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METHODOLOGY FOR UNDERWATER NOISE LEVEL MEASUREMENT FROM DREDGING ACTIVITIES.

Santiago Núñez Gutiérrez[1] **Diego P. Ruiz-Padillo**[2]

[1] Eurofins Cavendish S.L.U, Spain. (santiagojose.nunez@etib.eurofins.com)
[2] Department of Applied Physics, University of Granada, Spain. (druiz@ugr.es)

ABSTRACT

Dredging activities are used for building new harbours or enlarge them, create artificial islands or to keep low river navigable. Dredging activities generate high levels of underwater noise. Measuring and assessing this noise is challenging, mainly due to three reasons. The first one is the complex propagation environment where dredging activities are carried out: shallow depth in sea or rivers, or flow streams significantly modify wave propagation. A second reason is the variability of machinery used for dredging activities depending on the type of substrate being dredged. The third cause is the implementation of the activity itself: remove or release of material, type of material (sediment or water) to be dredged, the use of a moving or a moored vessel, etc. In this article, the sources of the underwater noise coming from these activities are identified and some methodological considerations for assessing the noise level impact of these types of activities are provided. Based on the recorded data coming from an experimental setup and a measurement campaign, it is performed a noise level frequency analysis from the different operations of the dredging vessels to outline the range of possible impacts in this marine environment.

Keywords: *underwater acoustics, dredging noise, Descriptor D11, underwater noise propagation.*

1. INTRODUCTION

Dredging activities are a common activity on our coasts and rivers. It's mainly done to restore depth to rivers and estuaries. This allows them to be navigable during periods of high sedimentation in winter and spring. Prevent river overflows in the channels. Dredging activities are also necessary for the construction of ports, dikes, and beach regeneration.

The term dredging is very generic and encompasses different types of activities and types of vessels.

The most common dredging vessels are: the trailing suction hopper dredge (TSHD), Backhoe dredger and grab dredger [1-2].

The trailing suction hopper dredge (TSHD) is commonly used in dredging operations to support rivers and estuaries nourishment operations. Hopper dredges are self-propelled seagoing vessels that hydraulically remove sediment from the seafloor through dragheads. The dragheads are "trailed" beneath the dredge and held in contact with the substrate as the dredge advances. Large suction pumps transport the sediment from the seafloor and deposit the dredged material into one or more hoppers. Once capacity is reached, the TSHD sails to either a beach or an offshore placement site where the material is released through doors located in the hull of the ship, or the TSHD pumps out the material through pipes using a floating booster pump barge to the desired location. This "pump-out" method is generally employed during to return channels to authorized depths.

The main processes which contribute to generating noise associated with hopper dredging activities include: 1) sounds arising from the removal of material while the draghead is in contact with the seafloor; 2) sounds produced by suction pipes and pumps, and the movement of dredged material through the dragarm riser to the hopper; 3) deposition sounds associated with loading of the material into the hopper (including overflow if used); 4) sounds associated with the dredge machinery itself, such as winches, generators, thrusters and particularly propeller-induced cavitation; and 5) sounds associated with the off-loading of material from the hopper for placement on the beach

Corresponding author: santiagojose.nunez@etib.eurofins.com

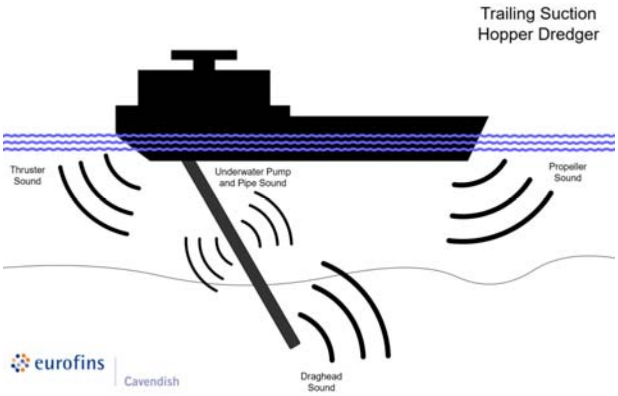

Figure 1. Trailing suction hopper dredge TSHD.

These sound waves are omnidirectional and continuous in nature. In some cases it may be possible to identify occasional discrete sound events such as contact of the draghead with the channel bottom or the turning on or off of suction pumps. In general, it is difficult to separate the individual processes involved in dredging by their temporal location in the record. However, the dredging operation as a whole can be separated into discrete dredging activities such as sediment excavation, or transiting to and from the borrow area.
In addition, backhoe dredger and grab dredger are commonly used in dredging operations to support nearshore operations and locate activities.

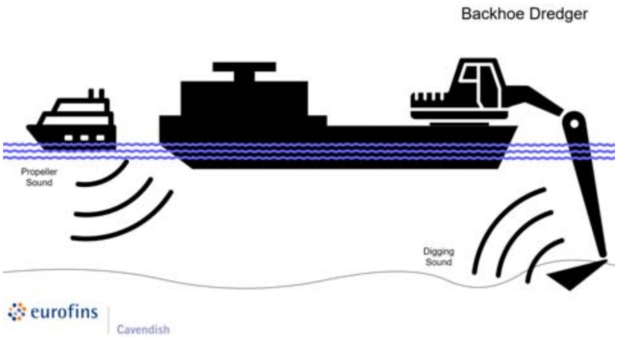

Figure 2. backhoe dredger.

The type of noise generated is not as continuous as those generated by TSHD. The moment of highest noise level is during the process of scraping the seabed. It depends mainly on the seabed material and the quantity and type of rocks.
The dredger is stationary and anchored to the seabed, so it doesn't generate propulsion noise. However, on some occasions, the Backhoe has an auxiliary vessel that does generate propulsion noise

Figure 3. Trailing suction hopper dredge TSHD.

The objective of this article is to identify the sources of the underwater noise coming from dredging activities and perform a spectral characterization of these waves, with the aim of assessing the noise level impact of these types of activities. To accomplish this, in section 2 it is described the instrumentation and data acquisition method to collect noise data, in section 3 a qualitative analysis of the recorded spectral data is presented, in terms of identifying the type of noise and the possible noise level impact of the operations. Finally in section 4 some discussions and conclusions are provided in terms of the underwater noise impact, based on the analysis of recorded data.

2. METHODS

Sound data coming from dredging operations were collected using a DORI recorder by ABYSsens over their full frequency range using National Institute of Standards and Technology (NIST) protocols. Horizontal directivity is omnidirectional + 2 dB at 100 kHz. Vertical directivity is 2700 + 2 dB at 15 kHz. The receiving sensitivity is -186 dB re 1V/µPa.. The DORI recorder consists of a sound DAQ (Data Acquisition Board), data processor, auxiliary data storage hard drive (500 GB). Figure 3 illustrates the type of hydrophones used to collect data, as described before.

Figure 4. Hydrophones used in this research.

A TSHD may generate noise from a number of its structural components (e.g., propellers, suction pumps, and dragheads during operation). Therefore, measurements were obtained at various orientations between the dredge and the listening platform (LP), including the following: LP directly astern of the dredge (dredge advancing away from the LP), bow (dredge approaching the LP), and either the port or starboard side of the dredge. For each vessel, hydrophone measurements were performed as a function of range from the TSHD at multiple distances. In addition to measuring noise from the dredging process, ambient noise was also measured at both the borrow area and pump-out stations. A total of 77 dredge recording sessions were conducted during the various phases of dredge operation. The monitoring ranges (25-2500 m) varied for each vessel and dredge activity, but measurements for most dredge modes typically did not exceed 1 km. Analysis included only data collected for ambient purposes that exceeded a distance of 3 km from the nearest dredge. A total of 24 ambient recording sessions were made. Each session generally consisted of two to six 15-minute files. Hydrophone deployment depths at the borrow area were 3 m for the upper listening depth (ULD) and 9.1 m for the lower listening depth (LLD). Given the shallower water conditions at the pump-out stations, the lower hydrophone depth was decreased to 7.1 m.

2.1 Sound data analysis

Real-time data collection files were obtained from the DORI recorder for each recording session. GPS position data were embedded within these files. Both SPL (rms) and GPS data were logged at 1-second intervals for both the upper (ULD) and lower (LLD) listening depths. Individual sound files were analyzed using Sound Technologies SpectraLab 4.32 sound spectrum analysis software. SpectraLab uses Fast Fourier Transform (FFT) to convert the time-domain (amplitude versus time) WAV files into the frequency domain (amplitude versus frequency). Files were processed to generate an average sound spectrum and SPL across the entire file from the time series values, and using 1/3-octave analysis averaged across the whole sound clip. Each of these spectral analyses was saved in a separate text file to create graphic displays of the results. Also noted during analysis of each sound clip file were the peak frequency (in Hz) and peak amplitude (dB re 1µPA rms) for both the collection of peaks and the 1/3-octave analysis. The 1/3-octave analysis computes SPL frequency "bands" of equal length. The lower frequency bands are narrower than the higher frequency bands. The frequency bands follow a logarithmic progression. The 1/3-octave analysis sums the dB values for each frequency in the individual frequency bands and produces a dB value of the collective frequencies in each band. Each band is defined by a center frequency. The 1/3-octave analysis/infinite average-peak frequency is the center frequency of the 1/3-octave band with the highest calculated dB band. Note that in most cases, single-peak values are not very meaningful, as they simply measure the peak amplitude of the strongest single frequency observed throughout the given sound clip. This is particularly true for sounds that are not of an impulse nature, such as the rotation of the cutterhead. In these cases, the total power is calculated from all of the collective peaks and would exaggerate any real sound levels at any single instant during the clip. The 1/3-octave analysis across the sound clip is a more meaningful value for comparing one clip to another. Conversely, if the sounds are of a more instantaneous impulse type (e.g., pile driver), an analysis of peak amplitudes and frequencies might be more appropriate.

Three data sets were assembled to complete the analysis. Data set 1 contained both the real-time SPL (rms) and the 1/3-octave analysis results at 1-second intervals. Data set 2 contained DQM data for all four dredges for the tree-week time period in which field data were collected. DQM data intervals varied from 2 to 300 seconds. DQM data were interpolated to 1-second intervals to match the GPS and sound data collection rate. Data set 3 (wind data) was obtained by downloading hourly measurements recorded at the weather station.

3. RESULTS

In this section we present a preliminary analysis of the data recorded using the methodology provided in the preceding section.

3.1 Frequency analysis from hopper dredge TSHD suction and emptying process

Results coming from the suction process and the emptying process are analysis with the aim of establishing the more relevant frequency intervals are shown in this subsection.

The analysis of the trailing suction hopper dredge or TSHD sound emission indicated that dredge noise occurs in the low frequency range (< 1200 Hz). This frequency interval is relevant since it is within the audible range of listed species of whales and sea turtles, as well as many species of fish.

Figure 4 shows the spectrogram of the suction process of the TSHD. It can be observed that the noise energy lies mainly in frequencies between 600 and 1200 Hz.

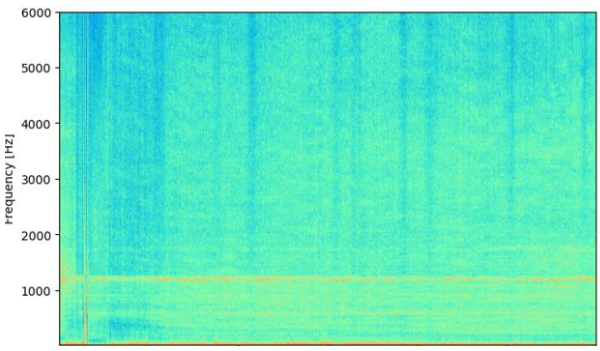

Figure 5. Spectrogram of the suction process TSHD.

In Figure 5 it is shown the same spectrogram of the suction process for the range of 1 Hz to 1500 Hz. In this figure it can be observed that the noise at the frequency of 1200 Hz appears more defined.

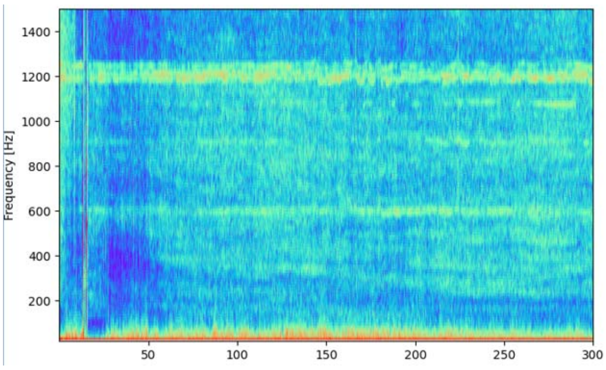

Figure 6. Spectrogram of the suction process TSHD (reduced range).

Figure 6 shows the main noise level at low frequencies. High energy levels are also observed between 250Hz and 1250Hz. The increase in noise at 1250Hz is very significant and appears in most of the samples obtained in the recording process.

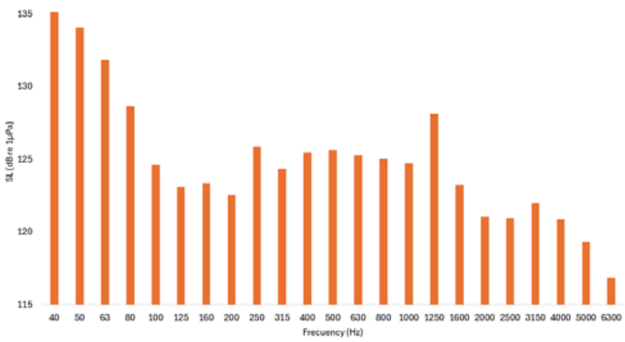

Figure 7. 1/3 octave analysis suction process TSHD.

Figures 7 through 11 show the emptying process. During this process, the dredge is not moving. This process is neither continuous nor rapid. The dredge slowly opens the different cargo compartments. This can be clearly seen in the spectrograms in Figures 7 and 9.

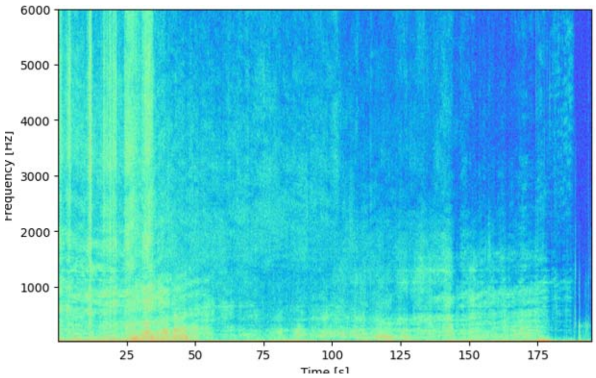

Figure 8. Spectrogram of the emptying process TSHD.

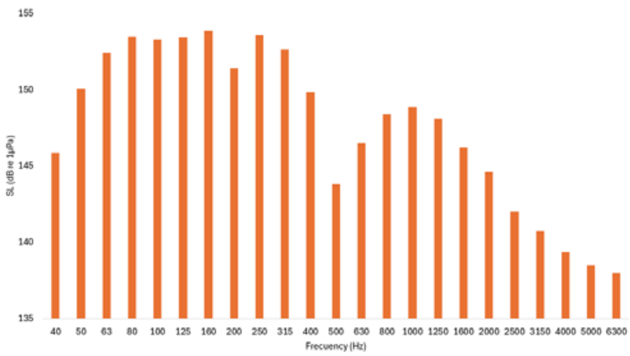

Figure 9. 1/3 octave analysis of the trailing suction hopper dredge TSHD.

These sounds are omnidirectional and continuous in nature. In spectrogram 9 it can be seen how at the beginning the emptyings are of short duration while at the end of the process spectrogram 10 the emptying is longer.

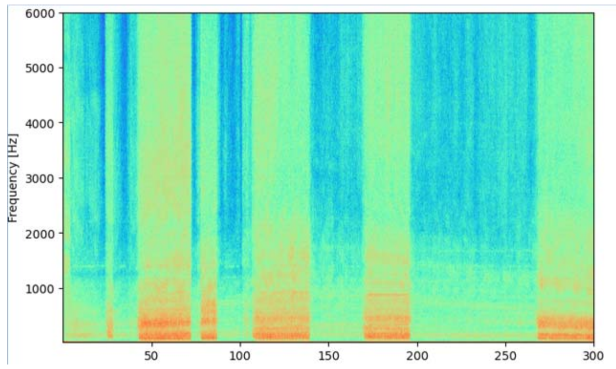

Figure 10. Spectrogram of the emptying process TSHD.

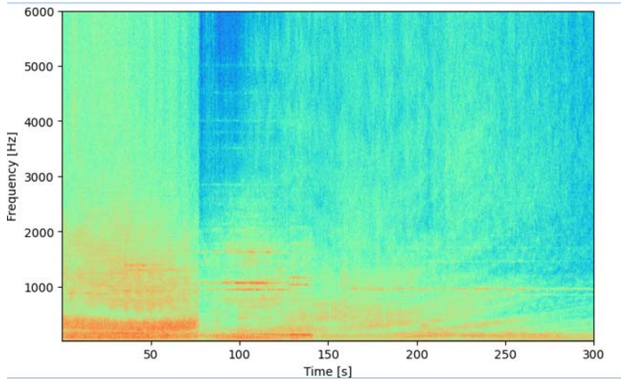

Figure 11. Spectrogram of the emptying process TSHD.

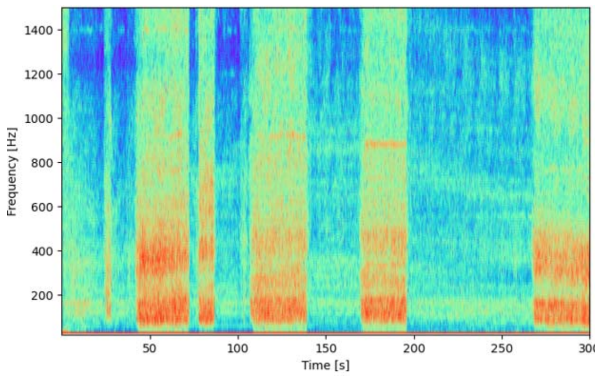

Figure 12. Spectrogram of the emptying process (figure 7)TSHD.

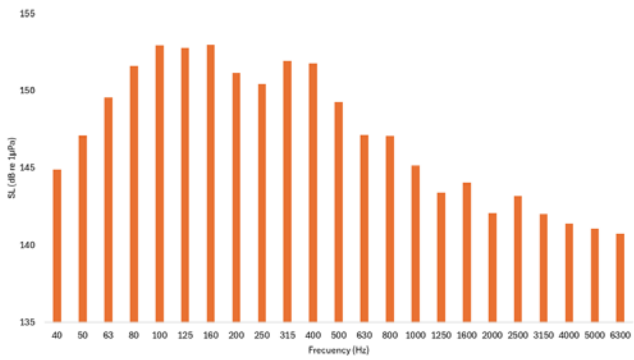

Figure 13. 1/3 octave analysis emptying process (figure 7) TSHD.

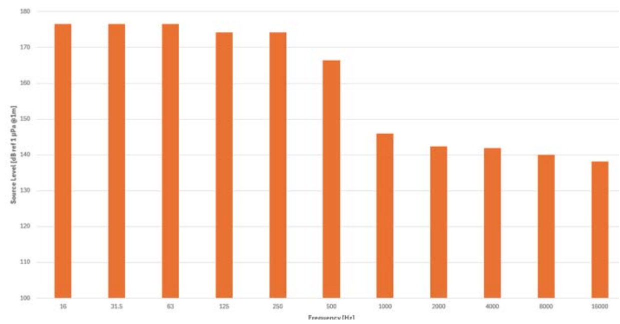

Figure 15. Frequency analysis of the backhoe dredger emission.

3.2 Frequency analysis from Backhoe dredge without auxiliary vessel emission.

Figures 13 and 14 show the spectrogram and the analysis in 1/3 octave bands of the Backhoe dredge without auxiliary vessel. The spectrogram shows that it is not a continuous noise. The highest noise levels correspond to the scraping of the seabed.

In the 1/3 octave frequency analysis, the highest levels are found at low frequencies up to 250 Hz. Occasionally, tones appear at frequencies higher than 2000 Hz.

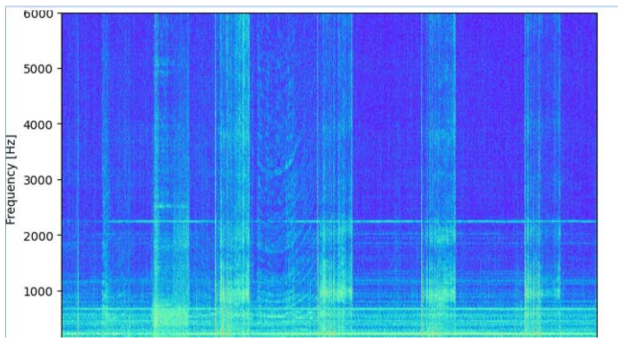

Figure 14. Spectrogram of the backhoe dredger noise emission.

3.3 Noise level analysis and comparison with other research

For comparison of results with other publications [2-3]. the Estimated source level dB re 1µPa @1m is used

Table 1. Table comparison with Estimated source level dB re 1µPa @1m.

Dregred	publications [4-6]	This research
TSHD (succion)	165/175	168/172
TSHD (Empty)	175/188	175/181
Backhoe	175/180	175/179

It can be seen that the range obtained from other publications is relatively wide. In comparison with our recorded data, they are in accordance with those reported in other research studies, which show a wide range of noise levels.

A detailed analysis of our measurements under repeatability conditions by sample justifies this wide range found in measurements, as can be observed in figures below. In figure 15, variations of 3dB can be seen in many of the frequencies, even in some of the samples it disappears at 1200Hz.

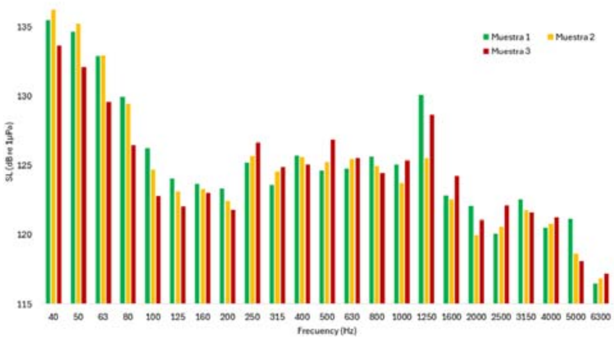

Figure 16. Spectral noise level of the Suction process TSHD.

For the dredge emptying process (figure 16) variations can exceed 5 dB between samples. Frequencies between 40 and 80 Hz show the greatest variability, although 315 Hz and 400 Hz also show the greatest variability.

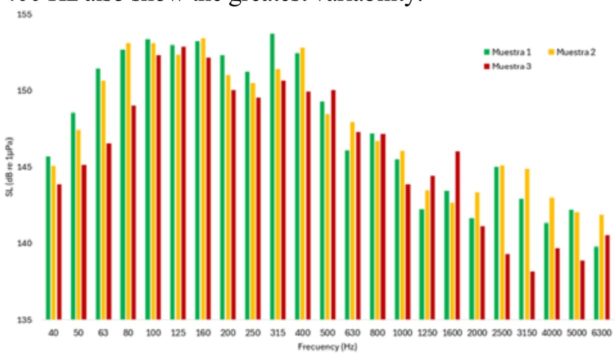

Figure 17. Spectral noise level of the emptying process TSHD.

4. CONCLUSIONS

As the results shown in the preceding section, there are a variety types of dredgers and operate differently. This means that the specific operation of these dredges must be taken into account when measuring the underwater noise generated by the activity. The duration of underwater noise measurements for a suction operation should not be the same as for the emptying process.

The suction process performed in the TSHD can produce underwater noise These sounds are omnidirectional and continuous in nature, at frequencies of 1200Hz and 800Hz. From our measurements, it can be observed that the results and spectrograms are very different depending on the suction or emptying process. While the suction process is very continuous and tones may appear at specific frequencies, the emptying process is not as continuous because it has different emptying phases.

The Backhoe dredger generates a different type of noise during scraping and extraction. The noise varies depending on the type of sediment. Blackhoe dredger has no propulsion during the dredging process so the frequency and noise levels differs significantly from those measured in other operations.

On the other hand, TSHD measurements have indicated that dredge noise occurs in the low frequency range (< 1200 Hz), and high noise levels between the ranges of 10Hz to 1200Hz are generated. This lies within the audible range of listed species of whales and sea turtles, as well as many species of fish so these type of activities can generate a relevant impact on underwater marine life. In this sense, there are numerous bioacoustic publications such as (Alfredo Bori et al 2022) [4]. that detect the chorus generated by different types of fish for communication events in the frequencies of 80 to 315Hz. Therefore, based on the D11 descriptor of Marine Strategies Frameworks Directive (MSFD), it is necessary to address the underwater noise generated by dredgers.
For future work, we will analyze Grab dredgers. We will also analyze special propagation conditions, such as the influence of river currents, and the possibility of testing under ISO 17208 in shallow water.

5. REFERENCES

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