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Tonal sound from onshore drilling rig top drive unit

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ABSTRACT

Over the last 10 years onshore drilling for hydrocarbons (natural gas and oil) in the Taranaki region of New Zealand has reached new levels of intensity. As exploration expanded between 2005 and 2015 so too did the potential for conflict with communities. Sound emissions from onshore drilling rigs are generally well understood and can be mitigated accordingly. However, the top drive unit of onshore rigs can emit strong tonal sound. This paper summarises the results of detailed analysis in determining whether drilling processes are influential in the causation of tonal sound from the top drive unit. The results of this analysis were also used to provide the rig operator guidance as to how to modify drilling, especially at night, to avoid generating tonal sound that may cause disruption to communities.

Keywords: Sound, tonal sound, onshore drilling, top-drive. I-INCE Classification of Subjects Number(s): 12.1.4 Motors and generators, 11.5.1 Electric motors , 12.1.8 Large rotating electrical equipment 52.1 Community noise levels, 72.1 Sound pressure level, 81.1 National standards.

1. BACKGROUND

Onshore exploration for hydrocarbons has been taking place in the Taranaki region of New Zealand since 1865 (1). These early explorations occurred in and around what is now Port Taranaki. Even today small naturally occurring oil seeps can be seen in the harbour.

Throughout the twentieth century the exploration occurred on a modest scale in between the two world wars and great depression of the 1930's. After the Second World War, United States army technology pioneered what we refer to as seismic surveying. In the early days this was known as 2D (2 dimensional) whereas today's continuation of this work adds 3D and 4D resolution to the analysis.

While oil was found in early discoveries and today in modest quantities, it is the natural gas component of the reservoir that is favoured in New Zealand today. Natural gas is an important source of energy for domestic heating and cooking and is used to generate 16% of the nation's electricity (2). By comparison 60% of New Zealand's energy is provided by hydro generation. Natural gas has several benefits. Firstly, gas fired peaker power stations can start generating power within 10 minutes of power demand being required. Secondly, the Taranaki region of New Zealand has plentiful supplies of natural gas which are distributed to domestic and commercial customers for use.

Several cornerstone natural gas fields in Taranaki are Kapuni, Maui and Pohokura fields. The Kapuni field was discovered in 1959 and began producing commercial quantities of natural gas in 1969 and is still a viable source today. The Maui offshore gas field was one of the biggest natural gas discoveries of its time and piped its first product to the onshore facility at Oanui in 1979. More recently the Pohokura gas field now produces around 40% of the domestic gas used in New Zealand (3).

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1.1 Onshore Drilling

The equipment used for onshore drilling has not largely changed for decades. The use of rotary drilling technology is still commonly used. However, the changes that have occurred relate to the depth that exploration can occur at as well as the protection of the health and safety of workers and the natural environment.

Onshore drilling for hydrocarbons in the Taranaki region of New Zealand requires wells of up to 4,500m in depth to access productive reservoirs. The forces applied by the reservoirs at this depth means the equipment used for exploration must be fit for purpose. This includes the ability to match the natural reservoir production forces with a controlled hydraulic equivalent to ensure the whole system is balanced and safe for operation to continue.

This equilibrium is maintained though mechanical and hydraulic averages. Mechanically this averages integration of blow out preventers as a final solution. Hydraulically, fluid referred to as mud, is pumped into the well and circulated so that it can remove the well cuttings, lubricate the drilling process and balance the reservoir forces generated by natural gas escaping the reservoir during drilling.

In order to target the reservoirs identified as having the most potential for hydrocarbons using 3D seismic data, the use of directional drilling technology has become commonplace. As the name suggests this averages the drill string does not simply penetrate the earth in a simple vertical direction, but rather can be controlled such that a path to the target zone is made that avoids subterranean features which are unfavourable for drilling.

When drilling to depths of 4,500m via a non linear or direct path, additional forces are applied to the equipment and need to be carefully monitored to avoid damage to equipment and the well/reservoir.

During drilling, several of the main parameters observed include the rate of progress (m), the top drive speed (revolution per minute, RPM), torque (Newton metres, Nm) and Weight on Bit (pounds, lbs) via the top drive unit. During the drilling progress, which is dynamic and ever changing, subtle changes and responses to these and many other parameters are made. Other factors that are closely monitored include the mud weight (hydraulic fluid) and the total amount of mud and its composition as it exits the well as an early indicator of a leak in the system.

2. INTRODUCTION

During a 9 month long drilling campaign in 2014 Marshall Day Acoustics was commissioned to undertake compliance sound monitoring of the onshore drilling rig which is the focus of this paper.

During a previous, much shorter drilling campaign a strong and clear tonal sound emission was noticed to occur from time to time during drilling activities. On site handheld sound monitoring confirmed the presence of a tonal sound and it was clear that the top drive unit was the source of the tonal sound. Through a series of tests under operational modes it was considered *likely* that the revolutions per minute of the top drive unit was the cause of the tonal sound.

However, it was not known conclusively whether the presence of a tonal sound from the top drive was due to the interaction of one or more other drilling factors. This analysis forms the basis of this paper and was undertaken by cross correlating large sets of noise logger data with rig operating parameter data.

The presence of a tonal sound is an undesirable and unwanted outcome from the operation of the drilling rig for two primary reasons. Firstly, the presence of tonal sound, even at a low total sound level can be annoying to the community. Secondly, the assessment of environmental sound in New Zealand requires determination of whether any tonal sound is present and a penalty to the sound of interest is applied. NZS6802 recommends a penalty of up to 5dB may applied (4).

The presence or otherwise of a tonal component is important to quantify when assessing environmental sound as the potential effects on the community must under New Zealand law be considered prior to consent for the development to occur.

3. INVESTIGATION METHODS

3.1 Noise Data

During the 9 month drilling campaign, the legislative requirement was for two continuous noise and weather loggers to be deployed and for specific noise levels to be achieved. These noise loggers were in excess of 250 metres away from the wellsite.

In addition to the two noise loggers at nearby houses, a noise logger was deployed approximately 30 metres away from the rig. This location was “off lease” and therefore equipment was not required to achieve any standards in terms of being intrinsically safe, which is a major safety consideration due to the potential for battery operated equipment to be a source of ignition.

The raw noise data collected included 15 minute statistical data, 1/3 octave band (Leq) and 1 second Leq data. All three noise loggers were paired with Vaisala WXT520 meteorological stations to capture wind speed, wind direction and rainfall. The noise data from the logger located 30m from the onshore drilling rig has been used for the analysis discussed in this paper.

3.2 Test for Tonal Sound

All noise data collected over the course of the drilling program was analysed for the presence of tonal sound from the top drive unit. In order to determine whether the sound of interest included a tonal component we assessed the data using New Zealand Standard NZS6802:2008 *‘Assessment of Environmental Sound’* (NZS6802)(4).

NZS6802 provides a simplified and reference test method for identifying noise sources which have special audible characteristics, commonly referred to as tonality. The NZS6802 test is considered somewhat simplistic in determining whether tonality in the sound of interest exists. However this simplicity provides an initial determination of tonality that can be undertaken in the field without the need for post processing data.

NZS6802 Appendix B4.3 Simplified test method for tonality states:

“A test for the presence of a prominent discrete-frequency spectral component (tonality) can be made by comparing the levels of neighbouring one third octave bands in the sound spectrum. An adjustment for tonality shall be applied if the L_{eq} in both adjacent bands by more than the values given in Table B2.”

Table 1: Reproduction of NZS 6802:2008 Table B2 (4)

Range of third-octave band centre frequencies	Level difference
25 – 125 Hz	15 dB
160 – 400 Hz	8 dB
500 – 10000 Hz	5 dB

NZS6802 Appendix B4.4 recommends use of a reference method for determining the presence of special audible characteristics where detailed determination is required. The reference method cited is “ISO 1996-2:2007 or an equivalent”.

In general, where a sound is considered to display tonality using the NZS6802 simplified method it is highly likely to be the case when analysed using the reference method.

For this study, analysis of the presence of tonality from the top drive was confined to the NZS6802 simplified method only.

Figure 1 illustrates the typical one third-octave frequency components, along with the corresponding narrow band trace of a tonal noise recording from the top drive unit.

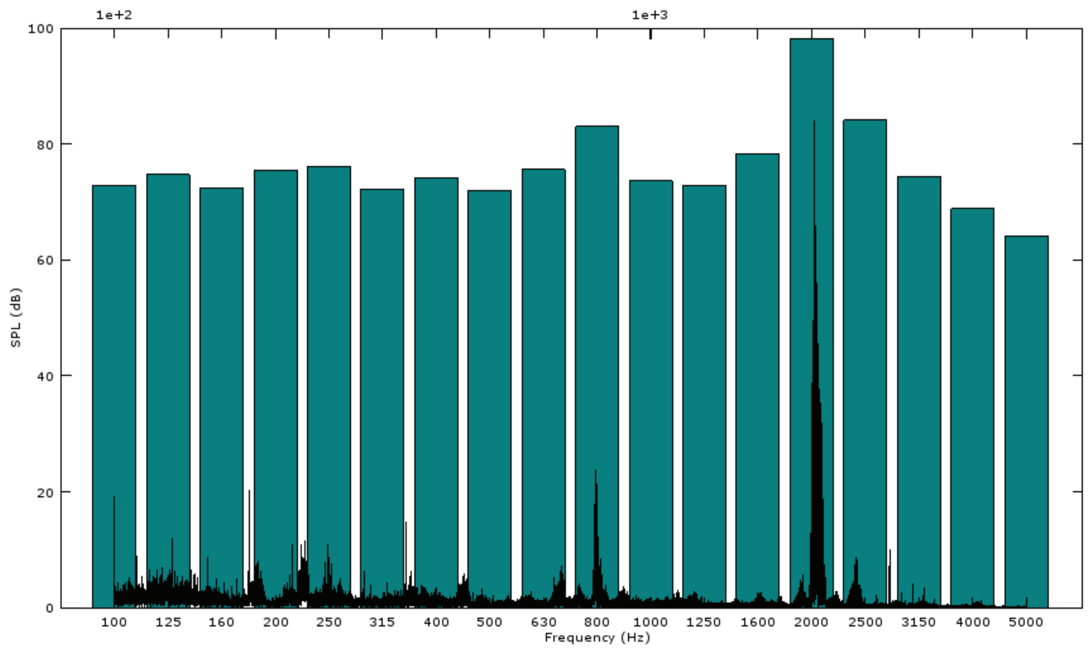

Figure 1 - Illustrative comparison of one-third octave band and narrow band trace of the top drive.

3.3 Drilling Parameter Data

In addition to the noise and weather data, company data was obtained providing a record of the drilling rig parameters every 5 seconds. This provided a very large dataset, importantly including the key operating parameters of interest. Every period where the rig was operating was grouped and labelled with one of five processes described in Table 2.

Table 2 - Constituent process categories making up the overall drilling program

Drilling Rig Process	Description
Other	Miscellaneous processes not included in the other categories
Trip In	Feeding the drill string into the well
Trip Out	Pulling the drill string out of the well
Drilling	Drill string rotating and weight applied to the bit
Circulating	Stationary drill string with pumps still running to circulate drilling fluid

The drilling rig operational data also provided information on specific drilling variables when drilling was underway. Within the drilling process a major focus was on the top drive variables that are of most importance to the drilling crew in terms of operating the top drive unit. These are:

- Revolutions per minute (RPM).
  Operating range typically 50-200RPM. Top drive rated for maximum 240RPM.
- Weight on Bit (WOB) – total weight of drill string hanging off the top drive. Unit is pound (lb), where 2,200lb equals 1,000kg.
  Operating range typically 5,000-25,000lb.
- Torque – measure of the rotational resistance of the drill string measured at the top drive. Unit is Nm.
  Operating range typically 10,000-30,000Nm

4. DATA ANALYSIS

4.1 Analysis Method

The data analysis was completed using a numerical computation program called Octave.
Initially, the useful data was identified with the following process:

- Noise, weather and rig parameter data sets were aligned on the basis of time and date
- Data was excluded from analysis if meteorological conditions were considered unacceptable for noise measurement (presence of rain or wind speed > 3 m/s)
- Data was excluded from the analysis if the drilling rig was not operational

Secondary data filtering was applied to focus the analysis on the data which is determined to be tonal. Every fifteen minute noise measurement period was analysed for tonality using the NZS6802 simplified method in each of the one-third octave bands frequencies from 8 Hz to 6.3 kHz.

The results of this process were also separated into the five drilling processes, as shown in Figure 2.

Figure 2 illustrates the percentage data considered tonal by the NZS6802 simplified method at each one-third octave band, and within each one-third octave band which process was underway while the tonal noise was produced.

Two conclusions were drawn from this filtering process. First, that one significant group of tonal data is shown to be present across all processes within the 31.5 Hz one-third octave band. This tonal data is assumed attributable to large vibrating machinery on site called mud shakers, and is not the focus of this paper. Second, that apart from 31.5 Hz tonality, almost all tonal sound is present while drilling is underway.

The process/noise data shown in Figure 2 was used as a basis to focus exclusively on tonal noise due to drilling only. The dataset was therefore reduced to the subset of: noise data produced during suitable meteorological conditions for noise measurement, and while the drilling process was underway.

Further, the main focus of analysis within the drilling process was the predominant tonal sound illustrated in Figure 2, in the one-third octave frequency bands with centre frequencies of 2 kHz and 2.5 kHz.

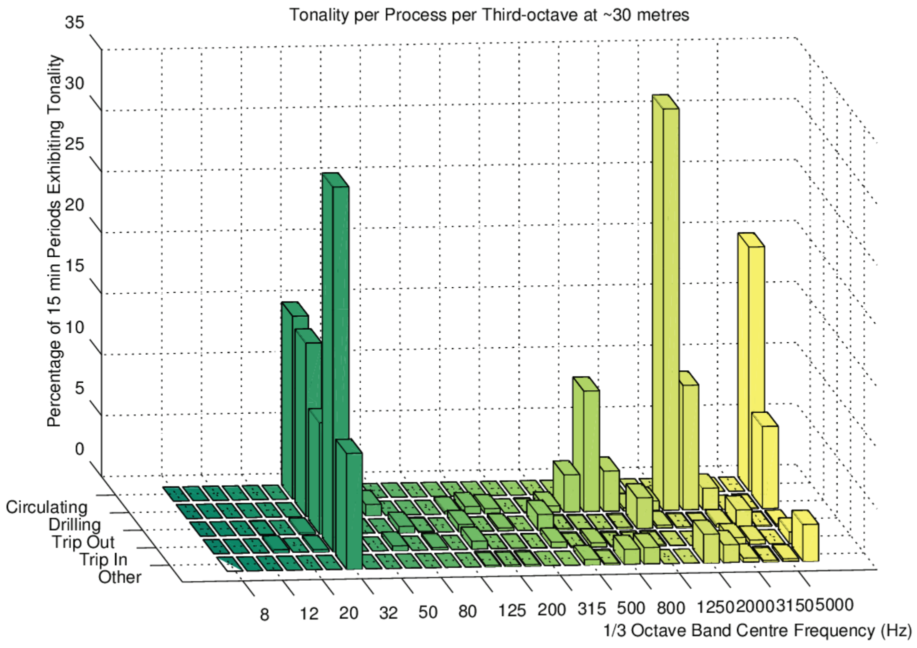

Figure 2 - Illustration of the presence of tonal noise produced by the drilling rig per process.

The initial filtering process demonstrates the extent of tonal noise data within the data subsets of frequency band and process. As described the result was the decision to focus on the drilling process subset of data. Within this subset the analysis would investigate tonal noise data in the 2 kHz and 2.5 kHz one-third octave frequency bands.

The detailed analysis of tonal noise during drilling focused on overall noise level and the presence of tonal sound with respect to the value of several drilling parameters which are variable throughout the drilling process.

Two important operator controllable drilling parameters WOB and RPM of the top drive unit. The WOB is controlled via a large winch from which the top-drive motor and drill string are suspended.WOB (the weight force exerted on the ground by the drill bit) is calculated by subtracting the weight measured at the winch from the total suspended weight (weight of top-drive motor and entire drill string). RPM of the drill bit is controlled via the variable speed top-drive electric motor.

A further important variable, dependent upon WOB and RPM, is the torque experienced at the top drive during drilling. As described above, the typical torque operating range is 10,000-30,000 Nm. WOB and RPM are adjusted to maintain the torque within the desired range.

The detailed analysis of tonal noise during the drilling process included:

- Overall noise levels with respect to RPM, WOB and Torque
- Presence of tonality with respect to RPM and WOB
- Presence of tonality with respect to RPM and Torque
- Noise level and tonality in the 2 kHz one-third octave band with respect to RPM, WOB and Torque
- Noise level and tonality in the 2.5 kHz one-third octave band with respect to RPM, WOB and Torque

5. RESULTS

Figure 3 illustrates a trend of increasing SPL with increased RPM and Torque. The torque value at each data point is illustrated with colour and particularly high torque values appear to correlate with the highest SPL emission.

The same analysis was completed for WOB, but no correlation was identified between WOB and overall SPL emission. Therefore we have not plotted this result or discussed it further in this paper.

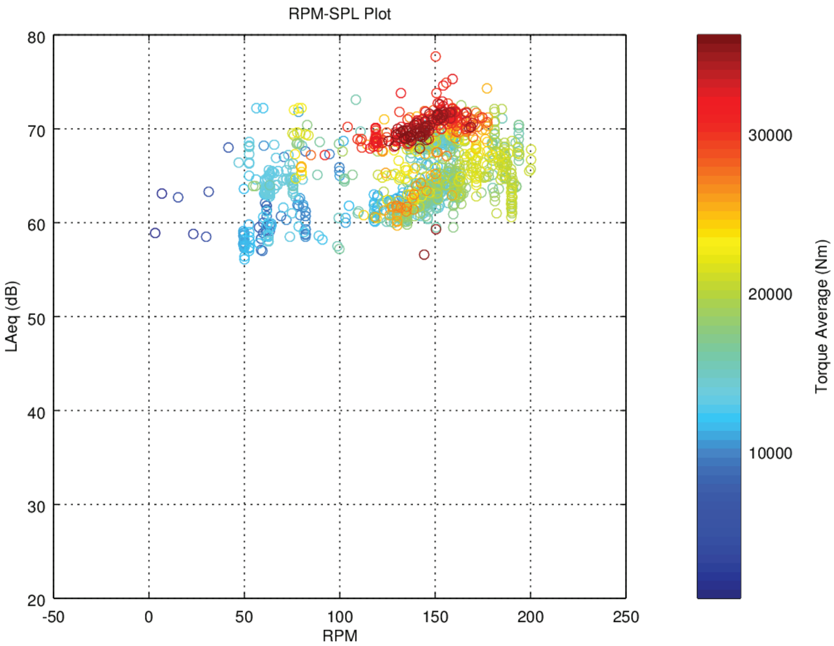

Figure 3 - Overall SPL, RPM and Torque.

Figures 4 illustrates overall WOB plotted against RPM. The data shown includes the presence of tonal sound at 2 kHz and 2.5 kHz. Figure 4 illustrates that while tonal sound occurs above a clearly defined RPM it is present at a wide range of WOB values from <5 up to 30 klb. This indicates there is no correlation between WOB and the presence of tonal sound.

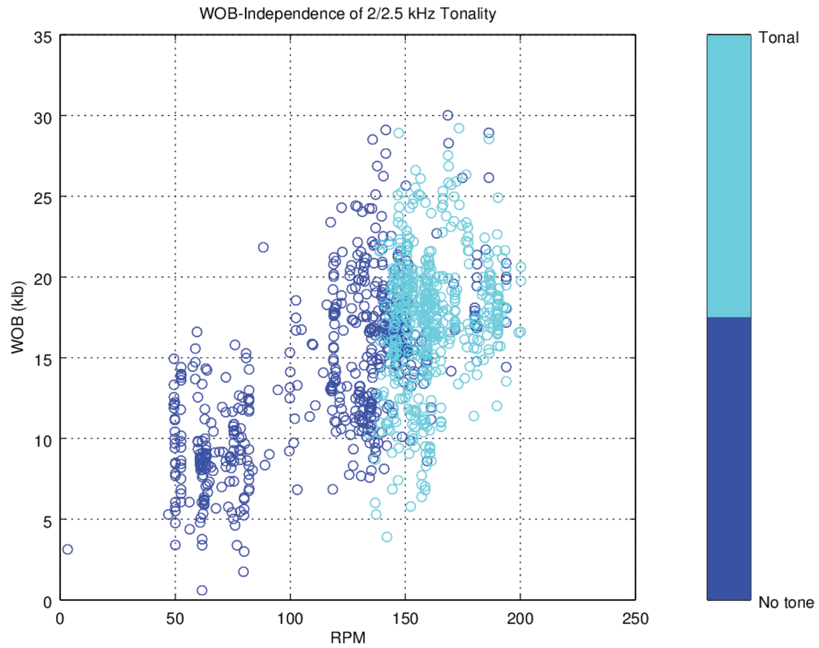

Figure 4 - RPM - WOB illustrating 2 kHz and 2.5 kHz tonal sound

Figures 5 illustrates overall Torque plotted against RPM. The data shown includes the presence of tonal sound at 2 kHz and 2.5 kHz. Figure 5 illustrates that while tonal sound occurs above a clearly defined RPM it is present at a wide range of Torque values from ~11,000 Nm up to 36,000 Nm. This indicates there is no correlation between Torque and the presence of tonal sound.

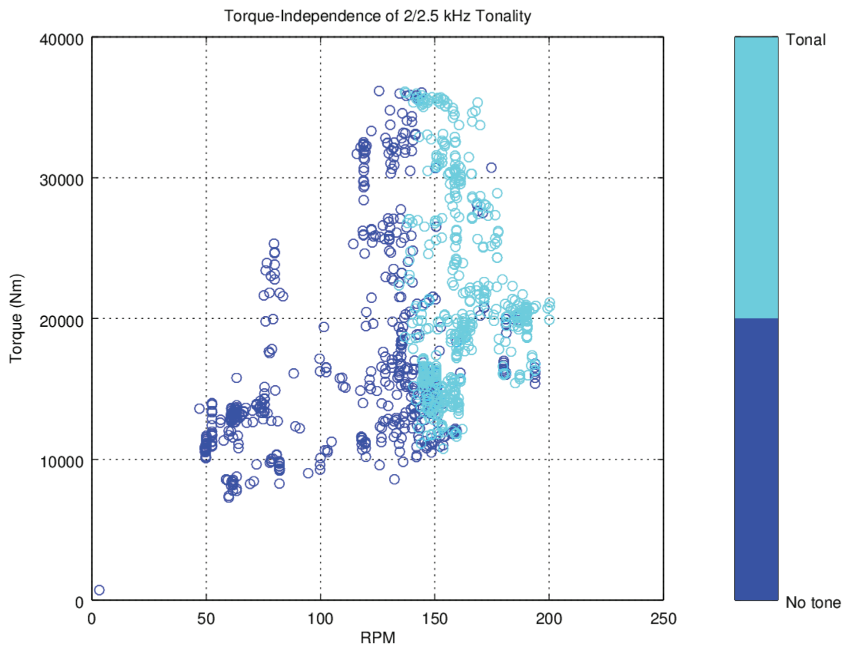

Figure 5 - RPM – Torque illustrating 2 kHz and 2.5 kHz tonal sound

Figures 6 and 7 illustrate overall SPL plotted against RPM for 2 kHz and 2.5 kHz respectively. Figure 6 demonstrates that 2 kHz tonal sound is present when the top drive is operating between 135 and 170 RPM. Figure 7 demonstrates a 2.5 kHz tonal sound is present when the top drive is operating above 170 RPM.

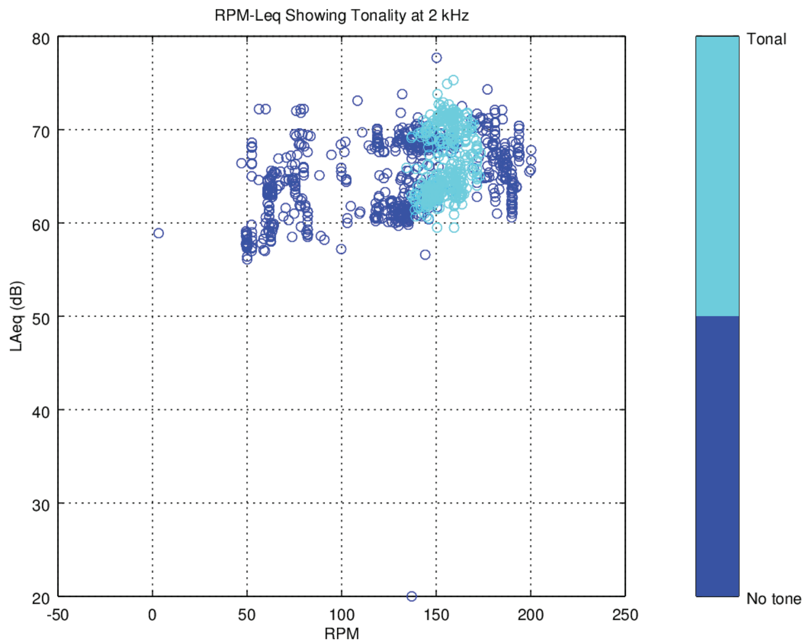

Figure 6 - RPM-SPL illustrating 2 kHz tone

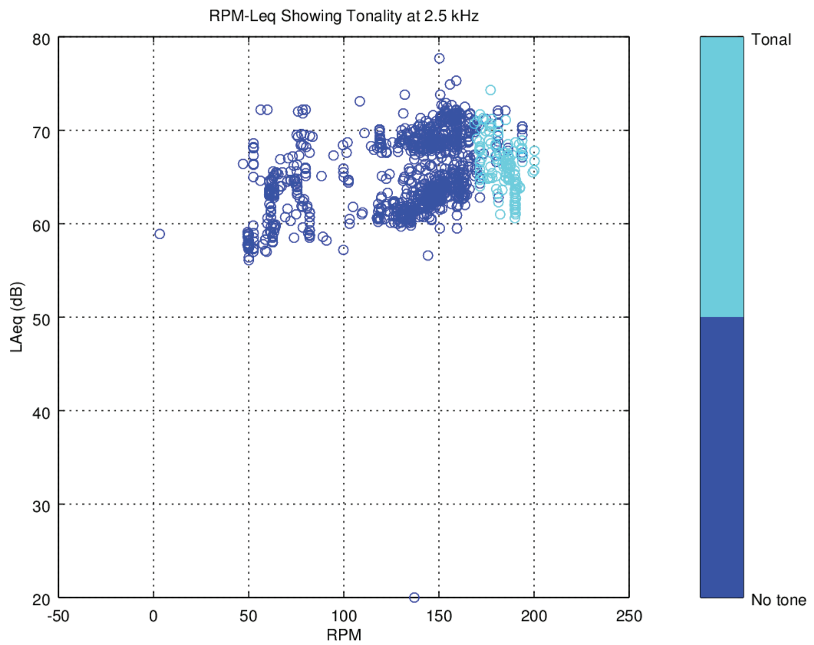

Figure 7 - RPM-SPL illustrating 2.5 kHz tonal sound

6. SUMMARY

During a recent onshore drilling campaign in New Zealand a tonal sound emission was noted from the top drive unit of a rig. A noise logger was located very close to the drilling rig and this data in conjunction with the rig operational parameters were analysed.

Our analysis does not show any evidence that the torque or weight on bit as contributing to the occurrence of tonal sound being emitted from the top drive unit.

From our data analysis we conclude the single cause of tonal noise at 2 kHz and 2.5 kHz was due to the revolutions per minute of the top drive unit.

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