C2 - Restricted

CP1146 CARRICKMINES TO POOLBEG PROJECT

Risk Assessment for Annex IV Species

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1 INTRODUCTION

1.1 Overview

EirGrid was established to act as the independent Transmission System Operator (TSO), in line with the requirements of the EU Electricity Directive. EirGrid became operational as the TSO on 1 July 2006 and is a public limited company, registered under the Companies Acts.

While EirGrid operates the flow of power on the grid and plans for its future, ESB Networks is responsible for carrying out maintenance, repairs and construction on the grid as the Distribution System Operator. ESB is the licenced Transmission System Owner pursuant to the Electricity Regulation Act, 1999. EirGrid uses the grid to supply power to industry and businesses that use large amounts of electricity. The grid also powers the distribution network. This supplies the electricity used every day in homes, businesses, schools, hospitals, and farms.

Dublin's electricity infrastructure is ageing and reaching its end of life. Work must be done to transform and modernise the city's electricity infrastructure, so Dublin can continue to develop and thrive, while increasingly using power from renewable sources.

The Powering Up Dublin Programme is a critical programme that will strengthen key electricity infrastructure in Dublin and the surrounding areas, making the city 'renewable ready.' This programme is set to replace and upgrade five 220kV circuits across Dublin city and the surrounding areas.

As part of the ongoing upgrade and development of Ireland’s electrical grid, EirGrid are undertaking a programme to replace and upgrade five of the 220kV circuits across Dublin city and the surrounding areas. This is part of EirGrid’s wider Dublin programme, to ensure continued reliability of electrical supply across the city, while also enabling future development and possible offshore wind farm development.

Replacing the existing circuits in an offline route means the new circuit follows a separate route to the existing circuit. The advantage of this is that there are minimal disruptions to the existing circuit and no, or very few, planned outages would be needed during construction.

Due to the electricity needs of Dublin, an online replacement is not feasible. For this reason, offline installation will be considered for the replacement of this circuit. EirGrid proposes to replace all the existing circuits with cross-linked polyethylene (XLPE) cable primarily on an offline route. These XLPE cables are more efficient and robust, which will enable the grid to carry more power, making the city ‘renewable ready’.

The programme is set to replace and upgrade five 220kV circuits across Dublin city, with this report focusing on the marine section of one of the cable circuits to be replaced, i.e., the CP1146 Carrickmines to Poolbeg project.

1.2 Purpose of the Report

This report has been prepared by RPS, on behalf of the EirGrid, to provide information on the marine site investigation (SI) works proposed to be undertaken for the CP1146 Carrickmines to Poolbeg project in support of the Maritime Usage Licence Application (MULA) to MARA. The MULA is for site survey and investigation works to inform engineering design and environmental assessment. The results of these surveys will also provide baseline data for any subsequent environmental assessments, e.g., Appropriate Assessment (AA).

This Risk Assessment for Annex IV Species report provides the required level of detail to the MARA for them to complete a risk assessment of the effects of the SI works on Annex IV species occurring within the zone of influence of the SI works.

1.3 Statement of Authority

This report has been prepared by RPS on behalf of EirGrid. The technical competence of the authors is outlined below:

[redacted] is a Senior Scientist in the Environmental Services Business Unit in RPS. She has over 10 years' experience in the marine ecology field. She holds an honours degree in Marine Science from NUI, Galway, and a master’s in marine biology from UCC. [redacted] has contributed to numerous marine environmental projects including appropriate assessments, Annex IV species reports, natura impact statements and EIA chapters.

[redacted] is a 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 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.

[redacted] 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. [redacted] 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 PROJECT DESCRIPTION

2.1 Location

The CP1146 Carrickmines to Poolbeg project is a proposed new underground electricity cable from the Carrickmines 220 kV substation to the Poolbeg 220 kV substation and includes a section of marine cable as shown in Figure 2.1. The cable route for the CP1146 Carrickmines to Poolbeg project traverses the administrative areas of two local authorities: Dun Laoghaire Rathdown County Council and Dublin City Council.

A site location map of the marine section of the CP1146 Carrickmines to Poolbeg project, showing the MULA area (redline boundary), is presented in Figure 2.2 below. Note that the cable route element shown in the figure below represents a 500m wide routing corridor and that final routing will be determined following the surveys being described in this project description. More detailed drawings are provided in Appendix A.

The Area of Interest (AoI) of this report is an area of 2101 Ha extending from Blackrock Park to the Shelley Banks car park on the Poolbeg peninsula. The majority of geophysical and geotechnical surveys will be conducted within the 500m wide corridor, however, some addition surveys may be required within the wider South Dublin Bay area, e.g. environmental walk-over surveys. Therefore the entire 2101 Ha area is the subject of the MULA.

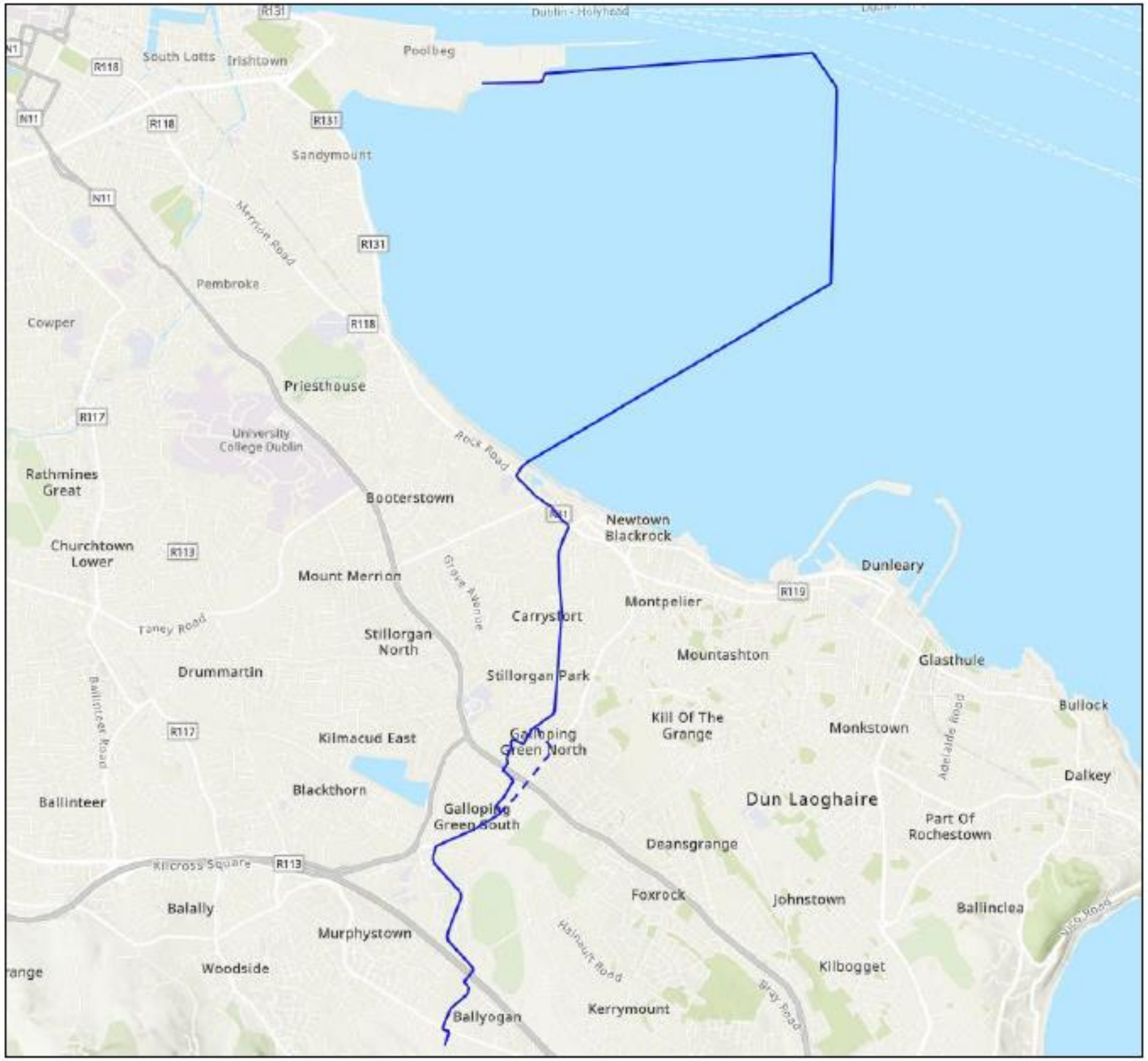

Figure 2.1 Proposed Entire Route of CP1146 Carrickmines to Poolbeg project

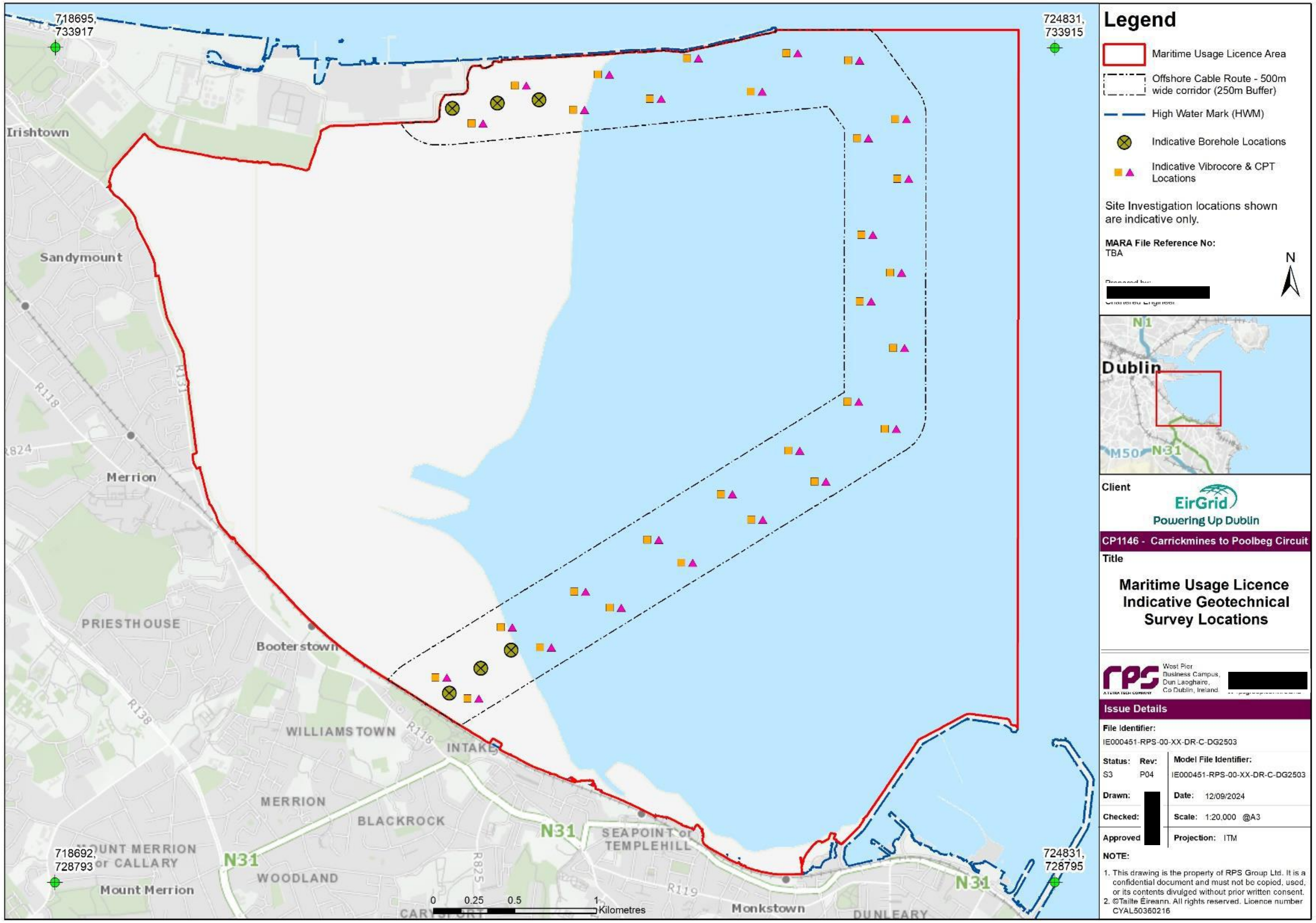

Figure 2.2 Proposed Marine Cable Section of CP1146 Carrickmines to Poolbeg project (500m wide route corridor) and MULA Area

2.2 Description of the Marine Site Investigation Works

2.2.1 Overview

In order to provide a reliable basis for design development, and to support the consenting and construction phases of the marine section of the CP1146 Carrickmines to Poolbeg project, surveys and investigations are necessary. The aim of the SI works is to acquire data to a high quality and specification within the AoI as summarised below and described in the following sections.

Marine SI Works comprise the following elements:

Table 2.1 Marine Site Investigation Surveys

Survey Type	Survey Elements
Marine Geophysical Surveys	Drop-down camera/ video
	ROV
	Multi Beam Echosounder (MBES)
	Side Scan Sonar (SSS)
	Sub-bottom profiler (SBP)
	Magnetometer
	Ultrashort Baseline (USBL) acoustic positioning system
	Seismic Refraction
	Ground Penetrating Radar
	Drones/UAVs
Marine Environmental/ Ecological Surveys	Benthic sampling/ grab samples
	Water samples
	Conductivity, Temperature, Depth (CTD) water measurements
	Static underwater noise recorders
	Shipping and navigation surveys
	Marine archaeology surveys
	Marine habitat surveys
	Other ecological surveys
Metocean Surveys	Acoustic Doppler Current Profiler (ADCP)
Geotechnical Investigations/ Surveys	Geotechnical Boreholes
	Vibro-core Sampling
	Cone Penetration Test (CPT)

It should be noted that all locations shown are provisional only and subject to change on-site 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.

The following drawings have been prepared in support of the MULA:

- Proposed Licence Area Map (Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502)
- Maritime Usage Licence Indicative Geotechnical Survey Locations (Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2503)
- Maritime Usage Licence Indicative Benthic Sample Locations Map (Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2504)
- Maritime Usage Licence Indicative ADCP Locations Map (Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2505)

The drawings are included in Appendix A to this report.

2.2.2 Marine Geophysical Surveys

The geophysical survey scope is intended to provide significant seabed and sub-seabed information. It is therefore foreseen to gather, as a minimum, detailed information on:

- Water depths, reduced to lowest astronomical tide (LAT), throughout the AoI;
- The nature of any seabed features, obstructions, sediments, and shallow geological conditions throughout the AoI;
- The nature of the sub-seabed conditions and horizons down to circa 10-15m below chart datum (CD) depending on the geological conditions encountered and the choice of system used;
- Seabed conditions/ hazards to any SI works equipment which may need to be located on the seabed;
- Seabed habitats to inform further benthic surveys and preparation of environmental assessments; Identify sensitive marine habitats which will need to be avoided during geotechnical and environmental sampling;
- Archaeological features within the AoI;
- Unexploded ordnance (UXO).

The foreseen scope of the SI works will consist of primarily non-intrusive survey methods, in that they will not physically interact with the seabed, such as Multi Beam Echosounder (MBES), sub-bottom profiler (SBP), Side Scan Sonar (SSS) and Magnetometer surveys but may also incorporate visual surveys (e.g., drop down video, ROV, etc.) pending the development of the project’s ground model.

Figure 2.3 Typical offshore geophysical survey vessel (GeoSurveyor XI Call Sign; ORVI)

As detailed in Section 2.2.3 below some intrusive seabed sampling will also be undertaken during the geophysical survey campaign to ground-truth geophysical data, assist in early seabed characterisation and provide data for benthic analyses and archaeological interpretation.

Typical nearshore vessels for geophysical surveys will be circa 10 – 20m in length. See Figure 2.3 for an example of a geophysical survey vessel. A smaller nearshore vessel may be required to complete surveys in the intertidal area, See Figure 2.4 for an example of a typical nearshore vessel.

Figure 2.4 Typical nearshore geophysical survey vessel (RV GEO)

A brief description of the geophysical survey methods has been provided in the subsequent sections. The exact technical specifications of the equipment to be used will not be known until the survey contract has been awarded, however such vessels and equipment will be within the parameters assessed within this document.

Typical acoustic properties of equipment are provided in Section 2.2.6.

The intertidal area will be subject to surveys using predominantly terrestrial geophysical survey methods and techniques such Ground Penetrating Radar (GPR), shallow seismic refraction, electrical resistivity, magnetometer, drones and photogrammetry.

2.2.2.1 Multibeam Echo sounder

Full 100% coverage of the area concerned associated with the survey and area classification will be required. Surveys shall identify the level, nature, and detailed coverage of the seabed to ensure identification of features on the seabed within the area shown, identify potential large upstanding archaeological features and guide habitat mapping with the backscatter function if available. Processing of data sets shall include processing for archaeological indicators. The area shall be surveyed in such a way as to produce a comprehensive data set required to enable the generation of multiple sections through the survey area in any direction.

Method: A remote sensing acoustic device which will be either attached to the vessel(s) hull at the bow or mounted on a side pole.

Indicative Equipment:

- Teledyne Reson Seabat T50-R;
- R2 Sonic 2024 (see Figure 2.5); or
- similar.

Figure 2.5 MBES R2Sonic 2024

Swath width: Swath width will be optimised to provide 100% seafloor coverage with typical swath widths of 3 to 6 times water depth depending on arrangement of equipment hardware.

Location: MBES survey may be performed throughout the entire sub-tidal area illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A). The survey area is 2101 Ha.

2.2.2.2 Side Scan Sonar (SSS)

Method: A submerged acoustic device (SONAR – Sound Navigation & Ranging) for imaging areas of the seafloor will be either hull mounted or towed.

Indicative Equipment:

- Kongsberg Geoacoustic 160
- Edgetech 4200 (see Figure 2.6);
- C-Max CM2 system;
- Klein Hydro Scan; or
- similar.

Figure 2.6 Edgetech 4200 SSS

Swath width: The swath width will be based on the water depth encountered. A 100% overlap between each swath is envisaged.

Location: SSS survey may be performed throughout the entire sub-tidal area illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A). The survey area is 2101 Ha.

2.2.2.3 Sub-bottom Profiling

A typical sub bottom profiling (SBP) survey is completed using single or multi-channel seismic reflection systems such as Chirp, Sparker, or Parametric system. Sub bottom profiling over the site and specified runs is yet to be determined.

The geophysical SBP survey shall identify the bed level and the nature, thickness, and location of the sub surface strata to rock head.

The survey shall include both items detailed below:

1. Completion of specified runs.

2. Completion of a Free Line Survey.

Method: SBP are acoustic devices for imaging sections of the seabed. The images produced are used to produce profiles beneath the seafloor, enabling delimitation of major sedimentary interfaces. They are either mounted on the vessel / pole or towed behind the vessel.

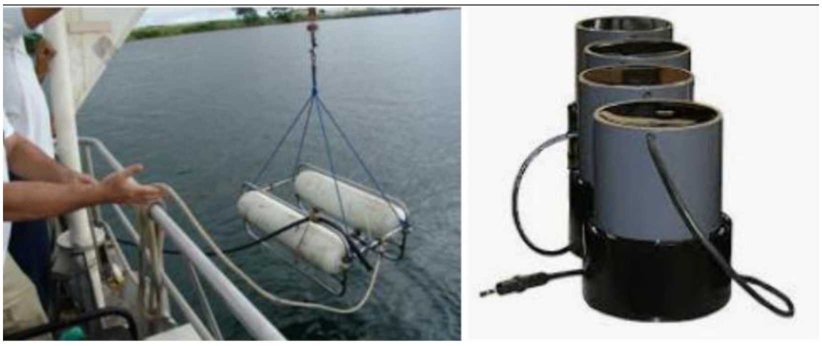

Figure 2.7 Left - Applied Acoustics AA300 being deployed & Right - Typical Hull Mounted SBP - Edgetech 3300

Indicative Equipment:

- Edgetech 3100;
- Edgetech 3300 (see Figure 2.7);
- Geopulse 5430A (pinger system);
- 400 Joule Generic sparker;
- Innomar Parametric (dual frequency); or
- similar.

Swath width: n/a

Location: SPB survey may be performed throughout the entire sub-tidal area illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A). The survey area is 2101 Ha.

2.2.2.4 Magnetometer

The magnetometer survey will be undertaken at suitable line spacing to ensure complete coverage of the seabed for archaeological purposes (and in line with UAU guidelines), i.e., identify large metal debris or metallic archaeological remains.

Method: Magnetometers provide information on embedded magnetic/ferrous objects such as cable crossings, debris and potentially UXO's. They are towed from the vessel.

Indicative Equipment:

- Geometrics G-882 caesium vapour magnetometer – see Figure 2.8;
- Marine Magnetics SeaSPY,
- G-Tec Magwing System, or
- similar.

Figure 2.8 Geometrics G-882

Survey spacing: Line spacing will be dependent on water depth encountered, with additional runs of higher density line spacing within areas where any magnetic signal is recorded.

Location: Magnetometer surveys may be performed throughout the entire sub-tidal area illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A). The survey area is 2101 Ha.

2.2.2.5 Ultrashort Baseline (USBL) – Acoustic Positioning System

An ultrashort baseline acoustic positioning system is a highly accurate and precise method of underwater acoustic positioning. It determines the orientation and position of the transponders relative to the transceiver and can be used during the set up and positioning of other geophysical and geotechnical survey equipment.

Method: The system consists of a transceiver unit and a set of transponders. The transceiver unit emits acoustic signals, which are picked up by the transponders.

Figure 2.9 Applied Acoustics EasyTrak Nexus Model EZT-2691

Indicative Equipment:

- Applied Acoustics EasyTrak Nexus Model EZT-2691 (Figure 2.9), or
- similar

Location: USBL surveys may be performed throughout the entire sub-tidal area illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A). The survey area is 2101 Ha.

2.2.2.6 Seismic Refraction (Beach and Intertidal)

The seismic refraction method utilizes the refraction of seismic waves as they pass through various rock or soil layers to analyse underground geological conditions and structures.

Method: Seismic refraction profiles will be conducted using onshore survey tools during low tide in the intertidal zone. A sound source (typically a sledgehammer striking a metal plate) will generate compressional wave energy. These refracted waves will be captured by a series of geophones and logged on a digital seismograph. The locations and elevations of the geophones will be documented using GPS technology.

Figure 2.10 Geometrics Geode Seismograph

Indicative Equipment:

- Geophone Arrays:
  - Geosense 4.5 Hz Geophones;
  - Mark Products L-28LB Geophone;
  - Geospace GS-11D Geophone; or
  - similar
- Digital Seismographs
  - Geometrics Geode Seismograph (Figure 2.10);
  - Seistronix RAS-24;
  - ABEM Terraloc Pro: or
  - similar

Location: Refraction Seismic methods may be undertaken throughout the entire inter-tidal areas illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A).

2.2.2.7 Ground Penetrating Radar (Beach and Intertidal)

Ground Penetrating Radar (GPR) utilizes the reflection of electromagnetic waves as they are returned by rock or soil layers to analyse underground geological conditions and structures.

Method: GPR will be completed during low tide in the intertidal zone. A GPR trolley will be pushed over the area to be scanned or a GRP array will be towed using an ATV and the results analysed by a technician to determine subsurface characteristics.

Figure 2.12 Stream X Towed GPR System

Figure 2.11 Leica DS2000 GPR Trolley

Indicative Equipment:

- IDS GeoRadar Stream X Towed GPR System (Figure 2.12);
- IDS GeoRadar Stream DP GPR System;
- Leica DS2000 GPR System (Figure 2.11); or
- similar

Location: Refraction Seismic methods may be undertaken throughout the entire inter-tidal areas illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A).

2.2.2.8 Drones

Drones or Unmanned Aerial Vehicles (UAVs) are capable of mapping coastal and intertidal areas with a high degree of vertical accuracy. Drones or UAVs equipped with a high-resolution camera can be used to collect high resolution spatial data for coastal and intertidal surveys.

Method: Drones/UAVs will be used to survey intertidal zones.

Location: Drone surveys may be undertaken throughout the inter-tidal areas illustrated in Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2502 (Appendix A).

2.2.3 Marine Environmental/ Ecological Surveys

The aim of the proposed environmental surveys is to collect baseline data which will be used to inform the environmental assessments. Environmental surveys will cover both the onshore area above the high-water mark and areas below the high water mark including intertidal and subtidal areas. This will include a benthic sampling programme using grab sampling, video or still photographs and, where deemed necessary, the deployment of static acoustic monitoring to measure marine mammal activity and other background noise.

2.2.3.1 Benthic Sampling/ Grab Samples

Seabed samples will be recovered to inform benthic habitat distribution mapping as well as contamination testing (where relevant). Standard sampling techniques for subtidal and intertidal collection will be employed to include collection of macrofauna and associated sediment particle size and organic content, as described below.

Macrofaunal grab samples may be taken with a number of different grab types depending on the substrate type, e.g., Day grab, Van Veen, mini-Hamon (not suitable for undisturbed samples). The benthic sampling will be complemented by video and still photography. Seabed sampling will likely be undertaken as part of either the geophysical or geotechnical surveys or may be a standalone survey.

Indicative Quantity: It is anticipated that 11 no. stations will be required to be sampled. Three (3 no.) replicate benthic samples will be obtained at each sampling station. Two benthic samples from each sampling station will be processed for macro-invertebrate benthos larger than 1 mm. The remaining one sample will be analysed for sediment particle size analysis and sediment chemistry. Samples will be sent to a suitably accredited (NMBAQC level participation) laboratory for analysis and reporting which will include benthic analysis, sediment particle size analysis and sediment chemistry. GPS coordinates and depths will be recorded for each location.

Method: Camera will be used to ensure seabed is suitable for sampling prior to using grab. Surface grab samples will be taken by box corer, grab sampler (e.g., Day grab, Van Veen grab or similar). These devices are typically deployed from a crane on the vessel.

Depth: Grab sample will be taken on the seabed at depths ranging between -4m CD and -10m CD. It is estimated that each sample will have a sample size up to 0.1m^2.

Location: Grab sampling will be performed within the area defined in CP1146-RPS-00-XX-DR-C-DG2504 (Appendix A). The final sampling locations will be determined based upon interpretation of the geophysical data and selected to sample different marine habitats.

2.2.3.2 Water Samples

Water sampling and profiling will be taken in sufficient locations to provide an even distribution of results across the site. Two water samples shall be taken at each location. 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.

2.2.3.3 Conductivity, Temperature and Depth

Conductivity, Temperature, Depth (CTD) water measurements shall be taken at a number of locations at three depths, i.e. near-surface, mid-water, and near-seabed. Measurements shall be taken only after stabilisation of the temperature at each location.

2.2.3.4 Static Underwater Acoustic Recorders

Static underwater acoustic recorder(s) may be deployed within the sea in the AoI. The recorder(s) will be Wildlife Acoustics Model: SM2M Unit with hydrophones contained in a single unit (see Figure 2.13), or similar. The location for the deployment of the recorder(s) will be determined based on factors such as tide, sediment and currents, as well as distance from shipping/ onshore noise sources that may impact on baseline noise levels. This information will be collected as part of the early SI works and therefore deployment locations are not yet known although they will be within the MUL area.

Figure 2.13 Deployment of static underwater acoustic recorders

2.2.3.5 Other Environmental Surveys

Further marine environmental surveys will be undertaken during the course of the project's development comprising the following:

- Shipping and Navigation Surveys
  - The need for shipping and navigation surveys will be determined following consultation with the relevant stakeholders. These will be shore-based visual vessel traffic surveys.
- Marine Archaeology Surveys
  - The aim of the proposed surveys, which will be undertaken by a suitably qualified archaeologist are to collect baseline data which will be used to inform the cultural heritage impact assessment. Surveys will be undertaken in advance of any intrusive survey work and generally coordinated with the geophysical survey proposed herein. Surveys will comprise an identification programme using marine magnetometer survey (see Section 2.2.2.4), side scan sonar (see Section 2.2.2.2) data analysis and diving as required in order to identify and assess metallics and other targets. They may include dive surveys, wade surveys and archaeological walkover surveys.
- Marine Habitat Surveys
  - The aim of the proposed surveys, which will be undertaken by a suitably qualified marine ecologist, are to collect baseline habitat data which will be used to inform the environmental assessments, e.g., Appropriate Assessment (AA). Surveys will be undertaken in advance of any geotechnical survey work and generally coordinated with the geophysical survey proposed herein. Surveys will comprise drop down camera and/or Remote Operated Vehicle (ROV) inspection and diving as required in order to identify benthic habitats.
  - Intertidal walkover surveys habitat characterisation sampling, with core 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);
  - It is expected that a minimum of 9 primary transect stations are selected per landfall location, with 3 sampling points along each, (minimum 9 transects and a minimum total of 27 sampling points).
- Other Ecological Surveys
  - Terrestrial habitat walkover surveys (including protected and notable flora, and invasive alien plants and animals);
  - Bats roost assessment surveys;
  - Mammal surveys (including otters); and
  - Bird surveys including wintering bird surveys (low and high tide surveys), breeding bird surveys (vantage point surveys, boat based surveys).

It should be noted that these surveys will straddle both the marine and the terrestrial environment.

2.2.4 Metocean Surveys

The main purpose of the meteorological and oceanographic (metocean) campaign is to collect accurate wind wave, temperature, current and water levels information from the project site. The information collected will be used to inform engineering design and environmental assessments. The exact details of the surveys (equipment, locations, and deployment/retrieval methods) will be confirmed upon appointment of a preferred contractor.

2.2.4.1 Equipment Deployment & Recovery Vessel

The methodology for deployment of metocean monitoring equipment will be using a suitable vessel to either tow and/or lift and deploy from vessel deck via onboard crane. An example of a suitable vessel for this scope would be a shallow draft anchor handling tug or a utility type vessel such as that shown in Figure 2.14 or similar.

Figure 2.14 Ocean Energy DP1 Multi Cat 2309

2.2.4.2 Acoustic Doppler Current Profiler (ADCP) to measure ocean currents.

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

Indicative Quantity: Three.

Method: Deployed to the seabed via a crane from a survey vessel for a duration of at least 5 weeks to capture a full lunar cycle including spring and neap tides.

Indicative Equipment: The ADCP unit (Figure 2.15) is mounted in a seabed frame (circa 1.8m wide and 0.6m high) with a weight of approximately 300kg. 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.

Figure 2.15 Typical seabed frame with ADCP (Ocean Scientific International Ltd)

Location: Indicative locations for the deployment of ADCP are illustrated on Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2505 (Appendix A). The actual locations will be determined based upon interpretation of the geophysical data and following a navigation safety assessment.

2.2.5 Marine Geotechnical Investigations

The aim of the geotechnical survey is to provide sufficient geotechnical data to allow the characterisation of the sub-seabed strata and composition of the seabed and the level of Rock head (including follow on coring to confirm rock head).

Normal industry standards for performance of all positioning, drilling, sampling, SPT testing, CPTu testing, laboratory testing and analysis and reporting will apply. Material sampling, in situ testing, data logging, laboratory testing and reporting (factual and interpretative) will be required.

The works will include the following:

- Sampling/ coring boreholes at 6 locations to a maximum of 20m investigation depth below seabed level;
- Vibro-cores at c. 30 locations.
- Cone Penetration Testing – CPT at 30 locations (at the vibro-core locations).

The indicative quantities given above relate to the requirements for the preliminary geotechnical campaign, the final quantity, location, and specification of equipment will be determined following interpretation of the geophysical survey data and considering environmental constraints (i.e., proximity to sensitive receptors). The final proposed locations will be subject to environmental conditions.

2.2.5.1 Geotechnical Boreholes

Indicative Quantity: 6 focused primarily at the landfall locations of the cable routes.

Method: A drill head is lowered to the seabed from the drilling platform (where used) via a drill string. The drill head penetrates the seabed via rotation of the drill string and the application of a downward pressure. Soils and rock samples are then retrieved for laboratory testing via the drill string.

Sample Diameter: up to 102mm.

Depth: Up to 20m below the seabed, or refusal.

Indicative Equipment: Indicative equipment to be used would be Camacchio 205 or Comacchio 602 drill rigs using traditional drill string or a triple core barrel system (e.g., Geobor ‘S’) and associated ancillary equipment (water bowser, air compressor)

Depending on the specifics of each borehole location the drill rig and ancillary equipment may be deployed in two different methods, the choice of method will be determined based on the geophysical surveys, tidal working windows, as well as availability of plant and equipment.

For investigations at all borehole locations where there is sufficient depth of water (draft) to deploy a jack-up barge, the drill rig and equipment can be mounted on a jack up barge and boreholes completed from this barge during any phase of the tide (see Figure 2.16).

Figure 2.16 Jack-up Barge and drill rig

Figure 2.17 Landing Craft deploying onto beach (MV Spanish Jonh II)

For investigations located within the intertidal zone where sufficient time is available between inundation by tides, a tracked borehole / CPT rig and ancillary equipment may be deployed from a small landing craft (see Figure 2.17) to complete the borehole during the intertidal window.

Location: Indicative geotechnical locations for the boreholes are illustrated on Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2503 (Appendix A). The final borehole locations will be determined based upon interpretation of the geophysical data and selected based on the preliminary engineering design. The micro siting of individual geotechnical site investigation locations will take into consideration environmental constraints such as the position of sensitive habitats or archaeological features.

2.2.5.2 Vibro-core Sampling

Indicative Quantity: 30 vibrocores.

Method: Gravity or piston core (self-weight penetration sampler), deployed from a works vessel equipped with Dynamic Positioning. An example of a suitable vessel for this scope would be a shallow draft anchor handling tug or a utility type vessel such as that shown in Figure 2.14 (above) or similar.

Sample Diameter: up to 150mm.

Depth: Vibrocore up to 6m depth.

Indicative Equipment: The exact equipment to be used will be confirmed following a tender process to procure the site investigation contractor.

Location: Vibro-core sampling will be performed at representative locations within the cable route corridor - Refer to Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2503 (Appendix A). The final sampling locations will be determined based upon interpretation of the geophysical data and selected based on the preliminary engineering design. Some locations may need to be avoided due to environmental reasons including sensitive archaeological features or unsuitable substrate types.

2.2.5.3 Cone Penetration Testing (CPT)

Indicative Quantity: 30 CPT

Method: Cone Penetration Test (CPT) using a cone penetrometer deployed from a works vessel. An example of a suitable vessel for this scope would be a shallow draft anchor handling tug or a utility type vessel such as that shown in Figure 2.14 (above) or similar.

Sample Diameter: 32 mm (standard cone diameter).

Depth: CPT up to 6m depth, or refusal.

Indicative Equipment: The exact equipment to be used will be confirmed following a tender process to procure the site investigation contractor.

Location: Cone Penetration Testing will be performed at representative locations within the cable route corridor - Refer to Dwg Ref: CP1146-RPS-00-XX-DR-C-DG2503 (Appendix A). The final sampling locations will be determined based upon interpretation of the geophysical data and selected based on the preliminary engineering design. Some locations may need to be avoided due to environmental reasons including sensitive archaeological features or unsuitable substrate types.

2.2.6 Marine Noise Level Summary

All survey works that involve the use of acoustic instrumentation will follow the *Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters* (DAHG, 2014).

A summary of the noise sources, for the main activities proposed to be undertaken as part of the SI works is included in Table 2.2 (see Appendix B: Subsea Noise Technical Report for further detail).

Table 2.2 Summary of Noise 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	161 dB SPL	10-16,000 Hz	Based on <20 m generic survey vessel.	Non-impulsive
Survey vessel, Geotechnical	168 dB SPL	10 – 25,000 Hz	Based on <30 m tug with dynamic positioning system	Non-impulsive
MBES	187 dB SPL (Spherical equivalent level)	200,000-800,000 Hz	Based on Reason SeaBat T50 & R2 Sonic 2024.	Impulsive
SSS	166 dB SPL (Spherical equivalent level)	100,000-1,000,000 Hz	Generic SSS from 400-1,000 kHz.	Impulsive
USBL	190 dB SPL	18,000-31,500 Hz	Active with non-hull mounted SSS* & during vibro-core operations, 2 Hz ping rate, ping length 10 ms.	Impulsive
SBP-parametric (P-SBP)	204 dB SPL	80,000-150,000 Hz (Primary) 2,000-22,000 Hz (Secondary)	Source level adjusted for sediment effects and beam widths. Based on Innomar Standard, worst-case for shallow water.	Impulsive
SBP-chirper/pinger (C-SBP)	181 dB SPL	2,000-12,000 Hz	Generic shallow water SBP of chirper/pinger type. Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-sparker/UHRS (S-SBP)	184 dB SPL	600 – 6,300 Hz	Based on GeoSource 400. Firing rate of 1 Hz assumed	Impulsive

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
ADCP (**Not modelled given high frequency**)	114 dB SPL	500,000-1,260,000 Hz	Based on suitable ADCP for depths <100 m (e.g. Nortek AWAC, Teledyne Reason Sentinel, Workhorse or Monitor) Source level adjusted for sediment effects and beam widths.	Impulsive
Drilling/ rotary coring (Boreholes, no USBL)	145 dB SPL	10-500,000 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	187 dB SPL	50 – 16,000 Hz	Based on levels from previous work & (Reiser, et al., 2010)	Non-impulsive

*If the SSS and SBP are hull-mounted, there is no need for a positioning device (USBL) and this noise source should be removed from consideration.

2.2.7 Programme and Timescale

EirGrid propose a site investigation activities schedule that will be phased over a two-year period. The intention is to begin survey activities as soon as feasible following license award, with a phased programme of investigations, capitalising on suitable weather windows over this time period. This phased approach will progress the overall development towards detailed design stage. It is worth noting that the exact survey schedule is dependent on the availability of the supply chain and therefore exact timelines for the surveys cannot be determined until closer to the time.

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 duration of each SI works phase scope has been estimated in Table 2.3 below. The estimated durations are subject to change based on variables such as weather conditions onsite, 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, for example, could include Dublin, Dún Laoghaire, Howth or Malahide depending on vessel size and marine traffic restrictions. Any changes to the anticipated SI works schedule and port mobilisation locations are not predicted to affect the findings in this assessment.

It is proposed to complete a number of follow on geophysical surveys to determined seabed mobility, these will be completed over the course of the two year license period.

Table 2.3 Estimated SI works Schedule

Phase	Scope of Work	Total No of SI Locations	Estimated Duration
Phase One	Marine Geophysical Surveys	n/a	4-6 weeks (weather dependent)
	Benthic Sampling	11	4-6 days (weather dependant)
	Intertidal Sampling	27	2-3 days (tide/weather dependant)
Phase Two	Vibrocore & CPT Sampling	30	4-6 weeks
	Borehole Sampling	6	4-6 weeks
Phase Three	Follow up Marine Geophysical Surveys	n/a	4-6 weeks (weather dependent)
All Phases	Other Environmental/ Ecological Surveys	Varies	As appropriate to environmental/ ecological survey requirements.

2.3 General Survey Requirements

All appointed survey contractors shall obtain and comply with all necessary marine operational permits including routine and customary vessel/crew/equipment clearances from Customs Agencies, Port Authorities, Marine Survey Office, etc.

2.3.1 Quality Assurance

Each of the appointed survey contractors shall comply with the following as a minimum:

- Quality and Environmental Management Systems based on ISO9001:2015.
- Provision of Quality Management Plans for all the marine operations.
- Provision of site and activity specific Method Statements for all the marine operations within their scope.

2.3.2 Health & Safety

Health, safety, environment, and welfare considerations will be a priority in the evaluation of possible contractors for the various survey scopes and will be actively managed during the course of the survey scopes of work.

Appointed contractors will be required to comply with all legislation relevant to the activities within their scope of work.

Prior to survey works taking place, both Project Supervisor for Design Process (PSDP) and Project Supervisor for Construction Stage (PSCS) will be appointed under the relevant legislation and project / survey specific HSE plans will be put in place which will form part of the survey project execution plans.

Temporary barriers, warning notices, lighting, and other measures necessary to provide for the safety of the workers on the site and/or the public will be erected and maintained for the duration of the SI works.

2.3.3 Working Hours

The working hours for the SI works are proposed to be 24 hours a day, seven days a week.

Tides, weather conditions and/or sea-state will impact on the working hours, and it may be necessary to temporarily suspend operations when adverse weather conditions and/or sea-states are encountered or forecast. Similarly, equipment maintenance and repair may impact on operational activities resulting in downtime.

Following downtime or suspension of operations, recommencement of sound producing activities shall only occur after the successful implementation of the measures contained in the Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (DAHG, 2014).

2.3.4 Vessels

All vessels will be fit for purpose, certified and capable of safely undertaking all required survey work. Marine vessels will be governed by the provisions of the Sea Pollution Act 1991, as amended, including the requirements of MARPOL. In addition, all vessels will adhere to published guidelines and best working practices such as: the National Maritime Oil/HNS Spill Contingency Plan (NMOSCP), Marine Pollution Contingency Plan (MPCP), Chemicals Act 2008 (No. 13 of 2008), Chemicals (Amendment) Act 2010 (No. 32 of 2010) and associated regulations.

Vessels shall have a Health, Safety and Environmental Managements system which should conform to the requirements of the latest International Maritime Organization (IMO), Safety of Life at Sea (SOLAS) and environmental requirements for their classification and with any national requirement of the territorial or continental / EEZ waters to be operated in.

The SI works will be undertaken from vessels in accordance with the relevant guidelines required to manage the risk to marine mammals from man-made sound sources in Irish waters.

3 RISK ASSESSMENT FOR ANNEX IV SPECIES

3.1 Legislative Context

Under Article 12 and 13 of the Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (as amended) (the Habitats Directive), Member States must establish systems of strict protection for animal species which are listed on Annex IV (a) of the Directive. Article 16 provides for derogations from these legal protections under certain, specific, circumstances. Article 12 and 16 of the Habitats Directive are transposed into Irish law by Regulations 51- 52 and 54- 55 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;
- Deliberately pick, collect, cut, uproot, or destroy any specimen of species in the wild; or
- Keep, transport, sell, exchange, offer for sale or offer for exchange any specimen of these species taken in the wild, other than those taken legally as referred to in Article 12(2) of the Directive.

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 Methodology

This risk assessment for Annex IV species has been carried out in compliance with 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 Annex IV species broadly follows the methodology structure outlined in NPWS (2021), as follows:

- Use existing information to determine the probability of the protected species being present in the area affected by the works.
- Ecological survey, if required.
- Examination of impacts and mitigation measures and satisfactory alternatives (if required). For each species or species group, an assessment was made against each of the strict protections taking into account project details and the available evidence base for each species.

If the examination of impacts concludes that the SI works will not conform with the strict protections afforded to Annex IV species, then an application will be made for a derogation licence under Regulation 54 of the Regulations.

3.3 Relevant Annex IV Species

The geophysical and environmental surveys (including metocean surveys) will be taking place across the AoI whereas the geotechnical SI works are likely to be confined to the cable route corridor as shown in the drawings in Appendix A.

The EC Habitats Directive (92/43/EEC) lists species of community interest 'in need of strict protection' within Annex IV. This list was reviewed and all species/species groups with the potential to occur within the area of the proposed SI works were considered further. Of the animal and plant species on Annex IV known to occur in Ireland[1], the following species were identified as potentially relevant to the proposed SI works:

- All bat species;
- Otter;
- All cetacean species; and
- All turtle species.

3.4 Evidence Base

3.4.1 Desk Study

In order to assess the probability of the above species/species groups being present in the area affected by the SI works, a desk study was undertaken, in addition to application of professional judgement and knowledge of the geographical area.

The following sources were consulted during the desk study:

- Irish Whale and Dolphin Group Sightings Log https://iwdg.ie/browsers/sightings.php/ Accessed October 2024;
- Distribution records for Annex IV species held online by the National Biodiversity Data Centre (NBDC) www.biodiversityireland.ie, Accessed October 2024;
- BCI (2024). [online] Available at: https://www.batconservationireland.org/. Accessed October 2024.
- IAMMWG. (2022). Updated abundance estimates for cetacean Management Units in UK waters (Revised 2022). JNCC Report No. 680, JNCC Peterborough, ISSN 0963-8091;
- Macklin, R., Brazier, B. & Sleeman, P. (2019). Dublin City otter survey. Report prepared by Triturus Environmental Ltd. for Dublin City Council as an action of the Dublin City Biodiversity Action Plan 2015-2020;
- NPWS (2009) Threat Response Plan: Otter (2009-2011). National Parks & Wildlife Service, Department of the Environment, Heritage & Local Government, Dublin;
- Mullen, E., Marnell, F. & Nelson, B. (2021) Strict Protection of Animal Species. National Parks and Wildlife Service Guidance, No. 2. National Parks and Wildlife Service, Department of Housing. Local Government and Heritage; and
- 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.

[1] https://www.npws.ie/legislation

3.4.2 Ecological Surveys

The SI works will be conducted wholly within the AoI outlined in the drawings in Appendix A covering a total area of 2101 Ha. To inform the SI works and future environmental assessment of the CP1146 Carrickmines to Poolbeg project, a desk-based assessment of the available information for the area was undertaken utilising the most up-to-date and relevant sources.

3.4.3 Bat Species

All native bat species in Ireland receive the same level of strict protection. The presence or otherwise of bats is typically relevant only to onshore SI activities; although bats are known to forage over water and along coastlines, they will not interact with underwater works. Interaction between bats and the proposed SI works although unlikely is still possible due to the potential for disturbance caused by the lighting and noise from intertidal and subtidal SI works (e.g., night time construction and increased night-time activity). According to NBDC (2024a)[2] soprano pipistrelle (*Pipistrellus pygmaeus*), common pipistrelle (*Pipistrellus pipistrellus sensu stricto*) and Nathusius' pipistrelle (*Pipistrellus nathusii*) have been recorded along the coastline at south Dublin Bay and to the north of the proposed SI works at Dublin Port within the 1 km grid squares that cover the coastline and their adjacent waters. According to NBDC (2024a), bay activity has been recorded from Dun Laoghaire to Dublin Port for common pipistrelle. Ten common pipistrelle were recorded in 2020 at Blackrock and a further 20 were recorded between Blackrock and Sandymount. To the north at Dublin Port, between Sandymount Beach and Shellbanks Car Park approximately 29 common pipistrelle were recorded in 2020. Between Sandymount Beach and Blackrock six soprano pipistrelle were recorded in 2020. None were recorded at Dublin Port for the same year. Three Nathusius' pipistrelle were recorded in 2020 between Sean Moore Park and Booterstown (NBDC, 2024a). Some of these species have been recorded outside of Ireland as migratory particularly during the breeding season in Europe, i.e. migration south during autumn and north during the springtime (BCI, 2024). Bats are typically classified as terrestrial mammals and it is now understood that some bat species undertake seasonal migrations within Ireland but due to the lack of scientific studies these migration patterns are poorly understood. Other evidence suggests that bat species follow prey into coastal waters if conditions are favourable (Limpens et al., 2017).

Given the existing use of surrounding area as a busy recreational, commercial and industrial area, including Dublin Port and its environs, it is expected that any bats using the area are habituated to some level of night-time lighting and noise. Therefore, impacts on bat species that may utilise the South Dublin Bay area and those adjacent to the proposed SI works will be negligible.

3.4.4 Otter

Otter (*Lutra lutra*) occurs throughout Ireland, including along the coasts in County Dublin (NPWS, 2019) with populations also found along rivers, lakes, and coasts, where fish and other prey are abundant, and where the bank-side habitat offers plenty of cover. Otter is an opportunistic predator with a broad and varied diet. They have diverse habitat preferences: lakes, canals, riverine (streams up to major river systems) marshland and estuaries. Otters that live nearer to the coast tend to require access to freshwater for bathing purposes, while any aquatic environment which has nearby vegetation or rock cover will be used by otters (NPWS, 2019). Otters are a mobile species and maintain territories. In lowland rivers and fish-rich lakes otters only need to maintain small territories (up to 6 km), but along smaller river systems and in upland areas where prey may be less abundant, otter territories can stretch to 20 km (Mullen et al., 2021). Coastal territories tend to be between 3 km to 4 km along the coastline where freshwater is available to clean their fur after exposure to saltwater (Chanin, 2003). In general, otters exploit a narrow strip of habitat, about 10m wide at the aquatic-terrestrial interface (Mullen et al., 2021), however, otters have been observed to forage out to a maximum of 80 m from the coast (NPWS, 2009).

There are 45 SACs designated for otter in Ireland, the Wicklow Mountains SAC (002122) is the only SAC for which otter is a QI within 20 km of the proposed SI works. A desk-based study utilising records from NBDC (2024b)[3], indicated that otters few otter sightings have been recorded in the last ten years in the intertidal habitats located adjacent to the AoI. These records show that in 2015 one live otter sighting was recorded

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[2] https://maps.biodiversityireland.ie/Map Accessed October 2024

[3] Maps - Biodiversity Maps (biodiversityireland.ie) Accessed October 2024

adjacent to the AoI at West Pier Dun Laoghaire. No otter sightings were recorded along the coastline between Blackrock and Sandymount and none were recorded along the coastline adjacent to the AoI at Dublin Port (NBDC, 2024b). The Dublin City otter survey was conducted in 2019 along river systems which flow into Dublin Bay (Macklin et al., 2019). The Elm Park stream which was the only stream surveyed that flowed into the south Dublin Bay is adjacent to the SI works AoI at Merrion Strand. A single jelly smear (scent mark) was noted on the seaward side of the stream. However, no other otter signs were recorded potentially due to the highly modified and disturbed nature of the channel (Macklin et al., 2019). The coastal habitats of Dublin Bay were surveyed including the coastline adjacent to the SI works. No signs of otter were identified in south Dublin Port and along Merrion Strand although two spraints were recorded on the quay steps near the Poolbeg Lighthouse. The survey concluded that the north side of Dublin Port was considered the most important area of the coastal boundary for otter (Macklin et al., 2019).

It can, therefore, be concluded that sightings of otters within or adjacent to the AoI are possible but rare with the most recent recorded sighting (spraint and jelly smear) in 2019 (Macklin et al., 2019). It can be reasonably assumed based on the information above that otter activity within the South Dublin Bay region and adjacent to the proposed SI works will be minimal. Any otter activity on the site will be habituated to the existing levels of noise in the South Dublin Bay region given its busy residential, recreational and commercial nature adjacent to the proposed SI works.

The main threats to otter include pollution, particularly organic pollution resulting in fish kills; and accidental deaths, e.g., road traffic and fishing gear (NPWS, 2019). The most recent Article 17 conservation assessment for otters in Ireland deemed the species as being in favourable conservation status (NPWS, 2019).

3.4.5 Cetacean Species

Twenty-six species of cetacean have been recorded in the waters around Ireland (NBDC, 2024c). The Irish Whale and Dolphin Group (IWDG) holds 60 records of cetacean sightings within the Dublin Bay area for the period October 2023 to October 2024 (IWDG, 2024). Species identified include harbour porpoise (*Phocoena phocoena*), common dolphin (*Delphinus delphis*) and bottlenose dolphin (*Tursiops truncates*). No other cetacean species was recorded in Dublin Bay between October 2023 to October 2024.

Phase II of the Irish ObSERVE programme (2021-2023) was conducted to investigate the occurrence, distribution and abundance of key marine species in Irelands offshore and coastal regions. These aerial surveys included four offshore areas and coastal waters including the Irish Sea (Stratum 5), which the AoI is located. Common dolphin, harbour porpoise and bottlenose dolphin were the most frequently sighted species throughout the survey programme while minke whale was the most common sighted mysticete species (Paradell et al., 2024). Harbour porpoise was sighted across all strata but predominately observed in the Irish Sea (Stratum 5). Paradell et al (2024), noted that bottlenose dolphins were recorded more so over the continental shelf waters and only recorded occasionally in the Irish Sea. While common dolphins were the most sighted cetacean species across the survey area in 2021 and 2022. Common dolphins were seen across all strata but infrequently recorded in the Irish Sea, a clear preference for continental shelf waters was noted where they occurred in both the coastal and offshore areas (Paradell et al., 2024). The results of the Phase II ObSERVE programme builds on those findings from the Phase I survey programme in 2015 and 2017.

Management Unit (MU) boundaries, defined by the 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.

3.4.5.1 Harbour porpoise

Harbour porpoise are widespread around the Irish coast (Wall, D. et al., 2013 as cited in NBDC, undated) and the Celtic and Irish Seas (CIS) MU is recognised for the management of harbour porpoise in Celtic and Irish waters (IAMMWG, 2022). According to Paradell et al (2024), greatest abundance and densities were seen in the Irish Sea. The predicted distribution of harbour porpoise for summer highlights the northern section of the Irish Sea as an area of importance (Paradell et al., 2024). Harbour porpoise can be regularly seen in Irelands inshore waters particularly off Howth Head and Dalkey in Co. Dublin (IWDG, 2015a). The highest sightings are usually between June and September with a reduction in sightings between March and June, suggesting that harbour porpoise move further offshore in spring for calving or for breeding grounds (IWDG, 2015a).

Potential threats to harbour porpoise include underwater noise, entanglement in fishing gear, shipping traffic, and coastal development including ORE and other forms of human disturbance (ORCA, 2024a). Abundance of harbour porpoise in the CIS MU is estimated at 62,517 animals (IAMMWG, 2022).

3.4.5.2 Common dolphin

Common dolphins are typically found in deeper offshore waters over the continental shelf but can inhabit coastal waters. They can be seen in the southern Irish Sea and show strong inshore winter migrations presumed to be associated with prey abundance off the south of Ireland (IWDG, 2015b). According to Paradell et al (2024), strong seasonal difference were observed with more common dolphins recorded in the summer of 2021 than in 2022. Common dolphins were infrequently recorded in the Irish Sea as they showed a preference for continental waters (Paradell et al., 2024).

Common dolphins face threats such as underwater noise, interactions with fisheries through bycatch, ship strikes, and chemical and plastic pollution (ORCA, 2024b). Common dolphins have been assigned to a single MU, the Celtic & Greater North Seas MU (IAMMWG, 2023).

3.4.5.3 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, 2024d). 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. According to Paradell et al (2024), an increased encounter rate was shown for the summer of 2022 for bottlenose dolphins. Distribution maps highlighted the Irish Sea as an area of importance despite the low sightings recorded in this region.

Bottlenose dolphins are exposed to several threats as they utilise coastal areas. These threats include underwater noise, interactions with fishing gear, habitat destruction and degradation (ORCA, 2024c). Bottlenose dolphins have been assigned to the Irish Sea MU (IAMMWG, 2023).

3.4.6 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*). Leatherback turtle has been reported on a number of occasions around the Irish coastline and in the Irish Sea, most recently in 2023 at Curracloe Beach in Co. Wexford (NBDC, 2024e). Between 2003 and 2023, 249 observations of leatherback turtles were recorded in Irish waters (NBDC, 2024e). 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).

From 2005, there are 2 records of a leatherback turtle east of Dublin Bay (approximately 17 km to the east of Dublin Bay) from the MULA Area (NBDC, 2024e). Loggerhead turtles have been more commonly recorded all along the west and south coast of Ireland, however, one stranding of a loggerhead turtle was recorded at Kilbarrick Strand to the north of Dublin Bay in 2004 (NBDC, 2024f). The occurrence of turtles in Irish waters is relatively rare, with the leatherback and loggerhead turtles the most common species. Other turtle species have been less commonly observed in Irish waters. The last record of hawksbill turtle in Ireland was in 1983[4] off the coast of Cork. Several strandings of the Kemps Ridley turtle have been recorded along the west coast of Ireland with the most recent stranding recorded in 2021 in Co. Kerry, one stranding was recorded along Irelands east coast at Howth Head in 1968 (NBDC, 2024g). No turtle sightings have been recorded within the AoI in Dublin Bay.

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[4] https://maps.biodiversityireland.ie/Species/128441 Accessed online 15 October 2024.

It can, therefore, be concluded that the occurrence of turtles in Irish waters is rare, with the leatherback and loggerhead turtles the most common species. No turtle sightings have been recorded in the nearshore area of the South Coast Dublin Bay.

3.5 Examination of Impacts to Strict Protections

3.5.1 Bat Species

Based on the available evidence, the proposed SI works including access/egress from each location 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.

Any artificial lighting used will be localised to either the vessels or at onshore trial pit/test locations. Existing artificial lighting is used extensively alone the shoreline. Therefore, given the existing levels of artificial lighting on-site, there is no likelihood of any significant disturbance or displacement of foraging, commuting, or migrating bats.

Given that the SI works conform with the strict protections afforded to bat species and based on the current evidence base, it is considered that no derogation is required.

The proposed SI works are consistent with the system of strict protection of bats under Article 12 of the Habitats Directive.

3.5.2 Otter

Based on the available evidence gathered in the desk study, otters are unlikely to be present in the vicinity of the SI works. The SI works will result in limited activity around the shore of South Dublin Bay. The area of works are adjacent to two busy areas where there is constant activity on-site including personnel, vehicle movements, deliveries, noise, artificial lighting, railway line, etc. The beach and intertidal surveys will involve a small team of surveyors walking along the beach/intertidal zone conducting intertidal habitat characterisation sampling and GPR equipment. For most survey types, no above-water noise, vibration or light will be emitted beyond baseline levels (potential landfall locations are at Blackrock and at Shelly Banks car park on the Poolbeg Peninsula which are busy recreational, residential and commercial areas). Coastal surveys with the potential to emit above-water noise and vibration beyond baseline levels are the geotechnical boreholes from jack up barge (JUB) and those within the intertidal zone where a tracked borehole, CPT rig and ancillary equipment may be deployed from a small landing craft. Based on the available evidence from the desk study discussed in Section 3.4.3, sightings of otter were rare along the coastline and within the south Dublin Bay (NBDC, 2024b, Macklin et al., 2019). Any artificial lighting will be localised to either the vessels (or JUB) or at onshore borehole locations. It is considered highly unlikely that intrusive sampling works will interact with otter holts or couches as these are not likely to be in the intertidal zone/on beaches where intrusive sampling will take place.

However, as otters tend to forage within 80 m of the shoreline (NPWS, 2009), any potential effects are likely to be associated with the survey activity at the potential landfall locations rather than activity further offshore. While it is still possible but rare for potential interactions between foraging otters and underwater noise generated during the marine surveys particularly for otters foraging in the marine environment, this has the potential to result in injury and/or disturbance. While there are no published underwear noise injury criteria for Eurasian otter, Southall et al. (2019) has provided injury criteria for the ‘Other marine carnivores in water (OCW)’ hearing group, which includes sea otters. The OCW criteria is extended to Eurasian otter in the current assessment in the absence of more suitable criteria. The underwater noise assessment undertaken to inform this Annex IV Risk Assessment has concluded the following with respect to injury and/or disturbance to OCW:

- Both geophysical and geotechnical sound sources have the potential to cause PTS and TTS to OCW less than 10 m of the sound source (for all geophysical and geotechnical survey equipment while in use). Behavioural disturbance for OCW range from less than 20 m (geotechnical surveys drilling and boreholes) to 8000 m (for Sparker SBP & USBL). It is expected that the physical presence of the vessel and/or JUB will cause otter to avoid the area.

It is considered highly unlikely that the limited risk ranges identified for underwater noise effects to otter will lead to the removal of the strict protections afforded to otters. Including that there will be no likelihood of any significant disturbance or displacement of breeding, resting or commuting otters due to the proposed SI works.

Therefore, the proposed SI works conform with the strict protection afforded to otters under Article 12 of the Habitats Directive, and therefore, it is considered that no derogation is required.

3.5.3 Cetacean Species

Potential impacts to cetaceans (i.e. harbour porpoise, common and bottlenose dolphin), and on the strict protections afforded to these species, associated with the SI works are:

- Underwater noise generated during the geophysical and geotechnical surveys resulting in injury and/or disturbance;
- Accidental pollution event; and
- Collision risk with survey vessels, resulting in injury.

3.5.3.1 Underwater Noise

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 Subsea Noise Technical Report in Appendix B.

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 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 water depth within the AoI ranges between 0-10m with a mixed substrate type of fine muds, sands, and potentially coarser gravel types. All factors listed above reduce the propagation of the sound, decreasing the zone of influence of the geophysical survey.

The active acoustic instruments, such as those proposed on this survey, operate by emitting extremely short pulses and are 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 60m 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.

Auditory injury in cetaceans can be defined as a permanent threshold shift (PTS) leading to non-reversible auditory injury, or as a temporary threshold shift (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., PTS 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).

A summary of the equipment proposed to be used in the SI Works and modelled for the Subsea Noise technical Report is provided in Section 2.2.6.

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[5]. However, the guidance goes on to specify the use of thresholds from a 2007 publication (Southall et al., 2007) which has since been superseded (by (Southall, et al., 2019)) 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 intent, we have applied the latest guidance, reflecting the current best available method for assessing impact from noise on marine mammals.

Should the noise levels from sources provided in Section 2.2.6 exceed the thresholds, 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.

Marine mammal species can be split into functional hearing groupings, according to their frequency-specific hearing sensitivity (Southall *et al*., 2019). The Subsea Noise Technical Report assessed all hearing groups listed in Table 3.1 however the following section will focus on those Annex IV cetaceans which were identified as being within the ZoI of the proposed SI works, these are harbour porpoise, common and bottlenose dolphin. Harbour porpoise a very high frequency cetacean (VHF) and common and bottlenose dolphin are considered high frequency cetaceans (HF). See Table 3.1 below for a list of species contained within each functional hearing group.

Table 3.1 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).

Southall et al. (2019) provides impact thresholds for both PTS and TTS, addressing both peak sound pressure levels (SPL) and sound exposure levels (SEL) and these are provided below in Table 3.2. It should be noted that although the DAHG (2014) guidance refers to Southall et al. (2007), the more recent Southall et al. (2019) outlines more precautionary thresholds than those outlined in 2007 for PTS and TTS and it is therefore the most recent Southall et al. (2019) that is utilised in this assessment and included in Table 3.2 below.

Table 3.2 Summary of PTS and TTS Onset Thresholds (Southall et al., 2019)

Hearing Group	Parameter	Impulsive		Non-Impulsive	
		TTS	PTS	TTS	PTS
High-frequency (HF) cetaceans (e.g., bottlenose dolphin)	L_P (unweighted)	224	230	-	-
	L_E (HF weighted)	170	185	178	198
Very High frequency (VHF) cetaceans (e.g., harbour porpoise)	L_P (unweighted)	196	202	-	-
	L_E (VHF weighted)	140	155	153	173
Other Marine Carnivores in Water (OCW) (e.g., otters)	L_P (unweighted)	226	232	-	-
	L_E (OCW weighted)	188	203	199	219

[5] 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

To assess the impacts of the geophysical survey, each type of sub-bottom profiler (SBP) was modelled as a different scenario. Each scenario assumed the vessel, SSS, MBES sources were active with only the type of SBP and presence of USBL (active/inactive) changing between the scenarios modelled.

The only cetacean species likely to occur within this area of the Irish Sea are bottlenose dolphin (HF hearing group) and harbour porpoise (VHF hearing group). The results for the worst-case scenarios for each of these two hearing groups is summarised below (refer to Section 6.2 of the Subsea Noise Technical Report Appendix B), and it should be noted that no mitigation (i.e. soft-start measures, or marine mammal observers) has been applied at this stage.

HF Group (bottlenose dolphin):

- PTS out to 50 m from the sound source.
- TTS out to 310 m from the sound source.
- Behavioural disturbance out to 8000 m from the sound source.

VHF hearing group (harbour porpoise)

- PTS out to 500 m from the sound source.
- TTS out to 2,800 m from the sound source.
- Behavioural disturbance out to 8000 m from the sound source.

The Subsea Noise Technical Report concludes that there is risk of inducing hearing injury (PTS) and TTS as a result of subsea noise from the SI works. However, with the implementation of suitable mitigation as outlined below, the distances for PTS and TTS can be reduced effectively to make the risks of PTS and TTS low for all hearing groups assessed.

3.5.3.1.1 Mitigation

The mitigation measures proposed below will reduce the impact distances of PTS and TTS on cetaceans from the proposed SI works (reproduced from Section 6.2 in the Subsea Noise Technical Report Appendix B):

Geophysical surveys

For the HF hearing group, a 20-minute soft-start would reduce PTS and TTS risk ranges to below 10 m from the sound source for all geophysical survey scenarios and geotechnical survey (Vibro-coring, CPT).

For the VHF hearing group, a 20-minute soft start would reduce PTS for all geophysical survey scenarios to 50 m. A 20-minute soft start would reduce TTS to 1,500 m for each type of SBP scenario where the USBL is active and where the USBL is not active and a 20-minute soft start reduces PTS for VHF hearing group to 170 m for all geophysical survey types.

Geotechnical surveys

For the geotechnical surveys (vibro-coring, CPT), a 20-minute soft start would reduce PTS to less than 10 m and TTS to within 1,500 m for the VHF hearing group.

For the geotechnical survey (drilling/boreholes), the risk ranges for PTS and TTS are below 10 m for all hearing groups. The vessel will itself emit similar noise to the sampling activity and will therefore serve as a type of soft-start.

For the geophysical and 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 i.e. those activities listed in **Table 2.2** 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. In commencing sound producing activities using the equipment listed above, a “Ramp Up” procedure (i.e. 20-minute soft-start) must be used. Once the Ramp-Up 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 Ramp-up

Procedure (where appropriate following Pre-Start Monitoring) must be undertaken (DAHG Guidance, 2014). These measures will ensure that impacts on marine mammals will be reduced to the lowest possible risk to ensure there is no significant risk to marine mammals from impulsive noise.

For all survey equipment where the threshold for TTS is exceeded beyond the 500 m monitored zone, the zone of impact for TTS is estimated to occur up to 1,600 m from the sound source. Whilst there is the potential for harbour porpoise to occur within the zone of impact for TTS. In addition, it is highly likely that the presence of vessels will disturb harbour porpoise away from the zone of impact. Although the focus is on mitigation for permanent injury (i.e. PTS), the implementation of the proposed mitigation measures will also reduce the risk of very high frequency cetaceans i.e. harbour porpoise experiencing TTS. Further, the equipment causing the TTS is generally narrowband and thus only affects a small portion of the frequency range audible by the VHF cetaceans, meaning it has little or no overlap with biologically relevant sounds. The risk of biologically relevant TTS in harbour porpoise is therefore considered to be low.

These measures will be implemented in accordance with the strict protection requirements provided for under Article 12 to prevent any potential temporary disturbance of cetacean species within the Zone of Influence of the SI works during operations. The measures include the requirement to have an MMO on-board at all times during geophysical and geotechnical surveys. As required by the DAHG Guidelines (2014), survey activity will be planned to commence at the innermost part of the Bay to be surveyed and thereafter work outwards, to ensure that marine mammals are not driven into or artificially confined within an enclosed comparatively shallow area.

3.5.3.1.2 Conclusion

Based on the current evidence base, and suggested mitigation measures, it is considered that no derogation is required, and the proposed SI works do have the potential to offend the system of strict protection of cetaceans under Article 12 of the Habitats Directive.

3.5.4 Turtle Species

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). While the majority of the survey equipment to be used operates across higher frequency range (see Section 2.2.6), injury and disturbance to turtles due to noise impacts is unlikely given the rarity of turtle occurrence. Due to the rarity of turtles within nearshore of south Dublin Bay, 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.

3.5.4.1 Mitigation Measures for Turtles

While the DAHG (2014) guidelines do not specifically refer to turtles, the MMO will monitor for the presence of turtles. This precautionary measure will ensure that the works conform with the strict protections afforded to turtles, in the extremely unlikely event of turtles being present within the SI works area.

Therefore, in view of the current evidence base, it is considered that no derogation is required, and the proposed SI works will be consistent with the strict protection of turtles under Article 12 of the Habitats Directive.

3.5.5 Accidental Pollution Risk

All vessels operating in the marine environment must adhere to the International Convention for the Prevention of Pollution from Ships (MARPOL) which is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. The Sea Pollution Act, 1991 ratified MARPOL in Ireland. In addition, all substances handled and/or used whilst undertaking the works are required to be handled, used, stored, and documented in accordance with assessments and the Chemicals Act 2008 (No. 13 of 2008) and Chemicals (Amendment) Act 2010 (No. 32 of 2010) and associated Regulations.

Given the standard legal and regulatory pollution control requirements that apply to all vessels, the nature of the proposed SI works, their limited scale and duration, and the insignificant increase in vessel activity, it can be concluded that there will be no impact on any Annex IV species as a result of an accidental pollution event. Therefore, it can be concluded that the proposed SI works are consistent with the system of strict protection of Annex IV species under Article 12 of the Habitats Directive.

3.5.6 Risk of collision

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 two vessels would be operating at any one time within the survey area. Due to the nature of the surveys, the vessels would be stationary, or travelling at low speeds. No significant effects are predicted as a result of collision with survey vessels.

Therefore, it is considered the proposed SI works do not present a collision risk and therefore are consistent with the system of strict protection of cetaceans under Article 12 of the Habitats Directive in this regard.

4 SUMMARY & CONCLUSION

In summary, the potential for death, injury, disturbance or damage/destruction of breeding/resting sites to occur to Annex IV species as a result of the SI works is considered to be low. This risk will be further reduced by the implementation of the mitigation measures 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 kill, disturb or destroy the species listed under Annex IV of the Habitats Directive.

Following the assessment of the evidence base and available information on relevant Annex IV species, it is concluded that the SI works are consistent 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. This applies to the following Annex IV species:

- All bat species;
- Otter;
- All cetacean species; and
- All turtle species.

Based on the current available evidence, no derogation licence(s) are considered necessary for the SI works.

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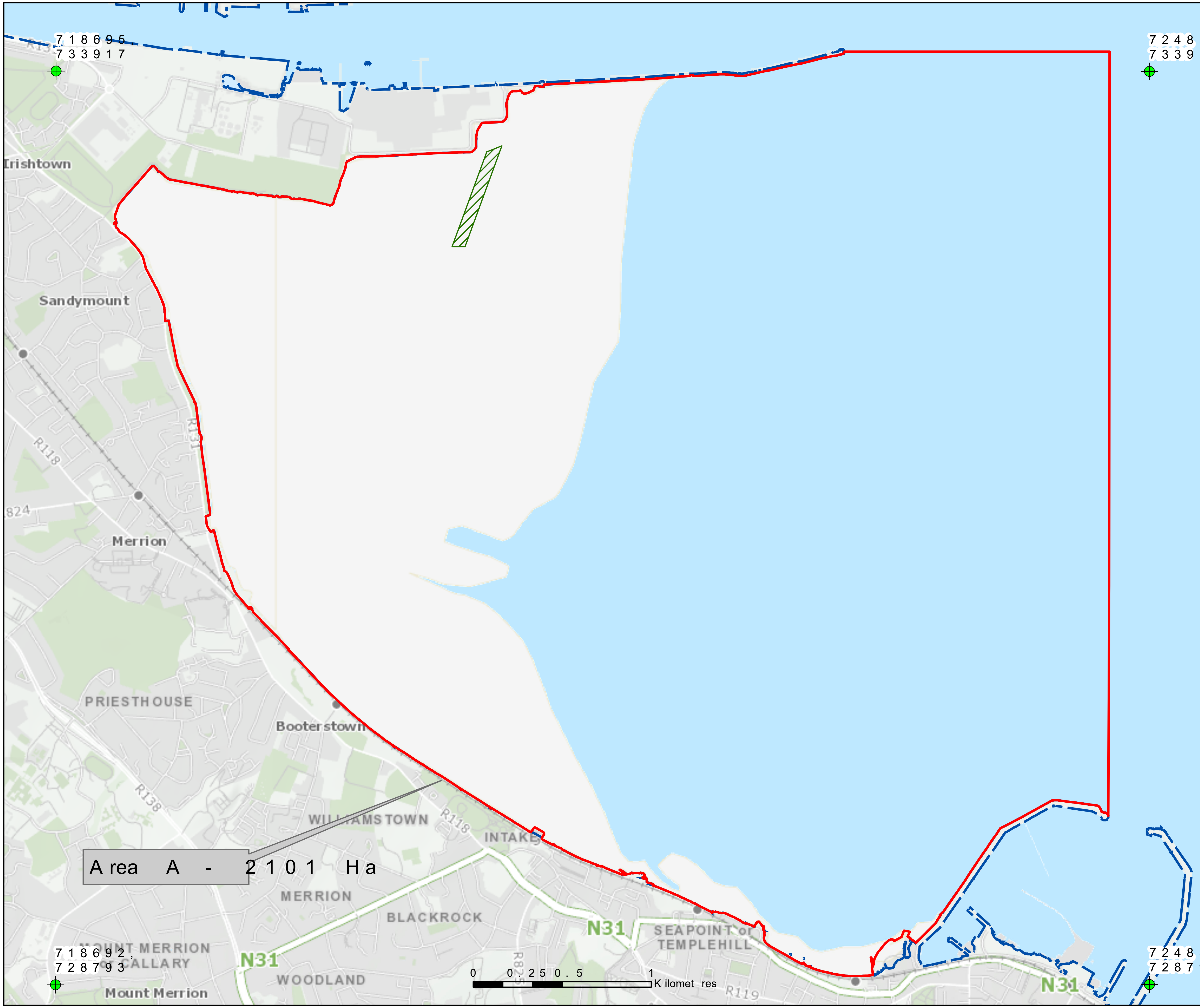
Appendix A
Drawings



Legend

- Maritime Usage Licence Area
- Private Foreshore – Folio DN44335F
- High Water Mark (HWM)

Where the licence area adjoins or abuts the land the High Wa as defined by the Chief Bounda Surveyor is the boundary of t area.

MARA File Reference No: MUL240010

Prepared by: [redacted]
Chartered Engineer

Client

EirGrid
Powering Up Dublin

Carrickmines to Poolbeg Cable Replacement

Title

Proposed Licence Area Map

rps A TETRA TECH COMPANY
West Pier
Business Ca[redacted]
Dun Laoghaire
Co Dublin, I www.rpsgroup.com/ireland

Issue Details

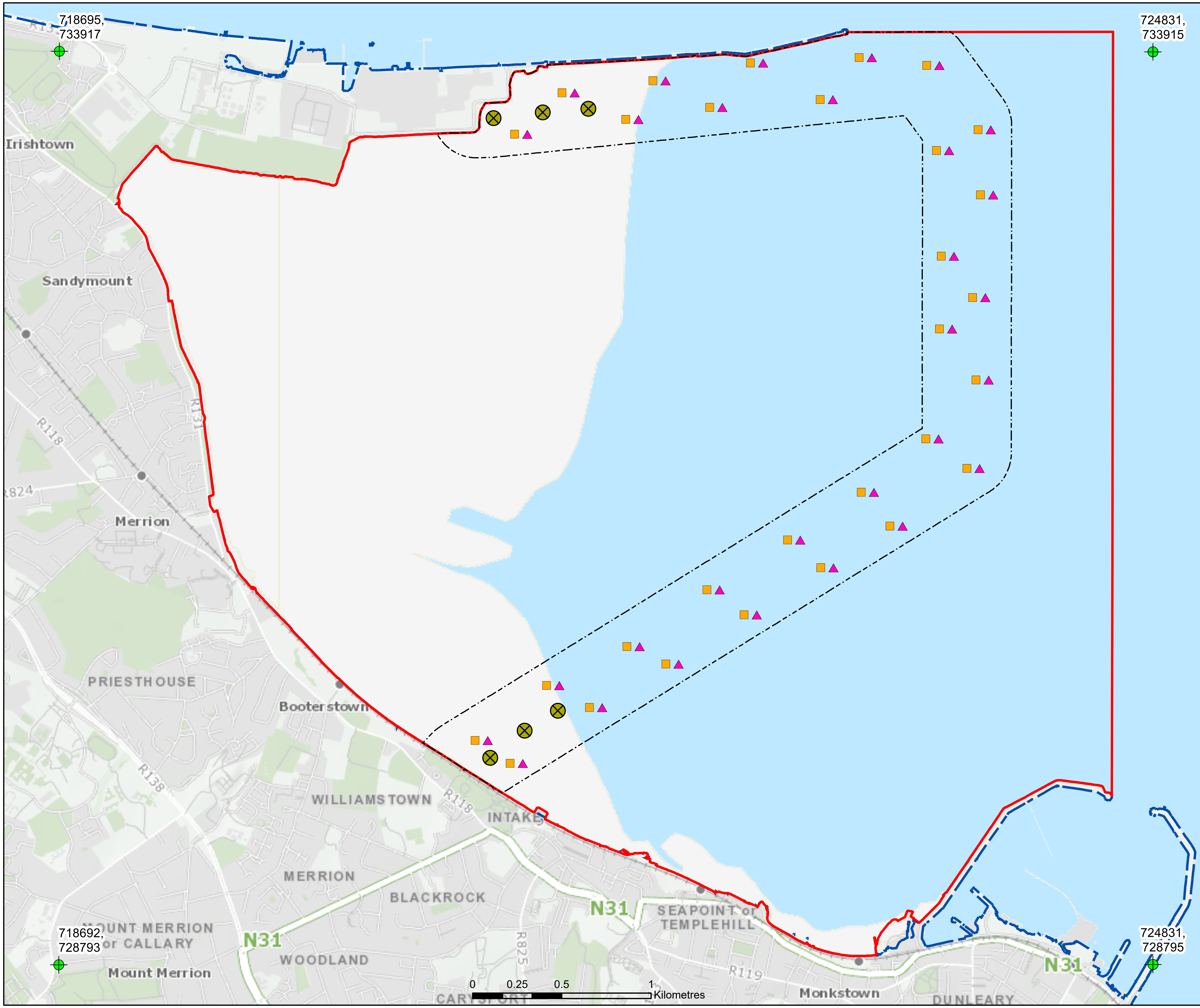
File Identifier: IE000451-RPS-00-XX-DR-C-DG2502

Status:	Rev:	Model File Identifier:
S5	P01	IE000451-RPS-00-XX-DR-

Drawn:	[redacted]	Date: 22/10/2024
Checked:		Scale: 1:20,000@A0
Approved:		Projection: ITM

NOTE:

1. This drawing is the property of RPS confidential document and must not or its contents divulged without pr
2.



Legend

- Maritime Usage Licence Area
- Offshore Cable Route - 500m wide corridor (250m Buffer)
- High Water Mark (HWM)
- Indicative Borehole Locations
- Indicative Vibrocore & CPT Locations

Site Investigation locations shown are indicative only.

MARA File Reference No:
MUL240010

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Prepared by: [redacted]
Chartered Engineer

Client

EirGrid
Powering Up Dublin

CP1146 - Carrickmines to Poolbeg Circuit

Title

Maritime Usage Licence Indicative Geotechnical Survey Locations

rps
A TETRA TECH COMPANY
West Pier
Business Campus,
Dun Laoghaire,
Co Dublin, Ireland.
[redacted]
W rpsgroup.com/ireland

Issue Details

File Identifier:
IE000451-RPS-00-XX-DR-C-DG2503

Status:	Rev:	Model File Identifier:
S5	P01	IE000451-RPS-00-XX-DR-C-DG2503

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Approved:	[redacted]	Projection:	ITM

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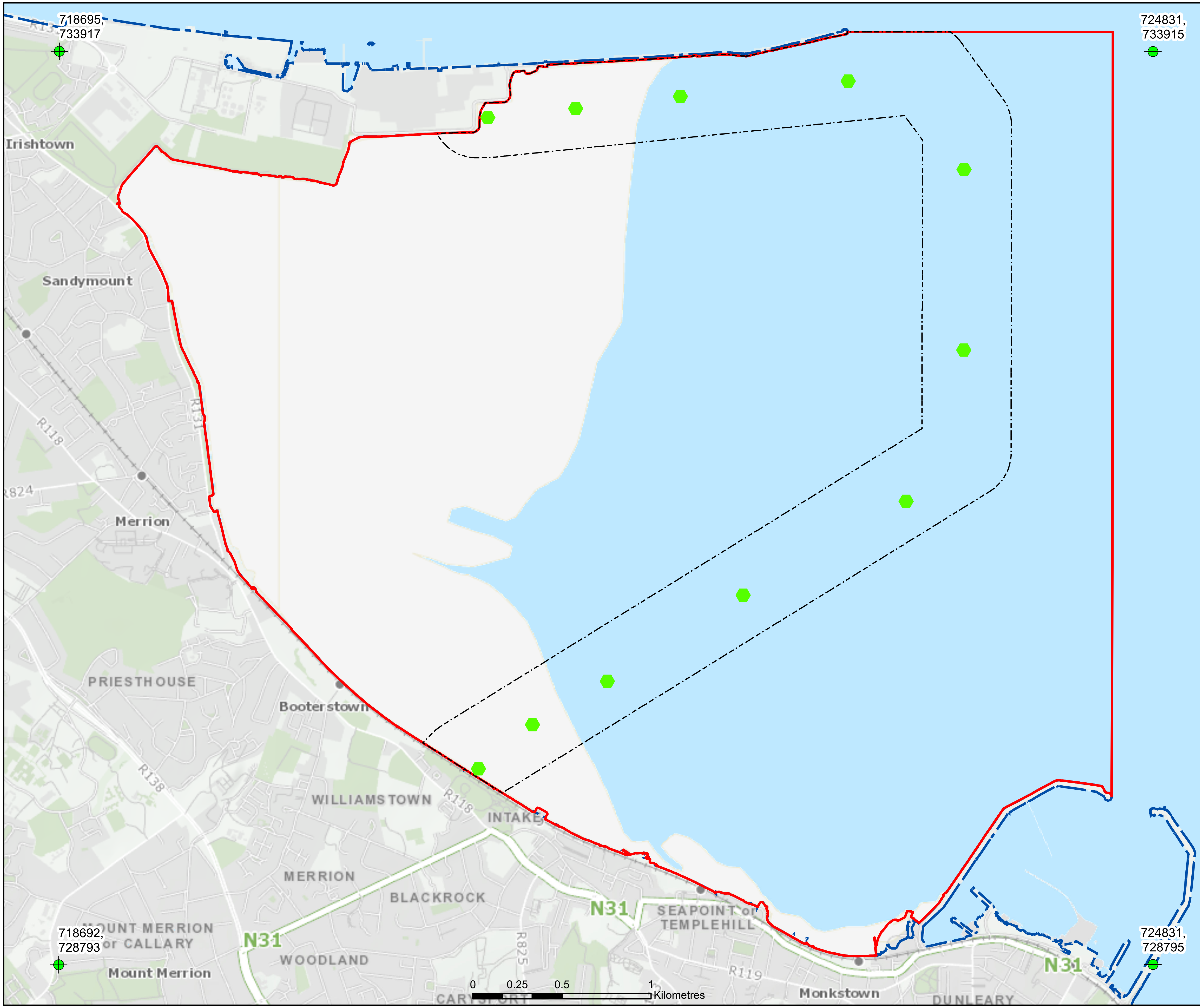

Legend

- Maritime Usage Licence Area
- Offhsore Cable Route - 250m Buffer
- High Water Mark (HWM)
- Indicative Benthic Sampling Locations

Benthic Sample locations shown are indicative only.

MARA File Reference No:
MUL240010

Prepared by:
[redacted]
Chartered Engineer

N

Client

EirGrid
Powering Up Dublin

CP1146 - Carrickmines to Poolbeg Circuit

Title

Maritime Usage Licence Indicative Benthic Sample Locations

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Issue Details

File Identifier:
IE000451-RPS-00-XX-DR-C-DG2504

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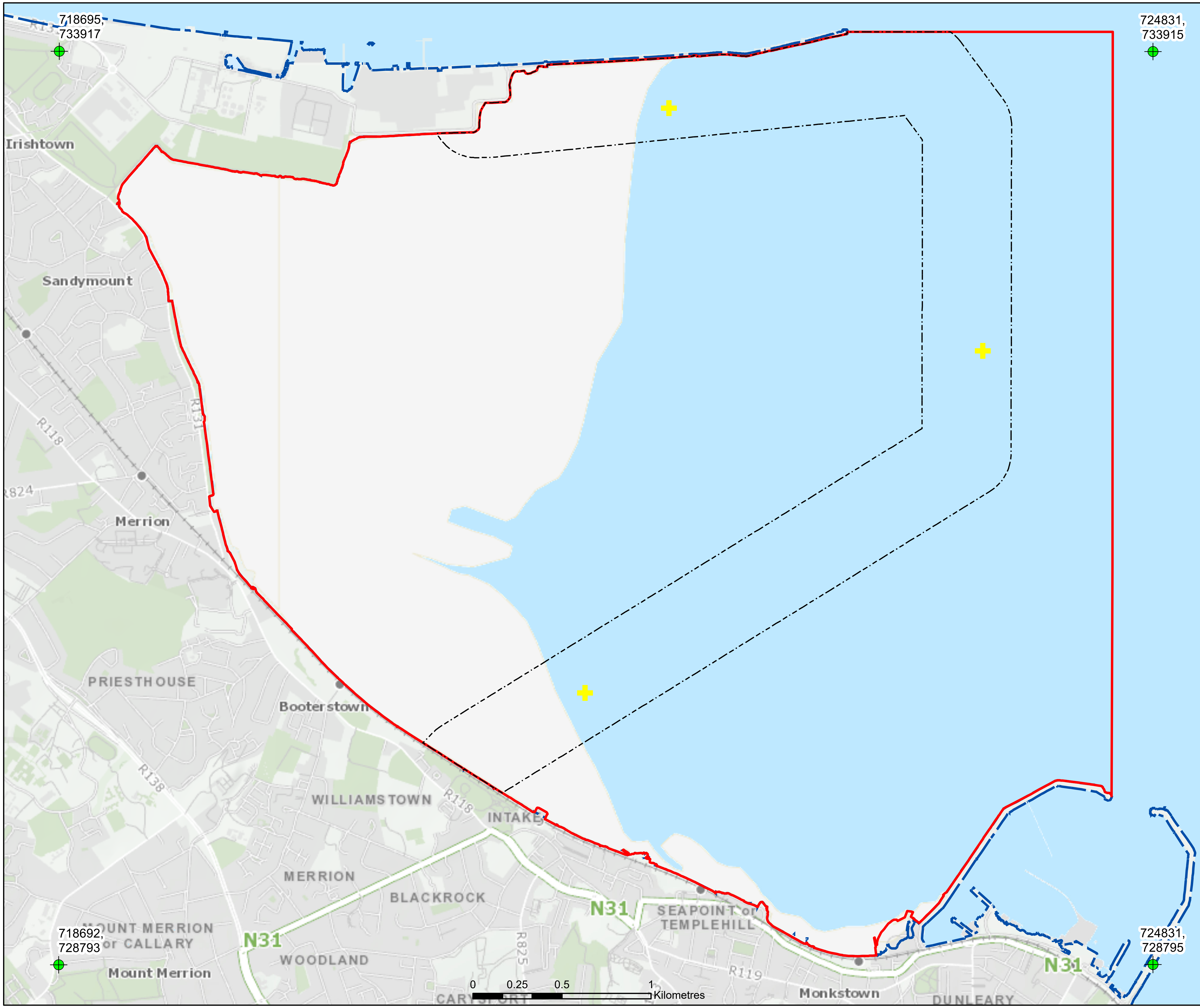

Legend

- Acoustic Doppler Current Profiler Indicative Locations
- Offhsore Cable Route - 250m Buffer
- Maritime Usage Licence Area
- High Water Mark (HWM)

ADCP deployment locations shown are indicative only.

MARA File Reference No:
MUL240010

Prepared by: [redacted]
Chartered Engineer

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Client

EirGrid
Powering Up Dublin

CP1146 - Carrickmines to Poolbeg Circuit

Title

Maritime Usage Licence Indicative ADCP Locations

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Issue Details

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Appendix B
Subsea Noise Technical Report

C2 - Restricted

CP1146 CARRICKMINES TO POOLBEG PROJECT

Subsea Noise Technical Report

CP1146-RPS-00-XX-RP-N-RP1021
A1 C01
23 October 2024

rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
S3 P01	Draft for Client Review	[redacted]	[redacted]	[redacted]	18/07/2024
S5 P01	Draft	[redacted]	[redacted]	[redacted]	15/08/2024
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[redacted]	23 October 2024

Prepared by:

RPS

Prepared for:

EirGrid

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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).
Permanent Threshold Shift (PTS)	A total or partial permanent loss of hearing caused by some kind of acoustic trauma. PTS 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 ≈ 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
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·s) or (Pa·s)/m^3]

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

1 INTRODUCTION

The CP1146 Carrickmines to Poolbeg project is a proposed new underground electricity cable from the Carrickmines 220 kV substation to the Poolbeg 220 kV substation and includes a section of marine cable. The marine section is located between Blackrock Park and Shelley Banks car-park on the Poolbeg peninsula, Co. Dublin

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 geophysical and geotechnical surveys in Dublin Bay (hereafter referred to as “SI Works”) for the CP1146 Carrickmines to Poolbeg project. 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. the metocean device (ADCP) operates at frequencies well above the hearing ranges of sensitive receptors.

The aim of the SI Works is to acquire data to a high quality and specification for the site. The SI Works covers an area of 2101 Ha within Dublin Bay between the south side of the Poolbeg peninsula and Dun Laoghaire West Pier. The sediment within the survey area is mostly silty to sandy and water properties in the area are relatively stable given the lack of major river outflows and a modest tidal range. Geophysical and geotechnical surveys such as those proposed for the SI Works use equipment that generate loud and potentially injurious noise to marine life.

Sound is readily transmitted in the underwater environment and there is potential for the sound emissions from anthropogenic sources 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 to 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 on the surrounding marine environment based on the Southall et al. 2019 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

[redacted] 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. [redacted] has over 11 years’ experience as a marine biologist and over 9 years’ experience with underwater noise modelling and marine noise impact assessments. [redacted] 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.

[redacted]s 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. [redacted] has 20 years’ experience in environmental projects including planning applications and environmental impact assessments for a wide range of strategic infrastructure projects.

[redacted] 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. [redacted] 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).

[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).
- **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).
- **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 Permanent Threshold Shift (PTS). 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 (PTS) 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 (by (Southall, et al., 2019)) and no longer represents best available science, nor reflects best practice internationally. Thus, the following excerpt from the guidance is relevant:

---

[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

"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 intent, we have applied the latest guidance, reflecting the current best available method for assessing impact from noise on marine mammals.

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 PTS 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*); hearing in air is considered separately in the group PCA.
- **Other Marine Carnivores in Water (OCW)**: Including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; in-air hearing is considered separately in the group Other Marine Carnivores in Air (OCA).
- **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 survey area, but all hearing groups are presented in this report for completeness.

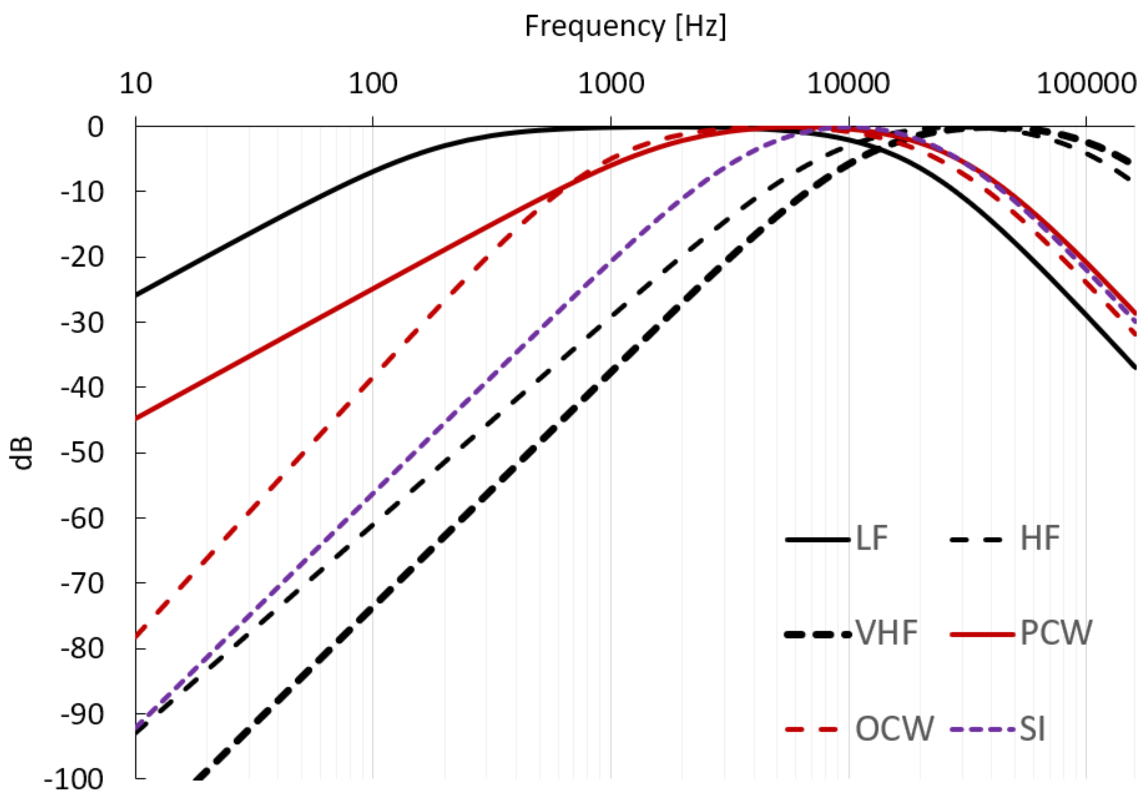

Figure 2-1: Auditory weighting functions for seals, whales and sirenians (NMFS, 2018; Southall et al. 2019)

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 PTS and TTS criteria proposed by Southall *et al*. (2019) are summarised in Table 2-1.

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

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		PTS	TTS	PTS	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	219	213	-	-
	SEL, (LF weighted)	183	168	199	179
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (MF weighted)	185	170	198	178
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (HF weighted)	155	140	173	153
Phocid carnivores in water (PCW)	L_P, (unweighted)	218	212	-	-
	SEL, (PW weighted)	185	170	201	181
Other marine carnivores in water (OCW)	L_P, (unweighted)	232	226	-	-
	SEL, (OW weighted)	203	188	219	199
Sirenians (SI) (NOAA only)	L_P, (unweighted)	226	220	-	-
	SEL, (OW weighted)	190	175	206	186

These updated marine mammal injury criteria were published in March 2019 (Southall, et al., 2019). The paper utilised the same hearing weighting curves and thresholds as presented in the preceding regulations document NMFS (2018) with the main difference being the naming of the hearing groups and introduction of additional thresholds for animals not covered by NMFS (2018). A comparison between the two naming conventions is shown in Table 2-2.

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

Table 2-2: Comparison of Hearing Group Names between NMFS (2018) and Southall *et al.* (2019)

NMFS (2018) hearing group name	Southall *et al*. (2019) hearing group name
Low-frequency cetaceans (LF)	LF
Mid-frequency cetaceans (MF)	HF
High-frequency cetaceans (HF)	VHF
Phocid pinnipeds in water (PW)	PCW
Otariid pinnipeds in water (OW)	OCW
Sirenians (SI)	Not included

2.4 Disturbance to Marine Mammals

Disturbance thresholds for marine mammals are summarised in Table 2-3. 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/PTS is *larger* than the range to the behavioural threshold, e.g., the PTS threshold for impulsive sound for the VHS group is 155 dB SEL, while the behavioural threshold is 160 dB SPL. 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 approximately twice the range to the PTS threshold (a difference of 5 dB). This is just one of the reasons why this behavioural threshold should be interpreted with caution.

Table 2-3: 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 $SEL_{single\ impulse}$ or 1-second SEL

2.5 Injury and Disturbance to Fishes

The injury criteria used in this noise assessment are given in Table 2-4 and Table 2-5 for impulsive noises and continuous noise respectively. L_P and SEL criteria presented in the tables are unweighted. 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 ("PTS" 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 PTS 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 158 dB L_P.

Given the large variations in the data from the two sources above, we have rounded the value to 160 dB L_P as the behavioural threshold for fishes for impulsive sound, and 150 dB SPL for non-impulsive sound.

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 PTS/TTS for impulsive sound & 222/204 PTS/TTS for non-impulsive sound). These lower thresholds also cover “Eggs and Larvae.

Table 2-4: 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 (PTS) [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]
Fish: where swim bladder is not involved in hearing (particle motion detection). Example: Salmonoids.	SEL	210[1]	203[1]	186[1]	150[3]
	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 PTS, TTS, and behaviour are given in Table 2-5. 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 2-5: 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 (PTS) [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 shallow water (c. 14 m at the deepest extents), generally silty to sandy sediment and stable water properties (Figure 3-1).

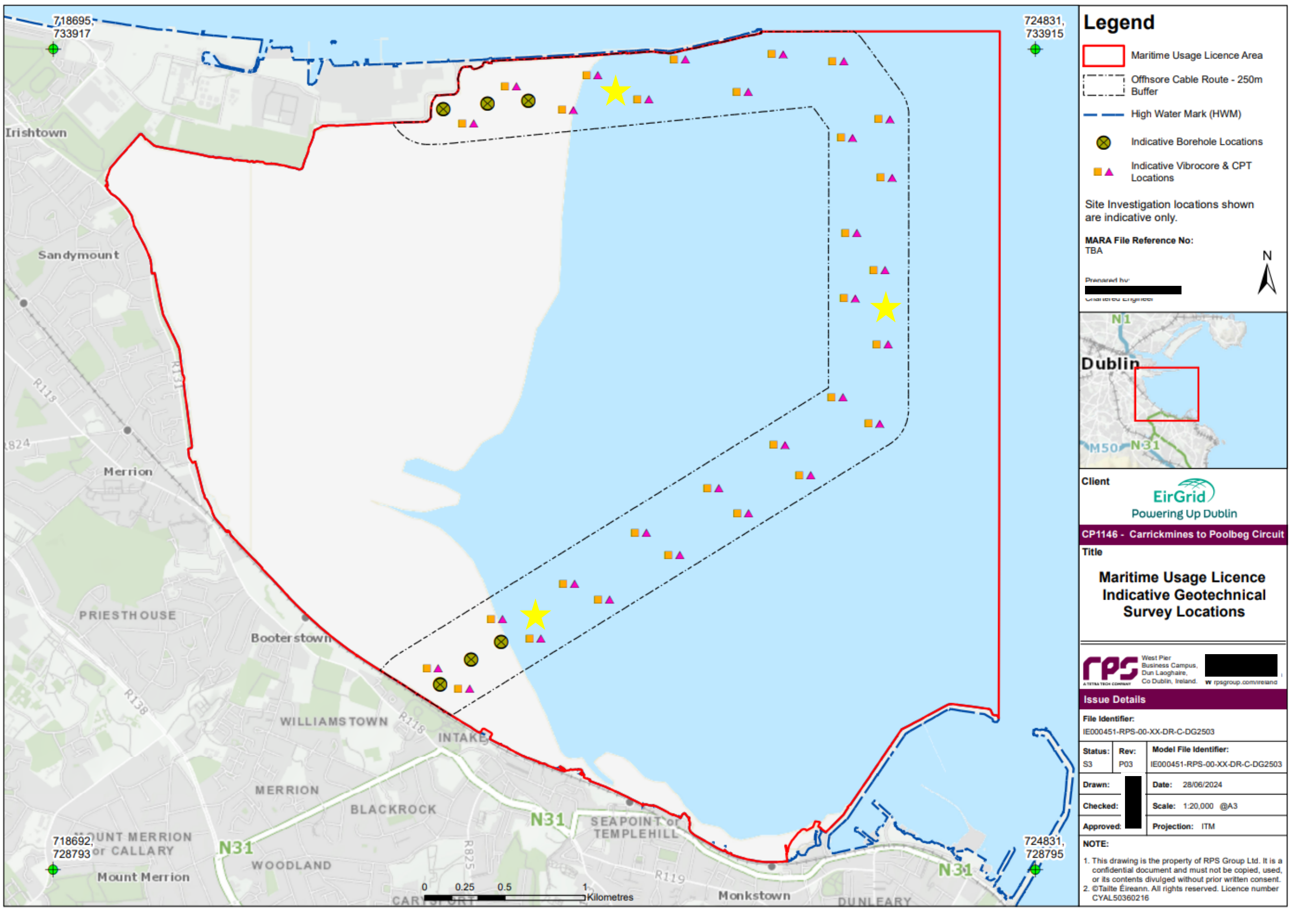

Figure 3-1: Maximal extent of surveys (red line). Indicative cable route (dot-dash line) with indicative locations for boreholes and geotechnical sampling locations. Additionally (yellow stars) are 3 indicative locations for ADCP deployments.

The maximal area to be surveyed is 2101 Ha of depths up to 14 meters (at mean high water springs "MHWS").

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 survey area 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: 18°C – maximal summer temperature given by seatemperature.net for the past seven years for bay Dublin.

- Salinity: 34.5 psu – Measurements in relation to Ringsend Wastewater Treatment Plant Upgrade Project[5]
- Soundspeed profile: Assumed uniform given high mixing as a result of tidal flows and generally shallow water and absence of river outflows.

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[6] (European Commision, 2024). 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.

Site	Sediment type (ISO 14688-1:2017)	Density [kg/m³]	Soundspeed [m/s]	Grain size [mm] (nominal)
Outer/deeper part of the Survey area	Medium Silt	1551	1544	0.011
Inner/shallower part of the Survey area	Sand	2123	1801	0.35

[5] "Ringsend WwTP - EIAR modelling services" Figure 5.39 available online (2024/07/11)

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

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.

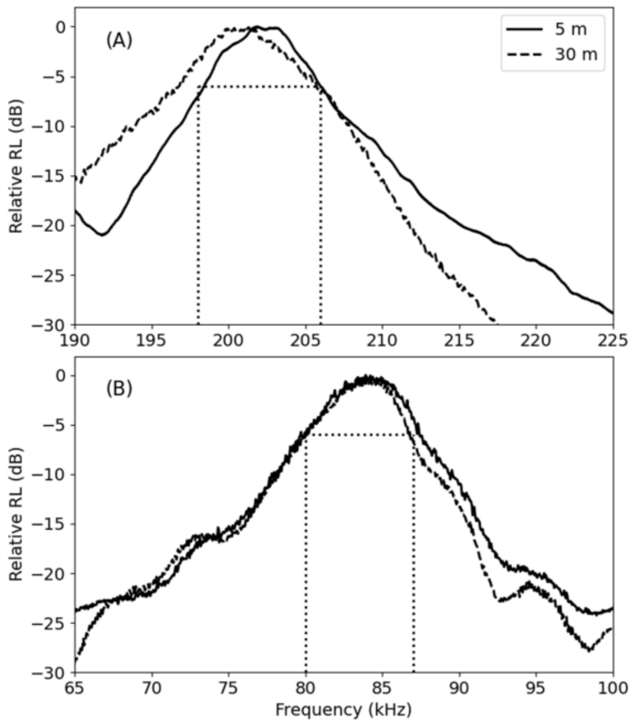

Figure 4. The relative received levels (RLs, in decibels (dB)) of the signals of the acoustic frequency bandwidth of the dual-frequency echosounder used in this study, as observed at two different depths. The dotted lines indicate the −6 dB acoustic bandwidths of 198–206 (**A**) and 80–87 kHz (**B**). 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 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	161 dB SPL	10-16,000 Hz	Based on <20 m generic survey vessel.	Non-impulsive
Survey vessel, Geotechnical	168 dB SPL	10 – 25,000 Hz	Based on <30 m tug with dynamic positioning system	Non-impulsive
MBES	187 dB SPL (Spherical equivalent level)	200,000-800,000 Hz	Based on Reason SeaBat T50 & R2 Sonic 2024.	Impulsive

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
SSS	166 dB SPL (Spherical equivalent level)	100,000-1,000,000 Hz	Generic SSS from 400-1,000 kHz.	Impulsive
USBL	190 dB SPL	18,000-31,500 Hz	Active with non-hull mounted SSS* & during vibro-core operations, 2 Hz ping rate, ping length 10 ms.	Impulsive
SBP-parametric (P-SBP)	204 dB SPL	80,000-150,000 Hz (Primary) 2,000-22,000 Hz (Secondary)	Source level adjusted for sediment effects and beam widths. Based on Innomar Standard, worst-case for shallow water.	Impulsive
SBP-chirper/pinger (C-SBP)	181 dB SPL	2,000-12,000 Hz	Generic shallow water SBP of chirper/pinger type. Source level adjusted for sediment effects and beam widths.	Impulsive
SBP-sparker/UHRS (S-SBP)	184 dB SPL	600 – 6,300 Hz	Based on GeoSource 400. Firing rate of 1 Hz assumed	Impulsive
ADCP (**Not modelled given high frequency**)	114 dB SPL	500,000-1,260,000 Hz	Based on suitable ADCP for depths <100 m (e.g. Nortek AWAC, Teledyne Reason Sentinel, Workhorse or Monitor) Source level adjusted for sediment effects and beam widths.	Impulsive
Drilling/ rotary coring (Boreholes, no USBL)	145 dB SPL	10-500,000 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	187 dB SPL	50 – 16,000 Hz	Based on levels from previous work & (Reiser, et al., 2010)	Non-impulsive

*If the SSS and SBP are hull-mounted, there is no need for a positioning device (USBL) and this noise source should be removed from consideration.

The ADCP has not been modelled due to its lowest frequency being significantly above the upper frequency limit of hearing of any marine animal. Furthermore, the extremely high frequencies will attenuate rapidly with range, meaning that on top of the spreading loss there will be an additional c. 140 dB/km loss from absorption[8].

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.

[8] See e.g., APPENDIX A, Figure 8-12 or http://resource.npl.co.uk/acoustics/techguides/seaabsorption/ for further information.

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.

4.1.1.1 Survey Vessel, Geophysical

A small survey vessel of up to 20 m in length, travelling at 4 knots (equipment limited), has been assessed in this report as this represents the anticipated vessel parameters for the geophysical and geotechnical surveys. Broadband level of the vessel is 161 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.

This vessel is also used as a proxy for a suitable platform for support vessels, representing generic machinery noise.

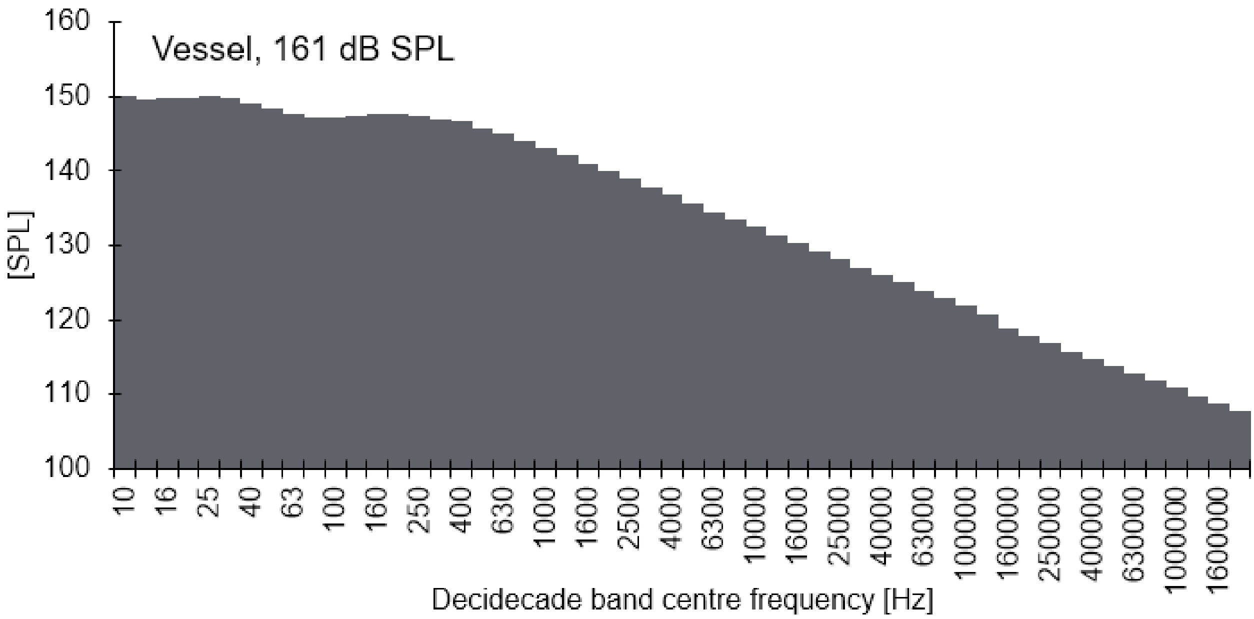

Figure 4-2. Vessel source band levels. Broadband level: 161 dB SPL. Based on generic survey craft at 4 kn.

4.1.1.2 Survey Vessel, Geotechnical

A small survey vessel of up to 30 m in length, travelling at 4 knots transiting to SI locations (equipment limited), has been assessed in this report as this represents the anticipated vessel parameters for carrying out the geotechnical survey. Broadband level of the vessel is 168 dB SPL with decidecade band levels given in Figure 4-2 (maximal band level is 157 dB SPL at the 400 Hz band). Smaller vessels will have lower emitted levels and are therefore covered by this assessment.

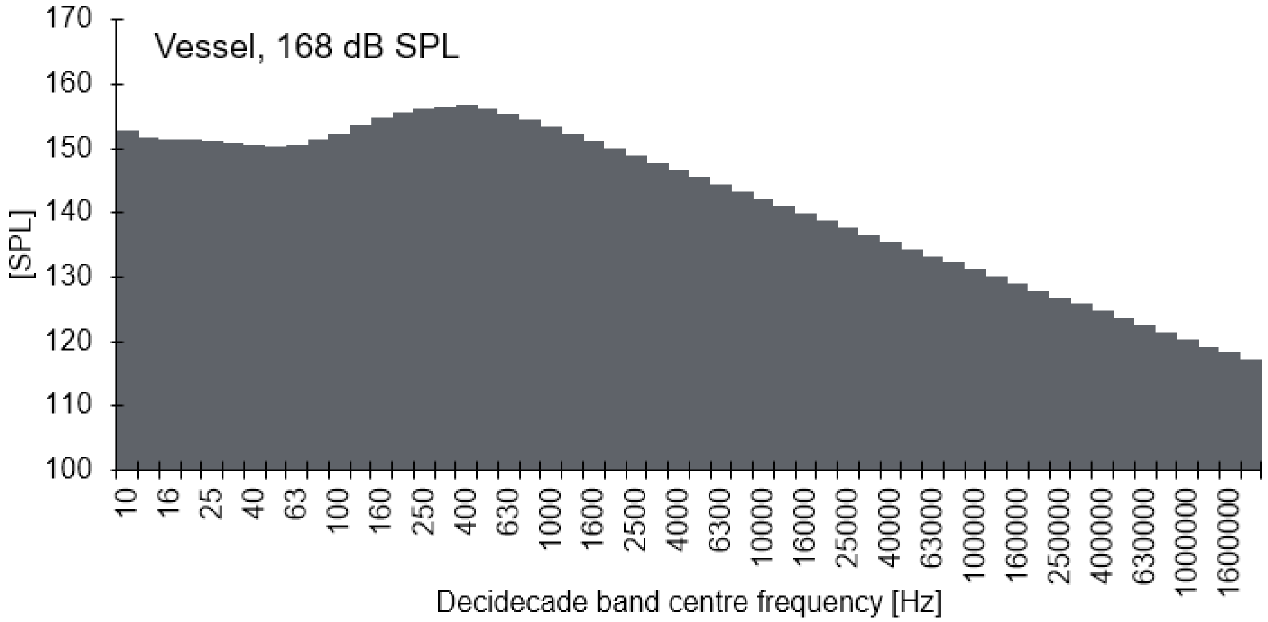

Figure 4-3. Vessel source band levels. Broadband level: 168 dB SPL. Based on generic tug with DP system at 4 kn.

4.1.1.3 Multibeam Echosounder (MBES)

The "Reason SeaBat T50-P", "R2 Sonic 2024", or similar shallow water model, is a likely MBES for this survey. Nominal frequencies from 200 kHz to 800 kHz have been modelled. The equivalent spherical level is 187 dB SPL (maximally 179 dB SPL in each band). Band levels are presented in Figure 4-4.

Given the shallow water (<14 m depth), it is likely that shorter pulses will be used as they offer sufficient energy for a clear returning echo. This will increase kurtosis ("impulsiveness") for realistic ping rates for the depth. Therefore, the MBES is modelled as an impulsive noise source.

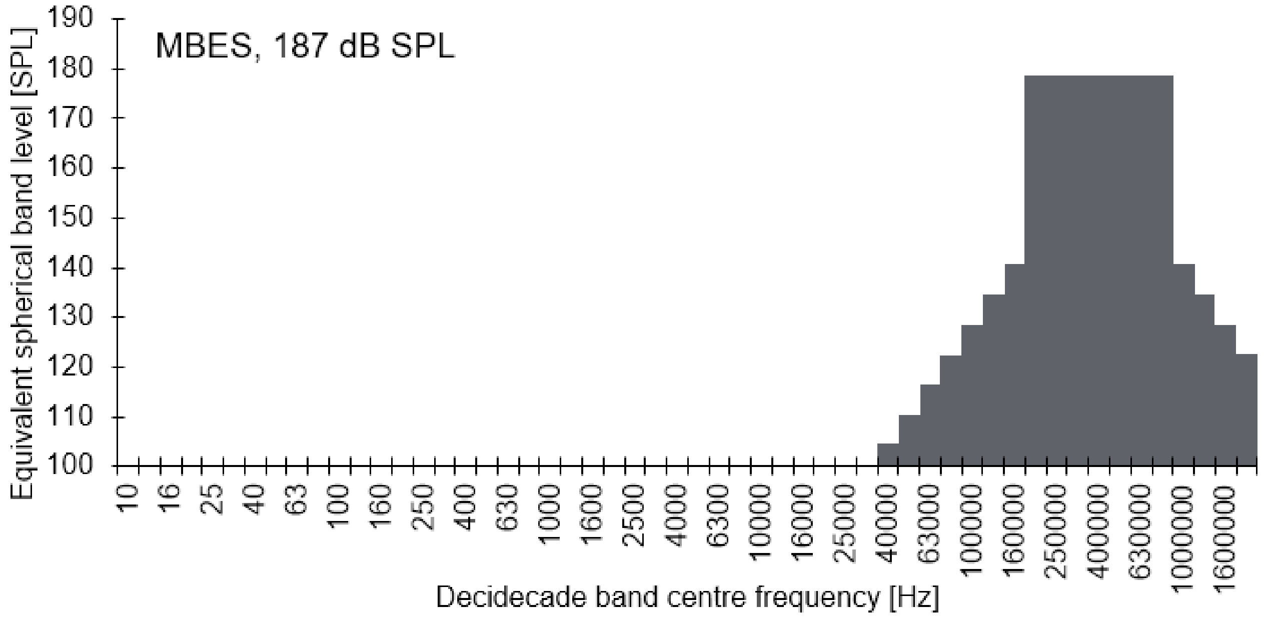

Figure 4-4. MBES source band levels as equivalent spherical/omnidirectional levels.

4.1.1.4 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 – 1,000 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 166 dB SPL (Figure 4-5).

Given the shallow water (<14 m depth), it is likely that shorter pulses will be used as they offer sufficient energy for a clear returning echo. This will increase kurtosis ("impulsiveness") for realistic ping rates for the depth. Therefore, the SSS is modelled as an impulsive noise source.

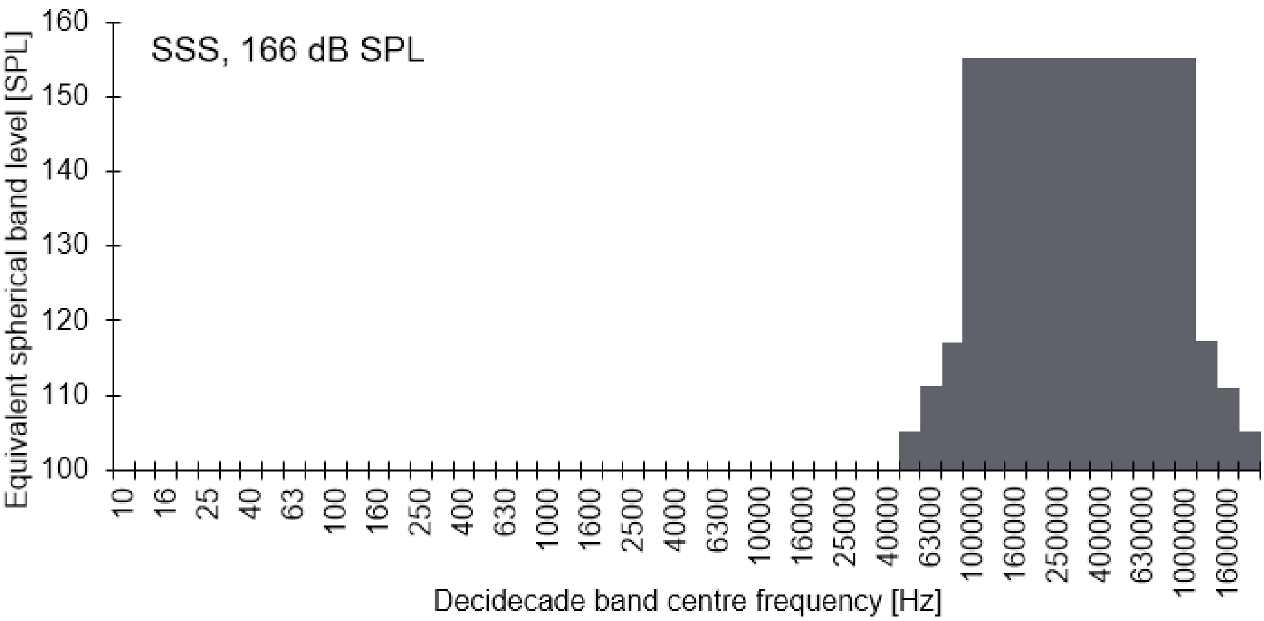

Figure 4-5. SSS source band levels as equivalent spherical/omnidirectional levels.

4.1.1.5 Ultra Short Base-Line positioning system (USBL)

If the SSS or SBP is deployed as a towfish (towed behind the vessel), its accurate positions will need to be known. A USBL positioning system is a common solution. This is also the case for the deployed Vibro-corer units. 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 have been modelled, giving an SPL of 190 dB (Figure 4-6).

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.

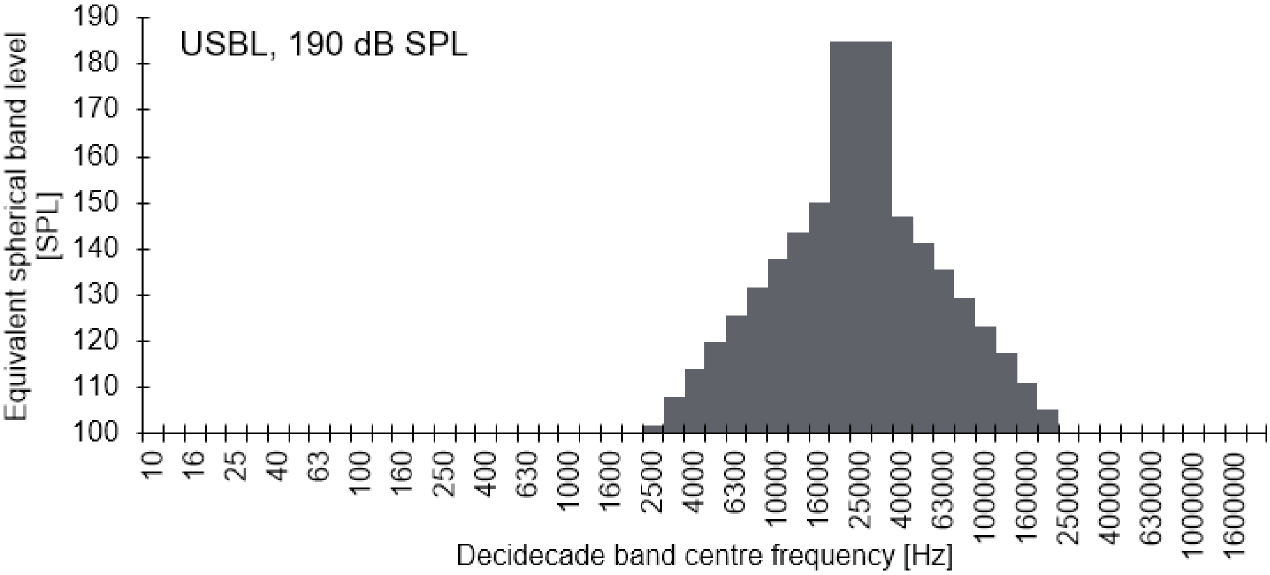

Figure 4-6. USBL source band levels.

4.1.1.6 Sub-bottom Profilers (SBP)

4.1.1.6.1 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 4-7) 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 204 dB SPL, with the secondary frequencies being 144 dB SPL.

Given the shallow water (<14 m depth), it is likely that shorter pulses will be used as they offer sufficient energy for a clear returning echo. This will increase kurtosis ("impulsiveness") for realistic ping rates for the depth. Therefore, the P-SBP is modelled as an impulsive noise source.

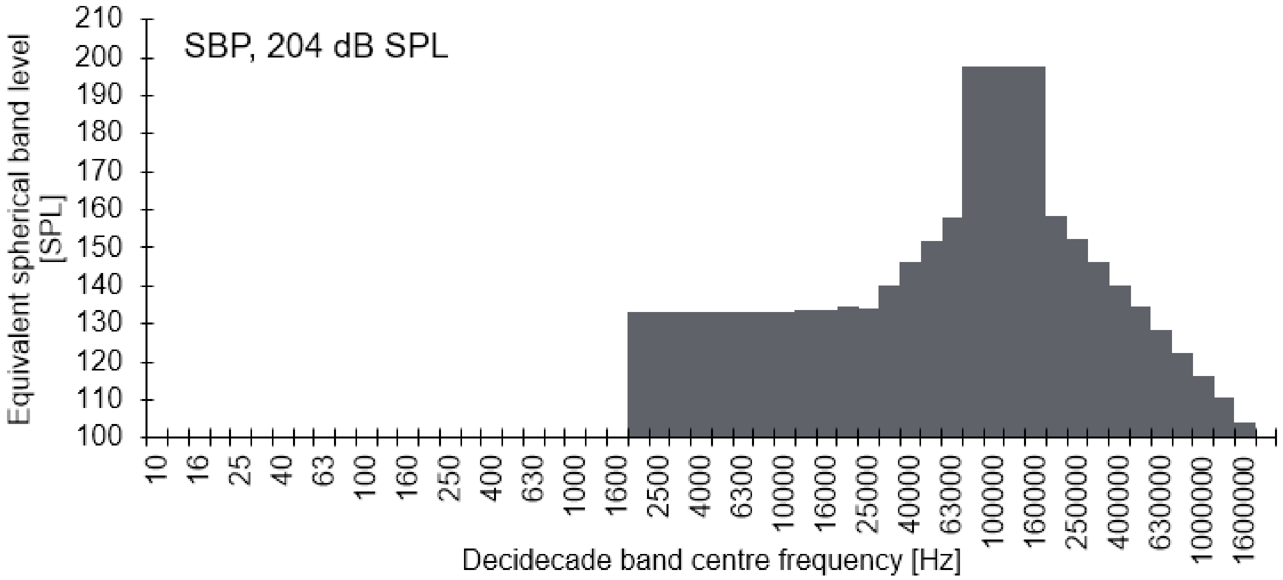

Figure 4-7. Parametric SBP source band levels as equivalent spherical/omnidirectional levels. Primary frequencies 85 kHz – 150 kHz, secondary frequencies 2 kHz – 22 kHz.

4.1.1.6.2 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 181 dB SPL with band levels given in Figure 4-8.

Given the shallow water (<14 m depth), it is likely that shorter pulses will be used as they offer sufficient energy for a clear returning echo. This will increase kurtosis ("impulsiveness") for realistic ping rates for the depth. Therefore, the C-SBP is modelled as an impulsive noise source.

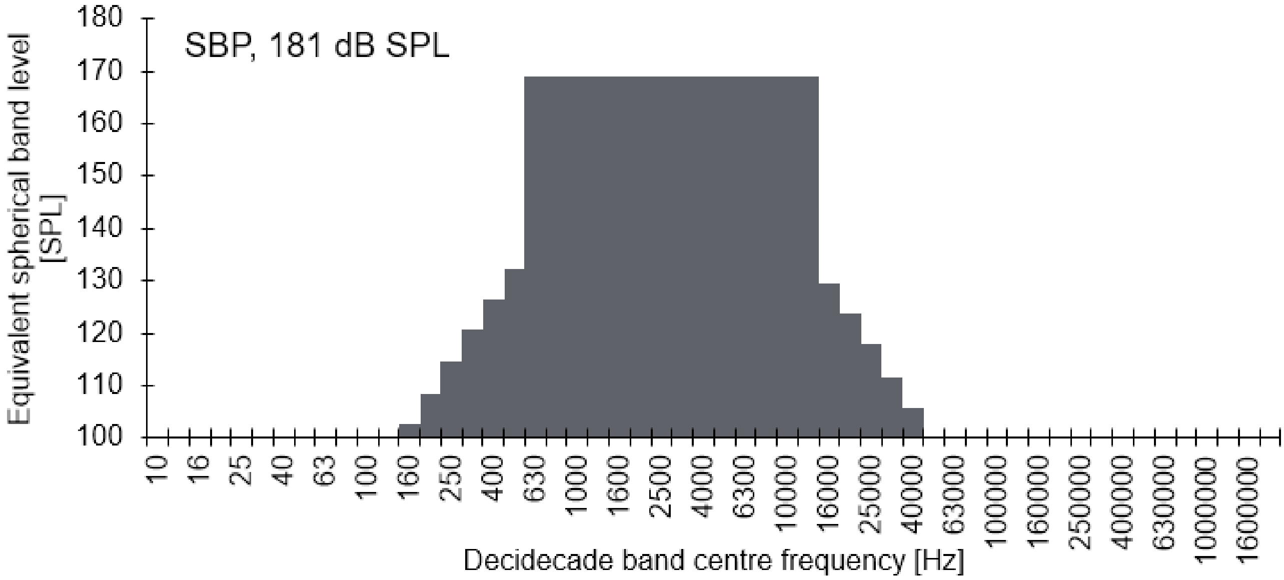

Figure 4-8. Chirper/Pinger type SBP band levels.

4.1.1.6.3 Sparker 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 400 J and 1 firing per second. The total broadband level for this SBP is 184 dB SPL, with band levels given in Figure 4-8. Levels at frequencies below 100 Hz are taken from a spectral analysis of the timeseries in Figure 4-10.

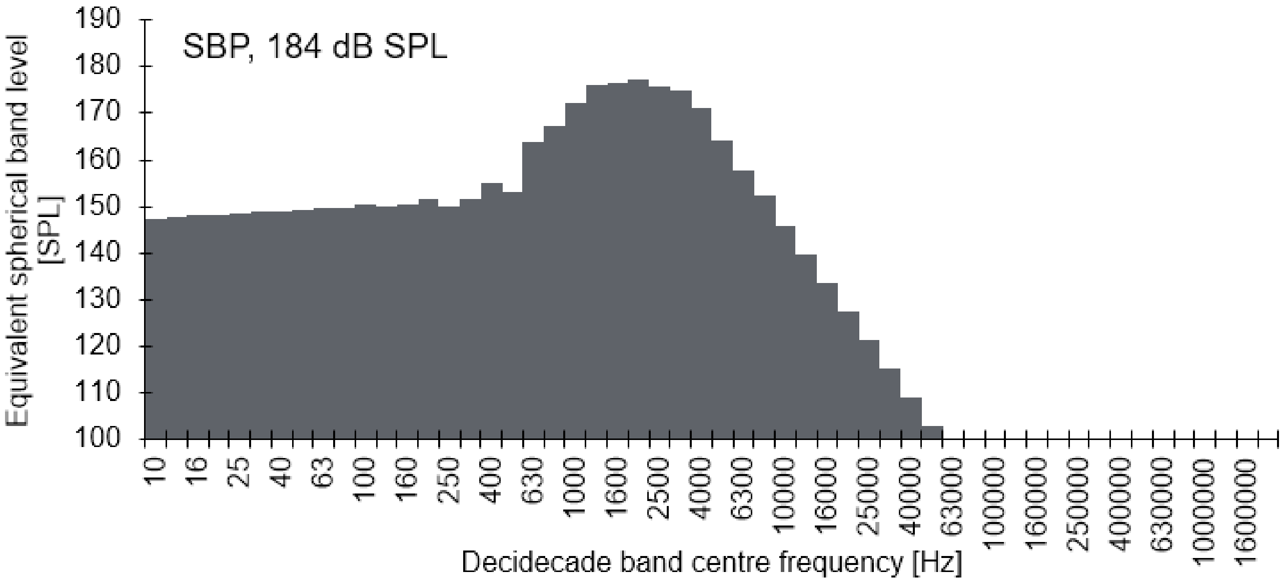

Figure 4-9. Chirper/Pinger type SBP band levels.

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

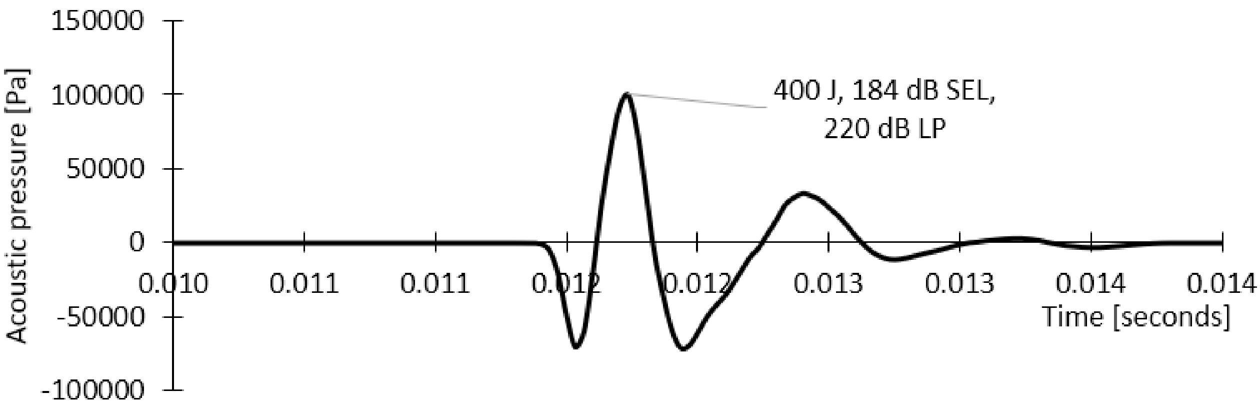

Figure 4-10. Example of an impulse from a sparker type SBP.

4.1.1.7 Boreholes Drilling

Boreholes are planned in the shallow parts of the SI Works area, with a drill of c. 0.1 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 4-11. This activity is a non-impulsive sound source with a broadband level of 145 dB SPL.

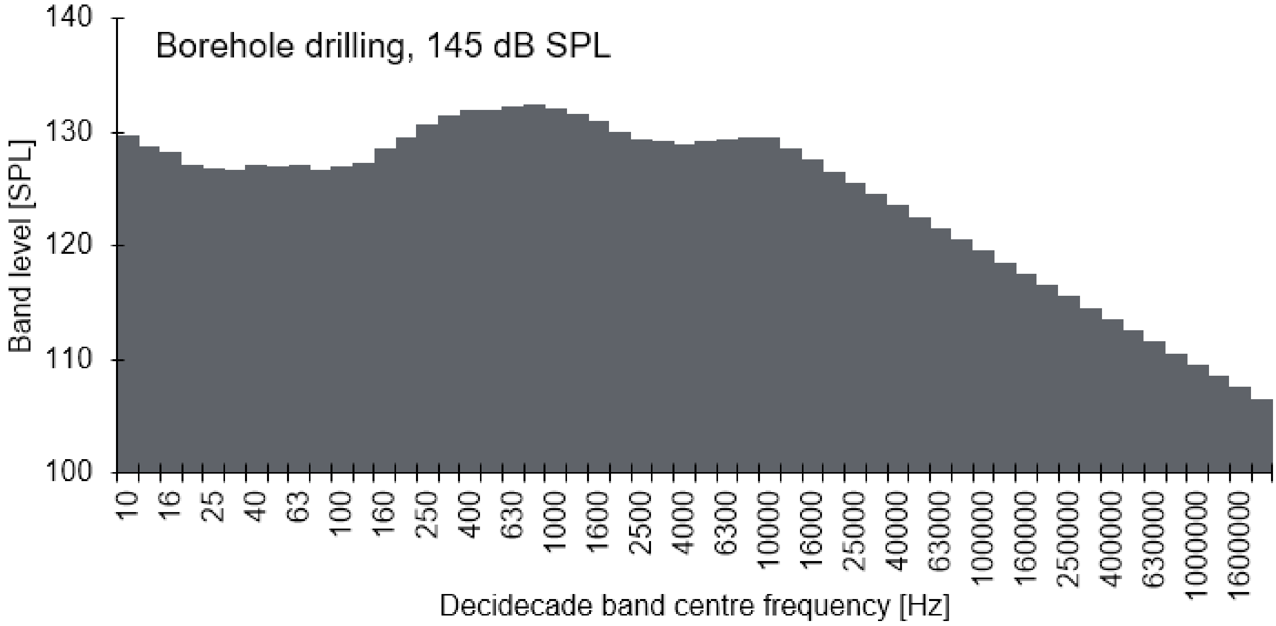

Figure 4-11. Band levels for drilling, Levels above 25 kHz are extrapolated based on trend in bands at lower frequencies.

4.1.1.8 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 4-11. The “Vibro-coring & CPT” activity is a non-impulsive sound source with a broadband level of 187 dB SPL.

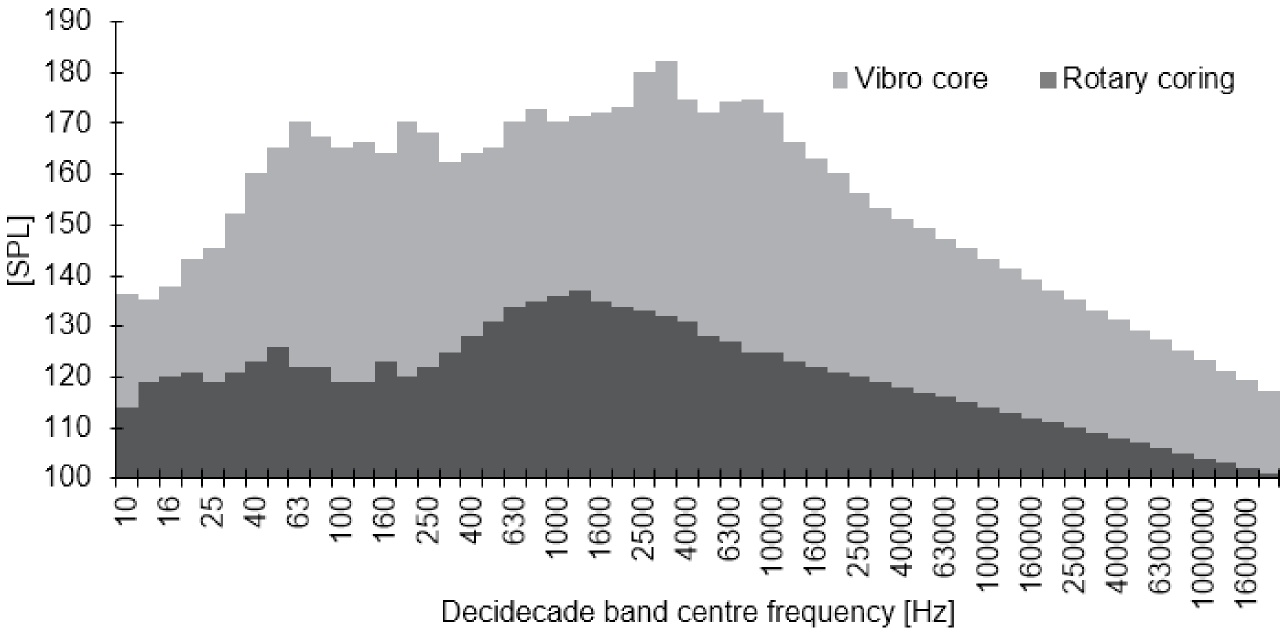

Figure 4-12. Band levels vibro-coring and CPT. Levels above 25 kHz are extrapolated based on trend in bands at lower frequencies.

4.1.2 Combined Sources

The relevant equipment for each survey type has been grouped into six scenarios that represent the most combinations for the survey equipment proposed to be used in the SI works.

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

The "Vessel" noise source is active for all sources of both geophysical and geotechnical surveys.

4.1.2.1 Geophysical Survey (Parametric SBP & USBL Active)

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 204 dB SPL.

Active equipment:

- Vessel
- MBES
- SSS
- USBL
- Parametric SBP

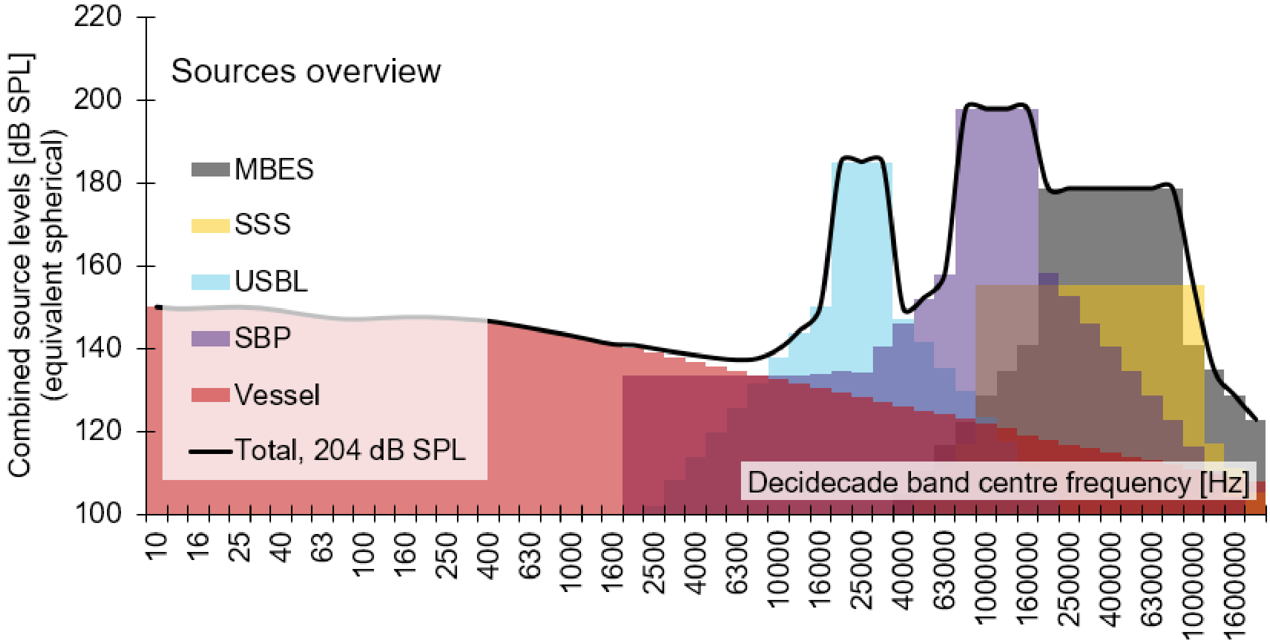

Figure 4-13. Source band level during geophysical survey (parametric SBP & USBL active).

4.1.2.2 Geophysical Survey (Parametric SBP & USBL Not Active)

This scenario assumes the geophysical survey is using a parametric SBP and that there is no need for a USBL (hull mounted SBP and SSS with known positions). Total broadband level of 204 dB SPL.

Active equipment:

- Vessel
- MBES
- SSS
- Parametric SBP

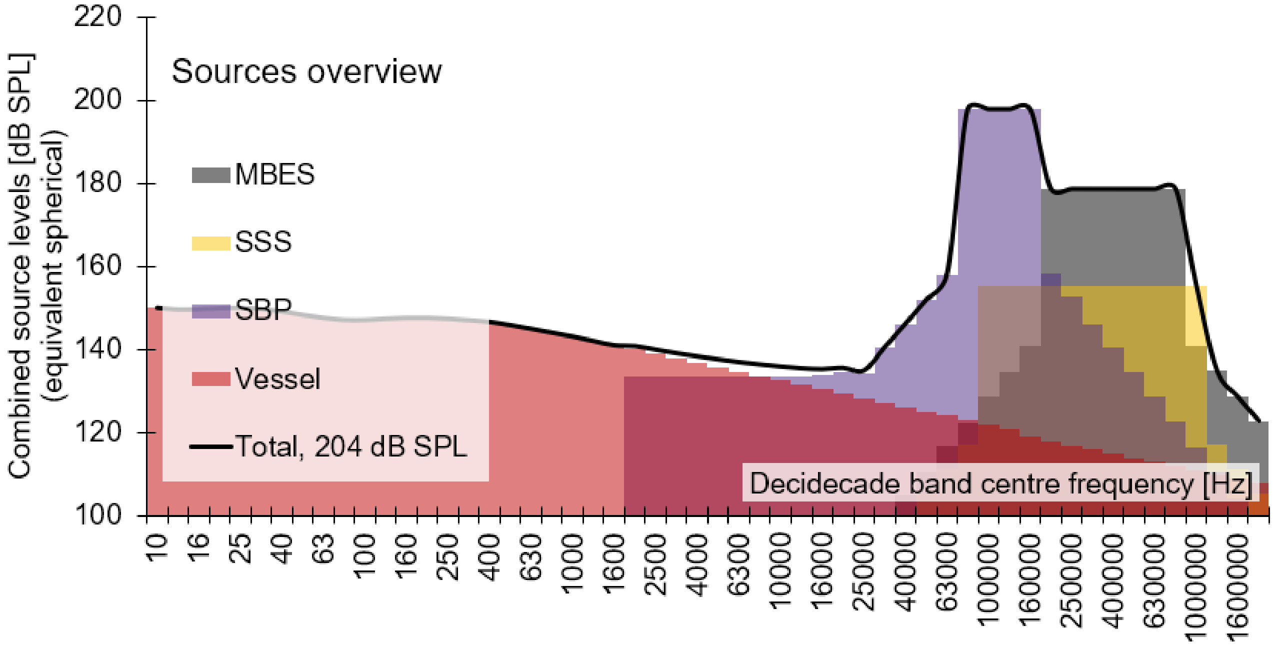

Figure 4-14. Source band level during geophysical survey (parametric SBP & USBL not active).

4.1.2.3 Geophysical Survey (Chirper/Pinger SBP & USBL Active)

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
- MBES
- SSS
- USBL
- Chirper/pinger SBP

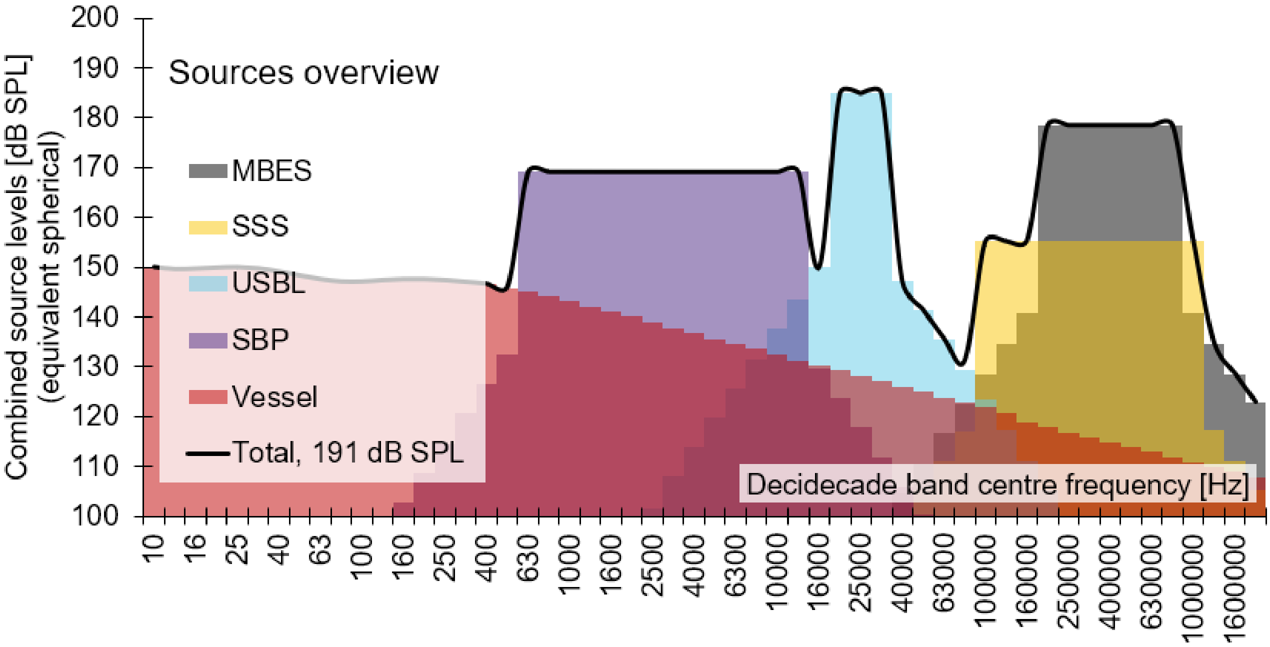

Figure 4-15. Source band level during geophysical survey (chirper/pinger SBP & USBL active).

4.1.2.4 Geophysical Survey (Chirper/Pinger SBP & USBL Not Active)

This scenario assumes the geophysical survey is using a chirper or pinger type SBP and that there is no need for a USBL (hull mounted SBP and SSS, with known positions). Total broadband level of 183 dB SPL.

Active equipment:

- Vessel
- MBES
- SSS
- Chirper/pinger SBP

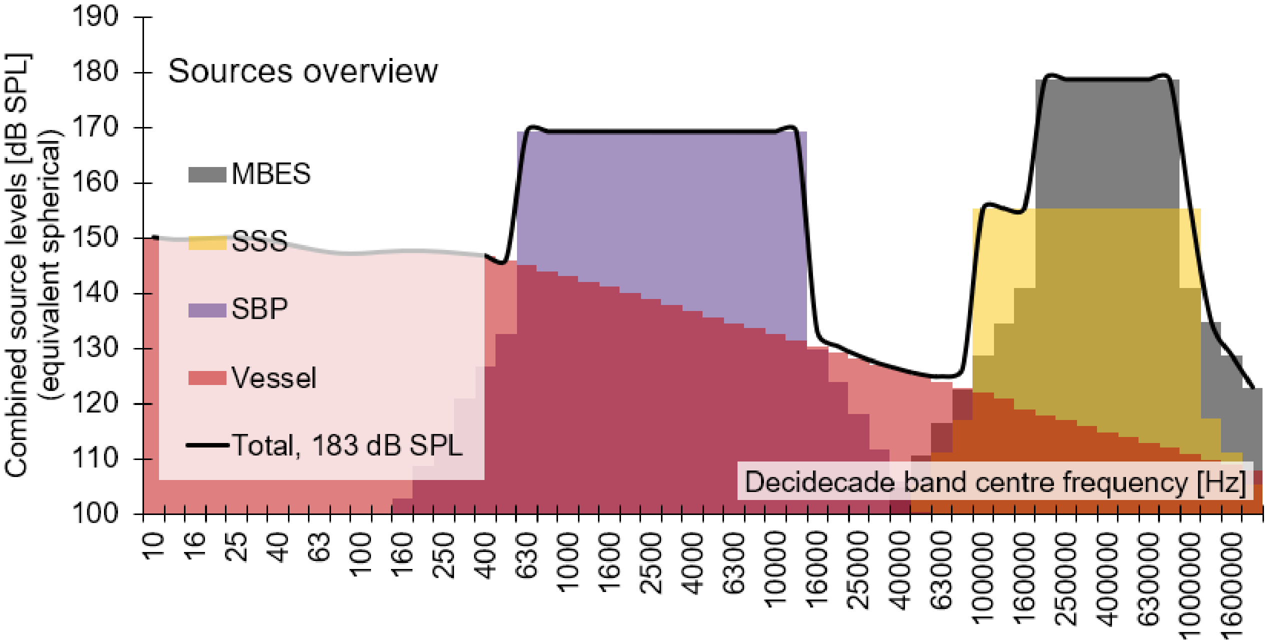

Figure 4-16. Source band level during geophysical survey (chirper/pinger SBP & USBL not active).

4.1.2.5 Geophysical Survey (Sparker SBP & USBL Active)

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
- MBES
- SSS
- USBL
- Sparker

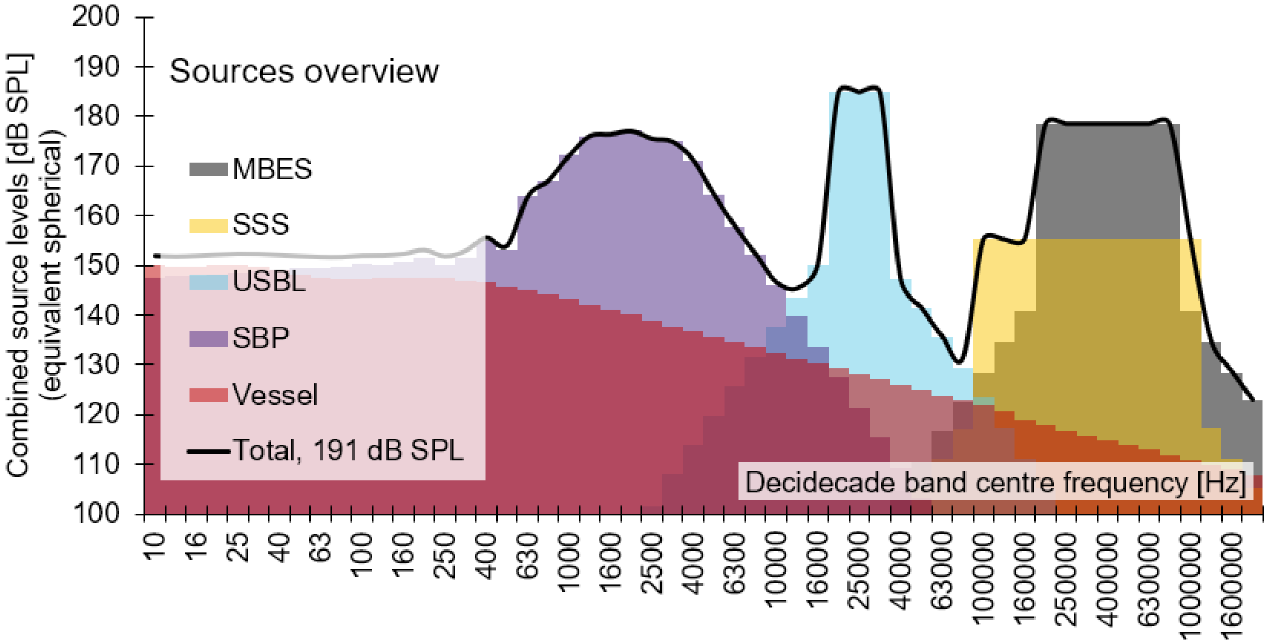

Figure 4-17. Source band level during geophysical survey (sparker SBP & USBL active).

4.1.2.6 Geophysical Survey (Sparker SBP & USBL not Active)

This scenario assumes the geophysical survey is using a sparker type SBP and that there is no need for a USBL (hull mounted SBP and SSS, with known positions). Total broadband level of 185 dB SPL.

Active equipment:

- Vessel
- MBES
- SSS
- Sparker

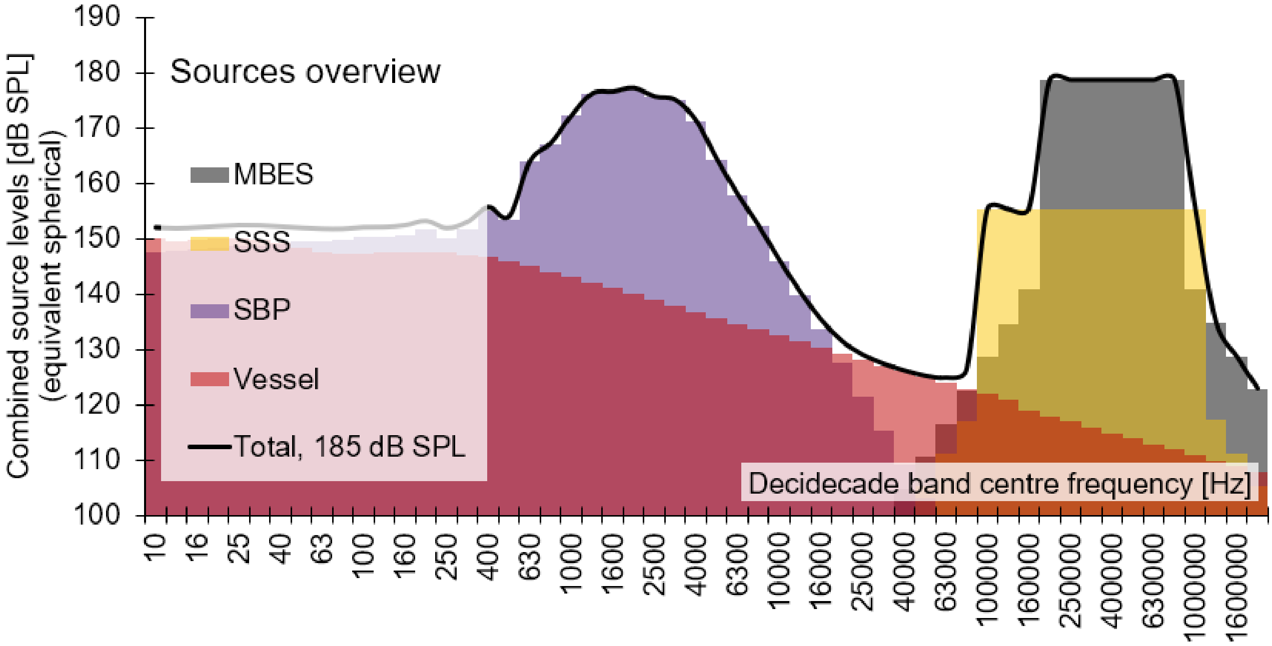

Figure 4-18. Source band level during geophysical survey (sparker SBP & USBL not active).

4.1.2.7 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 179 dB SPL.

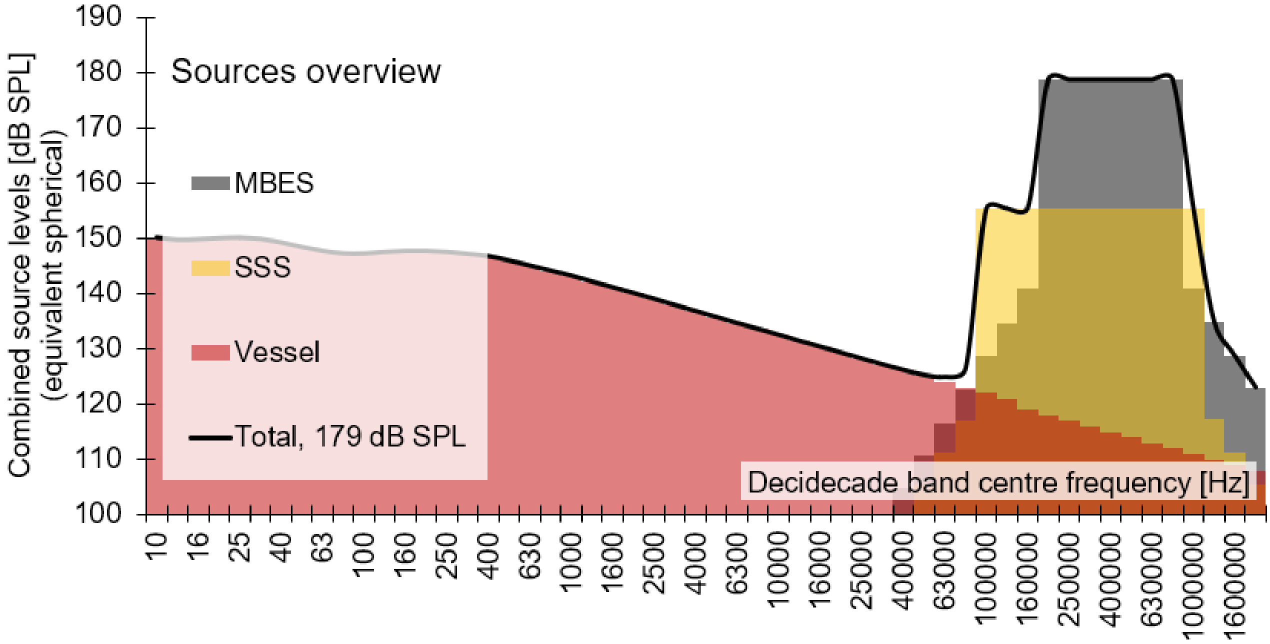

Figure 4-19. Source band level during geophysical survey soft start.

4.1.2.8 Geotechnical Survey (Drilling, boreholes)

Equipment related to drilling boreholes are active. Additionally, the "Vessel" source is active to account for support vessels and general machinery. Total broadband level of 162 dB SPL.

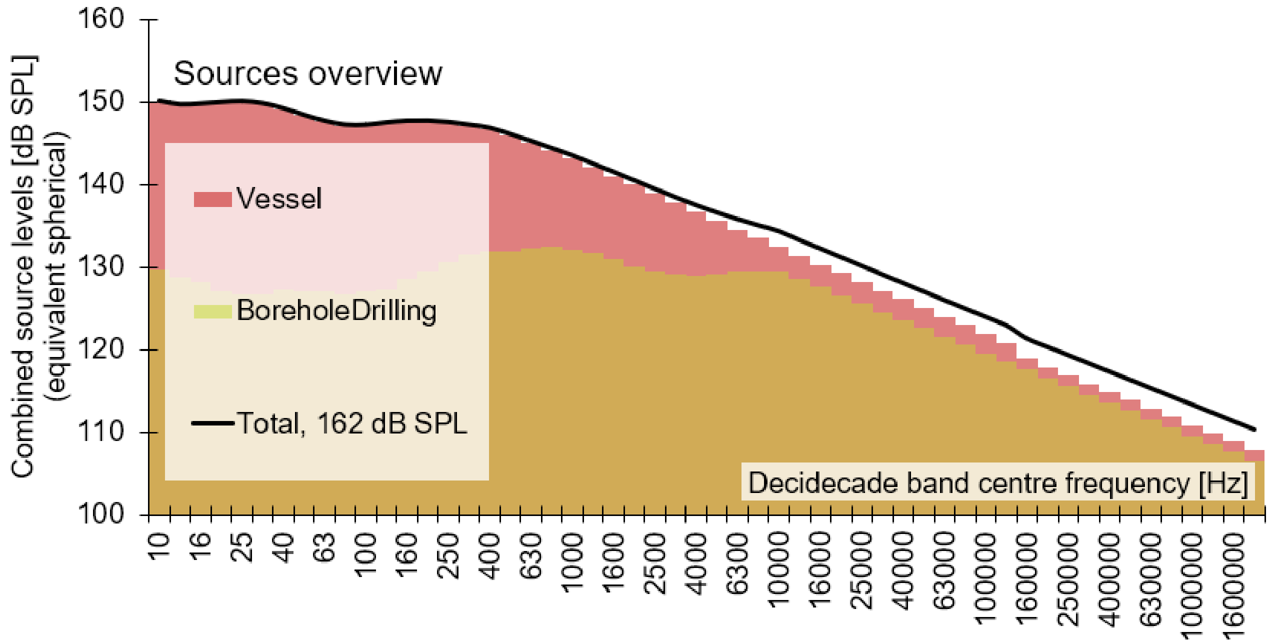

Figure 4-20. Source band level during geotechnical survey – borehole drilling.

4.1.2.9 Geotechnical Survey (Vibro-coring & CPT)

Vibro-coring, CPT, vessel (geotechnical) and USBL are active. Total broadband level of 192 dB SPL.

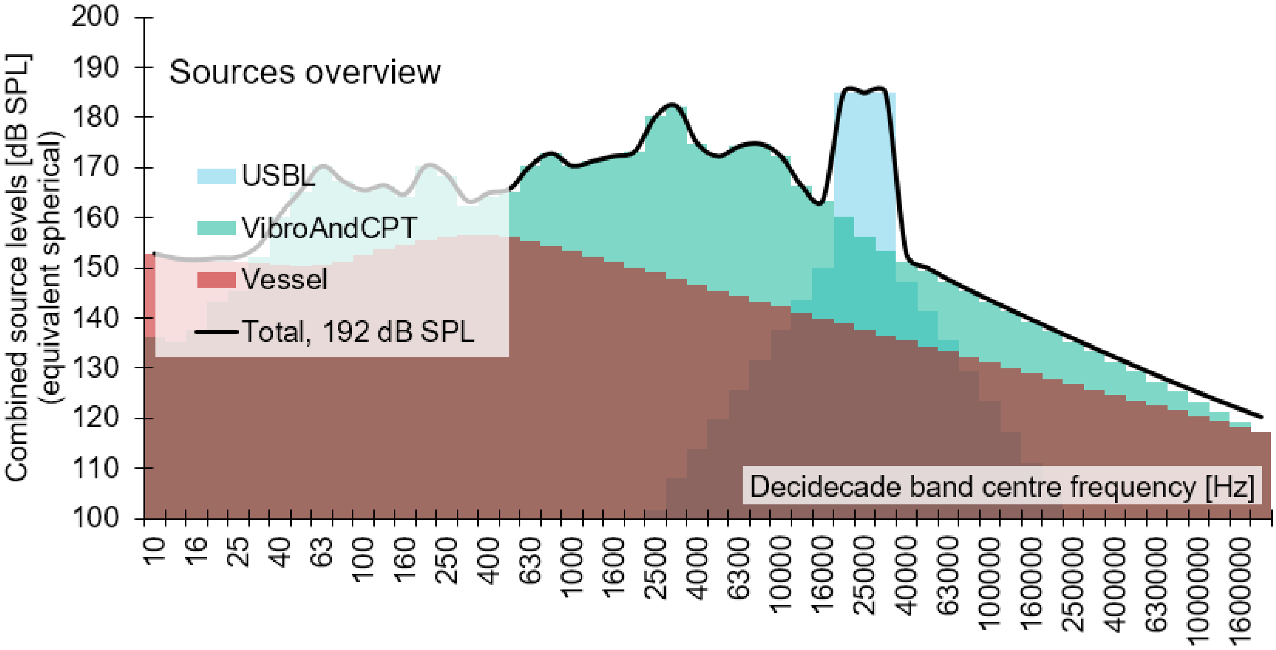

Figure 4-21. Source band level during geotechnical survey – vibro-coring and CPT.

4.1.2.10 Soft Start Source (Geotechnical – Vibro-coring & CPT)

As the geotechnical survey plans to use a USBL, it is likely that some form of soft start will need to be considered. Here, the vessel itself (with no active USBL) will perform this function. Total broadband level of 168 dB SPL.

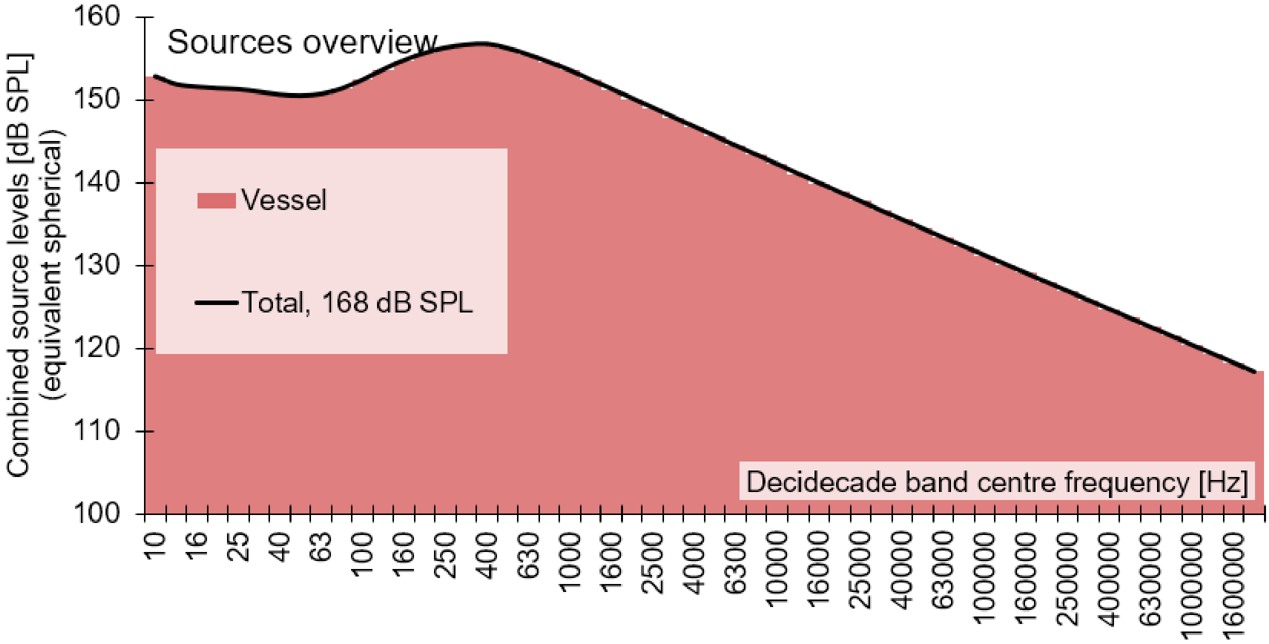

Figure 4-22. Source band level during geotechnical (vibro-core & CPT) survey soft start.

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))[9].

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 made for the modelling are:

1. A soft start where no SBP and no USBL is active, but MBES and/or SSS is active (section 4.1.2.7) 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.
2. Animals fleeing the area will not return within a 24-hour period.
3. 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.
4. Modelling assumes high tide; this is a worst-case assumption.
5. Results assume a transition from impulsive (kurtosis >40) to non-impulsive (kurtosis <40) at a 500 m distance from the source. This means that all ranges greater than 500 m are 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 (Southall et al. 2019 & 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. The conversion is relatively easy:

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

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

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

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

[9] 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:

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

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 a PTS 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 117.5 dB, weighted for the VHF group, will exceed the non-impulsive TTS threshold of 153 dB SEL after 2 hours' exposure[10]. For this assessment, we consider fleeing durations of 2 hours (7200 seconds, allowing 10800 m of fleeing), meaning that weighted levels of 117.5 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)

[10] 117.5 dB SPL + 10*$\log_{10}$(3600 seconds) = 153.1 dB SEL, TTS non-impulsive threshold for the VHF group is 153 dB SEL.

6 RESULTS AND ASSESSMENT

Results are presented here as the geographical "risk range" to an auditory threshold (TTS/PTS/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/PTS 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/PTS 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. **"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 2 significant digits. This can lead to some curious appearing overlaps in risk ranges.
- Results for behavioural disturbance mainly rely on the non-impulsive threshold of 120 dB SPL (for marine mammals), as the impulsive noise transitions to non-impulsive at c. 500 m. 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 also exceed this threshold to ranges of 500-5000 m (assuming 160-175 dB SPL source level).
- The soft start has little effect on the TTS ranges for the VHF group when the USBL is active. This is due to the relatively low threshold for TTS for the VHF group (153 dB SEL) and the logarithmic nature of transmission losses. A constant reduction of received level with a multiplication of range – a 3-6 dB reduction per doubling of distance, such as from 2 km to 4 km (until ranges become large enough for absorption to become significant) – means that fleeing is not very effective at reducing received 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 15 km from the source.
- No modelling of risk ranges for *mortality* for fishes are presented as risk ranges to PTS (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 <30 m for fish (TTS: 193 dB L_P) and <20 m for marine mammals (VHF TTS: 196 dB L_P).
- Results are *only* given in relation to the behavioural thresholds (SPL) and TTS/PTS 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).

6.2 Results – Tabulated

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

6.2.1 Geophysical Survey (Parametric SBP & USBL Active)

This scenario assumes that the geophysical survey is using a parametric SBP and that a towfish is deployed, requiring an active USBL (Section 4.1.2.1).

Risk ranges for exceeding PTS is below 50 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 500 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to 50 m.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-1: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Parametric SBP & USBL active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	4000	4000	4000	4000	4000	380

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

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	40	770	<10	<10	<10
Fleeing receiver, no soft start	80	310	2700	140	<10	130
Fleeing receiver, 20 min soft start	<10	<10	1500	<10	<10	<10

*See Comments, Section 6.1 on results limitations.

Table 6-3. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Parametric SBP & USBL active).

PTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	240	<10	<10	<10
Fleeing receiver, no soft start	<10	50	500	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.2 Geophysical Survey (Parametric SBP & USBL Not Active)

This scenario assumes that the geophysical survey is using a parametric SBP and that there is no need for a USBL as the SBP and SSS are hull-mounted with known positions (Section 4.1.2.2).

Risk ranges for exceeding PTS is below 40 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 470 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to 50 m.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-4: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Parametric SBP & USBL not active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	1100	1100	1100	1100	1100	330

Table 6-5: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Parametric SBP & USBL not active).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	40	500	<10	<10	<10
Fleeing receiver, no soft start	<10	230	640	30	<10	120
Fleeing receiver, 20 min soft start	<10	<10	160	<10	<10	<10

Table 6-6. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Parametric SBP & USBL not active).

PTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	210	<10	<10	<10
Fleeing receiver, no soft start	<10	40	470	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.3 Geophysical Survey (Chirper/Pinger SBP & USBL Active)

This scenario assumes that the geophysical survey is using a chirper or pinger type SBP and that a towfish is deployed requiring an active USBL (Section 4.1.2.3).

Risk ranges for exceeding PTS is below 10 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 490 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to 50 m.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-7: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	5700	5700	5700	5700	5700	270

Table 6-8: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL active).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	10	750	<10	<10	<10
Fleeing receiver, no soft start	140	250	2800	160	<10	30
Fleeing receiver, 20 min soft start	<10	<10	1600	<10	<10	<10

Table 6-9. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL active).

PTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	110	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	490	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.4 Geophysical Survey (Chirper/Pinger SBP & USBL Not Active)

This scenario that assumes that the geophysical survey is using a chirper or pinger type SBP and that there is no need for a USBL as the SBP and SSS are hull mounted with known positions (Section 4.1.2.4).

Risk ranges for exceeding PTS is below 10 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 120 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to 50 m.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-10: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL not active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	5200	5200	5200	5200	5200	90

Table 6-11: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL not active).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	70	<10	<10	<10
Fleeing receiver, no soft start	70	<10	490	30	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	170	<10	<10	<10

Table 6-12. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Chirper/pinger SBP & USBL not active).

PTS 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	120	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.5 Geophysical Survey (Sparker SBP & USBL Active)

This scenario assumes the geophysical survey is using a Sparker type SBP and that a towfish is deployed requiring an active USBL (Section 4.1.2.5).

Risk ranges for exceeding PTS is below 10 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 490 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to 50 m.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-13: Risk ranges for exceeding the peak pressure level impulsive threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL active).

Risk ranges (L_P thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
TTS	10	<10	20.1	10	<10	30.1
PTS	10	<10	20.1	10	<10	10

Table 6-14: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	8000	8000	8000	8000	8000	290

Table 6-15: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL active).

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	10	750	<10	<10	<10
Fleeing receiver, no soft start	220	250	2700	180	<10	30
Fleeing receiver, 20 min soft start	<10	<10	1500	<10	<10	<10

Table 6-16. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL active).

PTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	110	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	490	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.6 Geophysical Survey (Sparker SBP & USBL Not Active)

This scenario assumes the geophysical survey is using a Sparker type SBP and that there is no need for a USBL as the SBP and SSS are hull mounted with known positions (Section 4.1.2.6).

Risk ranges for exceeding PTS is below 10 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 50 m with no soft start.

A soft start of 20 minutes will not reduce this range for the VHF group.

The soft start itself has a PTS risk range of 50 m for the VHF group. Therefore, extension of the soft start duration will not decrease the PTS risk range further.

Table 6-17: Risk ranges for exceeding the peak pressure level impulsive threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL not active).

Risk ranges (L_P thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
TTS	10	<10	20.1	10	<10	30.1
PTS	10	<10	20.1	10	<10	10

Table 6-18: Risk ranges for exceeding the behavioural threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL not active).

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	7900	7900	7900	7900	7900	120

Table 6-19: Risk ranges for exceeding the TTS threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL not active).

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	<10
Fleeing receiver, no soft start	160	<10	330	60	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	160	<10	<10	<10

Table 6-20. Risk ranges for exceeding the PTS threshold for all hearing groups during Geophysical survey (Sparker SBP & USBL not active).

PTS 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	50	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	50	<10	<10	<10

6.2.7 Geotechnical Survey (Drilling, boreholes)

This scenario assumes the drilling and vessel source is active (Section 6.2.7).

No soft start has been modelled for this activity; this is based on:

1. Risk ranges for exceeding PTS are below 10 meters for all groups.
2. The sampling platform (vessel or barge) will itself emit similar noise to the sampling activity and will serve as a type of soft start exceeding normal soft start durations.
3. The geotechnical equipment itself cannot easily be operated at reduced noise output.

Table 6-21: Risk ranges for exceeding the behavioural threshold for all hearing groups during drilling.

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	<20	<20	<20	<20	<20	<10

Table 6-22: Risk ranges for exceeding the TTS threshold for all hearing groups during drilling.

TTS 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	<10	<10	<10	<10

Table 6-23. Risk ranges for exceeding the PTS threshold for all hearing groups during drilling.

PTS 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	<10	<10	<10	<10

6.2.8 Geotechnical Survey (Vibro-coring & CPT)

This scenario assumes the vessel, vibro-corer, CPT and USBL sources are active (Section 4.1.2.9).

Risk ranges for exceeding PTS is below 10 m for all groups except the VHF group, which risks exceeding the PTS threshold to a range of 490 m with no soft start.

A soft start of 20 minutes will allow sufficient time for the VHF group to swim away to reduce the PTS exceedance risk range to less than 10 m.

Table 6-24: Risk ranges for exceeding the behavioural threshold for all hearing groups during Vibro-coring and CPT.

Behavioural Threshold exceedance Risk ranges (SPL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
Non-impulsive	5700	5700	5700	5700	5700	270

Table 6-25: Risk ranges for exceeding the TTS threshold for all hearing groups during Vibro-coring and CPT.

TTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	10	750	<10	<10	<10
Fleeing receiver, no soft start	130	250	2700	160	<10	20
Fleeing receiver, 20 min soft start	<10	<10	1500	<10	<10	<10

Table 6-26. Risk ranges for exceeding the PTS threshold for all hearing groups during Vibro-coring and CPT.

PTS Threshold Exceedance Risk ranges (SEL thresholds)	LF [m]	HF [m]	VHF [m]	PCW [m]	OCW [m]	Fish [m]
One second	<10	<10	110	<10	<10	<10
Fleeing receiver, no soft start	<10	<10	490	<10	<10	<10
Fleeing receiver, 20 min soft start	<10	<10	<10	<10	<10	<10

6.3 Results Summary

6.3.1 Geophysical Survey

PTS – hearing injury

Apart from the VHF hearing group, all risk ranges to PTS exceedance for fleeing receivers is below 50 m with no soft start.

For the VHF hearing group, the risk range for PTS exceedance for fleeing receivers is up to 500 m with no soft start and below 50 m with a 20-minute soft start.

TTS – temporary hearing impairment

Apart from the VHF hearing group, all risk ranges to TTS exceedance for fleeing receivers is below 310 m with no soft start and below 10 m with a 20-minute soft start.

For the VHF hearing group, the risk range for TTS exceedance for fleeing receivers is up to 2800 m with no soft start and below 1600 m with a 20-minute soft start.

Behavioural disturbance

Ranges for behavioural disturbance for all hearing groups except Fish is up to 8 km (driven by the sparker type SBP). For Fish the range for behavioural disturbance is much less at up to 380 m (driven by the parametric SBP & USBL).

6.3.2 Geotechnical Survey

Drilling, Boreholes

The drilling of boreholes has virtually no risk of exceeding PTS or TTS thresholds for any hearing group, with all risk ranges to PTS and TTS exceedance below 10 m.

Behavioural threshold is also not exceeded beyond 20 m.

Vibro-coring & CPT with USBL

PTS – hearing injury

The VHF group has a PTS exceedance risk for moving receivers to 490 m with no soft start, reducing to under 10 m with a 20-minute soft start.

All remaining hearing groups have PTS risk exceedance ranges for moving receivers below 10 m, even with no soft start.

TTS – temporary hearing impairment

The VHF group has a TTS exceedance risk for moving receivers to 2700 m with no soft start, reducing to 1500 m with a 20-minute soft start.

All remaining hearing groups have risk ranges for PTS exceedance for moving receivers at or below 260 m, with no soft start, reducing to below 10 m with a 20-minute soft start.

Behavioural disturbance

Ranges for behavioural disturbance for all hearing groups except Fish is up to 5700 m (driven by the USBL). For Fish the range for behavioural disturbance is much less at up to 270 m (driven by the USBL).

7 CONCLUSIONS

This assessment concludes that the risk of inducing hearing injury (PTS – Permanent Threshold Shift) following noise from the SI Works is below 50 m with no soft start for all hearing groups except the VHF group . The VHF group (harbour porpoise) has an injury risk up to 500m from the active noise sources with no soft start. Applying a 20-minute soft start reduces the injury risk to below 50 m.

There is risk of inducing temporary hearing effects (TTS – Temporary Threshold Shift). This extends to c. 3000 m for the VHF group (harbour porpoise) and below c. 300 m for remaining marine mammals and fishes. Introducing a 20-minute soft start, where only some equipment is active, will reduce the risk of TTS for the VHF group to within 1600 m, and to below 10 m for the remaining marine mammals and fishes.

Behavioural disturbance ranges of up to 8,000 m have been modelled for the geophysical survey for marine mammals while the Sparker type SBP is active. For the geotechnical survey, the use of a USBL means that behavioural disturbance ranges up to 5,700 m. The low noise levels of the borehole drilling means that the behavioural disturbance limit is within 20 m.

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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-P} for the level in dB), Note that L_{P-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".

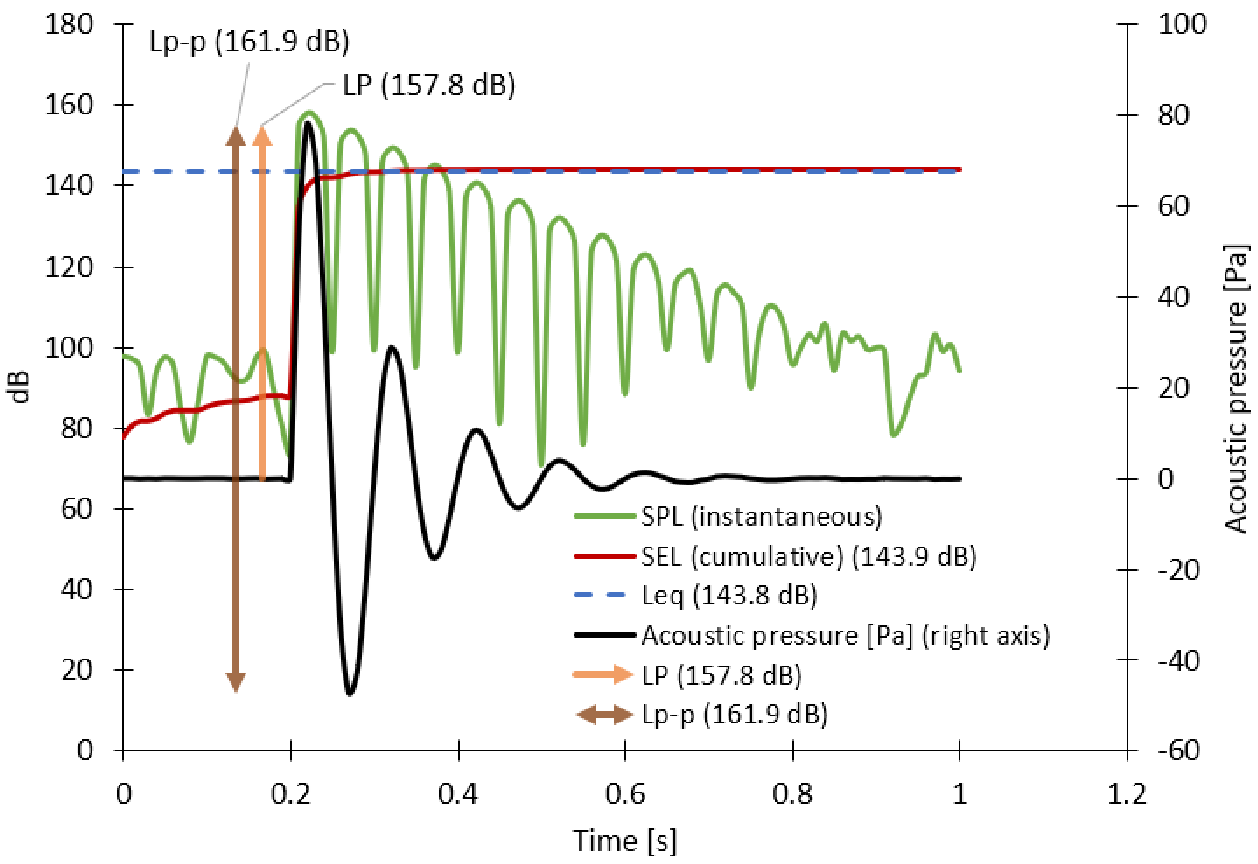

Figure 8-1: Graphical representation of acoustic wave descriptors ("LE" = SEL).

The sound pressure level (SPL[11]) 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:

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

[11] 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.

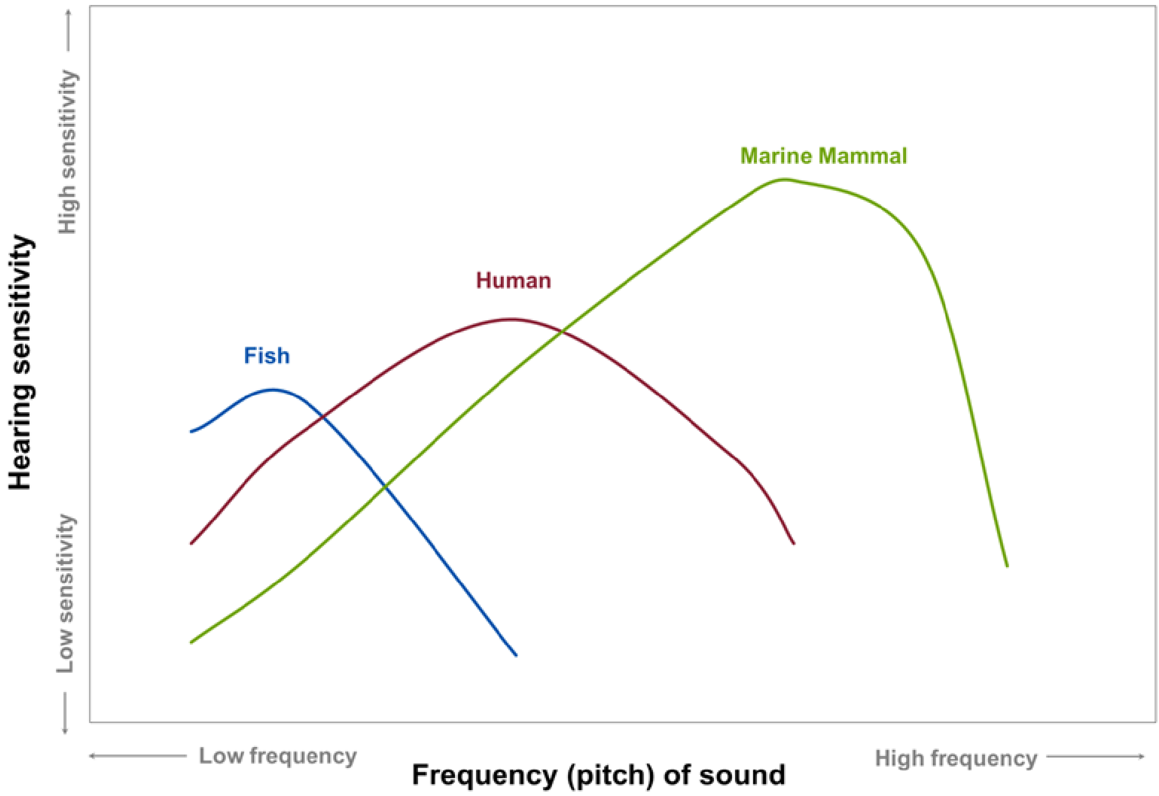

Figure 8-2: Comparison between hearing thresholds of different marine animals and humans.

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.

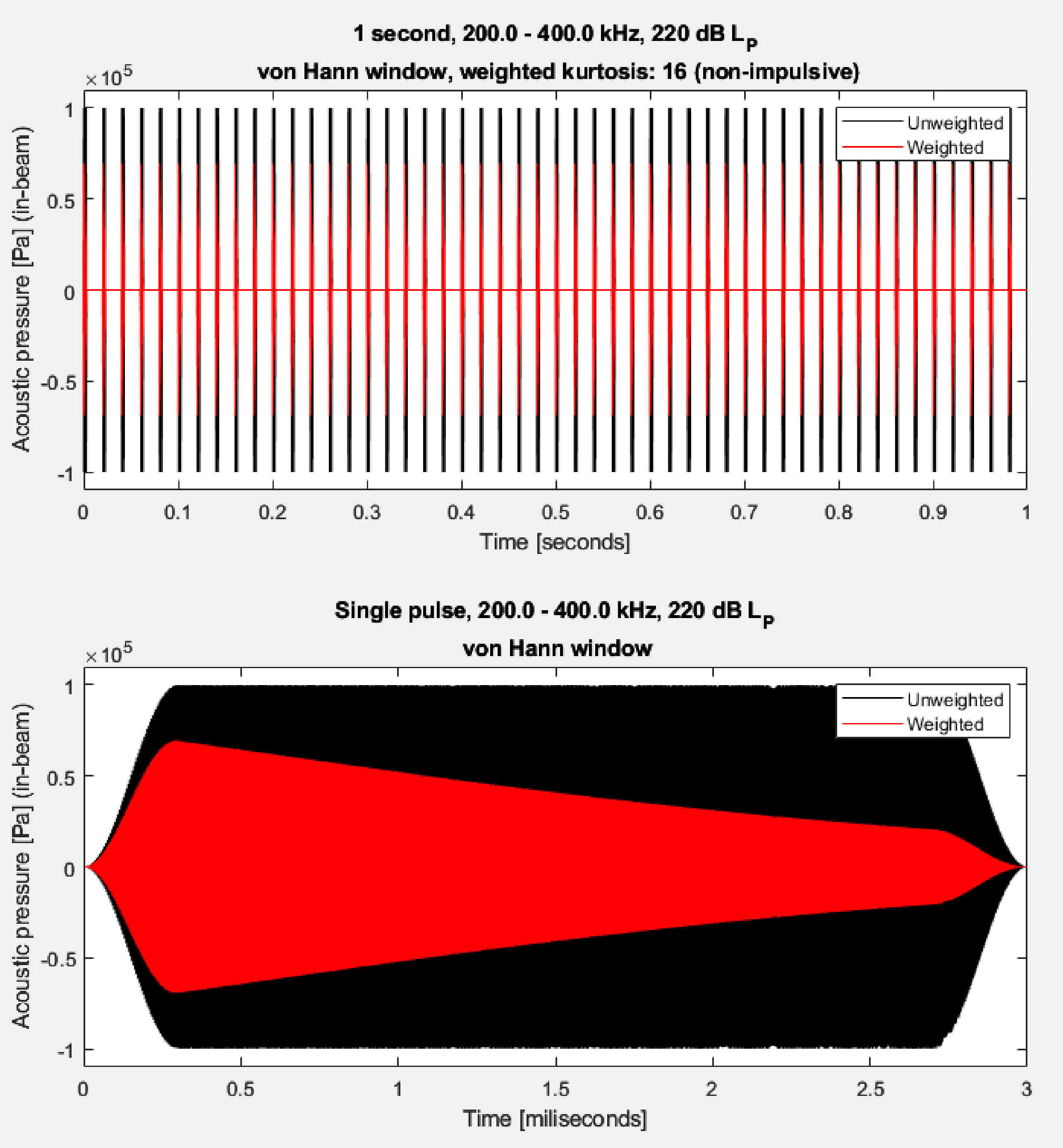

Figure 8-3. Example of a multibeam echosounder at 15 m depth (achieving 50 ping/sec) with a 3 ms ping duration. VHF-weighted kurtosis of 16 – non-impulsive.

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.

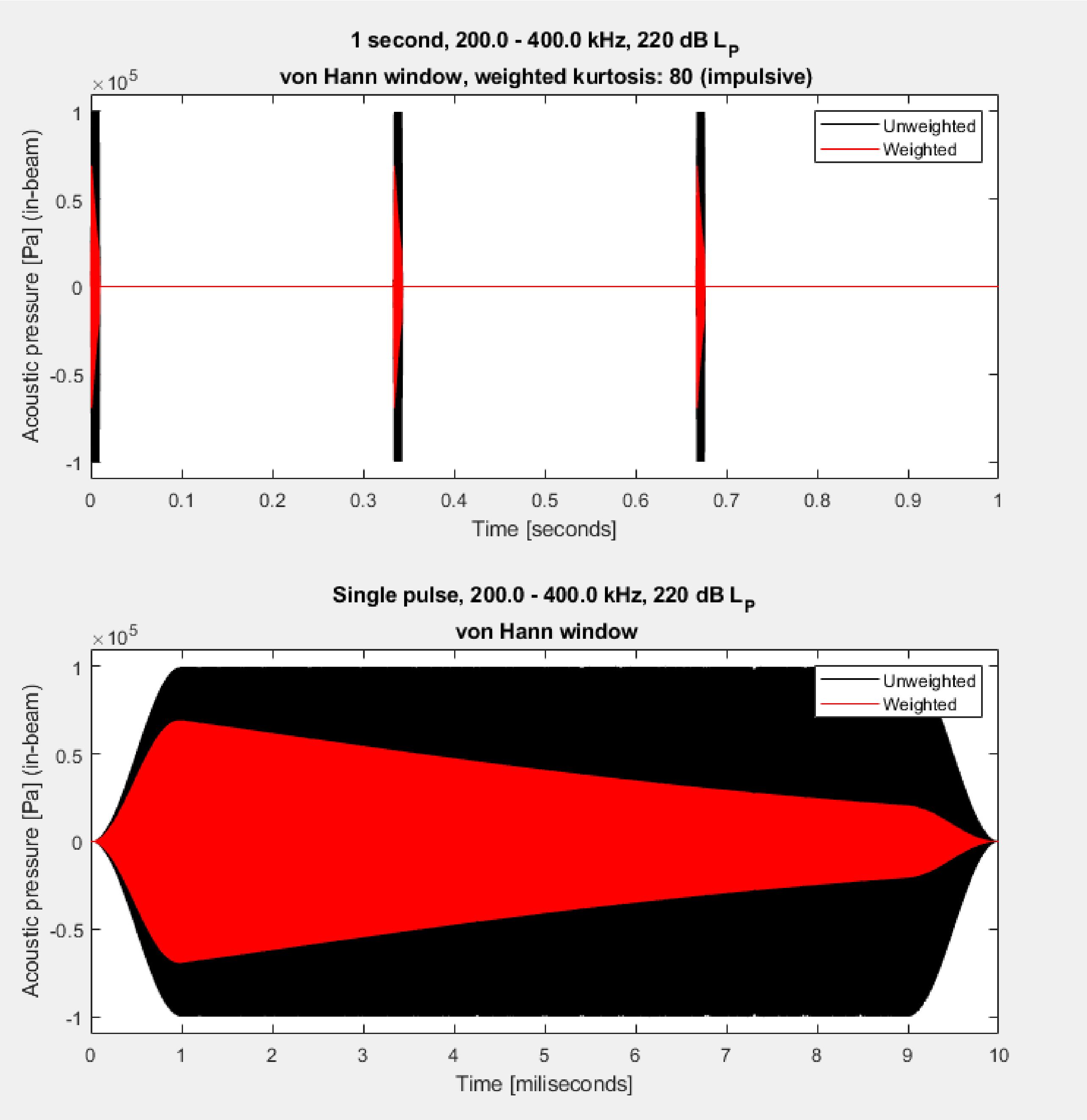

Figure 8-4. Example of a multibeam echosounder at 250 m depth (achieving 3 ping/sec) with a 10 ms ping duration. VHF-weighted kurtosis of 80 – impulsive.

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.

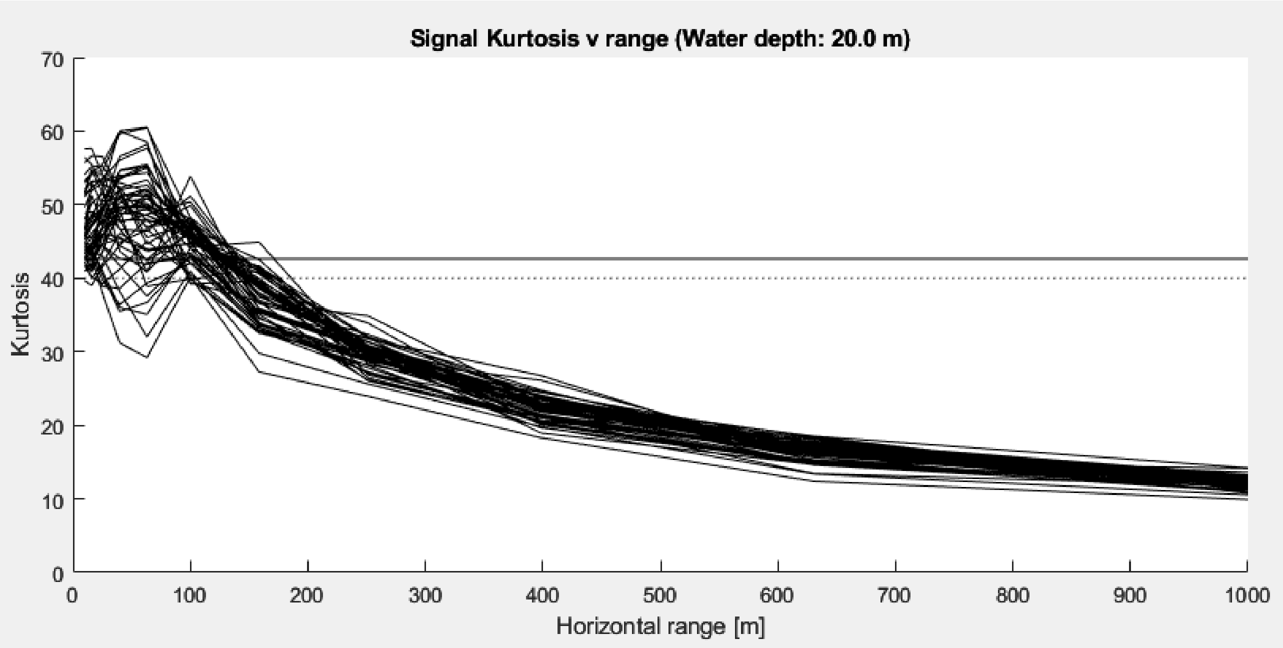

Figure 8-5. Example of USBL signal kurtosis decreasing with range at 20 m depth. Multiple lines are various combinations of source and receiver depths.

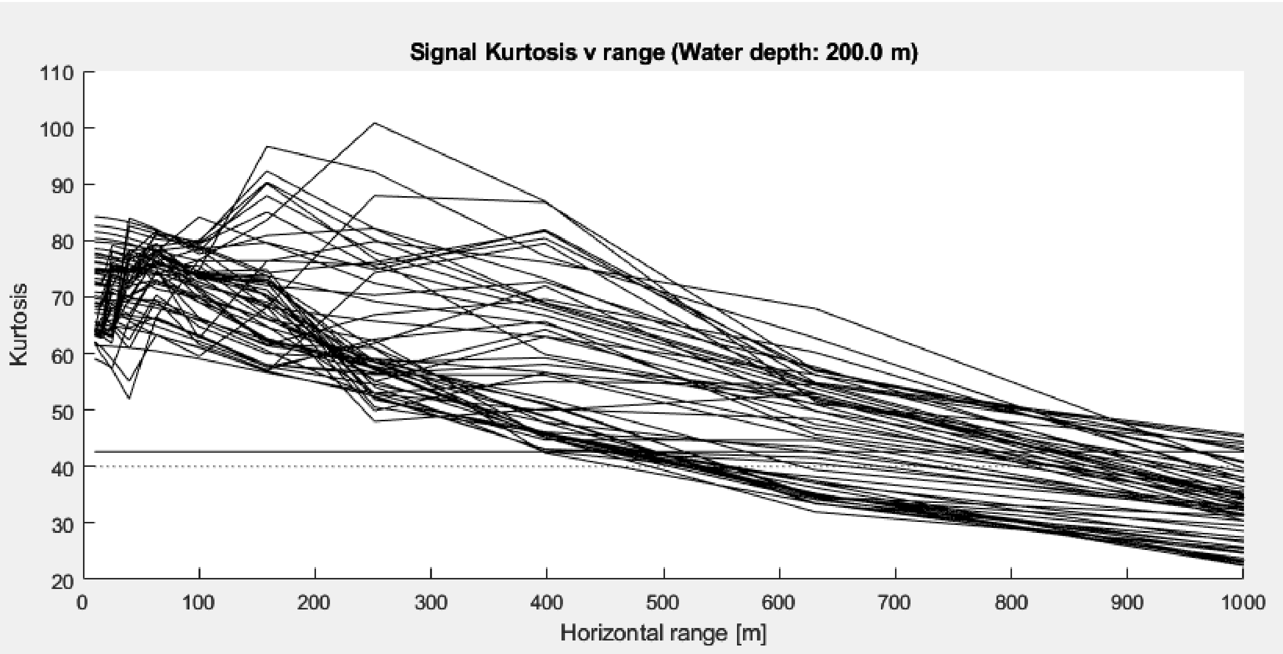

Figure 8-6. Example of USBL signal kurtosis decreasing with range at 200 m depth. Multiple lines are various combinations of source and receiver depths.

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[12] 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[13]) 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).

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[12] 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.

[13] 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.

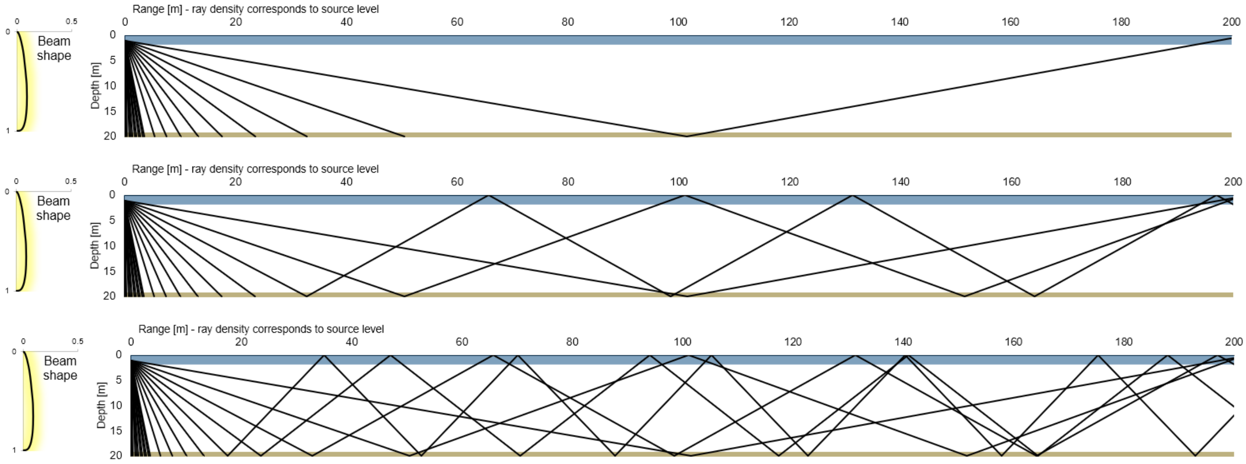

Figure 8-7: Schematic of the effect of sediment on sources with narrow beams. Sediments range from fine silt (top panel), sand (middle panel), and gravel (lower panel).

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.

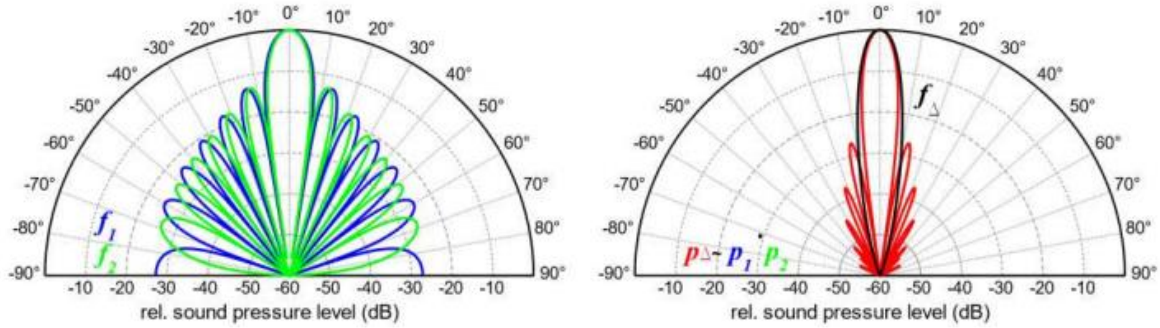

Figure 8-8. Example of a beam pattern on an Innomar SES 2000. Primary frequencies left (f1 & f2), the interference pattern between the primary frequencies means that the beam pattern for the secondary frequency (right plot) is very narrow (Source: Innomar technical note TN-01).

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.

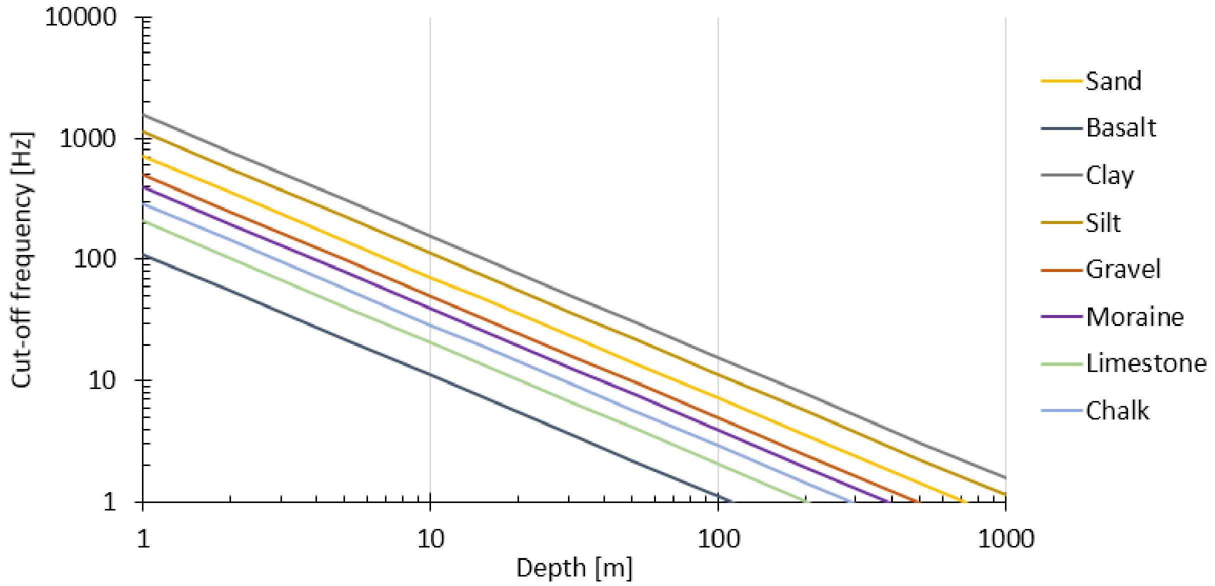

Figure 8-9: Lower cut-off frequency as a function of depth for a range of seabed types.

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.

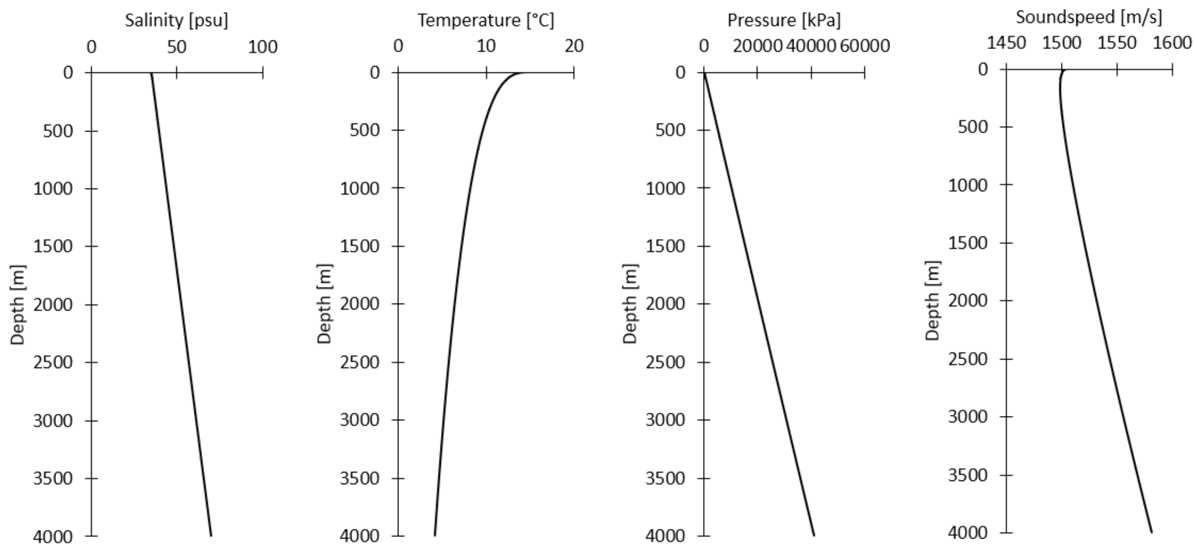

Figure 8-10: Soundspeed profile as a function of salinity, temperature and pressure.

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.

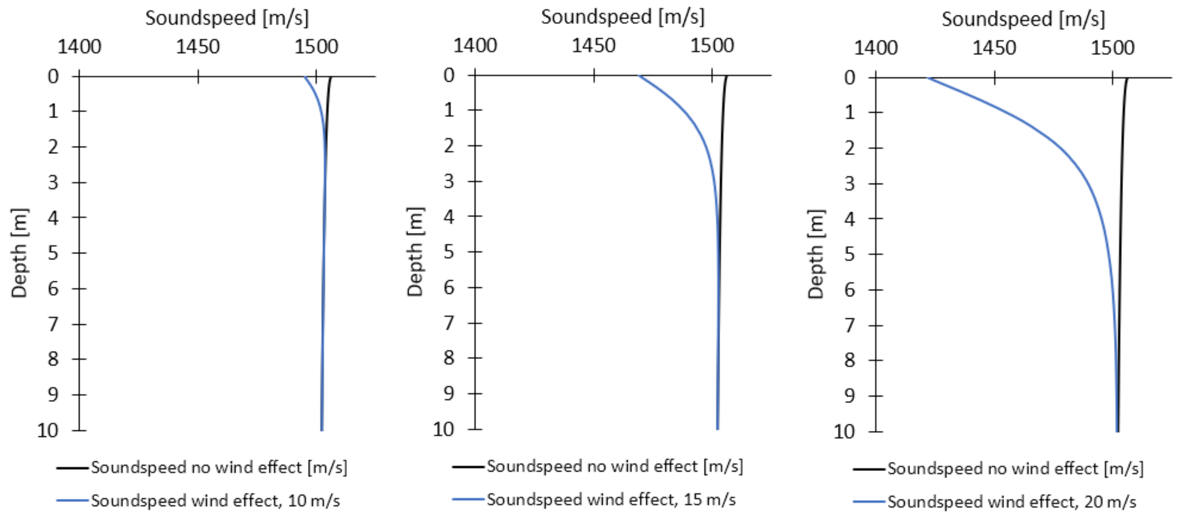

Figure 8-11: Effect of wind (at 10 m height) on upper portion of soundspeed profile.

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.

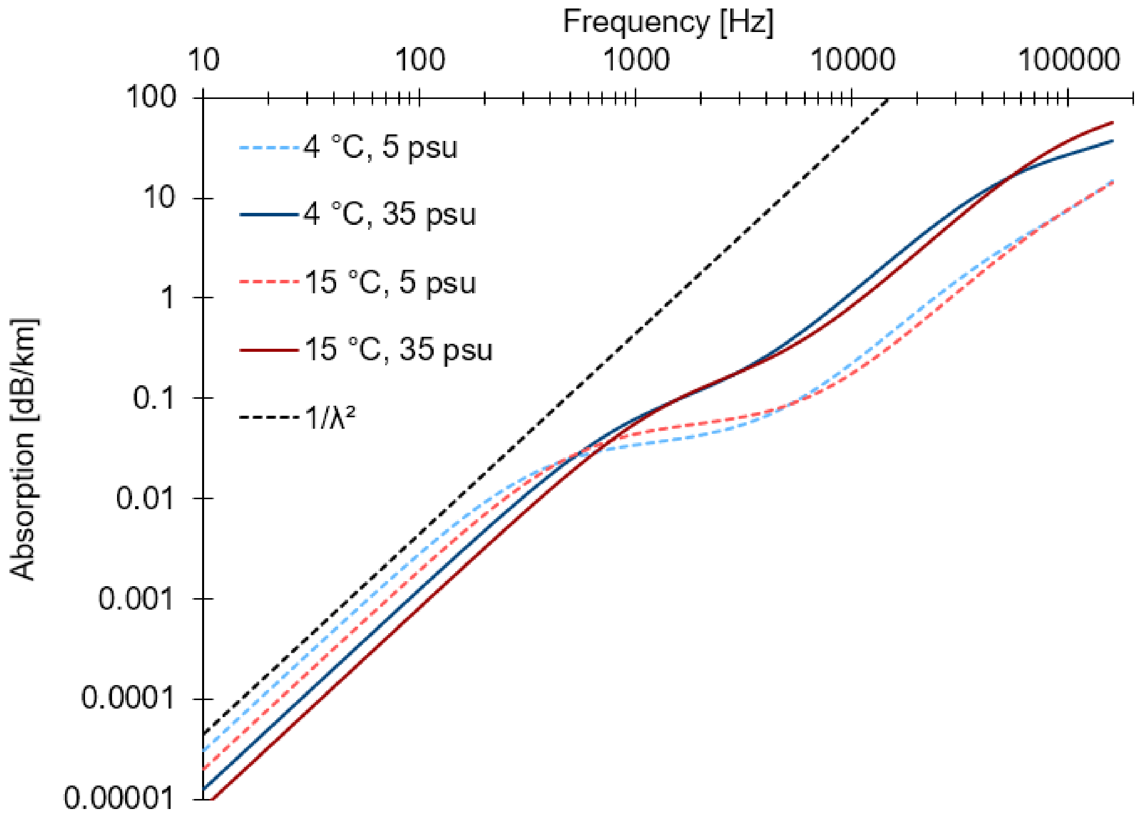

Figure 8-12: Absorption loss coefficient (dB/km) for various salinities and temperature.