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12 Quays Birkenhead, Underwater Noise during Rotary Drilling

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1 Introduction

1.1 Project overview

Liverpool City Council proposed to develop a permanent Cruise Terminal Facility at the site of the former Princes Jetty off Princes Parade, Liverpool to replace the temporary cruise facility located on Princes Parade. The construction works will include the installation of foundation piles into the River Mersey and there is concern that this operation will generate noise in the water, which has the potential to affect fish in the river.

Rotary drilling works are ongoing to upgrade the Stena Ferry terminal at 12 Quays on the River Mersey using a similar drilling technique as anticipated for the new cruise terminal. Subacoustech were requested to undertake monitoring of underwater noise rotary drilling at 12 Quays in order to ascertain the noise levels that may be expected from the rotary drilling works at the new cruise terminal. Measurements of background noise levels in the water around 12 Quays were also taken along with other local noise sources, particularly the Stena Mersey ferry.

1.2 Monitoring

Monitoring of underwater noise sound pressure levels in the river on Friday 25th October and Tuesday October 29th, 2019. The survey was undertaken using a mobile monitor from a vessel, the *Mersey Lass*, on the River Mersey. The measurements were taken in a drift with the current, with the vessel passing the noise source, or measuring the ambient noise.

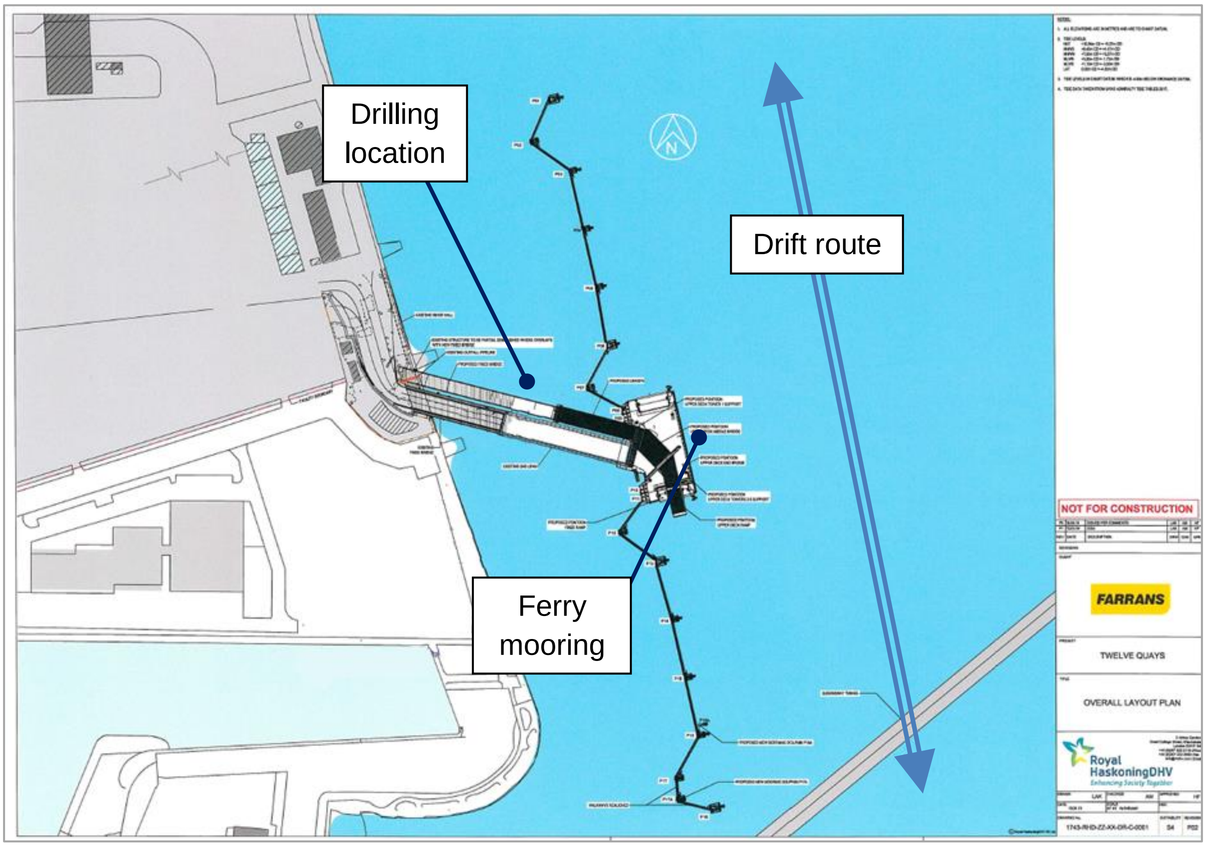

Figure 1 Sketch of the jetty showing key locations

This report presents the results of the underwater noise monitoring exercise undertaken at the facility.

2 Introduction to underwater noise concepts

This report is intended to provide an overview of the potential impact of the activities that could generate noise in the River Mersey, near the 12 Quays redevelopment. The following basic acoustical concepts should be understood.

The decibel (dB), by which a level of sound is described, is a ratio measure and as such requires a reference sound pressure to compare with the noise level under consideration. In underwater noise this is conventionally 1 micropascal (1 µPa), as a minimum noise level that could be present. Noise levels presented in this report are all referenced to this value and are thus a sound pressure level (SPL) re 1 µPa. Please note that this is different to the reference used for airborne noise, which is 20 µPa, and airborne and underwater decibel noise levels should not be directly compared.

SPL is normally used to characterise noise and vibration of a continuous nature such as drilling, boring, 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 RMS (root-mean square) level of the time varying acoustic pressure. The SPL_{RMS} can therefore be considered to be a measure of the average unweighted level of the sound over the measurement period. The SPL is calculated using the following formula where p is the sound pressure in Pascals (Pa), and $pref$ is the reference sound pressure, which is typically 1 µPa for underwater sound as noted above.

$$SPL = 20 \log_{10}\left(\frac{p}{p_{ref}}\right)$$

As an example, small sea-going vessels typically produce broadband noise at source SPLs of between 170 and 180 dB re 1 µPa @ 1 m (Richardson *et al*., 1995[1]), whereas a supertanker generates SPLs in the region of 198 dB re 1 µPa @ 1 m (Hildebrand, 2004[2]).

All measurements stated in this report, sampled during surveys, include a 10 Hz high pass filter and are SPL_{RMS} re 1 µPa unless noted otherwise.

Other measures can use the ‘peak’ or ‘peak-to-peak’ SPL, although these are for impulsive sound such as pulses or blast, which are not relevant to the more continuous-type noise sources in this investigation and will not be considered further here.

The attenuation of sound in the water as it propagates from the noise source must be considered in an assessment such as this. As the measurement or receiver point moves away from the source, the sound pressure measured will decrease due to spreading. To standardise all source levels, regardless of where they are measured, they are referred back to a conceptual point 1 m away from the point of origin of the noise.

[1] Richardson W J, Greene C R, Malme C I, Thompson D H (1995). Marine mammals and noise. Academic Press Inc., San Diego, 1995.
[2] Hildebrand J (2004). Impacts of anthropometric sound on cetaceans. International Whaling Commission. IWC/SC/56/E13 report, Sorrento, Italy. Available at http://cetus.ucsd.edu/ projects/pub/SC-56-E13Hilde.pdf

3 Measurement methodology

3.1 Objective

The objective of the survey was to provide measurements of underwater noise during rotary drilling in the River Mersey. Baseline measurements were undertaken to determine the pre-existing levels of ambient noise in the river as well as other noise sources present in the water in the area.

The construction equipment in use was a B300 XP hydraulic rotary piling rig for drilling and installing 1219 mm diameter steel tubular piles. The piling process involves initially lowering the drill string to the riverbed and the drilling begins at a low speed as a ‘soft start’, and the rotation slowly increases to full speed. The piling equipment is shown in Figure 3-1 below.

Figure 3-1 Photos of the B300 piling rig at 12 Quays (credit: C Penman, Farrans)

3.2 Measurement Programme

3.2.1 Background (baseline) noise measurements

Baseline noise measurements were made outside of periods of construction at the site to characterise the pre-existing environment. Measurements were also taken to characterise the pre-existing noise around the proposed site from vessel movements, particularly the Stena Mersey ferry. These measurements were taken from the *Mersey Lass* survey vessel. A hydrophone was deployed off the vessel, drifting with the current where it was able to pass without causing an obstruction or hindrance to any other river users, nor on a course with any fixed river objects (including the ferry and construction rig). The engines and echosounder of the survey vessel were shut down during drifts.

A calibrated Bruel & Kjaer 8106 hydrophone (serial number #2256725) was suspended at depths of 1.5 m, 3 m and 6 m below the surface. The formal calibration certificate is provided in Appendix A and the full system was calibrated using a field calibrator prior to the survey on each day.

The cable was supported by an anti-heave (spar) buoy to hold it at the appropriate depth and minimise the influence of surface movement on the hydrophone. The hydrophone was connected to a laptop computer on the vessel. This drifting technique minimises flow noise on the hydrophone. The overall water depth was confirmed by the vessel depth sounder.

The Stena Mersey ferry was present at the start of the measurement day on 29th October. Measurements at multiple distances were taken around this vessel to ascertain its noise emissions and effect on the background as a reference.

Measurements were also taken on 25th October using a fixed underwater noise monitor suspended from the linkspan between the terminal and the ferry jetty, approximately 10 m from the drilling. On review, the flow noise from the tidal currents in the River Mersey was so high as to completely mask any other noise, which would include the adjacent drilling. No useful noise levels were able to be extracted from the data and as such will not be discussed further. Results will focus instead on the drifting measurements.

3.2.2 Measurements during rotary drilling works

During the drilling, measurements of underwater noise were undertaken using the same drifting technique as during the background noise survey. The hydrophone was deployed from the vessel and allowed to drift with the water flow at the same three depths. Fixed position (i.e. non-drifting) measurements from the vessel could not be undertaken due to high water flow.

Measurements were carried out at several positions from the rotary drilling to characterise the levels of noise that propagate upstream, downstream and directly across the river from activities carried out. These were up to 1 km from the noise source, and approximately 50 m at the closest point that was safe to approach in the river conditions. The distances were identified on the vessel using a laser rangefinder. Noise samples were limited to 10 seconds due to the high current.

3.3 Survey conditions

Weather conditions were recorded throughout the survey during measurements and was mostly sunny with light cloud and a north to north-easterly breeze. Light precipitation was present during 25th October. No precipitation was recorded on 29th October.

Strong currents were present for much of the time during the survey. On both days, the tide was a very high spring tide (close to the maximum which would be expected in the year), and as a result, currents of up to 10 knots were experienced. On 25th October the tidal range was 6.7 m and on 29th the range was 10 m.

Under such strong tidal conditions, navigation inside of the ferry mooring piles (between the moorings and shoreline) could not be safely undertaken. Timing and opportunity was limited by the construction work schedule.

4 Measurement results

4.1 Background noise levels

Background noise levels were sampled on 25th October, between 12:50 and 14:30, during drifts on the *Mersey Lass*. Samples were taken from a maximum of approximately 1 km upstream to 1 km downstream of the jetty and the upcoming drilling location. Measurements were approximate as the vessel was constantly moving.

The background noise levels measured are presented in Figure 4-1 below. These are presented relative to the latitude to identify and variation with position along the river, as the River Mersey at this position (and thus the drifts) were approximately north/south. For reference, the jetty and drilling works were situated between a latitude of 53.400° and 53.401°. At the time of background measurements, the Stena Mersey ferry was not at the terminal.

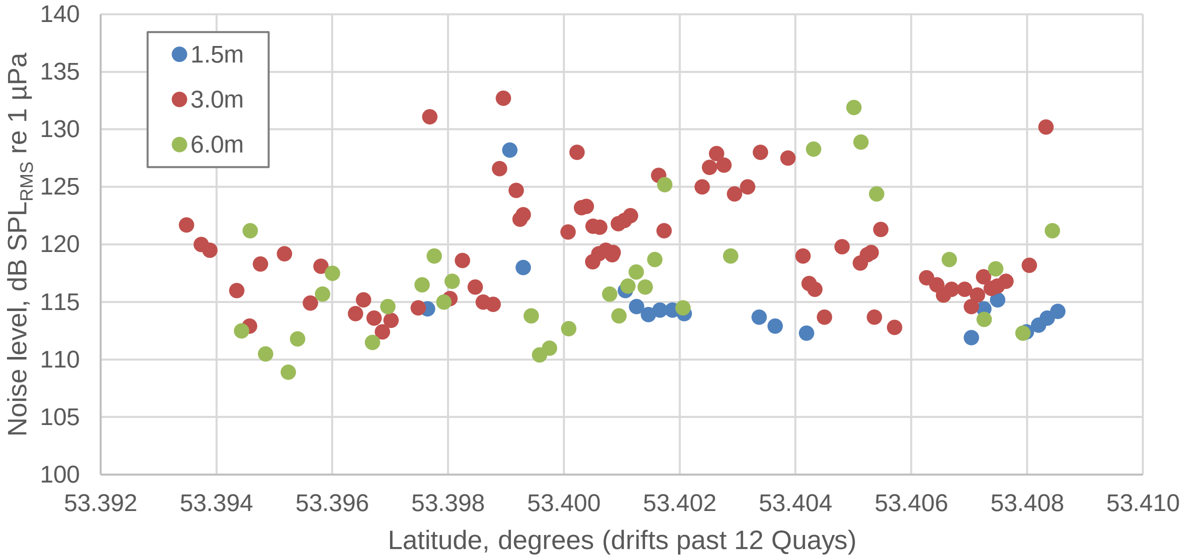

Figure 4-1 Background sound level measurements taken on drifts past the ferry terminal on 25th October 2019

The measurements are separated by the depth at which the hydrophone was positioned, relative to the water surface. The difference in measured levels at different depths appears to be negligible, although the measurements taken nearest the surface appear to be lower in general.

In the vicinity of the terminal (in the middle of the drifts) the average noise levels increase by over 10 dB, and levels were typically around 128 dB SPL_{RMS}, with some up to 132.7 dB. The average ambient noise level across all measurements and positions was 118.2 dB.

A typical frequency spectrum of the background noise is shown in Figure 4-2.

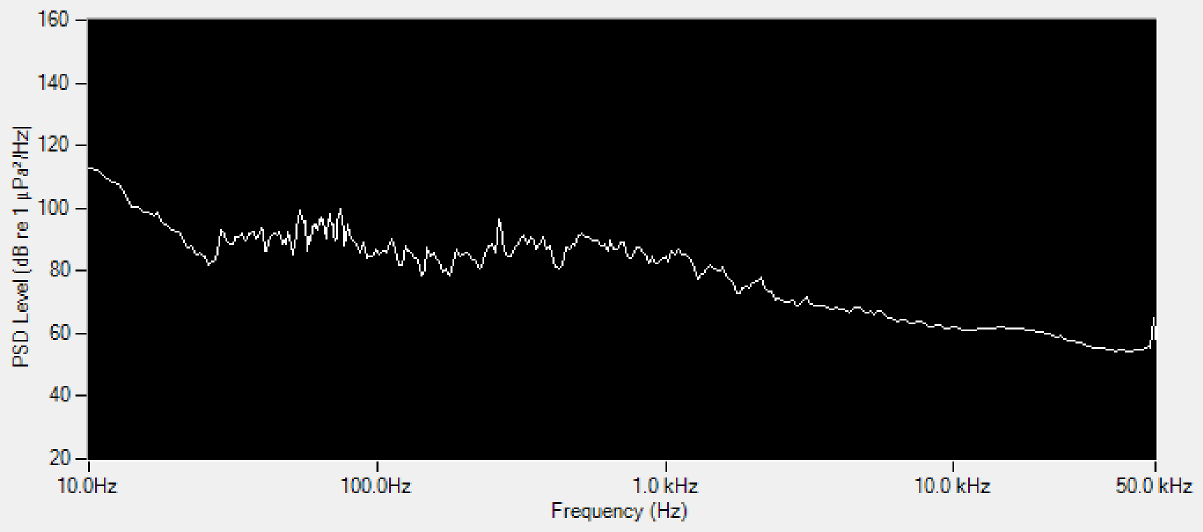

Figure 4-2 Typical background frequency spectrum (power spectral density), 3m depth

4.2 Rotary Drilling

Measurements were taken in the vicinity of the rotary drilling, as close as possible to the site of the works and the drilling rig. Due to the tidal currents and the position of the rig, the closest safe position that the measurements could be taken at was 85 m from the drilling.

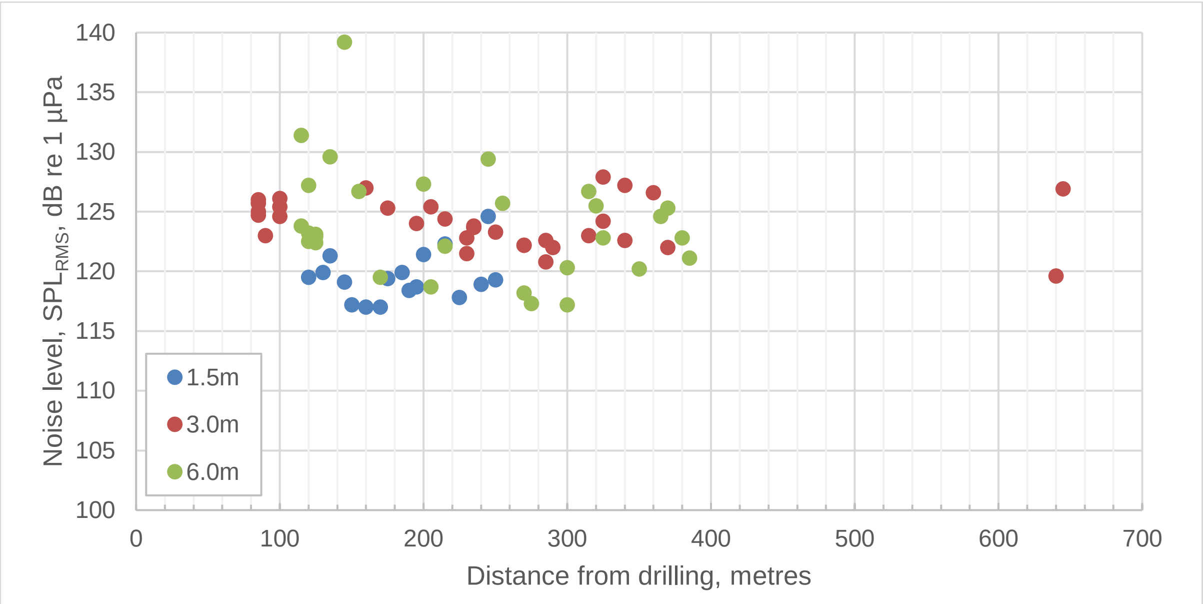

Figure 4-3 Sound level measurements taken during rotary drilling on drifts past the ferry terminal on 29th October 2019

Measured noise levels at all depths varied between 117.0 dB SPL_{RMS} and 131.4 dB SPL_{RMS}. There was one instance at 139.2 dB which, on audio review, was not caused by drilling noise. There was no clear trend on the noise outputs with range, with measurements generally remaining within a 115 dB to 130 dB envelope. Although machinery noise is audible in most recorded measurements at less than 200 m from the drill, the noise from the drilling appears to be largely subsumed within the ambient noise.

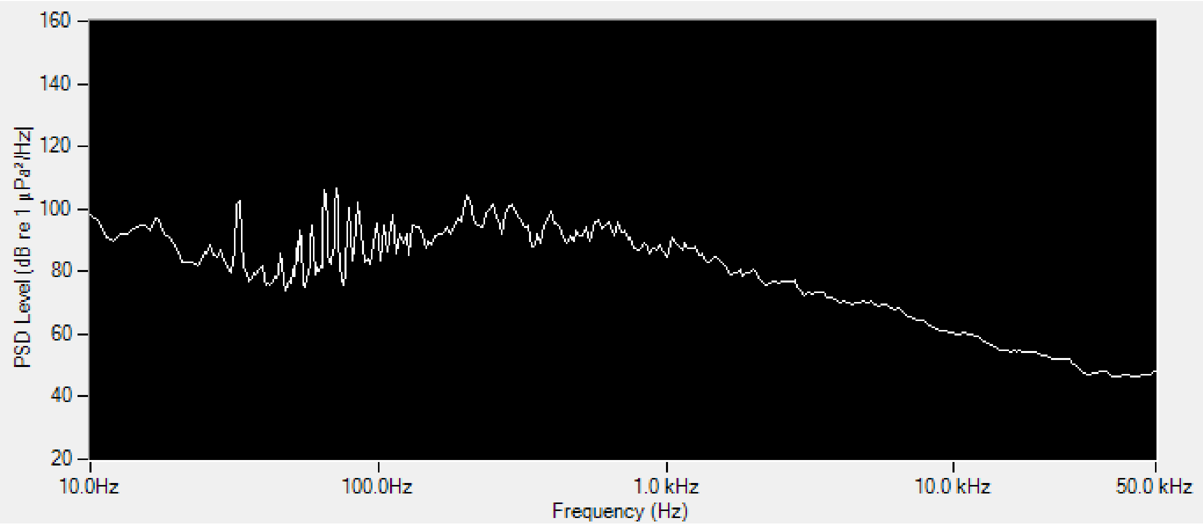

Figure 4-4 Frequency spectrum (power spectral density) at 100 m from drilling, 3m depth

Figure 4-4 shows slightly elevated levels in the low to mid-frequencies between approximately 20 Hz to 200 Hz, although the difference is small.

The lack of variation with distance in the samples during drilling and the fact that they remain within the range of noise levels sampled during the background noise survey indicates that they have a negligible impact on the overall noise level.

A fit to the data to show the extrapolation of noise to and from the source over short or long range could not be undertaken as the construction noise could not be clearly identified over the background. Fixed position monitoring was not feasible in the close vicinity of the drilling due to the self-noise that would have been produced by the rapid water flow over the hydrophone. As a result of the relatively low construction noise levels, it is not possible to determine a source level at 1 m from the drilling.

4.3 Stena Mersey Ferry measurements

Measurements of the Stena Mersey ferry were taken on 29th October between 10:30 and 11:00 while it was berthed at 12 Quays. The measurements were taken at a fixed 3 m hydrophone depth below the water surface. The noise levels measured are shown in Figure 4-5, compared to the distance from the ferry. The drift began 310 m upstream of the ferry and ended 610 m downstream; measurements have been sorted into absolute distance, irrespective of direction.

The noise levels measured were clearly in excess of the background noise. At the closest point on the drift, approximately 90 m from the side of the ferry, the measured noise level was 160.9 dB SPL_{RMS}, approximately 30 dB above the upper bounds of background and drilling noise level measured.

The attenuation of the noise with distance is clear, with a measured noise level of 138 dB SPL_{RMS} at the furthest position, 610 m. The ferry was clearly audible in all samples.

Based on the trend, it is expected that the ferry would reach noise levels of the order of the background noise at a distance in excess of 1 km.

The frequency spectrum of the ferry at 100 m shown in Figure 4-6 shows a clear broadband increase in noise level at all frequencies above approximately 20 Hz.

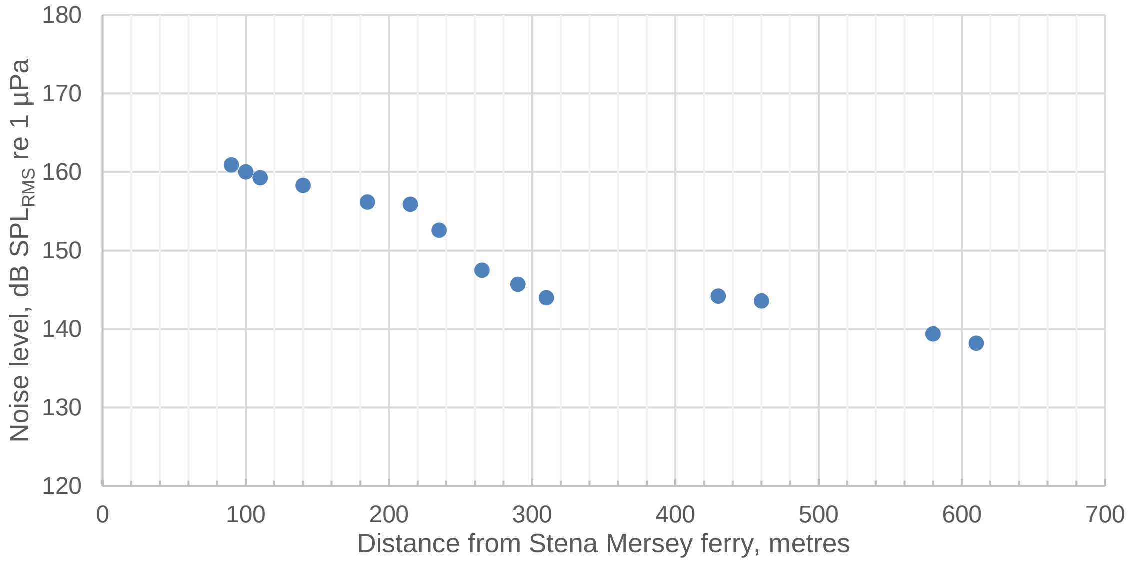

Figure 4-5 Sound level measurements taken near the Stena Mersey ferry on 29th October 2019

Based on the trend in Figure 4-5, the source noise level for the ferry is between 165 and 170 dB SPL$_{RMS}$ at 1 m.

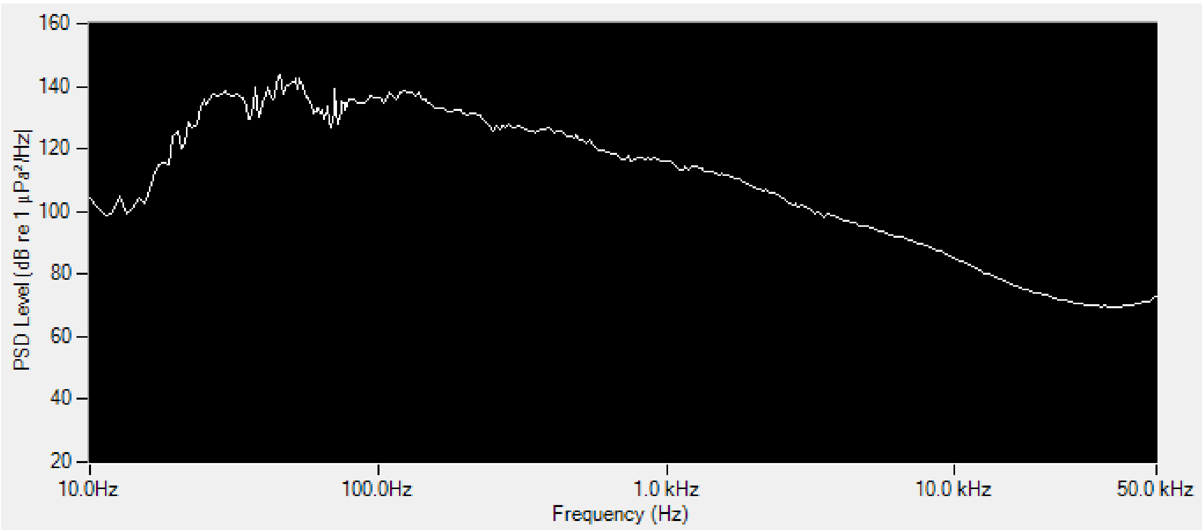

Figure 4-6 Frequency spectrum (power spectral density) at 100 m from Stena Mersey ferry, 3m depth

5 Conclusions

Underwater noise measurements have been undertaken in the vicinity of 12 Quays, prior to and during rotary drilling works by the existing jetty. Measurements were taken of the background noise to establish a baseline, while the rotary drilling was ongoing and while the Stena Mersey ferry was berthed at 12 Quays. These measurements were taken on drift courses down the river at 1.5 m, 3.0 m and 6.0 m below the surface, except at the ferry where only measurements at 3.0 m were possible.

Baseline data showed relatively high noise levels present on the River Mersey in the vicinity of the works. Noise levels were measured between approximately 110 dB re 1 µPa SPL_{RMS} and 132 dB re 1 µPa SPL_{RMS}.

During rotary drilling, noise levels sampled were not clearly above the background noise measured previously. The closest safe distance to acquire measurements was 85 m from the drill. The highest measurement of the rotary drilling was 131.4 dB re 1 µPa SPL_{RMS}, at 115 m. No clear trend of noise reduction with distance was notable during rotary drilling, which indicates that the noise source was already of the order of background noise at this range. This is confirmed by the measured noise levels, although marginal increases could be seen at 100 m in the frequency spectrum. Thus, it was not possible to determine a reasonable source noise level for the rotary drilling.

An additional set of measurements was taken in a drift past the Stena Mersey ferry. Noise levels were measured that were clearly above the background noise; a noise level of 160.9 dB re 1 µPa SPL_{RMS} was sampled at 90 m from the side of the vessel and continued to be clearly audible in excess of 600 m downriver. These are shown in comparison with the measurements of rotary drilling and background noise in Figure 5-1 below.

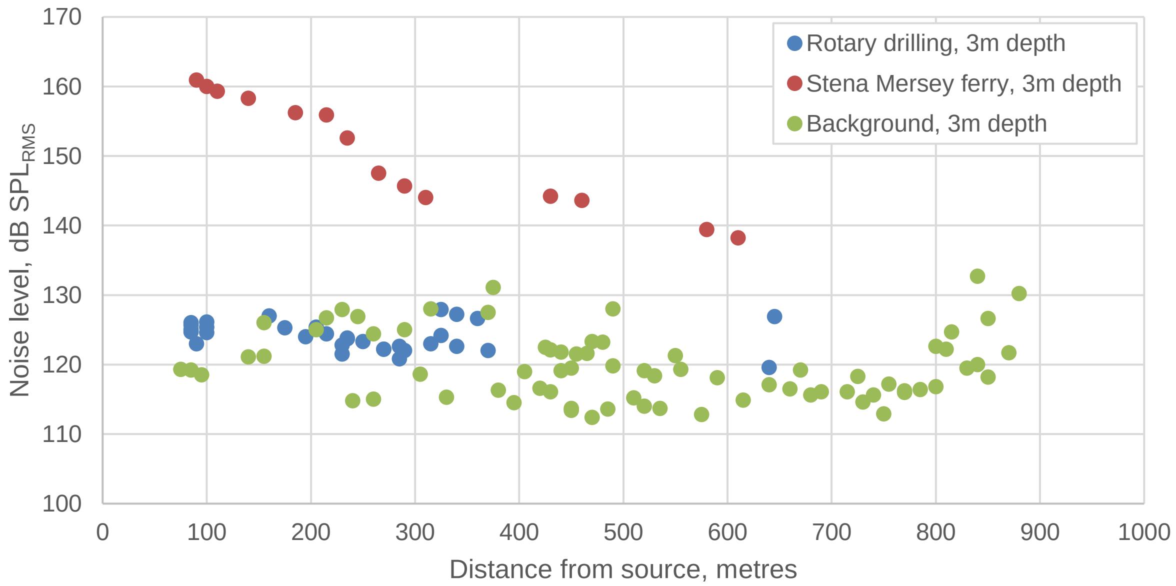

Figure 5-1 Comparison between measurements taken during operation of the rotary drill, near the Stena Mersey ferry and background noise (background noise distance has been calculated from the location of the drill)

Appendix A Hydrophone calibration certificate

NEPTUNE SONAR LTD

ACOUSTIC CALIBRATION LABORATORY

TEST CERTIFICATE

PROJECT REF:	6404
SERIAL NUMBER:	2256725
TRANSDUCER TYPE:	B+K 8106
DESCRIPTION:	Hydrophone
TEST SPECIFICATION:	6404-10-01-01
ISSUE DATE:	21 December 2017

Ref Projector:	D/11_18684	**Ref Projector:**	D/26_22769
Ref Projector:	D/70_34376		

TABULATED RESULTS	**(5 pages)**
ADMITTANCE LOOP	**(1 page)**
ADMITTANCE GRAPH	**(1 page)**
HYDROPHONE SENSITIVITY GRAPH	**(2 pages)**
POLAR PLOT	**(2 pages)**

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The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor k = 2, providing a level of confidence of approximately 95%

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