Appendix H.1: Tarbert Ferry Terminal – Subtidal Benthic Ecology Survey Report

Tarbert Ferry Terminal - Subtidal Benthic Ecology Survey Report

Aspect Land & Hydrographic Surveys Ltd.

APEM Ref P00002178

January 2018

Redacted

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Revision and Amendment Register

Version Number	Date	Section(s)	Page(s)	Summary of Changes	Approved by
1	25/01/2018	All	All	Document creation	Re
2	31/01/2018	2	All	Amendment following ALHS review	Re

Contents

List of Figures and Tables

1. Introduction

APEM Ltd has been commissioned to undertake a survey of the subtidal benthic ecological habitats and species present in Tarbert Harbour on the Isle of Harris, on behalf of Aspect Land & Hydrographic Surveys (ALHS) and Caledonian Maritime Assets Ltd (CMAL). Tarbert Ferry Terminal is located in a sheltered bay on the east coast of the Isle of Harris, and provides a direct ferry link to the Isle of Skye. This survey will provide data to enable an Environmental Impact Assessment (EIA) of proposed improvements to Tarbert Ferry Terminal (the proposed development) to be conducted.

In accordance with Saunders et al. (2011), this survey will gather information for the EIA process by identifying whether there are any benthic habitats or species of note present (i.e. priority, rare, protected or invasive) and identify the spatial distribution and abundance of these species in the area. This will allow an assessment to be conducted of how these habitats or species will be affected by the proposed development and the significance or implications of any damage or loss incurred, which is beyond the scope of this survey report but it is understood will be conducted by CMAL and Affric Ltd. for the proposed development.

The aim of the survey was to collect underwater video and grab samples to provide data on the subtidal benthic ecology habitats, community composition and sediment composition within the area of the proposed development, to enable the subtidal benthic ecology of Tarbert Harbour to be characterised, and the effect of the improvements to Tarbert Ferry Terminal to be assessed.

This report provides a full description of the survey and analysis conducted by APEM Ltd. to obtain the data for characterisation, and the complete datasets for use along with a summary description of the datasets obtained.

2. Methodology

2.1 Field survey

All survey permissions, including a Marine Licence Exemption and Crown Estate Consent, were obtained by CMAL prior to the survey commencing.

The survey operations were conducted in December 2017 from the vessel Remote Sensor, operated by ALHS and shown in Figure 2-1 below. Remote Sensor is an 8.4m catamaran survey vessel (MCA Cat III) with high manoeuvrability, which was an essential requirement due to the constrained characteristics of the survey area.

The survey was overseen by an attending marine ecologist from Affric Ltd., on behalf of CMAL, who conducted quality assurance during the survey and specified grab sample locations whilst on-site using the footage from the underwater video.

The methodologies for collection of the underwater video and grab samples are provided in Sections 2.1.1 and 2.1.2 below respectively.

Figure 2-1 The survey vessel Remote Sensor used for the Tarbert Ferry Terminal subtidal benthic ecology surveys

2.1.1 Underwater video survey

The underwater video survey was conducted on the 12th December 2017 in daylight hours.

Although not yet operational at the time of the survey, a new floating pontoon had been installed shortly prior to the survey. The pontoon anchorage and other entanglement hazards likely to be present in the area as a result of the new pontoon were considered in the survey design phase, leading to the requirement for use of a Remote Operated Vehicle (ROV) for the underwater video survey, rather than a Drop Down Video (DDV) camera.

APEM's methodology was discussed with Scottish Natural Heritage (SNH), who confirmed that they were content with the use of a video system, and that there was not a requirement to use a camera system capable of taking independent still photographs. Instead, SNH requested pauses in the transects to allow capture of the seabed:

"The proposed benthic baseline monitoring grid at Tarbert looks suitable and I'd be content that the transects are taken between the months you have indicated - please ensure there is sufficient lighting and the operator makes frequent 'pauses' in the footage to allow the camera to capture a 'still' of the seabed (approximately every 20-30 metres). The pauses should be long enough to let any sediment plume disperse and allow the camera focus (if on auto) to perform. Should the survey discover any sensitive habitat or species of conservation interest it'd be helpful to chart its full character and extent by adapting the methodology at the time of survey. This would avoid any possible requirement to re-survey should anything of conservation importance be found (unlikely as that may be)."

APEM was provided with a specification of transect routes for the underwater video survey, shown in Figure 2-2, which had been discussed and agreed with Scottish Natural Heritage (SNH) by CMAL and Affric Ltd. prior to the pontoon being constructed. APEM was therefore allowed dispensation to adapt the transect routes whilst on-site to avoid the pontoon and pontoon anchorage if required due to accessibility or entanglement risk, whilst still maintaining a series of transects across the site (approximately south west to north east) and a single transect down the site and seabed contours (approximately south east to north west).

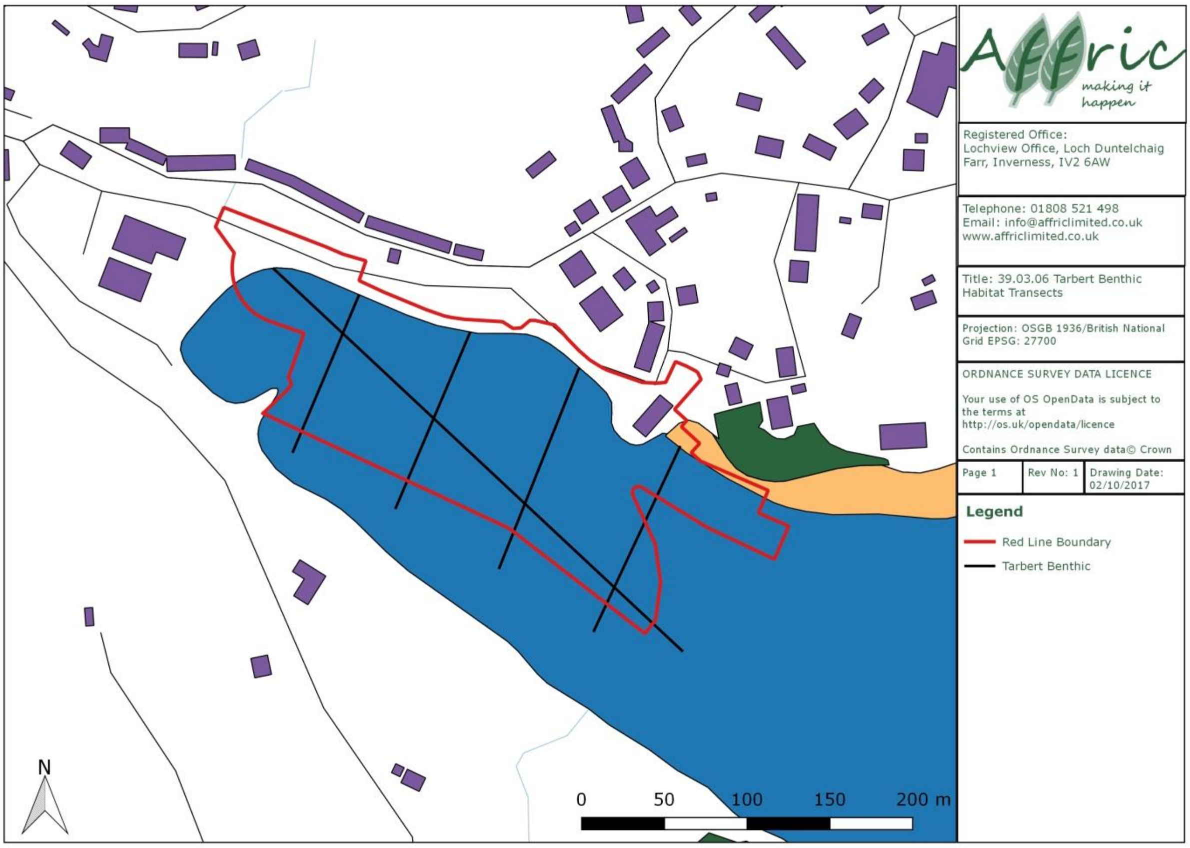

Figure 2-2 Tarbert Ferry Terminal transect location specification for underwater video survey

The underwater video transects were completed using Subsea Technology and Rental's (STR) "BlueROV2", a small hand-launch 6-thruster ROV with a high-definition 1080p resolution camera. The ROV was flown by a trained ROV pilot provided by STR, and the transect routes flown are shown in Figure 2-3, with grid coordinates of the start and end points of each transect given in Table 2-1. Whilst APEM had to make small adjustments to the transect routes to avoid entanglement, these were limited given the choice of a manoeuvrable vessel and ROV system, and so the transects were obtain in a similar layout to the required specification.

Although most of the underwater video transects were conducted from south west to north east, Transect 4 was repeated in the opposite direction due to some bottom low visibility on the first attempt. The second attempt collected enough data to integrate with the first passage.

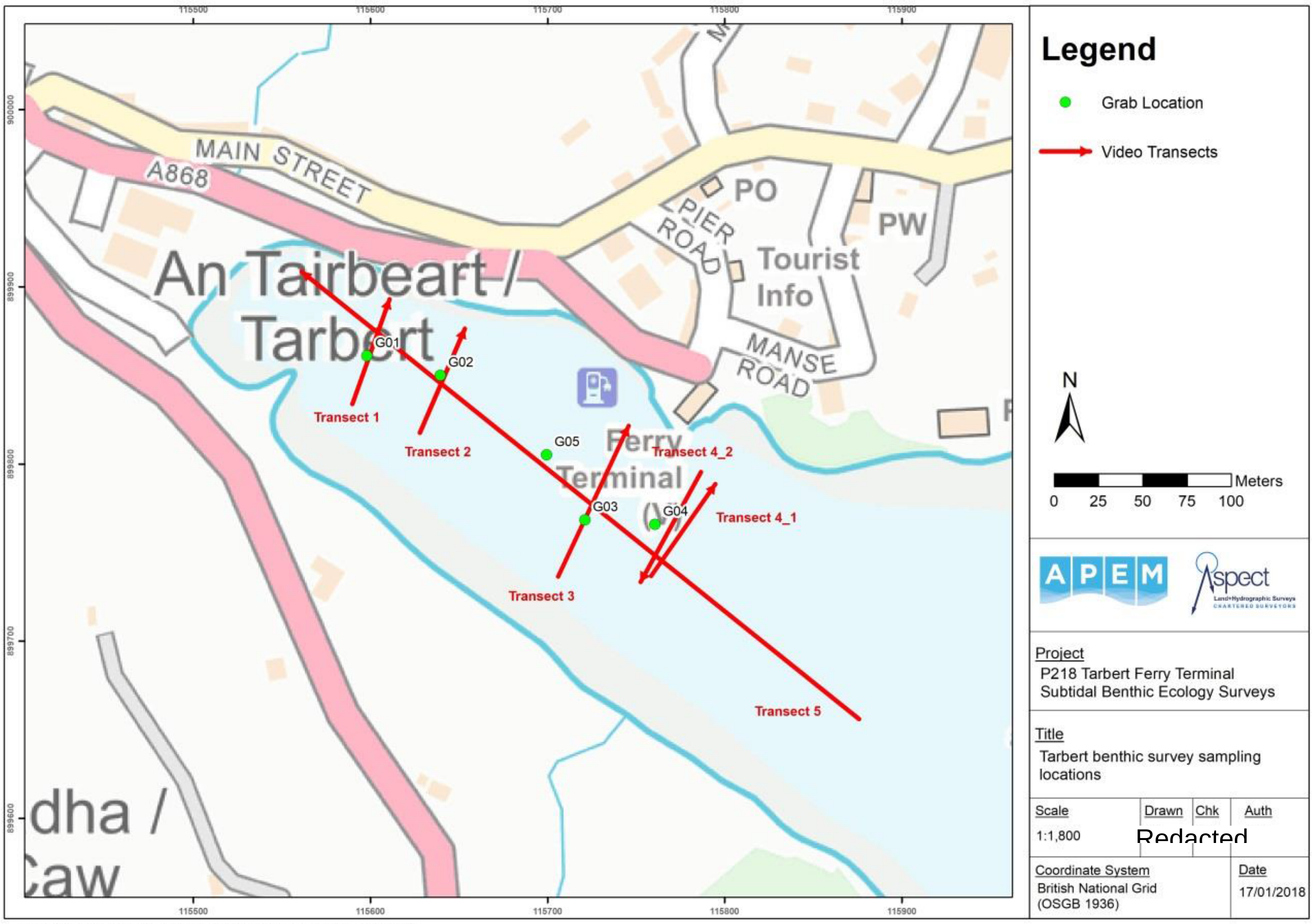

Figure 2-3 Location of the underwater video transect routes, with arrows indicating the transect direction flow, and location of the grab sampling stations.

Table 2-1 Start and end point coordinates for each underwater video transect. Coordinates are presented in the Ordnance Survey/British National Grid Project Coordinate System format.

Underwater video transect	Start coordinates		End coordinates	
	X	Y	X	Y
Transect 1	115589	899833	115611	899893
Transect 2	115628	899818	115653	899876
Transect 3	115706	899736	115746	899821
Transect 4_1 (original)	115758	899737	115795	899789
Transect 4_2 (repeated)	115787	899785	115752	899733
Transect 5	115788	899656	115561	899908

2.1.2 Grab sampling survey

The subtidal grab sampling survey was conducted on the 13th December 2017 in daylight hours.

No specification for the number or location of the grab sampling stations was provided by CMAL or Affric Ltd. prior to the survey, as the grab sampling stations were to be sited by Affric Ltd.'s attending marine ecologist based on the findings of the underwater video survey conducted on 12th December 2017.

During the survey design phase, it was specified by CMAL and Affric Ltd. that there was no requirement to obtain replicate grab samples for macrobenthic analysis. It was stated that the purpose of the survey was to characterise the subtidal benthic ecology habitats, community composition and PSD to assess the habitat and species types that may be lost as a result of the proposed development. As the habitats surveyed will be lost under the footprint of the proposed development they will be subject to a direct effect, and so there is no requirement to obtain replicate grab samples for compilation of a baseline dataset upon which a future monitoring programme for indirect effects could be defined. This also meant that there was no requirement to conduct formal *a priori* statistical power analysis to define the number of samples required by the survey, as the data collected prior to construction would not be quantitatively compared to any data collected post-construction and as such the statistical power of the survey design was not a relevant consideration.

Following review of the underwater video survey outputs, APEM proposed five grab sampling station locations within Tarbert Harbour that were agreed with Affric Ltd., and these are shown on Figure 2-3 with coordinates provided in Table 2-2. At each of these stations, grab samples were collected for macrobenthic and Particle Size Distribution (PSD) analysis using a 0.1 m^2 Day Grab. A single grab sample was obtained for macrobenthic analysis, and a further separate single grab sample was obtained for PSD analysis as close as possible to the original macrobenthic grab sample location.

Table 2-2 Coordinates for each grab sample station. Coordinates are presented in the Ordnance Survey/British National Grid Project Coordinate System format.

Grab sample station	Site code	X	Y
Station 1	G01	115598	899861
Station 2	G02	115640	899850
Station 3	G03	115721	899768
Station 4	G04	115761	899766
Station 5	G05	115700	899805

Whilst conducting the grab sampling, a minimum sediment volume limit of 5 litres was defined as an acceptable size for a grab sample to be considered successful. If this minimum volume was not obtained then a further two attempts were to be made at the same location, followed by three attempts at a different location at least 50m from the original target. At station 3, the first PSD grab attempt was rejected due to a stone blocking the grab jaws. The second attempt retrieved a suitable size sample (>7l).

For each grab attempt the following information was recorded on the survey log-sheet:

- Survey name, location and project code;
- Survey Date;
- Survey Team staff;
- Site information including: site/replicate, sample position (lat/lon; WGS84), collection time, water depth, weather conditions;
- Sampling equipment including sieve mesh size;
- Salinity for later use in the WFD IQI calculation
- Sample description, including sediment description, grab depth in cm, volume, type, profile, concretions, surface features, burrows, algae, colour and colour changes, smell, etc.;

- Any obvious or notable (e.g. Annex 2 species) taxa observed;
- Notes (e.g. anoxia, anthropogenic debris, any problems encountered, etc.);
- Photograph of the unsieved sample (an example is presented in Figure 2-4 below).

Figure 2-4 Unsieved grab sample from Station 4 in Tarbert Harbour.

Biological samples were sieved on board through a 1.0mm sieve as is standard for subtidal surveys in marine conditions. All material retained on the sieves was fixed with 4% buffered formaldehyde solution in seawater and stored in sealed crates.

2.2 Sample analysis

2.2.1 Macrobenthic analysis of grab samples

Samples were processed according APEM's in-house Standard Operating Procedures (SOP's) and in full compliance with North East Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) guidance (Worsfold and Hall, 2010). To standardise the sizes of organisms and improve sorting efficiency, samples were sieved through a stack of sieves of 4.0, 2.0 and 1.0 mm meshes in a fume cupboard following UKTAG guidance for benthic invertebrate sample analysis for coastal waters (WFD-UKTAG, 2014). All biota retained in the sieves were then extracted under low power microscopes, identified and enumerated, where applicable.

Taxa were identified to the lowest possible practicable taxonomic level using the appropriate taxonomic literature. For certain taxonomic groups (e.g. nemerteans and, nematodes), higher taxonomic levels were used due to the widely acknowledged lack of appropriate identification tools for these groups. The NMBAQC Scheme has produced a Taxonomic Discrimination Protocol (TDP) (Worsfold and Hall 2010) which gives guidance on the most appropriate level to which different marine taxa should be identified, and this guidance was adhered to for the laboratory analysis. Where required, specimens were also compared with material maintained within the laboratory reference collection. Nomenclature followed the World Register of Marine Species (WoRMS), except where more recent revisions were known to supersede WoRMS.

At least one example of each taxon recorded from the surveys was set aside for inclusion in APEM's in-house reference collection. This collection acts as a permanent record of the biota recorded.

2.2.2 PSD analysis of grab samples

PSD analysis was performed in accordance with NMBAQC Scheme best practice guidance for PSA for supporting biological analysis (Mason, 2016). A combination of dry sieving and laser diffraction was used due to the range of particle sizes present in the samples.

The PSA data were entered into GRADISTAT (Blott and Pye, 2001) to produce sediment classifications, following Folk (1954) (Figure 2-5). Summary statistics were also calculated including mean particle size, sorting, skewness and kurtosis (following Blott and Pye, 2001).

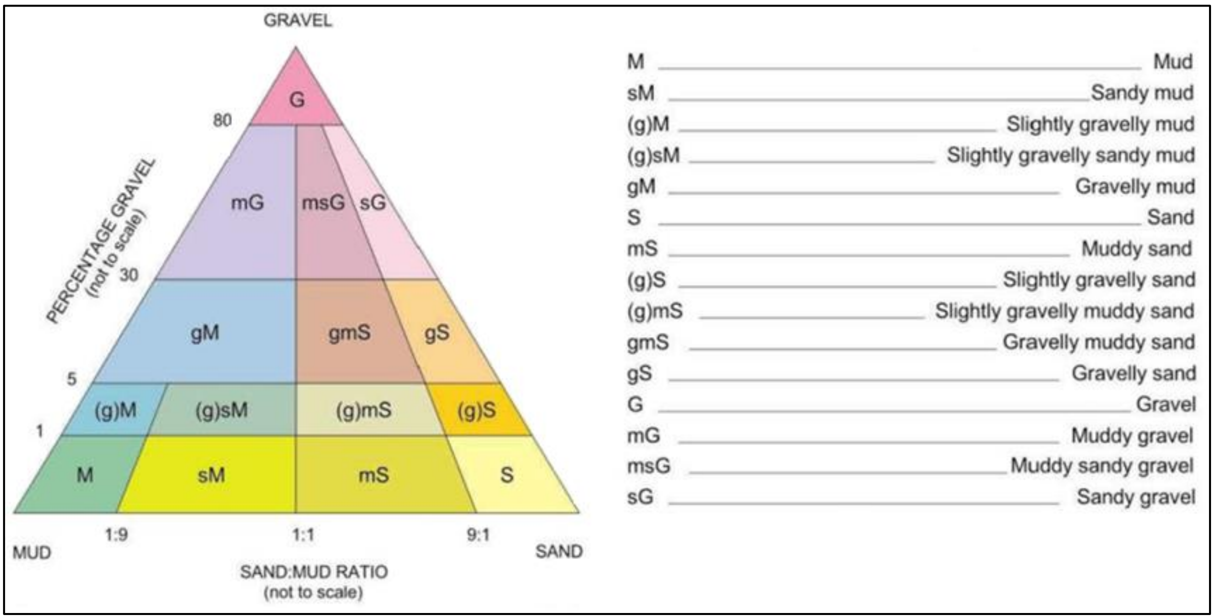

Figure 2-5 Folk sediment classification pyramid (Folk, 1954).

2.2.3 Imagery analysis of underwater video capture

The underwater video was analysed by an experienced marine benthic taxonomist and image analyst to provide habitat/biotope extent and transition data and enable the identification of any small-scale habitats outside the subtidal grab sampling target habitats (such as rock outcrops).. The video captures for each transect were re-played in the laboratory and the biotopes and notable taxa along each transect identified and recorded.

The timing of the transitions between each habitat along the transects in the underwater video were also noted, and these were then related to the ROV and vessel position within the survey logs to identify the position of habitat transitions.

3. Results

3.1 Macrobenthic analysis data

The full suite of enumerated macrobenthic data from each grab sample is provided in Appendix 1. A summary of the prevailing conditions at the time of each macrobenthic grab sample is provided in Table 3-1 below, and the biotopes assigned to each grab sample are provided in Table 3-2. The most abundant species was the Polychaete *Lumbrineris cingulata* agg. with more than 300 individuals across 5 samples and an abundance peak of more than 160 individuals in Station 3. The most abundant Mollusc was the Gastropod *Philine quadripartita* with 82 individuals in Station 2.

Table 3-1 Prevailing water depth and salinity conditions at the time of collection of each macrobenthic grab sample

Grab sample station	Collection time	Water depth (m)	Volume (l)	Salinity (ppm)
Station 1	10:06	0.7	10	35.66
Station 2	13:05	1.5	9.8	35.94
Station 3	12:19	4.2	10	35.96
Station 4	11:35	5.2	10	35.48
Station 5	13:46	3	7	35.67

Table 3-2 Biotopes assigned to macrobenthic grab samples

Grab sample station	Biotope	Description
Station 1	SS.SMu.ISaMu	Infralittoral sandy mud
Station 2	SS.SMu.IFiMu.PhiVir	Philine aperta and Virgularia mirabilis in soft stable infralittoral mud
Station 3	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel
Station 4	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel
Station 5	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel

3.2 PSD analysis data

The full suite of PSD analysis data from each grab sample is provided in Appendix 2. A summary of the prevailing conditions at the time of each PSD grab sample is provided in Table 3-3 below and the Folk (1954) classifications provided in Table 3-4. Finally, histograms of particle size classifications are presented in Figure 3-1 for each PSD grab sample.

Table 3-3 Prevailing water depth and salinity conditions at the time of collection of each PSD grab sample

Grab sample station	Time	Water depth (m)	Volume (l)	Salinity (ppm)
Station 1	10:37	0.7	10	35.66
Station 2	14:16	1.5	10	35.94
Station 3	12:55	4.2	7	35.96
Station 4	12:10	5.3	10	35.48
Station 5	14:07	3	9.8	35.67

Table 3-4 Visual descriptions and Folk (1954) classifications of PSD grab samples

Grab sample station	Visual description of >1 mm fraction	Folk (1954) classification
Station 1	Slag/cinders, shell and organics including peat	Gravelly Mud
Station 2	Very minor shell	Slightly Gravelly Sandy Mud
Station 3	Degraded shell, gravel/slag	Muddy Gravel
Station 4	Largely shell	Gravelly Mud
Station 5	Largely shell	Gravelly Mud

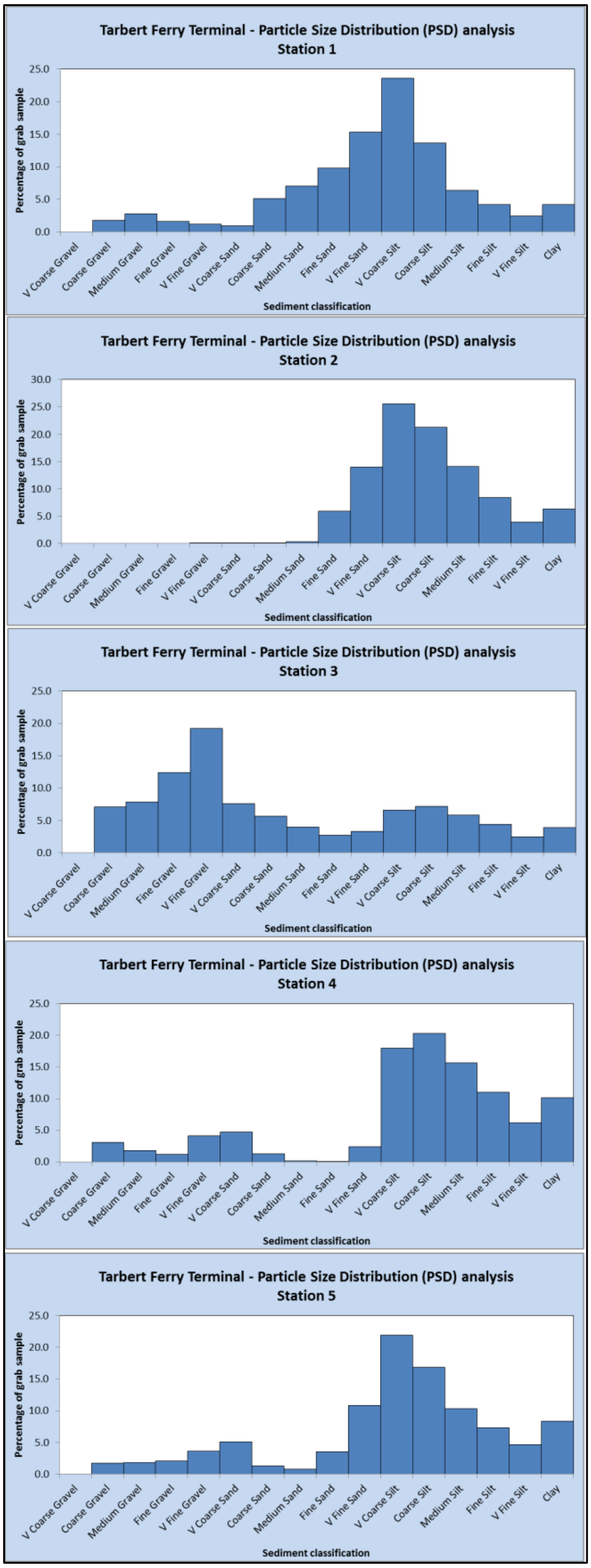

Figure 3-1 Sediment classification distribution graphs for each sample station

3.3 Underwater video data

The full suite of habitat classification data for each transect is provided in Appendix 3. The biotopes found to be present in Tarbert Harbour, with example images of each biotope from the underwater video survey, are provided in Figures 3-2, 3-3 and 3-4. The biotopes identified by the underwater video imagery have been mapped along each of the transect routes in Figure 3-5.


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Figure 3-2 SS.SMu.IFiMu – Infralittoral fine mud

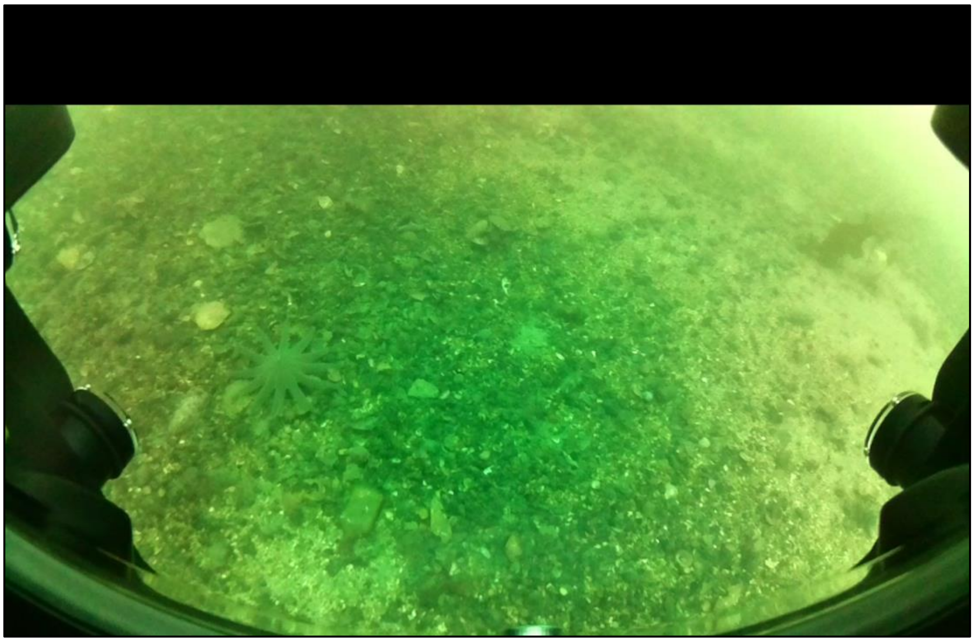

Figure 3-3 SS.SMx – Sublittoral mixed sediment

Figure 3-4 LR.LLR.F.Fser.X – *Fucus serratus* on full salinity lower eulittoral mixed substrata

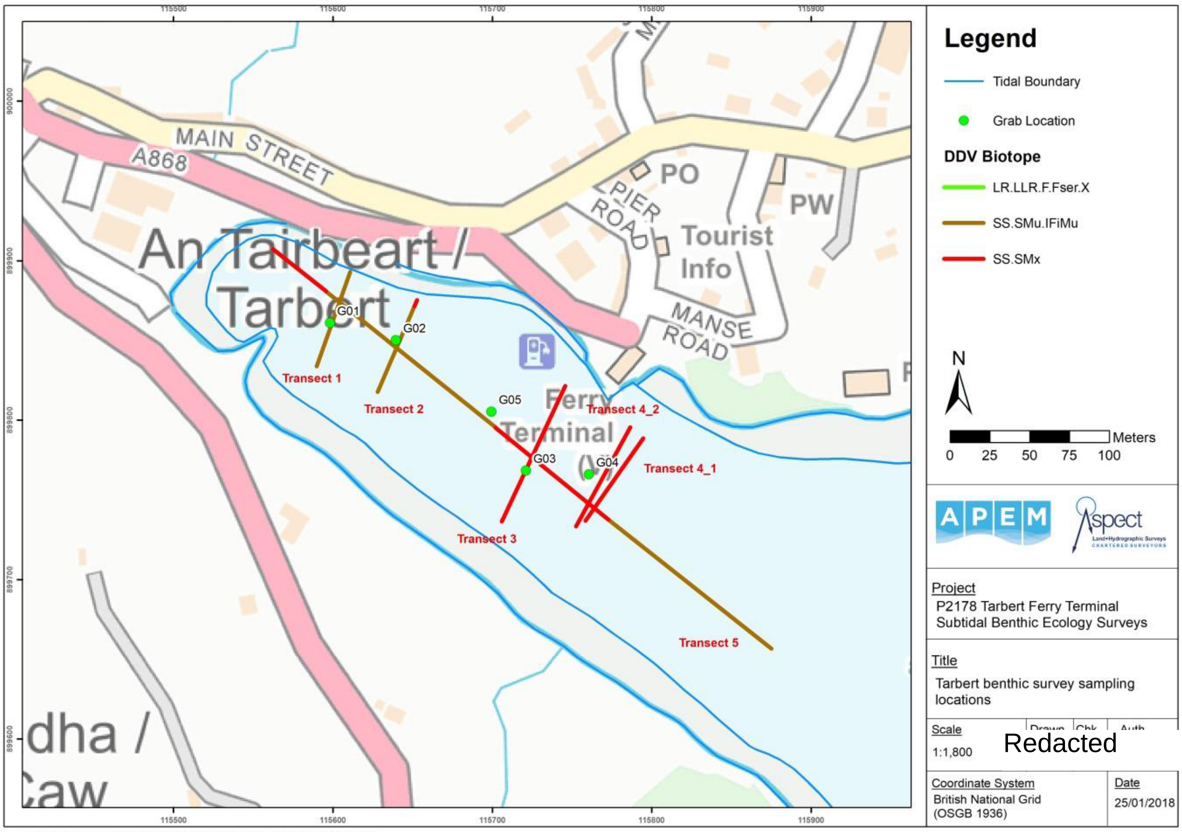

Figure 3-5 Transect routes with mapped biotopes overlaid

3.4 Tarbert Harbour biotope mapping

The macrobenthic count data, PSA data and underwater video biotope classification data has been compiled to allocate biotopes to each point along the underwater video transects and at the grab sample stations. Biotopes were allocated following JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor *et al*. 2004). EUNIS codes corresponding to each biotope have also been provided (JNCC 2010, Parry 2015).

As the survey coverage across Tarbert Harbour has transects running across the harbour and down the full length of the shore and at various depths, it has been possible to extrapolate between the known biotopes along the transects to provide a more complete biotope map of the harbour. This plan is shown in Figure 3-6. It is acknowledged that this is an extrapolation of the known data and so the biotope assignment away from the transects and grab sample locations is with a lower level of confidence to the biotope assignment at the grab sample stations and transects.

The biotope map presented in Figure 3-6 is an interpretive map based on an extrapolation of the raw data collected in the grab samples and along the underwater video transects, to delineate approximate habitat biotope boundaries within Tarbert Harbour. Following the approach set out by Saunders et al. (2011) the confidence in this biotope map would be enhanced by conducting a geophysical survey of the harbour to allow the grab sample point data and underwater video line data to act as reference points for the habitats in the rest of the harbour defined using the geophysical survey.

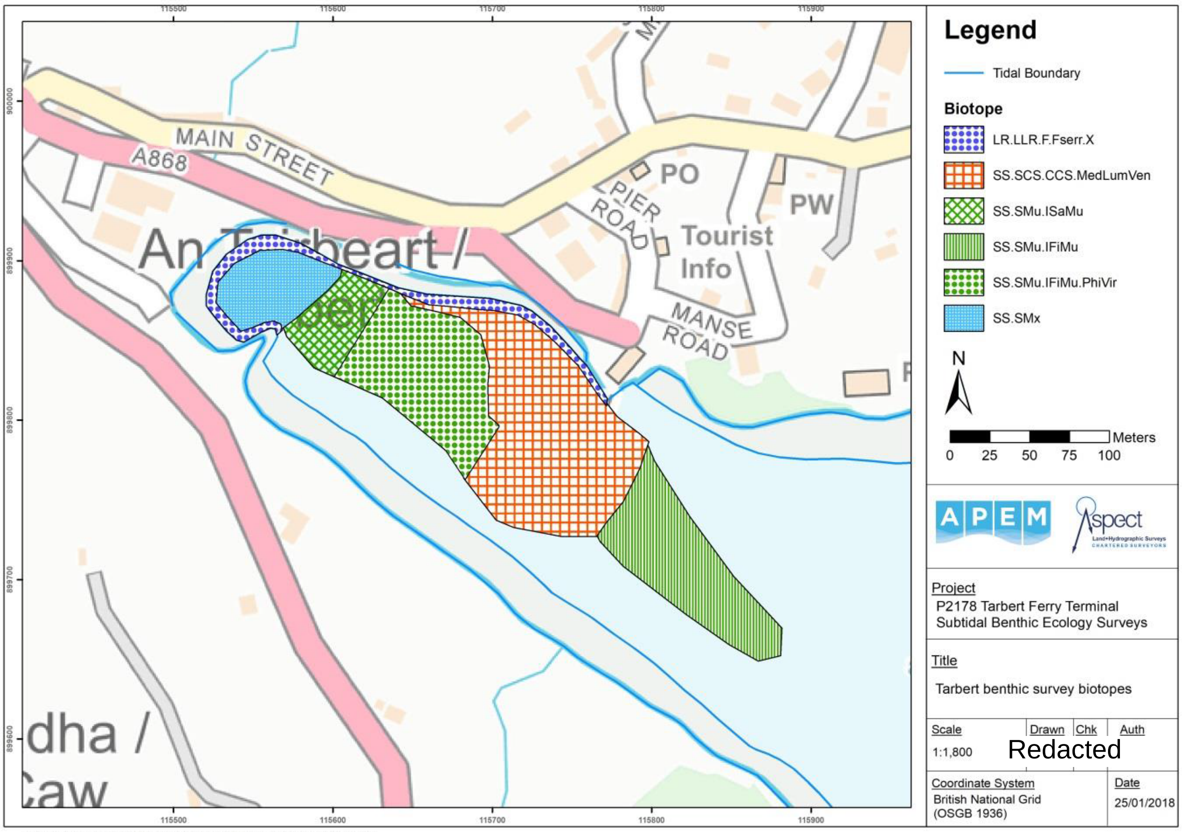

Figure 3-6 Tarbert Harbour mapped subtidal benthic biotopes

4. References

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Appendix 1 Macrobenthic data from grab samples

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Marine Benthic Invertebrate Analysis Report

The analysis on adjacent tab(s) of this workbook has been carried out by APEM Ltd under method MINV-01.

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Approved and issued by:	Redacted	Marine Technical Specialist
Issue Date:	25/01/2018	

If you have any comments or complaints regarding this or any other piece of work conducted by APEM Ltd, please contact Redacted

APEM Report No. P00002178-01

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Sample Number	Sample Date	Sample Method	Watercourse	Site Description	Analysis Type	Analysis Date	Analyst	QC Date	APEM location	Notes
60531	13/12/2018	Day Grab	Isle of Harris	Grab St. 1	1.0mm mesh	08/01/2018	CA	08/01/2018	Letchworth	-
60532	13/12/2018	Day Grab	Isle of Harris	Grab St. 2	1.0mm mesh	04/01/2018	CA	04/01/2018	Letchworth	-
60533	13/12/2018	Day Grab	Isle of Harris	Grab St. 3	1.0mm mesh	08/01/2018	NP	08/01/2018	Letchworth	-
60534	13/12/2018	Day Grab	Isle of Harris	Grab St. 4	1.0mm mesh	04/01/2018	NP	04/01/2018	Letchworth	-
60535	13/12/2018	Day Grab	Isle of Harris	Grab St. 5	1.0mm mesh	04/01/2018	CA	05/01/2018	Letchworth	-

APEM Report No. P00002178-01					
	Sample Number		60531	60532	60533
	Sample Date		13/12/2018	13/12/2018	13/12/2018
	Sample Method		Day Grab	Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris	Isle of Harris
	Site Description		Grab St. 1	Grab St. 2	Grab St. 3
	Analysis Type		1.0mm mesh	1.0mm mesh	1.0mm mesh
	Analysis Date		08/01/2018	04/01/2018	08/01/2018
	Analyst		CA	CA	NP
Code	Taxa ID	Qualifiers	60531	60532	60533
D0759	Edwardsiidae		-	-	2
F0002	Turbellaria		-	-	1
G0001	Nemertea		-	-	6
G0047	Lineidae		-	-	-
HD0001	Nematoda		-	2	8
K0030	Loxosomella murmanica		-	-	P
N0014	Golfingia elongata		-	-	1
N0017	Golfingia vulgaris		-	-	2
N0034	Phascolion strombus		-	-	2
P0050	Malmgrenia darbouxi		-	-	12
P0065	Harmothoe impar	aggregate	-	-	4
P0067	Malmgrenia arenicolae		-	-	2
P0092	Pholoe baltica (sensu Petersen)		-	-	2
P0094	Pholoe inornata (sensu Petersen)		-	-	-
P0118	Eteone longa	aggregate	-	-	3
P0152	Eulalia bilineata		-	-	2
P0167	Eumida sanguinea	aggregate	-	-	15
P0176	Paranaitis kosteriensis		-	-	-
P0256	Glycera alba		-	-	-
P0260	Glycera lapidum	aggregate	-	-	5
P0268	Glycinde nordmanni		-	-	-
P0271	Goniada maculata		-	-	-
P0305	Psamathe fusca		-	-	8
P0312	Oxydromus pallidus		-	-	2
P0313	Oxydromus flexuosus		-	-	2
P0319	Podarkeopsis capensis		-	-	11
P0358	Syllis parapari		-	-	2
P0421	Parexogone hebes		-	-	2
P0494	Nephtys	juvenile	43	18	-
P0499	Nephtys hombergii		7	13	-
P0574	Lumbrineris cingulata	aggregate	-	-	138
P0638	Protodorvillea kefersteini		-	-	28
P0699	Paradoneis lyra		-	-	-
P0722	Aonides oxycephala		-	-	8
P0731	Laonice	juvenile	-	-	-
P0750	Dipolydora coeca		-	-	-
P0754	Dipolydora flava		-	-	1
P0761	Dipolydora saintjosephi		-	-	3
P0765	Prionospio fallax		2	1	-
P0790	Spio symphyta		-	-	-
P0804	Magelona alleni		-	-	4
P0806	Magelona minuta		-	-	-
P0827	Chaetozone vivipara		-	1	-
P0829	Caulleriella alata		-	-	-
P0832	Chaetozone elakata		-	-	-
P0840	Dodecaceria		-	-	-

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	Sample Number		60531	60532	60533
	Sample Date		13/12/2018	13/12/2018	13/12/2018
	Sample Method		Day Grab	Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris	Isle of Harris
	Site Description		Grab St. 1	Grab St. 2	Grab St. 3
	Analysis Type		1.0mm mesh	1.0mm mesh	1.0mm mesh
	Analysis Date		08/01/2018	04/01/2018	08/01/2018
	Analyst		CA	CA	NP
Code	Taxa ID	Qualifiers	60531	60532	60533
P0889	Macrochaeta		-	-	3
P0906	Capitella		-	-	-
P0919	Mediomastus fragilis		-	-	93
P0923	Notomastus		-	-	11
P1025	Scalibregma inflatum		-	-	6
P1026	Scalibregma celticum		-	-	1
P1093	Galathowenia oculata		-	-	-
P1102	Amphictene auricoma		-	-	-
P1124	Melinna palmata		-	-	6
P1174	Terebellides		-	-	3
P1185	Amphitritides gracilis		-	-	-
P1210	Nicolea venustula		-	-	3
P1216	Pista	juvenile	-	-	-
P1217	Pista mediterranea		-	-	1
P1235	Polycirrus		-	-	12
P1257	Sabellidae		-	-	-
P1268	Chone fauveli		-	-	-
P1315	Pseudopotamilla		-	-	-
P1324	Serpulidae		-	-	22
P1334	Hydroides norvegica		-	-	-
P1340	Spirobranchus lamarcki		-	-	51
P1341	Spirobranchus triqueter		-	-	3
R2173	Melinnacheres terebellidis		-	-	-
S0131	Perioculodes longimanus		-	1	-
S0503	Cheirocratus	female	-	-	2
S0792	Gnathiidae	juvenile	-	-	1
S1445	Paguridae	juvenile	-	-	-
S1472	Galathea intermedia	juvenile	-	-	1
W0053	Leptochiton asellus		-	-	5
W0159	Gibbula magus		-	-	7
W0161	Gibbula tumida		-	-	2
W0163	Steromphala cineraria		-	1	4
W0174	Jujubinus montagui		-	-	1
W0371	Onoba semicostata		-	-	10
W0747	Tritia incrassata		-	-	-
W0748	Tritia pygmaea		-	-	-
W0804	Mangelia costata		-	-	-
W1038	Philine quadripartita		1	82	-
W1118	Elysia viridis		-	-	1
W1569	Nucula nitidosa		-	-	-
W1837	Thyasira flexuosa		1	-	-
W1906	Kurtiella bidentata		2	-	67
W2006	Phaxas pellucidus		-	-	-
W2059	Abra alba		12	11	-
W2061	Abra nitida		2	11	-
W2098	Chamelea striatula	juvenile	-	-	-

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			60531	60532	60533
	Sample Number		60531	60532	60533
	Sample Date		13/12/2018	13/12/2018	13/12/2018
	Sample Method		Day Grab	Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris	Isle of Harris
	Site Description		Grab St. 1	Grab St. 2	Grab St. 3
	Analysis Type		1.0mm mesh	1.0mm mesh	1.0mm mesh
	Analysis Date		08/01/2018	04/01/2018	08/01/2018
	Analyst		CA	CA	NP
Code	Taxa ID	Qualifiers	60531	60532	60533
W2147	Mya truncata		-	-	-
W2147	Mya truncata	juvenile	-	-	1
ZA0003	Phoronis		-	-	-
ZB0018	Asteroidea	juvenile	-	-	1
ZB0161	Amphipholis squamata		-	-	12
ZB0165	Ophiuridae	juvenile	-	-	1
ZB0193	Psammechinus miliaris		-	-	-
ZB0266	Cucumariidae	juvenile	-	-	-
ZM	Bryophyta		P	P	-
ZM0002	Rhodophyta		-	-	-
ZM0131	Cruoria		-	-	P
ZM0189	Hildenbrandia		-	-	-
ZM0431	Gracilaria		-	-	P
ZM0554	Pterothamnion plumula		-	-	P
ZM0581	Heterosiphonia plumosa		-	P	-
ZM0655	Polysiphonia		-	-	P
ZR0191	Ralfsia verrucosa		-	-	-
ZR0288	Sphacelaria		-	-	P
ZS0174	Ulva		-	-	P

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	Sample Number		60534	60535
	Sample Date		13/12/2018	13/12/2018
	Sample Method		Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris
	Site Description		Grab St. 4	Grab St. 5
	Analysis Type		1.0mm mesh	1.0mm mesh
	Analysis Date		04/01/2018	04/01/2018
	Analyst		NP	CA
Code	Taxa ID	Qualifiers	60534	60535
D0759	Edwardsiidae		-	1
F0002	Turbellaria		-	-
G0001	Nemertea		5	14
G0047	Lineidae		5	-
HD0001	Nematoda		5	-
K0030	Loxosomella murmanica		P	-
N0014	Golfingia elongata		-	-
N0017	Golfingia vulgaris		-	-
N0034	Phascolion strombus		1	-
P0050	Malmgrenia darbouxi		-	-
P0065	Harmothoe impar	aggregate	1	-
P0067	Malmgrenia arenicolae		-	-
P0092	Pholoe baltica (sensu Petersen)		1	1
P0094	Pholoe inornata (sensu Petersen)		1	-
P0118	Eteone longa	aggregate	1	2
P0152	Eulalia bilineata		-	-
P0167	Eumida sanguinea	aggregate	-	1
P0176	Paranaitis kosteriensis		1	1
P0256	Glycera alba		-	9
P0260	Glycera lapidum	aggregate	3	-
P0268	Glycinde nordmanni		-	5
P0271	Goniada maculata		1	-
P0305	Psamathe fusca		2	-
P0312	Oxydromus pallidus		-	-
P0313	Oxydromus flexuosus		2	4
P0319	Podarkeopsis capensis		3	3
P0358	Syllis parapari		1	-
P0421	Parexogone hebes		-	1
P0494	Nephtys	juvenile	-	-
P0499	Nephtys hombergii		-	1
P0574	Lumbrineris cingulata	aggregate	164	52
P0638	Protodorvillea kefersteini		12	-
P0699	Paradoneis lyra		1	-
P0722	Aonides oxycephala		35	2
P0731	Laonice	juvenile	-	2
P0750	Dipolydora coeca		1	-
P0754	Dipolydora flava		-	-
P0761	Dipolydora saintjosephi		3	-
P0765	Prionospio fallax		-	36
P0790	Spio symphyta		-	2
P0804	Magelona alleni		7	2
P0806	Magelona minuta		-	2
P0827	Chaetozone vivipara		-	-
P0829	Caulleriella alata		2	2
P0832	Chaetozone elakata		-	1
P0840	Dodecaceria		2	-

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	Sample Number		60534	60535
	Sample Date		13/12/2018	13/12/2018
	Sample Method		Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris
	Site Description		Grab St. 4	Grab St. 5
	Analysis Type		1.0mm mesh	1.0mm mesh
	Analysis Date		04/01/2018	04/01/2018
	Analyst		NP	CA
Code	**Taxa ID**	**Qualifiers**	**60534**	**60535**
P0889	Macrochaeta		-	-
P0906	Capitella		-	1
P0919	Mediomastus fragilis		47	32
P0923	Notomastus		20	25
P1025	Scalibregma inflatum		-	-
P1026	Scalibregma celticum		-	-
P1093	Galathowenia oculata		-	17
P1102	Amphictene auricoma		-	1
P1124	Melinna palmata		18	42
P1174	Terebellides		15	-
P1185	Amphitritides gracilis		5	-
P1210	Nicolea venustula		-	-
P1216	Pista	juvenile	-	1
P1217	Pista mediterranea		2	-
P1235	Polycirrus		13	-
P1257	Sabellidae		1	-
P1268	Chone fauveli		1	-
P1315	Pseudopotamilla		1	-
P1324	Serpulidae		48	-
P1334	Hydroides norvegica		1	-
P1340	Spirobranchus lamarcki		93	-
P1341	Spirobranchus triqueter		5	-
R2173	Melinnacheres terebellidis		2	-
S0131	Perioculodes longimanus		-	-
S0503	Cheirocratus	female	-	-
S0792	Gnathiidae	juvenile	-	-
S1445	Paguridae	juvenile	2	-
S1472	Galathea intermedia	juvenile	-	-
W0053	Leptochiton asellus		3	-
W0159	Gibbula magus		-	-
W0161	Gibbula tumida		-	-
W0163	Steromphala cineraria		4	-
W0174	Jujubinus montagui		-	-
W0371	Onoba semicostata		1	-
W0747	Tritia incrassata		1	-
W0748	Tritia pygmaea		2	-
W0804	Mangelia costata		1	-
W1038	Philine quadripartita		-	1
W1118	Elysia viridis		-	-
W1569	Nucula nitidosa		1	2
W1837	Thyasira flexuosa		-	12
W1906	Kurtiella bidentata		23	-
W2006	Phaxas pellucidus		-	2
W2059	Abra alba		-	25
W2061	Abra nitida		-	7
W2098	Chamelea striatula	juvenile	-	2

APEM Report No. P00002178-01

		Sample Number	60534	60535
		Sample Date	13/12/2018	13/12/2018
		Sample Method	Day Grab	Day Grab
		Watercourse	Isle of Harris	Isle of Harris
		Site Description	Grab St. 4	Grab St. 5
		Analysis Type	1.0mm mesh	1.0mm mesh
		Analysis Date	04/01/2018	04/01/2018
		Analyst	NP	CA
Code	Taxa ID	Qualifiers	60534	60535
W2147	Mya truncata		1	-
W2147	Mya truncata	juvenile	1	-
ZA0003	Phoronis		1	-
ZB0018	Asteroidea	juvenile	1	-
ZB0161	Amphipholis squamata		-	-
ZB0165	Ophiuridae	juvenile	-	3
ZB0193	Psammechinus miliaris		1	-
ZB0266	Cucumariidae	juvenile	-	1
ZM	Bryophyta		-	-
ZM0002	Rhodophyta		P	-
ZM0131	Cruoria		P	-
ZM0189	Hildenbrandia		P	-
ZM0431	Gracilaria		-	-
ZM0554	Pterothamnion plumula		-	-
ZM0581	Heterosiphonia plumosa		-	-
ZM0655	Polysiphonia		-	-
ZR0191	Ralfsia verrucosa		P	-
ZR0288	Sphacelaria		P	-
ZS0174	Ulva		-	-

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Sample Number	Sample Date	Site Description	Biotope	Description	EUNIS
60531	13/12/2018	Grab St. 1	SS.SMu.ISaMu	Infralittoral sandy mud	A5.33
60532	13/12/2018	Grab St. 2	SS.SMu.IFiMu.PhiVir	Philine aperta and Virgularia mirabilis in soft stable infralittoral mud	A5.343
60533	13/12/2018	Grab St. 3	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel	A5.142
60534	13/12/2018	Grab St. 4	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel	A5.142
60535	13/12/2018	Grab St. 5	SS.SCS.CCS.MedLumVen	Mediomastus fragilis, Lumbrineris spp. and venerid bivalves in circalittoral coarse sand or gravel	A5.142

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Code	Taxa ID	Qualifiers	Notes
P0092	Pholoe baltica (sensu Petersen)		sensu Petersen, 1998;
P0094	Pholoe inornata (sensu Petersen)		sensu Petersen, 1998;
P0319	Podarkeopsis capensis		Traditional usage; but possibly a related species;
P0358	Syllis parapari		Not formally recorded from UK;
P0574	Lumbrineris cingulata	aggregate	(Previously recorded as Lumbrineris aniara/cingulata);
P0750	Dipolydora coeca		May include undescribed species;
P0754	Dipolydora flava		(Previously included in D. coeca agg.);
P0761	Dipolydora saintjosephi		(Previously included in D. coeca agg.);
P0790	Spio symphyta		(Previously recorded as Spio filicornis agg.); Not formally recorded from UK;
P0827	Chaetozone vivipara		Cryptogenic;
P0832	Chaetozone elakata		(Previously recorded as Chaetozone species D);
P0906	Capitella		Representative of organic enrichment;
P1174	Terebellides		(Previously recorded as Terebellides stroemii; might include additional species);
P1315	Pseudopotamilla		May include undescribed species;
W0748	Tritia pygmaea		Possibly close to northern limit of distribution
W1038	Philine quadripartita		(Previously recorded as Philine aperta);

Appendix 2 PSD data from grab samples

APEM Project P00002178 - Tarbert Ferry Terminal Subtidal Benthic Ecology survey PSD analysis results

Sample	Date collected	Visual description of >1 mm fraction	Folk (1954) classification	Mean (µm)	Mean (description)	Sorting (µm)	Sorting (description)	Skewness (µm)	Skewness (description)	Kurtosis (µm)	Kurtosis (description)	Primary Mode (µm)	d10 (µm)	d50 (µm)	d90 (µm)
Station 1	13/12/2017	slag/cinders, shell and organics including peat	Gravelly Mud	67.0	Very Fine Sand	7.592	Very Poorly Sorted	0.203	Coarse Skewed	1.660	Very Leptokurtic	37.7	6.9	54.4	720.2
Station 2	13/12/2017	very minor shell	Slightly Gravelly Sandy	24.0	Coarse Silt	3.777	Poorly Sorted	-0.243	Fine Skewed	1.207	Leptokurtic	37.7	3.8	27.9	103.5
Station 3	13/12/2017	degraded shell, gravel/slag	Muddy Gravel	559.9	Coarse Sand	18.237	Extremely Poorly Sorted	-0.466	Very Fine Skewed	0.753	Platykurtic	3400.0	7.1	1607.2	12359.7
Station 4	13/12/2017	largely shell	Gravelly Mud	36.9	Very Coarse Silt	14.842	Very Poorly Sorted	0.308	Very Coarse Skewed	1.995	Very Leptokurtic	26.7	1.9	20.3	2063.9
Station 5	13/12/2017	largely shell	Gravelly Mud	37.4	Very Coarse Silt	9.864	Very Poorly Sorted	0.117	Coarse Skewed	1.704	Very Leptokurtic	37.7	2.6	33.6	1783.8

Statistics calculated using Folk and Ward (1957) formulae

Sample	Gravel (>2 mm) (%)	Sand (63-2000 µm) (%)	Mud (<63 µm) (%)	V Coarse Gravel (32-64 mm) (%)	Coarse Gravel (16-32 mm) (%)	Medium Gravel (8-16 mm) (%)	Fine Gravel (4-8 mm) (%)	V Fine Gravel (2-4 mm) (%)	V Coarse Sand (1-2 mm) (%)	Coarse Sand (500-1000 µm) (%)	Medium Sand (250-500 µm) (%)	Fine Sand (125-250 µm) (%)	V Fine Sand (63-125 µm) (%)	V Coarse Silt (31-63 µm) (%)	Coarse Silt (16-31 µm) (%)	Medium Silt (8-16 µm) (%)	Fine Silt (4-8 µm) (%)	V Fine Silt (2-4 µm) (%)	Clay (<2 µm) (%)
Station 1	7.3	38.2	54.5	0.0	1.8	2.7	1.6	1.2	0.9	5.1	7.0	9.8	15.3	23.6	13.7	6.4	4.2	2.4	4.2
Station 2	0.1	20.4	79.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.4	5.9	14.0	25.5	21.3	14.1	8.4	3.9	6.3
Station 3	46.5	23.2	30.3	0.0	7.0	7.9	12.4	19.2	7.6	5.6	4.0	2.7	3.3	6.6	7.2	5.9	4.4	2.4	3.9
Station 4	10.2	8.7	81.1	0.0	3.1	1.8	1.2	4.1	4.7	1.3	0.2	0.1	2.4	17.9	20.3	15.6	11.0	6.1	10.2
Station 5	9.1	21.5	69.4	0.0	1.7	1.8	2.0	3.6	5.1	1.3	0.8	3.5	10.8	21.9	16.9	10.3	7.3	4.6	8.3

Percentages of the distribution in each 'half-phi' size interval, expressed in µm

Sample	>63000	45000 to 63000	31500 to 45000	22400 to 31500	16000 to 22400	11200 to 16000	8000 to 11200	5600 to 8000	4000 to 5600	2800 to 4000	2000 to 2800	1400 to 2000	1000 to 1400	710 to 1000	500 to 710	355 to 500	250 to 355	180 to 250	125 to 180	90 to 125	63 to 90
Station 1	0.0	0.0	0.0	0.6	1.2	1.4	1.4	0.8	0.8	0.7	0.5	0.5	0.4	1.8	3.3	4.0	3.0	3.7	6.1	6.9	8.2
Station 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.3	1.5	4.3	6.1	7.7
Station 3	0.0	0.0	0.0	4.5	2.6	4.1	3.8	5.1	7.4	11.1	8.1	5.7	1.8	2.6	3.1	2.4	1.5	1.3	1.4	1.4	1.8
Station 4	0.0	0.0	0.0	2.3	0.8	1.5	0.4	0.4	0.8	1.8	2.3	2.7	2.0	1.0	0.3	0.1	0.1	0.0	0.0	0.0	2.2
Station 5	0.0	0.0	0.0	0.3	1.4	1.3	0.5	0.8	1.2	1.8	1.8	2.7	2.4	1.0	0.3	0.1	0.7	1.1	2.4	4.5	6.1

Sample	44.19 to 63	31.25 to 44.19	22.097 to 31.25	15.625 to 22.097	11.049 to 15.625	7.813 to 11.049	5.524 to 7.813	3.906 to 5.524	2.762 to 3.906	1.953 to 2.762	1.381 to 1.953	0.977 to 1.381	0.691 to 0.977	0.488 to 0.691	0.345 to 0.488	0.244 to 0.345	0.173 to 0.244	0.122 to 0.173	0.086 to 0.122	0.061 to 0.086	0.043 to 0.061
Station 1	11.4	12.4	8.5	5.2	3.6	2.8	2.3	1.9	1.4	1.0	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.0
Station 2	11.6	14.2	11.9	9.3	7.7	6.3	4.9	3.5	2.3	1.6	1.2	0.9	0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.1	0.0
Station 3	2.8	3.9	3.8	3.4	3.1	2.8	2.4	2.0	1.4	1.0	0.7	0.6	0.6	0.5	0.4	0.4	0.3	0.2	0.1	0.0	0.0
Station 4	7.3	10.8	10.9	9.4	8.3	7.3	6.1	4.9	3.6	2.6	2.0	1.7	1.4	1.3	1.1	0.9	0.7	0.5	0.3	0.1	0.0
Station 5	10.0	12.2	9.7	7.2	5.6	4.7	4.0	3.3	2.6	2.0	1.6	1.4	1.2	1.1	0.9	0.7	0.5	0.4	0.2	0.1	0.0

Appendix 3 Underwater video analysis log

APEM Project P00002178 - Tarbert Ferry Terminal Benthic Ecology Survey video imagery analysis results

Transect	Transect biotope assignment	Start time	End Time	Video track time	Assigned Biotope (MNCR Code)	Classification (Exact copy of MNCR descriptor)	Notes
Transect 1	Tr 1 - 2017-12-12_11.32.08_Biotope 1	11:32:08	11:54:09	00:22:01	SS.SMu.IFiMu	Infralittoral fine mud	
Transect 2	Tr 2 - 2017-12-12_10.51.27_Biotope 1	10:51:27	11:10:55	00:19:28	SS.SMu.IFiMu	Infralittoral fine mud	
	Tr 2 - 2017-12-12_10.51.27_Biotope 2	11:10:55	11:13:07	00:21:40	SS.SMx	Sublittoral mixed sediment	
	Tr 2 - 2017-12-12_10.51.27_Biotope 3	11:13:07	11:14:15	00:22:48	LR.LLR.F.Fser.X	*Fucus serratus* on full salinity lower eulittoral mixed substrata	Area exposed at low tide
Transect 3	Tr 3 - 2017-12-12_13.59.08_Biotope 1	13:59:08	14:12:05	00:12:57	SS.SMx	Sublittoral mixed sediment	Small patches of *Mytilus edulis* present
Transect 4_1	Tr 4.1 - 2017-12-12_14.17.54_Biotope 1	14:17:54	14:25:10	00:07:16	SS.SMx	Sublittoral mixed sediment	Small patches of *Mytilus edulis* present
Transect 4_2	Tr 4.2 - 2017-12-12_14.28.47_Biotope 1	14:28:47	14:37:10	00:08:23	SS.SMx	Sublittoral mixed sediment	Small patches of *Mytilus edulis* present
Transect 5	Tr 5 - 2017-12-12_12.59.36_Biotope 1	12:59:36	13:15:16	00:15:40	SS.SMu.IFiMu	Infralittoral fine mud	
	Tr 5 - 2017-12-12_12.59.36_Biotope 2	13:15:16	13:27:46	00:28:10	SS.SMx	Sublittoral mixed sediment	
	Tr 5 - 2017-12-12_12.59.36_Biotope 3	13:27:46	13:39:31	00:39:55	SS.SMu.IFiMu	Infralittoral fine mud	
	Tr 5 - 2017-12-12_12.59.36_Biotope 4	13:39:31	13:43:26	00:43:50	SS.SMx	Sublittoral mixed sediment	
	Tr 5 - 2017-12-12_12.59.36_Biotope 5	13:43:26	13:43:53	00:44:17	LR.LLR.F.Fser.X	*Fucus serratus* on full salinity lower eulittoral mixed substrata	Area exposed at low tide

Appendix H.2: Tarbert Ferry Terminal – Subtidal Benthic Ecology Re-visit Survey Report

CMAL
Caledonian Maritime Assets Ltd
Stòras Mara Cailleannach Eta

Tarbert Ferry Terminal - Subtidal Benthic Ecology Re-visit Survey Report

Aspect Land & Hydrographic Surveys Ltd.

APEM Ref P00002258a

June 2018

Redacted

Client: Aspect Land & Hydrographic Surveys Ltd.

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1	04/06/2018	All	All	Document creation	Re

Contents

List of Figures and Tables

1. Introduction

APEM Ltd has been commissioned to undertake a further survey of the subtidal benthic ecological habitats and species present in Tarbert Harbour on the Isle of Harris, on behalf of Aspect Land & Hydrographic Surveys (ALHS) and Caledonian Maritime Assets Ltd (CMAL). This survey is of an area to the east of the original survey conducted by APEM in December 2017 (APEM, 2018). Tarbert Ferry Terminal is located in a sheltered bay on the east coast of the Isle of Harris, and provides a direct ferry link to the Isle of Skye. The aim of this survey is to provide data to enable an Environmental Impact Assessment (EIA) of proposed improvements to Tarbert harbour to be conducted.

In accordance with Saunders et al. (2011), this survey will gather information for the EIA process by identifying whether there are any benthic habitats or species of note present (i.e. priority, rare, protected or invasive) and identify the spatial distribution and abundance of these species in the area. This will allow an assessment to be conducted of how these habitats or species will be affected by the proposed development and the significance or implications of any damage or loss incurred, which is beyond the scope of this survey report but it is understood will be conducted by CMAL and Affric Ltd. for the proposed development.

The aim of the survey was to collect underwater video and grab samples to provide data on the subtidal benthic ecology habitats and community composition within the area of the proposed development, to enable the subtidal benthic ecology of Tarbert Harbour to be characterised, and the effect of the improvements to Tarbert Ferry Terminal to be assessed.

This report provides a full description of the survey and analysis conducted by APEM Ltd. to obtain the data for characterisation, and the complete datasets for use along with a summary description of the datasets obtained.

2. Methodology

2.1 Field survey

All survey permissions, including a Marine Licence Exemption and Crown Estate Consent, were obtained by CMAL prior to the survey commencing.

The survey operations were conducted in April 2018 from the vessel Remote Sensor, operated by ALHS and shown in Figure 2-1 below. Remote Sensor is an 8.4m catamaran survey vessel (MCA Cat III) with high manoeuvrability.

The survey was overseen by an attending marine ecologist from Affric Ltd., on behalf of CMAL, who conducted quality assurance during the survey and specified grab sample locations whilst on-site using the footage from the underwater video.

The methodologies for collection of the underwater video and grab samples are provided in Sections 2.1.1 and 2.1.2 below respectively.

Figure 2-1 The survey vessel Remote Sensor used for the Tarbert Ferry Terminal subtidal benthic ecology re-visit survey (Photo from APEM's survey at Tarbert Ferry Terminal in April 2018)

2.1.1 Underwater video survey

The underwater video survey was conducted on the 9th April 2018 in daylight hours.

APEM was provided with a specification of three transect routes for the underwater video survey by CMAL. These transect routes were not in the vicinity of the new pontoon in Tarbert Harbour and therefore a Drop Down Video (DDV) camera system could be used.

The three underwater video transects (plus an additional fourth transect) were completed using an Imenco 'Tiger Shark' underwater stills camera. This was mounted onto a frame along with a flash, lighting and multiplexer equipment as shown in Figure 2-2. A video recording device was used on the vessel to capture the video outputs of the DDV camera. The DDV camera was deployed from the Remote Sensor and captured imagery of the seabed looking vertically downward as the Remote Sensor navigated along the transects. The transects, as shown in Figure 2-3 and Table 2-1, are considered to provide a good coverage of the area of interest.

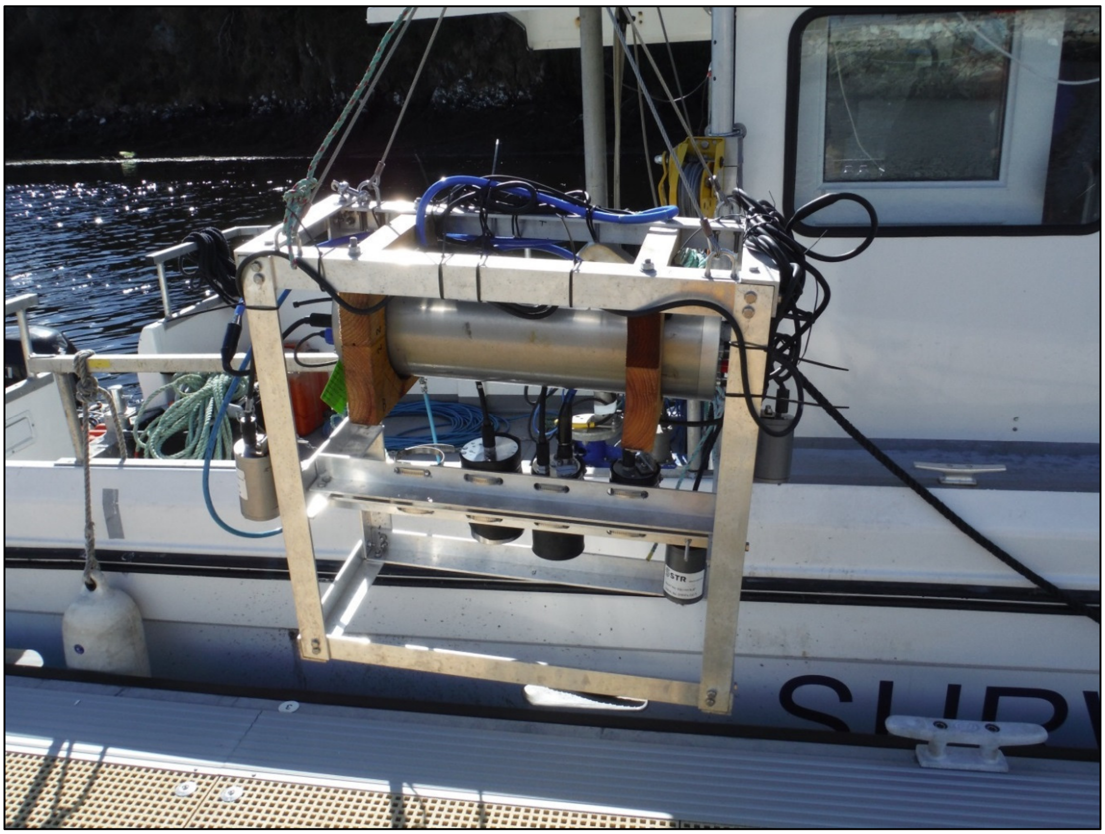

Figure 2-2 The Imenco 'Tiger Shark' subsea camera and Imenco 'Lantern Shark' flash as mounted onto the ALHS frame which was deployed from the davit of the Remote Sensor.

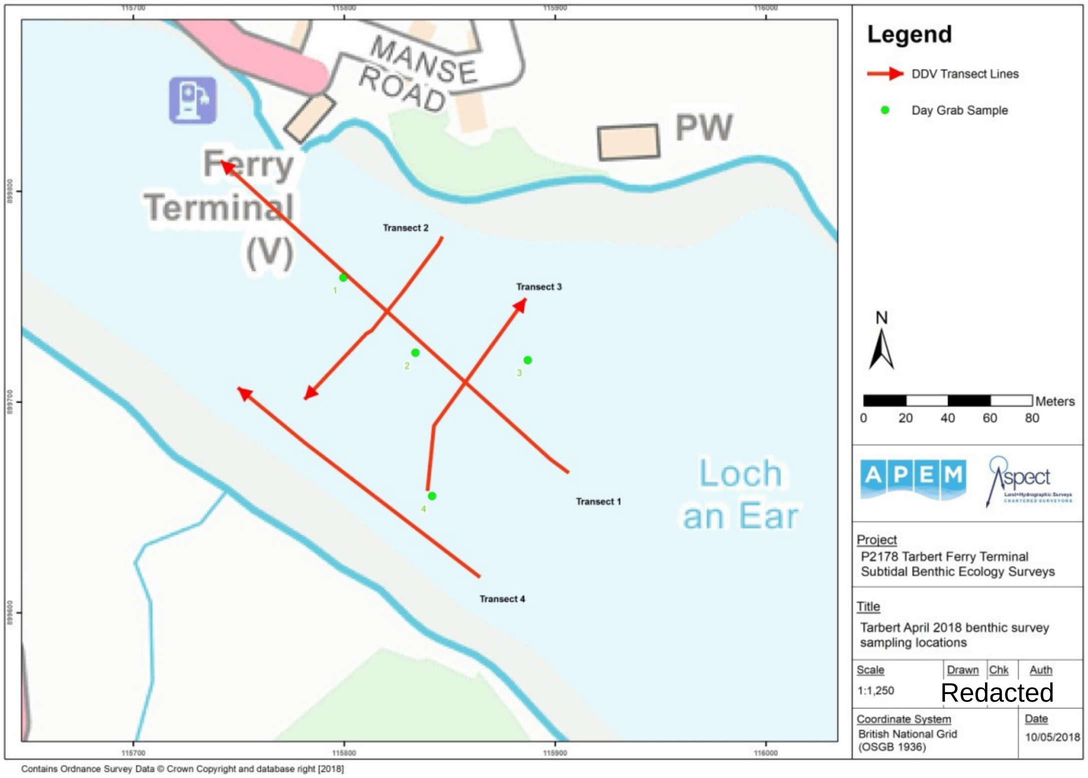

Figure 2-3 Location of the underwater video transect routes, with arrows indicating the transect direction flow, and location of the grab sampling stations.

Table 2-1 Start and end point coordinates for each underwater video transect. Coordinates are presented in the Ordnance Survey/British National Grid Projected Coordinate System format.

Underwater video transect	Start coordinates		End coordinates	
	X	Y	X	Y
Transect 1	115906.47	899669.87	115741.40	899817.97
Transect 2	115846.54	899781.97	115781.11	899704.72
Transect 3	115839.41	899661.32	115886.08	899752.73
Transect 4	115864.39	899620.48	115749.51	899710.32

2.1.2 Grab sampling survey

The subtidal grab sampling survey was conducted on the 10th April 2018 in daylight hours.

Four pre-defined grab sample station locations were specified by CMAL prior to the survey, as shown in Figure 2-3 and Table 2-2. At these sample stations, it was specified that macrobenthic samples were to be taken but there was no requirement to obtain samples for Particle Size Distribution (PSD) analysis. At each of these stations, grab samples were collected for macrobenthic analysis using a 0.1m^2 Day Grab.

Table 2-2 Coordinates for each grab sample station. Coordinates are presented in the Ordnance Survey/British National Grid Projected Coordinate System format.

Grab sample station	Site code	X	Y
Station 1	G01	115793.66	899768.33
Station 2	G02	115826.98	899728.55
Station 3	G03	115892.46	899729.18
Station 4	G04	115844.14	899662.19

Whilst conducting the grab sampling, a minimum sediment volume limit of 5 litres was defined as an acceptable size for a grab sample to be considered successful. If this minimum volume was not obtained then a further two attempts were to be made at the same location, followed by three attempts at a different location at least 50m from the original target. The first two attempts at station 1 collected an insufficient volume due to the presence of cobbles causing incomplete closure of the grab's jaws. Furthermore, the first attempt at station 3 captured large debris but no sediments and so the sample was discarded. Subsequent attempts at both station 1 and station 3 successfully collected an appropriate sample.

For each grab attempt the following information was recorded on the survey log-sheet:

- Survey name, location and project code;
- Survey Date;
- Survey Team staff;
- Site information including: site/replicate, sample position (lat/lon; WGS84), collection time, water depth, weather conditions;
- Sampling equipment including sieve mesh size;
- Salinity for later use in the WFD IQI calculation
- Sample description, including sediment description, grab depth in cm, volume, type, profile, concretions, surface features, burrows, algae, colour and colour changes, smell, etc.;
- Any obvious or notable (e.g. Annex 2 species) taxa observed;
- Notes (e.g. anoxia, anthropogenic debris, any problems encountered, etc.);
- Photograph of the unsieved sample (an example is presented in Figure 2-4 below).

Figure 2-4 Unsieved grab sample from Station 3 in Tarbert Harbour (attempt 2).

Biological samples were sieved on board through a 1.0mm sieve as is standard for subtidal surveys in marine conditions. All material retained on the sieves was fixed with 4% buffered formaldehyde solution in seawater and stored in sealed crates.

2.2 Sample analysis

2.2.1 Macrobenthic analysis of grab samples

Samples were processed according APEM's in-house Standard Operating Procedures (SOP's) and in full compliance with North East Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) guidance (Worsfold and Hall, 2010). To standardise the sizes of organisms and improve sorting efficiency, samples were sieved through a stack of sieves of 4.0, 2.0 and 1.0 mm meshes in a fume cupboard following UKTAG guidance for benthic invertebrate sample analysis for coastal waters (WFD-UKTAG, 2014). All biota retained in the sieves were then extracted under low power microscopes, identified and enumerated, where applicable.

Taxa were identified to the lowest possible practicable taxonomic level using the appropriate taxonomic literature. For certain taxonomic groups (e.g. nemerteans and, nematodes), higher taxonomic levels were used due to the widely acknowledged lack of appropriate identification tools for these groups. The NMBAQC Scheme has produced a Taxonomic Discrimination Protocol (TDP) (Worsfold and Hall 2010) which gives guidance on the most appropriate level to which different marine taxa should be identified, and this guidance was adhered to for the laboratory analysis. Where required, specimens were also compared with material maintained within the laboratory reference collection. Nomenclature followed the World Register of Marine Species (WoRMS), except where more recent revisions were known to supersede WoRMS.

At least one example of each taxon recorded from the surveys was set aside for inclusion in APEM's in-house reference collection. This collection acts as a permanent record of the biota recorded.

2.2.2 Imagery analysis of underwater video capture

The underwater video was analysed by an experienced marine benthic taxonomist and image analyst to provide habitat/biotope extent and transition data and enable the identification of any small-scale habitats outside the subtidal grab sampling target habitats (such as rock outcrops). The video captures for each transect were re-played in the laboratory and the biotopes and notable taxa along each transect identified and recorded. The timing of the transitions between each habitat along the transects in the underwater video were also noted, and these were then related to the vessel position within the survey logs to identify the position of habitat transitions.

3. Results

3.1 Macrobenthic analysis data

The full suite of enumerated macrobenthic data from each grab sample is provided in Appendix 1. A summary of the prevailing conditions at the time of each macrobenthic grab sample is provided in Table 3-1 below, and the biotopes assigned to each grab sample are provided in Table 3-2. The most abundant species (> 100 individuals) were Polychaetes *Lumbrineris cingulata* agg. (n=166) and *Kurtiella bidentate* (n=118) recorded across stations 1 to 3; and *Capitella* (n=106) only recorded at station 4. Other species present in appreciable numbers included *Spirobranchus lamarcki* (n=43), *Melinna palmate* (n=42), *Nematoda* (n=32), *Mediomastus fragilis* (n=32), *Polycirrus* (n=23), *Leptochiton asellus* (n=20), *Dodecaceria* (n=19) and *Magelona alleni* (n=11).

Table 3-1 Prevailing water and depth conditions at the time of collection of each macrobenthic grab sample

Grab sample station	Collection time	Water depth (m)	Volume (l)	Salinity (ppm)
Station 1	9:37	9.3	5	26.17
Station 2	10:14	10.9	9	26.40
Station 3	10:51	11.6	8	26.66
Station 4	11:05	10.5	9	27.45

Table 3-2 Biotopes assigned to macrobenthic grab samples

Grab sample station	Biotope	Description
Station 1	SS.SMp.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments
Station 2	SS.SMp.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments.
Station 3	SS.SMp.KSwSS.LsacR.Mu	*Laminaria saccharina* with red and brown seaweeds on lower muddy mixed sediments.
Station 4	SS.SMu.IFiMu	Infralittoral fine mud.

3.2 Underwater video data

The full suite of habitat classification data for each transect is provided in Appendix 2. The biotopes found to be present in Tarbert Harbour, with example images of each biotope from the underwater video survey, are provided in Figures 3-1, 3-2, 3-3 and 3-4. The biotopes identified by the underwater video imagery have been mapped along each of the transect routes in Figure 3-5.

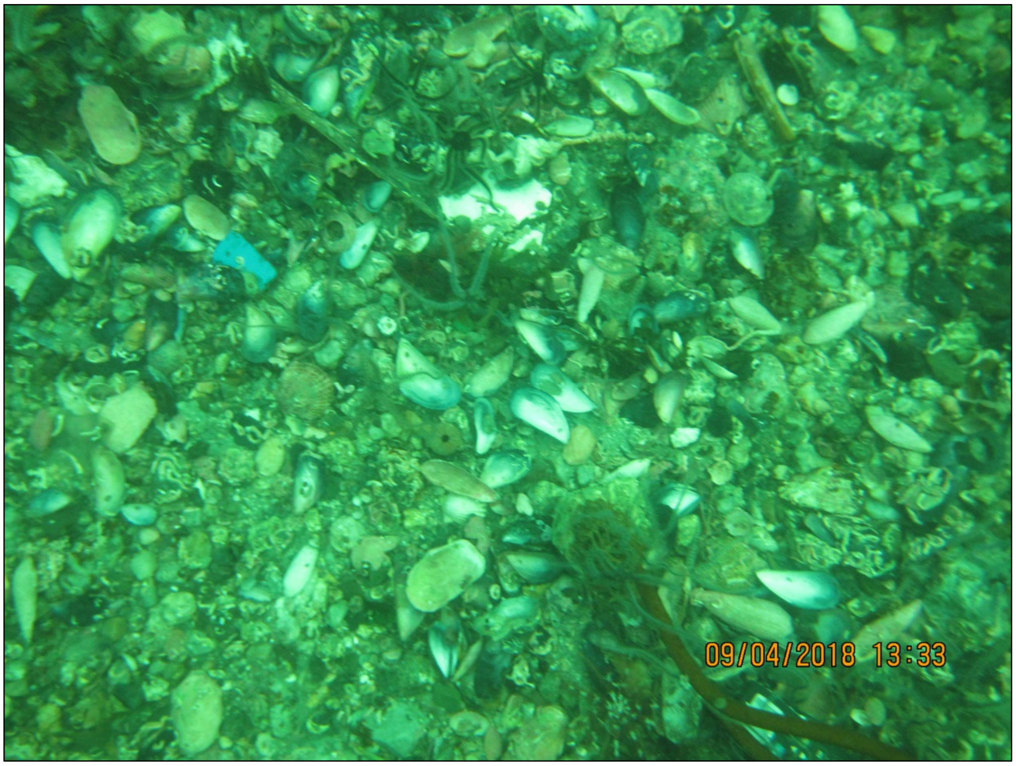

Figure 3-1 SS.SMx.CMx.OphMx: Ophiothrix fragilis andor Ophiocomina nigra brittlestar beds on sublittoral mixed sediment

Figure 3-2 SS.SMp.KSwSS.LsacR: Laminaria saccharina and red seaweeds on infralittoral sediments

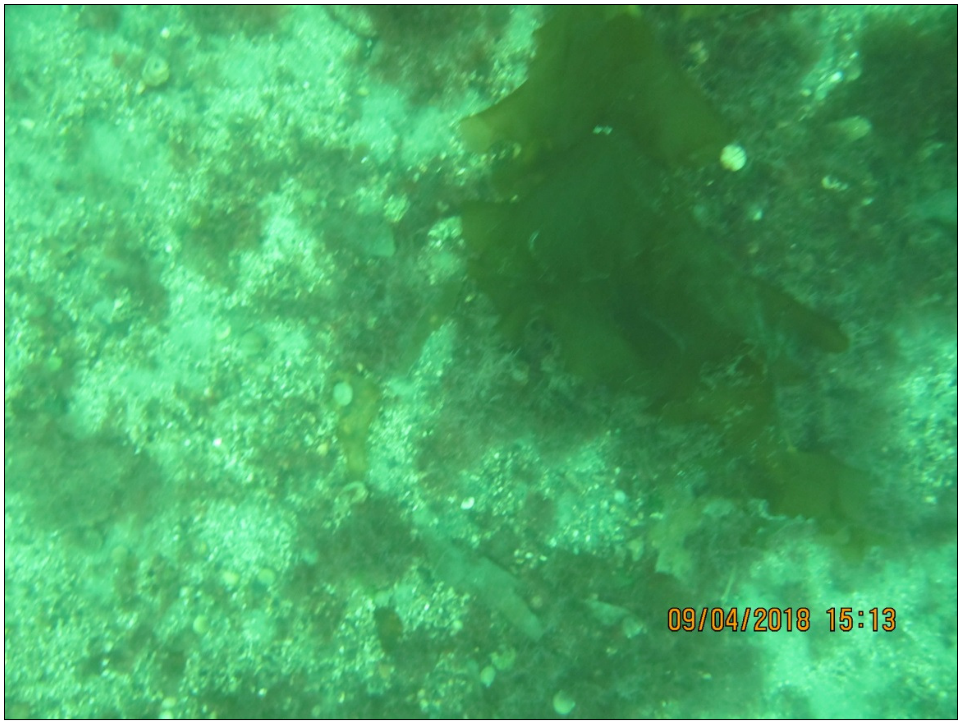

Figure 3-3 Transect 3- SS.SMp.KSwSS.LsacR.Mu: Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments

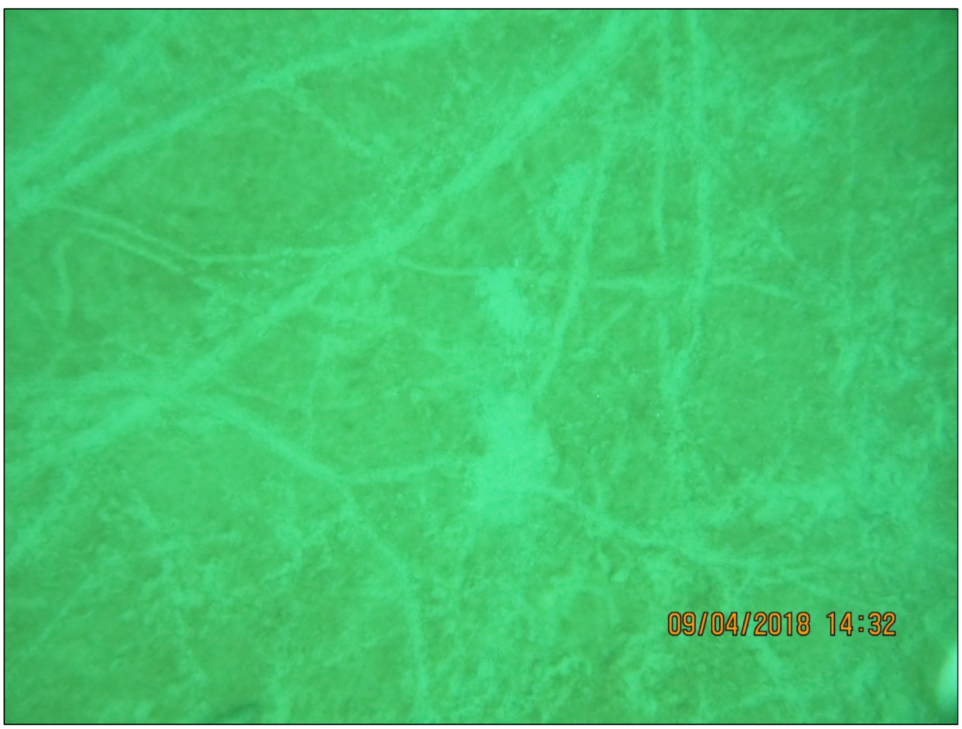

Figure 3-4 SS.SMu.IFiMu: Infralittoral fine mud

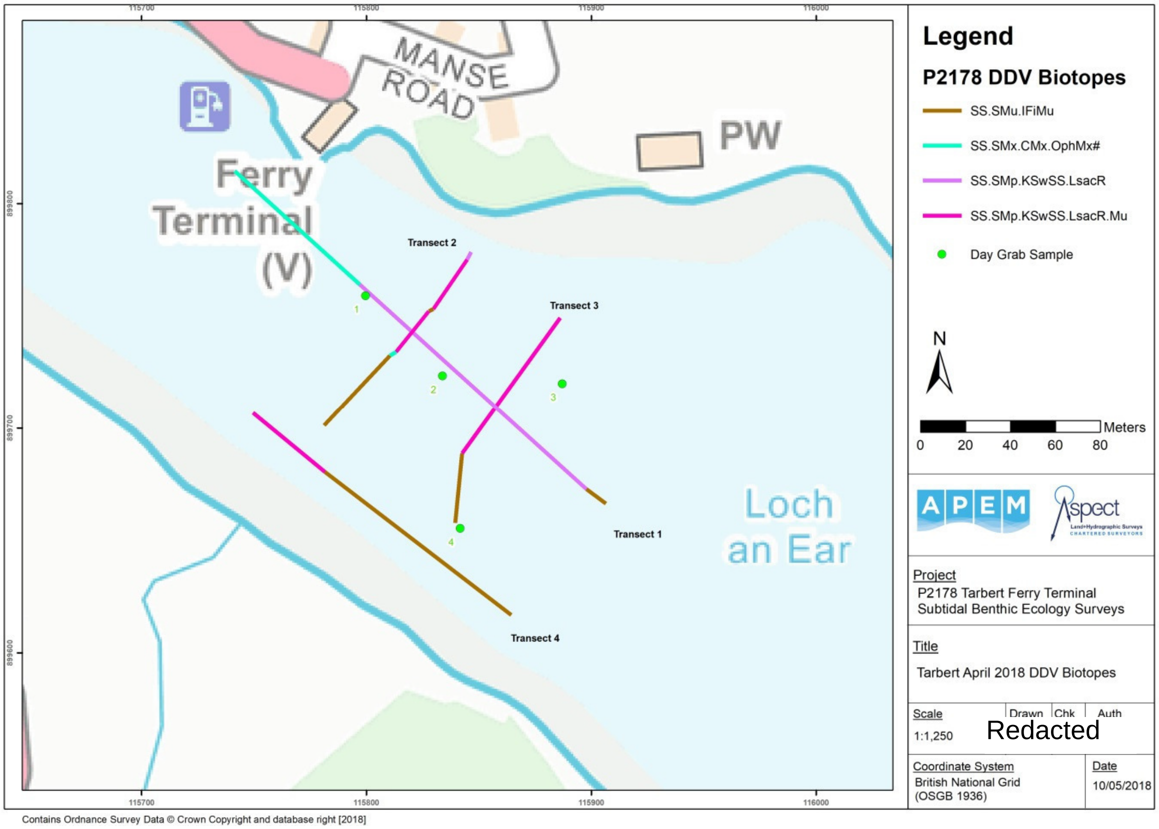

Figure 3-5 Transect routes with mapped biotopes overlaid

3.3 Tarbert Harbour biotope mapping

The macrobenthic count data and underwater video biotope classification data has been compiled to allocate biotopes to each point along the underwater video transects and at the grab sample stations. Biotopes were allocated following JNCC's National Marine Habitat Classification for Britain and Ireland: Version 04.05 (Connor *et al*. 2004). EUNIS codes corresponding to each biotope have also been provided (JNCC, 2010; Parry, 2015).

As the survey coverage across Tarbert Harbour has transects running both across and down the full extent of the survey area and at a representative range of depths, it has been possible to extrapolate between the known biotopes along the transects to provide a more complete biotope map of the harbour. This plan is shown in Figure 3-6. It is acknowledged that this is an extrapolation of the known data and so the biotope assignment away from the transects and grab sample locations is with a lower level of confidence to the biotope assignment at the grab sample stations and transects.

The biotope map presented in Figure 3-6 is an interpretive map based on an extrapolation of the raw data collected in the grab samples and along the underwater video transects, to delineate approximate habitat biotope boundaries within Tarbert Harbour. Following the approach set out by Saunders et al. (2011) the confidence in this biotope map would be enhanced by conducting a geophysical survey of the harbour to allow the grab sample point data and underwater video line data to act as reference points for the habitats in the rest of the harbour defined using the geophysical survey.

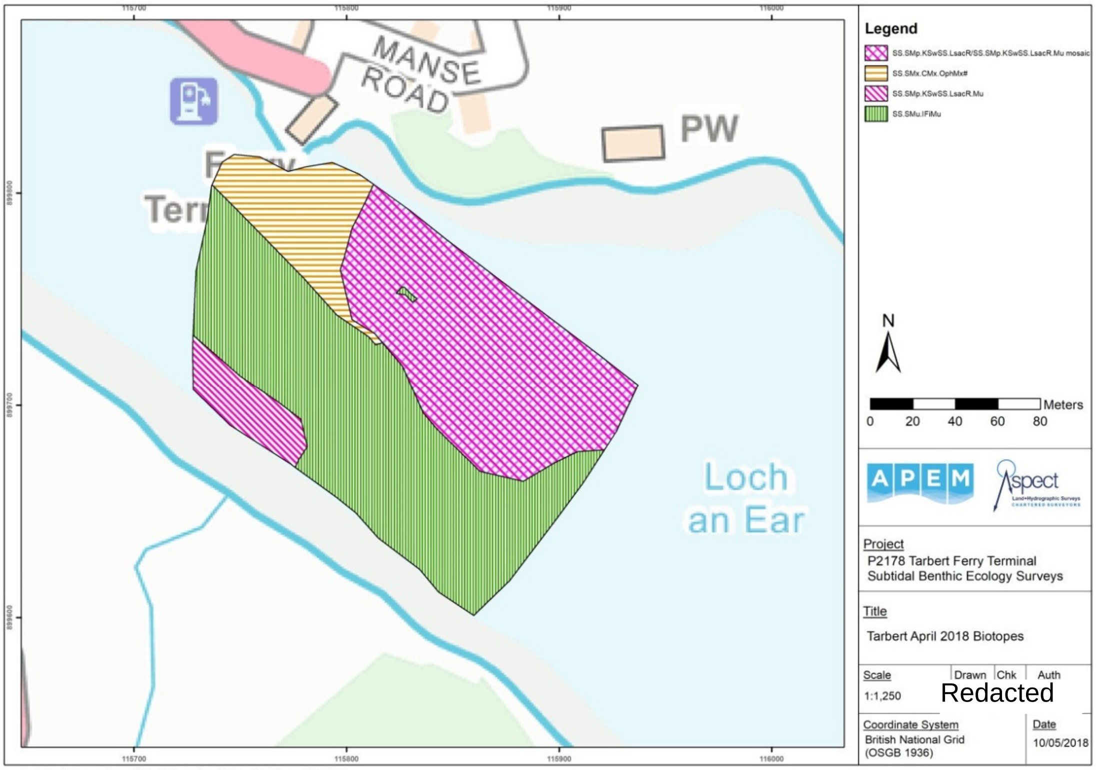

Figure 3-6 Tarbert Harbour mapped subtidal benthic biotopes (Biotope code references: SS.SMp.KSwSS.LsacR.Mu: *Laminaria saccharina* with red and brown seaweeds on lower muddy mixed sediments. SS.SMp.KSwSS.LsacR: *Laminaria saccharina* and red seaweeds on infralittoral sediments SS.SMx.CMx.OphMx: *Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment. SS.SMu.IFiMu: Infralittoral fine mud)

4. Conclusions

APEM's survey of the subtidal benthic ecological habitats and species present in Tarbert Harbour identified the following biotopes to be present on the seabed:

- **SS.SMx.CMx.OphMx:** Ophiothrix fragilis and/or Ophiocomina nigra brittlestar beds on sublittoral mixed sediment.
- **SS.SMp.KSwSS.LsacR**: Laminaria saccharina and red seaweeds on infralittoral sediments.
- **SS.SMp.KSwSS.LsacR.Mu:** Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments.
- **SS.SMu.IFiMu:** Infralittoral fine mud.

A full species list of individuals recorded within the grab samples in Tarbert Harbour is provided in Appendix 1.

Biotopes SS.SMp.KSwSS.LsacR and SS.SMp.KSwSS.LsacR.Mu fall under the Scottish Priority Marine Feature (PMF) 'Kelp and seaweed communities on sublittoral sediment', which encompasses all biotopes under SS.SMp.KSwSS apart from SS.SMp.KSwSS.Tra (Mats of *Trailliella* on infralittoral muddy gravel) and SS.SMp.KSwSS.FilG (Filamentous green seaweeds on low salinity infralittoral mixed sediment or rock).

None of the other biotopes or species identified are designated as Scottish Priority Marine Features (PMFs), or designated under the Conservation (Natural Habitats, &c.) Regulations 1994 and Conservation of Habitats and Species Regulations 2010.

A single *Sabellaria spinulosa* individual and single *Serpula vermicularis* individual were recorded at Station 3, but no evidence of reef habitat formed by these species was found during the survey. Three *Mytilus edulis* individuals were recorded in Station 1 and Station 3.

Within the genus of red algae *Gracilaria* found to be present at Station 1 and Station 3, there is the potential for invasive non-native species (INNS) to be present, including those listed by the GB non-native species secretariat (NNSS), *Gracilaria multipartite* and *Gracilaria vermiculophylla*.

5. References

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Appendix 1 Macrobenthic data from grab samples

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Marine Benthic Invertebrate Analysis Report

The analysis on adjacent tab(s) of this workbook has been carried out by APEM Ltd under method MINV-01.

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Issue Date:	09/05/2018	

If you have any comments or complaints regarding this or any other piece of work conducted by APEM Ltd, please contact Redacted

APEM Report No. P00002258a-v1

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Sample Number	Sample Date	Sample Method	Watercourse	Site Description	Analysis Type	Analysis Date	Analyst	QC Date	APEM location	Notes
61006	10/04/2018	Day Grab	Isle of Harris	St 1	1.0mm mesh	03/05/2018	Re	03/05/2018	Letchworth	-
61007	10/04/2018	Day Grab	Isle of Harris	St 2	1.0mm mesh	26/04/2018	Re	26/04/2018	Letchworth	-
61008	10/04/2018	Day Grab	Isle of Harris	St 3	1.0mm mesh	30/04/2018	Re	30/04/2018	Letchworth	-
61009	10/04/2018	Day Grab	Isle of Harris	St 4	1.0mm mesh	24/04/2018	Re	24/04/2018	Letchworth	-

APEM Report No. P00002258a-v1

Code	Taxa ID	Qualifiers	61006	61007	61008	61009
	Sample Number		61006	61007	61008	61009
	Sample Date		10/04/2018	10/04/2018	10/04/2018	10/04/2018
	Sample Method		Day Grab	Day Grab	Day Grab	Day Grab
	Watercourse		Isle of Harris	Isle of Harris	Isle of Harris	Isle of Harris
	Site Description		St 1	St 2	St 3	St 4
	Analysis Type		1.0mm mesh	1.0mm mesh	1.0mm mesh	1.0mm mesh
	Analysis Date		03/05/2018	26/04/2018	30/04/2018	24/04/2018
	Analyst		GBJ	RHS	RHS	RHS
A5050	Folliculinidae				P	
D0216	Filifera			P		
D0272	Hydractinia			P		
D0759	Edwardsiidae				8	
F0002	Turbellaria			1		
G0001	Nemertea		3	2	3	
G0039	Cerebratulus		2	2	5	
HD0001	Nematoda		23		9	
K0015	Loxosomella		P			
N0017	Golfingia vulgaris		1		1	
P0050	Malmgrenia darbouxi		3		2	
P0058	Harmothoe extenuata		2			
P0064	Harmothoe imbricata		1			
P0065	Harmothoe impar	aggregate			3	
P0092	Pholoe baltica (sensu Petersen)		3		3	1
P0151	Eulalia aurea				1	
P0167	Eumida sanguinea	aggregate	1		4	
P0174	Notophyllum foliosum		1			
P0176	Paranaitis kosteriensis		1			
P0256	Glycera alba		1		5	
P0260	Glycera lapidum	aggregate	4			
P0268	Glycinde nordmanni				1	
P0271	Goniada maculata			1	5	
P0305	Psamathe fusca		1		1	
P0311	Nereimyra punctata		1			
P0312	Oxydromus pallidus		2			
P0319	Podarkeopsis capensis				1	
P0358	Syllis armillaris	aggregate	1		2	
P0475	Eunereis longissima			2		
P0499	Nephtys hombergii					2
P0502	Nephtys kersivalensis				2	
P0574	Lumbrineris cingulata	aggregate	70	13	83	
P0638	Protodorvillea kefersteini		3			
P0664	Orbinia latreillii				1	
P0693	Levinsenia gracilis				1	
P0699	Paradoneis lyra				5	
P0719	Uncispio reesi			1		
P0722	Aonides oxycephala		1	3	5	
P0751	Dipolydora caulleryi	aggregate	1			
P0761	Dipolydora saintjosephi				3	
P0766	Aurospio banyulensis				1	
P0771	Pseudopolydora species A				3	
P0796	Spiophanes kroyeri				1	
P0804	Magelona alleni			1	10	
P0806	Magelona minuta				2	
P0840	Dodecaceria				19	
P0906	Capitella					106
P0919	Mediomastus fragilis		21	7	4	
P0923	Notomastus		1	1	3	
P1014	Ophelina acuminata					1
P1025	Scalibregma inflatum		3			
P1026	Scalibregma celticum		1			
P1117	Sabellaria spinulosa				1	
P1124	Melinna palmata			2	40	
P1139	Ampharete lindstroemi				7	
P1174	Terebellides		1		6	
P1182	Amphitrite cirrata				2	
P1217	Pista mediterranea		1			
P1235	Polycirrus		13		10	
P1268	Chone fauveli				1	
P1287	Jasmineira				2	
P1307	Perkinsiana rubra				1	
P1324	Serpulidae		1		6	
P1334	Hydroides norvegica				1	
P1340	Spirobranchus lamarcki		25	1	17	
P1343	Serpula vermicularis				1	
P1489	Tubificoides amplivasatus				1	
Q0044	Anoplodactylus petiolatus				1	
R0041	Verruca stroemia				6	
S0429	Ampelisca diadema				6	
S0503	Cheirocratus	female				1
S1419	Upogebia deltaura			1		
S1445	Paguridae	juvenile	1			
S1472	Galathea intermedia	juvenile			1	
W0053	Leptochiton asellus		19		1	
W0079	Lepidochitona cinerea		1			
W0081	Tonicella marmorea		1			
W0223	Testudinalia testudinalis		3			
W0330	Rissoa lilacina				1	
W0344	Alvania punctura				1	
W0371	Onoba semicostata				1	
W0376	Pusillina inconspicua				1	
W0377	Pusillina sarsii					1
W0708	Buccinum undatum	juvenile	2		1	
W0748	Tritia pygmaea			1		
W0861	Raphitoma linearis		1			
W1569	Nucula nitidosa		1			3
W1696	Mytilus edulis	juvenile	1		2	
W1708	Modiolula phaseolina				1	
W1805	Anomiidae	juvenile		1	1	
W1837	Thyasira flexuosa		1		3	3
W1906	Kurtiella bidentata		51	14	53	
W1942	Acanthocardia echinata				1	
W1951	Parvicardium pinnulatum		1			
W2006	Phaxas pellucidus				2	
W2059	Abra alba				3	1
W2061	Abra nitida					6
W2113	Polititapes rhomboides	juvenile	1			
W2147	Mya truncata		1			
W2147	Mya truncata	juvenile	4			
W2157	Corbula gibba		1		1	
W2166	Hiatella arctica				9	
W2181	Barnea candida	juvenile		2		
Y0153	Aetea				P	
ZB0148	Amphiuridae	juvenile				1
ZB0154	Amphiura filiformis				1	
ZB0161	Amphipholis squamata		1		1	
ZB0190	Camarodonta	juvenile			1	
ZB0193	Psammechinus miliaris	juvenile	1			
ZB0266	Cucumariidae	juvenile			1	
ZC0012	Enteropneusta				1	
ZD0120	Dendrodoa grossularia				2	
ZM0181	Rhodothamniella				P	
ZM0194	Corallinaceae				P	
ZM0406	Phyllophora				P	
ZM0431	Gracilaria		P		P	
ZM0443	Plocamium cartilagineum				P	
ZM0456	Lomentaria clavellosa				P	
ZM0471	Aglaothamnion				P	
ZM0507	Ceramium			P	P	
ZM0554	Pterothamnion plumula			P	P	
ZM0594	Delesseria sanguinea				P	
ZM0616	Phycodrys rubens				P	
ZM0628	Vertebrata byssoides				P	P
ZM0655	Polysiphonia			P	P	
ZR0288	Sphacelaria			P	P	
ZS0174	Ulva					P

APEM Report No. P00002258a-v1

Sample Number	Sample Date	Site Description	Biotope	Description	EUNIS
61006	10/04/2018	Grab St. 1	SS.SMp.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments	A5.521
61007	10/04/2018	Grab St. 2	SS.SMp.KSwSS.LsacR	*Laminaria saccharina* and red seaweeds on infralittoral sediments.	A5.521
61008	10/04/2018	Grab St. 3	SS.SMp.KSwSS.LsacR.Mu	*Laminaria saccharina* with red and brown seaweeds on lower muddy mixed sediments.	A5.5214
61009	10/04/2018	Grab St. 4	SS.Smu.IFiMu	Infralittoral fine mud.	A5.34

APEM Report No. P00002258a-v1

Code	Taxa ID	Qualifiers	Notes
P0319	Podarkeopsis capensis		Traditional usage; but possibly a related species;
P0719	Uncispio reesi		Rarely recorded;
P0771	Pseudopolydora species A		Undescribed species;
P0906	Capitella		Representative of organic enrichment;
P1117	Sabellaria spinulosa		Represents priority habitat, if reef-forming
P1182	Amphitrite cirrata		Possible undescribed species;
P1343	Serpula vermicularis		Represents priority habitat, if reef-forming
W0081	Tonicella marmorea		Northern species in UK;
W0223	Testudinalia testudinalis		Northern species in UK;
W0708	Buccinum undatum	juvenile	Commercially important;
W0748	Tritia pygmaea		Possibly close to northern limit of distribution;
W1696	Mytilus edulis	juvenile	Commercially important;
ZM0431	Gracilaria		May include non-native species;

Appendix 2 Underwater video analysis log

Station	Start time	End Time	Video track time	Start Lat	Start Long	End Lat	End Long	Assigned Biotope (MNCR Code)	Classification (Exact copy of MNCR descriptor)	Notes
Tr 1 - 2018-04-09_14.14.50_Biotope 1	14:15:11	14:16:04	00:00:53	5753.73875N	00647.77719W	5753.74192N	00647.78647W	SS.SMu.IFiMu	Infralittoral fine mud	
Tr 1 - 2018-04-09_14.14.50_Biotope 2	14:16:04	14:31:20	00:15:16	5753.74192N	00647.78647W	5753.78701N	00647.89454W	SS.SMp.KSwSS.LsacR	Laminaria saccharina and red seaweeds on infralittoral sediments	
Tr 1 - 2018-04-09_14.14.50_Biotope 3	14:31:20	14:37:56	00:06:36	5753.78701N	00647.89454W	5753.81198N	00647.95429W	poss. SS.SMx.CMx.OphMx	Ophiothrix fragilis and/or Ophiocomina nigra brittlestar beds on sublittoral mixed sediment	A small number of brittlestars seen in localised patches. Pebbles and cobbles have *Spirobranchus* tubes covering the surfaces and there is comparativley little algal growth.
Tr 2 - 2018-04-09_15.02.19_Biotope 1	15:02:39	15:03:09	00:00:30	5753.79666N	00647.84567W	5753.79479N	00647.84727W	SS.SMp.KSwSS.LsacR	Laminaria saccharina and red seaweeds on infralittoral sediments	Algal growth is dense (*Laminaria* and *Ulva*) and predominantly on boulders or hard substrata.
Tr 2 - 2018-04-09_15.02.19_Biotope 2	15:03:09	15:07:10	00:04:01	5753.79479N	00647.84727W	5753.78236N	00647.86088W	SS.SMp.KSwSS.LsacR.Mu	Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments	Algal growth is more sproradic with pebbles as attachment points or isolated boulders. Algae is often heavily silted with a greater proportion of the visible substrate being infralittoral mud.
Tr 2 - 2018-04-09_15.02.19_Biotope 3	15:07:10	15:07:22	00:00:12	5753.78236N	00647.86088W	5753.78183N	00647.86284W	SS.SMu.IFiMu	Infralittoral fine mud	
Tr 2 - 2018-04-09_15.02.19_Biotope 2	15:07:22	15:11:31	00:04:09	5753.78183N	00647.86284W	5753.77151N	00647.87614W	SS.SMp.KSwSS.LsacR.Mu	Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments	
Tr 2 - 2018-04-09_15.02.19_Biotope 4	15:11:31	15:15:31	00:04:00	5753.77151N	00647.87614W	5753.77055N	00647.87881W	poss. SS.SMx.CMx.OphMx	Ophiothrix fragilis and/or Ophiocomina nigra brittlestar beds on sublittoral mixed sediment	
Tr 2 - 2018-04-09_15.02.19_Biotope 3	15:15:31	15:23:15	00:07:44	5753.77055N	00647.87881W	5753.75268N	00647.90612W	SS.SMu.IFiMu	Infralittoral fine mud	
Tr 3 - 2018-04-09_15.53.24_Biotope 1	15:53:45	16:03:02	00:09:17	5753.73160N	00647.84421W	5753.74833N	00647.84328W	SS.SMu.IFiMu	Infralittoral fine mud	Targets: Boulder with macro algal growth 14:56:41.81, 15:00:39.79
Tr 3 - 2018-04-09_15.53.24_Biotope 2	16:03:02	16:15:25	00:12:23	5753.74833N	00647.84328W	5753.78247N	00647:80369W	SS.SMp.KSwSS.LsacR.Mu	Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments	
Tr 4 - 2018-04-09_15.29.27_Biotope 1	15:29:47	15:45:48	00:16:01	5753.71062N	00647.81608W	5753.74161N	00647.90422W	SS.SMu.IFiMu	Infralittoral fine mud	Aditional transect behind trot line.
Tr 4 - 2018-04-09_15.29.27_Biotope 2	15:45:48	15:48:25	00:02:37	5753.74161N	00647.90422W	5753.75448N	00647.93839W	SS.SMp.KSwSS.LsacR.Mu	Laminaria saccharina with red and brown seaweeds on lower muddy mixed sediments	

Appendix J.1: Baseline Noise Level Data

SLM015

CERTIFICATE OF CALIBRATION

Date of Issue: 25 January 2017

Certificate Number: TCRT17/1025

Page 1 of 2 Pages

Issued by:
ANV Measurement Systems
Beaufort Court
17 Roebuck Way
Milton Keynes MK5 8HL
Telephone 01908 642846 Fax 01908 642814
E-Mail: info@noise-and-vibration.co.uk
Web: www.noise-and-vibration.co.uk
Acoustics Noise and Vibration Ltd trading as ANV Measurement Systems

Approved Signatory
Redacted

Customer: TNEI Services Ltd
Milburn House
Dean Street
Newcastle Upon Tyne
NE1 1LE

Order No.: PO 5001

Description: Sound Level Meter / Pre-amp / Microphone / Associated Calibrator

Identification:

Manufacturer	*Instrument*	*Type*	*Serial No. / Version*
Rion	Sound Level Meter	NA-28	00680882
Rion	Firmware		2.0
Rion	Pre Amplifier	NH-23	80933
Rion	Microphone	UC-59	01056
Rion	Calibrator	NC-74	34762316
	Calibrator adaptor type if applicable		NC-74-002

Performance Class: 1

Test Procedure: TP 2.SLM 61672-3 TPS-49

Procedures from IEC 61672-3:2006 were used to perform the periodic tests.

Type Approved to IEC 61672-1:2002 Yes Approval Number 21.21/07.01

If YES above there is public evidence that the SLM has successfully completed the applicable pattern evaluation tests of IEC 61672-2:2003

Date Received: 23 January 2017 ANV Job No. TRAC17/01008

Date Calibrated: 25 January 2017

The sound level meter submitted for testing has successfully completed the class 1 periodic tests of IEC 61672-3:2006, for the environmental conditions under which the tests were performed. As public evidence was available, from an independent testing organisation responsible for approving the results of pattern evaluation tests performed in accordance with IEC 61672-2:2003, to demonstrate that the model of sound level meter fully conformed to the requirements in IEC 61672-1:2002, the sound level meter submitted for testing conforms to the class 1 requirements of IEC 61672-1:2002.

Previous Certificate	*Dated*	*Certificate No.*	*Laboratory*
	05 November 2015	TCRT15/1303	ANV Measurement Systems

Sound Level Meter Instruction manual and data used to adjust the sound levels indicated.

SLM instruction manual title	Sound Level Meter NA-28
SLM instruction manual ref / issue	06-11
SLM instruction manual source	Manufacturer
Internet download date if applicable	N/A
Case corrections available	Yes
Uncertainties of case corrections	Yes
Source of case data	Manufacturer
Wind screen corrections available	Yes
Uncertainties of wind screen corrections	Yes
Source of wind screen data	Manufacturer
Mic pressure to free field corrections	Yes
Uncertainties of Mic to F.F. corrections	Yes
Source of Mic to F.F. corrections	Manufacturer
Total expanded uncertainties within the requirements of IEC 61672-1:2002	Yes

Specified or equivalent Calibrator	Specified		
Customer or Lab Calibrator	Customers Calibrator		
Calibrator adaptor type if applicable	NC-74-002		
Calibrator cal. date	24 January 2017		
Calibrator cert. number	UCRT17/1033		
Calibrator cal cert issued by Lab	7623		
Calibrator SPL @ STP	94.02	dB	Calibration reference sound pressure level
Calibrator frequency	1002.52	Hz	Calibration check frequency
Reference level range	20 - 120	dB	

Accessories used or corrected for during calibration - Wind Shield
Note - if a pre-amp extension cable is listed then it was used between the SLM and the pre-amp.

Environmental conditions during tests	Start	End			
Temperature	23.31	23.32	±	0.20	°C
Humidity	36.0	35.5	±	3.00	%RH
Ambient Pressure	101.54	101.54	±	0.03	kPa

Response to associated Calibrator at the environmental conditions above.

Initial indicated level	94.0	dB	Adjusted indicated level	94.0	dB
The uncertainty of the associated calibrator supplied with the sound level meter ±				0.10	dB

Self Generated Noise — This test is currently not performed by this Lab.

Microphone installed (if requested by customer) = Less Than	N/A	dB	A Weighting
Uncertainty of the microphone installed self generated noise ±	N/A	dB	

Microphone replaced with electrical input device - UR = Under Range indicated

Weighting	A			C			Z		
	9.7	dB	UR	14.1	dB	UR	21.0	dB	UR

Uncertainty of the electrical self generated noise ±	0.12	dB

The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k=2, providing a coverage probability of approximately 95%. The uncertainty evaluation has been carried out in accordance with the Guide to the Expression of Uncertainty in Measurement published by ISO.

For the test of the frequency weightings as per paragraph 12. of IEC 61672-3:2006 the actual microphone free field response was used.

The acoustical frequency tests of a frequency weighting as per paragraph 11 of IEC 61672-3:2006 were carried out using an electrostatic actuator.

END

Calibrated by: Redacted

Additional Comments
None

Certificate of Calibration

Cirrus Research plc
dedicated to noise measurement

Equipment Details

Instrument Manufacturer	Cirrus Research plc
Instrument Type	CR:171B
Description	Sound Level Meter
Serial Number	G078532

Calibration Procedure

The instrument detailed above has been calibrated to the publish test and calibration data as detailed in the instrument hand book, using the techniques recommended in the latest revisions of the International Standards IEC 61672-1:2013, IEC 61672-1:2002, IEC 60651:1979, IEC 60804:2001, IEC 61260:1995, IEC 60942:2003, IEC 60942:1997, IEC 61252:1993, ANSI S1.4-1983, ANSI S1.11-1986 and ANSI S1.43-1997 where applicable.

Sound Level Meters: All Calibration procedures were carried out by substituting the microphone capsule with a suitable electrical signal, apart from the final acoustic calibration.

Calibration Traceability

The equipment detailed above was calibrated against the calibration laboratory standards held by Cirrus Research plc. These are traceable to International Standards {A.0.6}. The standards are:

Microphone Type	B&K 4192	Serial Number	1920791	Calibration Ref.	S6450
Pistonphone Type	B&K 4220	Serial Number	613843	Calibration Ref.	S6388

Redacted

Calibrated by

Calibration Date	26 September 2017
Calibration Certificate Number	252819

This Calibration Certificate is valid for 12 months from the date above.

Cirrus Research plc, Acoustic House, Bridlington Road, Hunmanby, North Yorkshire, YO14 0PH
Telephone: +44 (0) 1723 891655 Fax: +44 (0) 1723 891742
Email: sales@cirrusresearch.co.uk

Certificate of Calibration

Cirrus Research plc
dedicated to noise measurement

Certificate Number: **114121**

Date of Issue: **26 September 2017**

Microphone Capsule

Manufacturer: **Cirrus Research plc** Serial Number: **206546A**

Model Number: **MK:224**

Calibration Procedure

The microphone capsule detailed above has been calibrated to the published data as described in the operating manual of the associated sound level meter (where applicable).

The frequency response was measured using an electrostatic actuator in accordance with BS EN 61094-6:2005 with the free-field response derived via standard correction data traceable to the National Physical Laboratory, Middlesex, UK.

The absolute sensitivity at 1 kHz was measured using an acoustic calibrator conforming to IEC 60942:2003 Class 1.

Date of Calibration: **25 September 2017**

Open Circuit Sensitivity at 1 kHz: **54.7 mV/Pa** **-25.2 dB rel 1 V/Pa**

Environmental Conditions

Pressure: **101.50 kPa**

Temperature: **24.0 °C**

Humidity: **54.0 %**

Calibration Laboratory

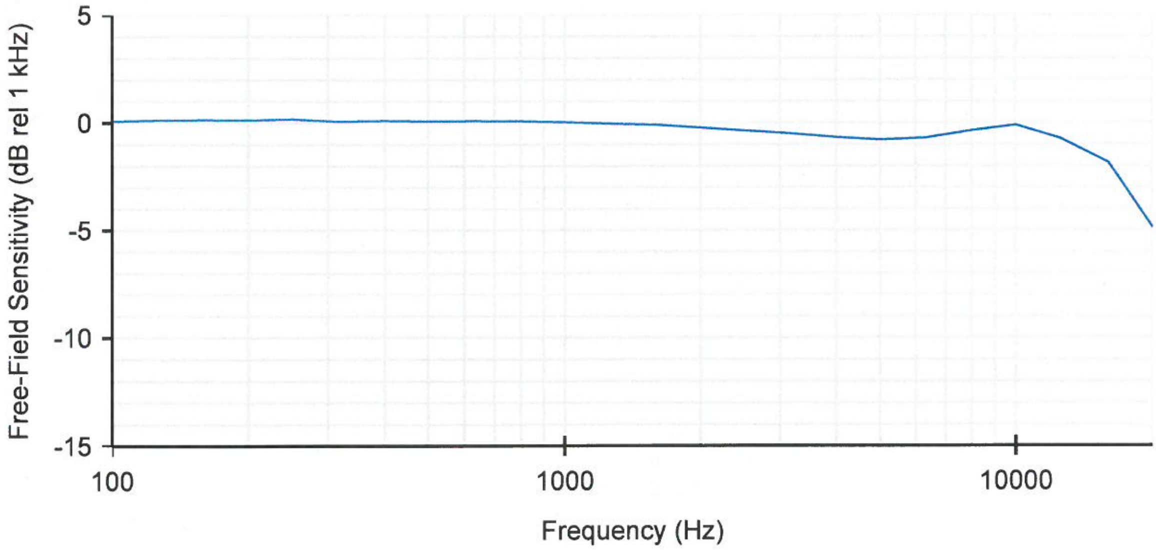
Laboratory: Cirrus Research plc
Acoustic House, Bridlington Road, Hunmanby
North Yorkshire, YO14 0PH, United Kingdom

Test Engineer: Redacted

Cirrus Research plc, Acoustic House, Bridlington Road
Hunmanby, North Yorkshire, YO14 0PH, United Kingdom
Telephone: 0845 230 2434 **Int**: +44 1723 891655
Email: sales@cirrusresearch.co.uk
Web: www.cirrusresearch.co.uk
UK Registration No. 987160

Free-Field Frequency Response

Frequency (Hz)	Free-Field Sensitivity (dB rel 1 kHz)	Actuator Response (dB)
100	0.07	0.19
125	0.11	0.21
160	0.11	0.22
200	0.11	0.23
250	0.15	0.25
315	0.05	0.15
400	0.07	0.16
500	0.05	0.14
630	0.06	0.12
800	0.05	0.08
1 000	0.00	0.02
1 250	-0.07	-0.09
1 600	-0.14	-0.22
2 000	-0.27	-0.45
2 500	-0.40	-0.74
3 150	-0.53	-1.15
4 000	-0.71	-1.70
5 000	-0.82	-2.32
6 300	-0.74	-3.00
8 000	-0.40	-3.72
10 000	-0.15	-5.00
12 500	-0.76	-6.93
16 000	-1.88	-9.72
20 000	-4.90	-13.98



Certificate of Calibration

Certificate Number: **114119**
Date of Issue: **26 September 2017**

Cirrus Research plc
dedicated to noise measurement

Instrument

Manufacturer: **Cirrus Research plc** Serial Number: **78219**
Model Number: **CR:515**

Calibration Procedure

The sound calibrator detailed above has been calibrated to the published data as described in the operating manual and in the half-inch configuration. The procedures and techniques used are as described in IEC 60942:2003 Annex B – Periodic Tests and three determinations of the sound pressure level, frequency and total distortion were made.

The sound pressure level was measured using a WS2F condenser microphone type MK:224 manufactured by Cirrus Research plc.

The results have been corrected to the reference pressure of 101.33 kPa using the manufacturer s data.

Date of Calibration: **26 September 2017**

Calibration Results

Measurement	Level (dB)	Frequency (Hz)	Distortion (% THD + Noise)
1	94.01	1000.3	0.31
2	94.00	1000.3	0.31
3	94.02	1000.3	0.31
Average	**94.01**	**1000.3**	**0.31**
Uncertainty	± 0.13	± 0.1	± 0.10

The reported uncertainties of measurement are expanded by a coverage factor of k=2, providing a 95% confidence level.

Cirrus Research plc, Acoustic House, Bridlington Road
Hunmanby, North Yorkshire, YO14 0PH, United Kingdom
Telephone: 0845 230 2434 **Int**: +44 1723 891655
Email: sales@cirrusresearch.co.uk
Web: www.cirrusresearch.co.uk
UK Registration No. 987160

bsi. ISO 9001 Quality Management ISO 14001 Environmental Management
FM 531001 EMS 552104

Environmental Conditions

Pressure:	**101.60 kPa**
Temperature:	**23.9 °C**
Humidity:	**52.2 %**

Evidence of Pattern Approval

The manufacturer's product information indicates that this model of sound calibrator has been formally pattern approved to IEC 60942:2003 Annex A to Class 1. This has been confirmed with the PhysikalischTechnische Bundesanstalt (PTB).

Statement of Calibration

As public evidence was available, from a testing organisation responsible for approving the results of pattern evaluation tests, to demonstrate that the model of sound calibrator fully conformed to the requirements for pattern evaluation described in Annex A of IEC 60942:2003, the sound calibrator tested is considered to conform to all the Class 1 requirements of IEC 60942:2003.

Calibration Laboratory

Laboratory: Cirrus Research plc
Acoustic House, Bridlington Road, Hunmanby
North Yorkshire, YO14 0PH, United Kingdom

Redacted
Test Engineer:

Appendix J.2: Construction Noise Assessment Data

Construction Phases							
Phase No.	Phase	Duration	Estimated Start	Estimated End	Proposed Working Hours	Plant Type	Make and Model
1	Reclaim Area up to Linkspan Approach	4 Weeks	07/05/2019	03/06/2019	12hrs / Day	Excavator	Volvo EC250EL
							JCB 220LC
						Dumper	Bell B30E
						Roller	Bomag BW 213DH
2	Construct RC Walls and Backfill	6 Weeks	04/06/2019	15/07/2019	12hrs / Day	Excavator	Volvo EC250EL
							JCB 220LC
						Dumper	Bell B30E
						Roller	Bomag BW 213DH
						Concrete Lorry	Hymix P2 Series
						Generator	Clarke FG5100ES 5.5kVA
3	Pontoon Relocation	2 Weeks	30/09/2019	11/10/2019	12hrs / Day	Work Boat	Multicat

Construction Phases							
Phase No.	Phase	Duration	Estimated Start	Estimated End	Proposed Working Hours	Plant Type	Make and Model
4	Dredging	10 Weeks	14/10/2019	20/12/2019	12hrs / Day	Dredger (THSD)	Sospan Dau
						Dredger (BHD)	Backhoe on Floating Platform
						Barge (SHB)	Frigg & Rind
						Excavator	JCB 220LC
5	Pontoon Reinstatement	2 Weeks	06/01/2020	17/01/2020	12hrs / Day	Work Boat	Multicat
6	Rock Armour/ Earthworks/ Services / Surfacing	25 Weeks	28/10/2019	05/05/2020	12hrs / Day	Excavator	Volvo EC250EL
							Sany SY335C
							JCB 220LC
						Dumper	Bell B30E
						Roller	Bomag BW 213DH
						Road Planer	Wirtgen W 150CFi
7	Establish Temporary Terminal Building	6 Weeks	16/07/2019	26/08/2019	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						60t Mobile Crane	LTM 1060-3.1

Construction Phases							
Phase No.	Phase	Duration	Estimated Start	Estimated End	Proposed Working Hours	Plant Type	Make and Model
8	Demolish Terminal Building	2 weeks	27/08/2019	09/09/2019	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Hand tools	Hand Held Circular Saw
						Dumper	Bell B30E
						Excavator	JCB 220LC
						60t Mobile Crane	LTM 1060-3.1
9	Install Temporary Pier Works	10 Weeks	10/09/2019	02/12/2019	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Excavator	JCB 220LC
						Work Boat	Multicat
						100t Crawler Crane	Kobelco CKE1100G
10	Pier Demolition	12 Weeks	10/09/2019	02/12/2019	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Excavator	JCB 220LC
						100t Crawler Crane	Kobelco CKE1100G

Construction Phases							
Phase No.	Phase	Duration	Estimated Start	Estimated End	Proposed Working Hours	Plant Type	Make and Model
11	Building Foundation - Piling and RC Slab	8 Weeks	05/11/2019	13/01/2020	12hrs / Day	Tube Vibro Hammer	PVE 40VM
						Tube Impact Hammer	BSP CG300
						Concrete Lorry	Hymix P2 Series
						Generator	Clarke FG5100ES 5.5kVA
						100t Crawler Crane	Kobelco CKE1100G
12	Pier Piling	16 Weeks	03/12/2019	06/04/2020	12hrs / Day	Tube Vibro Hammer	PVE 40VM
						Tube Impact Hammer	BSP CG300
						100t Crawler Crane	Kobelco CKE1100G
13	Pier Deck	20 Weeks	17/12/2019	20/05/2020	12hrs / Day	Concrete Lorry	Hymix P2 Series
						Generator	Clarke FG5100ES 5.5kVA
						Excavator	JCB 220LC
						100t Crawler Crane	Kobelco CKE1100G

Construction Phases							
Phase No.	Phase	Duration	Estimated Start	Estimated End	Proposed Working Hours	Plant Type	Make and Model
14	Fendering	4 Weeks	30/04/2020	27/05/2020	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Work Boat	Multicat
						100t Crawler Crane	Kobelco CKE1100G
15	Cathodic Protection	4 Weeks	07/05/2020	03/06/2020	12hrs / Day	Work Boat	Multicat
						Generator	Clarke FG5100ES 5.5kVA
						60t Mobile Crane	LTM 1060-3.1
16	Remove Temporary Pier Works	3 Weeks	14/05/2020	03/06/2020	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Excavator	JCB 220LC
						Work Boat	Multicat
						100t Crawler Crane	Kobelco CKE1100G
17	New Terminal Building Works	42 Weeks	23/07/2020	28/05/2021	12hrs / Day	Generator	Clarke FG5100ES 5.5kVA
						Excavator	JCB 220LC
						60t Mobile Crane	LTM 1060-3.1

	B	C	D	E	F	G
2–3	**Plant Used per Scenario**					
4	No.	**Phase**	**Plant Type**	**Make and Model**	**Number on Site**	**Estimated % on Time**
5	**Scenario 01: Placement of Rock Armour and Earthworks**					
6	6	**Rock Armour/ Earthworks/ Services / Surfacing**	Excavator	Volvo EC250EL	1	60
7				Sany SY335C	1	60
8				JCB 220LC	1	60
9			Dumper	Bell B30E	1	60
10			Roller	Bomag BW 213DH	1	20
11			Road Planer	Wirtgen W 150CFi	1	10
12	**Scenario 02: Demolition of the Terminal Building**					
13	8	**Demolish Terminal Building**	Generator	Clarke FG5100ES 5.5kVA	2	60
14			Hand tools	Hand Held Circular Saw	2	25
15			Dumper	Bell B30E	1	25
16			Excavator	JCB 220LC	1	20
17			60t Mobile Crane	LTM 1060-3.1	1	10

	B	C	D	E	F	G
2–3	**Plant Used per Scenario**					
4	No.	Phase	Plant Type	Make and Model	Number on Site	Estimated % on Time
18	**Scenario 03: Preliminary Pier Works plus Activities Within Marshalling Area and Dredging**					
19	4	**Dredging**	Dredger (THSD)	Sospan Dau	1	30
20			Dredger (BHD)	Backhoe on Floating Platform	1	50
21			Barge (SHB)	Frigg & Rind	1	50
22			Excavator	JCB 220LC	1	10
23	6	**Rock Armour/ Earthworks/ Services / Surfacing**	Excavator	Volvo EC250EL	1	60
24				Sany SY335C	1	60
25				JCB 220LC	1	60
26			Dumper	Bell B30E	1	60
27			Roller	Bomag BW 213DH	1	20
28			Road Planer	Wirtgen W 150CFi	1	10
29	9,10,11	**Install Temporary Pier Works**	Generator	Clarke FG5100ES 5.5kVA	1	100%
30			Excavator	JCB 220LC	1	50
31			Work Boat	Multicat	1	25
32			100t Crawler Crane	Kobelco CKE1100G	2	100
33		**Pier Demolition**	Tube Vibro Hammer	PVE 40VM	1	5
34		**Building Foundation - Piling and RC Slab**	Tube Impact Hammer	BSP CG300	1	5
35			Concrete Lorry	Hymix P2 Series	1	5

	B	C	D	E	F	G
2, 3	**Plant Used per Scenario**					
4	No.	**Phase**	**Plant Type**	**Make and Model**	**Number on Site**	**Estimated % on Time**
36	**Scenario 04: Terminal Building Construction plus Activities Within Marshalling Area and Dredging**					
37	4	**Dredging**	Dredger (THSD)	Sospan Dau	1	30
38			Dredger (BHD)	Backhoe on Floating Platform	1	50
39			Barge (SHB)	Frigg & Rind	1	50
40			Excavator	JCB 220LC	1	10
41	6	**Rock Armour/ Earthworks/ Services / Surfacing**	Excavator	Volvo EC250EL	1	60
42				Sany SY335C	1	60
43				JCB 220LC	1	60
44			Dumper	Bell B30E	1	60
45			Roller	Bomag BW 213DH	1	20
46			Road Planer	Wirtgen W 150CFi	1	10
47	11, 12, 13	**Building Foundation - Piling and RC Slab**	Drop Hammer Pile Rig Power Pack	BS5228-1 Annex C - C3.5	1	5
48			Hydraulic Hammer Rig	BS5228-1 Annex C - C3.3	1	5
49		**Pier Piling**	Concrete Lorry	Hymix P2 Series	1	15
50			Generator	Clarke FG5100ES 5.5kVA	1	10
51		**Pier Deck**	100t Crawler Crane	Kobelco CKE1100G	2	100
52			Excavator	JCB 220LC	1	10

	B	C	D	E	F	G
2 3	**Plant Used per Scenario**					
4	No.	**Phase**	**Plant Type**	**Make and Model**	**Number on Site**	**Estimated % on Time**
53	**Scenario 05: Pier Construction plus Activities Within Marshalling Area**					
54	6	**Rock Armour/ Earthworks/ Services / Surfacing**	Excavator	Volvo EC250EL	1	60
55				Sany SY335C	1	60
56				JCB 220LC	1	60
57			Dumper	Bell B30E	1	60
58			Roller	Bomag BW 213DH	1	20
59			Road Planer	Wirtgen W 150CFi	1	10
60	11, 12, 13	**Piling and RC Slab**	Drop Hammer Pile Rig Power Pack	BS5228-1 Annex C - C3.5	1	5
61			Hydraulic Hammer Rig	BS5228-1 Annex C - C3.3	1	5
62		**Pier Piling**	Concrete Lorry	Hymix P2 Series	1	15
63			Generator	Clarke FG5100ES 5.5kVA	1	10
64		**Pier Deck**	100t Crawler Crane	Kobelco CKE1100G	2	100
65			Excavator	JCB 220LC	1	10

	B	C	D	E	F	G
2 3	**Plant Used per Scenario**					
4	No.	**Phase**	**Plant Type**	**Make and Model**	**Number on Site**	**Estimated % on Time**
66	**Scenario 06: Completion of Pier Works plus Activities Within Marshalling Area**					
67	6	**Rock Armour/ Earthworks/ Services / Surfacing**	Excavator	Volvo EC250EL	1	60
68				Sany SY335C	1	60
69				JCB 220LC	1	60
70			Dumper	Bell B30E	1	60
71			Roller	Bomag BW 213DH	1	20
72			Road Planer	Wirtgen W 150CFi	1	10
73	13,14,15,16	**Pier Deck**	Concrete Lorry	Hymix P2 Series	1	10
74		**Fendering**	Generator	Clarke FG5100ES 5.5kVA	2	80
75		**Cathodic Protection**	Excavator	JCB 220LC	1	60
76		**Remove Temporary Pier Works**	100t Crawler Crane	Kobelco CKE1100G	2	65
77			Work Boat	Multicat	1	100
78			60t Mobile Crane	LTM 1060-3.1	1	10

Noise Source Library used within Noise Model															
Name	ID	Type	Octave Spectrum (dB)										A	lin	Source
			Weight.	31.5	63	125	250	500	1000	2000	4000	8000			
Tracked excavator Volvo EC250EL	C2.3	Lw (c)			105.1	108.1	101.1	98.1	97.1	95.1	94.1	91.1	103	111.1	BS 5228-1:2009+A1:2014: Annex C
Tracked Excavator Sany 335C	C2.15	Lw (c)			105	113	98	101	98	96	91	85	104	114.2	BS 5228-1:2009+A1:2014: Annex C
Articulated Dump Truck (tipping fill) Bell B30E	C2.32	Lw (c)			108	104	101	98	97	94	91	86	102	110.6	BS 5228-1:2009+A1:2014: Annex C
Lorry Rock armour delivery Lorry	C2.34	Lw (c)			101	106	106	106	102	101	96	94	108.1	112.2	BS 5228-1:2009+A1:2014: Annex C
Roller Bomag BW 213DH	C2.38	Lw (c)			108	103	105	100	95	90	82	74	101.6	111.1	BS 5228-1:2009+A1:2014: Annex C
Diesel generator Clarke 5100	C.4.76	Lw (c)			115.6	109.6	92.6	89.6	88.6	83.6	80.6	72.6	97	116.6	BS 5228-1:2009+A1:2014: Annex C
Tug Boat Multicat	TUG01	Lw	A					87					87	90.2	Aberdeen Harbour Expansion ES App. 20 d
Mobile telescopic crane Liebherr LTM 1060-3.1	C.4.45	Lw (c)			118	109	106	102	105	104	97	89	109.4	119.2	BS 5228-1:2009+A1:2014: Annex C
Hydraulic Hammer Rig	C3.3	Lw (c)			118	124	116	118	114	111	106	103	119.5	126.6	BS 5228-1:2009+A1:2014: Annex C
Drop Hammer Pile Rig Power Pack	C3.5	Lw (c)			107	93	88	87	94	91	81	74	96.8	107.6	BS 5228-1:2009+A1:2014: Annex C
Tracked mobile crane Kobelco CKE1100G	C.3.28	Lw (c)			109	105	94	90	87	85	79	74	94.5	110.6	BS 5228-1:2009+A1:2014: Annex C
Tracked excavator JCB220LC	C2.3b	Lw (c)			108	111	104	101	100	98	97	94	105.9	114	BS 5228-1:2009+A1:2014: Annex C
Road Planer Wirtgen W 150CFi	C5.7	Lw (c)			109	115	107	105	105	102	98	95	109.7	117.3	BS 5228-1:2009+A1:2014: Annex C
Suction Dredger Vessel	SDV01	Lw	A					99.9					99.9	103.1	Internoise_2010_Rob_Witte_Noise_from_moored_ships
Hand-held circular saw (petrol-cutting concrete blocks)	C4.72	Lw (c)		28	97	103	105	102	99	98	102	97	107.2	110.3	BS 5228-1:2009+A1:2014: Annex C
Sand Pump Output	SPO01	Lw		51.9	63.3	70.9	78.9	91.9	98.9	94.9	85.9	74.9	101.1		SET-T Module (Spec taken from Boskalis Argonaut dredger)
Jet Pump Output	JPO01	Lw		49.7	61.1	68.7	76.7	89.7	96.7	92.7	83.7	72.7	98.9		SET-T Module (Spec taken from Boskalis Argonaut dredger)
Pump Ashore Output	PAO01	Lw		56.5	67.9	75.5	83.5	96.5	103.5	99.5	90.5	79.5	105.8		SET-T Module (Spec taken from Boskalis Argonaut dredger)

Modelling Scenario 1								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates X (m)	Coordinates Y (m)
Bell B30E	!0201!DUMP01	102	Lw	C2.32	432	1.5	115636.7	899888.4
Volvo EC250EL	!0201!EXCAV01	103	Lw	C2.3	432	1.5	115636.9	899890.4
Sany SY335C	!0201!EXCAV02	104	Lw	C2.15	432	1.5	115725.6	899870.2
JCB 220LC	!0201!EXCAV03	105.9	Lw	C2.3b	432	1.5	115665.3	899897.8
Wirtgen W 150CFi	!0201!PLANER01	109.7	Lw	C5.7	72	1.5	115661.4	899899.1
Bomag BW 213DH	!0201!ROLL01	101.6	Lw	C2.38	144	1.5	115599.9	899904.7

Modelling Scenario 2								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates X (m)	Coordinates Y (m)
LTM 1060-3.1	!0202!CRANE01	109.4	Lw	C.4.45	72	1.5	115794.5	899848.8
Bell B30E	!0202!DUMP02	102	Lw	C2.32	180	1.5	115796.1	899850.8
JCB 220LC	!0202!EXCAV04	105.9	Lw	C2.3b	144	1.5	115792.4	899850.4
Clarke FG5100ES	!0202!GEN01	97	Lw	C.4.76	432	0.5	115794.3	899852.5
Hand Tools	!0202!HT01	107.2	Lw	C4.72	180	1.5	115794.5	899850.5
Hand Tools	!0202!HT02	107.2	Lw	C4.72	180	1.5	115794.0	899851.0

Modelling Scenario 3								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates X (m)	Coordinates Y (m)
Floating Platform (Backhoe Dredger)	!0203!BHD01	87	Lw	TUG01	360	1.5	115636.38	899841.05
Excavator (Backhoe Dredger)	!0203!BHD02	105.9	Lw	C2.3b	72	1.5	115637.07	899840.73
Kobelco CKE1100G	!0203!CRANE02	94.5	Lw	C.3.28	720	1.5	115803.49	899798.53
Bell B30E	!0203!DUMP03	102	Lw	C2.32	432	1.5	115636.74	899888.37
Volvo EC250EL	!0203!EXCAV05	103	Lw	C2.3	432	1.5	115636.94	899890.39
Sany SY335C	!0203!EXCAV06	104	Lw	C2.15	432	1.5	115725.44	899870.13
JCB 220LC	!0203!EXCAV07	105.9	Lw	C2.3b	432	1.5	115665.07	899897.72
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115774.37	899826.12
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115775.91	899824.7
Impact Hammer	!0203!IMPHAM01	119.5	Lw	C3.3	36	3.5	115787.07	899838.64
Impact Hammer Power Pack	!0203!IMPP01	96.8	Lw	C3.5	36	1.5	115787.21	899835.17
Hymix P2 Series	!0203!LORRY01	108.1	Lw	C2.34	36	1.5	115787.7	899843.44
Wirtgen W 150CFi	!0203!PLANER02	109.7	Lw	C5.7	72	1.5	115661.31	899899.05
Bomag BW 213DH	!0203!ROLL02	101.6	Lw	C2.38	144	1.5	115600.03	899904.66

Modelling Scenario 3								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates X (m)	Coordinates Y (m)
Sospan Dau (Engine)	!0203!SD01	99.9	Lw	SDV01	216	1.5	115638.07	899843.17
Sospan Dau (Sand Pump)	!0203!SD02	101.1	Lw	SPO01	216	1.5	115637.01	899843.03
Sospan Dau (Jet Pump)	!0203!SD03	98.9	Lw	JPO01	216	1.5	115637.81	899842.72
Sospan Dau (Pump Ashore)	!0203!SD04	105.8	Lw	PAO01	216	1.5	115638.54	899842.41
Work Boat	!0203!WB01	87	Lw	TUG01	180	1.5	115807.44	899803.91
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115789.2	899835.15
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115805.08	899797.2
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115801.2	899800.04
Kobelco CKE1100G	!0203!CRANE02	94.5	Lw	C.3.28	720	1.5	115777.74	899840.83
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115806.1	899796.08
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115807.63	899794.65
Floating Platform (Backhoe Dredger)	!0203!BHD01	87	Lw	TUG01	360	1.5	115636.38	899841.05
Excavator (Backhoe Dredger)	!0203!BHD02	105.9	Lw	C2.3b	72	1.5	115637.07	899840.73

Modelling Scenario 3								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
Kobelco CKE1100G	!0203!CRANE02	94.5	Lw	C.3.28	720	1.5	115803.49	899798.53
Bell B30E	!0203!DUMP03	102	Lw	C2.32	432	1.5	115636.74	899888.37
Volvo EC250EL	!0203!EXCAV05	103	Lw	C2.3	432	1.5	115636.94	899890.39
Sany SY335C	!0203!EXCAV06	104	Lw	C2.15	432	1.5	115725.44	899870.13
JCB 220LC	!0203!EXCAV07	105.9	Lw	C2.3b	432	1.5	115665.07	899897.72
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115774.37	899826.12
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115775.91	899824.7
Impact Hammer	!0203!IMPHAM01	119.5	Lw	C3.3	36	3.5	115787.07	899838.64
Impact Hammer Power Pack	!0203!IMPP01	96.8	Lw	C3.5	36	1.5	115787.21	899835.17
Hymix P2 Series	!0203!LORRY01	108.1	Lw	C2.34	36	1.5	115787.7	899843.44
Wirtgen W 150CFi	!0203!PLANER02	109.7	Lw	C5.7	72	1.5	115661.31	899899.05
Bomag BW 213DH	!0203!ROLL02	101.6	Lw	C2.38	144	1.5	115600.03	899904.66
Sospan Dau (Engine)	!0203!SD01	99.9	Lw	SDV01	216	1.5	115638.07	899843.17

Modelling Scenario 3								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
Sospan Dau (Sand Pump)	!0203!SD02	101.1	Lw	SPO01	216	1.5	115637.01	899843.03
Sospan Dau (Jet Pump)	!0203!SD03	98.9	Lw	JPO01	216	1.5	115637.81	899842.72
Sospan Dau (Pump Ashore)	!0203!SD04	105.8	Lw	PAO01	216	1.5	115638.54	899842.41
Work Boat	!0203!WB01	87	Lw	TUG01	180	1.5	115807.44	899803.91
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115789.2	899835.15
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115805.08	899797.2
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115801.2	899800.04
Kobelco CKE1100G	!0203!CRANE02	94.5	Lw	C.3.28	720	1.5	115777.74	899840.83
JCB 220LC	!0203!EXCAV08	105.9	Lw	C2.3b	360	1.5	115806.1	899796.08
Clarke FG5100ES	!0203!GEN02	97	Lw	C.4.76	72	0.5	115807.63	899794.65

Modelling Scenario 4								
Name	ID	(dBA)	Type	SWL ID	Operating Time	Height	Coordinates	
							X	Y
					(min)	(m)	(m)	(m)
Excavator (Backhoe Dredger)	!0204!BHD03	105.9	Lw	C2.3b	72	1.5	115637.07	899840.73
Floating Platform (Backhoe Dredger)	!0204!BHD04	87	Lw	TUG01	360	1.5	115636.38	899841.05
Kobelco CKE1100G	!0204!CRANE03	94.5	Lw	C.3.28	720	2.5	115781.83	899826.7
Bell B30E	!0204!DUMP04	102	Lw	C2.32	432	1.5	115636.74	899888.37
JCB 220LC	!0204!EXCAV09	105.9	Lw	C2.3b	360	1.5	115772.36	899830.63
Sany SY335C	!0204!EXCAV11	104	Lw	C2.15	432	1.5	115725.12	899870.34
Volvo EC250EL	!0204!EXCAV12	103	Lw	C2.3	432	1.5	115636.94	899890.39
Clarke FG5100ES	!0204!GEN03	97	Lw	C.4.76	72	0.5	115770.72	899830.05
Impact Hammer	!0204!IMPHAM02	119.5	Lw	C3.3	36	3.5	115777.36	899824.77
Impact Hammer Power Pack	!0204!IMPP02	96.8	Lw	C3.5	36	1.5	115777.84	899823.05
Hymix P2 Series	!0204!LORRY02	108.1	Lw	C2.34	36	1.5	115774.66	899831.23
Wirtgen W 150CFi	!0204!PLANER03	109.7	Lw	C5.7	72	1.5	115660.99	899899.16
Bomag BW 213DH	!0204!ROLL03	101.6	Lw	C2.38	144	1.5	115600.03	899904.35
Sospan Dau (Pump Ashore)	!0204!SD05	105.8	Lw	PAO01	216	1.5	115638.54	899842.41

Modelling Scenario 4								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
Sospan Dau (Jet Pump)	!0204!SD06	98.9	Lw	JPO01	216	1.5	115637.81	899842.72
Sospan Dau (Sand Pump)	!0204!SD07	101.1	Lw	SPO01	216	1.5	115637.01	899843.03
Sospan Dau (Engine)	!0204!SD08	99.9	Lw	SDV01	216	1.5	115638.07	899843.17

Modelling Scenario 5								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
JCB 220LC	!0205!EXCAV10	105.9	Lw	C2.3b	432	1.5	115665.07	899897.61
Kobelco CKE1100G	!0205!CRANE03	94.5	Lw	C.3.28	720	3	115812.98	899798.91
JCB 220LC	!0205!EXCAV09	105.9	Lw	C2.3b	360	1.5	115803.67	899796.91
Clarke FG5100ES	!0205!GEN03	97	Lw	C.4.76	72	0.5	115800.7	899792.73
Impact Hammer	!0205!IMPHAM02	119.5	Lw	C3.3	36	3.5	115809.09	899794.73
Impact Hammer Power Pack	!0205!IMPP02	96.8	Lw	C3.5	36	1.5	115809.57	899793
Hymix P2 Series	!0205!LORRY02	108.1	Lw	C2.34	36	1.5	115801.71	899795.92
Sany SY335C	!0205!EXCAV11	104	Lw	C2.15	432	1.5	115725.12	899870.24
Bomag BW 213DH	!0205!ROLL04	101.6	Lw	C2.38	144	1.5	115600.03	899904.24
Wirtgen W 150CFi	!0205!PLANER04	109.7	Lw	C5.7	72	1.5	115661.31	899898.95
Volvo EC250EL	!0205!EXCAV13	103	Lw	C2.3	432	1.5	115636.94	899890.39
Bell B30E	!0205!DUMP05	102	Lw	C2.32	432	1.5	115636.74	899888.37

Modelling Scenario 6								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
LTM 1060-3.1	!0206!CRANE	109.4	Lw	C.4.45	36	1.5	115793.25	899808.64
Kobelco CKE1100G	!0206!CRANE02	94.5	Lw	C.3.28	720	1.5	115810.05	899794.97
Bell B30E	!0206!DUMP05	102	Lw	C2.32	432	1.5	115636.74	899888.37
JCB 220LC	!0206!EXCAV08	105.9	Lw	C2.3b	360	1.5	115807.9	899796.17
JCB 220LC	!0206!EXCAV11	105.9	Lw	C2.3b	432	1.5	115665.07	899897.72
Sany SY335C	!0206!EXCAV12	104	Lw	C2.15	432	1.5	115724.91	899870.34
Volvo EC250EL	!0206!EXCAV13	103	Lw	C2.3	432	1.5	115636.94	899890.39
Clarke FG5100ES	!0206!GEN02	97	Lw	C.4.76	72	0.5	115773.09	899823.31
Hymix P2 Series	!0206!LORRY01	108.1	Lw	C2.34	36	1.5	115774.69	899822.03
Wirtgen W 150CFi	!0206!PLANER04	109.7	Lw	C5.7	72	1.5	115661.31	899898.95
Bomag BW 213DH	!0206!ROLL04	101.6	Lw	C2.38	144	1.5	115600.03	899904.24
Work Boat	!0206!WB01	87	Lw	TUG01	180	1.5	115800.59	899782.95
Kobelco CKE1100G	!0206!CRANE02	94.5	Lw	C.3.28	720	1.5	115777.66	899840.83
Clarke FG5100ES	!0206!GEN02	97	Lw	C.4.76	72	0.5	115792.6	899807.85

Modelling Scenario 6								
Name	ID	(dBA)	Type	SWL ID	Operating Time (min)	Height (m)	Coordinates	
							X (m)	Y (m)
Clarke FG5100ES	!0206!GEN02	97	Lw	C.4.76	72	0.5	115808.65	899797.44

Appendix K.1: Underwater Noise Technical Report

Submitted to:

Redacted
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Lochview Office
Loch Duntelchaig
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Inverness
IV2 6AW

Redacted

Redac Redacted
Website: www.affriclimited.co.uk

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Underwater noise propagation modelling at the Tarbert ferry terminal, Isle of Harris, Scotland

Redacted

11th October 2018

Subacoustech Environmental Report No. P220R1103

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P220R1101	*10/01/2018*	Redacted	Redac	Redacted
P220R1102	*10/09/2018*	Redacted	Redac	Redacted
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1 Introduction

Subacoustech Environmental have been instructed by Affric Limited to undertake acoustic propagation modelling for impact piling and other related noise-making operations linked to the proposed upgrade at the Tarbert ferry terminal.

The purpose of the modelling is to estimate the received sound pressure levels in the region, with particular concern for the impacts on marine mammals and fish. This report has been prepared by Subacoustech Environmental Ltd for Affric and presents the results and findings of the modelling assessment.

1.1 Survey area

Figure 1-1 details the Tarbert ferry terminal site on the south-east coast of the Isle of Harris, Scotland. As the area of operational activity for the works is relatively small, a single representative modelling location has been selected (approximate coordinates: 57.8968°N, 006.7986°W), this is shown by the red marker in the figure below.

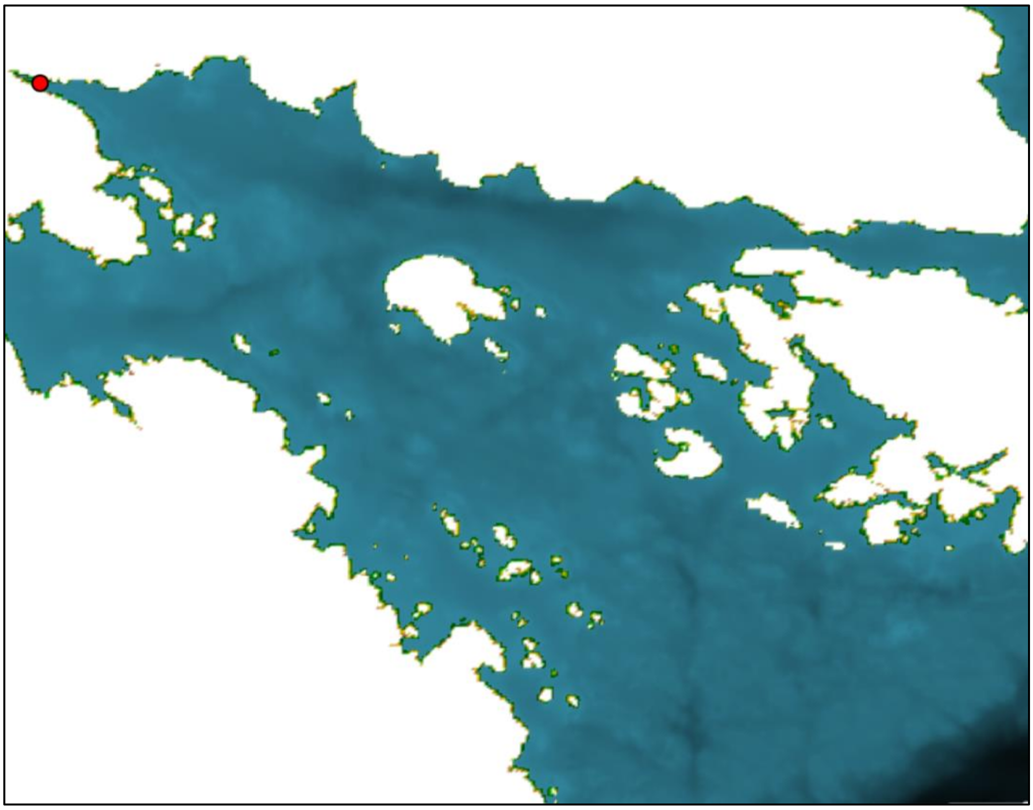

Figure 1-1 Image showing the location of Tarbert ferry terminal and the surrounding bathymetry (bathymetry supplied by Find Mapping Ltd - © British Crown and OceanWise, 2017. All rights reserved. Not to be used for Navigation.)

1.2 Impact piling

Three types of pile are expected to be installed at the ferry terminal; fender piles measuring 762 mm and 910 mm in diameter, bearing/raking piles measuring 610 mm in diameter, and temporary works piles measuring approximately 508 mm in diameter. The piles will be installed using a hammer such as a BSP CX hydraulic piling hammer with expected blow energies of between 50 and 150 kJ. The 34 temporary works piles are expected to be installed over a period of 1 month, and 12 fender piles and 51 bearing/raking piles are expected to be installed within a further month. It is expected that each pile should take between 30 minutes and 1 hour to install depending on conditions.

1.3 Other noise sources

In addition to impact piling, there is the possibility of using vibratory hammer (vibro piling) to install the piles. Rock breaking using a machine mounted pecker is also being considered for removal of rocks. The activities have been considered using a high-level, simple modelling approach based on a conservative worst case.

Backhoe dredging and vessel movements are also expected during the terminal upgrades, however due to the low level of noise from these activities, they have only been assessed qualitatively.

1.4 Assessment overview

This report presents a detailed assessment of the potential underwater noise from works at the Tarbert ferry terminal and covers the following:

- Review of background information on the units for measuring and assessing underwater noise
- Discussion of the approach, input parameters and assumptions for the noise modelling undertaken;
- Presentation of detailed subsea noise modelling using unweighted metrics and interpretation of the results using suitable noise metrics and criteria; and
- Summary and conclusions

2 Measurement of underwater noise

Sound travels much faster in water (approximately 1,500 ms^{-1}) than in air (340 ms^{-1}). Since water is a relatively incompressible, dense medium, the pressures associated with underwater sound tend to be much higher than in air. As an example, background levels of sea noise of approximately 130 dB re 1 µPa for UK coastal waters are not uncommon (Nedwell *et al*, 2003 and 2007). This level equates to about 100 dB re 20 µPa in the units that would be used to describe a sound level in air.

2.1 Units of measurement

Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound. A logarithmic scale is used because rather than equal increments of sound having an equal increase in effect, typically a constant ratio is required for this to be the case. That is, each doubling of sound level will cause a roughly equal increase in "loudness".

Any quantity expressed in this scale is termed a "level". If the unit is sound pressure, expressed on the dB scale, it will be termed a "Sound Pressure Level". The fundamental definition of the dB scale is given by:

$$Level = 10 \times \log_{10}\left(\frac{Q}{Q_{ref}}\right)$$

where Q is the quantity being expressed on the scale, and Q_{ref} is the reference quantity.

The dB scale represents a ratio and, for instance, 6 dB really means "twice as much as…" (such as a doubling of peak or RMS pressure, exposure etc). It is, therefore, used with a reference unit, which expresses the base from which the ratio is expressed. The reference quantity is conventionally smaller than the smallest value to be expressed on the scale, so that any level quoted is positive. For instance, a reference quantity of 20 µPa is used for sound in air, since this is the threshold of human hearing.

A refinement is that the scale, when used with sound pressure, is applied to the pressure squared rather than the pressure. If this were not the case, when the acoustic power level of a source rose by 10 dB the Sound Pressure Level would rise by 20 dB. So that variations in the units agree, the sound pressure must be specified in units of root mean square (RMS) pressure squared. This is equivalent to expressing the sound as:

$$Sound\ Pressure\ Level = 20 \times \log_{10}\left(\frac{P_{RMS}}{P_{ref}}\right)$$

For underwater sound, typically a unit of one micropascal (µPa) is used as the reference unit; a Pascal is equal to the pressure exerted by one Newton over one square metre; one micropascal equals one millionth of this.

2.2 Quantities of measurement

Sound may be expressed in many ways depending upon the type of noise, and the parameters of the noise that allow it to be evaluated in terms of a biological effect. These are described in more detail below.

2.2.1 <u>Sound pressure level (SPL)</u>

The Sound Pressure Level is normally used to characterise noise and vibration of a continuous nature such as drilling, boring, continuous wave sonar, or background sea and river noise levels. To calculate the SPL, the variation in sound pressure is measured over a specific time period to determine the Root Mean Square (RMS) level of the time varying sound. The SPL can therefore be considered a measure of the average unweighted level of sound over the measurement period.

Where an SPL is used to characterise transient pressure waves such as that from seismic airguns, underwater blasting or impact piling, it is critical that the period over which the RMS level is calculated is quoted. For instance, in the case of pile strike lasting, say, a tenth of a second, the mean taken over a tenth of a second will be ten times higher than the mean taken over one second. Often, transient sounds such as these are quantified using “peak” SPLs.

2.2.2 Peak sound pressure level (SPL_{peak})

Peak SPLs are often used to characterise sound transients from impulsive sources, such as percussive impact piling and seismic airgun sources. A peak SPL is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

A further variation of this is the peak-to-peak SPL where the maximum variation of the pressure from positive to negative within the wave is considered. Where the wave is symmetrically distributed in positive and negative pressure, the peak-to-peak level will be twice the peak level, or 6 dB higher.

2.2.3 Sound exposure level (SEL)

When assessing the noise from transient sources such as blast waves, impact piling or seismic airgun noise, the issue of the period of the pressure wave is often addressed by measuring the total acoustic energy (energy flux density) of the wave. This form of analysis was used by Bebb and Wright (1953, 1954a, 1954b and 1955), and later by Rawlins (1987) to explain the apparent discrepancies in the biological effect of short and long-range blast waves on human divers. More recently, this form of analysis has been used to develop criteria for assessing the injury range from fish for various noise sources (Popper *et al*, 2014).

The Sound Exposure Level (SEL) sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration the sound is present in the acoustic environment. Sound Exposure (SE) is defined by the equation:

$$SE = \int_0^T p^2(t)dt$$

where p is the acoustic pressure in Pascals, T is the duration of the sound in seconds, and t is the time in seconds. The Sound Exposure is a measure of the acoustic energy and, therefore, has units of Pascal squared seconds (Pa^2s).

To express the Sound Exposure on a logarithmic scale by means of a dB, it is compared with a reference acoustic energy level ($P^2{}_{ref}$) and a reference time (T_{ref}). The SEL is then defined by:

$$SEL = 10 \times \log_{10}\left(\frac{\int_0^T p^2(t)dt}{P^2{}_{ref}T_{ref}}\right)$$

By selecting a common reference pressure P_{ref} of 1 µPa for assessments of underwater noise, the SEL and SPL can be compared using the expression:

$$SEL = SPL + 10 \times \log_{10} T$$

Where the SPL is a measure of the average level of the broadband noise, and the SEL sums the cumulative broadband noise energy.

This means that, for continuous sounds of less than one second, the SEL will be lower than the SPL. For periods greater than one second the SEL will be numerically greater than the SPL (i.e. for a sound of ten seconds duration, the SEL will be 10 dB higher than the SPL, for a sound of 100 seconds duration the SEL will be 20 dB higher than the SPL, and so on).

Weighted metrics for marine mammals have been proposed by the National Marine Fisheries Service (NMFS) (2016), these assign a frequency response to groups of marine mammals, and are discussed in detail in the following section.

3 Modelling methodology

Three modelling methodologies have been used for this assessment based on the likely severity of impact of each noise source based on noise levels previously measured by Subacoustech.

- High noise sources (impact piling) have been assessed using detailed modelling considering all environmental parameters;
- Moderate sources (vibro piling and rock breaking) use a simple modelling approach based on a conservative worst case; and
- Low noise sources (dredging and vessel movements) have been considered qualitatively based on previously measured data.

3.1 Detailed modelling inputs

To estimate the likely noise levels from impact piling operations, modelling has been carried out using an approach that is widely used and accepted by the acoustics community, in combination with publicly available environmental data and information provided by Affric. The approach is described in more detail below.

Modelling has been undertaken at one representative location to predict the levels of underwater noise from the impact piling activities. The modelling location is shown in Figure 1-1.

Modelling of underwater noise is complex and can be approached in several different ways. Subacoustech have chosen to use a numerical approach that is based on two different solvers:

- A parabolic equation (PE) method for lower frequencies (12.5 Hz to 250 Hz); and
- A ray tracing method for higher frequencies (315 Hz to 100 kHz).

The PE method is widely used within the underwater acoustics community but has computational limitations at high frequencies. Ray tracing is more computationally efficient at higher frequencies but is not suited to low frequencies (Etter, 1991). This study utilises the dBSea implementation of these numerical solutions.

These solvers account for a wide array of input parameters, including bathymetry, sediment data, sound speed and source frequency content to ensure as detailed results as possible. These input parameters are described in the following sections.

3.1.1 Bathymetry

The bathymetry data used in the modelling was supplied by Find Mapping Ltd; this data has a resolution of 1 arc second (a grid of squares measuring approximately 30 m by 60 m). A high tide of 4.8 m (Mean High Water Springs) has been used throughout the modelling as this represents a conservative approach with regards to noise propagation.

3.1.2 Sound speed profile

The speed of sound in the water, shown in Figure 3-1, has been calculated using temperature and salinity data from Marine Scotland (Bresnan *et al*. 2016) and the underwater sound speed equation from Mackenzie (1981).

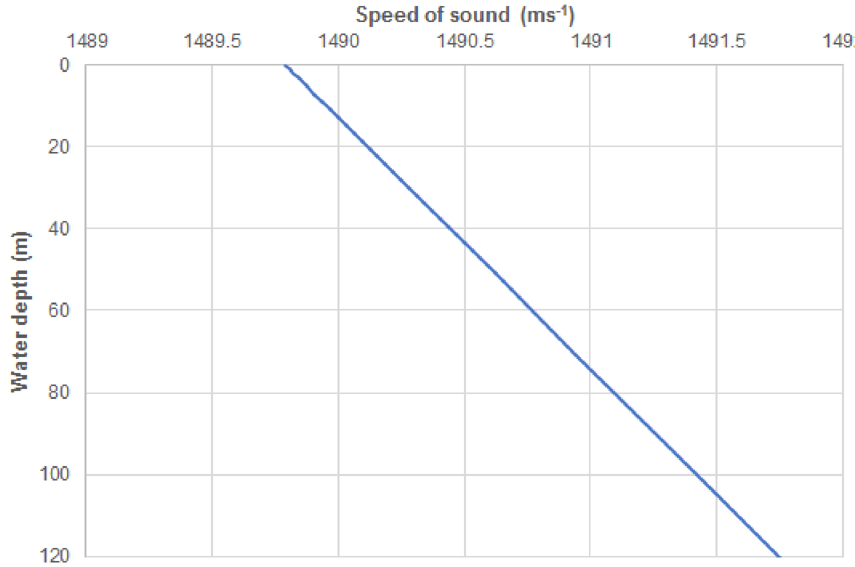

Figure 3-1 Sound speed profile used for modelling

3.1.3 Seabed properties

Based on data from the Marine Environment Mapping Programme (MAREMAP) the seabed properties used for modelling were assumed to be predominantly gravel and sand. Geo-acoustic properties for the seabed were based on available data from Jensen *et al.* (2011), and are provided in Table 3-1.

Seabed type	Compressive sound speed in substrate (ms^{-1})	Density profile in substrate (kg/m^3)	Attenuation profile in substrate (dB/wavelength)
Sand	1650	1900	0.8
Gravel	1800	2000	0.6

Table 3-1 Seabed geo-acoustic properties used for modelling

3.1.4 Impact piling source levels

The proposed impact piling operations at Tarbert include three pile sizes, as detailed in section 1.2, driven using a hammer blow energy of between 50 and 150 kJ. In order to cover a range of the likely noise levels; two pile sizes have been modelled (914 mm and 508 mm), and both 50 kJ and 150 kJ blow energies have been modelled.

The source levels used for the modelling of these two pile sizes and hammer energies are based on Subacoustech's extensive database of impact piling noise, with the predicted source level calculated from the blow energy and water depth of a piling location. These have been shown to be the primary factors determining the subsea noise levels produced. The size of the pile has been used to determine the frequency content of the noise. As the model assumes that the noise source acts as a single point, the water depth at the noise source (accounting for tide) has been used to adjust the source level to allow for the length of the pile in contact with the water.

The unweighted SPL_{peak} source levels estimated for Tarbert are:

- 197.1 dB re 1 µPa SPL_{peak} (50 kJ blow energy)
- 205.4 dB re 1 µPa SPL_{peak} (150 kJ blow energy)

These source levels equate to single strike SEL source levels of 173.2 dB re 1 µPa^{2}s for a 50 kJ hammer and 181.6 dB re 1 µPa^{2}s for a 150 kJ hammer

The third octave levels used for modelling are illustrated in Figure 3-2 and Figure 3-3. As the frequency content is determined by the dimensions of the pile, the shape of the two spectra are the same for both blow energies, with the overall source levels adjusted.

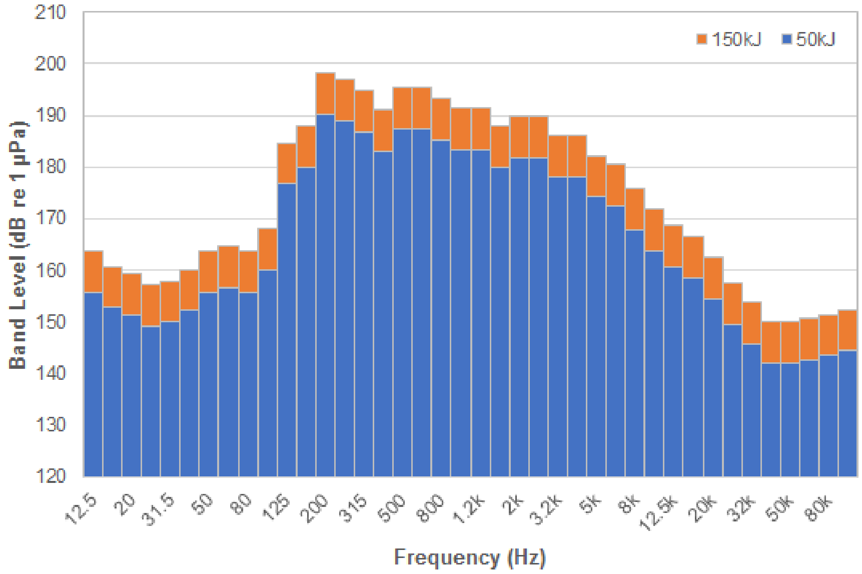

Figure 3-2 Source third octave band levels to be used to model impact piling for a 910 mm diameter pile (SPL$_{peak}$)

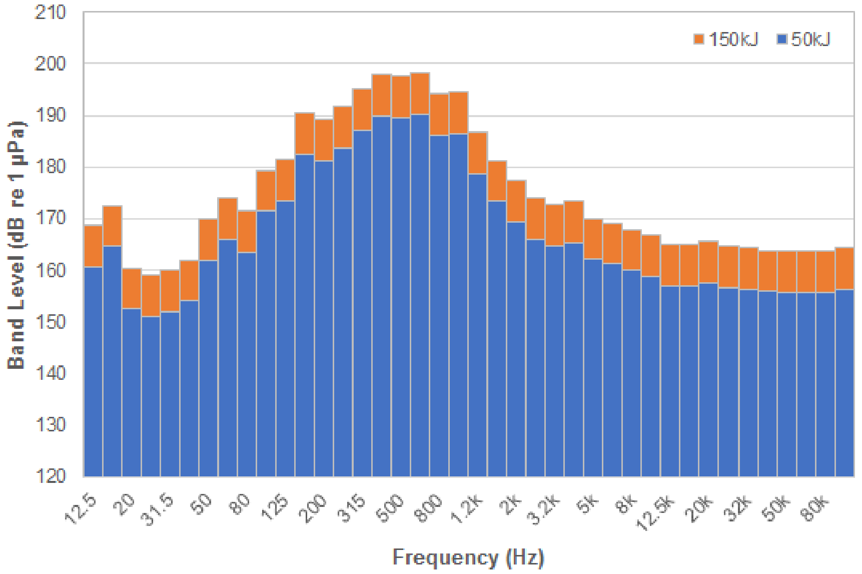

Figure 3-3 Source third octave band levels to be used to model impact piling for a 508 mm diameter pile (SPL$_{peak}$)

It is likely that the energy and strike rate of the piling hammer will slowly increase (ramp-up) over time, due to how hydraulic piling hammers work, however due to the limited information available, this modelling has assumed the same blow energy and strike rate (1 strike per second) over the entire duration of 1 hour. If a ramp-up or soft start were introduced it would likely act as a mitigating factor to the overall noise levels.

3.2 Simple modelling

Modelling of noise from vibro piling and rock breaking have been undertaken using a simple modelling approach; Subacoustech's SPEAR model. This methodology has been chosen due to either low levels of noise or limited data availability. This simple modelling methodology comprises of using existing measurement data from similar activities taken by Subacoustech and modifying the source level to best match the scenario being modelled.

3.2.1 Vibro piling and rock breaking source levels

Source levels used for vibro piling have been based on third octave band measurements undertaken by Subacoustech of the vibro piling of sheet piles. Although tubular piles are being considered for these works, these measurements are considered comparable.

Source levels used for rock breaking are based on data from a report by Marshall Day Acoustics (Lawrence, 2016) and is, at the time of writing, the best available information on underwater noise levels from rock breaking activities. The proposed methodology does differ in that the measurements are of a ripper device, which penetrates the rock and pulls in up, whereas a peckering device is proposed for Tarbert. The differences between the rock breaking methods have been acknowledged and accounted for by modifying the source levels based on the differences in power outputs of the machinery.

The unweighted RMS source levels (1 s SEL) used for the SPEAR modelling are given in Table 3-2.

	Vibro piling	Rock breaking
RMS Source level @ 1 m	188.0 dB re 1 µPa	175.4 dB re 1 µPa

Table 3-2 Unweighted RMS source levels used for SPEAR modelling

The simple modelling is based on a simple geometric spreading model of the form $N \log_{10} R - \alpha R$ where R is the range and values for N and α are based on approximations from field measurements taken by Subacoustech. In contrast, the PE / Ray tracing solution is based on a physical approximations of underwater wave propagation and considers variations in bathymetry, seabed type and sound speed profile for multiple depths and for each frequency band. With the simple methodology these factors are intrinsic to the conditions of the measurements. In practice, the complex numerical modelling is extremely resource intensive and a single scenario can take over 48 hours to complete and it is common practice to use different modelling techniques according to the source being modelled and the anticipated impact range.

3.2.2 Other noise sources

The low-level noise sources (backhoe dredging and vessel movements) have been assessed qualitatively in this report using measured noise levels from the Subacoustech noise measurement database.

3.3 Assessment criteria

3.3.1 Background

Over the past 20 years it has become increasingly evident that noise from human activities in and around underwater environments can have an impact on the marine species in the area. The extent to which intense underwater sound might cause an adverse environmental impact in a species is dependent upon the incident sound level, sound frequency, duration of exposure, and/or repetition rate of the sound wave (see for example Hastings and Popper, 2005). As a result, scientific interest in the hearing abilities of aquatic animal species has increased. These studies are primarily based on evidence from high level sources of underwater noise such as blasting or impact piling, as these sources are likely to have the greatest environmental impact and therefore the clearest observable effects.

The impacts of underwater sound can be broadly summarised into three categories:

- Physical traumatic injury and fatality;

- Auditory injury (either permanent or temporary); and
- Disturbance.

The following sections discussed the agreed upon criteria for assessing these impacts in key marine species. The metrics and criteria that have been used in this study to assess environmental effect come from the latest guidance from the U.S. National Marine and Fisheries Service (NMFS) concerning underwater noise and its effects on marine mammals (NMFS (2016)) and Popper *et al* (2014) for the impacts of noise on species of fish.

3.3.2 Marine mammals

Since it was published, Southall *et al* (2007) has been the source of the most widely used criteria to assess the effects of noise on marine mammals. NMFS (2016) was co-authored by many of the same academics from the Southall *et al* (2007) paper, and effectively updates it. In the updated guidelines, the frequency weightings have changed along with the criteria. As a result, the criteria have generally become more strict and potential impact ranges may increase substantially in some cases.

The NMFS (2016) guidance groups marine mammals into functional hearing groups and applies filters to the unweighted noise to approximate the hearing response of the receptor. The hearing groups given in the NMFS (2016) are summarised in Table 3-3.

The auditory weighting functions for each hearing group are provided in Figure 3-4.

Hearing group	Example species	Generalised hearing range
Low Frequency (LF) Cetaceans	Baleen Whales	7 Hz to 35 kHz
Mid Frequency (MF) Cetaceans	Dolphins, Toothed Whales, Beaked Whales, Bottlenose Whales (including Bottlenose Dolphin)	150 Hz to 160 kHz
High Frequency (HF) Cetaceans	True Porpoises (including Harbour Porpoise)	275 Hz to 160 kHz
Phocid Pinnipeds (PW) (underwater)	True Seals (including Harbour Seal)	50 Hz to 86 kHz

Table 3-3 Marine mammal hearing groups (from NMFS, 2016)

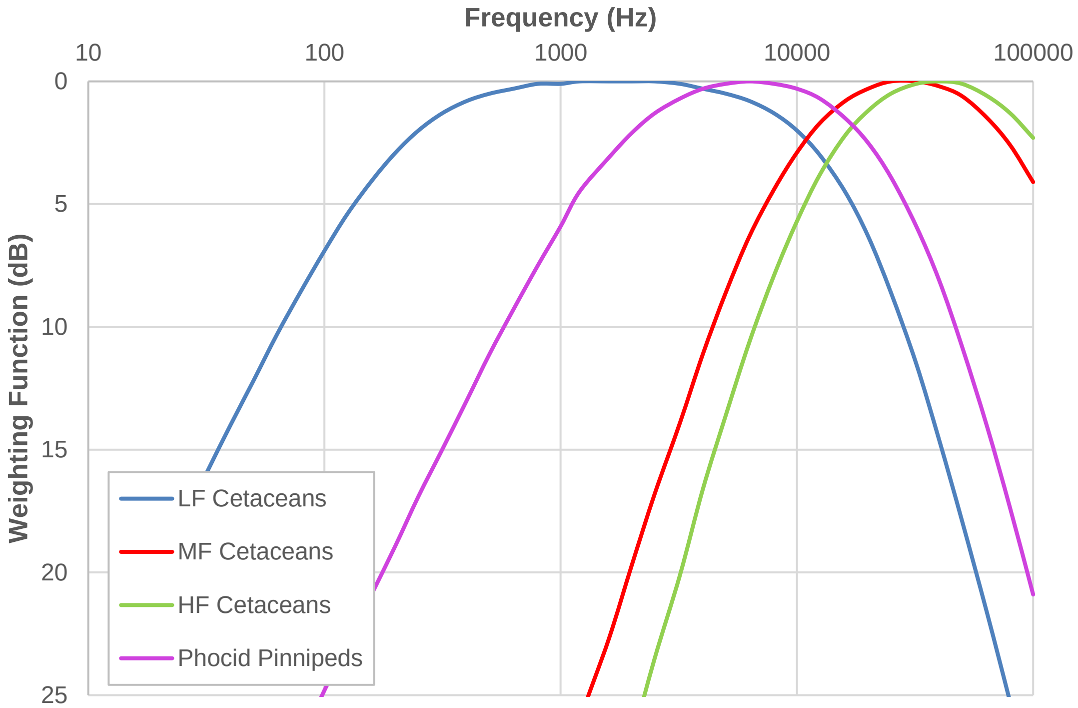

Figure 3-4 Auditory weighting functions for low frequency (LF) cetaceans, mid frequency (MF) cetaceans, high frequency (HF) cetaceans, phocid pinnipeds (PW) (underwater) (from NMFS, 2016)

Based on the species of marine mammal located near the ferry terminal works only the first four weighting groups (LF Cetacean, MF Cetacean, HF Cetacean, and Phocid Pinnipeds) have been considered in this study. Further discussion of the species weightings applied for this study are given in section 3.3.4.

NMFS (2016) presents unweighted peak criteria (SPL_{peak}) and cumulative, weighted sound exposure criteria (SEL_{cum}) for both permanent threshold shift (PTS) where unrecoverable hearing damage may occur and temporary threshold shift (TTS) where a temporary reduction in hearing sensitivity may occur in individual receptors. Table 3-4 and Table 3-5 summarise the NMFS (2016) criteria for onset of risk of PTS and TTS for each of the key marine mammal hearing groups for impulse and non-impulsive noise.

In the assessment of cumulative SEL values, a stationary animal model has been used assuming as a worst case, that the receptor stays at the same range from a noise source for its entire duration.

Impulsive noise	TTS criteria		PTS criteria	
Functional Group	SEL_{cum} (weighted) dB re 1 µPa²s	SPL_{peak} (unweighted) dB re 1 µPa	SEL_{cum} (weighted) dB re 1 µPa²s	SPL_{peak} (unweighted) dB re 1 µPa²s
LF Cetaceans	168	213	183	219
MF Cetaceans	170	224	185	230
HF Cetaceans	140	196	155	202
PW Pinnipeds	170	212	185	218

Table 3-4 Assessment criteria for marine mammals from NMFS (2016) for impulsive noise (impact piling)

Non-impulsive noise	TTS criteria	PTS criteria
Functional Group	**SEL_{cum} (weighted) dB re 1 µPa²s**	**SEL_{cum} (weighted) dB re 1 µPa²s**
LF Cetaceans	179	199
MF Cetaceans	178	198
HF Cetaceans	153	173
PW Pinnipeds	181	201

Table 3-5 Assessment criteria for marine mammals from NMFS (2016) for non-impulsive noise (vibro piling and rock breaking)

3.3.3 Fish

The effects of noise on fish have been assessed using criteria from Popper *et al*. (2014), which gives specific criteria for mortality and potential mortal injury, recoverable injury and TTS, masking and behaviour from various stimuli, including impact piling and continuous noises. Species of fish are grouped by whether or not they have a swim bladder and whether than swim bladder is involved in its hearing. The criteria are given as unweighted SPL_{peak}, RMS, and SEL_{cum} values and are summarised in Table 3-6 and Table 3-7.

Impact Piling	Mortality & potential mortal injury	Impairment	
Type of animal		**Recoverable injury**	**TTS**
Fish: no swim bladder	> 219 dB SEL_{cum} > 213 dB SPL_{peak}	> 216 dB SEL_{cum} > 213 dB SPL_{peak}	>> 186 dB SEL_{cum}
Fish: swim bladder not involved in hearing	210 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	> 186 dB SEL_{cum}
Fish: swim bladder involved in hearing	207 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	186 dB SEL_{cum}

Table 3-6 Assessment criteria for species of fish from Popper et al. (2014) for impact piling noise

Shipping and other continuous noise	Mortality & potential mortal injury	Impairment	
Type of animal		**Recoverable injury**	**TTS**
Fish: no swim bladder	-	-	-
Fish: swim bladder not involved in hearing	-	-	-
Fish: swim bladder involved in hearing	-	170 dB RMS for 48 hours	158 dB RMS for 12 hours

Table 3-7 Assessment criteria for species of fish from Popper et al. (2014) for shipping and other continuous noises

Where insufficient data is available (shown by a dash in the previous tables), qualitative criteria have been given, summarising the effect of the noise as having either a high, moderate or low effect on an individual in either the near-field (tens of metres), intermediate-field (hundreds of metres), or far-field (thousands of metres). This also includes information for masking and behavioural effect. These qualitative effects are reproduced in Table 3-8 to Table 3-9.

Impact Piling Type of animal	Recoverable injury	TTS	Masking	Behaviour
Fish: no swim bladder	-	-	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	-	-	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing	-	-	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate

Table 3-8 Summary of the qualitative effects on fish from impact piling noise from Popper et al. (2014) (N=Near-field, I=Intermediate-field, F=Far-field)

Shipping and other continuous noise Type of animal	Recoverable injury	TTS	Masking	Behaviour
Fish: no swim bladder	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder not involved in hearing	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: swim bladder involved in hearing	-	-	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low

Table 3-9 Summary of the qualitative effects on fish from shipping and other continuous noises from Popper et al. (2014) (N=Near-field, I=Intermediate-field, F=Far-field)

3.3.4 Weighted source levels

To undertake the modelling for the NMFS (2016) criteria with regards to the weighted criteria, the source levels were first adjusted using the auditory weighting functions shown in Figure 3-4. This significantly alters the source level for each functional group as shown in Figure 3-5 and Figure 3-6.

Noise from impact piling is predominantly low frequency in nature and reduces significantly at frequencies above 1 kHz. The impact piling source levels for the 910 mm pile, 150 kJ modelling are given in Figure 3-5 and Figure 3-6 show that the weighting makes only a modest difference to source levels for LF cetaceans when frequency weightings are applied and a significant reduction for other functional groups. The source levels for the other noise sources show a similar pattern, a summary of the weighted source levels is given in Table 3-10 and Table 3-12.

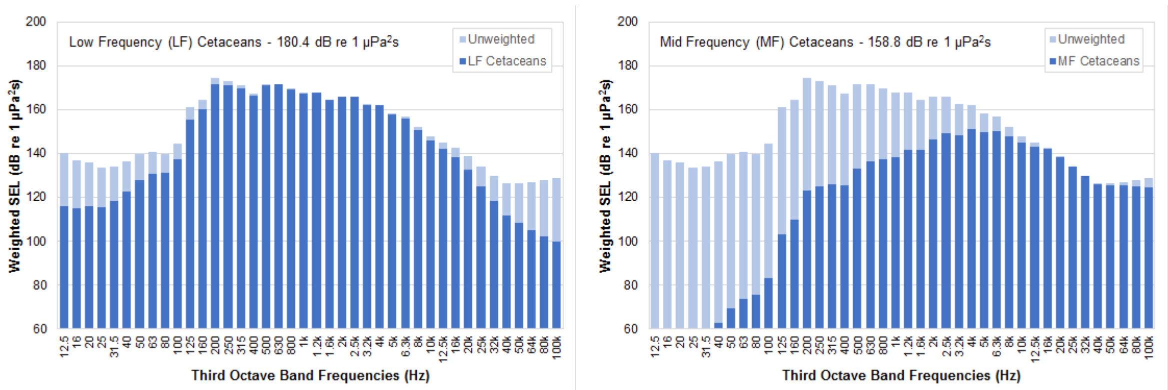

Figure 3-5 Unweighted and NMFS (2016) weighted SEL source level third octave values for LF and MF cetaceans (impact piling, 908 mm diameter pile, 150 kJ)

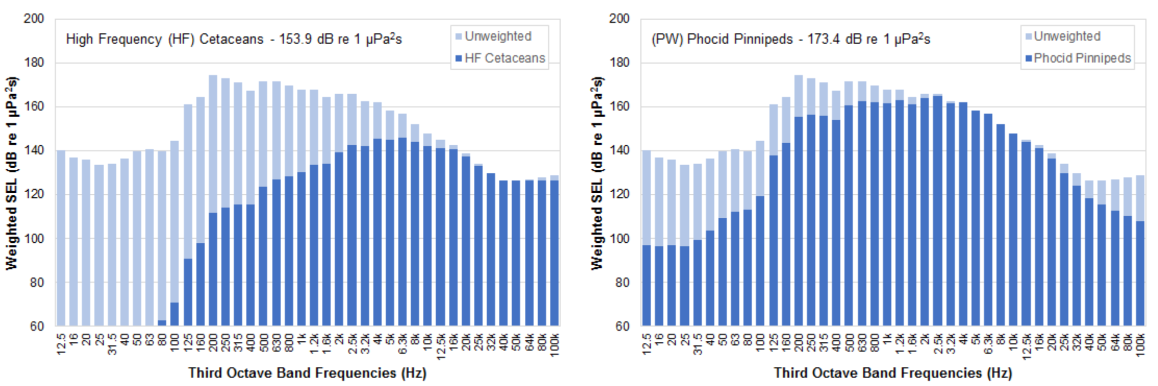

Figure 3-6 Unweighted and NMFS (2016) weighted SEL source level third octave values for HF cetaceans and phocid pinnipeds (impact piling, 908 mm diameter pile, 150 kJ)

910 mm pile	**Impact piling source level (50 kJ) (single pulse SEL)**	**Impact piling source level (150 kJ) (single pulse SEL)**
Unweighted	173.2 dB re 1 µPa²s	181.6 dB re 1 µPa²s
LF Cetaceans	172.0 dB re 1 µPa²s	180.4 dB re 1 µPa²s
MF Cetaceans	150.4 dB re 1 µPa²s	158.8 dB re 1 µPa²s
HF Cetaceans	145.5 dB re 1 µPa²s	153.9 dB re 1 µPa²s
Phocid Pinnipeds	165.0 dB re 1 µPa²s	173.4 dB re 1 µPa²s

Table 3-10 Summary of the NMFS (2016) weighted source levels at 1 metre used impact piling modelling for a 910 mm pile

508 mm pile	**Impact piling source level (50 kJ) (single pulse SEL)**	**Impact piling source level (150 kJ) (single pulse SEL)**
Unweighted	173.2 dB re 1 µPa²s	181.6 dB re 1 µPa²s
LF Cetaceans	172.4 dB re 1 µPa²s	180.8 dB re 1 µPa²s
MF Cetaceans	144.6 dB re 1 µPa²s	153.0 dB re 1 µPa²s
HF Cetaceans	142.5 dB re 1 µPa²s	150.9 dB re 1 µPa²s
Phocid Pinnipeds	163.3 dB re 1 µPa²s	171.7 dB re 1 µPa²s

Table 3-11 Summary of the NMFS (2016) weighted source levels at 1 metre used impact piling modelling for a 508 mm pile

	Vibro piling source level (1 second SEL)	**Rock breaking source level (1 second SEL)**
Unweighted	188.0 dB re 1 µPa²s	175.4 dB re 1 µPa²s
LF Cetaceans	185.6 dB re 1 µPa²s	174.8 dB re 1 µPa²s
MF Cetaceans	172.0 dB re 1 µPa²s	157.5 dB re 1 µPa²s
HF Cetaceans	167.2 dB re 1 µPa²s	154.9 dB re 1 µPa²s
Phocid Pinnipeds	183.6 dB re 1 µPa²s	169.1 dB re 1 µPa²s

Table 3-12 Summary of the NMFS (2016) weighted source levels at 1 metre used for simple modelling

4 Modelling results

4.1 Impact piling

4.1.1 Unweighted SPL_{peak}

The SPL_{peak} noise level from impact piling for 910 and 508 mm diameter piles using blow energies of 50 and 150 kJ are presented in Figure 4-1 to Figure 4-4 for the maximum level in the water column. Cross sections of a south-easterly transect (112°) are presented in Figure 4-5 to Figure 4-8 to show the distribution of noise through the water column along with the water depth profile. These results have been analysed for their potential impact on marine mammals and fish using the criteria detailed in section 3.3 in Table 4-1 to Table 4-4.

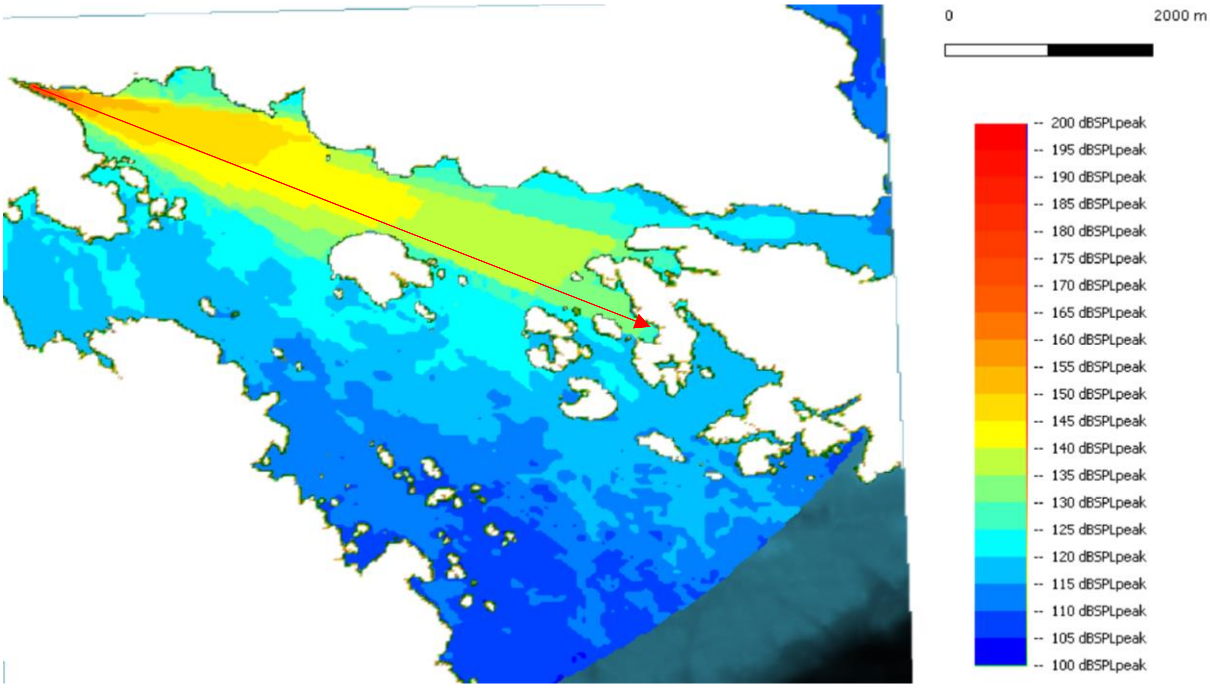

Figure 4-1 Impact piling (910 mm pile, 50 kJ blow energy), unweighted SPL_{peak} showing 112° transect

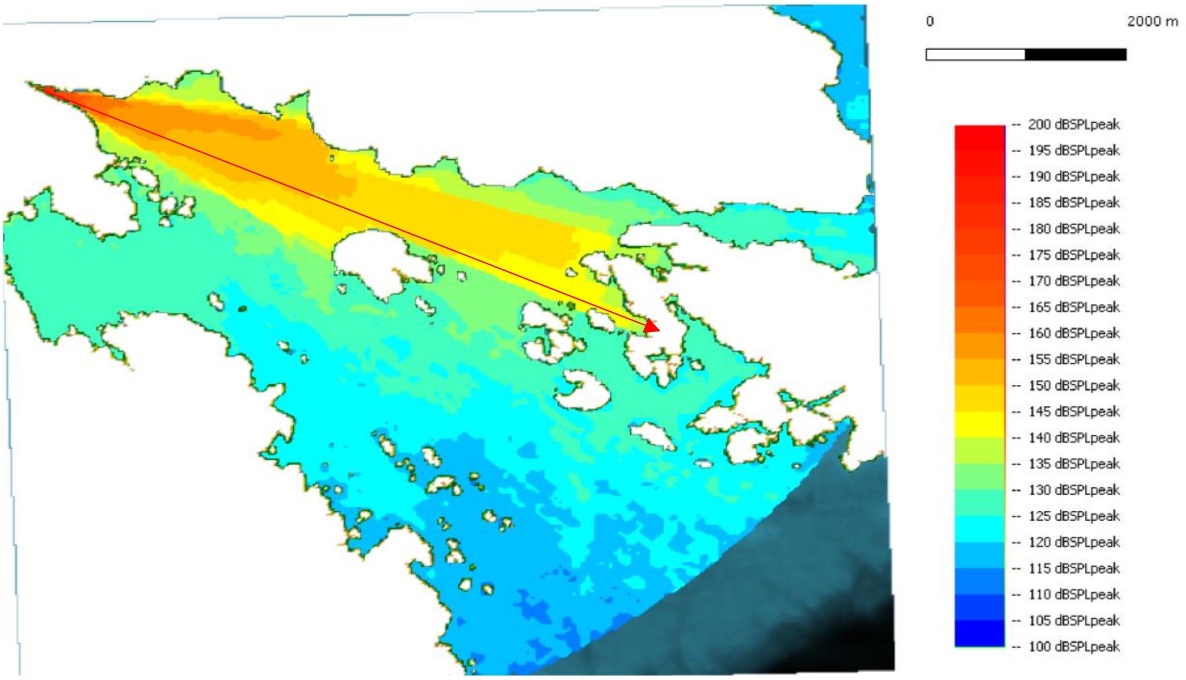

Figure 4-2 Impact piling (910 mm pile, 150 kJ blow energy), unweighted SPL_{peak} showing 112° transect

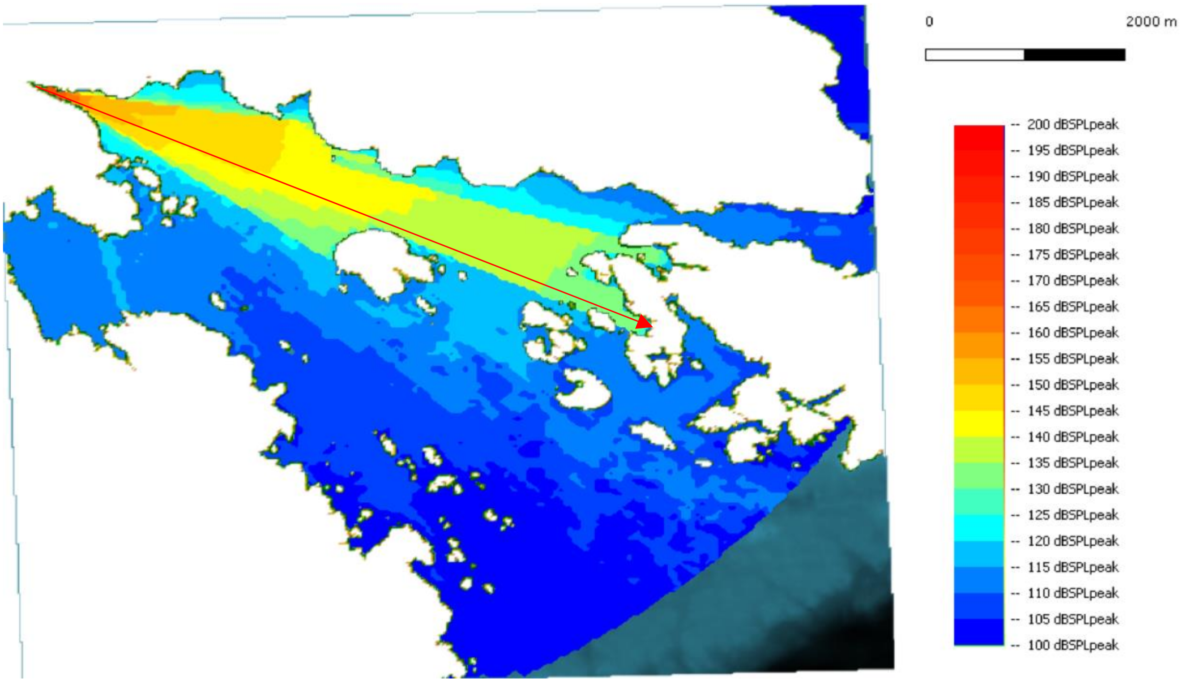

Figure 4-3 Impact piling (508 mm pile, 50 kJ blow energy), unweighted SPL_{peak} showing 112° transect

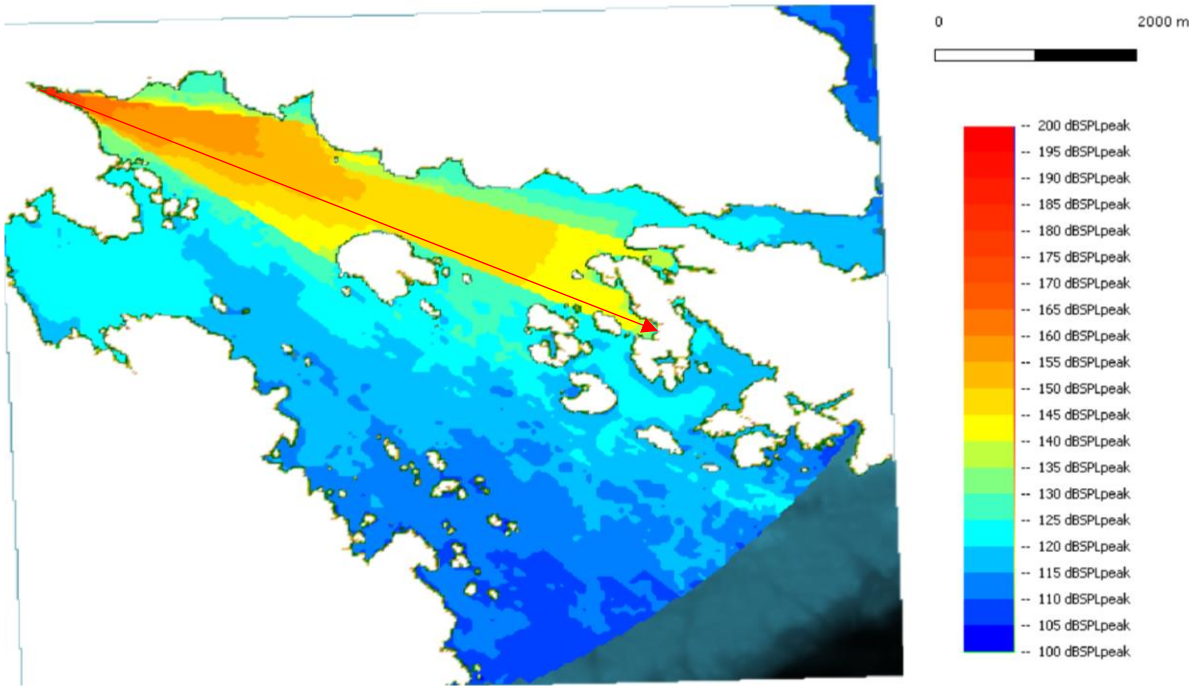

Figure 4-4 Impact piling (508 mm pile, 150 kJ blow energy), unweighted SPL_{peak} showing 112° transect

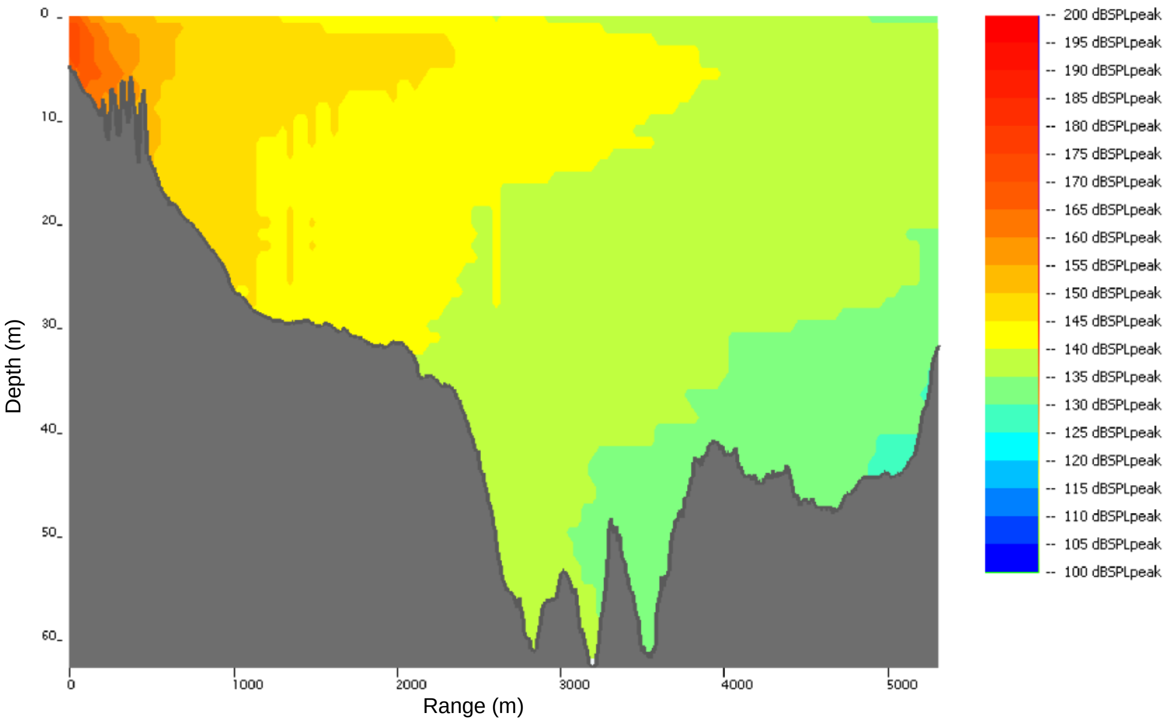

Figure 4-5 Cross section of the 112° transect from impact piling (910 mm pile, 50 kJ blow energy), unweighted SPL_{peak}

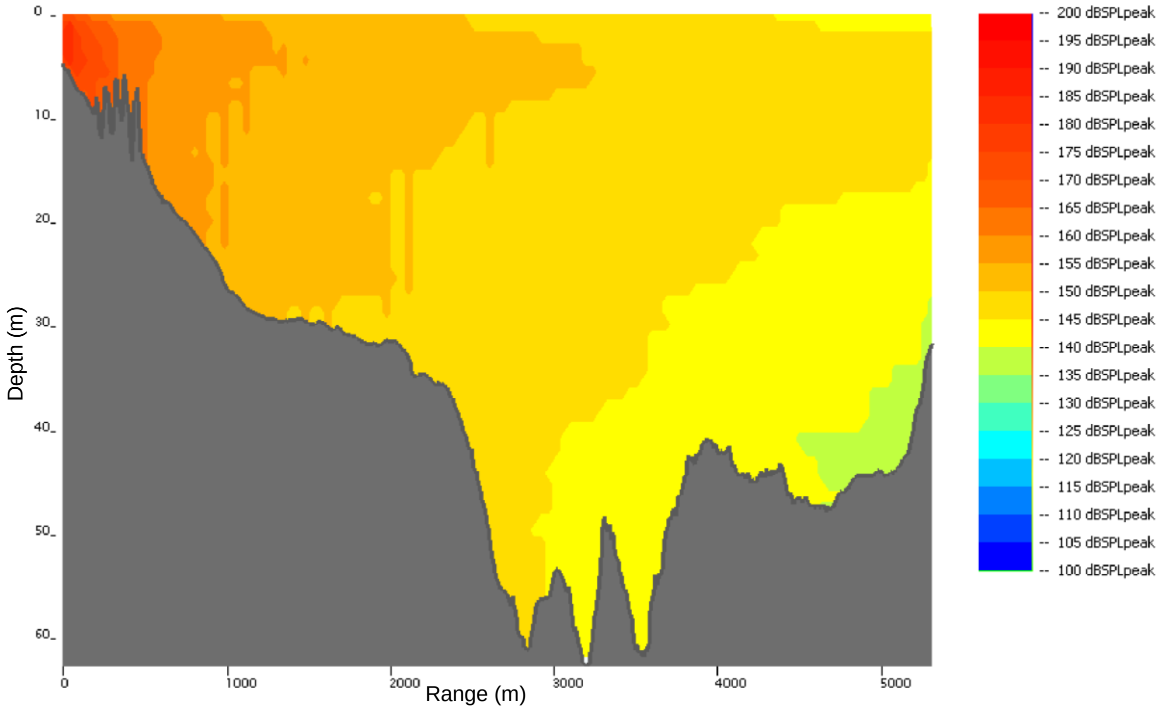

Figure 4-6 Cross section of the 112° transect from impact piling (910 mm pile, 150 kJ blow energy), unweighted SPL_{peak}

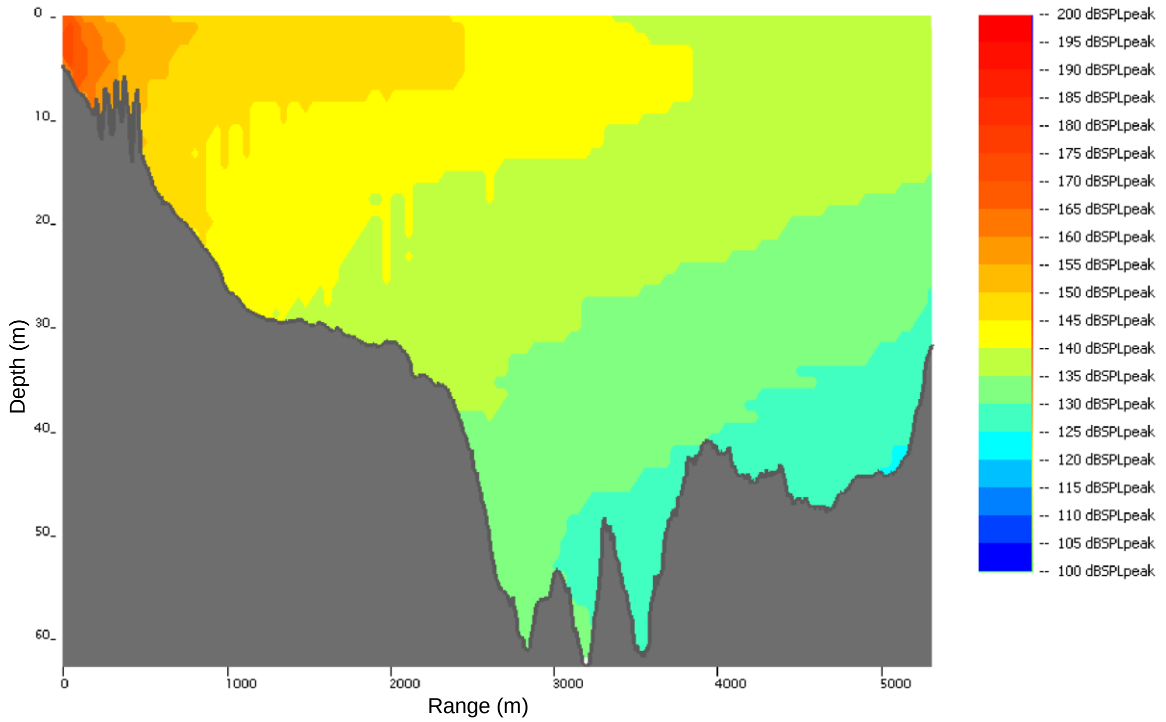

Figure 4-7 Cross section of the 112° transect from impact piling (508 mm pile, 50 kJ blow energy), unweighted SPL_{peak}

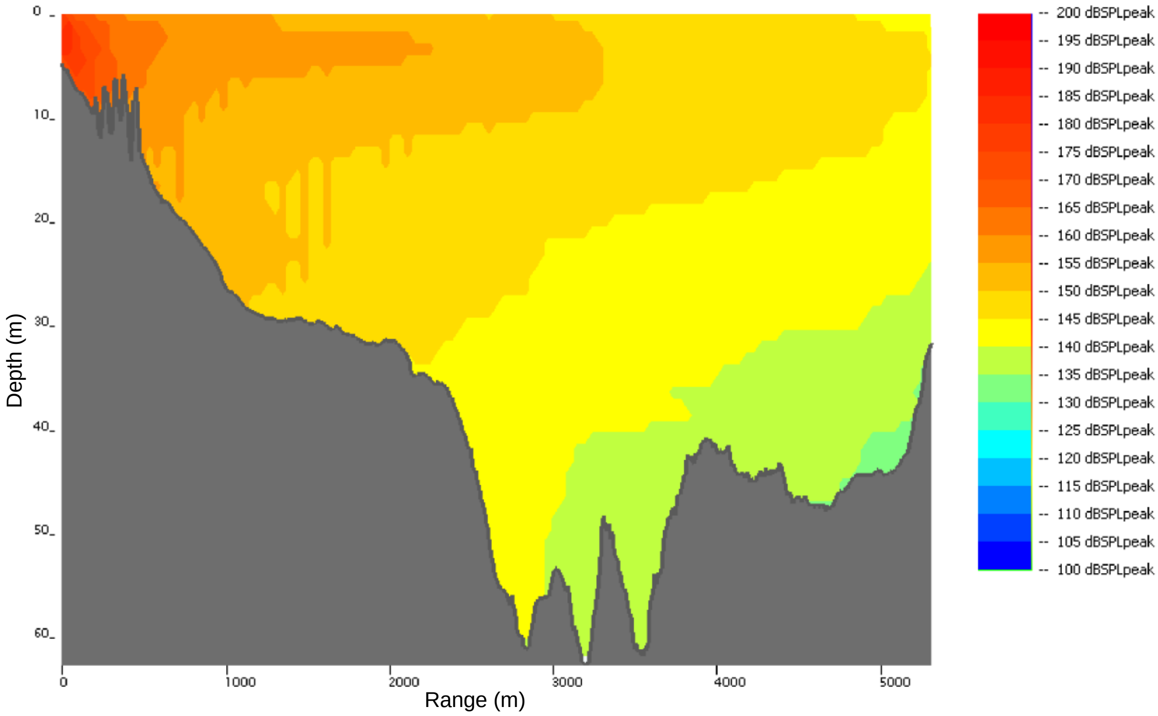

Figure 4-8 Cross section of the 112° transect from impact piling (508 mm pile, 150 kJ blow energy), unweighted SPL_{peak}

Threshold	Criteria SPL_{peak} (unweighted)	Impact piling (910 mm, 50 kJ) SPL_{peak} Maximum range	Impact piling (910 mm, 150 kJ) SPL_{peak} Maximum range
LF Cetaceans TTS	213 dB re 1 µPa	< 1 m	< 1 m
MF Cetaceans TTS	224 dB re 1 µPa	< 1 m	< 1 m
HF Cetaceans TTS	196 dB re 1 µPa	1 m	5 m
PW Pinnipeds TTS	212 dB re 1 µPa	< 1 m	< 1 m
LF Cetaceans PTS	219 dB re 1 µPa	< 1 m	< 1 m
MF Cetaceans PTS	230 dB re 1 µPa	< 1 m	< 1 m
HF Cetaceans PTS	202 dB re 1 µPa	< 1 m	1 m
PW Pinnipeds PTS	218 dB re 1 µPa	< 1 m	< 1 m

Table 4-1 Maximum ranges to NMFS (2016) SPL_{peak} injury criteria for marine mammals from impact piling noise from 910 mm diameter piles for two hammer sizes based on the maximum level in the water column

Threshold	Criteria SPL_{peak} (unweighted)	Impact piling (910 mm, 50 kJ) SPL_{peak} Maximum range	Impact piling (910 mm, 150 kJ) SPL_{peak} Maximum range
Fish (no swim bladder) injury	213 dB re 1 µPa	< 1 m	< 1 m
Fish (with swim bladder) injury	207 dB re 1 µPa	< 1 m	< 1 m

Table 4-2 Maximum ranges to Popper et al. (2014) SPL_{peak} injury criteria for species of fish from impact piling noise from 910 mm diameter piles for two hammer sizes based on the maximum level in the water column

Threshold	Criteria SPL_{peak} (unweighted)	Impact piling (508 mm, 50 kJ) SPL_{peak} Maximum range	Impact piling (508 mm, 150 kJ) SPL_{peak} Maximum range
LF Cetaceans TTS	213 dB re 1 µPa	< 1 m	< 1 m
MF Cetaceans TTS	224 dB re 1 µPa	< 1 m	< 1 m
HF Cetaceans TTS	196 dB re 1 µPa	1 m	6 m
PW Pinnipeds TTS	212 dB re 1 µPa	< 1 m	< 1 m
LF Cetaceans PTS	219 dB re 1 µPa	< 1 m	< 1 m
MF Cetaceans PTS	230 dB re 1 µPa	< 1 m	< 1 m
HF Cetaceans PTS	202 dB re 1 µPa	< 1 m	2 m
PW Pinnipeds PTS	218 dB re 1 µPa	< 1 m	< 1 m

Table 4-3 Maximum ranges to NMFS (2016) SPL_{peak} injury criteria for marine mammals from impact piling noise from 508 mm diameter piles for two hammer sizes based on the maximum level in the water column

Threshold	Criteria SPL_{peak} (unweighted)	Impact piling (508 mm, 50 kJ) SPL_{peak} Maximum range	Impact piling (508 mm, 150 kJ) SPL_{peak} Maximum range
Fish (no swim bladder) injury	213 dB re 1 µPa	< 1 m	< 1 m
Fish (with swim bladder) injury	207 dB re 1 µPa	< 1 m	< 1 m

Table 4-4 Maximum ranges to Popper et al. (2014) SPL_{peak} injury criteria for species of fish from impact piling noise from 508 mm diameter piles for two hammer sizes based on the maximum level in the water column

The results are based on the maximum predicted noise level in the water column and this approach has been used as it is not possible to predict the depth of a marine mammal at the time of a single impulsive event. Figure 4-5 to Figure 4-8 indicate an even distribution of noise through the water column with the maximum generally occurring in the mid-water region indicating that the use of maximum noise level is a reasonable approach.

Given the proximity to the coast, only the maximum ranges have been presented above as any attempt to present a mean range would be subject to considerable bias from many very short transects and would therefore be misleading. In practice only a very small number of transects will be subject to the maximum range. Figure 4-9 shows the ranges out to a level of 150 dB SPL_{peak} along each transect and only 5 transects exceed 3 km and 15 out of 180 transects exceed 1 km.

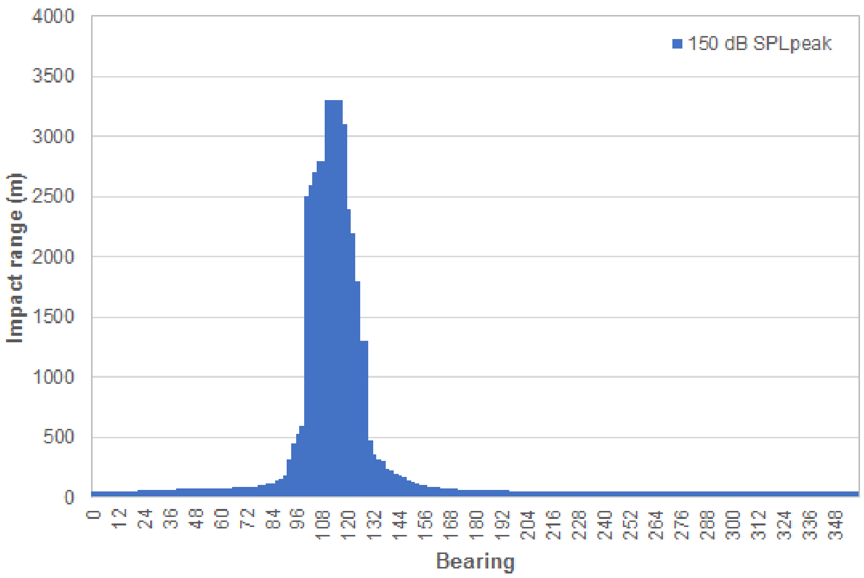

Figure 4-9 Ranges to 150 dB SPL_{peak} for each transect for impact piling noise from a 910 mm diameter pile using a blow energy of 150 kJ

4.1.2 Cumulative SEL (SEL_{cum})

The noise from impact piling is a multiple pulse source and as such cumulative SEL values have been calculated assuming piling lasting 1 hour (the worst-case duration for piling). Table 4-5 and Table 4-8 present the impact ranges for marine mammal and fish assuming a stationary receptor. If a fleeing receptor were assumed for these results, the predicted impact ranges would be reduced.

Threshold	Criteria SEL_{cum} (weighted)	Impact piling (910 mm, 50 kJ) SEL_{cum} (1 hour) Maximum range	Impact piling (910 mm, 150 kJ) SEL_{cum} (1 hour) Maximum range
LF Cetaceans TTS	168 dB re 1 µPa²s	450 m	1.4 km
MF Cetaceans TTS	170 dB re 1 µPa²s	20 m	71 m
HF Cetaceans TTS	140 dB re 1 µPa²s	540 m	2.2 km
PW Pinnipeds TTS	170 dB re 1 µPa²s	150 m	410 m
LF Cetaceans PTS	183 dB re 1 µPa²s	73 m	210 m
MF Cetaceans PTS	185 dB re 1 µPa²s	1 m	5 m
HF Cetaceans PTS	155 dB re 1 µPa²s	87 m	250 m
PW Pinnipeds PTS	185 dB re 1 µPa²s	18 m	68 m

Table 4-5 Maximum ranges to NMFS (2016) weighted SEL_{cum} injury criteria for marine mammals from impact piling noise from 910 mm diameter piles for two hammer sizes assuming a stationary animal and 1 hour of piling based on the maximum level in the water column

Threshold	Criteria SEL_{cum} (unweighted)	Impact piling (910 mm, 50 kJ) SEL_{cum} (1 hour) Maximum range	Impact piling (910 mm, 150 kJ) SEL_{cum} (1 hour) Maximum range
Fish (no swim bladder) mortality and potential mortal injury	219 dB re 1 µPa²s	< 1 m	< 1 m
Fish (no swim bladder) recoverable injury	216 dB re 1 µPa²s	< 1 m	1 m
Fish (with swim bladder not involved in hearing) mortality and potential mortal injury	210 dB re 1 µPa²s	< 1 m	3 m
Fish (with swim bladder involved in hearing) mortality and potential mortal injury	207 dB re 1 µPa²s	1 m	6 m
Fish (with swim bladder) recoverable injury	203 dB re 1 µPa²s	2 m	14 m
Fish TTS	186 dB re 1 µPa²s	60 m	160 m

Table 4-6 Maximum ranges to Popper et al. (2014) unweighted SEL_{cum} injury criteria for species of fish from impact piling noise from 910 mm diameter piles for two hammer sizes assuming a stationary animal and 1 hour of piling based on the maximum level in the water column

Threshold	Criteria SEL_{cum} (weighted)	Impact piling (508 mm, 50 kJ) SEL_{cum} (1 hour) Maximum range	Impact piling (508 mm, 150 kJ) SEL_{cum} (1 hour) Maximum range
LF Cetaceans TTS	168 dB re 1 µPa²s	390 m	1.3 km
MF Cetaceans TTS	170 dB re 1 µPa²s	8 m	45 m
HF Cetaceans TTS	140 dB re 1 µPa²s	320 m	1.2 km
PW Pinnipeds TTS	170 dB re 1 µPa²s	120 m	290 m
LF Cetaceans PTS	183 dB re 1 µPa²s	83 m	220 m
MF Cetaceans PTS	185 dB re 1 µPa²s	< 1 m	2 m
HF Cetaceans PTS	155 dB re 1 µPa²s	69 m	150 m
PW Pinnipeds PTS	185 dB re 1 µPa²s	17 m	63 m

Table 4-7 Maximum ranges to NMFS (2016) weighted SEL_{cum} injury criteria for marine mammals from impact piling noise from 508 mm diameter piles for two hammer sizes assuming a stationary animal and 1 hour of piling based on the maximum level in the water column

Threshold	Criteria SEL_{cum} (unweighted)	Impact piling (910 mm, 50 kJ) SEL_{cum} (1 hour) Maximum range	Impact piling (910 mm, 150 kJ) SEL_{cum} (1 hour) Maximum range
Fish (no swim bladder) mortality and potential mortal injury	219 dB re 1 µPa²s	< 1 m	< 1 m
Fish (no swim bladder) recoverable injury	216 dB re 1 µPa²s	< 1 m	1 m
Fish (with swim bladder not involved in hearing) mortality and potential mortal injury	210 dB re 1 µPa²s	< 1 m	4 m
Fish (with swim bladder involved in hearing) mortality and potential mortal injury	207 dB re 1 µPa²s	1 m	8 m
Fish (with swim bladder) recoverable injury	203 dB re 1 µPa²s	3 m	18 m
Fish TTS	186 dB re 1 µPa²s	67 m	150 m

Table 4-8 Maximum ranges to Popper et al. (2014) unweighted SEL_{cum} injury criteria for species of fish from impact piling noise from 508 mm diameter piles for two hammer sizes assuming a stationary animal and 1 hour of piling based on the maximum level in the water column

4.2 Vibro piling and rock breaking (simple modelling)

Underwater noise from the piling using a vibratory pile driver along with rock breaking have been modelled using Subacoustech's SPEAR model. This is a simple model which uses Subacoustech's measurement database to estimate noise levels with range.

For vibro piling, ranges have been calculated for a stationary animal and are based on 1 hour of operation in a given 24-hour period (the same duration given for impact piling). The ranges for rock breaking have assumed a stationary animal and rock breaking being undertaken for up to 8 hours in a given 24-hour period. The predicted ranges are given in Table 4-9 and Table 4-10.

Threshold	Criteria SEL_{cum} (weighted)	Vibro piling (1 hour)	Rock breaking (8 hours)
LF Cetaceans TTS	179 dB re 1 µPa²s	200 m	300 m
MF Cetaceans TTS	178 dB re 1 µPa²s	40 m	40 m
HF Cetaceans TTS	153 dB re 1 µPa²s	500 m	600 m
PW Pinnipeds TTS	181 dB re 1 µPa²s	100 m	100 m
LF Cetaceans PTS	199 dB re 1 µPa²s	10 m	20 m
MF Cetaceans PTS	198 dB re 1 µPa²s	3 m	1 m
HF Cetaceans PTS	173 dB re 1 µPa²s	40 m	50 m
PW Pinnipeds PTS	201 dB re 1 µPa²s	10 m	7 m

Table 4-9 Ranges to NMFS (2016) SEL_{cum} non-impulsive injury criteria for marine mammals from vibro piling and rock breaking noise

Threshold	Criteria SPL_{RMS} (unweighted)	Vibro piling	Rock breaking
Fish (with swim bladder involved in hearing) recoverable injury	170 dB re 1 µPa (for 48 hours)	18 m	2 m
Fish (with swim bladder involved in hearing) TTS	158 dB re 1 µPa (for 12 hours)	87 m	14 m

Table 4-10 Ranges to Popper et al. (2014) SPL_{RMS} continuous noise injury criteria for species of fish from vibro piling and rock breaking noise

4.3 Other noise sources

4.3.1 Backhoe Dredging

Backhoe dredging is undertaken by an excavator mounted on a barge. All machinery is located on the deck of the barge, above the waterline. Noise radiates into the water through the hull of the barge or from the action of the excavator on the seabed. No noise generating plant is located in the water. Measurements undertaken by Subacoustech indicate that an unweighted RMS source level of up to 165 dB re 1 µPa could be expected. Measurement data show that underwater noise levels from backhoe dredging reduce quickly with range to approximately 133 dB re. 1 µPa within 50 m from the source.

For marine mammals, when NMFS weightings are applied levels are further reduced such that a stationary animal located at 50 m from the source would need to be exposed for a minimum of 19 hours in a 24-hour period for the TTS criteria to be exceeded.

For fish, the source level is below the recoverable injury criteria specified in Popper et al. (2014). The range at which the Popper et al. (2014) TTS criteria would be exceeded is less than 5 m.

4.3.2 Vessel Movements

Underwater noise from vessels varies significantly depending on the size, speed and operating conditions. Underwater noise from small vessels of the type typically used for inshore development projects (workboats, safety boats, dredging barges) have been measured by Subacoustech and source levels at 1 m have been found to be in the range of 140 dB to 160 dB RMS re 1 µPa with peak frequencies occurring between 100 Hz and 800 Hz.

At the time of writing no detail about the type of vessels or number of movements was available to enable a detailed assessment. However, no vessels likely to be involved in the construction works are likely to exceed the noise level of the existing ferry. Overall, vessel movements are likely to produce a lower noise level than the other sources considered in this report and as such are not expected to have a significant impact.

4.4 Discussion

The impact ranges seen in the preceding sections vary significantly depending on the functional hearing (species) group and the NMFS (2016) criteria that defines the onset of PTS and TTS.

NMFS (2016) requires that where an assessment includes both SPL_{peak} and SEL_{cum} then the greater of the two impact ranges should be used in the assessment. For impact piling, the SEL_{cum} criteria gave rise to the greatest ranges across all functional groups due to the multiple pulse nature of the noise and the small scale of the piling. The greatest impact ranges were seen for HF and LF cetaceans, this is not unexpected given the stricter SEL_{cum} criteria specified by NMFS (2016) for those groups. This can be seen in Table 4-11 Maximum range to PTS criteria for each activity and species groupswhich details the greatest PTS impact range modelled for each activity and species group.

	LF Cetaceans	MF Cetaceans	HF Cetaceans	PW Cetaceans	Fish
Impact piling 910mm 50 kJ (1 hour)	73 m	< 10 m	87 m	18 m	< 10 m
Impact piling 910mm 150 kJ (1 hour)	210 m	< 10 m	250 m	68 m	14 m
Impact piling 508 mm 50 kJ (1 hour)	83 m	< 10 m	69 m	17 m	< 10 m
Impact piling 508 mm 150 kJ (1 hour)	220 m	< 10 m	150 m	63 m	18 m
Vibro piling (1 hour)	10 m	< 10 m	40 m	10 m	18 m
Rock Breaking	20 m	< 10 m	50 m	< 10 m	< 10 m
Dredging	< 20 m	< 10 m	< 50 m	< 10 m	< 10 m

Table 4-11 Maximum range to PTS criteria for each activity and species groups

Despite this, the SPL_{peak} ranges should still be considered conservative as physical processes in propagation alter the shape of the waveform and reduce the peaks with increasing range. NMFS (2016) refers to this effect (p27, paragraph 2) but it is not easily quantified or accounted for in the modelling.

5 Summary and conclusions

Subacoustech Environmental has undertaken a study of noise propagation for Affric Limited at the Tarbert ferry terminal, Scotland, for impact piling and other related noise making activities.

The level of underwater noise from impact piling has been estimated using a parabolic equation (PE) method for lower frequencies and a ray tracing solution at higher frequencies. The modelling considers a wide variety of input parameters including source noise levels, frequency content, duty cycle, seabed properties and the sound speed profile in the water column. Full account is taken of the complex bathymetry in the area.

A representative location at the ferry terminal has been modelled to give worst case ranges into the open water.

Further simple modelling has been carried out to assess the effects of vibro piling and rock breaking in the area. A qualitative assessment of noise from dredging and vessel noise has also been completed.

Noise levels have been assessed in terms of the criteria provided by NMFS (2016) for SPL_{peak} and SEL_{cum} for marine mammals and Popper et al (2014) for SPL_{peak}, SEL_{cum} and SPL_{RMS} for fish. In the case of the NMFS (2016) criteria, the 1/3 octave band spectrum of the source level has been weighted according the LF, MF, HF and PW frequency weightings stipulated in the guidelines.

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