Underwater Acoustic Measurement of the Spartan 151 Jack-up Drilling Rig in the Cook Inlet Beluga Whale Critical Habitat

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1.0 ABSTRACT

Compliance with underwater noise environmental regulations for offshore drilling rig operations is of increasing concern for the oil industry, especially in designated critical habit areas. Furie Operating Alaska, LLC, began drilling an exploration well in Cook Inlet Basin of Alaska in September 2011 within the newly designated National Marine Fisheries Service critical habitat for beluga whales. Furie Operating Alaska, LLC, contracted Marine Acoustics, Inc. (MAI), to monitor and record acoustic energy radiated from the jack-up rig before and during drilling operations to meet their environmental commitment. Cook Inlet tidal currents, in excess of 5 knots (9.3 kph), are a challenge to traditional underwater noise monitoring. MAI's experience with military sonar testing and at-sea environmental conservation resulted in two approaches to acoustic data collection using light-weight, man-deployed systems that are not flow-noise limited by the high currents. A tethered hydrophone array was deployed from the Research Vessel (RV) Thunder while drifting with the current and collecting data. This reduced the flow noise from tidal currents to acceptable levels. Acoustic data were processed using a laptop computer with MAI-generated software to process peak noise levels in ⅓ octave bands from 10 Hz to 1.25 kHz per second in real time, and GPS to compute distance from the jack-up rig. This Real-Time data collection and processing system used battery-supplied electrical power to eliminate own-ship generator noise. MAI's second approach was deployment of an autonomous, self-recording moored hydrophone monitor system at slack tides, at pre-determined ranges from the rig. The moored recorder collected acoustic data at a 4 kHz sample rate and stored data on solid-state memory. Data were processed after recovery using the same MAI software. Final analysis gave broad-band ambient noise levels and rig-generated noise levels vs. range from the rig in ⅓ octave bands from 10 to 1,000 Hz, along with discrete (narrow band) noise levels of pumps and generators operated during data collection. Continuous acoustic received levels exceeding 180 dB re 1 µPa (MMPA Level A threshold) or 160 dB re 1 µPa (MMPA Level B threshold) were never measured. Non-continuous (less than 1 second) levels exceeding 120 dB re 1 µPa were measured to a maximum range of 0.63 to 0.75 nm (1.2 to 1.4 km).

Primary sources of rig-based acoustic energy were identified as coming from the D399/D398 diesel engines, the PZ-10 mud pump, ventilation fans (and associated exhaust), and electrical generators. The source level of one of the strongest acoustic sources, the diesel engines, was estimated to be 137 dB re 1 µPa @ 1 m (rms). If this is an accurate estimate, the 120 dB re 1 µPa received level isopleth would be 164 ft (50 m) away from the where energy enters the water (jack-up leg or drill riser).

Note: Escopeta Oil Company, LLC, changed its name to Furie Operating Alaska, LLC, in December 2011, after the commission of this report.

2.0 ACKNOWLEDGMENTS

The data collection field work was completed by Dr. Adam Frankel, Mr. Mark Wilson, and Mr. Lee Shores of Marine Acoustics, Inc under the direction of Mr. Clayton Spikes. Technical advice was provided by Dr. William Ellison, and Mr. Kenneth Graf provided contract administration. The Real-Time Processor and post-processing software was developed by Dr. Frankel and Mr. Shores. Mr. Wilson preformed the in-air data collection and analysis. Mr. Shores preformed the reconstruction and post-processing analysis.

MAI wishes to thank Captain Dave Mastolier and the crew of RV Thunder for their hard work, local knowledge, enthusiastic support, and warm hospitality. MAI would also like to thank Mr. Rick Wilson of Offshore System Kenai and Mr. Jeff Johnson of Peregrine Marine for their logistical support in Alaska.

Finally, MAI wishes to thank Mr. Bruce Webb, Vice President of Furie Operating Alaska, LLC, for his business, his trust and the company's commitment to protecting the Cook Inlet beluga whale and their environmental stewardship.

3.0 INTRODUCTION AND PURPOSE

This report details underwater acoustic measurements in the vicinity of the Spartan 151 jack-up drilling rig in the Kitchen Lights Unit of Cook Inlet, Alaska, and the analysis of the collected data. The measurements were performed by Marine Acoustics, Inc. (MAI) in September 2011 under contract to Furie Operating Alaska, LLC. Spartan 151 (Figure 1) is an independent leg, cantilever jack-up rig, capable of drilling in up to 150 ft (45.7 m) of water depth. Spartan 151 was positioned in 80 to 90 ft (24.4 to 27.4 m) water depth 12 nm northeast of Nikiski Bay, Alaska (Figure 2), and started drilling an exploratory well in September 2011.

Figure 1. Spartan 151 at the Kitchen Lights Unit of the Cook Inlet.

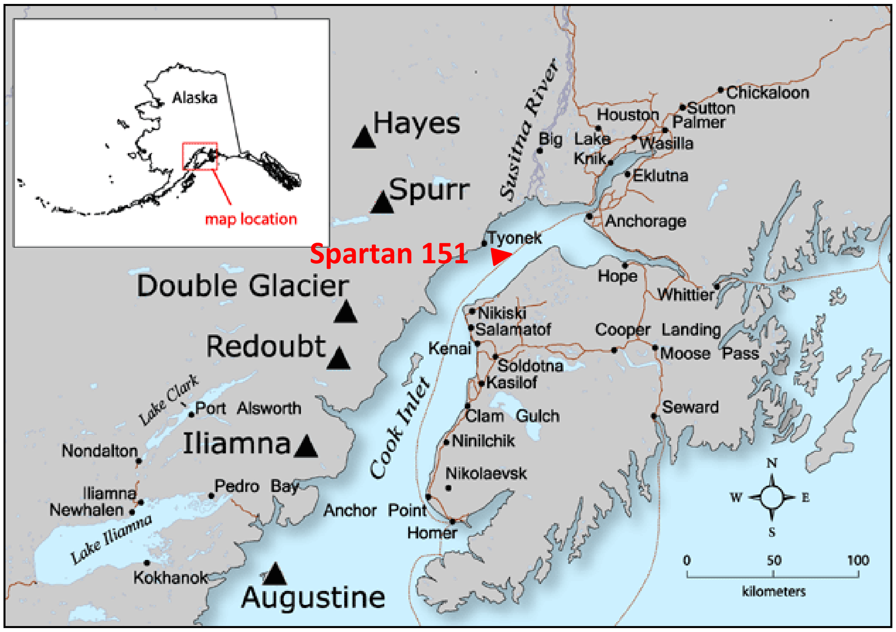

Figure 2. Cook Inlet and the Location of Spartan 151 (graphic from avo.alaska.edu).

Compliance with underwater noise environmental regulations for offshore drilling rig operations is of increasing concern for the oil industry, especially in designated critical habit areas. Furie Operating Alaska, LLC, began drilling an exploration well in Cook Inlet Basin of Alaska in September 2011 within the newly designated National Marine Fisheries Service (NMFS) critical habitat for beluga whales. Furie Operating Alaska contracted MAI to monitor and record acoustic energy radiated from the jack-up rig during drilling operations to meet their environmental commitment.

National Marine Fisheries Service (NMFS) currently uses generic threshold exposure level criteria to determine whether anthropogenic underwater noise impacts attain Marine Mammal Protection Act (MMPA) Level A (harm) or Level B (harassment) levels. Level A impact is defined as exposure to received levels of 180 dB re 1 µPa or greater in a ⅓ octave band. Level B impact is defined as exposure to received levels of 160 dB re 1 µPa or higher in a ⅓ octave band for pulsed (non-continuous) noise and 120 dB re 1 µPa or higher in a ⅓ octave band for continuous noise. The purpose of this study was to determine if operations of the Spartan 151 drilling rig in the Cook Inlet exceeded Level A or Level B exposure levels as defined by NMFS.

4.0 DATA COLLECTION

4.1 Description of the Operating Environment

The Spartan 151 jack-up rig performed exploratory drilling operations in Alaska's Cook Inlet. The Cook Inlet (Figure 2) is a very dynamic shallow body of water that challenges any marine operation with extreme tides, swift currents, and quickly changing weather patterns. The inlet width (10 to 47 nm [19 to 87 km]) is defined by the Kenai Peninsula on the eastern coast and the Alaskan Peninsula on the west. Cook Inlet stretches 156 nm (290 km) from the Gulf of Alaska to Anchorage and provides navigable access to the port of Anchorage for large vessels. The smaller port of Homer is on the southern end of Cook Inlet. Commercial activities on the inlet include commercial fishing, multiple oil and gas production platforms, shipping traffic, and tourism.

The tidal range of the Cook Inlet regularly reaches 25 ft (7.6 m) and can be as extreme as 40 ft (12.2 m). Tidal currents in excess of 5 kts (9.3 kph) are common and have been recorded as high at 8 kts (14.8 kph). Water depth of the Cook Inlet is approximately 600 ft (183 m) in the southern mouth of the inlet, but is generally 65 to 130 ft (20 to 40 m) and shallower in the northern section. Water depth in the vicinity of the Spartan 151 varies from approximately 60 ft to 120 ft (18.3 to 37 m). Surface water temperature was 45°F to 50°F (7.2°C to10°C) during data collection. The waters were well mixed from the surface to the bottom due to the winds and tides. Winds varied from calm to 35 kts (65 kph) over the 5-day data collection period, with waves from 1-2 ft to 7-9 ft (0.3-0.6 m to 2.1-2.7 m).

4.2 Data Collection Platform

The research vessel (RV) Thunder, operated by Northern Telecommunications Consultants, Inc., was chartered to be the acoustic data collection platform. RV Thunder (Figure 3) is a 60 ft (18.3

m) high-speed, low-draft aluminum catamaran, home ported in Homer, Alaska. It is driven by two diesel pump-jet motors capable of speeds up to 25 knots with a cruising range of approximately 900 miles at 12 kts (46.3 kph), with a cruising range of approximately 900 nm (1,667 km) at 12 kts (22.2 kph). The jet-drive, shallow-draft configuration makes RV Thunder very maneuverable and allowed positioning close to the drilling rig. RV Thunder was ideally suited for acoustic data collection, which was uncontaminated by ship generators when using the 12-hour battery back-up system to power data collection equipment.

Figure 3. RV Thunder. (graphic from www.homernews.com)

4.3 Data Collection Equipment

MAI applied two approaches to acoustic data collection, using light-weight, man-deployed systems to reduce flow noise generated by the Cook Inlet tidal currents. A tethered hydrophone array was deployed from RV Thunder while drifting with the current and collecting data. This system used battery-supplied electrical power to eliminate own-ship generator noise and allowed processing in real-time. MAI's second approach was deployment of an autonomous, self-recording hydrophone monitor system, either drifting with the tidal current or moored at slack tides, at pre-determined ranges from the rig. Data from the autonomous recorder were processed after recovery.

4.3.1 Ship-based 'Real-Time' Data Collection and Processing

MAI utilized a Real-Time data collection and analysis system deployed from RV Thunder to collect acoustic data for detailed processing to characterize underwater noise levels in real time. Table 1 summarizes the electrical elements of the floating / tethered Real-Time system. The hydrophone of the Real-Time system was rigged to float 30 ft (9.1 m) below a surface float, which was rigged to drift 300 ft (91.4 m) from RV Thunder to reduce contamination from ship noise. The data cable to RV Thunder was supported using equally-spaced small foam floats to dampen wave motion.

Real-Time Data Collection System Elements	Purpose
HTI MIN-96 hydrophone array	Convert acoustic energy into electrical energy
Low-loss coax cable	Transmit electrical signal to pre-amplifier
Reson VP-2000 hydrophone pre-amplifier	Amplify and band-pass signals for processing
National Instruments USB-4431 Analog to Digital Converter	Convert analog signals to digital data at 4 kHz sample rate using 24-bit conversion
Dell Precision M6500 workstation running MATLAB R2011A	Record digital data and display acoustic received level per second in ⅓ octave bands from 10 Hz to 1.25 kHz per second

Table 1. Real-Time Data Collection System Elements and Purpose.

Figure 4. HTI MIN 96 Hydrophone with 328 ft (100 m) of Coaxial Cable.

The HTI MIN-96 hydrophone (Figure 4) has a frequency response from 2 Hz to 30 kHz with a fairly flat sensitivity of -163.9 dB. The VP 2000 pre-amplifier receives raw acoustic data from the HTI MIN 96 hydrophone via low-loss coaxial cable and amplifies / band-passes the received acoustic data. Band-passing the data filters out unwanted acoustic data outside the processing band window. The output of the VP 2000 pre-amplifier was sent to the four input channels of a National Instruments USB-4431 Analog to Digital Converter to convert analog signals to digital data at a 4 kHz sample rate, using 24-bit conversion. The analog to digital converter was programmed using MATLAB software written by MAI for this project. The MATLAB program recorded the data to disk and calculated, in real-time, the measured noise level in ⅓ octave bands from 10 Hz to 1.25 kHz for every second. Table 2 presents the ⅓ octave bands from 10 Hz to

1.25 kHz used for this analysis. GPS was used to collect ship/hydrophone location data vs. time and therefore range from drilling. The above processing resulted in **⅓** octave band noise levels vs. range from the drilling rig.

Center Frequency of Band (Hz)	⅓ octave Band (Hz)	Bandwidth (Hz)
10	8.9 to 11.2	2.3
12.5	11.1 to 14.0	2.9
16	14.3 to 18.0	3.7
20	17.8 to 22.4	4.6
25	22.3 to 28.1	5.8
31.5	28.1 to 35.4	7.3
40	35.6 to 44.9	9.3
50	44.5 to 56.1	11.6
63	56.1 to 70.7	14.6
80	71.3 to 89.8	18.5
100	89.1 to 112.2	23.2
125	111.4 to 140.3	29.0
160	142.5 to 179.6	37.1
200	178.2 to 224.5	46.3
250	222.7 to 280.6	57.9
315	280.6 to 353.6	72.9
400	356.4 to 449.0	92.6
500	445.4 to 561.2	115.8
630	561.3 to 707.2	145.9
800	712.7 to 898.0	185.3
1000	890.9 to 1,122.5	231.6
1250	1,120.0 to 1,410.0	290.0

Table 2. ⅓ Octave Bands from 10 Hz to 1.25 kHz used for Analysis.

This system has the advantage that real-time data can be collected as range to the rig changes. The disadvantage of this system is contamination of noise from own-ship (pumps, valves, etc) or noise generated by movement in the water.

Motion of the hydrophone data cable / rigging line assembly in the current was observed to be an issue in the field. The rigging of the data cable was changed in the field from a 'heavy' 3/16-inch nylon line to a 'light' 1/4-inch line to reduce this motion, and decrease the potential for contaminated data collection.

4.3.2 Autonomous Data Recorder

MAI utilized an autonomous data recorder to collect data to provide a redundant source of acoustic data that was removed from possible acoustic contamination from RV Thunder, rigging, or current flow noise. The Song Meter SM2M recorder is a battery-powered autonomous submersible recorder, capable of recording data at depths up to 492 ft (150 m), with the same

HTI MIN-96 hydrophone used by MAI's Real-Time system. Data are written to internal SD memory cards at a sample rate of 8 kHz for later processing using the programming of MAI's Real-Time processor. The amount of data that can be recorded depends on the storage size and number of SD memory cards used, and the type and number of batteries used. For this application, the SM2M recorder was configured to record for 2 weeks.

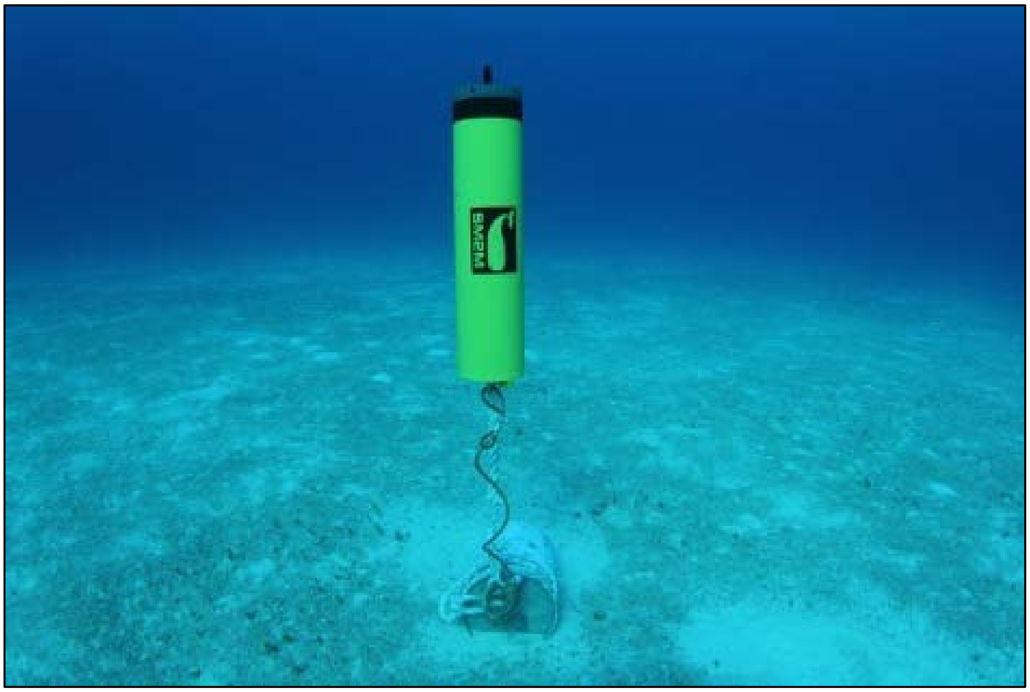

Figure 5. Moored Autonomous Data Recorder (from www.wildlifeacoustics.com)

The Autonomous Data Recorder was deployed in two configurations. The originally planned configuration had the positively buoyant recorder moored (Figure 5) at a fixed location near the rig. The mooring was held in place using a 75 lb (34 kg) halibut anchor and line. A surface buoy was also attached to the anchor for recorder recovery by hand. The advantage with this method was the separation of the recorder from any noise contamination and the location was known. The disadvantage with this configuration was the data collection could only occur at one range at a time and could only be deployed at slack tide, without the risk of flow noise or loss due to current. The second configuration had the weighted recorder deployed from a free-drifting surface buoy (Figure 6). A second surface buoy was attached to aid recovery by hand. The advantage with this method was the separation of the recorder from any noise contamination and the data were recorded at different ranges from the rig to determine noise vs. range. This was a modification to the recorder and necessitated estimating the location of the free-floating recorder. It was anticipated that RV Thunder's radar could locate the buoys in calm seas, but this was not always the case. Moreover, the back-up laser range finder used from RV Thunder could not range the surface buoys at distances greater than 656 ft (200 m), and moving the RV closer to the drifter would contaminate the acoustic data, necessitating cessation of the data collection using the Real-Time system. To overcome these obstacles, the location of the hydrophone was calculated using an estimate of off-set range and bearing from RV Thunder.

Figure 6. Drifting Autonomous Data Recorder.

4.3.3 In-Air Acoustic Measurements on Spartan 151

Spartan 151 utilizes pumps, diesel generators, DC motors, air compressors, and hydraulic pumps during normal drilling operations. All these equipment are capable of producing sound levels that may be transmitted into the waters. There are multiple units of each type installed on the rig, which are operated simultaneously or independently depending on operational requirements. In many instances, multiple units of the same type (such as diesel generators) operate at the same time. To the greatest extent possible, all of the potential noise generating equipment was identified by purpose, equipment type and model, and unit number (if multiple units are installed). The types of sounds and associated frequencies emitted from each type of equipment were catalogued using in-air acoustic measurements on the rig for the purposes of comparison with underwater acoustic data recorded during the underwater data collection phase of the test.

When rig operations permitted, an MAI technician was transferred from RV Thunder to Spartan 151 to identify and cataloged in-air acoustic signatures on the rig. A PC laptop computer, using the organic microphone and the Audacity acoustic analysis program, sampled the in-air acoustic signature of noise generating equipment. The use of the un-calibrated organic microphone was appropriate because levels were not determined from these recordings, only the frequency of the acoustic signature.

4.3.4 Position / Time Data Collection

A Garmin GPS 76 Global Positioning System (GPS) receiver was used to determine RV Thunder's position vs. time as well as determine time of acoustic data collection. GPS data were recorded directly by the signal processing laptop. All positional data were plotted using Nobletec's Visual Navigator program and NOAA electronic charts. The location of the hydrophone was calculated using an estimate of off-set range and bearing from RV Thunder.

4.4 Data Collection Methodology

The following data collection methodology was formulated to overcome the challenge of collecting acoustic data in Cook Inlet and to meet the analysis objectives, while remaining within budget. The high current speeds in the Alaskan Cook Inlet can induce flow noise from the water passing the hydrophone, which could not be attributed to drilling rig operations. Water current can also induce vibrations on the hydrophone cable that can contaminate acoustic recordings. These currents place restrictions on the type of low-cost rigging that can be used to deploy a hydrophone into water. Float and subsurface debris, such as logs and whole trees, were also a concern for the data collection rig and boat safety. The threat of floating debris limited data collection to daylight hours. In September, weather in the Cook Inlet can be a concern. Periods of good weather and low seas tend to be broken by passing fronts and storms. Data can be collected in high sea states, but the noise of the winds and larger waves can cause data contamination. The presence of a noise-generating vessel (e.g., daily supply boat) near the drilling rig also limited the time of data collection. Noise contamination from other transiting vessels in Cook Inlet also limited data collection periods.

The objective of this effort was to report underwater acoustic levels as a function of range from the Spartan 151 rig. The reference location of Spartan 151 was given to MAI as 60-56.083 N / 151-09.017 W. This was to be the origin for all range calculations of acoustic level measured from the rig. However, on arrival at Spartan 151, it was noted that the drilling rig was not exactly at this position, as seen by the Garmin GPS. The location of Spartan 151 used in this study was determined as 60-56.056 N / 151-09.050 W, or approximately 192 ft (58.5 m) to the south-southwest of the given position.

The updated position was determined by the following procedure:

1. Lines of bearing were determined by driving RV Thunder down lines of bearing using each pair of legs of the jack-up rig as "range" markers.
2. The track of RV Thunder was recorded and plotted to determine the intersection of these 3 lines of bearing. These locations were considered the position of each leg.
3. The position of the rig was determined by the center point of the triangle of the location of each rig leg.

This off-set may be associated with normal GPS range error or it may be an actual rig off-set from the given position. Error or off-set is not important. Range from the rig is the important value to determine for this analysis. Range is calculated as the distance between two locations. The same GPS was used to calculate range (rig location and location of the acoustic measurement). Therefore, any error or off-set of the two points was subtracted out of the calculation of range.

4.4.1 Real-Time system

The Real-Time system was installed on RV Thunder and the following procedure was used to collect acoustic data in the vicinity of Spartan 151. This procedure was repeated as much as possible during the good weather, daylight hours of the data collection period.

1. Drift direction due to tide and current was determined by allowing RV Thunder to drift and recording the drift track using GPS.
2. RV Thunder was positioned to drift. This position was either close to Spartan 151 or a position that would allow RV Thunder to drift by Spartan 151.
3. The Real-Time hydrophone was lowered into the water and allowed to hang from the surface float. Float line / cable was paid-out to allow the array to drift away from RV Thunder.
4. RV Thunder's engines, generators and all possible pumps were shut off.
5. Acoustic data were recorded to PC disk in the form of time series at a 4 kHz sample rate.
6. Acoustic levels per second were calculated in real-time for every ⅓ octave band from 8.9 Hz to 1410 Hz, and recorded to PC disk.
7. Hydrophone position and distance to Spartan 151 were determined using GPS and observation of hydrophone range and bearing from RV Thunder. These data were recorded to PC disk.
8. The acoustic array was recovered if RV Thunder drifted too close to Spartan 151 or drifted far enough away that no rig-generated acoustic energy was detected.

4.4.2 Autonomous Data Recorder

The RV to be provided by Furie Operating Alaska was not known at the time MAI's equipment was shipped to the data collection site. Therefore, it was important that the deployment of data collection equipment not be dependent on unknown or non-existing deck equipment (winches, cranes, A-frame, etc.). Use of the lightweight SM2M Autonomous Data Recorder allowed hand-deployable configurations, for both the moored and drifting rig configuration. The following sections describe the methodology for each configuration.

4.4.2.1 Moored Autonomous Data Recorder

The moored installation of the Autonomous Data Recorder (Figure 7) was configured with a 75 lb (34 kg) halibut anchor, a 24-inch (61 cm) inflatable buoy and 1/2-inch nylon line. The positively-buoyant recorder was held in place 30 ft (9.1 m) above the anchor by the nylon line. The anchor was connected to the surface buoy for recovery.

Figure 7. Rigging of the Autonomous Data Recorder in Moored Configuration.

The following procedure was used to collect acoustic data in the vicinity of Spartan 151 using the moored Autonomous Data Recorder. This procedure was repeated as often as possible during the good weather, daylight hours during slack tides, when noise contaminates were not present near the drilling rig.

1. The internal data recorder was programmed to start at the top of every hour and stop at 0:59 of every hour. A one-minute gap is required by the internal recorder software.
2. The recorder was attached to the mooring hardware.
3. RV Thunder was positioned at the desired mooring location when tidal current drift was observed to be below 2 kts (3.7 kph).
4. The anchor was lowered to the bottom by hand using the buoy line. The recorder was released into the water by hand as the anchor was lowered to the bottom. The float buoy was released when the anchor was on the bottom.
5. RV Thunder re-positioned to record data using the Real-Time system at the same time.
6. RV Thunder recovered the Real-Time system and moved to recover the data recorder when the tide was observed between 1 and 2 kts (1.9-3.7 kph) to prevent the current from pulling the recovery buoy under the surface.
7. SD cards containing the recorder data were removed from the Autonomous Data Recorder and data were copied to the MAI signal processing laptop for backup and analysis. Acoustic levels per second were calculated for every ⅓ octave band from 8.9 Hz to 1410 Hz and recorded to PC disk.

4.4.2.2 Drifting Autonomous Data Recorder

The drifting configuration of the Autonomous Data Recorder was a field adaptation to increase the amount of autonomous recorder data. The drifting recorder was hung 30 ft (9.1 m) below the surface on a 1/2-inch nylon line between a surface float and a 30 lb (34 kg) weight. A second surface float was attached to the surface buoy to aid recovery.

The following procedure was used to collect acoustic data in the vicinity of Spartan 151 with the drifting Autonomous Data Recorder. This procedure was repeated as often as possible during the daylight hours during high current periods when noise contaminates were not present near the drilling rig.

1. The internal data recorder was programmed to start recording at the top of every hour of the day and stop at 0:59 of every hour. A one-minute gap is required by the internal recorder software.
2. The recorder was attached to the drifting hardware.
3. RV Thunder was positioned close to the drilling rig when current drift was observed to be above 2 kts (3.7 kph).
4. The weight, recorder, surface buoy, and recovery buoy were lowered by hand into the water.
5. RV Thunder re-positioned to record data using the Real-Time system at the same time all recorder data were collected.
6. Drifter position was estimated from RV Thunder GPS position and range/bearing estimates from RV Thunder using radar, laser, or eye to determine range and compass bearing to the drifting data recorder.
7. RV Thunder recovered the Real-Time system and moved to recover the data recorder when it had drifted to sufficient range.
8. SD cards containing the recorder data were removed from the Autonomous Data Recorder and data were copied to the MAI signal processing laptop for backup and analysis. Acoustic levels per second were calculated for every ⅓ octave band from 8.9 Hz to 1410 Hz, and recorded to PC disk.

4.4.3 On-Rig, In-Air Data Collection

When possible, in-air acoustic data were collected from the actual on-rig equipment in their normal operating environment on Spartan 151. This equipment included, but was not limited to diesel generators, DC motors, air compressors, hydraulic pumps and mud pumps used during normal drilling operations. The PC-based Audacity program was used to capture equipment acoustic signatures for comparison against the underwater acoustic signature data. The MAI in-air acoustic technician was transferred from RV Thunder to Spartan 151 when possible, and when the transfer would not interfere with rig operations. Under the supervision of the Rig Safety Supervisory, the acoustic technician recorded the acoustic signatures of each piece of equipment operating at the time, using the PC laptop. (The PZ-10 mud pump was not operating during this collection and the signature was not recorded.)

Figure 8 through Figure 11 provide graphic illustrations of the data recordings made onboard Spartan 151 during non-drilling operations. The D-398 diesel engines and PZ-10 triplex mud pumps were not in operation at the time these data were recorded. Both of these equipments are expected to be significant sound producers. The acoustic signature of the D-398 diesel engines is expected to be similar to the D-399 engines in both harmonic structure and source level.

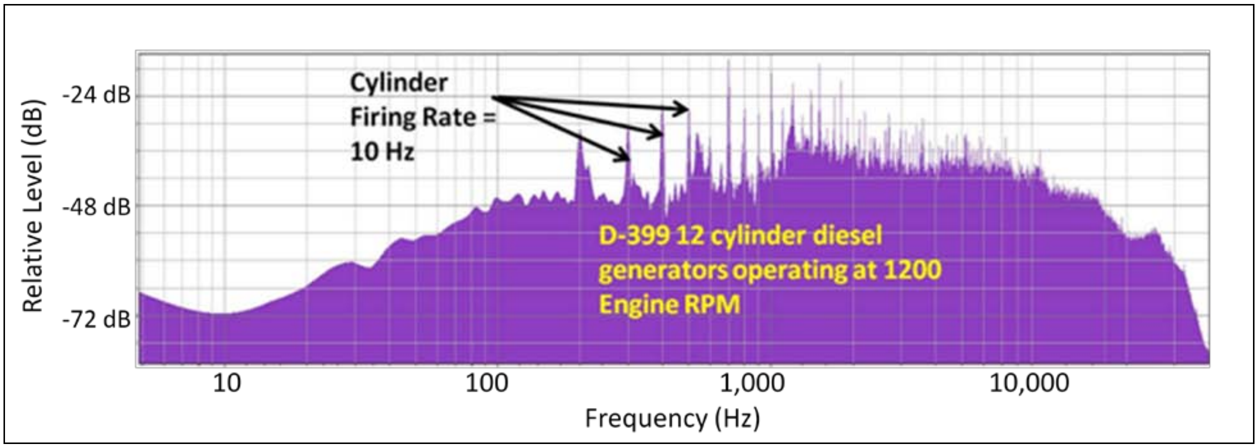

Figure 8. D-399 Diesel Generator Acoustic Signature.

The Caterpillar D-399 diesel generators were providing hotel power for the Spartan 151. Two generators were operating at the time these data were recorded. The primary sound producers from these engines are the individual cylinders firing at a rate of ten times per second. The normal engine RPM for these engines is 1200 RPM. The highest sound levels produced by these engines occur in the 10 Hz to 600 Hz spectrum.

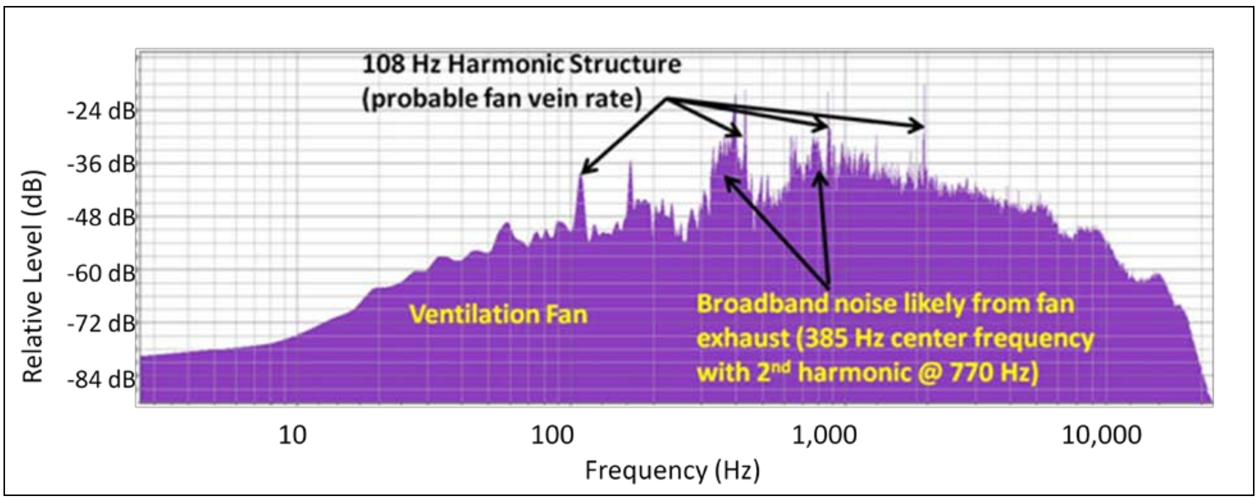

Figure 9. Ventilation Fan Acoustic Signature.

The ventilation fans in the generator room operate continuously during normal rig operations. These fans exhibit a 108 Hz harmonic structure most likely attributed to the fan vanes which are the primary air movers in these units. Vane rate harmonics are predominant up to 2 kHz. There are also broadband noise swaths detectable at 385 Hz and 770 Hz. This broadband source is most likely attributable to the exhaust vents, as air is expelled from the fan.

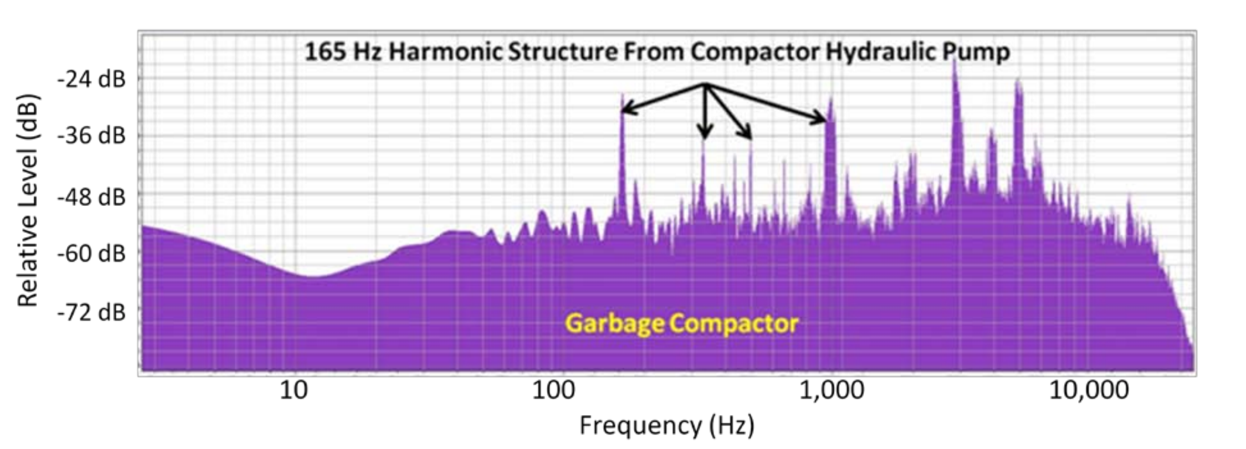

Figure 10. Garbage Compactor Acoustic Signature.

The garbage compactor is a transient (not constant) acoustic source capable of producing intense sound levels. This equipment is operated intermittently, as required, by rig personnel. The primary sounds are produced by the hydraulic pump, which emits a fundamental frequency of 165 Hz.

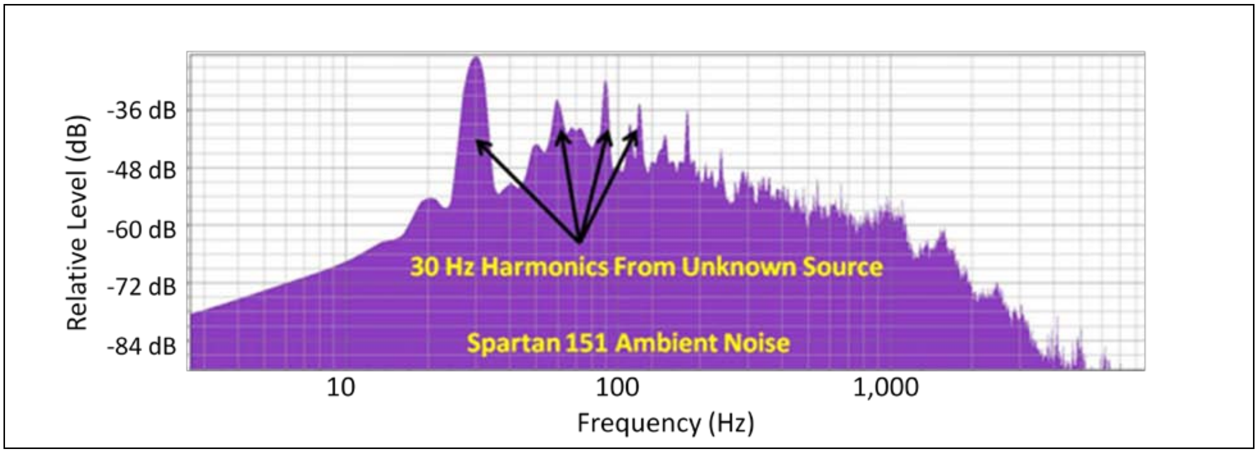

Figure 11. In-Air Acoustic Signature of an Unknown Source on Spartan 151.

During rig operations when drilling is not being conducted, the primary sounds generated are from an unknown source exhibiting a fundamental frequency of 30 Hz with predominant harmonics detected up to 240 Hz. It is possible that these are third order harmonics, which are emitted from the D-399 diesel generators. However, the only way to verify this is by performing an engine RPM change, which could not occur during this data collection period.

4.5 Collected Data

This section outlines the underwater acoustic data collected in the vicinity of the Spartan 151 jack-up rig, using the equipment and methods outlined above. MAI was contracted by Furie Operating Alaska to begin data collection by installing equipment on RV Thunder on 8 September 2011, and begin data collection on 9 September 2011, in the anticipation of the beginning of drilling operations. Drilling operations were only executed on Spartan 151 on 9-10 September 2011. Heavy weather precluded data collection on 12-13 September 2011. MAI resumed data collection on 14 September 2011. Data collection was terminated the afternoon of 14 September at the direction of Furie Operating Alaska because drilling operations were suspended indefinitely.

Table 3 summarizes the 31.2 hours of underwater acoustic data collected. The sum of underwater acoustic data collection includes 22 hours of real-time data collection and analysis. MAI also collected 3 hours of in-air acoustic data on Spartan 151.

Date	Start	Stop	Sensor Deployed	CPA to Rig	Comments (times in local)
9 Sept	13:45	14:07	Real-time System	300 m @ 1356	Set-up data collection to adjust pre-amp and filters, not good data for analysis
9 Sept	14:35	15:34	Real-time System	0.51 nm @ 1437	Set-up data collection to adjust pre-amp and filters, not good data for analysis 14:57 – 15:17 – sand blasting noise
9 Sept	16:12	17:01	Real-time System	430 m @ 1623	Sound of note at 10:55 into the file, Supply boat – range 0.8 nm @ 16:21, Supply boat – range 0.1 nm @ 16:24 Supply boat alongside rig @ 16:45
9 Sept	18:45	19:59	Real-time System	0.76 nm @ 1919	Supply boat alongside rig during recording
10 Sept	**09:14**	**10:15**	**Drifting Data Recorder**	**0.2 nm @ 0926**	**RV Thunder alongside recorder @ 10:27, Looks like rig is drilling**
10 Sept	**09:25**	**10:15**	**Real-time System**	**400 m @ 0928**	**Helo in area @ 10:10**
10 Sept	11:33	13:30	Drifting Data Recorder	0.7 nm @ 1133	RV Thunder engines on – 12:10-12:15
10 Sept	**11:35**	**12:09**	**Real-time System**	**100 m @ 1209**	**Stop recording to reposition RV Thunder, too close to rig**
11 Sept	08:42	08:59	Real-time System	300 m @ 0842	Tug and barge 1.0 nm @ 09:00
11 Sept	09:02	10:30	Real-time System	0.9 nm @ 0902	Supply boat moving to rig from start of recording, 0.5 nm from rig @ 09:15 “Sandblasting” noise starting 1000, Head flush @ 10:07
11 Sept	11:50	12:29	Real-time System	0.4 nm @ 1150	Supply boat leaving area @ end of recording
11 Sept	12:51	14:10	Moored Data Recorder	160 yds 60 56.119 N / 151 09.181 W	92 ft water depth, sensor @ 42 ft depth RV Thunder engines start @ 15:59 Tug and barge 1.1 from rig/mooring @ 13:59
11 Sept	13:10	13:58	Real-time System	0.57 @ 1358 Slack tide	GPS power interrupted at start of recording, Tug / barge 3.5 nm south @ 13:48 Tug and barge 1.1 nm from rig/mooring @ 13:59
11 Sept	14:33	15:21	Real-time System	0.7 nm @ 1433	-
11 Sept	15:44	16:11	Real-time System	120 m @ 1545	“Sandblasting” noise @ 16:03
11 Sept	16:35	17:15	Real-time System	23 m @ 1636	Discreet lines drop out 0.75 nm from rig (16:47)
11 Sept	17:41	18:24	Real-time System	200 m @ 1741	East side of rig, Impact wrench sound
11 Sept	18:43	19:42	Moored Data Recorder	0.23 nm 60 56.222 N / 151 09.361 W	Water depth 120 ft, sensor depth 70 ft, Engines on till 18:50 Large fast (19.5 kts) merchant CPA 0.9 nm from recorder @ 18:44 Large fast merchant 8.0 nm from RV Thunder @ 19:20, RV Thunder engines on @ 19:26
11 Sept	18:57	19:26	Real-time System	0.72 nm @ 1911	Large fast merchant CPA 1.4 nm @ 19:00 Large fast merchant 8.0 nm @ 19:20
14 Sept	14:28	15:56	Real-time System	350 yds @ 1427	Rig PA and grinding sound @ 1432, Grinding sound from rig @ 14:33 Air tugger sound @ 14:45 for minutes & @ 1458 for minutes

Table 3. Summaries of Underwater Acoustic Data Collection (31.2 hours, **analysis below of periods in bold).**

5.0 ANALYSIS RESULTS

This section describes the analysis results of the underwater data collected in the vicinity of Spartan 151 during drilling operations. Furie Operating Alaska provided drilling reports for this period (Appendix A). The intersection of time periods of reported drilling operations and underwater acoustic data collection yield three datasets for analysis as outlined in Table 4. Datasets presented here are identified by their starting date/time. For example, the first dataset presented (10 Sept 0925) is for the period 10 September 2011 from 0925 to 1015 (local time).

Date / Time Period	Sensor	Comment / Collection Range
10 September 09:25 - 10:15	Real-time hydrophone	Drilling data from 0.1 to 1.5 nm
10 September 11:35 - 12:09	Real-time hydrophone	Drilling data from 0.01 to 0.95 nm
10 September 09:14 - 10:15	Drifting recorder	Drilling data from 0.2 to 2.15 nm

Table 4. Time periods of Reported Drilling Operations and Underwater Acoustic Data Collection

5.1 10 September 09:25 Real-Time System Dataset

This dataset was collected using the Real-Time system with the hydrophone rigged with a heavy line. This was the first dataset collected without acoustic interference from supply boats near the rig, and after filter and pre-amplifiers were adjusted to local conditions. As outlined above, the acoustic data were processed into acoustic levels (dB re 1 µPa @ 1 m) for every ⅓ octave band up to 1 kHz, as required by environmental regulation. These levels were assigned a corresponding range of the hydrophone from the center of Spartan 151 and presented Figure 12.

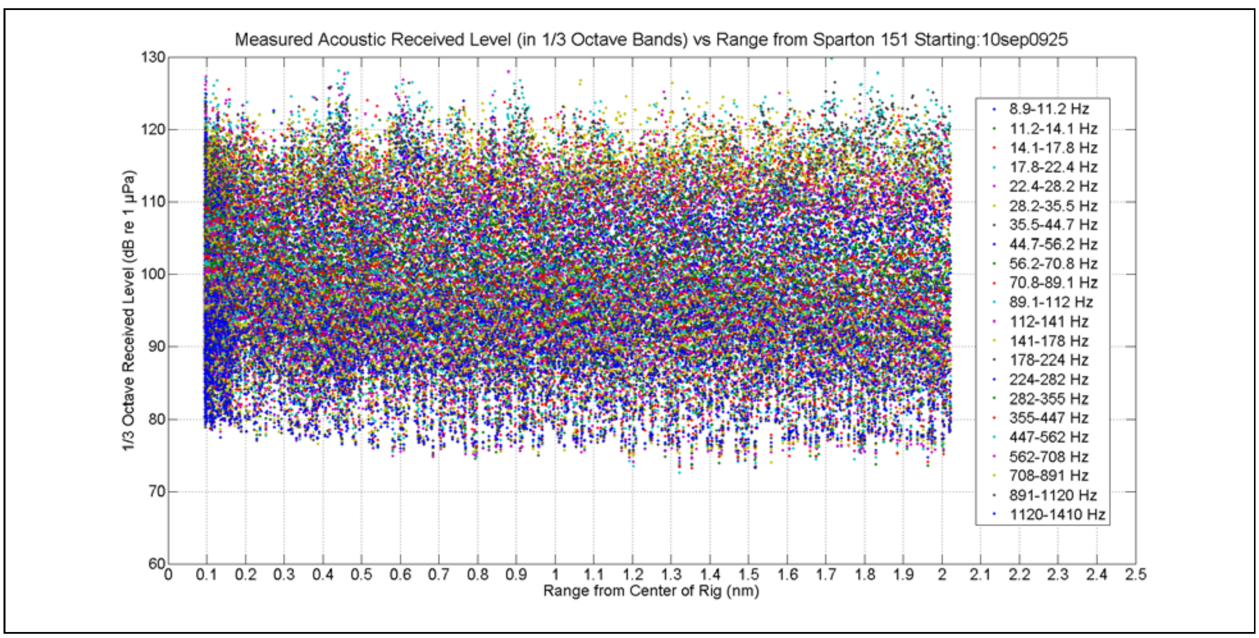

Figure 12. Measured Acoustic Received Level vs. Range from Drilling Rig Starting 10 Sept at 09:25.

The above results behaved as expected in all bands except the 20 - 40 Hz bands. Levels in these bands increased with range from the rig and the higher portions of this band had more energy than the lower portions. To illustrate this point, the data are presented in Figure 13 with a running 128 point average. It can be seen that levels in the 20 – 40 Hz bands remain constant or increase with range (note the 35 – 44 Hz band).

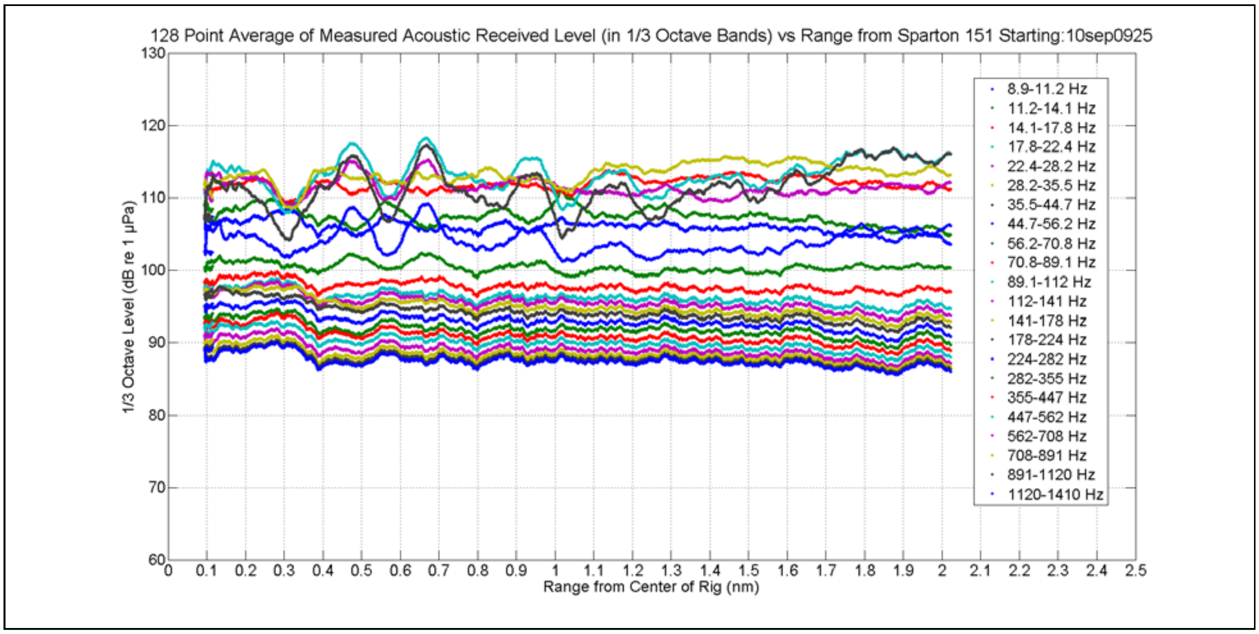

Figure 13. Averaged Acoustic Received Level vs. Range from Drilling Rig Starting 10 Sept at 09:25.

The source of increasing acoustic energy with increasing range could not be Spartan 151. There were no other observed man-made structures (Nikiski pier 12.6 nm [23.3 km] away and the ConocoPhillips Tyonek platform 9 nm [16.7 km] away) that could contribute to this increase in acoustic energy. RV Thunder was running on batteries without pumps or generators.

It was determined the cable strumming caused the movement of the cable in water, inducing vibrations that is induced by the shedding of eddies and vortices of water off the cable. This vibration was transferred down the cable to the hydrophone and recorded as acoustic energy. The frequency of cable strumming can be calculated given speed of the cable movement in water and the cable diameter, using the simple formula:

$$F = s\,v / d$$

Where: s=0.18 (Strouhal Number Constant)

v = speed (cable relative to water)

d = diameter of cable

This formula was used to calculate the frequency of cable strumming that could be observed in this dataset. It can be seen that the frequency of strumming is inversely proportional to the cable diameter. The rigging for the Real-Time hydrophone used ¼ inch electronic cable, with 3/16 inch nylon line zip-tied together. The combined cables make a cross-section diameter maximum of 7/16 inch and could present a minimum cross-section diameter minimum of ¼ inch. Using these two diameters give the strum frequency envelope of 30 to 50 Hz (Figure 14). The average acoustic level in the 30 to 50 Hz band was calculated and plotted with boat speed for the observation period. It was assumed the boat drift speed, measured by GPS on RV Thunder, was the speed of the cabling being pulled in the water.

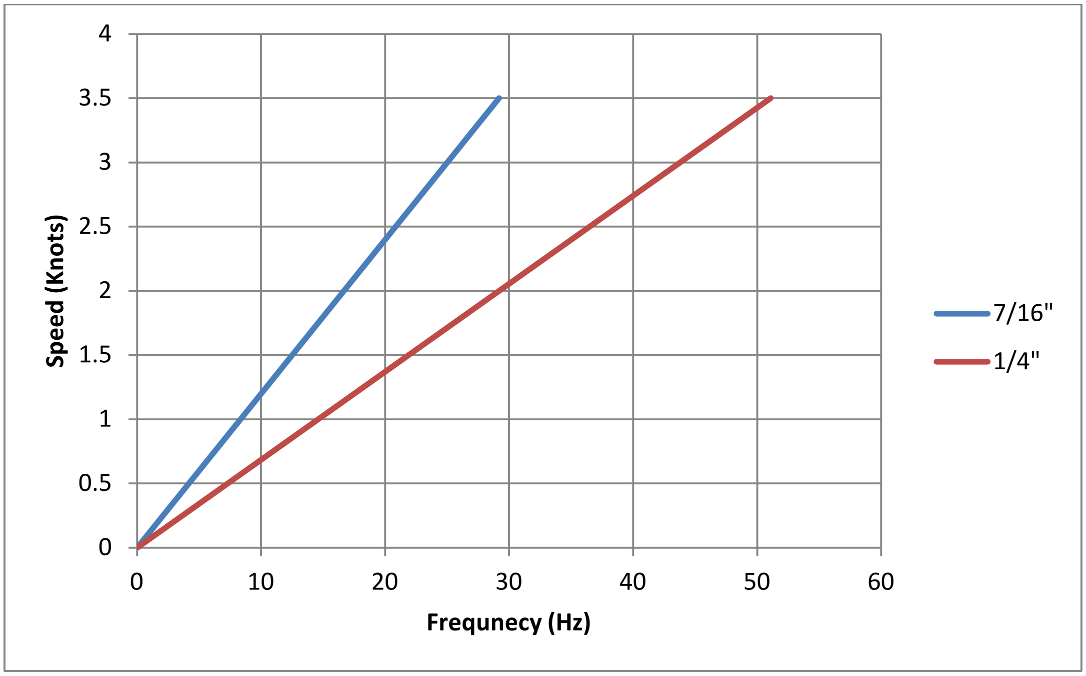

Figure 14. Strum Frequency Envelope for Two Cable Diameters.

It can be seen (Figure 15) that power in the 30 to 50 Hz band follows boat speed from 09:54 to the end of the data collection. This is the period the hydrophone was 1 nm (1.9 km) or greater from the rig and when boat speed was 2.7 knots (5.0 kph) or greater. Power in the band does not follow boat speed prior to 9:54. This does not mean strumming was not present during this period. It only means additional energy was received from another source, likely the rig. In fact, cable strumming can be heard on the data from 09:38 to 09:42 (0.4 to 0.5 nm [0.74 to 0.93 km] in range) and from 09:44 to 09:46 (0.6 to 0.7 nm [1.1 to 1.3 km] in range). These periods can be seen to correspond to increases in boat speed and that could have led to strumming. The conclusion is strumming contaminated the data in the 30-50 Hz band because of high drift speeds associated with operating during Cook Inlet tidal cycles.

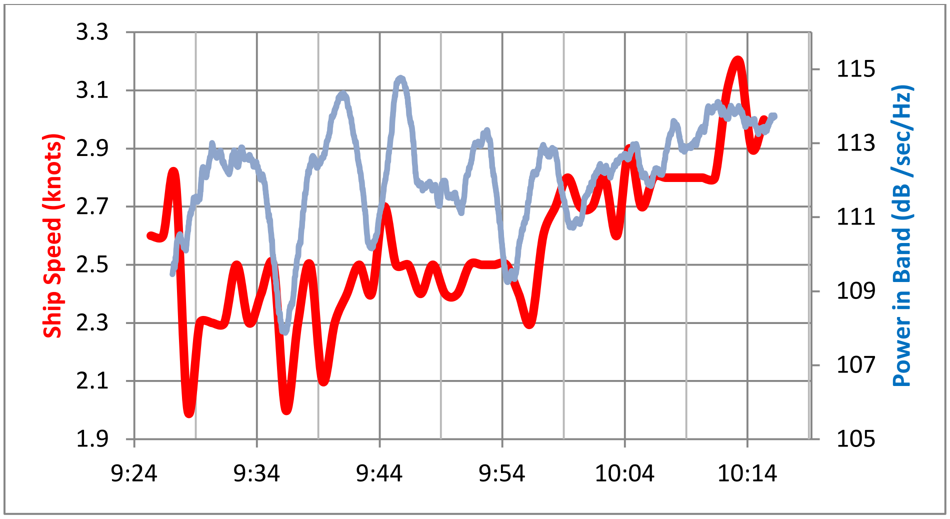

Figure 15. 10 Sept 09:24 Acoustic Received Power Average in 30 to 50 Hz Band and Boat Drift Speed.

Figure 16 presents the acoustic levels vs. range from the rig collected in this dataset that are not contaminated with cable strum. Each data point is calculated using approximately ¼ second of data, normalized to the 'per second' level. The increased density of data points in the 0.2 to 0.1 nm (0.37 to 0.19 km) range is due to the hydrophone drifting toward the rig before drifting away, thereby doubling data collection from 0.1 to 0.2 nm (0.37 – 0.19 km). Levels in the 8.9 to 11.2 Hz band and 11.2 to 14.1 Hz band infrequently exceed 120 dB re 1 µPa at ranges less than 0.9 nm (1.7 km) and never more than 1 second at a time. However, literature shows that very low frequency ambient noise levels such as these are expected and not unusual in high tidal currents.

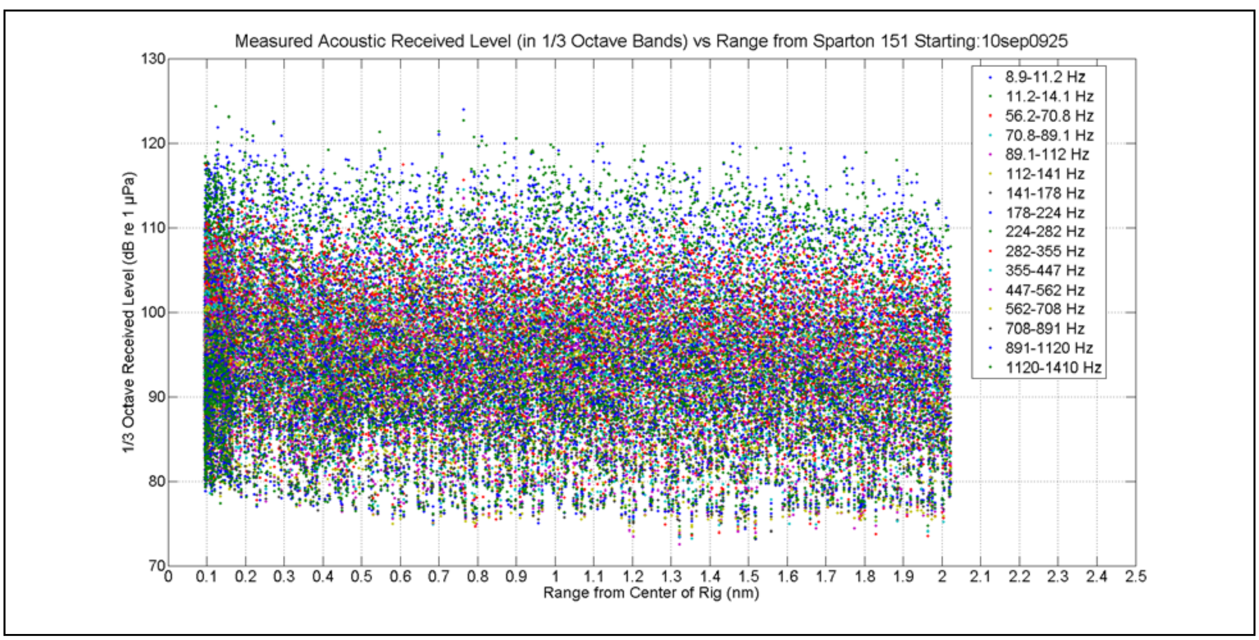

Figure 16. Non-Strum Measured Acoustic Received Level vs. Range from Spartan 151 10 Sept 09:25.

The analysis presented in this report used a very fine time sampling (1/4 second per data point) compared to most noise level analyses where time-averaging on the order of 30 minutes is common. Comparisons with other analyses need to consider the amount of data (time) used to calculate the ⅓ octave levels. If the comparison of long-term averages is important, the 128-point average plot presented in Figure 13 should be used. It can be seen that long-term average received levels never exceeded 120 dB re 1 µPa, even with strumming contamination.

These data were analyzed to identify the source of sound generated by the rig and transmitted into the water environment. A contour plot of the frequency component of the data was generated using the output of a Fast Fourier Transform of every 4-seconds of data, and plotted vs. time (Figure 17). Each pixel of the plot represents 1.3 Hz bandwidth in the x-direction and time increase along the y-direction from bottom to top. Generally, range from the rig increases with time. This plot is useful for identifying the frequency of narrow band acoustic sources radiating from the rig, but combines all acoustic sources into the same picture. The dark bands of energy seen below 50 Hz are the result of cable strumming at low frequency.

The dominant feature seen in the contour plot is the broad acoustic signature from 160 to 600 Hz characteristic of a four stroke diesel engine seen in other work. This signature can be attributed to the operations of the D399/D398 diesel engine and possibly the PZ-10 mud pump operations during drilling. Also present is the narrow band signature of the ventilation fans at 108 Hz and 216 Hz. A signature of unknown origin can be seen at 695 Hz. This signature was not recorded in air, on the rig, and may be the PZ-10 mud pump. These signature structures fade with time as the hydrophone drifts away from the rig. But not all signatures seen at the closest point of approach can be contributed to diesel engines and venation fans. Aural examination of the collected data (listening to the data) yields a banging pipe sound. This banging pipe sound is not constant, but can be heard every 5-10 seconds and fades with time/range. This sound was not measured or observed on the rig. It is theorized that this sound is associated with the riser pipe running from the rig to the inlet bottom. It should be noted that none of these narrow band signatures were measured at received levels near or above 120 dB re 1 µPa in the water.

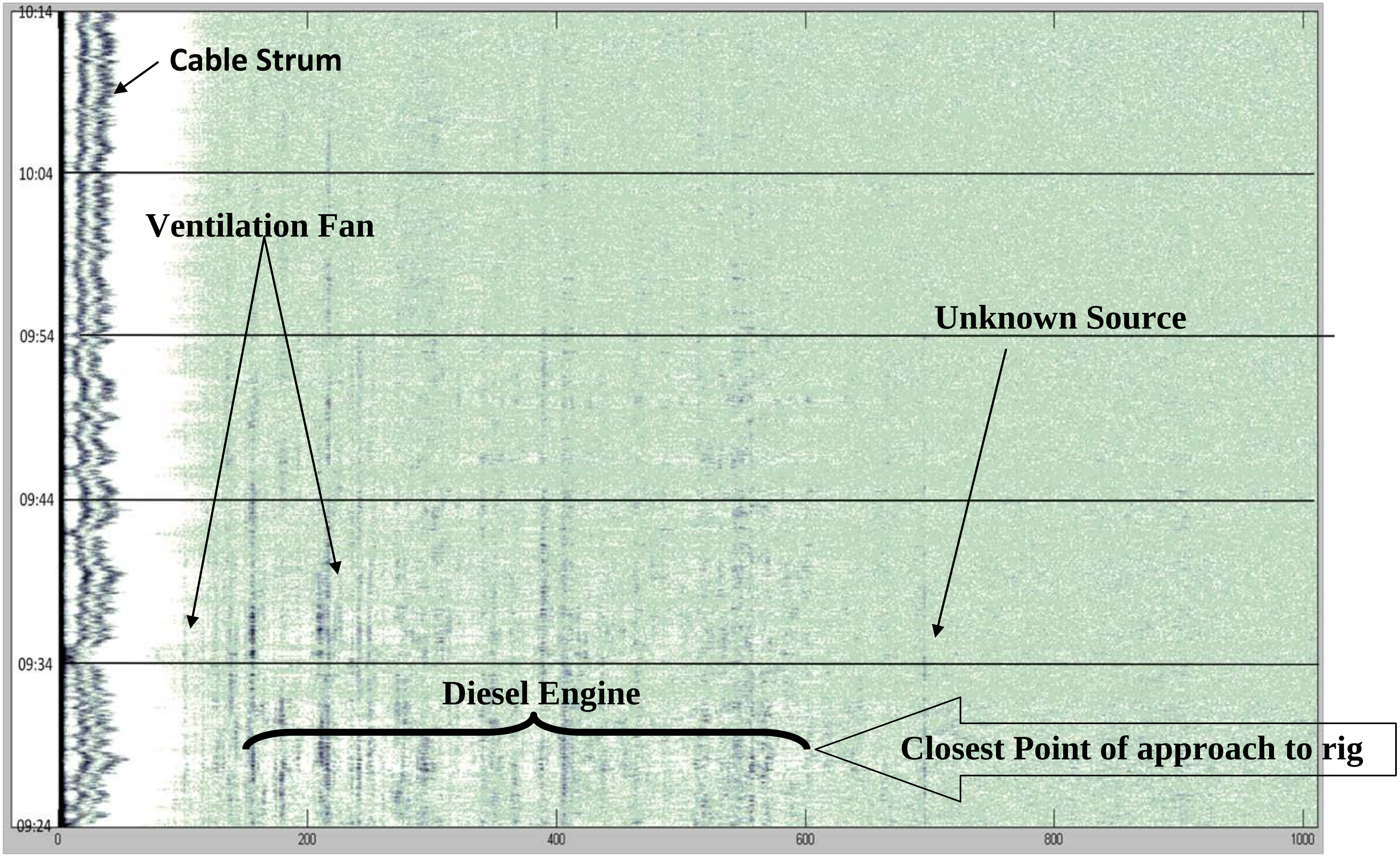

Figure 17. Contour Plot of Acoustic Received Level vs. Frequency and Time for 10 Sept 09:25 Dataset.

The initial strength of continuous acoustic signal generated by the diesel engines can be estimated by measuring the received strength of the acoustic signal, and estimating transmission loss to the signal as it travels from the rig to the hydrophone. Figure 18 is a plot of received levels vs. time of acoustic bands of diesel-generated noise. The peak acoustic received level of 110 dB re 1 µPa (141-178 Hz band) occurs at 9:35. The hydrophone was 0.27 nm (500 m) from the rig at 09:35.

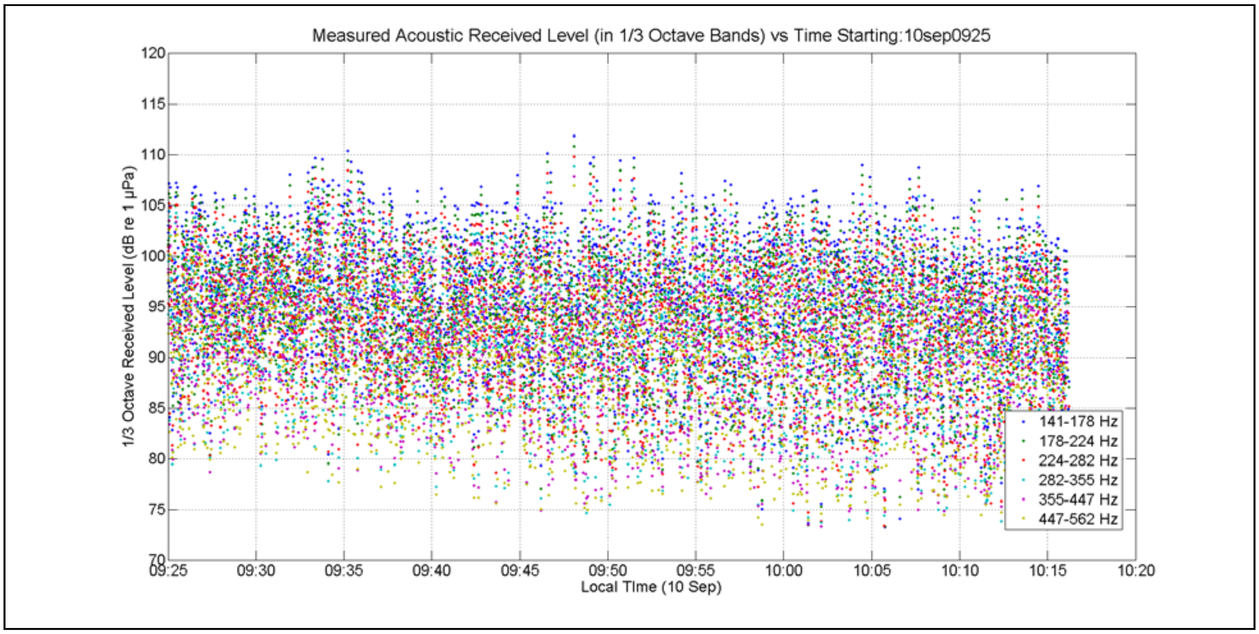

Figure 18. Measured Acoustic Received Level vs. Time Starting 10 September at 09:25.

Source level can be estimated assuming cylindrical spreading transmission loss, which is appropriate because the distance traveled is greater than water depth. Source level is a measure of the initial signal strength in water of the diesel engines in the peak ⅓ octave band measured 1 m from the engine.

Source Level = Received Level at 500 m + Transmission Loss at 500 m
= 110 + 10 Log (500)
= 137 dB re 1 µPa @ 1 m

If the above assumptions are correct, the 120 dB re 1 µPa received level contour occurs at 50 m from the center of the platform, where transmission loss reduces source level by 17 dB (10Log50).

5.2 10 September 11:35 Real-Time System Dataset

This dataset was collected using the Real-Time system with the hydrophone rigged with a heavy line and additional hydrophone strumming isolation. This dataset was the second dataset collected without acoustic interference from supply boats near the rig, while the rig was drilling.

This was the last Real-Time dataset collected during drilling operations because seas were building to 7 ft (2.13 m) at the end of the collection period.

As outlined above, the acoustic data were processed into acoustic received levels (dB re 1 µPa) for every ⅓ octave band up to 1 kHz as required by environmental regulation. Ranges were calculated for each received level from the center of Spartan 151 and are presented in Figure 19. The speed of the hydrophone in the water ranged between 0.7 and 2.0 kts (1.3 and 3.7 kph). Cable strumming may still be an issue, but received levels do not show a continuous source above 120 dB re 1 µPa.

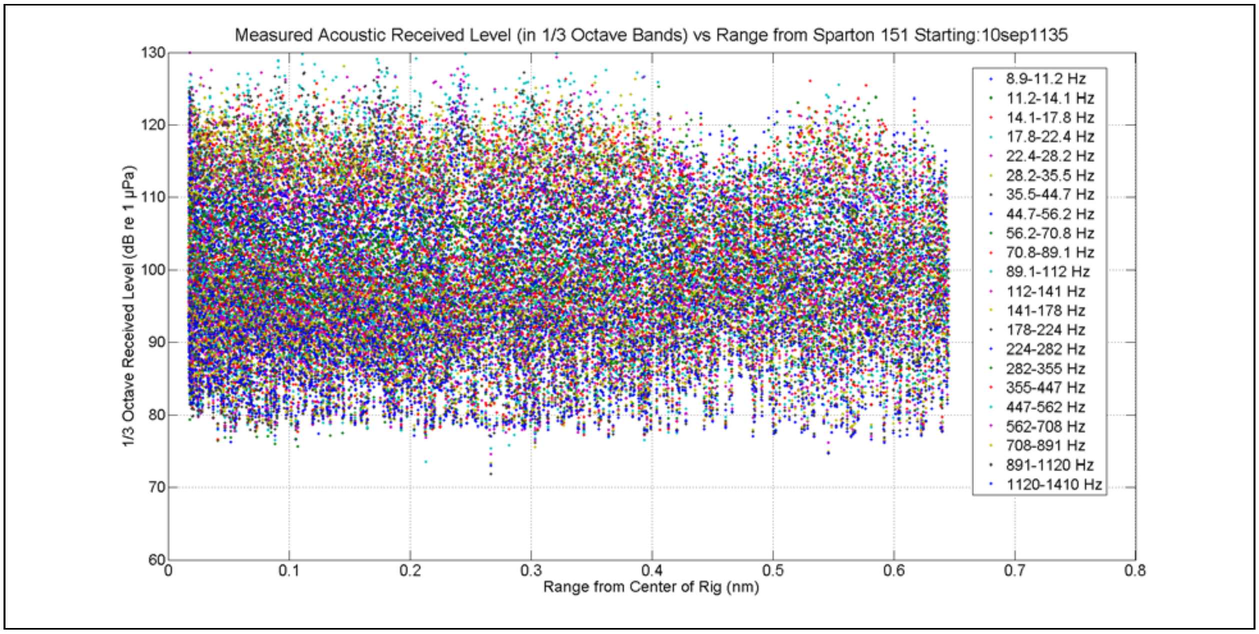

Figure 19. Measured Acoustic Received Level vs. Range from Drilling Rig Starting 10 Sept at 11:35.

As discussed in Section 3, the 120 dB re 1 µPa received level threshold is important to this analysis because NMFS regulators consider this to be the threshold for potential behavioral harassment (also known as MMPA Level B) when marine mammals are exposed to continuous sounds. The 160 dB re 1 µPa threshold is important because regulators consider this to be the threshold for Level B when marine mammals are exposed to impulsive sounds. The 180 dB re 1 µPa threshold is important because regulators consider this to be the threshold for potential harm (also known as Level A) when marine mammals are exposed to continuous sounds.

Received levels for each ⅓ octave band were examined to determine the maximum range at which each threshold was exceeded, as measured from 0.02 to 0.65 nm (37 meters to 1.2 km). Figure 20 is an example of this process, which presents the received level vs. range from the rig center for one of the ⅓ octave bands. It can be seen that the maximum range the level exceeded 120 dB re 1 µPa is 0.54 nm (1 km). This process was repeated for every band from 8.9 Hz to 1,410 Hz and recorded in Table 5. Acoustic received levels exceeding 160 dB re 1 µPa were never recorded for a continuous sound. A maximum range of 0.63 nm (1.2 km) was recorded for an acoustic received level exceeding 120 dB re 1 µPa for an impulsive sound. The threshold of

120 dB re 1 µPa for an impulsive sound is presented for illustration purposes and is not a regulated threshold.

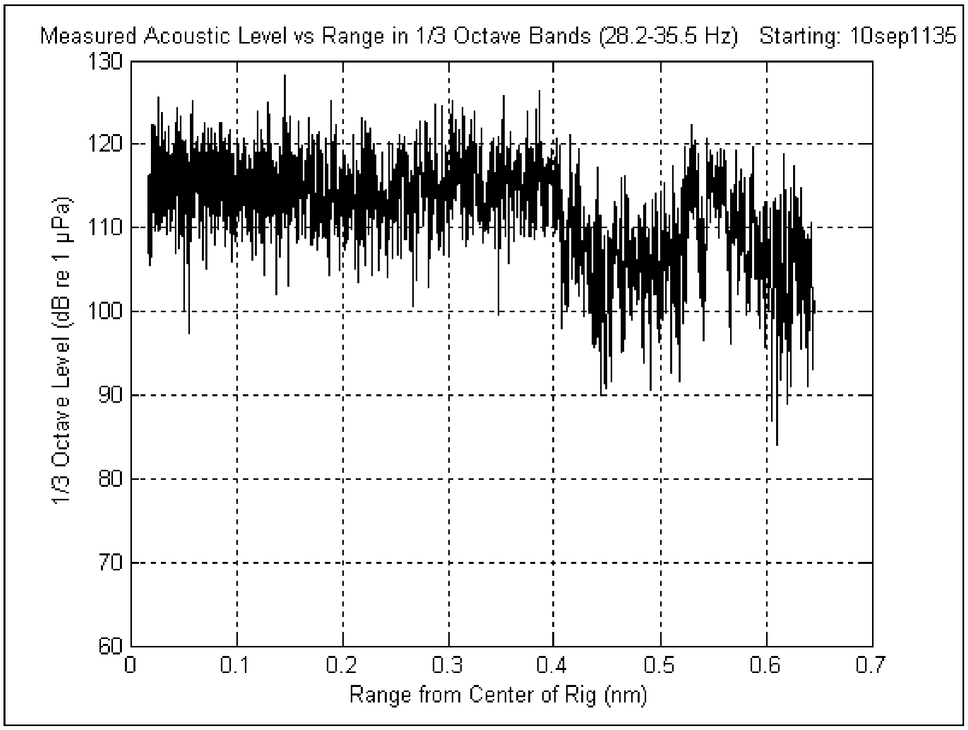

Figure 20. One ⅓ Octave Band Acoustic Received Levels vs. Range from Drilling Rig - 10Sept 11:35.

Band (Hz)	Max Range (nm) 120 dB <u>Impulsive</u> Signals (not regulated)	Max Range (nm) 120 dB <u>Continuous</u> Signals (Level B)	Max Range (nm) 160 dB <u>Impulsive</u> Signal (Level B)	Max Range (nm) 180 dB <u>Impulsive</u> Signal (Level A)
8.9 - 11.2	0.62	Never exceded	Never exceded	Never exceded
11.2 - 14.1	0.62	Never exceded	Never exceded	Never exceded
14.1 - 17.8	0.62	Never exceded	Never exceded	Never exceded
17.8 - 22.4	0.62	Never exceded	Never exceded	Never exceded
22.4 - 28.2	0.63	Never exceded	Never exceded	Never exceded
28.2 - 35.5	0.54	Never exceded	Never exceded	Never exceded
35.5 - 44.7	0.55	Never exceded	Never exceded	Never exceded
44.7 - 56.2	Never exceded	Never exceded	Never exceded	Never exceded
56.2 - 70.8	Never exceded	Never exceded	Never exceded	Never exceded
70.8 - 89.1	Never exceded	Never exceded	Never exceded	Never exceded
89.1 - 112	Never exceded	Never exceded	Never exceded	Never exceded
112 - 141	Never exceded	Never exceded	Never exceded	Never exceded
141 - 178	Never exceded	Never exceded	Never exceded	Never exceded
178 - 224	Never exceded	Never exceded	Never exceded	Never exceded
224 - 282	Never exceded	Never exceded	Never exceded	Never exceded
282 - 355	Never exceded	Never exceded	Never exceded	Never exceded
355 - 447	Never exceded	Never exceded	Never exceded	Never exceded
447 - 562	Never exceded	Never exceded	Never exceded	Never exceded
562 - 708	Never exceded	Never exceded	Never exceded	Never exceded
708 - 891	Never exceded	Never exceded	Never exceded	Never exceded
891 - 1120	Never exceded	Never exceded	Never exceded	Never exceded
1120 - 1410	Never exceded	Never exceded	Never exceded	Never exceded

Table 5. Maximum Range from Rig to Exceeded Thresholds per Band for 10 Sept 11:35 Dataset.

The data recording was analyzed using a Fast Fourier Transform contour plot to identify the source of sound generated by the rig and transmitted into the water environment. This contour plot (Figure 21) was generated using a 4-second integration and 1.3-Hz band resolution. The distance to the rig decreases with increasing time, with the closest point of approach to the rig at the top of the figure. This dataset is dominated by sound generated by the diesel engines from 160 Hz to 600 Hz. The unknown signature, possibly the PZ-10 mud pump or an unobserved mechanical gear set, can be seen again at 695 Hz, and possibly the fundamental signature frequency of 410 Hz. The 30 Hz harmonics of the unknown source identified on the rig can also be seen here. Cable strumming can also be seen to start as the drift speed increased later in the dataset.

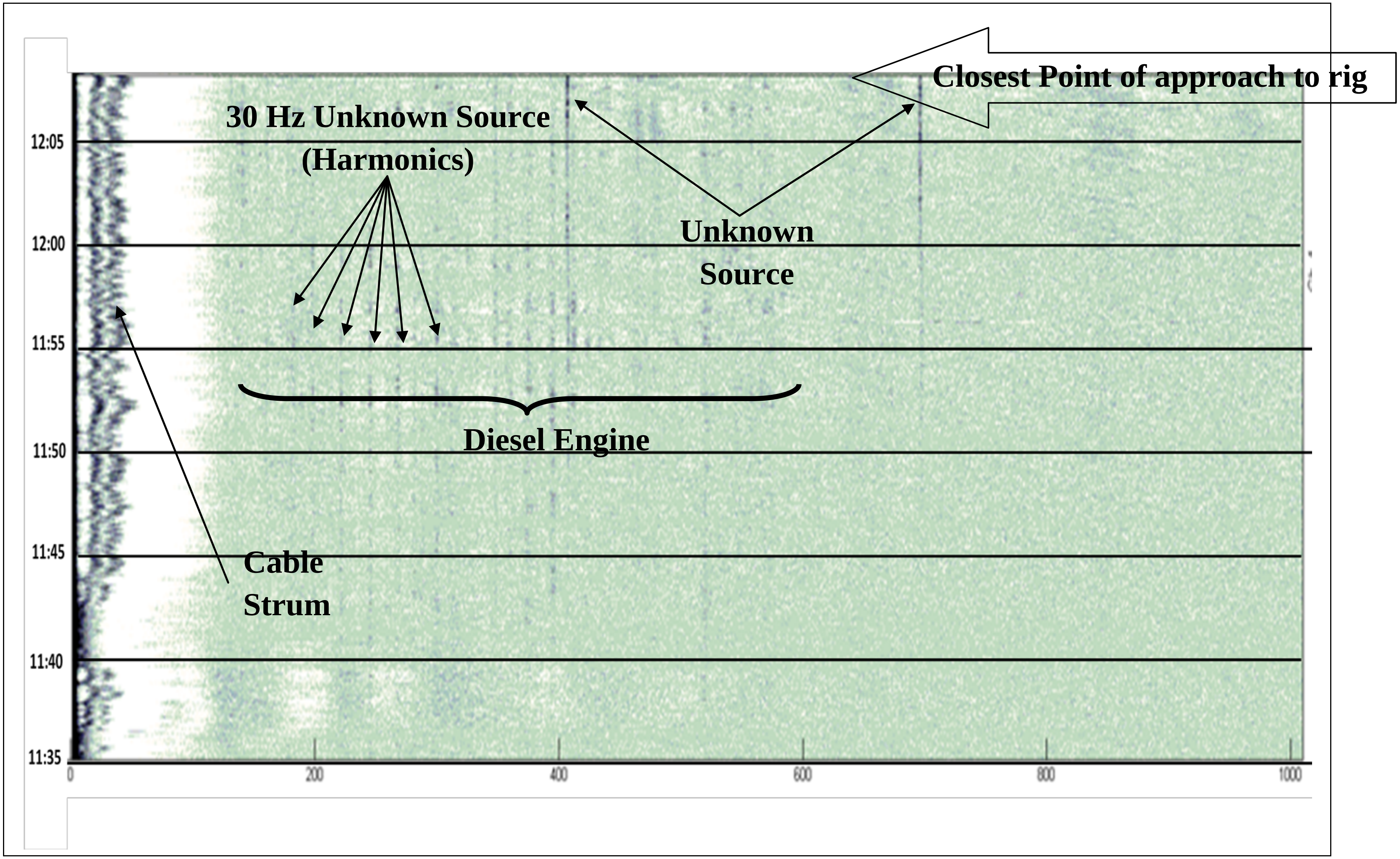

Figure 21. Contour Plot of Acoustic Received Level vs. Frequency and Time for 10 Sept 11:35 Dataset.

As seen in Table 5, the signature frequency bands that propagate to the furthest range are the lowest bands (<45 Hz). Figure 22 presents the contour plot of levels at frequencies less than 45 Hz to identify the sources of these signatures. Cable strumming can be observed between 20 and 50 Hz as the drift speed increases later in the dataset. The acoustic signature of cable strumming does not originate with the rig. (This signature will be verified as non-rig-generated by a separate data collection method and analysis later in this report.). The 10 Hz harmonic of the diesel engine cylinder firing rate can be seen to dominate rig-generated acoustic energy in the low bands. The D399/D398 diesel engines are the largest contributor to underwater rig-generated acoustic energy.

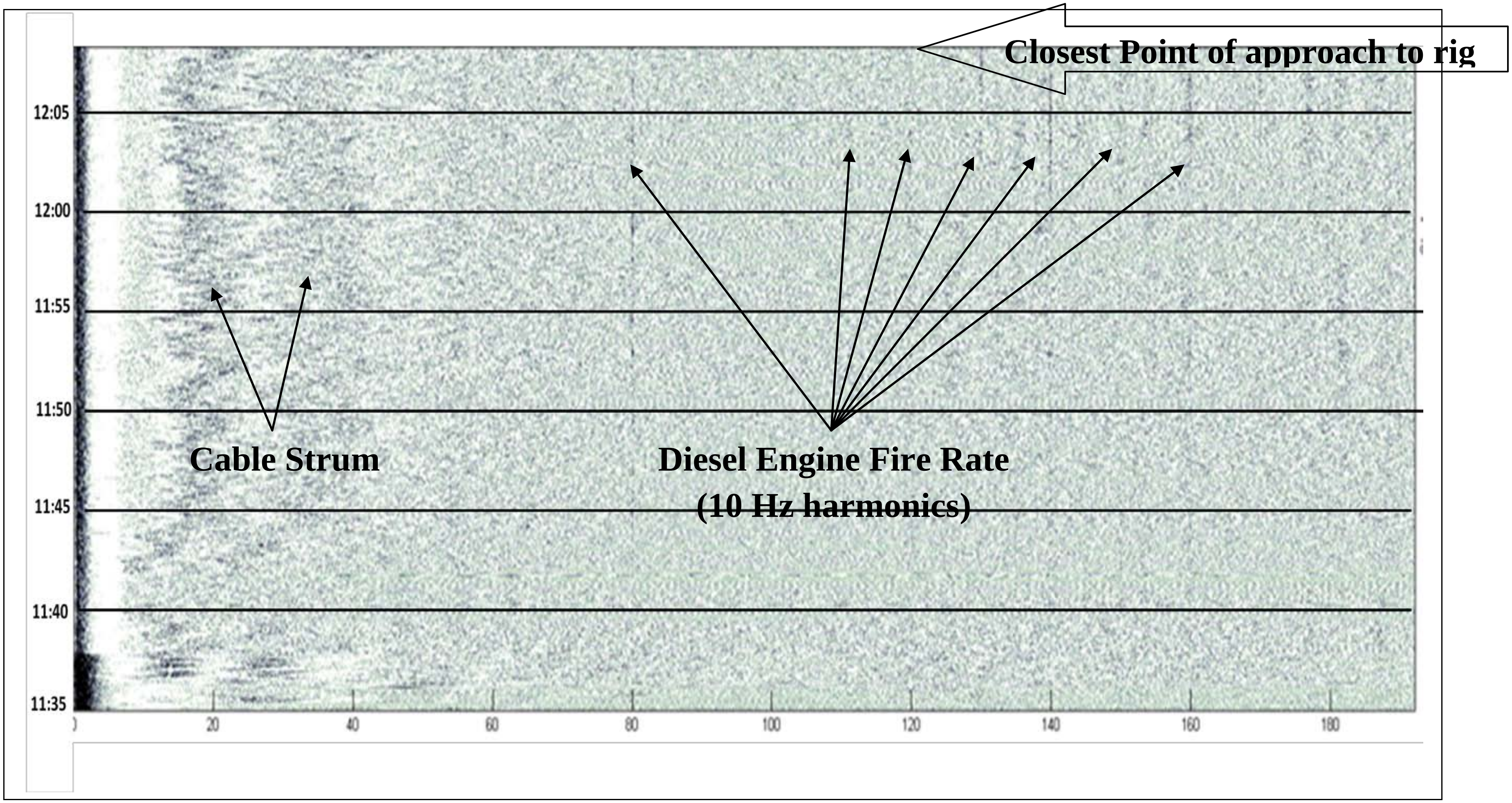

Figure 22. Lower Frequency Contour Plot of Acoustic Received Level for 10 Sept 11:35 Dataset.

5.3 10 September 09:14 Drifter Autonomous Recorder Dataset

The original data collection plan called for the mooring of the Autonomous Recorder at fixed ranges from the rig to assist in signature analysis. However, that plan was changed when high levels of cable strumming were observed in the field. The Autonomous Recorder was modified at sea to collect data, while drifting with the current, to eliminate the cable from the recording system, reduce the relative speed of water past the hydrophone and collect data with increasing range. Position of the drifting recorder was estimated the best means possible (radar, laser range finder, estimate of range/bearing from RV Thunder, and GPS of the deployment and recovery point). The result was a dataset absent of cable strumming, but with range data. In the future, a GPS recorder will be installed on the buoy for position data.

The data recording was analyzed using a Fast Fourier Transform contour plot to identify the source of sound generated by the rig and transmitted into the water environment. This contour (Figure 23) was generated using 8-second integration and 0.5 Hz band resolution. The distance to the rig decreases with increasing time from the start of the recording (09:14) until the recorder reaches the closest point to the rig (0.2 nm) at 09:19. Distance to the rig increases with time after 09:19 until the end of the recording. All Autonomous Recorder datasets have a 1 minute gap for recorder reset, as seen at 09:59 to 10:00.

This dataset was collected at the same time as the 10 September 09:25 Real-Time System dataset that did show strumming in the 8 to 50 Hz band. There is no strumming seen in this dataset. This confirms the conclusion that the cable strumming acoustic signature in the 8 to 50 Hz band of the Real-Time system dataset was not present in the environment and was a result the Real-Time system rigging itself.

Once again, this dataset is dominated by sound generated by the diesel engines from 160 Hz to 600 Hz, along with the 10 Hz harmonic diesel engine fire rate signatures below 150 Hz. A 60 Hz signature normally associated with the generation of 60 Hz electrical power can be seen to decrease in strength as time/distance from the rig increase. The 108 Hz ventilation fan signature, along with the broader 385 Hz exhaust signature can also be seen in this dataset. The unknown signature, possibly the PZ-10 mud pump or an unobserved mechanical gear set, can be seen again at 695 Hz.

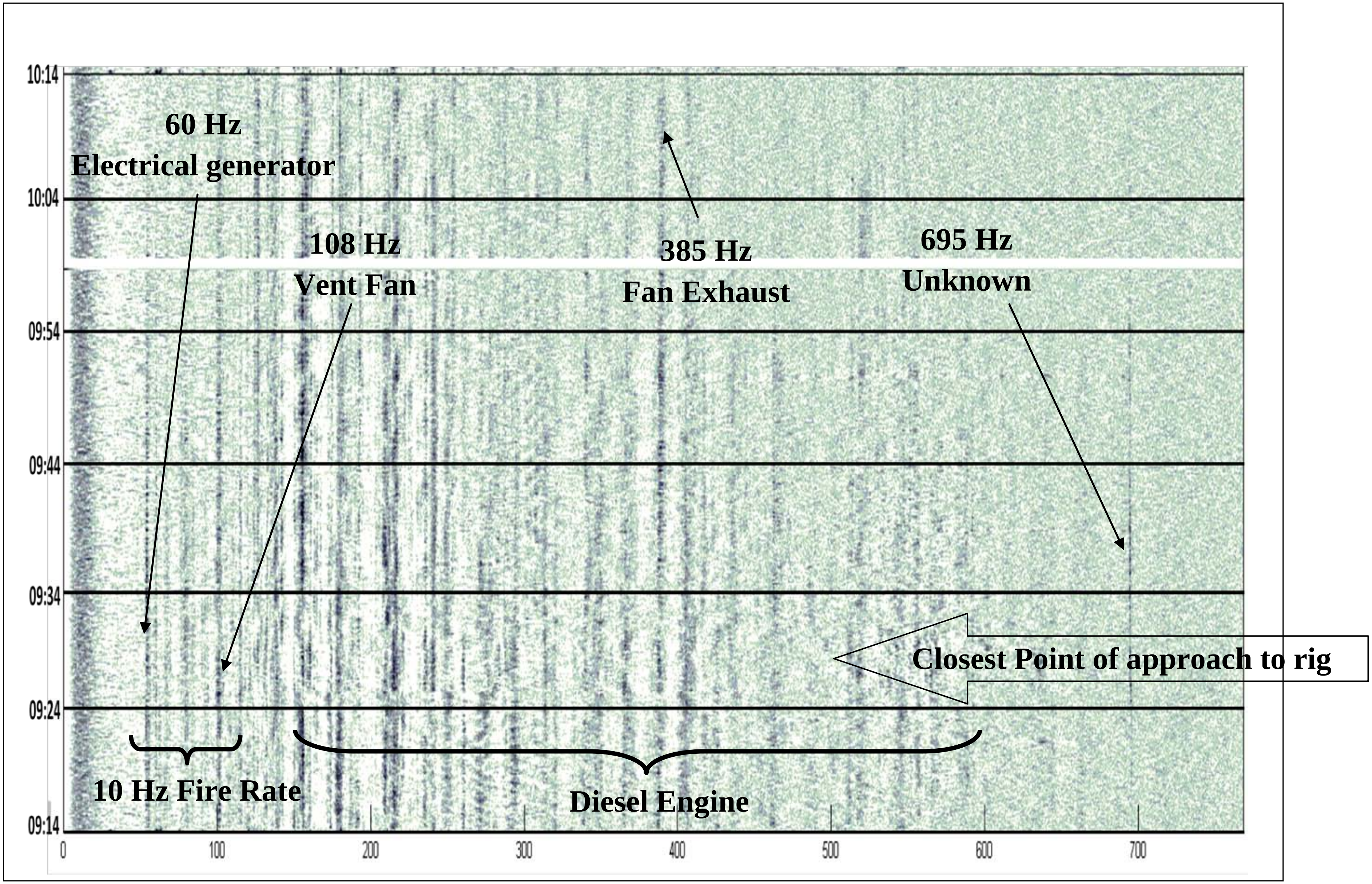

Figure 23. Contour Plot of Acoustic Received Level vs. Frequency and Time for 10 Sept 09:14 Dataset.

Drift speed can be estimated using Doppler analysis of the 695 Hz signature to qualitatively check the position estimate of the recorder. The Doppler effect shifts an acoustic signature according to the speed and direction of the source or receiver of the signature. This shift in frequency was observed as the receiver drifted toward and then away from the rig at 09:19. Speed can be calculated, assuming the transmitted acoustic source signature has a constant frequency. The signature frequency shifted from 695.95 Hz as the receiver was moving toward the rig to 693.95 Hz as the receiver moved away from the rig. This shift in frequency yields an estimate speed of 3.5 kts (6.5 kph), which was consistent with the positional data estimated for the receiver.

This acoustic dataset was processed the same as the Real-Time system datasets, acoustic received levels (dB re 1 µPa) for every ⅓ octave band up to 1 kHz, as required by environmental regulation. Range from the center of Spartan 151 was calculated for each level and is presented in Figure 24.   No cable strumming is present in this dataset because there is no hydrophone cable to expose to the current. This dataset was collected during drilling and at the same time as the Real-Time system dataset. At no time were acoustic received levels above 120 dB re 1 µPa for a continuous sound.

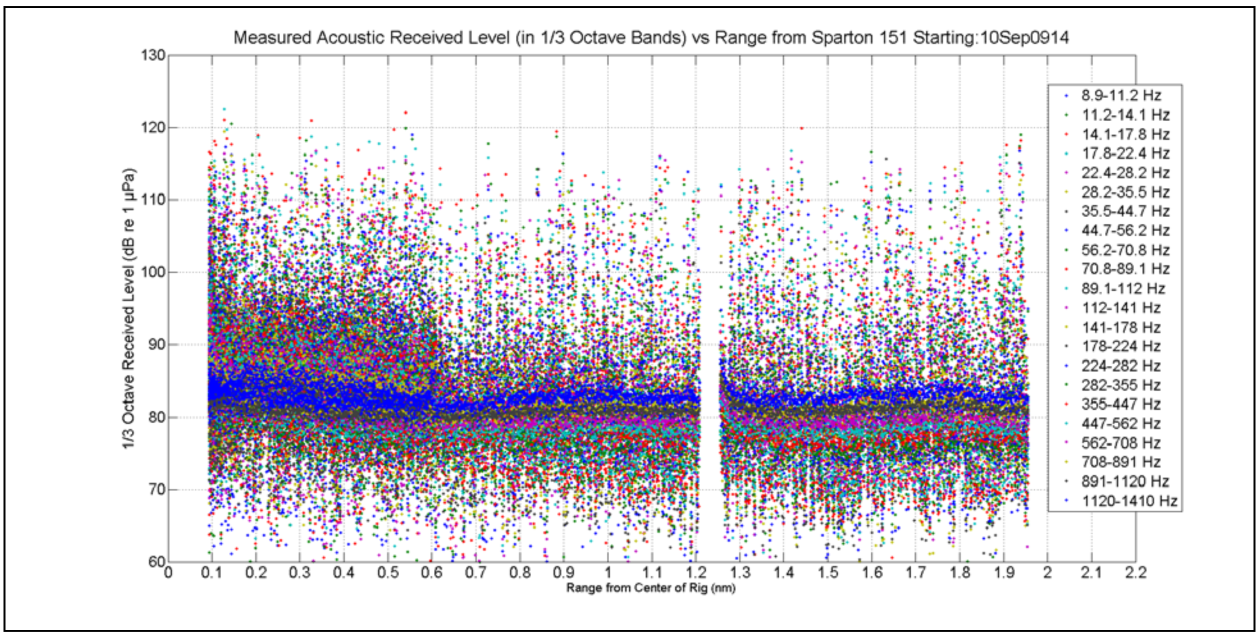

Figure 24. Measured Acoustic Received Level vs. Range from Spartan 151 Starting 10Sept 09:14.

Table 6 summarizes the maximum range each ⅓ octave band received levels exceeded the threshold as measured from 0.2 to 2.2 nm (0.37 – 4.07 km). These results were in the absence of cable strumming, but using an estimate of range, as outlined above. Acoustic received levels exceeding 160 dB re 1 µPa were never recorded for a continuous sound. A maximum range of 0.75 nm (1.4 km) was recorded for an acoustic received level exceeding 120 dB re 1 µPa for an impulsive sound. The threshold of 120 dB re 1 µPa for an impulsive sound is presented for illustration purposes and is not a regulated threshold.

Band (Hz)	Max Range (nm) 120 dB Impulsive Signals (not regulated)	Max Range (nm) 120 dB Continuous Signals (Level B)	Max Range (nm) 160 dB Impulsive Signal (Level B)	Max Range (nm) 180 dB Impulsive Signal (Level A)
8.9 - 11.2	Never exceded	Never exceded	Never exceded	Never exceded
11.2 - 14.1	0.75	Never exceded	Never exceded	Never exceded
14.1 - 17.8	0.75	Never exceded	Never exceded	Never exceded
17.8 - 22.4	0.20	Never exceded	Never exceded	Never exceded
22.4 - 28.2	Never exceded	Never exceded	Never exceded	Never exceded
28.2 - 35.5	Never exceded	Never exceded	Never exceded	Never exceded
35.5 - 44.7	Never exceded	Never exceded	Never exceded	Never exceded
44.7 - 56.2	Never exceded	Never exceded	Never exceded	Never exceded
56.2 - 70.8	Never exceded	Never exceded	Never exceded	Never exceded
70.8 - 89.1	Never exceded	Never exceded	Never exceded	Never exceded
89.1 - 112	Never exceded	Never exceded	Never exceded	Never exceded
112 - 141	Never exceded	Never exceded	Never exceded	Never exceded
141 - 178	Never exceded	Never exceded	Never exceded	Never exceded
178 - 224	Never exceded	Never exceded	Never exceded	Never exceded
224 - 282	Never exceded	Never exceded	Never exceded	Never exceded
282 - 355	Never exceded	Never exceded	Never exceded	Never exceded
355 - 447	Never exceded	Never exceded	Never exceded	Never exceded
447 - 562	Never exceded	Never exceded	Never exceded	Never exceded
562 - 708	Never exceded	Never exceded	Never exceded	Never exceded
708 - 891	Never exceded	Never exceded	Never exceded	Never exceded
891 - 1120	Never exceded	Never exceded	Never exceded	Never exceded
1120 - 1410	Never exceded	Never exceded	Never exceded	Never exceded

Table 6. Maximum Range from Rig to Exceeded Thresholds per Band for 10 Sept 09:14 Dataset.

6.0 CONCLUSIONS

The underwater acoustic energy radiated from the Cook Inlet-based Spartan 151 jack-up drilling rig during drilling operations was measured using two different measurement systems. Both systems measured consistent levels below thresholds required by NMFS environmental regulations concerning marine mammal exposure. Continuous sound acoustic received levels were never measured exceeding 180 dB re 1 µPa (MMPA Level A threshold) or 160 dB re 1 µPa (MMPA Level B threshold). Non-continuous (less than 1 second) levels exceeding 120 dB re 1 µPa were measured to a maximum range of 0.63 to 0.75 nm (1.17 – 1.4 km) in the frequency band of 8.9 Hz to 44.7 Hz.

Primary sources of rig-based acoustic energy were identified as coming from the D399/D398 diesel engines, the PZ-10 mud pump, ventilation fans (and associated exhaust), and electrical generators. There were unknown sources of rig-based acoustic energy, with one possible source associated with the drill riser. The source level of one of the strongest acoustic sources, the diesel engines, was estimated to be 137 dB re 1 µPa @ 1 m (rms) in the 141-178 Hz ⅓ octave band. If this is an accurate estimate, the 120 dB re 1 µPa acoustic received level isopleth would be 154 ft (50 m) away from the where the energy enters the water (jack-up leg or drill riser).

At no time during the study period were underwater acoustic received levels generated from the Spartan 151 drilling rig measured at received levels at or above harassment or harm levels as defined by NMFS in connection with the Cook Inlet critical habitat designation for the beluga whale.

Appendix A. Furie Operating Alaska Drilling Reports

9 September Daily Drilling Report

ESCOPETA OIL COMPANY ALASKA

DAILY DRILLING REPORT

RIG PH #504-620-8462
RIG FAX

KLU #1 Kitchen Lights Test		**PERMIT NUMBER: 211039**		**API #:**	50-733-20593-CO-OO
REPORT NO. 30	**FIELD** Kitchen Light #1		**COUNTY** Kenai Pen. Bor.	**STATE** Alaska	**DATE** 9/9/2011
RIG Spartan 151		**SUPERVISOR** Jim Mosley/Keith Matt	**DAILY COST**	**CUMULATIVE COST**	AFE NUMBER:

TODAY'S DEPTH	YESTERDAY	TVD	PROGRESS	HRS	AVERAGE ROP	LAST SHOE TEST	DAYS SINCE SPUD	AFE DAYS
1719	1800	1800	199	10.0	19.9	N/A	8	

PRESENT OPERATION: @ 0200 Working on Top Drive Blower Motor.Monitoring well on trip tank.

TIME LOG FROM	TO	ELAPSED TIME (HRS)	DETAILS OF OPERATIONS	OPERATION TIME ANALYSIS	DAILY	CUMMULATED
0000	0530	5.5	Continued opening hole from 1520' to 1557' with 860 GPM and 1400 psi.	R/U, R/D MOBE		
0530			CBU, POOH w/ HO. LD Balled up HO. PU 26" Bit & RIH. Functioned Diverter	DRILLING	10.0	
			Functioned diverter while out of hole, knife valves worked fine.	CIRCULATE		
	1200	6.5	Conducted trip drill - 45 seconds.	PU/LD BHA & tools		
1200			Checked for fill and had 4 feet of fill. Drilled from 1557' to 1719'.	TRIPPING	8.5	
	1630	4.5	Blower motor on top drive quit. Circulated & trouble shot while working pipe.	WASH & REAM		
1630	1830	2.0	Pull up hole to drive pipe shoe.	SURVEY		
1830		5.5	Worked on Top Drive Blower Motor.Monitoring well on trip tank,hole taking	RIG SERVICE		
	0000		1 to 2 bbls per hr.	RIG REPAIR	5.5	
				SLIP & CUT DRLG LINE		
				R/U & RUN CASING		
				PRIMARY CEMENTING		
				N/U BOP,WH & TEST		
				WELL CONTROL		
				WIRE LINE		
				SAFETY / OBM		
				WASH & DRLG CMT		
				WINDOW MILLING		
				SHUT DOWN FOR NITE		
				FISHING		
				OTHER		
				CLEAN MUD TANKS		
				W/O Cement		
				W/O FISHING TOOL's		
				COMPLETION OPS.		
			Participate in Pre-Tour Safety Meetings	FLOW WELL		
TOTAL HOURS		24.0	No Accidents, Incidents, or Spills.	**TOTALS**	24.0	

10 September Daily Drilling Report

ESCOPETA OIL COMPANY ALASKA

DAILY DRILLING REPORT

RIG PH #504-620-8462
RIG FAX

KLU #1 Kitchen Lights Test			PERMIT NUMBER: 211039		API #: 50-733-20593-CO-OO
REPORT NO. 31	FIELD Kitchen Light #1		COUNTY Kenai Pen. Bor.	STATE Alaska	DATE 9/10/2011
RIG Spartan 151	SUPERVISOR Jim Mosley/Keith Matt		DAILY COST	CUMULATIVE COST	AFE NUMBER:

TODAY'S DEPTH	YESTERDAY	TVD	PROGRESS	HRS	AVERAGE ROP	LAST SHOE TEST	DAYS SINCE SPUD	AFE DAYS
1805	1800	1805	86	4.5	19.1	N/A	9	

PRESENT OPERATION: 0230 building base plate for casing slips

FROM	TO	ELAPSED TIME (HRS)	DETAILS OF OPERATIONS	OPERATION TIME ANALYSIS	DAILY	CUMMULATED
0000	0600	6.0	Work on Top Drive Blower Motor replacement	R/U, R/D MOBE		
0600	0730	1.5	RIH and Break Circulation. 4 Feet of Fill at 1719'	DRILLING	4.5	
0730	1200	4.5	Drill from 1719 to 1805'.	CIRCULATE	5.5	
1200	1730	5.5	Circulated hole clean, made short trip 8 stands to HWDP, Had no fill but a	PU/LD BHA & tools		
			little sticky near bottom at 1774' Hole pulled 40 to 50K tight. Worked	TRIPPING	4.5	
			through and circulated bottoms up for trip to run casing.	WASH & REAM		
1730	2030	3.0	Pulled out of hole and laid down 26" Stabilizer and 26" bit.	SURVEY		
2030	2230	2.0	Cleaned rig floor and prepared to rig up casing tools.	RIG SERVICE		
2230		1.5	Held prejob with GBR, Cameron, Rig Crew, Crane Operator & deck crew	RIG REPAIR	6.0	
	0000		Started R/U GBR casing equipment.	SLIP & CUT DRLG LINE		
				R/U & RUN CASING	1.5	
				PRIMARY CEMENTING		
				N/U BOP,WH & TEST		
				WELL CONTROL		
				WIRE LINE		
				SAFETY / OBM		
				WASH & DRLG CMT		
				WINDOW MILLING		
				SHUT DOWN FOR NITE		
				FISHING		
				OTHER	2.0	
				CLEAN MUD TANKS		
				W/O Cement		
				W/O FISHING TOOL's		
				COMPLETION OPS.		
			Participate in Pre-Tour Safety Meetings	FLOW WELL		
TOTAL HOURS		24.0	No Accidents, Incidents, or Spills.	TOTALS	24.0	