# APPENDIX H:
# SOUND METRICS

Underwater sound levels are measured in dB re. 1 µPa. Different methods of representing the sound level exist to characterize the intensity, exposure level, or even max levels. Depending on the intended use of the results, and the type of source, it can be useful to use one sound level representation over another. For impulsive sound sources, such as an airgun array, the four most commonly used ones are:

1. The sound pressure level peak-peak ($SPL_{peak-peak}$) and zero-peak ($SPL_{zero-peak}$)

2. The root-mean-square sound pressure level ($SPL_{90\%rms}$)

3. The sound exposure level (SEL)

4. The cumulative energy flux

These four metrics are briefly explained in the following

**$SPL_{zero-peak}$ and $SPL_{peak-peak}$**

The $SPL_{zero-peak}$ is the maximum instantaneous sound pressure level of an impulse $p(t)$, given by:

$$SPL_{zero-peak} = 20 \log_{10}(\max|p(t)|)$$

The closely related $SPL_{peak-peak}$ is the maximum difference in sound pressure level of an impulse $p(t)$, given by:

$$SPL_{peak-peak} = 20 \log_{10}\big(\max(p(t)) + \big|\min(p(t))\big|\big)$$

which is also the metric used for the modelling in this project.

**SPL$_{90\%rms}$**

The SPL$_{90\%rms}$ is the root-mean-square pressure level over a time window, T, containing the impulse p(t):

$$SPL_{90\%\,rms} = 10\log_{10}\left(\frac{1}{T}\int_T p^2(t)dt\right)$$

The SPL$_{90\%rms}$ is defined as the mean value of a pulse with the time window T containing "90% of the pulse energy" as described in [Malme et al. 1986]. As a result of dividing by the time window T in the equation, pulses with the energy spread out over a long duration will have a lower SPL$_{90\%rms}$ than a short duration pulse with the same total energy. It is therefore a useful metric to describe the impulsivity of a source.

**SEL**

The SEL, also known as the sound exposure level is defined as the time-integral of the square pressure over a time window T covering the entire pulse duration, and is given by:

$$SEL = 10\log_{10}\left(\int_T p^2(t)dt\right)$$

**Cumulative Energy Flux**

The cumulative energy flux is a standard measure for airgun arrays. The power spectrum is integrated, and the result is shown with increasing frequency.