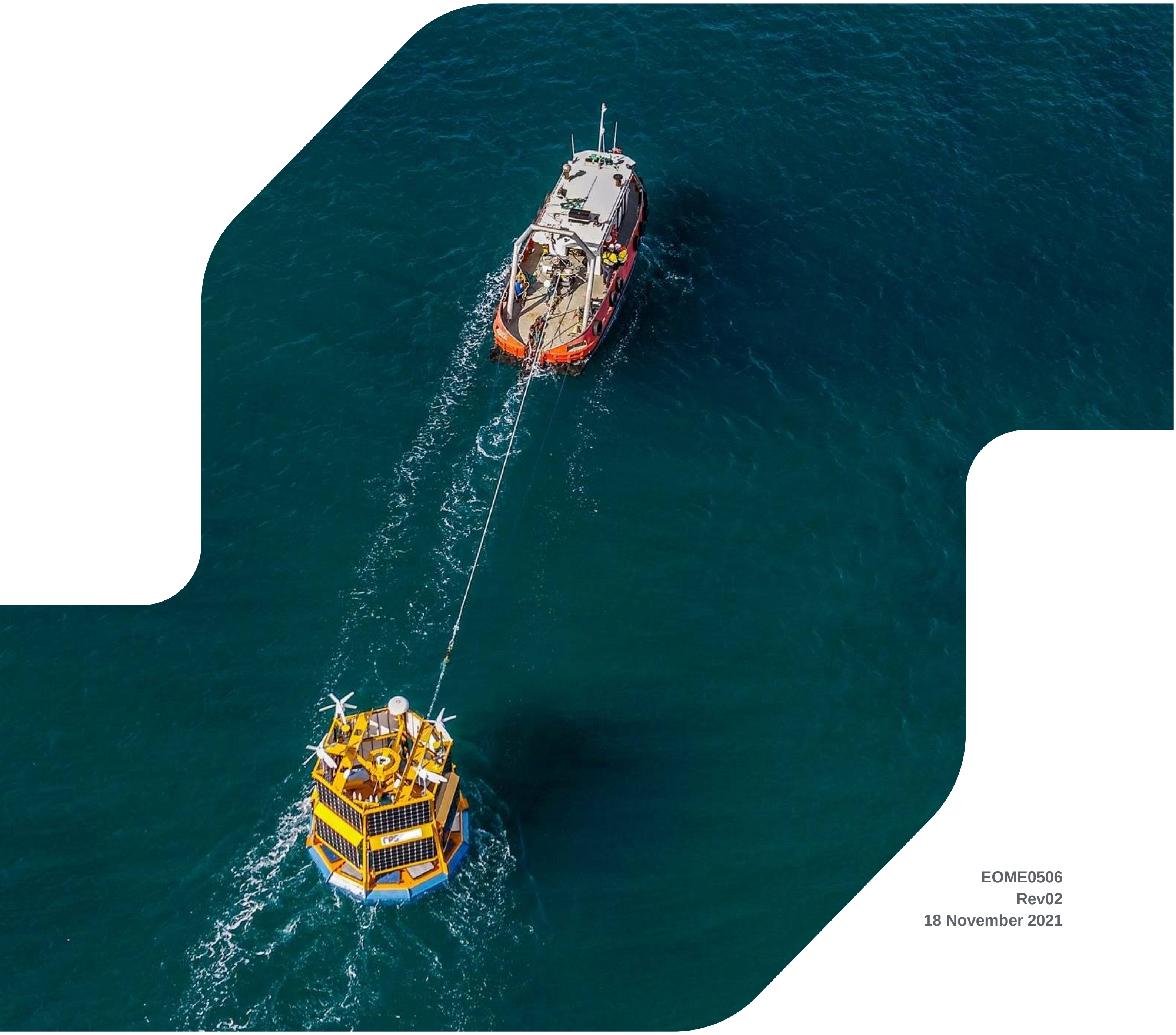
PEMBROKE DOCK INFRASTRUCTURE

Marine Licence Variation Environmental Appraisal



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1 INTRODUCTION

1.1 Background

Milford Haven Port Authority (MHPA) is redeveloping Pembroke Port in Pembroke Dock, located in Milford Haven (Figure 1.1), to support development of the offshore renewables industry in Wales.

An application for a Marine Licence for the Pembroke Dock Infrastructure (PDI) Project was submitted to Natural Resources Wales Permitting Service (NRW PS) on 18 December 2020, accompanied by an Environmental Statement (ES). The Project was subsequently granted a Marine Licence in June 2021 (CML2057).

Consent was granted for the following key marine elements of the project:

- Capital dredging around the slipways and within the Graving Dock;
- The creation of a single ‘mega’ slipway by combining the two existing westernmost slipways and extending the slipway into the Milford Haven Waterway into deeper water; and
- The infilling of the Graving Dock.

The licensed activities associated with the removal of sediment/rock around the slipways include only for the excavation of material above the water mark at the time of excavation (in the dry), by backhoe excavator. Any rock identified within this area was to be removed using a larger backhoe excavator or a hydraulic rock breaker. In areas below the existing water mark (in the wet) the only activities currently licensed are the removal of material by backhoe excavator with a closed bucket attachment positioned on a barge.

MHPA have recently progressed with the detailed design of the slipway, and their contractors have highlighted a requirement for the use of a hydraulic rock breaker, such as a vibro-ripper, below the existing water mark (i.e. in the wet) for the removal of areas of harder rock. In addition, it has been determined that the secant piled walls at the existing flank walls of the slipways will need to be extended to the end of the slipway on both sides to retain the superficial deposits.

The current Marine Licence (CML2057) does not permit the use of hydraulic rock breakers in the wet or any type of piling, such as that now required for the new secant piled walls, and no assessment of these activities was made within the ES for the Marine Licence. MHPA are, therefore, seeking a variation to the Marine Licence to incorporate these additional activities. In addition, MHPA are also seeking to revise the consent to include for the temporary installation of a stank across the entrance of the eastern slipway (within the footprint of the consented slipway extension) to facilitate the consented works to this part of the project.

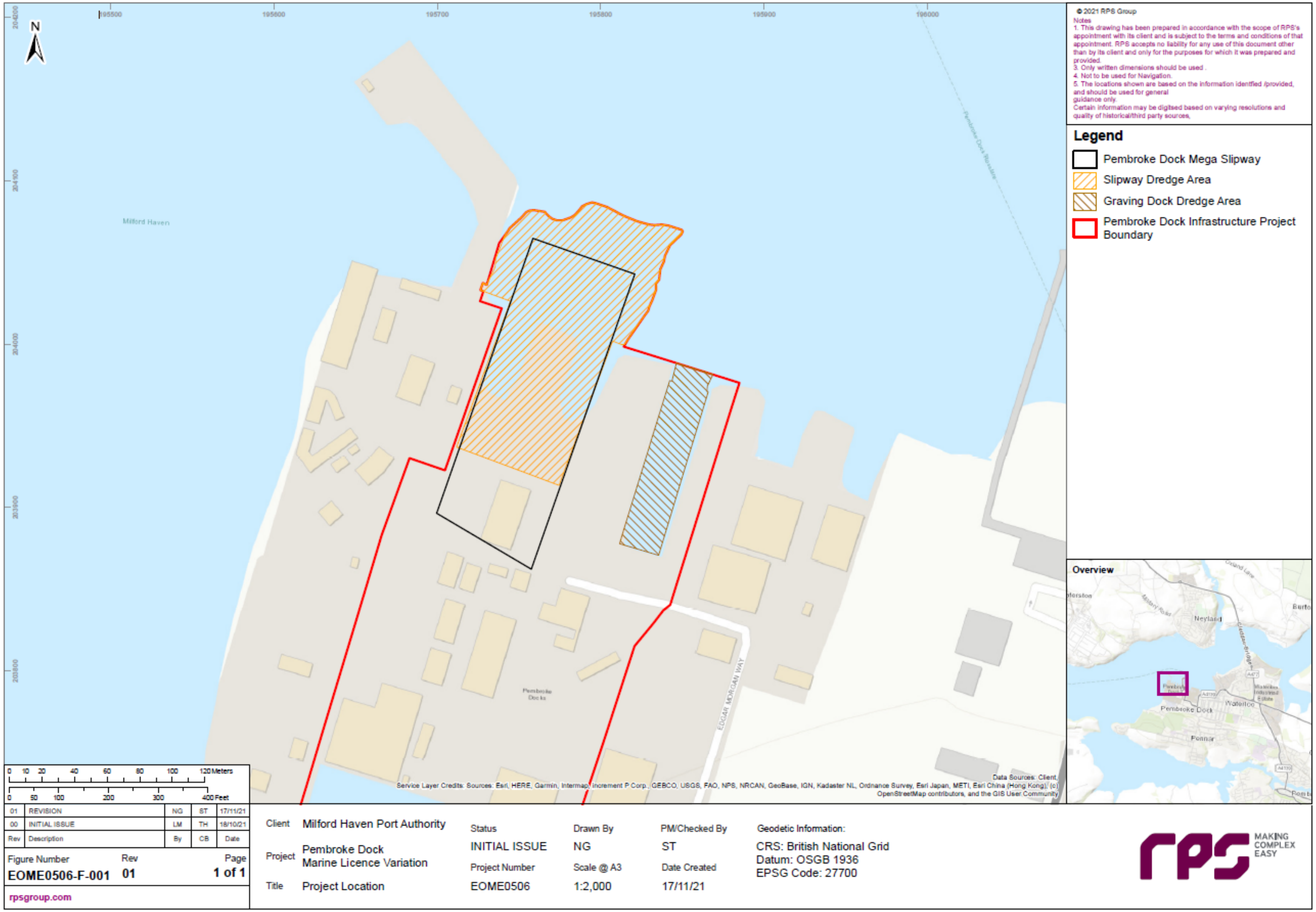

Figure 1.1: Location of the slipway

1.2 Consultation

Consultation with Natural Resources Wales – Marine Licencing Team (NRW-MLT) in August 2021 confirmed that these proposed activities are categorised as a complex marine licence variation and do not require a new marine licence application.

Consultation with NRW-MLT in October 2021 was undertaken to confirm the approach to the marine licence variation and NRW-MLT requested a table outlining the proposed updates against the currently licence parameters and their predicted environmental impact.

2 PROJECT DESCRIPTION

2.1 Licensable Activities

Under the Marine and Coastal Access Act 2009, a Marine Licence is required to construct, alter, or improve any works within the UK marine licensing area.

MHPA are seeking consent for the following additional activities to be added as a variation to the current Marine Licence (CML2057):

1. Revised slipway wall design from reinforced concrete walls to incorporate secant piled walls (no change to the overall slipway footprint);
2. The use of a hydraulic rock breaker in the wet for the excavation of rock material at the bottom of the slipway; and
3. Installation of a temporary stank at the current eastern slipway to facilitate works being undertaken in the dry.

2.2 Method Statement

2.2.1 Revised slipway wall design

Work will be undertaken to maintain the existing masonry flank walls of the existing slipway. Recent ground investigations have shown that the existing flank walls on both sides of the slipway are cut into and founded on the rock and that there are a few local fractures in the rock beneath the walls which may require stabilising.

Reinforced concrete secant piled walls will be installed to ensure the integrity of the existing flank walls is maintained. The secant piled walls at the existing flank walls will be extended to the end of the slipway on both sides to retain the superficial deposits, to the extent required to protect the existing structures and satisfy consent requirements. The design will ensure that, as far as possible, there is no reduction in stability compared to the existing situation.

The primary infill piles will be located at 1 m centres and will have a diameter of 600 mm. Embedment is expected to be 3 m below the new slipway slab level. Below the bottom of the existing slipways the secant wall will terminate at the existing bed level. Above the bottom of the existing slipways the secant wall will terminate at the existing slipway slab level.

The design life of the slipway will be 50 years.

The installation of secant piled wall comprises the following steps:

1. Mobilisation of equipment and jack-up barge.
2. Transferring drill rig and equipment onto jack-up barge.
3. Clearing to seabed in area of wall to check for potential artificial obstructions using an excavator from a barge. Any man-made materials discovered, will be taken to land for disposal.
4. Positioning of the piling gate and/or guide wall for primary piles to ensure accurate positioning of the secant wall.
5. Positioning of the drill string and drilling/twisting in of primary pile overburden casing.
6. Open hole drilling of the rock socket in rock for primary piles
7. Disposal of drilled arisings to land.
8. Concreting of the primary piles to existing bed level only. The level of concrete will be monitored by dipping and volume calculations.
9. Remove primary pile temporary casing.
10. Repeat items 4 – 9 but for reinforced secondary piles (Figure 2.1)

11. Placing reinforcement and concreting of secondary piles
12. Dismount equipment from jack-up barge and demobilisation.

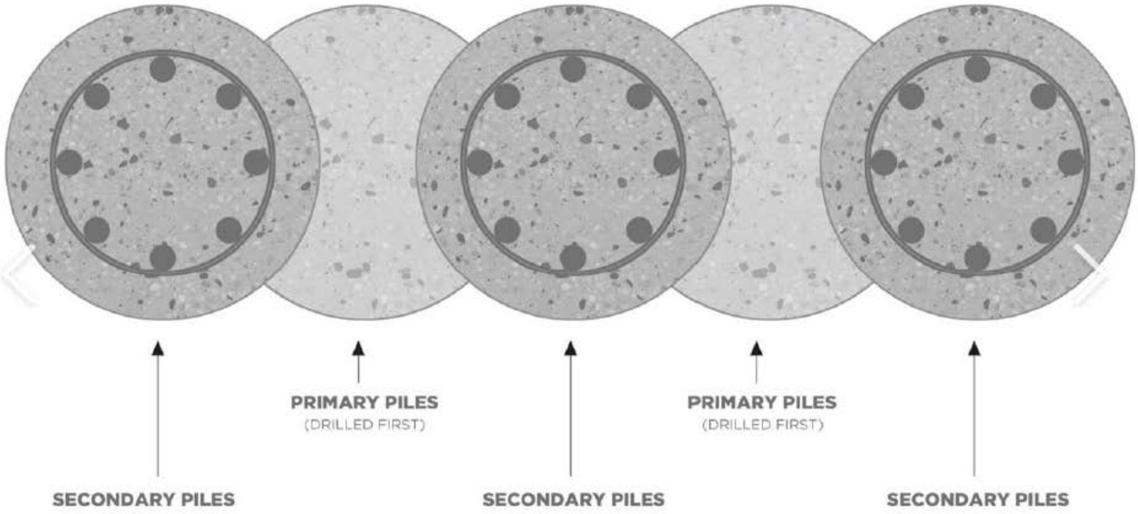

Figure 2.1: Typical layout of secant piles wall (BAM Nuttall, 2021)

2.2.2 Hydraulic rock breakers

Further detailed work on the design of the slipway carried out by MHPA and their contractors since the award of consent has highlighted that there may be hard substrate under the footprint of the slipway. Therefore, it may be required to use a hydraulic rock breaker, such as a vibro-ripper, below the existing water mark (i.e. in the wet) for the removal of areas of harder rock. A vibro-ripper may therefore be used as a secondary methodology where the consented backhoe dredger method cannot be used. The vibro-ripper will be used within the footprint originally considered for the backhoe dredger, there will be no increase in overall project seabed footprint. The vibro-ripper will generally use 2,7000 rpm high frequency vibrations and a claw attachment to break apart rock and construction materials.

2.2.3 Temporary stank

A temporary stank will be installed across the entrance of the eastern slipway (within the footprint of the consented slipway extension). It will be made up of two rows of three, double stacked 20 ft shipping containers which will be placed on the existing slipway floor to prevent water flow up the slipway while works are being carried out. The spaces between the shipping containers and the space between the containers and the quay wall will be filled with aggregate bags to maintain a water seal. The shipping containers will be placed within the footprint of the extended slipway and will be removed during construction of the extended slipway.

The existing east slipway floor at the end of the quay wall is -0.5m OD therefore the retained height of water is 3.79 m. The standard 20 ft shipping container is 2.59 m tall so two will be required to form a double staked barrier of 5.18 m high.

3 EXISTING ENVIRONMENT

3.1 Overview

The baseline description provided below draws on information established in the original ES which accompanies the Marine Licence application. Publicly available information sources were examined to inform the baseline characterisation for the purposes of the original ES. These include:

- Publicly available environmental datasets and information, e.g., EUNIS habitat data, reports by Cefas on seabed habitats, fish spawning and nursery habitats; and
- Information from other marine users, including Pembroke Port and the MHPA, licensed aggregate extraction and dredge disposal areas.

In addition, other publicly available information has been included where relevant.

3.2 Physical Processes

3.2.1 Suspended sediment concentrations

There is limited sediment input from offshore areas and the rivers that flow into the MHW, with anthropogenic factors identified as the primary source of sediment disturbance. Chronic sediment disturbance and re-suspension occur due to the continual development and industry throughout the MHW. Demolition of disused jetty structures, runoff from land disturbed, pile-driving for construction, propeller wash and bow-waves of tankers, tugs, ferries, cargo, and fishing vessels, by shellfish and bait-digging, and small vessel mooring have been found to be sources of sediment re-suspension. A major ongoing anthropogenic cause of sediment re-suspension within the MHW is likely to be periodic dredging as part of the capital and maintenance dredging operations by MHPA. Sediments re-suspended affect water transparency and therefore influence biotic processes.

Near the Dockyard, the suspended sediment concentrations (SSC) as measured by the turbidity and water transparency were found to be dependent on biogenic and anthropogenic factors. Turbidity data recorded in 2012 found that values ranged between a minimum of 2.3 formazin turbidity units (FTU) and a maximum of 19 FTU with a mean value over the period of 9.5 FTU.

Turbidity peak values were recorded in spring and may have coincided with phytoplankton blooms, with lower values recorded during summer months potentially due to low rainfall and decreasing current speeds. Water transparency, determined by a Secchi disk, is dependent on particulate matter and dissolved substances in the water. Recorded values between 2009 and 2011 ranged from 1.2 m to 3.1 m.

3.2.2 Physical sediment conditions

Marine sediments below Mean High Water Spring (MHWS) within Pembroke Port comprise gravel sand and mud fractions. 15 sediment samples were collected at varying depth intervals to the proposed dredge depth within the proposed slipway dredge footprint and analysed for Particle Size Distribution (PSD) across two sampling events undertaken in 2018 and 2020 in support of the EIA for the project.

In 2018 four samples collected within the slipway dredge footprint consisted of 74% mud with sand fractions constituting the remaining 26%.

The 2020 sampling survey identified surface sediment samples to be primarily composed of gravel fractions (45% ±28.3). Small amounts of sand were identified (17% ±9.0) with clay and silt fractions comprising 38% (±25.8).

Sampled sediments across both sampling events were generally considered to be poorly sorted with a conglomerate of silt, sand and clay fractions mixed together across all sites. These areas of mud predominantly derive from the rivers flowing into the waterway which have accumulated primarily in sheltered mudflats, including the area between Carr Jetty and Hobbs Point. The PSA results from 2020 sampling were found to differ from sediment samples collected in 2018 in that samples comprised of increased fractions of gravel replacing the silt and clay fractions identified in 2018.

These results are considered typical of the sediments found within the MHW (Carey *et al*. 2015).

3.3 Benthic Ecology

3.3.1 Subtidal ecology

The subtidal habitats of the Milford Haven Waterway (MHW) are represented by mixed sediments, reef, and eelgrass beds. Oligochaetes, polychaetes, and amphipods characterise the mixed sediments with dominant species including *Paradoneis lyra, Pholoe synophthamica, Sphaerosyllis* spp. and the non-native amphipod *Corophium sextonae*. Bivalves, such as the white furrow shell *Abra alba* are abundant towards the mouth of the MHW. Subtidal reef habitat has a patchy distribution throughout the MHW and is typically characterised by algae and bivalves on hard substrate, for example, the biotope red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles (SS.SMp.KSwSS.LsacR.CbPb) has been recorded as reef habitat near the Cleddau bridge. The reef building polychaete *Sabellaria spinulosa* has also been noted within the MHW and in undisturbed areas may form reef structures.

There are three populations of the subtidal seagrass *Zostera marina* within MHW, the largest of which lies 7 km to the west of Pembroke Port, located in Littlewick Bay on the northern shoreline of MHW. Two smaller populations of *Z. marina* lie approximately 3 km further from the Pembroke Port to the north west of the Littlewick Bay population, near Great Castle Head in Longoar Bay and Dale Bay located approximately 14 km to the west of Pembroke Port. *Zostera marina* is typically found on sand to fine gravel in depths of up to 5 m. Seagrass is a UK Biodiversity Action Plan (BAP) Priority Habitat, Habitat of Principal Importance under the Environmental (Wales) Act 2016, and is a sub-feature of 'large, shallow inlets and bays', 'estuaries' and 'subtidal sandbanks' which are designated features of the Pembrokeshire Marine/ Sir Benfro Forol SAC.

Maerl beds are formed by slow-growing coralline algae and typically occur either on the open coast or in tide-swept channels of marine inlets. Maerl forms a unique habitat that supports a diverse assemblage of infauna and epifaunal species. A previously well-established maerl bed that has become degraded in recent years lies 7 km to 9 km to the west of Pembroke Port, in the vicinity of Littlewick Bay to Stack Rock. This is the only known living maerl bed in Wales, excluding small amounts of maerl not constituting a bed. Maerl is legally protected under several designations including Annex V (b) of the EC Habitats Directive (92/43/EEC) as amended in 2010 on the Conservation of Natural Habitats and of Wild Fauna and Flora, the UK BAP for the diversity of flora and fauna (1994), and the Welsh Government's Habitats and Species of Principal Importance for Wales list. Maerl is a sub-feature of 'large, shallow inlets and bays', 'estuaries' and 'subtidal sandbanks' which are designated features of the Pembrokeshire Marine/ Sir Benfro Forol SAC.

The subtidal substrate near to Pembroke Port is mixed with varying proportions of silt/clay, fine sand, coarse sand and shells and cobble and rocky reef. Subtidal benthic ecological communities in this area are characterised by annelids, bivalves, and green and brown algae. A recent review of data collected between 2008 to 2017 found that the most abundant species near the Pembroke Port were the polychaetes *Melinna palmata* and *Chaetozone gibber*, seed shrimps *Ostracoda* spp., and amphipods *Ampelisca diadema* and *Photis longicaudata* (Warwick, 2017).

3.4 Fish and Shellfish Ecology

3.4.1 Fish

The fish assemblages of the MHW are typical of an estuarine environment with different characterising species towards the outer reaches of the estuary compared to the inner estuary, reflecting the changes in environmental conditions, including substrate type, water flow and salinity. Gobies *Pomatoschistus* spp. are the most abundant species group with sand smelt *Atherina presbyter* and bass *Dicentrachus labrax* also occurring in relatively high numbers. Three species of thick-lipped mullet *Mugilidae* were also regularly recorded within the MHW. Otter trawls conducted for the Pembroke Power Station, approximately 2.5 km from Pembroke Port, recorded 19 species of fish including elasmobranchs, (thornback ray *Raja clavata*, lesser spotted dogfish *Scyliohinus caniculus*), demersal flat fish (plaice *Pleuronectes platessa*) and abundant gobies.

Several species of diadromous fish migrate through the MHW between seawater and freshwater, all of which are of conservation importance as Annex II species protected under European legislation or as Welsh BAP priority species. Four of the species of diadromous fish are qualifying features of the Pembrokeshire Marine/ Sir Benfro Forol SAC: sea *lamprey Petromyzon marinus*, river lamprey *Lampetra fluviatilis*, allis shad *Alosa alosa* and twaite shad *Alosa fallax*. River lamprey is a primary reason for selection of the Cleddau Rivers

/Afonydd Cleddau SAC and sea lamprey is a qualifying feature of this SAC. Atlantic salmon, sea trout and European eel are all listed as OSPAR threatened/declining species. All of these species are listed as UK BAP species, and species of Principal Importance under the Environment (Wales) Act 2016.

According to Ellis *et al*. (2012), spawning habitats for sandeel *Ammodytidae*, plaice, herring *Clupea 8arengus* and sole *Solea solea* may coincide with the MHW. Although all are considered to be of low intensity except for sandeel which is considered to have high intensity spawning ground within the MHW.

The sheltered estuarine conditions also provide a safe environment for juvenile fish and therefore the waters of the MHW are mapped as an important nursery area for sandeel, plaice, sole, whiting *Merlangius merlangus*, herring, mackerel *Scomber scombrus*, spotted ray *Raja montagui*, thornback ray and tope shark *Galeorhinus galeus* (Ellis *et al*., 2012). The Pembroke River and the tidal waters of the Daugleddau upstream of the Cleddau Bridge have been identified as bass nursery areas, as has an area in Pembroke Bay around the old power station outfall (Pawson *et al*., 2002).

3.4.2 Shellfish

Historically, MHW has been historically harvested for Pacific oyster *Crasseotrea gigas*, carpet shell clam *Ruditapes decussatus*, razor clams *Pharidae* spp. and native oyster *Ostrea edulis* (Cefas, 2012), although no permits for collection of native oysters have been awarded within MHW since 2010 (PNP, 2017). The large area, diverse marine habitats and sediment types, results in a variety of shellfish species, some of which have conservation and commercial interests. Pawson *et al*. (2002) describe the Pembrokeshire coast as a valuable potting ground for European lobster *Homarus gammarus*, shore crab *Carcinus maenus*, spider crab *Maja squinado* and velvet swimming crab *Necora puber*. Other abundant shellfish within along the coast include the common periwinkle *Littorina littorea*, king scallop *Pecten maximus*, common whelk *Buccinum undatum* and queen scallop *Aequipecten opercularis*.

Most of the shellfish found within the MHW also spawn within the area. Typically, these species produce very large numbers of eggs and there is a planktonic larval phase which allows dispersal over a wide area and settlement into favoured habitats both within the MHW and outside the estuary in coastal waters.

The substrates around Pembroke Port support several common bivalve species, which are typical of estuarine environments.

3.5 Marine Mammals

3.5.1 Cetaceans

Of the 18 species of cetaceans found within Welsh coastal and offshore waters, only harbour porpoise *Phocoena phocoena* and bottlenose dolphin *Tursiops truncatus* are known to occur within the MHW. Most individuals are likely to occur within the lower reaches of the MHW with very few venturing as far as Pembroke Port.

Harbour porpoise is widespread and abundant throughout British waters and the harbour porpoise abundance for the Celtic/Irish Sea Management Unit (CIS MU) was estimated as 104,695 animals (95% Confidence Interval (CI) 56,774 to 193,065) (IAMMWG, 2015). The most recent SCANS (Small Cetacean Abundance in the North Sea) surveys (SCANS III) estimated abundance in Block D as 5,734 (95% CI = 1,697 – 12,452) with a density estimate of 0.118 animals/km^2 (coinciding with the MHW) (Hammond *et al*., 2021). Locally, high densities of harbour porpoise are known from coastal waters off southwest Wales (Reid *et al*., 2003), and are particularly abundant around the Pembrokeshire Islands (De Boer and Simmonds, 2003). Harbour porpoise are found in water depths of 3 m to 100 m but normally less than 50 m and are often in coastal waters, particularly during the summer months. As a species with a high metabolic rate, they need to feed regularly. Key prey items include schooling gadoids (Read, 1999) such as pollack, cod, poor cod *Trisopterus minutus*, whiting and hake, and inshore shoaling fish such as herring, sandeel, sprat, mackerel, squid, octopus, and crustaceans (Hutchinson *et al*., 1995).

Bottlenose dolphin occurs regularly within Welsh waters with most sightings around Cardigan Bay, where there is a resident population (Baines and Evans, 2012). There are frequent sightings elsewhere along the Pembrokeshire coast, particularly off Skokholm and Skomer and sometimes off Strumble Head, especially between July and September. The bottlenose dolphin abundance for the Offshore Channel, Celtic Sea and South West England (OCSW) MU was estimated as 4,856 animals (95% CI = 1,638 – 14,398) (IAMMWG, 2015). During the most recent SCANS III surveys, 2,938 bottlenose dolphins were estimated within SCANS

III survey Block D (95% CI = 914 – 5,867), with an estimated density of 0.06 animals/km2 (Hammond *et al*., 2021). Bottlenose dolphins are typically found within 10 miles of the coast and often occur in large groups of up to 60 individuals near to Cardigan Bay.

The waters near Pembroke Port are not a key area for cetacean species. Baseline data shows infrequent sightings of harbour porpoise and bottlenose dolphin within the MHW with a low likelihood of occurrence as far up as Pembroke Port.

3.5.2 Pinnipeds

Only one species of pinniped, the grey seal *Halichoerus grypus*, occurs in Welsh waters. The Pembrokeshire coast contains the main colony in Wales and is the most southerly in Europe of any significant size (Baines *et al*., 1995). Grey seals haul out to rest, pup, and nurse their young and moulting and resting haul-out sites are distributed throughout the Pembrokeshire Marine/ Sir Benfro Forol SAC. Pupping takes place throughout the Pembrokeshire Marine/ Sir Benfro Forol SAC on open coast in suitable habitat (i.e., physically accessible, remote and/or undisturbed rocky coast beaches, coves, and caves). The most recent estimates for pup production at the major haul-outs in Wales are 465 pups in North Pembrokeshire in 2005 (Strong *et al*., 2006) and 345 pups born on Skomer and adjacent mainland sites on Marloes Peninsula in 2016 (NRW, 2017). Historic data suggests that grey seal may occasionally occur in low numbers within the MHW and near to Pembroke Port.

Grey seal are highly mobile, and forage widely and frequently travel up to 100 km between their haul-out sites and foraging areas, though they can travel further (SCOS, 2017). As generalist feeders, grey seal feed on a wide range of prey items including whiting, cod *Gadus mordua*, haddock *Melanogrammus aeglefinus*, ling *Molva molva* and various species of flatfish. A study of grey seal diets from scats collected in Pembrokeshire, found that gadoids (mainly whiting) and flatfish (mainly sole) dominated the diet (Strong, 1996).

3.5.3 Otters

Otter *Lutra lutra* inhabit freshwater, brackish and marine environments and are known to occur in Welsh coastal waters. The otter has a wide range and distribution throughout Pembrokeshire coastal waters, including within the MHW (known from spraint records and foreshore access points from watercourses with suitable breeding and feeding habitat; CCW, 2009; Liles, 2003). With a varied diet, spraints collected from the open coast of Pembrokeshire and within the MHW were analysed and found to contain remains of many different species of marine, estuarine, and saltwater fish.

Boulders on the front of the dock within the ferry terminal area, over 100 m from the boundary of the application site (RPS, 2019), were identified as having the potential to contain gaps in which otter could rest up. The terrestrial areas of the dock are largely devoid of features of potential value for otter.

Due to the high levels of otter activity recorded within the MHW it is likely that this species occurs near Pembroke Port, although there is less likely to be breeding sites in this area due to the potential disturbance from the existing anthropogenic activities associated with Pembroke Port.

3.6 Designated sites

Pembroke Port lies outside any international, national, or local environmentally designated sites. Table 3.1 and Figure 3.1 detail internationally and nationally designated sites that occur within the vicinity of Pembroke Port or in the wider region and for which a potential receptor-impact pathway has been identified with respect to particular features within those sites.

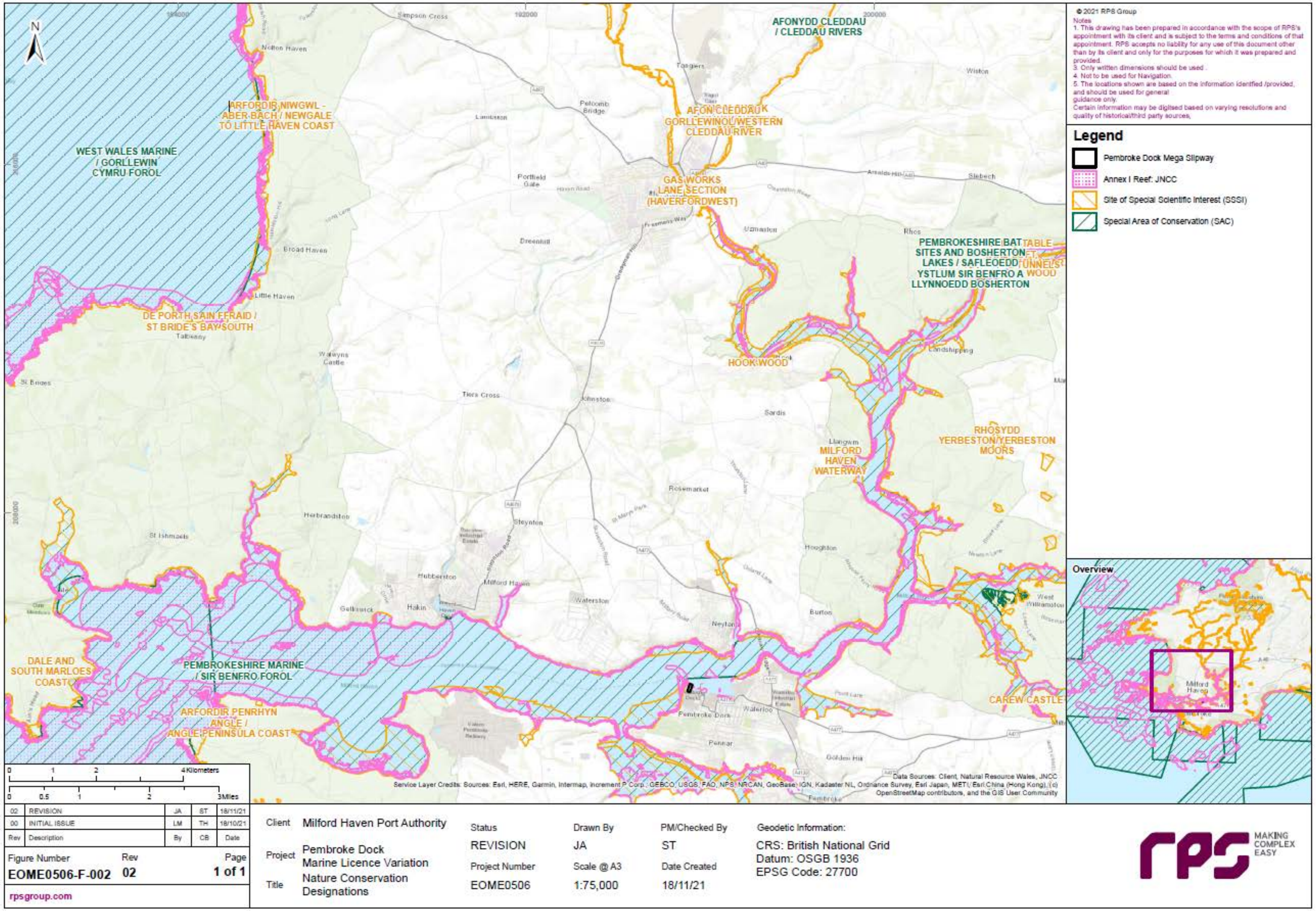

Figure 3.1: Designated sites in close proximity to Pembroke Port

Table 3.1: Designated sites in close proximity to Pembroke Port (features not applicable to this assessment are greyed out)

Designated site	Distance from the project boundary	Relevant Qualifying Interest Features	Conservation Objective
Pembrokeshire Marine/ Sir Benfro Forol SAC	~50 m	• Large shallow inlets and bays • Estuaries • Reefs • Mudflats and sandflats not covered by seawater at low tide • Sandbanks which are slightly covered by sea water all the time • Coastal lagoons • Atlantic salt meadows (Glauco-*Puccinellietalia maritimae*) • Submerged or partially submerged sea caves • Grey seal *Halichoerus grypus* • Mobile fish species: – Sea lamprey *Petromyzon marinus* – River lamprey *Lampetra fluviatilis* – Allis shad *Alosa alosa* – Twaite shad *Alosa fallax* • Otter *Lutra lutra* • Shore dock *Rumex rupestris*	• To meet the aims of the Habitats Directive, the conservation objectives seek to maintain (or restore) the habitat and species features, as a whole, at (or to) favourable conservation status (FCS) within the site. • In order to achieve FCS for qualifying features (habitats), all of the following, subject to natural processes, need to be fulfilled and maintained in the long-term. If these objectives are not met restoration measures will be needed to achieve FCS: – Range – the overall distribution and extent of the habitat features within the site, and each of their main component parts is stable or increasing; – Structure and function – the physical biological and chemical structure and functions necessary for the long-term maintenance and quality of the habitat are not degraded; and – Typical species – the presence, abundance, condition and diversity of typical species is such that habitat quality is not degraded. • To ensure for qualifying features (species population) that, subject to natural change, the following attributes are maintained or restored in the long term: – The population is maintaining itself on a long-term basis as a viable component of its natural habitat. Important elements include: population size; structure, production; and condition of the species within the site; – The species population within the site is such that the natural range of the population is not being reduced or likely to be reduced for the foreseeable future; and – The presence, abundance, condition and diversity of habitats and species required to support this species is such that the distribution, abundance and population dynamics of the species within the site and population beyond the site is stable or increasing.
Cleddau Rivers/Afonydd Cleddau SAC	11 km	• Mobile fish species: – River lamprey *Lampetra fluviatilis* – Sea lamprey *Petromyzon marinus* – Bullhead *Cottus gobio*	• To avoid deterioration of the habitats of the qualifying features or significant disturbance to the qualifying features, thus ensuring that the integrity of the site is maintained, and the site makes an appropriate contribution to maintaining FCS for the qualifying features.

Designated site	Distance from the project boundary	Relevant Qualifying Interest Features	Conservation Objective
		– Brook lamprey *Lampetra planeri* • Otter *Lutra lutra* • Habitats: – Water courses of plain to montane levels with the *Ranunculion fluitantis* and Callitricho-Batrachion vegetation – Active raised bogs • Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alnion incanae*, *Salicion albae*). Alno-Padion (forest type according to European Environment Agency)	• To ensure for qualifying features that, subject to natural change, the following attributes are maintained or restored in the long term: – The species is a viable component of the site; – There is no significant disturbance of the species; and – The supporting habitats and processes relevant to qualifying features and their prey are maintained.
West Wales Marine/Gorllewin Cymru Forol SAC	10 km	• Harbour porpoise *Phocoena phocoena*	• 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: – Harbour porpoise is a viable component of the site; – There is no significant disturbance of the species; and – The condition of supporting habitats and processes, and the availability of prey is maintained.
Milford Haven Waterway Site of Special Scientific Interest (SSSI)	<50 m	Intertidal rocky shore, sandflats, mudflats	N/A

4 MEASURES ADOPTED AS PART OF THE PROJECT

There are several mitigation measures that have been adopted as part of the project and were committed to as part of the awarded Marine Licence. In assessing the impacts of the PDI project, it has been assumed that these measures are in place and therefore the assessment of sensitivity, magnitude and significance includes implementation of these measures. These measures are listed in Table 4.1.

Table 4.1: Mitigation measure adopted as part of the project

Measure	Description
Construction Environmental Management Plan (CEMP)	Control of pollution during construction will be set out in a CEMP. This will include best practice measures to prevent accidental spillage of chemicals during construction activities.
Environmental Management Plan (EMP)	The EMP will manage the risks of all operational activities, facilities and cargos handled by the port and will include best practice measures to control pollution following standard guidelines such as the Environment Agency Pollution Prevention Guidelines.
Invasive and Non-Native Species (INNS) Management Plan	A document detailing how the risk of potential introduction and spread of INNS will be minimised will be produced. The plan will outline measures to ensure vessels comply with the International Maritime Organization (IMO) ballast water management guidelines, it will consider the origin of vessels and contain standard housekeeping measures for such vessels as well as measures to be adopted in the event that a high alert species is recorded.
Installation of a Cofferdam at the entrance to Graving Dock	To restrict the migration of sediment plumes during dredging and therefore reducing potential for increases turbidity and release of contaminants into receiving waterbody

5 ASSESSMENT OF EFFECTS

5.1 Approach

A scoping exercise was carried out to inform this environmental appraisal, based on RPS's extensive experience in preparing similar assessments for comparable licensable activities. The following sections provide an assessment of the potential environmental impacts of the installation of a temporary stank, secant piled wall and the use of a hydraulic rock breaker in relation to the following environmental topics:

- Physical Processes;
- Benthic Ecology;
- Fish and Shellfish; and
- Marine Mammals.

Activities, topics, and impacts scoped out of the assessment are presented in together with justification in Appendix A.

The assessment presented in this section considers the maximum scenario for the updated activities for the PDI project as presented in Section 2, however this is considered likely to result in a highly precautionary impact assessment. The most likely impact is likely to be less than that predicted as part of the assessment.

Potential impacts in relation to each of the environmental topics identified have been assessed using the authors experience gained through undertaking assessments for similar projects within the UK and available evidence. Each assessment concludes whether the licensable activities are likely to result in a negligible, minor, moderate, or major effect on the receptor. For the purpose of this assessment the following has been assumed:

- Negligible effects are those that are not considered to be detectable above natural variation;
- Minor effects are those that may be detectable above natural variation but are not considered likely to affect receptors in the medium term (months).
- Moderate effects are those that may affect receptors in the medium to long-term (months – years);
- Major effects are those that may affect receptors in the long term (years).

Consideration of the potential for Likely Significant Effect (LSE – as defined by the Habitats Regulations 2017) on Natura 2000 sites is presented in Section 7 and an assessment against the Water Framework Directive is presented in Section8.

5.2 Physical Processes

5.2.1 Increases in suspended sediment concentrations

Increases in suspended sediment concentrations may occur as a result of installation and removal of a temporary stank at the current eastern slipway and rotary drilling for the new secant piled slipway walls. Only very small volumes of sediment are expected to be released as a result of these updated activities, which will be substantially less than the volumes associated with the consented capital dredging works in this area. Increases in suspended sediments as a result of seabed clearance via hydraulic rock breaker for the mega slipway are not considered to be different from what was assessed in the original ES for the capital dredging works to clear this area.

Sediments at the Pembroke Port are made up of muds, sands and gravels with various proportions recorded across different survey years (Section 3.2.2). Based on the maximum current velocities, the physical processes assessment undertaken to inform the PDI EIA (RPS, 2019) showed that a typically sized gravel particle would be transported 2 m from its origin during dredging. For coarse sand (which is the same as finest gravel) would be carried 10 m on peak ebb and 2 m on peak flood. The finest of the sand fraction was predicted to be transported 260 m and 100 m in ebb and flood flows, respectively (RPS, 2019; Aarninkhof *et al*. 2018; Becker *et al*, 2015). Therefore, the very small volumes of suspended sediments arising from the proposed works (i.e. rotary drilling and installation/removal of the temporary stank) would be quickly diluted and dispersed.

The EIA for the original Marine Licence application assessed the impact of increases suspended sediments as a result of dredging of a total volume of up to 45,840 m^3. It concluded that suspended sediments would remain in the immediate area of the works and sediment deposition would only occur in the order of 2-3 mm. Baseline levels of suspended sediment concentrations in the Pembroke Port are already high due to anthropogenic activities, mainly capital and maintenance dredging operations. Therefore, the effect of the temporary stank and rotary drilling on suspended sediment concentration is considered to be **negligible**, and therefore no greater than that concluded for the original EIA for the PDI project.

5.3 Benthic Ecology

5.3.1 Temporary habitat disturbance associated with the temporary stank and installation of the secant piled walls.

Installation of the temporary stank will result in temporary habitat disturbance within the footprint of the temporary stank. As discussed in Section 2.2.3, the temporary stank will be installed across the entrance of the eastern slipway and will be made up of two rows of double stacked 20 ft shipping containers. The footprint of the container is 6.06 m long and 2.44 m wide therefore the total seabed footprint of the temporary stank will be 88.74 m^2 (the two containers will be stacked to only 6 containers will be on the seabed). The temporary stank will be placed within the footprint of the slipway extension which has been granted consent under the marine licence (CML2057). The temporary stank will be removed directly before the slipway extensions is constructed. This area therefore was already assessed in the EIA as long-term habitat loss and there will be no additional footprint of habitat loss as a result of the installation of the temporary stank.

The jack-ups will be required to stabilise the rotary drilling process for the secant piled walls. 26 jack-up events will be required however most of them will be within the footprint of the slipway and therefore do not represent additional seabed disturbance outside of the footprint assessed in the original EIA. Up to 10 jack-up events have been allowed for outside the slipway footprint, this represents an area of additional disturbance of 48 m^2 as each jack-up event will disturb an area of 4.8 m^2. Overall, there is a potential additional seabed disturbance footprint of 136.74 m^2. This is a very small increase in temporary habitat disturbance compared to the assessment in the original EIA and Marine Licence application which assessed habitat loss around the slipway of 5,669 m^2 whilst dredging and infilling of the Graving Dock would remove 2,503 m^2 of habitat.

Benthic habitats under the footprint of the temporary stank and secant piled walls are likely to be sands and muddy sands as well as silt/clay and coarse sediments, colonised by annelids and bivalves. The JNCC reef layer shown in Figure 3.1 shows a reef has been recorded in the footprint of the extended slipway. The temporary stank however will be placed within the footprint of the already licenced slipway extension and therefore no additional habitat loss will result from the installation of the temporary stank. The sensitivity of this sand and mud habitat to surface disturbance is low. Characterising species comprise burrowing species which can better avoid the effects of penetration disturbance and highly mobile swimmers which are adapted to life in unstable sediments (Tillin *et al.*, 2019a,b; Tillin & Budd, 2016; Tillin and Rayment, 2016). The life traits of characteristic species such as *Ampelisca diadema* and *Photis longicaudata* mean they are likely to recover quickly to recolonise the area (Tyler-Walters and Bastos, 2020). Disturbance may damage the proportion of sessile bivalve however they are like to recruit and recover rapidly as the area disturbed is very small compared to the surrounding similar habitat.

Coarse sediment habitats at the Pembroke Port (Warwick, 2017) are not sensitive or have low sensitivity to disturbance. Characterising species are robust and mobile and can therefore avoid disturbance by swimming (Tillin, 2016a). Burrowing bivalves would also be unaffected by surface abrasion however venerid bivalves which live close to the surface are more likely to be damaged. Trawling studies on coarse sediments have suggested that the characterising species are relatively tolerate to disturbance (Tillin, 2016b; Capasso *et al*, 2010).

No habitat loss will occur within the boundary of the Pembrokeshire Marine/ Sir Benfro Forol SAC.

Therefore, the effect of the habitat disturbance associated with the temporary stank and installation of the secant piled walls on benthic habitats is considered to be **negligible**, and therefore no greater than that concluded for the original EIA for the PDI project.

5.3.2 Effects on benthic ecology associated with pumping grout and/or cement underwater

The current activities licensed under CML2057 allow for the construction of the new mega slipway from concrete with structural steel members and for the associated deposition of site manufactured materials (concrete/masonry based) and steel. This was considered in the EIA (RPS, 2019), indirectly as part of the assessment of the accidental release of pollutants during construction. The Applicant is not proposing any change to the originally licenced activity but have included a more detailed assessment to explicitly cover and consider the licensed activity of pumping concrete underwater.

Pumping grout and/or cement into the foundations for the slipway may impact benthic ecology receptors through habitat disturbance and minor changes in the water pH directly adjacent to the works. It is not possible to quantify the area of seabed that may disturbed by the pumping of grout and/ or cement however, it is likely to be very small, especially in context of the similar habitats in the wider area.

Grout and concrete are alkaline and therefore, when pumped underwater, have the potential to change the water pH where it makes contact with the water. Fitch (2003) reported that the introduction of concrete to a freshwater environment from bridge building caused an increase of pH, however this returned to baseline levels after five hours. This study however took place in a freshwater river system therefore is less applicable to a marine environment which is generally slightly alkaline.

The grout and/ or concrete used will be designed for use in the marine environment and will set quickly. Any pH change is likely to be minor and will dissipate quickly with the currents and high turbidity caused by works with the Port. The effects on benthic ecology associated with pumping group and/ or cement were considered within the assessment of the project activities in the original ES and was considered to be not significant in EIA terms. Therefore, the effect pumping grout and/or cement underwater on benthic ecology is considered to be **negligible**, and therefore no greater than that concluded for the original EIA for the PDI project.

5.4 Fish and Shellfish Ecology

5.4.1 Underwater noise effects on fish and shellfish receptors associated with the installation of the secant piled walls

Underwater noise has the potential to affect fish in different ways depending on the noise level and characteristics. The activities related to the installation of piled walls using rotor drilling methodology can result in non-impulsive (continuous) sound. Non-impulsive sound is typical of continuous running machinery, and vessels. If the frequency of non-impulsive noise emissions overlaps with the frequencies audible by fish, this may influence the animal (Weilgart, 2007). The level of influence varies with distance from the source and level.

For this Marine Licence variation, one method of pile installation is proposed, rotary drilling. The sound source was modelled to understand the potential impact on fish. The full noise report can be found in Appendix C. The source sound levels for rotary drilling have been based on pile drilling for the Oyster 800 project (Kongsberg 2011). The source levels used in the assessment are summarised in Table 5.1. The guidelines set out criteria for injury due to different sources of noise. The criteria include a range of indices such as sound exposure level (SEL, the total sound energy of an event normalised to 1 second), and peak sound pressure levels (the difference between the highest-pressure variation and the mean pressure). RMS is the average amplitude of variation in pressure over a specific time period, in this case 90 seconds.

Table 5.1: Rotary drilling noise source levels used in assessment (un-weighted).

Parameter	Source level at 1 m
SEL per second of operation @ 1 m, dB re 1 μPa^2s	163
Peak sound pressure level @ 1 m, dB re 1 μPa	166
rms_{T90} sound pressure level @ 1 m, dB re 1 μPa	163

For fish, the most relevant criteria for injury from sound are considered to be those contained in the recent Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*. 2014). These guidelines do not group by species but instead broadly group fish into the following categories based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

- **Group 1 fish:** fishes with no swim bladder or other gas chamber (e.g., elasmobranchs, flatfishes and lampreys). These species are less susceptible to barotrauma and are only sensitive to particle motion, not sound pressure. Basking shark, which does not have a swim bladder, falls into this hearing group;
- **Group 2 fish:** fishes with swim bladders but the swim bladder does not play a role in hearing (e.g., salmonids). These species are susceptible to barotrauma, although hearing only involves particle motion, not sound pressure;
- **Group 3:** Fishes with swim bladders that are close, but not connected, to the ear (e.g., gadoids and eels). These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than groups 1 and 2, extending to about 500 Hz;
- **Group 4:** Fishes that have special structures mechanically linking the swim bladder to the ear (e.g., clupeids such as herring, sprat and shads). These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3;
- **Sea Turtles:** There is limited information on auditory criteria for sea turtles and the effect of impulsive noise is therefore inferred from documented effects to other vertebrates. Bone conducted hearing is the most likely mechanism for auditory reception in sea turtles and, since high frequencies are attenuated by bone, the range of hearing are limited to low frequencies only (Tonndorf, 1972). For leatherback turtle the hearing range has been recorded as between 50 and 1,200 Hz with maximum sensitivity between 100 and 400 Hz (Piniak, 2012); and
- **Fish eggs and larvae**.

The guidelines set out criteria for injury due to different sources of noise. The criteria include a range of indices such as the South Exposure Level (SEL, the total sound energy of an event normalised to 1 second), and peak sound pressure levels (the difference between the highest-pressure variation and the mean pressure). Where insufficient data exist to determine a quantitative guideline value, the risk is categorised in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e., in the tens of metres), “intermediate” (i.e. in the hundreds of metres) or “far” (i.e. in the thousands of metres). It should be noted that these qualitative criteria cannot differentiate between exposures to different noise levels and therefore all sources of noise, no matter how noisy, would theoretically elicit the same assessment result. To establish the temporary threshold shift (TTS) (when noise is great enough to cause temporary damage to the ear tissue) the following criteria (Popper *et al.,* 2014) were used:

- For continuous sound – 158 dB re 1 µPa (rms) for 12 hours.

Based on the existing environmental information Allis shad and twaite shad, which are qualifying features of the Pembrokeshire Marine/ Sir Benfro Forol SAC have been identified as group 3 and 4 species. Furthermore, sea lamprey, and river lamprey are qualifying features of the Pembrokeshire Marine/ Sir Benfro Forol SAC and Cleddau Rivers/Afonydd Cleddau SAC and are group 1 fish but of least concern in terms of underwater noise.

The criteria used in this noise assessment for the onset of injury from rotary drilling (non-impulsive) are given in Table 5.2.

Table 5.2: Criteria for onset of injury to fish due to non-impulsive sound (Popper *et al*., 2014).

Receptor	Mortality and potential mortal injury	Recoverable Injury	TTS
Group 1 Fish – including sea lamprey and river lamprey	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Moderate (Far) Low

Groups 3 and 4 Fish – including Twaite shad and Allis shad	(Near) Low (Intermediate) Low (Far) Low	170 dB re 1 µPa (rms) for 48 hours	158 dB re 1 µPa (rms) for 12 hours

Behavioural reaction of fish to sound has been found to vary between species based on their hearing sensitivity. Typically, fish sense sound via particle motion in the inner ear which is detected from sound-induced motions in the fish's body. The detection of sound pressure is restricted to those fish which have air filled swim bladders; however, particle motion (induced by sound) can be detected by fish without swim bladders. Highly sensitive species such as Allis shad have elaborate specialisations of their auditory apparatus, known as an otic bulla – a gas-filled sphere, connected to the swim bladder, which enhances hearing ability.

The most recent criteria for disturbance are considered to be those contained in Popper *et al*. (2014) which set out criteria for disturbance due to different sources of noise (Table 5.3).

Table 5.3: Criteria for onset of behavioural effects to fish due to non-impulsive sound (Popper *et al*., 2014).

Receptor	Relative risk of behavioural effects
Group 1 Fish – including sea lamprey, river lamprey, sand eel, plaice, sole and mackerel	(Near) Moderate (Intermediate) Moderate (Far) Low
Group 2 Fish – including Atlantic salmon	(Near) Moderate (Intermediate) Moderate (Far) Low
Groups 3 and 4 Fish – including Twaite shad, Allis shad, European eel, and herring	(Near) High (Intermediate) Moderate (Far) Low

It is important to note that the Popper *et al*. (2014) criteria for disturbance due to sound are qualitative rather than quantitative. Consequently, a source of noise of a particular type (e.g., drilling) would result in the same predicted impact, no matter the level of noise produced or the propagation characteristics. Pile installation through rotor drilling will take place over 83 days.

The results of the noise modelling for rotary drilling are displayed below in Table 5.4.

Table 5.4: Summary of potential injury and disturbance zones for rotary drilling (N/E – not exceeded)

Receptor	Piling Method	Mortality / potential mortal injury	Recoverable Injury	TTS
Groups 1 and 2 Fish	Rotary drilling	No threshold	No threshold	No threshold
Groups 3 and 4 Fish		No threshold	N/E	N/E

Overall, the model provided as part of the noise assessment (Table 5.4) suggest that for the non-impulsive rotary drilling there is little potential for injury (PTS or TTS) to fish in the vicinity of the works.

The impact of underwater noise on the behaviour of fish is highly dependent on their proximity to the noise source. Table 5.2 highlights that Twaite and Allis shad and other group 3 and 4 fish have high risk of behaviour change in the near field (10's of meters). The boundary of the nearest SAC which is designated for both shad is approximately 50 m away, making the potential impacts from noise on the features of the SAC minimal. The risk to the most sensitive group 3 and 4 fish is moderate at intermediate distances for both shad however the background noise of Pembroke Port has the potential to deter the shad from entering this site preventing them from experiencing the levels of noise required for behavioural effects as a result of piling. Group 1 and 2 fish, including lamprey species, are at moderate risk of behaviour change in the near and intermediate fields, although as outlined above these species are not anticipated to occur within the boundaries of the Port.

Adult fish not in the immediate vicinity of the noise generating activity are generally able to vacate the area and avoid physical injury. Furthermore, the installation site sits within the highly active Pembroke Port which produces underwater noise from vessels on a daily basis. Noise sensitive fish are therefore unlikely to frequent this area. The additional vessels need for the installation of the secant walls are therefore unlikely to exceed the background noise levels of the port. Therefore, the effect of underwater noise from the installation of the secant piled walls at the existing flank wall of the slipway on fish and shellfish is considered to be **negligible**, and therefore no greater than that concluded for the original EIA for the PDI project.

5.4.2 Underwater noise effects on and fish and shellfish receptors associated with hydraulic rock breaking equipment

The potential of underwater noise has the potential to affect fish in different ways is discussed in section 5.4.1. The activities related to the operation of the hydraulic rock breaking equipment below the existing water mark may result in non-impulsive (continuous) sound emissions. The sound source was modelled to understand the potential impact on fish. The full noise report can be found in Appendix C. The hydraulic rock breaking source sound levels are based on those measured by Lawrence (2016). The source levels used in the assessment are summarised in Table 5.5.

Table 5.5: Hydraulic breaking equipment noise source levels used in assessment (un-weighted).

Parameter	Source level at 1 m
SEL per second of operation @ 1 m, dB re 1 $\mu Pa^2 s$	177
Peak sound pressure level @ 1 m, dB re 1 μPa	212
rms_{T90} sound pressure level @ 1 m, dB re 1 μPa	177

For fish, the most relevant criteria for injury from impulsive sounds are those presented in the Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*. 2014) and are shown in Table 5.6.

Table 5.6: Criteria for onset of injury to fish due to impulsive piling (Popper *et al*., 2014).

Receptor	Parameter	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	SEL, dB re 1 $\mu Pa^2 s$	>219	>216	>>186
	Peak, dB re 1 μPa	>213	>213	
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL, dB re 1 $\mu Pa^2 s$	210	203	>186
	Peak, dB re 1 μPa	>207	>207	
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL, dB re 1 $\mu Pa^2 s$	207	203	186
	Peak, dB re 1 μPa	>207	>207	

Behavioural reaction of fish to sound is as described previously in Section 5.4.1 and the criteria for behavioural effects to fish to impulsive noise is in Table 5.7.

Table 5.7: Criteria for onset of behavioural effects to fish due to impulsive sound (Popper *et al*., 2014).

Receptor	Relative risk of behavioural effects
Group 1 Fish – including sea lamprey, river lamprey, sand eel, plaice, sole and mackerel	(Near) High (Intermediate) Moderate (Far) Low
Group 2 Fish – including Atlantic salmon	(Near) High (Intermediate) Moderate (Far) Low
Groups 3 and 4 Fish – including Twaite shad, Allis shad, European eel, and herring	(Near) High (Intermediate) High (Far) Moderate

The results of the noise modelling regarding the impact of the hydraulic rock breaker can be seen below in Table 5.8.

Table 5.8: Summary of potential injury and disturbance zones for operation of the hydraulic rock breaker (N/E – not exceeded)

Receptor	Piling Method	Mortality / potential mortal injury	Recoverable Injury	TTS
Groups 1 and 2 Fish	Rotary drilling	No threshold	No threshold	No threshold
Groups 3 and 4 Fish		N/E	N/E	N/E

Overall, the model provided as part of the noise assessment (Table 5.8) suggest that for the impulsive hydraulic rock breaker there is little risk of PTS or TTS to fish occurring in the vicinity of the works.

Adult fish not in the immediate vicinity of the noise generating activity are generally able to vacate the area and avoid physical injury. Furthermore, the installation site sits within the highly active Pembroke Port which produces underwater noise from vessels on a daily basis. Noise sensitive fish are therefore unlikely to frequent this area. The additional vessels need for the operation of the hydraulic rock breaker are therefore unlikely to exceed the background noise levels of the port. Therefore, the effect of underwater noise from the operation of hydraulic rock breaking equipment below the existing water mark on fish and shellfish is considered to be **negligible**, and therefore no greater than that concluded for the original EIA for the PDI project.

5.5 Marine Mammals

5.5.1 Underwater noise effects on marine mammals associated with the installation of the secant piled walls

Underwater noise has the potential to affect marine mammals in different ways depending on the noise level and characteristics. The activities related to the installation of piled walls using rotor drilling methodology can result in non-impulsive (continuous) sound. If the frequency of non-impulsive noise emissions overlaps with the frequencies audible by marine mammals, this may influence the animal (Weilgart, 2007). The level of influence varies with distance from the source and level. The sound source was modelled to understand the potential impact on marine mammals. The full noise report can be found in Appendix C. The source sound levels for rotary drilling have been based on pile drilling for the Oyster 800 project (Kongsberg 2011). The source levels used in the assessment are as summarised previously in Table 5.1.

Southall *et al.* (2007) classified cetacean and seal species into functional hearing groups based on similarities in known or expected hearing capabilities. The hearing weighting function is designed to represent the bandwidth for groups of marine mammals within which acoustic exposures can have auditory effects. The categories include:

- **low-frequency (LF) cetaceans** (i.e., marine mammal species such as baleen whales);
- **high-frequency (HF) cetaceans** (i.e., marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales);
- **very high-frequency (VHF) cetaceans** (i.e., marine mammal species such as true porpoises, river dolphins and pygmy/dwarf sperm whales and some oceanic dolphins, generally with auditory centre frequencies above 100 kHz);
- **phocid pinnipeds (PCW)** (i.e., true seals; hearing in air is considered separately in the group PCA); and
- **other marine carnivores (OCW)** (including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; air hearing considered separately in the group OCA).

Non-impulsive noise can have different implications for marine mammals potentially resulting in temporary threshold shift (TTS) or permanent threshold shift (PTS), the relevant criteria proposed by Southall *et al*. (2019) are as summarised in Table 5.9. The zone of auditory injury in this study is classified as the distance over which a marine mammal may suffer a PTS leading to non-reversible auditory injury. UK Industry guidelines on the prevention of injury to marine mammals recommend that PTS is the relevant threshold considered likely to result in injury and for which appropriate mitigation should be followed (JNCC, 2010).

At lower hearing thresholds than those that can cause an instantaneous injury resulting in PTS a marine mammal may experience a TTS. The NMFS (2018) and Southall *et al.* (2007) define TTS as a 6 dB shift in the hearing threshold which is the minimum shift distinguishable from any day-to-day variation in a subject's normal hearing. The distinction between TTS and PTS depends on whether there is complete recovery of the individual's hearing. The most likely response of a marine mammal to noise levels that could induce TTS is to flee from the ensonified area (Southall *et al.,* 2007) and subsequently the onset of TTS is referred to as the fleeing response. The duration of effect can vary widely from 1 hour up to several days and, as described above, indicates the level of noise exposure which could induce any measurable shift.

This range in response makes it difficult to interpret the biological consequences of TTS, and as described for PTS, the noise modelling makes a number of precautionary assumptions that lead to the prediction of very conservative ranges. For these reasons, the TTS ranges should be interpreted with caution since in reality the injury ranges are likely to be smaller than those predicted by the modelling. The potential ranges presented for injury and disturbance are not a hard and fast 'line' where an impact will occur on one side and not on the other. Potential impact is more probabilistic than that; dose dependency in PTS onset, individual variations and uncertainties regarding behavioural response and swim speed/direction all mean that it is much more complex than drawing a contour around a location. Therefore, it is also necessary to calculate the SEL for a mammal using the relevant weightings described previously considering the amount of sound energy to which it is exposed over the course of a 24-hour period. In order to carry out this calculation, it has been assumed that a mammal will swim away from the noise source at an average speed of 1.5 ms^{-1}. As the mammal swims away, the noise will become progressively quieter. The real-world situation is more complex, and the noise source will vary in space and time and the animal is likely to move in a more complex manner.

For this site the marine mammals of interest include harbour porpoises (VHF), bottlenose dolphins (HF), grey seals (PCW) and otters (OCW) as specified in Section 3.5. The relevant criteria proposed by Southall *et al*. (2019) are as summarised in Table 5.9.

Table 5.9: Summary of injury (PTS and TTS) onset acoustic thresholds in marine mammals (Southall *et al*. 2019)

Hearing Group	Parameter	Impulsive		Non-impulsive	
		PTS	TTS	PTS	TTS
High-frequency (HF) cetaceans	Peak, unweighted	230	224	-	
	SEL, MF weighted	185	170	198	
	Peak, unweighted	202	196	-	

Very High-frequency (VHF) cetaceans	SEL, HF weighted	155	140	173	153
Phocid Carnivores in Water (PCW)	Peak, unweighted	218	212	-	
	SEL, PW weighted	185	170	201	181
Other Marine Carnivores in Water (OCW)	Peak, unweighted	232	226	-	
	SEL, OW weighted	203	188	219	199

In order to assess potential disturbance to marine mammals, criteria for non-impulsive sounds are based on NMFS (2005) and HESS (1997). The criteria are as follows:

- Potential disturbance due to non-impulsive sound: 120 dB re 1 µPa (rms).

Injury and disturbance impact ranges for the sources studied in the current study are summarised in Table 5.10. The distances presented in the table reflect the start point of the mammal relative to the source when the source first starts up. All ranges are rounded to the nearest 5 m.

Table 5.10: Summary of potential injury and disturbance zones for rotary drilling (N/E – not exceeded)

Species	Range of effect		
	PTS	TTS	Disturbance
Bottlenose dolphin (HF)	N/E	N/E	295 m
Harbour porpoise (VHF)	N/E	N/E	295 m
Grey seal (PCW)	N/E	N/E	295 m
Otters (OCW)	N/E	N/E	295 m

These noise modelling results suggest that the risk of PTS and TTS is highly unlikely, although disturbance is possible at a distance of 295 m for all types of marine mammal.

Harbour Porpoise

The noise modelling results indicate that the thresholds for PTS and TTS are unlikely to be exceeded for harbour porpoise during rotary drilling, although disturbance may occur out to a distance of 295 m. Pile installation is expected to occur intermittently over a period of up to 83 days

Harbour porpoises are regularly sighted around the south west Wales coastline and are particularly abundant around the Pembrokeshire Islands (De Boer and Simmonds, 2003). They are a designated species for the West Wales SAC; however, this SAC does not extend only 5 km into the Waterway which is 11 km from the Pembroke Port. This suggest this is not ideal habitat for harbour porpoises and they are very unlikely to be occur at this location.

Bottlenose Dolphin

The noise modelling results indicate that the thresholds for PTS and TTS are unlikely to be exceeded for bottlenose dolphin during rotary drilling, although disturbance may occur out to a distance of 295 m. Pile installation is expected to occur intermittently over a period of up to 83 days.

Bottlenose dolphin occurs regularly within Welsh waters with most sightings around Cardigan Bay, where there is a resident population (Baines and Evans, 2012). The latest SCANS III survey estimated density of 0.06 animals per km^2 across a large area of welsh coast as well as extending into the Celtic sea (Hammond *et al*., 2021). Additionally, they have not been recognised as a designated species in this area suggesting they are unlikely to be found at this site.

Grey Seal

The noise modelling results indicate that the thresholds for PTS and TTS are unlikely to be exceeded for grey seal during rotary drilling, although disturbance may occur out to a distance of 295 m. Pile installation is expected to occur intermittently over a period of up to 83 days.

Grey seals are a common feature along the Pembrokeshire coast especially on islands such as Skomer. They are however not commonly seen in the Waterway, with no regular haul out sites.

Otter

Otters are the marine mammal which Section 3.5.3 suggest could occur closest to the site. They are a qualifying feature of the Cleddau Rivers/Afonydd Cleddau SAC and the Pembrokeshire Marine/Sir Benfro Forol SAC.

Neither of these sites extends into the port area and the lack of viable habitat makes then unlikely to enter the site. Pembroke Port is approximately 50 m from the border of the Pembrokeshire Marine SAC which leaves only a small area in which otters would experience a mild disturbance.

Conclusion

The noise assessment has demonstrated that there is no risk of injury to any marine mammal as a result of the secant pile installation works and any behavioural disturbance will be limited to within 295 m of the works. The noise from the port makes it unlikely that marine mammals will venture close to the works and other activities are unlikely to exceed the background noise made by the port. Therefore, the effect of underwater noise from the installation of the secant piled walls at the existing flank wall of the slipway on marine mammals is considered to be **negligible** and no greater than that concluded for the original EIA for the PDI project. and no mitigation is considered necessary.

5.5.2 Underwater noise effects on marine mammals associated with hydraulic rock breaking equipment

The potential for of underwater noise to affect marine mammals in different ways is discussed in Section 5.5.1. The activities related to the operation of the hydraulic rock breaking equipment can result in non-impulsive (continuous) sound. Non-impulsive noise can have different implications for marine mammals potentially resulting in TTS or PTS, the relevant criteria proposed by Southall *et al*. (2019) are as summarised in Table 5.9.

The specific effects of impulsive sound as well as TTS and PTS are described in Section 5.5.1 and the relevant criteria for PTS and TTS are outlined previously in Table 5.9.

For this site the marine mammals of interest include harbour porpoises (VHF), bottlenose dolphins (HF), grey seals (PCW) and otters (OCW) as specified in Section 3.5. In order to assess potential disturbance to marine mammals, criteria for impulsive sounds are based on NMFS (2005) and HESS (1997). The criteria are as follows:

- Potential mild disturbance due to impulsive sound: 140 dB re 1 µPa (rms); and
- Potential significant disturbance due to impulsive sound: 160 dB re 1 µPa (rms).

The predicted injury and disturbance impact ranges for the sources studied in the current study are summarised in Table 5.11. The distances presented in the table reflect the start point of the mammal relative to the source when the source first starts up. All ranges are rounded to the nearest 5 m.

Table 5.11: Summary of potential injury and disturbance zones for operation of hydraulic breaking equipment (N/E – not exceeded)

Species	Range of effect		
	PTS	**TTS**	**Disturbance**
Bottlenose dolphin (HF)	N/E	N/E	150 m
Harbour porpoise (VHF)	N/E	N/E	150 m
Grey seal (PCW)	N/E	N/E	150 m
Otters (OCW)	N/E	N/E	150 m

These noise modelling results suggest that the risk of PTS and TTS is highly unlikely for all marine mammals, although disturbance is possible at a distance of 150 m for all marine mammals.

The sensitivity of marine mammals in the area to continuous noise is considered under Section 5.5.1. Therefore, the effect of underwater noise from the operation of hydraulic breaking equipment below the existing water mark on marine mammals is considered to be **negligible** and no greater than that concluded in the EIA for the PDI project. No mitigation is considered necessary.

6 CUMULATIVE EFFECTS

6.1 Approach

The cumulative effects of new proposed activities associated with the PDI project, in conjunction with other proposed schemes will be considered within the Cumulative Effects Assessment (CEA). The new proposed activities associated with the PDI project will be assessed for impacts with other plans or projects within a pre-defined geographical area (Study Area). The geographical area may be different for different receptors. The CEA will consider any developments that are at the Scoping stage or later in the consenting process. Developments that are built and operational at the time of assessment will be considered as part of the baseline. These other activities are described in Table 6.1 and are presented in Figure 6.1.

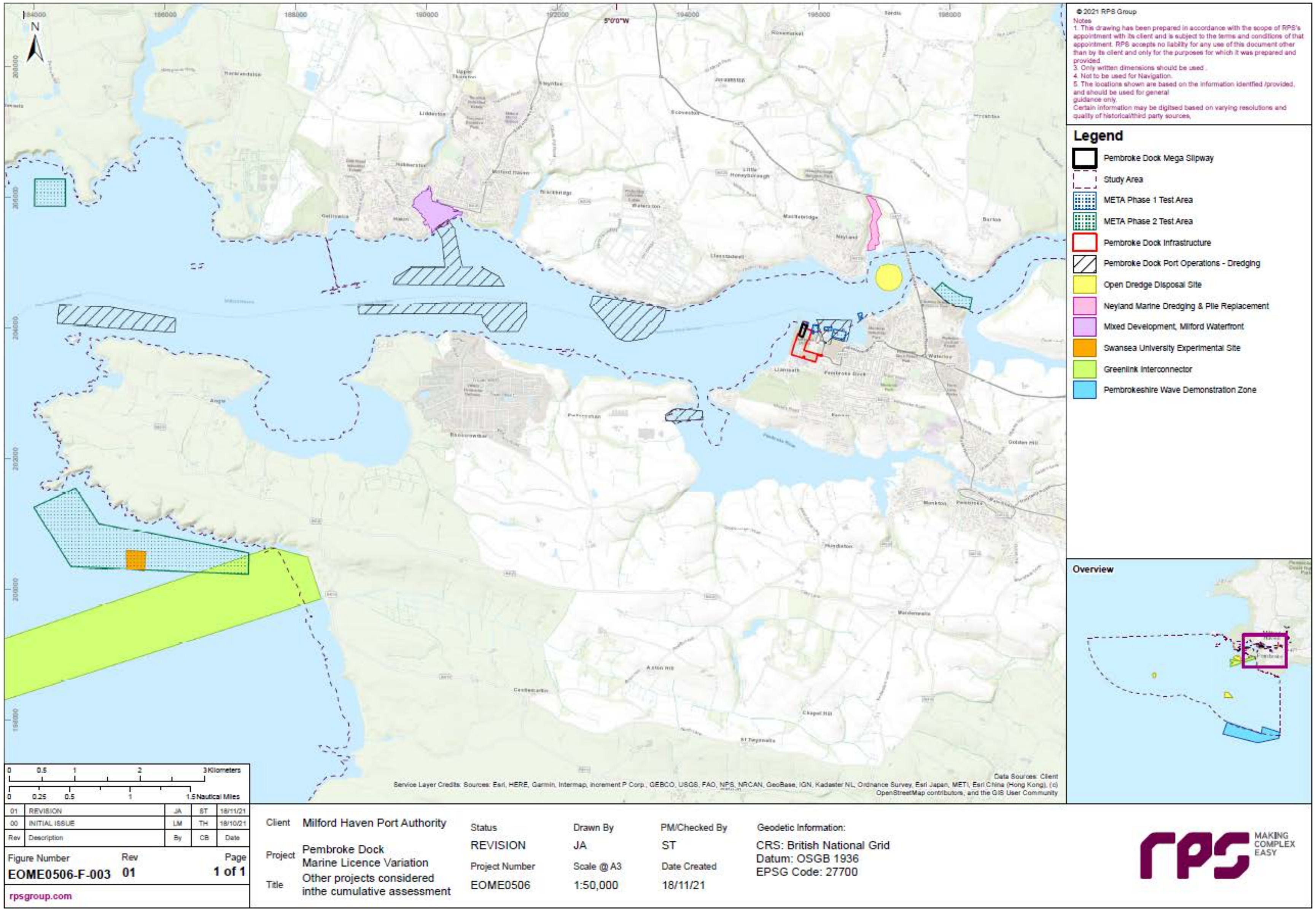

Figure 6.1: Location of projects and activities that have been considered for cumulative impact assessment

Table 6.1: Projects and activities considered for cumulative effects assessment (CEA)

Project (Developer)	Spatial Overlap	Temporal Overlap	Description and proposed development activities	Further Assessment Required	Justification
Cables/pipelines	Yes	Yes	There are a number of cables and pipelines in the vicinity of the Pembroke Port.	No	Existing cables/pipelines are not expected to interact with the updated activities associated with the PDI project as there are no ongoing impacts from this infrastructure on receptors and impact pathways identified for this project, and any potential impacts from existing cables/pipelines are considered to form part of the existing baseline. No new/proposed cables/pipelines are planned.
Dredging and disposal sites	In bold	Yes	DML1646 – Milford Haven maintenance dredging, 2017-2022 (MHPA). Annual volume 5500 m^3, **no spatial overlap (but 100 m away)**, see Figure 6.1. DML1950 - Newport maintenance dredge 2020-2030. 499,999 tonnes per year. **no spatial overlap.** DML1955- Barry maintenance dredge disposal 2019-2029. 99,999 tonnes per year. **no spatial overlap** MMML15480 Nobel Bank marine mineral dredging 2016-2023. **no spatial overlap**	Yes	There may be a potential for cumulative impact from increased underwater noise from dredging and disposal activities which may present potential cumulative effects with the updated activities associated with the PDI project.
Deployment of scientific equipment and marker buoys (University College of Swansea) - DEML1845	No	No	Deposition and subsequent removal of marker buoys with environmental monitoring and mid-water settlement plates, 2018-2019	No	No spatial or temporal overlap and impact pathway identified.
Neyland Marina pile replacement - CML1658	Yes	No	Pile replacement in Neyland Marine, 2016-2019.	No	Pile replacement was completed in 2019. There is therefore no potential for cumulative underwater noise effects on identified receptors
Pembrokeshire Wave Energy Demonstration Zone	No	No	The Project entails the development of 90 km^2 of seabed with water depths of approximately 50 metres and a wave	No	This project will not be taken forward in the CEA as no spatial overlap or temporal overlap with the updated

Project (Developer)	Spatial Overlap	Temporal Overlap	Description and proposed development activities	Further Assessment Required	Justification
(Wave Hub Ltd.) (a Pembroke Dock Marine project)			resource of approximately 19 kW/m; to support the demonstration of wave arrays with a generating capacity of up to 30MW for each project. Consent for this Project could be achieved in 2022, infrastructure could be built by 2024 and the first technology could be installed in 2025.		activities for the Pembroke Dock redevelopment have been identified (Figure 6.1).
Marine Energy Test Areas (META) Phase 2 project (a Pembroke Dock Marine project)	No	Yes	The Project aims to create pre-consented marine energy test areas within the Waterway and adjacent waters. Three test areas are proposed – Warrior Way (site 6), Dale Roads (site 7) and East Pickard Bay (site 8). The test areas will have licensable activities to suit testing of wave or tidal devices or subassemblies, and floating offshore wind components.	No	This project is to be excluded from the CEA on the grounds that there is no spatial overlap with Pembroke Port and any potential impacts will be minimal and not interact cumulatively between the projects.
Mixed use development (MHPA) - LPA reference: 14/0158/PA	No	Yes	Demolition of several existing buildings and the mixed-use redevelopment of Milford Waterfront comprising up to 26,266 m^2 of commercial, hotel, leisure, retail and fishery related floorspace. Up to 190 residential properties, up to 70 additional marina berths, replacement boat yards, landscaping, public realm enhancements, access and ancillary works. The development was conditionally approved in November 2019.	No	Given the distance from the project and likely impact pathways. There is no potential for cumulative impacts to affects the marine environment.
Cable Interconnector (Greenlink) - Welsh Government reference: qA1296053 Ground investigations - RML1827	No	Yes	The Project is a 500MW subsea electricity interconnector linking the power markets in Ireland and Great Britain and is planned for commissioning in 2023. As an EU Project of Common Interest, it is one of Europe’s most important energy infrastructure projects. The interconnector is planned to make Landfall at Fresh Water West beach to the south of the mouth of the Waterway. A marine licence application was approved in March 2021.	No	This project is to be excluded from the CEA on the grounds that there is no spatial overlap with Pembroke Port and any potential impacts will be minimal and not interact cumulatively between the projects.

Project (Developer)	Spatial Overlap	Temporal Overlap	Description and proposed development activities	Further Assessment Required	Justification
Military practice (Ministry of Defence)[1]	No	Yes	The Castlemartin Range is located immediately south of the entrance to the Waterway and extends for up to 12 NM from the coast between Little Furznip (at the southern extent of Freshwater West) and St Govan's Head (Milford Haven Port Authority 2019). The range at Castlemartin supports the training of military personnel (Army) in the firing of a range of munitions at land-based targets. The seaward danger area provides a safety zone for overfire and shrapnel which may result from the striking of targets (RPS, 2010). The Castlemartin Range is used every day of the week and on some weekends (RPS, 2010).	No	This project is to be excluded from the CEA on the grounds that there is no spatial overlap with Pembroke Port and any potential impacts will be minimal and not interact cumulatively between the projects.
Project Erebus floating offshore wind farm (SC1905)	No	No	Floating offshore wind farm in the outer Severn Estuary. Project will have up to 10 wind turbine generators. Construction is expected to commence in 2026.	No	This project is to be excluded from the CEA on the grounds that there is no spatial or temporal overlap with Pembroke Port.
Milford Haven Port Authority Ground Investigation Works	No	No	The project aims to replaces slipways with new wider and longer structures, as well as building a new quay and new winch house. Ground investigation works are thought to take 3 months. The full project is scheduled to last from 06/05/2020 to 05/05/2021.	No	This project is to be excluded from the CEA on the grounds that project was expected to be completed in May 2021 and largely takes place on land with only minor works occurring in the subtidal area.
Marine Energy Test Areas (META) Phase 1 project, deposit and removal	Yes	Yes	Within the licenced period (10/06/2019 to 09/06/2029) the sites will be us to test marine energy devices, specifically at the Ferryside site there will be a maximum of two testing activities at once, deployed from a pontoon.	Yes	There may be spatial overlap and temporal overlap therefore there is potential for cumulative impacts.

[1] Unable to be included in Figure 3.1 due to data licensing.

6.2 Physical Processes

6.2.1 Increases in suspended sediment concentrations

Action from the Milford Haven maintenance dredging and META Phase 1 operations have the potential to contribute to a cumulative impact (Table 6.1). In terms of suspended sediment concentrations, META Phase 1 operations to install and remove wave and tidal energy devices requires minimal time and would only contribute to suspended sediments through increased vessel activity for a very short period. Milford Haven maintenance dredging is an annual occurrence which is likely to increase suspended sediments however this activity will also be brief and is unlikely to overlap temporally with the proposed works. The cumulative impact on suspended sediment concentration is, therefore, expected to be **minor**.

6.3 Benthic Ecology

6.3.1 Temporary habitat disturbance associated with the installation of the temporary stank and secant piled walls

The potential for cumulative temporary habitat disturbance for benthic ecology requires the consideration of numerous projects in the vicinity of Pembroke Port. The installation and removal work involved in the META Phase 1 project are unlikely to cause a disturbance above background levels as this activity largely involves vessel movement which occurred on a larger scale and more frequently as part of Pembroke Port operations. The maintenance dredging within Pembroke Port is annual and unlikely to temporally overlap with the works on the slipway, however, the contribution would mainly be in suspended sediment which is regularly moved within these sites from vessels coming in and out of the docks. The implication of these activities occurring in the same timeframe would be an increase in suspended sediments from vessels and dredging but over a small timeframe and rarely above the background levels experienced regularly at the site. The cumulative impact on suspended sediment concentration is, therefore, expected to be **minor**.

6.3.2 Effects on benthic ecology associated with pumping ground and/or cement underwater

There are no other projects in the area which require the pumping of grout and/or cement underwater, therefore there is no potential for direct cumulative impacts associated with this receptor.

6.4 Fish and Shellfish Ecology

6.4.1 Underwater noise effects on fish and shellfish receptors associated with the installation of the secant piled walls

Milford Haven maintenance dredging and META Phase 1 operations are potentially able to contribute to the cumulative impact of underwater noise on fish and shellfish. The sources of noise from these projects and operations involve dredging and vessel movement which involve a lower level of noise than the piling for the flank walls which is not expected to cause injury to fish (Section 5.4.1). The noise from these projects and operations is also similar to the regular baseline noise produced by the daily port operations which fish and shellfish are routinely exposed to. It is also unlikely that the dredging will occur at the same time as the piling as it is only happens once a year. The cumulative impact of this noise is therefore unlikely to be greater than the impact of the rotary drilling alone, therefore the cumulative impact of underwater noise is likely to be **negligible.**

6.4.2 Underwater noise effects on fish and shellfish receptors associated with the hydraulic rock breaking equipment

Milford Haven maintenance dredging and META Phase 1 operations are potentially able to contribute to the cumulative impact of underwater noise on fish and shellfish. The sources of noise from these projects and operations involve dredging and vessel movement which involve a lower level of noise than the hydraulic rock breaking equipment which is not expected to cause injury to noise sensitive fish (Section 5.4.2). The noise from these projects and operations is also similar to the regular baseline noise produced by the daily port operations which fish and shellfish are routinely exposed to. It is also unlikely that the dredging will occur at the same time as the hydraulic rock breaking as it is an annual occurrence. The cumulative impact of this noise is therefore unlikely to be greater than the impact of the hydraulic rock breaking alone, therefore the cumulative impact of underwater noise is likely to be **negligible.**

6.5 Marine Mammals

6.5.1 Underwater noise effects on marine mammal associated with the installation of the secant piled walls

Milford Haven maintenance dredging and META Phase 1 operations are potentially able to contribute to the cumulative impact of underwater noise on marine mammals. The sources of noise from these projects and operations involve dredging and vessel movement which involve a lower level of noise than the piling which has the potential to disturb marine mammals within 295 m of the source (Section 5.5.1). The noise from these projects and operations is also similar to the regular baseline noise produced by the daily port operations which marine mammals would are routinely exposed to if they frequented this site.

Marine mammals are however not thought to frequent this site (Section 3.5) due to the lack of suitable habitat and frequent disruptive noise. It is also unlikely that the dredging will occur at the same time as the piling as it only happens once a year. The cumulative impact of this noise is therefore unlikely to be greater than the impact of the rotary drilling alone, therefore the cumulative impact of underwater noise is likely to be **negligible.**

6.5.2 Underwater noise effects on marine mammal receptors associated with the operation hydraulic breaking equipment below the existing water mark.

Milford Haven maintenance dredging and META Phase 1 operations are potentially able to contribute to the cumulative impact of underwater noise on marine mammals. The sources of noise from these projects and operations involve dredging and vessel movement which involve a lower level of noise than the hydraulic breaking below the existing water mark which has the potential to disturb marine mammals within 150 m of the source (Section 5.5.2). The noise from these projects and operations is also similar to the regular baseline noise produced by the daily port operations which marine mammals would are routinely exposed to if they frequented this site.

Marine mammals are however no thought to frequent this site (Section 3.5) due to the lack of suitable habitat and frequent disruptive noise. It is also unlikely that the dredging will occur at the same time as the hydraulic breaking. The cumulative impact of this noise is therefore unlikely to be greater than the impact of the hydraulic rock breaking alone, therefore the cumulative impact of underwater noise is likely to be **negligible.**

7 HRA SCREENING: CONSIDERATION OF LIKLEY SIGNIFICANT EFFECTS

The location of Pembroke Port in relation to the National Sites Network identified in Section 3.6 are shown in Table 3.1. The need to consider the potential for Likely Significant Effect (LSE) on these sites is discussed below. It should be noted that “Likely Significant Effect” is terminology used by both EIA Regulations and The Conservation of Habitats and Species Regulations 2017 (Habitats Regulations). As such, in the context of this environmental appraisal, the use of “Likely Significant Effect” is as defined by the Habitat Regulations 2017.

The HRA screening step (LSE) is the process by which the likely effects of a project upon a European site, either alone or in combination with other projects and plans, consider whether these effects may be significant. The assessment must show that there will be no significant effect, and if there is any uncertainty or where it cannot be determined that there is no LSE, an Appropriate Assessment is required.

7.1 Pembrokeshire Marine/ Sir Benfro Forol SAC

The Pembrokeshire Marine/ Sir Benfro Forol SAC lies immediately to the north of Pembroke Port and covers an area of 1,380.38 km^2 extending from just north of Abereiddy on the north Pembrokeshire coast, to just east of Manorbier in the south, and includes the coast of the islands of Ramsey, Skomer, Grassholm, Skokholm, the Bishops and Clerks and The Smalls.

7.1.1 Estuaries, Reefs and Large shallow inlets and bays (Primary habitat feature), Mudflats and Sandflats not covered by seawater at low tide (Secondary habitat feature)

Pembrokeshire Marine/ Sir Benfro Forol SAC comprises a wide range of environmental conditions, particularly seabed substrates, tidal streams, and salinity gradients, which in turn supports a wide diversity of marine communities and species. The species-richness of sediment communities throughout Milford Haven is high. The site includes smaller estuaries entering the Waterway, and wide intertidal mudflats with rich and productive invertebrate annelid and mollusc communities, occurring in ‘pills’ (creeks).

All works will occur outside of the SAC site boundary and therefore there will be no direct impact on the ‘Estuaries’, ‘Reefs’, ‘Large Shallow Inlets and Bays’ or ‘Mudflats and Sandflats not covered by seawater at low tide’ qualifying features of the SAC. Given that impacts are considered to be temporary, reversible and do not overlap with the SAC site boundary, no LSE is predicted.

7.1.2 Grey Seal

The grey seal population in Pembrokeshire Marine/ Sir Benfro Forol SAC represents the largest breeding colony on the west coast south of the Solway Firth, representing over 2% of annual UK pup production (JNCC, 2021). The Pembrokeshire coast contains the main colony in Wales and is the most southerly in Europe of any significant size (NRW, 2017a). Grey seals present within the SAC at any one time do not form a discrete population but are centred (in terms of abundance) on the Pembrokeshire coast and are considered part of the SW England and Wales management unit (IAMMWG, 2013). Adults and weaned pups are assumed to feed throughout the site, and some are known to make long foraging trips offshore to deeper waters from south through south-west to north-west off the Pembrokeshire coast. Pupping tends to occur at a limited number of favourable sites (towards the south-western end of the SAC). The most recent estimates for pup production at the major haul-outs in Wales are 465 pups in North Pembrokeshire in 2005 (Strong *et al*., 2006) and 243 pups born on Skomer island in 2020 (NRW, 2020). They are generalist predators (Section 3.5.2).

No reduction to the population, range, or structure of the grey seal population as a result of the updated activities for the PDI project is predicted due to the restricted nature of activities proposed and the very low numbers of animals predicted at the Pembroke Port. Rotary drilling or use of the hydraulic rock breaker are not expected to cause PTS or TTS in grey seals with behavioural effects possible up to 295 m for rotary drilling and 150 m for operation of the hydraulic rock breaker.

On this basis, no significant disturbance of the species is predicted, and grey seal will remain a viable component of the site. It can therefore be concluded that there is no potential for LSE as a result of the installation of the secant piled wall or the use of the hydraulic rock breaking equipment.

7.1.3 Migratory fish species

Twaite shad and Allis shad are Annex II species present as qualifying interest features, but not primary reasons for the selection of the Pembrokeshire Marine/Sir Benfro Forol SAC. Shad migrate through estuaries in March-May on their way to spawning grounds and most adults die after spawning, but a proportion of UK fish are known to repeat spawn: these presumably migrate back to sea immediately after spawning in June-July. Juveniles generally migrate from estuaries between August and October, where they spend some time feeding. Further seaward migration is triggered by falling temperatures in winter, but it is possible that at least a proportion of the juvenile fish overwinter in the estuary. At all stages of their life cycle, shad are pelagic fish, and in estuaries the juveniles predominantly occur in the surface layers of the water column.

Adult river lampreys migrate through the Pembrokeshire Marine/ Sir Benfro Forol SAC to reach the Afonydd Cleddau river on their spawning migration, entering freshwater between October and December. Juvenile river lampreys generally migrate downstream into estuaries and inshore waters in spring, though autumn migrations have also been recorded. Since river lampreys feed and grow in estuaries and inshore waters, it should be assumed that juveniles are present in the Pembrokeshire Marine/ Sir Benfro Forol SAC throughout the year.

Adult sea lampreys migrate through the site between March and June to reach the Afonydd Cleddau. Mature adults enter the estuaries from April onwards and migrate some distance upstream. Juvenile sea lampreys migrate downstream between December and June and spend some time feeding in the estuary and inshore waters before moving offshore in search of larger prey. However, no sea lamprey has been recorded in the monitoring of the SAC since 2004 so there is no evidence that the site currently supports sea lamprey.

Whilst there is potential for fish to enter/pass through Pembroke Port, no barriers to migration or potential impact have been identified and Pembroke Port is not typically used for spawning (given the high levels of disturbance of the Pembroke Port area). The installation of the secant piled wall, or the use of the hydraulic rock breaking equipment are not expected to cause PTS or TTS in shad or lamprey. It is considered highly unlikely that these species will be within the port and given that the majority of behavioural effects will be limited to within the Pembroke Port area, underwater noise associated with the rotary drilling and hydraulic breaking are unlikely to present a barrier to migration.

The updated activities for the PDI project either alone or in-combination with other plans or projects (Section6) are therefore not expected to have a significant impact on these qualifying interest feature, therefore no LSE can be concluded.

7.1.4 Otters

The otter population in Wales is increasing and there has been an increase in areas used by otters. Any otters present within the SAC are part of a wider population living around freshwater habitats in Pembrokeshire. It is likely that there are movements and exchanges between areas supporting otters. The proportion of the otter population within the SAC at any time, and its distribution, is likely to be dynamic and it is not known whether the numbers of animals that use the site are a fixed or variable proportion of the wider population with a preference for using marine habitat.

The most prominent risk to otters is through underwater noise, modelling however shows that there is not expected to be any risk of injury and behavioural disturbance is only likely within 295 m for the rotary drilling (Table 5.10) or 150 m for the hydraulic rock breaker (Table 5.11). The minimal and unlikely risk of disturbance uphold the conservation objectives within the SAC by preventing any significant disturbance.

On this basis, no significant disturbance of the species is predicted, and otter will remain a viable component of the site. It can, therefore, be concluded that there is no potential for LSE as a result of the proposed works.

7.2 Cleddau Rivers/Afonydd Cleddau SAC

The Cleddau Rivers/Afonydd Cleddau SAC lies 11 km north from Pembroke Port. The River Cleddau is one of the westernmost rivers in Britain and can be broadly divided into the eastern and western arms. The

Eastern Cleddau River, starting at an altitude of 225 m and approximately 1.5 km from Mynachlog-ddu at the foot of the Preseli hills of north Pembrokeshire, flows for 26 km (74 km including tributaries) south to its tidal limit at Blackpool Bridge, where it discharges into the Pembrokeshire Marine/ Sir Benfro Forol SAC. The main channel of the Western Cleddau River stretches for 30 km between its source at Mathry, which lies at an altitude of 112 m, to the tidal limit of the Daugleddau Estuary at Haverfordwest, flowing over sands and gravels deposited as the ice sheets from the last glaciation retreated.

7.2.1 Migratory fish species

For the qualifying features of the Cleddau Rivers/Afonydd Cleddau SAC, no adverse impact is expected for the group 1 sea and river lamprey, from secant piled wall installation or the use of a hydraulic rock breaker. Potential behavioural changes would be restricted to the near field and, as detailed in Section 5.4, there is little potential for TTS/PTS to be experienced by fish due to the rotary drilling or hydraulic rock breaking. There is a moderate risk of behavioural effects in the near field is possible.

It is considered highly unlikely that lamprey will be within the docks and given that the majority of behavioural effects will be limited to within the Pembroke Dock area, underwater noise associated with the update's activities for the Pembroke Dock re-development is unlikely to present a barrier to migration. The proposed activities either alone or in-combination with other plans or projects (Section 6) are therefore not expected to have a significant impact on these qualifying interest features of Cleddau Rivers/Afonydd Cleddau SAC.

The minimal and unlikely risk of disturbance uphold the conservation objectives within the SAC by preventing any significant disturbance. As mentioned in the Section 6.4, no barriers to migratory routes are predicted during the updated activities for the PDI project, and Pembroke Port is not typically used for spawning (given the high levels of disturbance of the Pembroke Port area), therefore no LSE can be concluded.

7.2.2 Otter

The SAC is capable of supporting 11 breeding females on the Western Cleddau, and eight breeding females on the Eastern Cleddau. This is determined by the number of existing breeding territories as identified by Jones, (2004). Food availability is an important factor. Fish biomass should stay within expected natural fluctuations as there is no spatial overlap with the SAC and Pembroke Port.

It is considered highly unlikely that PTS/TTS will be experienced by otter during the proposed activities and behavioural disturbance would be limited to within 295 m for the rotary drilling (Table 5.10) or 150 m for the hydraulic rock breaker (Table 5.11). On this basis, no significant disturbance of the species is predicted, and otter will remain a viable component of the site. Due to the considerable distance within the known territorial ranges (1 – 40 km) of otter as a qualifying interest feature of the SAC and Pembroke Port, there is no potential route to impact, therefore no LSE can be concluded

7.3 West Wales Marine / Gorllewin Cymru Forol SAC

The West Wales Marine SAC is located off the coast of Wales, from the Llŷn peninsula in the north, to Pembrokeshire in the south-west, covering 7,376 km^2. It was designated in 2019 for harbour porpoise. This SAC overlaps a number of other SACs including parts of the Pembrokeshire Marine/ Sir Benfro Forol and Pen Llŷn a'r Sarnau SACs and overlaps entirely with the Cardigan Bay SAC. Along the westward boundary, water depths of up to 100 m are reached, though much of the site is 50 m or shallower. The area included within the site covers important summer habitat for harbour porpoise, while part of the site in Cardigan Bay was also identified as important during the winter.

7.3.1 Harbour Porpoise

Harbour porpoise are the most abundant cetacean in UK waters, with the West Wales Marine /Gorllewin Cymru Forol SAC site being identified as being within the top 10% of persistent high-density areas for harbour porpoise in UK waters during the summer season. It is estimated (based on the SCANS-II survey which took place in July 2005) that the SAC supports approximately 2,506 individuals (95% Confidence Interval: 1410 – 4455) for at least part of the year, as seasonal differences are likely to occur. This represents approximately 9% of the population within the UK part of the Celtic and Irish Sea MU (NRW and JNCC, 2016). Key prey items vary during the year but include species with pelagic and demersal habitats such as whiting, sandeels and herring.

Although there is the potential for harbour porpoise to enter the Waterway, there are no records of this species occurring within the Waterway on the NBN gateway, and therefore the abundance within the Waterway itself is predicted to be extremely low/negligible, with any animals that do occur more likely to be present at the mouth of the Waterway. The main potential impact of the updated activities for the Pembroke Port redevelopment on marine mammals is disturbance due to piling and hydraulic rock breaker noise (Section5.5).

In the unlikely event that a harbour porpoise is present within Pembroke Port, it can be assumed that the animal would be tolerant of existing levels of vessel noise already in the Waterway, and no disturbance of the animal would therefore be likely. It is likely marine mammals will avoid the area due to background noise levels already occurring within the Waterway therefore avoiding direct contact with vessel movements. Piling is not expected to cause PTS or TTS in harbour porpoises with behavioural effects possible up to 295 m for rotary drilling and up to 150 m for operation of the hydraulic rock breaker.

On this basis, no significant disturbance of the species is predicted, and harbour porpoise will remain a viable component of the site. The potential for a significant effect on harbour porpoise from the updated activities for the PDI project, either alone or in-combination with other plans or projects is negligible due to the lack of receptor-impact pathway, therefore no LSE can be concluded.

8 WATER FRAMEWORK DIRECTIVE ASSESSMENT

EU Directive 2000/60/EC, better known as the Water Framework Directive (WFD), established a framework for community action in the field of water policy. The WFD came into force in 2000 and requires EU Member States to ensure that all inland and coastal waters achieved 'good' water quality status by 2015 (the WFD has been retained in UK law following the UKs from the European Union). The aims of the WFD are for the UK to:

1. Implement the necessary measures to prevent deterioration of the status of all bodies of surface water;
2. Protect, enhance and restore all bodies of surface water, subject to the application of subparagraph (iii) for artificial and heavily modified bodies of water, with the aim of achieving good surface water status by 2015;
3. Protect and enhance all artificial and heavily modified bodies of water, with the aim of achieving good ecological potential and good surface water chemical status by 2015; and
4. Implement the necessary measures in accordance with Article 16 (1) and (8), with the aim of progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges, and losses of priority hazardous substances.

8.1 WFD Waterbodies

The project has the potential to impact on two WFD water bodies either directly or indirectly: transitional water body Milford Haven Inner, and coastal waterbody Milford Haven Outer. Milford Haven Inner waterbody overlaps with the footprint of the Pembroke Port. The Milford Haven outer waterbody is located approximately 2 km to the west of Pembroke Port.

A baseline description of the biological, physico-chemical and hydromorphological quality elements, as presented in the Water Framework Directive (2000/60/EC) are provided in Section 3.2 to Section 3.6 (inclusive) for Milford haven Inner and Milford Haven Outer respectively.

8.1.1 Milford Haven Inner Waterbody

The Milford Haven Inner waterbody current overall potential to meet its objectives is 'Moderate', with ecological potential as 'Moderate (very certain)' and Chemical Status as 'Fail' (WWW, 2018). Current justification for not meeting the overall status objective of 'Good' is that proposed mitigation measures are disproportionately expensive or technically not feasible (WWW, 2018).

The reason for failing to meet good ecological status is due to high levels of dissolved inorganic nitrogen and macroalgae. Justification for not achieving good status by 2015 is because mitigation measures are not in place as they are disproportionately expensive.

The reasons for the chemical status of fail is currently not specified, and mitigation measures are currently not in place.

As such the current status objective for this waterbody is to attain an overall objective of Good by 2027 (WWW, 2018).

Table 8.1: Milford Haven Inner waterbody WFD features and objectives

Water Body[2]	Description, notes or more information
WFD water body name	Milford Haven Inner
Water body ID	GB531006114100
River basin district name	Western Wales

[2] Water body information was extracted from Water Watch Wales website. Magic maps provided additional information on habitats and protected areas.

Water Body[2]	Description, notes or more information
Catchment	Cleddau and Pembrokeshire Coastal Rivers TraC
Water body type (estuarine or coastal)	Transitional
Water body total area (km2)	21.02
Overall waterbody status (2015)	Moderate
Ecological status	Moderate
Chemical status	Fail
Target water body status and deadline	Good 2027
Hydromorphology status of waterbody	Supports Good
Heavily modified waterbody and for what use	No
Phytoplankton Status	High
History of Harmful Algae	Not monitored
Angiosperm Status	High
Invertebrates status	Good
Macroalgae status	Moderate
Fish status	Good
WFD protected areas within 2 km	Yes

8.1.2 Milford Haven Outer waterbody

The Milford Haven Outer waterbody current overall potential to meet its objectives is 'Moderate', with ecological potential as 'Moderate (very certain)' and Chemical Status as 'fail'. Current justification for not meeting the overall status objective of 'Good' is that proposed mitigation measures are disproportionately expensive or technically not feasible (WWW, 2018).

The reason for failing to meet good ecological status is due to high levels of dissolved inorganic nitrogen. Justification for not achieving good status by 2015 is because mitigation measures are not in place as they are disproportionately expensive.

It is currently not specified the reasons for the chemical status of fail, and mitigation measures are currently not in place.

As such the current status objective for this waterbody is to attain an overall objective of Good by 2027.

Table 8.2: Milford Haven Outer waterbody WFD features and objectives

Water Body[3]	Description, notes or more information
WFD water body name	Milford Haven Outer
Water body ID	GB641008220000
River basin district name	Western Wales
Catchment	Not Applicable
Water body type (estuarine or coastal)	Coastal
Water body total area (km2)	35.39

[3] Water body information was extracted from Water Watch Wales website. Magic maps provided additional information on habitats and protected areas.

Water Body[3]	Description, notes or more information
Overall water body status (2015)	Good
Ecological status	Moderate
Chemical status	Good
Target water body status and deadline	Good 2027
Hydromorphology status of water body	Supports Good
Heavily modified water body and for what use	No
Phytoplankton status	High
History of Harmful Algae	Not monitored
Angiosperm status	Good
Invertebrates' status	Not monitored
Macroalgae status	Good
Fish status	Not monitored
WFD protected areas within 2km	Yes

A WFD assessment can comprise of up to three stages. All stages may not require completion dependent on the outcomes of each stage. The stages are:

- Screening – excludes any activities that do not need to go through the scoping or impact assessment stages.
- Scoping – identifies the receptors that are potentially at risk from your activity and need impact assessment.
- Impact assessment – considers the potential impacts of your activity, identifies ways to avoid or minimise impacts, and shows if your activity may cause deterioration or jeopardise the water body achieving good status.

8.2 Screening

The aim of the WFD assessment screening stage is to ensure that only those activities that may cause deterioration or prevent a water body from meeting its objectives are assessed further. The screening stage excludes any low-risk activities that do not require a WFD scoping to be undertaken and therefore associated impact assessment.

According to the Table 5, Appendix 4 of the NRW OG072 guidance document (NRW, 2018), detailed assessment is required as the updated activities for the PDI project do not fall into any of the listed categories of activities where assessment is not required (NRW 2018).

8.3 Scoping

Scoping assists with identifying elements within water bodies which may be impacted as a result of the activities, these will then progress to detailed compliance assessment. As part of scoping, the focus is on identifying components of the activity or project that have the potential to cause an impact and the quality elements potentially impacted (NRW 2018). A scoping assessment should be undertaken for each water body potentially affected by the project. Water bodies can be scoped out at this stage if it can be robustly demonstrated that there will be no impacts.

A project scoping exercise was completed for project activities against the receptors and criteria provided in the NRW OGN072 guidance note (NRW 2018) for two waterbodies, Milford Haven Inner and Milford Haven Outer, that were identified as being potentially impacted by the updated activities for the PDI project. Results of the scoping assessment are provided in Appendix B. A summary of the scoping results is provided below in Table 8.3.

Table 8.3: Summary of results from scoping assessment undertaken and detailed in Appendix B

Receptor	Waterbody	Potential risk to receptor	Note the risk issue(s) for impact assessment
Hydromorphology	Milford Haven Inner	No	The project will not affect the physical form or cause changes to sediment transport within the waterbody, depth or intertidal zone structure
	Milford Haven Outer	No	The project will not affect the physical form or cause changes to sediment transport within the waterbody, depth or intertidal zone structure
Biology	Milford Haven Inner	Yes	Biological Quality Elements benthic invertebrates have been taken forward for further assessment.
	Milford Haven Outer	No	No potential impacts are predicted to biological quality elements.
Fish	Milford Haven Inner	Yes	Underwater noise effects during drilling and operation of hydraulic rock breaker have the potential to cause disturbance effects to fish.
	Milford Haven Outer	Yes	Underwater noise effects during drilling and operation of hydraulic rock breaker have the potential to cause disturbance effects on migratory fish associated with the waterbody.
Water quality	Milford Haven Inner	No	Sediment plumes generated by installation and removal of a temporary stank may cause changes to water clarity will be made up of very small volumes of sediment, would be quickly diluted and only be transported a few hundred metres from the source.
	Milford Haven Outer	No	As above
Protected areas	Milford Haven Inner	Yes	Within 2 km of the project footprint the following protected areas are found: • Pembrokeshire Marine/ Sir Benfro Forol SAC (~50 m from project footprint) • Shellfish waters (1,770 m from project footprint)
	Milford Haven Outer	Yes	As above
Priority Habitats and Species	Milford Haven Inner	Yes	Several listed migratory and non-migratory fish species, harbour porpoise, and listed marine habitats exist within the waterbody.
	Milford Haven Outer	Yes	Several listed migratory and non-migratory fish species, harbour porpoise, and listed marine habitats exist within the waterbody.
Invasive non-native species	Milford Haven Inner	No	The equipment will be based onshore or on a support vessel that will be transported to site from within the Waterbodies
	Milford Haven Outer	No	As above

8.4 Detailed Compliance Assessment

This section considers the potential impacts of an activity, identifies ways to avoid or minimise impacts, and concludes if the activity may prevent any quality element within any waterbody achieving good status/potential or may cause deterioration.

Receptors or features identified as part of the scoping stage have been brought through for detailed assessment. Listed priority species and habitats have been included as part of Section B.1.6. Section 7 addresses impact on identified protected areas and in particular special areas of conservation within the two waterbodies, which forms part of the shadow Habitat Regulations Screening Assessment and the overall licence application to NRW-MLT.

8.4.1 Biology- Benthic Invertebrates

As discussed in Section 5.3.1 an area of marine habitat may be disturbed through the use of jack up vessels for the secant piled wall installation and the installation and removal of the temporary stank. The area of habitat disturbed will be very small as the area disturbed by the installation and removal of the temporary stank is within the footprint of the mega slipway therefore does not represent and additional area of habitat disturbance.

Temporary habitat in the Milford Haven Inner Waterway is unlikely to result in mortality of sessile benthos associated with the priority listed intertidal and subtidal sand and mud sediments within site boundaries. These are dominated by benthic fauna such as *Hediste diversicolor* and *Macoma balthica* in intertidal areas, and by annelids and bivalves in subtidal areas. There is also the potential for mortality of some associated mobile species. This would lead to a temporary, localised loss of abundance; however, recovery is likely to occur with a similar suite of species re-colonising once the full works for the new slipway have been completed. Recovery rates will depend on the reproductive strategy of the disturbed species although the species disturbed would likely be tolerant to disturbance events given, they are located within an operational port. Identified habitats within site boundaries are extensive throughout the waterway and therefore the temporary reduction of habitats will not cause the extent of the habitat to significantly change within the Waterway.

Due to the potential reduction in a very small area of habitat in the context of the large extent of similar habitat throughout the Waterway and high potential for recovery of benthic communities, the effect of habitat loss on benthic communities as a result of the use of jack up vessels for the secant piled wall installation and the installation and removal of the temporary stank is predicted to not result in the deterioration of benthic communities and the WFD objectives of the waterbody restricted from being achieved by the project.

8.4.2 Biology- Fish

The fish assemblages of the Waterway are typical of an estuarine environment with different characterising species towards the outer reaches of the estuary compared to the inner estuary, reflecting the changes in environmental conditions present, including substrate type, water flow and salinity. Nineteen species of fish including elasmobranchs, (thornback ray *Raja clavata*, lesser spotted dogfish *Scyliohinus caniculus*), demersal flat fish (plaice *Pleuronectes platessa*) and abundant gobies have previously been recorded within identified waterbodies.

Several migratory fish species migrate through the estuary between seawater and freshwater, all of which are of conservation importance as Annex II species protected under European legislation or as Welsh BAP priority species. Four of the species of diadromous fish are qualifying interest features of the Pembrokeshire Marine/ Sir Benfro Forol SAC: sea lamprey *Petromyzon marinus*, river lamprey *Lampetra fluviatilis*, allis shad *Alosa alosa* and twaite shad *Alosa fallax*. River lamprey and sea lamprey are qualifying interest features of the Cleddau Rivers /Afonydd Cleddau SAC. Atlantic salmon, sea trout and European eel are all listed as OSPAR threatened/declining species and are listed as Welsh BAP priority species.

Fish species that are mentioned above and listed as priority species under Section 7 of the Environment (Wales) Act 2016 include:

- Sand-eel (*Ammodytes marinus*);
- Tope shark (*Galeorhinus galeus*);

- Herring (*Clupea harengus*);
- Whiting (*Merlangius merlangus*);
- Thornback ray (*Raja clavate*);
- Mackerel (*Scomber scombrus*);
- Sole (*Solea solea*);
- Plaice (*Pleuronectes platessa*);
- Allis shad (*Alosa alosa*);
- Twaite shad (*Alosa fallax*);
- European eel (*Anguilla Anguilla*);
- River lamprey (*Lampetra fluviatilis*);
- Smelt (*Osmerus eperlanus*);
- Sea lamprey (*Petromyzon marinus*);
- Atlantic salmon (*Salmo salar*); and
- Brown / Sea trout (*Salmo trutta*).

As discussed in Section 5.4, underwater noise from piling activities and operation of the hydraulic rock breakers. Noise from vessels is received as a low-level exposure (as opposed to acute impulse and intense noises from e.g., piling operations) and can affect fish and shellfish by masking of important acoustic cues and behavioural disturbance (Popper and Hastings, 2009). The noise created by piling depends on the method used, rotary drilling creates continuous non-impulsive sound. The noise created by rotary drilling is not expected to impact on noise sensitive fish.

Behavioural effects in fish as a response to noise, include a wide variety of responses including startle responses, strong or mild avoidance behaviour, changes in swimming or schooling behaviour or changes of position in the water column. For example, research looking at biases of vessel noise on the spatial distribution of fish showed that pelagic schooling fish respond by vertical or lateral avoidance of approaching vessels (Mitson and Knudsen, 2003).

While disturbance/masking in fish and shellfish is possible during drilling and operation of the hydraulic rock breaker, the effects of underwater noise are likely to be small given the activities will be temporary and will be undertaken within an operating port where background noise levels will already be elevated. There is also likely to be habituation associated with fish populations that occupy the port area and wider Waterway due to elevated background levels, therefore it is considered that the project is predicted to not result in the deterioration of fish communities and the WFD objectives of the waterbody restricted from being achieved by the project.

8.4.3 Biology- Marine Mammal (Priority Species)

The priority species include harbour porpoise, bottlenose dolphins, grey seals, and otters. As described in Section 3.5, occasional sightings of harbour porpoise and bottlenose dolphin have been recorded within the Waterway. The project has the potential to impact on these species through underwater noise from drilling and operation of a hydraulic rock breaker.

The impact of noise varies depending the sound type and source as discussed in Section 5.5. For marine mammals rotary drilling may cause disturbance up to 295 m. Underwater noise can have behavioural effects on these marine mammals. Harbour porpoise, as one of the most hearing sensitive species, generally avoid vessels, whilst other species such as bottlenose dolphins, are regularly sighted near vessels and may also approach vessels (e.g., bow-riding). However, bottlenose dolphins may also show avoidance behaviours such as increased swimming speed, spatial avoidance, increased group cohesion and longer dive duration (Miller *et al*., 2008). Resting bottlenose dolphins are likely to avoid vessels, foraging bottlenose dolphins may ignore them, and socialising dolphins may approach vessels (Richardson *et al.,* 1995).

Pembroke Port is not a key area for marine mammal species. Baseline data shows infrequent sightings of harbour porpoise and bottlenose dolphin within the Waterway with a low likelihood of occurrence as far up as

Pembroke Port. There may be otter activity in the area, although it is more likely that the shores in this area would be used as a resting area rather than as a key breeding site.

It is therefore considered highly unlikely that the updated activities for the PDI project will cause injury or disturbance to harbour porpoise and bottlenose dolphin populations within the waterway for the following reasons:

- The updated activities for the PDI project are unlikely to emit noise levels that could cause injury to marine mammal species;
- Marine mammal species would need to be in very close proximity (tens metres) to the source of the noise, which is highly unlikely given Pembroke Port is an operating port where background noise levels are already elevated;
- Marine mammals are likely to avoid areas of increased anthropogenic noise; and
- Any animals that are disturbed are likely to recover quickly given the low level of noise predicted and therefore return to the area.

Therefore, no deterioration of this quality element is predicted and the objectives of the two water bodies restricted from being achieved.

8.4.4 Protected Areas

Within 2 km of the project footprint the following WFD protected areas are found:

- Pembrokeshire Marine/ Sir Benfro Forol SAC (~50 m from project footprint)
- Shellfish waters (1,770 m from project footprint)

Impacts on features associated with Pembrokeshire Marine/ Sir Benfro Forol SAC have been assessed as part of Section 7. Impacts to shellfish waters located 1,770 m are not predicted given the distance that shellfish waters are from Pembroke Port, and then nature, scale, and duration of proposed activities to be supported at these sites.

No deterioration of the features of identified protected areas is expected from the updated activities for the PDI project.

9 SUMMARY

Overall, as displayed in Table 9.1, the impacts from the variations from the original licence have a negligible or minor impact on the relevant environmental receptors at the Pembroke Port site requiring no mitigation.

Table 9.1: Summary of receptors, impacts and effects at the Pembroke Port site.

Description of receptor	Description of impact	Assessment of Effect
Physical Processes	Increases in suspended sediment concentrations	**Negligible**
Benthic Ecology	Temporary habitat disturbance associated with the installation of the temporary stank and installation of the secant piled walls	**Negligible**
	Effects on benthic ecology associated with pumping grout and/or cement underwater	**Negligible**
Fish and Shellfish	Underwater noise and vibration effects on fish and shellfish receptors associated with the installation of the secant piled walls	**Negligible**
	Underwater noise and vibration effects on and fish and shellfish receptors associated with hydraulic rock breaking equipment	**Negligible**
Marine Mammals	Underwater noise effects on marine mammal receptors associated with the installation of the secant piled walls	**Negligible**
	Underwater noise effects on marine mammal receptors associated with hydraulic rock breaking equipment	**Negligible**

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Appendix A: Environmental Impact Scoping Exercise

A scoping exercise was carried out to inform the assessment, based on RPS's extensive experience in preparing similar assessments for comparable licensable activities. Activities, topics and impacts scoped out of the assessment are presented in together with justification.

Table A. 1: Environmental topics and impacts scoped out of the assessment.

Environmental Topic	Impact	Justification
Ornithology	All	Scoped out on the basis that no impact pathway for marine birds will be created as a result of the updated activities for the Pembroke Dock redevelopment. In addition, whilst substantial marine bird populations have been found to the west of the Waterway (i.e., Skomer SPA), it is considered highly unlikely that the majority of marine birds will be found outside of their preferred habitat and feeding ranges which do not occur within the Waterway. No impact pathway has been identified that may directly impact bird communities and their prey species/abundances. Any marine birds such as gulls (Laridae) which are known to enter the Waterway, will be habituated to ongoing port activities within Pembroke Port and are therefore considered unlikely to be adversely impacted by updated activities for the PDI project.
Commercial Fisheries	All	Scoped out on the basis that no commercial fishing activity is undertaken within the Pembroke Port area, and therefore in or adjacent to the updated activities for the PDI project.
Marine Archaeology	All	Scoped out on the basis that no impact pathway for marine archaeology will be created as a result of the updated activities for the PDI project.
Infrastructure and other users	All	Scoped out on the basis that all proposed activities will be undertaken within an existing port area which restricts other users and activities.
Shipping and Navigation	All	Scoped out on the basis that the updated activities for the PDI project will occur inside Pembroke Port which consistently has high levels of vessel traffic and therefore these activities will represent a negligible increase. In addition, all vessel movement within the Waterway is closely controlled by the MHPA, and restricted due to deep water channels.
Physical Processes	Changes to sediment transport processes.	Scoped out on the basis that no impact pathway for any changes to sediment transport processes will be created as a result of the updated activities for the PDI project.
Physical Processes	Changes to wave or tidal conditions	Scoped out on the basis that no impact pathway for any changes to wave and tidal conditions will be created as a result of the updated activities for the PDI project.
Benthic Ecology	Release of sediment bound contaminants	Scoped out on the basis that the seabed that will be disturbed is already subject to regular disturbance as a result of port activities therefore the updated activities for the PDI project will not cause any additional release of sediment bound contaminants beyond what was assessed in the original EIA.
Benthic Ecology	Long term habitat loss associated with pile installation	Scoped out on the basis that this area will be within the footprint of the slipway and therefore does not represent any additional long term habitat loss
Fish and Shellfish Ecology & Marine Mammals	Temporary habitat disturbance associated with the footprint of the installation of the temporary stank	Scoped out on the basis that the temporary habitat disturbance area will be very small in the context of the wider available suitable habitat for fish. There will have a negligible effect.
Fish and Shellfish Ecology & Marine Mammals	Long term habitat loss associated with pile installation	Scoped out on the basis that this area will be within the footprint of the slipway and therefore does not represent any additional long term habitat loss

Appendix B: WFD Scoping Table

The scoping assessment for the project has been undertaken in accordance with NRW guidance note OGN072 (Table B.1). Findings from the assessment have been undertaken with respect to two identified water bodies that could be potentially affected by the project:

- Milford Haven Inner is located within the project footprint; and
- Milford Haven outer is located approximately 2 km to the west of the project footprint.

Table B.1 WFD Scoping Table

Your activity	Description, notes or more information
Applicant name	Milford Haven Port Authority
Application reference number (where applicable)	Not applicable
Name of activity	Change of methodology for slipway construction and seabed clearance
Brief description of activity	MHPA are looking to revise the consent use hydraulic rock breakers in the wet and to use rotary piling for the new secant piled walls. In addition, MHPA are also seeking to include for the temporary installation of a stank across the entrance of the eastern slipway (within the footprint of the consented slipway extension) to facilitate the consented works to this part of the project.
Location of activity (central point XY coordinates or national grid reference)	Pembroke Docks Mega Slipway 51º41'49" N 4º57'21" W
Footprint of activity (ha)	The activity associated with the temporary stank, secant piled wall and hydraulic breaking all occur within the footprint of the originally licenced area of the mega slipway. There is only expected to be 42 m^2 of additional temporary disturbance from ten jack-ups which will support the installation of the secant piled wall.
Timings of activity (including start and finish dates)	11th of April 2022 to 06th of Sept 2023 = 348 days for the complete slipway construction. (For the secant wall section, the works will start 14th of March 2022 -12th of July 2022, making a total of 83 days)
Extent of activity (for example size, scale frequency, expected volumes of output or discharge)	Activities will be wholly within Pembroke Port. MHPA are seeking consent for the following additional activities to be added as a variation to the current Marine Licence (CML2057):

Your activity	Description, notes or more information
	1. Revised slipway wall design to incorporate piled walls (no change to the slipway footprint); 2. The use of a hydraulic rock breaker in the wet for the excavation of rock material at the bottom of the slipway; and 3. A temporary stank at the current eastern slipway to facilitate works being undertaken in the dry. Total seabed footprint of the temporary stank will be 88.74 m^2. The temporary stank will be placed within the footprint of the slipway extension which has been granted consent under the marine licence therefore this does not represent additional seabed footprint for disturbance. There will be an addition seabed footprint impact of 48 m^2 for jack up events.
Use or release of chemicals (state which ones)	Grout and Cement

B.1 Specific risk information

Potential risks of the updated activities for the Pembroke Dock redevelopment were considered for each of the following receptors: hydromorphology, biology (fish), water quality, priority habitats, priority species, INNS and protected areas within each identified waterbody. Potential cumulative Impacts have also been assessed.

B.1.1 Section 1: Hydromorphology

Consider if hydromorphology is at risk from your activity.

Use the water body summary table to find out the hydromorphology status of the water body, if it is classed as heavily modified and for what use (Table B. 2).

Table B. 2: Waterbody assessment for hydromorphology

Consider if your activity:	Hydromorphology risk issue(s) to Milford Haven Inner Waterbody	Hydromorphology risk issue(s) to Milford Haven Outer Waterbody
Changes the physical form or alters the process of sediment transport (erosion, deposition or transfer)	No; impact assessment not required. The project will not affect the physical form or cause changes to sediment transport within the waterbody	No; impact assessment not required. The project will not affect the physical form or cause changes to sediment transport within the waterbody

Consider if your activity:	Hydromorphology risk issue(s) to Milford Haven Inner Waterbody	Hydromorphology risk issue(s) to Milford Haven Outer Waterbody
Have a significant impact on the hydromorphology conditions of a waterbody, for example changes to: depth variation, the seabed and intertidal zone structure, tidal patterns, for example dominant currents, freshwater flow and wave exposure.	No; impact assessment not required. The project will not affect the hydromorphology conditions within the waterbody	No; impact assessment not required. The project is not located within the waterbody any and will therefore not cause change to depth, the seabed or intertidal zone structure.
Has a physical footprint greater than 1% of the area of a surface water body or greater than 0.5 km², then it should be scoped in for hydromorphology	No; impact assessment not required. The physical footprint of the project will comprise of <1% of the area of both identified waterbodies and constitutes and area of 42 m^2 for ten jack-events to support the installation of the secant piled wall.	No; impact assessment not required. The physical footprint of the project is located outside the waterbody and therefore will not impact on waterbody
Is in a water body that is heavily modified for the same use as your activity	No; impact assessment not required. Both identified waterbodies are not considered as heavily modified in accordance with extracted data.	No; impact assessment not required. Both identified waterbodies are not considered as heavily modified in accordance with extracted data.

B.1.2 Section 2: Water quality

A scoping assessment has been undertaken on water quality and how physicochemical parameters could be affected by the project is provided in the table below (Table B. 3: Waterbody assessment for water quality):

Table B. 3: Waterbody assessment for water quality

Consider if your activity:	Water quality risk issue(s) to Milford Haven Inner Waterbody	Water quality risk issue(s) to Milford Haven Outer Waterbody
Could affect water clarity, temperature, salinity, oxygen levels, nutrients or microbial patterns continuously for longer than a spring neap tidal cycle (about 14 days)	No. Impact assessment not required Sediment plumes generated by drilling will not extend for more than a few hours following operation.	No. Impact assessment not required Sediment plumes generated by propeller wash will be localised and not be continuous for a period of more than 14 days and will not impact on waterbody.

Consider if your activity:	Water quality risk issue(s) to Milford Haven Inner Waterbody	Water quality risk issue(s) to Milford Haven Outer Waterbody
Is in a water body with a phytoplankton status of moderate, poor or bad	No. Impact assessment not required Waterbody is classified as high	No. Impact assessment not required Waterbody is classified as high
Is in a water body with a history of harmful algae	No. Impact assessment not required Not previously monitored	No. Impact assessment not required Not previously monitored

Potential for release or disturbance of chemicals has been considered in the table below (Table B. 4: Chemical disturbance risk assessment):

Table B. 4: Chemical disturbance risk assessment

If your activity uses or releases chemicals (for example through sediment disturbance or building works) consider if:	Water quality risk issue(s) to Milford Haven Inner Waterbody	Water quality risk issue(s) to Milford Haven Outer Waterbody
The chemicals are on the Environmental Quality Standards Directive (EQSD) list	No. Impact assessment not required Use of chemicals is not predicted during project.	No. Impact assessment not required Use of chemicals is not predicted during project.
It disturbs sediment with contaminants above Cefas Action Level 1	No. Impact assessment not required Small, localised disturbance of sediments is predicted from installation and removal of the temporary stank although it is not considered that contaminants will be released from sediments as part of these activities given the small scale, or temporary nature of disturbance events.	No. Impact assessment not required Small, localised disturbance of sediments is predicted from installation and removal of the temporary stank although it is not considered that contaminants will be released from sediments as part of these activities given the small scale, or temporary nature of disturbance events.
If your activity has a mixing zone (like a discharge pipeline or outfall) consider if:	**Water quality risk issue(s) to Milford Haven Inner Waterbody**	**Water quality risk issue(s) to Milford Haven Outer Waterbody**
The chemicals released are on the Environmental Quality Standards Directive (EQSD) list	No. Impact assessment not required The project will not have a mixing zone associated with the activity and therefore no chemicals listed on Environmental	No. Impact assessment not required The project will not have a mixing zone associated with the activity and therefore no chemicals listed on Environmental

	Quality Standards Directive (EQSD) list that will be released as part of the project activities.	Quality Standards Directive (EQSD) list that will be released as part of the project activities.

B.1.3 Section 3: Biology

Annex V of the Directive sets out Biological Quality Elements (BQEs) which are used to classify ecological status using five classes from high to bad including elements such as fish, invertebrates, or algae (Table B. 5: Ecological classification summary).

Table B. 5: Ecological classification summary

Quality Element	Pressure Description
Phytoplankton	Nutrient enrichment
Macroalgae	Nutrient enrichment, hazardous chemicals
Angiosperms	Nutrient enrichment, morphological alterations
Benthic invertebrates	Organic pollution, hazardous chemicals and some morphological alterations
Fish (transitional only)	Organic enrichment (dissolved oxygen), habitat destruction

Following consideration of the proposed project activities and the pressure descriptions for each receptor, only **benthic invertebrate** receptors have been taken forward for further assessment for the Milford Haven Inner water way. No impacts to Milford Haven Outer are predicted. The project will not cause nutrient enrichment of the waterbody that could potentially impact on phytoplankton.

B.1.4 Section 3: Fish

A scoping assessment has been undertaken on whether fish could be potentially affected by the project and the results are provided in the table below (Table B. 6: Waterbody assessment for fish):

Table B. 6: Waterbody assessment for fish

Consider if your activity:	Biology fish risk issue(s) to Milford Haven Inner Waterbody	Biology fish risk issue(s) to Milford Haven Outer Waterbody
Could impact on normal fish behaviour like movement, migration or spawning (for example creating a physical barrier, noise, chemical change or a change in depth or flow)	Yes; requires impact assessment. Underwater noise effects during drilling of secant walls and operation of the hydraulic rock have the potential to cause disturbance effects to fish.	No. Impact assessment not required Disturbance to fish within waterbody is not expect given all disturbance will be localised to within the project area.
Could cause mechanical injury or death to fish through: Entrainment, e.g., fish being drawn into cooling water systems or turbines	No; impact assessment not required. There are no intakes associated with the project that could cause entrainment or impingement to fish within the waterbody.	No; impact assessment not required. The project is not located within the waterbody and therefore no mechanical injury is predicted to fish within the waterbody.

Consider if your activity:	Biology fish risk issue(s) to Milford Haven Inner Waterbody	Biology fish risk issue(s) to Milford Haven Outer Waterbody
Impingement, e.g., fish trapped against debris screens		
Is in a transitional water body and could affect fish or is outside of the transitional water body but could impact upon migratory fish	Yes; requires impact assessment. Project footprint is located within the Milford Haven Inner Waterbody which is characterised as transitional	Yes; requires impact assessment. Project could potentially impact migratory fish associated with the waterbody.

B.1.5 Section 4: WFD protected areas

An assessment of the following WFD protected areas have been considered at risk if they are located within located 2 km of the project footprint (Table B. 7: Location of Waterbodies within 2 km):

- special areas of conservation (SAC)
- special protection areas (SPA)
- shellfish waters
- bathing waters
- nutrient sensitive areas

Table B. 7: Location of Waterbodies within 2 km

Consider if your activity is:	Protected areas risk issue(s)
Within 2 km of any WFD protected area	Within 2km of the project footprint the following WFD protected areas are found: 1) Pembrokeshire Marine/ Sir Benfro Forol SAC (~50 m from project footprint)

2) Shellfish waters (1,770 m from project footprint) (NRW, 2013)

No other WFD protected areas are located within 2 km of the project footprint.

B.1.6 Section 5: Priority habitats and species

An assessment of whether the project to cause impacts on priority habitats and species under Environment (Wales) Act 2016 (Table B. 8: Waterbody assessment on priority habitats).

Table B. 8: Waterbody assessment on priority habitats

Consider if:	Priority species and habitat risk associated with Milford Haven Inner Waterbody	Priority species and habitat risk associated with Milford Haven Outer Waterbody
There are priority species and habitats within identified waterbody	Yes. Several listed migratory and non-migratory fish species as well as harbour porpoise, bottlenose dolphins, grey seals and otters, may occur within the waterbody. Several listed habitats also occur.	Yes. Several listed migratory and non-migratory fish species and harbour porpoise may occur within the waterbody. Several listed habitats also occur
Consider if the project could:	**Priority species and habitat risk associated with Milford Haven Inner Waterbody**	**Priority species and habitat risk associated with Milford Haven Inner Waterbody**
Impact on identified priority species	Yes; requires impact assessment. Underwater noise effects during drilling and operation of the hydraulic rock breaker have the potential to cause disturbance to fish and harbour porpoise.	Yes; requires impact assessment. Underwater noise effects during piling and operation of the hydraulic rock breaker have the potential to cause disturbance to fish and harbour porpoise.
Impact on identified priority habitats	No; requires impact assessment. Project activities will not impact on priority habitats within the waterbody.	No; impact assessment not required. Project activities will not impact on the priority habitats within the waterbody.

B.1.7 Section 6: Invasive non-native species

An assessment was undertaken to determine whether the project could introduce or spread INNS (Table B. 9: Waterbody assessment on INNS).

Risks of introducing or spreading INNS include:

- materials or equipment that have come from, had use in or travelled through other water bodies
- activities that help spread existing INNS, either within the immediate water body or other water bodies

Table B. 9: Waterbody assessment on INNS

Consider if your activity could:	INNS risk issue(s)
Introduce or spread INNS	No: The support vessel that will transit to site from within the Waterbodies. In addition, an INNS Management Plan will outline measures to ensure vessels comply with the International Maritime Organization (IMO) ballast water management guidelines, it will consider the origin of vessels and contain standard housekeeping measures for such vessels as well as measures to be adopted in the event that a high alert species is recorded.

B.1.8 Section 7: Summary

A summary of the results of the scoping assessment on the Milford Haven Inner and outer waterway are provided below (Table B. 10: Waterbody assessment summary):

Table B. 10: Waterbody assessment summary

Receptor	Waterbody	Potential risk to receptor	Note the risk issue(s) for impact assessment
Hydromorphology	Milford Haven Inner	No	The project will not affect the physical form or cause changes to sediment transport within the waterbody, depth or intertidal zone structure
	Milford Haven Outer	No	The project will not affect the physical form or cause changes to sediment transport within the waterbody, depth or intertidal zone structure
Biology	Milford Haven Inner	Yes	Biological Quality Elements benthic invertebrates have been taken forward for further assessment.
	Milford Haven Outer	No	No potential impacts are predicted to biological quality elements.
Fish	Milford Haven Inner	Yes	Underwater noise effects during installation drilling and operation of hydraulic rock breaker have the potential to cause disturbance effects to fish.

Receptor	Waterbody	Potential risk to receptor	Note the risk issue(s) for impact assessment
	Milford Haven Outer	Yes	Underwater noise effects during installation drilling and operation of hydraulic rock breaker have the potential to cause disturbance effects on migratory fish associated with the waterbody.
Water quality	Milford Haven Inner	No	Sediment plumes generated by installation and removal of a temporary stank may cause changes to water clarity will be made up of very small volumes of sediment, would be quickly diluted and only be transported a few hundred metres from the source.
	Milford Haven Outer	No	As above
Protected areas	Milford Haven Inner	Yes	Within 2 km of the project footprint the following protected areas are found: • Pembrokeshire Marine/ Sir Benfro Forol SAC (~50 m from project footprint) • Shellfish waters (1770 m from project footprint)
	Milford Haven Outer	Yes	As above
Priority Habitats and Species	Milford Haven Inner	Yes	Several listed migratory and non-migratory fish species, harbour porpoise, and listed marine habitats exist within the waterbody.
	Milford Haven Outer	Yes	Several listed migratory and non-migratory fish species, harbour porpoise, and listed marine habitats exist within the waterbody.
Invasive non-native species	Milford Haven Inner	No	The equipment will be based onshore or on a support vessel that will be transported to site from within the Waterbodies
	Milford Haven Outer	No	As above

Appendix C: Subsea noise modelling report

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Pembroke Dock Infrastructure

Subsea Noise Modelling

Document Control

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Table of Contents

1 Introduction

Milford Haven Port Authority (MHPA) is seeking to vary the Marine Licence for the Pembroke Dock upgrade to include:

- Rotary piling for the flank walls for the new slipway (the current Marine License does not include for any piling); and
- Use of rock breaking equipment (e.g. impact ripper excavator, hydraulic breaker) in the wet for the slipway (The licensed activities associated with the removal of sediment/rock around the slipways include only for the excavation of material above the water mark at the time of excavation (in the dry), by backhoe excavator. Any rock identified within this area was to be removed using a larger backhoe excavator or a hydraulic rock breaker. In areas below the existing water mark (in the wet) the only activities currently licensed are the removal of material by backhoe excavator with a closed bucket attachment positioned on a barge).

Noise is readily transmitted underwater and there is potential for sound emissions from the survey to affect marine mammals and fish. At long ranges the introduction of additional noise could potentially cause short-term behavioural changes, for example to the ability of species to communicate and to determine the presence of predators, food, underwater features, and obstructions. At close ranges and with high noise source levels, permanent or temporary hearing damage may occur, while at very close range, gross physical trauma is possible.

This report presents the results of a supplementary subsea noise assessment considering the potential effects of underwater noise on the marine environment from the proposed additional construction activities at Pembroke Dock.

2 Acoustic Concepts and Terminology

Sound travels through the water as vibrations of the fluid particles in a series of pressure waves. The waves comprise a series of alternating compressions (positive pressure) and rarefactions (negative pressure). Because sound consists of variations in pressure, the unit for measuring sound is usually referenced to a unit of pressure, the Pascal (Pa). The decibel (dB) scale is used to conveniently communicate the large range of acoustic pressures encountered, with a known pressure amplitude chosen as a reference value (i.e., 0 dB). In the case of underwater sound, the reference value (P_{ref}) is taken as 1 µPa, whereas the airborne sound is usually referenced to a pressure of 20 µPa. To convert from a sound pressure level referenced to 20 µPa to one referenced to 1 µPa, a factor of 20 log (20/1) i.e., 26 dB has to be added to the former quantity. Thus 60 dB re 20 µPa is the same as 86 dB re 1 µPa, although differences in sound speeds and different densities mean that the decibel level difference in sound intensity is much more than the 26 dB when converting pressure from air to water. All underwater sound pressure levels in this report are quantified in dB re 1 µPa.

There are several descriptors used to characterise a sound wave. The difference between the lowest pressure variation (rarefaction) and the highest-pressure variation (compression) is called the peak to peak (or pk-pk) sound pressure level. The difference between the highest variation (either positive or negative) and the mean pressure is called the peak pressure level. Lastly, the root mean square (rms) sound pressure level is used as a description of the average amplitude of the variations in pressure over a specific time window. Decibel values reported should always be quoted along with the P_{ref} value employed during calculations. For example, the measured SPL_{rms} value of a pulse may be reported as 100 dB re 1 µPa. These descriptions are shown graphically in Figure 2.1.

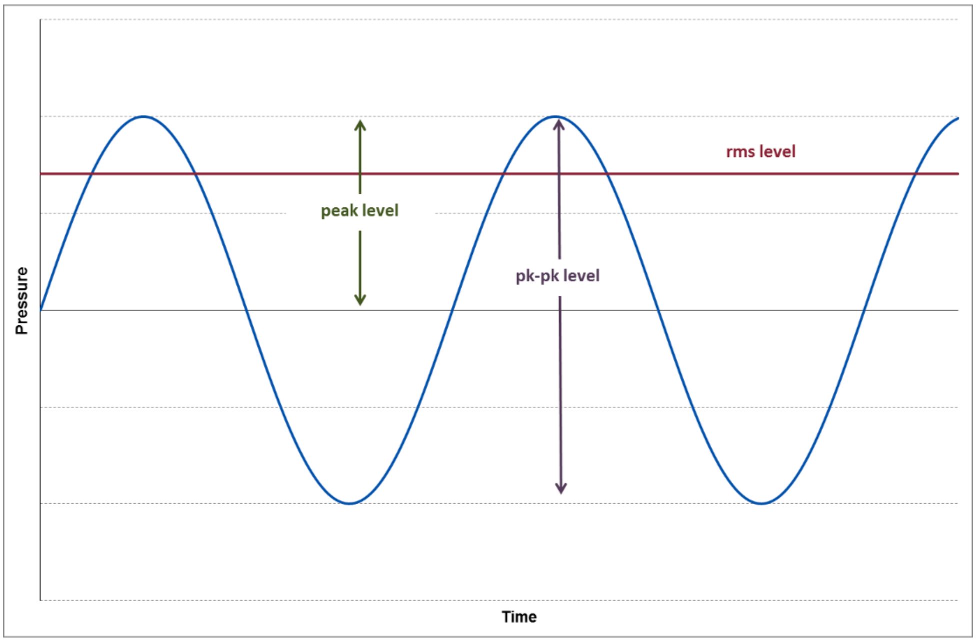

Figure 2.1: Graphical representation of acoustic wave descriptors

The rms sound pressure level (SPL) is defined as follows:

$$SPL_{rms} = 10log_{10}\left(\frac{1}{T}\int_{0}^{T}\left(\frac{p^2}{p_{ref}^2}\right)dt\right).$$

The magnitude of the rms sound pressure level for an impulsive sound (such as that from a seismic source array) will depend upon the integration time, T, used for the calculation (Madsen 2005). It has become customary to utilise the T90 time period for calculating and reporting rms sound pressure levels. This is the interval over which the cumulative energy curve rises from 5% to 95% of the total energy and therefore contains 90% of the sound energy.

Another useful measure of sound used in underwater acoustics is the Sound Exposure Level, or SEL. This descriptor is used as a measure of the total sound energy of an event or a number of events (e.g., over the course of a day) and is normalised to one second. This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like for like basis[1]. The SEL is defined as follows:

$$SEL = 10log_{10}\left(\int_0^T \left(\frac{p^2(t)}{p_{ref}^2 t_{ref}}\right) dt\right).$$

The frequency, or pitch, of the sound is the rate at which the acoustic oscillations occur in the medium (air/water) and is measured in cycles per second, or Hertz (Hz). When sound is measured in a way which approximates to how a human would perceive it using an A-weighting filter on a sound level meter, the resulting level is described in values of dBA. However, the hearing faculty of marine mammals is not the same as humans, with marine mammals hearing over a wider range of frequencies and with a different sensitivity. It is therefore important to understand how an animal's hearing varies over its entire frequency range to assess the effects of anthropogenic sound on marine mammals. Consequently, use can be made of frequency weighting scales (m-weighting) to determine the level of the sound in comparison with the auditory response of the animal concerned. A comparison between the typical hearing response curves for fish, humans and marine mammals is shown in Figure 2.2. It is worth noting that hearing thresholds are sometimes shown as audiograms with sound level on the y-axis rather than sensitivity, resulting in the graph shape being the inverse of the graph shown.

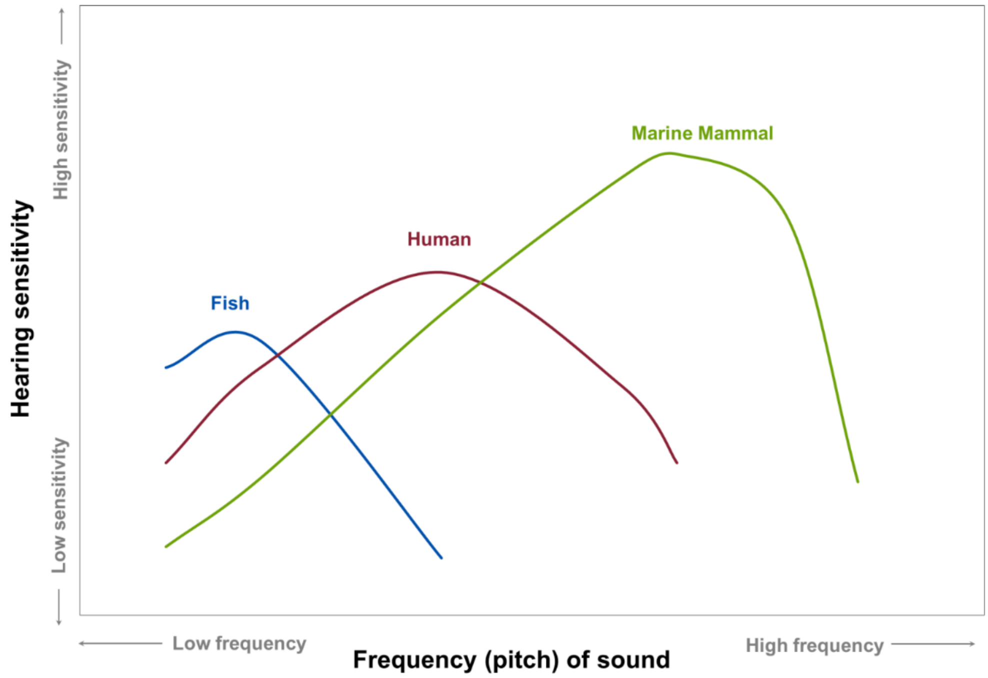

Figure 2.2: Comparison between hearing thresholds of different animals

Other relevant acoustic terminology and their definitions used in the report are detailed below.

<u>1/3rd octave bands</u>

The broadband acoustic power (i.e., containing all the possible frequencies) emitted by a sound source, measured/modelled at a location within the survey region is generally split into and reported in a series of frequency bands. In marine acoustics, the spectrum is generally reported in standard 1/3rd octave band frequencies, where an octave represents a doubling in sound frequency.

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1 Historically, use was primarily made of rms and peak sound pressure level metrics for assessing the potential effects of sound on marine life. However, the SEL is increasingly being used as it allows exposure duration and the effect of exposure to multiple events to be considered.

Source level (SL)

The source level is the sound pressure level of an equivalent and infinitesimally small version of the source (known as *point source*) at a hypothetical distance of 1 m from it. The source level may be combined with the transmission loss (TL) associated with the environment to obtain the received level (RL) in the *far field* of the source. The far field distance is chosen so that the behaviour of the distributed source can be approximated to that of a point source. Source levels do not indicate the real sound pressure level at 1 m.

Transmission loss (TL)

TL at a frequency of interest is defined as the loss of acoustic energy as the signal propagates from a hypothetical (point) source location to the chosen receiver location. The TL is dependent on water depth, source depth, receiver depth, frequency, geology, and environmental conditions. The TL values are generally evaluated using an acoustic propagation model (various numerical methods exist) accounting for the above dependencies.

Received level (RL)

The RL is the sound level of the acoustic signal recorded (or modelled) at a given location, that corresponds to the acoustic pressure/energy generated by a known active sound source. This considers the acoustic output of a source and is modified by propagation effects. This RL value is strongly dependant on the source, environmental properties, geological properties and measurement location/depth. The RL is reported in dB either in rms or peak-to-peak SPL, and SEL metrics, within the relevant third-octave band frequencies. The RL is related to the SL as

$$RL = SL - TL$$

where TL is the transmission loss of the acoustic energy within the survey region.

The directional dependence of the source signature and the variation of TL with azimuthal direction α (which is strongly dependent on bathymetry) are generally combined and interpolated to report a 2-D plot of the RL around the chosen source point up to a chosen distance.

3 Acoustic Assessment Criteria

3.1 Introduction

Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Richardson et al. (1995) defined four zones of noise influence which vary with distance from the source and level. These are:

- **The zone of audibility:** this is the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will have an effect on the marine mammal.
- **The zone of masking:** this is defined as the area within which noise can interfere with detection of other sounds such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how marine mammals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall noise level).
- **The zone of responsiveness:** this is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, as stated previously, audibility does not necessarily evoke a reaction.
- **The zone of injury / hearing loss:** this is the area where the sound level is high enough to cause tissue damage in the ear. This can be classified as either temporary threshold shift (TTS) or permanent threshold shift (PTS). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or even death are possible.

For this study, it is the zones of injury and disturbance (i.e., responsiveness) that are of concern (there is insufficient scientific evidence to properly evaluate masking). To determine the potential spatial range of injury and disturbance, a review has been undertaken of available evidence, including international guidance and scientific literature. The following sections summarise the relevant thresholds for onset of effects and describe the evidence base used to derive them.

3.2 Marine Mammals

Sound propagation models can be constructed to allow the received noise level at different distances from the source to be calculated. To determine the consequence of these received levels on any marine mammals which might experience such noise emissions, it is necessary to relate the levels to known or estimated impact thresholds. The injury criteria proposed by Southall et al (2019). are based on a combination of linear (i.e., un-weighted) peak pressure levels and mammal-hearing-weighted sound exposure levels (SEL). The hearing weighting function is designed to represent the bandwidth for each group within which acoustic exposures can have auditory effects. The categories include:

- **low-frequency (LF) cetaceans** (i.e., marine mammal species such as baleen whales);
- **high-frequency (HF) cetaceans** (i.e., marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales);
- **very high-frequency (VHF) cetaceans** (i.e., marine mammal species such as true porpoises, river dolphins and pygmy/dwarf sperm whales and some oceanic dolphins, generally with auditory centre frequencies above 100 kHz);
- **phocid pinnipeds (PCW)** (i.e., true seals; hearing in air is considered separately in the group PCA); and
- **other marine carnivores (OCW)** (including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; air hearing considered separately in the group OCA).

These weightings have therefore been used in this study and are shown in Figure 3.1.

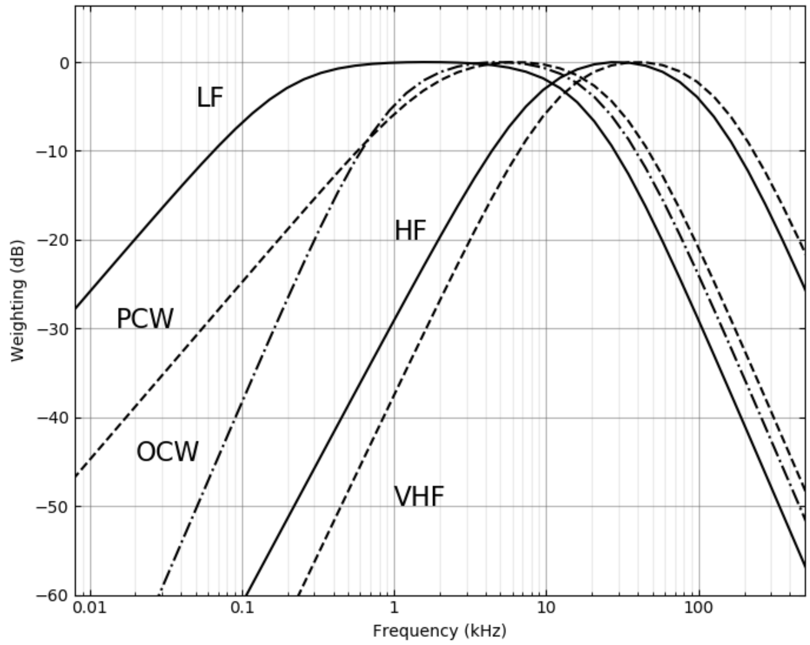

Figure 3.1: Hearing weighting functions for pinnipeds and cetaceans (Southall et al. 2019)

Injury criteria are proposed in Southall et al. (2019) are for two different types of sound as follows:

- **Impulsive sounds** which are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI 1986; NIOSH 1998; ANSI 2005). This category includes sound sources such as seismic surveys, impact piling and underwater explosions; and
- **Non-impulsive sounds** which can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise/decay time that impulsive sounds do (ANSI 1995; NIOSH 1998). This category includes sound sources such as continuous running machinery, sonar and vessels.

The relevant criteria proposed by Southall et al. (2019) are as summarised in Table 3.1.

Table 3.1: Summary of PTS onset acoustic thresholds (Southall et al. 2019)

Hearing Group	Parameter	Impulsive		Non-impulsive	
		PTS	TTS	PTS	TTS
Low-frequency (LF) cetaceans	Peak, unweighted	219	213	-	
	SEL, LF weighted	183	168	199	179
High-frequency (HF) cetaceans	Peak, unweighted	230	224	-	
	SEL, MF weighted	185	170	198	178
Very High-frequency (VHF) cetaceans	Peak, unweighted	202	196	-	
	SEL, HF weighted	155	140	173	153
Phocid Carnivores in Water (PCW)	Peak, unweighted	218	212	-	
	SEL, PW weighted	185	170	201	181
Other Marine Carnivores in Water (OCW)	Peak, unweighted	232	226	-	
	SEL, OW weighted	203	188	219	199

These updated marine mammal injury criteria were published in March 2019 (Southall et al. 2019). The paper utilised the same hearing weighting curves and thresholds as presented in the preceding regulations document (NMFS 2018) with the main difference being the naming of the hearing groups and introduction of additional thresholds for animals not covered by NMFS (2018). A comparison between the two naming conventions is shown in Table 3.2.

For avoidance of doubt, the naming convention used in this report is based upon those set out in Southall et al. (2019). Consequently, this assessment utilises criteria which are applicable to both NMFS (2018) and Southall et al. (2019).

Table 3.2: Comparison of hearing group names between NMFS 2018 and Southall 2019

NMFS (2018) hearing group name	Southall et al. (2019) hearing group name
Low frequency cetaceans (LF)	Low-frequency cetaceans (LF)
Mid frequency cetaceans (MF)	High-frequency cetaceans (HF)
High frequency cetaceans (HF)	Very high-frequency cetaceans (VHF)
Phocid pinnipeds in water (PW)	Phocid carnivores in water (PCW)

In order to assess potential disturbance to marine mammals, criteria for impulsive and non-impulsive sounds are based on NMFS (2005) and HESS (1997). The criteria are as follows:

- Potential disturbance due to non-impulsive sound: 120 dB re 1 µPa (rms)
- Potential mild disturbance due to impulsive sound: 140 dB re 1 µPa (rms)
- Potential significant disturbance due to impulsive sound: 160 dB re 1 µPa (rms)

3.3 Fish

Adult fish not in the immediate vicinity of the noise generating activity are generally able to vacate the area and avoid physical injury. However, larvae and eggs are not highly mobile and are therefore more likely to incur injuries from the sound energy in the immediate vicinity of the sound source, including damage to their hearing, kidneys, hearts and swim bladders. Such effects are unlikely to happen outside of the immediate vicinity of even the highest energy sound sources.

For fish, the most relevant criteria for injury are considered to be those contained in the recent Sound Exposure Guidelines for Fishes and Sea Turtles (Popper et al. 2014). These guidelines do not group by species but instead broadly group fish into the following categories based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

- **Group 1 fish:** fishes with no swim bladder or other gas chamber (e.g. elasmobranchs, flatfishes and lampreys). These species are less susceptible to barotrauma and are only sensitive to particle motion, not sound pressure. Basking shark, which does not have a swim bladder, falls into this hearing group;
- **Group 2 fish:** fishes with swim bladders but the swim bladder does not play a role in hearing (e.g. salmonids). These species are susceptible to barotrauma, although hearing only involves particle motion, not sound pressure;
- **Group 3:** Fishes with swim bladders that are close, but not connected, to the ear (e.g. gadoids and eels). These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than groups 1 and 2, extending to about 500 Hz;
- **Group 4:** Fishes that have special structures mechanically linking the swim bladder to the ear (e.g. clupeids such as herring, sprat and shads). These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range, extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3;
- **Sea Turtles:** There is limited information on auditory criteria for sea turtles and the effect of impulsive noise is therefore inferred from documented effects to other vertebrates. Bone conducted hearing is the most likely mechanism for auditory reception in sea turtles and, since high frequencies are

attenuated by bone, the range of hearing are limited to low frequencies only (Tonndorf, 1972). For leatherback turtle the hearing range has been recorded as between 50 and 1,200 Hz with maximum sensitivity between 100 and 400 Hz (Piniak, 2012); and

- **Fish eggs and larvae**.

The guidelines set out criteria for injury due to different sources of noise. Those relevant to the proposed activities are considered to be those for injury due to impulsive piling and continuous sound. The criteria include a range of indices including SEL, rms and peak sound pressure levels. Where insufficient data exist to determine a quantitative guideline value, the risk is categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e. in the tens of metres), "intermediate" (i.e. in the hundreds of metres) or "far" (i.e. in the thousands of metres). It should be noted that these qualitative criteria cannot differentiate between exposures to different noise levels and therefore all sources of noise, no matter how noisy, would theoretically elicit the same assessment result. However, because the qualitative risks are generally qualified as "low", with the exception of a moderate risk at "near" range (i.e. within tens of metres) for some types of animal and impairment effects, this is not considered to be a significant issue with respect to determining the potential effect of noise on fish.

The criteria used in this noise assessment for impulsive piling are given in Table 3.3. In the table, both peak and SEL criteria are unweighted.

Table 3.3: Criteria for onset of injury to fish and sea turtles due to impulsive piling (Popper et al., 2014).

Type of animal	Parameter	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	SEL, dB re 1 μPa^2s	>219	>216	>>186
	Peak, dB re 1 μPa	>213	>213	
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL, dB re 1 μPa^2s	210	203	>186
	Peak, dB re 1 μPa	>207	>207	
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL, dB re 1 μPa^2s	207	203	186
	Peak, dB re 1 μPa	>207	>207	
Sea turtles	SEL, dB re 1 μPa^2s	210	(Near) High (Intermediate) Low (Far) Low	(Near) High (Intermediate) Low (Far) Low
	Peak, dB re 1 μPa	>207		
Eggs and larvae	SEL, dB re 1 μPa^2s	>210	(Near) Moderate (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
	Peak, dB re 1 μPa	>207		

The criteria used in this noise assessment for non-impulsive sound are given in Table 3.4.

Table 3.4: Criteria for onset of injury to fish and sea turtles due to non-impulsive sound (Popper et al., 2014).

Type of animal	Mortality and potential mortal injury	Recoverable injury	TTS
Group 1 Fish: no swim bladder (particle motion detection)	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	(Near) Low (Intermediate) Low (Far) Low	170 dB re 1 μPa (rms) for 48 hours	158 dB re 1 μPa (rms) for 12 hours
Sea turtles	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Low (Far) Low
Eggs and larvae	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low	(Near) Low (Intermediate) Low (Far) Low

Behavioural reaction of fish to sound has been found to vary between species based on their hearing sensitivity. Typically, fish sense sound via particle motion in the inner ear which is detected from sound-induced motions in the fish's body. The detection of sound pressure is restricted to those fish which have air filled swim bladders; however, particle motion (induced by sound) can be detected by fish without swim bladders[2].

Highly sensitive species such as herring have elaborate specialisations of their auditory apparatus, known as an otic bulla – a gas-filled sphere, connected to the swim bladder, which enhances hearing ability. The gas filled swim bladder in species such as cod and salmon may be involved in their hearing capabilities, so although there is no direct link to the inner ear, these species are able to detect lower sound frequencies and as such are considered to be of medium sensitivity to noise. Flat fish and elasmobranchs have no swim bladders and as such are considered to be relatively less sensitive to sound pressure.

The most recent criteria for disturbance are considered to be those contained in Popper et al. (2014) which set out criteria for disturbance due to different sources of noise. The risk of behavioural effects is categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e. in the tens of metres), "intermediate" (i.e. in the hundreds of metres) or "far" (i.e. in the thousands of metres), as shown in Table 3.5.

[2] It should be noted that the presence of a swim bladder does not necessarily mean that the fish can detect pressure. Some fish have swim bladders that are not involved in the hearing mechanism and can only detect particle motion.

Table 3.5: Criteria for onset of behavioural effects in fish and sea turtles for impulsive and non-impulsive sound (Popper et al., 2014).

Type of animal	Relative risk of behavioural effects	
	Impulsive sound	Non-impulsive sound
Group 1 Fish: no swim bladder (particle motion detection)	(Near) High (Intermediate) Moderate (Far) Low	(Near) Moderate (Intermediate) Moderate (Far) Low
Group 2 Fish: where swim bladder is not involved in hearing (particle motion detection)	(Near) High (Intermediate) Moderate (Far) Low	(Near) Moderate (Intermediate) Moderate (Far) Low
Groups 3 and 4 Fish: where swim bladder is involved in hearing (primarily pressure detection)	(Near) High (Intermediate) High (Far) Moderate	(Near) High (Intermediate) Moderate (Far) Low
Sea turtles	(Near) High (Intermediate) Moderate (Far) Low	(Near) High (Intermediate) Moderate (Far) Low
Eggs and larvae	(Near) Moderate (Intermediate) Low (Far) Low	(Near) Moderate (Intermediate) Moderate (Far) Low

It is important to note that the Popper et al. (2014) criteria for disturbance due to sound are qualitative rather than quantitative. Consequently, a source of noise of a particular type (e.g. piling) would result in the same predicted impact, no matter the level of noise produced or the propagation characteristics.

Therefore, the criteria presented in the Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual (WSDOT, 2011) are also used in this assessment for predicting the extent of behavioural effects due to impulsive piling. The manual suggests an un-weighted sound pressure level of 150 dB re 1 μPa (rms) as the criterion for onset of behavioural effects, based on work by Hastings (2002). Sound pressure levels in excess of 150 dB re 1 μPa (rms) are expected to cause temporary behavioural changes, such as elicitation of a startle response, disruption of feeding, or avoidance of an area. The document notes that levels exceeding this threshold are not expected to cause direct permanent injury but may indirectly affect the individual fish (such as by impairing predator detection). It is important to note that this threshold is for onset of potential effects, and not necessarily an 'adverse effect' threshold.

4 Assessment Methodology

4.1 Source Levels

Underwater noise sources are usually quantified in dB re 1 µPa, as if measured at a hypothetical distance of 1 m from the source (the Source Level). In practice, it is not usually possible to measure at 1 m from a source, but this metric allows comparison and reporting of different source levels on a like-for-like basis. In reality, for a large sound source this imagined point at 1 m from the acoustic centre does not exist. Furthermore, the energy is distributed across the source and does not all emanate from this imagined acoustic centre point. Therefore, the stated sound pressure level at 1 m does not actually occur for large sources. In the acoustic near-field (i.e. close to the source), the sound pressure level will be significantly lower than the value predicted by the source level.

For rotary drilled piling, source sound levels have been based on pile drilling for the Oyster 800 project (Kongsberg 2011). The hydraulic rock breaking source sound levels are based on those measured by Lawrence (2016). The source levels used in the assessment are summarised in Table 4.1.

Both sources of sound are non-impulsive in character and therefore the non-impulsive injury and behavioural thresholds have been adopted for the assessment.

Table 4.1: Piling noise source levels used in assessment (un-weighted).

Parameter	Source level at 1 m
Rotary Drilled Piling	
SEL per second of operation @ 1 m, dB re 1 µPa^2s	163
Peak sound pressure level @ 1 m, dB re 1 µPa	166
rms_{T90} sound pressure level @ 1 m, dB re 1 µPa	163
Hydraulic Rock Breaking	
SEL per second of operation @ 1 m, dB re 1 µPa^2s	177
Peak sound pressure level @ 1 m, dB re 1 µPa	212
rms_{T90} sound pressure level @ 1 m, dB re 1 µPa	177

4.2 Propagation Model

As distance from the sound source increases the level of sound recorded reduces, primarily due to the spreading of the sound energy with distance, in combination with attenuation due to absorption of sound energy by molecules in the water. This latter mechanism is more important for higher frequency sound than for lower frequencies.

The way that the sound spreads (geometrical divergence) will depend upon several factors such as water column depth, pressure, temperature gradients, salinity as well as water surface and bottom (i.e. seabed) conditions. Thus, even for a given locality, there are temporal variations to the way that sound will propagate. In simple terms, the sound energy may spread out in a spherical pattern (close to the source) or a cylindrical pattern (much further from the source), although other factors mean that decay in sound energy may be somewhere between these two simplistic cases.

In acoustically shallow waters[3] in particular, the propagation mechanism is coloured by multiple interactions with the seabed and the water surface (Lurton 2002; Etter 2013; Urick 1983; Brekhovskikh and Lysanov

3 Acoustically, shallow water conditions exist whenever the propagation is characterised by multiple reflections with both the sea surface and bottom (Etter 2013). Consequently, the depth at which water can be classified as acoustically deep or shallow depends upon numerous factors including the sound speed gradient, water depth, frequency of the sound and distance between the source and receiver.

2014; Kinsler et al., 1999). Whereas in deeper waters, the sound will propagate further without encountering the surface or bottom of the sea, in shallower waters the sound may be reflected from either or both boundaries (potentially more than once).

At the sea surface, the majority of sound is reflected back into the water due to the difference in acoustic impedance (i.e. sound speed and density) between air and water. However, scattering of sound at the surface of the sea can be an important factor with respect to the propagation of sound. In an ideal case (i.e. for a perfectly smooth sea surface), the majority of sound energy will be reflected back into the sea. However, for rough seas, much of the sound energy is scattered (e.g. Eckart 1953; Fortuin 1970; Marsh, Schulkin, and Kneale 1961; Urick and Hoover 1956). Scattering can also occur due to bubbles near the surface such as those generated by wind or fish or due to suspended solids in the water such as particulates and marine life. Scattering is more pronounced for higher frequencies than for low frequencies and is dependent on the sea state (i.e. wave height). However, the various factors affecting this mechanism are complex.

Because surface scattering results in differences in reflected sound, its effect will be more important at longer ranges from the sound source and in acoustically shallow water (i.e. where there are multiple reflections between the source and receiver). The degree of scattering will depend upon the sea state/wind speed, water depth, frequency of the sound, temperature gradient, grazing angle and range from source. It should be noted that variations in propagation due to scattering will vary temporally within an area primarily due to different sea-states / wind speeds at different times. However, over shorter ranges (e.g. several hundred meters or less) the sound will experience fewer reflections and so the effect of scattering should not be significant.

When sound waves encounter the bottom, the amount of sound reflected will depend on the geoacoustic properties of the bottom (e.g. grain size, porosity, density, sound speed, absorption coefficient and roughness) as well as the grazing angle and frequency of the sound (Cole 1965; Hamilton 1970; Mackenzie 1960; McKinney and Anderson 1964; Etter 2013; Lurton 2002; Urick 1983). Thus, bottoms comprising primarily mud or other acoustically soft sediment will reflect less sound than acoustically harder bottoms such as rock or sand. This will also depend on the profile of the bottom (e.g. the depth of the sediment layer and how the geoacoustic properties vary with depth below the sea floor). The effect is less pronounced at low frequencies (a few kHz and below). A scattering effect (similar to that which occurs at the surface) also occurs at the bottom (Essen 1994; Greaves and Stephen 2003; McKinney and Anderson 1964; Kuo 1992), particularly on rough substrates (e.g. pebbles).

Waveguide effect should also be considered, which defines the shallow water columns do not allow the propagation of low frequency sound (Urick 1983; Etter 2013). The cut-off frequency of the lowest mode in a channel can be calculated based on the water depth and knowledge of the sediment geoacoustic properties. Any sound below this frequency will not propagate far due to energy losses through multiple reflections.

Sound speed gradient is the final piece of the puzzle. Changes in the water temperature and the hydrostatic pressure with depth imply that the speed of sound varies throughout the water column. This can lead to significant variations in sound propagation and can also lead to sound channels, particularly for high frequency sound. Sound can propagate in a duct-like manner within these channels, effectively focussing the sound, and conversely they can also lead to shadow zones. The frequency at which this occurs depends on the characteristics of the sound channel. The temperature gradient can vary throughout the year and thus there will be potential variation in sound propagation depending on the season.

Sound energy is also absorbed due to interactions at the molecular level converting the acoustic energy into heat. This is another frequency dependent effect with higher frequencies experiencing much higher losses than lower frequencies.

4.2.1 Modelling approach

There are several methods available for modelling the propagation of sound between a source and receiver ranging from very simple models which simply assume spreading according to a 10 log R or 20 log R relationship (for cylindrical or spherical spreading respectively, as discussed above) to full acoustic models (e.g. ray tracing, normal mode, parabolic equation, wavenumber integration and energy flux models). In addition, semi-empirical models are available which lie somewhere in between these two extremes in terms of complexity.

In choosing which propagation model to employ, it is important to ensure that it is fit for purpose and produces results with a suitable degree of accuracy for the application in question, taking into account the context (as detailed in NPL Guidance and Farcas et al., 2016). Thus, in some situations (e.g. low risk due to underwater noise, range dependent bathymetry is not an issue, non-impulsive sound) a simple (N log R) model will be sufficient, particularly where other uncertainties outweigh the uncertainties due to modelling. On the other hand, some situations (e.g. high source levels, impulsive sound, complex source and propagation path characteristics, highly sensitive receivers and low uncertainties in assessment criteria) warrant a more complex modelling methodology.

The first step in choosing a propagation model is therefore to examine these various factors, such as set out below:

- balancing of errors / uncertainties;
- range dependant bathymetry;
- frequency dependence; and
- source characteristics.

Sound propagation modelling for this assessment was based on an established, peer reviewed sound propagation model which utilises the semi-empirical model developed by Rogers (1981). The model provides a robust balance between complexity and technical rigour over a wide range of frequencies, has been validated by numerous field studies and has been benchmarked against a range of other models.

The propagation loss is calculated using the formula

$$TL = 15log_{10}R + 5\log_{10}(H\beta) + \frac{\beta R\theta_L^2}{4H} - 7.18 + \alpha_w R$$

where R is the range, H the water depth, β the bottom loss, θ_L the limiting angle and α_w the absorption coefficient of sea water (α_w is a frequency dependant term which is calculated based on Ainslie and McColm, 1998).

The limiting angle θ_L is the larger of θ_g and θ_c, where θ_g is the maximum grazing angle for a skip distance and θ_c is the effective plane wave angle corresponding to the lowest propagating mode:

$$\theta_g = \sqrt{\frac{2Hg}{c_w}}, \qquad \theta_c = \frac{c_w}{2fH},$$

where g is the sound speed gradient in water, c_w the sound speed in water and f is the frequency.

The bottom loss β is approximated as

$$\beta \approx \frac{0.477(\rho_s/\rho_w)(c_w/c_s)K_s}{[1-(c_w/c_s)^2]^{3/2}}$$

where ρ_s is the density of sediment, ρ_w the density of water, c_s the sound speed in the sediment and K_s is the sediment attenuation coefficient.

The propagation model also takes into account the depth dependent cut-off frequency for propagation of sound (i.e. the frequency below which sound does not propagate):

$$f_{cut-off} = \frac{c_w}{4H\sqrt{1-\frac{c_w^2}{c_s^2}}}.$$

The level of detail presented in terms of noise modelling needs to be considered in relation to the level of uncertainty for animal injury and disturbance thresholds. Uncertainty in the sound level predictions will be higher over larger propagation distances (i.e. in relation to disturbance thresholds) and much lower over shorter ones (i.e. in relation to injury thresholds). Nevertheless, it is considered that the uncertainty in animal injury and disturbance thresholds is likely to be higher than uncertainty in sound predictions. This is further compounded by differences in individual animal response, sensitivity and behaviour. It would therefore be wholly misleading to present any injury or disturbance ranges as a hard and fast line beyond which no effect can occur, and it would be equally misleading to present any noise modelling results in such a way.

It should be borne in mind that noise levels (and associated range of effects) will vary depending on actual conditions at the time (day-to-day and season-to-season) and that the model predicts a typical worst case scenario. Taking into account factors such as animal behaviour and habituation, any injury and disturbance ranges should be viewed as indicative and probabilistic ranges to assist in understanding potential impacts on marine life rather than lines either side of which an impact definitely will or will not occur. (This is a similar approach to that adopted for airborne noise where a typical worst case is taken, though it is known that day-to-day levels may vary to those calculated by 5 to 10 dB depending on wind direction etc.)

As well as calculating the sound pressure levels at various distances from the source, it is also necessary to calculate the SEL for a mammal or fish using the relevant weightings described previously taking into account the amount of sound energy to which it is exposed over the course of a 24-hour period. In order to carry out this calculation, it has been assumed that a mammal will swim away from the noise source at an average speed of 1.5 ms^{-1} (or 0.5 ms^{-1} for fish). The calculation considers each second of exposure separately resulting in a series of discrete SEL values of decreasing magnitude. As the mammal or fish swims away, the noise will become progressively quieter; the cumulative SEL is worked out by logarithmically adding the SEL to which the mammal is exposed as it travels away from the source. This calculation was used to estimate the approximate minimum start distance for a marine mammal or fish in order for it to be exposed to sufficient sound energy to result in the onset of potential injury. It should be noted that the sound exposure calculations are based on the simplistic assumption that the source is active continuously over the piling period and that the animal will continue to swim away at a fairly constant relative speed. The real-world situation is more complex and the noise source will vary in space and time and the animal is likely to move in a more complex manner[4].

[4] *Swim speeds of marine mammals have been shown to be up to 5 ms^{-1} (e.g. cruising minke whale 3.25 ms^{-1} (Cooper et al. 2008) and, harbour porpoise up to 4.3 ms^{-1} (Otani et al. 2000)). The more conservative swim speed of 1.5 ms^{-1} used in this assessment allows some headroom to account for the potential that the marine mammal might not swim directly away from the source, could change direction or does not maintain a fast swim speed over a prolonged period.*

5 Sound Modelling Results

Injury and disturbance impact ranges for the sources studied in the current study are summarised in Table 5.1 and Table 5.2. The distances presented in the table reflect the start point of the mammal relative to the source when the source first starts up. The thresholds for the rotary drilled piling are based on the non-impulsive thresholds whereas those for hydraulic rock breaking are based on impulsive sound thresholds. All ranges are rounded to the nearest 5 m.

Table 5.1: Summary of potential injury and disturbance zones for rotary drilled piling (N/E – not exceeded)

Species	Range of effect		
	PTS	**TTS**	**Disturbance**
Low-frequency (LF) cetaceans	N/E	N/E	295 m
High-frequency (HF) cetaceans	N/E	N/E	295 m
Very High-frequency (VHF) cetaceans	N/E	N/E	295 m
Phocid Carnivores in Water (PCW)	N/E	N/E	295 m
Other Marine Carnivores in Water (OCW)	N/E	N/E	295 m
	Mortality / potential mortal injury	**Recoverable Injury**	**TTS**
Groups 1 and 2Fish	No threshold	No threshold	No threshold
Groups 3 and 4 Fish	No threshold	N/E	N/E

Table 5.2: Summary of potential injury and disturbance zones for hydraulic rock breaking (N/E – not exceeded)

Species	Range of effect		
	PTS	**TTS**	**Disturbance**
Low-frequency (LF) cetaceans	N/E	45 m	150 m
High-frequency (HF) cetaceans	N/E	N/E	150 m
Very High-frequency (VHF) cetaceans	N/E	140 m	150 m
Phocid Carnivores in Water (PCW)	N/E	N/E	150 m
Other Marine Carnivores in Water (OCW)	N/E	N/E	150 m
	Mortality / potential mortal injury	**Recoverable Injury**	**TTS**
Groups 1 and 2 Fish	N/E	N/E	N/E
Groups 3 and 4 Fish	N/E	N/E	N/E

The potential ranges presented for injury and disturbance are not a hard and fast 'line' where an impact will occur on one side and not on the other. Potential impact is more probabilistic than that; dose dependency in PTS onset, individual variations and uncertainties regarding behavioural response and swim speed/direction all mean that it is much more complex than drawing a contour around a location. These ranges are designed to provide an understandable way in which a wider audience can appreciate the potential spatial extent of the impact.

6 Conclusions

Based on the modelling conducted as part of this assessment, it is concluded that:

- There is little potential for TTS/PTS to be experienced by marine mammals or fish due to the rotary drilled piling activities. Disturbance to marine mammals could occur within 295 m of piling activities.
- For rock breaking, there is little potential for PTS to marine mammals although TTS could occur for LF cetaceans within 45 m and for VHF cetaceans within 140 m. However, these injury ranges assume 24 hours continuous operations which is considered highly unlikely.
- Mild disturbance to marine mammals could occur within 150 m of rock breaking activities.

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