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Memo

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Subject: Pile Drilling Underwater Noise Estimation

1. Operation Background

JASCO has reviewed the project information detailed in Dampier Seawater Desalination Plant Environmental Review Document (Hamersley Iron Pty Ltd, 2022), in particular Section 2.2 which contains information about the seawater intake pond, the existing culverts and their size, and the construction methods proposed. It is understood that up to six piles will be installed into the bedrock to secure the seawater intake pumps in the pond. The estimated maximum diameter of the piles is 1050 mm and estimated maximum wall thickness is 20 mm. The drilling activities are confined within the existing intake pond. Before construction works begin within the existing intake pond, the existing culverts will be completely blocked on the pond side using pipeline plugging methods.

2. Relevant Acoustic Information

The source of the noise from the pile drilling operation is the vibration transferred from the drill bit into the surrounding bedrock and sediment, and also the water within the seawater intake pond. This noise from the operation may then propagates through both media until it reaches the seawater intake pond wall, where it could be transferred into the marine environment. The materials through which the noise will propagate, will likely cause the main components of acoustic emissions into the marine environment to be significantly lower than if the drilling was occurring in open water.

JASCO recently completed a confidential monitoring program of the drilling operations installing 600 mm diameter piles into rock next to a coastal marine environment. While the specific results are unable to be shared, general descriptions and understandings gained through the project can be used to provide context to the operations proposed in Dampier. This measurement program measured the land-based drilling operations at 11 m from the pile using a hydrophone. There was negligible contributions of energy above 3 kHz, received levels varied with drill speed, with the maximum received sound pressure level (SPL) at the hydrophone being approximately 170 dB re 1 µPa.

JASCO also recently completed a confidential modelling project for installation of sheet piles using a vibratory hammer, where the piles were 10 m from a 7 m thick rock wall, which had water on the other side. This detailed modelling study demonstrated an attenuation of approximately 15 dB when the piling noise passed through the wall. Vibratory pile driving is a non-impulsive noise source, and the

noise type is similar to that from drilling operations, thus making this an appropriate proxy. Therefore, this information can be used to provide context to the potential attenuation of the seawater intake pond wall.

3. Estimation of Drilling Noise Levels

The activity description, along with the information from JASCO's aforementioned monitoring and modelling studies can be used to estimate the noise levels from the drilling operations. The noise levels generated by the drilling of a 1050 mm diameter pile, as opposed to a 600 mm pile, are likely to be similar, although potentially louder. The drilling operations are approximately 90 m from the seawater intake pond wall, which is approximately 30 m thick. The total distance between source and the open marine environment is therefore about 120 m and the propagation path traverses several different contrasting media.

A conservative assumption to estimate the levels of the drilling operations at the inside side of the seawater intake pond wall would be to use the levels JASCO measured 11 m from the 600 mm pile as described above. This is conservative because it ignores the attenuation which would occur over a 90 m distance between the pile location to the wall, and therefore makes any uncertainty about the difference in levels from a larger pile negligible.

The attenuation within the rock wall could be conservatively approximated as being three times that modelled from the vibratory piling operations, due to the wall being four times thicker and thus be equivalent to 45 dB re 1 µPa.

The result of this attenuation from the rock wall therefore could be that a pile drilling noise of approximately 135 dB could be emitted into the water at the rock wall / marine environment interface. Considering a conservative assumption of attenuation being $15*\log_{10}(\text{range})$, within 11 m from the rock wall the sound levels from the drilling would have attenuated to 120 dB re 1 µPa.

4. Relevant Noise Effect Criteria

To assess the potential impacts of a sound-producing activity, it is necessary to first establish exposure criteria (thresholds) for which sound levels may be expected to have a negative impact on animals. Whether acoustic exposure levels might injure or disturb megafauna is an active research topic. Since 2007, several expert groups have developed SEL-based assessment approaches for evaluating auditory injury, with key works including Southall et al. (2007), Finneran and Jenkins (2012), Popper et al. (2014), United States National Marine Fisheries Service (NMFS 2018), and Southall et al. (2019). The number of studies that investigate the level of behavioural disturbance to megafauna by anthropogenic sound has also increased substantially.

Several sound level metrics, such as peak pressure (PK), sound pressure level (SPL), and sound exposure level (SEL), are commonly used to evaluate noise and its effects on marine life. The acoustic metrics in this report reflect the updated ANSI and ISO standards for acoustic terminology, ANSI S1.1 (S1.1-2013) and ISO 18405:2017 (2017).

The analysis presented here considers impulsive and non-impulsive (continuous) noise criteria. The following noise criteria are considered, and are chosen for their acceptance by regulatory agencies and because they represent current best available science:

1. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Southall et al. (2019) for the onset of permanent threshold shift (PTS) and temporary

threshold shift (TTS) in marine mammals, including low-frequency (LF) and high-frequency (HF) cetaceans and sirenians (dugong).

2. Marine mammal behavioural threshold based on the current US National Oceanic and Atmospheric Administration (NOAA 2019) criterion for marine mammals of 120 dB re 1 µPa (SPL; L_p) for non-impulsive sound sources.
3. Peak pressure levels (PK; L_{pk}) and frequency-weighted accumulated sound exposure levels (SEL; $L_{E,24h}$) from Finneran et al. (2017) for the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS) in sea turtles. Sea turtle behavioural response to non-impulsive noise to be assessed using the relative risk criteria from Popper et al. (2014).

There are two categories of auditory threshold shifts or hearing loss: Permanent Threshold Shift (PTS), a physical injury to an animal's hearing organs; and Temporary Threshold Shift (TTS), a temporary reduction in an animal's hearing sensitivity. To help assess the potential for the possible injury and hearing sensitivity changes in marine mammals (auditory injury, approvals documentation as physiological injury), this report considers the criteria recommended by Southall et al. (2019), considering both PTS and TTS. These criteria, along with the considered behavioural response criteria (NOAA 2019), are summarised in Table 1.

The auditory injury effect criteria for megafauna use dual metrics (PK and SEL_{24h}), with both being considered in this assessment, and the longest distance associated with either metric is required to be applied in any impact assessment and the determination of exclusion zones. The SEL-based criteria are typically assessed over 24 h, or the period of operations, which in this case includes daylight hours only.

Table 1. Acoustic effects of non-impulsive noise on marine mammals: Unweighted SPL and SEL_{24h} thresholds.

Hearing group	NOAA (2019)	Southall et al. (2019)	
	Behaviour	PTS onset thresholds (received level)	TTS onset thresholds (received level)
	SPL (L_p; dB re 1 µPa)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)	Weighted SEL_{24h} ($L_{E,24h}$; dB re 1 µPa^2·s)
LF cetaceans (mysticetes, e.g., humpback whales)	120	199	179
HF cetaceans (odontocetes)		198	178
Sirenians (Dugong)		206	186

L_p denotes sound pressure level period and has a reference value of 1 µPa.
L_E denotes cumulative sound exposure over a 24 h period and has a reference value of 1 µPa^{2}s.

There is a paucity of data regarding responses of turtles to acoustic exposure, and no studies of hearing loss due to exposure to loud sounds. Popper et al. (2014) suggested thresholds for onset of mortal injury (including PTS) and mortality for sea turtles and, in absence of taxon-specific information, adopted the levels for fish that do not hear well (suggesting that this likely would be conservative for sea turtles).

Finneran et al. (2017) presented revised thresholds for sea turtle injury and hearing impairment (TTS and PTS). Their rationale is that sea turtles have best sensitivity at low frequencies and are known to have poor auditory sensitivity (Bartol and Ketten 2006, Dow Piniak et al. 2012). Accordingly, TTS and PTS thresholds for turtles are likely more similar to those of fishes than to marine mammals (Popper et al. 2014).

There are no suggested quantitative threshold for behavioural response in sea turtles from non-impulsive noise, therefore the relative risk criteria from Popper et al. (2014) should be applied

The thresholds for auditory effect (PTS and TTS) from non-impulsive noise sources are listed in Table 2, and the relative risk criteria presented in Table 3.

Table 2. Acoustic effects of non-impulsive noise on sea turtles, weighted SEL_{24h}, according to Finneran et al. (2017).

PTS onset thresholds (received level)	TTS onset thresholds (received level)
220	200

Table 3. Criteria for non-impulsive (vessel)noise exposure for sea turtles, adapted from Popper et al. (2014).

Type of animal	Mortality and Potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Sea turtles	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low

Sound pressure level dB re 1 µPa.
Relative risk (high, moderate, low) is given for animals at three ranges from the source defined in relative terms as near (N) – tens of metres, intermediate (I) – hundreds of metres, and far (F) – thousands of metres.

5. Summary

Given the points discussed above, it is unlikely that noise levels from pile installed on land 120 m from the coastline edge will results in significant acoustic energy emitted into shallow water environment around the construction site. A sound level threshold of 120 dB SPL appropriate for considered fauna may, under conservative assumptions, be reached within 11 m of the seawater intake pond wall. It is far more likely that this level may not be exceeded at all from the drilling operations.

Considering the noise effect criteria in Section 4, and the expected sound levels within the water, none of the criteria for PTS or TTS could be exceeded by the drilling operations. The estimated sound levels in the water could exceed 120 dB, the marine mammal behavioural threshold for non-impulsive sound sources, at approximately 11 m from the seawater intake pond wall.

Turtles could exhibit signs of behavioural response within hundreds of metres, considering the criteria in Table 3, however it is likely to be restricted to Near (tens of metres) due to the low sound levels expected in the water and the high ambient noise conditions likely in the vicinity of the seawater intake pond due to vessel traffic.

5.1. Recommendations of Management Measures

The recommended mitigations to apply which should minimise the effects on marine mammals and sea turtles are as follows:

- Construction personnel to keep watch for marine fauna within a 100 m exclusion zone around the seawater intake pond, and shutdown operations if marine fauna occur within this exclusion zone.

- Operations should implement a soft-start style approach, where the drilling increases in speed gradually over the period of a few minutes, to allow nearby fauna to move away.

6. References

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