Offshore Environmental Statement for the Northern Endurance Partnership

Reference: D/4271/2021

Document: NS051-EV-REP-000-00021

September 2023

VOLUME 1/2: ENVIRONMENTAL STATEMENT

Part A

Project Name	Northern Endurance Partnership
Development Location	Southern North Sea
Licence No	CS001
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	25 years' experience, onshore and offshore environment

	Manager	
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 metres (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 (MtPA) of CO_2. The Development represents the initial phase (Phase 1) of the ECC and has an ambition to capture the initial 4 MtPA.

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.

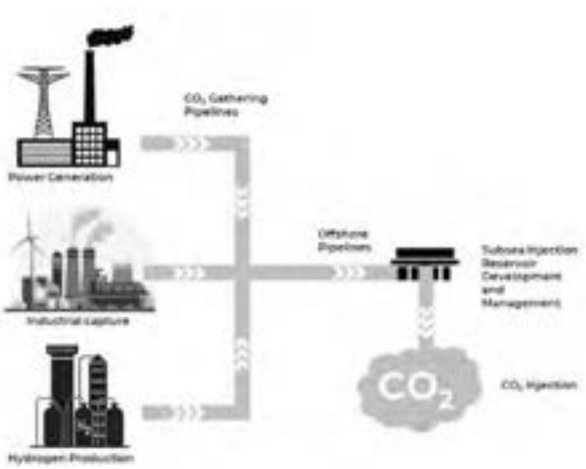

Figure 1 - Overview of CO_2 transportation and storage

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.

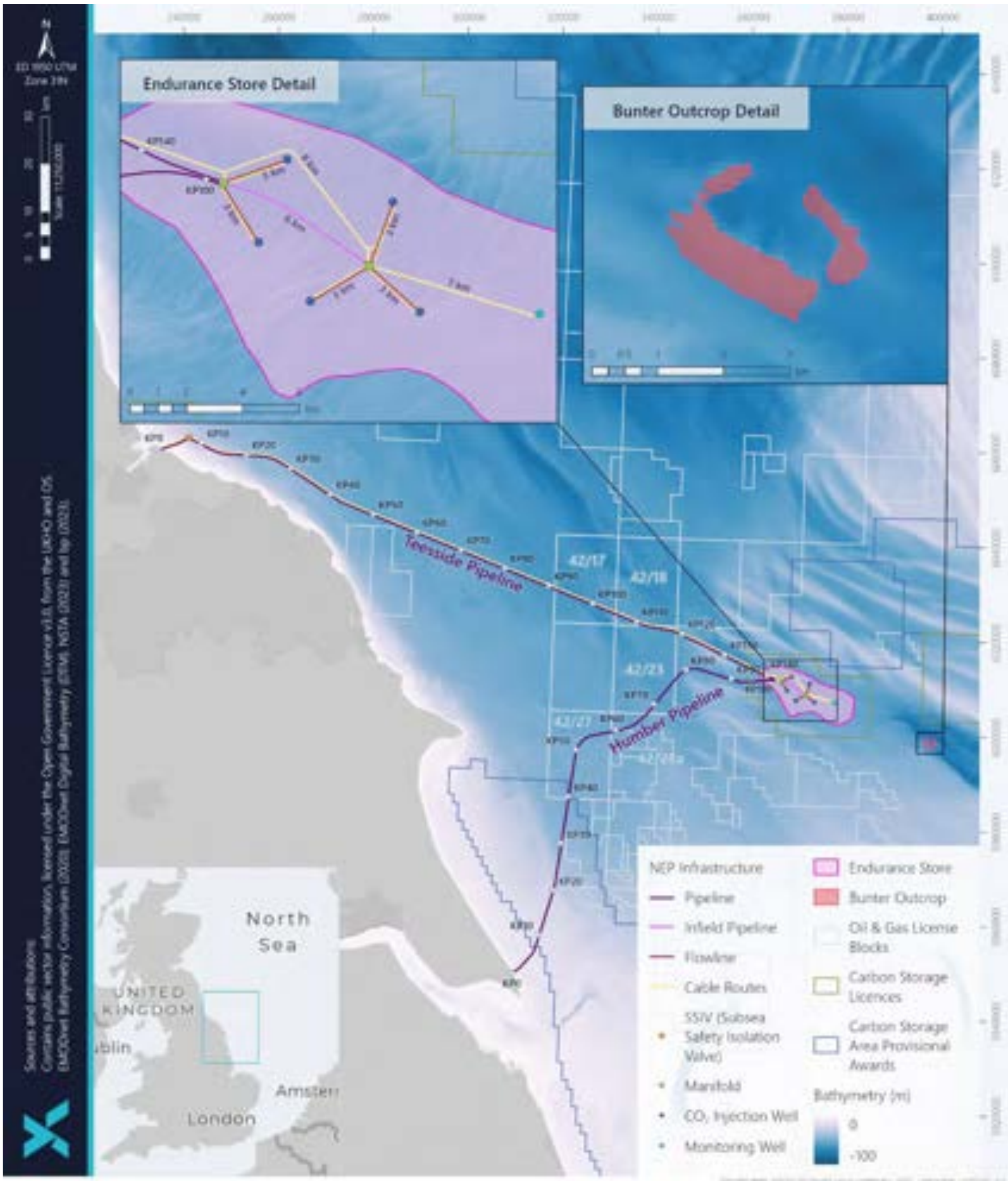

Figure 2 - Overview of Development area showing the Endurance Store and the Teesside and Humber Pipelines

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.

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'.

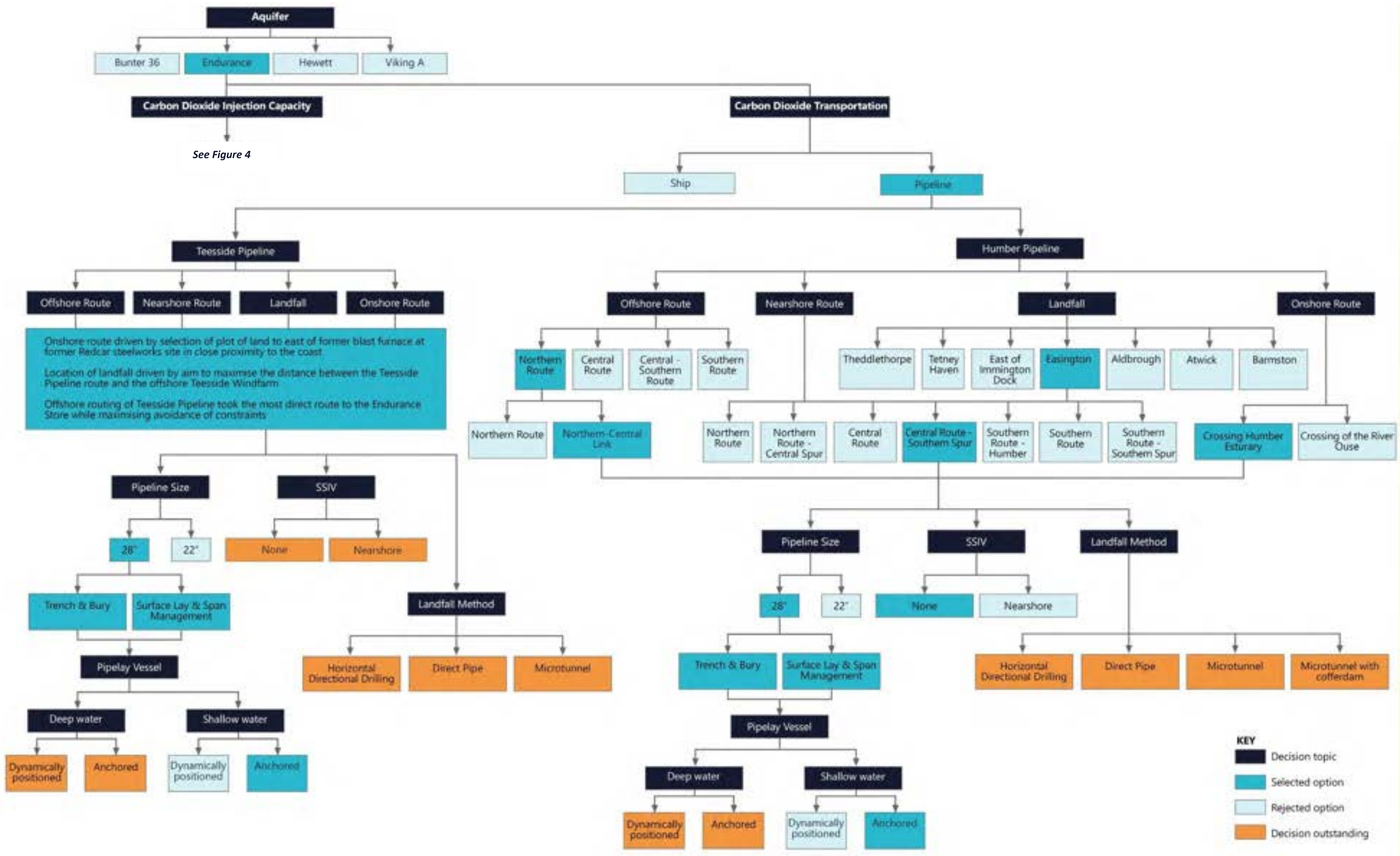

Figure 3 - NEP Development consideration of alternatives: Aquifer and CO_2 transportation

See Figure 3

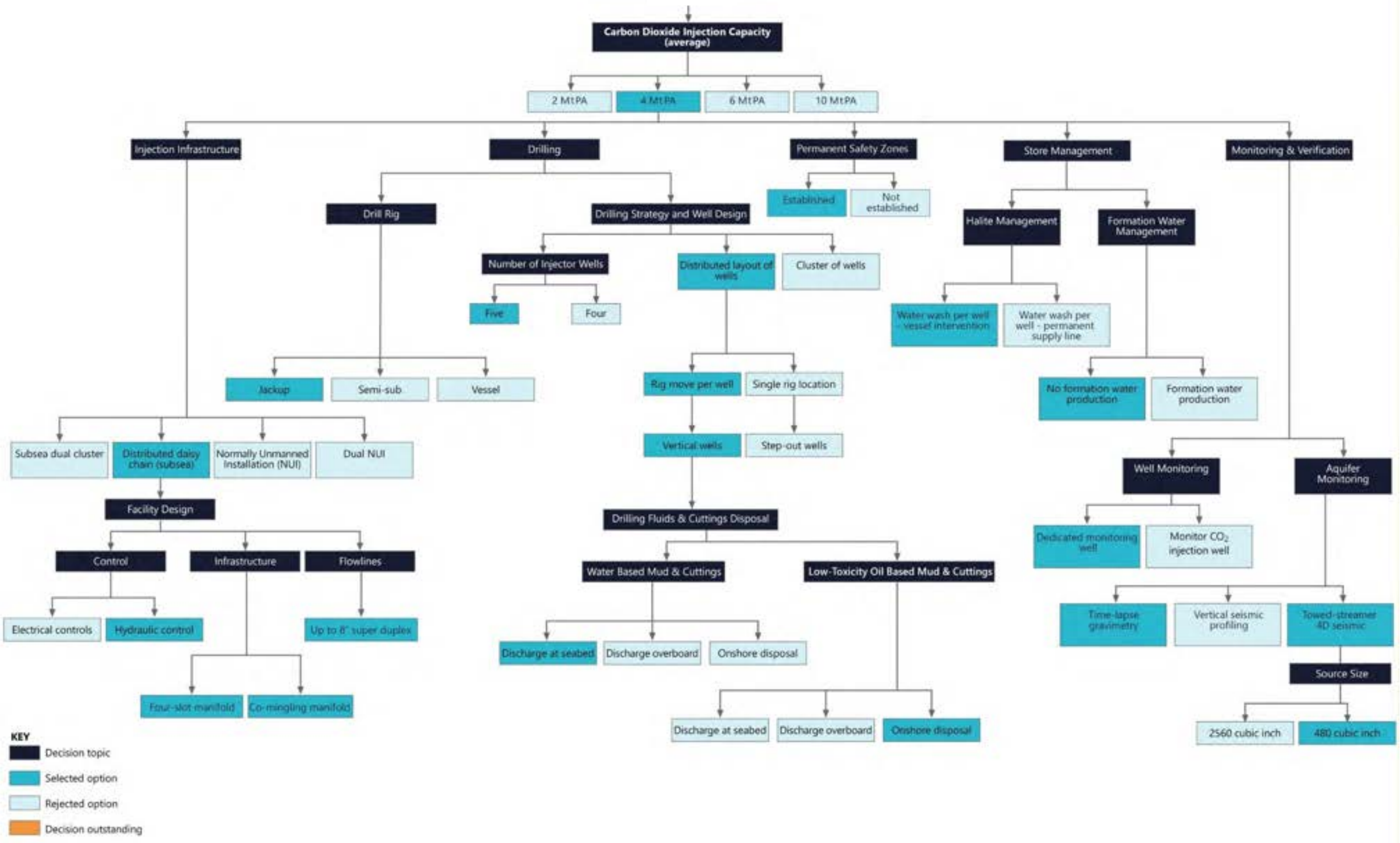

Figure 4 - NEP Development consideration of alternatives: CO_2 injection

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 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.

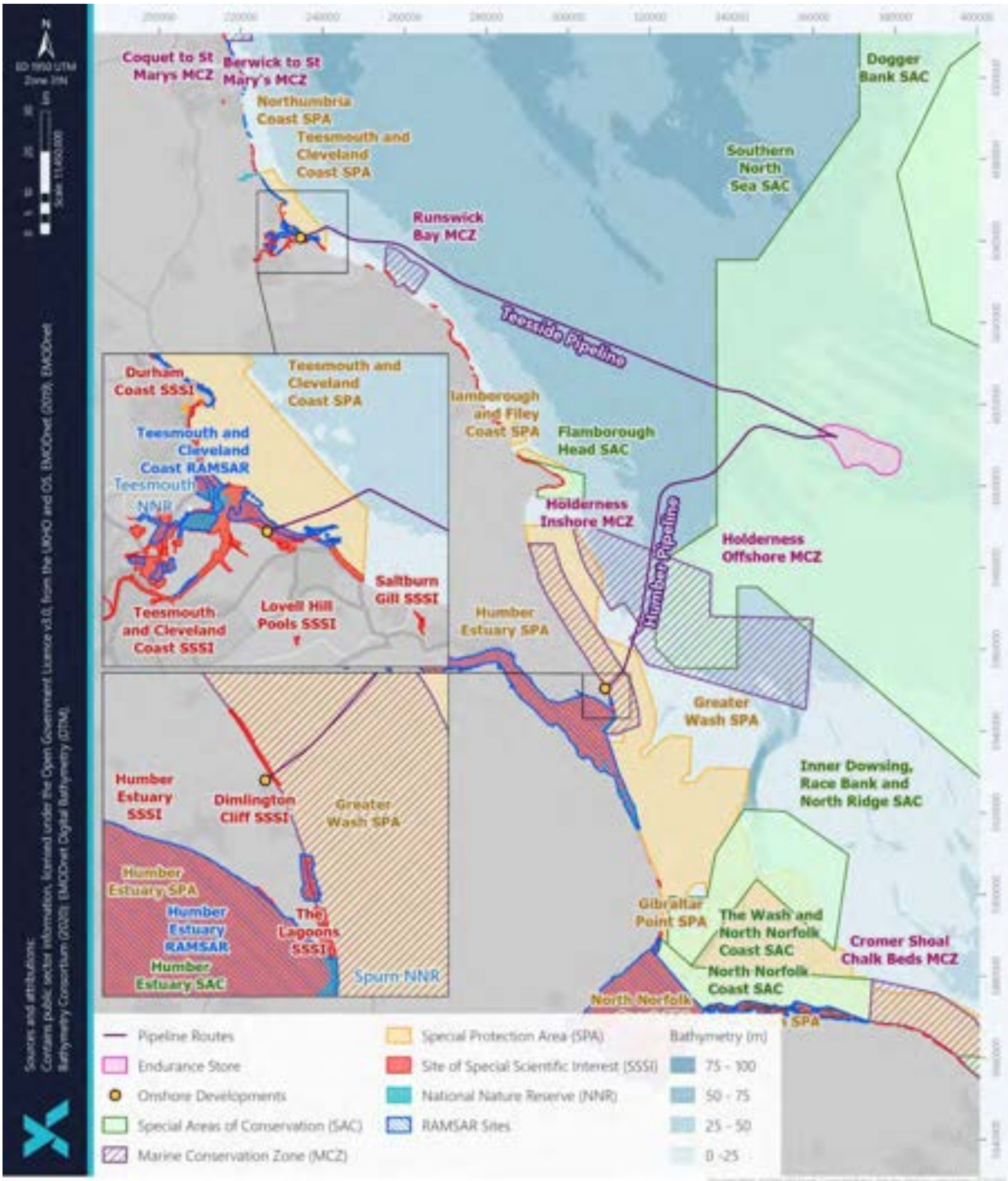

Figure 5 - Conservation sites in the vicinity of the Development

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.

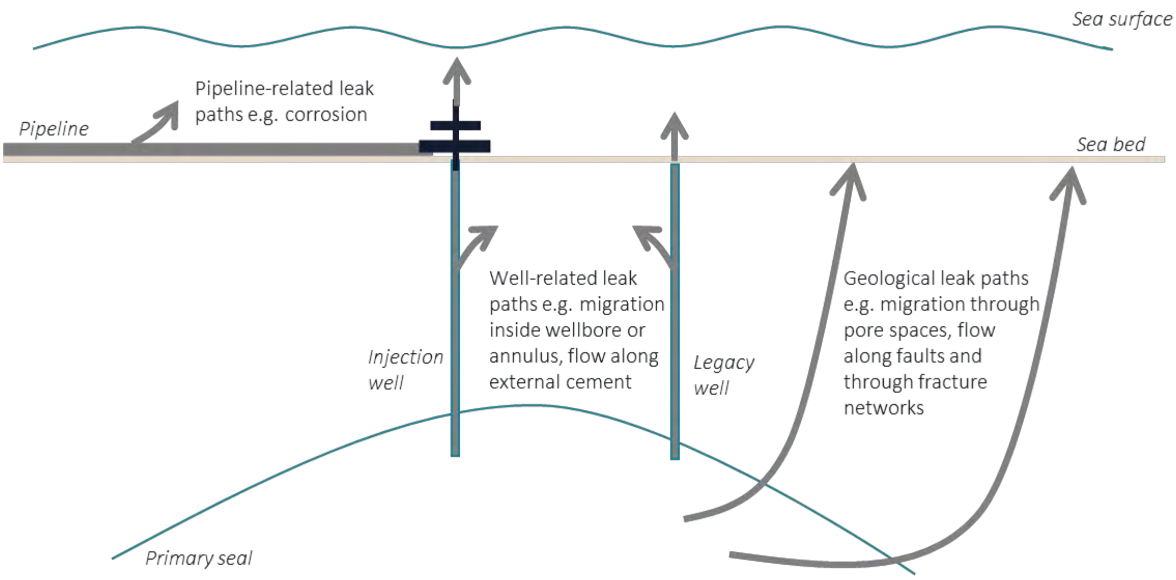

Figure 6 - Potential CO_2 leak pathways

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.

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[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, particulate matter, 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.

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[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.*

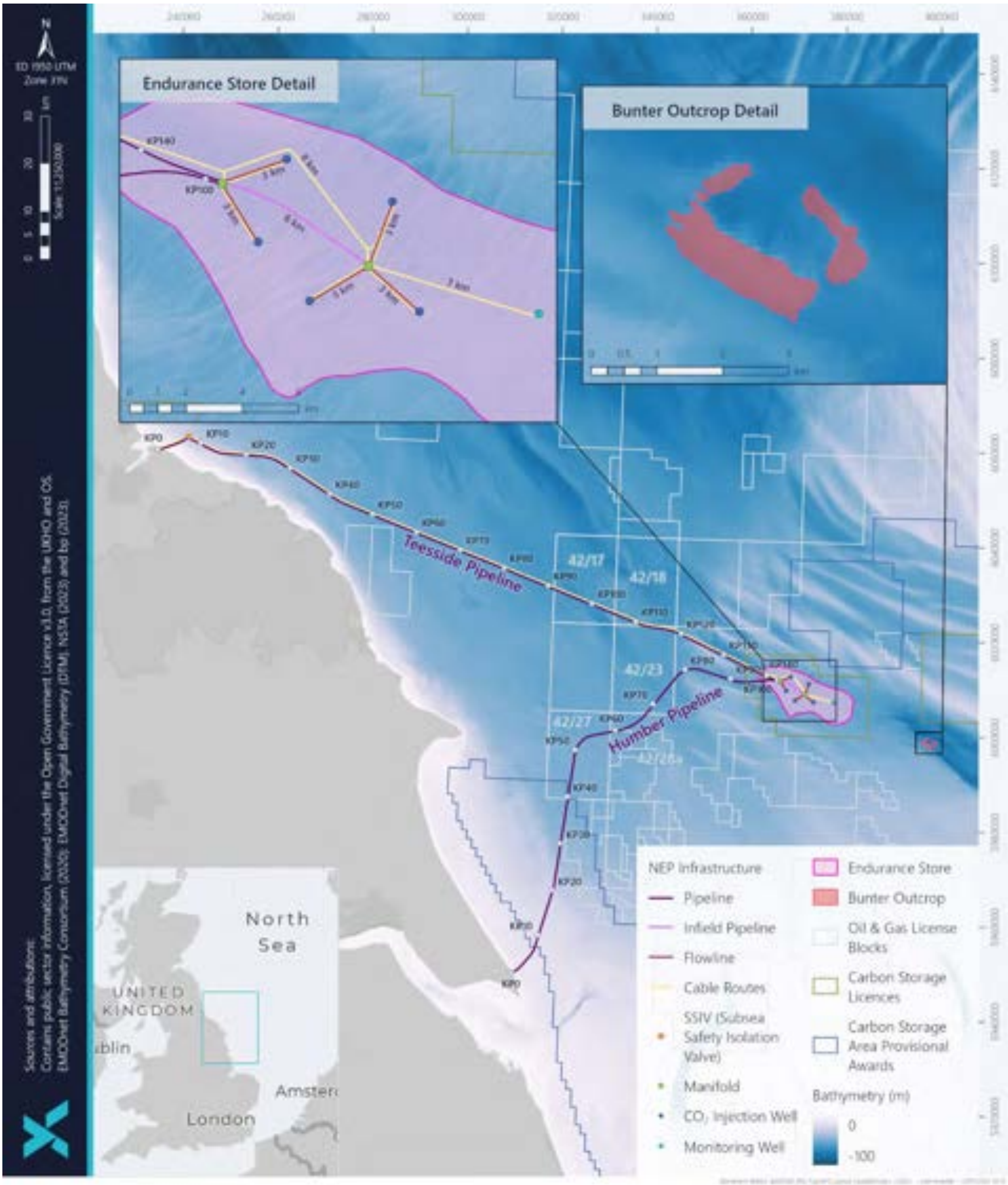

Figure 1-1 - Schematic (to scale) of pipeline routing and infrastructure locations

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).

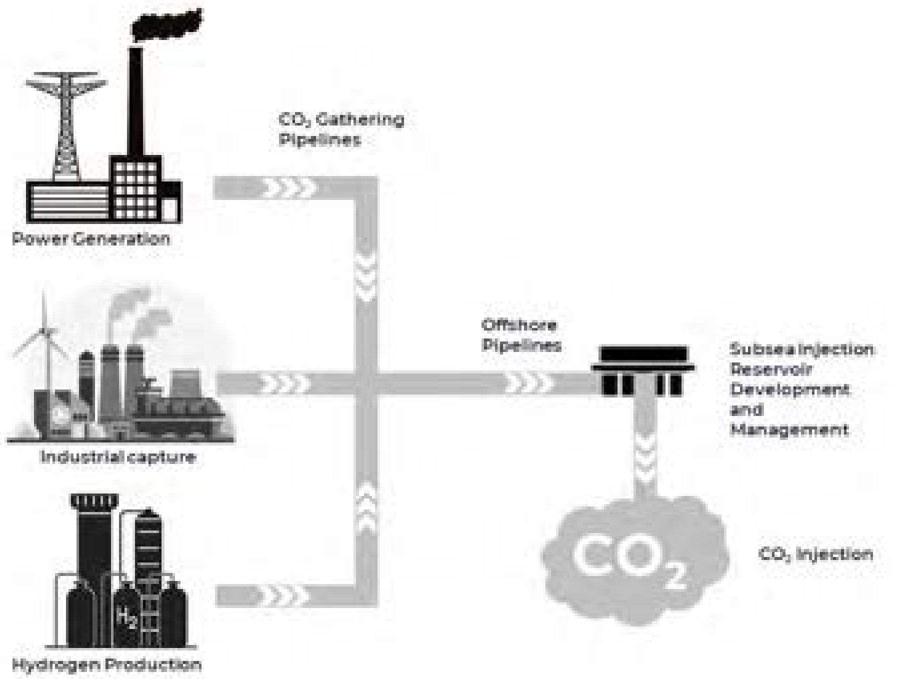

Figure 1-2 - Overview of CO_2 transportation and storage

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[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.

[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

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[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

[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.

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

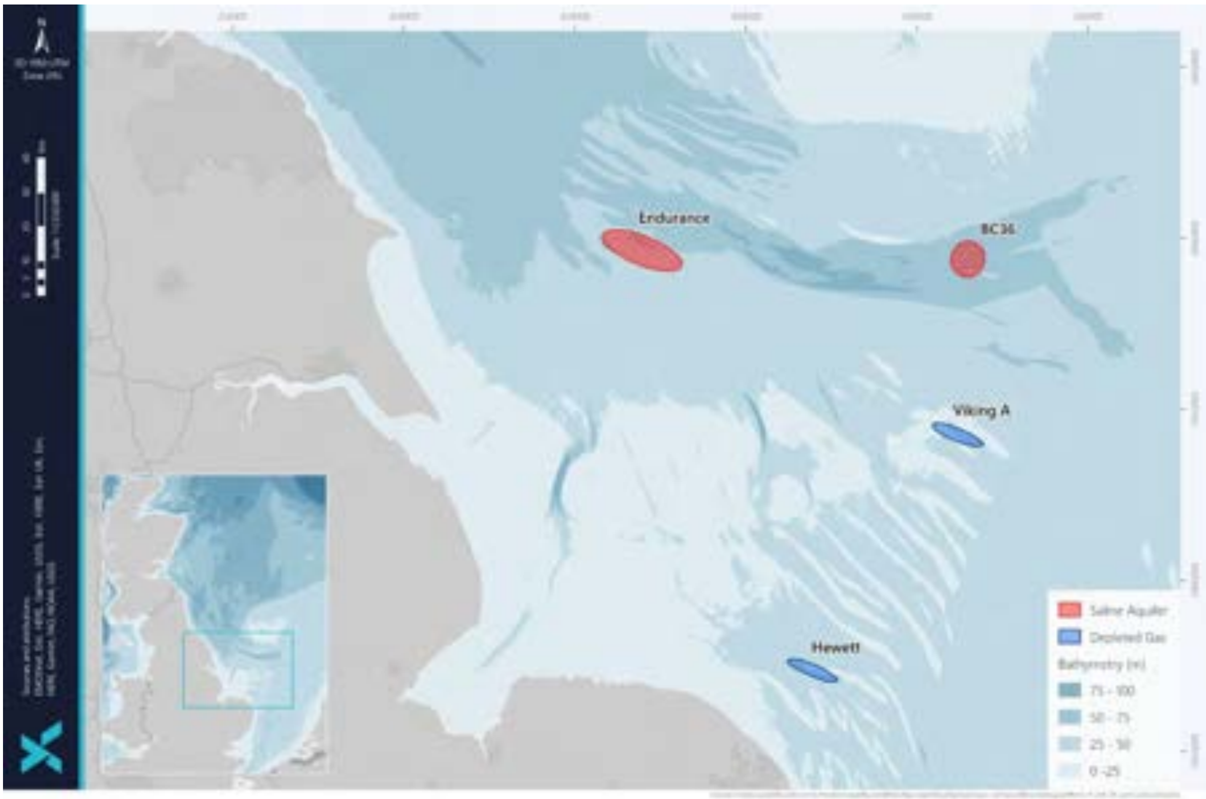

Figure 2-1 - Location of the four potential offshore CO_2 stores

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).

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[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.

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[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).

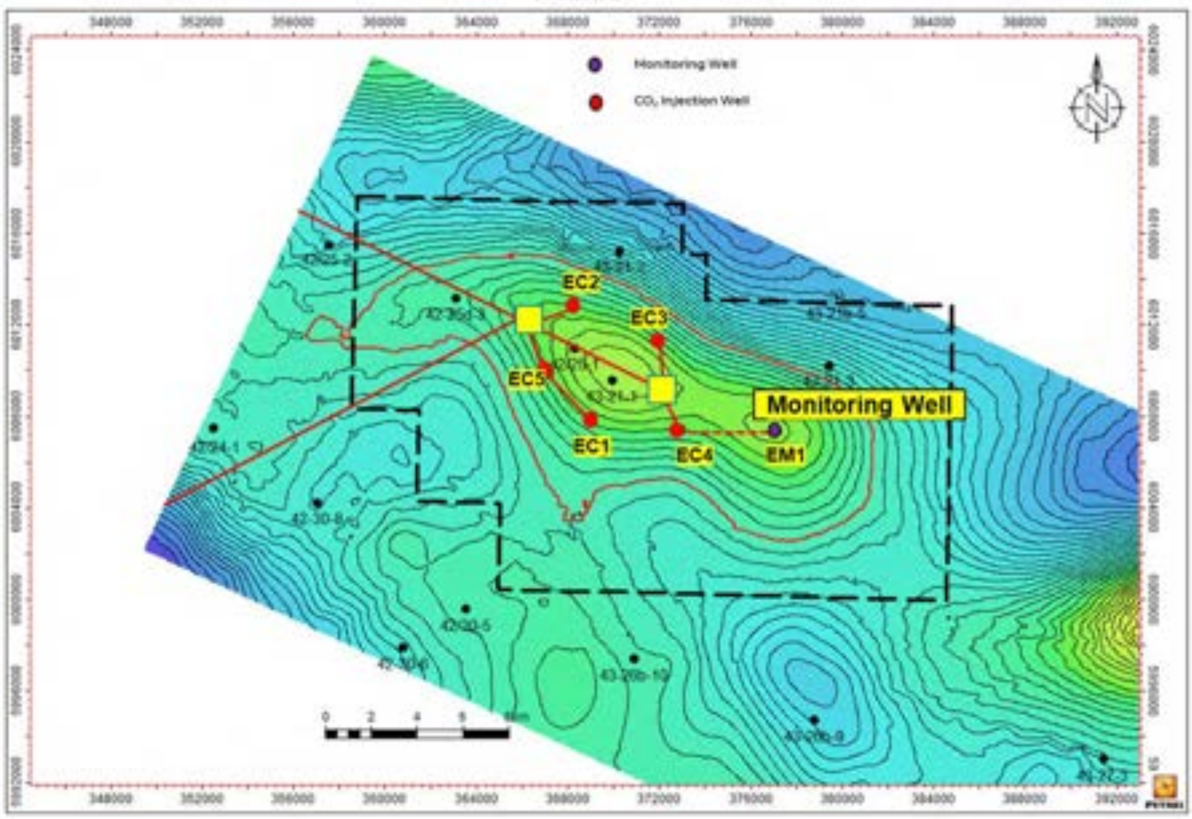

Figure 2-2 - Location of monitoring well in relation to five CO_2 injection wells

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).

[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

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[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, further studies, pipeline failure frequency assessment, refinements in cost estimates and consultee engagement were conducted. These studies and assessments identified sufficient barriers without an SSIV to ensure all possible threats leading to loss of primary containment are as low as reasonably practicable. Therefore, it has been concluded that an SSIV is not required in the design base case. However, no final decision has been made to exclude the SSIV from the Development, should further design work identify scenarios requiring the risk reduction achieved by the installation of an SSIV. For the purposes of the ES therefore, and to ensure assessment of maximum design envelope, it is 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

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[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.

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 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.

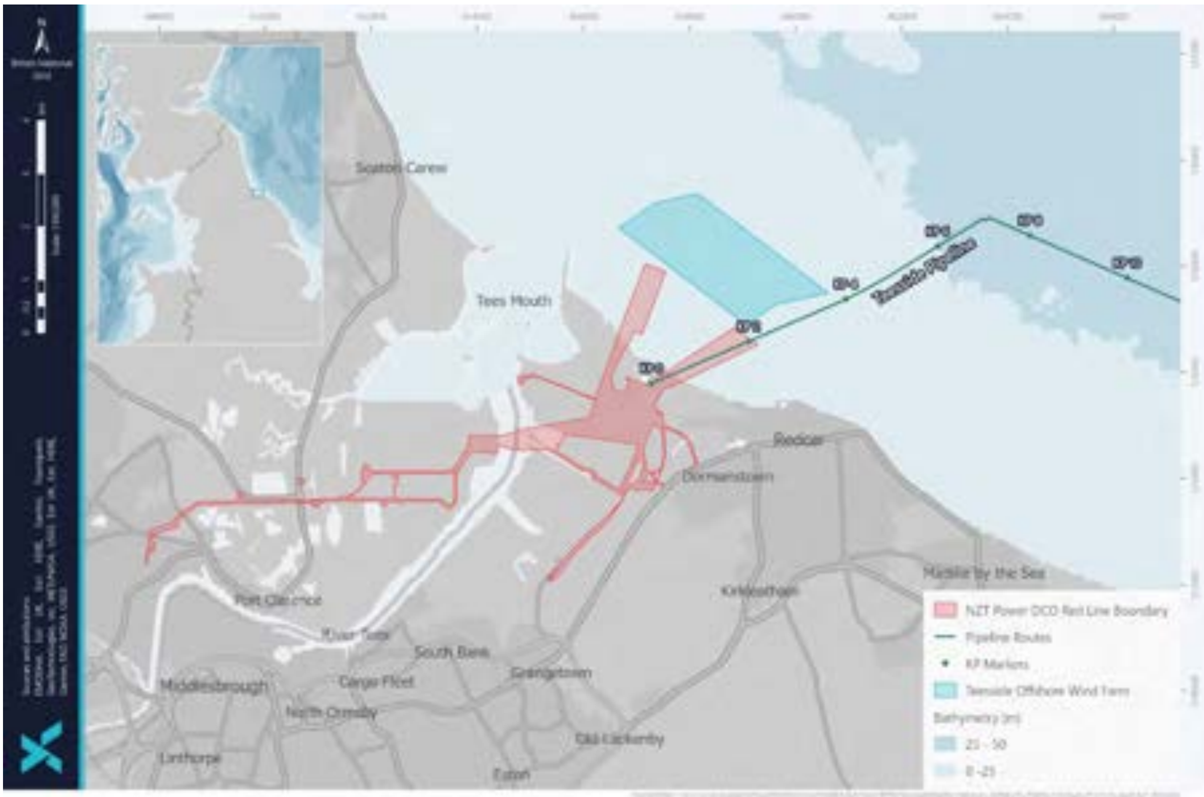

Figure 2-3 - NZT Project DCO red line boundary

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].

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).

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

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

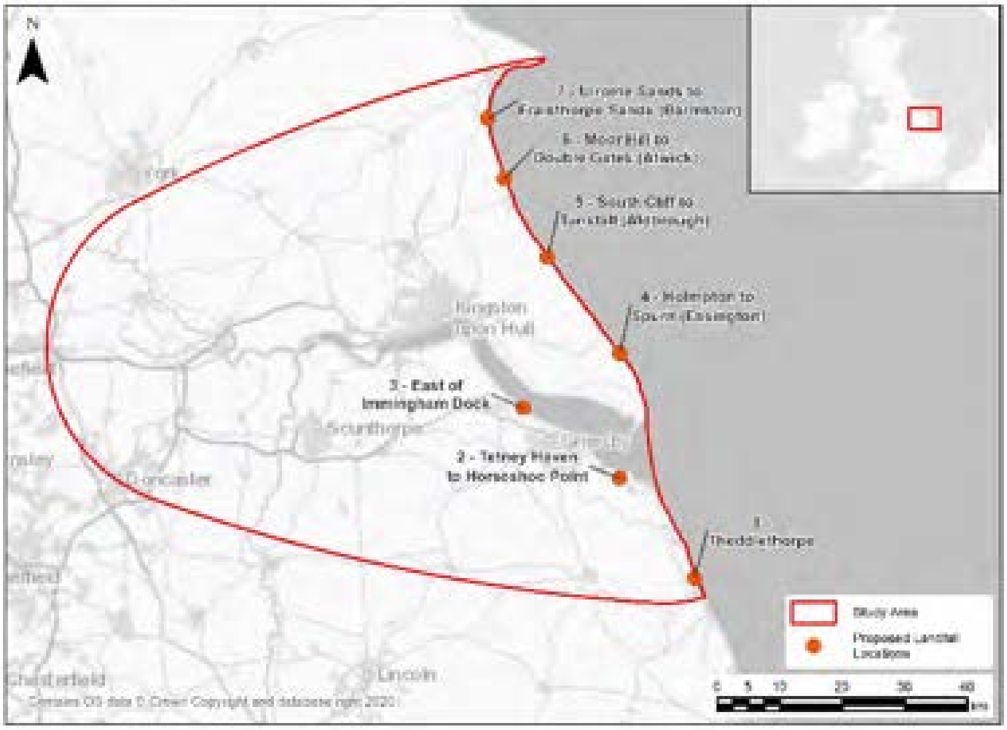

Figure 2-5 - Humber landfall location options evaluated

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.

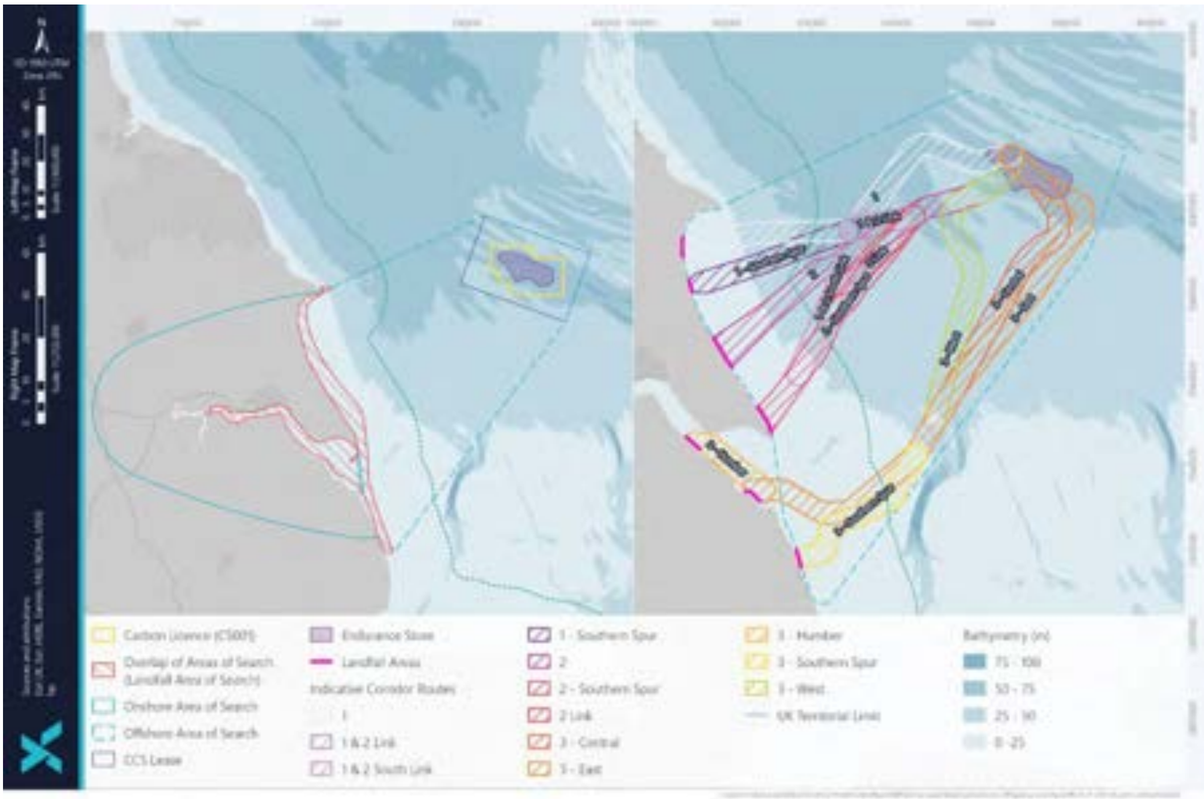

Figure 2-6 - Humber Pipeline route corridor options (after Hartley Anderson, 2020)

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 progresses 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.

[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*

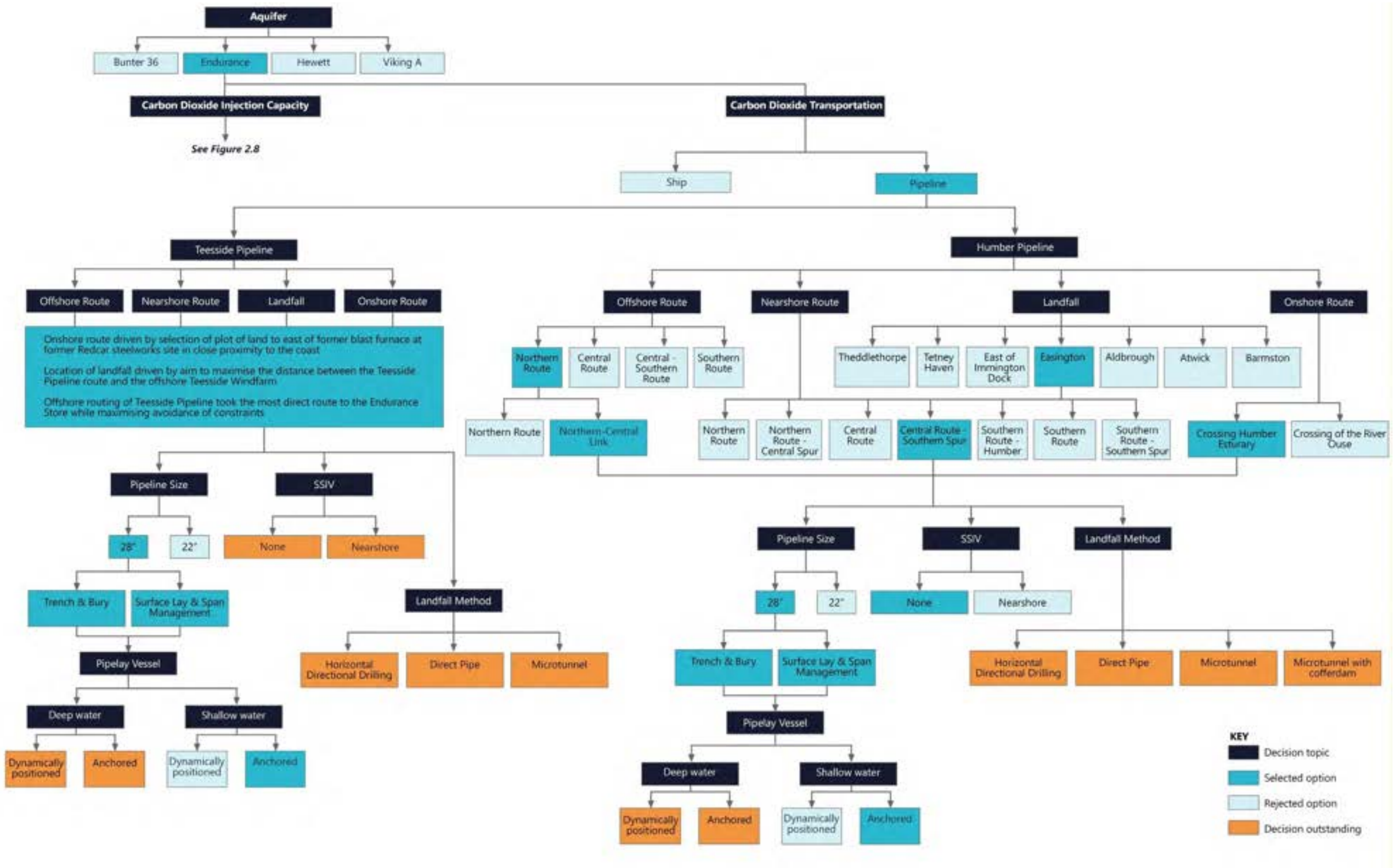

Figure 2-7 - Consideration of alternatives: Aquifer and CO_2 transportation

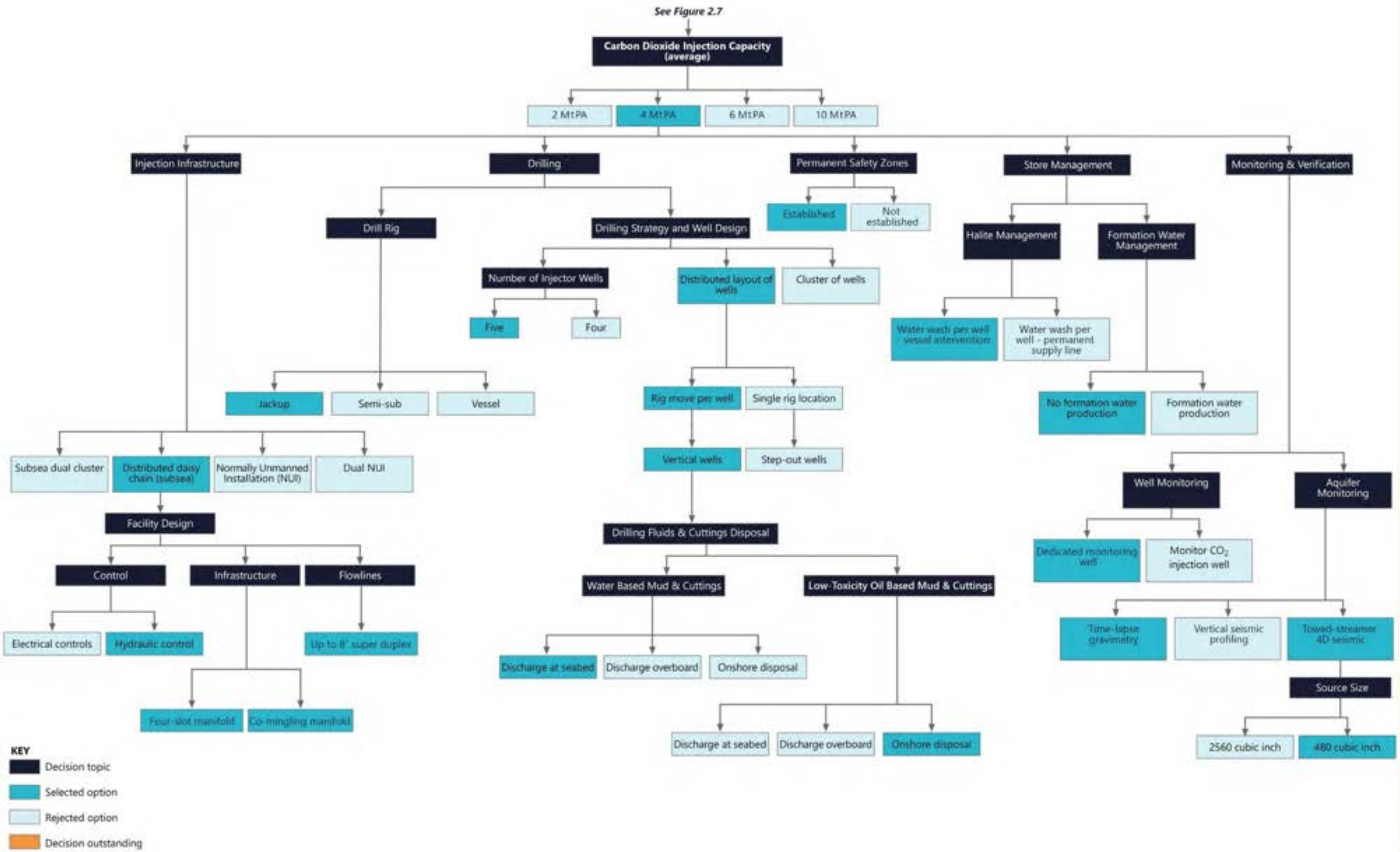

Figure 2-8 - Consideration of alternatives: CO_2 injection

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).

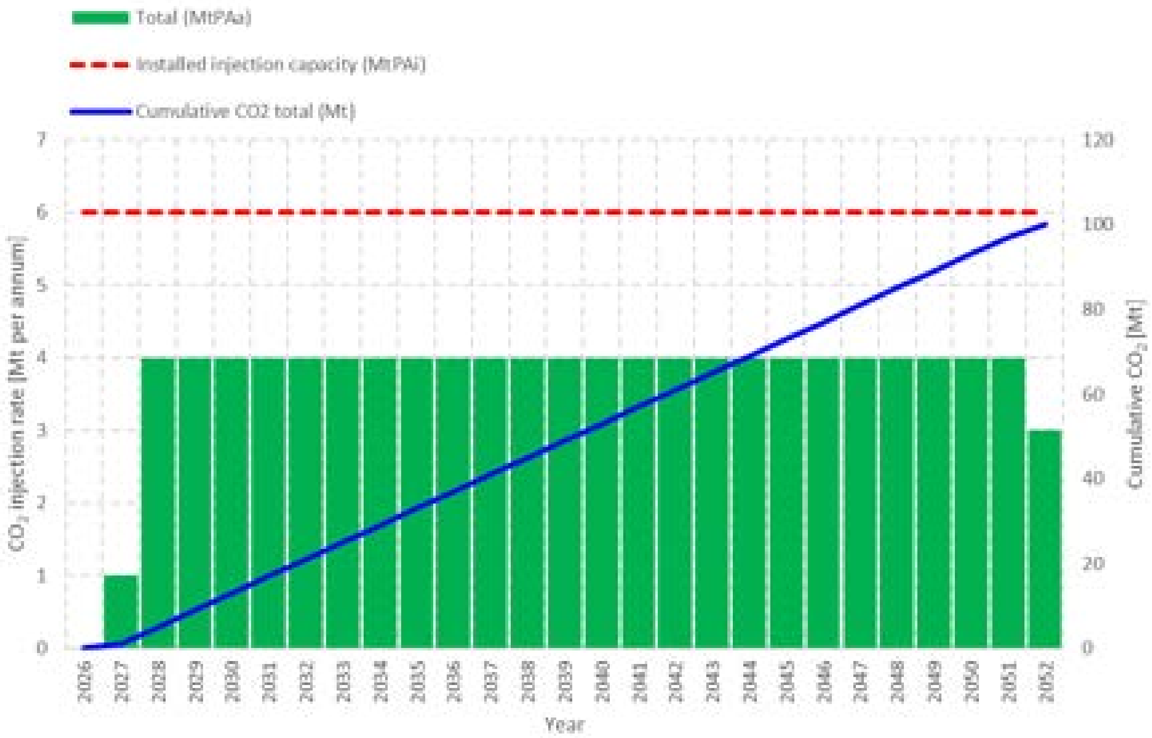

Figure 3-1 - Endurance CO_2 Injection Profile

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 3-2.

[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.

	2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Preparatory Works & Landfalls Construction												
Pipeline & Subsea Infrastructure Installation												
Drilling												
Commissioning												
First Injection												

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.

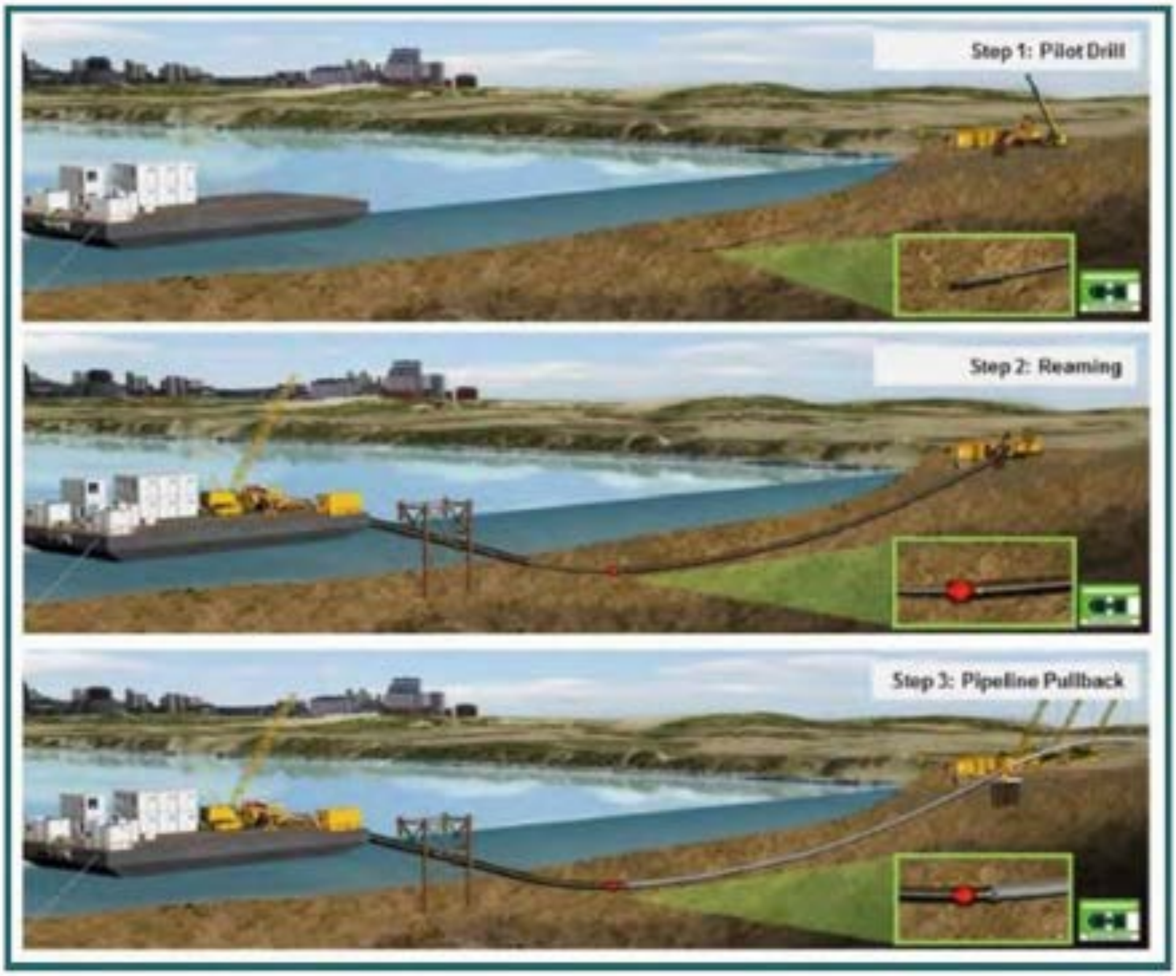

Figure 3-4 - HDD schematic showing the phases of pilot drill, reaming and pipeline and the temporary trestle structure required to support the casing pipe during reaming and pipeline pullback (image courtesy of Herrenknecht and SDL)

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.

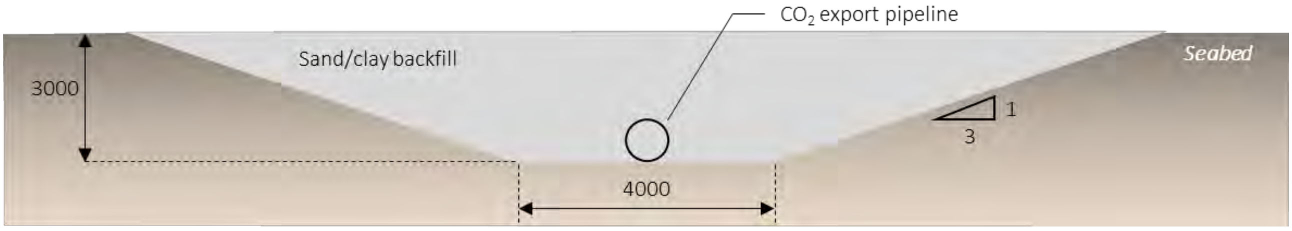

Figure 3-7 - Illustration of likely pre-cut trench (in mm)

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

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[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.

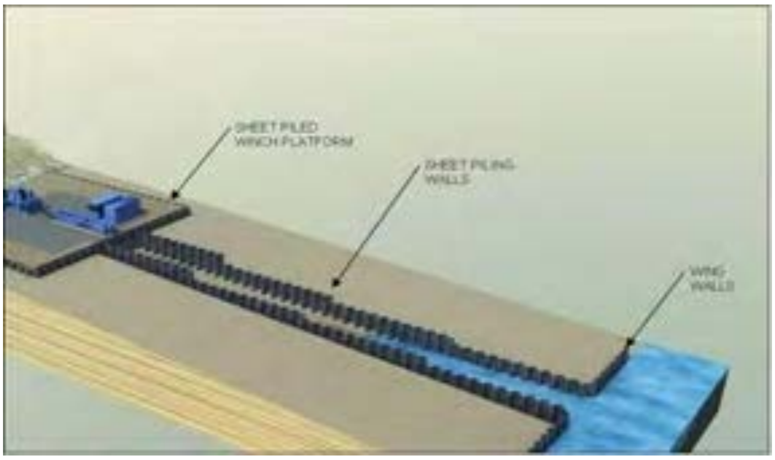

Figure 3-11 - Example of beach crossing cofferdam and working platform

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.

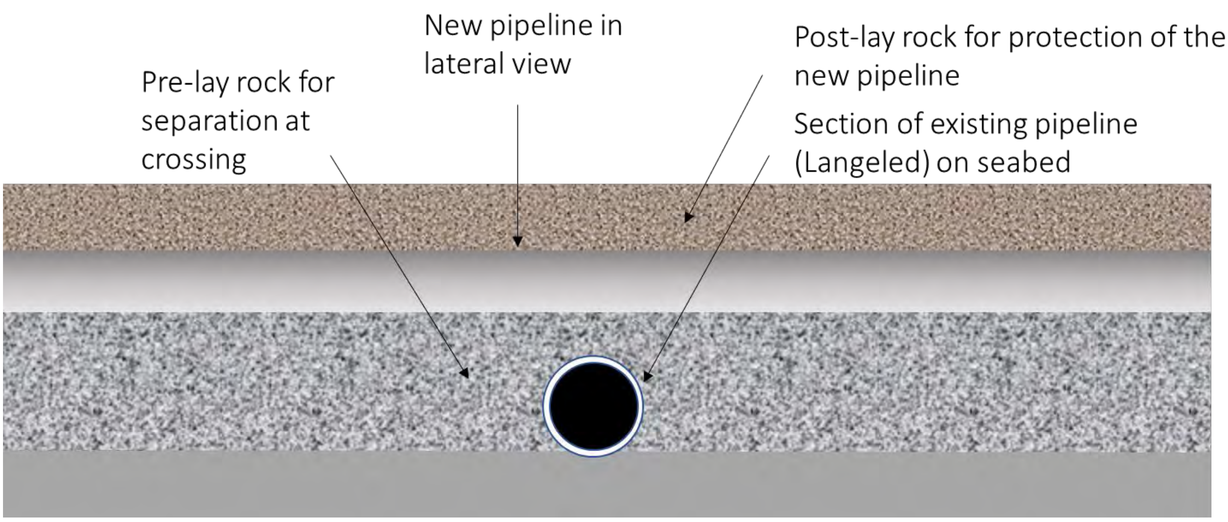

Figure 3-13 - Typical crossing of surface infrastructure (Langeled pipeline)

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[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

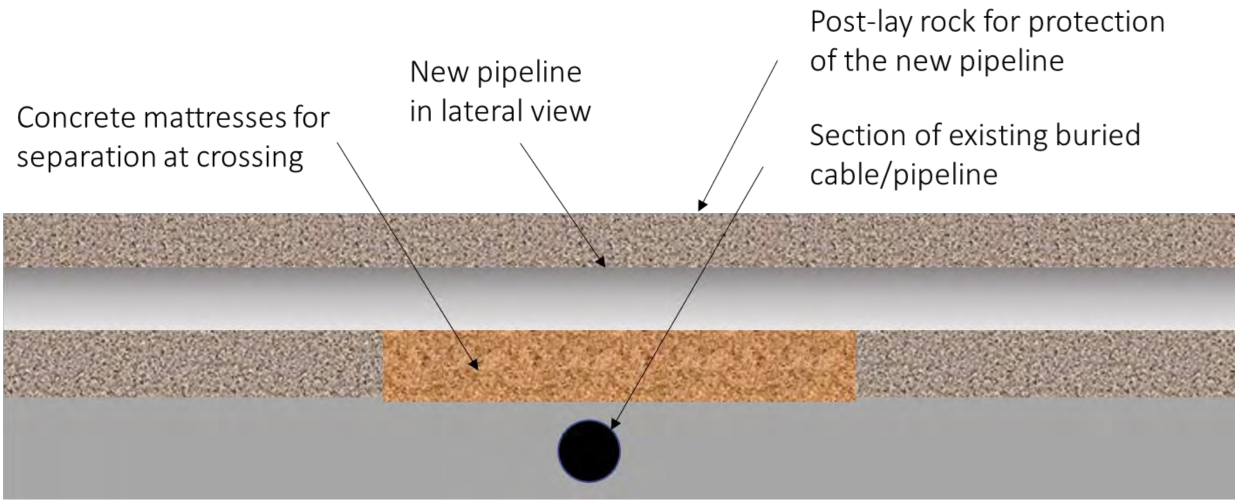

Figure 3-14 - Typical crossing of buried infrastructure

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.

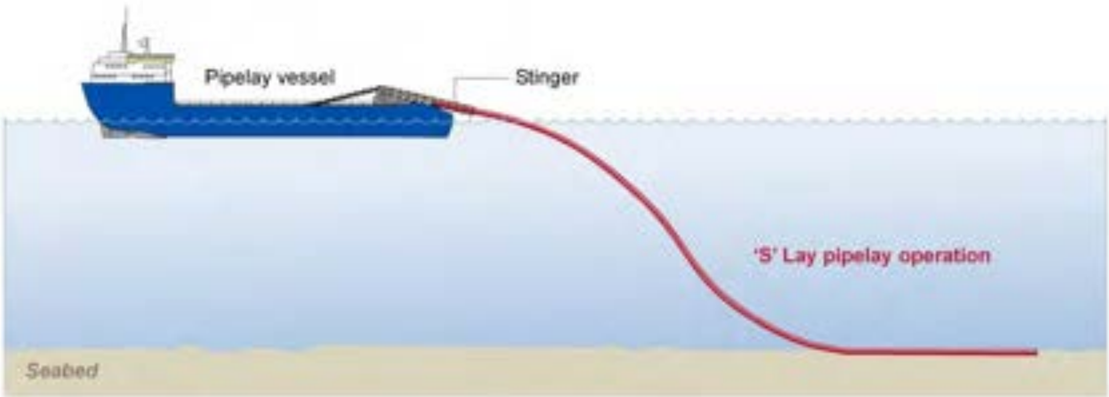

Figure 3-16 - Typical 'S' lay installation

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.

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[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.

[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.

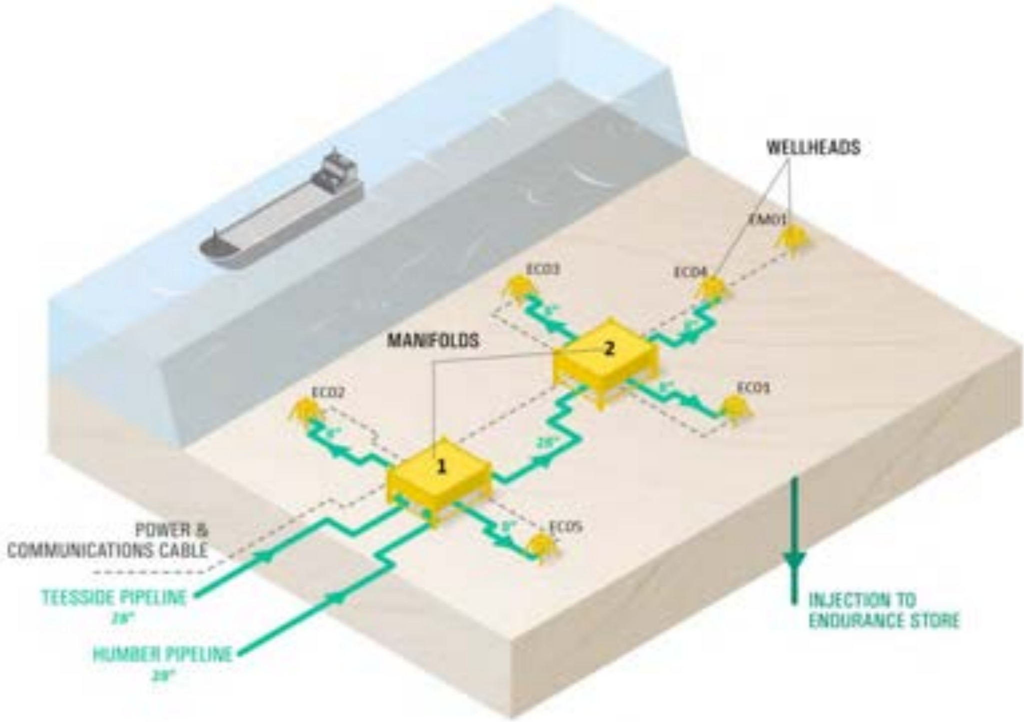

Figure 3-17 - Schematic of the subsea infrastructure at the Endurance Store area (not to scale) showing the crossover co-mingling manifold (1) and the four-slot manifold (2)

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

[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.

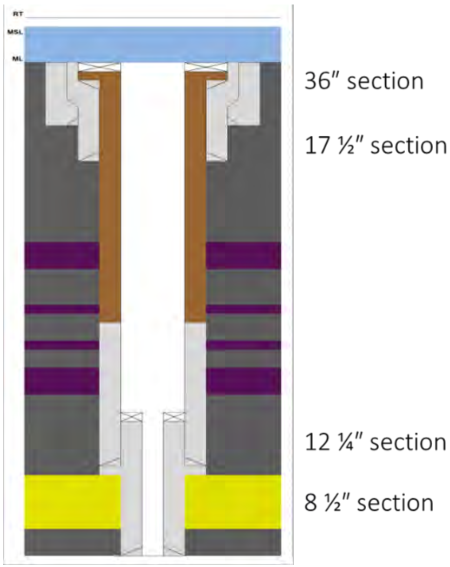

Figure 3-18 - Development well schematic

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

[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.

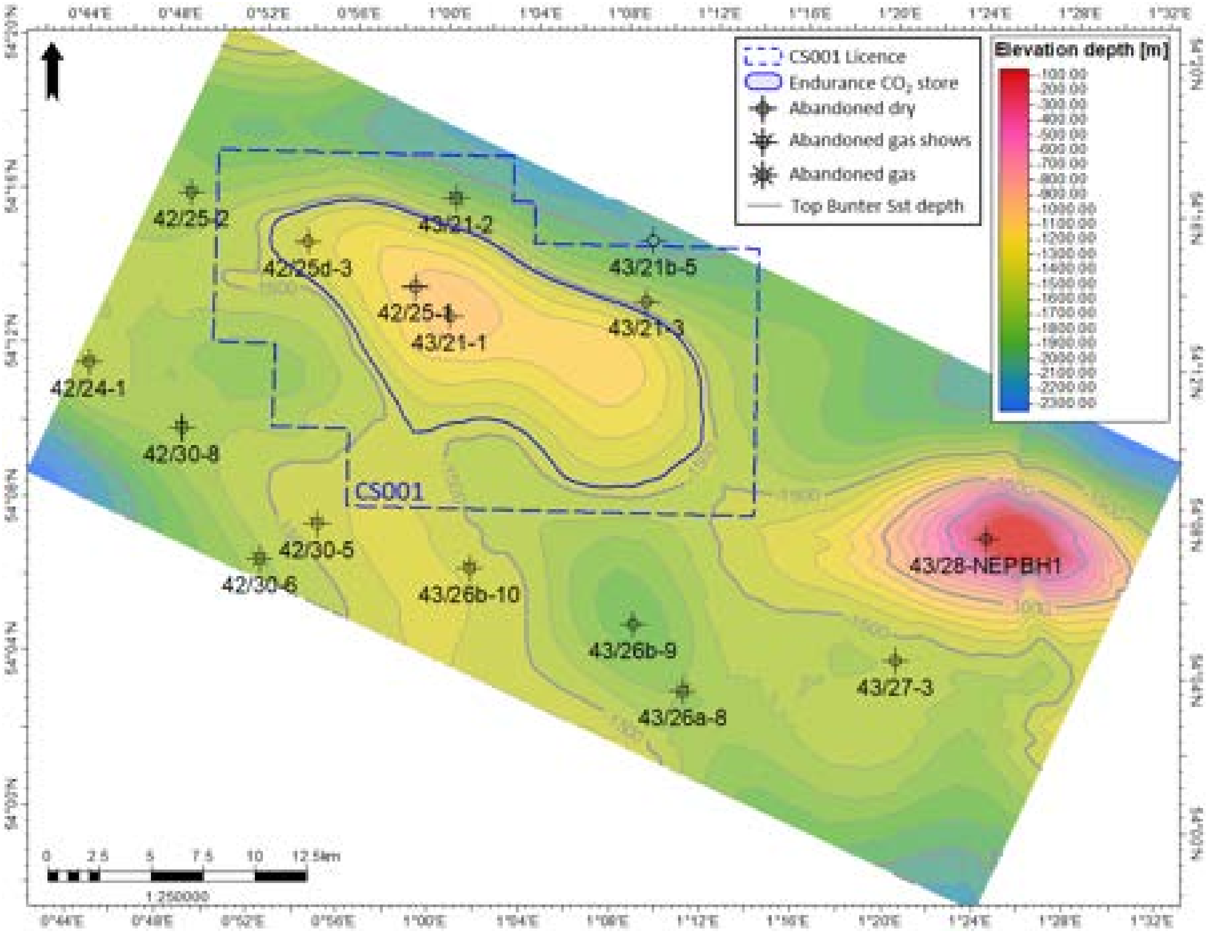

Figure 3-19 - Top Bunter structural map of the vicinity of the Endurance structure

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

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[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.

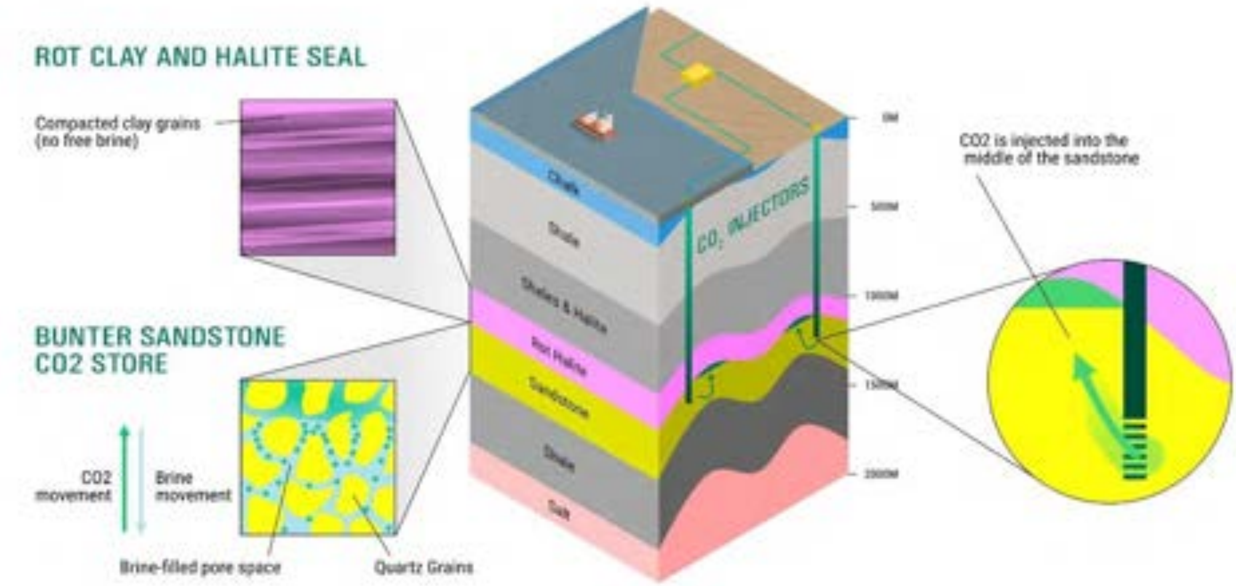

Figure 3-20 - Endurance Store cross-section and Development overview

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.

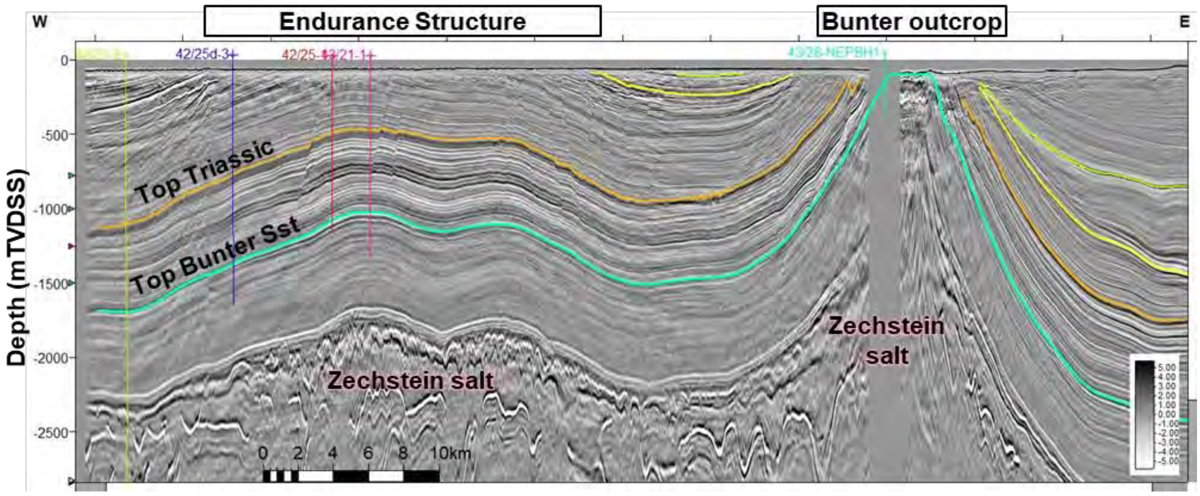

Figure 3-21 - Cross-section from Endurance Store structure to outcrop area, from seismic imagery

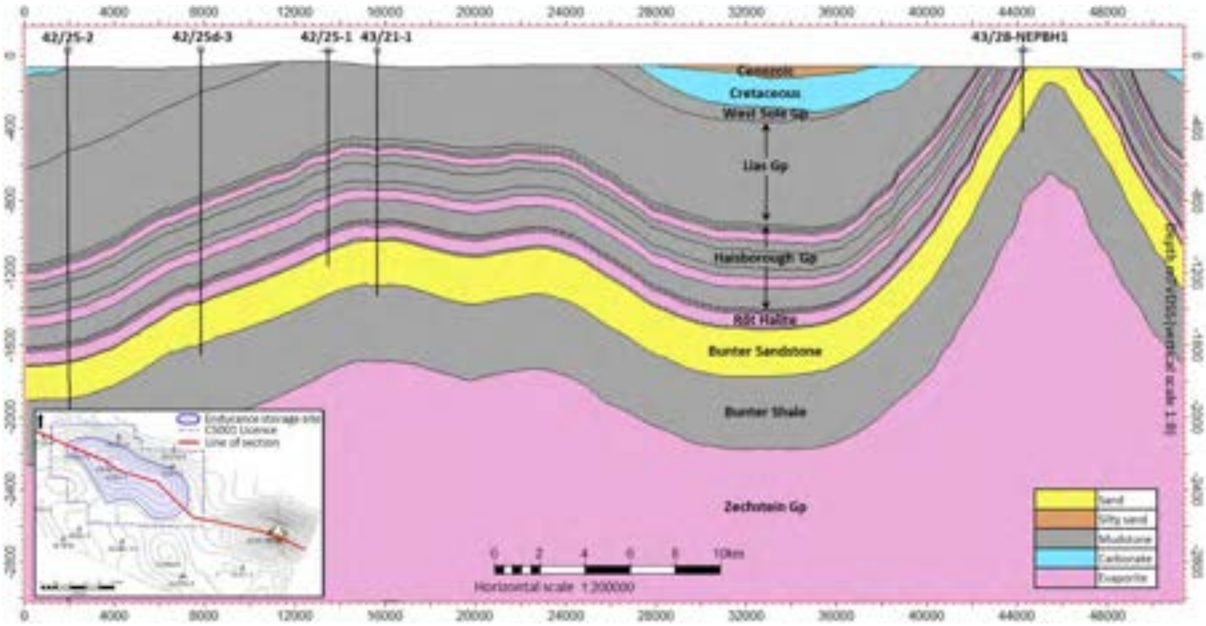

Figure 3-22 - Cross-section through Endurance Store structure showing Bunter Sandstone Formation occurring at the seabed and the relative location of previous (legacy) wells

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

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[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 approx. 80 cm diameter at the top, approx. 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.

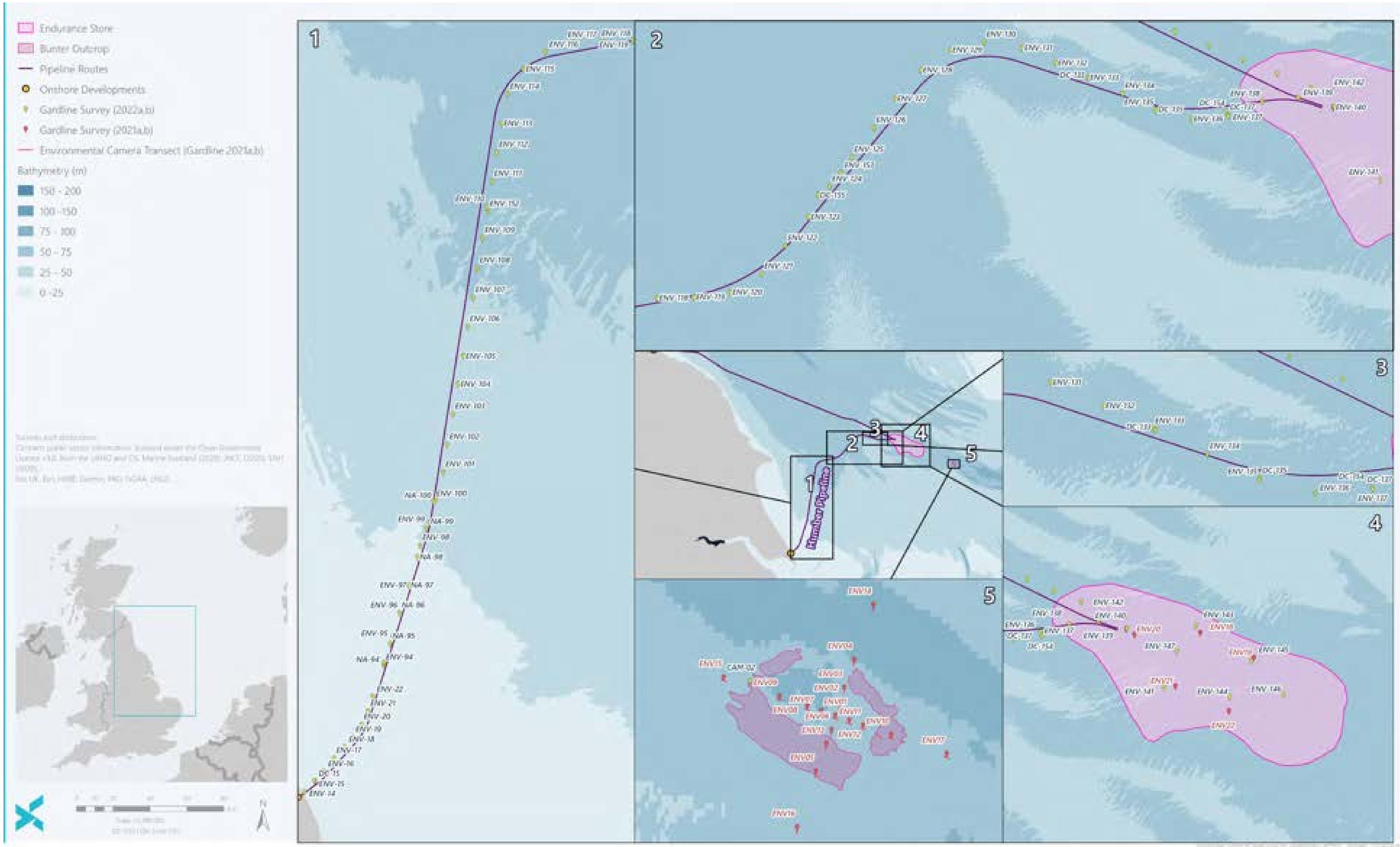


Figure 4-1 - Survey sample locations across the Endurance Store (inset 4), Bunter Sandstone Outcrop (inset 5) and along the Humber Pipeline route

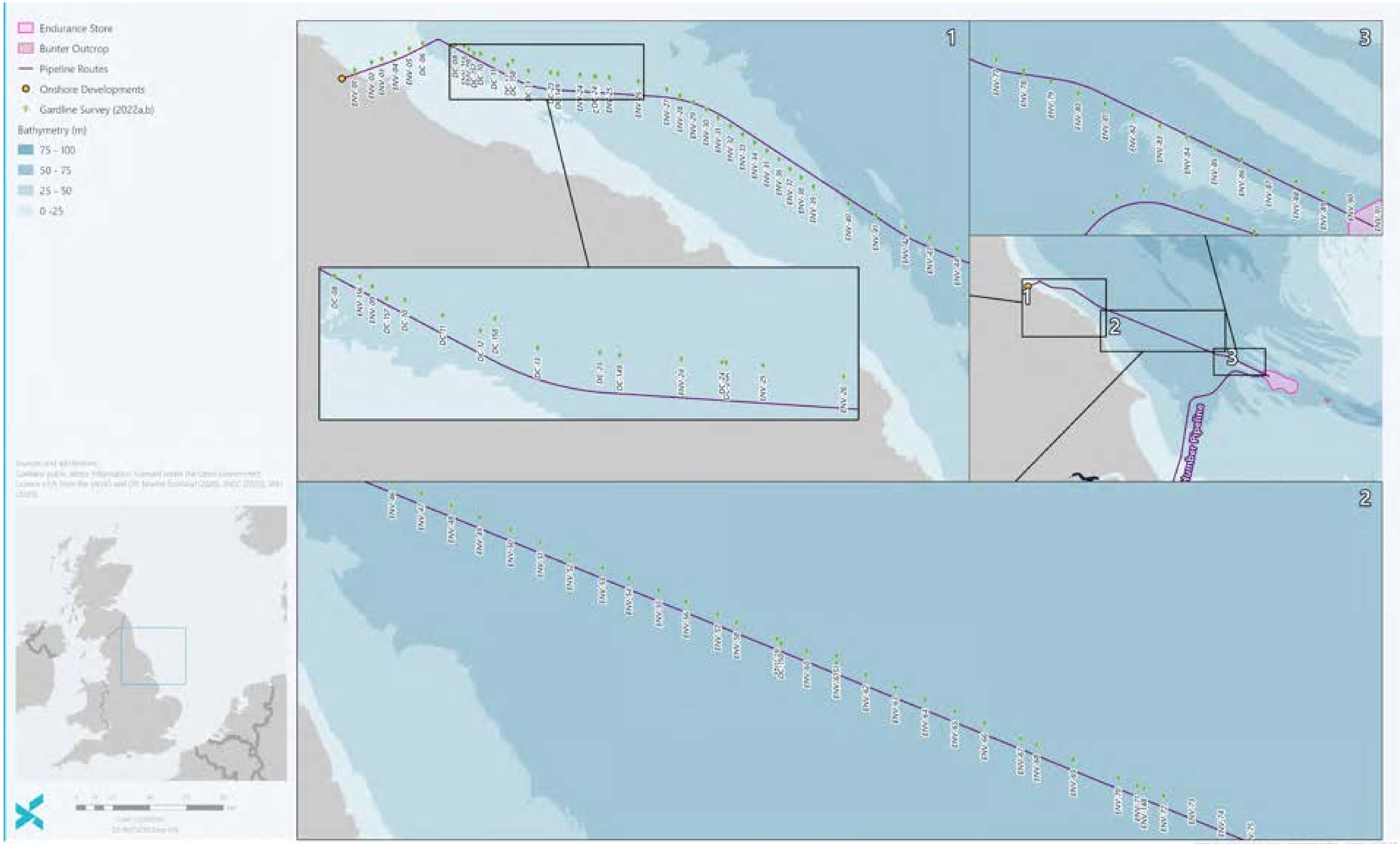


Figure 4-2 - Survey sample locations along the Teesside Pipeline route

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.

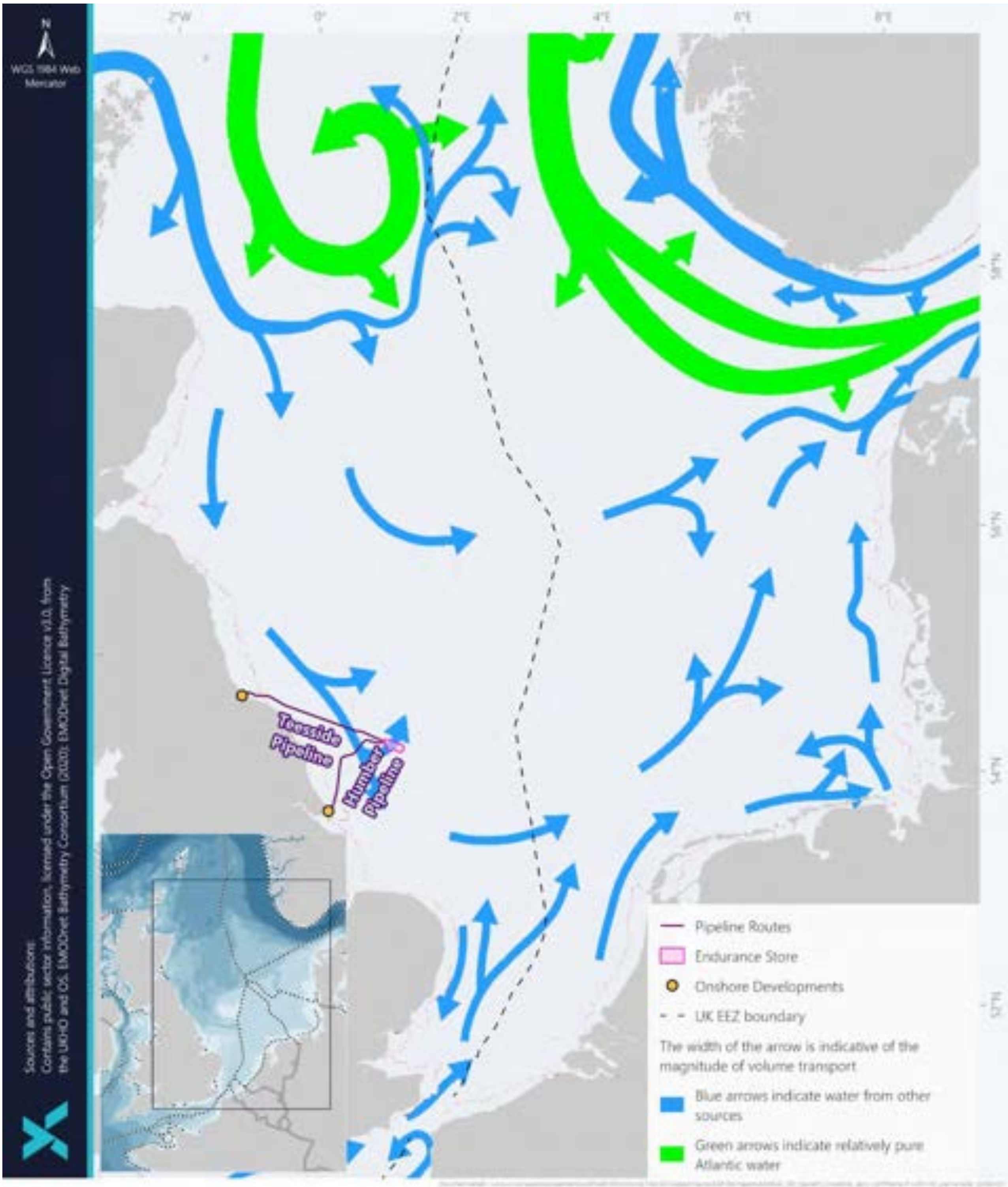


Figure 4-3 - Circulation patterns in the North Sea

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).

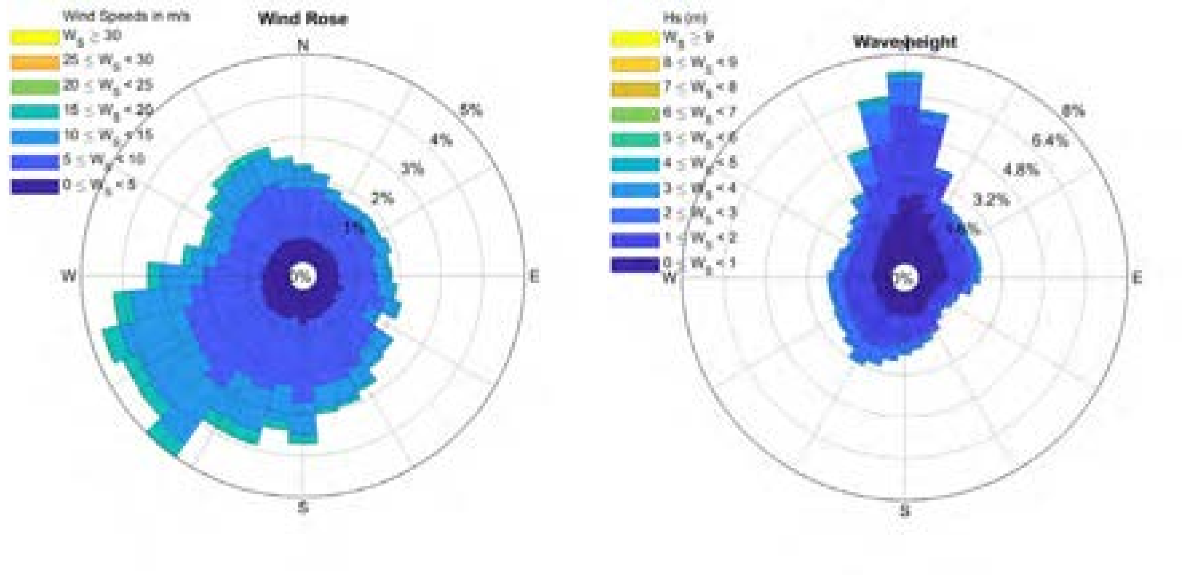


Figure 4-4 - Mean wind direction and speed and mean significant wave height and direction (coming from) at the Endurance Store area (bp, 2020c)

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.

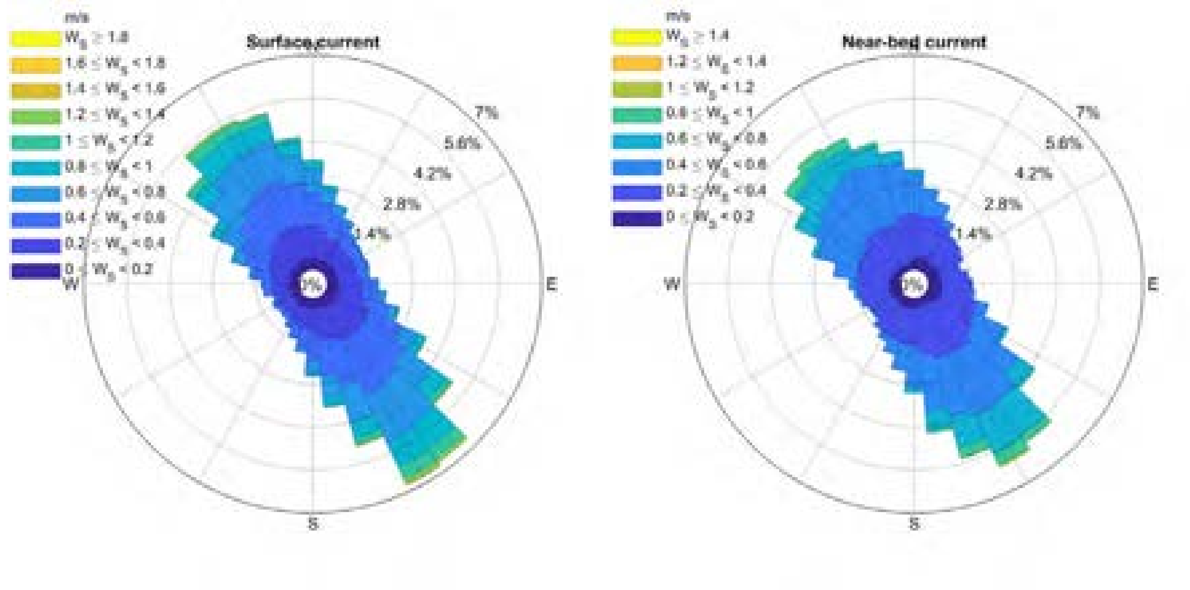


Figure 4-5 - Surface and near-bed annual current speeds at the Endurance Store (going towards) (bp, 2020c)

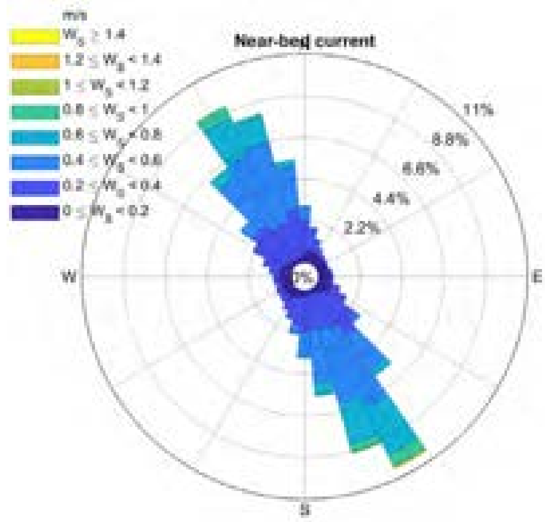
4.3.1.2 Teesside Pipeline

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).

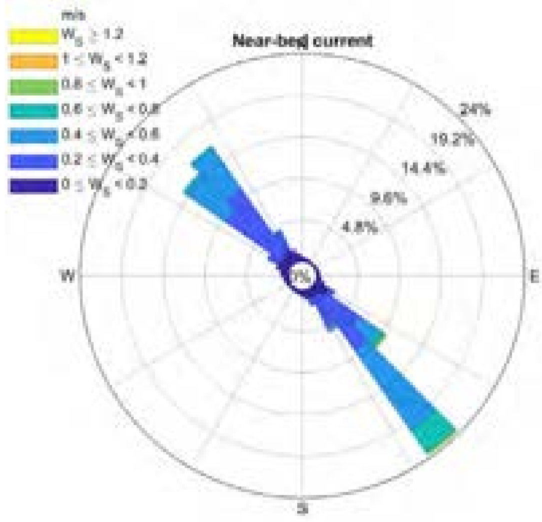
Modelled surface currents under operational conditions along the Teesside Pipeline route increase with distance from shore. In terms of frequency of occurrence, currents at the shore are most likely to be between 0.1 and 0.4 m/s, compared to speeds of 0.3-0.5 m/s nearer the Store (bp, 2020c). Figure 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).

a)



b)



c)

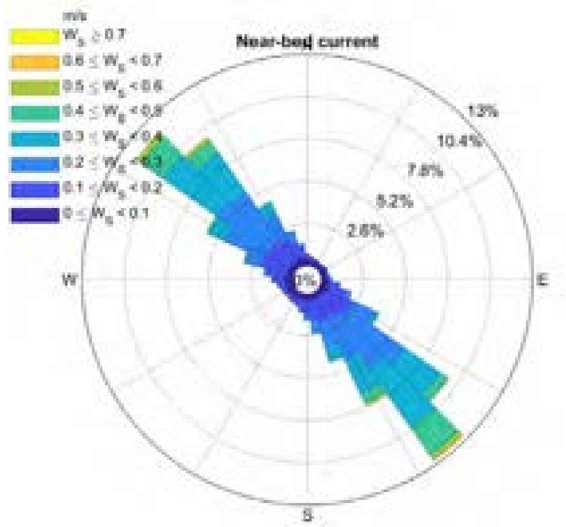


Figure 4-6 - Near-bed annual current speeds (going towards) along the Teesside Pipeline route (a) close to the Endurance Store (b) at a mid-point along the pipeline and (c) close to shore (bp, 2020c)

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)

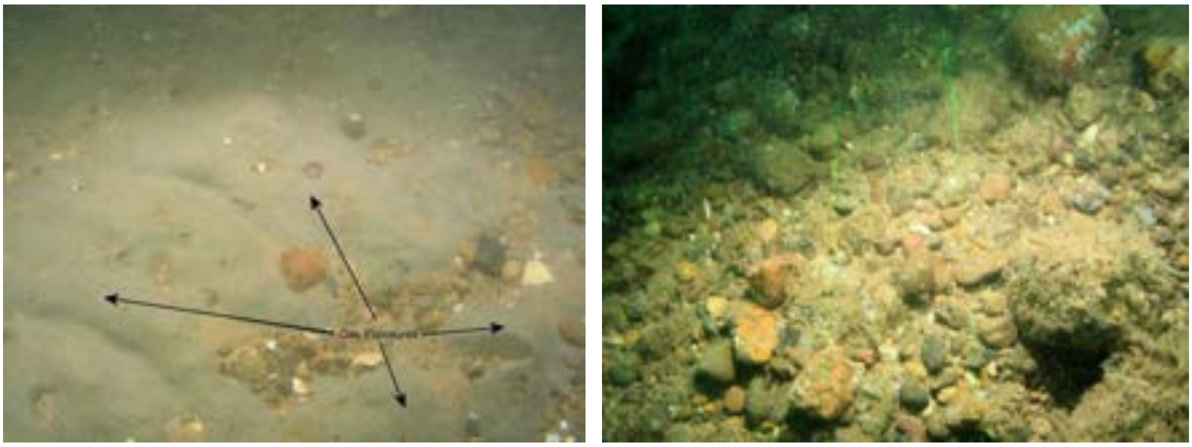


Figure 4-7 - (a) Clay exposures at ENV-15 and (b) typical cobble pavement proximal to a clay ridge feature (XOGS, 2023)

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).

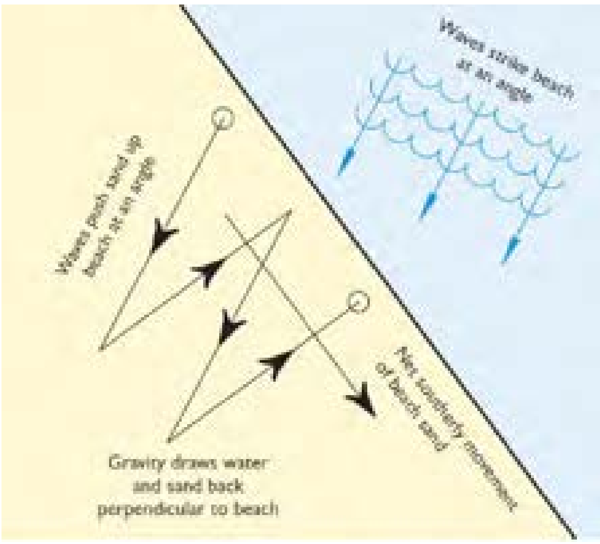
4.3.4.3 Humber Pipeline

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.

a)



b)

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.

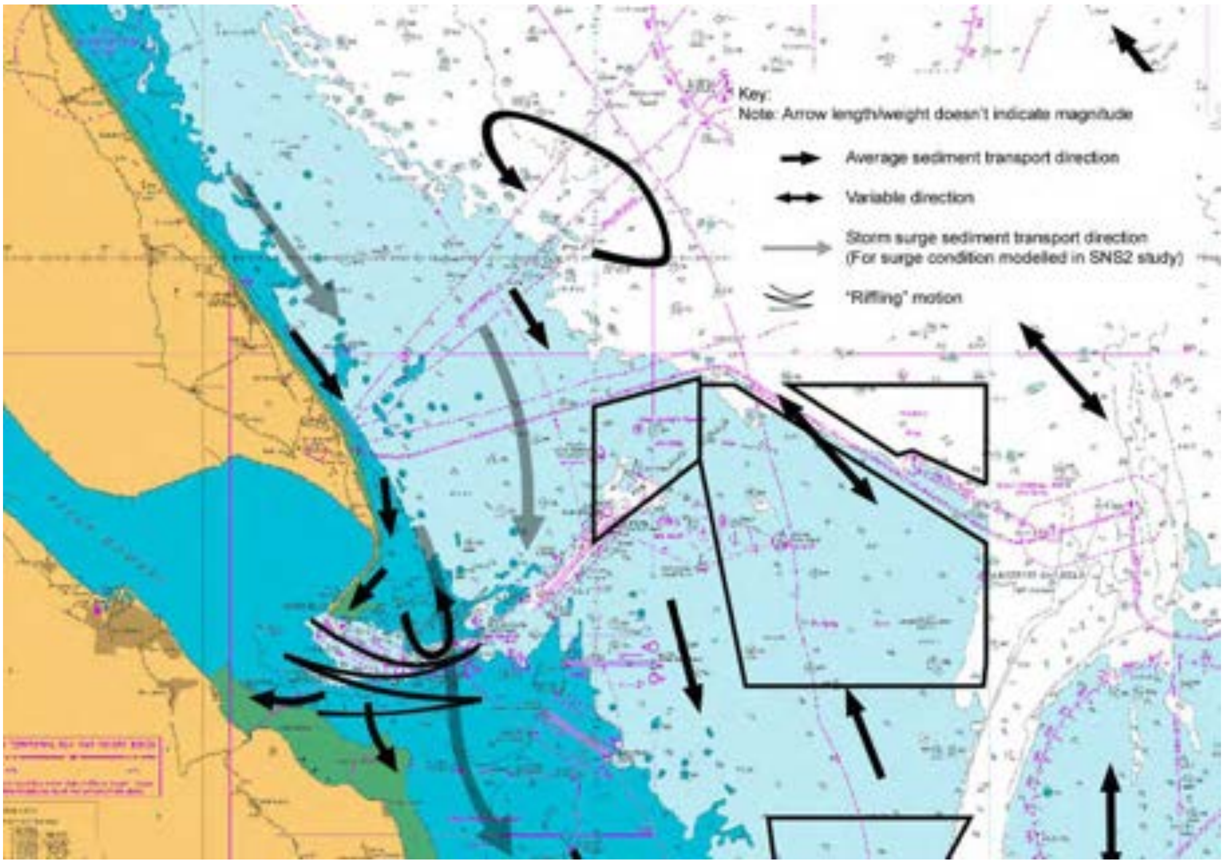


Figure 4-9 - Schematic sediment transport pathways for South Holderness, the entrance to the Humber and North Lincolnshire (the black boxes show licensed aggregate dredging areas) (HR Wallingford *et al.*, 2002)

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.

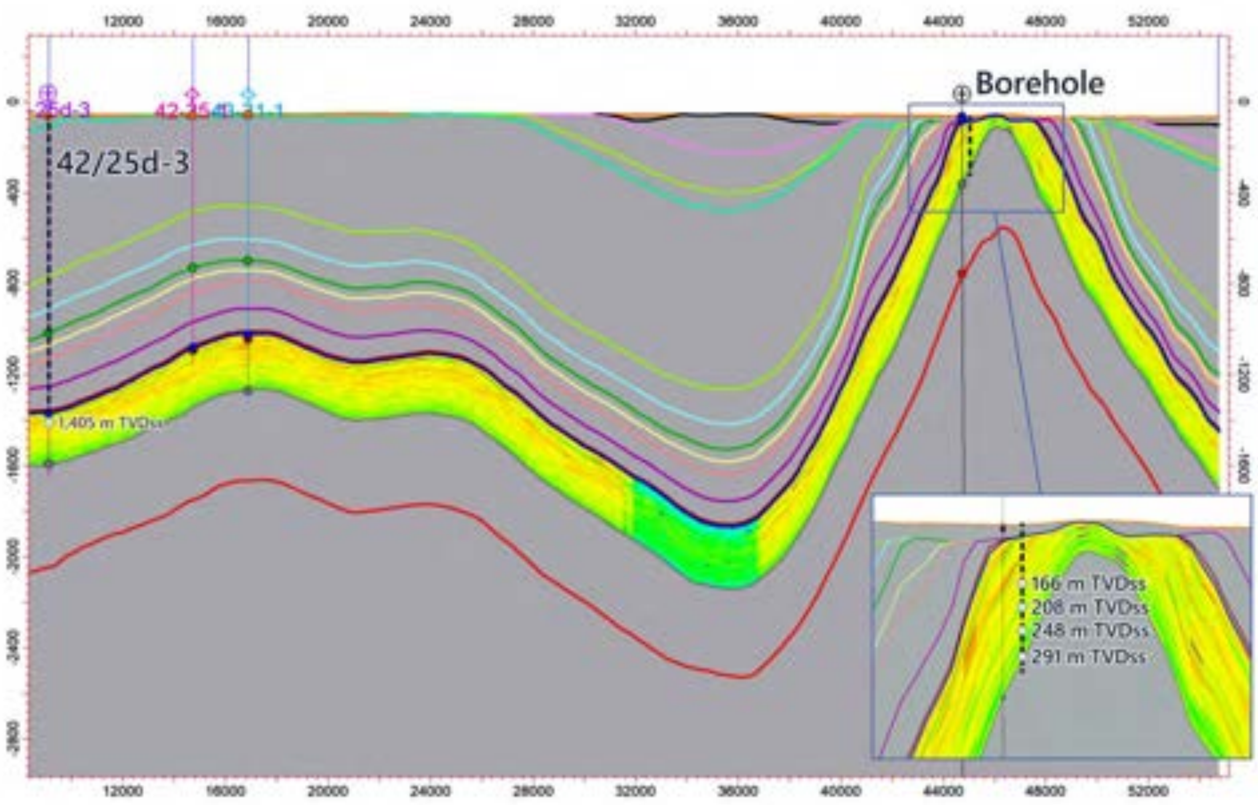


Figure 4-10 - Locations where Store and Outcrop Formation Water samples were obtained from the Bunter Sandstone Formation (True Vertical Depth subsurface, TVDss). Yellow and green shading represents Formation Water. Coloured lines represent boundaries of different subsurface layers.

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.

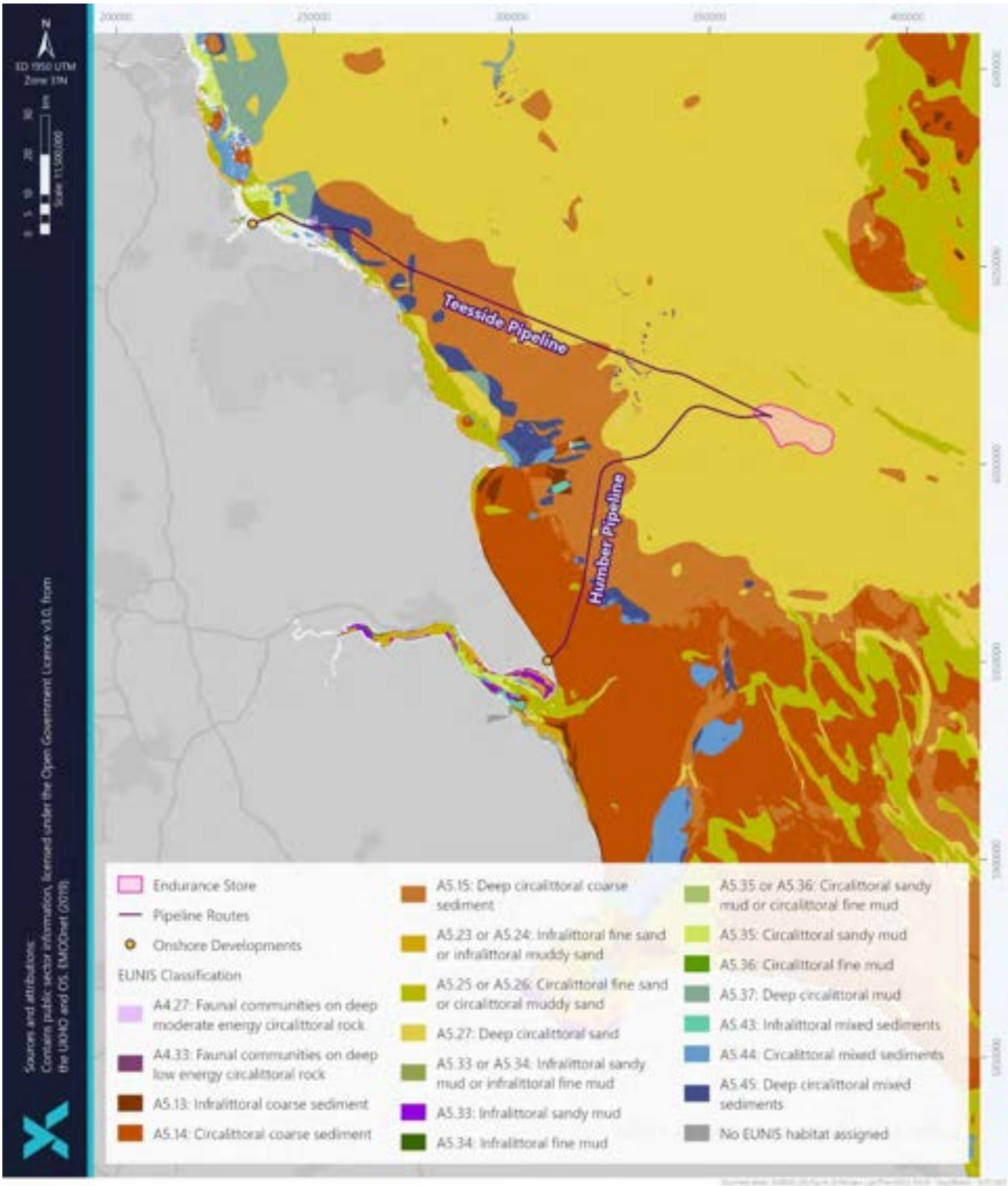


Figure 4-11 - EUNIS habitats across the Development area

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.

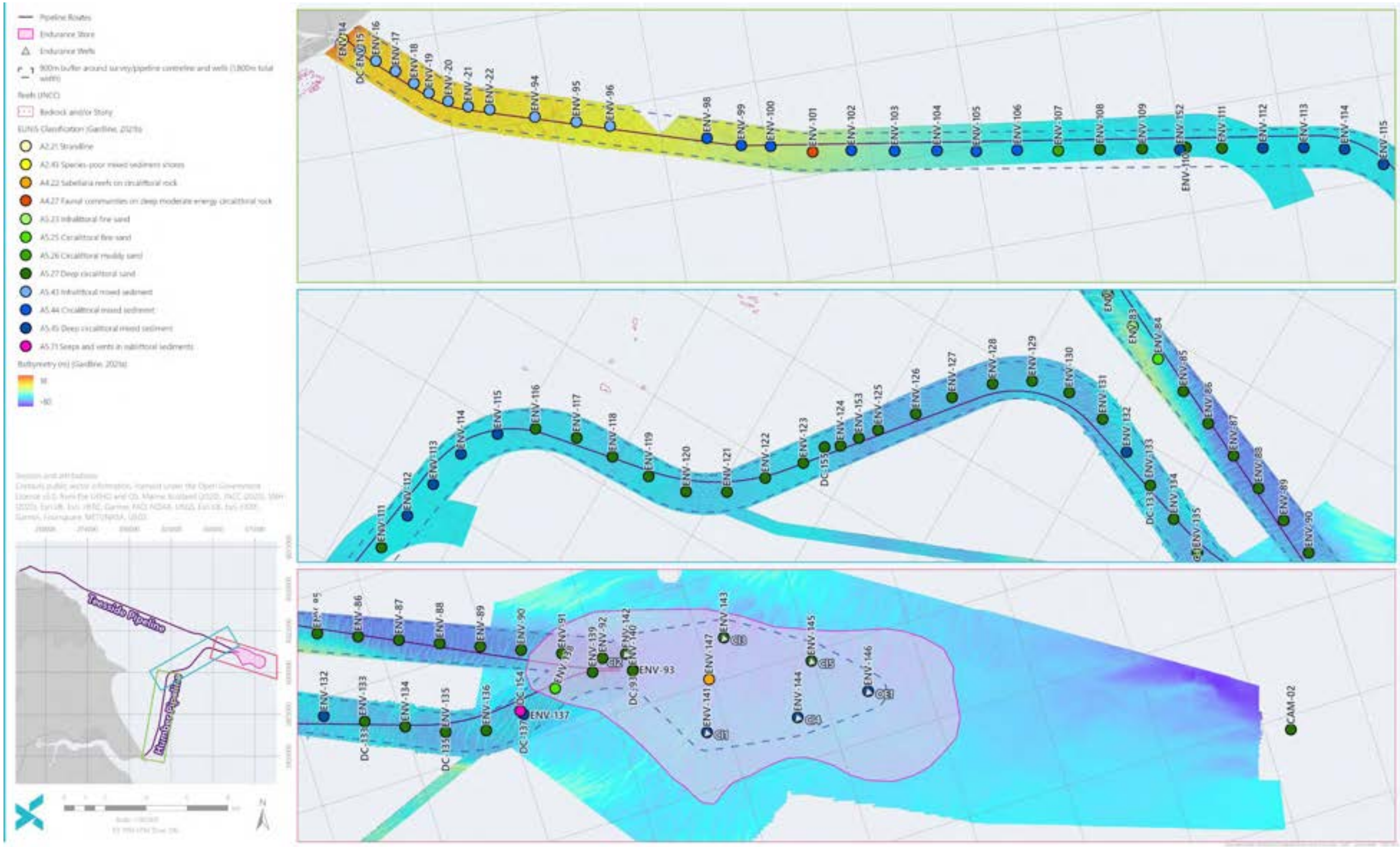


Figure 4-12 - EUNIS habitats at the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

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

ENV21

ENV05

ENV10

ENV12

ENV15

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).

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[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)

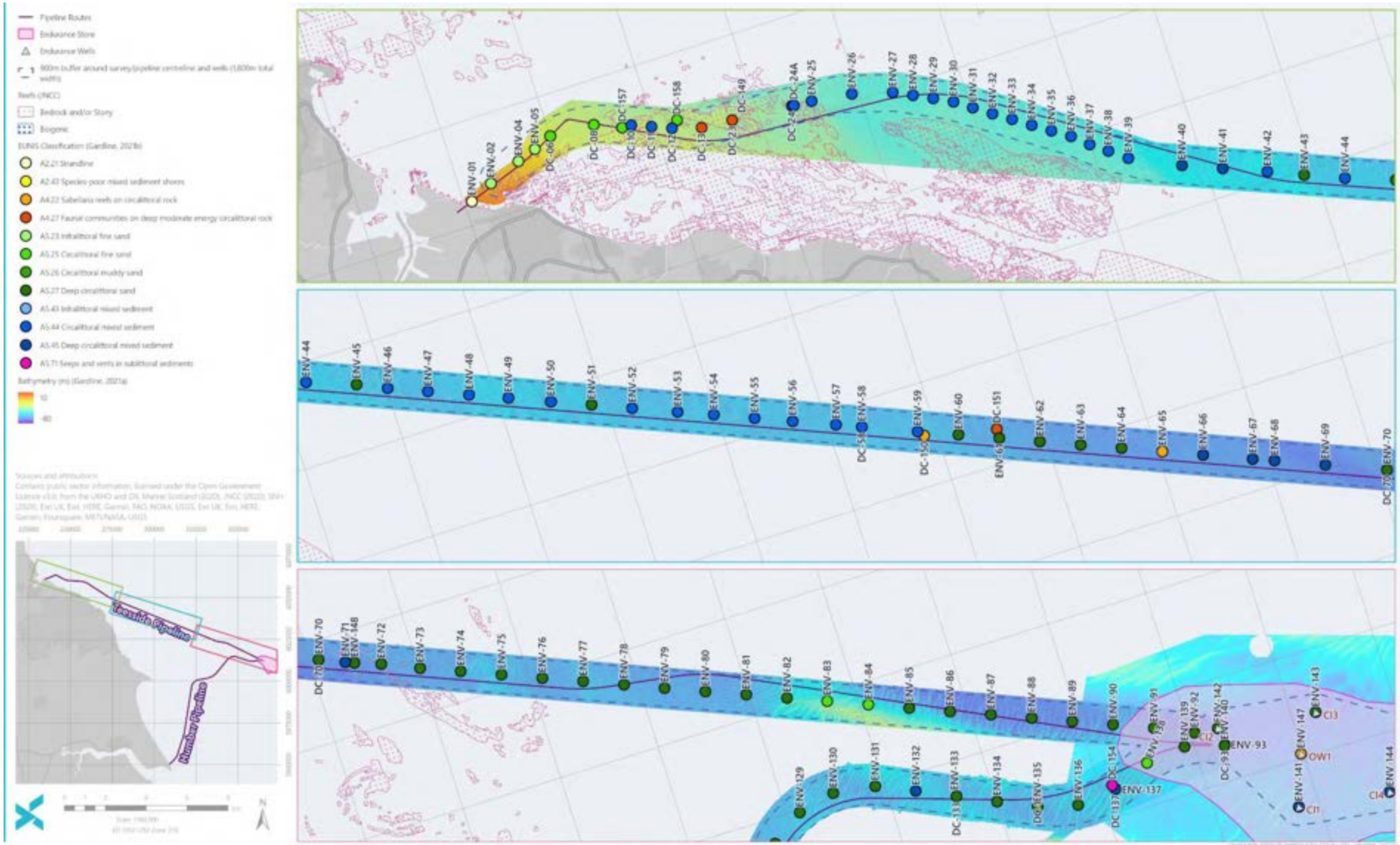

Figure 4-15 - EUNIS habitats along the Teesside Pipeline route (Gardline, 2022b)

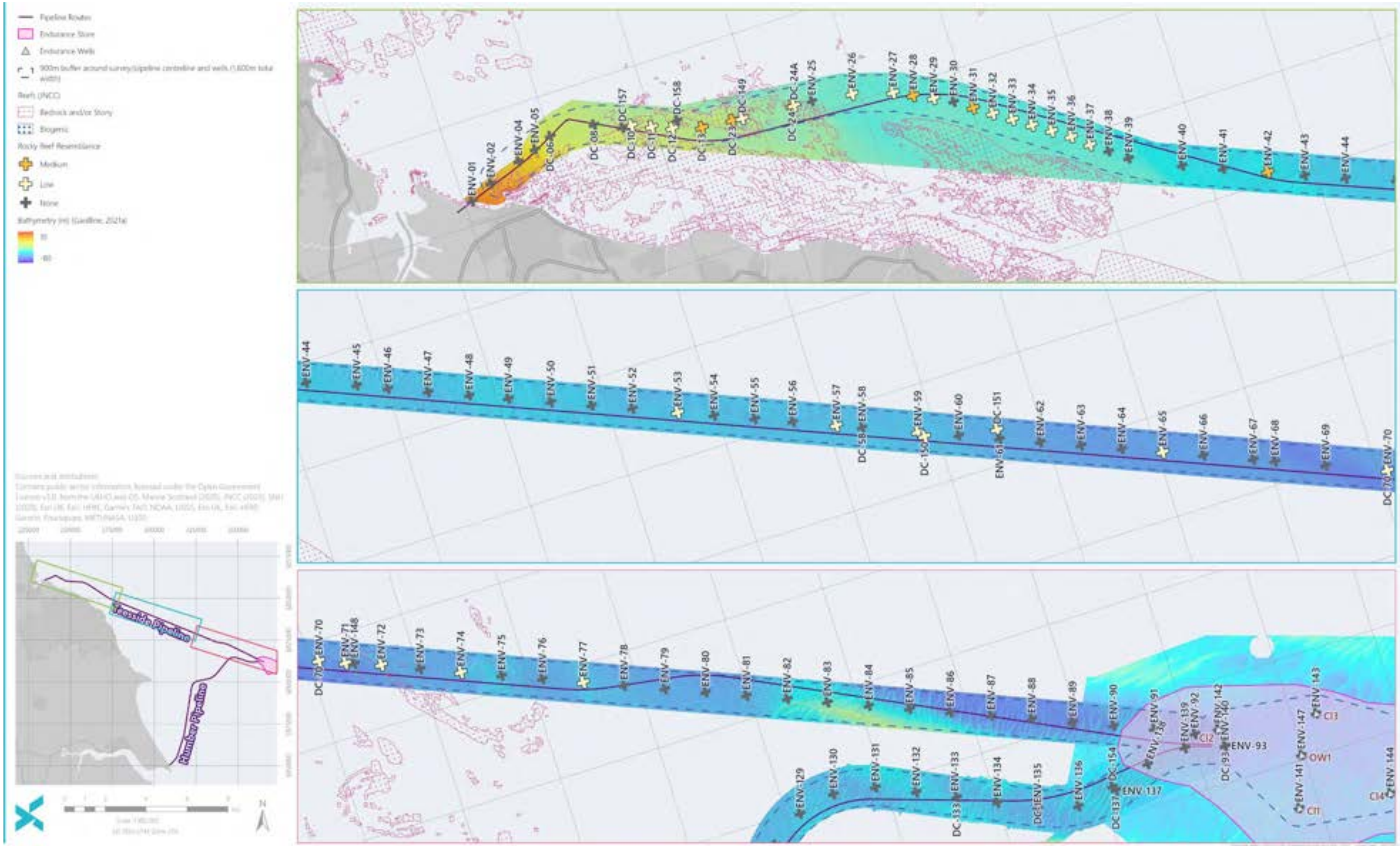

Figure 4-16 - Rocky reef presence and resemblance along the Teesside Pipeline route (Gardline, 2022b)

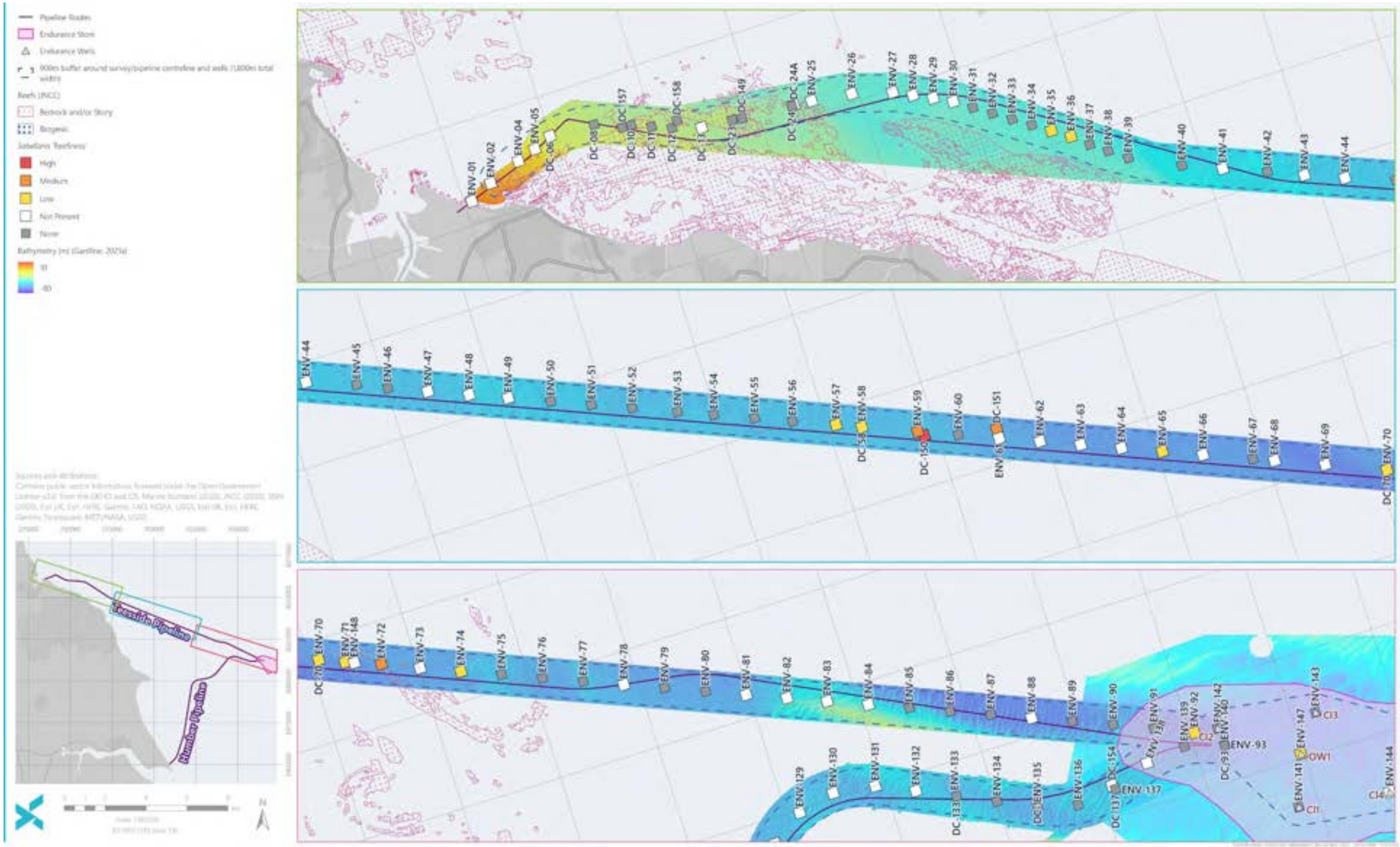

Figure 4-17 - Sabellaria reefiness along the Teesside Pipeline route (Gardline, 2022b)

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)

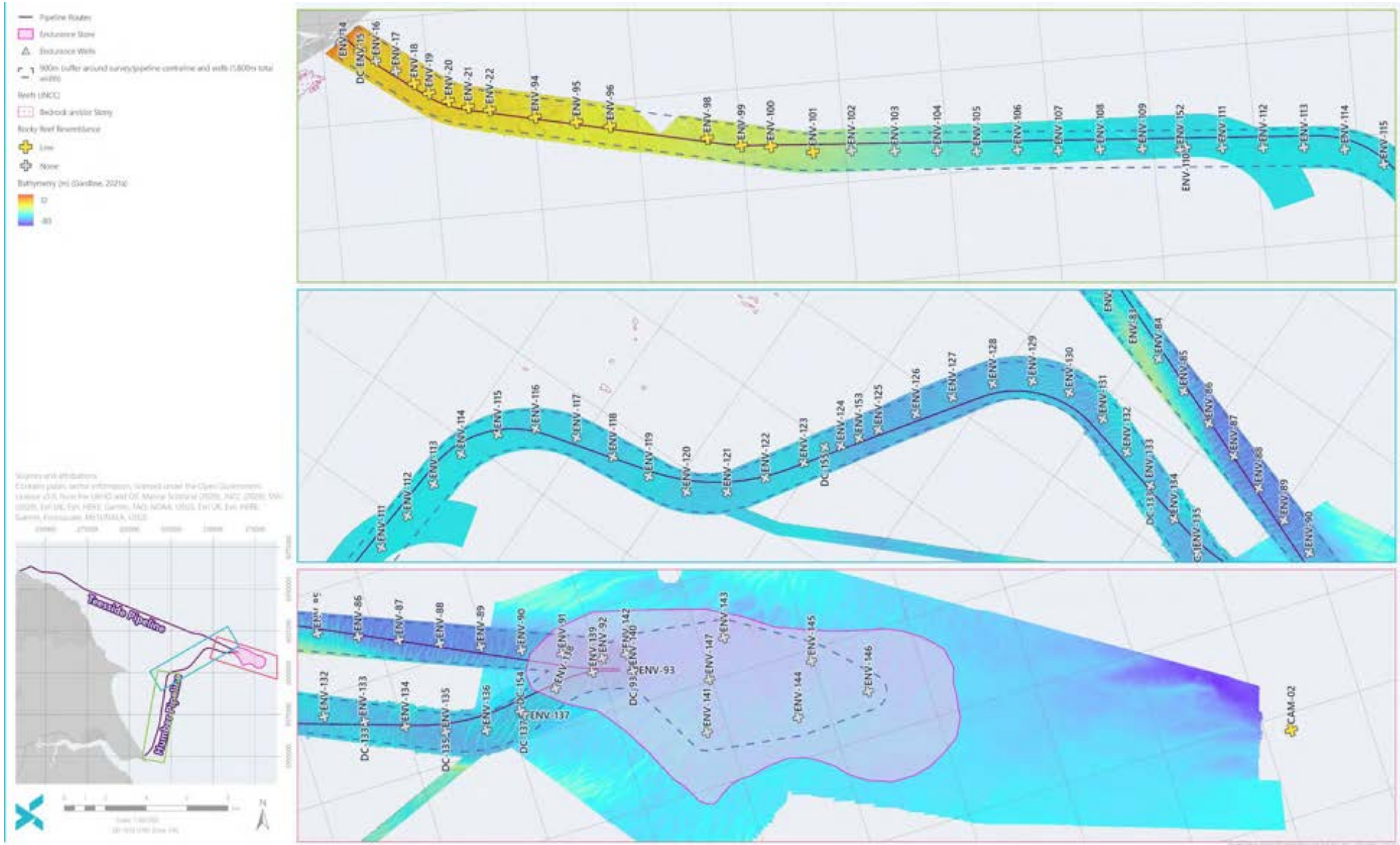

Figure 4-19 - Rocky reef presence and resemblance along the Humber Pipeline route (Gardline, 2022b)

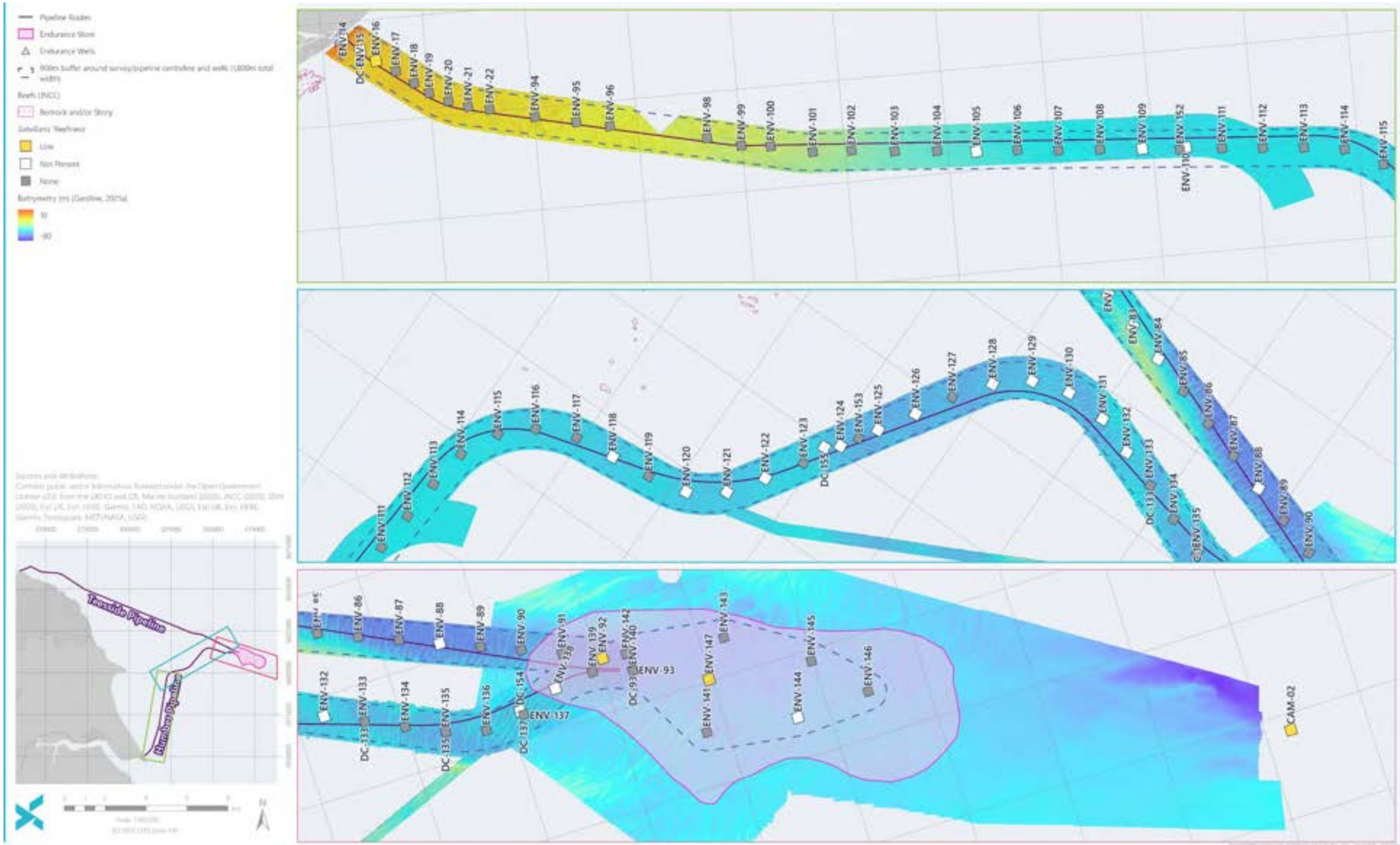

Figure 4-20 - Sabellaria reefiness along the Humber Pipeline route (Gardline, 2022b)

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)

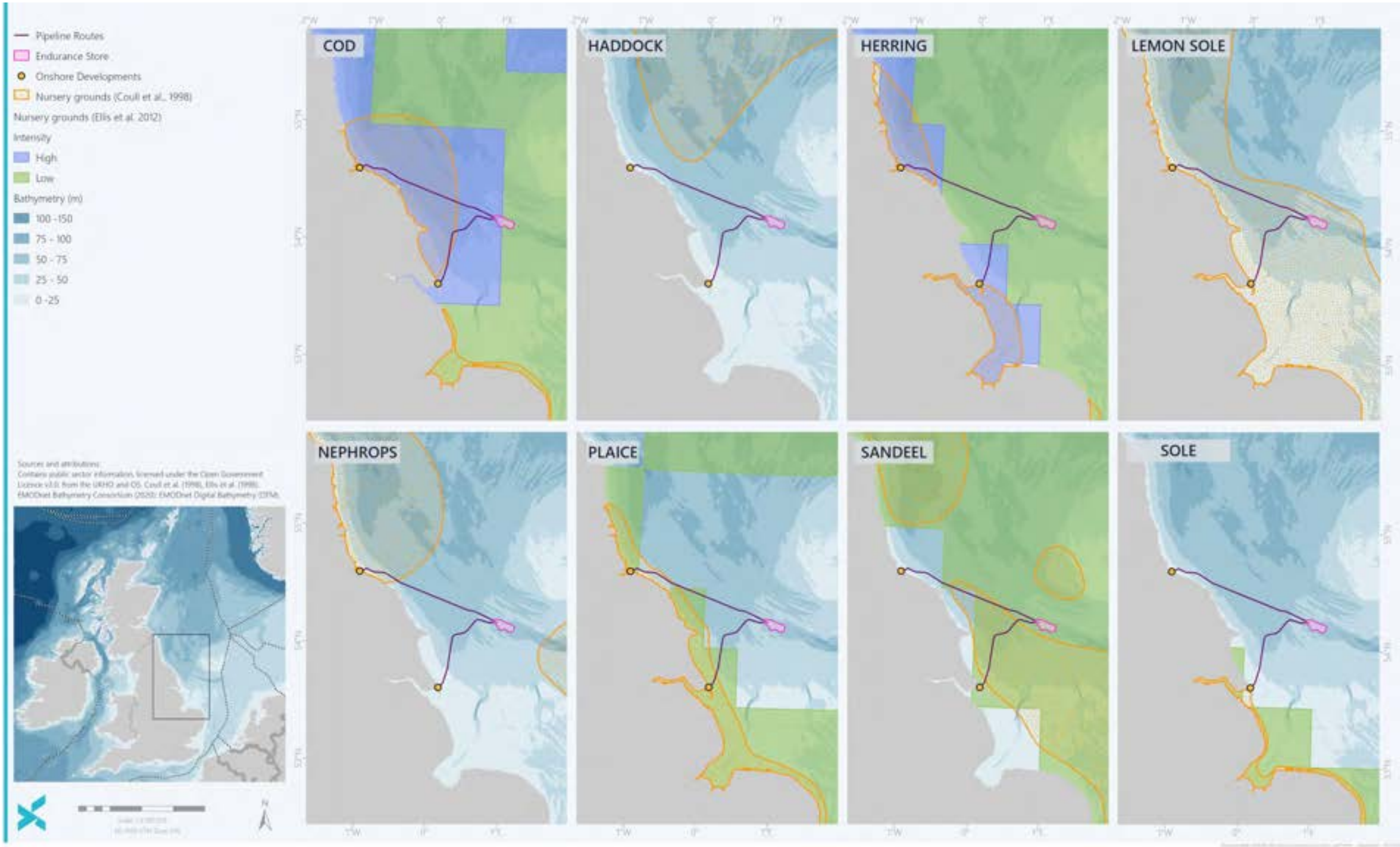

Figure 4-21 - Nursery grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b) (1 of 2)

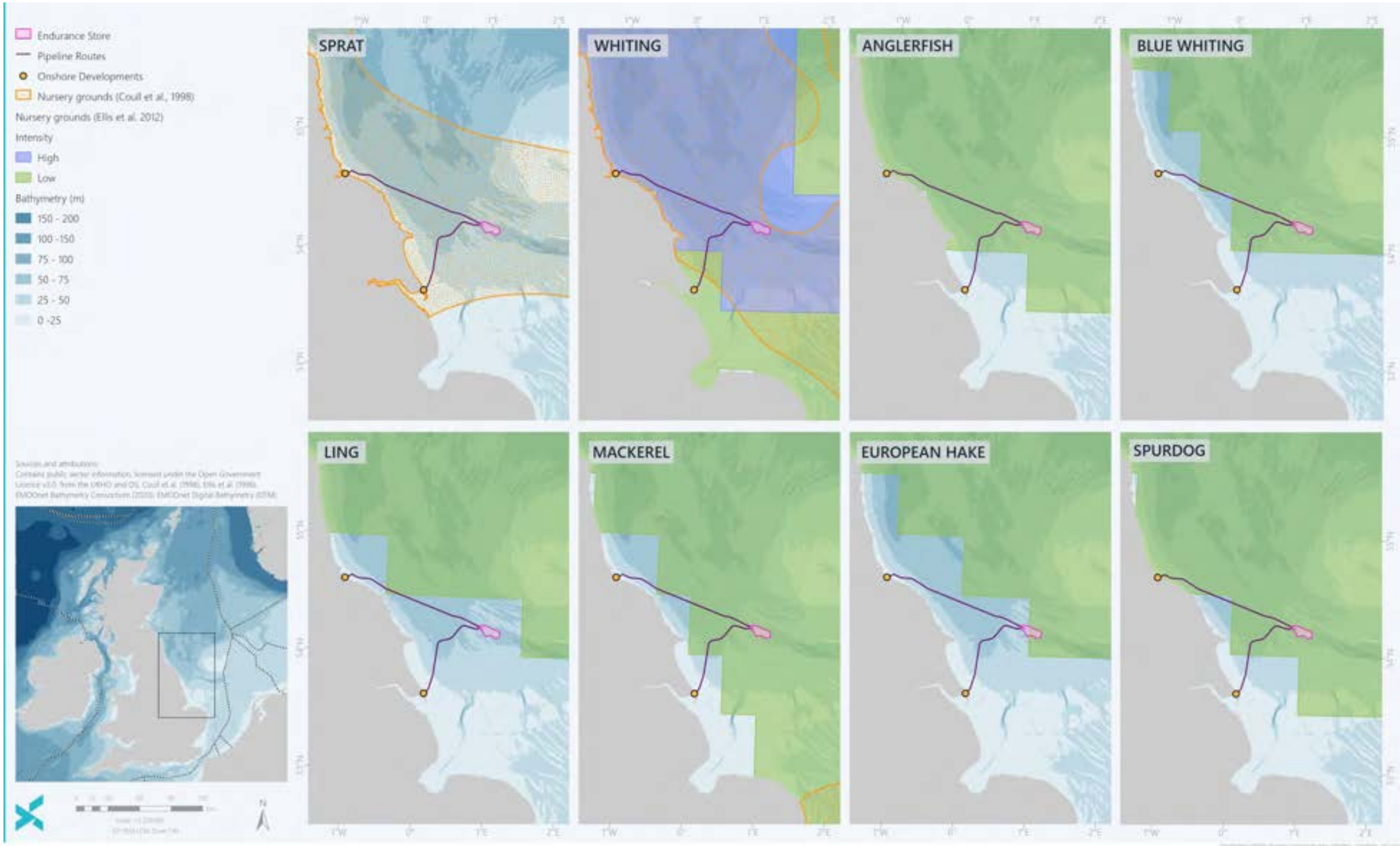

Figure 4-22 - Nursery grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b) (2 of 2)

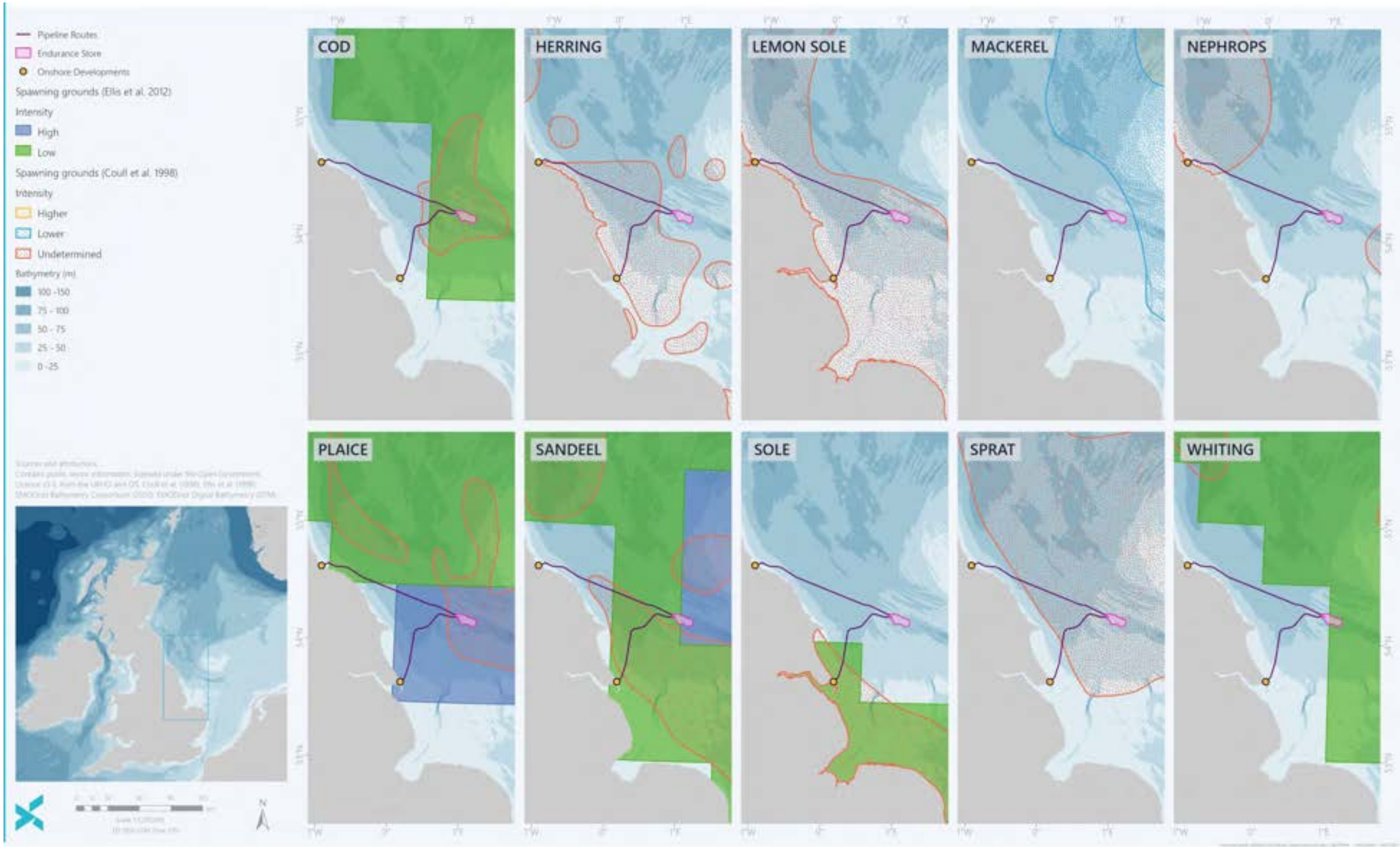

Figure 4-23 - Spawning grounds of fish species in the Development area (Coull *et al.*, 1998; Ellis *et al.*, 2012b)

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.

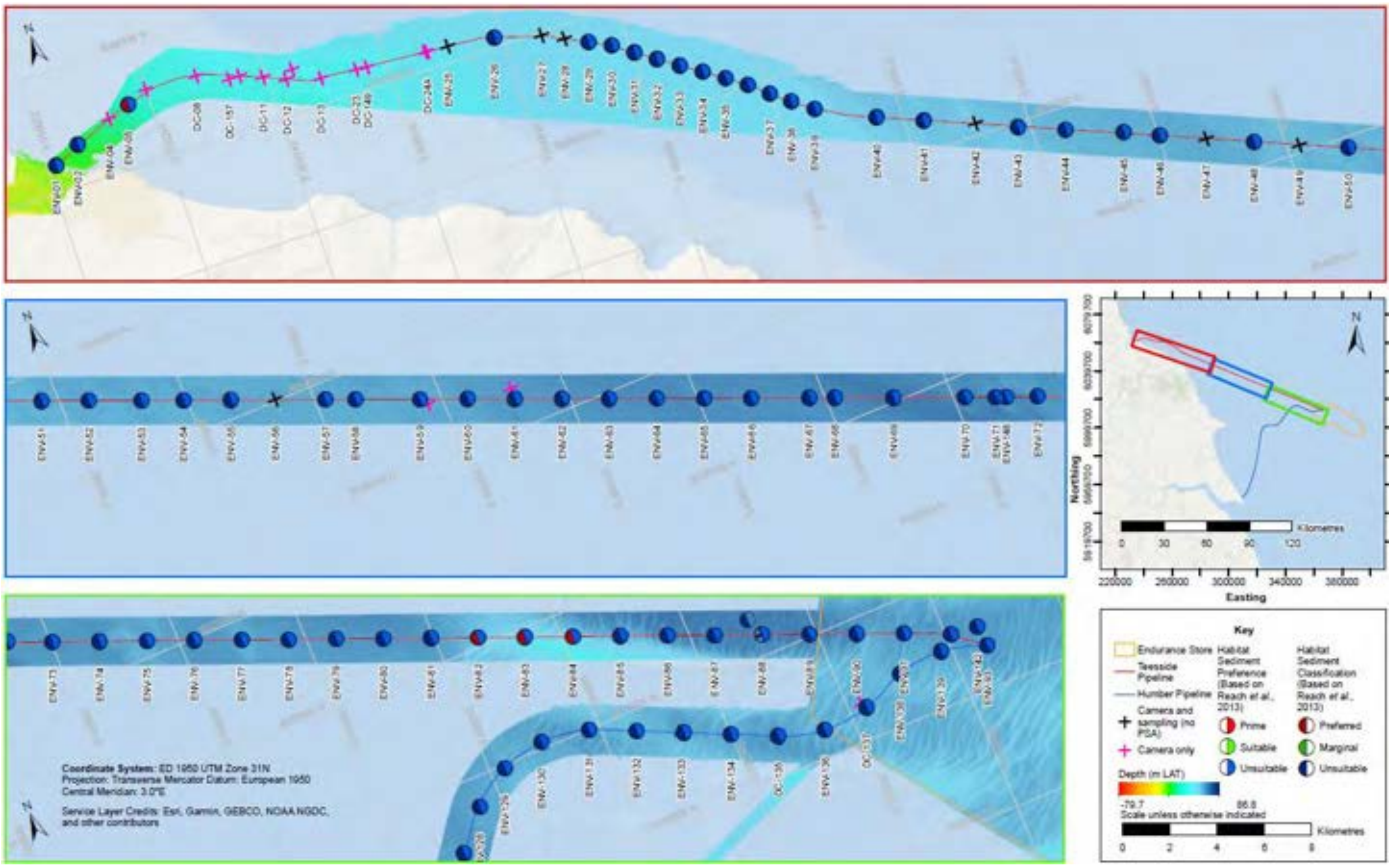

Figure 4-24 - Herring spawning ground potential along the Teesside Pipeline route (Gardline, 2022b)

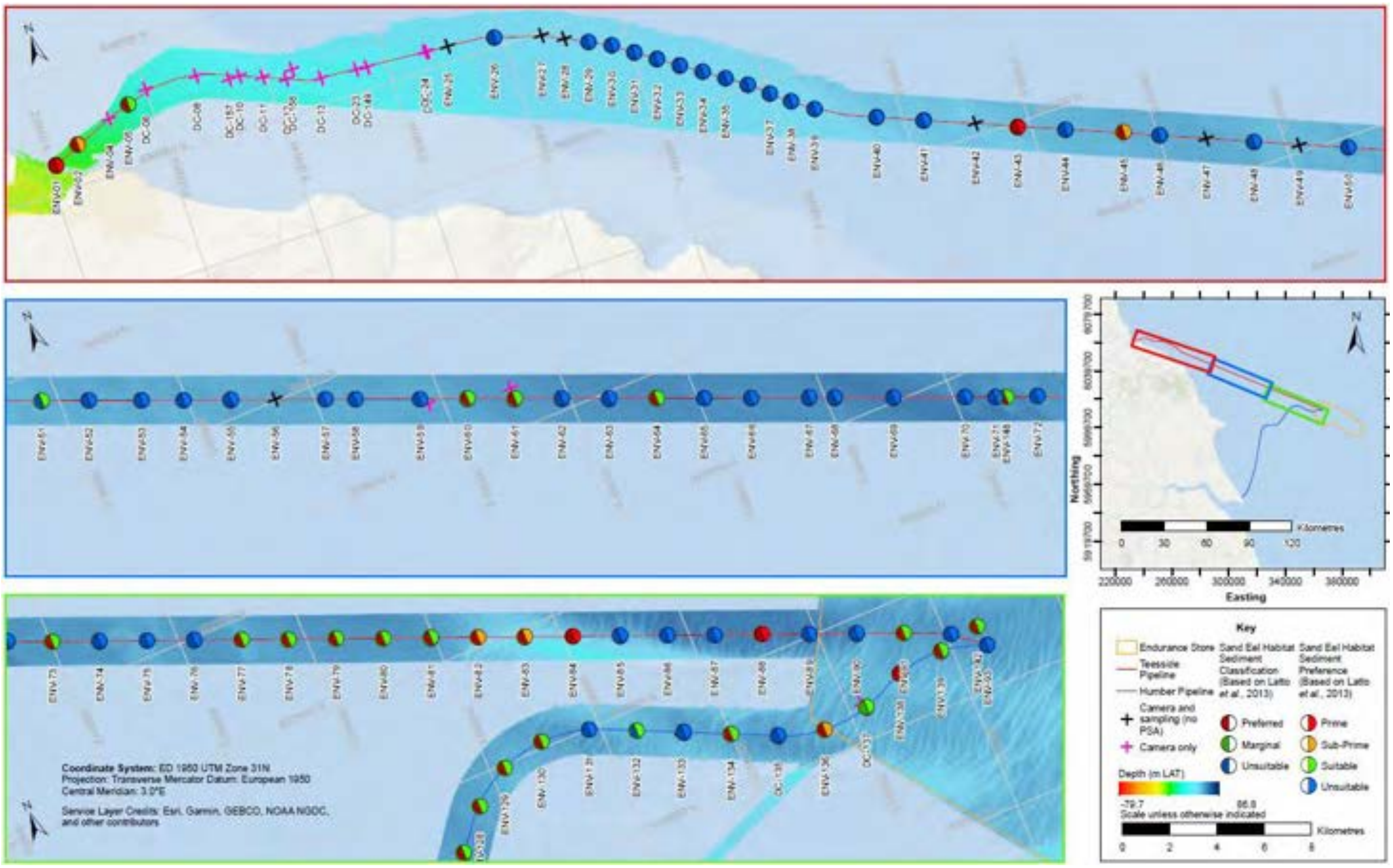

Figure 4-25 - Sandeel spawning group potential along the Teesside Pipeline route (Gardline, 2022b)

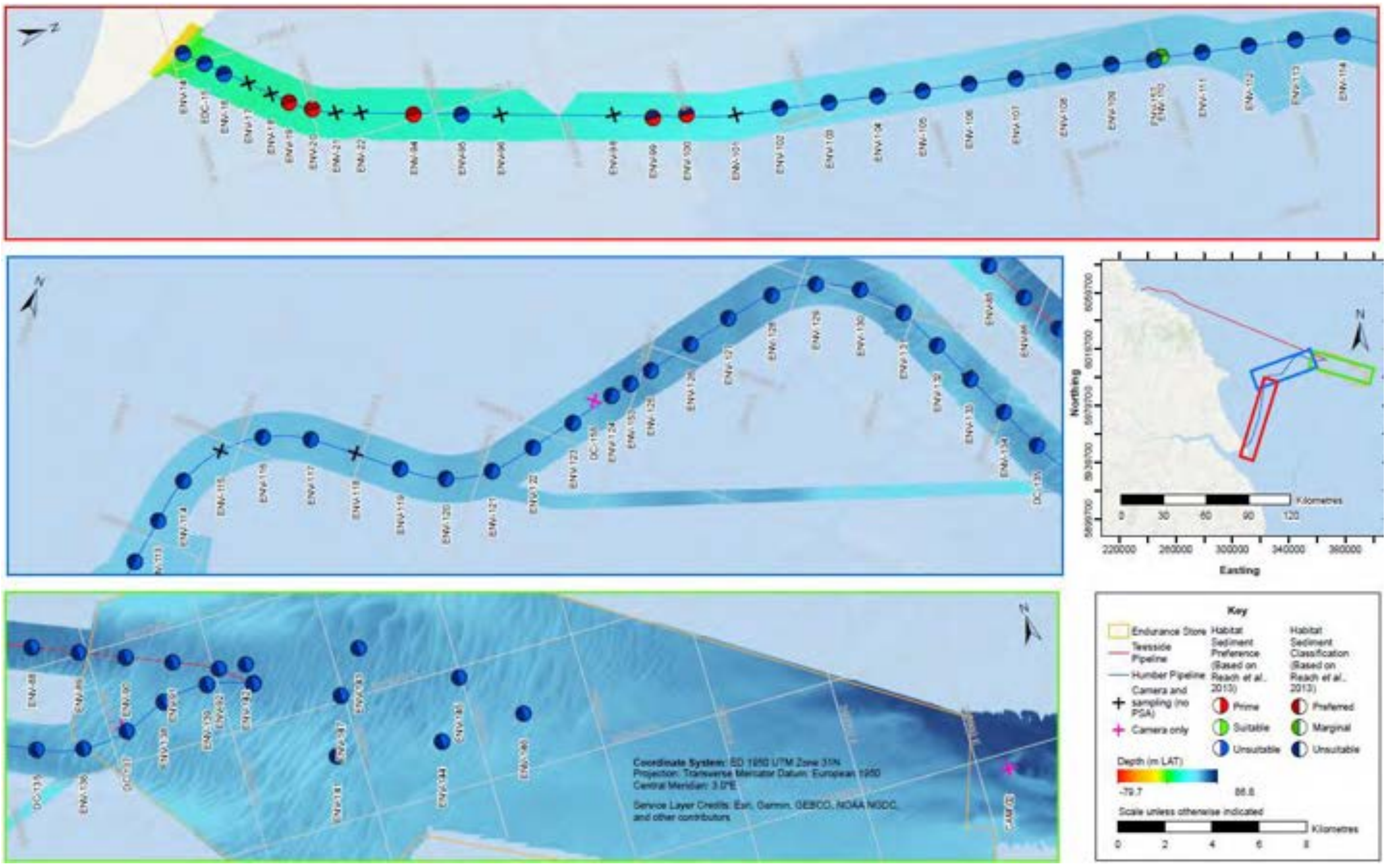

Figure 4-26 - Herring spawning ground potential within the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

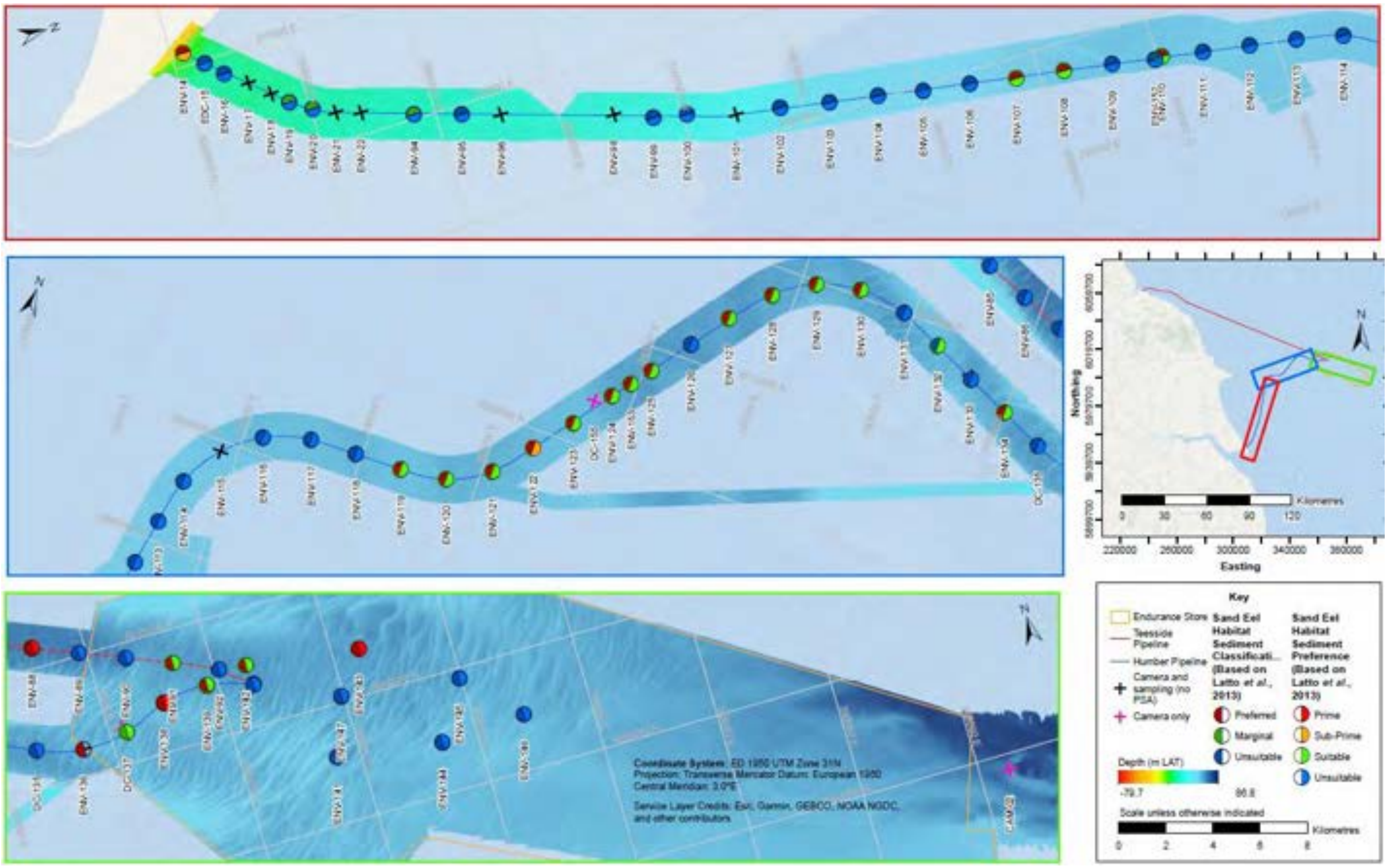

Figure 4-27 - Sandeel spawning ground potential within the Endurance Store and along the Humber Pipeline route (Gardline, 2022b)

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).

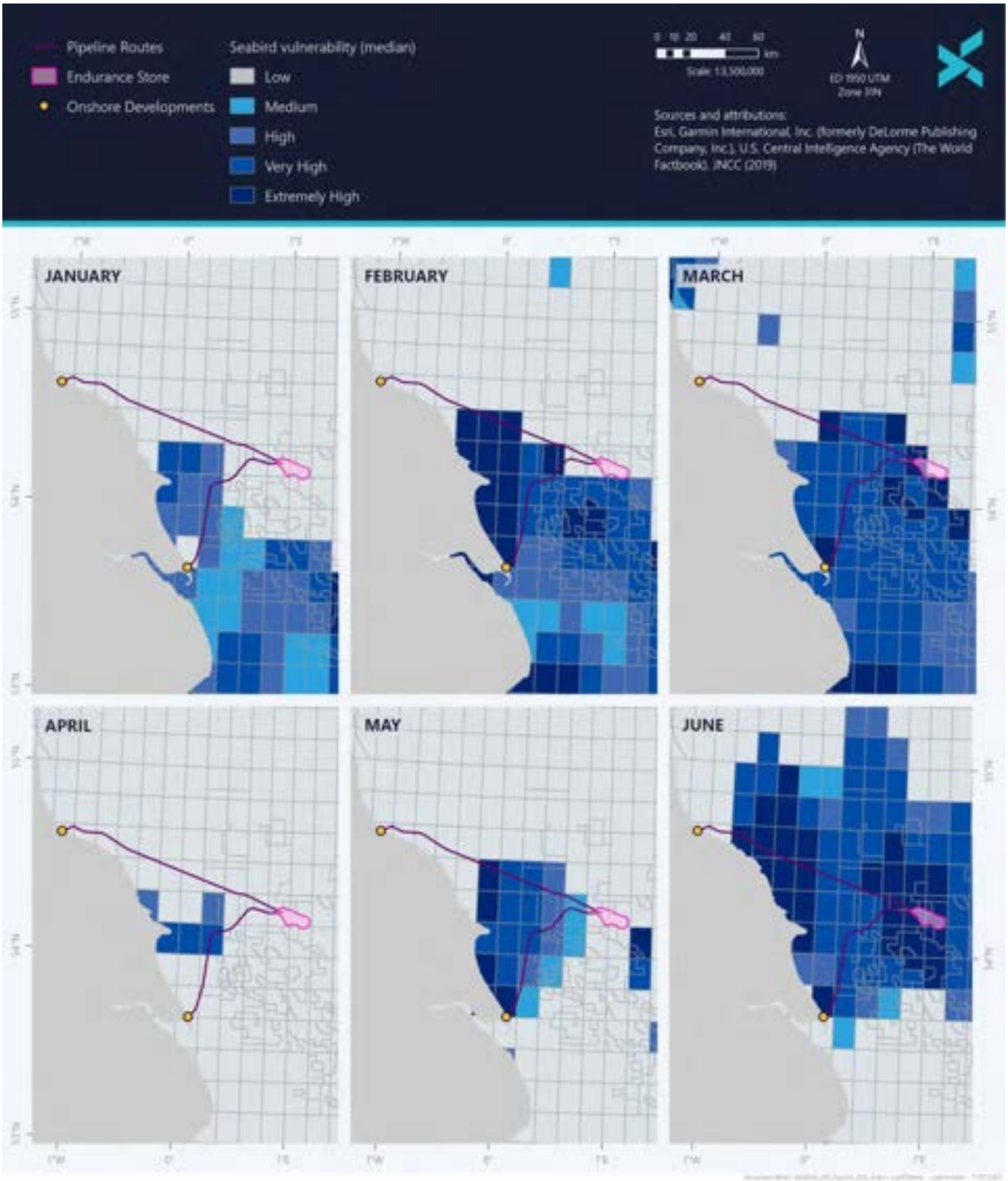

Figure 4-28 - SOSI across the Development area (Webb *et al.*, 2016) (1 of 2)

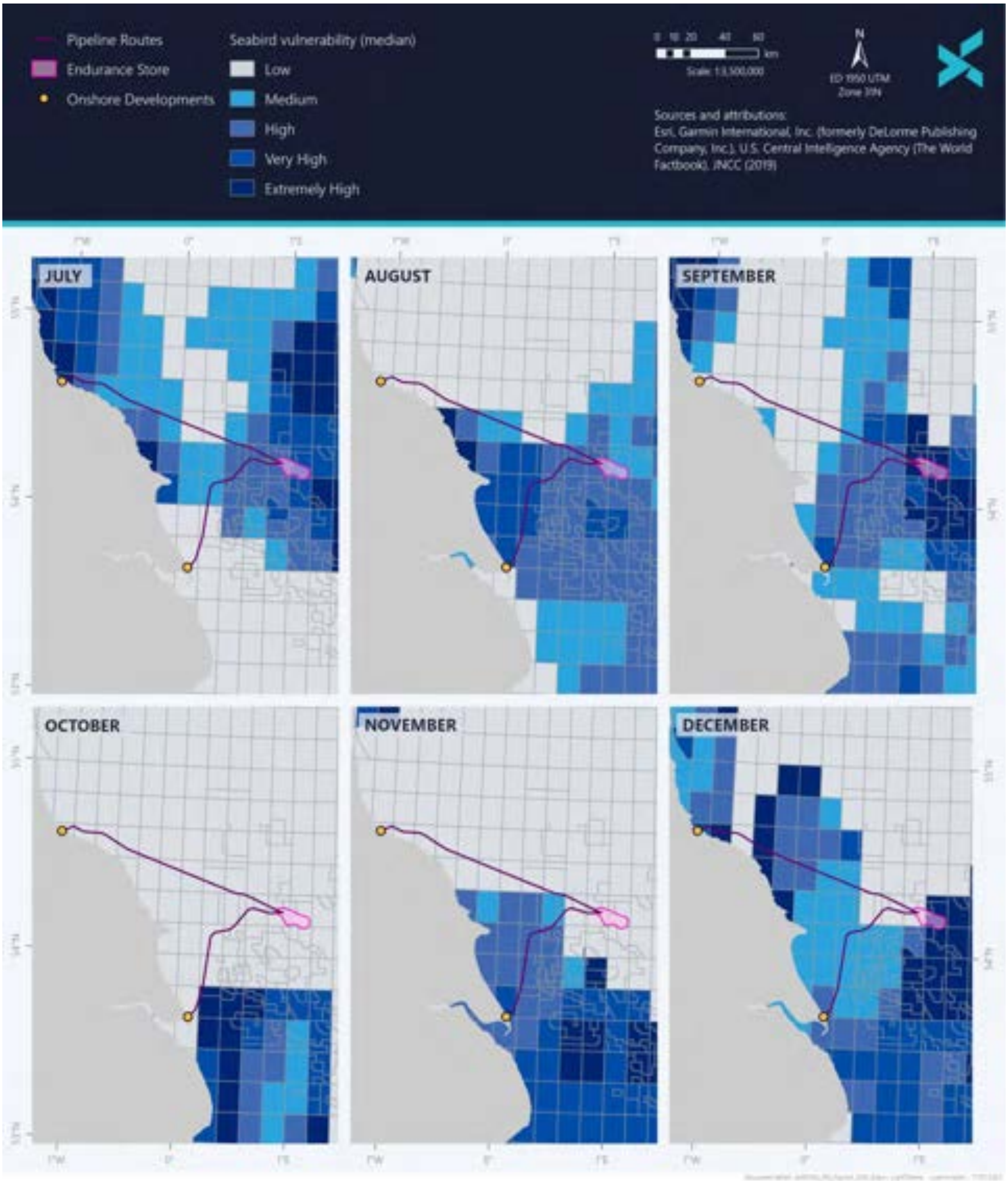

Figure 4-29 - SOSI across the Development area (Webb *et al.*, 2016) (2 of 2)

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).

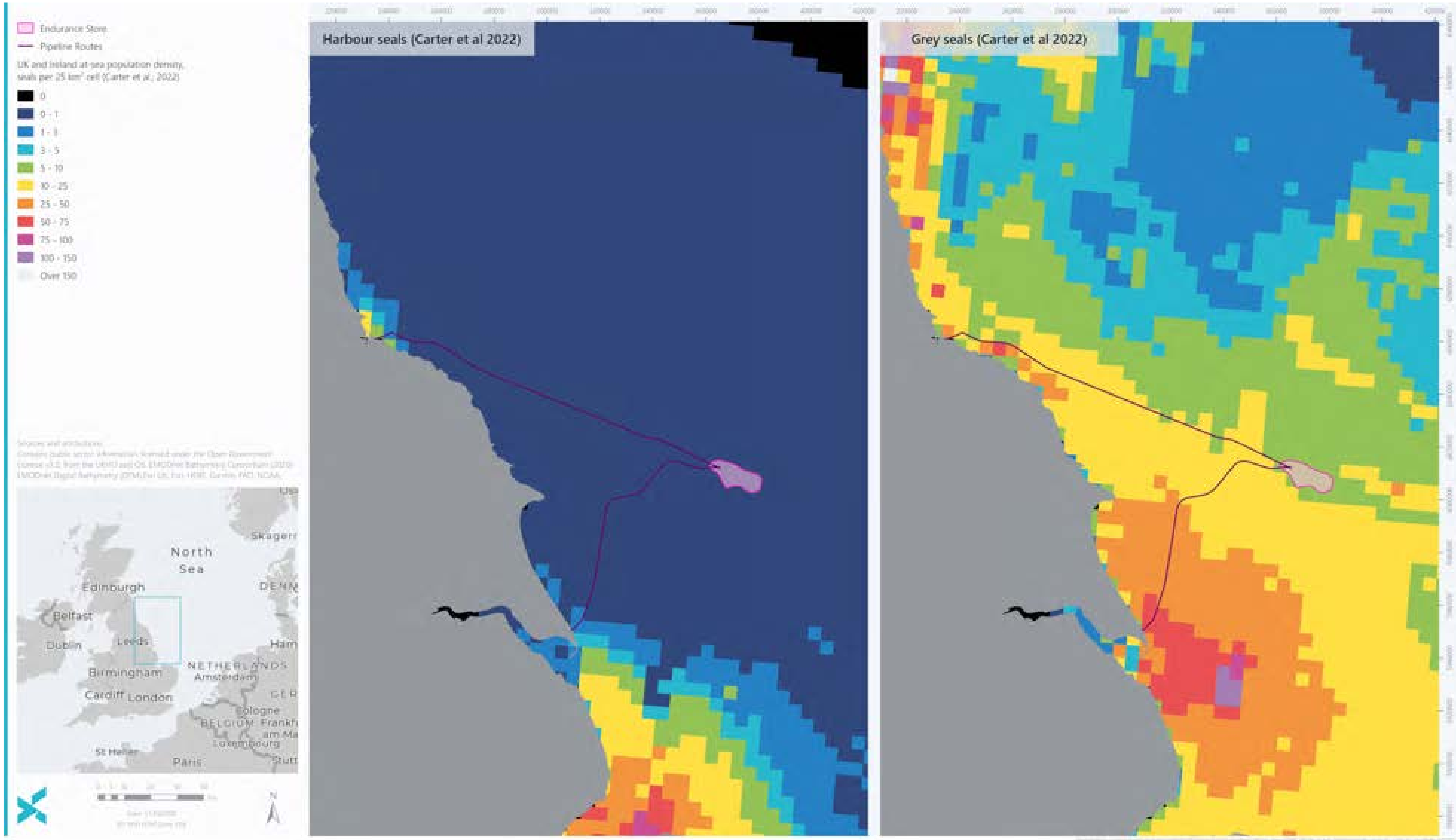

Figure 4-30 - Seal at sea density across the Development area (Russel *et al.*, 2017, Carter *et al.*, 2020)

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 three 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.

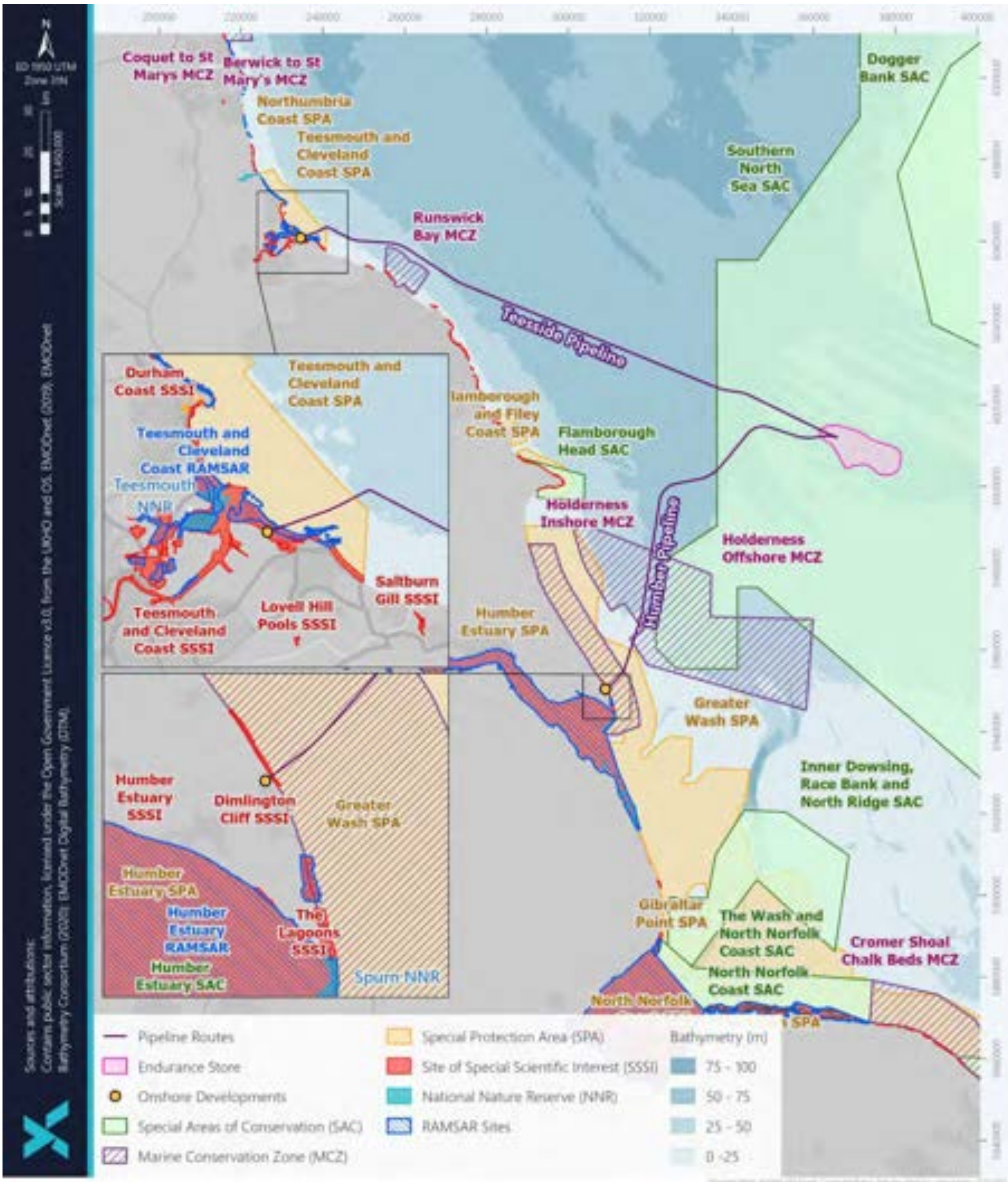

Figure 4-31 - Location of designated sites in the vicinity of the Development

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.

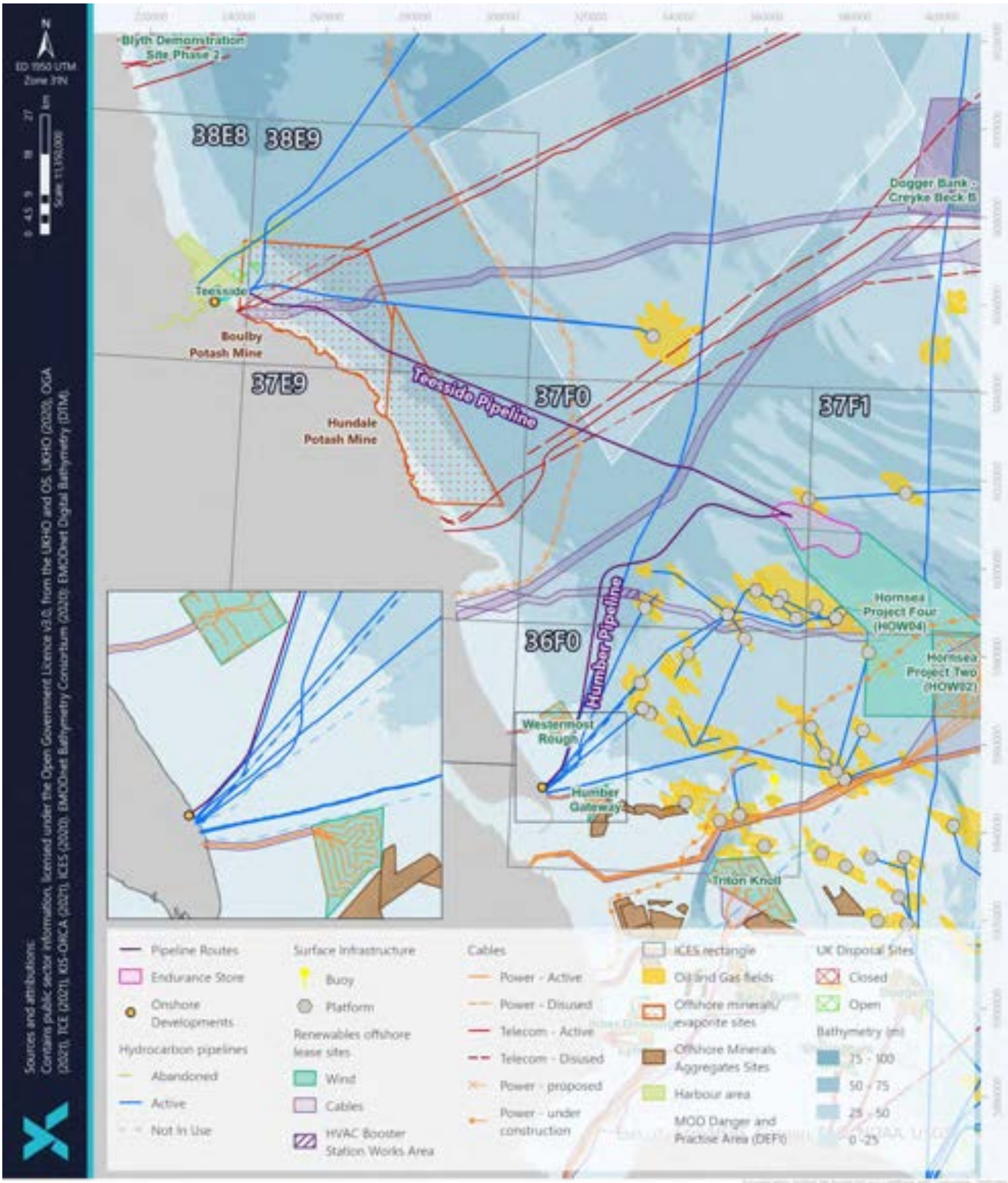

Figure 4-32 - Summary of other infrastructure in the Development area

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.*

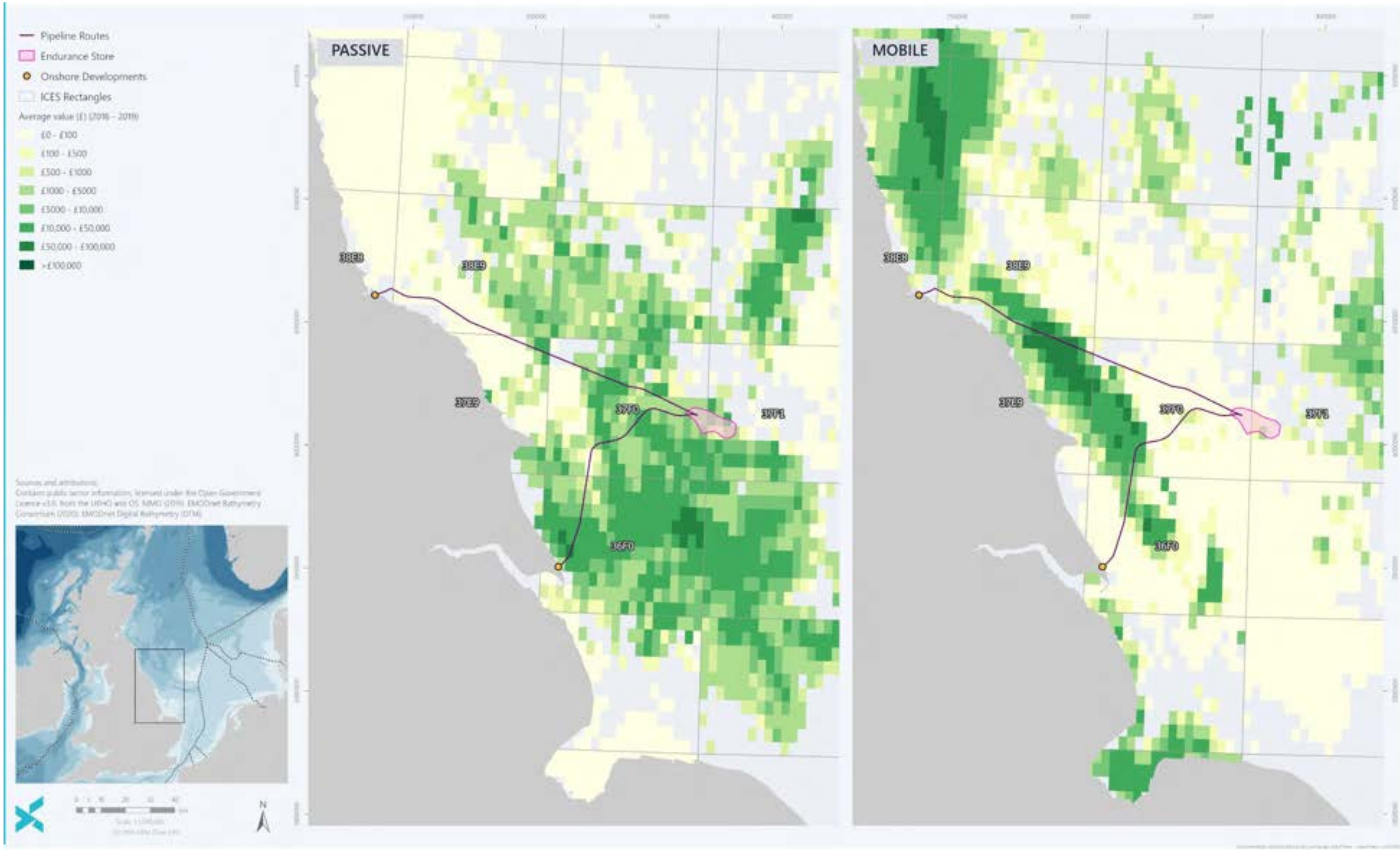

Figure 4-33 - Average value of catch in the Development area according to gear type 2016-2019

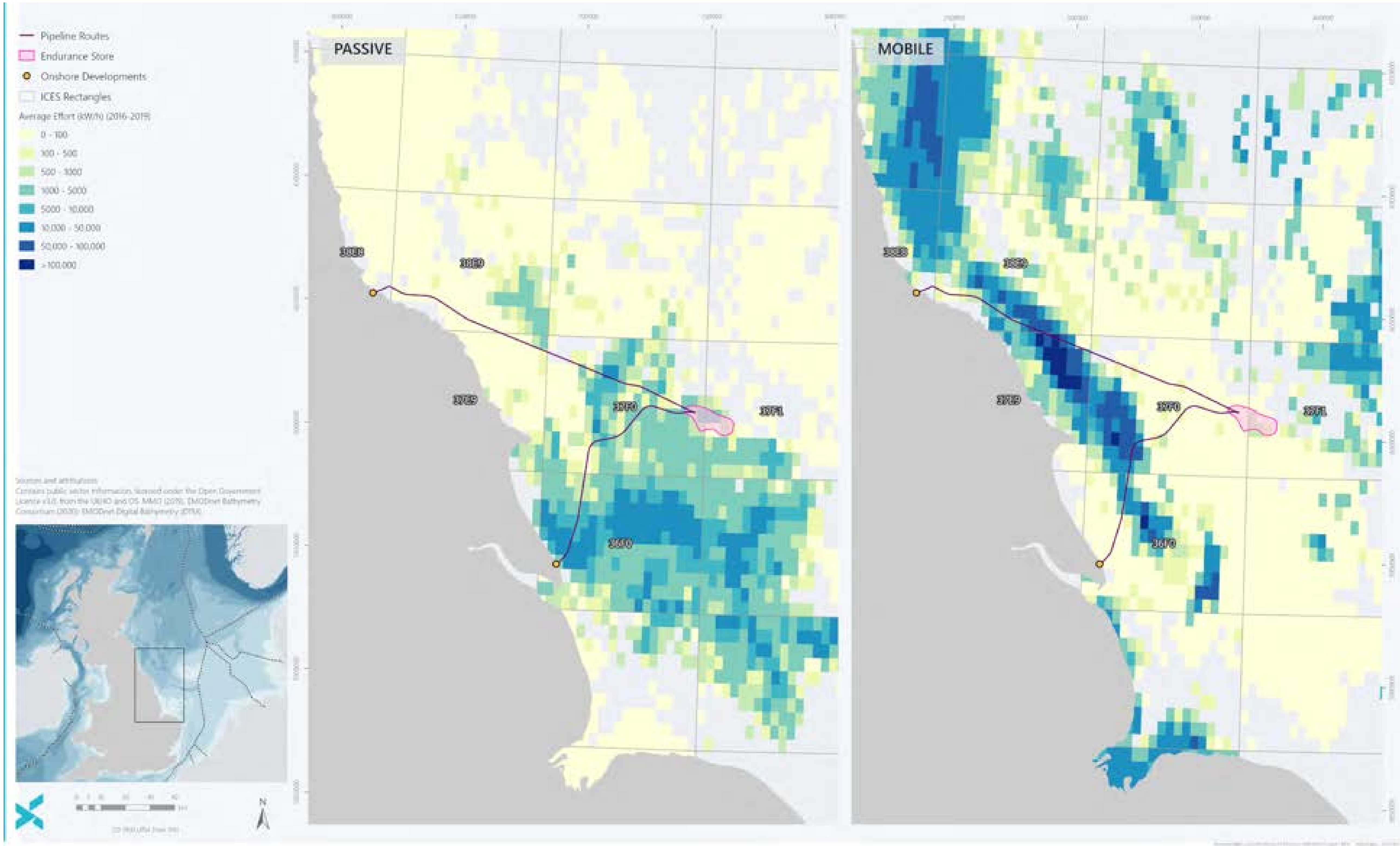

Figure 4-34 - Average fishing effort in the Development area according to gear type 2016-2019

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 (previously known as Creyke Beck A), Dogger Bank B (previously known as Creyke Beck B), Dogger Bank C (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 Dogger Bank A and Dogger Bank B 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 are located within 10 km of the Humber Pipeline route, associated with the Hornsea Development Two, Hornsea One and Triton Knoll OWFs. Only the later is operational, the other two cables are under construction.

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).

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[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 approximately 41 km from the Humber Pipeline route. As of January 2022, turbine commissioning has been completed and the OWF is now operational. The OWF will have a capacity of 857 MW. The project is jointly owned but construction and operation have been undertaken 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).

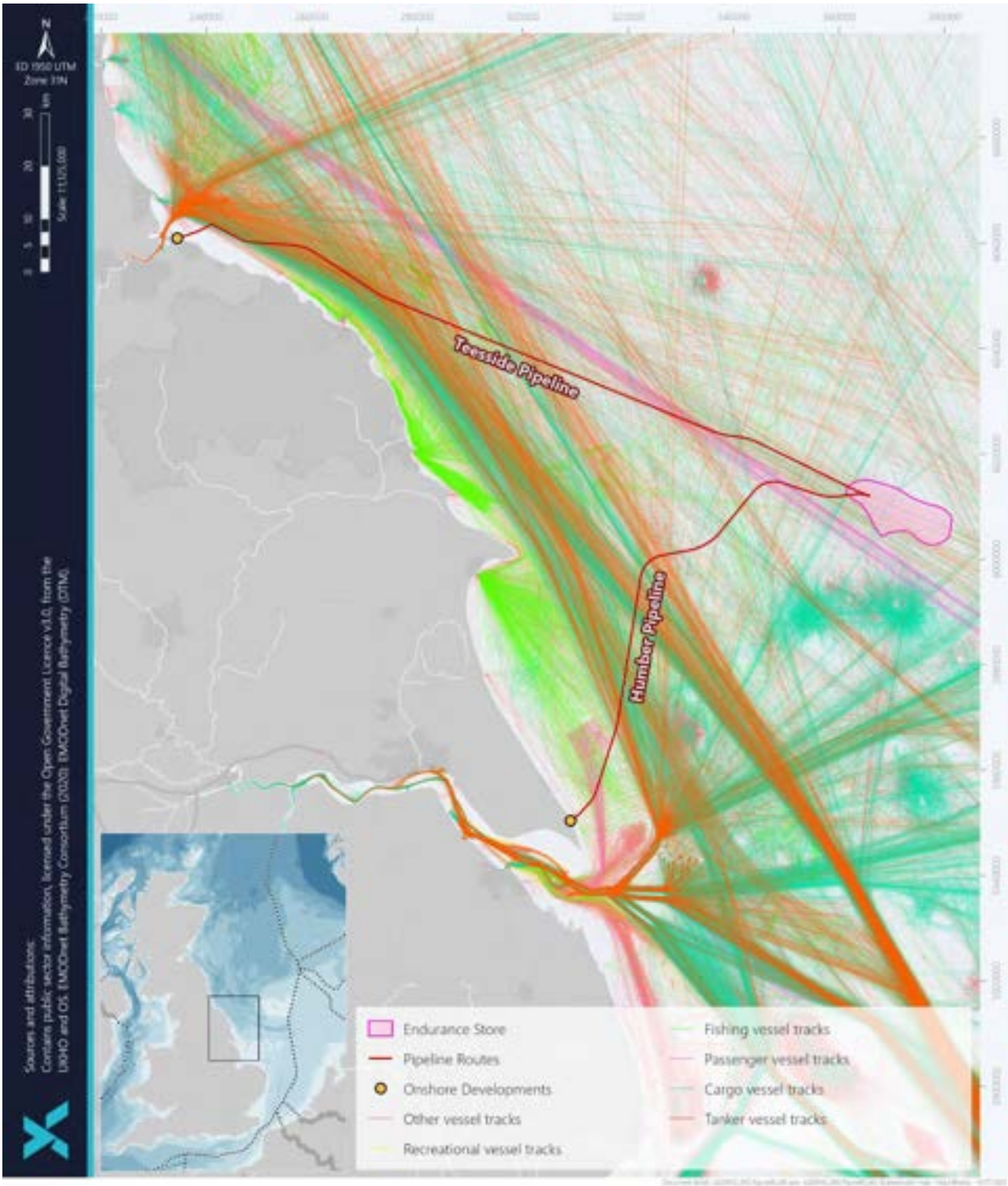

Figure 4-35 - AIS tracks in the Development area

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].

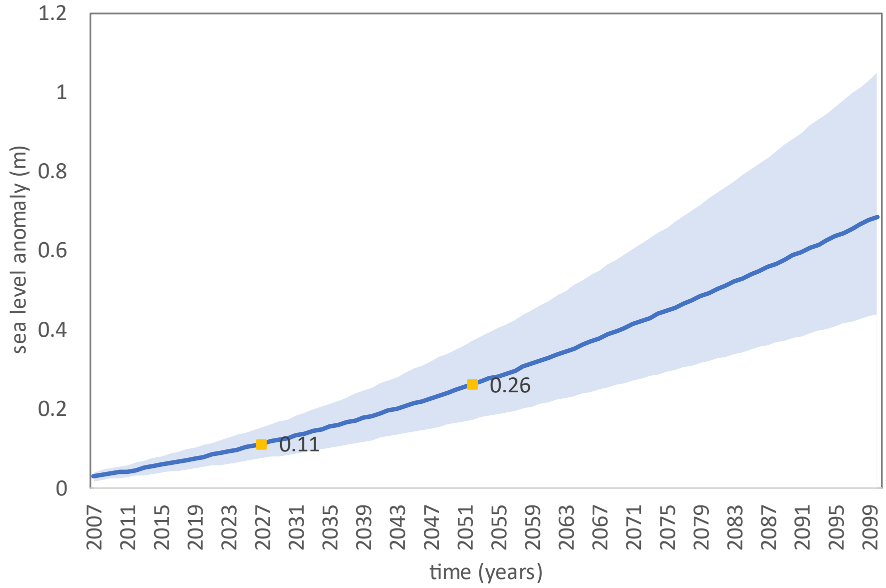

Figure 4-36 - Mean sea level projections for the Teesside landfall, relative to a baseline period of 1981-2000 (RCP8.5). The shaded region represents the projection range (produced using data from Palmer *et al.*, 2018)

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.

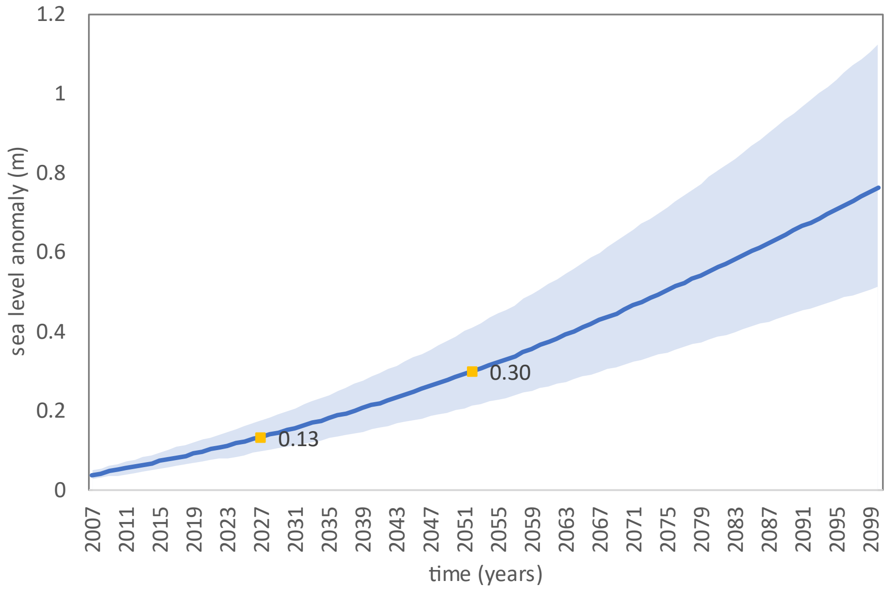

Figure 4-37 - Mean sea level projections for the Humber landfall, relative to a baseline period of 1981-2000 (RCP8.5). The shaded region represents the projection range (produced using data from Palmer *et al.*, 2018)

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.