increased vessel traffic and collision risk, temporary and long-term exclusion, snagging risk and dropped objects on commercial fisheries. With regards to increased vessel traffic and collision risk and temporary and long-term exclusion, impacts will largely be temporary and localised to the Development area. Exclusion impacts are mainly expected to result from the temporary 500 m safety zone in place around the drilling rig for 370 days and from any permanent safety zones around wellheads, manifolds and the SSIV. No permanent exclusion is anticipated around the pipeline routes or cable infrastructure, although it is acknowledged that some fishers may refrain from deploying gear in areas where subsea infrastructure present. All subsea infrastructure in the Endurance Store, the SSIV and the rock / gravel placement will be designed to be fishing friendly and the locations of all infrastructure will be charted and communicated to the fishing industry. The risk of snagging will be mitigated by adequately communicating the locations of the infrastructure to the fishing industry and by surveying the infrastructure on a regular basis to identify and remediate against any potential snagging risks (e.g. free spans). The impacts from dropped objects will be mitigated through the measures proposed in Section 9.5.4, including the development of a dropped objects procedure and the completion of a pre-and post-installation debris survey at the Endurance Store and 'as-built' surveys along the pipelines.

Overall, for the reasons outline above, the magnitude of impact assessed as **low.** Consequence is therefore assessed as **minor.**

Other sea users

The Development is located in a busy area of the North Sea. The sensitivity of other sea users to the physical presence of the Development is considered to be **medium**, as other sea users are expected to be able to tolerate short-term exclusion and be able to rapidly recover from impacts. The vulnerability is assessed as **low** no permanent effects are anticipated. The value is considered to be **high**, as the other sea users are considered to have a high economic value and several other sea users in the area are contributing towards the UK's net zero ambitions.

This chapter has assessed the potential impact of temporary or long-term exclusion on other sea users in the vicinity of the Development, such as the OWFs, including the Hornsea Project Four OWF which overlaps with the Endurance Store, oil and gas assets, cables and dredge disposal sites. Impacts to other sea users will be mitigated through adequate promulgation of information to other users and charting of infrastructure. bp, as operator of the Development, will aim to minimise disruption to other sea users and promote co-existence and will consult relevant parties to achieve this. Therefore, the magnitude of impact is considered to be **low,** as the majority of impacts will be short-term and localised and will be reduced through the management and mitigation measures described in Section 9.5. Therefore, the consequence is assessed to be **minor**.

Beach users

The sensitivity of the receptor is considered **negligible** as the beach users have a high capability to change their behaviour. The vulnerability is **low** as there will be a short-term change to behaviour of beach users. The value of the receptor is considered **medium** as the area at the landfall areas may provide recreational amenity at a regional scale. Impacts on beach users are expected to be minimal at the Teesside landfall, as the landfall methodology here will involve HDD. At Humber, the magnitude is considered to be **low** as the impact is localised in scale and is temporary and short-term. Consequence is therefore assessed to be **negligible / minor**.

Marine mammals

The sensitivity of the receptor is considered **low** as marine mammal species are considered to have some tolerance to accommodate any potential impact and also have the ability to recover or adapt. The vulnerability is considered to be **low** as there will be no long-term change to the functioning of any marine mammal population.

The value of the receptor is considered to be **high** as a number of species are protected or are qualifying features of nearby protected areas.

The risk of collision arising from the Development is expected to be greatest during the construction phase. However, vessels will likely be travelling at slow speeds, meaning the collision risk is low. Disturbance is also expected to minimal, when placed in the context of the vessels already present in the region. Any disturbance will be short-term, temporary and localised. No impacts to seals at seal haul-outs are expected. Therefore, the magnitude is considered to be **low**. Consequence is therefore assessed as **negligible / minor.**

Birds

The sensitivity of bird species ranges from **high to low**. The vulnerability of all bird species is considered **low**. The species of interest are of **very high or high** value.

This chapter has assessed the potential impact of increased vessel traffic and the presence of infrastructure within the marine environment which may result in different forms of disturbance. The Development is located within or adjacent to areas that are important for a number of species. Any increase in vessel traffic will be temporary with birds able to utilise other areas if disturbed. Any temporary exclusion will predominantly occur during the construction period. Disturbance is however, expected to minimal, when placed in the context of the vessels and other infrastructure already present in the region. Any disturbance is expected to be short-term, temporary and localised.

The effect of impact is considered **negligible** as the effect on seabirds from increased vessel movement leading to disturbance will be of local spatial extent representing a very small proportion of the habitat available to these species, will not occur over a long time period, will be intermittent and be highly reversible. Effects on populations because of the extent of disturbance around vessels is limited. Consequence is therefore assessed as **minor**.

Consequence	Impact Significance
Minor	Not significant

10 ACCIDENTAL EVENTS

10.1 Introduction

All activities carry with them some risk of accidents. Accidents caused by human error, equipment failure or by extreme natural conditions may result in significant environmental impacts. The risk of accidental events is therefore an area of public concern if potentially significant impacts may result on water quality, flora, fauna or other users of the sea.

The potential impact of any accidental event will be determined by the location of the event, the type of release (e.g. diesel, CO_2), the characteristics, properties and direction of travel of any released material, and the environmental sensitivities which may lie in the path of the release. As environmental sensitivities vary spatially and temporally, the risk of any accidental release having an impact on the environment is influenced by the probability of occurrence, the consequence of the release reaching an environmentally sensitive area and the environmental sensitivities present at that time.

Accidental events related to the Development could impact the environment through releases of:

- Diesel from the jackup rig and installation vessels;
- Chemicals from the jackup rig and installation vessels;
- CO_2 from the pipelines, the wells or the Endurance Store; and
- Store Formation Water from wells.

For each of these types of releases, the potential impact of the accidental events has been evaluated as follows:

- Potential events and their probability of occurrence, including how risks will be sufficiently controlled;
- The potential impacts on the environment of any releases;
- The interventions that will be used to prevent or reduce the scale of any releases;
- The scale of residual risks remaining after consideration of the preventive measures, mitigations and interventions; and
- The risk of cumulative releases in and around the Development.

The Development does not present any unusual risks in relation to diesel or chemical releases: Development activities utilising these materials are also common to the oil and gas and renewables sectors. The section considering CO_2 and its transport, injection and ultimate storage in the aquifer is relatively more extensive as accidental events involving CO_2 in the marine environment are less familiar. This is also the case for accidental release of Store Formation Water.

A risk pathway approach to identify causes, impacts and consequences has been adopted in this chapter. Barriers to prevent the event occurring and the escalation of the event if it did occur are presented in this chapter with a description of the residual risk after mitigation.

The following specialists have contributed to this assessment:

- Xodus Group – diesel release modelling, impact assessment and ES section write up.

Table 10-1 provides a list of all the supporting studies which relate to the accidental events impact assessment.

Table 10-1– Supporting studies

Specialist	Details of study
National Oceanography Centre (NOC) and Plymouth Marine Laboratory (PML)	Endurance Reservoir and Bunter Outcrop Seabed Monitoring Technology Review. NOC and PML. NOC (2022).

10.2 Regulatory Controls

10.2.1 Hydrocarbon Release Regulatory Controls

The key regulatory drivers associated with the prevention and response to hydrocarbon (diesel) spill risks are summarised as follows:

- *The International Convention on Oil Pollution, Preparedness, Response and Cooperation (OPRC),* which has been ratified by the UK, requires the UK Government to ensure that operators have a formally approved OPEP, outlining emergency response procedures, in place for each offshore operation or agreed grouping of facilities. This is enacted through the Merchant Shipping (OPRC) Regulations 1998 (as amended);
- *The Offshore Installations (Emergency Pollution Control) Regulations 2002* give the Government power to intervene in the event of an incident involving an offshore installation where there is, or may be, a risk of significant pollution, or where an operator has failed to implement proper control and preventative measures. These regulations apply to accidental hydrocarbon releases; and
- *The International Convention for the Prevention of Pollution from Ships (MARPOL)* is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes.

10.2.2 CO_2 Storage Regulatory Controls

The Energy Act 2008 provides for a licensing regime that governs the offshore storage of CO_2. It forms part of the transposition into UK law of EU Directive 2009/31/EC on the geological storage of CO_2. The Carbon Dioxide (Licensing etc.) Regulations 2010 (SI 2010/2221, 'Licensing Regulations') transpose many other requirements of the directive. These requirements remain unchanged following UK departure from the EU.

The Licensing Regulations require:

- *Storage permit:* A consent granted by the NSTA under a licence, authorising the use of a place as a storage site[226]. The storage permit must be accompanied by supporting documents including (but not limited to) a MP, a corrective measures plan and a provisional post-closure[227] plan;

[226] *'storage site' means defined volume area within a geological formation used for the geological storage of CO_2 and associated surface and injection facilities.*
[227] *'post-closure' means the period after the closure of a storage site, including the period after the transfer of responsibility to the NSTA.*

- *Monitoring plan:* Must be risk-based and detail the monitoring to be deployed at the main stages of a project involving the geological storage of CO_2, including baseline, operational and post-closure monitoring;
- *Corrective measures plan:* Details the measures to be taken to prevent or stop the leakage of CO_2 from the storage complex; and
- *Proposed provisional post-closure plan:* The plan shall be based on the information collected and modelled during the implementation of the MP. It will provide information to inform the transfer of responsibility for the storage site from the operator to the competent authority (NSTA), a transfer that will occur no less than 20 years after the site has closed. Note that post-closure includes the period after the transfer of responsibility to the competent authority.

The Licensing Regulations also apply the Environmental Damage (Prevention and Remediation) Regulations 2009 to the geological storage of CO_2. This places responsibility on an operator to implement measures to prevent and remediate (if required) environmental damage.

10.3 Diesel Release Risks

10.3.1 Vessel Release Risks

10.3.1.1 Risk Description

During the lifecycle of the Development, multiple types of vessels will be used including construction, installation and supply vessels as well as jackup rigs. As is common with all marine operations, there is a risk of accidental events resulting in a release of diesel from vessels. The causes of diesel releases are generally grouped within six categories:

- Allision/Collision;
- Grounding;
- Hull Failure;
- Equipment Failure;
- Fire/Explosion; and
- Other.

Table 10-2 shows the number of spills that occurred in the UK Continental Shelf (UKCS) between 1970 and 2019 which were greater than 700 tonnes (t). The data is categorised by the operation underway at the time of the incident, and the primary cause of the spill. Equivalent data for spills of between 7 and 700 t is presented in Table 10-2. As indicated by the data in Table 10-3, spills greater than 700 t primarily occur while vessels are underway, either in open or restricted waters, and because of allision/collision, grounding, or hull failure (through structure failure or fatigue). The cause of 17.5% of spills were due to other operations or unknown. While it is not clear what the “other operations” incorporate, the unknown classification may be attributable to incident reporting requirements either historically or by flag state.

The number of incidents has decreased over the decades, with a notably significant reduction in grounding incidents between the 1970s (71 incidents) and 2010s (two incidents). During the 1990’s, incidents recorded as allisions/collisions became the primary cause of oil spills greater the 700 t. The decrease in incidents resulted from factors including improvements to vessel design, increased awareness, improved regulation, and greater regulatory scrutiny. shows that at 55%, the primary cause of oil spills between 7 and 700 t tends to be recorded as unknown. The main known cause is equipment failure during operations, particularly during loading and discharging operations.

Table 10-2 - The number of spills > 700 t by the operation underway at time of incident and primary cause of spill, 1970-2019 (MAIB, 2020)

Operation								
Causes	At anchor (Inland/ Restricted)	At anchor (Open Water)	Underway (Inland/ Restricted)	Underway (Open Water)	Loading/ discharging	Bunkering	Other Operations/ Unknown	Total
Allision / Collision	7	5	35	67	2	0	23	139
Grounding	5	1	46	68	2	0	28	150
Hull Failure	2	1	0	49	0	0	8	60
Equipment Failure	0	0	0	6	11	0	1	18
Fire / Explosion	2	2	1	25	13	1	9	53
Other	2	0	0	16	8	0	7	33
Unknown	0	0	0	1	6	0	6	13
Total	**18**	**9**	**82**	**232**	**42**	**1**	**82**	**466**
Percentage (%)	**4**	**2**	**17.5**	**50**	**9**	**0**	**17.5**	

Table 10-3 - The number of spills 7-700 t by the operation underway at the time of the incident and the primary cause of the spill, 1970 – 2019 (MAIB, 2020)

Operation					
Causes	Loading / Discharging	Bunkering	Other Operations	Unknown	Total
Allision/Collision	5	0	61	300	366
Grounding	0	0	27	244	271
Hull Failure	37	4	15	45	101
Equipment Failure	147	7	17	39	210
Fire / Explosion	9	0	14	26	49
Other	98	13	38	28	177
Unknown	99	9	14	81	203
Total	**395**	**33**	**186**	**763**	**1,377**
Percentage (%)	**29**	**2**	**14**	**55**	

The UKCS oil and gas industry typically relies upon some 170 platform supply vessels and 20 anchor handling tugs to deliver logistical support to mainly production assets located in the 299 producing fields. This same highly experienced fleet will provide the vessels used in the installation and construction activities for the Development. Globally the age profile of these upstream support vessels, logistical support vessels and other vessels that are likely to be required during this phase of the development (such as Crane, Pipe and Cable, Heavy lift and Barges, DSV and ROV Support) are around 15 to 20 years (Clarkson Research, 2020).

Whilst the shipping industry is investigating the use of alternative fuels and electric vessels, it should be expected that for the installation and construction activities of the Development, the vessels will be using marine diesel.

Diesel is a widely used name for hydrocarbon fuels, and is applied to a range of products. In its strictest sense, diesel is defined as a complex combination of hydrocarbons obtained by treating a petroleum fraction with hydrogen in the presence of a catalyst. It contains hydrocarbons having carbon numbers in the range C11 to C25 and boiling in the range 205°C to 400°C. This definition is often shortened to “distillates (petroleum) hydrotreated middle light” and describes a fuel that is a mixture of hydrocarbons produced for use primarily in the automotive industry. In marine applications this same hydrocarbon fraction, with certain additives, is a commonly used fuel, usually known as diesel fuel No. 2, marine gas oil (MGO) or marine diesel. For the purposes of this chapter, the fuel assumed for the vessels used as part of the Development will herein be referred to as marine diesel.

Due to lack of reactivity towards water, abiotic degradation of diesel hydrocarbons is negligible, except for those aromatic components (such as poly aromatic hydrocarbons (PAH)) that undergo photodegradation in the upper water column. By far the most significant method by which diesel hydrocarbons are removed from surface water is volatilisation, a process that is described by the vapour pressure of the diesel and its Henry's law constant. Hydrocarbons with the greatest propensity to volatilise also have the greater solubility in water, thereby undergoing both dissolution and volatilisation from a surface slick. The important factors controlling this are temperature and time as the mechanism responsible for the evaporation does not require the consideration of a boundary layer. The ECHA dataset for Diesel Fuel No. 2 states a vapour pressure 0.4 kPa at 40°C. However, due to the variable composition of this material, no Henry's law, solubility or partitioning data are available. Older European Chemical Bureau (ECB) data indicate that the partition coefficient (Log P_{ow}) for diesel is in the range 3.9–- 6.0.

Oil weathering models were undertaken for marine diesel to display evaporation, dispersion and surface oil over a period of 48-hours at different wind speeds, presented in Figure 10-1 to Figure 10-4. A worst case sea surface temperature of 14°C was chosen for the models, which represents the summer sea surface temperature at the Endurance Store. These models illustrate the importance of wind velocity in the dissipation of a diesel spill from the sea surface, for example, as seen in Figure 10-1 and Figure 10-4, a wind speed of 20 m/s reduces surface oil percentage to zero within 6 hours, while a wind speed of 10 m/s takes 38 hours.

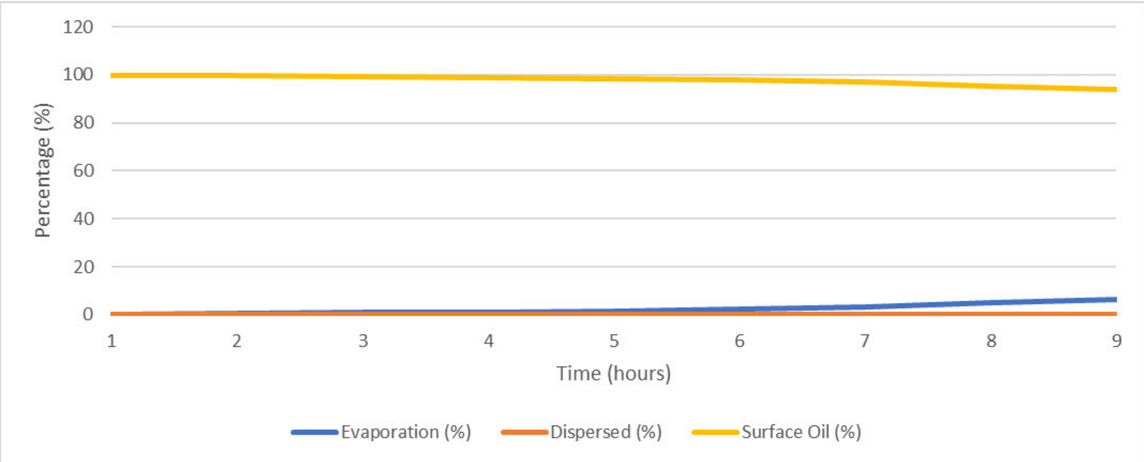

Figure 10-1 - Oil weathering model of marine diesel with a wind speed of 1 m/s

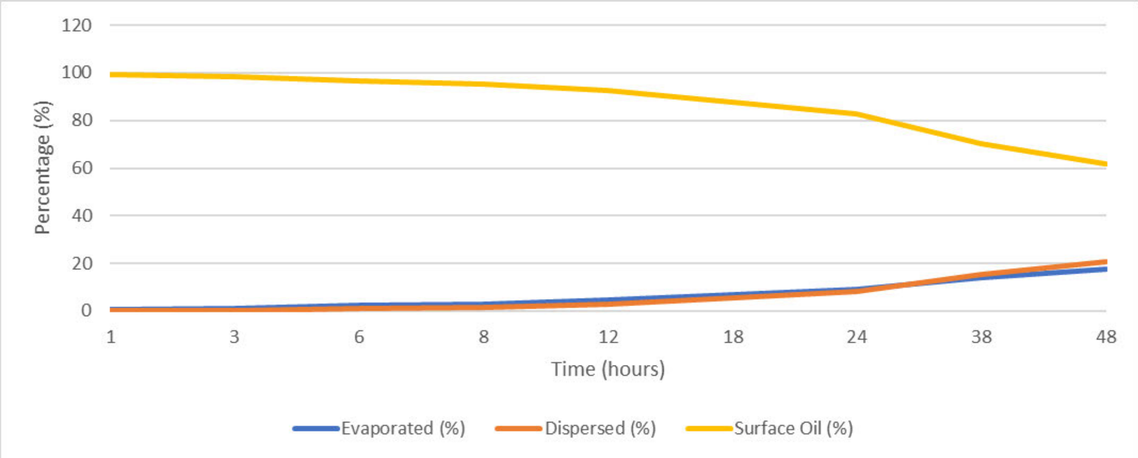

Figure 10-2 - Oil weathering model of marine diesel with a wind speed of 5 m/s

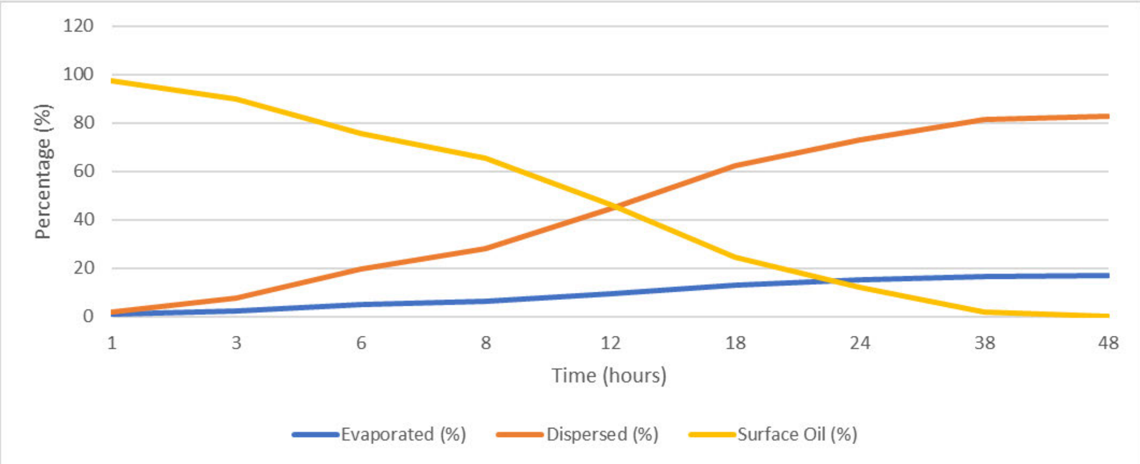

Figure 10-3 - Oil weathering model of marine diesel with a wind speed of 10 m/s

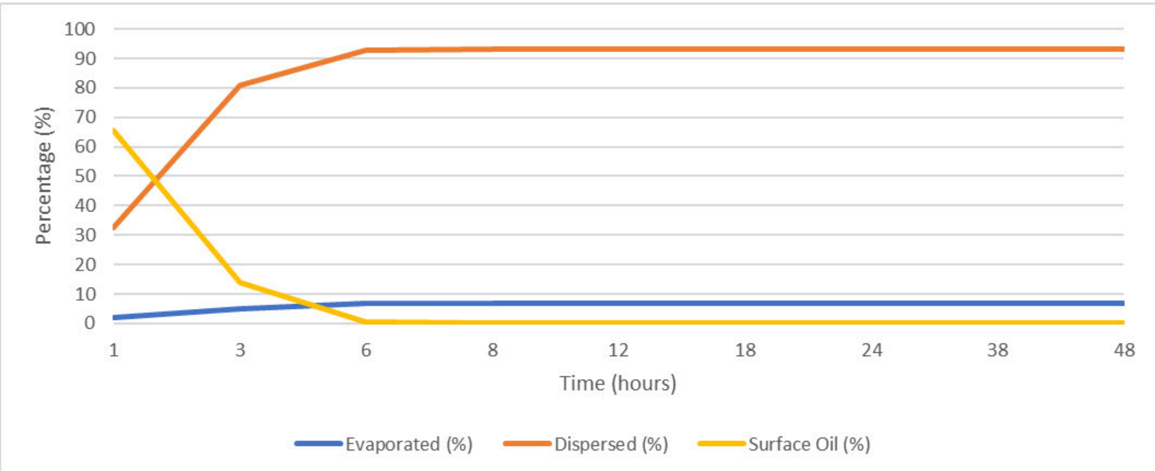

Figure 10-4 - Oil weathering model of marine diesel with a wind speed of 20 m/s

To identify theoretical worst case release scenarios, a review of the vessels which may be used during the lifetime of the Development was undertaken. This included vessels which may be used for the installation of the Teesside and Humber Pipelines and for the drilling of wells at the Endurance Store. The jackup rig used for drilling of wells at the Endurance Store has not yet been selected

(Section 3.3.2), however given the proposed well design and the water depth, the total diesel inventory for the size of jackup that will be utilised, will not exceed 736 m^3.

Pipelay vessels contain the greatest diesel inventories of the vessels operating closest to shore. Initial screening identified that the worst case release scenarios were associated with deep water pipelay vessels which could have a total diesel inventory of up to 8,098 m^3. Due to their draughts, deep water pipelay vessels are limited to a minimum water depth of 25 m. To model the worst case release, i.e. that which could occur closest to shore, release locations were selected along the pipelines at water depths of 25 m. Given the differences in seabed profile at Teesside and Humber, 25 m water depth occurs 4 km from the coast at Teesside and 21 km from the coast at Humber.

In summary, the worst case scenarios modelled include:

- Loss of entire rig diesel inventory (736 m^3) instantaneously at the Endurance Store;
- Loss of entire deepwater pipelay vessel diesel inventory (8,098 m^3) instantaneously in 25 m water depth during pipelay for the Teesside Pipeline; and
- Loss of entire deepwater pipelay vessel diesel inventory (8,098 m^3) instantaneously in 25 m water depth during pipelay for the Humber Pipeline.

As the drilling activity at the Endurance Store is occurring in an area of extensive historical hydrocarbon exploration, where there is a good understanding of the subsurface geology and into a stratum that is depleted of hydrocarbons there is no risk of a blowout of reservoir hydrocarbons or shallow gas hazard occurring. These accidental events have therefore been scoped out from further assessment.

10.3.2 Impact Assessment

10.3.2.1 Behaviour of Hydrocarbons (Diesel) at Sea

The potential environmental impact of an accidental hydrocarbon release depends on a wide variety of factors, which include:

- Accidental release volume;
- Type of hydrocarbon release;
- Direction of travel of the surface slick;
- Weathering properties of the hydrocarbon;
- Any environmental sensitivities present in the path of the slick (these may change with time); and
- Sensitivity of the sea and beaching locations.

The Oil Spill Contingency and Response (OSCAR) model has been developed by SINTEF to model the fate of hydrocarbons at sea. To understand the specific behaviour of releases from the Development, release modelling was conducted in accordance with BEIS (now DESNZ) guidance (BEIS Sept 2021) using this model. Further information on the rig and vessel types is provided in Chapter 3: Project Description. As justified in Section 10.3.1.1, the three worst case release scenarios modelled were[228]:

[228] These scenarios assume vessel fuel tanks are full at the time of loss and take no account of the reduction in fuel volumes given the fuel used to transit to the release location or for the storage of the fuel in a number of separate fuel tanks.

- Loss of entire rig diesel inventory (736 m^3) instantaneously at the Endurance Store;
- Loss of entire pipelay vessel diesel inventory (8,098 m^3) instantaneously near shore at Teesside (4 km from the shoreline); and
- Loss of entire pipelay vessel diesel inventory (8,098 m^3) instantaneously near shore at Humber (21 km from the shoreline).

These models were run on the basis that there was no intervention by any third-party to respond to the released marine diesel. The accidental release scenarios for the Development are detailed in Table 10-4.

Table 10-4 - Summary of accidental release scenarios modelled for the Development

Scenario number	Scenario description	Hydrocarbon type	Release volume (m^3)	Modelled depth of release	Model type
1	Loss of entire rig diesel inventory instantaneously at the Endurance Store (63 km from the nearest coastline in the SNS)	Marine Diesel	736	Sea Surface	Stochastic and deterministic
2	Loss of entire pipelay vessel diesel inventory instantaneously near shore (4 km from the shoreline) at Teesside	Marine Diesel	8,098	Sea Surface	Stochastic and deterministic
3	Loss of entire pipelay vessel diesel inventory instantaneously near shore (21 km from the shoreline) at Humber	Marine Diesel	8,098	Sea Surface	Stochastic and deterministic

10.3.2.2 Scenario 1: Jackup rig diesel inventory – Endurance Store

Modelling indicated that the diesel is not predicted to cross any median lines in all the seasons. The probability of surface oiling is presented in Figure 10-5. Beaching based on stochastic modelling was predicted to occur on the east coast of Northern England between South Tyneside to Great Yarmouth District. The maximum probabilities of shoreline oiling to shore from the rig at the Endurance Store was predicted to be 31.8% at the East Riding of Yorkshire and the minimum arrival time was predicted to occur at Scarborough District in 1 day 21 hours.

This predicted shoreline oiling arises from very small quantities of marine diesel moving through the water column to shore (rather than as a surface slick), as well as marine diesel below a sea surface thickness of 0.0003 mm (i.e. sheen) reaching the shoreline, and do not represent a significant oiling risk to the shoreline. The maximum quantity of marine diesel predicted to be onshore from any run during stochastic modelling was 19 kg in spring, 21 kg in winter, with no mass on shore from summer and autumn scenarios. This quantity of oil would not be detectible on the shoreline and the results of this modelling should be interpreted as no detectable shoreline oiling occurring[229].

Additional worst case deterministic runs were conducted based upon the results of the stochastic modelling to fully evaluate this conclusion. Worst case shoreline oiling was predicted to be a maximum of 0.4 g/m^2 after 30 days, across a total shoreline area extent of 120 m^2. This further supports the modelling interpretation of no detectable shoreline oiling.

[229] *In stochastic oil spill modelling no removal of the oil from the shore is simulated. Therefore, the quantities of oil recorded are those that arrive at the shore over the entire duration of the model. In reality wave action, volatilisation and biodegradation would all act on the shoreline oil reducing further the amount present on the shore.*

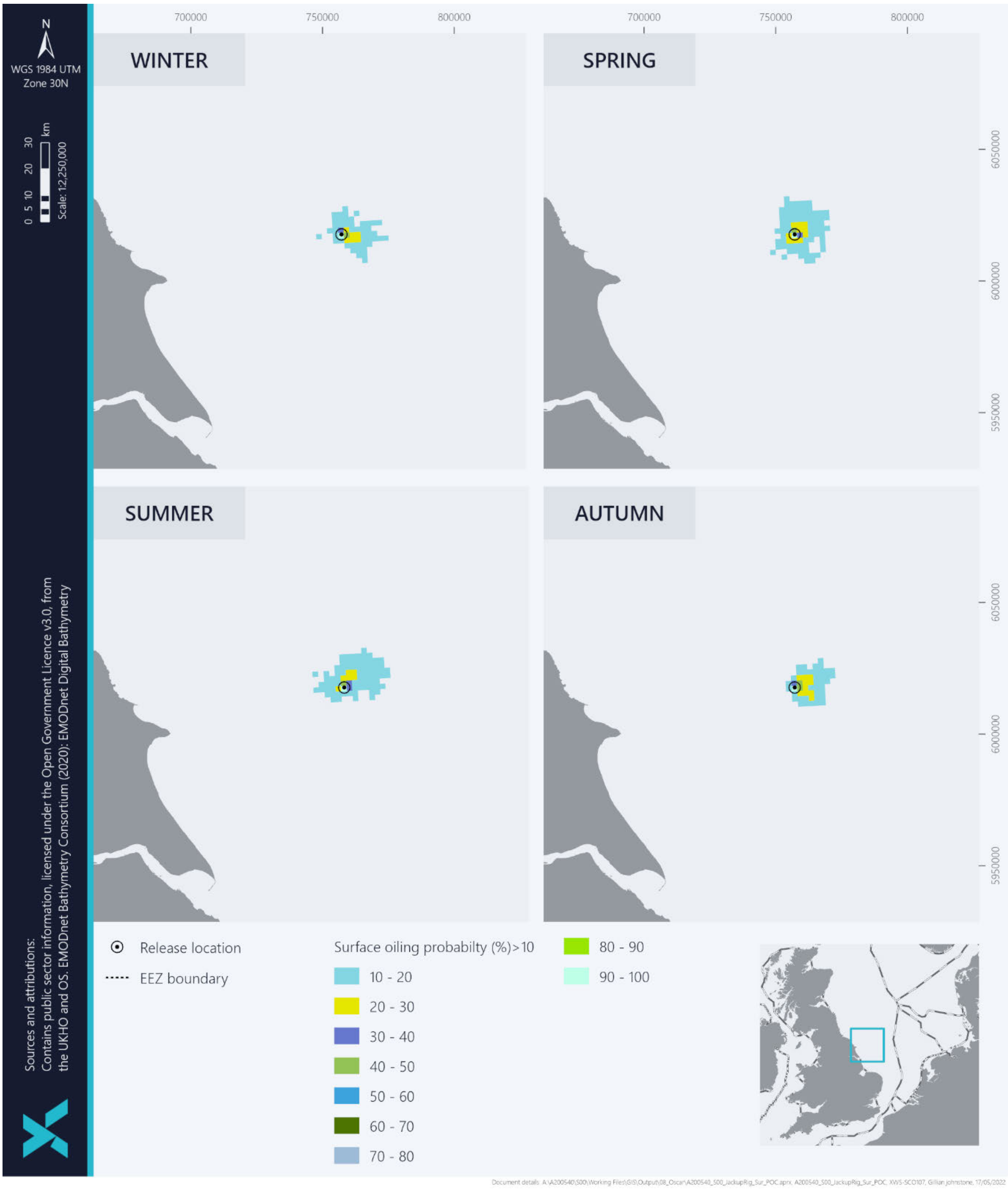

Figure 10-5 - Scenario 1: Loss of entire rig diesel inventory instantaneously at the Endurance Store – Probability of surface oiling (above 0.3 µm) above 10%

Release Behaviour

The mass balance of marine diesel over the duration of the release is presented in Figure 10-6. The deterministic model indicated that the most common predicted fate of the released oil was evaporation (46.50% by mass), followed by biodegradation which accounted for approximately 25.82% of the marine diesel. Approximately 27.70% of the diesel was predicted to deposit within the seabed sediment. Approximately 0.04% and << 0.01% accounted for diesel stranded onshore and oil present on the sea surface, respectively. No diesel was predicted to leave the modelled grid area.

The marine diesel is predicted to move rapidly from the sea surface within the first day of release. Initially dispersion and evaporation (up to four days) are the major removal mechanisms of oil from the sea surface. At five days, the diesel in the water column is incorporated into the sediment. This occurs when the mixing depth of the dispersed oil in the water column is sufficiently deep for the oil to interact with the seabed. It was predicted that very little of the marine diesel would reach the shore. Biodegradation of marine diesel is also predicted to be rapid over the first five to 10 days post spill, resulting in its removal from the environment.

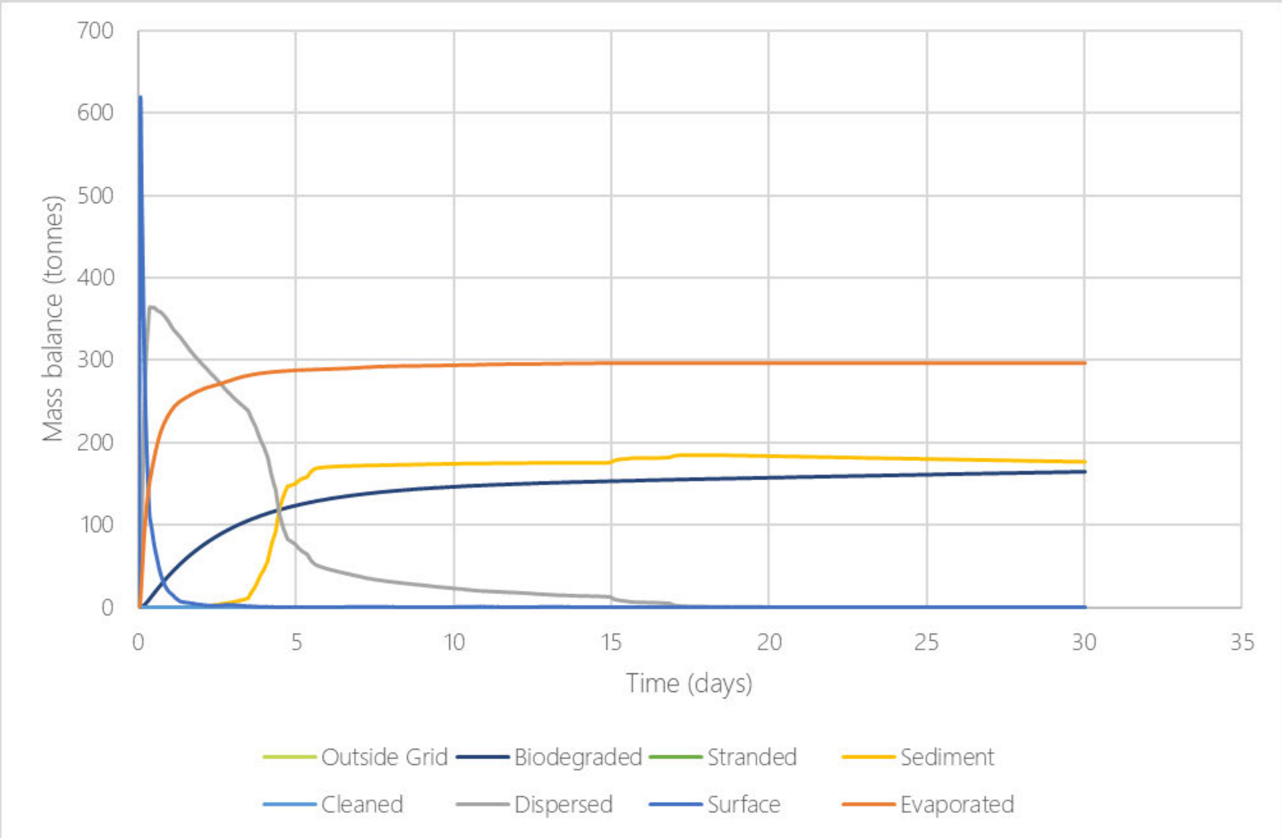

Figure 10-6 - Scenario 1: Loss of entire rig diesel inventory instantaneously at the Endurance Store deterministic scenario – Mass balance of marine diesel over time

Table 10-5 - Scenario 1: Loss of entire rig diesel inventory instantaneously at the Endurance Store deterministic scenario – Mass balance of marine diesel by day 30

Fate	Mass (kg)	Percentage (%)
Surface	0.01054	<< 0.01
Evaporated	297,100	46.50
Water Column	25.07	0.04
Sediment	177,100	27.70
Beached Onshore[230]	25.1	0.04
Biodegraded	165,100	25.82
Outside Gridded Area	0	0.00

10.3.2.3 Scenario 2: Pipelay vessel diesel inventory – Teesside

As expected from a nearshore release, scenario modelling indicated that diesel is not predicted to cross any median lines in all the seasons. The probability of surface oiling is presented in Figure 10-8. Beaching based on the results of the stochastic modelling was predicted to occur on the east coast of Northern England between North Tyneside to King's Lynn and West Norfolk District. Figure 10-7 presents the maximum mass onshore with a mass greater than 100 t from the total 110 stochastic model runs. The model showed that 24 out of the total 110 model runs resulted in a maximum mass onshore of over 100 t, while 70 runs resulted in a maximum mass onshore of less than 10 t. The maximum quantity of marine diesel predicted onshore from any run was 1,308 t (in winter). The range of probabilities of shoreline oiling and the minimum arrival times to shore are summarised in Table 10-6. The maximum probability of contamination to a UK shoreline (99.1%) occurred at Redcar and Cleveland with an arrival time of 3 hours.

Additional worst case deterministic runs were conducted based upon the results of the stochastic modelling to fully evaluate the predicted mass onshore, presented in Figure 10-9. Worst case shoreline oiling was predicted to be a maximum of 701 g/m^2 after 30 days, extending over a total shoreline area of 17.8 km^2.

The International Tankers Owners Pollution Federation (ITOPF) have produced a Technical Information Paper providing guidance on estimating stranded oil volumes (ITOPF, 2011). The ITOPF's Shoreline Clean-Up Assessment Team or Techniques (SCAT) threshold considers the specific gravity of the marine diesel, the length and type of the coastline and the cell size of the model to categorise light, moderate and heavy oiling. Using this methodology, it was estimated that a light oiling of marine diesel equated to between 0.0843 kg/m^2 and 0.843 kg/m^2, moderate oiling equated to between 0.843 kg/m^2 and 8.43 kg/m^2 and heavy oiling equated to greater 8.43 kg/m^2. Based on the worst case shoreline oiling after 30 days of 701 g/m^2 (0.701 kg/m^2), oiling was predicted to be in the light oiling

[230] *Total length of beached shoreline in scenario 1 is 0.06 km*

threshold of 0.843 kg/m^2 initially which would be predicted to decrease further as biodegradation of the marine diesel continues to occur.

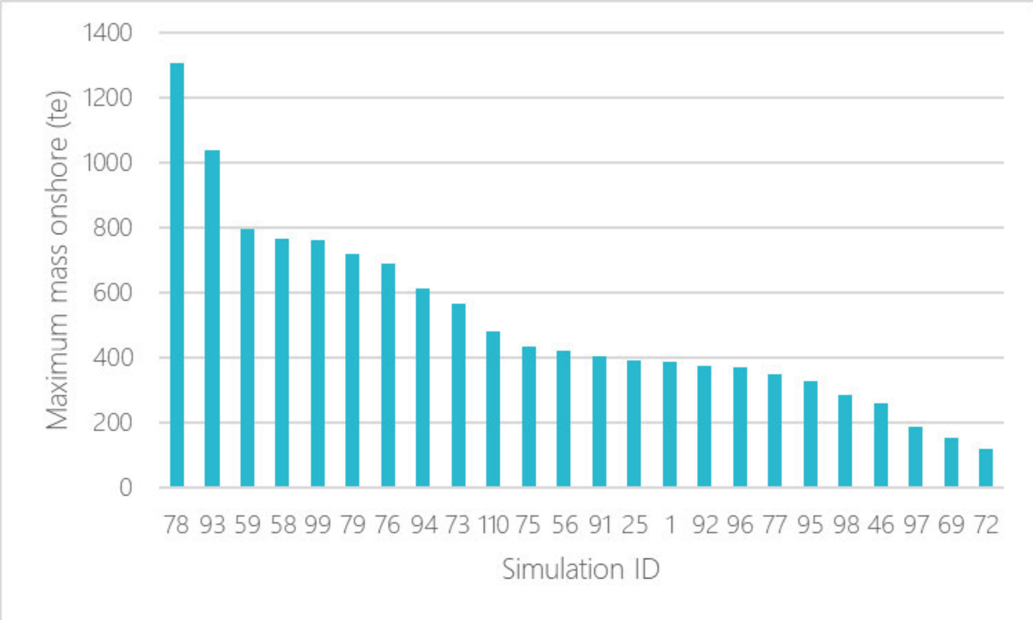

Figure 10-7 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside – Stochastic simulation runs with maximum mass onshore above 100 t out of a total 110 simulation runs

Table 10-6 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside – Probability of contamination and minimum arrival time for potentially affected UK regions[231,232]

Region	Probability of contamination (%)	Minimum arrival time
North Tyneside District	1.8 – 12.7	9 d 10 h
South Tyneside District	0.9 – 24.5	2 d 22 h
Sunderland District	3.6 – 35.5	2 d 11 h
County Durham	3.6 – 44.5	0 d 18 h
East Riding of Yorkshire	0.9 – 60	6 d 19 h
Hartlepool	6.4 – 65.5	0 d 9 h
Redcar and Cleveland	0.9 – 99.1	0 d 3 h
Northumberland	0.9	11 d 6 h
Kings Lynn and West Norfolk District	0.9	26 d 8 h
Scarborough District	0.9 – 92.7	0 d 13 h
East Lindsey District	0.9 – 7.3	18 d 0 h

[231] *Probabilities of 0.9% are resultant from contamination predicted during one out of the total 110 simulation runs.*
[232] *It should be noted that the probability of contamination and the minimum arrival time do not consider the concentration of contaminant.*

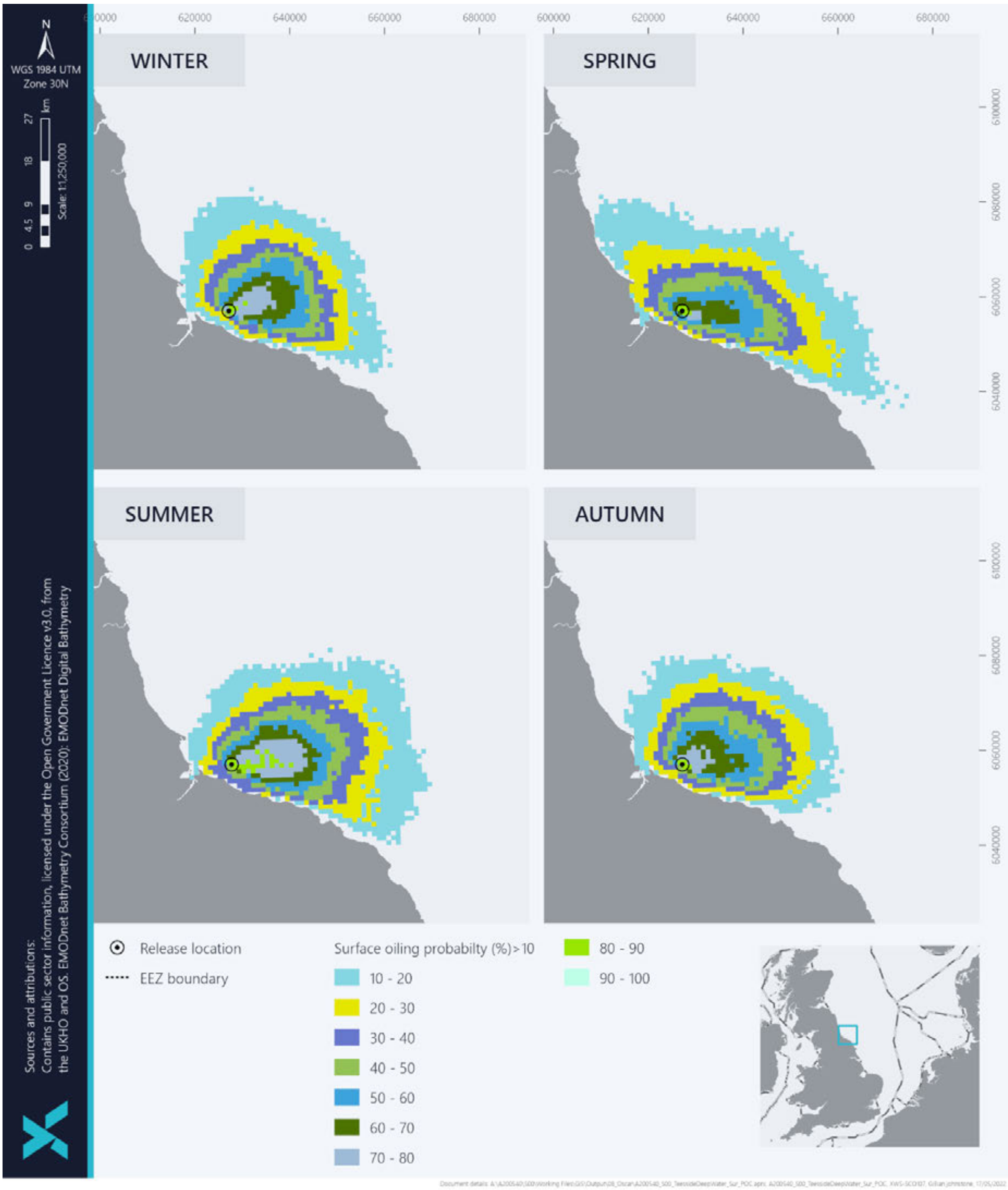

Figure 10-8 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside -Probability of surface oiling (above 0.3 µm) above 10%

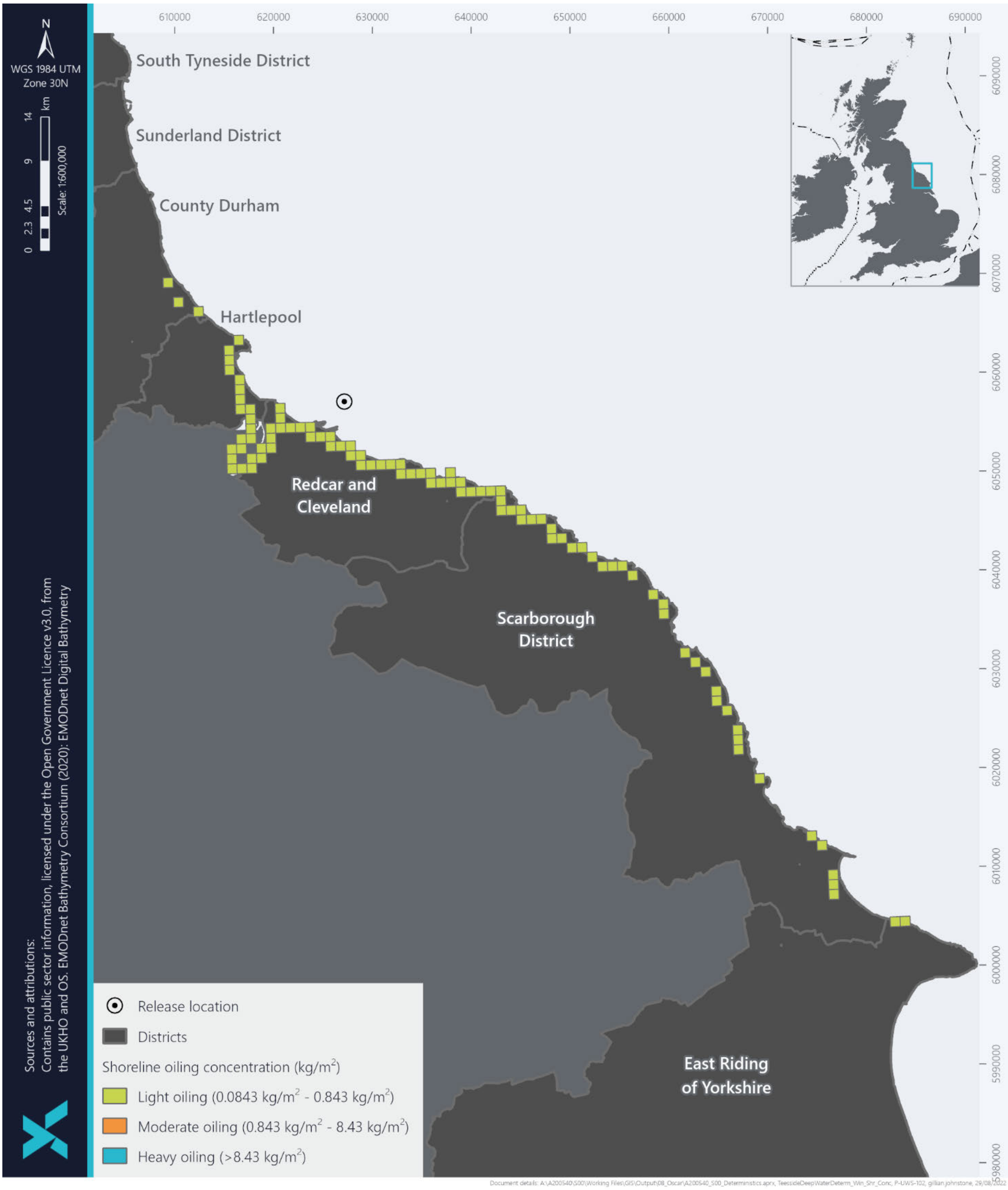

Figure 10-9 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside Deterministic model based on worst case mass onshore after 30 days

Release Behaviour

The mass balance of marine diesel over the duration of the release is presented in Figure 10-10. The deterministic model indicated that the most common predicted fate of the released oil was evaporation (57.74%), followed by biodegradation, which accounted for approximately 16.05% of the marine diesel. Approximately 25.12% of the oil was deposited within the seabed sediment, while 0.70% and 0.02% accounted for oil stranded onshore and oil present on the sea surface, respectively. No diesel was predicted to leave the modelled grid area.

The marine diesel is predicted to move rapidly from the sea surface within the first few days of release. Initially dispersion and evaporation (up to five days) are the major removal mechanisms of oil from the sea surface. The marine diesel is gradually incorporated into the sediment. This occurs when the mixing depth of the dispersed oil in the water column is sufficiently deep for the oil to interact with the seabed, with very little of the marine diesel predicted to reach the shore. Biodegradation of the marine diesel is also predicted to be rapid over the first five to 10 days post spill, resulting in its removal from the environment.

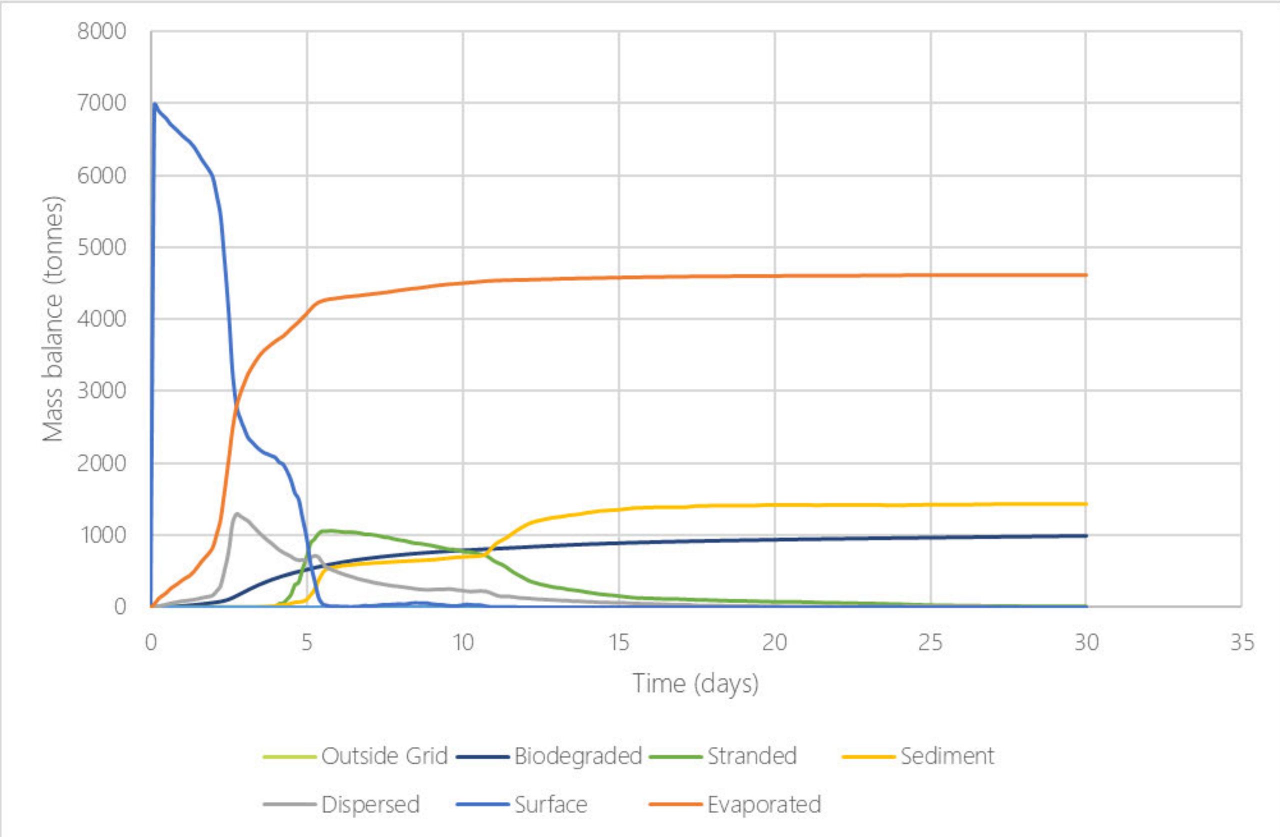

Figure 10-10 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside – Mass balance of marine diesel over time

Table 10-7 - Scenario 2: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Teesside – Mass Balance of marine diesel by day 30

Fate	Mass (kg)	Percentage (%)
Surface	1,250	0.02
Evaporated	4,062,000	57.74
Water Column	26,110	0.37
Sediment	1,767,000	25.12
Beached Onshore[233]	49,370	0.70
Biodegraded	1,129,000	16.05
Outside Gridded Area	0	0.00

10.3.2.4 Scenario 3: Pipelay vessel diesel inventory – Humber

As is expected from a nearshore release, modelling indicated that diesel is not predicted to cross any median lines in all seasons. The probability of surface oiling is presented in Figure 10-12. Beaching based on stochastic modelling was predicted to occur on the east coast of Northern England between City of Kingston upon Hull to Great Yarmouth District. Figure 10-11 presents the maximum mass onshore with a mass of greater than 100 t out of the total 110 stochastic model runs. The model showed out of the total 110 model runs, three stochastic runs had a maximum mass onshore over 100 t. 26 runs had a mass on shore below one tonne, and a further 64 model runs displayed no mass onshore at all. The maximum quantity of marine diesel predicted to be onshore from any run was 944 t (in winter). The range of probabilities of shoreline oiling and the minimum arrival times to shore from the vessel pipelay at Humber are summarised in Table 10-8. The maximum probability of contamination to a shoreline (77.3%) occurred at East Lindsey District with an arrival time of 1 day 4 hours.

Additional worst case deterministic runs were conducted based upon the results of the stochastic modelling to fully evaluate the predicted mass onshore, presented in Figure 10-13. Worst case shoreline oiling was predicted to be a maximum of 35.7 g/m^2 after 30 days, extending over a total shoreline area of 8.7 km^2.

Further analysis was undertaken to determine the level of contamination against the ITOPF thresholds for oil contamination ITOPF (2011). Based on the worst case shoreline oiling after 30 days of 35.7 g/m^2 (0.0357 kg/m^2), oiling was predicted to be below the light oiling threshold of between 0.0843 kg/m^2 and 0.843 kg/m^2. This would be predicted to further decrease as biodegradation of the marine diesel continues to occur.

[233] *Total area of beached shoreline in scenario 2 is 8.9 km*

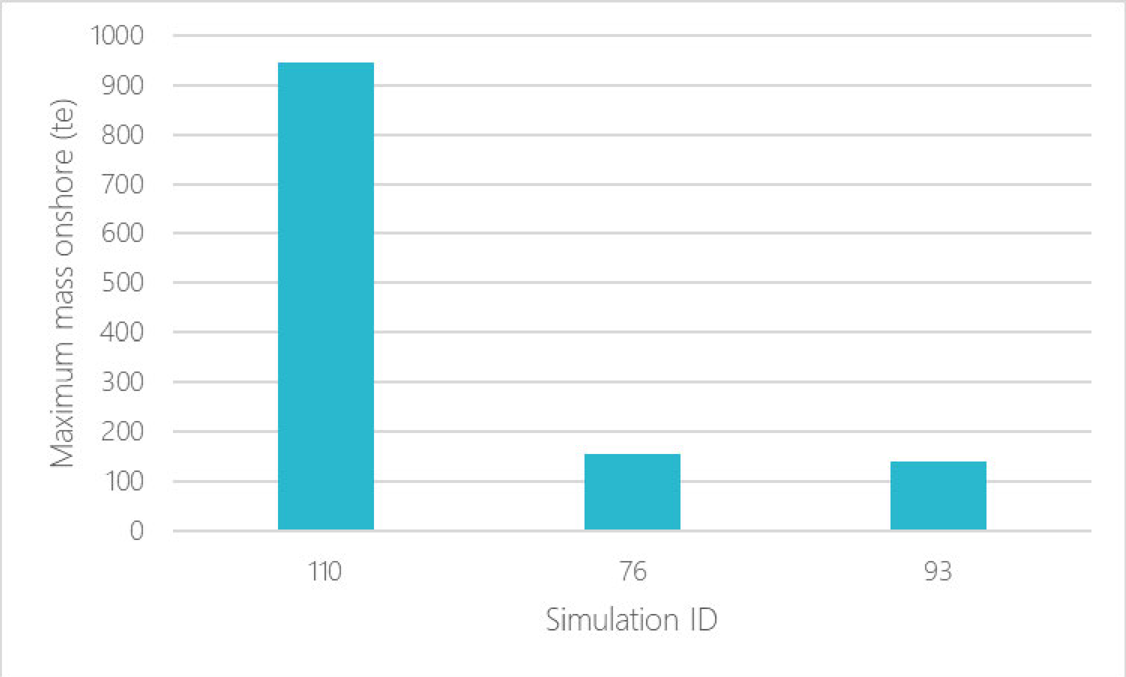

Figure 10-11 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber – Stochastic simulation runs with maximum mass onshore above 100 t out of a total 110 simulation runs

Table 10-8 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber – Probability of contamination and minimum arrival time for potentially affected UK regions[232]

Region	Probability of contamination (%)	Minimum arrival time
City of Kingston upon Hull	0.9	8 d 10 h
East Riding of Yorkshire	0.9 – 74.5	0 d 10 h
Boston District	0.9 – 10	11 d 7 h
Kings Lynn and West Norfolk District	0.9 – 24.5	6 d 13 h
Scarborough District	0.9 – 20	6 d 0 h
East Lindsey District	0.9 – 77.3	1 d 4 h
Great Yarmouth District	0.9 – 6.4	11 d 6 h

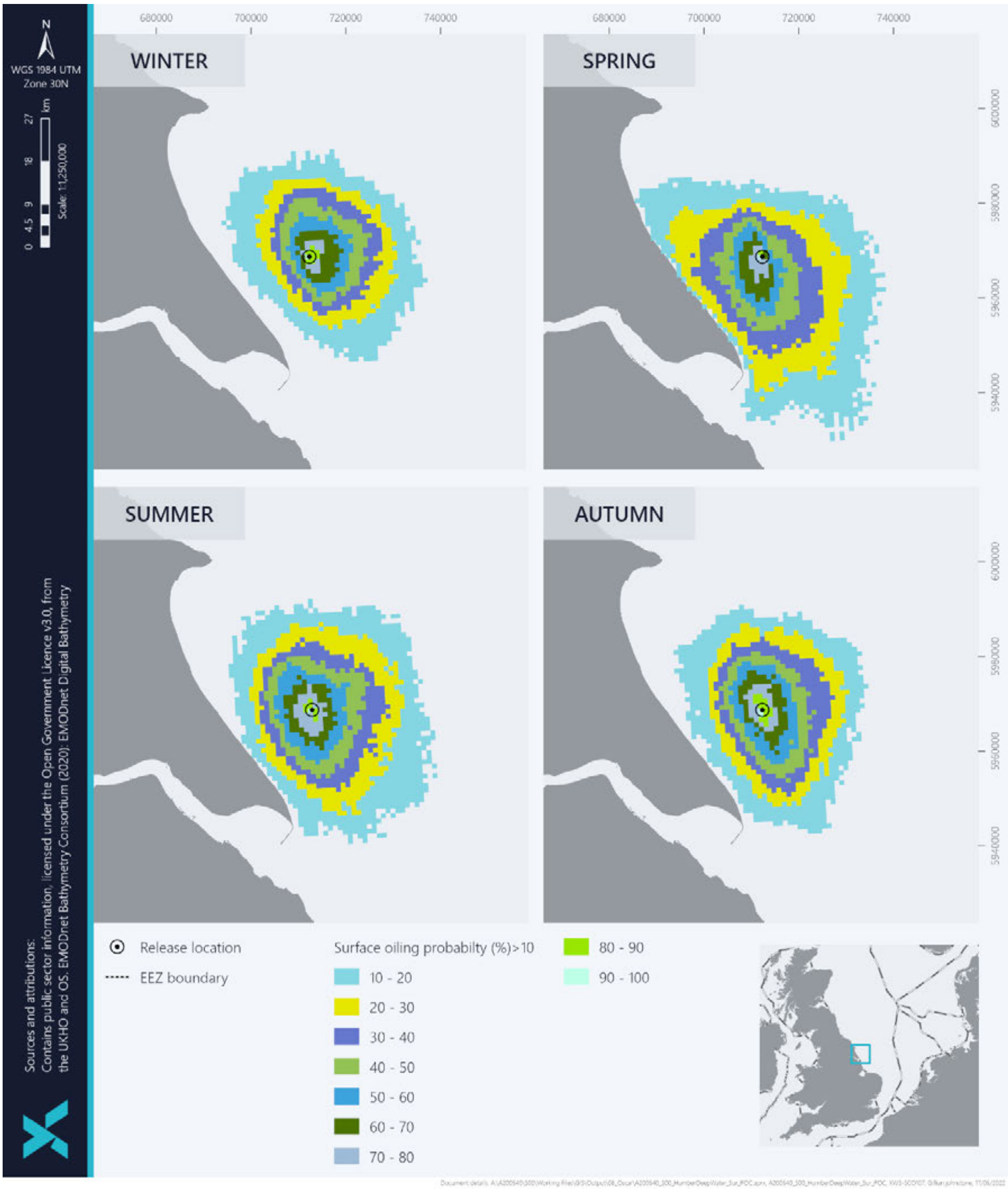

Figure 10-12 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber - Probability of surface oiling (above 0.3 µm) above 10%

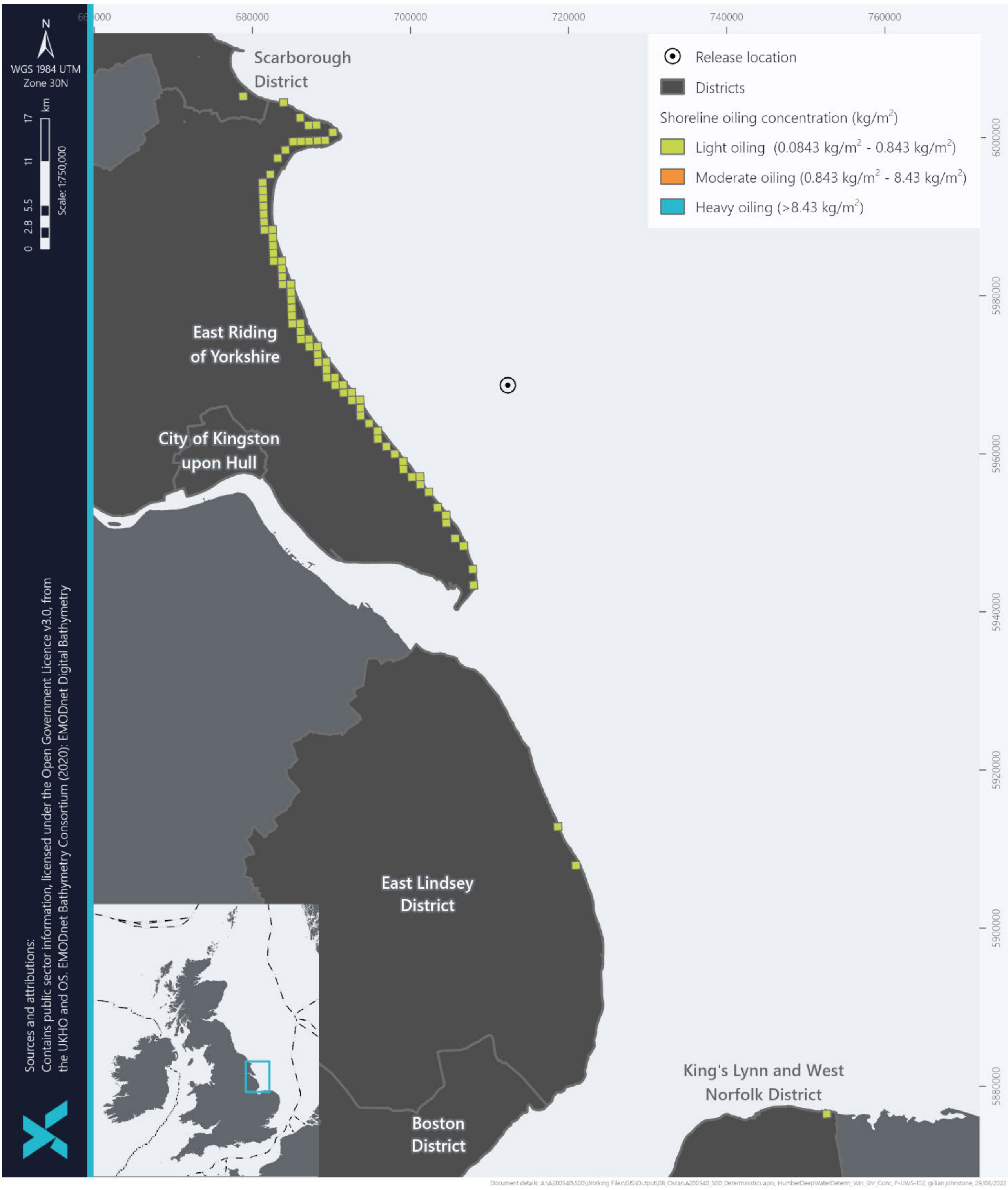

Figure 10-13 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber Deterministic model based on worst case mass onshore after 30 days

Release Behaviour

The mass balance of marine diesel the duration of the release is presented in Figure 10-14. The deterministic model indicated that the most common predicted fate of the released diesel was evaporation (65.5%) followed by biodegradation, which accounted for approximately 14.1% of the marine diesel. Approximately 20.3% was deposited within the seabed sediment, while approximately <<0.001% and << 0.001% accounted for diesel stranded onshore and diesel present on the sea surface, respectively.

The marine diesel is predicted to move rapidly from the sea surface within the initial days of the release. In the immediate days after the release (up to five days), dispersion and evaporation are the major removal mechanisms of diesel from the sea surface. The marine diesel is gradually incorporated into the sediment. This occurs when the mixing depth of the dispersed hydrocarbon in the water column is sufficiently deep for the hydrocarbon to interact with the seabed. Very little of the marine diesel is predicted to reach the shore. Biodegradation of the marine diesel is also predicted to be rapid over the first five to 10 days post spill, resulting in its removal from the environment.

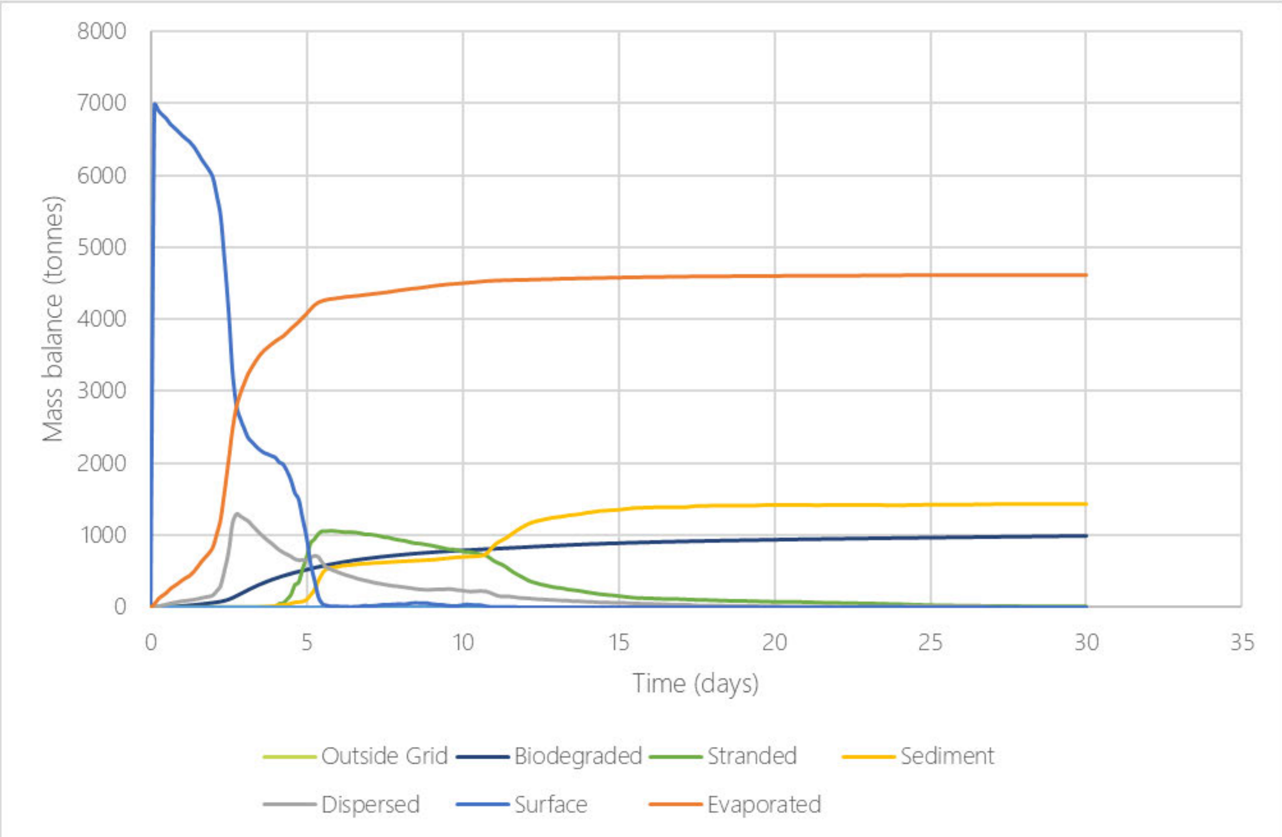

Figure 10-14 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber – Mass balance of marine diesel over time

Table 10-9 - Scenario 3: Loss of entire pipelay vessel diesel inventory instantaneously near shore at Humber – Mass Balance of marine diesel at 30 days

Fate	Mass (kg)	Percentage (%)
Surface	27	<< 0.001
Evaporated	4,608,000	65.5
Water Column	942	0.01
Sediment	1,426,000	20.3
Beached Onshore[234]	7,544	0.1
Biodegraded	992,000	14.1
Outside Gridded Area	0	0

10.3.2.5 Potential Environmental Impacts

Marine diesel is a refined hydrocarbon and, as demonstrated by the simulations presented above, will be rapidly removed from the sea surface and the marine environment due to evaporation and biodegradation. Marine diesel would be expected to dissipate from the sea surface within 18 to 36 hours of release, and any reaching the shore would be in low amounts that may well not be discernible to an observer on the shoreline. Response options for diesel are limited due to these properties, with surface agitation to mix the diesel into the water column being the only practical option available in the event of a release. The spill scenarios considered also do not account for the compartmentalisation of fuel into separate bunkers (tanks) on-board a vessel; a design feature that should significantly reduce the quantity of marine diesel released to sea in the event of an accident. The following assessment considered the worst case spill (low probability) scenario, which is an unmitigated release of marine diesel, (i.e. no response action initiated).

Coastal Environment

The likelihood of a diesel spill impacting the coastal environment is a function of the likelihood of a diesel spill occurring and the probability of the released diesel beaching. The level of impact is also directly related to the volume of diesel beaching, the composition of the beached diesel, and the type of beach.

Coastal environmental sensitivities to spills include nearshore breeding seabird populations, shore birds, over wintering diver and duck species, marine mammals, aquaculture operations and sub-littoral and coastal habitats including SACs and SPAs.

Intertidal areas of the coast show varying degrees of sensitivity to spills; this variability is a function of both actual effects on specific organisms and the physical fate of the released substances within the habitat concerned. For example, high-energy rock, boulder or cliff coastlines tend to have lower

[234] *Total length of shoreline is 4.35 km*

sensitivity to hydrocarbon pollution because the pollutant is rapidly broken up and dispersed by wave action, and beached hydrocarbon remains on the surface of rocks and is exposed to weathering. In contrast, sheltered, low-energy shorelines tend to have moderate to high sensitivity because hydrocarbon is not broken up by wave action and it can be mixed into the sediment, where it is not exposed to weathering and therefore persists for longer.

Whilst there is a range of sensitivities in the areas predicted to be exposed to a diesel release, it is unlikely that any discernible impact with long-term consequences would result from a spill of marine diesel. These sensitivities are detailed below

10.3.2.6 Protected Sites

Sea surface and shoreline probability of contamination data exported from the stochastic modelling (see Section 10.3.2) were examined to identify protected sites at risk of hydrocarbon (diesel) contamination. Protected sites were then further assessed where the probability of shoreline and surface contamination was found to be equal to or above 40% in any of the release scenarios. The selection of 40% was based on a typical likelihood and consequence matrix used as a significance screening matrix. When using these matrices a probability of less than 40% is considered to be remote or extremely remote with those above ranging through unlikely through possible to likely. As such it is only when the probability is greater than 40% and the consequence is similarly above moderate that the environmental significance of the event would be considered major or severe.

Qualifying features of a protected area, specifically SACs, SPAs include species and habitats which are the primary reason for the selection of a site under Annex I of the Birds Directive and under Annex II and IV of the Habitats Directive. The qualifying features in the majority of coastal sites identified as having the potential to be impacted as a result of oiling are estuaries, exposed reefs mud and sandflats and dune features. These habitats are also more likely to be negatively affected by hydrocarbon (diesel) contamination than sea cliff habitats.

The potential of contamination at protected sites was assessed for the following worst case scenarios:

- an entire, instantaneous loss of jackup barge diesel inventory at the Endurance Store;
- an entire, instantaneous loss of pipelay vessel inventory at Teesside; and
- an entire, instantaneous loss of pipelay vessel inventory at Humber.

The protected sites included in the assessment were SACs (including candidate SACs), SPAs (including proposed SPAs) and MCZs (including pMCZs). The eight sites with the potential to be impacted by shoreline oiling are presented in Table 10-10. The five sites with the potential to be impacted by surface oiling are presented in Table 10-11. The impact of contamination on the designation features are discussed below in the relevant sections. It should be noted that Scenario 1 (entire loss of diesel inventory instantaneously at the Endurance Store) is located within the SNS SAC, therefore surface contamination will occur in the unlikely event of the scenario being realised. Likewise, Scenario 3 (an entire, instantaneous loss of pipelay vessel inventory at Humber) occurs within 8 km of the SAC and therefore surface contamination may occur in the unlikely event of the scenario being realised. However, marine diesel would be expected to dissipate from the sea surface within 18 to 36 hours of release therefore contamination of features for which the sites are designated is predicted to be unlikely. No protected areas were impacted as a result of shoreline hydrocarbon (diesel) contamination from Scenario 1 (entire loss of diesel inventory instantaneously at the Endurance Store) therefore Scenario 1 has been excluded from Table 10-10.

Table 10-10 - Protected sites potentially impacted as a result of hydrocarbon contamination from loss of diesel inventory that is predicted to enter the site at a probability sufficient to dictate further assessment (> 40% probability of shoreline contamination)

Site	Maximum probability of contamination (%)		Primary designation features
	Scenario 2 Teesside, pipelay vessel	Scenario 3 Humber, pipelay vessel	
Humber Estuary SAC	Does not cross	77	Annex I habitats that are a primary reason for selection of this site: • Estuaries.
Flamborough Head SAC	61	42	Annex I habitats that are a primary reason for selection of this site: • Reefs; • Vegetated sea cliffs of the Atlantic and Baltic Coasts; and • Submerged/partially submerged sea caves.
Northumbria Coast SPA	43	Does not cross	Annex I Species that are primary reason for selection: • Arctic tern (*Sterna paradisaea*).
Humber Estuary SPA	68	Does not cross	Directive 2009/147/EC Article 4.1 (Annex I) species: • Breeding (% British breeding population): bittern (10.5%), marsh harrier (6.3%), Pied avocet (*Recurvirostra avosetta*) (8.6%), little tern (Sternula albifrons) (2.1%); • Over wintering (as % of British over wintering population): bittern (4%), hen harrier (*Circus cyaneus*) (1.1%), bar tailed godwit (4.4%), golden plover (*Pluvialis apricaria*) (12.3%), avocet (1.7%); and • Passage (% British passage population): Ruff (*Philomachus pugnax*) (1.4%).

Site	Maximum probability of contamination (%)		Primary designation features
	Scenario 2 Teesside, pipelay vessel	Scenario 3 Humber, pipelay vessel	
Teesmouth and Cleveland Coast SPA	78	Does not cross	Directive 2009/147/EC Article 4.1 (Annex I) species: • Pied avocet; • Sandwich tern (*Thalasseus sandvicensis*); • Common tern (*Sterna hirundo*); • Little tern; and • Ruff (*Caldris pugnax*).
Holderness Inshore MCZ	Does not cross	70	Annex I habitats that are a primary reason for selection of this site: • Intertidal mixed sediments; • Subtidal course sediments; • Subtidal sand; • Peat and clay exposures; • Ross worm reefs; • Subtidal chalk; • Subtidal sands and gravels; and • Spurn Head.
Lincs Belt rMCZ	Does not cross	68	Recommended MCZ: • UK Grey Seal (*Halichoerus grypus)* Breeding at Donna Nook.
Runswick Bay MCZ	93	Does not cross	Annex I Species that are primary reason for selection: • Ocean Quahog (*Arctica islandica*).

Table 10-11 - Protected sites potentially impacted as a result of hydrocarbon contamination from loss of diesel inventory (> 40% probability of surface contamination)

Site	Maximum probability of contamination (%)			Primary designation features
	Scenario 1 Endurance Store, jackup barge	Scenario 2 Teesside, pipelay vessel	Scenario 3 Humber, pipelay vessel	
SNS SAC	100	Does not cross	100	Annex II species that are a primary reason for selection of this site • Harbour porpoise (*Phocoena phocoena).*
Holderness Inshore MCZ	Does not cross	Does not cross	48	Annex I habitats that are a primary reason for selection of this site: • Intertidal mixed sediments; • Subtidal course sediments; • Subtidal sand; • Peat and clay exposures; • Ross worm reefs; • Subtidal chalk; • Subtidal sands and gravels; and • Spurn Head.
Holderness Offshore MCZ	Does not cross	Does not cross	100	Annex I habitats that are a primary reason for selection of this site: • Subtidal coarse sediment; and • Subtidal mixed sediments.
Runswick Bay MCZ	Does not cross	61	Does not cross	Annex I Species that are primary reason for selection:

Site	Maximum probability of contamination (%)			Primary designation features
	Scenario 1 Endurance Store, jackup barge	Scenario 2 Teesside, pipelay vessel	Scenario 3 Humber, pipelay vessel	
				• Ocean Quahog.
Teesmouth and Cleveland Coast SPA	Does not cross	51	Does not cross	Directive 2009/147/EC Article 4.1 (Annex I) species: • Pied avocet; • Sandwich tern; • Common tern; • Little tern; and • Ruff (*Caldris pugnax*).

Benthic Environments

Although there are a number of sites with the potential to be impacted by surface oiling (Table 10-6 and Table 10-8), it is very unlikely that the diesel would be mixed with the water column in sufficient quantities and depth to interact with protected seabed features. As such, no significant impact is expected on the benthic environment.

Birds

The JNCC has stated in a memorandum to the UK Parliament that the greatest risks to nature conservation from oil on the offshore sea surface is to seabirds (JNCC, 2011b). This is primarily due to the high affinity of oil for seabird plumage. Once oil becomes incorporated into the feathers, there is a very high chance of death due to loss of body heat, starvation, drowning or oil ingestion from preening activity. Plumage is essential to flight, waterproofing and heat insulation and even small effects on any of these functions can result in mortality.

Some groups of seabirds are more vulnerable than others due to their particular behaviours. Guillemots, which spend much of their time on the sea surface and typically dive to avoid danger, are particularly sensitive to oil slicks. Common guillemots are particularly vulnerable in the post-breeding period because the male parents accompany their flightless young in swimming offshore from the breeding colonies. This generally occurs in late spring and early summer. Gannets are also sensitive due to their diving behaviour, which causes them to repeatedly pass through any sea surface hydrocarbon layer.

Species that nest on cliffs and cliff tops are unlikely to have their nesting sites directly adversely affected by an accidental hydrocarbon release, although following the Sea Empress incident gannets were observed collecting contaminated nesting material (Santillo *et al.*, 1998).

Sheltered habitats that encourage wading or resting on calm water may suffer significant losses of birds in the event of sea surface oiling due to the greater likelihood that large accumulations of birds will be exposed. Following the Sivand spill in the Humber Estuary, the Royal Society for the Protection of Birds (RSPB) reported that 160 dead oiled birds were found and estimated that 4,000 birds may have been oiled in total (NOAA, 1992). It is likely that the vast majority of oiled birds would have died due to hypothermia and toxicity; it is common that only a small proportion of bird carcasses are recovered following hydrocarbon release mortality events.

Sensitivity of particular species also varies in line with the total biogeographical population, which influences the potential for population recovery following an incident.

The seasonal vulnerability of seabirds to surface pollutants is identified using the SOSI, derived from JNCC block-specific data; In the immediate vicinity of the Development, seabird sensitivity to oil releases ranges from low to high (see Section 4.4.5 for further detail). The magnitude of any impact will depend on the number of birds present, the percentage of the population present, their vulnerability to released hydrocarbons, and their recovery rates from hydrocarbon contamination. The physical impact of a release is one of plumage damage leading to loss of insulation and waterproofing.

Seabirds that rest and breed within SPA boundaries commonly feed in waters outside the protected site boundary, meaning that diesel releases may impact protected site features without the diesel entering the site.

There are two SPAs listed in Table 10-10 and Table 10-11 that support five bird species that vary in seasonal presence, breeding, feeding and nesting behaviour. There is a range of probability of shoreline and surface contamination at these SPAs, from 78% to 51% respectively.

Hartung and Hunt (1966) investigated experimentally induced acute toxic effects of ingestion of diesel fuel on two species of duck (Mallard and Pekin) kept in both optimal and sub-optimal conditions and compared the results with autopsied wild ducks that had been killed in historical oil pollution episodes. Similar physiological effects were observed between the experiments and wild duck autopsies and it was found that individuals could survive ingestion of up to 24 ml/kg diesel oil. The research found that ingestion of 4 ml/kg diesel was possible given previous research into the amount of oil adhering to duck plumage during spill events, and the rate at which ducks preen oil from their plumage.

However, marine diesel is rapidly removed from the sea surface and the marine environment due to evaporation and biodegradation. Modelling for the Development found that marine diesel would be expected to dissipate from the sea surface within 18 to 36 hours of release, and any reaching the shore would be in low amounts that are unlikely to be discernible to an observer on the shoreline. Thus, it is considered unlikely that bird species would be exposed to acutely toxic levels for a sustained period of time as a result of the Development and any discernible impact with long-term consequences resulting from a spill of marine diesel is considered unlikely.

Marine Mammals

Marine mammals such as cetaceans and seals are highly mobile and generally able to avoid a release. The impact of released oil on these species will depend on the encounter rate of each species with the diesel and includes a behavioural component (e.g. avoidance behaviour) (Geraci and St. Aubin, 1990).

Cetaceans are present in the vicinity of the Development (Section 4.4.6). Scenarios 1 and 2 are located within the SNS SAC, which is designated for Harbour porpoise. In the event of a release, the potential impact will depend on the encounter rate of the species with the diesel and their feeding habits; the overall health of individuals before exposure; and the characteristics of the hydrocarbons. Cetaceans are pelagic (move freely in the water column) and migrate. Their strong attraction to specific areas for breeding or feeding may override any tendency cetaceans have to avoid hydrocarbon-contaminated areas. It is thought unlikely that a population of cetaceans in the open sea would be affected by a spill in the long-term (St. Aubin, 1990). In contrast to seabirds, there is relatively little evidence of direct mortality associated with hydrocarbon releases (Geraci & St. Aubin, 1990; Hammond *et al.*, 2002), although the aggregated distribution of some species (especially dolphins) may expose large numbers of individuals to localised oiling.

Seals are widespread in the North Sea and come ashore to breed and pup (Section 4.4.6). There are a number of seal haul-out sites along the coast of Teesside and Humber. Seal pups are susceptible to external oil contamination (Ekker *et al.*, 1992) because they are born without any blubber and rely on their prenatal fur and metabolic activity for thermal balance. The pups remain in breeding colonies until they are weaned and, unlike adults or juveniles, would be unable to leave an impacted area.

It is possible that some marine mammals could encounter surface accumulations of oil and would be affected through inhalation or skin absorption. However, avoidance behaviour is considered to reduce the potential for impact and it is unlikely that any marine mammal listed under the Habitats Directive would be impacted on a population level.

10.3.2.7 Water Quality

Dissolved and dispersed hydrocarbons in the water column may cause a degradation in water quality with fish exposed to this water likely to become tainted with hydrocarbons. As such, degradation of water quality may impact the status of transitional and estuarine waters designated under the Water Environment (Water Framework Directive) (England and Wales) Regulations or as shellfish waters. The potential taint and associated health effect may result in the closure of aquaculture sites and fishing grounds for a prolonged period. In general, fish are not particularly sensitive in themselves to oil spills unless their eggs and larvae are exposed to dissolved and dispersed hydrocarbon in the water column. Furthermore, due to the nature of the marine diesel, it has shown it would evaporate, biodegrade and dissipate throughout the water column between approximately 18 – 36 hours. Therefore, the diesel would not likely persist in the environment for a sustained period of time. Thus, the impacts on water quality would be reduced.

10.3.3 Residual Risk and Mitigation

- Combined operations of vessels during pipelay and construction are to be expected for a project of this magnitude. These will be carefully coordinated and managed to reduce any risk of collision or allision resulting in a release of hydrocarbons to sea;
- Prior to a vessel mobilizing to work on the Development, vessels will either undergo an Offshore Vessel Inspection Database (OVID) or a Common Marine Inspection Documents (CMID) inspection in line with industry standards. Assurance activities will also be conducted in line with the bp internal vessel assurance system;
- NRAs and appropriate notifications to mariners will be made prior to any activities occurring that may cause navigational issues (e.g. pipelay, jackup in location offshore);
- The jackup rig (while on location drilling) will have an OPEP in place that has been approved by the relevant UK authorities; all vessels will have similarly approved Shipboard Oil Pollution Emergency Plans (SOPEPs) in place;
- The OPEPs/SOPEPs will contain actions to be taken in the event of a release, and will be scalable to deal with releases of different volumes of diesel as follows:
    - Tier 1 – low quantity spill that may be dealt with by the equipment and staff at the spill location when it occurs – for diesel spills this will likely be restricted to spill tracking and assisted dispersion (by prop washing of fire monitors);
    - Tier 2 – intermediate quantity spill that will require support from onshore – for diesel this is likely to include aerial spill observation and shoreline response activities (including oiled wild-life recovery and cleaning); and
    - Tier 3 – large volume spill involving the activation of the National oil spill contingency plan and associated international agreements – this level of response is not expected to be required due to the nature and maximum quantity of diesel that could be released as a consequence of this scope of work;
- Offshore training drills will be conducted to evaluate the response readiness of all staff and equipment to an oil spill event;
- Appropriate contracts will be in place to facilitate a response to a release should an event occur – as is routine for marine vessel activities.

10.3.4 Cumulative, In-combination and Transboundary Impacts

A large diesel release from the vessels associated with the Development is a highly unlikely event and would have a highly transient potential impact. The likelihood of a large diesel release occurring from the Development within the same time period as another large diesel release from a concurrent project and for both to impact the same receptors is highly unlikely. As such there would be extremely remote likelihood of a diesel release from the Development posing a cumulative impact on the marine environment.

Worst case scenario modelling undertaken for the Development indicates no probability of diesel crossing the UK/Netherlands median line and therefore no transboundary impacts are expected.

10.4 Chemical Release Risks

10.4.1 Jackup rig and Installation Vessel Release Risks

10.4.1.1 Risk Description

The use of chemicals in the drilling and installation phases of this project will be subject to the provisions of the UK OCR (which implement the OSPAR Harmonised Mandatory Control Scheme in UK waters). As such, all chemical selected for use will be on the Cefas list of notified chemicals and will be selected based on both their efficacy for the function they are selected to fulfil, as well as their environmental profile. This approach will apply to drilling chemicals and pipeline commissioning chemicals. All chemicals selected for use will be subject to risk assessment as part of the permit application for use and discharge offshore.

Other chemicals not regulated by OSPAR used offshore are regulated under UK Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (as applicable) and the Regulations governing the carriage of chemicals by ship contained in the IMDG Code, International Convention for the Safety of Life at Sea (SOLAS) and the International Convention for the Prevention of Marine Pollution from Ships, as modified by the Protocol of 1978 relating thereto (MARPOL).

Approved operational procedures will be implemented to mitigate the likelihood of the accidental release of chemicals and to minimise their impact should they occur. For example, the quantities of chemicals stored will be optimised. Control of Substances Hazardous to Health (COSHH) assessments will be completed and Safety Data Sheets (SDS) will be made available. Spill kits will be located in close proximity to chemical storage areas to enable a quick response.

Procedures, in line with best industry practice guidelines will be in place to minimise the risk of an accidental spill from bunkering. These will include, for example, regular checks of the integrity of the hose and competence of operators. Trained personnel will undertake bunkering operations in accordance with approved procedures. Containment facilities and drains will be inspected as part of marine assurance standards. Crews will have been trained in spill response.

Generally, the amounts of chemicals carried and used as part of the development activities will be small and any spill will quickly disperse in the highly dispersive North Sea environment.

The risk of a major environmental impact arising from the accidental release of the chemicals specifically used for the Development are assessed to be negligible due to the low quantities of chemicals present, the nature of these chemicals and the low probability of an incident resulting in a release. The risk from accidental chemical release is therefore not considered further as part of this assessment.

10.5 CO_2 Leakage Risk

While considered low probability, the accidental leakage of CO_2 from pipelines, wells or the Endurance Store could potentially impact the environment. The potential impact of a leak has been assessed against the following:

- The probability of occurrence of the leak and the effectiveness of the planned control measures in place which will mitigate the likelihood of such an event and interventions that will be used to prevent or reduce the impacts of any leaks;
- The potential for any leaks to impact the environment;
- The residual risks remaining after consideration of the preventive measures, mitigations and interventions; and
- The cumulative risks of leaks in and around the Development.

Accidental leakage of CO_2 may originate from the Development via the pathways illustrated in Figure 10-15, specifically:

- Via the Humber or the Teesside Pipeline routes;
- Via wells penetrating the Endurance Store; or
- Leakage[235] through the subsurface rock column to the sea floor.

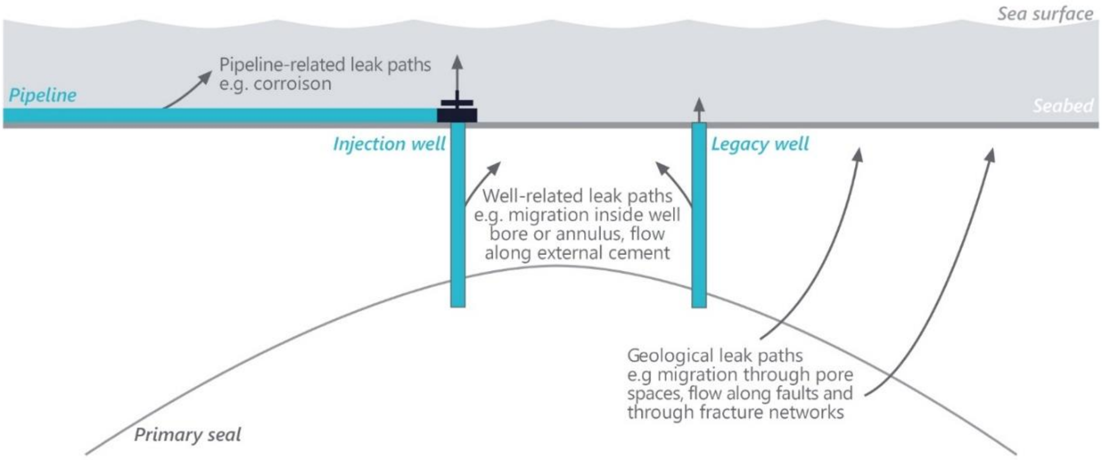

Figure 10-15 - Example CO_2 leakage mechanisms from the Development

In the ENVID (Appendix A), the scale and probability of fugitive CO_2 emissions[236] were determined to be insufficient to warrant further investigation; therefore, these are not considered herein.

[235] *Note, in this section, leakage is the term used to describe CO_2 leaving the Endurance Store and reaching the surface of the seabed. Migration is the term used to describe movement of CO_2 within the Store.*
[236] *Diffusive emissions of CO_2 from flanges, valves and seals.*

10.5.1 Definition of Size and Frequency of CO_2 Leaks

The potential size and likelihood of CO_2 leaks are described below to convey the potential size and likelihood of events.

The definitions used to characterize the size of CO_2 leaks (bp, 2022d) are:

- ***Small***, less than ten t of CO_2 per day;
- ***Medium***, less than 100 t of CO_2 per day; or
- ***Large***, less than 1,000 t of CO_2 per day; or
- ***Very large***, greater than 1,000 t of CO_2 per day.

For comparison, the planned rate of CO_2 injection averages 11,000 t per day.

The values for the frequency of accidental CO_2 leaks are those stated within Section 5.3.3.3 for accidental/unplanned events, i.e.

- ***Likely*** – More than once per year;
- ***Possible*** – Once in 10 years;
- ***Unlikely*** – Once in 100 years;
- ***Remote*** – Once in 1,000 years; and
- ***Extremely remote*** – Once in 10,000 years.

The following sections outline each accidental CO_2 leakage scenario (from pipelines, wells or the subsurface), describing the risk as well as prevention and mitigation measures.

10.5.2 CO_2 Leakage from Pipelines

10.5.2.1 Risk Description

Significant experience in relation to CO_2 pipelines has been accrued onshore US, where CO_2 pipelines number more than 50 and transport approximately 68 Mt per annum of CO_2. Incorporation of key considerations including pipeline design and route selection minimise risk resulting in no greater risks of leaks of CO_2 relative to natural gas transport (GCCSI, 2015).

The maximum volume of CO_2 leaked from the pipelines at any time would be the inventory contained within the pipelines at the time of the leak[237]. For the Teesside Pipeline route that figure is approximately 54,000 t, and for the Humber Pipeline route it is approximately 39,000 t. A more credible scenario is a smaller leak over a number of days. This could occur as a result of corrosion or localised impact e.g. anchor dragging.

Given the limited number of hydrocarbon containing pipeline incidents that have taken place offshore in the UKCS[238], and the relatively lower number of CO_2 pipelines in comparison to hydrocarbon pipelines, even fewer incidents have occurred involving CO_2 pipelines. Consequently, there are significant uncertainties in the failure frequencies quoted. The level of uncertainty increases for large hole sizes and equipment sizes/types where few leaks have been recorded. The International Association of Oil and Gas Producers (IOGP) collated UKCS offshore hydrocarbon pipeline failure data,

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[237] Detection of reduced pipeline pressure would lead to isolation of the pipeline.

[238] Between 2001 and 2012 there were 7 incidents in steel pipelines > 16", resulting in experience of 108,195 km-years relative to e.g. steel pipeline <= 6" where there were 32.4 incidents and 47,052 km-years' experience (IOGP, 2019).

concluding that steel pipelines of a diameter greater than 16” in offshore waters have a failure frequency of 5.3 x 10^{-5} per km-year (IOGP, 2019). Application of the above frequency to the Humber and Teesside Pipelines is shown in Table 10-12. The recommended hole size distribution for offshore steel pipelines is presented in Table 10-13. Vitali *et al. (*2022) report on analysis of incident data relating to onshore CO_2 pipelines in the U.S from the Pipeline and Hazardous Materials Safety Administration (PHMSA) database of the U.S. Department of Transportation between 1986 and 2021. It was concluded that the estimated values for failure rates for CO_2 pipelines are in the same range as those reported for hydrocarbon pipelines (Vitali *et al.,* 2022).

Table 10-12 - Pipeline failure frequencies (Open sea, IOGP, 2019; Onshore, Vitali *et al*., 2022) applied to the Teesside and Humber Pipelines

	Pipeline length (km)	Failure frequency (per km-year)	Leak frequency (per year)
Teesside Pipeline	142	5.3 x 10^{-5}	7.5 x 10^{-3}
Humber Pipeline	100	5.3 x 10^{-5}	5.4 x 10^{-3}

Table 10-13 - Recommended hole size distributions for offshore, hydrocarbon containing, steel pipelines (IOGP, 2019)

	Very small (< 5 mm)	Small (5 – 20 mm)	Medium (20 – 80 mm)	Large (> 80 mm)	Full rupture
Steel Pipeline	70%	15%	10%	2%	3%

In the remote event of an incident, a leak would be detected via onshore pressure monitoring instrumentation and CO_2 pumping from onshore would cease. Leakage of the full pipeline inventory is unlikely and significant leakage is estimated to be a short-term event of the order of a day. The pressure drop from a small hole is not sufficient to be detectable by the planned leak detection system due to technology limitations, detection would occur via planned periodic visual inspections.

There is no significant routine venting of CO_2 from the offshore pipelines and infrastructure. Any small volumes of CO_2 vented as part of isolations required on the subsea infrastructure during operational activity (e.g. pipeline inspection and well intervention) are considered to form *de minimis* amounts, and are thus excluded from further assessment. These are detailed in Table 11-1.

Any measurable venting of CO_2 would only occur as a result of an unplanned event. There is ongoing engineering work on the onshore and offshore pipeline systems to confirm possible venting scenarios and operational response requirements in the remote event of an unplanned event occurring. Of the options being considered (venting onshore at Teesside or Humber, venting offshore and onshore simultaneously, venting only offshore) no permanent offshore venting facilities will be included in the design. Option selection is informed by factors including the anticipated frequency of a venting scenario occurring in response to an unplanned event.

CO_2 is transported in the dense phase (Chapter 3: Project Description), a phase maintained by temperature and pressure conditions within the pipeline. Should a leak occur, the CO_2 pressure will rapidly decrease to ambient pressure and the CO_2 will change from dense phase to gas phase (Figure 10-16). The impacts of gaseous phase CO_2 in the environment are considered in Section 10.5.5.

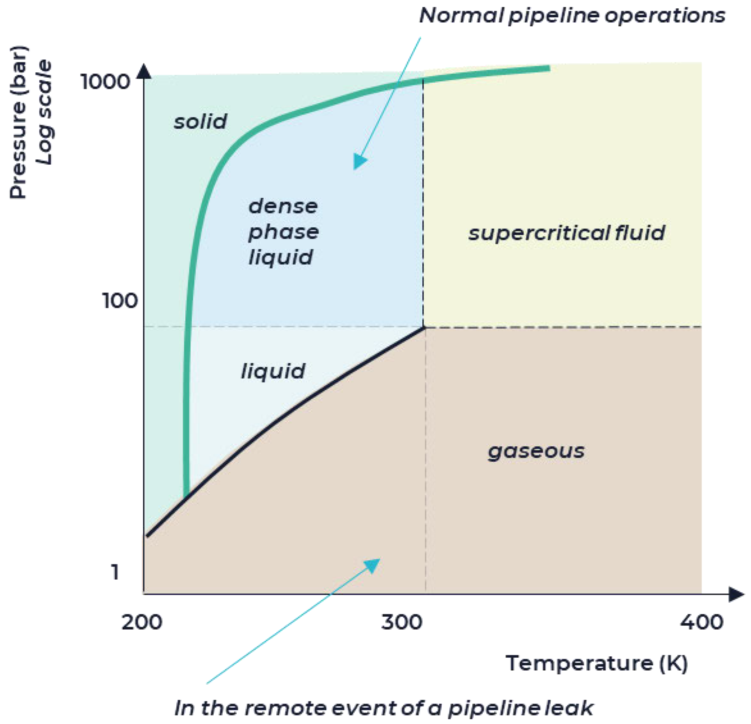

Figure 10-16 - CO_2 phase diagram schematically illustrating the change in phase from dense phase to gas which occurs as a result of reduced pressure, should a pipeline leak occur. Note a) 0 °C equates to 273 K b) typical ambient hydrostatic water pressure will be no greater than 6 bar at the approximately 60 m water depth at the Endurance Store

10.5.2.2 Prevention and Mitigation

As described in Section 3.2, the pipelines are carbon steel, of 28" diameter and concrete coated. Design, construction and operation will be carried out to recognised international standards, DNV-ST-F101, DNV-RP-F104 and industry guidance[239]. During the injection phase, CO_2 will be compressed onshore and transported offshore. Emergency shutdown valve (ESDV's) will be located on each 2" export lines and will be the last valves prior to export offshore. A power, control and hydraulics cable will be installed to the SSIV between 6 and 8 km offshore on the Teesside Pipeline route (Section 3.2.1).

Pipeline integrity will be strengthened via:

- Transportation of CO_2 in dense phase[240] to avoid sudden phase changes prone to occur in a stream of pure CO_2;

[239] *HSE (2021) Guidance on conveying CO_2 in pipelines in connection with CCS projects https://www.hse.gov.uk/pipelines/co2conveying-full.htm*

[240] *Dense phase means the CO_2 demonstrates properties of both liquid and gas. The dense phase has a viscosity similar to that of a gas, but a density closer to that of a liquid.*

- Removing water[241] from the CO_2 stream to prevent corrosion and water freeze out which could block pipework and wells;
- Maintenance of required pressures and temperatures within pipeline; and
- Pipeline inspection, repair and maintenance programme to regularly verify pipeline integrity.

10.5.3 CO_2 Leakage from Wells

10.5.3.1 Risk Description

Wells are conduits for controlled flow through otherwise impenetrable rocks. While wells may therefore be the most probable route of a leak[242], multiple engineered barriers prevent uncontrolled flow.

The Endurance Store is a normally pressured saline aquifer so injection wells will not be able to flow to the surface during initial development drilling of the five CO_2 injection wells and the monitoring well. Despite this, the aquifer sections will be drilled with routine, best practice, barriers and mitigation measures in place which include an overbalanced hydrostatic drilling fluid column[243] and the use of blowout preventers[244]. For sections which are drilled without a riser (i.e. above the aquifer), a shallow hazard assessment will be conducted to inform selection of well locations where there is negligible risk of shallow gas. If this is not feasible and well(s) have to be drilled where a low risk of shallow gas has been identified, additional shallow hazard best practice operational plans would be adopted, including drilling of an exploratory smaller pilot hole prior to drilling a full-size surface hole section.

Once CO_2 injection is initiated, the aquifer will pressurise over time. Theoretically, surface blowout[245] at the injection wells could occur if a well experiences primary loss of containment. This could only occur if the downhole safety valve failed, i.e. a blowout is very unlikely.

Leakage to surface via wells may occur by means of:

- Wells designed, drilled and used to inject CO_2 (***injection wells***) or to monitor the Store (***monitoring well***), where CO_2 could potentially flow up tubing, in the annulus or up casing; and
- Wells which have previously been drilled in the vicinity of the Endurance Store but which are no longer operational (***legacy wells***).

Five ***injection wells*** will be drilled. Leaks could up to the large size (per the above definition), but the chance of such an occurrence is extremely remote[246] (bp, 2021f; bp, 2022d).

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[241] Water removal from the CO_2 stream occurs onshore, above MLWS and is outwith the scope of the ES. Allowable water content is part of the CO_2 entry specification for emitters.

[242] A liquid tracer will be injected with the CO_2 at the wellhead to facilitate the diagnosis of the source of any leaks if detected. This tracer will be present at a concentration of less than 10 parts per billion.

[243] The weight of drilling mud used is greater than the opposing aquifer pressure.

[244] Assemblies of valves and other devices installed on top of a wellhead during drilling operations to provide a means to contain unexpected flow and high pressures.

[245] Uncontrolled leak of CO_2 after pressure control systems have failed.

[246] The assessment of the likelihood of a CO_2 release mechanism occurring here and throughout this chapter is based on the opinion of specialists and should not be considered as definitive values, rather order of magnitude estimations.

Three legacy wells penetrate the Endurance Store and will be exposed to CO_2. There are two nearby off-structure wells which will not see CO_2. Leaks from the three on-structure wells could potentially be up to "large" size but the chance of such an occurrence is considered extremely remote (bp, 2021f; bp, 2022d).

Once injection ceases (i.e. post-injection), one or more of the five injection wells may provide a leak path, similar to that described for legacy wells; however, as pressures dissipate into the broader aquifer, the driving force of CO_2 leakage diminishes. Eventually, any leaks would be expected to be of "small" size and the chance of occurrence would be extremely remote.

10.5.3.2 Prevention and Mitigation

While considered unlikely to occur given that injection wells are designed with multiple barriers (Table 10-14), the tubing used to inject CO_2 into the aquifer would be the most likely pathway for a leak of CO_2 from injection wells.

Table 10-14 - Key barriers to preventing leakage of CO_2 via injection wells

Failure mechanism	Key barriers
CO_2 flows up tubing[247]	- Downhole Safety Valve prevents CO_2 flow up tubing; and - Wellhead tree[248] prevents leak of CO_2 outside of well
CO_2 in annulus[249]	- Annulus packer prevents CO_2 flow in annulus; - Annulus monitoring to detect any CO_2 in the annulus; and - Wellhead tree prevents leak of CO_2 outside of well.
CO_2 flows up casing[250]	- Casing material specified as corrosion resistant alloy to maintain integrity; and - Verification of integrity of cementing.

To reduce the risk of leakage of reservoir fluids along the outside of wells, cement is put in place to bond steel casing to the surrounding rock formation. In principle, corrosive, CO_2-rich fluids could degrade cement via annulus/casing monitoring and/or casing over time, allowing leakage of CO_2 along the outside of the well. The probability of CO_2 being leaked undetected to the surface in this way is considered extremely remote because:

- It is unlikely that the flow required to corrode a leakage pathway could be sustained long enough or far enough to reach the surface;
- If such long-distance corrosion occurred, it is likely that some flow would enter the well interior, where the leak would be detected via annulus/casing monitoring; and

[247] *Inner lining of well, transports CO_2.*
[248] *Assembly of valves, spools, pressure gauges and chokes mounted at opening of well on seabed.*
[249] *Space between two concentric objects e.g. tubing and casing.*
[250] *Outer tube separates well from surrounding material. Cemented into place.*

- Migrating flow would very likely be diverted into a porous formation and not reach the surface.

While CO_2 can chemically modify Portland cement, based on reaction rate (bp, 2021e), it has been documented that cement degradation is expected to take tens of thousands of years. If reaction with CO_2 does take place resulting in carbonate precipitation, this may lead to seals being improved as cement porosity is then "plugged" by carbonation, which prevents further leakage of CO_2.

Well integrity and leak monitoring techniques for injection and legacy wells are summarised in Section 3.3.1 and Section 3.4.5 and presented in full in the Management, Monitoring and Verification plan (Section 3.4.7) which will fulfil the requirements of Article 13 of the CCS Directive, and which will be submitted as part of the Storage Permit application (Section 3.4.7). Post-closure monitoring, documented in the Post closure plan (Section 11.2) and informed by monitoring data acquired during operations will be utilised to mitigate any risk of post-injection leaks.

10.5.4 CO_2 Leakage from the Subsurface

10.5.4.1 Risk Description

The UKCS contains oil, condensate and gas trapped in a large variety of reservoirs. There are numerous extensive caprocks[251] that are known to be effective seals for oil and gas, and these can be expected to be similarly effective at containing CO_2 (ZEP, 2019). Although the Endurance Store is not a previously producing reservoir with an operating history, data about the subsurface is available from seismic surveys conducted over the area and from the three exploration wells drilled into the structure. The most recent of these wells was specifically drilled to acquire additional data for the National Grid, White Rose CCS project.

A leak from the subsurface[252] could occur if:

- CO_2 moved beyond the boundaries of the Store (***lateral leakage pathway***); or
- CO_2 moved towards the surface of the seabed through the overlying seal material (***vertical leakage pathway***).

While ***lateral leakage pathway*** is a potential release mechanism, due to the volumes of CO_2 to be injected, leaks would be small and the chance of occurrence rare.

As described in Section 2.2, the aquifer is overlain by a primary seal. This primary seal (comprised of the Rot Clay and Rot Halite Formations) forms a very robust barrier to ***vertical leakage pathway*** of CO_2 due to the low porosity of the formations. However, potential failure mechanisms which could lead to a leak of CO_2 from the aquifer by flow towards the surface through the overlying seal material are summarised in Table 10-15. Leaks would be "Small" and the chance of occurrence extremely remote.

Induced seismicity is a risk associated with CCS projects (ZEP, 2019). For the Development, the properties of the primary seal act to prevent fault reactivation and injection rates and pressures will be maintained below predetermined levels. Consequently, the residual likelihood of induced

[251] Relatively impermeable rocks layers that seal the top of reservoirs and other geologic formations.

[252] A liquid tracer will be injected with the CO2 at the wellhead to facilitate the diagnosis of the source of any leaks if detected. This tracer will be present at a concentration of less than 10 parts per billion.

seismicity resulting in damage to the primary seal or offshore infrastructure and environmental harm is considered extremely remote, and the residual risk is low.

10.5.4.2 Prevention and Mitigation

CO_2 storage sites are selected to comply with the CCS Directive (see Section 11.2) which lays down extensive requirements for the selection of sites for CO_2 storage. A site can only be selected if prior analysis shows that, under the proposed conditions of use, there is no significant risk of leak or damage to human health or the environment. No geological storage of CO_2 will be possible without a storage permit.

For all currently operational CCS projects, no geological leak of CO_2 to the surface or the sea floor has been detected (ZEP, 2019). The concept of Endurance Store (i.e. large-scale storage within a saline aquifer) is proven by experience gained in other operations such as Gorgon, In Salah, Sleipner and Snøhvit (Bui *et al.*, 2018; Loria and Bright, 2021).

Further controls preventing the ***lateral leakage pathway*** of CO_2 from the Endurance Store are the natural shape of the structure[253] and adherence to defined operating limits to minimise any risk that, during injection, CO_2 does not extend beyond the spill point[254].

Table 10-15 - Key barriers to preventing leakage of CO_2 from the Endurance Store via vertical leakage pathway

Failure mechanism	Description	Key barrier
Diffusion/capillary flow through primary seal	Continuous diffusion takes place infinitesimally slowly over geological timescales. Actual time taken depends on overall seal package thickness, its permeability and the pressure difference created by CO_2 at the top of the Store. Simulations indicate 10,000-30,000 years for CO_2 to cross the primary seal.	• Selection of site where capacity, injectivity and seal integrity can be proven; and • Slow rate of CO_2 movement through caprock.
Mechanical failure of primary seal	The thermal or pressure-related stress from injection or store filling can theoretically create new fractures in the primary seal.	• Selection of site where capacity, injectivity and seal integrity can be proven; • Adherence to defined injection limits based on geomechanical analysis; and

[253] *The structure is a four-way dip closure which dips away in all four possible directions, indicating that any fluid beneath a sealing stratum will be trapped in this feature.*
[254] *Location from where CO_2 will leak when the Store volume is filled up.*

Failure mechanism	Description	Key barrier
	No evidence of mechanically induced fracturing of the caprock. Existing studies and modelling show that thermally induced fracturing of the primary seal is similarly unlikely.	• Rot Clay is overlain by the Rot Halite (together forming the primary seal). Rot Halite does not tend to fracture in response to pressure and is separated from direct contact with the Store CO_2.
Chemical alteration of primary seal	Acidic fluids, including CO_2, can react with minerals and perforate the primary seal or other sealing layers. There is no supply of CO_2-saturated water flowing past the caprock to dissolve it.	• Selection of site where capacity, injectivity and seal integrity can be proven; and • Rot Clay is overlain by the Rot Halite (together forming the primary seal). Rot Halite is separated from direct contact with the Store CO_2.
Existing fracture networks	Provide pathway for CO_2 out of the Endurance Store.	• Selection of site where capacity, injectivity and seal integrity can be proven; • No evidence of any connected fault or fracture networks; and • "Self-healing[255]" properties of Rot Halite.
Flow through existing faults in primary seal or fault reactivation	Provide pathway for CO_2 out of the Endurance Store.	• Selection of site where capacity, injectivity and seal integrity can be proven; • No evidence of any faults that cross the primary seal; and • Adherence to defined injection limits based on geomechanical analysis.

Geophysical and downhole monitoring during injection, as part of monitoring, would detect any ***induced seismicity***, allowing corrective action such as stopping injection or altering the injection pattern.

[255] *The ability of a material to heal (recover/repair) damages without any external intervention.*

10.5.5 Impact Assessment

If CO_2 were to leak into the marine environment[256], the initial fate of the leak would depend on the size and duration of the leak and its nature, including the rate of the leakage and the water depth at which the leak occurred. Dissolution rate depends partly on bubble size, which in turn depends on the geometry of the leak opening and on the plume dynamics just above the leak location. The fraction of gas reaching the sea surface will also depend on the leak rate.

Ultimately, any CO_2 that is leaked will enter the global carbon cycle and has the potential to contribute to climate change. In context, 100 Mt CO_2 is the total high case CO_2 inventory at the end of injection in 2050, equivalent to 18% of the net annual UK emissions in 2019 (550 Mt of CO_2 equivalent) (ONS, 2021).

Potential impacts on the environment described within this section are worst case impacts on the water column (Section 10.5.5.1) and seabed sediment (Section 10.5.5.2), given that understanding to date is largely drawn from laboratory studies and a small number of release experiments. Actual impacts from the predicted rates of leak from the Development (in the unlikely event of accidental leakage) are therefore expected to be significantly lower and probably undetectable against background variation.

Recent key studies, which investigated the impacts of CO_2 leaks, are summarised in Table 10-16 and discussed in further detail in subsequent sections.

Table 10-16 - Key experiments investigating the impact of CO_2 leaks

Project	Summary	References	Conclusions
Quantifying and monitoring potential ecosystem impacts of geological carbon storage (QICS)	2012; Ardmucknish Bay, West of Scotland Novel injection of CO_2 into marine sediments to mimic, as realistically as possible, leakage at the sea floor	Watanabe *et al.*, 2015; Tait *et al.*, 2015; Widdicombe *et al.*, 2015; Pratt *et al.*, 2015; Kita *et al.*, 2015; Phelps *et al.*, 2015.	Environmental impacts from small-scale leaks will be minimal and not ecologically significant. In the unlikely event of larger leaks, impact could be locally more significant but limited to a few kilometres of the leak.
Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEMM-CCS)	2017; Goldeneye site, North Sea Controlled release of CO_2 beneath surface sediments at seabed at 120 m water depth	de Beer *et al.*, 2021; Falcon-Suarez *et al.*, 2021; Lichtschlag *et al.*, 2021;	Small operational leaks of CO_2 have very limited, localised impact on the benthic environment and the water column.

[256] *Note that any well or subsurface leakage scenario would result in CO_2 at the seabed in gaseous phase: CO_2 leaving the Store would be in dense phase but would turn into gaseous phase in the shallow subsurface where the ambient pressure is well below the pressure at which CO_2 remains in dense phase.*

10.5.5.1 CO_2 leaks into the water column

On release into the marine environment, CO_2 is less dense than the surrounding water so will rise towards the surface, dissolving at a radial speed of approximately 0.1 cm hr^{-1} (IPCC, 2015). Larger bubbles moving rapidly and dissolving more slowly, such as those associated with medium-large rapid leaks from a pipeline or well rupture, may reach the water surface and be released into the atmosphere (Sellami *et al.*, 2015). Smaller bubbles from small, continuous leaks associated with subsurface percolation of the reservoir rock and small sized pipeline holes would dissolve completely before reaching the surface and are unlikely to penetrate more than a few metres from the seabed (Jones *et al.*, 2015).

The behaviour of CO_2 in seawater is complex and dependent on a number of factors including water depth, temperature and background saturation levels of CO_2. Simply put, when CO_2 dissolves into water, it forms carbonic acid, which is relatively unstable and dissociates to form bicarbonate and carbonate ions (dissolved inorganic carbon). As the level of bicarbonate ions increase, associated with a release of hydrogen ions, the pH of water reduces. The effects of increased CO_2 levels in seawater may therefore include a decrease in pH (i.e. increase in acidity) and a decrease in the availability of carbonate ions (due to their reaction with hydrogen ions). However, because seawater is a complex buffering solution, ocean chemistry can be resistant to change (Middelburg *et al.,* 2020).

$$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \rightleftharpoons CO_3^{2-} + 2H^+$$

Location specific modelling

High resolution models enable the release of CO_2 into marine environments to be simulated, facilitating the assessment of potential dispersal pathways to a resolution as fine as 1 m (Dewar *et al.*, 2015). The Unstructured Grid, Finite-Volume Coastal Ocean Model (FVCOM) very high-resolution hydrodynamic model system (Chen *et al.*, 2007) was used to assess the dispersion of CO_2 in the marine environment at the Endurance Store and simulate the primary physical mixing process acting on shelf seas. FVCOM is an unstructured-grid, coastal hydrodynamic circulation model, with the atmospheric weather forcing through the free surface. Input of detailed bathymetry enables the impact of seabed morphology on the dispersal or retention of CO_2 solution to be assessed (NOC, 2022). Model set up and results have been described in detail in NOC (2022) and are summarised in this section.

Two CO_2 leakage scenarios from the Endurance Store were modelled, 100,000 t per year[257] and a comparison scenario an order of magnitude smaller of 10,000 t per year. These were modelled during periods of maximum and minimum seabed current. CO_2 bubbles of size distribution obtained from experimental observations (Dewar *et al.*, In Review) were released from the seabed and travelled within the model through interactions with the oceanic turbulent flows, whilst dissolving. All of the bubbles rose and dissolved, with an average terminal height of 9.8 m and a maximum terminal height of 21.6 m (observed at the highest leakage rate when the largest bubbles, 29 mm, were released). While alternate modelling (Woods, 2022) indicated that a freely rising bubble of 1 cm in diameter will only partially dissolve during the rise to the sea surface, and a fraction of gas will always reach the surface, this is a potentially conservative estimate after accounting for the ambient currents (of the order of 0.3-0.6 m/s in the Endurance Store area) and the impact of bubble size.

[257] *As per the Endurance Risk Management Plan (bp, 2021f) following the QRA analysis performed by Risk Tec for well 43/21-1.*

The impact from CO_2 leakage is expected to be first determined by analysing pH changes (NOC, 2022). The simulated area of impact on the seafloor for both leakage rates is shown in Table 10-17.

Table 10-17 - Summary of predicted areas of pH reduction on the seabed

Leakage rate Mt/yr	Impacted area (km^2)			
	Maximum area	Average area	Maximum area	Average area
	pH reductions greater than 0.1		pH reductions greater than 0.1	
0.1	0.47	0.25	8.6	3.68
0.01	0.08	0.004	0.45	0.02

In all of the modelled CO_2 leakage scenarios, the bubble plume rose and fully dissolved within 40% of the water column, with up to 90% of the dissolution occurring within the first 5 m. This rate of dissolution is dependant, however, on the assumed initial bubble size distribution. The impact of bubble collisions and the potential breakup of larger bubbles into smaller bubbles (Blackford *et al.*, 2020), which reduces the maximum plume height, has not been incorporated.

The model outputs also indicate that the build-up of CO_2 during intervals of low current increases the scale of the plume of higher pH change. However, as currents increase, the solution is redispersed, resulting in lower pH change values.

The dilution and dispersion of these effects over a longer period than the assessed timeframes would provide buffering capacity, including the transportation of dissolved CO_2 into deeper waters as well as the exchange of CO_2 between surface water and air. Such processes would affect the impact of larger scale leakages.

The impacted area of seafloor determined using the FVCOM model can be compared against other model outputs using the relationship determined by Blackford *et al. (*2020; Figure 10-17). Applying the inferred relationship between leakage rate and impacted area[258] predicts an impacted area of ~6 km^2 for the high leakage rate scenario and ~0.14 km^2 for the low leakage rate scenario used in this modelling (NOC, 2022).

[258] *Y=629.49* X^1.6274 (where X represents the leakage rate in t/d and Y represents the impact area from Blackford et al. (2020).*

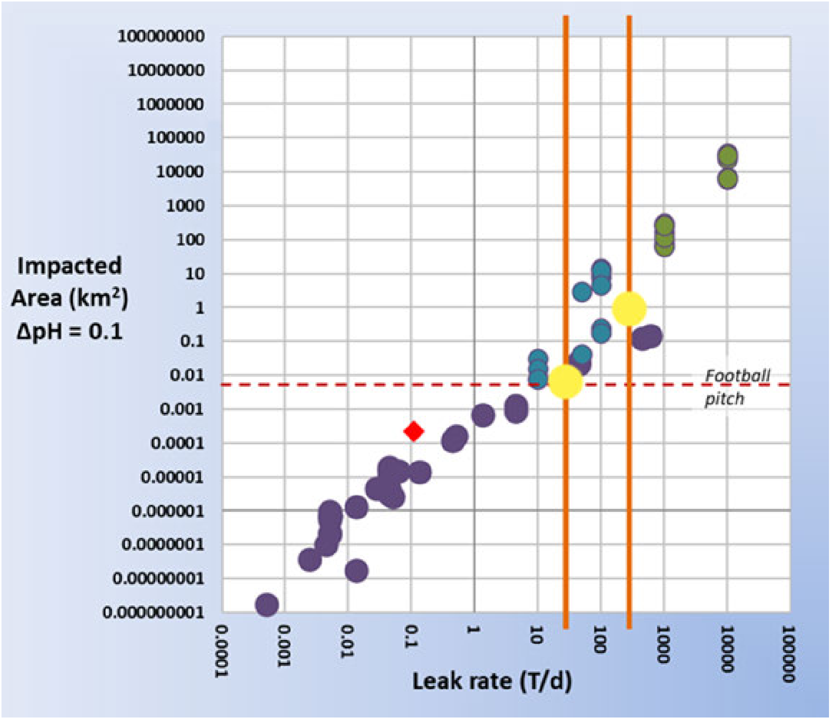

Figure 10-17 - Illustration of model-derived relationship between CO_2 release rate and impacted area. Symbols relate to the model system used in Blackford *et al.*, 2020 (Purple: high resolution model, Teal: medium resolution model, Green: low resolution model). Yellow: Development simulations. Red diamond: data from real world release experiment (NOC, 2022).

Marine ecosystems

Marine ecosystems are particularly tolerant to fluctuations in CO_2 concentrations and subsequent short-term variations in seawater acidity. Typically, shelf seas will experience an annual range of 0.2-0.4 pH units, with a mean between 8.0 and 8.1 (Thomas *et al.*, 2005; Artioli *et al.*, 2012). Long-term reductions in pH approaching or exceeding 1.0 unit can be considered as significantly harmful, while reductions in the order of 0.2–0.5 are considered potentially harmful, and reductions of < 0.1 are considered unlikely to have an impact (Widdicombe *et al.*,2013). Short-term (hours to a few days) reductions in pH will be much less deleterious to marine biota (Phelps *et al.*, 2015).

All CO_2 leakage events which reach the water column will produce a gradient of pH and other chemical changes between the leak location and the periphery of the affected area, with the potential to impact ecosystems in the vicinity of the leak. The length of the gradient will depend primarily on the leakage rate but will also be influenced by other factors associated with the form of leak and hydrodynamic mixing (Jones *et al.*, 2015). A small seep (< 1 t/day) will only have a spatial impact of a few tens of meters radius. A very large leak (> 100 t/day), but which is very unlikely to occur, would have a kilometre scale footprint (Phelps *et al.*, 2015). Both scenarios will have decreasing concentrations away from the point of release.

The baseline environment at the Endurance Store area has been described in Section 4.3.7. The organisms most vulnerable to the effects of acidification are those that rely on a calcified shell such as crustaceans. As well as permanent members of the zooplankton such as *Calanus* species, the plankton includes larval forms of many benthic mollusc and crustacean species. While effects of acidification may not be lethal, physiological effects may result due to trade-offs between respiration, growth and reproduction (Jones *et al.*, 2015). Analysis of a long-term natural volcanic CO_2 vent system at ambient seawater temperature and without toxic sulphur compounds demonstrated significant alteration in marine community structure. However, this change was constrained to a region with a measurable pH change within approximately 100 m of the vent (Hall-Spencer *et al.*, 2008) and required a long duration rather than short-term exposure to display a change in organisms.

Recent studies on fish have focussed on responses to ocean acidification where a wide range of behavioural effects have been identified (Clements and Hunt, 2015). However, due to the localised nature of the impacts in comparison to the large feeding areas and the mobile nature of fish species in North Sea environment, fish are unlikely to be significantly impacted by temporarily elevated CO_2 levels.

Marine mammal species are also mobile in nature and feed over large areas. If a CO_2 leak were to cause significant impacts on the marine mammal food chain, potential effects could result on marine mammals. However, as shown above, CO_2 is estimated to disperse and therefore any impacts are likely to be minor.

10.5.5.2 CO_2 leaks through seabed sediments

A CO_2 leak from the wells or subsurface may reach the seabed sediment where the majority will dissolve in the sediment pore water and reduce the pH, precipitate in the mineral phase, or accumulate as gas pockets within the sediment. Some may emerge into the water column and dissolve (Taylor *et al.*, 2015).

Elevated CO_2 levels in sediment have the potential to alter both the composition and function of benthic microbial communities, with implications for the turnover of organic matter and the benthic supply of nutrients to fuel pelagic primary production (Tait *et al.*, 2015).

Benthic organisms are likely to be at risk, with the primary mechanism for harm being a decrease in pH (increase in acidity). The potential impacts are dependent on the leak rates and leak areas; currents and water mixing, leading to dilution and dispersion; the individual species and lifecycle stage; the duration of exposure; and other environmental factors. The benthic environment in the vicinity of the Endurance Store is characterised in Section 4.4.2 and supports a wide variety of epifaunal and infaunal species. The organisms most vulnerable to the effects of acidification are those that rely on a calcified shell such as crustaceans and molluscs, which may experience sublethal effects as discussed above for water column impacts.

Possible records (unconfirmed) of the long-lived bivalve mollusc ocean quahog, featured on the OSPAR (2008) list of threatened and/or declining species, have been made in the Development area. Although this species may have high sensitivity to ocean acidification (NOAA, 2022), the findings of experiments conducted by Bamber and Westerlund (2016) suggested that it is tolerant of reductions in seawater pH equivalent to those predicted for substantial losses of CO_2 through leakage from geological storage.

Studies such as the QICS experiment have investigated the response of a range of benthic and bottom dwelling species to temporarily elevated concentrations of CO_2. Whilst evidence of disturbance to bivalves and megafauna was absent (Pratt *et al.*, 2015; Kita *et al.*, 2015) impacts were seen in microbial communities (Tait *et al.*, 2015) and microbenthic community structure (Widdicombe *et al.*, 2015; Blackford *et al.*, 2014). The experiment demonstrated that biological systems recovered within a few weeks of exposure.

Small short-term CO_2 leaks are therefore likely to cause highly localised and short-term impacts on macro faunal communities. It is expected that changes to the pore waters would return to background levels within a few weeks of the leak ceasing due to advection away from the point of the leak and tidal mixing. There is the potential for rapid recovery to occur, depending on the characteristics of the communities and habitats impacted.

10.5.6 Residual Risk and Mitigation

There is some risk that stored CO_2 could be leaked via wells or through the rock column or that CO_2 could be leaked during pipeline transportation. Multiple types of barrier exist to reduce this risk including barriers that are natural/passive, engineered, operational strategy, monitoring/detection, modelling and corrective action. Examples barriers are illustrated in Figure 10-18.

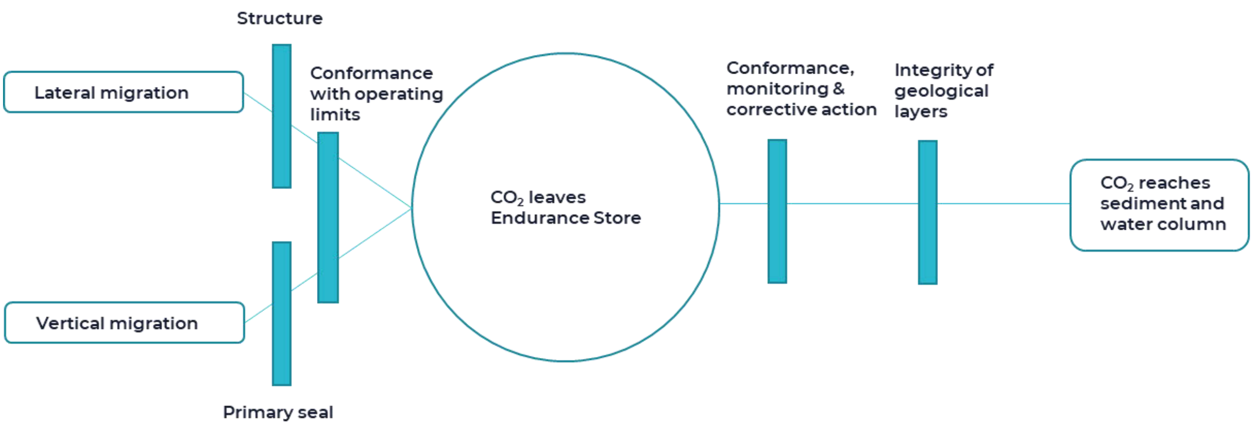

Figure 10-18 - Example barriers to prevent and mitigate leakage of CO_2 due to potential geological leak paths

In addition to the design mitigations, monitoring the migration of the CO_2 will be utilised to confirm conformance with predictions and/or checking for the presence of CO_2 (in accordance with MPs) and intervening if reasonably practical (i.e. carry out corrective measures). Monitoring and corrective action also prevents leakage by identifying non-conformances in the migration of CO_2 before leakage out of the site occurs, enabling amendment of injection pattern or rates if required.

The Endurance Store is planned with five, distributed, subsea injection wells, which allows for flexibility in injection patterns and for pressure management across the reservoir. The CO_2-specific well design combined with the downhole and surface monitoring and corrective measures in place reduces the likelihood of a sustained leak to the environment to extremely remote, with a corresponding low level of risk. Instrumentation will be incorporated into the completion of each well to provide early warning should a leak occur. Standard oil field techniques would then be used to repair the well.

The MP proposed for Endurance Store includes targeted monitoring at key locations such as ***legacy well bores*** to identify signs of CO_2 leaks and this supplements the planned seismic monitoring to detect the presence of CO_2 within the formations. In the unlikely event that CO_2 is found to be present outside of the expected locations, injection patterns and volumes will be adjusted.

- The MP will also incorporate periodic environmental surveys of the Endurance Store area using mobile platforms (ships/AUVs) to assess any long-term changes in marine environments or ecosystems. In addition, a suite of seabed monitoring solutions to detect CO_2 emissions into the water column will be employed (NOC, 2022). This will be achieved via a series of landers (Section 3.4.7), with core monitoring capabilities which may include:

- Integrated CTDs: to monitor salinity, temperature and depth;
- DO: to assess changes in biological productivity/organic matter degradation;
- pH/TA sensors: to constrain changes in marine carbonate chemistry;
- Phosphate/Nitrate sensors: to facilitate process-based attribution of any perturbation in carbonate chemistry;
- Hydrophones: passive or active to detect the leakage of gas; and
- Acoustic Doppler Current Profilers (ADCPs): to monitor current conditions over the sensor suite.

The ***Corrective Measures Plan*** details any measures that would be taken to prevent or stop the leakage of CO_2 from the storage complex. The measures will be described in detail in the Corrective Measures Plan and will be submitted as part of the Store Permit application. Based on the identified risks, the measures will include:

- Altering injection pattern or rates;
- Stopping injection;
- Well repair; or
- Well permanent closure.

Due to the Store selection process and the proposed monitoring and management strategies, the incremental risk of a CO_2 leak in the regional and global context is considered negligible. When considering the probability of the scenarios involving loss of CO_2 containment, all of the residual likelihood assignments are assessed as extremely remote once the Development specific prevention and mitigation measures are taken into account.

10.5.7 Cumulative, In-combination and Transboundary Impacts

The incremental increase in leak risk due to the Development is limited. CCS technology has been proven via a number of projects that have injected CO_2 into deep stores without incident. Furthermore, large-scale transportation and storage of CO_2 has been carried out in North America for a number of years. CO_2 pipeline leaks are estimated to occur with the same frequency as hydrocarbon pipeline leaks, therefore the probability of a CO_2 leak event is considered to be extremely remote.

Based on studies and modelling undertaken to date, the probability of CO_2 leakage from the Endurance Store are extremely remote. Ongoing monitoring and modelling studies during the operational and post-injection phases will add to the understanding of CO_2 behaviour in the Store and will help build understanding towards other potential CCS projects.

Studies to date suggest that the impacts from many lower-level fault or well-related leakage scenarios are likely to be limited spatially and temporarily, and rapid recovery of the environment is expected. The effects are often ameliorated by mixing and dispersion of the leak and by buffering and other reactions. Larger leaks, with potentially higher impact, are possible from open wells or major pipeline leaks but these are of extremely remote probability and will be more readily and rapidly detectable. As such, they can be stopped to prevent further leakage and escalation (Jones *et al.*, 2015).

In the unlikely event of a leak, impacts will only occur over a limited area and will not result in any transboundary impacts. As there are no other CCS projects in the vicinity, cumulative impacts resulting from the leak will not occur.

10.6 Store Formation Water Leakage Risk

While considered unlikely to occur, the accidental leakage of Store Formation Water from legacy wells could potentially impact the environment. The potential impact of a leak has been assessed against the following:

- The probability of occurrence of the leaks and the effectiveness of the planned control measures in place which will mitigate and interventions that will be used to prevent or reduce the impacts of any leaks;
- The potential of any leaks to impact the environment;
- The residual risks remaining after consideration of the preventive measures, mitigations and interventions; and
- The cumulative risks of leaks in and around the Development.

The Bunter Sandstone Formation formed in the end of the Triassic period during the breakup of Pangea. In an area that spread across present day Poland, Germany, Denmark, the southern regions of the North Sea and Baltic Sea, the Netherlands and south England a large sedimentary basin (Germanic Basin) formed. In the late Permian this region had an arid climate, and it was covered by inland seas which deposited the Zechstein evaporites. Whilst the inland seas were not connected, the metamorphic and igneous rocks that provided the deposited minerals were from the same source and all the seas experienced high sedimentation rates and rapid evaporation. These conditions lead to relatively rapid and spatially distinct formation of these evaporites; resulting in the compositional variation that is seen in these sedimentary rocks. At the end of the Permian, sea water flowed into this area periodically forming a tropical sea and the deposition of large alluvial fans which now form the red mudstone and siltstone of the Bunter Sandstone Formation.

As the basin has evolved over geological time (millions of years), dissolution of minerals and groundwater mixing has occurred in a non-uniform manner to produce Formation Water that is variable in its composition (Variation which is typically seen in e.g. the wide variation of naturally occurring substances concentrations from a single source during biannual analysis of produced water conducted by the oil and gas industry). The variation of chemical concentrations in environmental media both spatially and temporally results from a range of chemical fate processes occurring over various scales of time and space. As such, whilst analysis of the Store Formation Water and the Outcrop Formation Water provides a good description of the Formation Waters at these locations (Section 4.3.7), the actual characteristics of the Formation Water may be different in regions where the legacy wells are located. For the purposes of the assessment, the fluid which could be accidentally released from legacy wells is assumed to be Store Formation Water, for simplicity termed brine in this section.

10.6.1 Definition of Frequency of Brine Leakage

The definitions for the frequency of accidental brine leaks are those stated within Section 11.10.4 for accidental/unplanned events, i.e.:

- ***Likely*** – More than once per year;

- ***Possible*** – Once in 10 years;
- ***Unlikely*** – Once in 100 years;
- ***Remote*** – Once in 1,000 years; and
- ***Extremely remote*** – Once in 10,000 years.

The following sections outline the accidental brine leakage scenario from legacy wells, describing the risk as well as prevention and mitigation measures.

10.6.2 Brine Leakage from Legacy Well

10.6.2.1 Risk Description

The risk of CO_2 leakage via a leak path associated with a legacy well is primarily a risk for the on-structure wells as the off-structure wells[259] should not see any CO_2 assuming the plume does not migrate beyond the spill point. As CO_2 is injected into the Endurance Store, the off-structure legacy wells will experience an increase in pressure in the brine within the Bunter Sandstone Formation due to displacement of brine by CO_2 from the Store. Brine could potentially leak from these wells should the cement casing come into contact with the aquifer fluid, the cement casing corrodes and provide a leak path to surface.

The potential for cement degradation, thereby allowing brine-casing contact, has been evaluated with a cumulative probability of a brine leak of > 2,000 barrels per day from the closest two off-structure wells. Under worst case assumptions, the probability is estimated as being remote. Wells further away have an even lower likelihood of leakage (extremely remote) (bp, 2021e).

10.6.2.2 Prevention and Mitigation

Saline brine is near-neutral and anoxic, so a low corrosion risk is expected. Pressurisation alone of the brine will not change the anticipated corrosion rates and corrosion rates would be expected to be remain extremely slow. However, corrosion rates cannot be said to be zero were there to be contact with the aquifer water. Some minor corrosion could occur and over centuries this could lead to perforation of the 13 3/8" casing local to the Bunter Sandstone Formation.

The Bunter Sandstone Formation is overlain by the Rot clay and Rot Halite. Based on clay type, experience indicates that the Rot Halite is expected to creep over time (i.e., close in and form a seal) and provide further isolation. The basis for this expectation is industry experience, academic models, published papers and direct indications from offset wells around the Endurance Store.

Drilling into the off-structure legacy wells pre-emptively to implement remedial works is complex, not guaranteed to succeed and therefore not recommended. Following cessation of CO_2 injection, pressure within the Bunter Sandstone Formation will gradually dissipate, reducing any potential for brine leakage.

10.6.3 Impact Assessment

In their undiluted form, brines have the potential to be detrimental to ecosystems as they may be hypersaline, hot, anoxic and/or contain elevated metal concentrations (Dewar *et al.,* 2022). As reviewed in Dewar *et al*. (2022), such stressors can cause significant impact on individuals, species or

[259] *Wells which were drilled previously and which do not penetrate the aquifer.*

ecosystems. However, assessment of impact potential is highly complex and dependent on multiple factors, including but not limited to exposure time, range of stressors present and life-stage of the species present.

In well mixed shelf sea environments such as at the Endurance Store, processes such as dispersion and dilution act to reduce the impact potential of these stressors (in the remote-extremely remote likelihood of occurrence as a result of brine leakage from a legacy well).

To verify this assumption, simulations of unplanned brine releases were conducted, utilising high resolution modelling which integrated detailed bathymetry[260] to model the impact of seabed morphology on brine dispersal (NOC, 2022). Any release of brine will have a momentum flux and a buoyancy flux component that describe the initial plume behaviour. The momentum flux is caused by the pressure forcing the brine from the seabed and the area of the fissure through which the brine enters the water column. The buoyancy flux is caused by relative difference in density between the brine leak and the ambient marine environment; undiluted brine will therefore have a tendency to sink in the water column once the momentum flux from the leak has been dissipated. Leaks higher in the water column will fall to the seabed undergoing turbulent mixing as they do so. This results in an initial dilution of the leak, which undergoes further mixing and spread as it contacts the seabed. The impact with the seabed causes a radial spreading of the plume that can cause a wide area of the seabed to experience high salinities, before the current can begin to cause dilution. With seabed leaks the height the initial plume achieves in the water column is limited and thus the downward movement of the brine is limited, thus reducing the initial dilution and radial spreading effect. Whilst the hypersalinity in the immediate vicinity of the leak point is highly concentrated, dilution by the ambient current means that seabed impacts from a near seabed leak extend over a smaller area than for a leak higher in the water column.

The simulations suggest that the negatively buoyant[261] brine plumes would disperse rapidly in the relatively shallow and well mixed environments above the Endurance Store that are dominated by natural mixing due to tidal flow. Even at a relatively shallow depth of ~50 m, any potential impacts in the water column were found to be localised (on the order of 10's – 100's of meters in any direction).

Contaminants are inferred to impact a distance up to 500 m away from the source for the legacy well leaks (NOC, 2022). Within the narrow limits of the plume, the salinity threshold (salinity greater than 36.75 practical salinity units (PSU) or 5% increase over regional mean salinity) is breached at distances up to 100 m from the source. Beyond the initial source, the temperature change dilutes to within natural variability very quickly and is considered too small to have any impact. Tidal currents would strongly influence the movement of the leak and no significant accumulation of brine is predicted within sandwave troughs.

The impact potential with respect to elevated temperature or hypoxia is highly localised and unlikely to be consequential for the environment in either the short or long-term. Plumes of elevated salinity are restricted to 10–100 s of meters for the scenarios tested with no significant accumulation within the sandwave troughs (NOC, 2022).

[260] The bathymetry is set by data from the European Marine Observation and Data Network (EMODnet) and the North-West Shelf Operational Oceanographic System (NOOS), the latter, for the North Sea east of 0° E, are interpolated onto the model mesh.
[261] i.e. denser than seawater and therefore expected to sink

It is concluded that any changes in salinity, temperature, anoxia or metal contamination which occur as a result of brine leakage from a legacy well would dilute to within natural variability very quickly and are considered too small to have any impact on biodiversity.

10.6.4 Residual Risk and Mitigation

As described in Section 10.5.6, the MP proposed for the Endurance Store includes targeted monitoring at key locations such as ***legacy well bores***. Monitoring will be conducted to identify any indication of unplanned events such as brine leakage[262].

The deployment of standard CTD sensors on seafloor landers to monitor salinity, temperature and depth offers the most effective means for monitoring Formation Water. Contaminant concentrations (metals) and DO levels will also be monitored to help quantify the extent of plume dilution in the unlikely event of a leak of brine from a legacy well.

The ***Corrective Measures Plan*** which will be submitted as part of the Store Permit application, will describe in detail measures that would be taken to prevent or stop the leak of brine. The submission will contain a detailed plan for remedial well operations, in the remote chance they be required.

10.6.5 Cumulative, In-combination and Transboundary Impacts

The incremental increase in leakage risk due to the Development is limited. Based on studies and modelling undertaken to date, the probability of brine leak from off-structure wells is remote.

In the unlikely event of a leak, impacts will only occur over a limited area and will not result in any transboundary impacts. As there are no projects in the vicinity which could result in the leak of brine, cumulative impacts resulting from the leak of brine will not occur.

There is no scenario in which brine could be leaked as a consequence of the onshore schemes and therefore a whole scheme assessment is not conducted for accidental brine leakage.

10.7 Residual Impacts

10.7.1 Accidental Diesel Release

Regulations require bp, as operator of the Development, to have in place a range of response/mitigation measures to address the diesel release risks detailed above. All activities will be covered by appropriate OPEPs, which will set out the responses required and the available resources for dealing with releases of all sizes.

The residual impact for the receptors of protected sites and socio-economic features is described below. It is concluded that the residual impact is considered not significant. This is due to the mitigation measures in place and the remote likelihood of a release in the first place. It should also be reiterated that modelling represented a worst case scenario where no response measures are in place, therefore this represents a conservative estimate as to the magnitude of the impact and the vulnerability of receptors as it assumes, for example, birds will be present at protected sites when diesel arrives.

[262] *Monitoring of formation water displacement is described in Section 8.4.4.*

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Protected sites	Medium	Medium	High	Low
Rationale				
Given the possibility of interaction between a range of potential receptors following a release of diesel, the receptor sensitivity has been designated as **medium**. Furthermore, it is anticipated that some features could exhibit **high** value as protected sites contain habitats and species protected under the EC Habitats Directive therefore the value has been assigned as such. The magnitude of an accidental spill is expected to be **low** as the potential diesel release is not expected to extend across a large area of the UKCS and has no transboundary impact. The magnitude of an accidental spill is low due to the marine diesel exhibiting a volatile nature. The model shows marine diesel to evaporate, biodegrade and dissipate throughout the water column during the first 30 days. Therefore, the diesel would not likely persist in the environment for a sustained period of time. When taking into account the remote likelihood of the release happening and the mitigation measures that will be in place to prevent accidental spills, the residual magnitude is ranked as **low**. It is recognised that a diesel release could result in demonstrable change in receptors. However, for this type of accidental event, it is especially important to assess the likelihood of the impact occurring. A review of UKCS historical data relating to release events confirm that the likelihood of an event like this is remote. Given the mitigation measures that are in place (Section 10.3.3) and the remote likelihood of the release happening, the consequence is considered **negligible**, and the impact is assessed to be **not significant**.				

Consequence	Impact Significance
Negligible	Not significant

10.7.2 Accidental CO_2 Leakage

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Ecosystems in the vicinity of the leak	Medium	Medium	Medium	Low
Rationale				
Accidental leakage of CO_2 due to the Development has the potential to impact ecosystems in the vicinity of the leak. In the extremely unlikely event of a small CO_2 leak, minor localised influence on the marine environment may occur. However, the ecosystems are naturally resilient to minor fluctuations in CO_2 concentrations. Even in the extremely unlikely event of a major leak, there will be a limited, temporary, local effect on marine ecosystems in a range limited to the kilometre scale				

(ZEP, 2019) The Development thus poses small risks of accidental CO_2 leakage with the residual magnitude ranked as **low**.

It is recognised that an accidental CO_2 leak could result in demonstrable change in receptors. However, for this type of accidental event, it is especially important to assess the likelihood of the impact occurring. Given the mitigation measures that are in place (Section 10.5.6) and the remote likelihood of an accidental CO_2 leak happening, the consequence is considered **minor**, and the impact is assessed as **not significant**.

Consequence	Impact Significance
Minor	Not significant

10.7.3 Accidental Brine Leakage

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Ecosystems in the vicinity of the leak	Medium	Medium	Medium	Low
Rationale				
Accidental leakage of brine due to the Development has the potential to impact ecosystems in the vicinity of the release. In the unlikely event of a brine leak, minor localised influence on the marine environment may occur. The Development thus poses small risks of accidental brine leak with the residual magnitude ranked as **low**. It is recognised that an accidental brine leak could result in demonstrable change in receptors. However, for this type of accidental event, consideration is required of the likelihood of the impact occurring. Given the mitigation measures that are in place (Section 10.6.4) and the remote likelihood of an accidental brine leak happening, the consequence is considered **minor**, and the impact is assessed as **not significant**.				

Consequence	Impact Significance
Minor	Not significant

11 ATMOSPHERIC EMISSIONS

11.1 Introduction

Atmospheric emissions from the Development will arise from[263]:

- Vessel fuel combustion during installation, commissioning, drilling of wells and O&M; and
- Emissions associated with the generation of onshore electricity which is exported offshore to power the subsea infrastructure.

Atmospheric emissions from the Development, which will primarily result from complete or in-complete combustion of fuels, will contribute to impacts at a local, regional, national, transboundary and global scale. This chapter quantifies the emissions anticipated to result from the Development (Section 11.4) and assesses potential impacts of:

- The Development on local air quality (Section 11.5);
- The Development on global climate change (Section 11.7.2);
- Global climate change on the Development (Section 11.10.3); and
- Global climate change and the Development on the receiving environment (Section 11.10.4).

GHGs are the gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere and clouds. These substances prevent energy from leaving the atmosphere and thus contribute to heating of the atmosphere.

On a global scale, concern with regard to atmospheric emissions of GHGs (including water vapour, CO_2, methane (CH_4), nitrous oxides (N_2O), Ozone (O_3) and chlorofluorocarbons) is focused on the impact they have on global climate change. The IPCC in its sixth assessment report (AR6) states that '*it is unequivocal that the increase of CO_2, methane (CH_4) and nitrous oxide (N_2O) in the atmosphere over the industrial era is the result of human activities and that human influence is the principal driver of many changes observed across the atmosphere, ocean, cryosphere and biosphere.*' (IPCC, 2021). AR6 reports that each of the last four decades have been successively warmer than any decade that preceded it since 1850. IPCC (2021) reports a 47% increase in CO_2 concentrations since 1750 which far exceed the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years, stating that the combustion of fossil fuels is the primary contributor to the observed global warming.

The effect GHGs have on the heating of the atmosphere is quantified in the global warming potential (GWP) of the substance, a value describing the radiative forcing impact of one mass-based unit of a given GHG relative to an equivalent unit of CO_2 over a given period. Thus, it is possible to calculate a value for the GWP of all GHGs emitted in terms of an equivalent mass of CO_2. This value is called the carbon dioxide equivalent (CO_2e). This CO_2e value can be used to compare the emissions from the Development with UK shipping emissions and the UK carbon budget, which is also described in CO_2e.

The quantification of atmospheric emissions associated with the Development will facilitate the assessment of the impact of the activities on the global climate:

[263] *Atmospheric emissions associated with the decommissioning of the Development's infrastructure are subject to a separate environmental appraisal process and are not covered by the EIA Directive requirements. As such, they are not included within the scope of this ES.*

- To assess the impact of the Development on the UK goal of achieving net zero by 2050, vessel emission calculations form a carbon assessment of the Development; and
- Predictions of the future environment (Section 4.7) are used to inform the climate change resilience (Section 11.10.3) and in-combination climate change assessment (Section 11.10.4) presented in this chapter.

This assessment puts vessel CO_2e emissions in the context of shipping emissions[264] which occur in the vicinity of the Development, selected as being the most representative baseline data that is available for comparison, in the absence of other sources of offshore CO_2e data.

On a local scale, emissions such as nitrogen and sulphur oxides (NO_x and SO_x), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) may affect local air quality with potential impacts on human health and the environment.

- NO_x emissions form photochemical pollution in the presence of sunlight which can damage human respiratory tracts;
- SO_x emissions are a precursor to acid rain and atmospheric particulates and can exacerbate respiratory illnesses;
- CO can directly affect human health at elevated levels, acting as an asphyxiant; and
- NMVOCs can contribute to the deterioration of local air quality.

Emissions arising from the Development have been derived according to industry guidance[265], multiplying activity data by published emissions factors to calculate quantities for individual gases.

The following specialists have contributed to this assessment:

- Xodus Group – preparation of the baseline description, impact assessment and ES section.

11.1.1 The Development

The Development is FOAK infrastructure (Section 3.1) to transport CO_2 captured by the onshore developments at Teesside and Humber to the Endurance Store for geological storage. The assessment presented in this chapter only considers the emissions associated with the installation and operation of the Development, and excludes consideration of CO_2 injected into the Endurance Store. The injected CO_2 will originate from onshore activity and not from activities occurring within the scope of this ES.

The Development is an integral element of the overall ECC development and will deliver CO_2 transport and storage, contributing to reductions in UK emissions and achievement of net zero goals. Without the Development, the ECC could not inject and store CO_2 generated by onshore activities.

[264] Sourced from the UK's National Atmospheric Emissions Inventory (NAEI), 1A3d Domestic navigation, Shipping - coastal
[265] The GHG Protocol and the EEMS Atmospheric Emissions Calculations (OGUK, 2008).

11.2 Regulatory Controls

In addition to the regulations detailed in (Section 1.5), there are other areas of UK legislation and policy, international treaties and agreements which require the provision of atmospheric emissions inventories and the assessment of carbon.

The Paris Agreement is a legally binding, global climate change agreement, which aims to address GHG emission mitigation, adaptation and finance. It was adopted in 2015 and provides for all signatories to keep the increase in global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C (UNFCCC, 2016). In line with Article 4 of the Paris Agreement, the UK has submitted a Nationally Determined Contribution (NDC), which commits the UK to reducing economy-wide GHG emissions by at least 68% by 2030, compared to 1990 levels.

The Climate Change Act 2008 (UK Government, 2008) set a legally binding target for the UK to reduce its GHG emissions from 1990 levels by at least 80% by 2050. This target is supported by a system of legally binding five-year 'carbon budgets' and an independent body to monitor progress, the CCC. The UK carbon budgets restrict the amount of GHG emissions the UK can legally emit in a defined five-year period.

The Act was amended in 2019 to revise the existing 80% reduction target and legislate for a net zero emissions by 2050 (through the Climate Change Act 2008 (2050 Target Amendment) Order 2019) (UK Government, 2019). In 2020, the 6^{th} carbon budget was published by the CCC for consideration by Government and is the first budget to reflect the amended trajectory to net zero by 2050. The existing UK carbon budgets are used to determine significance of GHG emissions from the Development, as described and used in Section 11.7.2.

The Net Zero Strategy: Build Back Greener (UK Government, 2021) outlines the key policies set by the UK Government to reach net zero targets. This includes a commitment to collaborate with the maritime sector to investigate the feasibility of establishing a UK Shipping Office for Reducing Emissions (UK-SHORE) which will play a key role in promoting the UK's involvement in developing clean maritime technology. Decarbonising Transport (Department for Transport, 2021) details the commitments and actions required for accelerating maritime decarbonisation in the UK with the overall ambition to achieve net zero in the maritime sector by 2050 or earlier. In addition, a review of the existing monitoring, reporting and verification system for GHG emissions from international shipping is planned. This system will provide a basis for how similar information can be gathered for domestic maritime activity and shape future evidence-based policy interventions for maritime emissions.

The East Marine Plans and North East Marine Plans (Section 1.5.1 and Section 1.5.2) seek to ensure that developments consider and address potential direct or indirect air pollution or GHG impacts and avoid, minimise or mitigate them accordingly.

The Merchant Shipping (Prevention of Air Pollution from Ships) Regulations 2008 implement MARPOL Annex VI in the UK and establish controls on marine engines and marine fuel to limit emissions, in particular NO_x and SO_x. All vessels used during the proposed drilling and installation will have the appropriate UK Air Pollution Prevention Certificate (UKAPP) or International Air Pollution Prevention Certification (IAPP) in place, as required:

- Regulation 14 designated the North Sea for the purposes of SO_x and particulate matter control Sulfur Oxides Emission Control (SECA); and

- Regulation 13 requires Nitrogen Oxides emissions (NECA) to be included within Emission Control Areas (ECA) as evidenced by the issue of Engine International Air Pollution Prevention Certifications (EIAPP).

The National Emissions Ceiling Regulations 2018 outline a requirement to develop a reduction programme for SO_x, NO_x and NMVOCs in the UK. NMVOCs, a product of incomplete combustion, are a significant GHG and can also lead to deterioration of local air quality.

11.3 Assumptions and Data Gaps

The assumptions detailed in this section have been made to inform the impact assessment for the Development. The scope of the assessment (Figure 11-1) includes the offshore activities (seaward of MLWS) associated with the phases of the Development described in Section 11.1. The emissions associated with each phase of the Development are calculated in Section 11.4.

Vessel associated emissions were calculated by multiplying activity data by the relevant emissions factor (see Section 11.4).

In order to ensure that the assessment of the release of atmospheric emissions reflects the worst case scenario, a number of assumptions have been made about the installation of subsea infrastructure and the operation of the offshore elements of the Development. For example, vessel numbers represent the maximum that could be used for the Development. At this time, the landfall installation methodology is not known, and multiple options exist (Section 2.5.3.2). The assessment of atmospheric emissions has therefore assumed:

- **HDD or microtunnelling at Teesside:** both options are predicted to require the same level of vessel activity and therefore result in the same level of emissions. These options are associated with more emissions than result from the “direct pipe” alternative (Section 3.2.1); and
- **HDD at Humber:** predicted to require more vessel activity than the other options under consideration, (such as “direct pipe” or “microtunnel”) (Section 3.2.2).

Pipelay may be executed using anchored or DP vessels. The relative duration of vessel activity when utilising anchored vessels versus DP vessels is greater than the approximately 25% increase in fuel consumption associated with DP relative to anchoring (e.g. Łebkowski and Wnorowski, 2021). Consequently, to ensure assessment of worst case atmospheric emissions, use of anchored vessel pipelay is assumed.

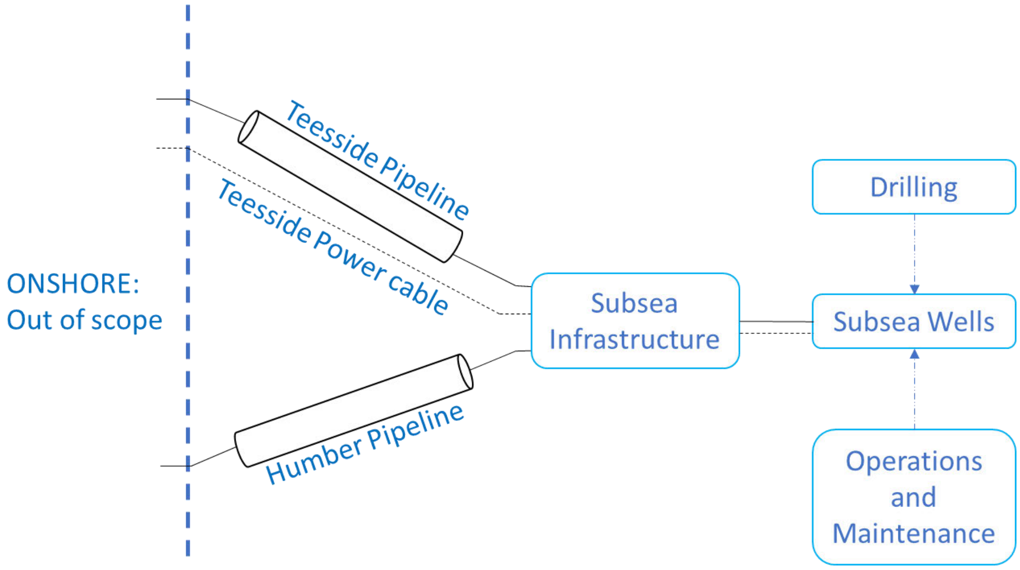

Figure 11-1 - Scope of the assessment. Includes power from shore and all vessel activity associated with installation, commissioning, drilling, and O&M of the above infrastructure.

All small volumes of CO_2 vented as part of isolations required on the subsea infrastructure during operational activity (e.g. pipeline inspection and well intervention) are considered to form *de minimis* amounts (Table 11-1), and are thus excluded from further assessment.

Table 11-1 - CO_2 venting required during O&M phase (worst case)

Requirement	Frequency	CO_2 vented per isolation (Tonnes)	CO_2 vented over O&M phase (Tonnes)	Comment
Well subsurface safety valve (SSSV) pressure testing	Annually per well	5.6	700	Wells filled with N_2 (base case)/CO_2 (alternative) CO_2 venting will only occur from this scenario if wells filled with CO_2. Volume above SSSV in wellbore released to enable pressure testing across the valve
Well lubricator pressure testing	3 runs per well every 5 years	0.12	9	Pressure test required to prove isolations
Pig receiver venting	3 times over O&M phase	2.7	8.1	Venting allows pig recovery
Wellhead valve testing	Test per well every 5 years	0.36	9	

11.3.1 Atmospheric Emissions: Fuel Combustion

Atmospheric emissions resulting from fuel combustion associated with vessel[266] activity will occur during the Development. Each vessel is assumed to be powered by marine diesel engines resulting in emissions of CO_2, CO, NO_X, N_2O, SO_X, CH_4, and NMVOC. Helicopters associated with the drilling campaign are assumed to be powered by an aviation kerosene engine, with similar combustion emissions. Details of vessel requirements are described in Section 3.5. The following assumptions have been made to calculate the emissions:

- The fuel is assumed to be low sulphur marine diesel (< 0.1% Sulphur);
- The associated fuel use for each vessel type was taken from the Institute of Petroleum (IP, 2000). Benchmarking using confidential vessel fuel consumption data from 2021-2022 showed that the IP (2000) data contained both over and under estimates of fuel consumption. Overall, there was no clear trend that the IP (2000) data appreciably over-estimated fuel consumption and therefore, the IP (2000) data is retained as the basis for estimates of atmospheric emissions attributable to vessel fuel consumption.
- Estimated daily fuel use per vessel type has been applied to the number of each type of vessel required for the Development to produce an estimated total fuel use per vessel type;
- Conversion factors were used to calculate emissions per vessel type, and then the CO_2e values were calculated based on IP (2000), Environmental and Environmental Emissions Monitoring System (EEMS), Atmospheric Emissions Calculations (OGUK, 2008) and IPCC (2021);
- During drilling, five helicopter flights per week are assumed from Aberdeen (worst case), with each round trip estimated to take approximately one hour;
- It is assumed that helicopters will use A1 Jet fuel (containing a maximum of 0.3% sulphur content); and
- During installation activity, it is assumed that crew changes for installation vessels will be via port calls rather than helicopter transfer.

11.4 Quantification of Emissions Inventory

The atmospheric emissions from vessel fuel combustion and imported power have been assessed for the scope of installation, commissioning, drilling and O&M of the Development (Section 1.6). The quantification of the atmospheric emissions from vessel fuel combustion are included in Section 11.4.1 and from imported power in Section 11.4.2. The impact assessment on local air quality is presented in Section 11.5, and on global climate change in Section 11.7.2.

11.4.1 Vessel Activity

Atmospheric emissions have been calculated from the estimated total volume of fuel that will be required by vessels working on the Development. Conversion factors to convert fuel use into gaseous emissions (CO_2, CO, NO_x, N_2O, SO_2, CH_4, NMVOC) have been taken from IP (2000) and EEMS Atmospheric Emissions Calculations (OGUK, 2008). The GWPs used in the GHG emissions calculations are sourced from AR5 (IPCC, 2013) and are listed in Table 11-2 (based on a 100-year horizon).

[266] Other than helicopter usage during the year-long drilling campaign, all activity is related to vessels (including jackup barge for drilling at the Endurance Store). For succinctness, therefore, the term vessels includes helicopters and vessels associated with drilling activity.

Atmospheric emissions as a result of fuel combustion during vessel activity per phase of the Development are summarised in Table 11-3, and presented in detail in Appendix O. The percentage of CO_2e emissions per phase of the Development (from vessels) is presented in Figure 11-2.

Table 11-2 - The GWP (GWP, 100 year horizon) of relevant GHGs - CO_2e (te/te) (IPCC, 2013)

Emission	CO_2	N_2O	CH_4
GWP	1	265	28

Table 11-3 - Summary table: Vessel emissions (tonnes) per phase of the Development[267]

Phase		Fuel use (Tonnes)	Emissions (Tonnes)							
			CO_2	N_2O	CH_4	CO_2e	CO	NMVOC	SO_2	NO_x
Landfall	Teesside	19,170	60,769	4	3	61,983	301	46	230	1,131
	Humber	19,170	60,769	4	3	61,983	301	46	230	1,131
Pipeline Installation		51,925	164,602	11	9	167,892	815	125	623	3,064
Subsea Infrastructure Installation		3,169	10,046	1	1	10,246	50	8	38	187
Drilling		11,325	35,899	2	2	36,615	177	27	136	660
Commissioning		3,078	9,757	1	1	9,952	48	7	37	182
O&M		24,671	78,207	5	4	79,769	387	59	296	1,456
Total		**132,508**	**420,049**	**29**	**24**	**428,440**	**2,079**	**318**	**1,590**	**7,810**

[267] *Fuel use and emissions factors derived from IP (2000) and OGUK (2008).*

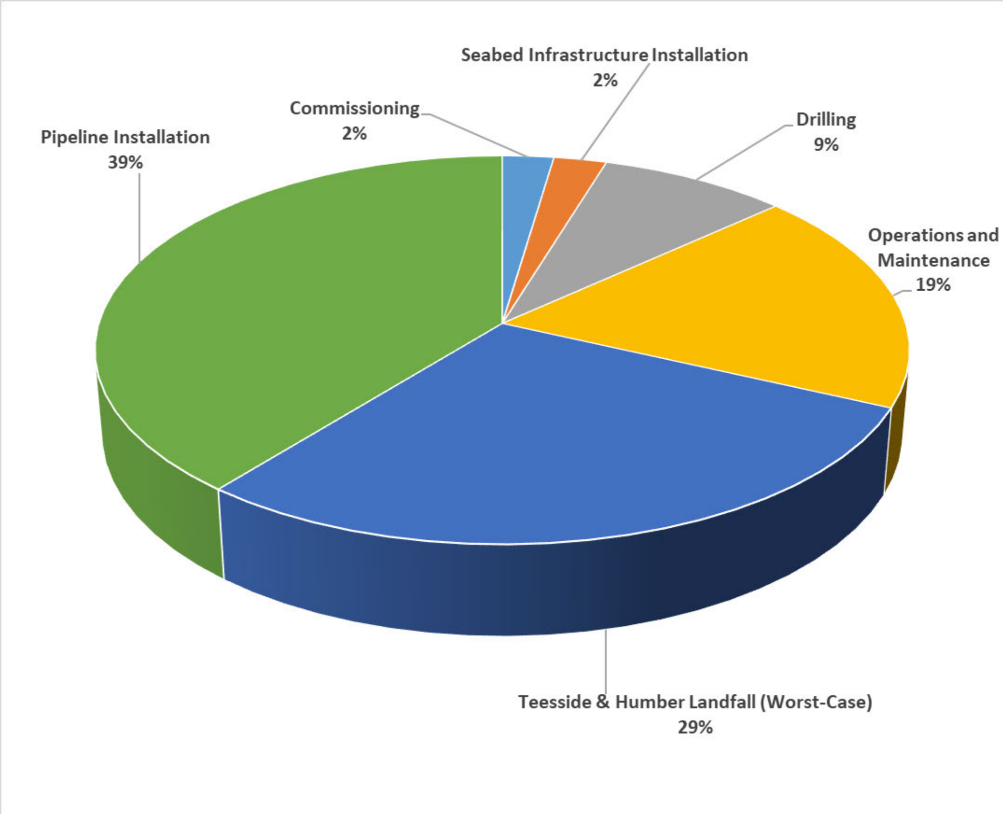

Figure 11-2 - Summary figure: Percentage of vessel CO_2e emissions per phase of the Development

Figure 11-2 shows that the majority (81%) of the estimated vessel CO_2e emissions associated with the Development occur during the initial phases, i.e. landfall works, installation of the pipelines, subsea infrastructure, drilling activity and commissioning. Emissions associated with pipeline installation are estimated to represent the greatest contribution during these initial phases (39%) given associated vessel requirements. Emissions during O&M are estimated to contribute 19% to total vessel emissions from the Development.

11.4.2 Imported Power to the Development

The reference case for power imported to the Development via the Teesside – Store cable is that 95% of the power would be taken from the Teesside Power Plant and 5% would be taken from the National Grid. The project electrical load schedule predicts an energy demand of 237.3 kW maximum normal running load .

The Carbon Assessment, Energy Use & Greenhouse Gas Forecast (NS051-EV-REP-040-00003) report used during the pre-FEED assessment was used as the basis for National Grid future emissions factors contributing to the Development. This report accounts for the gradual decarbonisation of the National Grid to 2050 in line with the UK Government's Net Zero commitments.

Table 11-4 outlines the imported power demands and emissions factors.

Table 11-4 - Power demand and emissions factors

Power source	Power input assumption (%)	Power demand (MWhr/yr)	Emissions factor (tCO_2e/MWh)
Teesside Power Plant	95	1974.7	0.0248
National Grid	5	103.9	0.0556

Using the information provided in Table 11-4 and assuming a 25-year life of operations, the emissions arising from the total power imported to the Development are 1,369 t CO_2e.

11.4.3 Summary of the Carbon Assessment

Total carbon emissions from the Development are presented in Table 11-5. Total emissions are estimated to be 430 kt CO_2e. Landfall works, installation, drilling and commissioning activity are associated with an estimated 349 kt CO_2e (assumed to occur between 2025 and 2027). Operational activities are limited to regular surveys of the Store area, pipeline inspections and well maintenance (Section 3.5). During the O&M period, a total of 1 kt CO_2e is associated with imported power. Overall, emissions during the O&M period average approximately 3 kt CO_2e per year.

Table 11-5 - Development emissions (kt CO_2e)

Year	2025	2026	2027	2028-2052	Total
Landfall Works, Installation, Drilling and Commissioning	116.2	116.2	116.2	-	348.7
O&M (including imported power)	-	-	-	81.1	81.1
TOTAL	116.2	116.2	116.2	81.1	429.8

11.5 Local Air Quality

In this section, any potential local air quality impacts are qualitatively considered via an overview of:

- Potential receptors;
- Background air quality and the receiving environment; and
- Emissions associated with the Development.

Receptors that have the potential to be affected by changes in air quality include ecological receptors (see Section 11.8) and human receptors. Offshore, the nearest permanently manned installation to the Endurance Store is in the Ravenspurn Field (approximately 13 km south-southwest). At Teesside, the nearest human receptors are recreational and include the Cleveland Golf Links and Redcar Beach Caravan Park which lie within 1 km of the landfall. At Humber, there are no recreational or residential receptors within 1 km of the landfall.

Background air quality will be influenced by nearby sources of emissions. These were identified as:

- Endurance Store;
  - The nearest offshore installation to the Endurance Store area is in the Ravenspurn Field (approximately 13 km south-southwest);
  - (OWF licence areas and projects in the vicinity of the Development (Section 4.6.2.3) which would be expected to have regular vessel-based maintenance activity; and
  - Transient shipping and aviation traffic;
- Teesside Pipeline route (nearshore);
  - Transient shipping and aviation traffic, including shipping transiting to/from Teessport;
- Humber Pipeline route (nearshore); and
  - Transient shipping and aviation traffic, including shipping transiting to/from Associated British Ports (ABP) Humber Port.

Onshore at Teesside, it is noted that Redcar and Cleveland Borough Council has no Air Quality Management Areas (AQMAs) declared[268], i.e. there are no areas within the local authority area where the UK national air quality objectives are not likely to be achieved. It is noted that East Riding Council

[268] *https://uk-air.defra.gov.uk/aqma/maps/*

of Yorkshire has no Air Quality Management Areas declared and air quality is generally good (ERYC, 2022).

A wind rose based on nine years of recent data in the Endurance Store area is presented in Figure 11-3. This shows that wind in the region predominantly originates from the west-southwest and is typically between 2 to 16 m/s. Omni directional windspeeds of less than 2 m/s occurred less than 3.4% of the time, with windspeeds greater than 20 m/s occurring less than 1% of the time. This data shows that the offshore environment at the Endurance Store is highly dispersive for gaseous emissions and will widely disperse pollutants that may affect local air quality to levels well below those expected to cause a concern within a short distance from the vessels from which they would be emitted.

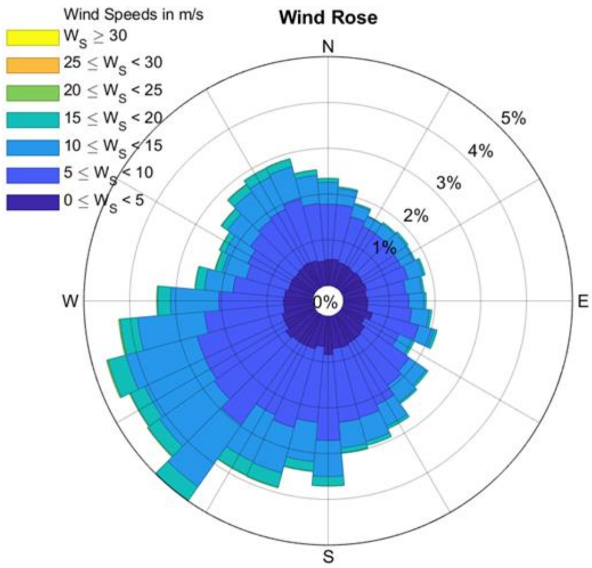

Figure 11-3 - Windrose for Endurance Store area (Data from 2011 to 2020) (bp, 2020c)

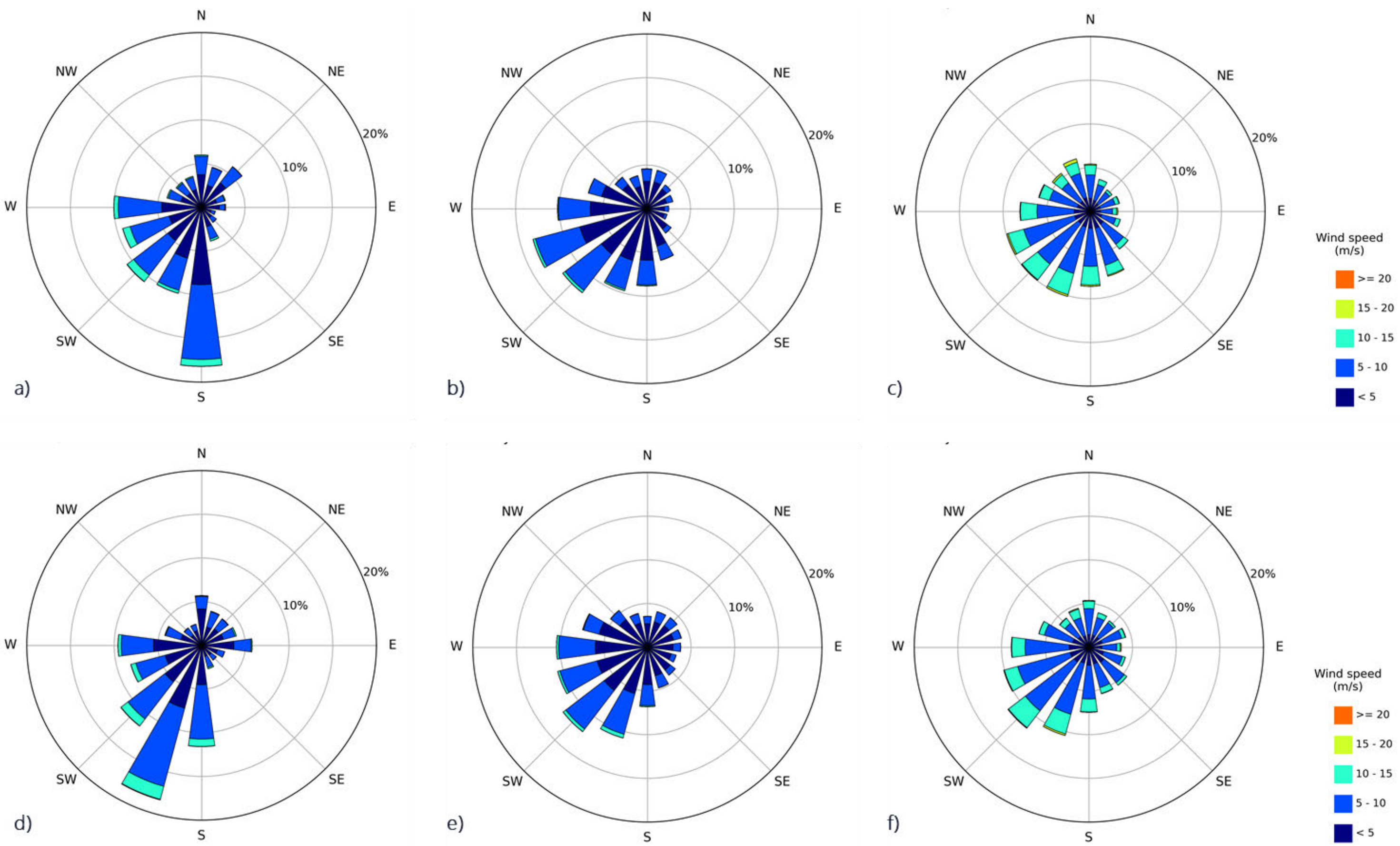

Figure 11-4 - All year wind roses (Data from 2017 – 2021) a) Teesside Airport METAR observations b) ECMWF reanalysis model near Teesside Airport c) ECMWF reanalysis model offshore Teesside d) Humberside Airport METAR observations e) ECMWF reanalysis model near Humberside Airport f) ECMWF reanalysis model offshore Humberside

Wind rose data was obtained from Meteorological Terminal Air Reports (METARs) at Humberside and Teesside Airports for the period 2017 – 2021 (Figure 11-4, a, d). To investigate any biases in the measured data, the European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis 5th Generation (ERA5) data is also plotted as wind roses (Figure 11-4, b, e). The same years of data are used as for the METARs, and the model data is hourly. The directionality from the model is more evenly spread with less predominant main directions. This suggests that some local effects may be influencing the METAR wind observations, that are not present in the large-scale atmospheric patterns. The wind speeds from the ECMWF model are slightly lower than the METAR observations. The wind speed from the ECMWF samples offshore is higher (Figure 11-4, c, f) as would be expected. The wind roses show that winds generally blow from onshore to offshore, away from any onshore receptors.

Throughout the lifecycle of the Development, there will be atmospheric emissions from vessel activity. Each vessel will be powered by combustion engines, resulting in emissions of CO_2, CO, NO_x, N_2O, SO_x, CH_4, and NMVOC, which have the potential for effects on local air quality. Any emissions will be temporary and controlled through best practice mitigation measures. There will be no dust associated with any phase of the Development.

Baseline shipping activity (Section 4.6.4) shows that the entire Development area is a busy shipping area[269]. Offshore, all background emissions are from mobile sources, with the exception of fixed installations from the oil and gas industry. The nearest of these fixed installations is in the Ravenspurn Field, located approximately 13 km away, and therefore unlikely to be impacted by the Development´s offshore activity. Nearshore, emissions from vessels that are temporarily present as a result of the Development for relatively short periods of time (Table 3-21) are unlikely to be discernible from the general shipping and offshore activities occurring in the area.

11.6 Management and Mitigation

The identification, assessment, and minimisation of atmospheric emissions is embedded within the Development. As described within Chapter 3: Project Description a structured decision-making process has been applied during design to limit emissions associated with the Development. This includes selection of an entirely subsea solution (Section 2.4) that is electrically powered (Section 2.4.1) and pipelines which are specified to allow future increases in CO_2 injection rates without additional construction activity (Section 3.2).

Identification, assessment and delivery of the opportunities are achieved via the bp management system and are not limited to the preparation of the regulatory EIA submission. As the Development progresses through design, opportunities will be sought to minimise emissions. Emissions reduction reviews are part of further detailed design and the installation process, including third party contractors where appropriate.

Opportunities to manage and reduce atmospheric emissions during subsequent phases of the Development will be identified and evaluated. These include:

- Drilling operations will be carefully planned to optimise the vessel fleet and the duration of operations, which will subsequently reduce the quantity of emissions generated;

[269] *Baseline shipping emissions, broken down by pollutant, for a particular region are not available in the public domain.*

- All vessels and rigs employed during installation and drilling activities will be required to comply with the Merchant Shipping (Prevention of Air Pollution from Ships) (Amendment) Regulations 2014;
- Vessel CMID or the Offshore Vessel Inspection Database (OVID) and HSE assurance audits conducted to confirm whether contracted vessels meet IMO/ MARPOL and bp marine and HSE standards;
- bp, as operator of NEP, to verify use of low sulphur fuels in accordance with applicable UK regulatory requirements;
- Prior to a vessel mobilizing to work on the Development, bp marine assurance and mobilisation audit will be completed for all vessels and the jackup rig;
- As part of the selection process for the offshore engineering, procure, construct and install (EPCI) tendering, bidders are required to submit Sustainability Plans. These plans should include consideration of opportunities to reduce number of vessels, vessel days and to optimise vessel speeds to improve fuel efficiency and reduce atmospheric emissions, where reasonably practical. Bidders will be evaluated, in part, against their plans submitted. There will also be a requirement for selected EPCI contractors to develop a 'Carbon Reduction Plan' that should include strategies for minimising equipment and materials transportation and reducing construction vehicle and vessel emissions where reasonably practical. This may include green dynamic positioning or economical speeds when operationally appropriate; and
- bp will conduct assurance to verify that any Fluorinated-gases (F-gases) in vessel cooling systems will be required to be managed in accordance with applicable legislation (F-gas regulations as amended 2018 SI 98).

Ship operators and designers are developing alternative fuels and electric vessels to create a greener and more sustainable fuel source. Several offshore support vessels have been delivered in the last three years running on liquefied natural gas (LNG). Similarly, innovation is leading to experimentation with ammonia as a fuel given its potential for zero-carbon emissions and its generation from renewable primary energy sources. It is expected that there will be an increased trend in the use of 'alternatively powered' vessels, which will in turn reduce vessel emissions.

The Development has, and will continue, to utilise ASV[270], in survey work conducted along pipeline routes and at the Endurance Store. Such applications reduce emissions associated with offshore activity while efficiently acquiring all necessary data.

In 2020, bp, as operator of the Development, announced its ambition to be a net zero company by 2050 or sooner and to help the world get to net zero, with interim targets and aims for 2025 and 2030[271]. bp developed a sustainability framework which takes an integrated approach to get to net zero, improve people's lives and to care for the planet and which sets 20 aims to deliver the framework. Further detail is provided in Section 1.5.

bp also recognise its position of influence as the purchaser of services, and measures to achieve net zero are also being introduced into the supply chain, to support the UK's net zero commitment. For example, questions relating to emission reduction opportunities are incorporated into the tendering process, across the value chain of the lifecycle of the Development. Key areas where this could contribute to reduction in emissions include, but are not limited to, the rig and vessel selection process

[270] *Robotic vehicles that sit on the sea surface and are typically powered solely or partially by solar, wind or wave power*
[271] *https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-esg-investor-pack.pdf*

and contracts. Streamlining of activities through planning to reduce the time required for rig, vessels and helicopters is a key priority for these activities and will further support the drive to reduce emissions. Assurance through monitoring and measurement will be carried out to report the emissions incurred during these activities and evaluate the effectiveness of the process.

11.7 Cumulative, In-combination and Transboundary Impacts

11.7.1 Local Air Quality

As described above, the Development will include several sources of atmospheric emissions. The main pollutants with the potential to contribute to impacts are described in Section 11.1. As the environment is highly dispersive, local air quality is not expected to be adversely affected by vessel emissions occurring as part of the Development either individually or cumulatively with those already occurring.

As the Development lies within an already busy shipping area, the limited duration of activities and the associated vessel emissions are not expected to cumulatively result in any discernible impact on local air quality above the baseline levels.

The UK/Netherlands median lies approximately 105 km away from the nearest part of the Development. The emissions are expected to be localised to the Development activities and are not expected to result in any discernible impact on local air quality above the baseline levels, therefore a significant transboundary impact is not expected.

11.7.2 Global Climate Change

As noted in Section 11.1.1, the Development is an integral element of the overall ECC development and will deliver CO_2 transport and storage, helping contribute to reductions in UK emissions and ultimately the achievement of net zero goals. Without the Development, the ECC could not inject and store CO_2 generated by onshore activities at Teesside and Humber.

Institute of Environmental Management and Assessment (IEMA, 2022) guidance states that "The crux of significance is not whether a project emits GHG emissions, nor even the magnitude of GHG emissions alone, but whether it contributes to reducing GHG emissions relative to a comparable baseline consistent with a trajectory towards net zero by 2050." In the absence of sector-based or local emissions budgets, the UK Carbon Budgets can be used to contextualise the level of significance. As per IEMA (2022) guidance, all GHG emissions are classed as having the potential to be significant as all emissions contribute to climate change. In establishing the scope and boundary of GHG emission assessment, it is standard accounting practice to exclude minor sources, as these are not material. Inventories that exclude these minor sources are still considered complete for verification purposes. This exclusion of emission sources that are < 1% of a given emissions inventory is on the basis of a 'de minimis' (relatively minimal) contribution (BSI, 2019).

On this basis, where GHG emissions from the Development are greater than 1% of the relevant annual UK Carbon Budgets the impact of the Proposed Development on the climate is considered to be major. This is summarised in Table 11-6 and Table 11-7.

There is currently no published standard definition for receptor sensitivity of GHG emissions. The global climate has been identified as the receptor for the purposes of the GHG assessment. The sensitivity of the climate to GHG emissions is considered to be 'high' (IEMA, 2022). The rationale supporting this includes:

- any additional GHG impacts could compromise the UK's ability to reduce its GHG emissions and therefore the ability to meet its future carbon budgets; and
- the importance of meeting the Paris Agreement goal of limiting global average temperature increase to well below 2°C above pre-industrial levels. Additionally, a recent report by the IPCC highlighted the importance of limiting global warming below 1.5°C (IPCC, 2021).

Table 11-6 - Magnitude criteria for GHG impact assessment

Magnitude	Magnitude criteria description
Beneficial reduction	Estimated emissions equate to a reduction of > 0.1% of total emissions across relevant five-year UK Carbon Budget period in which they arise
Negligible change	Estimated emissions equate to ± 0.1% of total emissions across relevant five-year UK Carbon Budget period in which they arise
Small increase	Estimated emissions equate to between 0.1 & 1% of total emissions across relevant five-year UK Carbon Budget period in which they arise
Large increase	Estimated emissions equate to > 1% of total emissions across the relevant five-year UK Carbon Budget period in which they arise

Table 11-7 - Consequence matrix for GHG emissions impact assessment

Magnitude of GHG emissions	Sensitivity of receptor
	High
Beneficial reduction	Beneficial
Negligible change	Minor
Small increase	Minor/Moderate
Large increase	Major

In the following paragraphs, the GHG emissions associated with the Development are set in the context of wider UK emissions and climate policy and other tests considered in addition to the UK carbon budget which may be of relevance.

11.7.2.1 Development Emissions as Proportion of UK Carbon Budget

The UK Government has set a target of reducing the UK's overall GHG emissions to net zero by 2050 as part of the Climate Change Act 2008 and a series of phased, legally binding budgets have been implemented (Table 11-**8**), with the sixth carbon budget setting a 78% reduction by 2035. The UK is currently in the fourth carbon budget period.

Table 11-8 - UK carbon budget (Committee on Climate Change, 2020)

Budget	Annual carbon budget (Mt CO_2e)	% reduction below base year (1990)
4th carbon budget (2023 to 2027)	1,950	50 % by 2025
5th carbon budget (2028 to 2032)	1,765	57 % by 2030
6th carbon budget (2033 to 2037)	965	78 % by 2035

Table 11-9 presents the Development's CO_2e emissions against UK carbon budgets. The Development emissions will largely occur in the fourth carbon budget with only O&M emissions applicable in subsequent carbon budgets. As carbon budgets are not yet determined past 2037, it is not possible to quantify the percentage of the Development's CO_2e emissions between 2037 and 2052 (the estimated end date for the operational phase of the Development).

Table 11-9 - Development CO_2e emissions against UK carbon budget (Committee on Climate Change, 2020)

Emission Item	Carbon accounting period		
	2023 to 2027	2028 to 2032	2033 to 2037
UK carbon budget for period (t CO_2e)	1,950,000,000	1,765,000,000	965,000,000
Development emissions for period (t CO_2e)	348,671	16,228	16,228
Development CO_2e emissions as a % of UK budget	0.01788	0.00092	0.00168

Based on Table 11-9, emissions from the Development would result in a negligible increase to the UK Carbon Budget and therefore any consequence would be expected to be minor. Furthermore, these emissions are an integral element of the overall ECC development that will deliver CO_2 transport and storage, contributing to reductions in UK emissions and achievement of net zero goals.

11.7.2.2 Vessel Emissions as Proportion of Annual UK Shipping Emissions

Vessel emissions from the Development, which constitute a very small proportion of annual UK shipping emissions, are transient with the majority occurring during pipeline installation and landfall works (Table 11-3). In 2019[272], commercial fishing in UK waters emitted 782 kt CO_2e, coastal shipping 4,521 kt CO_2e, and leisure craft 186 kt CO_2e. The maximum annual emissions from the vessels associated with the Development would occur in the initial three years when landfall works, pipeline / subsea infrastructure installation, and drilling would occur. Vessel emissions for that initial period

[272] NAEI dataset These figures are from the NAEI dataset and do not include international shipping passing through UK waters.

are estimated to be 116 kt CO_2e per year. Annual emissions from this phase would represent about 2.1% of the sum of the emissions from the sources described above for shipping in 2019. During O&M, vessel emissions related to the Development will be around 3 kt CO_2e per annum, which represents 0.06% of UK shipping emissions (based on 2019 levels).

11.7.2.3 Other Tests Considered

The North Sea Transition Deal (NSTD) (OGUK, 2021) is a partnership between the government and the oil and gas sector which aims to transform the sector and deliver the energy transition. It is aimed at delivering on the commitments set out in the oil and gas chapter of the government's Energy White Paper and is closely aligned to the Prime Minister's Ten Point Plan. The scope of the deal includes a reduction in production emissions of 10% in 2025, 25% in 2027, and 50% in 2030 on the pathway to Net Zero by 2050. Non-production emissions (e.g. those associated with CCS) are understood to be outwith the scope of the NSTD targets and therefore this test is not considered relevant to inform the assessment of LSEs of the Development.

The 2023 IMO GHG Strategy (IMO, 2023) has the main ambitions of:

- GHG emissions from international shipping to peak as soon as possible and to reach net-zero GHG emissions by or around, i.e., close to, 2050 compared with their level in 2008. Indicative checkpoints include:
  - Total annual GHG emissions from international shipping to reduce by at least 20%, striving for 30%, by 2030, compared to 2008; and
  - Total annual GHG emissions from international shipping to reduce by at least 70%, striving for 80%, by 2040, compared to 2008.
- Uptake of zero or near-zero GHG emission technologies, fuels and/or energy sources to represent at least 5%, striving for 10%, of the energy used by international shipping by 2030; and
- Reduction in the carbon intensity of international shipping (to reduce CO_2 emissions per transport work), as an average across international shipping, by at least 40% by 2030, compared to 2008. Further improvements in the energy efficiency of new ships is targeted.

In the Climate Change Committee UK wide carbon budget as determined for shipping (CCC, 2020; CCC, 2022), the Government's Net Zero pathway requires sectoral emissions (including both domestic and the UK's share of international shipping) to fall by around 28% by 2035, relative to 2019 levels (i.e. from 14.3 MtCO_2e/year to 10.3 MtCO_2e/year). The UK's share of international shipping emissions is included in the UK's Net Zero target and, from 2033, will be included within carbon budgets. Sectoral emissions will be achieved by reduced vessel emission intensities (i.e. low-carbon shipping fuels and improved vessel efficiency) and more efficient shipping operations (i.e. more fuel efficient voyages and lower shipping demand). In 2035, vessel emissions from the Development are estimated to be around 3 kt CO_2e, representing 0.03% of the 10.3 MtCO_2e carbon budget.

The calculation basis for Development emissions is conservative (Section 11.4) and no vessel decarbonisation has been assumed over the lifetime of the Development. bp, as operator of the Development, has committed to measures (Section 11.6) which will aim to reduce vessel carbon intensity and cut annual GHG emissions from vessels used during O&M of the Development. The Development is not therefore anticipated to have a significant effect on the goals of the IMO strategy being met or the UK wide carbon budget, as determined for shipping. The conclusion of Section 11.7.2.1 remains unchanged, and any consequence is minor.

11.8 Protected Sites

As discussed in Section 4.5, the Development intersects with a number of protected sites. Vessel activity will be short-term in nature relative to the 25 years of operation, and will not appreciably add to the number of vessels that are already present in the existing busy shipping area. In addition, the duration of drilling and vessel operations and the required fleet will be optimised to reduce the quantity of emissions generated (Section 11.6).

Offshore protected sites e.g. SNS SAC, Holderness Inshore MCZ, Holderness Offshore MCZ, Teesmouth and Cleveland Coast SPA and Runswick Bay MCZ are not sensitive to atmospheric emissions associated with vessel activity. Therefore, the emissions associated with the Development are:

- Not considered to cause a LSE on the conservation objectives of the SAC or SPA;
- Not considered to adversely affect site integrity under the Habitats Regulation; and
- Not considered to pose a significant risk of hindering the achievement of the conservation objectives for the MCZs.

Atmospheric emissions are not expected to cause any significant impact to onshore protected sites or vegetation sensitive to local air quality changes, as emissions are likely to be dispersed before they reach the shore.

11.9 Residual Impacts

Given the temporary and limited nature of the atmospheric emissions from the Development and taking into account:

- The dispersive nature of the environment (BEIS, 2022);
- The direction of prevailing winds from onshore to offshore (Section 11.5);
- The distance from any potentially sensitive receptors (recreational receptors, i.e. golf course and caravan site within 1 km of landfall at Teesside, none at Humber and offshore, 13 km to the nearest installation from the Store); and
- The lack of onshore AQMAs at either landfall (Section 11.5),

It is not expected that atmospheric emissions from the Development will negatively impact local air quality. As the Development is located within an already busy shipping area with a large proportion of cargo/tanker traffic (approximately 40% of AIS vessel tracks; Appendix M), no significant local cumulative air quality impacts are anticipated to occur above the background[273]. Indeed in the coming years, background and Development emissions will likely decline as vessel efficiency is predicted to increase and low-carbon shipping fuels occupy a greater market share.

In the absence of any widely accepted guidance on assessing the significance of the impact effect of GHG emissions, guidance published by IEMA (2022) has been followed. In terms of global climate change (i.e. cumulative and transboundary impacts), the Development will add a relatively small increment to UK emissions and the release of GHG into the environment, and its contribution to global

[273] Baseline shipping emissions, broken down by pollutant, for a particular region are not available in the public domain. Air quality is not monitored routinely offshore (BEIS, 2022).

warming will be negligible (see Table 11-13). Indeed, the emissions associated with the Development are an integral element of the overall ECC development that will deliver CO_2 transport and storage, helping to contribute to reductions in UK emissions and ultimately achievement of net zero goals.

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Air Quality	Low	Low	Low	Low
Rationale				
Information regarding emissions has been used to assign the sensitivity, vulnerability and value of the receptor as follows. On the basis that the majority of activity will only occur in the highly dispersive marine environment, the receptor sensitivity and vulnerability is ranked as **low**. A ranking of **low** has been assigned to the vulnerability of the receptor as there are no air quality issues identified in the vicinity and any impact will occur in the immediate vicinity of the Development. Magnitude is ranked as **minor** as the emissions are short-term in duration, intermittent and distributed and therefore unlikely to be discernible or measurable. On this basis, the consequence is **negligible** and the impact is assessed to be **not significant.**				
Consequence		**Impact Significance**		
Negligible		Not significant		

Receptor	Sensitivity	Vulnerability	Value	Magnitude
Contribution to Global Climate Change	High	High	High	Negligible
Rationale				
Information regarding CO_2e emissions has been used to assign the sensitivity, vulnerability and value of the receptor as follows: On a global scale, the IPCC in its AR6 states that it is unequivocal that the increase of CO_2, CH_4 and N_2O in the atmosphere over the industrial era is the result of human activities and that human influence is the principal driver of many changes observed across the atmosphere, ocean, cryosphere and biosphere. (IPCC, 2021). Climate change estimates in the AR6 report that each of the last four decades have been successively warmer than any decade that preceded it since 1850. IPCC (2021) reports a 47% increase in CO_2 concentrations since 1750, which far exceeds the natural multi-millennial changes between glacial and interglacial periods over at least the past 800,000 years, and states that fossil fuel combustion is the primary contributor to the observed climate change. On this basis, the receptor sensitivity, vulnerability and value are all ranked as **high**. The magnitude of the impact is ranked as **negligible** due to the low level of additional emissions of CO_2e resulting from the Development relative to the UK carbon budget.				

On this basis, the consequence is **minor** and the impact is assessed to be **not significant**.	
Consequence	**Impact Significance**
Minor	Not significant

11.10 Climate Change Assessment

11.10.1 Introduction

This section summarises the climate change impact assessment for the Development. The structure of this section differs from other impacts assessed within this ES, as it does not consider the potential impact of the Development on specific receptors, but instead the impact of the climate (i.e. an external factor) on the Development itself and the in-combination impacts of the Development and climate change (ICCI).

This section draws on the characterisation of the future baseline in Section 4.7, which identifies and describes future climate projections predicted to occur across the lifetime of the Development. The projected changes in climate variables are used to:

- Assess the resilience of the Development to climate change, in terms of the ability of the Development to withstand, respond to and recover from the projected changes in climate (climate change resilience, Section 11.10.3); and
- Assess the impacts of the Development on the physical, biological and socio-economic environment, as assessed within the topic chapters of the ES, in combination with any potential impacts from climate change (ICCI, Section 11.10.4).

The IEMA (2020) Climate Change Resilience and Adaptation guidance has been used to guide the structure and content of this section. This guidance document provides a framework to consider the vulnerability of the Development to climate change (i.e. climate change resilience) and the in-combination impacts of the Development and climate change.

As the construction phase is much shorter than the operational phase and will be undertaken between 2025 and 2027, future climate change for the construction phase is less relevant and not considered further. This review therefore focusses on potential impact posed by climate change on the Development during the operational phase, including both on the Development infrastructure itself and on O&M activities.

11.10.2 Data Gaps and Uncertainties

The key uncertainties associated with predicting the impact on the Development and the impacts assessed within this ES include:

- Uncertainty in the modelled predictions – based on the uncertainty around the future emissions scenario as well as an uncertainty in other model inputs (e.g. current conditions, parameters etc.);
- Uncertainty around the response of the physical, biological and socio-economic environment to changes in climate variables; and
- Difficulties in attributing changes in the physical, biological and socio-economic environment to climate change.

The climate change resilience review and the ICCI assessment are also limited by the data availability at the time of the assessment.

11.10.3 Climate Change Resilience

This section reviews the ability of the Development to withstand, respond to and recover from the projected changes in climate, as they are described in Section 4.7.

Climate change resilience is defined as the indication of a project's ability to withstand, respond to, and recover rapidly from disruptions caused by changing climate variables (IEMA, 2020). There is no single prescribed format for undertaking such assessments; therefore, the approach utilised draws on good practice from similar developments and is aligned with existing guidance e.g. IEMA (2020).

11.10.3.1 Assessment methodology

Climate change impact identification

A climate change impact refers to the effect (i.e. damage or interference) of a projected change in a climate variable (e.g. sea level rise, sea temperature) on the Development infrastructure, facilities or activities. The climate variables, as described in Section 4.7, with the potential to impact the Development include:

- Extreme weather events (e.g. storm surges and waves);
- Changes in sea conditions (e.g. change in average wave height); and
- Sea level rise and coastal erosion.

The potential impacts on the Development during the operational phase associated with projected changes for the climate variables listed above are listed in Table 11-13.

Defining the climate change risk

The risk posed by climate change on the Development is determined by defining the likelihood and magnitude of the potential climate change impact. Existing mitigations and management procedures identified within the EIA are accounted for when determining impact likelihood and magnitude.

The definitions for likelihood and magnitude are provided in Table 11-10 and Table 11-11, respectively. It should be noted that likelihood refers to the impact associated with the projected change in climate as outlined in Table 11-13, under the assumption that the projected change does occur (i.e. this does not refer to the confidence level for the projected change).

Table 11-10 - Definitions for likelihood

Likelihood	Definition
Certain (> 95%)	The event / impact will occur during the Development (i.e. it is inevitable)
Likely (66-95%)	The event / impact is likely to occur at some point during the Development.
Possible (33-65%)	The event / impact is possible during the Development.

Likelihood	Definition
Unlikely (10-32%)	The event / impact is unlikely to occur during the Development.
Extremely unlikely (0-9%)	The event / impact is extremely improbable.

Table 11-11 - Definitions for magnitude

Magnitude	Definition
High	• Permanent damage, loss or reduction in structural integrity of the Development's infrastructure and facilities; • Serious health and safety risk; and • Irreversible and irrecoverable financial or environmental impact.
Moderate	• Major damage, loss or reduction in structural integrity of the Development's infrastructure and facilities; • Major health and safety risk; and • Major financial or environmental impact.
Low	• Moderate damage, loss or reduction in structural integrity of Development infrastructure and facilities; • Moderate health and safety risk; and • Moderate financial or environmental impact.
Negligible	• Minimal damage, loss or reduction in the structural integrity of Development infrastructure; • Low health and safety risk; and • Minimal financial or environmental impact.
No change	• No damage or loss of infrastructure; • No health and safety risk; and • No financial or environmental impact.

Having determined the likelihood and magnitude of the climate change impact, the risk level is determined, as either negligible, minor, moderate or major, as shown in Table 11-12. Moderate and Major risks are defined as 'significant'.

Table 11-12 - Significance matrix

		Likelihood				
		Extremely unlikely	Unlikely	Possible	Likely	Certain
Magnitude	No Change	Negligible	Negligible	Negligible	Negligible	Negligible
	Negligible	Negligible	Negligible	Minor	Minor	Minor
	Low	Negligible	Minor	Minor	Moderate	Major
	Moderate	Negligible	Minor	Moderate	Major	Major
	High	Minor	Moderate	Major	Major	Major

11.10.3.2 Assessment of climate resilience

Table 11-13 outlines the climate change resilience review for the Development, which has been undertaken using the methodology described in Section 11.10.3.1.

Table 11-13 - Assessment of the Development resilience to climate change

Climate variable		Impact on development	Likelihood	Magnitude	Risk level	Significance	Adaptation required?
Extreme weather events	Increased frequency of high wind events.	Disruption or increased safety risk to O&M procedures or equipment / vessels as a result of high wind events.	Extremely unlikely – event is only likely to occur in extreme circumstances (i.e. the likelihood of extreme winds during O&M activities is low). Contractors will be required to monitor weather patterns ahead of maintenance works and adhere to health and safety protocols.	Low – potential health and safety risks for personnel working in poor weather conditions.	Negligible	Not Significant	No
	Increased mean maximum wave heights.	Disruption or increased safety risk to O&M procedures or equipment / vessels as a result of high waves.	Extremely unlikely – event is only likely to occur in extreme circumstances (i.e. the likelihood of extreme waves during O&M activities is low). Contractors will be required to monitor weather patterns ahead of maintenance works and adhere to health and safety protocols.	Low – potential health and safety risks for personnel working in poor weather conditions.	Negligible	Not Significant	No
Changing sea conditions	Increased sea temperature	Potential damage, loss or reduced structural integrity of Development infrastructure (e.g. thermal expansion)	Extremely unlikely – 1 in 1,000 year extreme sea surface temperature scenarios were considered for project design. Thus, the infrastructure is considered to be resilient to potential increases in sea temperature. Heat stress risk will also be mitigated through adequate protection of the pipelines.	Negligible – infrastructure will mostly be located on or near the seabed. Hence, increases in sea surface temperature are expected to have a negligible impact on the Development infrastructure.	Negligible	Not Significant	No
	Increased near-bed temperature	Potential damage, loss or reduced structural integrity of Development infrastructure (e.g. thermal expansion)	Extremely unlikely – 1 in 1,000 year extreme near-bed temperature scenarios were considered for project design. Thus, the infrastructure is considered to be resilient to potential increases in sea temperature. Heat stress will also be mitigated through adequate protection of the pipelines.	Negligible – increased near bed temperatures could result in heat stress, increasing the potential for structural damage and leaks. However, the design temperature range for the system is greater than any feasible near bed temperature change.	Negligible	Not Significant	No
Sea level rise and coastal erosion	Sea level rise and coastal erosion	Potential damage, loss or reduced structural integrity of coastal Development infrastructure (e.g. pipeline exposure).	Unlikely – At Humber, as the coastline is rapidly eroding, the pipeline will be installed in a deeper trench in the nearshore area, with an additional cover to account for the expected coastal erosion. This takes into account the erosion of the seabed that will take place over the design life of the pipeline. At Teesside, the coastline trends indicate that the dune coastline is accreting seawards. Pipelines will be inspected periodically (the frequency of which will be determined by ongoing risk assessment) and remedial works will be undertaken as needed.	Low – exposure of pipelines could increase potential damage from external threats in the nearshore area.	Minor	Not Significant	No

11.10.4 In-combination Climate Impact Assessment

An ICCI is defined as an interaction between a) a projected future climate change and b) an effect identified as a result of the Development, which exacerbates the scale of the impact (IEMA, 2020). Therefore, this assessment considers how the impacts assessed within this ES could be exacerbated or reduced by any predicted future changes in the physical environment.

11.10.4.1 Assessment methodology

The ICCI assessment considers all potential receptors that could be impacted by the Development, as outlined within this ES. It places the impact of the Development on relevant receptors in the context of future climate conditions, as outlined in Section 4.7. The approach and methodology is outlined in this section.

Receptor and impact identification

All impacts assessed within this ES are outlined in Chapter 6: Seabed Disturbance to 11: Atmospheric Emissions. These impacts and the physical, environmental and socio-economic receptors assessed within the impact chapters are considered within the ICCI assessment.

The future climate projections and future baseline descriptions for biological and socio-economic receptors are summarised in Section 4.7. The impacts of the Development are considered alongside any impacts associated with future climate projections to understand whether the impacts of the Development are exacerbated or reduced.

The following receptors have not been considered within the ICCI assessment. This is due to the complexity of teasing out the impacts of climate change amongst other factors that influence these receptors:

- Shipping and navigation;
- Commercial fisheries; and
- Other sea users.

Although all relevant receptors are assessed within the ICCI assessment, a focus is placed on the key features of conservation interest present across the Development, including:

- Harbour porpoise (qualifying feature of the SNS SAC);
- Ocean quahog (qualifying feature of the Holderness Offshore MCZ);
- *S. spinulosa* and Sabellaria biogenic reef;
- Sandbanks (specifically gravelly sandbanks); and
- Rocky reef.

The sensitivity of the key features of conservation interest to climate change is described in Section 4.5 and has been used to inform the ICCI assessment.

Defining likelihood and magnitude

The consequence of the ICCI is determined by defining the likelihood and magnitude of the impact. Existing mitigations / management procedures identified within the ES are accounted for when determining impact likelihood and magnitude.

The definitions for likelihood are the same as the climate change resilience and are provided in Table 11-10. The likelihood of the ICCI occurring considers the potential for the climate projection to occur alongside the sensitivity of the receptor and is based on expert judgement.

The definitions for magnitude are provided in Table 11-14. The magnitude considers the change in the significance of the impact from the Development when the in-combination effects from climate change are considered.

Table 11-14 - Definitions for magnitude

Magnitude	Definition
High	The significance of the impact from the Development increases to major when the in-combination impact from climate change is considered.
Moderate	The significance of the impact from the Development increases to moderate when the in-combination impact from climate change is considered.
Low	The significance of the impact from the Development increases from negligible to minor when the in-combination impact from climate change is considered.
Negligible / no change	There is no change in the impact from the Development in-combination with the projected change in the climate variable.

Having determined the likelihood and magnitude of the ICCI, the consequence is determined as either negligible, minor, moderate or major, as shown in Table 11-12.

The consequence categories in Table 11-12 provide a threshold to determine whether or not the ICCI is deemed ‘significant’. Moderate and Major consequences are defined as a ‘significant’ impact.

Where the assessment identifies a significant impact climate on the Development’s design, mitigation measures or design changes have been proposed to avoid or reduce impacts to an acceptable level.

11.10.4.2 In-combination climate assessment

Table 11-15 summarises the ICCI assessment, which has been undertaken using the methodology described in Section 11.10.4.

Overall, there were no impacts from the Development, when considered in-combination with climate change, that could result in a significant effect. Therefore, no additional mitigation, above and beyond the management and mitigation measures outlined in each assessment chapter, was required.

Table 11-15 - In-combination climate impact assessment

Receptors assessed	Relevant management / mitigation measures	Potential climate impact	Likelihood of an ICCI	Magnitude of ICCI	Consequence of ICCI	Significance	Additional mitigation?
Seabed disturbance (Chapter 6)							
Benthos	Pipeline route optimisation to minimise impacts on potential features of conservation interest.	1. Projected changes in temperature, salinity, oxygen and pH (i.e. ocean acidification) could exacerbate other seabed disturbance impacts	Extremely unlikely – Some benthic species may be highly sensitive to climate change, depending on their biogeographic range and life-history traits. However, although uncertain, it is expected that some species will be able to tolerate the changing climate, as studies indicate that not all species are affected equally (Moore *et al.*, 2020). During the O&M phase, limited and localised remedial works are the only activity associated with habitat loss, reducing the potential for any ICCI.	Negligible – the change in climate will be long-lasting, any impact from the Development remains highly localised and limited to remedial works and is unlikely to be exacerbated by changes in temperature, salinity, oxygen, or pH.	Negligible	Not Significant	No
	Pipeline route optimisation to minimise impacts on potential features of conservation interest; Pipeline depth of cover to provide protection over the Development lifetime given coastal erosion and climate change.	2. Potential for sea level rise and coastal erosion to exacerbate any seabed disturbance to intertidal habitats / species	Extremely unlikely – Sea level rise is predicted to occur at both landfalls. The sediments at Humber are highly mobile and erosion is expected to occur (ERYC, 2019). The coastline at Teesside is relatively stable. Coastal erosion could result in 'coastal squeeze', resulting in a reduction of intertidal habitats and species (Kaplanis *et al.*, 2020). The pipelines will be buried at the intertidal area, mitigating against any permanent habitat loss and reducing the potential for any ICCI.	Negligible – the change in climate will be long-lasting, any impact from the Development in the intertidal area remains highly localised and limited to remedial works, as the pipelines will be buried at the intertidal area.	Negligible	Not Significant	No
Fish and shellfish	Pipeline route optimisation to minimise impacts on potential features of conservation interest.	1. Projected changes in temperature, salinity, oxygen and pH (i.e. ocean acidification) could increase sensitivity to seabed disturbance impacts (e.g. increased physiological stress)	Extremely unlikely – while changes in the abiotic environment may result in physiological stress to fish and shellfish, it is difficult to isolate the impact of climate from other external factors. Fish and shellfish may be tolerant to changes in climate, to a degree (Wright *et al.*, 2020). Moreover, the wide distribution of the species present in the Development area, indicates tolerance of a range of conditions. During the O&M phase, limited and localised remedial works are the only activity associated with habitat loss, reducing the potential for any ICCI.	Negligible – the change in climate will be long-lasting, any impact from the Development remains highly localised and limited to habitat loss associated with the presence of infrastructure on the seabed and to any disturbance from remedial works.	Negligible	Not Significant	No
	Pipeline route optimisation to minimise impacts on potential features of conservation interest; Seabed surveys to identify habitats and species and the potential for herring and sandeel spawning to occur in the vicinity of the Development.	2. Changes in phenology resulting from changes in temperature could exacerbate any disturbance or loss of spawning grounds	Extremely unlikely – Rising sea temperatures may impede spawning and recruitment success, as the synchrony between hatching fish larvae and plankton prey is changing (Wright *et al.,* 2020). For example, it has been predicted that increases in sea temperature of 1.3°C could result in poorer sandeel recruitment, resulting from a mismatch in predatory-prey phenology (Régnier *et al.*, 2019). However, the understanding of the influence of temperature on recruitment success is not well understood and this is not expected to impact all species (Wright *et al.,* 2020). During the O&M phase, limited and	Negligible – the change in climate will be long-lasting, any impact from the Development remains highly localised and limited to habitat loss associated with the presence of infrastructure on the seabed and to any disturbance from remedial works.	Negligible	Not Significant	No

Receptors assessed	Relevant management / mitigation measures	Potential climate impact	Likelihood of an ICCI	Magnitude of ICCI	Consequence of ICCI	Significance	Additional mitigation?
			localised remedial works are the only activity associated with habitat loss, reducing the potential for any ICCI.				
Ornithology	Pipeline depth of cover to provide protection over the Development lifetime in light of coastal erosion and climate change.	1. Increased frequency of heavy rainfall and heavy wind events could impair foraging success of seabirds, exacerbating the potential loss of foraging grounds	Extremely unlikely – Heavy rainfall can impair the ability of seabirds to forage (Mitchell *et al.,* 2020). Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. The reduced foraging success could put additional pressure on birds and reduce ability to tolerate the impacts from the Development. During the O&M phase, limited and localised remedial works are the only activity associated with habitat loss, reducing the potential for any ICCI.	Negligible – The impact of the change in climate will occur during periods of extreme weather only. Any impact from the Development remains highly localised and is not expected to be discernibly exacerbated by extreme weather events.	Negligible	Not Significant	No
Cultural heritage	No ICCI identified						
Coastal processes	Pipeline depth of cover to provide protection over the Development lifetime in light of coastal erosion and climate change.	1. See level rise and coastal erosion may alter geomorphological processes. This could be exacerbated through increased frequency of heavy rainfall and wave heights at the coast.	Extremely unlikely – Sea level rise is predicted to occur at both landfalls (Palmer *et al.,* 2018). The sediments at Humber are highly mobile and erosion is expected to occur (ERYC, 2019). The coastline at Teesside is relatively stable. Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. Changes in geomorphological processes could impact sandbank features, an Annex I habitat. The pipelines will be buried at the intertidal area, mitigating against any impact of the Development on geomorphological processes, and therefore reducing the potential for any ICCI.	Negligible – Although the change in climate will be long-lasting, any impact from the Development remains highly localised and is anticipated to be effectively mitigated against through existing mitigation / management measures.	Negligible	Not Significant	No
Underwater sound (Chapter 7)							
Marine mammals	Pre-start search (MMO and PAM) within a designated mitigation zone ahead of seismic surveys; Soft-start to be conducted ahead of seismic survey operations.	1. Projected changes in temperature, salinity, oxygen and pH (i.e. ocean acidification) could increase sensitivity to underwater sound impacts (e.g. increased physiological stress)	Extremely unlikely – marine mammals, including harbour porpoise designated within the SNS SAC, could be affected by climate change impacts such as reduced prey availability resulting in nutritional stress, increased spread of infectious diseases and increased frequency and severity of toxic algal blooms (Evans and Waggit, 2020). These could increase the physiological stress on marine mammals, increasing sensitivity to any stress from underwater sound from the Development. Given the location of the Development in the SNS, marine mammals are expected to be relatively tolerant to warmer waters. Mitigation is expected to adequately mitigate against any potential physiological stress posed by underwater sound from the Development, and reduce the potential for this ICCI.	Negligible – the change in climate will be long-lasting. Given the mitigation / management measures implemented, impacts on marine mammals from underwater sound from seismic surveys during the operational phase of the Development are not expected to be discernibly exacerbated by climate change.	Negligible	Not Significant	No

Receptors assessed	Relevant management / mitigation measures	Potential climate impact	Likelihood of an ICCI	Magnitude of ICCI	Consequence of ICCI	Significance	Additional mitigation?
Fish	Pre-start search (MMO and PAM) within a designated mitigation zone ahead of seismic surveys; Soft-start to be conducted ahead of seismic survey operations.	1. Projected changes in temperature, salinity, oxygen and pH (i.e. ocean acidification) could increase sensitivity to underwater sound impacts (e.g. increased physiological stress)	Extremely unlikely – while changes in the abiotic environment may result in physiological stress to fish and shellfish, it is difficult to isolate the impact of climate from other external factors. Fish and shellfish may be tolerant to changes in climate, to a degree (Wright *et al.*, 2020). Moreover, the wide distribution of the species present in the Development area, indicates tolerance of a range of conditions. Mitigation will reduce the potential impact of underwater sound on fish and therefore, reduce the potential for this ICCI.	Negligible – the change in climate will be long-lasting. Given the mitigation / management measures implemented, impacts on fish from underwater sound from seismic surveys during the operational phase of the Development are not expected to be discernibly exacerbated by climate change.	Negligible	Not Significant	No
Discharges to sea and Formation Water displacement (Chapter 8)							
Plankton / Zooplankton	Preparation of MP to monitor Outcrop Formation Water displacement.	1. Projected changes in temperature and pH (i.e. ocean acidification) could increase sensitivity to Outcrop Formation Water displacement	Extremely unlikely – changes in plankton communities and range shifts as a result of temperature changes have been recorded, although this does not affect all species equally (Bedford *et al.,* 2020). Zooplankton may be affected by ocean acidification, which can affect calcification processes (Edwards *et al.*, 2020). Mitigations are in place to mitigate against impacts from discharges to sea and Outcrop Formation Water displacement during the operational phase of the Development to reduce the impacts and therefore reduce the potential for this ICCI.	Negligible – the change in climate will be long-lasting. However, considering the mitigation / management measures implemented, the impacts from the Development are not expected to be discernibly exacerbated by climate change.	Negligible	Not Significant	No
Physical presence (Chapter 9)							
Marine mammals	Relevant personnel will receive targeted environmental awareness training; Implementation of a Vessel Management Plan.	1. Indirect effects on prey species (e.g. reduced availability and distribution) could exacerbate any disturbance impacts affecting foraging success / opportunity	Extremely unlikely – marine mammals, including harbour porpoise designated within the SNS SAC, may be indirectly affected by changes in prey as a result of climate change (Evans and Waggit, 2020). Disturbance impacts from the Development will be short-term and mitigated appropriately and therefore reduce the potential for this ICCI.	Negligible - any impact from the Development remains highly localised and the impact is not expected to be exacerbated by indirect effects on prey species.	Negligible	Not Significant	No
	N/A	2. Seals hauling out may be vulnerable to sea level rise and storm surges (reducing haul-out areas), exacerbating impacts from disturbance at seal haul-outs	Extremely unlikely - the Development is located 4 km from the Humber Estuary SAC, which contains the Donna Nook seal haul out site. Considering this distance, disturbance to seals at haul-outs is considered highly unlikely (Brasseur and Reijnders, 1994, in Scottish Executive, 2007) and therefore reduce the potential for this ICCI.	Negligible - disturbance to seals at seal-haul outs is extremely unlikely to arise from the Development. Impacts from the Development are not expected to be discernibly exacerbated by climate change.	Negligible	Not Significant	No
Ornithology	Relevant personnel will receive targeted environmental awareness training; and Implementation of a Vessel Management Plan.	1. Increased frequency of heavy rainfall and heavy wind events could impair foraging success of seabirds, exacerbating any potential impact on foraging success at-sea	Extremely unlikely - heavy rainfall can impair the ability of seabirds to forage (Mitchell *et al.,* 2020). Projections indicate that rainfall levels will increase, although the extent of this increase is uncertain. The reduced foraging success could put additional pressure on birds and reduce ability to tolerate the impacts from the Development. Disturbance impacts from	Negligible - the change in climate will be evident during periods of extreme weather only. Any impact from the Development remains highly localised and the impact is	Negligible	Not Significant	No

Receptors assessed	Relevant management / mitigation measures	Potential climate impact	Likelihood of an ICCI	Magnitude of ICCI	Consequence of ICCI	Significance	Additional mitigation?
			the Development will be short-term and mitigated appropriately, reducing the potential for this ICCI.	not expected to be exacerbated by extreme weather events.			
	N/A	2. Loss of coastal habitats due to rising sea level, potential reducing the availability of nesting habitat and enhancing any other survival impairment	Extremely unlikely – coastal erosion and sea level rise which is predicted, particularly at the Humber landfall, could reduce or damage nesting habitat for seabirds (Mitchell *et al.*, 2020). This may increase seabird sensitivity to impacts during the operational phase. Disturbance impacts from the Development will be short-term and mitigated appropriately, reducing the potential for this ICCI.	Negligible – although the change in climate will be long-lasting, any impact from the Development remains highly localised and mitigated via existing mitigation / management measures.	Negligible	Not Significant	No
Accidental events (Chapter 10)							
All	As detailed in Chapter 10 and Appendix C	1. Projected changes in temperature, salinity, oxygen and pH could increase sensitivity to impacts from accidental releases (e.g. increase physiological stress)	Extremely unlikely - accidental events are considered highly unlikely, reducing the potential for an ICCI. This impact will be mitigated through measures that will reduce the potential for an accidental event to occur.	Negligible - the change in climate will be long-lasting, yet any accidental release are considered highly unlikely and mitigated via existing mitigation / management measures.	Negligible	Not Significant	No
		2. Increased likelihood of accidental events due to increased frequency of extreme weather events, e.g. heavy rainfall, high wind.	Extremely unlikely - accidental events are considered highly unlikely, reducing the potential for an ICCI. This impact will be mitigated through measures that will reduce the potential for an accidental event to occur, and these mitigation measures will remain effective under a scenario of increased extreme weather events.	Negligible -the change in climate will be long-lasting, yet any accidental releases are considered highly unlikely and mitigated via existing mitigation / management measures.	Negligible	Not Significant	No
Benthos and plankton / zooplankton		1. Ocean acidification could exacerbate impacts associated with a CO_2 release	Extremely unlikely - impacts associated with CO_2 release from the Development may be exacerbated by long-term reductions in pH associated with ocean acidification. Marine ecosystems are tolerant to short-term fluctuations in CO_2 concentrations and subsequent short-term variations in seawater acidity. A CO_2 release from the Development is expected to be highly unlikely given mitigation / management measures. This reduces the potential for any ICCI.	Negligible - although the change in climate will be long-lasting, any accidental release are considered highly unlikely and localised and mitigated via existing mitigation / management measures.	Negligible	Not Significant	No
Atmospheric emissions (Chapter 11)							
Air quality	Section 11.6	1. Increased frequency of high wind events could affect the dispersion of emissions	Extremely unlikely – potential for the dispersion of emissions from vessels present in the Development area to be increased during periods of high wind. Mitigation is in place to reduce the potential impact of the Development emissions on air quality and therefore reduce the potential for this ICCI.	Negligible – the operational phase of the Development vessels will be associated with short term vessel activity. Impacts from the Development are not expected to be discernibly exacerbated by climate change.	Negligible	Not Significant	No

12 WHOLE SCHEME ASSESSMENT

12.1 Introduction

The Development and onshore works (NZT Power and Onshore Humber) are being progressed by separate applicants and will be consented under separate regimes (Section 1.1 and Section 1.4).

NZT Power are seeking Development Consent for the construction, operation, maintenance and eventual decommissioning of NZT Power on land at Redcar and Stockton-on-Tees on Teesside. NGV are in commercial discussions with NEP partners on the sale of the CO_2 elements of Onshore Humber which will seek Development Consent for the construction, operation, maintenance and eventual decommissioning of Onshore Humber in the Humber region as part of a wider onshore pipeline connection network to transport CO_2. These projects will be consented via a DCO under the Planning Act 2008 for onshore elements (above MLWS[274]), supported by an EIA Report and a Marine Licence under the MCAA 2009 ('deemed' into the DCO in the case of NZT Power).

The Development (as described in this ES) is seeking a Carbon Storage Permit, supported by an ES developed under the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020 for the offshore elements (below MLWS), with reference made to impacts up to MHWS (Section 3.1).

To fully assess the complete effects arising from the whole scheme, assessment has been conducted for shared receptors with potential to be affected by both the Development and onshore works. This Whole Scheme Assessment (WSA) has been carried out in support of the ES for the Development however as part of the DCO for the onshore elements, NZT Power completed a similar assessment within their Statement of Combined Effects (AECOM, 2021b) and in response to a Secretary of State request for further information (bp, 2023e). A similar WSA will be carried out for Onshore Humber and submitted as part of the DCO process.

The interrelationships between the Development and onshore works will be within and around the marine sections of the onshore projects and the nearshore sections of the Development at Tees Bay and at the Dimlington/Easington coastline (the 'connection zone' for the Development and onshore works). Potential impacts are primarily restricted to the construction period with there being no potential for interrelationships which lead to significant impact during operation (Section 12.6). Relevant construction period activities include:

- NZT Power: outfall[275] construction seaward of MLWS (selection of trenchless landfall installation removes spatial overlap of activity for NZT Power and the Development);
- Onshore Humber: microtunnel and cofferdam construction[276] (worst case); and
- The Development: landfall construction seaward of MLWS; nearshore pipeline and cable trench and bury.

[274] *Including an extension below MLWS to accommodate a waste water disposal connection at Teesside.*
[275] *Effluent outfall for the discharge of treated effluent and surface water to Tees Bay during O&M phase. Installation may require pin-piling.*
[276] *Installation may require piling.*

Following a brief overview, the following assessment is presented by ES topic chapter[277].

12.2 Scheduling Principles

The potential for interrelationships is impacted by the nature of activities undertaken, the potential for activities to occur concurrently, the receptors present and the receiving environment.

While scheduling detail remains to be finalised, the following overarching principles apply:

- At Teesside, the same contractor will execute the landfall and outfall construction works, using the same equipment for both activities. Consequently, the work cannot occur concurrently but may occur sequentially. Pipeline lay will commence following completion of the landfall and outfall construction works; and
- At Humber, landfall activities will be completed prior to pipeline lay commencing.

As activities associated with the Development and onshore works will not occur concurrently, there is no potential for effects on any receptor to occur as a result of temporal overlap of activities.

12.3 Seabed Disturbance

As assessed within Chapter 6: Seabed Disturbance, all residual impacts are assessed as being of minor significance or below (see Section 6.10), when the management and mitigation measures outlined in Section 6.5 are considered.

Activities in the connection zone may lead to temporary direct and/or indirect disturbance or localised damage to seabed habitats and the associated biota that depend on the seabed (including benthos, fish and birds), localised loss/change of seabed substratum, direct and indirect disturbance or damage to cultural heritage (marine archaeology).

Direct impacts may include the placement of rock protection and abrasion of the seabed by dragging anchor lines. Many direct seabed impacts are localised and short-term.

Indirect impacts include increased sediment load in the water column due to the re-suspension of sediment from trenching, pipelay and seabed installation activities. This may affect the feeding behaviour of benthic epifauna, fish and seabirds, both within the Development area and down-current as far as the increased sediment load is present. Re-settling of suspended sediment may cause smothering of benthic epifauna and infauna. In addition, the construction of the landfalls may result in temporary localised scouring and interruption of sediment transport processes. Indirect impacts have been assessed at both Teesside and Humber landfalls, with no significant effects.

There may be a combined increase in direct and indirect seabed disturbance as a result of the onshore works and the Development in the connection zone. Comparable direct and indirect impacts to those detailed above have been assessed in-detail for NZT Power (AECOM, 2021b; AECOM, 2023); this assessment concluded that no significant cumulative effects are predicted. Based on the preliminary

[277] Discharges to Sea and Formation Water Displacement have been screened out of the WSA given the location of activities and potential impacts assessed within the chapter, i.e. at the Endurance Store which is remote from the onshore projects. No pathways exist by which activities associated with the Development may lead to impact to receptors potentially impacted by the onshore projects.

information available associated with Onshore Humber, no significant cumulative effects are anticipated.

MCZ Assessment

An MCZ assessment has been carried out for the Development which considers the Humber Pipeline route passing through the Holderness Inshore MCZ and the Holderness Offshore MCZ. A detailed feature-by-feature assessment of the designated interest features of the MCZs has been completed. It was concluded that the conservation objectives of both MCZs will not be hindered by activities required for the Development, including those nearshore activities which could have an interrelationship with Onshore Humber.

HRA Assessment

As demonstrated within the ES, there are no direct interactions with European Sites which are designated for physical features and the closest European Site which *is* designated for physical features is the Humber Estuary SAC. There is no pathway to this site and therefore it does not require further consideration as part of the WSA. In support of the Onshore Humber development, a HRA will be conducted to assess the potential for a LSE on this European Site, with further assessment conducted to consider potential for impacting upon site integrity, if required.

12.4 Underwater Sound

As assessed within Chapter 7: Underwater Sound, all residual impacts are assessed as being of minor significance or below (see Section 7.11), when the management and mitigation measures outlined in Section 7.6 are considered.

Based on the information available associated with NZT Power onshore project (AECOM, 2021b) and with Onshore Humber, any construction-phase effects occurring in the vicinity of the onshore schemes would be short-term. Underwater sound in the marine environment from the onshore works may result from small scale piling activities and sound from vessels associated with construction.

There is a potential pathway for the combined increase in underwater sound in the marine environment as a result of the onshore schemes and the Development, however, it is unlikely that sound generating activities will occur concurrently (Section 12.2). Subsequently, there would be periods during which unimpeded movement of receptors sensitive to underwater sound would be possible.

Given the temporary, short-term and intermittent nature of activity which could lead to behavioural disturbance effects as a result of underwater sound from the onshore scheme and the Development combined, the combined increase in sound is considered as negligible and the potential for cumulative effects is not significant.

HRA Assessment

The SNS SAC is the only protected site designated for marine mammals (i.e. harbour porpoise, an Annex II species and EPS) that intersects with the Development. The activity closest to the coast with the greatest potential to have impacts on coastal bottlenose dolphins is the HDD trestle piling. Given the calculated impact ranges for MF cetaceans, it is concluded that no LSE will occur on this species or on this protected site from HDD trestle piling (i.e. no impact on the conservation objectives).

For grey and harbour seals, the Development is within foraging range from a number of sites designated for grey and harbour seal features (Section 4.4.6.1). However, the assessment highlighted the low- density of seal in the Development and as such, no LSE on protected sites designated for seals are expected.

A detailed HRA has been carried out for the NZT Power project (including the SNS SAC) and concluded that there was no risk of an adverse effect on site integrity for the SNS SAC. An HRA has not yet been carried out for the Onshore Humber project, the available details of the project, combined with the predicted application of industry-standard best practice, the application of regulatory control and application of mitigation associated with underwater noise, it is highly unlikely that the Onshore Humber project would lead to a LSE (or indeed adverse effect).

12.5 Physical Presence

As assessed in Chapter 9: Physical Presence, all residual impacts are assessed as being of minor significant or below (see Section 9.10), when the management and mitigation measures outlined in Section 9.5 are considered.

Marine vessels may be required for the construction of infrastructure associated with the onshore works (e.g. replacement of outfalls and landfall construction) as well as those associated with the Development. This could result in additional temporary exclusion of other marine users. However, these disturbance and exclusion effects would largely be temporary and localised, and therefore, are not expected to result in any significant effects.

On this basis, for the topics of physical presence, the effect of the onshore and offshore schemes are considered to be negligible and the potential for cumulative effects is not significant.

HRA Assessment

The ES considered a number of European Sites including the following SPAs: Flamborough and Filey Coast; Farne Islands; Teesmouth and Cleveland Coast; Forth Islands; St Abb's to Fast Castle; Northumberland Marine; Northumbria Coast; Greater Wash; and Humber Estuary. It was not possible to conclude no LSE for the following SPAs: Flamborough and Filey Coast, Farne Islands, Teesmouth and Cleveland Coast, Northumberland Marine and Greater Wash. Following a detailed assessment, no adverse effect on site integrity was concluded for all SPAs taken into appropriate assessment.

A detailed HRA was conducted for NZT Power: Teesmouth and Cleveland Coast SPA / Ramsar taken forward into appropriate assessment. The HRA concluded no risk of an adverse effect on site integrity for the SPA / Ramsar. An HRA has not yet been carried out for Onshore Humber, however the available details, combined with the application of industry-standard best practice and mitigation and regulatory control, it is highly unlikely that the Onshore Humber project would lead to an LSE on European Sites designated for ornithological features.

12.6 Accidental Events

As assessed within Chapter 10: Accidental Events, , all residual impacts are assessed as being of minor significance or below (see Section 10.7), when the management and mitigation measures outlined in Sections 10.3.3, 10.5.6, and 10.6.4 are considered.

As assessed within Chapter 10: Accidental Events, it is recognised that in the highly unlikely event that a diesel release occurred, the magnitude of impact of an accidental spill is low due to the marine diesel exhibiting a volatile nature and there being a limited volume of release. Marine diesel has been shown to evaporate, biodegrade and dissipate throughout the water column between 18 and 36 hours. Therefore, the diesel would not likely persist in the environment for a prolonged period.

Onshore (NZT and Onshore Humber), there may be accidental events from spillages of fuel and oil which may cause indirect effects on marine ecology from changes in marine water quality. These will be prevented, mitigated and managed using appropriate standard and best practice control measures which will be outlined in the respective CEMP.

On this basis, for the topic of accidental diesel releases, there is no change to the impact assessment for the Development, and the potential for cumulative effects is considered to be not significant.

CO_2 will be introduced into the onshore infrastructure and the offshore transportation and storage infrastructure after completion of construction and commissioning, i.e. there is no potential for construction-related cumulative impacts. There could only be cumulative effects during operations from the Development and NZT Power or Onshore Humber if accidental release of CO_2 occurred simultaneously. The likelihood of a simultaneous release of CO_2 from the Development and onshore infrastructure is extremely remote. If releases did occur simultaneously, the probability that physical overlaps of any releases would result is even more remote.

On this basis, for accidental CO_2 releases, the likelihood of combined increases in CO_2 releases is considered negligible and the potential for cumulative effects not significant.

12.7 Atmospheric Emissions

As assessed within Chapter 11: Atmospheric Emissions, all residual impacts are assessed as being of minor significance or below (see Section 11.9), when the management and mitigation measures outlined in Section 11.6 are considered.

No key ecological or human receptors have been identified for Air Quality for the Development. It is anticipated that any construction-phase effects which would result from vessel activity associated with landfall construction and pipeline installation would be short-term and negligible.

Onshore, there may be dust from construction activities, emissions from construction vehicles and mobile construction plant; and emissions from construction phase road traffic.

On this basis, for the topics of local air quality and global climate change, the combined increase in emissions is considered short term and negligible and the potential for cumulative effects not significant. Indeed, the overall ECC development will contribute to reductions in UK emissions and achievement of net zero goals.

12.8 Conclusion

Based on the nature and scheduling of activities associated with NZT Power, Onshore Humber and the Development, and given the receptors and receiving environment which may potentially be impacted by activities in the connection zone, it is concluded that there is no potential for significant cumulative effects resulting as a consequence of the whole scheme.

13 ENVIRONMENTAL MANAGEMENT

13.1 Introduction

This chapter describes the environmental management philosophy and procedures that will be in place to ensure delivery of the environmental commitments made in the EIA through the lifecycle of the Development. bp, as operator of the Development, have environmental management processes in place which will facilitate delivery of the commitments (mitigations and controls) with measurement, monitoring and performance reporting. Environmental management plans in relation to NEP are presented within this chapter.

The preceding ES chapters present the potential environmental impacts identified during the EIA and the commitments that bp, as operator of the Development, has made to reducing the likelihood of any potentially significant impact occurring. However, consideration of the potential for impact on the environment does not end at ES submission but continues through the detailed design, execution, operation, and maintenance and decommissioning of the Development.

13.2 bp Management Systems

bp, as operator of the Development, is committed to conducting activities in compliance with all applicable legislation and in a manner that will minimise impacts on the environment. The bp HSSE Commitment, is shown in Figure 13-1 and bp is committed to attaining the highest standards of HSSE performance. bp's HSSE goals are simply stated:

- No accidents;
- No harm to people; and
- No damage to the environment.

bp's HSSE goals are enshrined in the bp Code of Conduct and the bp Operating Management System (OMS). The Code of Conduct is a public statement that bp is committed to acting responsibly and serves as a valuable resource to help employees and others make informed, ethical decisions. The OMS provides a framework for managing HSSE and operational risks in bp operating activities.

BP's Commitment to **health, safety, security** and **environmental** (HSSE) performance

Our HSSE goals are simply stated – no accidents, no harm to people and no damage to the environment.

We strive to be a safety leader in our industry, a world-class operator, a good corporate citizen and a great employer.

Nothing is more important to us than the health, safety and security of our workforce and the communities in which we operate, and behaving responsibly towards our shared environment. We must be vigilant, disciplined and always looking out for one another.

We are committed to:

– Complying with applicable laws and company policies and procedures.
– Systematically managing our operating activities and risks.
– Reporting our HSSE performance.
- Learning from internal and external HSSE events.

Everyone who works for BP has a part to play in meeting our HSSE commitment.

[redacted]

Bernard Looney,
Group Chief Executive
5 February 2020

Figure 13-1 - bp HSSE commitment

bp's environment management system (EMS) is embedded in the OMS which integrates all bp's operating standards into one consistent set of expectations, defining the requirements for how bp operating entities deliver safe and reliable operations. bp entities are required to identify and systematically manage the impact of their activities on the environment and integrate environmental requirements into the local OMS to drive continuous improvement in Environmental and Social (E&S) performance of projects and operations.

The bp OMS is aligned with ISO 14001:2015, a globally recognized international standard which sets specific requirements for an effective EMS.

Through the stages and associated HSSE management activities, the Development will build the foundations of its EMS in preparation for OMS implementation in the operate phase.

13.3 Carbon Management and Net Zero Strategy

In 2020, bp, as operator of the Development, announced its ambition to be a net zero company by 2050 or sooner and to help the world get to net zero, with interim targets and aims for 2025 and 2030[278]. Table 13-1 highlights the aims with particular relevance to the Development.

Table 13-1 - bp aims to deliver sustainability frame, as relevant to the Development

Focus area	Aim	Description
Get to net zero	Aim 1	Net zero operations: net zero across bp's entire operations on an absolute basis by 2050 or sooner
	Aim 3	Halving intensity: 50% reduction in carbon intensity of the products bp sells by 2050 or sooner
	Aim 5	More investment for new energies: Increase the proportion of investment into bp's non-oil & gas businesses

Emissions associated with the Development have been estimated and are presented in Chapter 11: Atmospheric Emissions. As part of continual improvement in the reduction of emissions, bp will seek emissions reduction opportunities through all phases of the Development. Supply chain will be engaged to update the carbon emissions relating to their specific scopes and to identify carbon emissions reduction opportunities.

13.4 NEP Environmental Management Plan

All activities associated with the design, installation and commissioning of the Development will be carried out under the bp NEP Environmental and Social Management and Monitoring Plan. This plan will set out the approach to avoiding or mitigating potential environmental impacts, to delivering regulatory compliance and to carrying out the commitments made within this ES.

When operating, bp will carry out all operational phase activities associated with the Development, including services provided by contractors, within bp's mature EMS. The system will provide the Development with a robust framework for establishing environmental objectives and targets, managing environmental impact and risk within these targets, monitoring, and reviewing effectiveness and compliance, and developing further technical and operational improvements, if required. bp has systems in place to identify and apply compliance and regulatory requirements across key phases, i.e. design, installation, commissioning, and operations.

[278] *https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/investors/bp-esg-investor-pack.pdf*

Due to the medium to high sensitivity and value of benthos, fish, marine mammal and ornithological receptors, both within and in proximity to the Development, and considering the recent Defra Marine Net Gain consultation[279], a biodiversity enhancement assessment shall be completed for the Development. This assessment shall inform any requirements for a biodiversity enhancement action plan that shall be implemented during execution and operation of the Development as necessary[280]. This assessment is in line with bp's biodiversity position[281] (Sustainability Aim 16) which aims to achieve a net positive impact on biodiversity for new projects.

13.5 Commitment Tracking

A commitment register has been developed for the Development (Appendix C) which summarises all mitigation and management requirements identified during the EIA process that have been or will be implemented as part of the Development. Each commitment will be incorporated into the Development's Environmental and Social Management and Monitoring Plan (Section 13.4) and reviewed regularly to ensure that it is being met. Delivery of all commitments will be tracked and managed to closure.

13.6 Environmental Awareness and Training

bp, as operator of the Development, recognises that personnel who perform or manage project work that may potentially have a significant impact on the environment must be trained. Environmental awareness training for bp staff and relevant contractors will be evaluated and implemented in accordance with the phases of the Development. bp supports a series of learning strategies to promote environmental awareness and necessary technical competency. Training is assigned in accordance with the role and job function and will reflect company, industry and Regulatory requirements. Training covers a range of environmental issues applicable to the operations including environmental aspects and impacts, and the integration of environmental considerations into the Operational Management System to achieve continuous improvement in environmental performance. Contractors are audited and monitored to check that they have systems and controls in place to manage their environmental responsibilities.

In addition, training programmes focusing on specific environmental aspects, such as emergency response and risk assessment, are provided to relevant staff and contractors.

13.7 Performance Management

13.7.1 Assurance

bp have established assurance processes and procedures. Assurance will be carried out on the delivery of the commitments throughout the Development from design to operational scopes. The results of all assurance activities will be reported to the Project Manager and associated actions will be tracked to closure.

[279] *https://www.gov.uk/government/consultations/consultation-on-the-principles-of-marine-net-gain*
[280] *Enhancement as defined by CIEEM (2018)*
[281] *https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/sustainability/our-biodiversity-position-2020.pdf*

13.7.2 Monitoring and Measurements

Environmental effects monitoring involves monitoring actual impacts on the receiving environment during or after development activities as part of the validation of analysis made in the EIA process. Environmental monitoring will be conducted during the construction, operations and decommissioning phases of a project to provide any data that may be required to assess:

- Actual impacts of the Development against those described in the impact assessment; and
- The effectiveness of mitigation and enhancement measures being implemented.

A review will be carried out to identify any requirements for environmental monitoring of planned activities and a plan will be developed during the Detailed Design phase of the Development, if required.

As described within Section 3.4.7, a MP for the Endurance Store will be developed and agreed with the NSTA as part of the storage permitting process. The domains of the MP include the Endurance Store, the injection and monitoring wells and the marine biosphere and shallow subsurface. Monitoring is expected to be split into a series of phases across the Development including baseline characterisation (pre-injection), operational phase (injection) and post-closure/pre-transfer phase (post-injection):

13.7.3 Reporting

Operational phase reporting for the Development will be aligned with regulatory requirements and managed via existing bp processes and procedures to fulfil reporting criteria.

13.8 Contractor Management

Engineering, Procurement, Construction, and Installation contractors will have their own HSSE Management System to help them deliver safe and reliable operations. This will include specific Environmental and Social Management and Monitoring Plan, tailored for their scope and work locations. Contractors will be responsible for their own performance and for self-verifying conformance in accordance with the contract work scope. bp, as operator of the Development, will perform oversight of the implementation and self-verification of contractor arrangements.

14 CONCLUSION

The Development considered alternatives to embed technical, economic, and environmental considerations into the project design. BAT / BEP principles were used to evaluate whether the optimal environmental design was chosen. The selected concept was then subject to a scoping consultation to obtain the views and environmental concerns of stakeholders to be addressed during the EIA. The scope and focus of the EIA were refined through an impact identification exercise, including an ENVID workshop. This process identified issues requiring further assessment based on the proposed activities, the known environmental sensitivities, industry experience and stakeholder concerns. The EIA was conducted in line with the Offshore Oil and Gas Exploration, Production, Unloading and Storage (Environmental Impact Assessment) Regulations 2020, as well as other relevant legislation and associated guidance as detailed in Section 1.4.

The EIA has considered the objectives and marine planning policies of the North East Inshore and Offshore Marine Plans and of the East Inshore and East Offshore Marine Plans. These have been considered across the range of policy topics including biodiversity, natural heritage, cumulative impacts and oil and gas. The Development is considered to align with such objectives and policies; as summarised in Appendix D.

Potentially significant impacts that were highlighted during the impact identification exercise were fully assessed in Chapters 6: Seabed Disturbance to 11: Atmospheric Emissions. Conclusions regarding significance of impacts were as follows:

- Seabed impacts – **not significant** based on the seabed area affected and the extent of similar habitat available;
- Underwater sound – **not significant** based on, the area and short time period over which the impact will occur, and the mitigation measures that will be enacted; and
- Discharges to sea and Formation Water displacement – **not significant** based on the low sensitivity / exposure of receptors (water column) and the limited area of habitat affected (seabed);
- Physical presence – **not significant** based on the low sensitivity of assessed receptors or the negligible magnitude of impact on higher sensitivity receptors;
- Accidental events – **not significant** based on the remote likelihood of a worst case release occurring, and the prevention, mitigation and monitoring measures that will be implemented; and
- Atmospherics and climate – **not significant** based on: (a) assessment concluding that emissions will not affect air quality in the local or wider area, and (b) the expected emissions from the Development comprising a negligible proportion of UK carbon budget.

The EIA Regulations require a description of aspects of the Development (mitigations) that are intended to avoid, prevent, reduce or offset likely significant adverse effects and how they are to be delivered. Mitigation measures were actively considered during the project design as detailed in Chapters 6: Seabed Disturbance to 11: Atmospheric Emissions and summarised in the Commitments Register (Appendix C).

All activities associated with the design, installation and commissioning of the Development will be carried out under the NEP Environmental and Social Management and Monitoring Plan. This plan will set out the approach to avoiding or mitigating potential environmental impacts, to delivering regulatory compliance and to carrying out the commitments made within this ES.

bp, as operator of the Development, will conduct all operational phase activities associated with the Development within bp's mature Environmental Management System (EMS). The system will provide the Development with a robust framework for establishing environmental objectives and targets, managing environmental impact and risk within these targets, monitoring, and reviewing effectiveness and compliance, and developing further technical and operational improvements, if required.

In conclusion, the EIA described in this ES demonstrates that, with the proposed mitigation measures in place, the Development is not expected to have a significant effect on the environment. Environmental effects will be managed, monitored and minimised through adherence to the bp EMS and regulatory compliance.

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16 ACRONYMS

Abbreviation/acronym	Term
AA	Appropriate Assessment
ABP	Associated British Ports
AET	Apparent Effects Thresholds
AEZ	Archaeological Exclusion Zone
AGI	Above Ground Installations
AIAA	Areas of Intense Aerial Activity
AIS	Automatic Identification System
Al	Aluminium
ALDS	Automatic Leak Detection Sonar
AMRC	Advanced Manufacturing Centre
AON	Apparently Occupied Nests
AR	Aqua Regia
AR6	Sixth Assessment Report
As	Arsenic
ASA	Archaeological Study Area
ASV	Autonomous Surface Vehicle
ATT	Admiralty TotalTide
AUV	Autonomous Underwater Vehicle
Ba	Barium
BAC	Background Assessment Concentrations
BAT	Best Available Technique
bbl	Barrel
Be	Beryllium
BEIS	Department for Business, Energy & Industrial Strategy
BEP	Best Environmental Practice
BGS	British Geological Survey
BHD	Backhoe Dredger
BMAPA	British Marine Aggregate Producers Association
BMV	Best and Most Versatile
BOCC	Birds of Conservation Concern

Abbreviation/acronym	Term
BPEOC	BP Exploration Operating Company Limited
BSAC	British Sub-Aqua Club
BT	British Telecom
CAPEX	Capital Expenditure
CATS	Central Area Transmission System
CCC	Committee on Climate Change
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilisation and Storage
Cd	Cadmium
CEC	Cation-exchange capacity
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CEMP	Construction Environmental Management Plan
CFD	Computational Fluid Dynamics
CH_4	Methane
CHARM	Chemical Hazard Assessment and Risk Management
CIEEM	Chartered Institute of Ecology and Environmental Management
CIN	Charm Implementation Network
CIRIA	Construction Industry Research and Information Association
CLV	Cable Lay Vessel
CMID	Common Marine Inspection Documents
CNS	Central North Sea
Co	Cobalt
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COLREGS	Compliance with Convention on the International Regulations for Preventing Collisions at Sea
COOPA	Cooperation Agreement
COSHH	Control of Substances Hazardous to Health
CPTU	Cone Penetrometer Test

Abbreviation/acronym	Term
Cr	Chromium
CSD	Cutter Suction Dredger
CTD	Current, Temperature and Depth Sensors
CtL	Consent to Locate
Cu	Copper
cu in	Cubic Inch
dB	Decibel
DBA	Dogger Bank A
DBB	Dogger Bank B
DBC	Dogger Bank C
DCO	Development Consent Order
DECC	Department of Energy & Climate Change
Defra	Department for Environment, Food and Rural Affairs
DESNZ	Department for Energy Security and Net Zero
DMA	Di-methylarsinic
DNA	Deoxyribonucleic acid
DO	Dissolved Oxygen
DP	Dynamically Positioned
DREAM	Dose-related Risk and Effects Assessment Model
DSV	Dive Support Vessel
DTE	Defence Training Estate
DTI	Department of Trade and Industry
EA	Environmental Appraisal
EC	European Commission
ECA	Emission Control Areas
ECB	European Chemical Bureau
ECC	East Coast Cluster
ECHA	European Chemicals Agency
ECMWF	European Centre for Medium-Range Weather Forecasts
eDNA	Environmental DNA
EDR	Effective Deterrence Range

Abbreviation/acronym	Term
EEMS	Environmental Emissions Monitoring System
EIA	Environmental Impact Assessment
EIAPP	Engine International Air Pollution Prevention Certifications
EIF	Environmental Impact Factor
EMS	Environment Management System
ENE	East-northeast
ENVID	Environmental Issues Identification
EPCI	engineering, procure, construct and install
EPS	European Protected Species
ERL	Effects Range Low
ERM	Effects Range Median
ES	Environmental Statement
ESE	East southeast
ESPOO Convention	United Nations Economic Commission for Europe Convention on EIA in a Transboundary Context
ETI	Energy Technologies Institute
EU	European Union
EUNIS	European Nature Information System
FAMS	Flow Assurance Management System
FCS	Favourable Conservation Status
Fe	Iron
FEED	Front End Engineering and Design
FLO	Fisheries Liaison Officer
FOAK	First of a Kind
FOCI	Feature of Conservation Interest
FVCOM	Finite-Volume Coastal Ocean Model
GEP	Good Ecological Potential
GES	Good Ecological Status
GHG	Greenhouse Gas
GPS	Global Positioning Systems
GSA	Geophysical Study Areas
GVA	Gross value added

Abbreviation/acronym	Term
GWP	Global Warming Potential
H_2O	Water
ha	Hectare
HAT	Highest Astronomical Tide
HDD	Horizontal Directional Drilling
HF	High Frequency
Hg	Mercury
HGS	Humber Gathering System
HMWB	Heavily Modified Water Body
HPU	Hydraulic Power Unit
HQ	Hazard Quotient
HRA	Habitats Regulations Assessment
HSE	Health Safety and Environment
HSSE	Health, Safety, Security and Environment
HTL	Hold the Line
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IAMMWG	Inter-Agency Marine Mammal Working Group
IAPP	International Air Pollution Prevention Certification
ICCI	In-Combination Climate Impact
ICES	International Council for the Exploration of the Seas
IEMA	Institute of Environmental Management and Assessment
ILT	Injection Logging Test
IMDG	International Maritime Dangerous Goods
IMO	International Maritime Organisation
in	Inches
IOGP	International Association of Oil and Gas Producers
IP	Institute of Petroleum
IPCC	Intergovernmental Panel on Climate Change
ISCF	Industrial Strategy Challenge Fund
ITOPF	International Tankers Owners Pollution Federation

Abbreviation/acronym	Term
IUCN	International Union for Conservation of Nature
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
kg	Kilogram
kHz	Kilohertz
kJ	Kilojoules
km	Kilometres
km^2	Square Kilometres
KP	Kilometre Point
Kt	Kilo tonne
kVA	Kilo Volt-Ampere
kW	Kilowatt
LAT	Lowest Astronomical Tide
LBL	Long Baseline
LF	Low Frequency
LGM	Last Glacial Maximum
Li	Lithium
LNG	Liquefied Natural Gas
LOD	Limit of Detection
LOEC	Lowest observed effect concentrations
LPG	Liquefied Petroleum Gas
LSE	Likely Significant Effect
LTOBM	Low Toxicity Oil Based Mud
m	Metres
m/s	Metres per Second
m^2	Square Metre
m^3	Cubic Metres
MA	Managed Realignment
MAIB	Marine Accident Investigation Branch
MAR	Major Accident Risk
MarLIN	Marine Life Information Network
MARPOL	International Convention for the Prevention of Marine Pollution from Ships

Abbreviation/acronym	Term
MBES	Multibeam Echosounder
MCA	Maritime and Coastguard Agency
MCAA	Marine and Coastal Access Act
MCCIP	Marine Climate Change Impacts Partnership
MCZ	Marine Conservation Zones
MDAC	Methane-derived authigenic carbonate
MEEB	Measures of Equivalent Environmental Benefit
MEG	Monoethylene Glycol
METAR	Meteorological Terminal Air Reports
MF	Mid Frequency
MFE	Mass Flow Excavator
Mg	Magnesium
mg/L	Milligrams per Litre
MGO	Marine gas oil
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLW	Mean Low Water
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
mm	Millimetres
MMA	Methylarsonic Acid
MMMU	Marine Mammal Management Unit
MMO	Marine Management Organisation
MMO	Marine Mammal Observer
MMscf	Million Standard Cubic Feet
MMscfd	Million Standard Cubic Feet per Day
Mn	Manganese
MoD	Ministry of Defence
MP	Monitoring Plan
MPA	Marine Protected Area
MSL	Mean Sea Level
Mt	Million Tonnes

Abbreviation/acronym	Term
mTBM	Micro Tunnel Boring Machine
MTM	MicroTunnel Machine
MtPA	Million Tonnes per Annum
MtPAa	Million Tonnes per Annum Average
MtPAi	Million Tonnes per Annum Instantaneous
MW	Megawatt
N_2O	Nitrous Oxides
NAI	No Active Intervention
NCA	Natural Character Area
NDC	Nationally Determined Contribution
NE	Natural England
NECA	Nitrogen Oxides Emissions
NEP	Northern Endurance Partnership
NERC	Natural Environment and Rural Communities
NFFO	National Federation of Fishermen’s Organisation
ng/g	Nanograms per Gram
NGCL	National Grid Carbon Limited
NGV	National Grid Ventures
Ni	Nickel
NM	Nautical Miles
NM^2	Square Nautical Miles
NMVOC	Non-Methane Volatile Organic Compound
NNE	North-northeast
NNR	National Nature Reserve
NNS	Northern North Sea
NOAA	National Oceanic and Atmospheric Administration
NOC	National Oceanography Centre
NOEC	No Observed Effect Concentration
NO_x	Nitrogen Oxides
NQ	Not Quantified
NRA	Navigational Risk Assessment
NSIP	Nationally Significant Infrastructure Project

Abbreviation/acronym	Term
NSTA	North Sea Transition Authority
NSTD	North Sea Transition Deal
NUI	Normally Unmanned Installation
NZT	Net Zero Teesside
NZT Project	Net Zero Teesside Project DCO
O_3	Ozone
OBN	Ocean Bottom Nodes
OCNS	Offshore Chemical Notification Scheme
OCP	organochlorine pesticides
OCR	Offshore Chemical Regulations
ODN	Ordnance Datum Newlyn
OFTO	Offshore Transmission Owner
OGA	Oil and Gas Authority
OGCI	Oil and Gas Climate Initiative
OH	hydroxides
OMS	Operating Management System
OOS	Out of Straightness
OPEP	Oil Pollution Emergency Plan
OPEX	Operational Expenditure
OPRC	Oil Pollution, Preparedness, Response and Cooperation
OPRED	Offshore Petroleum Regulator for Environment and Decommissioning
OSCAR	Oil Spill Contingency and Response
OSPAR	Protection of the Marine Environment of the North-East Atlantic
OWF	Offshore Windfarms
OVID	Offshore Vessel Inspection Database
PAD	Protocol for Archaeological Discoveries
PAH	Polyaromatic hydrocarbons
PAM	Passive Acoustic Monitoring
Pb	Lead
PCB	Polychlorinated biphenyls
PCO	Precipitated Carbonates

Abbreviation/acronym	Term
PEC	Predicted Environmental Concentration
PEXA	Practice and Exercise Area
pH	Potential of hydrogen/power of hydrogen
PHSA	Pipeline and Hazardous Materials Safety Administration
PIG	Pipeline Inspection Gauge
PLA	Pipeline Operations Application
PLONOR	Pose Little or No Risk to the environment
PML	Plymouth Marine Laboratories
PNEC	Predicted No Effect Concentration
POC	Particulate Organic Carbon
ppm	Parts per Million
PSA	Particle Size Analysis
psi	Pound per Square Inch
PSU	Practical Salinity Unit
PTG	Pressure / temperature gauge
PTS	Permanent Threshold Shift
PWA	Pipeline Works Authorisation
QICS	Quantifying and monitoring potential ecosystem impacts of geological carbon storage
RCP	Representative Concentration Pathway
REACH	Registration, evaluation, authorisation and restriction of chemicals
RMS	Root Mean Square
ROV	Remotely Operated Vehicles
RSPB	Royal Society for the Protection of Birds
RYA	Royal Yachting Association
s	Seconds
SAC	Special Area of Conservation
SACFOR	Super-abundant, Abundant, Common, Frequent, Occasional, Rare, Present
SAT	Subsidiary Application Template
SBM	Synthetic Based Mud
SBP	Sub-Bottom Profiling

Abbreviation/acronym	Term
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCAT	Shoreline Clean-Up Assessment Team or Techniques
SCOS	Special Committee on Seals
SCSSV	Surface-Controlled Subsurface Safety Valve
SDS	Safety Data Sheets
Se	Selenium
SEA	Strategic Environmental Assessments
SeaMaST	Seabird Mapping and Sensitivity Tool
SECA	Sulfur Oxides Emission Control Area
SEEMP	Shipboard Energy Efficiency Management Plan
SEGL2	Scotland England Green Link 2
SEL	Sound Exposure Level
SINTEF	Scandinavian Independent Research Organisation
SLT	Saturation Logging Tool
SMP	Shoreline Management Plan
SMRU	Sea Mammal Research Unit
SMU	Seal Management Unit
Sn	Tin
SNCB	Statutory Nature Conservation Bodies
SNS	Southern North Sea
SNSSTS	Southern North Sea Sediment Transport Study
SOLAS	International Convention for the Safety of Life at Sea
SOPEP	Shipboard Oil Pollution Emergency Plan
SoS	Secretary of State
SOSI	Seabird Oil Sensitivity Index
SOX	Sulphur Oxides
SPA	Special Protection Area
SPL	Sound Pressure Level
Sr	Strontium
SRES	Special Report on Emissions Scenario
SSE	South-southeast

Abbreviation/acronym	Term
SSE	Scottish and Southern Energy
SSIV	Subsea Safety Isolation Valve
SSS	Sidescan Sonar
SSSI	Site of Special Scientific Interest
SST	Sea-surface Temperature
SSW	South-southwest
SSSV	Subsurface Safety Valve
STDC	South Tees Development Corporation
STEMM-CCS	Strategies for Environmental Monitoring of Marine Carbon Capture and Storage
t	Tonne
T&S	Transport & Storage
TCE	The Crown Estate
TDS	Total Dissolved Solids
THC	Total Hydrocarbons
ThOD	Theoretical Oxygen Demand
Ti	Titanium
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TOM	Total Organic Matter
TSHD	Trailing Suction Hopper Dredger
TSS	Total Suspended Solids
TTS	Temporary Threshold Shift
TVDML	True Vertical Depth Below Mud Line
TVDSS	True Vertical Depth Sub Sea
TWT	The Wildlife Trust
UHB	Upheaval Buckling
UK	United Kingdom
UKC	Under Keel Clearance
UKAPP	UK Air Pollution Prevention Certificate
UKBAP	UK Biodiversity Action Plan
UKCP18	UK Climate Projections 2018
UKCS	United Kingdom Continental Shelf

Abbreviation/acronym	Term
UKHO	UK Hydrographic Office
UKOOA	UK Offshore Operators Association
UKRI	UK Research and Innovation
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNFCCC	United Nations Framework Convention on Climate Change
USBL	Ultra-Short Baseline
UTM	Universal Trans Mercator
UXO	Unexploded Ordnance
V	Vanadium
VMS	Vessel Monitoring System
VOC	Volatile Organic Compound
VOR	Valued Ornithological Receptor
VSP	Vertical Seismic Profiling
VTS	Vessel Traffic Survey
WBM	Water Based Mud
WET	Whole Effluent Testing
WFD	Water Framework Directive
WHS	World Heritage Site
WONS	Well Operations Notification System
WSA	Whole Scheme Assessment
WSI	Written Scheme of Investigation
WTG	Wind Turbine Generator
WWI	First World War
WWII	Second World War
Zn	Zinc
ZoI	Zone of Influence
°C	Degrees Celsius
µg/g	Microgram per Gram
µg/L	Microgram per Litre
µm	Micrometre
2D	Two-Dimensional

Abbreviation/acronym	Term
2DUHR	2D Underwater High Resolution
3D	Three-Dimensional
4D	Four-Dimensional