C2 - Restricted

POWERING UP OFFSHORE SOUTH COAST

Supporting Information for Derogation Licence

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1 INTRODUCTION

The Irish Government is taking major steps to make Ireland carbon neutral by 2050. These steps include a commitment to increase the proportion of electricity generated from renewable sources to 80% by 2030. The Climate Action Plan 2024 (DECC, 2024) places offshore wind power at the centre of this commitment, with a key target being the grid connection of at least 5 Gigawatts (GW) of offshore wind by 2030.

EirGrid develops, manages, and operates Ireland’s electricity grid and are responsible for the safe, secure and reliable supply of Ireland’s electricity. EirGrid was established to act as the independent Transmission System Operator (TSO), in line with the requirements of the EU Electricity Directive (EU) 2019/944 (EU Electricity Directive). EirGrid became operational as the TSO on 1 July 2006 and is a public limited company, registered under the Companies Acts. The Irish Government has also designated EirGrid as the TSO and Transmission Asset Owner (TAO)/ Offshore Asset Owner (OAO) for Ireland’s offshore electricity grid.

In March 2023, the Department of the Environment, Climate and Communications (DECC) published the “Accelerating Ireland’s Offshore Energy Programme; Policy Statement on the Framework for Phase Two Offshore Wind" (the Framework). This policy identified EirGrid as the developer of new offshore grid transmission infrastructure to connect new offshore wind farms on the south coast.

On the basis of the policy, EirGrid has initiated the Powering Up Offshore South Coast (PUOSC) project. This will be the first state led offshore renewable electricity connection in Ireland. The project was included in the European Network of Transmission System Operators for Electricity (ENTSO-E) Ten Year Network Development Plan (TYNDP) in 2024. While the project is at an early stage of development, it is expected to include the development of offshore substation(s) off the southern coast of Ireland, new onshore and offshore transmission cables and new onshore compensation compound as required to accommodate the connection on the existing onshore transmission system. The development area will be established based on the South Coast Designated Maritime Area Plan (SC-DMAP), which was published by the Government of Ireland on 25th October 2024. This infrastructure will facilitate up to 900 MW of power generated by offshore wind farms in Irish waters into our national electricity grid.

The DECC Framework outlined a four-phase process for developing offshore wind energy infrastructure. In the short-term, the framework is based on a developer-led approach, taking advantage of projects that have been in development for several years. In the medium to long-term it transitions to a plan-led approach in which EirGrid plays a key role.

EirGrid are undertaking the engineering, planning and environmental services necessary to provide the grid infrastructure to support the development of offshore wind.

PHASE 2

As part of the government-led approach to the delivery of offshore wind, known as Phase 2, approximately 900 MW of electricity will be supplied from wind farms off Ireland’s south coast. It is anticipated that these offshore wind farms will be constructed in Area A – Tonn Nua within the SC-DMAP area (see Figure 1.1).

These wind farms will be provided by private developers. EirGrid will be responsible for delivering the infrastructure that will connect the power from these wind farms off the south coast to the onshore grid. This will be realised through EirGrid’s PUOSC project.

Following publication of the SC-DMAP, EirGrid plans to develop offshore electricity substation(s) and associated offshore transmission cables. This new infrastructure will connect the power generated by offshore windfarms to the national electricity grid.

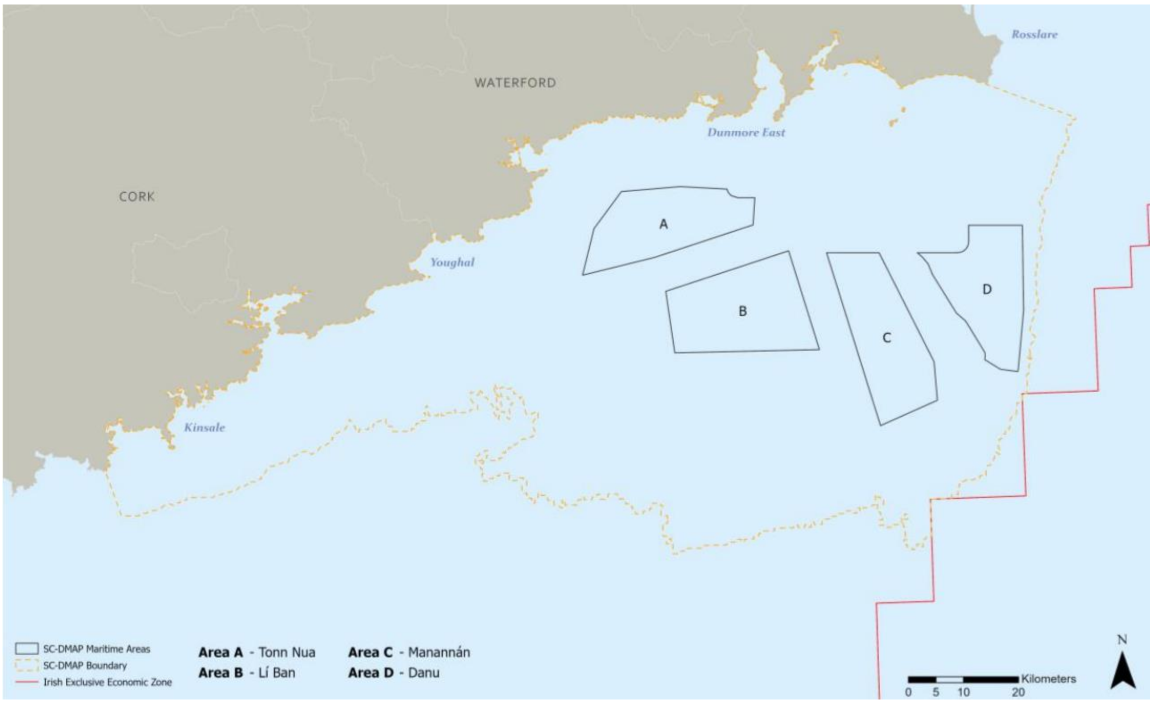

Figure 1.1 SC-DMAP Area

The main components of PUOSC project are:

- Offshore substation(s) – to be located within Maritime Area A (Tonn Nua) of the SC-DMAP (Figure 1.1).
- A connection between the offshore substation(s) and onshore compensation compounds. This will involve offshore transmission cables; and
- Onshore compensation compounds.

The precise location of the offshore substations have not yet been determined, nor has it been determined how and where they will connect to the national electricity grid onshore. However, due to onshore grid capacity constraints, it is anticipated that one 450 MW offshore to onshore connection will be developed in the Cork area and the other 450 MW offshore to onshore connection will be developed in the Waterford/ Wexford area.

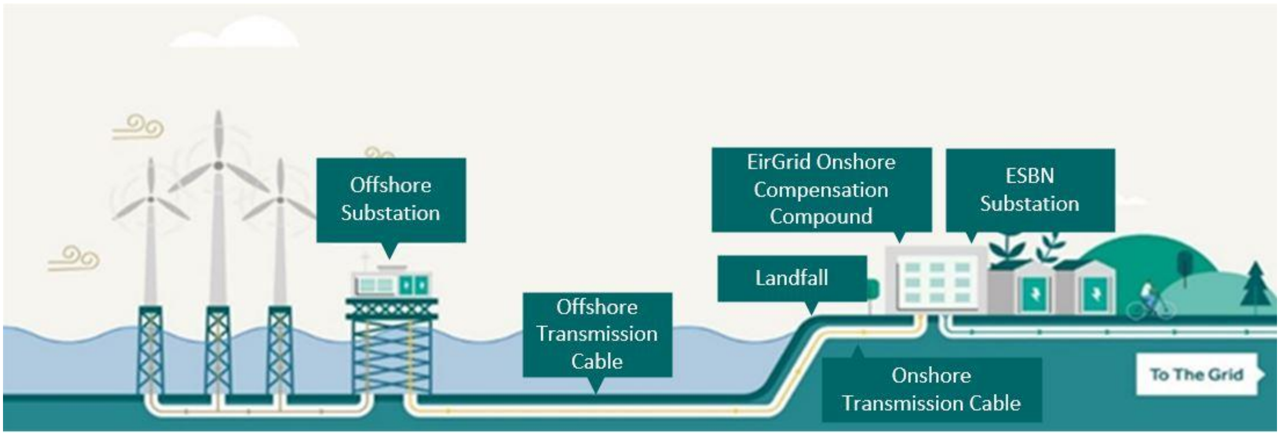

Figure 1.2 Typical Offshore Wind Project Schematic

1.1 Purpose of the Report

This report has been prepared by RPS, on behalf of the EirGrid, to provide information on the site investigation works (SI works) proposed to be undertaken for the PUOSC project, in support of an application for derogation under the European Communities (Birds and Natural Habitats) Regulations 2011, as amended. This application for derogation is made under Regulation 54(2)(c):

'In the interests of public health and public safety, or for other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences of primary importance for the environment'.

In May 2019, the Government of Ireland declared a Climate and Biodiversity Emergency in the Dáil[1] and has committed to increasing the proportion of electricity generated from renewable sources to 80% by 2030. A key target of the Climate Action Plan 2024 (DECC, 2024) is to connect at least 5 GW of offshore wind power to the grid by 2030. The PUOSC project is instrumental to this target, by facilitating the transfer of up to 900 MW of power generated by offshore wind farms in Irish waters into our national electricity grid. As the Transmission System Operator (TSO) and Transmission Asset Owner (TAO)/ Offshore Asset Owner (OAO) for Ireland's offshore electricity grid, EirGrid must undertake the PUOSC project to ensure that Ireland meets its renewable energy and climate action targets.

The proposed SI works are critical to the development of the PUOSC project, and therefore, qualify under Regulation 54(2)(c). The proposed SI works will provide the necessary engineering and environmental information to inform the design and environmental assessments necessary to support a planning application for the PUOSC project, which is imperative to Ireland achieving its offshore wind and renewable energy targets.

This report has been prepared on the basis that a derogation application will only be required for relevant marine species due to the potential, in the absence of mitigation measures, for underwater noise from the geophysical and geotechnical equipment and vessels to impact on cetacean species. However, based on the assessment below, the potential for injury or disturbance to occur to Annex IV cetacean and turtle species as a result of the SI works is considered to be low. This risk will be further reduced by the implementation of mitigation. This report provides the required level of detail to the NPWS on the effects of the SI works on relevant Annex IV species in order to allow them to make a decision on the application for derogation.

1.2 Statement of Authority

The technical competence of the authors is outlined below:

Gareth McElhinney is Technical Director in the Environmental Services Business Unit in RPS. He has over 24 years' experience. He holds an honours degree in Civil Engineering (B.E.) from NUI, Galway, a postgraduate diploma in Environmental Sustainability from NUI, Galway, and a Master's in Business Studies from the Irish Management Institute/ UCC. Gareth is also a Chartered Engineer and Project Management Professional with the Project Management Institute (PMI-PMP). He has managed the delivery of numerous environmental projects including marine and terrestrial projects that have required environmental impact assessment, appropriate assessment, and Annex IV species reports.

Aoife Edgely is a Principal Scientist in the Environmental Services Business Unit in RPS. She has over 13 years' experience in the marine science field and is a Chartered Environmentalist and a Full Member of the Institute of Environmental Sciences. Aoife holds an honours degree in Environmental Science from Trinity College Dublin and a Master's in Marine Environmental Protection from Bangor University, Wales. Aoife has delivered the environmental assessments for a wide range of marine and coastal projects, including environmental impact assessment, appropriate assessment and Annex IV species reports.

Rachael Shaw is a Project Scientist in the Environmental Services Business Unit in RPS. She holds a Bachelor's Degree in Marine Science from the University of Galway and Master's Degree in Climate Change and Managing the Marine Environment from Heriot-Watt University Edinburgh. She has over three years' experience working in consultancy, assisting on a wide range of projects from offshore renewable energy projects to flood relief schemes, including marine and terrestrial surveys. She is a qualifying CIEEM member.

[1] Report entitled 'Climate Change: A Cross-Party Consensus on Climate Action': Motion – Dáil Éireann (32nd Dáil) – Thursday, 9 May 2019 – Houses of the Oireachtas

2 PROJECT DESCRIPTION

2.1 Site Location

The PUOSC SI works Area of Interest (AoI) is located off the south coast of Ireland from the High Water Mark (HWM) out into the Celtic Sea. The AoI has been developed to include:

- Potential areas where offshore substations (OSS) may be constructed,
- Potential offshore transmission cable corridors from the OSS locations towards seven potential landfall zones in coastal areas, and
- The intertidal area below the HWM at seven potential landfall zones where the offshore transmission cables will come to shore and connect to onshore infrastructure.

The AoI for this application is illustrated in Figure 2.1. This area is almost entirely within the area of the SC-DMAP except for a number of coastal locations. The AoI also includes the full extent of SC-DMAP Area A Tonn Nua, within which the OSS will be located, as shown in Figure 2.1

A site location map with the proposed locations of SI works is shown in Figure 2.2 through to Figure 2.9.

The total AoI encompass an area of 2,336 km^2. The western extent of the AoI is at Ringroe in County Cork (approx. 10 km south of Crosshaven and 13 km east of Kinsale) and extends eastwards to Cullenstown in County Wexford (approx. 4 km east of Bannow Bay and 6 km south of Wellingtonbridge). The AoI extends into the offshore area to approx. 34 km (18.4 nm) from the coastline at its furthest distance (measured from Bunmahon).

The AoI includes coastal areas below the HWM from Ringroe, Co. Cork to Ballycrenane Co. Cork, and from west of Bunmahon, Co Waterford to east of Bannow Bay, Co. Wexford. These coastal areas include seven possible landfall zones for the offshore transmission cables as summarised in Table 2.1.

Table 2.1 Potential Landfall Zones to be Investigated

Landfall Zone	Nearest Townlands	County
A	Ballintra West, Ballintra East, Inch, Lahard	Cork
B	Ballybrangan, Ballycroneen West, Ballyrobin South	Cork
C	Garryvoe Lower, Ballybutler, Ballycrenane	Cork
D	Templeyvrick, Ballynasissala, Bunmahon, Ballynagigla, Knockmahon	Waterford
E	Ramstown	Wexford
F	Bannow	Wexford
G	Haggard, Blackhall, Ballymadder	Wexford

2.2 Note on the AoI, Offshore Transmission Cable Corridors and Potential Landfall Zones

It must be noted, that as of the date of this report, no decision has been made on the final location of any infrastructural elements of the PUOSC project.

The information provided in this report, including maps, is based on desktop research only and on this basis potential locations for OSS, offshore transmission cable corridors and landfall zones have been identified. The purpose of the SI works is to identify if these potential locations are indeed suitable for the proposed PUOSC infrastructure.

As information from the SI works is collected, processed and analysed, it will inform whether additional areas of investigation are required. Therefore, the AoI has been created to provide a wide enough area over which the required SI works can be completed in order to identify preferred locations for all of the PUOSC infrastructure.

A series of SI works and survey campaigns is proposed, as described later in this section.

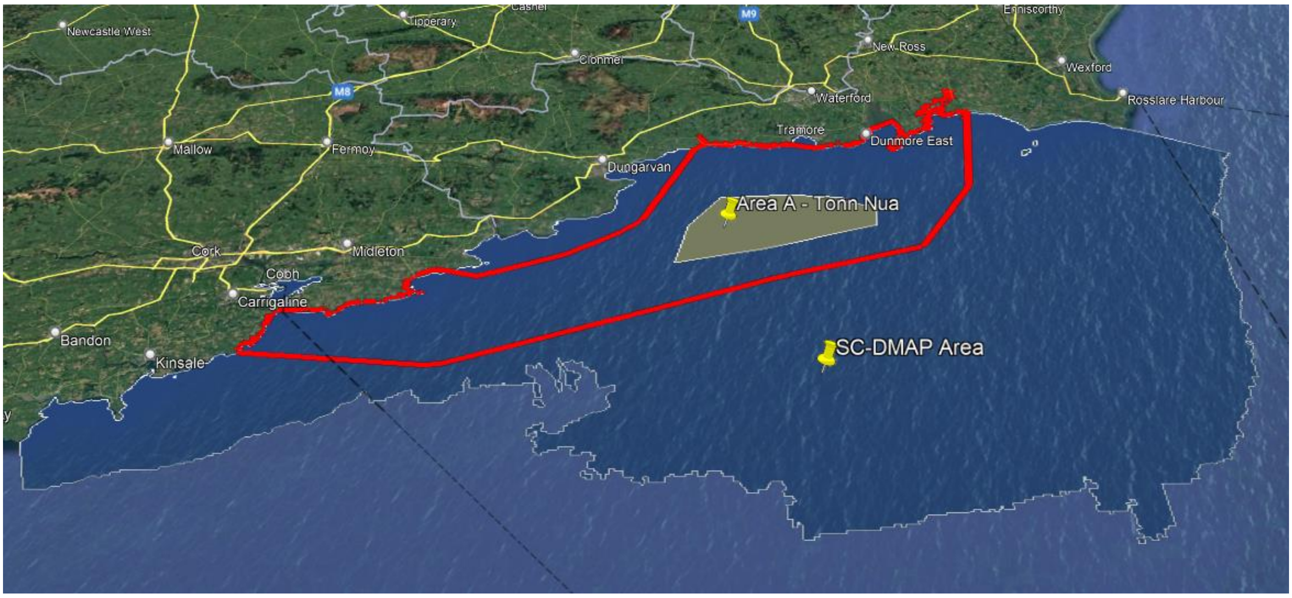

Figure 2.1 AoI (redline boundary) and Area A Tonn Nua within the SC-DMAP Area

Figure 2.2 Overview of Proposed Investigation Locations along the Potential Offshore Transmission Cable Corridors and Landfall Zones

Figure 2.3 Proposed Investigation Locations at Landfall Zone A, Co. Cork

Figure 2.4 Proposed Investigation Locations at Landfall Zone B, Co. Cork

Figure 2.5 Proposed Investigation Locations at Landfall Zone C, Co. Cork

Figure 2.6 Proposed Investigation Locations at Landfall Zone D, Co. Waterford

Figure 2.7 Proposed Investigation Locations at Landfall Zone E, Co. Wexford

Figure 2.8 Proposed Investigation Locations at Landfall Zone F, Co. Wexford

Figure 2.9 Proposed Investigation Locations at Landfall Zone G, Co. Wexford

2.3 Description of the SI Works

2.3.1 Overview

In order to provide a reliable basis for design development, and to support the consenting and construction phases of the PUOSC project, surveys and investigations are necessary. The aim of the SI works is to acquire data to a high quality and specification.

EirGrid are seeking a derogation licence for a period of five years from the date of the granting of the Maritime Usage Licence.

The proposed activities within the AoI are planned to take place across phases. Geophysical and geotechnical surveys and investigations will be sequential with the results of the geophysical campaign used to inform the geotechnical campaign. The remaining surveys and investigations (e.g., environmental, archaeological, metocean etc.) can take place at any time during the operational period of the derogation licence.

The first investigation phase will involve a non-intrusive geophysical survey campaign. The aim of the geophysical survey campaign is to collect data that will inform the site selection process for OSS and offshore transmission cables, and to inform planning of a subsequent geotechnical investigation campaign required to ground-truth and build upon initial findings. Data from geophysical surveys and Drop-Down Video (DDV) and/or Remote Operated Vehicle (ROV) is additionally required for the identification and assessment of marine archaeological features, the evaluation of Unexploded Ordnance (UXO) risk, and for the identification of potential environmental constraints.

The subsequent investigation phase will involve intrusive geotechnical surveys which will physically interact with the seabed. The geotechnical activities will only take place once information from the geophysical survey campaign has been assessed.

Where required, additional geophysical and geotechnical surveys (up to two within the derogation licence period) for specific zones (of smaller area) of interest will be undertaken. These will likely focus on the offshore transmission cable corridors and OSS locations using similar types of equipment and to similar depths of investigation to achieve a better understanding of potential man-made/ existing obstructions and to provide information on specific geohazards on the seabed to the installation and operations of the offshore infrastructure.

It should be noted that the geophysical and geotechnical campaigns may be further sub-divided depending on the availability of suitable vessels and equipment and the location of the surveys, e.g. intertidal, subtidal, nearshore and offshore areas. Therefore, geophysical and geotechnical activities in some areas may be completed in advance of geophysical and geotechnical activities in other areas.

Environmental, archaeological and other surveys will be undertaken within the AoI to characterize baseline conditions. The results of these surveys will be used as part of any future environmental assessments and associated planning consents. Depending on the specific requirements of these surveys and logistics, they may be undertaken simultaneously with and/or independently from the geophysical and geotechnical campaigns.

As described in more detail in the following sections, the proposed locations shown in the figures and drawings are subject to refinement based on the results of the geophysical and environmental surveys. Similarly, the location may be moved due to the presence of obstructions/ refusals at individual locations, i.e. where a physical object, e.g. a subsurface boulder, prevents the borehole, CPT, etc., from going to its target depth. In such circumstances, the borehole location is moved to another nearby location away from the obstruction and drilled again to the target depth.

Following the assessment of the results of the SI works, it may be necessary to undertake further SI works in particular areas within the AoI, e.g., potential OSS locations, along routes for the offshore transmission cable corridors and approaches to landfall zones. The proposed SI works, including the quantities detailed and assessed in this report, include contingencies to cover any follow up investigations that may be undertaken at refined locations.

The proposed SI activities are summarised in Table 2.2. It should be noted that the information provided in this table lists the proposed activities. Where possible and efficient to do so, activities will be grouped together and undertaken as part of one survey campaign. For example, the geophysical survey campaign will likely involve one vessel undertaking the multi-beam echosounder (MBES), sub-bottom profiler (SBP), side scan sonar (SSS) and magnetometer surveys, with the magnetometer survey providing the information necessary for the archaeological geophysical survey. Similarly, the environmental drop-down video and benthic grab sampling surveys will be undertaken from the geotechnical survey vessel.

Table 2.2 Proposed SI works Activities

Survey Type	Survey Elements	Maximum Quantity (where relevant)
Coastal Geophysical Surveys (land-based below the HWM)	Ground Penetrating Radar (GPR) and/or Seismic Refraction.	n/a
	Topographical surveying techniques including UAS, GPS, GNSS devices.	n/a
Marine Geophysical Surveys (undertaken from survey vessel(s))	Multi Beam Echosounder (MBES).	n/a
	Sub-bottom profiler (SBP) including Ultra-High Resolution Seismic (UHRS) survey.	n/a
	Side Scan Sonar (SSS).	n/a
	Magnetometer.	n/a
Coastal Geotechnical Surveys (undertaken on land below the HWM)	Trial Pit Investigations.	42
Marine Geotechnical Surveys (undertaken from survey vessel(s) or jack-up barge; JUB)	Grab sampling (this is the same campaign as the surveys included under the Environmental Surveys).	420 (subtidal)
	Vibrocore testing.	276
	Borehole investigations (including downhole Cone Penetration Testing; CPT and sampling).	21 (inshore) 8 (OSS locations)
	Shallow CPT.	276
	Deep Drive CPT.	16
Metocean and Marine Mammal Acoustic Device Deployment (deployed by vessel and moored to seabed)	Metocean buoy.	2
	Acoustic Doppler Current Profiler (ADCP).	3
	Marine Mammal Static Acoustic Monitoring (SAM).	16 locations (4 SAMS x 4 different locations)

Survey Type	Survey Elements	Maximum Quantity (where relevant)
Coastal Environmental Surveys (land-based below the HWM)	Ecological walkover surveys (habitats, bat activity and roose assessment, mammals including otter).	n/a
	Ornithological vantage point surveys.	n/a
	Marine mammal vantage point surveys.	n/a
	Intertidal core sampling survey.	Intertidal cores = 126
Marine Environmental Surveys (undertaken from survey vessel(s))	Drop-down video (DDV) and/or Remotely Operated Vehicles (ROV) survey.	n/a
	Grab sampling (this is the same campaign as the surveys included under the Marine Geotechnical Surveys Surveys).	Subtidal = As per geotechnical specification.
	Ornithological surveys (boat-based).	n/a
	Marine mammal surveys (boat-based) including passive acoustic monitoring (PAM).	Monthly surveys for minimum two-year period.
	Water Quality Samples, including Conductivity, Temperature and Depth (CTD) Measurements.	n/a
Archaeological Surveys	Intertidal Survey.	n/a
	Coastal and Marine Geophysical Surveys (this is the same campaign as the Coastal and Marine Geophysical Surveys described above).	n/a
	Sampling.	n/a
	Dive Survey.	n/a
	Wade Survey.	n/a
	Monitoring.	n/a
Other Surveys	Noise Surveys.	n/a
	Shipping & Navigation Survey.	n/a
	Unmanned Aircraft Systems (UAS)/ drone surveys.	n/a
	Aerial Surveys (birds and marine mammals).	n/a

2.3.2 Estimated Project Schedule/ Programme

EirGrid propose a SI works schedule that will be phased over a five-year period. The intention is to begin survey activities as soon as feasible following licence award, with a phased programme of investigations, capitalising on suitable weather windows and vessel availability over this time period. This phased approach will progress the overall development towards detailed design stage. The exact survey schedule is dependent on the availability of the supply chain and therefore exact timelines for the surveys cannot be determined in advance of securing a derogation licence.

The exact dates for the surveys are to be determined pending the appointment of survey contractors but based on the estimated scope of works to be conducted the likely timeframe for each project phase has been estimated in Table 2.3 below. It is anticipated that the majority of the SI works will be completed within the first 24 months from the date the licence is granted. However, contingencies have been built into the quantities to allow for future SI works within a five-year period as more information becomes available. The estimated timeframes are subject to change based on variables such as weather conditions, unforeseen seabed conditions, unforeseen obstructions, etc.

Mobilisation location will be dependent on the survey contractor, who may choose to mobilise from their home port, port of previous job or local port. The local port options for mobilisation could include Cork or Rosslare depending on vessel size and marine traffic restrictions.

As noted previously, the geophysical and geotechnical campaigns may be further sub-divided depending on the availability of suitable vessels and equipment and the location of the surveys, e.g. intertidal, subtidal, sea areas <15m at lowest astronomical tide (LAT) and sea areas >15m LAT. Therefore, geophysical and geotechnical activities in some areas may be completed in advance of geophysical and geotechnical activities in other areas.

Table 2.3 Estimated Project Schedule/ Programme

Type	Scope of Work	Location and number	Estimated Timeframe for Activities (weather dependent)
Geophysical and Geotechnical Campaigns	Coastal surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Geophysical surveys	The survey will focus on the potential landfall zones, offshore transmission cable corridors and Area A Tonn Nua. However, depending on the survey results, additional areas for geophysical survey within the AoI may be required.	Within the first 24 months. Additional targeted geophysical surveys may be undertaken at any time during the lifetime of the derogation.
	Sediment/ Benthic sampling	The offshore transmission cable corridors and the seven potential landfall zones. Up to 420 grab samples in total.	Within the first 24 months. Additional targeted sampling surveys may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 420 samples.
	Vibrocores	The offshore transmission cable corridors. Up to 276 vibrocores.	Within the first 24 months. Additional targeted vibrocores may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 276 locations.
	Boreholes (approaches to potential landfall zones)	The potential landfall zones. Up to 21 boreholes.	Within the first 24 months. Additional targeted boreholes may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 21 locations.
	Boreholes (OSS)	Each potential OSS location. Up to 8 boreholes.	Within the first 24 months. Additional targeted boreholes may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 8 locations.
	Shallow CPT (S-CPT)	The offshore transmission cable corridors and at the potential OSS locations. Up to 276 S-CPT.	Within the first 24 months. Additional targeted S-CPT may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 276 locations.
	Deep CPT (D-CPT)	The potential OSS locations. Up to 16 D-CPT.	Within the first 24 months. Additional targeted D-CPT may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 126 locations.
	Trail pits (TP)	Proposed landfall zones. Up to 42 TP.	Within the first 24 months. Additional targeted trial pits may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 42 locations.
	Metocean device(s)	The potential OSS locations. Up to 2 buoys and 2 ADCPs will be deployed at any one time.	Typically twelve months for any one deployment. It may take place at anytime over the lifetime of the derogation licence.
Environmental Surveys	Coastal ecological surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Ornithological surveys	Seven potential landfall zones and OSS locations.	Anytime over the lifetime of the derogation licence.
	Marine mammal monitoring	The potential OSS locations, the offshore transmission cable corridors, and at the potential landfall zones. Includes deployment of PAM equipment (towed or boat based) within the AoI and	Anytime over the lifetime of the derogation licence.

Type	Scope of Work	Location and number	Estimated Timeframe for Activities (weather dependent)
		of SAM devices (fixed locations) at potential OSS locations.	
	Sediment/ Benthic sampling	Intertidal: Seven potential landfall zones. Up to 126 samples.	Within the first 24 months. Additional targeted sampling may be undertaken at any time during the lifetime of the derogation licence. The total number will be limited to 126 samples.
		Subtidal: Refer to Sediment/ Benthic sampling under the Geophysical and Geotechnical Campaigns above.	Refer to Sediment/ Benthic sampling under the Geophysical and Geotechnical Campaigns above.
	Digital aerial surveys	Entire AoI	Anytime over the lifetime of the derogation licence.
	Water quality sampling and CTD	The potential OSS locations, the offshore transmission cable corridors, and at the landfall zones.	Anytime over the lifetime of the derogation licence.
	DDV and/or ROV	The potential OSS locations, the offshore transmission cable corridors, and at the landfall zones.	Anytime over the lifetime of the derogation licence.
Archaeological Surveys	Intertidal archaeology surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Geophysical surveys	Refer to Geophysical Surveys under the Geophysical and Geotechnical Campaigns above.	Refer to Geophysical Surveys under the Geophysical and Geotechnical Campaigns above.
	Archaeological samples	The potential OSS location, the offshore transmission cable corridors, and landfall zones.	Within the first 24 months. Additional samples may be taken during any further borehole drilling activities.
	Archaeological dive surveys	The potential OSS location, the offshore transmission cable corridors, and landfall zones.	Anytime over the lifetime of the derogation licence.
	Archaeological wade surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Archaeological monitoring	Where deemed necessary during survey and investigation campaigns.	Anytime over the lifetime of the derogation licence.
Other Surveys	Noise surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Shipping & navigation surveys	Within the AoI.	Anytime over the lifetime of the derogation licence.
	UAS/ Drone surveys	Seven potential landfall zones.	Anytime over the lifetime of the derogation licence.
	Aerial surveys	Within the AoI.	Anytime over the lifetime of the derogation licence.

2.3.3 Surveying Periods

Surveys will be conducted during the following daily periods:

- Landfall/Intertidal Zone – during daylight hours and subject to tidal conditions.
- <15m below LAT – during daylight hours up to 12 hours per day, seven days a week.
- >15m below LAT – 24 hours per day, seven days a week.

2.3.4 Vessels

At the time of this application specific details of the survey vessels to be used were not available and were subject to an ongoing tender process. Based on typical survey vessels operating in offshore waters, the SI works are proposed to utilise vessels which range in length between 15m and 75m, have an endurance of up to 30 days and require a draft depth greater than 15m below lowest astronomical tide (LAT) to safely operate. Such vessels will therefore generally be deployed for survey tasks from approximately the 15m depth contour of the LAT to the seaward extent of the AoI.

Survey vessels will be used to undertake the following surveys:

- Coastal and marine geophysical surveys (one vessel <15 m; another vessel >15 m LAT);
- Coastal and marine geotechnical surveys (one vessel <15 m and the JUB; another vessel >15 m LAT);
- Coastal and marine environmental surveys (one vessel <15 m and another vessel >15 m LAT. Usually undertaken from one of the geophysical and/or geotechnical survey vessels);
- Coastal and marine archaeological surveys (one vessel <15 m and another vessel >15 m LAT. Usually undertaken from one of the geophysical and/or geotechnical survey vessels);
- Boat-based ornithology surveys (one vessel); and
- Boat-based marine-mammal surveys (one vessel).

In addition, vessels will be required to deploy and retrieve the static recording devices; metocean buoy, ADCP and SAM. A tug will be required to tow the JUB into and from position, and a rigid inflatable boat (RIB) will be used to transfer personnel to and from the JUB as required.

Specific survey vessel details are subject to a procurement process and are currently unavailable, and it is not yet known if a multi-disciplinary survey vessel will be used, i.e. one vessel capable of undertaking geophysical, geotechnical and environmental surveys, or separate vessels for each survey type. It is extremely unlikely that all vessels will be mobilised at the same time. For example, the geophysical survey campaign will need to occur prior to geotechnical and environmental sampling. Vessels retrieving static recording devices, transferring personnel or positioning the JUB will operate for a short period of time, transiting to and from survey locations. It is estimated, on a precautionary basis, that up to eight vessels could be operating within the AoI at a time.

2.3.4.1 Greater than 15m below LAT

The survey vessels may use a local port for personnel/ equipment mobilization, bunkering, and provisioning as necessary. For clarity, no bunkering will take place offshore, with such operations carried out under quayside operations only. In the event survey vessels originate from overseas assessments will be undertaken to determine the risk of invasive species introduction. Related mitigation will be implemented accordingly in advance of entering Irish waters as appropriate, and as required under regulation and best practice.

The geophysical and geotechnical marine surveys will involve the deployment of dedicated marine spreads suitable for the scope of work required, the water depth expected, and the anticipated seabed conditions. The final details of equipment to be deployed are not yet confirmed. However, standard equipment proposed to meet the survey specifications is described in the following sections and has been assessed in this derogation licence. This information is considered adequate to enable the likelihood and significance of any related environmental impacts to be determined on a conservative basis. Appointed survey contractors will be required to use equipment which aligns with the parameters of the standard equipment described below and assessed in this derogation licence in order to ensure that no greater environmental impacts than those assessed in this derogation licence will arise.

All survey vessels will be fit for purpose, will possess all relevant classification certificates, and will be capable of safely undertaking the survey work required. Health, safety, environment, and welfare considerations will be a priority and will be actively managed. Vessels will comply with all applicable MARPOL requirements including vessel-based spill response planning. Appointed survey contractors will be required to comply with all legislation and licence conditions relevant to the activities within their scope of work including the provision of marine mammal observers (MMOs) where relevant to the activity scope. Prior to survey mobilization all statutory safety roles will be appointed and responsibilities assigned, and project/ survey-specific HSE plans will be approved for implementation as part of project execution planning.

Survey vessels will conform to the following minimum requirements as appropriate:

- Compliance with Safety of Life at Sea (SOLAS), International Maritime Organization (IMO), and national requirements for operating within Irish territorial waters;
- Compliance with applicable MARPOL requirements;
- Station-keeping and sea-keeping capabilities required to safely carry out the proposed survey activities;
- Calibrated equipment and spares with tools as necessary to undertake all specified works;
- Endurance to undertake the required survey works (e.g. in respect of fuel, water, stores, etc.) for up to 30 days;
- Sufficient qualified staff to allow the survey operations to be carried out efficiently (typically 24-hour continuous for offshore survey, 12-hour for nearshore survey) including anticipated requirements for marine mammal observers as appropriate; and
- Adequate accommodation and crew welfare facilities.

2.3.4.2 Less than 15m Below LAT

In cases where survey is required but larger survey vessels cannot be deployed safely (i.e. in waters typically shallower than 15m below LAT) smaller vessels may be used subject to safe vessel draft limits and other local conditions. All such smaller vessels will comply with the HSE requirements listed above as applicable to vessel class.

For the shallowest locations, including the intertidal zone, and where intrusive geotechnical survey is required (i.e. vibrocores, CPTs, boreholes and grab samples), such investigations may be undertaken from a jack-up barge (JUB). Where required, the JUB will be towed to and from the investigation sites by tugs.

Figure 2.10 Jack-Up-Barge (JUB)

At the time of this application procurement of the JUBs was subject to a tendering process and the specific details were not available. However, for the purposes of conservative assessment it is assumed that the most likely arrangement is that the JUB will have four legs that are deployed when on station. It is estimated that each leg has a plan area of 3 m^2 which interacts with the seabed. Therefore, approximately 12 m^2 of seabed will have the potential to be directly disturbed each time the JUB is deployed at a given survey location. The JUB model that is used may have slightly different dimensions to those described herein but EirGrid will ensure that the model is within the parameters described above such that no greater environmental impacts than those assessed in this derogation licence can arise.

Where feasible, some boreholes within the AoI below the maritime area land boundary and in the intertidal area may be drilled using a vehicle-mounted drilling spread and associated support vehicles. In any such cases existing land access routes to investigation locations will be used to the extent practicable.

2.3.5 Coastal Geophysical Surveys

Conventional land-based geophysical surveys will be undertaken below the HWM. Those elements of the land-based survey that occur within the AoI are activities included in this derogation licence. This derogation licence is not seeking a licence for any land-based works which will take place outside the maritime area.

Detailed topographical surveying is required to provide accurate and up-to-date maps detailing natural and man-made features, elevations, land boundaries and landforms. The topographical surveys provide high-quality information to enable the creation of accurate maps of the terrestrial and intertidal areas, including elevation models for use in Geographic Information Systems (GIS). These are then used to inform both the engineering and environmental designs.

Surveys will comprise conventional land-based topographical and photogrammetry techniques, airborne Light Detection and Ranging (LiDAR) and/or laser scanning.

Traditional land surveying techniques will involve the deployment of personnel and land surveying equipment. This can include the setting up of a survey station (e.g., tripod and total station) from which accurate measurements and levels can be taken. Similarly, more mobile surveying equipment can be used to accurately map the ground. These units can consist of handheld devices, backpacks, or hand-held pole mounted Global Navigation Satellite Systems (GNSS) devices.

LiDAR surveys are often undertaken using Unmanned Aerial Vehicles (UAV)/ Unmanned Aircraft Systems (UAS), more commonly known as drones. Fixed wing aircraft can also be used for aerial surveys for large scale data collection. UAS can also be equipped with cameras to take photographs and/or video of the surveyed area for use in aerial mapping and to create ortho-mosaic maps. For the purposes of the derogation licence, operators of the drones may need to be stationed within the maritime area while operating the drone. UAS will be deployed by qualified personnel and will comply with the relevant legislation including Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft (Regulation 2019/247).

Coastal surveys will also include seismic refraction and/or ground-penetrating radar (GPR) or electrical resistivity to profile geological features and infrastructure. In addition, magnetometer or electromagnetic survey will be undertaken for the detection of UXO, archaeological and other anthropogenic features and anomalies.


Figure 2.11 GPR Survey Equipment and Intertidal Magnetometer Survey Equipment

2.3.6 Marine Geophysical Surveys

Geophysical surveys are proposed to be conducted. These surveys will not physically interact with the seabed and will determine:

- Bathymetry data;
- Seabed conditions and hazard identification;
- Seismostratigraphic units and terrain models;
- Ground provinces and ground units; and

- Sub-bottom ground conditions and geohazards (magnetic anomalies, UXO etc.).

The exact geophysical equipment details will be confirmed following the procurement of a survey contractor. The assessment of the impacts of the SI works set out in this derogation licence is based on standard survey equipment that is expected to meet the survey specifications. Appointed survey contractors will be required to use equipment which aligns with the parameters of the standard equipment described and assessed in this derogation licence in order to ensure that no greater environmental impacts than those assessed in this derogation licence will arise.

Geophysical surveys may be conducted across the entirety of the AoI for the licence duration. Geophysical surveys will be conducted to the spatial specifications provided below.

In specific zones of interest (relating to manmade or natural geohazards, as well as involving marine archaeology artefacts as identified from the desktop studies, which is carried out prior to the surveys), a phased approach for the survey will be implemented. The first phase will collect information suitable at reconnaissance survey level and concept design for all the potential offshore transmission cable corridors and OSSs, and then, if required, the second phase will concentrate on much smaller zones of special needs within the AoI. Both phases will use the same equipment as described below and to the same spatial specifications.

2.3.6.1 Landfall/Intertidal Geophysical Survey Spatial Specifications

- Potential offshore transmisson cable corridor centre line and within 1000m width.
- 4 x wing lines at 250m intervals either side of centre line.
- Orthogonal tie-lines at 1000 m intervals.

2.3.6.2 Geophysical Survey <15 m LAT Spatial Specifications

- Bathymetry - 100% corridor MBES coverage with backscatter and velocity data.
- Seafloor imagery - SSS at 50 m line spacing, acquiring data at 75 m range together with (minimum of 150% coverage (200% preferable) including nadirs of adjacent lines). The full SSS coverage (150% or better) is specified including nadirs, at the required SSS along-track and across-track resolutions. This should be achievable in most areas with 50 m line interval at 75 m range. With shallow water inshore, infill lines will be mobilized to achieve the required coverage in accordance with the best of practice guidance (Historic England, 2013).
- Sub-bottom profiling (SBP) - parametric type, acquiring data to 10 m below seafloor (where geology allows) acquired along all survey lines, i.e. 5 parallel lines (250m spacing) and crossline.
- 2D-UHR seismic - single or multi-channel sparker system acquiring data up to 15 m below seafloor along 1 x centreline and up to 2 winglines along the offshore transmission cable corridors (spacing maximum of 500m).
- Single magnetometer - on all survey lines (i.e. at 50 m line spacing as per SSS). The magnetometer should ideally be on a dedicated winch, but if necessary can be piggy-backed to the SSS towfish.
- Multi-sensor magnetometer towed unit (preferably with set up of magnetometers of 4 on each scanfish) - approximate centre-line of corridor and up to 4 x parallel lines spaced up to 250m to each side of the centre-line.
- Cross-lines of spacing between 250-1000m, where the lower range (250m) shall be applied where there are changes in ground conditions especially near the boundary of the outcrop bedrocks.

2.3.6.3 Geophysical Survey >15 m LAT Spatial Specifications

Along potential offshore transmission cable corridors:

- As per Inshore Geophysical Survey.

At potential OSS locations:

- As per Inshore Geophysical Survey and with no requirement for SBP.

- Survey lines at 200 m spacing oriented north-south.
- Crosslines at 500 m spacing oriented east-west.

2.3.6.4 Multibeam Echosounder Survey

Method: A Multibeam Echosounder (MBES) sonar system will be used to map bathymetry within the AoI. MBES surveys are non-intrusive and do not physically interact with the seabed (Figure 2.12). The equipment is expected to be hull-mounted on the geo-referenced survey vessel but may be deployed over the vessel's side. Regardless of the final deployment method and vessel type the principles and potential impacts are the same. Appointed survey contractors will be required to use equipment and vessel types which align with the parameters of the standard equipment described and assessed in this derogation licence in order to ensure that no greater environmental impacts than those assessed in this derogation licence will arise.

MBES survey will be undertaken to provide 100% seabed coverage across the required survey area transects (specified to a minimum ping rate of 8 hits per m^2). Backscatter data will be collected, in addition to speed of sound measurements. The frequency of measurements may be increased if required to obtain the necessary bathymetry resolution. The swath widths for MBES surveys can vary between 4-6 times the water depth depending on the required bathymetry resolution. The estimated water depth in the survey area is between 4m and 90m, therefore the expected narrowest swath width is 16m.

Location: MBES survey will be undertaken within the AoI at the potential sites of the OSSs and along potential offshore transmission cable corridors to the practical operating limits of offshore survey vessels as dictated by draft depth and other safety requirements.

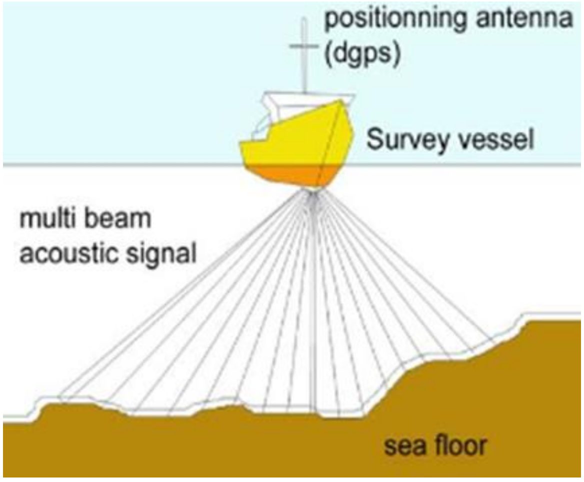

Figure 2.12 Indicative MBES Schematic

2.3.6.5 Sub-Bottom Profiling Survey and Ultra High Resolution Seismic Survey

Method: Sub-bottom profiling (SBP) is a survey technique that uses sound energy to map stratigraphy within the seabed's upper layers. Sonar pulses are directed at the seafloor which are selectively reflected from subsurface layers and detected by a receiving array at the surface. The wavelength and magnitude of the reflections allow geological characteristics and sediment thicknesses below the seabed to be mapped. It is non-intrusive and does not interact directly with the seabed. A parametric type SBP has been specified to gather data up to 10 m below the seabed. The SBP will be towed behind the survey vessel along with its receiving array (Figure 2.13).

Results from SBP survey will be enhanced and supported by 2D Ultra-High Resolution Seismic (UHRS) survey which will extend data gathering resolution for depths up to 15 m below the seabed. This will be based on either a single or multichannel sparker system. The UHRS sparking system and transmitter will be fixed to the survey vessel's hull. The sparking system will employ an electrical discharge to generate sound energy pulses that are directed to the seabed. Subsurface sound reflections are then captured at the surface by a towed detection array, similar in principle to SBP.

Location: This data will be collected across the AoI covering the same general areas as the MBES and SSS.

Figure 2.13 Parametric Sub-Bottom Profiler

2.3.6.6 Side-Scan Sonar Survey (SSS)

Method: A dual frequency Side Scan Sonar (SSS) will be used to generate seafloor imagery. This technique generates high resolution seabed imaging using an acoustic beam. The technique is non-intrusive and does not physically interact with the seabed. Collection of these data will enable the location and identification of debris, wrecks, potential archaeological features, sand waves, bedrock outcrops and subsurface geology within the AoI. SSS will be planned and conducted to ensure at least 150% seabed coverage (200% being preferrable) following the same transects as the MBES surveys. The SSS transceiver will be towed behind the offshore survey vessel in a ‘towfish’ arrangement at a controlled height within the water column.

The SSS uses piezoelectric transducers to generate high-frequency acoustic pulses which are directed at the seabed either side of the towfish. The intensity of the received acoustic reflections are then processed to generate the seabed imagery.

The SSS system offers real-time dual frequency operation which allows acquisition of both frequencies across a swath independently and simultaneously. The higher frequency produces higher resolution data and sharper images but with a narrow swath width while the lower frequency results in wider seabed coverage at lower resolutions.

Location: SSS will be undertaken within the AoI at the potential sites of the OSSs and along potential offshore transmission cable corridors to the practical safe operating limits of offshore survey vessel as dictated by draft requirements (estimated at the 15 m depth contour) and potential constraints presented by the towfish deployment.

SSS transects will be performed at potential OSS location covering an area of 1 km^2 centred on the OSSs, and along the potential offshore transmission cable corridors. At the OSS locations, SSS will be performed to ensure full coverage with 50 m spaced inline in a NW – SE orientation, and 200 m spaced crossline in a NE – SW orientation.

Along the potential offshore transmission cable corridors SSS will be performed to provide greater than 150% coverage over the seabed of interest. This will include full coverage of the nadir of the adjacent lines. For each potential offshore transmission cable corridor three longitudinal SSS survey lines will be performed: one at centre line of the corridor, and two parallel lines spaced at 250 m either side of the centre line.

The full SSS coverage (150% or better) is specified including nadirs, at the required SSS along-track and across-track resolutions. This should be achievable in most areas with 50 m line interval at 75 m range. With shallow water inshore, infill lines will be mobilized to achieve the required coverage in accordance with the best practice guidance (Historic England, 2013). Cross-lines will also be undertaken of spacing between 250-1000m, where the lower range (250m) shall be applied where there are changes in ground conditions especially near the boundary of the outcrop bedrocks.

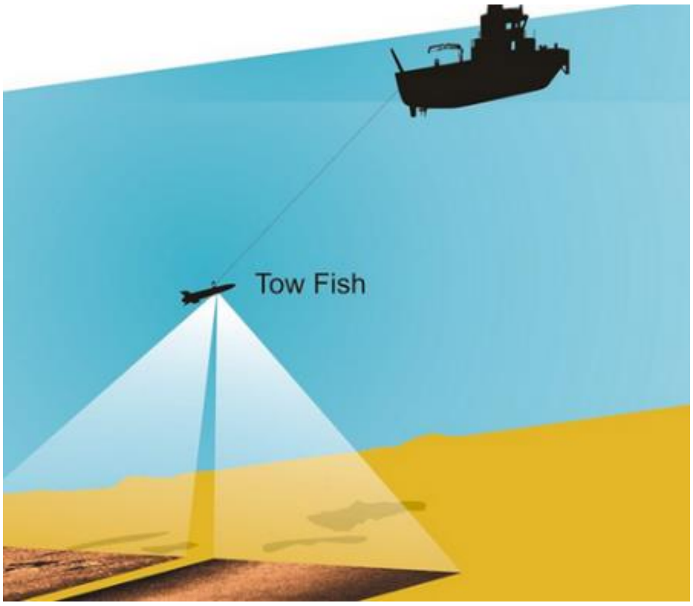

Figure 2.14 SSS Towfish Arrangement

2.3.6.7 Marine Magnetometer Survey

Method: A marine magnetometer will be deployed to locate and identify ferrous objects on or below the seabed. The device precisely measures the Earth's magnetic field and detects any ferrous anomalies such as anchors, Unexploded Ordnance (UXO), fishing gear, wrecks, pipelines, cables etc. The magnetometer is a passive system and will be towed behind the survey vessel. Whilst the exact equipment details are not available, the magnetometer has been specified to be of the caesium vapour type and capable of recording to an accuracy better than 0.1nT.

A single magnetometer will be deployed on all survey lines (i.e. at 50 m line spacing as per SSS). The magnetometer should ideally be on a dedicated winch, but if necessary can be piggy-backed to the SSS towfish.

A single multi-sensor magnetometer towed unit (preferably with set up of magnetometers of four on each scanfish) will also be undertaken along the approximate centre-line of each potential offshore transmission cable corridor and up to 4 x parallel lines spaced up to 250m to each side of the centre-line.

Location: The magnetometer will be deployed across the same locations described for the SSS.

Figure 2.15 Towed Magnetometer

2.3.6.8 Ultra-short Baseline Subsea Positioning

Method: Ultra-short baseline (USBL) subsea positioning is a method to accurately determine and log the 3D position of towed subsea equipment and sensors. USBL systems employ a transceiver fixed to the hull of the survey vessel in combination with transponders on the towed equipment. Triangulation is achieved using acoustic signals transmitted and detected at regular intervals from which bearing, depth and distance can be calculated.

Location: Coincident with towfish surveys (e.g. SSS, magnetometer).

2.3.7 Coastal and Marine Geotechnical and Other Intrusive Surveys

Based on the results of the geophysical surveys, the programme for geotechnical and other intrusive surveys will be developed to provide detailed, site-specific data within the AoI, and to ground-truth initial findings from the geophysical campaign.

2.3.7.1 Trial Pit Investigations

Method: Trial pits will be excavated across intertidal and onshore locations (below the HWM) at potential offshore transmission cable landfall zones and potential transition joint bay (TJB) sites. Trial pits will be excavated, logged, backfilled and reinstated during a single tidal cycle. Excavated material will be temporarily stored and replaced following the sequence in which it was removed. Subject to access and anticipated ground conditions trial pits will be excavated manually or using a mechanical backhoe. Existing land access routes to investigation locations will be used to the extent practicable.

Quantity/Dimensions: Trial pits will be excavated to a depth of 2 m and will be 2 m^2 in plan. Up to 42 trial pits will be undertaken, up to 6 trial pits at each of the seven potential landfall zones. These will be excavated, logged and subsequently backfilled within the AoI in intertidal and onshore areas.

Location: Proposed trial pit locations are shown in the drawings in Appendix A.

2.3.7.2 Grab Sampling

Sediment grab sampling will be carried out as part of the environmental survey campaign, the results of which will also inform the geotechnical assessments. Grab sampling methodologies are outlined in Section 2.3.10.1.

2.3.7.3 Vibrocore Investigations

Method: Details of the specific vibrocoring equipment to be used are not currently known and are subject to a tendering process. The assessment of the impacts of the SI works set out in this derogation licence is based on standard vibrocoring equipment that is proposed to meet the survey specifications. Appointed survey contractors will be required to use equipment which aligns with the parameters of the standard equipment described and assessed in this derogation licence in order to ensure that no greater environmental impacts than those assessed in this derogation licence will arise. Standard vibrocorers consist of steel coring barrel of between 75 – 120 mm diameter housed within a steel support frame designed to enable stable deployment to the sea floor from the survey vessel. The steel coring barrel is equipped with a cutting shoe and contains within it a plastic liner to capture the procured sample. A spring steel core catcher is fitted to the cutting shoe to retain the sample once the corer assembly has advanced to the required depth, or refusal. Linear electric motors enclosed in a pressure housing provide vibratory motion to advance the coring barrel into the seabed to the specified target depth of 6 m below seafloor (BSF). Electrical power is provided from the survey vessel to the vibrocorer assembly through an electrical control umbilical.

Vibrocores will be driven to 6 m BSF or to refusal. Following recovery of the vibrocorer to the vessel the sample container is removed from the steel barrel and the sample is split, logged, sealed and stored for subsequent laboratory analysis. At each new location the vibrocore sampling operation will typically take less than one hour to complete.

Noise from vibrocoring occurs as a series of impulses which correspond to the vibrating oscillating motors interacting with the steel coring barrel.

Figure 2.16 Method of Vibrocore Assembly

Quantity/Dimensions: Up to 276 vibrocores are planned, comprising 171 vibrocores in the area seaward of the 15m LAT contour and 105 vibrocores in the area landward of 15m LAT contour. The vibrocores will be undertaken across the AoI along potential offshore transmission cable corridors to a target depth of 6 m BSF. The locations will be generally coincident with Cone Penetrometer Test (CPT) locations and dependent upon the findings of the geophysical survey. However, the proposed sampling locations are indicated in the drawings in Appendix A.

Each vibrocore sample is expected to take up to one hour to procure. The vibrocore assembly has a footprint of 4 m^2 and it is conservatively assumed that this is also the area of seabed potentially disturbed with each deployment of the equipment additional to the sub-surface sample procured.

Location: Vibrocores will be performed along the potential offshore transmission cable corridors and respective landfall approaches. Representative locations are given in the drawings in Appendix A. Final locations will be subject to the analysis of geophysical survey findings regarding anticipated geology and any identified anomalies (e.g., uncharted archaeology features, potential UXO etc.).

2.3.7.4 Borehole Investigations (including downhole CPT and sampling)

Method: Within the AoI boreholes will be drilled at the potential OSS locations to a target depth of 100 m BSF and at potential offshore transmission cable landfall zones to a target depth of 15 m BSF.

As discussed in Section 2.3.4, the type of vessels used to drill the boreholes will depend on the depth of water and the available vessels.

The majority of boreholes will be drilled directly from a geotechnical survey vessel which will be held on station by Dynamic Positioning (DP). The vessel will accommodate the rig generators, drilling machinery and the rig itself.

Boreholes closer to shore along the potential offshore transmission cable corridors and landfall zones in intertidal/ nearshore areas will be drilled from a JUB where water depths allow.

Depending on feasibility, some boreholes within the AoI below the maritime area land boundary and in the intertidal area may be drilled using a vehicle-mounted drilling spread and associated support vehicles. In any such cases existing land access routes to investigation locations will be used to the extent practicable.

Borehole drilling allows the recovery of undisturbed subsurface samples to directly confirm in-situ geotechnical conditions. A drilling head with an outside diameter of 250 mm will be lowered to the seabed via a drill string at offshore locations. The assembly will be stabilized on the seabed using a support frame where necessary. The drill string will then be rotated to commence boring to the specified depth. Tools will be lowered into the drill string to recover samples or conduct in-situ soil testing. The downhole CPT will be conducted using a pushed CPT system similar to the seabed CPT system but within the casing of the borehole. The following requirements are applied to the downhole CPT mode:

- The stroke for a mud pressure system shall be not less than 1.5 m.
- The stroke for an umbilical system for a 5 cm^2 cone specifically intended to penetrate very dense sands or over-consolidated clays shall be not less than 1.5 m.
- The downhole CPT system shall be capable of achieving minimum cone resistances of 60 MPa cone resistance using the 10 cm^2 cones, and 90 MPa using 5 cm^2 cones.
- The downhole CPT system shall be capable of achieving minimum 1.0 MPa sleeve friction resistance using both 10 cm^2 and 5 cm^2 cones.

Any drill cuttings returned to the vessel or JUB will be stored for responsible onshore disposal and will not be discharged to sea. However, some loss of flush and cuttings would be expected at the seabed drilling location. Boreholes will be left to collapse naturally and will not be backfilled. The duration of the operations at each drilling location will be approximately 48 hours in deeper waters and 36 hours in shallower waters.

Quantity/Dimensions: Up to 21 boreholes will be drilled at potential landfall zones. In addition, up to 8 boreholes for two OSSs will be drilled offshore at potential OSS locations.

Location: Boreholes will be drilled offshore at the potential OSS locations and at potential landfall zones. Final locations will be confirmed following results of the geophysical surveys. However, the proposed locations are presented in the drawings in Appendix A.

Figure 2.17 Offshore Geotechnical Drilling Vessel

2.3.7.5 Shallow CPT

Method: Shallow cone penetration tests (CPTs including thermal testing at certain depth elevations TCPTs) with a minimum thrust at refusal of 50 kN will be undertaken from the geotechnical survey vessel crane or dedicated launch and recovery system to test in-situ soil characteristics at the seabed. At shallower water depths, CPTs/TCPTs may be deployed from a JUB.

The survey involves pushing an instrumented steel cone into the ground at a constant rate with continuous measurement of the cone end resistance, the friction along the sleeve of the cone, and the pore water pressure and thermal soil properties. No material will be removed from the seabed during CPT testing. The CPT spread has a footprint of 5 m^2.

Quantity/Dimensions: Up to 276 shallow CPTs will be performed to a penetration depth of 6m below seafloor (BSF) or refusal.

Location: CPTs will be performed along the potential offshore transmission cable corridors and at the OSS locations. Proposed locations are given in the drawings in Appendix A. Final locations will be subject to the analysis of geophysical survey findings with respect to anticipated geology and any identified anomalies (e.g., uncharted marine archaeology features, potential UXO etc.).

Figure 2.18 CPT Rig

2.3.7.6 Deep Drive CPT

Method: A deep drive CPT device with minimum thrust of 200 kN, and minimum stroke capability of 20m, will be utilized at the potential OSS locations. The Deep Drive CPT equipment will be deployed from the geotechnical survey vessel using the same principles as described for the shallow CPT testing.

Quantity/Dimensions: A maximum of 16 deep drive CPTs will be performed for two OSSs across the AoI to a minimum penetration depth of 15 m BSF. No sediment will be removed from the seabed.

Location: Representative locations at the potential OSS locations are shown in the drawings in Appendix A. Final locations will be subject to the analysis of geophysical survey findings with respect to anticipated geology and any identified anomalies (e.g., uncharted marine archaeology features, potential UXO etc.).

2.3.7.7 Summary of Geotechnical Investigations within AoI

A summary of geotechnical survey quantities involving direct interaction with the seabed and included in this derogation licence is presented in Table 2.4. Final sampling locations are not yet confirmed and are subject to geophysical survey findings. However, proposed locations are presented in the drawings in Appendix A.

Table 2.4 Summary of Ground Investigations within the AoI

Activity	Maximum Quantity
Trial pit investigations	42
Sediment/Benthic Sampling (Subtidal)	420
Vibrocore	276
Inshore/onshore borehole	21
Offshore borehole	8
Shallow CPT	276
Deep drive CPT	16

2.3.8 Metocean and Marine Mammal Acoustic Device Deployments

2.3.8.1 Metocean Buoys

Method: A metocean buoy will be deployed within the AoI to gather metocean data necessary to inform future OSS design. Mounted within the buoy is an accelerometer which registers the rate at which the buoy rises or falls as it follows the pattern of waves. By integrating against time, the acceleration signal can be converted to vertical displacement. The buoy may also incorporate Floating LiDAR (FLiDAR) technology or a stand-alone FLiDAR buoy may be deployed.

In addition, the buoy is specified to gather:

- Wind and water current velocities and directions;
- Atmospheric pressure, temperature, humidity, radiation and precipitation;
- Water quality: dissolved oxygen, pH, conductivity, temperature, salinity, turbidity, chlorophyll and cyanobacteria.

The metocean buoy will be equipped with solar panels, aids to navigation positioning, data recording and telemetry systems. It will be deployed for a minimum of twelve consecutive months.

All notifications and consents relating to navigation risk and corresponding public chart updates will be completed and approved prior to deployment.

Quantity/Dimensions: Up to two metocean buoys will be deployed within the AoI. Although the wave buoy is passive equipment, deployment will require an anchoring system that will necessarily interact with the seabed. Although the details of the buoy and associated anchor system are subject to a tendering exercise and not confirmed, it is conservatively estimated based on standard metocean buoy equipment that 10 m2 of the seabed will be potentially disturbed by the anchor system for the duration of deployment. Appointed metocean buoy survey contractors will be required to use equipment which aligns with these parameters in order to ensure that no greater environmental impacts than those assessed in this derogation licence will arise.

Location: The metocean buoy will be deployed within the AoI at a location representative of potential OSS location. The proposed location is presented in the drawings in Appendix A.

Figure 2.19 Metocean Buoy

2.3.8.2 Acoustic Doppler Current Profiler (ADCP)

An Acoustic Doppler Current Profiler (ADCP) is used to collect data on water movements, current speeds, and directions.

Method: The ADCP will be deployed to the seabed via a crane from a survey vessel for a duration of at least five weeks to capture a full lunar cycle including spring and neap tides.

Quantity/ Dimensions: Up to three ADCP units may be deployed at any one time within the AoI. The ADCP unit is mounted in a seabed frame (1.8m wide and 0.6m high) with a weight of 300 kg. This will be attached to a ground line, a clump weight and to an acoustic release system carrying a rope retrieval system. The precise equipment utilised will depend on the water depths at the locations proposed for survey.

ADCPs will operate at or above a frequency of 300 kHz in order to avoid impacts on marine species.

Location: Deployment of the ADCP is anticipated to be in proximity to the potential OSS locations. The actual locations will be determined based upon interpretation of the geophysical data and following a navigation safety assessment.

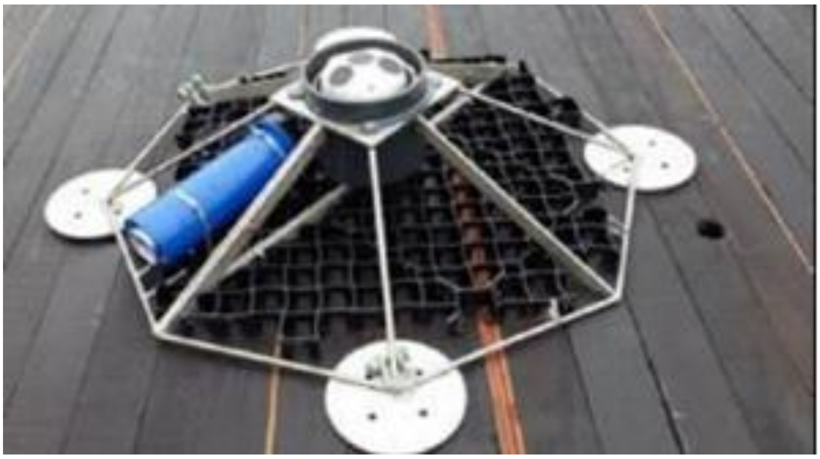

Figure 2.20 ADCP

2.3.8.3 Marine Mammal Static Acoustic Monitors (SAM)

Static Acoustic Monitors (SAM), Cetacean Porpoise Detectors (C-POD) and/or Full waveform capture POD (F-POD) will be deployed within the AoI to capture marine mammal activity with particular focus on areas proposed for infrastructure, i.e. potential OSS locations, potential offshore transmission cable corridors, and potential landfall zones, including suitable buffer zones around these potential locations.

SAM involves detectors that are deployed in a single location, for a period of weeks or months. The detection range will depend on the species and their orientation to the hydrophone, the frequencies of vocalisations, and the sensitivity of the SAM equipment and its deployment method. There are two main ways to deploy SAM devices: one is with moorings including surface floats/ buoys and the second is with moorings and an acoustic release with no surface floats/ buoys although a float is used to keep the unit within the water column. Moorings deployed on the bottom with no surface floats/ buoys are usually recommended as there is no self-noise from the buoys moving in the water and they are less likely to be interfered with. This method utilises acoustic releases to recover the equipment. The type of moorings used will depend on the type of SAM deployed but will typically include a clump weight(s)/ anchors with rope connections to the acoustic release, SAM and float/ buoy. The moorings for each SAM will be retrieved along with the SAM.

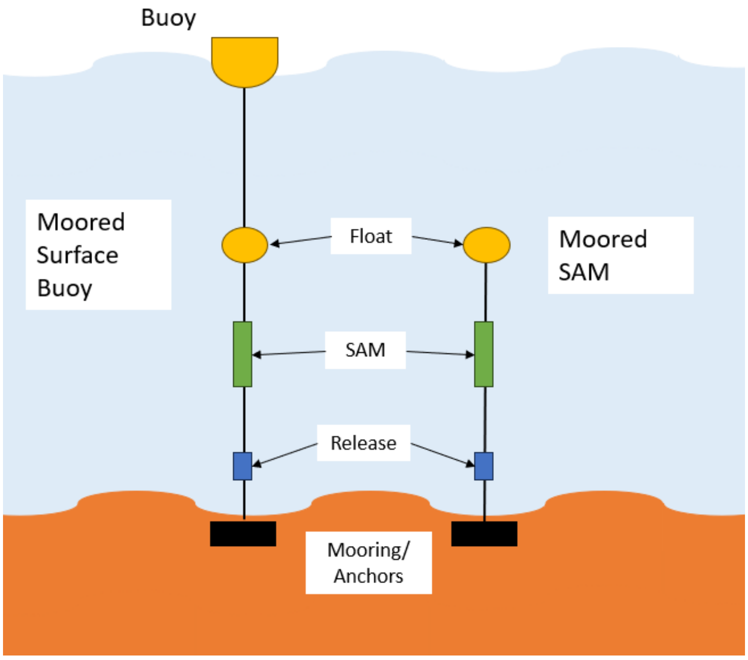

Figure 2.21 SAM Deployment Methods

The type, locations and number of SAM units deployed will be determined based on the proposed infrastructure element (e.g. OSS) and the type of construction works proposed in that area (e.g. offshore piling). Other factors taken into consideration will include tides, sediment and currents, as well as distance from shipping/ onshore noise sources that may impact on baseline noise levels and marine mammal activity.

The monitoring will involve stratified random sampling based upon bathymetric depth horizons and published frontal zones for static passive acoustic monitoring. There will also be a targeted array deployed around potential OSS locations for site specific data collection.

Consultation will be undertaken with relevant stakeholders prior to selecting the most appropriate locations for deployment and the duration of deployment. As further information from the geophysical and geotechnical campaigns is analysed, the survey areas within the AoI may be refined to reflect changes to the potential locations.

The deployment of the underwater acoustic monitoring equipment may be undertaken at any stage during the lifetime of the derogation licence with durations to be confirmed following initial investigations and consultations with relevant stakeholders.

Potential locations for the OSS have been identified and are shown in the drawings. The potential impact of construction of the OSS is much greater than from cabling and, therefore, a higher resolution survey, to identify any important local habitats, times of year, day or tide, will be undertaken using SAM. A minimum of four SAM arrays will be used and recovered every 3 months and re-deployed at four separate locations. This will enable a minimum of 4 x 4 = 16 locations to be sampled. It is proposed, subject to the availability of suitable equipment, that each array will have a combination of click detector and sound recorder to enable a broad sample of vocalizing animals, including seals, to be recorded as well as ambient noise, which is required for noise modelling to assess the potential acoustic Zone of Influence (ZoI) for environmental assessment.

2.3.9 Coastal Environmental Surveys

2.3.9.1 Ecological Walkover Surveys

Baseline coastal surveys at the potential landfall zones be undertaken for mammals, birds and habitats. Where deemed necessary by the project ecologist, camera traps may also be installed at discrete locations to monitor activity, e.g. at the location of otter holts or couches. The coastal surveys will include:

- Habitat walkover surveys (including protected and notable flora, and invasive alien plants and animals) with a c. 100 m buffer from proposed works areas;
- Bats activity and bat roost assessment surveys;
- Mammal surveys (including otters) with a c. 500 m buffer from proposed works areas;
- Ornithological surveys (see Section 2.3.9.2); and
- Other walkover surveys as deemed necessary for the purposes of environmental and SI works.

The coastal ecological surveys will be undertaken at the potential landfall zones including a circa 100 m to 500 m buffer from the potential works area(s) depending on the feature to be surveyed. It is envisaged that the majority of coastal ecological surveys will be undertaken during low tides to provide the greatest extent of intertidal area for survey.

Habitats will be classified in accordance with Fossit 2000 Level 3 and Annex 1 habitats. The extent of surveys undertaken will be appropriate to the level of development proposed at each location.

Other non-intrusive ecological surveys may be required as the preliminary design of the project progresses. Walkover surveys will be required to identify constraints, opportunities and risks within the AoI and especially at potential landfall zones.

Coastal ecological surveys may take place at any time over the lifetime of the derogation licence.

2.3.9.2 Ornithological Surveys

Coastal waterfowl surveys and breeding seabird surveys will be undertaken at the potential landfall zones, including a 1 km buffer area as standard, increasing to a 5 km buffer for breeding bird colonies. These surveys will be standard vantage point monitoring surveys and coastal seabird and waterfowl surveys with breeding marine sea bird colony surveys where appropriate. The derogation licence covers those ornithological surveys to be undertaken within the AoI that includes coastal areas below the HWM.

Coastal waterfowl surveys will be undertaken in accordance with ‘Through the Tidal Cycle’ (TTTC) method which is based on the ‘look-see’ methods (Gilbert et al, 1998). As outlined by Lewis and Tierney (2014), the TTTCC method is deemed the most appropriate approach to determine usage of the intertidal zone by waterbirds in Ireland. Surveyors will record the species present, their location, abundance, behaviour and note any disturbance events including the type, the intensity of the stimuli, and the reaction of the birds with a minimum of three visits for breeding seabirds (March-October).

The surveys will be undertaken on a monthly basis (subject to weather conditions) over a minimum two-year period but may take place at any time over the lifetime of the derogation licence.

2.3.9.3 Marine Mammal Surveys

Coastal marine mammal surveys will be undertaken from suitable Vantage Points (VP). They are being included here as the VPs may involve surveyors operating at coastal locations below the HWM within the AoI. These will be chosen based on the potential landfall zones or other suitable elevated positions within 1 km of the potential landfall zones. These MMO VP surveys are a cost effective and efficient marine mammal survey technique, particularly suited to shallower areas where boat-based and SAM survey techniques are not as effective. Equipment typically includes a good telescope or binoculars on tripod and a high quality spotting scope.

A protocol will be developed to ensure consistency of effort. The location of key ecological constraints such as possible areas of regular/frequent usage once recorded will be mapped to inform the site layout and appropriate mitigation measures and recommendations.

Dedicated watches will be carried out by an experienced MMO for at least 6 hours at each site, at least twice per month for a minimum two-year period.

2.3.9.4 Intertidal Sampling

Intertidal core sampling will be undertaken on foot using hand cores (0.01m^2). Cores in the intertidal area are proposed to be taken to a depth of 15cm-20cm.

At each potential landfall zone (7 no.) a walkover survey will be undertaken with two transects and three stations on each transect, giving a total of 6 locations at each potential landfall zone. A maximum of three samples will be collected at each location. Quadrat sampling will be undertaken with sediment cores removed for laboratory testing. The total quantity of samples will therefore be 126 (6 x 3 x 7).

The intertidal surveys and samples will aim to characterise habitats, with samples to be analysed for fauna, particle size analysis, total organic carbon, and chemical analysis, e.g., heavy and trace metals, hydrocarbons, and polycyclic aromatic hydrocarbons (PAH).

Intertidal surveys will take place at any time over the lifetime of the derogation licence.

2.3.10 Marine Environmental Surveys

2.3.10.1 Drop-down Video and Subtidal Grab Sampling

This section related to sampling in the subtidal zone for both geotechnical and environmental purposes. It is the same campaign as that required under Marine Geotechnical Surveys in Section 2.3.7.2.

The aim of the proposed surveys is to collect baseline sediment and benthic habitat data which will be used to inform future environmental assessments. Surveys will comprise Drop Down Video (DDV) and/or Remote Operated Vehicle (ROV) inspection, diving (if necessary), and the taking of grab samples as required in order to identify benthic habitats.

Where deemed necessary by the marine ecologist, a DDV high-resolution system will be deployed from a suitable vessel to characterise the flora and fauna at each survey location. This activity will be passive and non-intrusive and will not interact with the seabed. The DDV may require a 100 m transect to be conducted with still images taken at 10m intervals. The video footage will be analysed in real time and an assessment on the suitability of the survey station for grab sampling will be made.

At locations determined suitable for grab sampling effort by the DDV transect analysis, a 0.1 m^2 Day grab or 0.1 m^2 Hamon grab will be deployed from a suitable vessel to collect sediment samples.

Method: Superficial sediment/ benthic seabed samples will be obtained using grab samplers deployed from the survey vessels and potentially the JUB in nearshore/intertidal waters. Grab samplers employ mechanical force to close opposing steel clam shells which in turn scoop up superficial samples of seabed sediments and benthic material. Samplers operate to a seabed depth not exceeding 0.5m and sample over an area of 0.1m^2 with recovery of approximately 0.015 m^3 (~15 litres) of material. Two to three grab samples will be collected at each location, one for faunal analysis and a second for sediment physicochemical analysis (sediment particle size analysis (PSA) and loss on ignition (LOI) organic carbon analyses). A third sample may be recovered for sediment contaminant analysis. Faunal grab samples will be sieved on a 1 mm mesh sieve and preserved in 5-10% buffered formalin for analysis in a laboratory.

Different types of grab samplers are available according to the types of seabed conditions expected. Day and Van Veen type grab samplers are suited to general seabed conditions and Hamon type grab samplers are suited to the recovery of mixed and coarser sediments. While all types of grab samplers may be deployed in the proposed surveys across the AoI according to expected site-specific conditions, the principles of operation are the same.

Quantity/Dimensions: Up to 420 grab samples will be taken across the AoI. The grab samplers and their mounting frames have a footprint of 0.1 m^2. The quantity of material recovered is typically in the order of 0.015 m^3 depending on the nature and characteristics of the substrate being sampled.

Location: Sediment/ benthic grab samples will be performed along the potential offshore transmission cable corridors and at the OSS locations where practicable. Proposed locations are presented in the drawings in Appendix A. Final sampling locations will be subject to the analysis of geophysical survey findings with respect to anticipated geology and any identified anomalies (e.g., uncharted marine archaeology features, potential UXO, etc.) but they will nominally coincide with CPT and VC sampling and testing locations (see following sections) and/or where a potential change in habitat type is expected.

Figure 2.22 Day Grab Sampler and Hamon Grab Sampler

2.3.10.2 Ornithological Surveys

Marine ornithological surveys will be undertaken to determine the usage of sea regions by assemblages of marine birds. These data may be used to inform impact assessment and subsequent mitigation (if required).

The marine ornithological surveys will take place within the AoI with particular focus on areas for infrastructure, i.e. potential OSS locations, potential offshore transmission cable corridors, and potential landfall zones, including suitable buffer zones around these areas. As further information from the geophysical and geotechnical campaigns is analysed, the survey areas within the AoI may change to reflect changes to the potential locations.

The marine ornithological surveys will be undertaken from a vessel that will follow transects of the survey area within the AoI. The transects will be set apart at intervals of between c. 300 m and 500 m. Birds within the transect will be recorded alongside their species, count (numbers), and a relative measure of their fight height and behaviour.

Where possible, the surveys will be undertaken monthly, or at an interval of 3-4 weeks between surveys, but the exact timing of surveys will be dependent on suitable weather conditions and vessel availability. It is anticipated that the offshore ornithological surveys will be completed over a two-year period but may take place at any time over the lifetime of the derogation licence. Depending on the findings of the surveys, this survey intensity and duration may be increased or decreased as deemed necessary by the project ornithologist based on either desk study or preliminary survey data.

2.3.10.3 Marine Mammal Surveys and Passive Acoustic Monitors (PAM)

To take advantage of the mobilisation of vessels for the geophysical and geotechnical campaigns, Marine Mammal Observers (MMO) will be present to record marine mammal activities in the AoI. Where required by mitigation, the MMO will be a full-time presence on vessels, e.g., during geophysical surveys campaigns. Where a full-time presence is not required, MMO(s) will be present on vessels as deemed necessary by the marine mammal specialist for the purpose of compiling robust and complete survey data.

Separately, it is proposed that boat-based MMO visual surveys will be undertaken once per month over a minimum two-year period and potentially over the full five-year derogation licence period being sought. These surveys will focus on the potential OSS locations as well as the potential offshore transmission cable corridors and a suitable buffer zone around the potential offshore infrastructure locations.

In addition to MMOs, Passive Acoustic Monitoring (PAM)/ hydrophones will be deployed as deemed necessary for all boat based long transect works (i.e. Grab, Flidar and Vibracore along potential offshore transmission cable corridors and OSS areas). PAM typically involves towing a hydrophone through an area to detect vocalizing individuals within the detection range of the vessel. The detection range will depend on the species and their orientation to the hydrophone, the frequencies of vocalisation, and the sensitivity of the PAM equipment.

2.3.10.4 Water Quality Samples, including Conductivity, Temperature and Depth Measurements (CTD)

Water samples will be taken at various locations throughout the AoI, with a particular focus on areas proposed for infrastructure, i.e. potential OSS locations, potential offshore transmission cable corridors, and potential landfall zones, including suitable buffer zones around these potential locations. As further information from the geophysical and geotechnical campaigns is analysed, the survey areas may change to reflect changes to the potential locations.

Water quality samples are proposed to be taken every 1 km along the offshore transmission cable corridors and at least four sampling locations (one at each of the cardinal directions N, S, E and W) of impactful activities. Each water sample shall be analysed for the following: conductivity, temperature, pH, dissolved oxygen and turbidity. Where suitable, parameters will be tested in situ to receive accurate data. A Niskin bottle (or similar) will be used to obtain a sufficient sample of water at the surface (< 1m depth) and a second sample just above the seabed (~1m) for the subsequent chemical analysis.

Water quality sampling may take place at any time over the lifetime of the derogation licence. Where deemed necessary, samples will be taken once in each season, i.e., summer, autumn, winter and spring.

Conductivity, Temperature, Depth (CTD) water measurements shall be taken at a number of locations across the AoI. The CTD unit will be deployed from the survey vessel into the water column. Depending on conditions up to three measurements at each location may be taken, i.e. near surface, mid-water, and near-seabed. Measurements shall be taken only after stabilisation of the temperature at each location. At each location conductivity and temperature shall be recorded every hour during a complete semi-diurnal tidal cycle. A CTD profile shall be produced for each location.

2.3.11 Archaeological Surveys

Archaeological surveys will be undertaken by a suitably qualified archaeologist. The purpose of the surveys is to collect baseline data which will be used to inform the cultural heritage impact assessment.

Archaeological surveys will be undertaken in advance of any intrusive survey work. Archaeological surveys will include the following.

2.3.11.1 Intertidal Surveys

A team of archaeological personnel will be deployed to each potential landfall zone to undertake a walkover inspection of the intertidal area at Low Water Spring tide, during daylight hours. Surveys will include the use of handheld metal-detectors, photographic survey and drone survey where applicable. Surveys involving handheld metal-detectors will include a series of transects at 10 m intervals across the accessible intertidal area.

2.3.11.2 Coastal and Marine Geophysical Surveys

Geophysical survey for the purposes of archaeological investigation is the same campaign described in Section 2.3.6. This includes a multi-suite instrument deployment to provide comprehensive and robust survey information of the seabed surface and the sub-surface layers. Marine geophysical survey is subject to archaeological licensing from the National Monuments Services in the Department of Housing, Local Government and Heritage.

2.3.11.3 Sampling

Where deemed necessary by the project archaeologist, at the location of geotechnical investigations (both in the intertidal and subtidal areas) an archaeologist/ geoarchaeologist will be present to take samples for archaeological inspection. Samples may be removed from the investigation location, properly stored and transported from site for more detailed assessment and appraisal.

2.3.11.4 Dive Survey

Where deemed necessary by the project archaeologist, and where water depths and conditions permit, dive surveys will be undertaken at specified locations. This is anticipated to be necessary along the potential offshore transmission cable corridors and the surf zone in the event that data gaps exist between close-to-shore surveys and intertidal surveys. Such inspections will be conducted in accordance with safety legislation governing Diving at Work and would require specialist mobilisation and support. Deployment of Remotely Operated Vehicle (ROV) may also be used.

The dive/ ROV surveys will be inspections of target features recorded in the walkover, geophysical and geotechnical surveys that require further clarity in relation to their archaeological potential and extent.

2.3.11.5 Wade Survey

Where deemed necessary by the project archaeologist, and where water depths and conditions permit, wade surveys will be undertaken at specified locations reaching up to 75cm water depth seaward of the low water mark.

2.3.11.6 Monitoring

Where required, there will be an archaeological presence onboard the survey and geotechnical vessel(s) to observe the record being taken and recover material of archaeological potential where observed, to ensure such material is recovered and reported properly. The presence on-board will be agreed on a case-by-case basis. Key occasions where presence is anticipated to be required include working within an Archaeological Exclusion Zone; working in an area of known archaeology; working in a location that has a high volume of investigation locations.

2.3.12 Other Surveys

Other surveys are proposed to be undertaken with the AoI during the lifetime of the derogation licence as summarised below.

2.3.12.1 Noise Surveys

Measurements of baseline airborne ambient noise levels will be undertaken at each potential landfall zone to determine the potential for impacts on Noise Sensitive Locations (NSLs). Up to five locations may be monitored at each potential landfall zone. These will include one unattended monitoring location and up to four attended monitoring locations. Noise surveys will be undertaken in accordance with ISO 1996 Part1, 'Acoustics-Description, measurements and assessment of environmental noise' (2016) and BS 7445 British Standards Institution BS 7445 ‘Description and measurement of environmental noise. Part 1: Guide to quantities and procedures’ (2003).

2.3.12.2 Shipping and Navigation Surveys

The need for shipping and navigation surveys will be determined following consultation with the relevant stakeholders. These can be shore-based visual vessel traffic surveys or may be undertaken from vessels in the marine area. The at-sea surveys can be undertaken from the SI works vessels using on-board radar and AIS data.

2.3.12.3 Unmanned Aircraft Systems (UAS)/ drone surveys

UAS/ drone surveys are proposed to be undertaken in the intertidal and subtidal area to capture photogrammetry, orthomosaic, topography or other features of interest. Where required under Irish legislation, drones will be suitably authorised. The activity will be carried out above the intertidal and subtidal area, i.e. not within the definition of the maritime area. However, take-off and landing zones for the drone, and operatives, may be within the intertidal area.

Aerial surveys: Aerial surveys (e.g., from fixed wing aircraft) will be undertaken across the AoI to capture imagery and video. The aerial surveys will focus on the potential OSS, offshore transmission cable corridors and landfall zones but may be extended as the requirements of the project develop. The digital images will be analysed to record species of interest, e.g. seabirds, cetaceans. Aerial surveys are carried out once per month within the derogation licence period. The activity will be carried out above the intertidal and subtidal area, i.e. not within the definition of the maritime area.

2.3.12.4 Aerial Surveys

On digital aerial surveys no observers are used but images are acquired on the sea from a digital camera. Typically, up to four cameras might be used to capture a range of angles of the target to aid identification. Still images are taken almost continuously building a huge image database. Post-survey images are analysed for “snags” (features of interest) before being identified visually by trained and experienced observers. Development of algorithms and Artificial Intelligence (AI) are advancing to aid rapid analysis of these images and reduce human error.

Species (e.g. seabirds and marine mammals) of interest are recorded in bands at varying distances and orientation to the aircraft. Data providing good coverage of the site may be acquired (it is proposed that 25% of the AoI is surveyed). It is usual that not all the data are analysed but typically only 25% (one band). Similar to boat-based surveys, detection rate depends on the species being available to detect visually and as aircraft have a greater speed than boat-based surveys detection rates can be much lower. However digital aerial surveys can cover a much greater area in any period compared to boat-based surveys.

The location of the aerial surveys will focus on the potential OSS locations and offshore transmission cable corridors but may be expanded to encompass larger areas of the AoI.

Monthly surveys will be undertaken over a minimum 2-year duration within the derogation licence period.

2.4 Summary of Marine Survey Noise Generation Sources

Ranges of the noise expected in terms of frequency and sound pressure level from subsea surveys are summarised in Table 2.5.

Table 2.5 Noise Characteristics of Standard Survey Equipment

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
Survey vessel, Geophysical, nearshore	160 dB SPL	10-4,000 Hz	Based on 15 m generic survey vessel.	Non-impulsive
Survey vessel, Geophysical, offshore, with DP-system	183 dB SPL	10-2,500 Hz	Based on 75 m generic survey vessel with DP-system active.	Non-impulsive
Survey vessel, Geotechnical	176 dB SPL	10 – 2,000 Hz	Based on 75 m generic survey vessel.	Non-impulsive
MBES	178 dB SPL (Spherical equivalent level)	200,000-500,000 Hz	Based on units suitable for this survey.	Impulsive
SSS	165 dB SPL (Spherical equivalent level)	100,000-900,000 Hz	Generic SSS from 400-900 kHz.	Impulsive
USBL	190 dB SPL	8,000-40,000 Hz	Active with non-hull mounted SSS & SBP & during vibro-core operations, 2 Hz ping rate, ping length 10 ms.	Impulsive
SBP-parametric (P-SBP)	208 dB SPL	80,000-115,000 Hz (Primary) 2,000-22,000 Hz (Secondary)	Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-chirper/pinger (C-SBP)	185 dB SPL	1,000-20,000 Hz	Generic shallow water SBP of chirper/pinger type. Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-sparker/UHRS (S-SBP)	185 dB SPL 224 dB L_P	600 – 8,000 Hz	Based on GeoSource firing at 1000 J. Firing rate of 1 Hz assumed	Impulsive
SBP-boomer (B-SBP)	185 dB SPL 228 dB L_P	160 – 16,000 Hz	Based on generic boomer model firing at 1000 J. Firing rate of 1 Hz assumed	Impulsive
ADCP	114 dB SPL	300,000-600,000 Hz	Based on suitable ADCP for depths <65 m (e.g. Nortek AWAC, Teledyne Reason Sentinel, Workhorse or Monitor) Source level adjusted for sediment effects and beam widths.	Impulsive
Borehole drilling/ rotary coring	150 dB SPL	10-100,000 Hz	Based on published levels (Erbe, et al., 2017; Fisheries and Marine Service, 1975; MR, et al., 2010; L-F, et al., 2023)	Non-impulsive
Vibro-coring & CPT	189 dB SPL	50 – 16,000 Hz	Based on levels from previous work & (Reiser, et al., 2010)	Non-impulsive

2.5 Safety, Health, Environment & Quality Management

The survey contractor will be contractually required to maintain and operate ISO-accredited or compliant Safety, Health, Environmental and Quality (SHEQ) management systems for the duration of its contractual obligations regarding the described survey scopes. Reports and other submissions shall be provided as and when required for review and approval by law and/or by Company to ensure safe and secure operations and Worksites.

3 RISK ASSESSMENT FOR ANNEX IV MARINE SPECIES

3.1 Legislative Context

Under Article 12 and 13 of the Habitats Directive, Member States must establish systems of strict protection for animal and plant species which are particularly threatened, and which are listed on Annex IV of the Directive. Article 16 provides for derogations from these legal protections under certain, specific, circumstances. Article 12, 13 and 16 of the Habitats Directive are transposed into Irish law by Regulations 51, 52 and 54 of the European Communities (Birds and Natural Habitats) Regulations 2011, as amended.

Annex IV species are afforded strict protection throughout their range, both inside and outside of designated protected areas. It is an offence to:

- Deliberately capture or kill any specimen of these species in the wild;
- Deliberately disturb these species particularly during the period of breeding, rearing, hibernation and migration;
- Deliberately take or destroy eggs of these species in the wild;
- Damage or destroy a breeding or resting place of such an animal[2];
- Deliberately pick, collect, cut, uproot, or destroy any specimen of [plant] species in the wild; or
- Keep, transport, sell, exchange, offer for sale or offer for exchange any specimen of [animal or plant] species taken in the wild, other than those taken legally as referred to in Article 12(2) of the Directive[3].

The granting of another statutory consent (e.g., planning permission; MARA licence) does not remove the obligation to obtain a derogation licence in the event of the consented works being likely to not conform with the strict protections afforded to Annex IV species. As such, an application for derogation may have to be made to the Minister for Housing, Local Government & Heritage via the National Parks and Wildlife Service (NPWS) under Regulation 54, in addition to an application for development consent. If satisfied that an application meets the criteria for derogation, the Minister may grant a derogation licence, which may be subject to such conditions, restrictions, limitations, and requirements as the Minister considers appropriate, and these will be specified in the licence.

3.2 Relevant Annex IV Marine Species

This report has been prepared on the basis that a derogation application will only be required for relevant marine species due to the potential, in the absence of mitigation measures, for underwater noise from the geophysical and geotechnical equipment and vessels to impact on these species.

Bat species are not considered as part of this derogation application as the proposed SI works including access/egress from each potential landfall zone will not result in any direct or indirect impacts on any structure or feature which could be used by roosting bats. Therefore, there is no likelihood of the SI works resulting in any bats being captured or killed and disturbed during periods of breeding, rearing or hibernation. No breeding site or resting place of such animals will be damaged or destroyed during the SI works. Works at the potential landfall zones will be carried out during daylight hours only and will be subject to tidal conditions. Any artificial lighting, if used, will be localised to either the vessels (or JUB) or at trial pit/test locations within the intertidal zone. Therefore, there is no likelihood of any significant disturbance or displacement of foraging, commuting, or migrating bats and the proposed SI works will conform with the strict protections afforded to bat species.

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[2] Including any action resulting in damage to, or destruction of, a breeding or resting place of an animal. Breeding or resting places are protected even when the animals are not using them.

[3] National Parks and Wildlife Service (2021) Guidance on the Strict Protection of Certain Animal and Plant Species under the Habitats Directive in Ireland.

There will be no interaction with otter holts or couches as the intrusive/environmental sampling will take place on the intertidal zone/on beaches where holts and couches are unlikely to be found. As otter tend to forage within 80 m of the shoreline (NPWS, 2009), it is considered unlikely that there will be interaction between marine survey activity and otters foraging in coastal waters. In addition, marine surveys in coastal waters <15m deep will be carried out during daylight hours, when otters are likely to be less active. Therefore, the proposed SI works will conform with the strict protections afforded to otter.

All cetacean species and marine turtle species are listed under Annex IV of the Habitats Directive and have the potential to occur within the AoI. Therefore, these Annex IV species will be considered further.

3.3 Methodology

This risk assessment for marine mammal Annex IV species has had regard to the following guidance:

- European Commission (2021) Guidance document on the strict protection of species of community interest under the Habitats Directive. C. (2021) 7301 final. Brussels.
- Mullen, E., Marnell, F. & Nelson, B. (2021) Strict Protection of Animal Species. National Parks and Wildlife Service Guidance Series, No. 2. National Parks and Wildlife Service, Department of Housing. Local Government and Heritage.
- NPWS (2021) Guidance on the Strict Protection of Certain Animal and Plant Species under the Habitats Directive in Ireland. National Parks and Wildlife Service Guidance Series, No. 2. Department of Housing. Local Government and Heritage.

This risk assessment for marine mammal Annex IV species broadly follows the methodology structure outlined in Mullen et al., (2021), as follows:

3.3.1 Test 1: Reasons for Seeking Derogation

Reasons set out in Regulations 54(2) (a)- (e) below;

(a) In the interests of protecting wild flora and fauna and conserving natural habitats;

(b) To prevent serious damage, in particular to crops, livestock, forests, fisheries and water and other types of property;

(c) In the interests of public health and public safety, or for other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences of primary importance for the environment;

(d) For the purpose of research and education, of re-populating and reintroducing these species and for the breeding operations necessary for these purposes, including artificial propagation of plants, or;

(e) To allow, under strictly supervised conditions, on a selective basis and to a limited extent, the taking or keeping of certain specimens of the species to the extent specified therein, which are referred to in the First Schedule. If it cannot be clearly demonstrated that one or more of the reasons set out above apply, a derogation licence cannot be granted by the Minister.

In May 2019, the Government of Ireland declared a Climate and Biodiversity Emergency in the Dáil[4] and has committed to increasing the proportion of electricity generated from renewable sources to 80% by 2030. A key target of the Climate Action Plan 2024 (DECC, 2024) is to connect at least 5 GW of offshore wind power to the grid by 2030. The PUOSC project is instrumental to this target, by facilitating the transfer of up to 900 MW of power generated by offshore wind farms in Irish waters into our national electricity grid. As the Transmission System Operator (TSO) and Transmission Asset Owner (TAO)/ Offshore Asset Owner (OAO) for Ireland's offshore electricity grid, EirGrid must undertake the PUOSC project to ensure that Ireland meets its renewable energy and climate action targets.

The proposed SI works are critical to the development of the PUOSC project, and therefore, qualify under Regulation 54(2)(c). The proposed SI works will provide the necessary engineering and environmental

[4] Report entitled 'Climate Change: A Cross-Party Consensus on Climate Action': Motion – Dáil Éireann (32nd Dáil) – Thursday, 9 May 2019 – Houses of the Oireachtas

information to inform the design and environmental assessments necessary to support a planning application for the PUOSC project, which is imperative to Ireland achieving its offshore wind and renewable energy targets.

3.3.2 Test 2: There is No Satisfactory Alternative

NPWS (2021, p.18) states:

> *"Derogation from the Strict Protection provisions of the Directive must be seen as the last resort in any situation. It must therefore be clear that there is no other satisfactory solution to the situation presented by the proposal or project in question.*
>
> *Applicants for a derogation licence should include full details of the alternatives examined and should set out objective reasons demonstrating why these alternatives are not satisfactory. If there is a satisfactory alternative then the application has failed the second test and a derogation licence cannot be issued."*

The following consideration of alternatives provides the strategic basis for the PUOSC project followed by the project level consideration of alternatives.

3.3.2.1 Strategic Level Considerations

At a strategic level, international, European, national and local plans all underline the importance of developing renewable energy projects to provide for a sustainable future. Ireland was the second country in the world to declare a climate emergency[5]. The PUOSC project aligns with the strategic level policies and objectives of international plans and programmes such as the UN Sustainability Goals and the EU Green Deal, as well as those of the following relevant national, regional and local plans:

- Climate Action and Low Carbon Development Act 2015 to 2021
- National Energy and Climate Plan 2021-2030
- Climate Action Plan 2025
- Project Ireland 2040: National Planning Framework, 2018 and National Development Plan 2021-2030
- National Marine Planning Framework
- South Coast Designated Maritime Area Plan
- Ireland's Transition to a Low Carbon Future 2015-2030
- Government Policy Statement on Security of Electricity Supply
- Government Policy Statement on the Strategic Importance of Transmission and Other Energy Infrastructure
- Government Policy Statement on the Future Framework for Offshore Renewable Energy
- EirGrid's publications:
  - Transmission Development Plan 2024-2033
  - Ireland's Grid Development Strategy; Your Grid, Your Tomorrow
  - Grid Implementation Plan 2023 - 2028
  - Strategy 2020-25: Transform the Power System for Future Generations
  - Shaping our Electricity Future
- Regional Spatial and Economic Strategy for the Southern Region
- Wexford County Development Plan

[5] Available: Climate Action – how we can look after nature

- Waterford City and County Development Plan
- Cork County Development Plan 2022-2028

There is a legal obligation on Ireland, through the Climate Action and Low Carbon Development (Amendment) Act, 2021, to cut emissions by 51% by 2030 and achieve net-zero by 2050. One of the key elements in addressing this is to substantially decrease Ireland's reliance on fossil fuels and substantially increase the production of electricity from renewable sources. To achieve this, Ireland has set a target of producing at least 5 GW of offshore wind by 2030 rising to 20 GW by 2040 and 37 GW by 2050 (Future Framework for Offshore Renewable Energy, DECC, 2024). Ireland's Sectoral Plans under the Climate Action Plan reinforces this requirement.

There are no reasonable alternatives to Ireland needing to deliver offshore wind projects, including transmission grid infrastructure, to support our legally binding climate targets.

The PUOSC SI Works project is a key element in the delivery of the PUOSC transmission grid infrastructure for offshore wind projects to be developed within the geographical regions covered by the South-Coast Designated Maritime Area Plan (SC-DMAP). Project level alternatives are discussed in the following section.

3.3.2.2 Project Level Considerations

At the project level, a comprehensive assessment was undertaken to examine alternative solutions that would avoid the need to introduce underwater noise into the marine environment, and therefore, potential impacts to marine Annex IV species.

It should be noted that only the geophysical and geotechnical investigations listed in Table 2.2 are considered below in terms of project alternatives as the other survey activities will not require a derogation for Annex IV species.

With regards to alternatives, consideration has been given to a do-nothing/ do minimum scenario and do-something scenarios.

3.3.2.2.1 Do Nothing Scenario

In the do-nothing/ do-minimum scenario, there is insufficient existing engineering and environmental information to allow an engineering design to be developed and to allow for robust and up-to-date environmental assessments to be undertaken, both of which are essential to support any future planning application. Without new SI data, the PUOSC cannot be developed and with no offshore grid and substations to support offshore wind development, Ireland will fail to achieve its climate targets.

Existing geophysical and geotechnical information on Area A Tonn Nua, the transmission cable corridors, and the landfall locations is insufficient to allow the engineering and environmental teams working on PUOSC to select a preferred option. The PUOSC SI works will provide geophysical, geotechnical and environmental information necessary to support any futrue environmental assessments. Therefore, the do-nothing/ do-minimum scenario is not feasible.

3.3.2.2.2 Alternative Scale of Project

DECC published the South Coast Designated Maritime Area Plan (SC-DMAP) in October 2024. This plan identifies four (4) areas for potential future deployments of both grid connected and non-grid connected Offshore Renewable Energy (ORE). Area A Tonn Nua will be developed initially, while Areas B, C, and D will be developed subsequently subject to the required project level assessments and consents. The development of offshore wind in Area A will require offshore sub-stations (OSS) and transmission cables to bring the offshore wind energy to the national grid. As Area A Tonn Nua is identified in the SC-DMAP as the first area for development of offshore wind, the PUOSC project must develop the offshore sub-stations (OSS) within Area A. Undersea/ marine transmission cable are also required from the OSS to onshore Grid Interface Points (GIP) to connect the offshore wind farms to the national grid.

The development of the PUOSC project requires a number of technical decisions to be made with respect to the architecture of the offshore electricity transmission system. The following Table 3.1 provides a summary of the results of the technical decisions as set out in the EirGird report: *Powering Up Offshore South Coast – Update Report, 12/11/2024*[6].

Table 3.1 Key Technical Decisions

No.	Element	Technical Decision	Further information required?
1	Offshore substation (OSS).	A minimum of two OSS are required each with a capacity of 450 MW. within Area A Tonn Nua.	Yes. The exact location of each OSS will require evaluation of geophysical, geotechnical and environmental information to select the optimum location.
2	Transmission cables.	Two transmission cable are required, one from each OSS, each with a capacity of 450 MW. Each transmission cable route will require a separate landfall location to connect the transmission cable to the onshore grid infrastructure (the Grid Interface Points GIP).	Yes. The location of each transmission cable to a landfall location and GIP will require evaluation of geophysical, geotechnical and environmental information to select the optimum route.
3	Landfall locations	Two landfall locations are required, one for each transmission cable to provide a route to connect to the GIP.	Yes. The location of each landfall location will require evaluation of geophysical, geotechnical and environmental information to select the optimum location.

Once the decisions on the architecture were confirmed, an assessment was undertaken of the broad study area, i.e. the Area of Interest (AoI) shown in Figure 2.1, to identify possible landfall locations and transmission cable corridors from the OSS to the GIP.

As set out in *Powering Up Offshore South Coast – Update Report, 12/11/2024*, a long list of offshore transmission cable landfall locations was determined based on a desk top study using publicly available data. A total of 31 landfall locations were identified for the long list in proximity to the Cork, Waterford and Wexford coasts. The 31 sites were initially evaluated (Step A) against technical and economic criteria to arrive at reasonable alternatives. This resulted in eight short-listed landfall locations. These eight locations were subsequently evaluated (Step B) against the following criteria: Technical, Economic, Deliverability, **Environmental**, Socio-economic, and the Combination of the foregoing. Following this assessment, one of the eight short-listed locations was ruled out resulting in a final list of seven potential landfall locations. These seven locations provided the rationale for selecting seven transmission cable corridors from the Tonn Nua area to the landfall locations.

The area within which the geophysical and geotechnical PUOSC SI works will take place has been reduced from that of the AoI shown in Figure 2.1 to that shown in Figure 2.2. The scale of the SI works for the OSS locations, transmission cable corridors and landfall locations, has been reduced to only what is necessary to deliver the offshore transmission grid infrastructure.

Other OSS locations outside of Area A Tonn Nua are not feasible as they are not supported by the SC-DMAP.

Other landfall locations have been assessed and ruled out as they do not meet the project objectives. The seven short-listed locations provide the best alternatives to determine the optimum route for the transmission cables. Further refinement of the landfall locations and transmission cable corridors is only possible following detailed assessment of engineering and environmental information. The SI works are required to provide this information.

There is, therefore, no other alternative to the scale of the PUOSC SI Works project.

3.3.2.2.3 Alternative Design or Technology Use

Geophysical and geotechnical surveys are essential as they provide high-resolution and accurate data on the seabed, sediment layers and bedrock/ geological structures. These surveys produce underwater noise which has the potential to impact on Annex IV species. As described in this report, mitigation measures from

[6] Available: https://cms.eirgrid.ie/sites/default/files/publications/Powering-Up-Offshore-South-Coast-Update-Report-November-2024.pdf

the Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (DAHG, 2014) will be applied during the surveys to avoid impacts on marine mammals.

Not producing underwater noise is not feasible as it is inherent in the technologies required to collect the data.

The use of remotely operated vessels (ROV) is a potential alternative method of collecting data that is considered feasible and may be deployed as part of the overall SI works campaign. However, these craft are equipped with similar equipment that is deployed from manned vessels.

The proposed survey methodologies utilise the most effective techniques that reduce potential risks to Annex IV species while facilitating the collection of crucial data for the safe and efficient design of the PUOSC project. Although non-intrusive methods, such as desktop studies and remote sensing, were taken into account, they are inadequate on their own for obtaining the high-resolution geophysical and geotechnical data necessary to assess seabed conditions. The collection of the new high-resolution data will ensure that the PUOSC project is designed safely, economically and in an environmentally responsible manner that achieves the project objectives.

3.3.2.2.4 Timing and Intensity

It is anticipated that the PUOSC geophysical and geotechnical surveys will be undertaken within the first 24 months following award of the Maritime Usage Licence (MUL) from MARA (see Section 2.3.2 above). This is dependent on the date of award of the MUL with surveys more likely in spring, summer and autumn due to winter weather constraints.

There are no alternatives to the timing of the SI works. Completing the works is critical to informing the optimum location of the infrastructure. All subsequent work on the PUOSC is dependent on the timely delivery of the SI Works information, including: undertaking the preliminary design, applying for planning consent, undertaking detailed design, construction and commissioning of the offshore grid infrastructure. The project must be fully constructed to allow the connection of offshore wind projects to the national grid and this must be achieved prior to 2030 to contribute to Ireland’s legally binding target of reducing climate emissions by 51% by 2030.

Noise sources will be operated in accordance with the parameters set out in Section 2.3 as well as the Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (DAHG, 2014). The intensity of the sound producing activities has been selected to reduce the risk of impact on Annex IV species to levels that are as low as reasonably practicable while still obtaining the high-resolution data necessary from the surveys. The intensity will decrease with distance from source as shown in the Subsea Noise Technical Report in Appendix A. As discussed in Section 3.5, mitigation in the form of soft-starts will be implemented to reduce the impacts of underwater noise on Annex IV species.

3.3.2.3 Alternatives Conclusion

The PUOSC project is supported by international, European and national plans and policies, in particular, the SC-DMAP. There is no alternative to having to deliver the PUOSC project as it is required to enable Ireland to achieve its legally binding climate targets.

There is insufficient existing engineering and environmental information to allow the PUOSC to be design safely and in an environmentally responsible way. The PUOSC SI works are necessary to deliver the PUOSC project. The do-nothing scenario is therefore not feasible.

The SI works are required to collect environmental information for any future environmental assessments of the PUOSC project.

The scale of the PUOSC SI works has been reduced to only that necessary for the collection of data for the OSS, transmission cable corridors and landfall locations.

The timing and intensity of the surveys has been selected to enable the delivery of PUOSC within the necessary timeframes.

Mitigation measures will be implemented in accordance with those set out in this report to ensure the protection of Annex IV species.

3.3.3 Test 3: Favourable Conservation Status

In each case, consideration must be given to whether granting a derogation licence would be detrimental to the maintenance of the populations of the species in question at a favourable conservation status in their natural range (Regulation 54(2)). Annex IV species must be maintained at Favourable Conservation Status or restored to favourable status if this is not the case at present. The net result of granting a derogation licence must be neutral or positive for the species in question.

If a derogation licence is likely to have a significant negative effect on the population concerned (or the prospects of this population) or is likely to have a significant negative effect at the biogeographical level within Ireland, then a derogation licence cannot be considered. If a derogation is issued it may have conditions, restrictions, limitations or requirements attached. All derogation licences are also subject to the Animal Health and Welfare Act 2013. At the completion of the process the Minister will state reasons for issuing (or refusing to issue) the licence. This statement will include the reasons it was decided there was an absence of suitable alternatives and refer to any relevant technical, legal and scientific reports used in making the decision.

The potential effects of the proposed SI works on all cetacean species are discussed in Section 3.4 and 3.5 below. With the implementation of the mitigation measures outlined in this report, the impacts to Annex IV cetacean species will be neutral. Once the SI works are complete, there is no further potential for impacts to Annex IV cetacean species.

3.4 Evidence Base

3.4.1 Desk study sources

The following sources were consulted during the desk study in March 2025:

- Irish Whale and Dolphin Group Sightings Log https://iwdg.ie/browsers/sightings.php/;
- Distribution records for Annex IV species held online by the National Biodiversity Data Centre (NBDC) www.biodiversityireland.ie;
- NPWS (2019) The Status of EU Protected Habitats and Species in Ireland. Volume 3: Species Assessments. Unpublished Report, National Parks and Wildlife Service. Department of Culture, Heritage and the Gaeltacht, Dublin;
- Giralt Paradell, O., Cañadas, A., Bennison, A., Todd, N., Jessopp, M., Rogan, E. (2024). Aerial surveys of cetaceans and seabirds in Irish waters: Occurrence, distribution and abundance in 2021-2023. Department of the Environment, Climate & Communications and Department of Housing, Local Government & Heritage, Ireland. 260pp;
- IWDG (2015). Species profiles https://iwdg.ie/species/ .

3.4.2 Desk study results

Twenty-five species of cetacean have been recorded in the waters around Ireland. The Irish Whale and Dolphin Group (IWDG) holds 120 records of cetacean sightings off the Cork and Waterford coasts and within the Celtic Sea for the period of March 2024 to 2025 (IWDG, 2025). IWDG data show that the waters off the Cork and Waterford coasts are used by a wide range of cetacean species.

Species recorded were:

- Common dolphin (*Delphinus delphis*);
- Bottlenose dolphin (*Tursiops truncates*);
- Harbour porpoise (*Phocoena phocoena*);
- Minke whale (*Balaenoptera acutorostrata*);
- Humpback whale (*Megaptera novaeangliae*); and
- Fin whale (*Balaenoptera physalus*).

No other cetacean species was recorded in the Celtic Sea off the Cork and Waterford coast between March 2024 to March 2025.

Phase II of the Irish ObSERVE programme (2021-2023) was conducted to investigate the occurrence, distribution and abundance of key marine species in Ireland's offshore and coastal regions. These aerial surveys included four offshore areas and coastal waters. The AoI is within the coastal survey stratum 6C while stratum 4 (Celtic Sea) was also considered.

Common dolphin, harbour porpoise and bottlenose dolphin were the most frequently sighted species throughout the Phase II ObSERVE survey programme while minke whale was the most common sighted mysticete (baleen whale) species (Giralt Paradell et al., 2024).

According to Giralt Paradell et al (2024), common dolphin showed a preference for continental shelf waters in both coastal and offshore areas. Common dolphin was frequently recorded in stratum 6C and 4 with groups sizes ranging from one to 100 individuals. Bottlenose dolphin was recorded throughout the survey area primarily in the continental shelf waters of stratum 4 with no sightings recorded in the coastal waters off the south coastal stratum 6C (Giralt Paradell et al., 2024). Harbour porpoise was primarily recorded in the coastal strata including stratum 6C and in less numbers in stratum 4. Minke whale was observed in all strata including 6C and 4 however the majority of sightings were in waters <200 m. There were no confirmed records of humpback whale during the Phase II surveys although three records of unidentified large whales (>10m) were recorded. These sightings were recorded in the slope waters of the Porcupine Basin off the west coast of Ireland. All sightings of fin whales during the Phase II survey were recorded primarily in Ireland's offshore waters >500 m. One fin whale was recorded in stratum 4 while none were recorded in stratum 6C (Giralt Paradell et al., 2024).

According to the most recent Article 17 conservation assessment, bottlenose dolphin, common dolphin, harbour porpoise, minke and fin whale are deemed as being in favourable conservation condition, while the status of humpback whale is unknown (NPWS, 2019).

Management Unit (MU) boundaries, defined by the Inter Agency Marine Mammal Working Group (IAMMWG, (2015; 2022), refer to geographical areas in which the animals of a particular cetacean species are found, to which management of human activities is applied. These geographical areas are delineated based on the best scientific knowledge of the population structure of the species while taking into account jurisdictional boundaries or divisions which are already used for manging human activities (IAMMWG, 2023).

The following sections provide more detail on the most commonly recorded cetacean species within and around the AoI.

3.4.2.1 Common dolphin

Common dolphin is present all year round in Irish waters. Densities appear to be highest during autumn and summer off the south and southwest coasts, and higher along southeast coasts in the spring and summer (NBDC, 2025b). According to Giralt Paradell et al., (2024), common dolphins showed interannual variability with more sightings during the summer of 2021 than in 2022, mean group sizes were also larger in the summer (7.2) compared to winter (6.7). High densities of common dolphin were found to the south of Ireland in the Celtic Sea (stratum 4) and within the coastal waters off the south coast of Ireland (stratum 6C) (Giralt Paradell et al., 2024).

Common dolphins face threats such as underwater noise, interactions with fisheries through bycatch, ship strikes, and marine pollution (NBDC, 2025b). Common dolphins have been assigned to a single MU, the Celtic & Greater North Seas MU (IAMMWG, 2022), which includes the AoI. Abundance of common dolphin in the Celtic & Greater North Seas MU is estimated at 102,656 animals (IAMMWG, 2023).

3.4.2.2 Bottlenose dolphin

Bottlenose dolphin is found in both inshore and offshore waters and has been recorded all around the Irish coast. This species can also be found in much deeper waters off the continental shelf (NBDC, 2025c). Three distinct populations have been identified in Irish waters including an offshore group, a coastal transient group and a smaller resident population in the Shannon Estuary, Co. Clare. A semi-resident group of six bottlenose dolphins have also been recorded in the mouth of Cork Harbour between Crosshaven and Power Head. The group have been recorded in all seasons and move based on the tidal conditions (IWDG, 2010)[7].

According to Giralt Paradell et al., (2024), increased encounter rates were noted in the summer of 2022 and summer density distribution maps highlight the importance of the Celtic Sea, while increased bottlenose dolphin abundance during winter was predicted in the northern region of the Celtic Sea (stratum 4).

Bottlenose dolphins are exposed to several threats as they utilise coastal areas. These threats include underwater noise, interactions with fishing gear, marine water pollution, and ship strikes (NBDC, 2025d). Bottlenose dolphins within the AoI are assumed to belong to the Offshore Channel and Southwest England and Irish Sea (OCSW) MU (IAMMWG, 2022). Abundance of bottlenose dolphin in the OCSW MU is estimated at 10,653 animals (IAMMWG, 2023).

3.4.2.3 Harbour porpoise

Harbour porpoise is widespread around the Irish coast (Wall et al., 2013) and the Celtic and Irish Seas. The Celtic and Irish Seas (CIS) is recognised as the relevant MU for harbour porpoise occurring within the AoI (IAMMWG , 2022). According to Giralt Paradell et al., (2024), mean group sizes of harbour porpoise were notably higher during winter while increased densities were recorded throughout the coastal strata (6C) and stratum 4. A number of harbour porpoise calves were recorded during the Phase II survey however these were mainly within the Irish Sea. Harbour porpoise are also sighted regularly around the coasts of Ireland and throughout the year but are more commonly sighted along the east coast of Ireland (IWDG, 2015a).

Potential threats to harbour porpoise include underwater noise, entanglement in fishing gear, collision risk and marine water pollution (NBDC, 2025e). Abundance of harbour porpoise in the CIS MU is estimated at 62,517 animals (IAMMWG, 2023).

3.4.2.4 Minke whale

Minke whale is the most abundant of all baleen whales in Irish waters and can been seen throughout the year along the entire Irish coastline although most sightings are recorded from the south and west coasts between May and October. They are mostly seen in shallow waters (<200 m) over the Irish Shelf as well as shallow areas such as the Porcupine and Rockall Banks (IWDG, 2015b). A seasonal inshore migration occurs off Loop Head Co. Clare during September and October. Important foraging areas for minke whales between April to October have been recorded off the south coast on the outer Dingle Bay as well as from Cape Clear, Co. Cork to Hook Head, Co. Wexford between April to November (IWDG, 2015b). According to Giralt Paradell et al., (2024), minke whales were commonly recorded in Irish waters in all strata with most sightings in the continental shelf waters with only two sightings occurring in winter. Density distribution maps highlighted that there may be higher densities of minke whale along the south coast of Ireland particularly in west Cork waters (Giralt Paradell et al., 2024). Minke whale within the AoI have been assigned to the Celtic & Greater North Seas MU (IAMMWG, 2022). Abundance of minke whale in the Celtic & Greater North Seas MU is estimated at 20,118 animals (IAMMWG, 2023).

3.4.2.5 Humpback whale

Irish sightings of humpback whale are mainly off the west and south coast of Ireland, with sightings increasing in summer to peak in September, declining after that (NBDC, 2025f, Berrow et al., 2010). According to Giralt Paradell et al., (2024), there were no confirmed sightings of humpback during the survey however three unidentified large whales were noted which could potentially be humpback whales. These recordings were sighted off the Porcupine Basin slope waters. There is no MU for humpback whales.

3.4.2.6 Fin whale

Fin whale is recorded in Irish waters for most of the year, but records are higher in the summer and autumn, with fewer recordings during the spring and winter (NBDC, 2025g). Fin whales are typically recorded off the south coast of Ireland in the autumn (Wall et al., 2013). According to Giralt Paradell et al., (2024), fin whales were recorded across all seasons although the highest number of sightings was recorded in the summer of

[7] https://iwdg.ie/resident-cork-harbour-dolphins/ accessed March 2025

2021 and winter 2022. Only one sighting of fin whale was recorded in the Celtic Sea in Stratum 4 in the summer of 2021. Fin whales can be seen offshore along Irelands west coast, however they can be seen off Irelands headlands when feeding inshore along Irelands south coast (IWDG, 2015c).

Potential threats to fin whale include vessel strikes, entanglement in fishing gear and noise pollution. There is no MU for humpback whales.

3.4.2.7 Turtle Species

Four Annex IV species of turtle are known to occur in Ireland: leatherback turtle (*Dermochelys coriacea*), Kemp's Ridley turtle (*Lepidochelys kempii*), loggerhead turtle (*Caretta caretta*) and hawksbill turtle (*Eretmochelys imbricata*). All of the aforementioned species have been recorded along the south coast of Ireland (NBDC, 2024g). Leatherback turtle sightings data show several records along the south coast and within the AoI. The most recent recording was in 2021 where one animal was recorded stranded on Tramore beach in Co. Waterford (NBDC, 2024h). The most recent sighting of Kemp's Ridley turtle was in 2016 where the animal washed up stranded on Tramore beach in Co. Waterford (NBDC, 2024i) and the most recent recording of a hawksbill turtle was in 1983 at Cork Harbour (NBDC, 2024j). Loggerhead turtle was most recently recorded in 2015 where one animal was found stranded at Ballybrannigan beach in Co. Cork and one was stranded at Portally beach in Co. Waterford (NBDC, 2024k). Between 2004 and 2023[8], 224 observations of leatherback turtles were recorded in Irish waters (NBDC, 2024h). Leatherbacks are known to have an 'atypical migration pattern', as while they must return to tropical waters to breed and reach preferred nesting grounds, they are known to spend the summer months in productive temperate waters, like Ireland's, feeding on jellyfish and sea squirts (Doyle, 2007).

It can, therefore, be concluded that sightings of turtles within the AoI are possible but rare, with leatherback and loggerhead turtles being the most common species. The most recent sighting of turtles within the AoI was in 2015 and 2021 where two leatherback turtles were recorded as dead at Tramore Beach.

3.4.3 Desk study summary

The above sections discusses the species most likely to be found in the Celtic Sea off the Cork and Waterford coast, based on desk-based research. However, all cetaceans are considered in the examination of impacts and are assessed in Section 3.5 below, grouped according to hearing frequency (see Table 3.2). Data on turtle hearing is limited, and as turtle occurrence in Irish waters is rare, a brief, qualitative assessment is undertaken.

3.5 Examination of Impacts to Strict Protections for Annex IV Cetacean and Turtle Species

With respect to cetaceans and turtles, the following potential routes to impact are associated with the proposed marine SI works:

- Underwater noise; and
- Collision risk with survey vessels

3.5.1 Underwater Noise Impacts - Cetaceans

3.5.1.1 Underwater Noise Assessment

An underwater (subsea) noise assessment was carried out using indicative noise sources for the marine SI works. The assessment and results are presented in the accompanying Subsea Noise Technical Report in Appendix A. Only survey works with the potential to emit underwater noise (and therefore impact upon Annex IV marine species) are considered in this assessment.

When assessing the potential impact of underwater noise sources on the marine environment a range of variables such as source level, frequency, duration, and directivity were considered. Increasing the distance

[8] No data for 2024 was available when accessed October 2024

from the sound source usually results in attenuation with distance. The factors that affect the way noise propagates underwater include: water column depth, pressure, temperature gradients, salinity, as well as water surface and seabed type and thickness. When sound encounters the seabed the amount of noise/sound reflected back depends on the composition of the seabed, i.e., mud or other soft sediment will reflect less than rock. The SI works area and nearby surroundings are characterised by water depths of 0-70 m with a relatively gentle increase in depth with distance from the shore. The sediment properties are varied, from soft, muddy sediment to harder gravelly sediments, with some areas being exposed or near-exposed bedrock of chalk, limestone or sandstone (generally found within 20 km of the coast).

The active acoustic instruments, such as those proposed for this survey, operate by emitting extremely short pulses and are highly directional with narrow beams (Ruppell et al, 2022). While the swathe of the sonars and echosounders will have a maximum range of 6 to 60 m in diameter, many of the sources used for this survey, such as multibeam, side-scan sonar, sub-bottom profilers (SBP), ultra short base-line positioning system (USBL), chirper/pinger, and sparker operate at high frequency and attenuate quickly as they spread from the source. Coupled with the narrow beam angle and short duty cycles ('on' for microseconds or milliseconds per second) means that surveying sonars have relatively low acoustic impact.

Assessment Criteria

The NPWS/DAHG "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" 2014 (Department of Arts, Heritage and the Gealtacht, 2014) contains the following statement:

"It is therefore considered that anthropogenic sound sources with the potential to induce TTS in a receiving marine mammal contain the potential for both (a) disturbance, and (b) injury to the animal."

This states that TTS constitutes an injury and should thus be the main assessment criteria[9]. However, the guidance goes on to specify the use of thresholds from a 2007 publication (Southall et al., 2007) which has since been superseded (Southall, et al., 2019; National Oceanic and Atmospheric Administration, 2024) and no longer represents best available science, nor reflects best practice internationally. Thus, the following excerpt from the guidance is relevant:

"The document will be subject to periodic review to allow its efficacy to be reassessed, to consider new scientific findings and incorporate further developments in best practice."

As there has been no such update to date, but the guidance clearly states its intention to consider new scientific findings, we have applied the latest guidance (National Oceanic and Atmospheric Administration, 2024), reflecting the current best available method for assessing impact from noise on marine mammals. This means that it is auditory injury "AUD INJ" (previously "PTS")[10] that is the criteria for injury, not "TTS".

Auditory injury in cetaceans can be defined as AUD INJ leading to non-reversible auditory injury, or as a TTS in hearing sensitivity, which can have negative effects on the ability to use natural sounds (e.g., to communicate, navigate, locate prey) for a period of minutes, hours, or days. With increasing distance from the sound source, where it is audible to the animal, the effect is expected to diminish through identifiable stages (i.e., AUD INJ or TTS in hearing, avoidance, masking, reduced vocalisation) to a point where no significant response occurs. Factors such as local propagation and individual hearing ability can influence the actual effect (DAHG, 2014).

Cetacean species can be split into functional hearing groupings, according to their frequency-specific hearing sensitivity (Southall *et al*., 2019). Minke, fin and humpback whales are considered low frequency cetaceans (LF), common, bottlenose and Risso's dolphin are considered high frequency cetaceans (HF), harbour porpoise a very high frequency cetacean (VHF). See Table 3.2 below for a list of cetacean species contained within each functional hearing group.

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[9] Injury being the qualifying limit in the Irish Wildlife Act 1976, section 23, 5c : https://www.irishstatutebook.ie/eli/1976/act/39/enacted/en/print#sec23

[10] Based on NOAA revision of underwater noise guidelines (NOAA, 2018), (Southhall et al., 2019) and (Finneran, 2024). Weighting have been modified to include more low-frequency content (especially for the HF group), along with an increase in the threshold values for HF and VHF, but a decrease for PW and OW groups. The steepness of the weightings at high frequencies has increased so frequencies above region of best hearing are now excluded more effectively. The nomenclature has changed too, while the use of "TTS" remains unchanged to refer to temporary threshold shift, the use of "PTS" (permanent threshold shift) has stopped, with the shorthand "AUD INJ" taking its place (Auditory Injury), to highlight the severity of the effect.

Table 3.2 Functional Marine Mammal Hearing Groups for Marine Mammal Species

Southall *et al.* (2019) Hearing Group Name	Species Included in Group
Low-frequency cetaceans (LF)	Baleen whales (minke, fin and humpback whale).
High-frequency cetaceans (HF)	Most toothed whales and dolphins (bottlenose, common and Risso's dolphin, killer, and pilot whales).
Very high-frequency cetaceans (VHF)	Certain toothed whales and porpoises (harbour porpoise).
Other marine carnivores in water (OCW)	Includes sea lions, walrus, otters.
Phocid carnivores in water (PCW)	Earless seals (including harbour and grey seal).

A summary of the equipment likely to be used in the SI Works is presented in Table 4.1 of the accompanying Subsea Noise Technical Report.

Should the noise levels from sources provided in the accompanying Subsea Noise Technical Report exceed the thresholds (Table 3.3), there is the potential for underwater noise generated during the geophysical survey to result in injury and/or disturbance to Annex IV marine mammal species in the vicinity of the SI works.

Both the criteria for impulsive and non-impulsive sound are relevant given the nature of the sound sources used during the SI Works. The relevant AUD INJ and TTS criteria proposed by NOAA (2024) are summarised in Table 3.3 which addresses peak pressure levels (L_p) and sound exposure levels (SEL).

Table 3.3 AUD INJ and TTS onset acoustic thresholds (Southall et al., 2019; Tables 6 and 7)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		AUD INJ	TTS	AUD INJ	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	222	216	-	-
	SEL, (LF weighted)	183	168	197	177
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (MF weighted)	193	178	201	181
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (HF weighted)	159	144	181	161
Phocid carnivores in water (PCW)	L_P, (unweighted)	223	217	-	-
	SEL, (PW weighted)	183	168	195	175
Other marine carnivores in water (OCW)	L_P, (unweighted)	230	224	-	-
	SEL, (OW weighted)	185	170	199	179
Sirenians (SI) (NOAA only)	L_P, (unweighted)	225	219	-	-
	SEL, (OW weighted)	186	171	186	180

Assessment Results

To assess the impacts of the geophysical survey, each type of sub-bottom profiler (SBP) was modelled as a different scenario. Each scenario assumed that the vessel, SSS, USBL and MBES sources were active, with only the type of SBP changing between the scenarios modelled. The results have been summarised below to present the 'worst-case scenario', and it should be noted that no mitigation (i.e. soft-start measures, or marine mammal observers) has been applied at this stage.

Parametric SBP and chirper/pinger, no mitigation:

- LF group (minke, fin and humpback whale), auditory injury could occur within a radius of <10 m from the sound source, and TTS could occur within 230 m.
- HF group (bottlenose/common dolphin), auditory injury could occur within a radius of 20 m from the sound source, and TTS could occur within 200 m.
- VHF group (harbour porpoise), auditory injury could occur within a radius of 250 m of the sound source, while TTS could occur within 4,100 m.
- For all cetaceans, behavioural disturbance could occur out to 16 km.

Sparker and boomer, no mitigation:

- LF group (minke, fin and humpback whale), auditory injury could occur within a radius of <40 m from the sound source, and TTS could occur within 1,200 m.
- HF group (bottlenose/common dolphin), auditory injury could occur within a radius of <10 m from the sound source, and TTS could occur within 90 m.
- VHF group (harbour porpoise), auditory injury could occur within a radius of 2,200 m from the sound source, while TTS could occur within 4,300 m.
- For all cetaceans, behavioural disturbance could occur out to 19 km.

Geotechnical survey, no mitigation:

- LF group (minke, fin and humpback whale), auditory injury could occur within a radius of <10 m from the sound source, and TTS could occur within 180 m.
- HF group (bottlenose/common dolphin), auditory injury could occur within a radius of <10 m from the sound source, and TTS could occur within 130 m.
- VHF group (harbour porpoise), auditory injury could occur within a radius of 180 m from the sound source, while TTS could occur within 3,800 m.
- For all cetaceans, behavioural disturbance could occur out to 14 km.

ADCP, no mitigation:

- LF group (minke, fin and humpback whale), auditory injury and TTS could occur within a radius of <10 m from the sound source.
- HF group (bottlenose/common dolphin), auditory injury and TTS could occur within a radius of <10 m from the sound source.
- VHF group (harbour porpoise), auditory injury could occur within a radius of 40 m from the sound source, while TTS could occur within 100 m.
- For all cetaceans, behavioural disturbance could occur out to 440 m, when applying the criterion strictly (unweighted for hearing groups), however, given the ADCPs main energy is above 300 kHz (outside the hearing range of the receivers) the behavioural disturbance ranges while accounting for the receivers' hearing capabilities has also been included. Accounting for the frequency dependent sensitivity of the receivers, the behavioural disturbance range decreases to <10 m for all groups.

This assessment concludes that there is risk of inducing hearing injury (AUD INJ) and TTS following noise from the SI works, but with the implementation of suitable mitigation as outlined below, these can be mitigated effectively to make the risks of auditory injury and TTS low for all hearing groups assessed.

Behavioural disturbance ranges of up to 19 km for the geophysical survey, and 14 km for the geotechnical survey were modelled, however, effects due to behavioural disturbance are expected to be short term and intermittent, with the geophysical and geotechnical surveys mobilising as separate campaigns or being carried out concurrently. There is anticipated to be high potential for the rapid recovery of populations to baseline levels upon completion of the surveys such that there are no implications in the long-term for cetacean populations. Furthermore, the number of individual cetaceans affected is expected to be low, representing an extremely small proportion of the wider reference populations (IAMMWG, 2022, 2023). Therefore, the risk of disturbance to cetaceans is considered to be low.

3.5.1.2 Mitigation

The mitigation measures proposed will reduce the impact of AUD INJ and TTS on cetaceans from the proposed SI works (reproduced from Section 7.1 in the accompanying Subsea Noise Technical Report):

Geophysical surveys

The geophysical survey (sparker and boomer SBP) could give rise to risk ranges for AUD INJ within 2,200 m of the sound source and TTS within 4,300 m for VHF hearing group (worst-case scenario: sparker or boomer SBP, no mitigation applied).

The geophysical survey (parametric SBP and chirper/pinger) could give rise to risk ranges for AUD INJ within 250 m of the sound source and TTS within 4,100 m for VHF hearing group (worst-case scenario: parametric SBP and chirper/pinger, no mitigation applied).

Given the risk of exceedance of the AUD INJ and TTS thresholds, the following mitigation, in line with DAHG (2024), will be applied to limit risks to animals, by establishing their likely absence from the zone of injury prior to commencement of the noisy activity (pre-start monitoring) and by providing enough time for them to vacate the area (soft start).

The application of a soft start reduces risk ranges as follows:

- *Sparker (UHRS) or boomer type SBP:* A 30-minute soft start lowers the AUD INJ risk to below 500 m (390 m) for VHF species and TTS within 2,500 m for VHF species. The inclusion of a 30-minute soft start reduces AUD INJ and TTS to <10 m of the sound source for all other hearing groups.
- *Parametric or chirper/pinger type SBP:* A 20-minute soft start lowers AUD INJ risk to <10 m for all hearing groups and TTS within 2,900 m for VHF species. The inclusion of a 20-minute soft start reduces TTS to <10 m for all other hearing groups.

A qualified and experienced marine mammal observer (MMO) will be appointed to monitor for marine mammals within the monitored zone i.e. 500 m radial distance of the sound source intended for use. The 500 m pre-start-up survey will be conducted at least 30 minutes before the sound-producing activity, i.e. those activities described in Section 2.4 are due to commence. Sound-producing activity shall not commence until at least 30 minutes have elapsed with no marine mammals detected within the monitored zone (500 m) by the MMO. In commencing sound producing activities using the equipment listed above, a soft start procedure (i.e. 30 or 20-minute soft-start depending on the activity) must be used. Once the soft start procedure commences, there is no requirement to halt or discontinue the procedure at night-time, nor if weather or visibility conditions deteriorate nor if marine mammals occur within a 500 m radial distance, of the sound source. If there is a break in sound output for a period greater than 30 minutes (e.g., due to equipment failure, shut-down, survey line or station change) then all pre-start monitoring and a subsequent soft start procedure (where appropriate following pre-start monitoring) must be undertaken, in cognisance of DAHG (2014). These measures will ensure that impacts on cetaceans will be reduced to the lowest possible level to ensure there is no significant risk to marine mammals from impulsive noise.

As stated in Section 3.5.1.1, the DAHG (2014) guidance has been superseded by the most recent scientific evidence, NOAA (2024), which was applied for this assessment and reflects the best available methodology for assessing impact from noise on marine mammals. Therefore, given the most up to date scientific guidance, auditory injury (AUD INJ) is the criteria for injury, not TTS as stated in DAHG (2014). TTS is a temporary, reversible increase in the threshold of audibility at a specified frequency (NOAA, 2024). Once sound producing activities cease, TTS will cease, therefore no permanent or irreversible damage will occur to the VHF hearing group due to the proposed SI works. TTS risk ranges noted above will cause brief disturbance within the ranges stated above, however, harbour porpoise (VHF hearing group) are wide-ranging mobile species and it is likely they will utilise the wider environs of the CIS MU during the proposed SI works.

Therefore, with the inclusion of the mitigation measures above (soft start and MMO observer) AUD INJ and TTS will be reduced to as low as practically possible, and auditory injury will be avoided.

Geotechnical surveys

The vessel itself will act as a soft start to the noise expected from the geotechnical survey. With modest injury ranges, even with no soft start; 180 m AUD INJ risk for VHF group and below 20 m for the remaining groups, the presence of the vessel 20 minutes prior to vibro-coring start (the noisiest activity) will be sufficient to reduce the risk range for AUD INJ to <10 m. Risk ranges for exceeding TTS is below 550 m for all hearing groups except VHF hearing group which risks exceeding the AUD INJ threshold to a range of 3,800 m with no soft start. For the VHF group, a soft start of 20 minutes reduces the TTS risk range to 2,600 m.

For the geotechnical SI works a qualified and experienced MMO will be appointed to monitor for marine mammals within the monitored zone i.e. 500 m radial distance of the sound source intended for use. The 500 m pre-start-up survey will be conducted at least 30 minutes before the sound-producing activity is due to commence. Sound-producing activity shall not commence until at least 30 minutes have elapsed with no marine mammals detected within the monitored zone (500 m) by the MMO. It is expected that the presence of the vessel prior to switching on DP will act as a soft start prior to geotechnical survey works.

As stated in Section 3.5.1.1, the DAHG (2014) guidance has been superseded by the most recent scientific evidence, NOAA (2024), which was applied for this assessment and reflects the current best available method for assessing impact from noise on marine mammals. Therefore, given the most up to date scientific guidance, auditory injury (AUD INJ), which was previously PTS, is the criteria for injury not TTS as stated in DAHG (2014). TTS is a temporary, reversible increase in the threshold of audibility at a specified frequency (NOAA, 2024), once sound producing activities cease the TTS will cease, therefore no permanent or irreversible damage will occur to the VHF hearing group due to the proposed SI works. TTS risk ranges noted above will cause brief disturbance within the ranges stated above, however, harbour porpoise (VHF hearing group) are wide-ranging mobile species and it is likely they will utilise the wider environs of the CIS MU during the proposed SI works.

Therefore, with the inclusion of the mitigation measures above (soft start and MMO observer) AUD INJ and TTS will be reduced to as low as practically possible.

ADCP

The ADCP's main energy will be specified to be equal to or greater than 300 kHz (outside the hearing range of the receivers). Accounting for the frequency dependent sensitivity of the receivers, all impact ranges decrease to <10 m for all hearing group, and therefore no mitigation is required for ADCPs.

3.5.1.3 Underwater noise assessment conclusion

For the geophysical survey (sparker/boomer type SBP), the inclusion of a 30-minute soft start will reduce AUD INJ to within 390 m for the VHF hearing group and TTS within 2,500 m. A 30-minute soft start will reduce AUD INJ and TTS <10 m for all other hearing groups. While a 20-minute soft start prior to parametric chirper/pinger SI works reduces AUD INJ to < 10 m of the sound source for all hearing groups and TTS within 2,900 m for VHF hearing group. An MMO observer will also conduct a 500 m pre-start up survey as discussed above.

For the geotechnical survey, with the inclusion of a 30 minute-soft start (i.e. presence of the vessel prior to activities), AUD INJ risk range is reduced to < 10 m of the sound source for all hearing groups while TTS is within 2,000 m for VHF hearing group. As stated above, the principal noise from the geotechnical surveys is the vessel itself. It is expected that the presence of the vessel while conducting the SI works will act as a soft start giving species time to vacate the area and/or move away from the vessel prior to works commencing, and an MMO will be in place to ensure no marine mammals are detected within 500 m of the vessel prior to Dynamic Positioning use.

As stated above, for the ADCP, AUD INJ risk ranges are within 40 m of the sound source for VHF hearing group and < 10 m for all remaining hearing groups, while TTS could occur within 100 m for VHF hearing group and < 10 m for all other hearing groups without the inclusion of a soft start, therefore injury/disturbance is expected to be minimal. Behavioural disturbance could occur out to 440 m, however given the ADCPs main energy is above 300 kHz (outside the hearing range of the receivers) the behavioural disturbance ranges while accounting for the receivers' hearing capabilities has also been included. Accounting for the frequency dependent sensitivity of the receivers, the behavioural disturbance range decreases to <10 m for all groups.

As stated above, behavioural disturbance ranges to 14 km for the geotechnical SI works and 19 km for the geophysical SI works, effects are expected to be short term and intermittent as both SI campaigns are unlikely to mobilise at the same time (See Section 2.3.4 above). There is potential for rapid recovery of populations to baseline levels upon completion of the surveys such that there are no implications in the long-term for cetacean populations. Therefore, the number of individual cetaceans affected is expected to be low, representing an extremely small proportion of the wider reference populations (IAMMWG, 2022, 2023).

3.5.2 Underwater Noise Impacts - Turtles

Data on turtle hearing is limited, however, turtles are adapted to detect sound in water and are known to detect sound at less than 1,000 Hz (Popper et al., 2014). The majority of the survey equipment to be used operates across a higher frequency range (see Table 4-1 in the Subsea Noise Technical Report). In addition, injury and disturbance to turtles due to noise impacts is unlikely given the rarity of turtle occurrence. Due to the rarity of turtles within the AoI, the limited scale and duration of the survey activities, it is concluded that there will be no significant disturbance, injury, or death of turtle species as a result of the SI works. There will be no deterioration or destruction of breeding sites or resting places. Therefore, in view of the current evidence base, it is considered that the proposed SI works will conform with the system of strict protection of turtles under Article 12 of the Habitats Directive.

3.5.3 Collision Risk

Vessel strikes are a known cause of mortality in marine mammals (Laist et al., 2001). Non-lethal collisions have also been documented (Laist et al., 2001; Van Waerebeek et al., 2007). Injuries from such collisions can be divided into two broad categories: blunt trauma from impact and lacerations from propellers. Injuries may result in individuals becoming vulnerable to secondary infections or predation.

It is expected that a maximum of eight vessels would be operating at any one time within the AoI (see section 2.3.4 for details), although it is considered highly unlikely that all vessels will operate at the same time. For the geophysical surveys, the vessels will be travelling in a predefined trajectory. It is considered that this will allow animals to predict the movement of the vessels and therefore avoid collisions. The other survey vessels (i.e. benthic survey vessels, geotechnical survey vessel and metocean equipment deployment vessels) will be stationary for extended periods throughout their operations which will reduce the potential for collision with these vessels.

The AoI supports reasonably high levels of baseline marine traffic, with cargo vessels, fishing boats and pleasure craft traversing the AoI to access commercial and fishing ports and harbours in the region. It is, therefore, reasonable to assume that cetaceans in the area are exposed to vessel traffic on a regular basis and may exhibit some habituation. In addition, the increase in vessel traffic at any one time is considered to be very low (i.e. up to eight vessels operating within the AoI). On this basis it is predicted that collisions between survey vessels and cetaceans will be extremely unlikely and there is no likelihood of significant effects occurring. On this basis it is predicted that collisions between survey vessels and cetaceans will be extremely unlikely and there is no likelihood of significant effects occurring.

Turtles have the potential to occur within the vicinity of the AoI in low numbers, though it extremely unlikely. While turtles are vulnerable to collision risk whilst surfacing, it is highly likely that survey vessels will be stationary throughout survey operations for significant periods of time and those which are moving are unlikely to be travelling fast. While turtles would have limited tolerance to a collision if it occurred, there is a high likelihood of avoidance in response to vessel noise. Therefore, collision risk in sea turtles is considered to be low.

4 Summary & Conclusion

In summary, the potential for injury or disturbance to occur to Annex IV cetacean and turtle species as a result of the SI works is considered to be low. This risk will be further reduced by the implementation of mitigation, as outlined in this document and the Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (DAHG, 2014).

It is concluded that the SI works will not deliberately capture or kill any marine mammal species listed under Annex IV of the Habitats Directive. The SI works will not disturb marine mammal Annex IV species during periods of breeding or migration, and breeding or resting places of such Annex IV species will not be damaged or destroyed. The conservation status of the marine mammal Annex IV species will not be impacted by the proposed SI works. The habitat available to marine mammal Annex IV species will also continue to be sufficiently large to maintain its populations on a long-term basis.

Following the assessment of the evidence base and available information on marine mammal Annex IV species, it is concluded that the SI works comply with the system of strict protections afforded by Article 12 of the Habitats Directive and Regulations 51 and 52 of the European Communities (Birds and Natural Habitats) Regulations 2011, as amended.

It is concluded that the proposed SI works will not give rise to significant impacts to cetacean and turtle species listed under Annex IV of the Habitats Directive.

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Appendix A
Subsea Noise Technical Report

C2 - Restricted

POWERING UP OFFSHORE SOUTH COAST

Subsea Noise Technical Report

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27 January 2025

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Document status

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S3 P01	Draft for Client Review	RSP/SM	JM	GMcE	04/10/2024
S3 P03	Client Comments	RSP/SM	JM	GMcE	23/10/2024
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Glossary

Term	Meaning
Decibel (dB)	A relative scale most commonly used for reporting levels of sound. The actual sound measurement is compared to a fixed reference level and the "decibel" value is defined to be $10 \cdot \log_{10}$(“actual”/”reference”), where (“actual”/”reference”) is a power ratio. The standard reference for underwater sound pressure is 1 micro-Pascal (μPa), while 20 micro-Pascals is the standard for airborne sound. The dB symbol is often followed by a second symbol identifying the specific reference value (i.e. re 1 μPa).
Grazing angle	A glancing angle of incidence (the angle between a ray incident on a surface and the line perpendicular to the surface).
Auditory Injury (AUD INJ)	A total or partial permanent loss of hearing caused by some kind of acoustic trauma. AUD INJ results in irreversible damage to the sensory hair cells of the ear and thus, a permanent reduction of hearing acuity.
Temporary Threshold Shift (TTS)	Temporary loss of hearing as a result of exposure to sound over time. Exposure to high levels of sound over relatively short time periods will cause the same amount of TTS as exposure to lower levels of sound over longer time periods. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time.
Sound Exposure Level (SEL)	The cumulative sound energy in an event, formally: “ten times the base-ten logarithm of the integral of the squared pressures divided by the reference pressure squared”. Equal to the often seen “L_E” or “dB SEL” quantity. Defined in: ISO 18405:2017, 3.2.1.5
Sound Pressure level (SPL)	The average sound energy over a specified period of time, formally: “ten times the base-ten logarithm of the arithmetic mean of the squared pressures divided by the squared reference pressure”. Equal to the deprecated “RMS level”, “dB_{rms}” and to L_{eq} if the period is equal to the whole duration of an event. Defined in ISO 18405:2017, 3.2.1.1
Peak Level, Peak Pressure Level (L_P)	The maximal sound pressure level of an event, formally: “ten times the base-ten logarithm of the maximal squared pressure divided by the reference pressure squared” or “twenty times the base-ten logarithm of the peak sound pressure divided by the reference pressure, where the peak sound pressure is the maximal deviation from ambient pressure”. Defined in ISO 18405:2017, 3.2.2.1
Source Level (SL)	Taken here to mean the level (SEL/SPL/L_P) at 1 meter range. If not otherwise stated, it is assumed the source is omnidirectional (equal level in all directions). For sources larger than 1 m in radius, the Source Level is back-calculated to 1 m.
Decidecade	Used to refer to a step in frequency, similar to “one-third-octave”, defined as a ratio of $10^{0.1} \approx 1.259$ (one third octave is $21/3 \approx 1.260$). Used interchangeably with “3rd octave”.
Noise	Sound that is irrelevant, unwanted or harmful to the organism(s) in question. Noise is often detrimental, but not necessarily so.
Kurtosis	A statistical measure of “peakedness” of a distribution (of e.g. pressure values in a sound pulse). Defined in ISO 5479:1997

Acronyms

Term	Meaning
ADD	Acoustic Deterrent Device
ADCP	Acoustic Doppler Current Profiler
LF	Low Frequency (Cetaceans)
HF	High Frequency (Cetaceans)
VHF	Very High Frequency (Cetaceans)
MF	Mid Frequency (Cetaceans) – **DEPRECATED** only for reference to NOAA/NMFS 2018 groups
OW/OCW	Otariid pinnipeds/Other Carnivores in water (refers to the same weighting and animal groups)
PW/PCW	Phocid pinnipeds
NMFS	National Marine Fisheries Service
RMS	Root Mean Square
SEL	Sound Exposure Level, [dB]
SPL	Sound Pressure Level, [dB]
L_P	Peak Pressure Level, [dB]
SL	Source Level [dB]
TTS	Temporary Threshold Shift
PTS	Permanent Threshold Shift – **DEPRECATED**, see “AUD INJ”
AUD INJ	Auditory Injury (synonymous with deprecated “PTS”)
SSS	Side Scan Sonar – Towed sonar device typically positioned 10-15 m above the sediment. Its main purpose is to characterise the sediment surface texture.
MBES	Multibeam Echosounder – Uses multiple narrow beams to measure the depth across a swath below the vessel.
SBP	Sub-Bottom Profiler – Any device/system that uses acoustics to record echoes from within the sediment. Examples include seismic arrays, sparkers, boomers, chirpers, pingers and associated recorder array.
USBL	Ultra Short Baseline Array – Small array of at least 4 hydrophones and a pinger to measure positions of equipment under water.
UHRS	Ultra High-Resolution Seismic survey – Usually a sparker driven sub-bottom characterisation system.
c.	Circa, i.e., approximately
CPT	Cone Penetration Testing – insertion/pushing of rod with standardised, cone-shaped front into sediment to measure various characteristics of the sediment.

Units

Unit	Description
dB	Decibel (Sound)
Hz	Hertz (Frequency)
kHz	Kilohertz (Frequency)
kJ	Kilojoule (Energy)
km	Kilometre (Distance)
km^2	Kilometre squared (Area)
m	Metre
ms	Millisecond (10^{-3} seconds) (Time)
ms^{-1} or m/s	Metres per second (Velocity or speed)
kn	Knots (speed), 1 kn = 0.514 m/s, 1 m/s = 1.944 kn
µPa	Micro Pascal
Pa	Pascal (Pressure: newton/m^2)
psu	Practical Salinity Units (parts per thousand of equivalent salt in seawater, weight-based)
kg/m^3	Specific density (of water, sediment or air)
Z	Acoustic impedance [$kg/(m^2 \cdot s)$ or $(Pa \cdot s)/m^3$]

Units will generally be enclosed in square brackets e.g.: "[m/s]"

1 INTRODUCTION

This Subsea Noise Technical Report presents the results of a desktop study considering the potential effects of underwater noise on the marine environment from the proposed site investigation works (the “SI Works”), in particular those elements of the SI works consisting of marine geophysical and marine geotechnical surveys off the south coast of Ireland from the High Water Mark (HWM) out into the North Celtic Sea. The other surveys to be undertaken as part of the SI Works, have not been modelled as they will either not result in underwater noise or will not have any appreciable effect on receptors, e.g. marine mammals. The aim of the SI Works is to acquire data to a high quality and specification for the Area of Interest (AoI) which is the area subject to the Maritime Usage Licence (MUL) application . The total AoI encompasses 2,336 km².

The assessment presented in this Subsea Noise Technical Report is based on the entire AoI.

The sediment within the AoI survey area is fine sand to fine gravel and water properties in the area are relatively stable given the lack of major river outflows and a modest tidal range (especially when considered in relation to the overall water depth).

Geophysical and geotechnical surveys such as those proposed for the SI Works use equipment that generate loud and potentially injurious noise to marine life, and as sound is readily transmitted in the underwater environment there is potential for the sound emissions to adversely affect marine life such as marine mammals or fish. At close ranges from a noise source with high noise levels, permanent or temporary hearing damage may occur to marine species, while at a very close range, gross physical trauma is possible. At long ranges (several kilometres) the introduction of any additional noise could for the duration of the activity, potentially cause behavioural changes. For example, changing the ability of species to communicate and to determine the presence of predators, food, underwater features and obstructions.

This report provides an overview of the potential effects due to underwater noise from the SI Works within the AoI on the surrounding marine environment based on the Southall et al. 2019, NOAA 2024 and Popper et al. 2014 frameworks for assessing impact from noise on marine mammals and fish.

Consequently, the primary purpose of the underwater noise assessment is to predict the likely range of onset for potential physiological and behavioural effects due to increased anthropogenic noise as a result of the SI Works.

1.1 Statement of Authority

Rasmus Sloth Pedersen is a Senior Project Scientist with RPS. He holds a master’s degree in biology, biosonar and marine mammal hearing from University of Southern Denmark. Rasmus has over 11 years’ experience as a marine biologist and over 9 years’ experience with underwater noise modelling and marine noise impact assessments. Rasmus has co-developed commercially available underwater noise modelling software, as well developed multiple source models for e.g. impact piling, seismic airgun arrays and sonars.

John Mahon is an Associate in Acoustics with RPS. He holds a BA BAI in Mechanical Engineering from Trinity College Dublin (2004) and a PhD in Acoustics and Vibration from Trinity College Dublin (2008). He is a Chartered Engineer with Engineers Ireland. John has 20 years’ experience in environmental projects including planning applications and environmental impact assessments for a wide range of strategic infrastructure projects.

Gareth McElhinney is Technical Director in the Environmental Services Business Unit in RPS. He has over 24 years’ experience. He holds an honours degree in Civil Engineering (B.E.) from NUI, Galway, a postgraduate diploma in Environmental Sustainability from NUI, Galway, and a Master’s in Business Studies from the Irish Management Institute/ UCC. Gareth is also a Chartered Engineer and Project Management Professional with the Project Management Institute (PMI-PMP). He has managed the delivery of numerous environmental projects including marine and terrestrial projects that have required environmental impact assessment, appropriate assessment, and Annex IV species reports.

2 ASSESSMENT CRITERIA

2.1 General

To determine the potential spatial range of injury and disturbance, assessment criteria have been developed based on a review of available evidence including national and international guidance and scientific literature. The following sections summarise the relevant assessment criteria and describe the evidence base used to derive them.

Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Assessment criteria generally separate sound into two distinct types, as follows:

- **Impulsive sounds** which are typically transient, momentary (less than one second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI, 2005; ANSI, 1986; NIOSH, 1998). This category includes sound sources such as seismic surveys, impact piling and underwater explosions. Additionally included here are sounds under 1 second in duration with a weighted kurtosis over 40 (see note below*).
- **Non-impulsive** (and continuous) sounds which can be broadband, narrowband or tonal, momentary, 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 vibro-piling, running machinery, some sonar equipment and vessels. Additionally included here are sounds over 1 second in duration with a weighted kurtosis under 40 (see note below*).

  * Note that the European Guidance: "Monitoring Guidance for Underwater Noise in European Seas, Part II: Monitoring Guidance Specifications" (MSFD Technical Subgroup on Underwater Noise, 2014) includes sonar as impulsive sources (see Section 2.2). However, the guidance suggests that *"all loud sounds of duration less than 10 seconds should be included"* as impulsive.

  This contradicts research on impact from impulsive sounds suggesting that a limit for "impulsiveness" can be set at a kurtosis[1] of 40 (Martin, et al., 2020). See examples in Appendix A, Impulsiveness.

  This latter criterion has been used for classification of impulsive versus non-impulsive for sonars and similar sources. The justification for departing from the MSFD criterion is that the Southall et al. 2019 and the Popper et al. 2014 framework limits are based on the narrower definition of impulsive as given in "Impulsive sounds" above.

There is scope for some sounds to be classified as both impulsive and non-impulsive, depending on the criteria applied. Examples are pulses from sonar-like sources that can contain very rapid rise times (<0.5 ms), sweep a large frequency range and have high kurtosis. However, given that the scientific work carried out to identify impulsive thresholds were done with "pure" impulses (from a near instantaneous event), sonar-like sounds are sometimes not included in this, impulsive, category. This argument ignores that sounds used for establishing the non-impulsive thresholds (often narrowband slowly[2] rising pulses), are markedly less impulsive (lower kurtosis, narrower bandwidth) than what is sometimes seen in pulses from sonar-like sources and are thus also not representative for all sonar-like pulses.

Given impulsive sound's tendency to become less impulsive with increased range, a minimal range can be established where the noise is no longer impulsive (here kurtosis <40 is used) (Appendix A, Impulsiveness). This range is established using raytracing, but as the effect varies with exact depth and range of source and receiver, the transition range to non-impulsive used for exposure modelling is doubled from the modelled range where kurtosis goes below 40.

The acoustic assessment criteria for marine mammals and fish in this report has followed the latest international guidance (based on the best available scientific information), that are widely accepted for assessments in the UK, Europe and worldwide (Southall, et al., 2019; Popper, et al., 2014; National Oceanic and Atmospheric Administration, 2024).

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[1] Statistical measure of the asymmetry of a probability distribution.

[2] Slowly in this context is >10 ms – slow relative to the integration time of the auditory system of marine mammals.

2.2 Effects on Marine Animals

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, to which an additional zone has been added "zone of temporary hearing loss". These are:

- **The zone of audibility**: This is defined as the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will affect the animal.
- **The zone of masking**: This is defined as the area within which sound can interfere with the 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 animals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall sound level). Continuous sounds will generally have a greater masking potential than intermittent sound due to the latter providing some relative quiet between sounds. Masking only occurs if there is near-overlap in sound and signal, such that a loud sound at e.g., 1000 Hz will not be able to mask a signal at 10,000 Hz[3].
- **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. For most species there is very little data on response, but for species like harbour porpoise there exists several studies showing a relationship between received level and probability of response (Graham IM, 2019; Sarnoci´nska J, 2020; BOOTH, 2017; Benhemma-Le Gall A, 2021). This zone is quantified here with the use of behavioural thresholds (Table 2-2 & Table 2-3).
- **The zone of temporary hearing loss**: The area where the sound level is sufficient to cause the auditory system to lose sensitivity temporarily, causing loss of "acoustic habitat": the volume of water that can be sensed acoustically by the animal. This hearing loss is typically classified as Temporary Threshold Shift ("TTS", see section 2.3 & 2.5).
- **The zone of injury / permanent hearing loss**: This is the area where the sound level is sufficient to cause permanent hearing loss in an animal. This hearing loss is typically classified as Auditory Injury ("AUD INJ", see section 2.3 & 2.5). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or acute mortal injuries are possible.

For this study, it is the zones of injury ("AUD INJ") that are of primary interest, along with estimates of behavioural impact ranges. To determine the potential spatial range of injury and behavioural change, 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.

2.2.1 Irish Guidance Interpretation

We note that the DAHG "Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters" 2014 (Department of Arts, Heritage and the Gealtacht, 2014) contains the following statement:

"It is therefore considered that anthropogenic sound sources with the potential to induce TTS in a receiving marine mammal contain the potential for both (a) disturbance, and (b) injury to the animal."

This states that TTS constitutes an injury and should thus be the main assessment criteria[4]. However, the guidance goes on to specify the use of thresholds from a 2007 publication (Brandon L. Southall, 2007) which has since been superseded (Southall, et al., 2019; National Oceanic and Atmospheric Administration, 2024)

[3] The exact limit of how near a noise can get to the signal in frequency before causing masking will depend on the receivers' auditory frequency resolution ability, but for most practical applications noise and signal frequencies will need to be within 1/3rd octave to start to have a masking effect.

[4] Injury being the qualifying limit in the Irish Wildlife Act 1976, section 23, 5c : https://www.irishstatutebook.ie/eli/1976/act/39/enacted/en/print#sec23

and no longer represents best available science, nor reflects best practice internationally. Thus, the following excerpt from the guidance is relevant:

"The document will be subject to periodic review to allow its efficacy to be reassessed, to consider new scientific findings and incorporate further developments in best practice."

As there has been no such update to date, but the guidance clearly states its intention to consider new scientific findings, we have applied the latest guidance (National Oceanic and Atmospheric Administration, 2024), reflecting the current best available method for assessing impact from noise on marine mammals. This means that it is "AUD INJ" (previously "PTS") that is the criteria for injury, not "TTS".

2.3 Thresholds for Marine mammals

The zone of injury in this study is classified as the distance over which a fleeing marine mammal can suffer AUD INJ leading to non-reversible auditory injury. Injury thresholds are based on a dual criteria approach using both un-weighted L_P (maximal instantaneous SPL) and marine mammal hearing weighted SEL. The hearing weighting function is designed to represent the sensitivity for each group within which acoustic exposures can have auditory effects. The categories include:

- **Low Frequency (LF) cetaceans**: Marine mammal species such as baleen whales (e.g. minke whale *Balaenoptera acutorostrata*).

- **High Frequency (HF) cetaceans**: Marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales (e.g., bottlenose dolphin *Tursiops truncatus* and white-beaked dolphin *Lagenorhynchus albirostris*).

- **Very High Frequency (VHF) cetaceans**: 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) (e.g., harbour porpoise *Phocoena phocoena*).

- **Phocid Carnivores in Water (PCW)**: True seals, earless seals (e.g., harbour seal *Phoca vitulina* and grey seal *Halichoreus grypus*);

- **Other Marine Carnivores in Water (OCW)**: Including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears.

- **Sirenians (SI)**: Manatees and dugongs. This group is only represented in the NOAA guidelines.

These weightings are used in this study and are shown in Figure 2-1. It should be noted that not all of the above hearing groups of marine mammals will be present in the SI Works AoI, but all hearing groups are presented in this report for completeness.

2024 Update to Guidance

There has been a recent update to the NOAA 2018 guidelines, with NOAA publishing their final draft of their revision of the NOAA 2018, the Southall et al. 2019 and a large review by the US Navy, published February 2024 (Finneran, 2024). This revision, although in draft is being implemented in the US and represents an increase in scientific understanding of the frequency specific noise levels (peak and exposure) that likely lead to TTS and auditory injury.

Generally, weightings have been modified (Figure 2-1) to include more low-frequency content (especially for the HF group), along with an increase in the threshold values for HF and VHF, but a decrease for PW and OW groups. The steepness of the weightings at high frequencies has increased so frequencies above region of best hearing are now excluded more effectively.

The nomenclature has changed too, while the use of "TTS" remains unchanged to refer to temporary threshold shift, the use of "PTS" (permanent threshold shift) has stopped, with the shorthand "AUD INJ" taking its place (Auditory Injury), to highlight the severity of the effect.

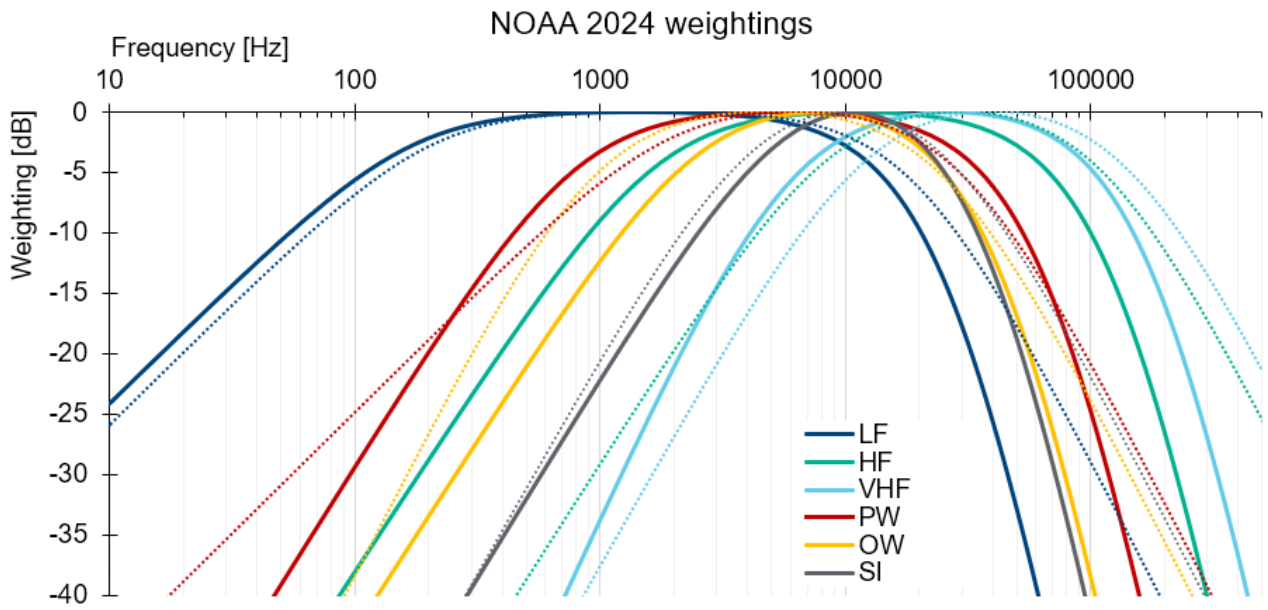

Figure 2-1: Auditory weighting functions for seals, whales and sirenians (National Oceanic and Atmospheric Administration, 2024). Older weightings in dotted lines for comparison.

Both the criteria for impulsive and non-impulsive sound are relevant for this study given the nature of the sound sources used during the SI Works. The relevant AUD INJ and TTS criteria proposed by NOAA 2024 are summarised in Table 2-1.

Table 2-1: AUD INJ and TTS onset acoustic thresholds (Southall *et al., 2019*; Tables 6 and 7)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		AUD INJ	TTS	AUD INJ	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	222	216	-	-
	SEL, (LF weighted)	183	168	197	177
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (MF weighted)	193	178	201	181
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (HF weighted)	159	144	181	161
Phocid carnivores in water (PCW)	L_P, (unweighted)	223	217	-	-
	SEL, (PW weighted)	183	168	195	175
Other marine carnivores in water (OCW)	L_P, (unweighted)	230	224	-	-
	SEL, (OW weighted)	185	170	199	179
Sirenians (SI) (NOAA only)	L_P, (unweighted)	225	219	-	-
	SEL, (OW weighted)	186	171	186	180

2.4 Disturbance to Marine Mammals

Disturbance thresholds for marine mammals are summarised in Table 2-2. Note that the non-impulsive threshold can often be lower than ambient noise for coastal waters with some human activity, meaning that ranges determined using this limit will tend to be higher than actual ranges. However, the levels are unweighted and ranges to threshold will be dominated by low-frequency sound, which for most hearing groups is outside their hearing range. For hearing groups with low thresholds this can mean that their range to TTS/AUD INJ is *larger* than the range to the behavioural threshold, e.g., the AUD INJ threshold for impulsive sound for the VHS group is 159 dB SEL (weighted), while the behavioural threshold is 160 dB SPL (unweighted). For a typical scenario, for 1 second's exposure (SEL equals SPL for 1-second durations) that means the range to the behavioural threshold will be larger than the range to the AUD INJ threshold (a difference of at least 1 dB). This effect will increase for noise with mostly low frequencies as they are "removed" by the weighting, and thus the comparison to the SEL threshold, but not from the comparison to the unweighted behavioural threshold. This is just one of the reasons why this behavioural threshold should be interpreted with caution.

Table 2-2: Disturbance Criteria for Marine Mammals Used in this Study based on Level B harassment of NMFS (National Marine Fisheries Service, 2005)

Effect	Non-Impulsive Threshold	Impulsive Threshold
Disturbance (all marine mammals)	120 dB SPL	160 dB SEL $_{\text{single impulse}}$ or 1-second SEL

2.5 Injury and Disturbance to Fishes

The injury criteria used in this noise assessment are given in Table 2-3 and Table 2-4 for impulsive noises and continuous noise respectively. L_P and SEL criteria presented in the tables are unweighted.

It's important to clarify that this lack of weighting for fishes reflects a lack of scientific consensus about the best method for applying frequency dependence to received levels for fishes, rather than a statement that fishes can hear all frequencies equally. Thus, fishes generally cannot hear above 10 kHz, and if they can the sensitivity is generally very poor (Figure 2-2, (Nedwell, et al., 2004)).

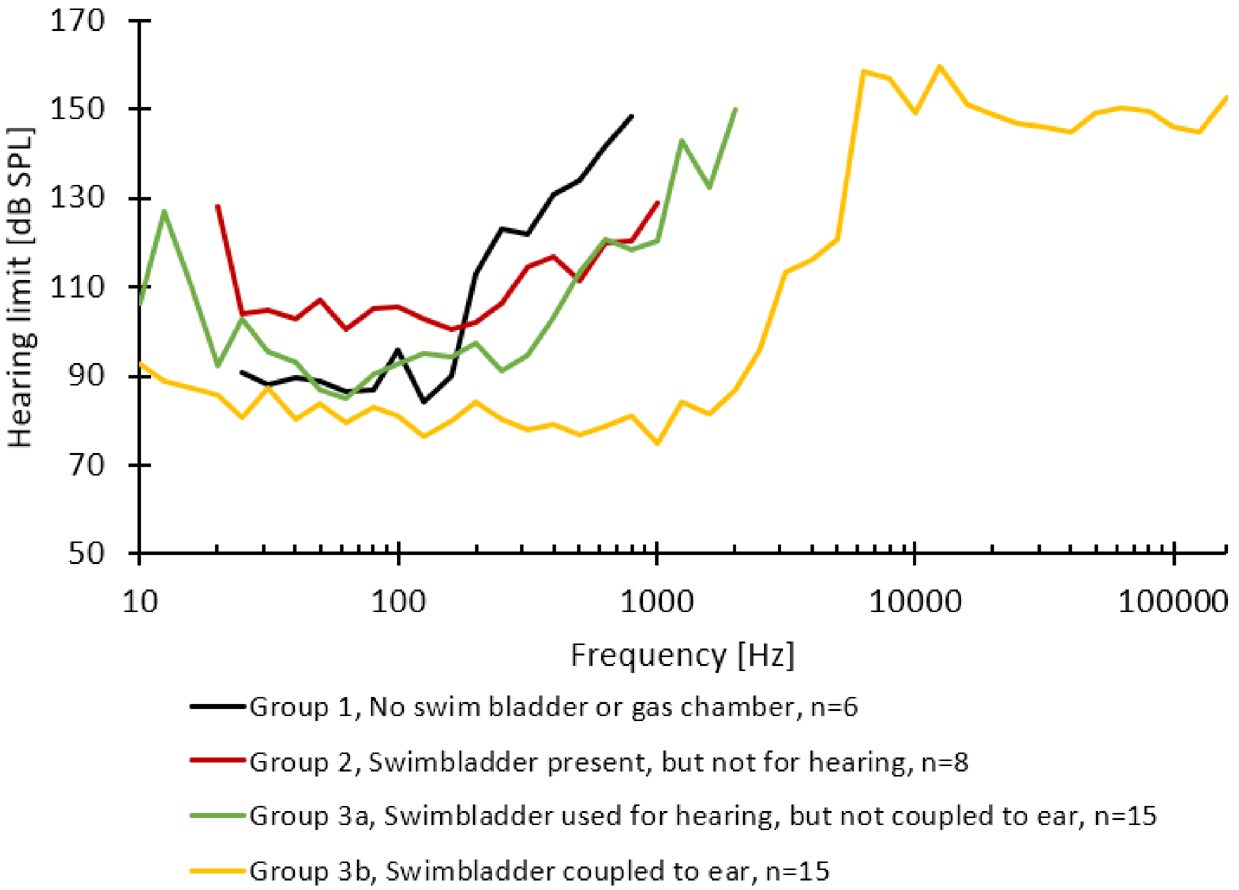

Figure 2-2 Generalised hearing thresholds for fishes grouped by the presence of a swim bladder and its role in hearing.

Physiological effects relating to injury criteria are described below (Popper, et al., 2014):

- **Mortality and potential mortal injury**: either immediate mortality or tissue and/or physiological damage that is sufficiently severe (e.g., a barotrauma) that death occurs sometime later due to decreased fitness. Mortality has a direct effect upon animal populations, especially if it affects individuals close to maturity.

- **Recoverable injury ("AUD INJ" in tables and figures)**: Tissue damage and other physical damage or physiological effects, that are recoverable, but which may place animals at lower levels of fitness, may render them more open to predation, impaired feeding and growth, or lack of breeding success, until recovery takes place.

  The AUD INJ term is used here to describe this, more serious impact, even though it is not strictly permanent for fish. This is to better reflect the fact that this level of impact is perceived as serious and detrimental to the fish.

- **Temporary Threshold Shift (TTS)**: Short term changes (minutes to few hours) in hearing sensitivity may, or may not, reduce fitness and survival. Impairment of hearing may affect the ability of animals to capture prey and avoid predators, and also cause deterioration in communication between individuals, affecting growth, survival, and reproductive success. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure.

Popper et al. 2014 does not set out specific TTS limits for L_P and for disturbance limits for impulsive noise for fishes. Therefore publications: "Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual" (WSDOT, 2020) and "Canadian Department of Fisheries and Ocean Effects of Seismic energy on Fish: A Literature review" (Worcester, 2006) on effects of seismic noise on fish are used to determine limits for these:

- The criteria presented in the Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual (WSDOT, 2020). The manual suggests an un-weighted sound pressure level of 150 dB SPL (assumed to be duration of 95 % of energy) as the criterion for onset of behavioural effects, based on work by (Hastings, 2002). Sound pressure levels in excess of 150 dB SPL 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. The threshold is implemented here as either single impulse SEL or 1 second SEL, whichever is greater.

- The report from the Canadian Department of Fisheries and Ocean "Effects of Seismic energy on Fish: A Literature review on fish" (Worcester, 2006) found large differences in response between experiments. Onset of behavioural response varied from 107-246 dB L_P, the 10th percentile level for behavioural response was 160 dB L_P (rounded to nearest 5 dB to reflect large variation in data).

Thus, the behavioural threshold for fishes for impulsive sound is 160 dB L_P, and for non-impulsive sound 150 dB SPL.

Note that while there are multiple groups of fish presented, we have used the thresholds of the more sensitive group for all fish thus covering all fishes (203/186 AUD INJ/TTS for impulsive sound & 222/204 AUD INJ/TTS for non-impulsive sound). These lower thresholds also cover "Eggs and Larvae.

Table 2-3: Criteria for onset of injury to fish and sea turtles due to impulsive noise. For this assessment the lowest threshold for any group is used for all groups (shown in bold).

Type of animal	Unit	Mortality and potential mortal injury [dB]	Recoverable injury (AUD INJ) [dB]	TTS [dB]	Behavioural [dB]
Fish: no swim bladder (particle motion detection) Example: Sharks.	SEL	219[1]	216[1]	186[1]	150[3]
	L_P	213[1]	213[1]	193[2]	160[2]
	SEL	210[1]	203[1]	186[1]	150[3]

Fish: where swim bladder is not involved in hearing (particle motion detection). Example: Salmonoids.	L_P	207[1]	207[1]	193[2]	160[2]
Fish: where swim bladder is involved in hearing (primarily pressure detection). Example: Gadoids (cod-like).	SEL	207[1]	**203[1]**	**186**	**150[3] [SPL]**
	L_P	207[1]	**207[1]**	**193[2]**	**160[2]**
Sea turtles	SEL	210[1]	(*Near*) High* (*Mid*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-
Eggs and larvae	SEL	210[1]	(*Near*) Moderate (*Mid*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-

[1] (Popper et al. 2014) table 7.4, [2] (Worcester, 2006), [3] (WSDOT, 2020)

* Indicate (range) and risk of effect, e.g., "(Near) High", meaning high risk of that effect when near the source.

Where Popper et al. 2014 present limits as ">" 207 or ">>" 186, we have ignored the "greater than" and used the threshold level as given.

Relevant thresholds for non-impulsive noise for fishes relating to AUD INJ, TTS, and behaviour are given in Table 2-4. Note that for the behaviour threshold we have used the impulsive threshold as basis for the continuous noise threshold, in absence of better evidence.

Table 2-4: Criteria for fish (incl. sharks) due to non-impulsive noise from Popper et al. 2014, table 7.7.

Type of animal	Unit	Mortality and potential mortal injury	Recoverable injury (AUD INJ) [dB]	TTS [dB]	Behavioural [dB]
All fishes	SEL	(*Near*) Low (*Mid*) Low (*Far*) Low	222†	204†	150 [SPL]*

*Based on the impulsive criteria.

†Based 48 hours of 170 dB SPL and 12 hours of 158 dB SPL

3 THE SITE ENVIRONMENT

3.1 SI Works Area of Interest

The SI Works Area of Interest (AoI) and nearby surroundings are characterised by water depths of 0-70 meters with a relatively gentle increase in depth with distance from the shore (Figure 3-1). The sediment properties are varied, from soft, muddy sediment to harder gravely sediments, with some areas being exposed or near-exposed bedrock of chalk, limestone or sandstone (generally found within 20 km of the coast).

Figure 3-1: MUL Area of Interest and Proposed SI works locations along offshore transmission cable corridors and landfall zones

The survey speed is expected to be 4 knots (2.1 m/s), limited by the survey equipment. The survey transects plan is yet to be determined so reasonable worst-case locations throughout the AoI have been used as basis for the modelling rather than a specific survey plan.

3.2 Water Properties

Water properties were determined from historical data for the area. Where a range of values are expected or observed, the value resulting in the lowest transmission loss was chosen for a more conservative assessment (more noise at range). Thus, this also covers seasonal variation.

- Temperature: 20°C – maximal summer temperature given by https://seatemperature.info/ardmore-water-temperature.html for Ardmore.
- Salinity: 34 psu – https://seatemperature.info/ardmore-water-temperature.html for Ardmore.
- Soundspeed profile: Assumed generally uniform as a conservative measure (a typical summer sound speed profile would increase transmission loss by refracting sound towards the sediment.

3.3 Sediment Properties

Sediment properties are based on sediments given in Table 3-1.

Sediment types are informed by the “Folk 7-class Classification” from EMODnet Geology[5] (European Commision, 2024) and from grab samples by GSI[6]. A sediment model (Ainslie, 2010) was used to derive the acoustic properties of the sediment from the grain size. (Table 3-1).

Table 3-1: Sediment Properties for the two survey areas.

Folk Sediment name	Sediment type (ISO 14688-1:2017)	Density [kg/m³]	Soundspeed [m/s]	Grain size [mm] (nominal)
Muddy sand	Fine sand	1862	1679	0.09
Gravelly muddy sand	Fine sand	1992	1739	0.2
Sandy gravel	Fine gravel	2779	2127	5.7
Sandstone or limestone	-	2400	3000	-

[5] https://drive.emodnet-geology.eu/geoserver/gtk/wms

[6] https://gsi.geodata.gov.ie/portal/home/item.html?id=27c9ef6e837a4ee3b08bc1dd7f870ead

4 SOURCE NOISE LEVELS

Underwater noise sources are usually quantified in dB scale with values generally referenced to 1 µPa pressure amplitude as if measured at a hypothetical distance of 1 m from the source (called the Source Level). In practice, it is not usually possible to measure at 1 m from a source, but the metric allows for 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 an imagined acoustic centre point. Therefore, the stated sound pressure level at 1 m does not 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 back-calculated source level (SL).

4.1 Source Models

The noise sources and activities investigated during this assessment are summarised in Table 4-1.

Note that:

1. The ping rate, and therefore the SPL and SEL of the sound source varies with the local depth.

2. Due to differences in sediment, the angle at which the sediment will tend to reflect sound back into the water column changes. As we use this information to derive practical source levels for highly directional sources, this will change with sediment type (further information below and in Appendix A & Figure 8-7).

3. To account for the shallow depth, and therefore assumed short duration of pulses from Multibeam Echo-Sounder (MBES), Side Scan Sonar (SSS) and pinger/chirper, we have assessed the weighted kurtosis in order to determine impulsiveness (Section 2.1).

Sonars and echosounders generally use tone pulses of either constant frequency or as a frequency sweep. These pulses are typically windowed to limit “spectral leakage[7]”. We assume use of a Von Hann window (sometimes “Hanning”) which gives effective attenuation of frequencies outside the intended frequencies. This means that while a sonar with a centre frequency of 200 kHz is well above the hearing range of any marine mammal, there will be energy at 100 kHz c. 50 dB lower than the source level at 200 kHz. This is accounted for in the assessment. Note that this might contrast with some guidelines, such as the “JNCC guidelines mitigation during geophysical surveys” (JNCC, 2017), which state that “*Multi-beam surveys in shallower waters (<200m) are not subject to these requirements* [mitigation for protection of European Protected Species]”. However, given the fact there is substantial energy outside the nominal frequency range of any echo sounder (see example in Figure 4-1), we have included this energy spread here.

[7] Acoustic phenomenon where a sharp change in pressure produces sound in a wide frequency range (similar to an ideal impulse) outside the intended frequencies.

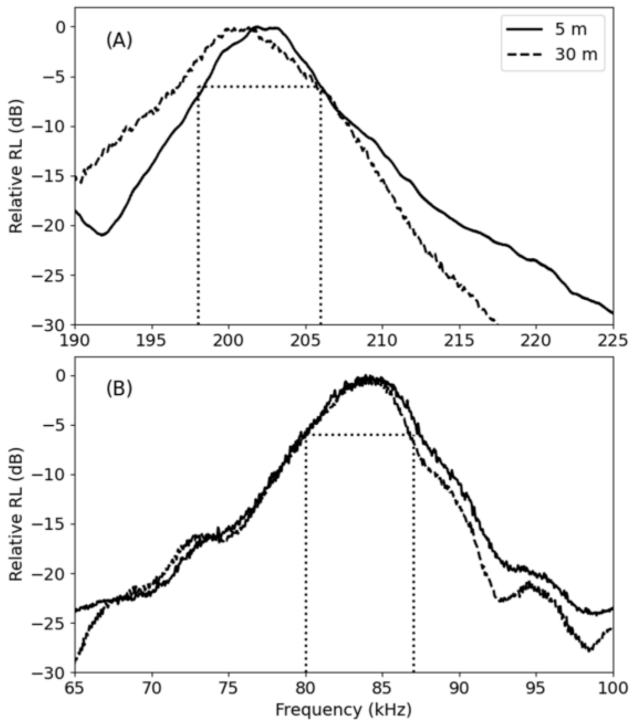

Figure 4. The relative received levels (RLs, in decibels (dB)) of the signals of the acoustic frequency bandwidth of the dual-frequency echosounder used in this study, as observed at two different depths. The dotted lines indicate the −6 dB acoustic bandwidths of 198–206 (**A**) and 80–87 kHz (**B**). The peak frequencies of the two channels were found to be 201.5 (**A**) and 84 kHz (**B**).

Figure 4-1. Example of recorded levels from an echosounder showing significant energy outside the nominal frequencies, necessitating assessment at those frequencies too (Burnham, et al., 2022).

Highly directional sources with narrow beams (sonars and echosounders) will tend to ensonify only a narrow cone of water at any given time. For multibeam echosounders or side scan sonars, the beam(s) sweeps though the water, side to side, to get wider sediment coverage. For this type of sonar, we have converted the source to an omnidirectional source with the same acoustic energy as the original but represented as omnidirectional. This simplifies the calculation process, but yields identical results, and means that we account for the probabilistic nature of an animal being “ensonified” by the source.

For beams only directed vertically down or up, such as sub-bottom profilers or ADCPs, we incorporate the directivity of the beam as well as the ability of the sediment to reflect the sound emitted. This means that we can account for the fact that primarily, a narrow cone directly below/above the source is ensonified with high sound levels and also that a significant attenuation occurs in the sediment where sound enters at steep angles. In practice, we use the angle with the highest output level after accounting for directivity combined with sediment loss to a range of 100 m.

Table 4-1: Summary of Sound Sources and Activities Included in the Subsea Noise Assessment

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
Survey vessel, Geophysical, nearshore	160 dB SPL	10-4,000 Hz	Based on 15 m generic survey vessel.	Non-impulsive
Survey vessel, Geophysical, offshore, with DP-system	183 dB SPL	10-2,500 Hz	Based on 75 m generic survey vessel with DP-system active.	Non-impulsive
Survey vessel, Geotechnical	176 dB SPL	10 – 2,000 Hz	Based on 75 m generic survey vessel.	Non-impulsive

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
MBES	178 dB SPL (Spherical equivalent level)	200,000-500,000 Hz	Based on units suitable for this survey.	Impulsive
SSS	165 dB SPL (Spherical equivalent level)	100,000-900,000 Hz	Generic SSS from 400-900 kHz.	Impulsive
USBL	190 dB SPL	8,000-40,000 Hz	Active with non-hull mounted SSS & SBP & during vibro-core operations, 2 Hz ping rate, ping length 10 ms.	Impulsive
SBP-parametric (P-SBP)	208 dB SPL	80,000-115,000 Hz (Primary) 2,000-22,000 Hz (Secondary)	Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-chirper/pinger (C-SBP)	185 dB SPL	1,000-20,000 Hz	Generic shallow water SBP of chirper/pinger type. Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-sparker/UHRS (S-SBP)	185 dB SPL 224 dB L_P	600 – 8,000 Hz	Based on GeoSource firing at 1000 J. Firing rate of 1 Hz assumed	Impulsive
SBP-boomer (B-SBP)	185 dB SPL 228 dB L_P	160 – 16,000 Hz	Based on generic boomer model firing at 1000 J. Firing rate of 1 Hz assumed	Impulsive
ADCP	207 dB SPL	300,000-600,000 Hz	Based on suitable ADCP for depths <65 m (e.g. Nortek AWAC, Teledyne Reason Sentinel or Monitor) Source level adjusted for sediment effects and beam widths.	Impulsive
Borehole drilling/ rotary coring	150 dB SPL	10-100,000 Hz	Based on published levels (Erbe, et al., 2017; Fisheries and Marine Service, 1975; MR, et al., 2010; L-F, et al., 2023)	Non-impulsive
Vibro-coring & CPT	189 dB SPL	50 – 16,000 Hz	Based on levels from previous work & (Reiser, et al., 2010)	Non-impulsive

In addition to the activities outlined above, there may also be grab sampling. However, this activity has not been modelled given the low noise levels associated with the activity. All other surveys undertaken in the intertidal area, e.g. environmental walkover surveys, intertidal sampling, etc. have not been included in this assessment as they will not result in underwater noise.

4.1.1 Equipment

This section presents details on each sound source individually. Combined sources, with expected combination of active equipment, are presented in Section 4.1.2.

The modelling has included for larger and smaller vessel types depending on water depths. Smaller vessels will operate in water depths less than 15m below lowest astronomical tides (<15 m bLAT) while larger vessels will operate at water depths greater than 15m below lowest astronomical tides (>15 m bLAT).

4.1.1.1 Survey Vessel, Geophysical <15 m bLAT

A small survey vessel of up to 15 m in length, travelling at 4 knots (equipment limited) has been assessed in this report as this represents the anticipated vessel parameters for the marine geophysical surveys <15 m bLAT. Broadband level of the vessel is 160 dB SPL with decidecade band levels given in Figure 4-2 (maximal band level is 150 dB SPL at the 25 Hz band). Smaller vessels will have lower emitted levels and are therefore covered by this assessment.

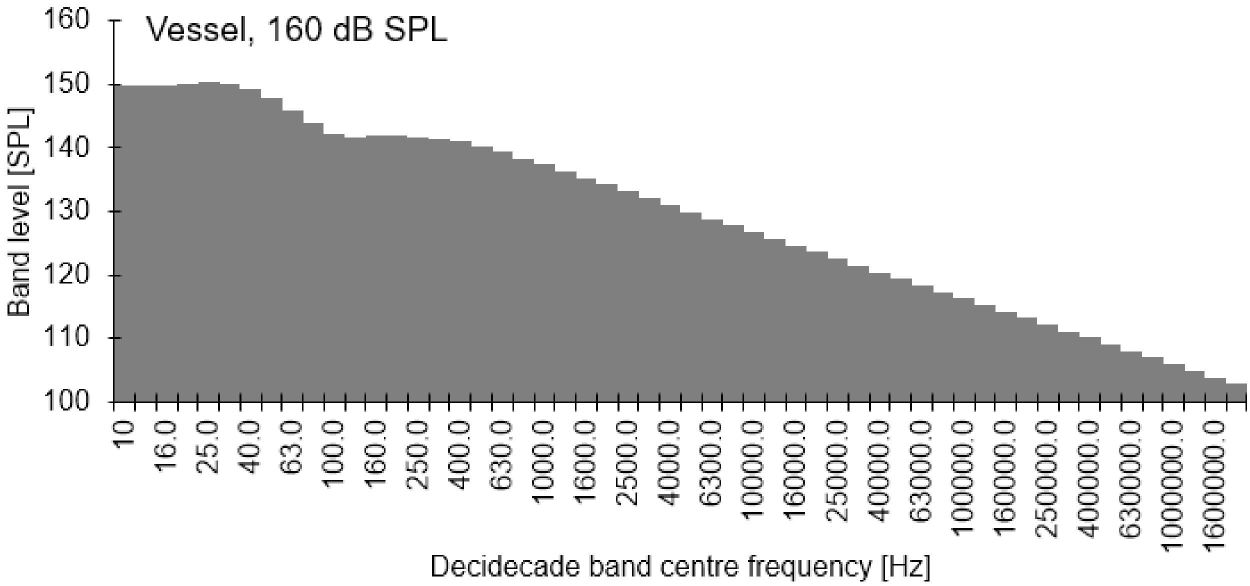

Figure 4-2. Vessel source band levels. Broadband level: 160 dB SPL. Based on generic small survey craft, c. 15 m length travelling at 4 kn.

4.1.1.2 Survey Vessel, Geophysical >15m bLAT

A large survey vessel of c. 75 m in length, travelling <9 knots (assumed cavitation inception speed) has been assessed in this report as this represents the anticipated vessel parameters for the marine geophysical surveys in deeper waters, i.e. > 15 m bLat . Broadband level of the vessel is 176 dB SPL with decidecade band levels given in Figure 4-3 (maximal band level is 166 dB SPL at the 10 Hz band). Smaller vessels will have lower emitted levels and are therefore covered by this assessment.

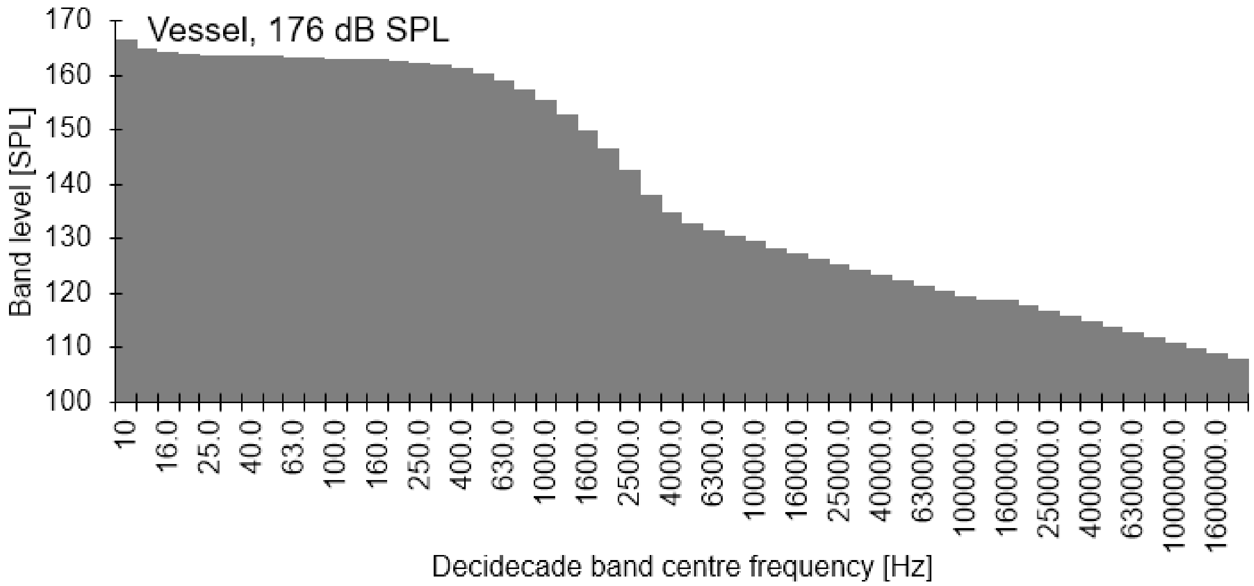

Figure 4-3. Vessel source band levels. Broadband level: 176 dB SPL. Based on generic larger survey craft, c. 75 m length travelling <9 kn.

4.1.1.3 Survey Vessel, Geotechnical

A large survey vessel of c. 75 m in length, travelling <9 knots (likely cavitation inception speed), with active dynamic positioning, has been modelled as a suitable vessel for carrying out the geotechnical survey in deeper water >15 m bLAT. Broadband level of the vessel is 183 dB SPL with decidecade band levels given in Figure 4-4 (maximal band level is 172 dB SPL at the 315 Hz band). Smaller vessels will have lower emitted levels and are therefore covered by this assessment.

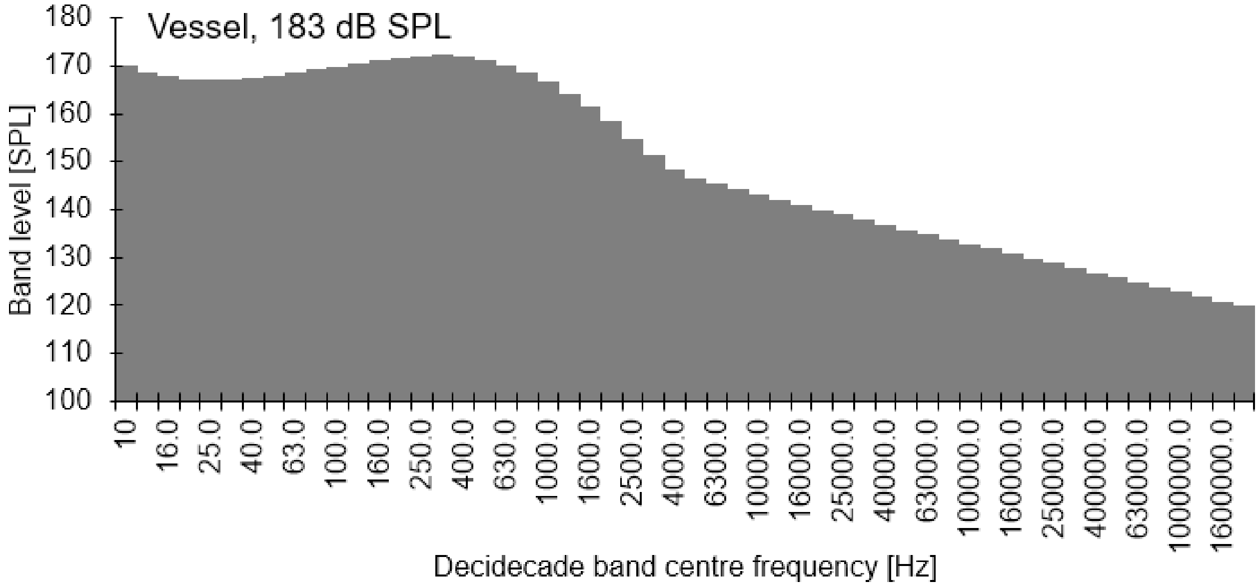

Figure 4-4. Vessel source band levels. Broadband level: 183 dB SPL. Based on generic larger survey craft, with an active DP system, c. 75 m length travelling <9 kn.

4.1.1.4 Multibeam Echosounder (MBES)

The “Reason SeaBat T50-P”, “R2 Sonic 2024”, “Kongsberg EM series”, or similar models, are a likely MBES candidate for this survey. Nominal frequencies from 200 kHz to 500 kHz have been modelled. The equivalent spherical level is 178 dB SPL (maximally 171 dB SPL in each band). Band levels are presented in Figure 4-5.

Given the relatively low duty cycle of the MBES, the kurtosis (“impulsiveness”) will be over 40 (indicating it is impulsive) at the source for realistic ping rates and ping lengths. Therefore, the MBES is modelled as an impulsive noise source.

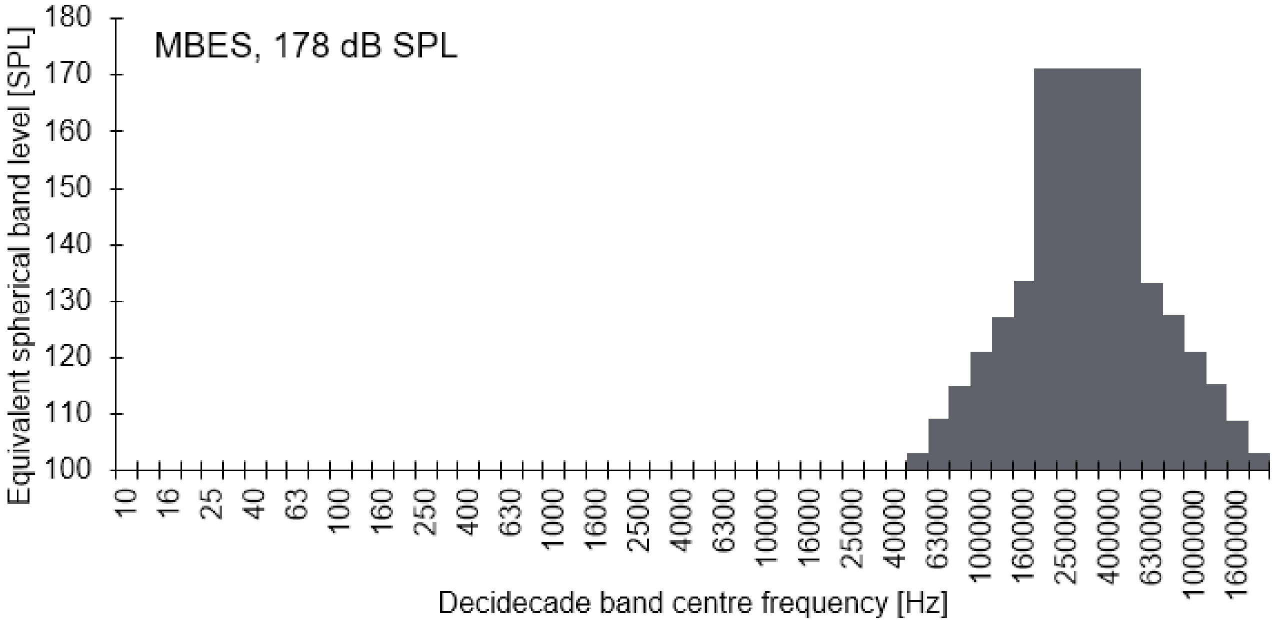

Figure 4-5. MBES source band levels as equivalent spherical/omnidirectional levels.

4.1.1.5 Side Scan Sonar (SSS)

No specific model of side scan sonar (SSS) has been determined for the survey, except for specification of nominal frequencies of 100 – 900 kHz. To address this uncertainty, a generic SSS model has been generated from seven commonly used SSS systems (from EdgeTech, C_MAX and Klein Systems). We have used the 90th percentile level as the representative level. The equivalent spherical broadband level is 165 dB SPL (Figure 4-6).

Given the relatively low duty cycle of the SSS, the kurtosis (“impulsiveness”) will be over 40 (indicating it is impulsive) at the source for realistic ping rates and ping lengths. Therefore, the SSS is modelled as an impulsive noise source.

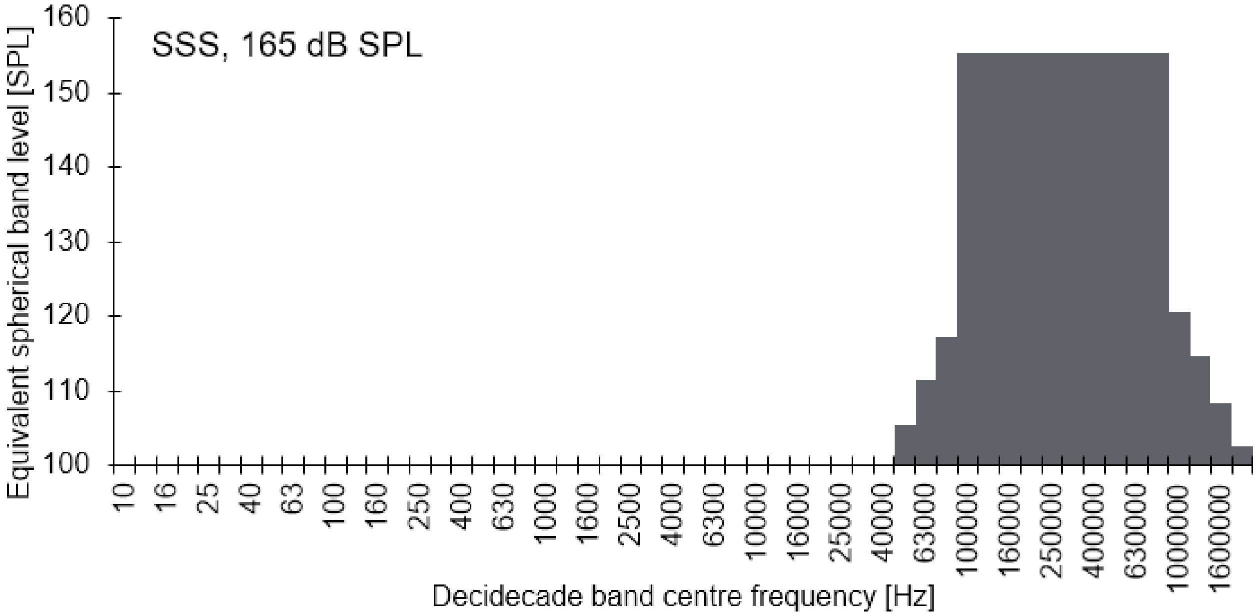

Figure 4-6. SSS source band levels as equivalent spherical/omnidirectional levels.

4.1.1.6 Ultra Short Base-Line positioning system (USBL)

Where the SSS or SBP is deployed as a towfish (towed behind the vessel), or vibrocores are deployed, their accurate positions will need to be known. A USBL positioning system is a common solution. Here, a generic USBL is used, with a 10 ms pulse length and 2 Hz ping rate, consistent with popular models (Edgetech BATS, IxBlue GAPS, Sonardyne Ranger). A max SPL [L_P] of 210 dB is modelled, giving an SPL of 190 dB (Figure 4-7).

The relatively short pulses and slow repetition of pulse gives a weighted kurtosis over the limit value (40), therefore, the USBL is modelled as an impulsive noise source.

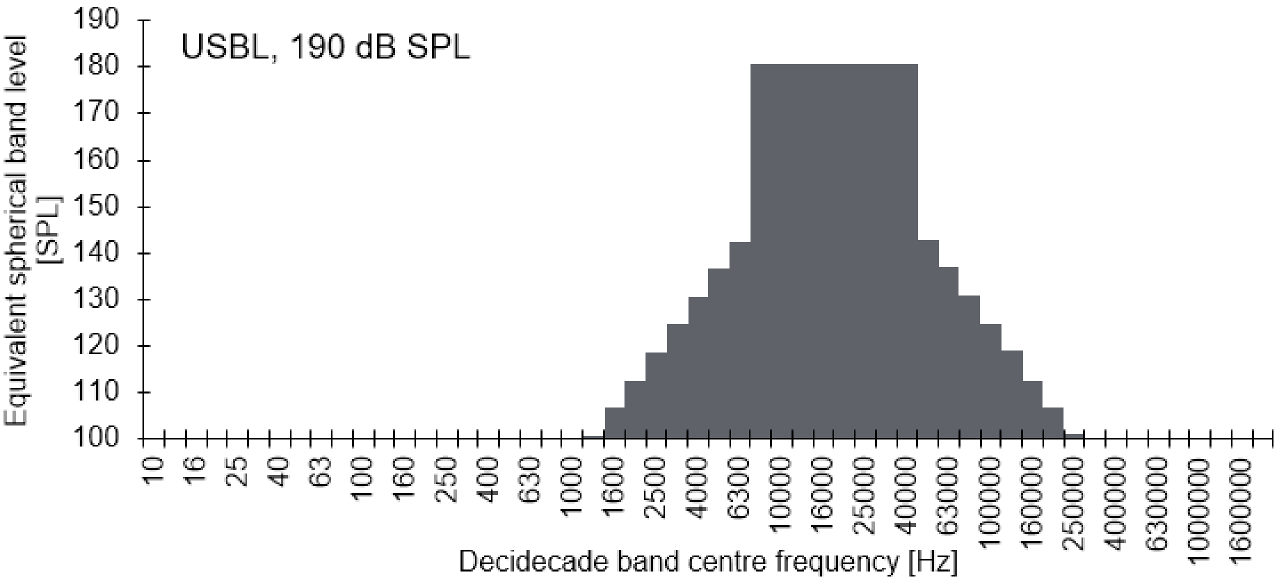

Figure 4-7. USBL source band levels.

4.1.1.7 Sub-bottom Profilers (SBP)

4.1.1.7.1 Parametric SBP (P-SBP)

The survey might use a parametric sub-bottom profiler (SBP) such as the “Innomar standard”. These SBPs use two higher frequencies (“primary frequencies”) to generate an interference pattern at lower frequencies (“secondary frequencies”). This means that the secondary beam can be made extraordinarily narrow, leading to a much smaller sound impact (Appendix A, Figure 8-8). We account for these differences in beam pattern by including the sediment reflection loss at high incidence angles (see Appendix A, Figure 8-7) to reduce the effective source level accordingly.

The source level for the P-SBP is split into two regions according to the nominal frequencies, accounting for some spectral leakage (Figure 4-8) and assuming the full range of frequencies is used during the survey (a conservative assumption). The total, broad band level for the parametric SBP is 208 dB SPL, with the secondary frequencies being 158 dB SPL.

Given the relatively low duty cycle of the P-SBP, the kurtosis (“impulsiveness”) will be over 40 at the source for realistic ping rates and ping lengths. Therefore, the P-SBP is modelled as an impulsive noise source.

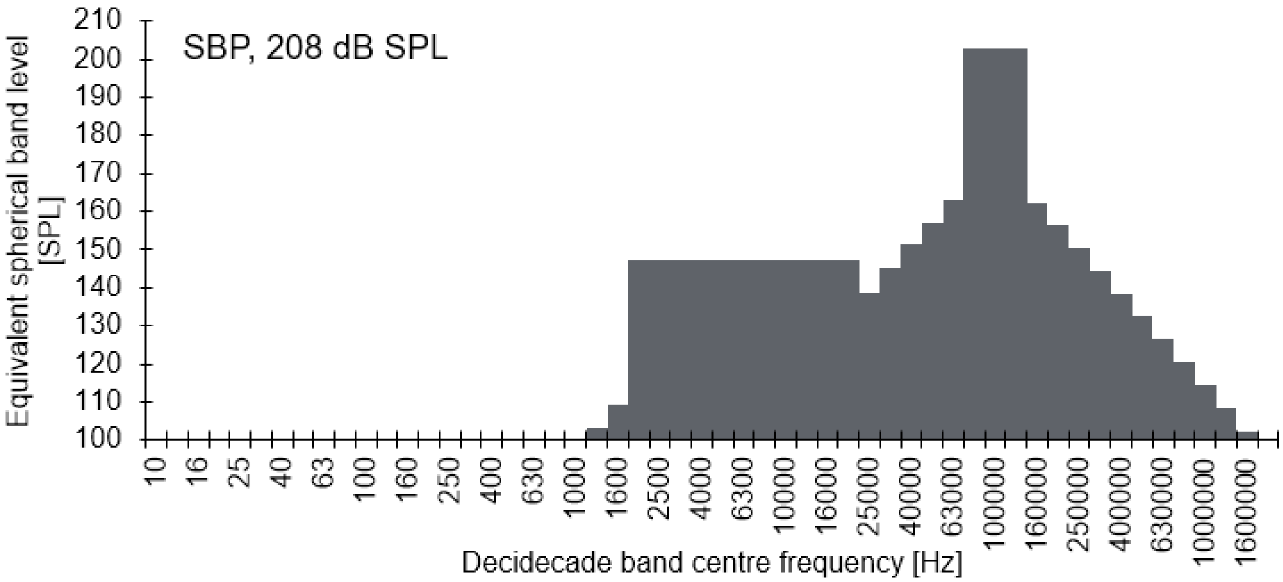

Figure 4-8. Parametric SBP source band levels as equivalent spherical/omnidirectional levels. Primary frequencies 85 kHz – 115 kHz, secondary frequencies 2 kHz – 22 kHz.

4.1.1.7.2 Chirper/Pinger SBP (C-SBP)

A chirper or pinger type SBP might be used for the survey. As no specific model has been specified, we have used a generic model based on common SBPs of this type. These have wide beams and therefore a comparatively higher noise impact, relative to their in-beam source levels. A single SBP source has been generated to represent both these sources as they are acoustically similar. Total broadband level for this SBP is 185 dB SPL with band levels given in Figure 4-9.

Given the relatively low duty cycle of the C-SBP, the kurtosis (“impulsiveness”) will be over 40 at the source for realistic ping rates and ping lengths. Therefore, the C-SBP is modelled as an impulsive noise source.

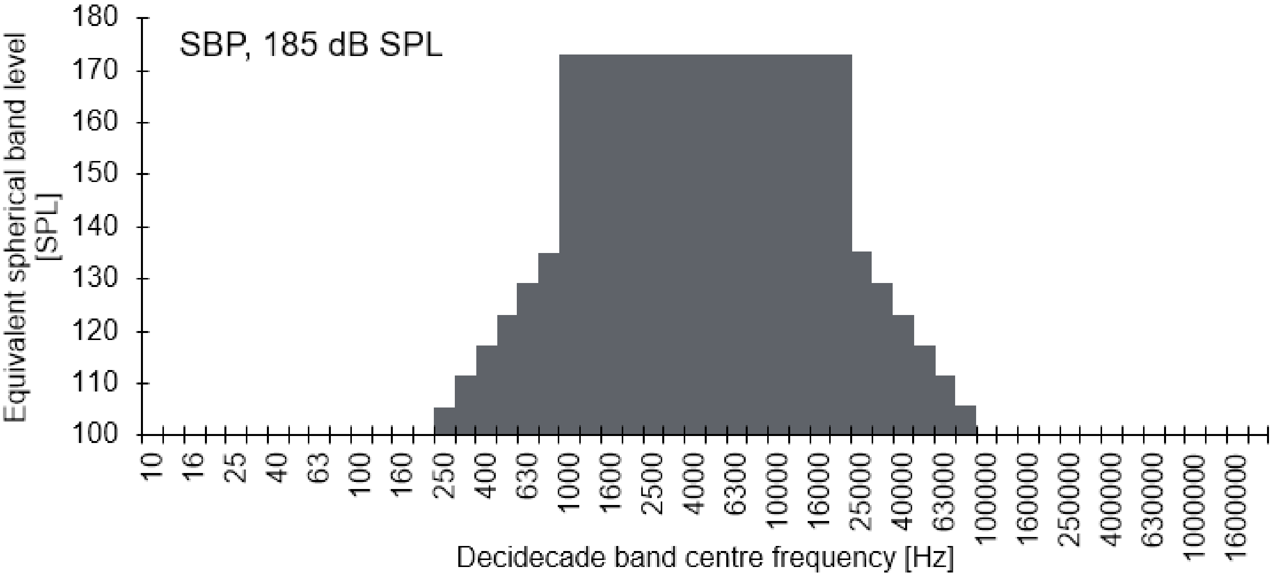

Figure 4-9. Chirper/Pinger type SBP band levels.

4.1.1.7.3 Sparker/UHRS SBP (S-SBP)

A sparker type SBP (sometimes "UHRS") might be used during the survey. As no specific model has been specified, we have used a generic model based on common SBPs of this type and an energy per firing of 1000 J and 1 firing per second. The total broadband level for this SBP is 185 dB SPL, with band levels given in Figure 4-10. Levels at frequencies below 100 Hz are taken from a spectral analysis of the timeseries in Figure 4-11, while levels above are extrapolated at a decay-rate of 3 dB/decidecade (this is a conservative measure).

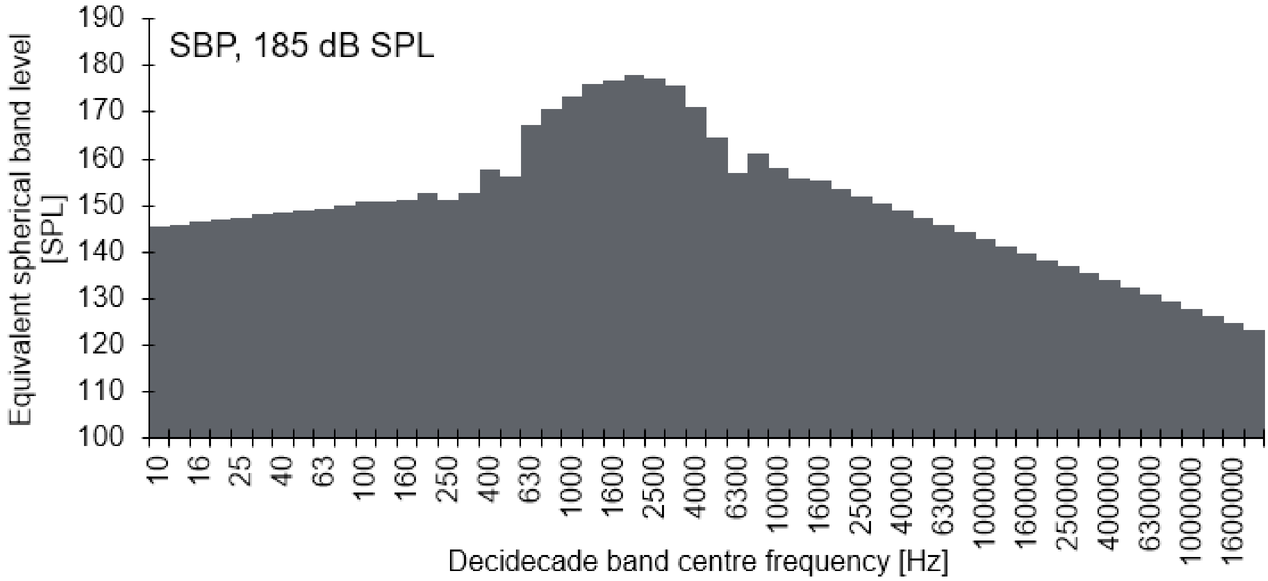

Figure 4-10. Sparker type SBP (UHRS) band levels.

The very short impulses and slow repetition mean that this source is modelled as an impulsive noise source.

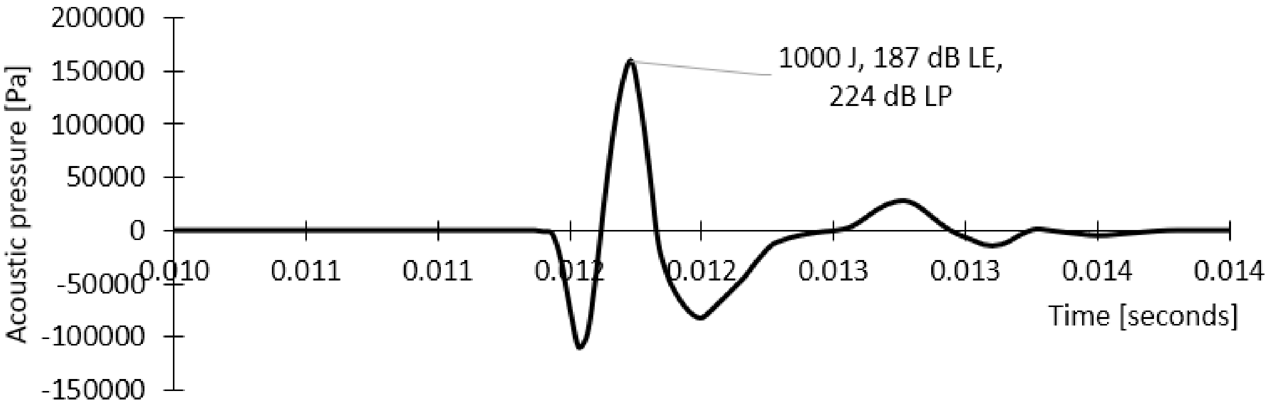

Figure 4-11. Example of an impulse from a sparker type SBP.

4.1.1.7.4 Boomer SBP (B-SBP)

A boomer type SBP might be used during the survey. As no specific model has been specified, we have used a generic model based on common SBPs of this type and an energy per firing of 1000 J and 1 firing per second. The total broadband level for this SBP is 187 dB SPL, with band levels given in Figure 4-12.

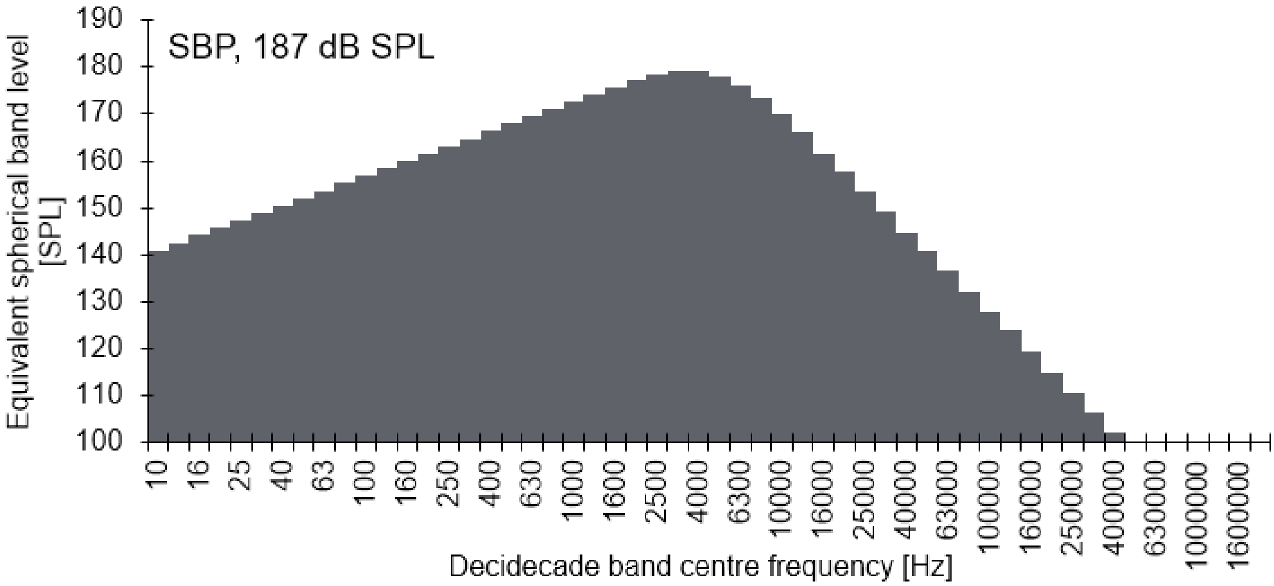

Figure 4-12. Boomer type SBP band levels.

The very short impulses and slow repetition mean that this source is modelled as an impulsive noise source.

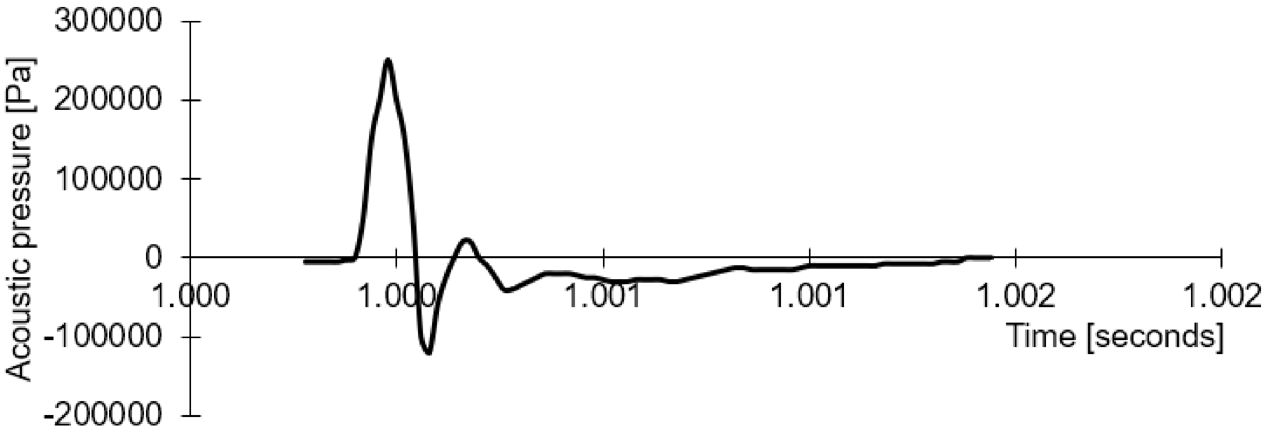

Figure 4-13. Example of an impulse as recorded from a boomer type SBP.

4.1.1.8 Boreholes Drilling

Boreholes are planned in the shallow parts of the SI Works area, with a drill of c. 0.25 m diameter. Recordings from similar equipment has informed the source levels used here (Erbe, et al., 2017; Fisheries and Marine Service, 1975; MR, et al., 2010; L-F, et al., 2023) Figure 4-14. This activity is a non-impulsive sound source with a broadband level of 150 dB SPL.

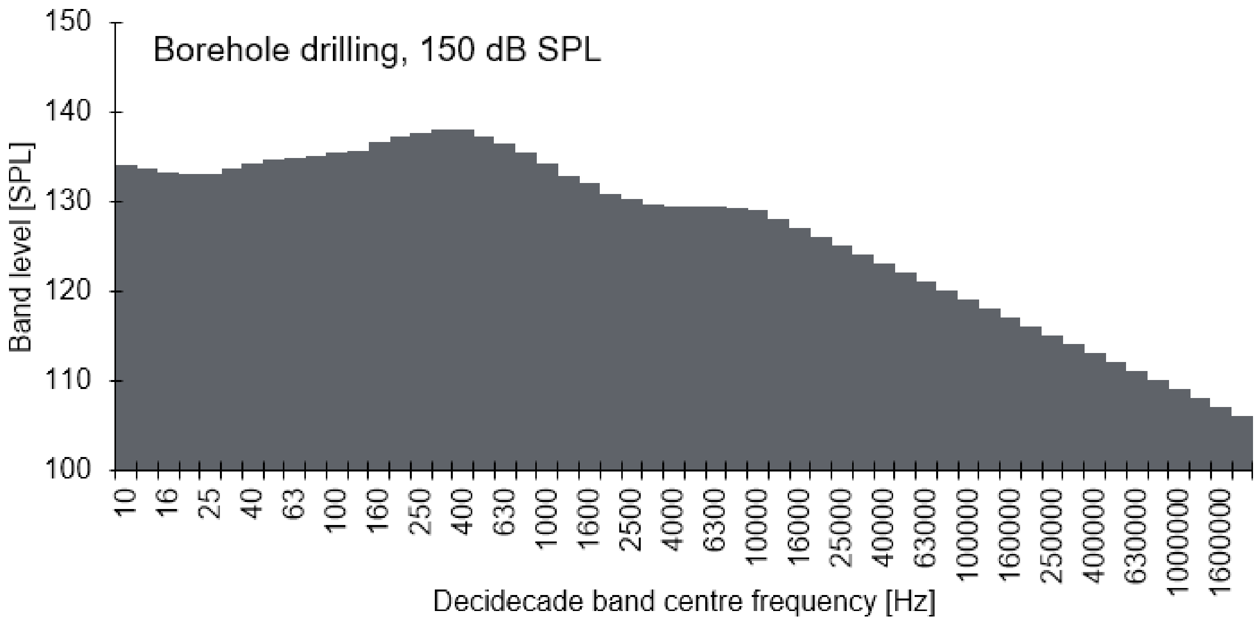

Figure 4-14. Band levels for borehole drilling, Levels above 25 kHz are extrapolated based on trend in bands at lower frequencies.

4.1.1.9 Vibro-coring & CPT

For extraction of physical samples and sediment testing, vibro-coring and Cone Penetration Testing (CPT) will be carried out. Band levels are shown in Figure 4-15. The “Vibro-coring & CPT” activity is a non-impulsive sound source with a broadband level of 189 dB SPL. Standard Penetration Testing (SPT) is here used as a proxy for CPT as the sampling tubes are of similar dimensions. SPT will be louder than CPT for comparable equipment dimensions given that SPT is generally hammered in, while CPT will be pressed hydraulicly. For this assessment the vibro-corer source is louder, and thus the main contributor of noise.

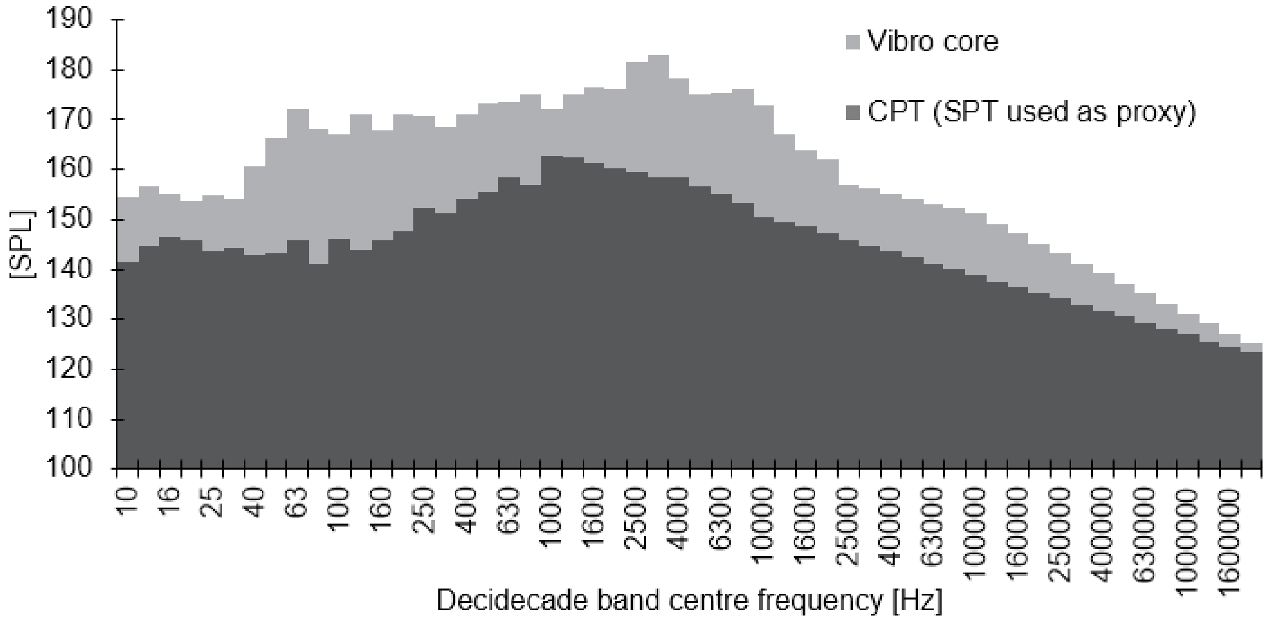

Figure 4-15. Band levels vibro-coring and CPT. Levels above 25 kHz are extrapolated based on trend in bands at lower frequencies.

4.1.1.10 ADCP

The ADCP will be deployed either on a metocean buoy, facing downward, or on the sediment, facing upwards. The source is based on suitable ADCPs for depths <65 m (e.g. Nortek AWAC, Teledyne Reason Sentinel, Workhorse or Monitor).

The source level is adjusted for sediment effects and beam widths. Band levels are shown in Figure 4-16. The ADCP activity is an impulsive sound source with a broadband level of 207 dB SPL.

ADCPs for shallower depths utilise higher frequencies and lower source output, meaning they are less noisy to marine life, and thus covered by the assessment of this source.

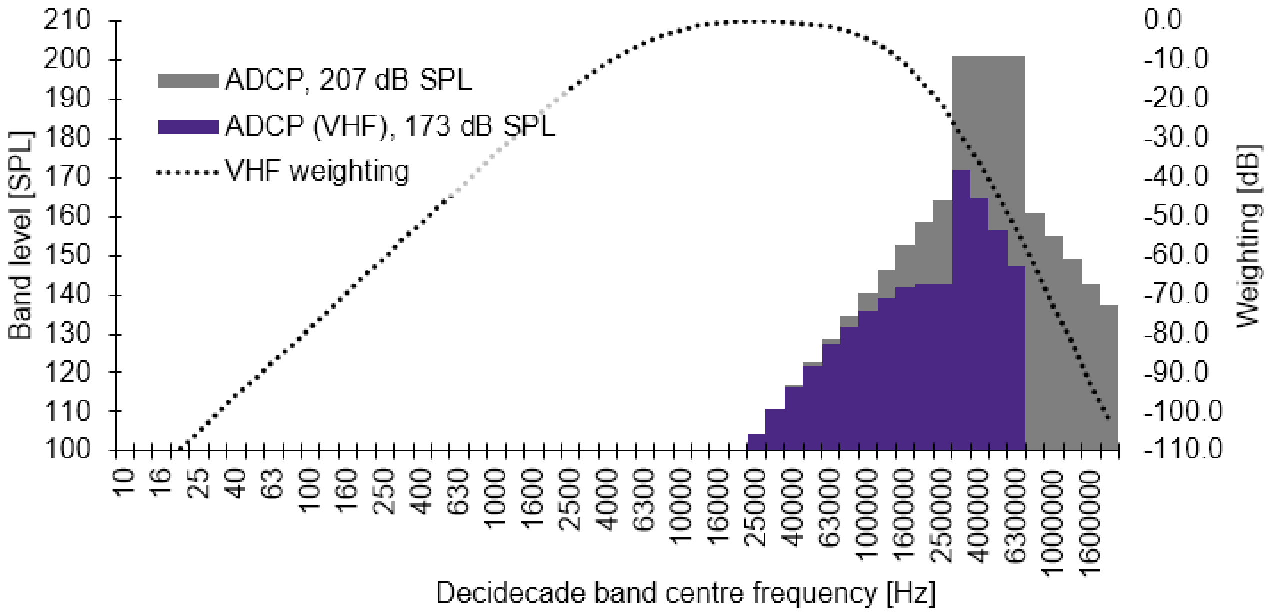

Figure 4-16. Band levels for a generic ADCP suitable for the depths of this survey. Also shown are the weighting curve for the VHF group (dotted, right axis) and the ADCP source band levels weighted for the VHF group (purple).

4.1.2 Combined Sources

The relevant equipment for each survey type has been grouped into eight activity types.

MBES and SSS are active for all combined sources of the geophysical survey.

The “Vessel” noise source varies with depth (nearshore and offshore) and activity types (geophysical and geotechnical).

4.1.2.1 Geophysical Survey (Parametric SBP)

This scenario assumes the geophysical survey is using a parametric SBP and that a towfish is deployed requiring an active USBL. Total broadband level of 208 dB SPL.

Active equipment:

- Vessel (75 m vessel shown in figure)
- MBES
- SSS
- USBL
- Parametric SBP

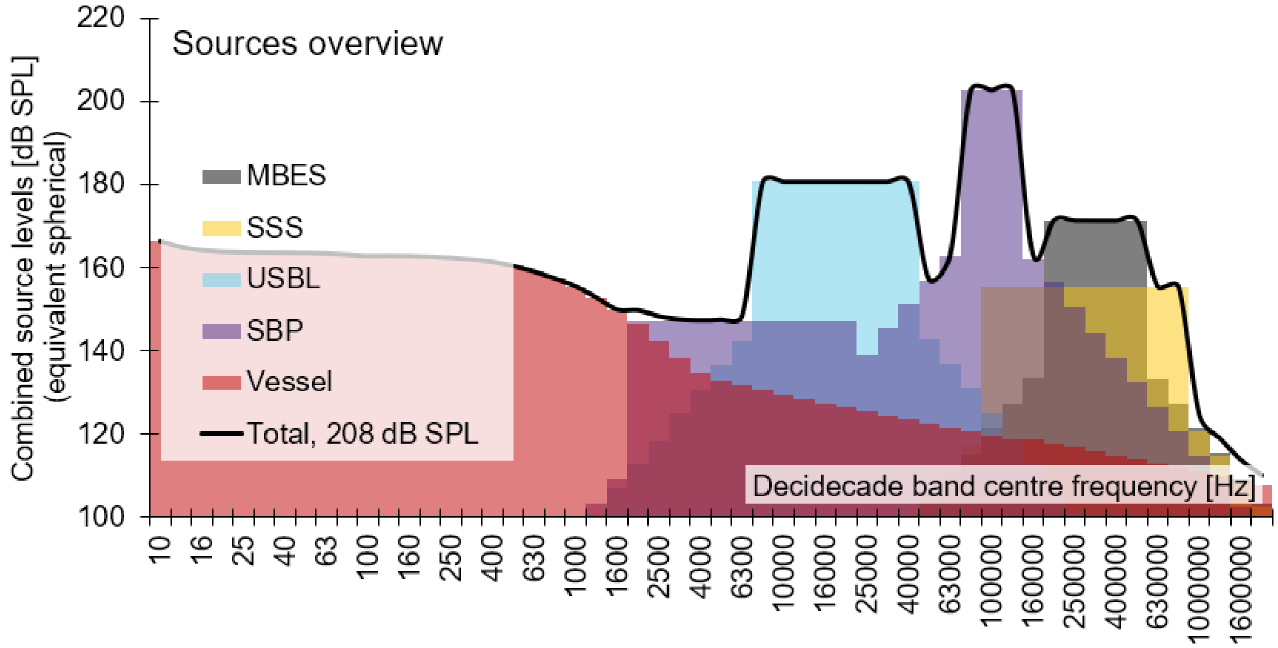

Figure 4-17. Source band level during geophysical survey (parametric SBP).

4.1.2.2 Geophysical Survey (Chirper/Pinger SBP)

This scenario assumes the geophysical survey is using a chirper or pinger type SBP and that a towfish is deployed requiring an active USBL. Total broadband level of 191 dB SPL.

Active equipment:

- Vessel (75 m vessel shown in figure)
- MBES
- SSS
- USBL
- Chirper/pinger SBP

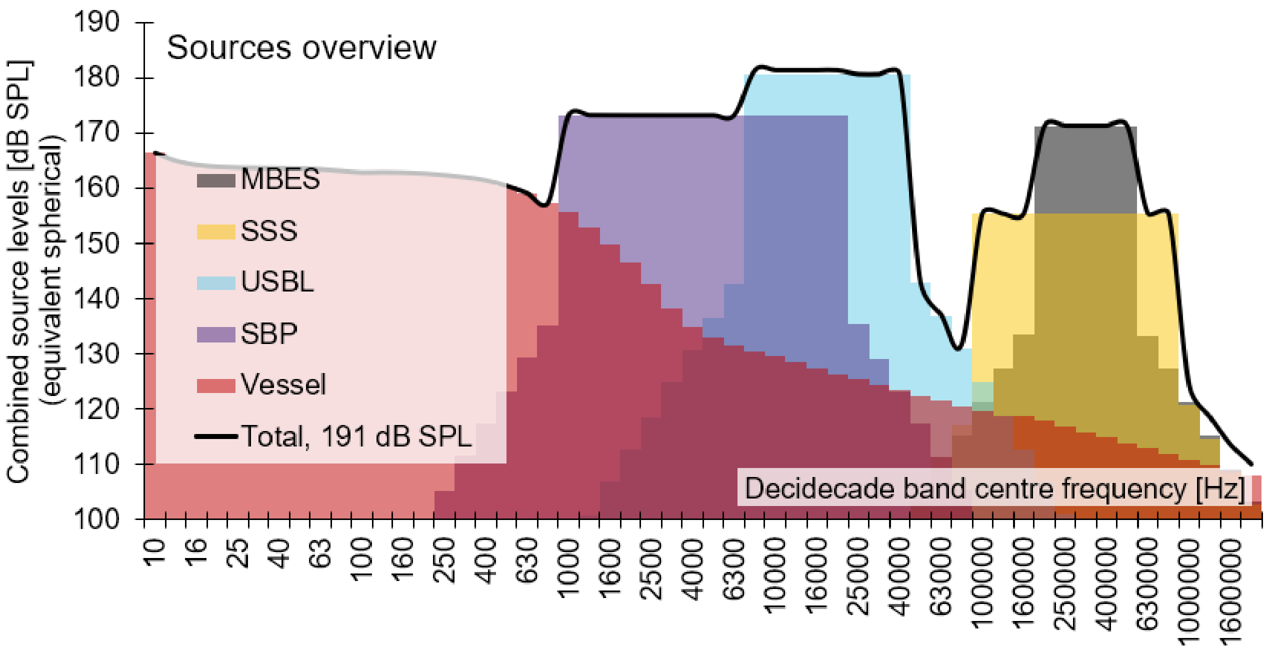

Figure 4-18. Source band level during geophysical survey (chirper/pinger SBP).

4.1.2.3 Geophysical Survey (Sparker/UHRS SBP)

This scenario assumes the geophysical survey is using a sparker type SBP and that a towfish is deployed requiring an active USBL. Total broadband level of 191 dB SPL.

Active equipment:

- Vessel (75 m vessel shown in figure)
- MBES
- SSS
- USBL
- Sparker SBP

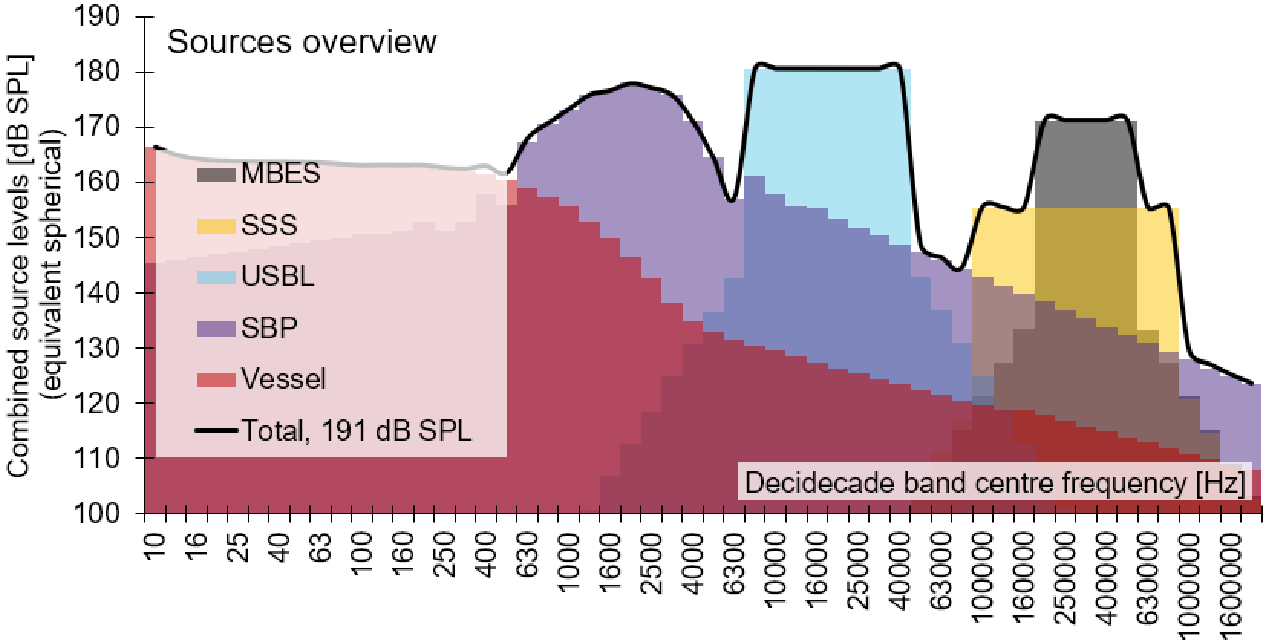

Figure 4-19. Source band level during geophysical survey (sparker SBP).

4.1.2.4 Geophysical Survey (Boomer SBP)

This scenario assumes the geophysical survey is using a Boomer type SBP and that a towfish is deployed requiring an active USBL. Total broadband level of 192 dB SPL.

Active equipment:

- Vessel (75 m vessel shown in figure)
- MBES
- SSS
- USBL
- Boomer SBP

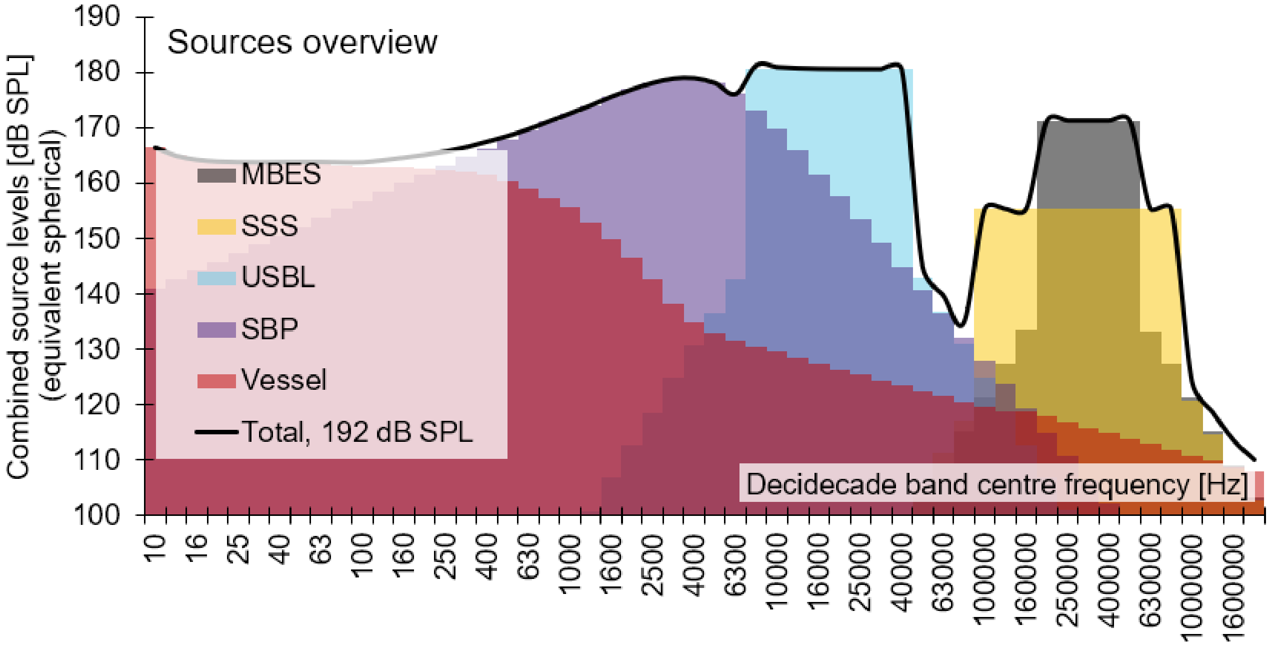

Figure 4-20. Source band level during geophysical survey (boomer SBP).

4.1.2.5 Soft Start Source (Geophysical)

During soft starts, it is assumed that any SBP and USBL will not be active but the MBES and/or the SSS will be active. Total broadband level of 178 dB SPL.

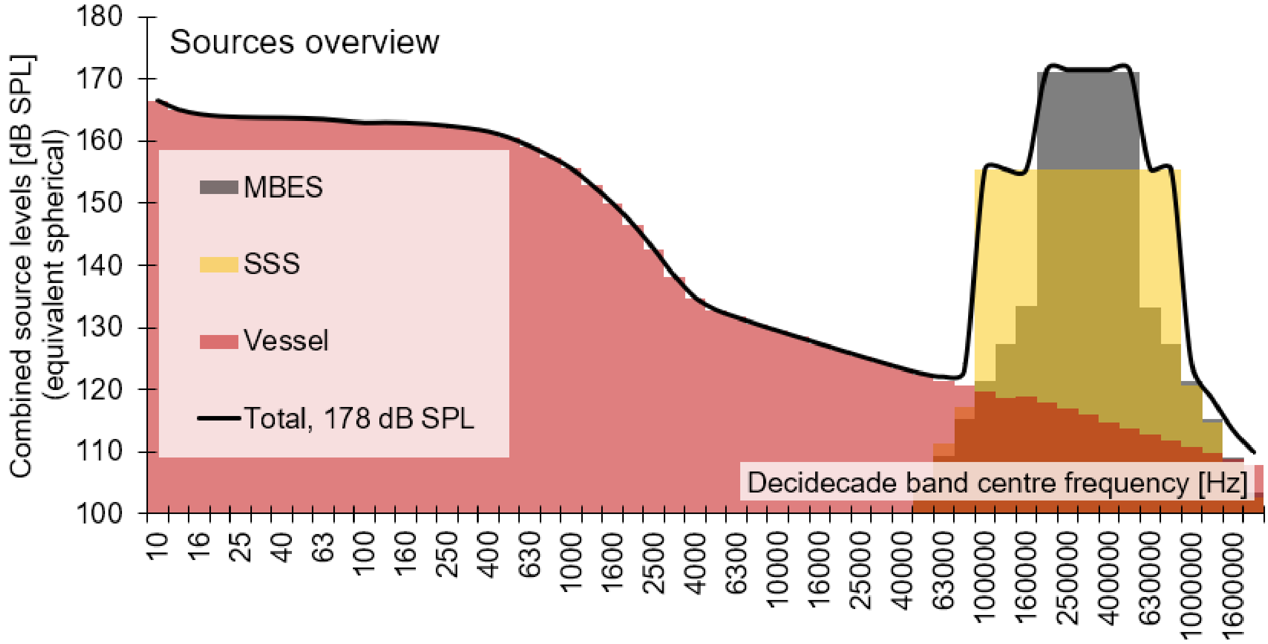

Figure 4-21. Source band level during geophysical survey soft start. Offshore vessel shown.

4.1.2.6 Geotechnical Survey (Borehole drilling, Vibro-core, CPT)

Geotechnical equipment is active and has been included into a single activity. The borehole drilling is thus covered by the Vibro-coring and CPT activity. Additionally, the USBL and Vessel source (incl. DP system) is active to account for support vessels, general machinery and positioning. Total broadband level of 193 dB SPL.

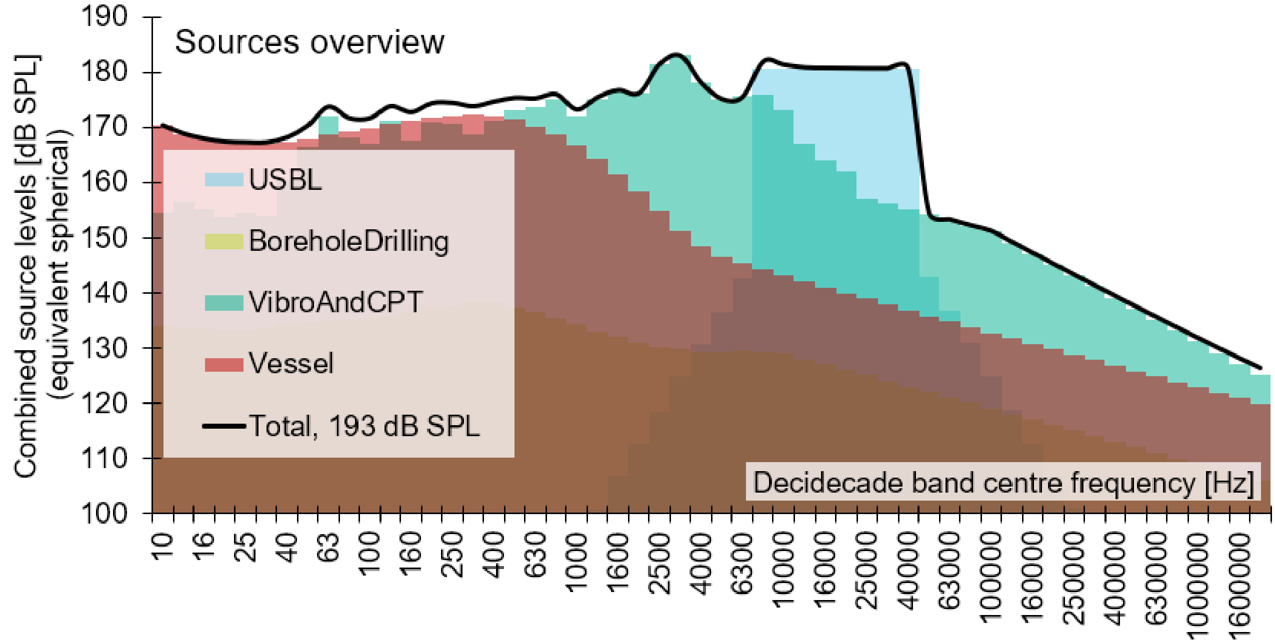

Figure 4-22. Source band level during geotechnical survey.

4.1.2.7 Soft Start Source (Geotechnical)

The vessel itself (modelled with DP system active, but with no active USBL) will perform the function of soft start source. Total broadband level of 183 dB SPL.

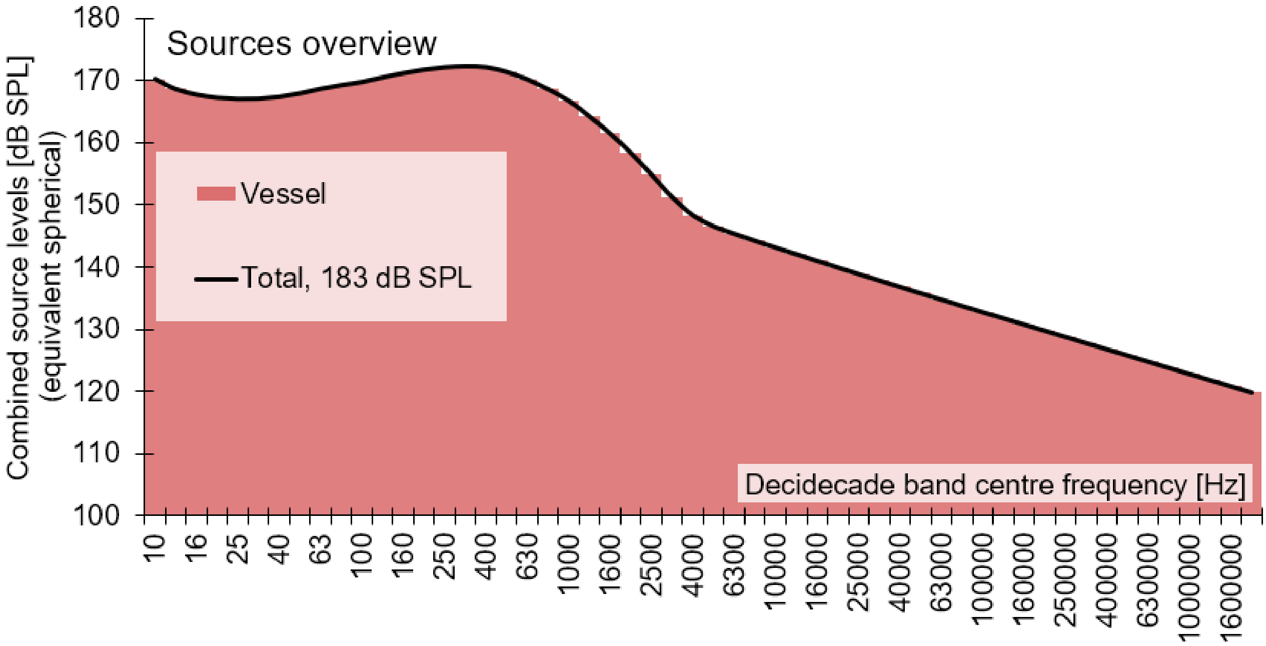

Figure 4-23. Source band level during geotechnical survey soft start.

4.1.2.8 ADCP

The ADCP systems deployed either on metocean buoys or on the seabed have been considered separately. Total broadband level of 207 dB SPL.

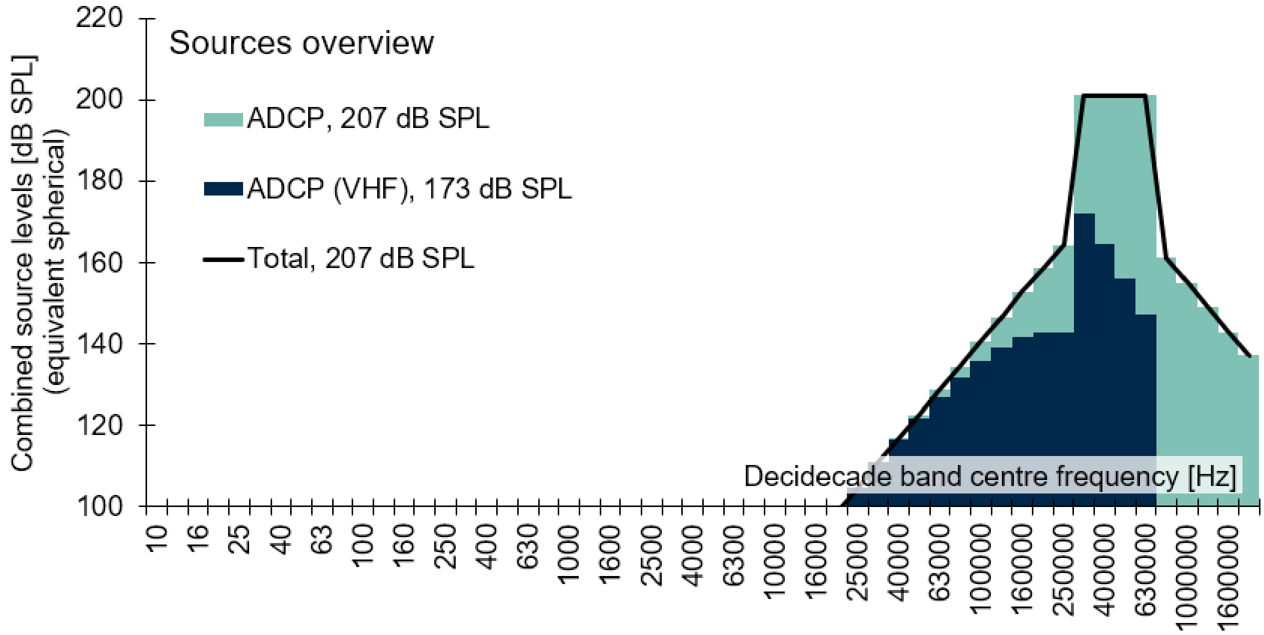

Figure 4-24. Source band level of ADCP (green) and for the ADCP when weighted for the VHF hearing group (blue).

5 SOUND PROPAGATION MODELLING METHODOLOGY

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 $10 \cdot \log_{10}$(range) or $20 \cdot \log_{10}$(range) relationship, 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 (e.g., (Rogers, 1981; Weston, 1971))[8].

For simpler scenarios, such as this one, where the sediment is relatively uniform and mostly flat or where great detail in the sound field is not needed, the speed of these simpler models is preferred over the higher accuracy of numerical models and are routinely used for these types of assessments. For this assessment, we have used the “Roger’s” model (Rogers, 1981) which is suitable to depths of c. 200 m and generally softer sediments.

This model will tend to underestimate the transmission losses (leading to estimates greater than actual impact), primarily due to the omission of surface roughness, wind effects and shear waves in the sediment.

5.1 Modelling Assumptions

The main assumptions used in the modelling are:

1. Animals fleeing the area will not return within a 24-hour period.
2. Animals flee for up to 2 hours, after which they will be up to 10.8 km and 3.6 km away for marine mammals and fish, respectively.
3. A soft start where no SBP and no USBL is active, but MBES and/or SSS is active (section 4.1.2.5) is a feasible and practical option for the survey operator. This gives the VHF group a c. 9-18 dB reduction in received level for the duration of the soft start, depending on exact equipment configuration.
4. Results assume a transition from impulsive (kurtosis >40) to non-impulsive (kurtosis <40) at some distance from the source (source, sediment and depth dependant). This means that for the sparker and boomer SBP, at ranges greater than 500-3300 m the received noise will have become non-impulsive, while for the remaining sources this transition occurs at 20-200 m range from the source. After the transition to non-impulsive noise the noise is assessed against the non-impulsive thresholds.

   This assumption is also applicable for the assessment of behavioural disturbance.

5.2 Exposure Calculations (dB SEL)

To compare modelled levels with the two impact assessment frameworks (NOAA 2024 & Popper et al. 2014) it is necessary to calculate received levels as exposure levels (SEL), weighted for marine mammals and unweighted for fishes. For ease of implementation, sources have generally been converted to an SPL source level, meaning converting to SEL from SPL or from a number of events.

To convert from SPL to SEL, the following relation can be used:

$$SEL = \mathrm{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \tag{1}$$

Or, where it is inappropriate to convert SEL from one event to SEL cumulative by relating to the number of events as:

$$SEL_{,n\ events} = SEL_{single\ event} + 10 \cdot Log_{10}(n) \tag{2}$$

[8] This model is compared to measurements in the paper (Rogers, 1981) describing it and is capable of accurate modelling in acoustically simpler scenarios. Simpler meaning shallow in relation to the wavelengths and with no significant sound speed gradient in the water column.

And SPL from SEL:

$$SPL = SEL_{single\ event} + 10 \cdot Log_{10}\left(\frac{n}{t_2 - t_1}\right) \quad (3)$$

As an animal swims away from the sound source, the noise it experiences will become progressively more attenuated; the cumulative, fleeing SEL is derived by logarithmically adding the SEL to which the mammal is exposed as it travels away from the source. This calculation is used to estimate the approximate minimum start distance for an animal in order for it to be exposed to sufficient sound energy to result in the exceedance of a threshold, or to check if a set exclusion zone is sufficient for an activity (e.g. will an exclusion zone of 500 m be sufficient to prevent exceeding an AUD INJ threshold). It should be noted that the sound exposure calculations are based on the simplistic assumption that the animal will continue to swim away at a constant speed. The real-world situation is more complex, and the animal is likely to move in a more varied manner. Reported swim speeds are summarised in Table 5-1 along with the source papers for the assumptions.

For this assessment, we used a swim speed of 1.5 m/s for marine mammals, and 0.5 m/s for fishes (including sharks).

For very long fleeing durations, the ambient sound itself can exceed the thresholds, e.g., an ambient sound level of 122.4 dB, weighted for the VHF group, will exceed the non-impulsive TTS threshold of 161 dB SEL after 2 hours' exposure[9]. For this assessment, we consider fleeing durations of 2 hours (7200 seconds, allowing 10800 m of fleeing), meaning that weighted levels of 122.4 dB SPL will exceed the VHF group's non-impulsive TTS threshold in the fleeing model.

Table 5-1: Swim speed examples from literature

Species	Hearing Group	Swim Speed (m/s)	Source Reference
Harbour porpoise	VHF	1.5	Otani *et al.,* 2000
Harbour seal	PCW	1.8	Thompson, 2015
Grey seal	PCW	1.8	Thompson, 2015
Minke whale	LF	2.3	Boisseau *et al.,* 2021
Bottlenose dolphin	HF	1.52	Bailey and Thompson, 2010
White-beaked dolphin	HF	1.52	Bailey and Thompson, 2010
Basking shark	Fish (unweighted)	1.0	Sims, 2000
All other fish groups	Fish (unweighted)	0.5	Popper *et al.,* 2014
Sea turtles	Fish (unweighted)	0.56-0.84 & 0.78-2.8	(F, et al., 1997; SA, 2002)

[9] 122.4 dB SPL + 10*$\log_{10}$(3600 seconds) = 161 dB SEL, TTS non-impulsive threshold for the VHF group is 161 dB SEL.

6 RESULTS AND ASSESSMENT

Results are presented here as the geographical “risk range” to an auditory threshold (AUD INJ/ TTS/ Behavioural), as given in Sections 2.3 and 2.5. A given risk range specifies the expected range, within which, a receiver would exceed the relevant threshold. Risk ranges are given for the 90th percentile value.

Several result types are presented for each activity to inform this assessment and to provide flexibility in mitigation:

1. **“1 second exposure risk range”:**
   This is the range of acute risk of impact from the activity (a one second exposure) and is presented to indicate instantaneous risk and for comparison with other studies. This assumes a stationary animal (during the 1-second exposure) with all equipment operating at full power and does not include a soft start.

2. **“Minimal starting range for a fleeing animal with no soft start”:**
   The minimal range a fleeing animal needs to start fleeing from to avoid being exposed to noise exceeding its TTS/AUD INJ threshold. Animals are moving in a straight line away from the source at a constant speed of 1.5 m/s (0.5 m/s for fish, including sharks).

3. **“Minimal starting range for a fleeing animal with a 20 min soft start with no SBP and no USBL active”:**
   The minimal range a fleeing animal needs to start fleeing from to avoid being exposed to noise exceeding its TTS/ AUD INJ threshold. Animals are moving in a straight line away from the source at a constant speed of 1.5 m/s (0.5 m/s for fish, including sharks).

4. **“Minimal starting range for a fleeing animal with a 30 min soft start with no SBP and no USBL active”:**
   The minimal range a fleeing animal needs to start fleeing from to avoid being exposed to noise exceeding its TTS/ AUD INJ threshold. Animals are moving in a straight line away from the source at a constant speed of 1.5 m/s (0.5 m/s for fish, including sharks).

5. **“Behavioural response range”:**
   The range at which the behavioural limit for the marine mammals (160/120 dB SPL impulsive/non-impulsive) or the fishes (including sharks) (150 dB SPL) is exceeded. No hearing group weightings are applied when assessing against this threshold.

6.1 Assumptions and Notes on Results

The results should be read while keeping the following in mind:

- Results are rounded to the nearest two significant digits. This can lead to some curious appearing overlaps in risk ranges.
- The modelling resolution of ten metres means that where results are lower than this “<10” is stated to mean “below ten metres”.
- Where risk ranges are large (often the case for TTS risk ranges), an increase in soft start duration will not be effective to lower the TTS risk range. This is due to the logarithmic nature of transmission losses:

  For a marine mammal that starts fleeing at 500 m range:

  - Increasing the soft start from 0 to 10 minutes allows a marine mammal to swim an additional 900 m (1.5 m/s * 600 sec), from 500 m range to 1400 m range.
    This result in in a c. 6.5 dB reduction in received level for the animal.
  - Increasing the soft start from 10 to 20 minutes allows the animal to swim an additional 900 m, from 1400 m range to 2300 m range.
    This results in in a c. 3.5 dB reduction in received level for the animal.
  - And for 20 to 30 minutes (2300 to 3200 m), the reduction is c. 2 dB.
- As the impulsive noise transitions to non-impulsive noise with increased ranges, the appropriate behavioural threshold for the assessment changes from 160 dB to 120 dB (a likely 10-fold increase in

range). This means that there are large ranges of disturbance, but should be considered in relation to, for example, the radiated noise from common vessels, which will exceed this threshold to ranges of 500-10000 m (assuming 160-180 dB SPL source level).

- Animals are modelled as fleeing in straight lines. Where sites are very confined, the maximal risk ranges will be restricted by line-of-sight ranges (and cut short where they meet land).
- Modelling assumed a maximal fleeing time of 7200 seconds (2 hours). This allows for 10.8 km of fleeing for marine mammals (3.6 km for fish).
- Modelling is limited to a range of 20 km from the source.
- No modelling of risk ranges for *mortality* for fishes are presented, as risk ranges to AUD INJ (recoverable injury) are all smaller than 30 m.
- No results are presented for assessment against the L_P thresholds as, for all scenarios, the risk ranges to the TTS thresholds were <120 m for fish (TTS: 193 dB L_P) and <100 m for marine mammals (VHF TTS: 196 dB L_P). AUD INJ risk ranges are <10 m for all hearing groups.
- Results are *only* given in relation to the behavioural thresholds (SPL) and TTS/ AUD INJ thresholds for sound exposure level (SEL).
- The hearing group “Fish” includes sharks and are for unweighted received levels assessed against the lowest thresholds for fishes as found in guidance (Popper, et al., 2014).
  This also means that very high frequency sources (MBESs or ADCP), which the fish cannot detect, can lead to significant risk ranges – this is a consequence of a lack of an agreed frequency weighting for fish, not an indication that fish can be injured by these.
- Given the large difference in behavioural thresholds between marine mammals and fish, 120 dB versus 150 dB, counterintuitive effects can arise due to the mechanics of sound propagation:

  Higher frequencies generally are absorbed less by the sediment but experience higher absorption. This leads to relatively lower transmission loss near the source, but higher transmission loss further away. Lower frequencies will be absorbed more by the sediment near the source but experience less transmission loss due to absorption. This leads to relatively higher initial transmission loss for lower frequencies with lower transmission loss at longer ranges. This can mean that a lower frequency sound will drop below 150 dB SPL (fishes’ threshold) quickly but remain above 120 dB SPL (marine mammal threshold) up to long ranges, leading to vary large differences in the behavioural threshold exceedance ranges.

  Conversely, higher frequency sound, will tend to drop below 150 dB SPL slower, with a comparatively faster continued loss to 120 dB SPL, resulting in more similar ranges for behavioural threshold exceedance.

6.2 Results – Tabulated

6.2.1 Geophysical Survey

For all geophysical survey results, the vessel, the SSS, the USBL and the MBES sources are active. Only the type of SBP is changing between the scenarios modelled.

6.2.1.1 Parametric SBP (P-SBP)

This scenario assumes that the geophysical survey is using a parametric SBP (Section 4.1.2.1).

6.2.1.1.1 Injury

Risk ranges for exceeding AUD INJ (Table 6-1) are below 30 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 250 m with no soft start.

A soft start of 20 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to <10 m.

Table 6-1. Risk ranges for exceeding the AUD INJ threshold for all hearing groups during Geophysical survey (Parametric SBP).

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	310	<10	<10	<10
Fleeing receiver, no soft start	<10	20	250	20	<10	30
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	<10	<10	<10	<10

6.2.1.1.2 TTS

Risk ranges for exceeding TTS (Table 6-2) is below 440 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 3700 m with no soft start.

For the VHF group, a soft start of 20minutes reduces the TTS risk range to 2500 while a soft start of 30 minutes reduces the TTS risk range to 2300 m. Further increasing the soft start duration will have diminishing effects on the reduction in TTs risk range.

Table 6-2: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Parametric SBP).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	30	660	40	10	30
Fleeing receiver, no soft start	120	200	3700	440	150	150
Fleeing receiver, 20 min soft start	<10	<10	2500	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	2300	<10	<10	<10

6.2.1.1.3 Behavioural

The range to exceedance of the behavioural thresholds (Table 6-3) are exceeded to 10 km for marine mammals and 660 m for fishes.

Table 6-3: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Parametric SBP).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	10000	10000	10000	10000	10000	660

6.2.1.2 Chirper/Pinger SBP (C-SBP)

This scenario assumes that the geophysical survey is using a chirper/pinger SBP (Section 4.1.2.2).

6.2.1.2.1 Injury

Risk ranges for exceeding AUD INJ (Table 6-4) is below 20 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 180 m with no soft start.

A soft start of 20 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to <10 m.

Table 6-4. Risk ranges for exceeding the AUD INJ threshold for all hearing groups during Geophysical survey (chirper/pinger SBP).

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	140	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	180	20	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	<10	<10	<10	<10

6.2.1.2.2 TTS

Risk ranges for exceeding TTS (Table 6-5) is below 690 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 4100 m with no soft start.

A soft start of 20 minutes reduces the TTS risk range to <10 m for all groups except the VHF group.

For the VHF group, a soft start of 20 minutes reduces the TTS risk range to 2900 while a soft start of 30 minutes reduces the TTS risk range to 2300 m. Further increasing the soft start duration will have diminishing effects on the reduction in TTs risk range.

Table 6-5: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (chirper/pinger SBP).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	10	<10	600	30	10	<10
Fleeing receiver, no soft start	230	150	4100	690	200	30
Fleeing receiver, 20 min soft start	<10	<10	2900	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	2300	<10	<10	<10

6.2.1.2.3 Behavioural

The range to exceedance of the behavioural thresholds (Table 6-6) are exceeded to 16 km for marine mammals and 620 m for fishes.

Table 6-6: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (chirper/pinger SBP).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	16000	16000	16000	16000	16000	620

6.2.1.3 Sparker/UHRS (S-SBP)

This scenario assumes that the geophysical survey is using a sparker SBP / UHRS (Section 4.1.2.3).

6.2.1.3.1 Injury

Risk ranges for exceeding AUD INJ (Table 6-7) is below 50 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 2100 m with no soft start.

A soft start of 20 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to 860 m and the remaining groups to <10 m.

A soft start of 30 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to 310 m.

Table 6-7. Risk ranges for exceeding the AUD INJ threshold for all hearing groups during Geophysical survey (sparker SBP/UHRS).

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	130	<10	<10	<10
Fleeing receiver, no soft start	30	<10	2100	50	20	<10
Fleeing receiver, 20 min soft start	<10	<10	860	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	310	<10	<10	<10

6.2.1.3.2 TTS

Risk ranges for exceeding TTS (Table 6-8) is below 1200 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 3800 m with no soft start.

A soft start of 30 minutes reduces the TTS risk range to <10 m for all groups except the VHF group.

For the VHF group, a soft start of 20 minutes reduces the TTS risk range to 2600 m while a soft start of 30 minutes reduces the TTS risk range to 2000 m. Further increasing the soft start duration will have diminishing effects on the reduction in TTS risk range.

Table 6-8: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (sparker SBP/UHRS).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	20	<10	940	30	10	<10
Fleeing receiver, no soft start	900	230	3800	1200	610	120
Fleeing receiver, 20 min soft start	<10	<10	2600	60	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	2000	<10	<10	<10

6.2.1.3.3 Behavioural

The range to exceedance of the behavioural thresholds (Table 6-9) are exceeded to 19 km for marine mammals and 630 m for fishes.

Table 6-9: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (sparker SBP/UHRS).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	19000	19000	19000	19000	19000	630

6.2.1.4 Boomer SBP (B-SBP)

This scenario assumes that the geophysical survey is using a boomer SBP (Section 4.1.2.4).

6.2.1.4.1 Injury

Risk ranges for exceeding AUD INJ (Table 6-10) is below 70 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 2200 m with no soft start.

A soft start of 20 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to 970 m and the remaining groups to <10 m.

A soft start of 30 minutes or more will allow sufficient time for the VHF group to swim away to reduce the AUD INJ exceedance risk range to 390 m.

Table 6-10. Risk ranges for exceeding the AUD INJ threshold for all hearing groups during Geophysical survey (boomer SBP).

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	140	<10	<10	<10
Fleeing receiver, no soft start	40	<10	2200	70	30	<10
Fleeing receiver, 20 min soft start	<10	<10	970	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	390	<10	<10	<10

6.2.1.4.2 TTS

Risk ranges for exceeding TTS (Table 6-11) is below 1200 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 4300 m with no soft start.

A soft start of 30 minutes reduces the TTS risk range to <10 m for all groups except the VHF group.

For the VHF group, a soft start of 20 minutes reduces the TTS risk range to 3100 m while a soft start of 30 minutes reduces the TTS risk range to 2500 m. Further increasing the soft start duration will have diminishing effects on the reduction in TTS risk range.

Table 6-11: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (boomer SBP).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	30	<10	980	40	20	<10
Fleeing receiver, no soft start	1200	290	4300	1500	800	140
Fleeing receiver, 20 min soft start	130	<10	3100	270	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	2500	<10	<10	<10

6.2.1.4.3 Behavioural

The range to exceedance of the behavioural thresholds (Table 6-12) are exceeded to 19 km for marine mammals and 720 m for fishes.

Table 6-12: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (boomer SBP).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	19000	19000	19000	19000	19000	720

6.2.2 Geotechnical Survey

This scenario assumes the equipment related to the geotechnical survey is active (Section 4.1.2.6).

Note that the soft start for this activity is the vessel itself, so if the vessel is active (using main or DP thrusters) this can be considered part of the soft start.

6.2.2.1 Borehole drilling, Vibro-cores and CPT

6.2.2.1.1 Injury

Risk ranges for exceeding AUD INJ (Table 6-13) is below 20 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 180 m with no soft start.

Table 6-13. Risk ranges for exceeding the AUD INJ threshold for all hearing groups during the geotechnical survey.

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	130	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	180	20	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	<10	<10	<10	<10

6.2.2.1.2 TTS

Risk ranges for exceeding TTS (Table 6-14) is below 550 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 3800 m with no soft start.

A soft start of 20 minutes reduces the TTS risk range to <10 m for all groups except the VHF group.

For the VHF group, a soft start of 20 minutes reduces the TTS risk range to 2600 while a soft start of 30 minutes reduces the TTS risk range to 2000 m. Further increasing the soft start duration will have diminishing effects on the reduction in TTS risk range.

Table 6-14: Risk ranges for exceeding the TTS threshold for all hearing groups during the geotechnical survey.

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	10	<10	560	30	10	<10
Fleeing receiver, no soft start	180	130	3800	550	170	30
Fleeing receiver, 20 min soft start	<10	<10	2600	<10	<10	<10
Fleeing receiver, 30 min soft start	<10	<10	2000	<10	<10	<10

6.2.2.1.3 Behavioural

The range to exceedance of the behavioural thresholds (Table 6-15) are exceeded to 14 km for marine mammals and 580 m for fishes.

Table 6-15: Risk ranges for exceeding the behavioural threshold for all hearing groups during the geotechnical survey.

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	14000	14000	14000	14000	14000	580

6.2.3 ADCP

This scenario assumes the ADCP source is active (Section 4.1.2.8).

Risk ranges for exceeding AUD INJ (Table 6-16) is below 20 m for all groups except the VHF group, which risks exceeding the AUD INJ threshold to a range of 40 m.

Note that this source might be switched on with no soft start, meaning the soft start scenario will only be realised if the ADCP is switched on while the vessel has been nearby for over 20 minutes.

Table 6-16. Risk ranges for exceeding the AUD INJ threshold for all hearing groups of the ADCP.

AUD INJ Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	<10	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	40	<10	<10	20
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10

The TTS exceedance risk range are up to 100 m for the VHF group, 70 m for the fishes and less than 10 m for the remaining groups (Table 6-16 and Table 6-17).

Note that fishes generally cannot hear above 10 kHz, so these ranges are more a result of the guidance having no mechanism for weighting the received noise, than actual impact risk.

Table 6-17: Risk ranges for exceeding the TTS threshold for all hearing groups of the ADCP.

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	50	<10	<10	20
Fleeing receiver, no soft start	<10	<10	100	<10	<10	70
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10

Behavioural threshold exceedance ranges are 440 for marine mammals and 200 for fishes (Table 6-18).

Note that to account for the fact that the ADCPs main output is above 300 kHz and that most animals cannot hear it, we have included the behavioural ranges after adjusting for the hearing sensitivity of the receivers. With this adjustment, the ADCP is below the behavioural threshold for all groups <10 m from the source.

Table 6-18: Risk ranges for exceeding the behavioural threshold for all hearing groups of the ADCP.

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	440	440	440	440	440	200
Weighted for hearing groups.	*<10*	*<10*	*<10*	*<10*	*<10*	*<10*

6.3 Results Summary

6.3.1 Geophysical Survey

6.3.1.1 Parametric and Chirper/Pinger (P-SBP & C-SBP)

AUD INJ – hearing injury

Apart from the VHF hearing group, all risk ranges to AUD INJ exceedance for fleeing receivers are below 30 m with no soft start.

For the VHF group, no soft start risks AUD INJ to 250 m.

With a 20-minute soft start the risk range for AUD INJ to <10 m for all hearing groups.

TTS – temporary hearing impairment

Apart from the VHF hearing group, all risk ranges to TTS exceedance for fleeing receivers are below 690 m with no soft start.

For the VHF group, no soft start risks TTS to 4100 m.

With a 20-minute soft start the risk range for TTS for the VHF group is reduced to 2900 m, and to <10 m for the remaining groups.

With a 30-minute soft start the risk range for TTS for the VHF group is reduced to 2300 m, and to <10 m for the remaining groups.

Behavioural disturbance

Ranges for behavioural disturbance are up to 16 km for marine mammals and 620 m for fishes.

6.3.1.2 Sparker and Boomer (S-SBP & B-SBP)

AUD INJ – hearing injury

Apart from the VHF hearing group, all risk ranges to AUD INJ exceedance for fleeing receivers are below 70 m with no soft start.

For the VHF group, no soft start risks AUD INJ to 2200 m.

With a 20-minute soft start the risk range for AUD INJ for the VHF group is reduced to 970 m, and to <10 m for the remaining groups.

With a 30-minute soft start the risk range for AUD INJ for the VHF group is reduced to 390 m.

TTS – temporary hearing impairment

Apart from the VHF hearing group, all risk ranges to TTS exceedance for fleeing receivers are below 1500 m with no soft start.

For the VHF group, no soft start risks TTS to 4300 m.

With a 20-minute soft start the risk range for TTS for the VHF group is reduced to 3100 m, and to 270 m for the remaining groups.

With a 30-minute soft start the risk range for TTS for the VHF group is reduced to 2500 m, and to <10 m for the remaining groups.

Behavioural disturbance

Ranges for behavioural disturbance are up to 19 km for marine mammals and 720 m for fishes.

6.3.2 Geotechnical Survey

AUD INJ – hearing injury

Apart from the VHF hearing group, all risk ranges to AUD INJ exceedance for fleeing receivers are below 20 m with no soft start.

For the VHF group, no soft start risks AUD INJ to 180 m.

With a 20-minute soft start the risk range for AUD INJ to <10 m for all hearing groups.

TTS – temporary hearing impairment

Apart from the VHF hearing group, all risk ranges to TTS exceedance for fleeing receivers are below 550 m with no soft start.

For the VHF group, no soft start risks TTS to 3800 m.

With a 20-minute soft start the risk range for TTS for the VHF group is reduced to 2600 m, and to <10 m for the remaining groups.

With a 30-minute soft start the risk range for TTS for the VHF group is reduced to 2000 m, and to <10 m for the remaining groups.

Behavioural disturbance

Ranges for behavioural disturbance are up to 14 km for marine mammals and 580 m for fishes.

6.3.3 ADCP

AUD INJ – hearing injury

Apart from the VHF hearing group, all risk ranges to AUD INJ exceedance for fleeing receivers are under 20 m with no soft start.

For the VHF group, the risks of AUD INJ extend to 40 m.

If the ADCP is switched on while the vessel has been nearby for over 20 minutes, this will act as a soft start to reduce the risk of AUD INJ to <10 m for all hearing groups.

TTS – temporary hearing impairment

Apart from the VHF hearing group, all risk ranges to TTS exceedance for fleeing receivers are below 70 m with no soft start.

For the VHF group, the risk of TTS extends to 100 m.

If the ADCP is switched on while the vessel has been nearby for over 20 minutes, this will act as a soft start to reduce the risk of TTS to <10 m for all hearing groups.

Behavioural disturbance

Ranges for behavioural disturbance are up to 440 m, when applying the criterion strictly (unweighted), however, given the ADCPs main energy is above 300 kHz (outside the hearing range of the receivers) we have also included the behavioural disturbance ranges while accounting for the receivers' hearing capabilities.

Accounting for the frequency dependent sensitivity of the receivers, the behavioural disturbance range decreases to <10 m for all groups.

7 CONCLUSIONS

This report has modelled equipment and vessels to be used in undertaking the marine geophysical and geotechnical surveys that form part of the SI works within the AoI of this MUL application. For modelling purposes it has been assumed that only one marine geophysical or geotechnical survey occurs at any one time within the ensonified area modelled.

There is risk of inducing hearing injury (AUD INJ – auditory injury) following noise from the SI Works, but with the implementation of soft starts, these distances will be minimised efficiently to make the risks of auditory injury low for all hearing groups assessed (fish and marine mammals).

There is risk of inducing temporary hearing effects (TTS – Temporary Threshold Shift). During geophysical survey, this extends to c. 4.3 km for the VHF group (harbour porpoise) and below c. 1.5 km for remaining marine mammals and fishes. Introducing a 20-minute soft start to the geophysical surveys, where only some equipment is active, will reduce the risk of TTS for the VHF group to within 3.1 km, and to below 270 m for the remaining marine mammals and fishes.

Behavioural disturbance ranges of up to 19 km have been identified during the geophysical survey for marine mammals for the worst-case scenario which is while the sparker or boomer type SBP is active.

For the geotechnical survey, the use of a USBL means that behavioural disturbance for marine mammals ranges up to 14 km under the worst-case scenario.

The ADCP will have minor risk of AUD INJ for the VHF group (up to 40 m), but otherwise no acoustic impact.

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Appendix A – Acoustic Concepts and Terminology

Sound travels through water as vibrations of the fluid particles in a series of pressure waves. The waves comprise a series of alternating compressions (positive pressure variations) and rarefactions (negative pressure fluctuations). Because sound consists of variations in pressure, the unit for measuring sound is usually referenced to a unit of pressure, the Pascal (Pa). The unit usually used to describe sound is the decibel (dB) and, in the case of underwater sound, the reference unit is taken as 1 μPa, one micro-pascal, whereas 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, a sound pressure of 60 dB re 20 μPa is the same as 86 dB re 1 μPa, although care also needs to be taken when converting from in air sound to in water sound levels due to the different sound speeds and densities of the two mediums resulting in a conversion factor of approximately 62 dB for comparing intensities (watt/m²), see Table 8-1 , below.

Table 8-1: Comparing sound quantities between air and water.

	Constant intensity		Constant pressure	
Properties	**Air**	**Water**	**Air**	**Water**
Soundspeed (C) [m/s]	340	1500	340	1500
Density (ρ) [kg/m³]	1.293	1026	1.293	1026
Acoustic impedance (Z=C·ρ) [kg/(m²·s) or (Pa·s)/m³]	440	1539000	440	1539000
Sound intensity (I=p²/Z) [Watt/m²]	1	1	22.7469	0.0065
Sound pressure (p=(I*Z)^½) [Pa]	21	1241	100	100
Particle velocity (I/p) [m/s]	0.04769	0.00081	0.22747	0.00006
dB re 1 μPa²	146.4	**181.9**	160.0	**160.0**
dB re 20 μPa²	**120.4**	155.9	**134.0**	134.0
Difference dB re 1 μPa² & dB re 20 μPa²	**61.5**		**26.0**	

All underwater sound pressure levels in this report are described in dB re 1 μPa². In water, the sound source strength is defined by its sound pressure level in dB re 1 μPa², referenced back to a representative distance of 1m from an assumed (infinitesimally small) point source. This allows calculation of sound levels in the far-field. For large, distributed sources, the actual sound pressure level in the near-field will be lower than predicted.

There are several descriptors used to characterise a sound wave. The difference between the lowest pressure deviation (rarefaction) and the highest pressure deviation (compression) from ambient is the peak to peak (or pk-pk) sound pressure ($L_{P\text{-}P}$ for the level in dB), Note that $L_{P\text{-}P}$ can be hard to measure consistently, as the maximal duration between the lowest and highest pressure deviation is not standardised. The difference between the highest deviation (either positive or negative) and the ambient pressure is called the peak pressure (L_P for the level in dB). Lastly, the average sound pressure is used as a description of the average amplitude of the variations in pressure over a specific time window (SPL for the level in dB). SPL is equal to the L_{eq} when the time window for the SPL is equal to the time window for the total duration of an event. The cumulative sound energy from pressure is the integrated squared pressure over a given period (SEL for the level in dB). These descriptions are shown graphically in Figure 8-1 and reflect the units as given in ISO 18405:2017, “Underwater Acoustics – Terminology”.

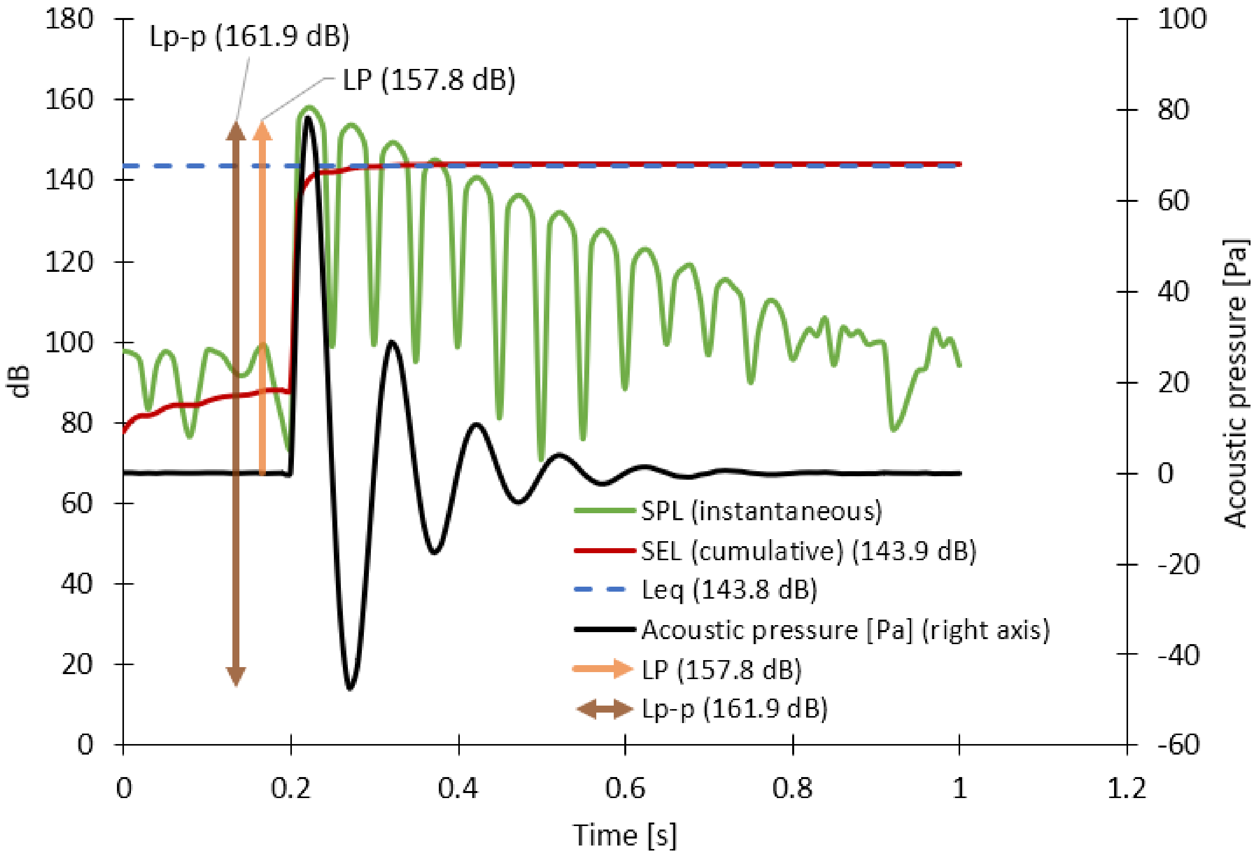

Figure 8-1: Graphical representation of acoustic wave descriptors.

The sound pressure level (SPL[10]) is defined as follows (ISO 18405:2017, 3.2.1.1):

$$SPL = 10 \cdot Log_{10}\left(\frac{\overline{p^2}}{1 \cdot 10^{-12} Pa}\right) \tag{1}$$

Here $\overline{p^2}$ is the arithmetic mean of the squared pressure values. Note that L_P is simply the instantaneous SPL (ISO 18405:2017, 3.2.2.1).

The peak sound pressure level, L_P, is the instantaneous decibel level of the maximal deviation from ambient pressure and is defined in (ISO 18405:2017, 3.2.2.1) and can be calculated as:

$$L_P = 10 \cdot Log_{10}\left(\frac{max(p^2)}{1 \cdot 10^{-12} Pa}\right)$$

Another useful measure of sound used in underwater acoustics is the Exposure Level, or SEL. This descriptor is used as a measure of the total sound energy of a single event or a number of events (e.g. over the course of a day). This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like for like basis. Historically, use was primarily made of SPL and L_P 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 over e.g. a 24-hour period to be taken into account. The SEL is defined as follows (ISO 18405:2017, 3.2.1.5):

$$SEL = 10 \cdot Log_{10}\left(\frac{\int_{t_1}^{t_2} p(t)^2 dt}{1 \cdot 10^{-12} Pa}\right) \tag{2}$$

To convert from SEL to SPL the following relation can be used:

$$SEL = \mathrm{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \tag{3}$$

[10] Equivalent to the commonly seen “RMS-level”.

Converting from a single event to multiple events for SEL:

$$SEL_{n\ events} = SEL_{single\ event} + 10 \cdot Log_{10}(n) \quad (4)$$

The frequency, or pitch, of the sound is the rate at which these oscillations occur 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 dB(A). However, the hearing faculties of marine mammals and fish are not the same as humans, with marine mammals hearing over a wider range of frequencies, fish over a typically smaller range of frequencies and both with different sensitivities. It is therefore important to understand how an animal's hearing varies over the entire frequency range to assess the effects of sound on marine life. Consequently, use can be made of frequency weighting scales 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 8-2. Note 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. It is also worth noting that some fish are sensitive to particle velocity rather than pressure, although paucity of data relating to particle velocity levels for anthropogenic sound sources means that it is often not possible to quantify this effect. Marine reptiles (mostly sea turtles) have relatively poor hearing underwater, lacking a good acoustic coupling mechanism from the sea water to the inner ear.

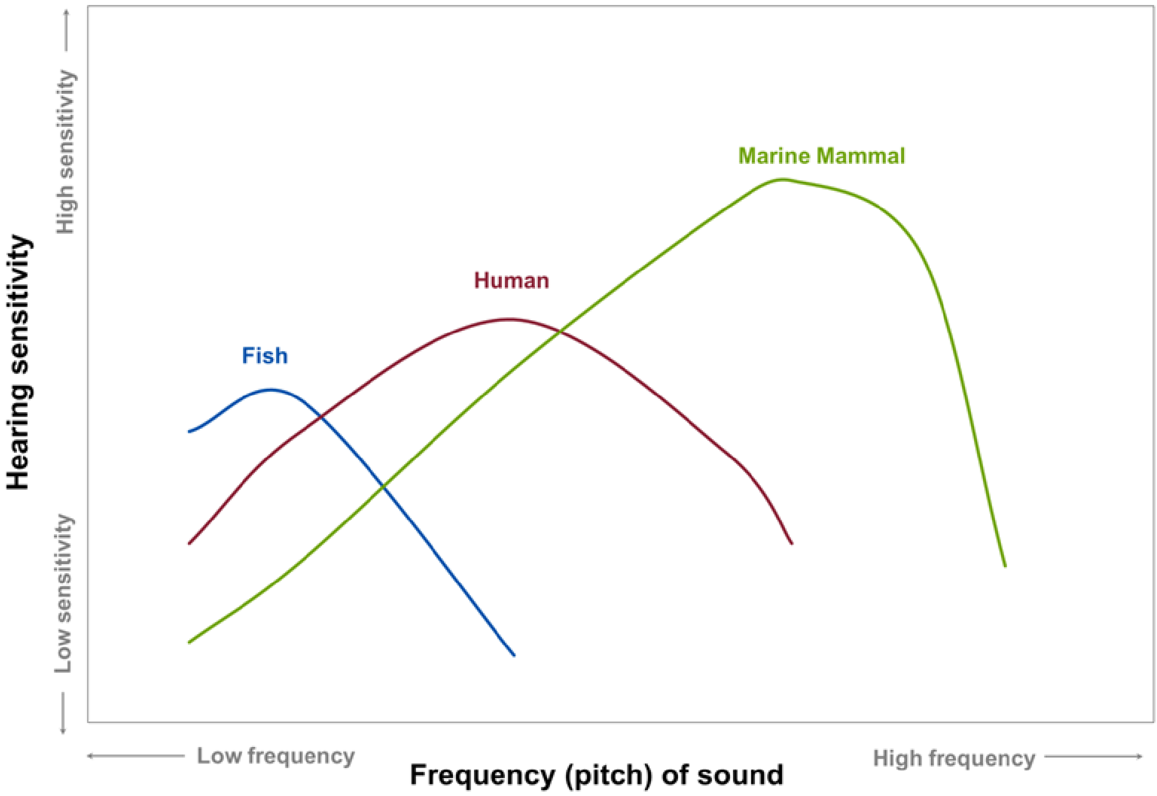

Figure 8-2: Comparison between hearing thresholds of different marine animals and humans.

Impulsiveness

The impulsiveness of a source can be estimated from the kurtosis of the weighted signal (as suggested by Matin et al. in “Techniques for distinguishing between impulsive and non-impulsive sound in the context of regulating sound exposure for marine mammals”, Journal of the Acoustical Society of America, 2020)

The consequence of this is that the same equipment can be both impulsive and non-impulsive, depending o marine mammal presence and the local environment.

Below is an example of a hull mounted echo sounder at 15 m depth and at 250 m depth.

In shallow water the ping rate can be high as reflections from the sediment return quickly, but the single pulse duration is usually shorter as less energy in the signal is required due to the short range the pulse must travel. This leads to high repetition rate (decreases kurtosis) and shorter pulses (increases kurtosis). Figure 8-3 shows an example where this leads to a non-impulsive source, to be compared to the thresholds for non-impulsive noise.

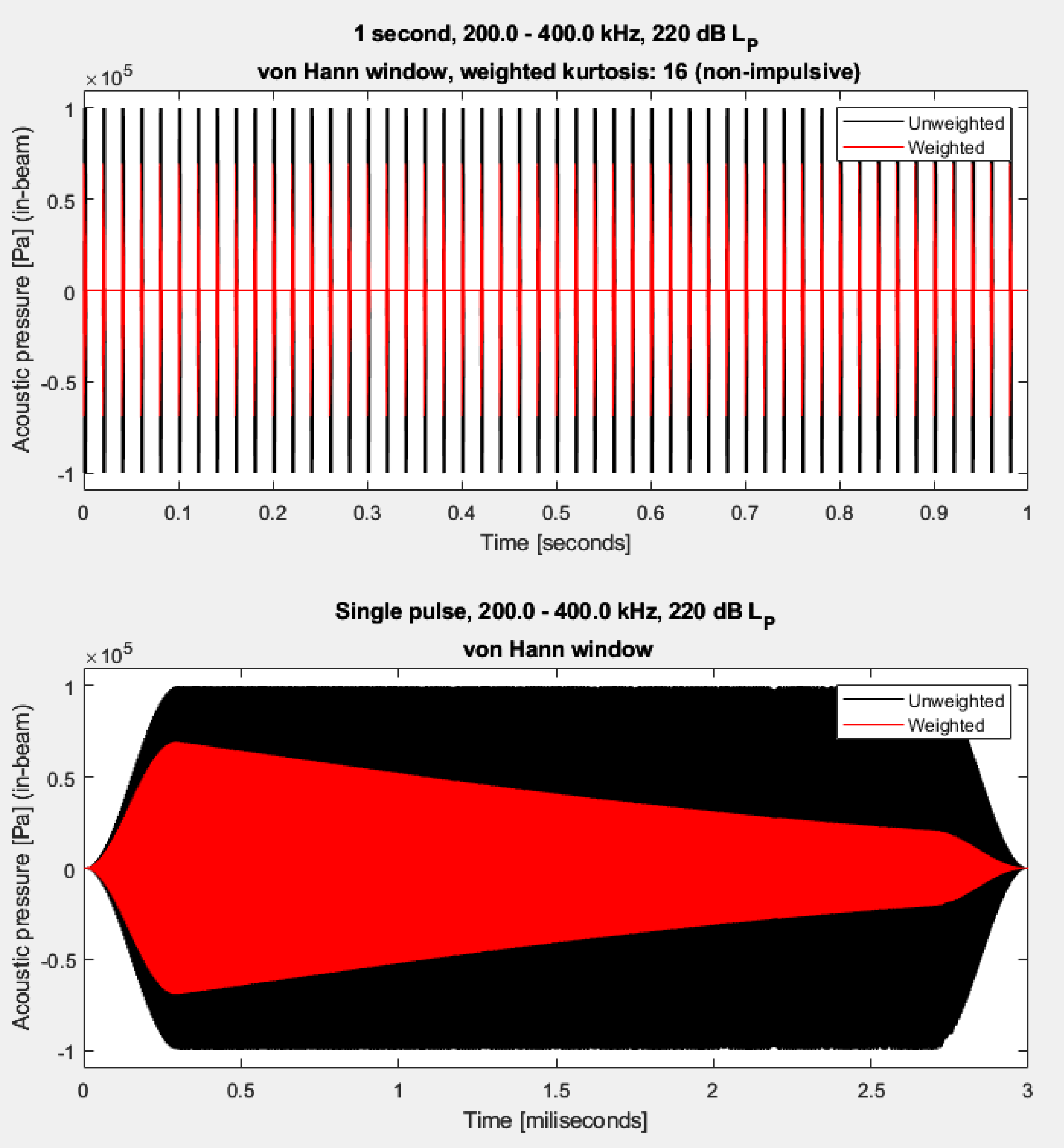

Figure 8-3. Example of a multibeam echosounder at 15 m depth (achieving 50 ping/sec) with a 3 ms ping duration. VHF-weighted kurtosis of 16 – non-impulsive.

In deeper water, the ping rate will usually be slower as echoes take longer to return to the sediment and the pulses will be longer to increase the energy in the pulses and make their echoes easier to detect. This leads to low repetition rate (increases kurtosis) and longer pulses (decreases kurtosis). Figure 8-4 shows an example where this combination resulted in an impulsive source, to be compared to the thresholds for impulsive noise.

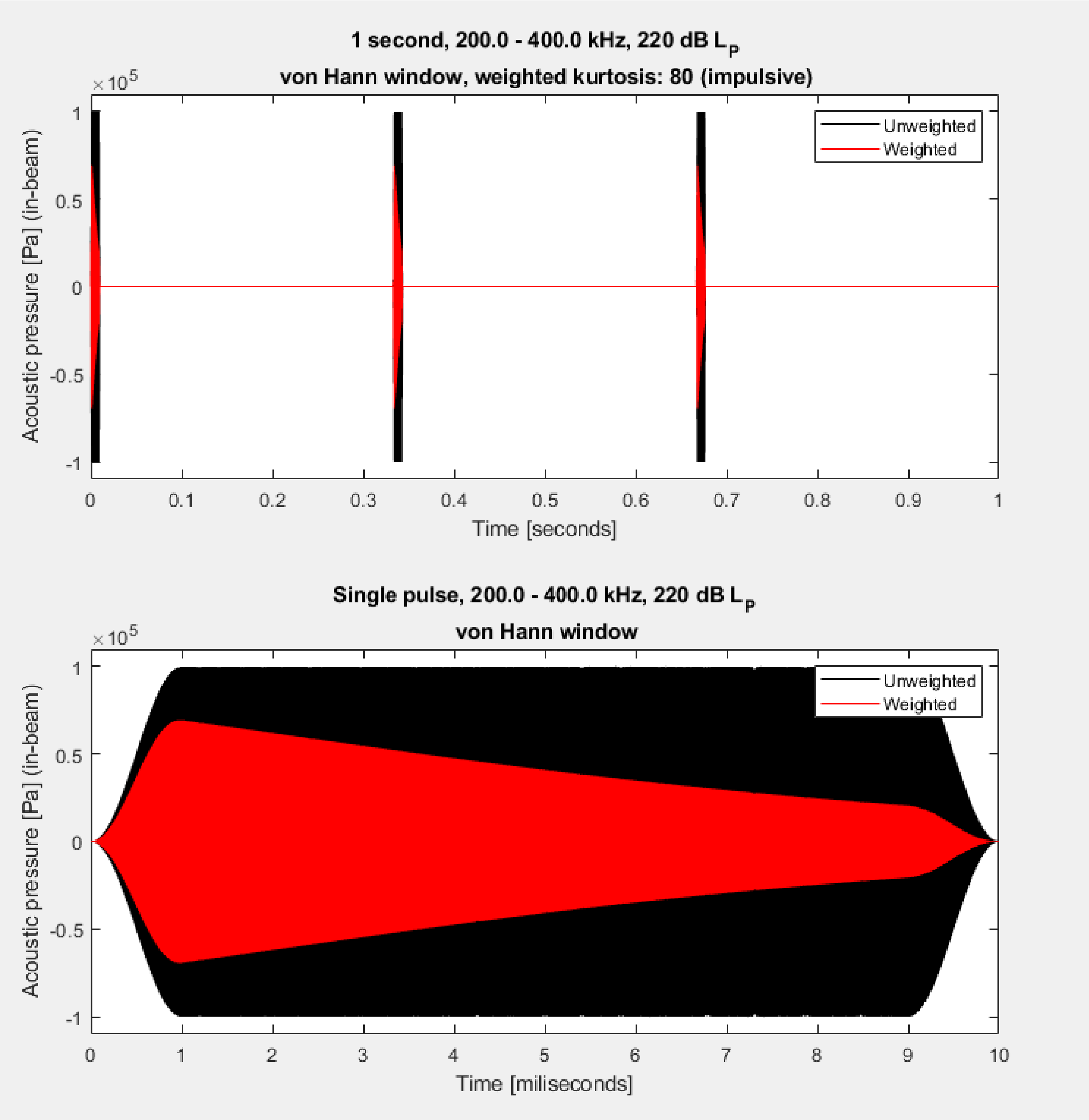

Figure 8-4. Example of a multibeam echosounder at 250 m depth (achieving 3 ping/sec) with a 10 ms ping duration. VHF-weighted kurtosis of 80 – impulsive.

With range, due to multiple reflections and scattering, the kurtosis will decrease with increased range, for shallow water this decrease will be quicker than for deeper water, compare Figure 8-5 & Figure 8-6, where a kurtosis <40 is reached at c. 200 m in 20 m depth, but at over 1000 m at 200 m depth.

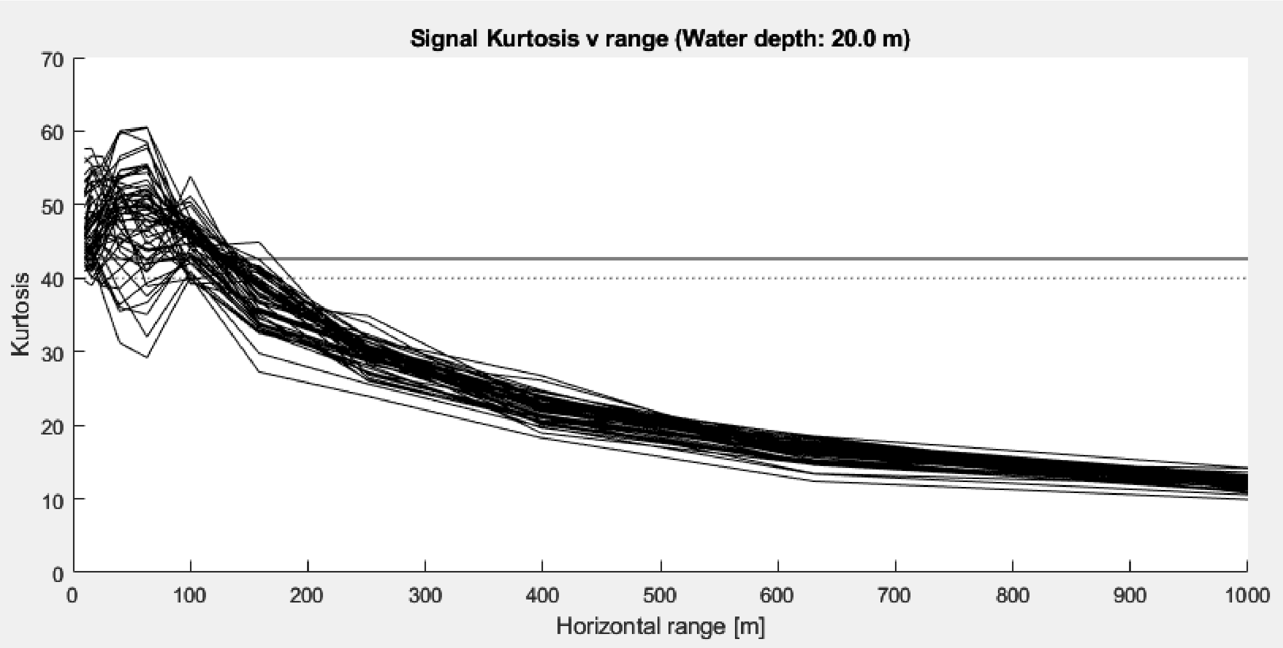

Figure 8-5. Example of USBL signal kurtosis decreasing with range at 20 m depth. Multiple lines are various combinations of source and receiver depths.

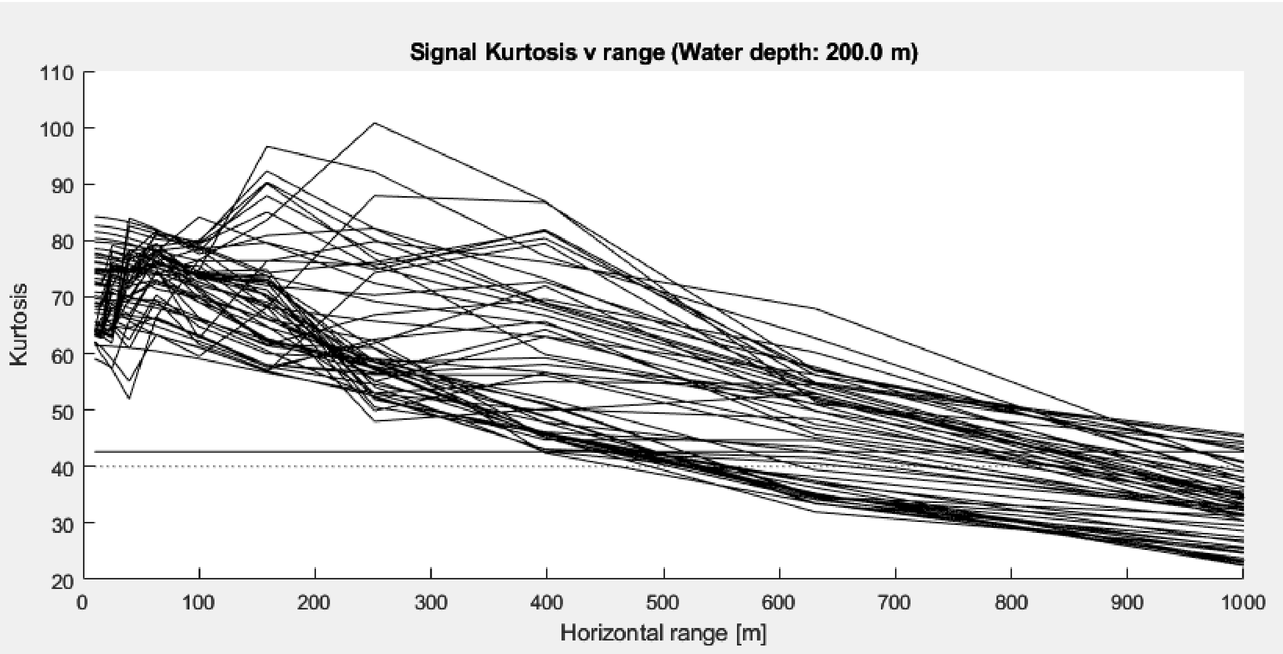

Figure 8-6. Example of USBL signal kurtosis decreasing with range at 200 m depth. Multiple lines are various combinations of source and receiver depths.

Review of Sound Propagation Concepts

Increasing the distance from the sound source usually results in the level of sound getting lower, due primarily to the spreading of the sound energy with distance, analogous to the way in which the ripples in a pond spread after a stone has been thrown in.

The way that the sound spreads will depend upon several factors such as water column depth, pressure, temperature gradients, salinity, as well as water surface and seabed conditions. Thus, even for a given locality, there are temporal variations to the way that sound will propagate. However, in simple terms, the sound energy may spread out in a spherical pattern (close to the source, with no boundaries) or a cylindrical pattern (much further from the source, bounded by the surface and the sediment), although other factors mean that decay in sound energy may be somewhere between these two simplistic cases.

In acoustically shallow waters[11] 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 2003, 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 is reflected many times by the surface and sediment.

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 is an important factor with respect to the propagation of sound from a source. In an ideal case (i.e. for a perfectly smooth sea surface), the majority of sound wave energy will be reflected back into the sea. However, for rough waters, much of the sound energy is scattered (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. Generally, the scattering effect at a particular frequency depends on the physical size of the roughness in relation to the wavelength of the frequency of interest.

As surface scattering results in differences in reflected sound, its effect will be more important at longer ranges from the source sound 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 water surface smoothness/wind speed, water depth, frequency of the sound, temperature gradient, grazing angle and range from source. Depending upon variations in the aforementioned factors, significant scattering could occur at sea state 3 or more for higher frequencies (e.g. 15 kHz or more). It should be noted that variations in propagation due to scattering will vary temporally (primarily due to different sea-states/wind speeds at different times) and that more sheltered areas (which are more likely to experience calmer waters) could experience surface scattering to a lesser extent, and less frequently, than less sheltered areas which are likely to encounter rougher waters. However, over shorter ranges (e.g. within 10-20 times the water depth) the sound will experience fewer reflections and so the effect of scattering should not be significant. Consequently, over the likely distances over which injury will occur, this effect is unlikely to significantly affect the injury ranges presented in this report, and not including this effect will overestimate the impact.

When sound waves encounter the seabed, the amount of sound reflected will depend on the geoacoustic properties of the seabed (e.g. grain size, porosity, density, sound speed, absorption coefficient and roughness) as well as the grazing angle (see Figure 8-7[12]) and frequency of the sound (Cole, 1965; Hamilton, 1970; Mackenzie, 1960; McKinney and Anderson, 1964; Etter, 2013; Lurton, 2002; Urick, 1983). Thus, seabeds comprising primarily of mud or other acoustically soft sediment will reflect less sound than acoustically harder seabeds such as rock or sand. This effect also depends on the profile of the seabed (e.g. the depth of the sediment layers and how the geoacoustic properties vary with depth below the sea floor). The sediment interaction is less pronounced at higher frequencies (a few kHz and above) where interaction is primarily with the top few cm of the sediment (related to the wavelength). A scattering effect (similar to that which occurs at the surface) also occurs at the seabed (Essen, 1994; Greaves and Stephen, 2003; McKinney and Anderson, 1964; Kuo, 1992), particularly on rough substrates (e.g. pebbles and larger).

[11] Acoustically, shallow water conditions exist whenever the propagation is characterised by multiple reflections with both the sea surface and seabed (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, sediment type, frequency of the sound and distance between the source and receiver.

[12] The density of “rays” indicate difference in effective propagation angle from the source, with acoustically harder sediments (gravel) having better reflection at steeper angles leading to more “rays” being effectively propagated (no significant bottom attenuation) in the waveguide. Beam shape indicated in left chart, with the black line showing the same received level.

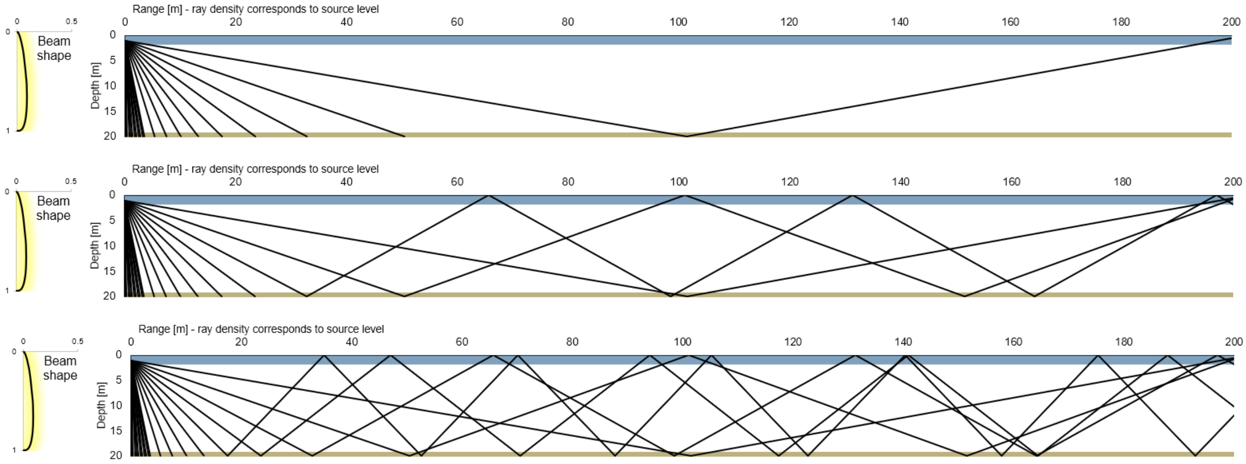

Figure 8-7: Schematic of the effect of sediment on sources with narrow beams. Sediments range from fine silt (top panel), sand (middle panel), and gravel (lower panel).

These sediment effects mean that the directivity of equipment such as sub-bottom profilers have a profound effect on the effective source level – the apparent source level to a far-away receiver.

A parametric SBP such as the “Innomar Medium” or “Standard” sub-bottom profiler use two higher frequencies (“primary frequencies”) to generate an interference pattern at lower frequencies (“secondary frequencies”). This means that the secondary beam can be made extraordinarily narrow, e.g. 5 degrees at -10 dB (Figure 8-8), versus c. 50 degrees for a chirper/pinger type, leading to a much smaller sound impact – even when a parametric sub-bottom profiler has higher sound output within the main beam. We account for these differences in beam pattern by including the sediment reflection loss at high incidence angles (Figure 8-7) to reduce the effective source level accordingly.

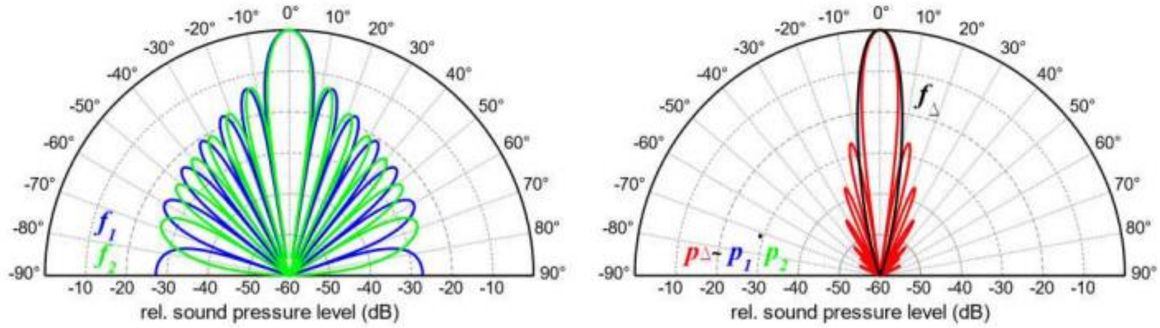

Figure 8-8. Example of a beam pattern on an Innomar SES 2000. Primary frequencies left (f1 & f2), the interference pattern between the primary frequencies means that the beam pattern for the secondary frequency (right plot) is very narrow (Source: Innomar technical note TN-01).

Another phenomenon is the waveguide effect which means that 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. The cut-off frequency as a function of water depth is shown in Figure 8-9 for a range of seabed types. Thus, for a water depth of 10m (i.e. shallow waters typical of coastal areas and estuaries) the cut-off frequency would be approximately 70Hz for sand, 115Hz for silt, 155Hz for clay and 10Hz for bedrock.

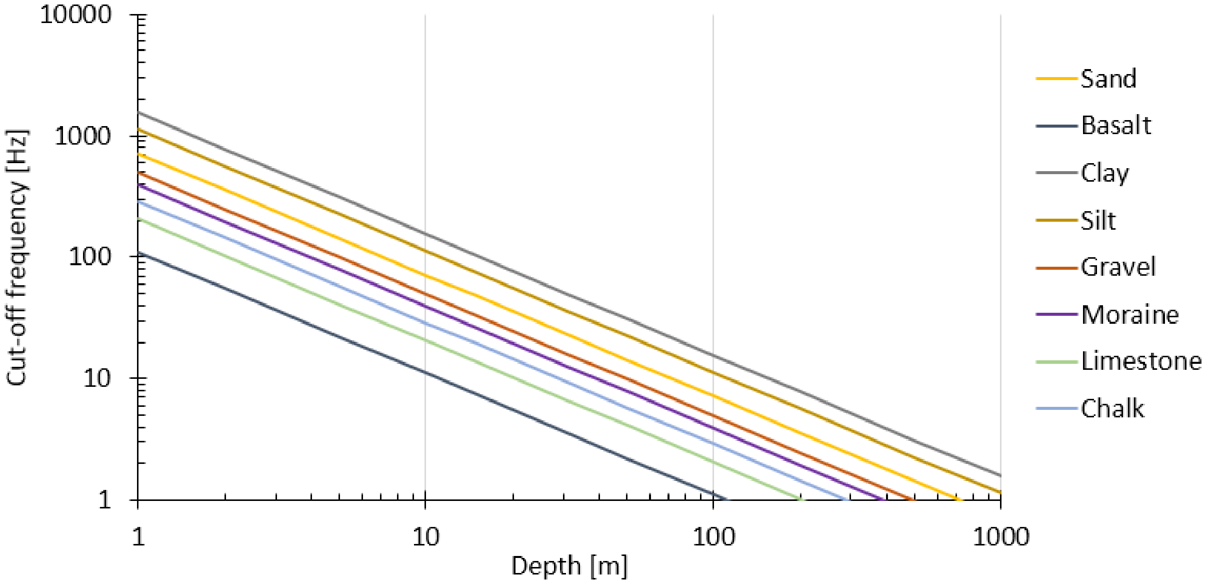

Figure 8-9: Lower cut-off frequency as a function of depth for a range of seabed types.

Changes in the water temperature and the hydrostatic pressure with depth mean 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 but, for example, a 25m thick layer would not act as a duct for frequencies below 1.5 kHz. The temperature gradient can vary throughout the year and thus there will be potential variation in sound propagation depending on the season.

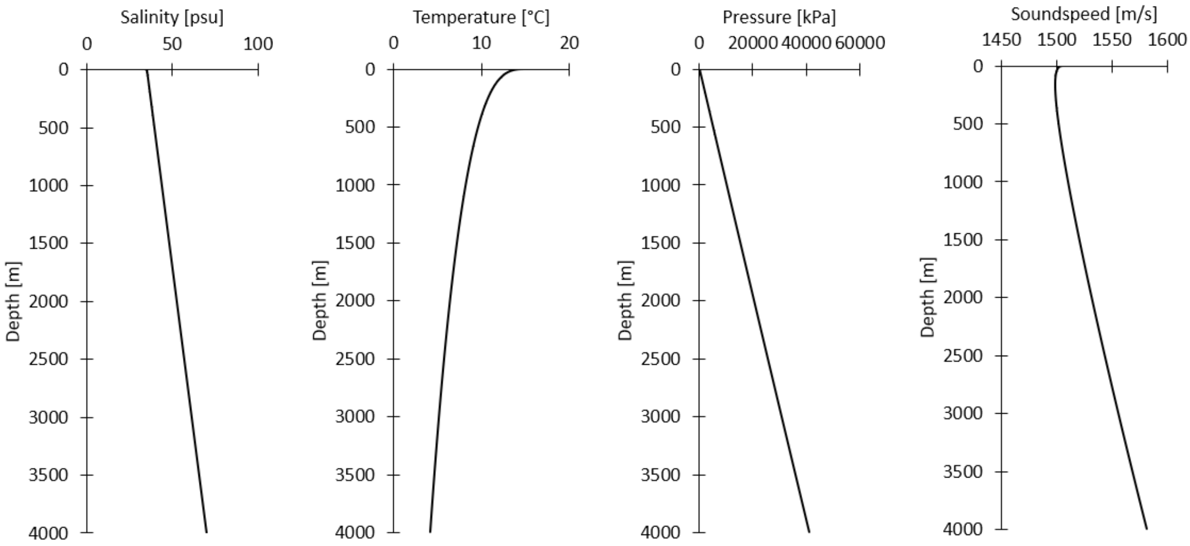

Figure 8-10: Soundspeed profile as a function of salinity, temperature and pressure.

Wind can make a significant difference to the soundspeed in the uppermost layers as the introductions of bubbles decreases the soundspeed and refracts (bends) the sound towards the surface, where the increased roughness and bubbles from the wind will cause increased transmission loss.

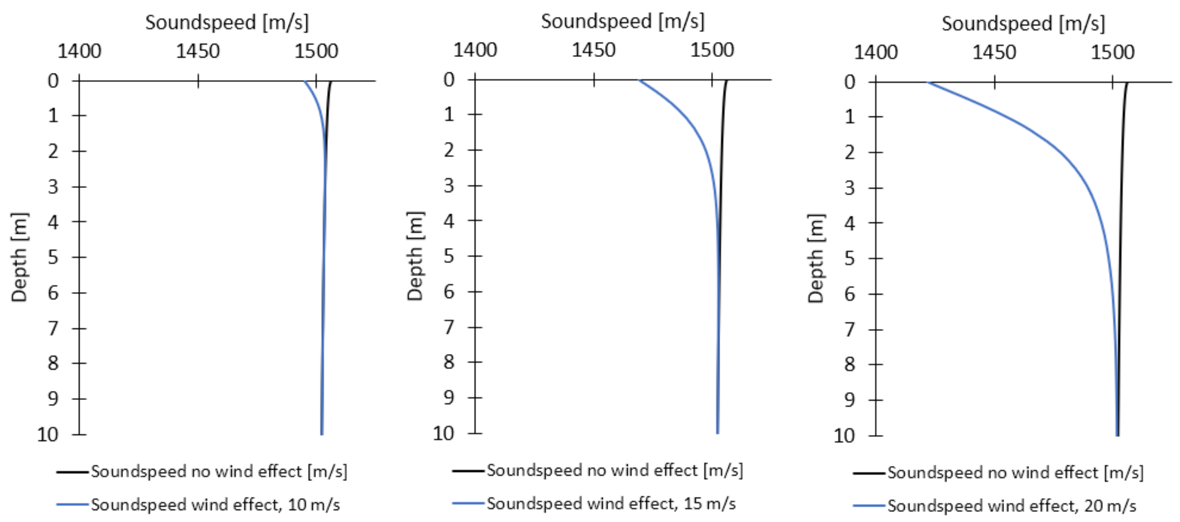

Figure 8-11: Effect of wind (at 10 m height) on upper portion of soundspeed profile.

Sound energy can also be 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. This is shown in Figure 8-12 where the variation of the absorption (sometimes called volume attenuation) is shown for various salinities and temperatures. As the effect is proportional to the wavelength, colder water, with slower soundspeed/period and being slightly more viscous, will have more absorption. Higher salinity slightly decreases absorption at low frequencies (mostly due to increase in soundspeed and wavelength/period), but much higher absorption at higher frequencies where interaction with pressure sensitive molecules of magnesium sulphite and boric acid increase the conversion acoustic energy to heat.

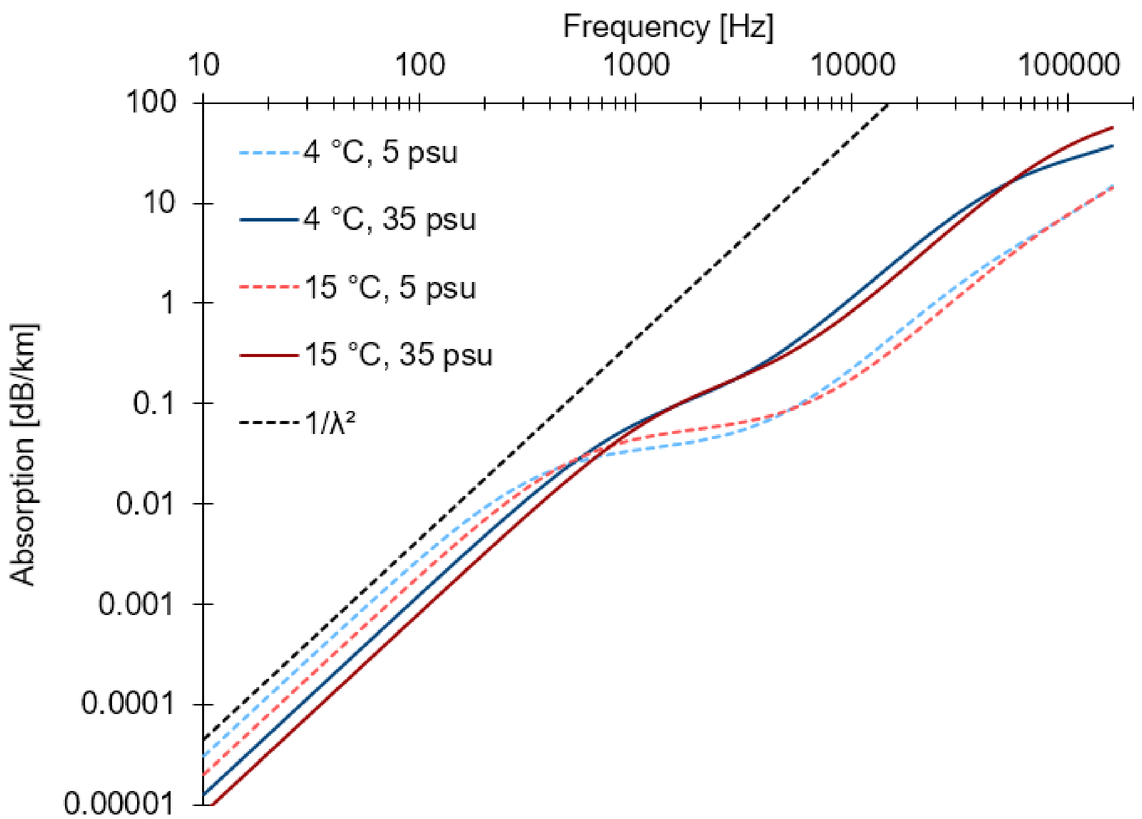

Figure 8-12: Absorption loss coefficient (dB/km) for various salinities and temperature.