CROWLEY KOTZEBUE DOCK REPLACEMENT PROJECT

HYDROACOUSTIC MONITORING PLAN

Prepared for:

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Prepared by:

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1. INTRODUCTION

The Crowley Dock Replacement Project (Project) in Kotzebue, AK provides an opportunity to perform real-time measurements of acoustic energy produced related to common dock construction practices and to gather data on the presence of marine mammals in Kotzebue Sound. The project components include nine 24" bollard piles, 170 18" steel temporary support piles, fifteen 14" HP steel anchor piles, and a nominally 560-feet OPEN CELL SHEET PILE™ dock consisting of 650 interlocking sheet piles (see Figure 1). The piles will be driven using vibratory pile driving techniques.

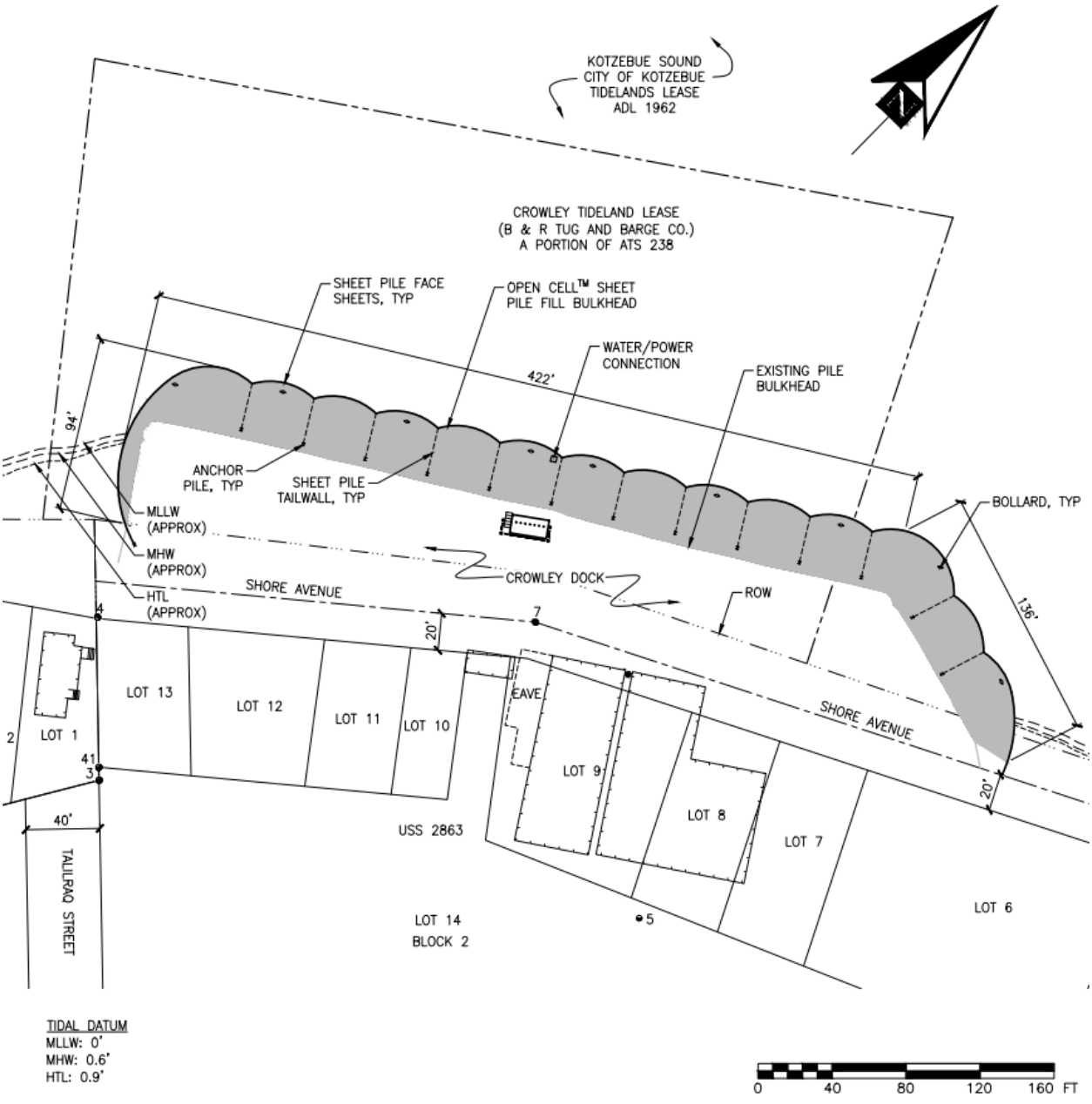

Figure 1. Project overview

Species of concern occurring in the project area include humpback whales, bowhead whales, fin whales, bearded seals, ringed seals, pacific walruses, minke whales, gray whales, killer whales, beluga whales, narwhals, spotted seals and ribbon seals. Project permit requirements require shutdown at various radii depending on the anticipated impacts on species observed during each type of construction activity.

Measurement of the actual range of acoustic energy will be useful to future projects and mitigation design. This monitoring work plan describes the methods for collection of this data during pile-driving activities for the Crowley Dock Replacement project and includes a list of monitoring equipment and procedures used for real-time underwater noise measurements.

In addition to the construction monitoring, Crowley will deploy a Passive Acoustic Monitoring (PAM) system to detect the presence of marine mammals within range. This information will be used to supplement the direct observations of the Protected Species Observers, whose duties are described in the Project's Marine Mammal Monitoring and Mitigation Plan. Data from the PAM system will be provided to NMFS for further processing

PND Engineers, Inc. will perform the monitoring and has experience with multiple acoustic monitoring projects including pile driving monitoring and ambient noise measurements at various locations in Alaska.

2. UNDERWATER NOISE IMPACTS

The effects of noise exposure on wildlife are divided into two categories, direct auditory tissue effects (injury) and behavioral disruptions (Southall et al. 2007). The Marine Mammal Protection Act of 1972 (as amended) classifies direct injury as a 'Level A harassment' and behavioral disruption as a 'Level B harassment.' 16 U.S.C. 1362(18)(A) and (B).

The difficulty in predicting impacts on local species lies between multiple challenges; research into behavioral responses has often involved insufficient measurements and controls, laboratory experiments "rarely approximate those in the field" and may evaluate behavior that has little relation to natural responses, and field experiments can lack "adequate controls and precision in quantifying exposures and responses" (Southall et al. 2007). This project provides an opportunity to directly monitor typical dock construction techniques, noise attenuation, and species presence while trained observers are monitoring behavior of local species of concern.

For this construction project, the presence of several species of concern within the project area have necessitated the application for permits to harass protected species, allowing 'Level B Harassment' to a certain extent and providing trained marine mammal observers to prevent 'Level A Harassment' caused by the project activities. The range of required observations and the various radii at which an animal can approach before causing project shutdown were dictated by agency practices and the predictions gleaned from the studies described above. Predicted source noise levels were estimated based on studies of similar, though not identical, projects. Through direct measurement of the actual noise levels experienced in these field conditions, it is our hope that these measurements will be of use for future impact assessments.

3. CONSTRUCTION MONITORING APPROACH

Acoustic monitoring will be conducted from single small working boat (if deemed safe) directly adjacent to the activity with a single operator and hydrophone system consiting of one or two

omnidirectional hydrophones, data acquisition sound card, preamplifier (for underwater ambient sound level recording) and rugged laptop.

Hydroacoustic monitoring will be conducted during driving of at least one sheet pile cell at four distances offshore alternately throughout various phases of installation activities.

For the first set of measurements, the hydrophone will be located as close as is practicable to 10 meters from each pile with a clear acoustic line-of-sight between the pile and the hydrophones. The exact distance between the hydrophone and pile will be recorded in the monitoring logs and may need to be adjusted depending on safe access within the construction area during driving activities. The underwater sound levels will be collected at various depth below the water surface (depending on bathymetry) at the bottom, mid-column, and at the surface. Measurements close to the surface will be done at least one meter (3.3 feet) below the water surface.

Following recording at the 10-meter location, additional measurements will be taken in the center of the navigational channel and offshore from the site at the following radii: 100 m, 500 m and 1,000 m. Duration of recording at each position will depend on field conditions and typical pile driving duration and so will be determined at the time of recording. Figure 2 indicates the approximate hydrophone locations for each pile during monitoring.

Prior to and during the pile-driving activity, environmental data will be gathered, such as water depth and tidal level, wave height, and other factors that could contribute to influencing the underwater sound levels (e.g. aircraft, boats, etc.). Underwater sound levels will be recorded continuously during each phase of pile driving. Start and stop time of each pile-driving event will be logged. Additional measurements of background sound levels, for baseline comparison, will be conducted several minutes prior to, or immediately after, each pile driving activity.

All acoustic data will be logged on a laptop computer setup on the monitoring boat. The display will be configured to show spectral plots of the acoustic metrics including amplitudes or Sound Pressure Levels (SPLs), Peak levels, Peak Frequencies, and Sound Exposure Levels (SELs).

Distance from the target pile and the hydrophone(s) will be measured through the use of a laser range finder and handheld GPS unit.

Complete information on the construction equipment being used, such as hammer model, pile cap or cushion type and hammer energy settings, as applicable, will be provided as attachments to the hydroacoustic data report. Relevant driving data such as depth each pile is driven will be recorded for each of the piles monitored.

Ancillary data, e.g. Conductivity, Temperature, Depth (CTD) will be collected intermittently to record changes in salinity and temperature of the water column that may change throughout the day and affect the propagation of underwater sound.

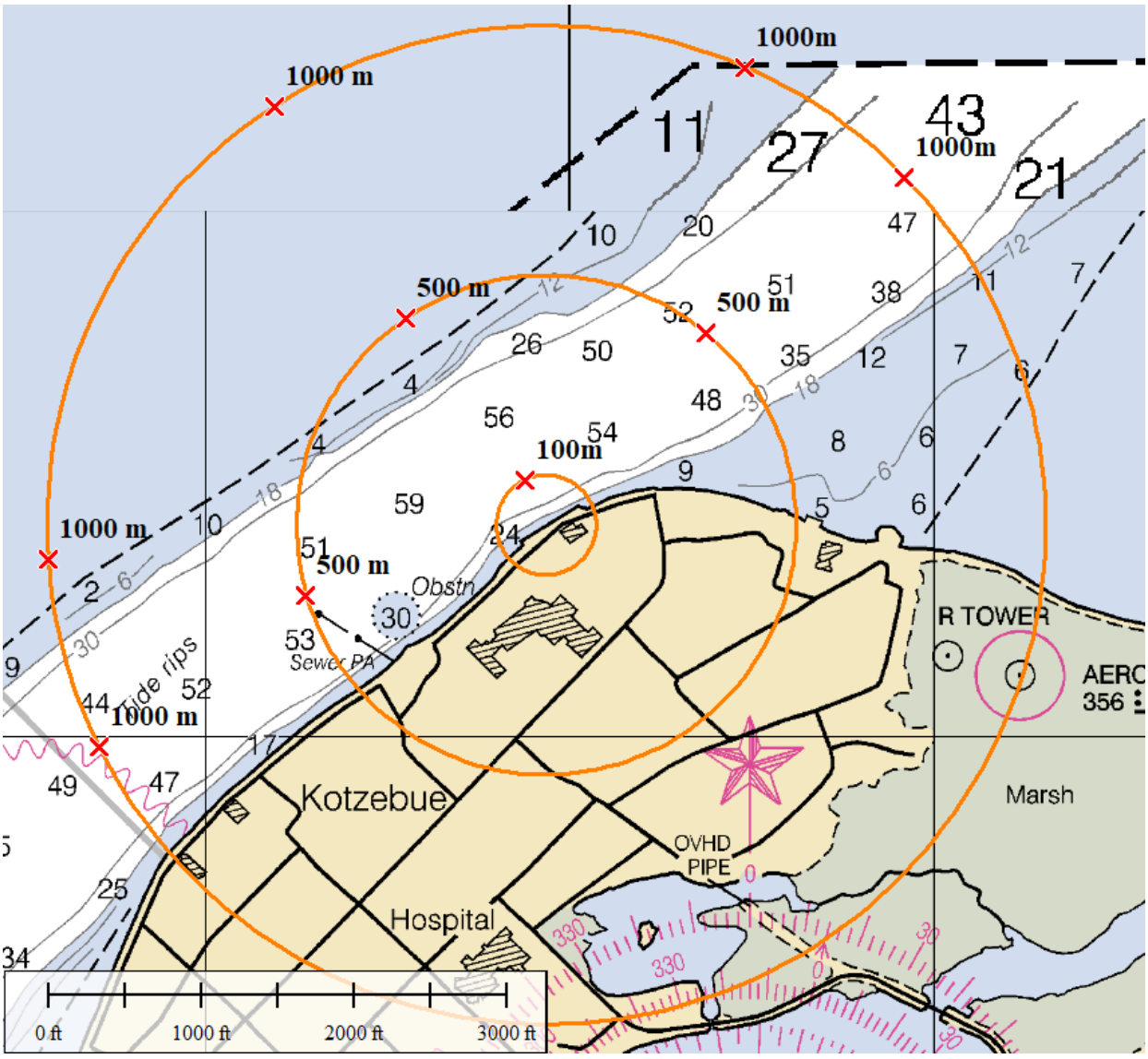

Figure 2 – Planned Measurement Locations (red crosses)

4. PASSIVE ACOUSTIC MONITORING APPROACH

A PAM Buoy will be acquired for this project and deployed before the start of the construction monitoring (to allow for maximum data collection time before retrieval). The proposed location for this buoy is shown in Figure 3. If conditions at this site are unsafe or unsuitable for deployment, an alternative similar location will be determined in the field at least 2,000 meters from the Project.

The PAM sensor will be calibrated in the factory before deployment. A small vessel will be used to deploy temporary anchor, sensor, and surface buoy for marking and retrieval. Location of the buoy and time and conditions at deployment will be recorded. Based on battery capacity and configuration, maximum duration of recording will be estimated before deployment. If the time available is sufficiently greater than the recording capacity, the buoy will be retrieved and serviced, (e.g. data downloaded and batteries replaced) before redeploying the system. Following the end of the construction monitoring, the system will be retrieved and data downloaded and sent to NMFS for further processing.

Figure 3 – Planned PAM buoy location (yellow box). Red circle is approximately 2000 meters from noise source.

5. PLANNED MONITORING EQUIPMENT

CR-1 hydrophones manufactured by Sensor Technology, LTD and assembled by Cetacean Research Technology will be used to document the sound frequency spectrum and pressure levels generated by pile driving activity. These hydrophones were designed specifically with a 198 dB re 1v/μPa nominal sensitivity without the need for pre-amplification and calibrated over a frequency range of 10 Hz to 68 kHz. Each hydrophone has a maximum cable length of 30-meters.

The hydrophone(s) are connected to their respective channels on a dual channel, SpectraDAQ-200 Precision Dynamic Signal Acquisition Interface manufactured by SpectraPLUS interfaced directly into a field laptop computer running *SpectraPLUS-SC FFT Spectral Analysis System* software, developed by Cetacean Research Technology in association with Pioneer Hill Software, LLC. Concurrent incoming analog signals are digitized from the hydrophone(s) and the real-time voltage signals are displayed on the computer as SPL and digitally stored for post-processing and analysis. A second dual-channel SpectraDAQ-200 system will be on site as backup.

All collected digital data will be stored on a USB hard drive as both a text file and a wave file for further post-processing and analysis. Pile driving activities will be logged in a project-driving log and will be included as attachments with the data report. All field notes will be recorded in water-resistant field notebooks. Notebook entries will include date, time, pile number, measurement positions,

relevant recording equipment system settings, and any relevant external noises that might affect the recorded data to make each measurement.

A Bushnell Laser rangefinder and/or handheld GPS will be used to take a direct distance from the pile to the monitoring location. Water depth will be determined using a sounding line or handheld depth sounder.

The PAM buoy proposed for this project is the Cetacean Research™ μRUDAR-mk2™ micro Remote Underwater Digital Acoustic Recorder. The system is capable of recording a variety of underwater sounds, including marine mammal vocalizations. The μRUDAR-mk2™ uses a SQ26-08 Hydrophone recording between 0.020 to 50 kHz with an effective sensitivity of -169 dB re 1V/μPa and SPL-equivalent self-noise of 44dB re 1μPa/√Hz at 1kHz. Additional detail is available in the attached specification sheet.

A manufacturer calibration certification of the measurement system and hydrophone sensitivities will be attached to the final report.

6. DATA PROCESSING

Construction monitoring data will be observed in the field to determine the SPLs and SELs in real time. A final report will be prepared and submitted within 30 days following hydroacoustic monitoring. The report shall include the following components:

1. Size and type of piles.
2. A description of the name type of noise attenuation device (if used).
3. The energy rating used to drive the piles, make and model of the hammer.
4. A description of the sound monitoring equipment.
5. The distance between hydrophone(s) and pile.
6. The depth of the hydrophone(s) and depth of water at hydrophone locations.
7. The distance from the pile to the water's edge.
8. The depth of water in which the pile was driven.
9. The depth into the substrate that the pile was driven.
10. The physical characteristics of the bottom substrate into which the piles were driven.
11. The total number of strikes to drive each pile.
12. The ranges, median, and means for RMS and peak SPL for each pile.
13. The duration and cumulative SEL for vibratory pile driving.
14. The observed typical and maximum peak pressures as recorded in field notebooks or depicted from instrument raw data output.
15. Plots of Peak Spectral Density and 1/3-octave band values.
16. Background/ambient levels.
17. Pile driving logs.
18. A description of any observable animal behavior in the immediate area.
19. A description of the PAM device, including sensitivity.
20. The deployment location of the PAM buoy, depth of recording device, water depth at deployment site, and duty cycle.

A report will be prepared summarizing the type of equipment used and how it was deployed. Plots will consist of time series of SPLs over driving event, time series plot of SELs (per pile), general frequency (spectrum plot) for each pile driving event, plot of peak waveform for each pile. The results will be summarized in graphical form and included summary statistics of sound values for each monitored pile. Source levels will be referenced to 10 meters. Report will include transmission loss

coefficients and estimated Level A and Level B harassment isopleths based on the Kotzebue Dock Replacement construction methodologies.

PAM data will be downloaded and provided to NMFS for data processing. If suitable and timely, the resulting information will be used to supplement observer data for the final marine mammal observations report for this project.

7. LITERATURE CITED

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. 2007. Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals* 33:411-521.

EQUIPMENT DATASHEETS

- CR Series Hydrophones
- SpectraDAQ-200
- VP2000 Voltage preamplifier
- SQ26-08 Hydrophone

CETACEAN RESEARCH TECHNOLOGY

HYDROPHONE SPECIFICATIONS

Model Number	C57 / C57X	C57RS / C57XRS	C305 / C305X	C75 / C75X
Linear Frequency Range (±3dB) [kHz]	0.015 – 45	0.015 – 50 & 124 – 250+	0.012–1200 / 0.012–250+	0.010 – 170
Useable Frequency Range (+3/-12dB) [kHz]	0.008 – 100	0.008 – 77 & 96 – 250+	0.005–2000+ / 0.005–250+	0.003 – 250
Transducer Sensitivity [dB, re 1V/µPa]	-187	-200	-198	-200
Preamplifier Gain [dB]	20 / 33	20 / 33	20 / 33	20 / 33
Effective Sensitivity* [dB, re 1V/µPa]	-167 / -154	-180 / -167	-178 / -165	-180 / -167
SPL Equiv. Noise at 1kHz [dB, re 1µPa/√Hz]	46 (*Sea State Zero*)	61	≈63	51
Power Requirement [Vdc]	5 to 32	5 to 32	5 to 32	5 to 32
RMS Overload Acoustic Pressure [dB, re 1µPa]	171 to 188 / 158 to 175	184 to 201 / 171 to 188	182 to 199 / 169 to 186	184 to 201 / 171 to 188
Maximum Operating Depth [m]	370	920	920	920
Operating Temperature Range [ºC]	-40 to 60	-40 to 60	-40 to 60	-40 to 85
Output Impedance [Ω]	10	10	10	10
Dimensions [mm]	116L x 25 dia.	116L x 25 dia.	110L x 38W x (25 to 11)T	92L x (25 to 18) dia.
Integral Connector‡	Subconn MCBH3MSS	Subconn MCBH3MSS	Subconn MCBH3MSS	Subconn MCBH3MSS

* Add preamplifier gain to transducer sensitivity to get effective hydrophone sensitivity. ‡ Connectors are rated to a depth of 7000m; see below for mating connector and cables. Calibrated spot sensitivity measurements and full frequency response measurements can be performed for an additional fee.

Directionality:
The C305 is very directional at high frequencies (e.g., 15° solid angle at 200 kHz, -3dB). This is also true of the C57, but its directionality will be focused in a plane rather than in a dipole pattern. All hydrophones are omnidirectional below 10kHz. The C75 is omnidirectional.

Battery/Connector Box:
Battery boxes are rated NEMA-4X water resistant. Signal connection is through a water-tight, BNC connector with gold center contact. The hydrophones are powered by one 9V battery (not included).

Standard Signal Output	Female BNC connector
Battery Life [hours]	>20
Box Dimensions [mm]	110 long x 90 wide x 50 high

Cable & Mating Connector*:

Connector molded to 15m of cable	Connector molded to 50m of cable	
Connector molded to 30m of cable	Connector molded to custom length	Please inquire

Additional Options:

Adapter Cables and Connectors
500Hz Inline High-Pass Filter Module
170kHz Isolation Transformer
Hydrophone Protection Cage
Hydrophone Sensitivity Measurement

Selected Accessories (many more items available):

Zoom *H1n* 24-bit/96kHz Flash Recorder
TASCAM *US-366* 24-bit/192kHz USB Interface
Zoom H4n Pro 24-bit/96kHz 4-Ch Digital Recorder.
TASCAM *DR-100mkIII* 24-bit/192kHz Recorder
Zoom F8n 24-bit/192kHz 8-Ch Digital Recorder

Hydrophones *not in stock* will ship within 8 weeks of the receipt of payment. Add 4 weeks to delivery time for custom orders. Acceptable payment includes: check or money order made out in US funds and drawn on a US bank; VISA, MasterCard, Discover or American Express cards; or money wire transfers. There is an added fee for foreign wire transfers. Qualifying nonprofit organizations may receive discounts.

All hydrophones carry a 90-day limited warranty. Extended warranties are available. Units will either be repaired or replaced at the discretion of Cetacean Research Technology. Misuse or damage to the connectors or cable voids the warranty.

Prices are for *advance payment only* and subject to change without notice. **All sales are final**.

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CETACEAN RESEARCH TECHNOLOGY

HYDROPHONE SPECIFICATIONS

Model Number	CR1A	CR2	CR3
Linear Frequency Range (±3dB) [kHz]	0.00016† – 48	0.0019† – 28	0.0004† – 180
Useable Frequency Range (+3/-12dB) [kHz]	0.00005† – 68	0.0005† – 60	0.0001† – 240
Sensitivity [dB, re 1V/µPa]	-199‡	-214	-207‡
SPL Equiv. Noise at 1kHz [dB, re 1µPa/√Hz]	38 (< *Sea State Zero*)	68	54
Maximum Operating Depth [m]	500	370	980
Operating Temperature Range [ºC]	-25 to 60‡	-40 to 70	-40 to 90‡
Capacitance [nF]	12	0.82	6.7
Dimensions [mm]	85L x 32 dia.	56L x 14 dia.	50L x 18 dia.
Coaxial Cable Length [m]	15	10	15
Directionality	Omni below 10kHz	Omni below 10kHz	Omnidirectional

† Requires a preamplifier with 100MΩ input impedance, such as VP1000. If a preamplifier with 330kΩ input impedance is used, such as the USB Dual Pre, then the low frequency -3dB point will be increased by a factor of 300 (e.g. 48Hz instead of 0.16Hz for the CR1A). ‡ Hydrophone is spot calibrated at the factory; calibration is guaranteed between -5C and 30C. Calibrated frequency response measurements can be performed for an additional fee.

Additional Options and Selected Accessories (many more items available):

Terminate cable with ¼" or BNC connector
Additional cable length
ART *USB Dual Pre* Preamp with USB
Grace Digital *EcoBoulder+* Waterproof Speaker
Reson *VP1000* Preamplifier
Reson *VP2000mk2* Preamplifier
Pioneer Hill *SpectraDAQ-200*
Pioneer Hill *SpectraPLUS-SC* software

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SPECTRADAQ-200

SpectraDAQ-200 is a precision data acquisition sound card optimized for test and measurement applications. Designed specifically for use with SpectraPLUS it features fixed gain steps for easy calibration to the transducer sensitivity, IEPE power for accelerometers or microphones, and standard BNC connectors. It is housed in a rugged steel case and powered by USB 3.0.

Excellent Performance

The A/D and D/A converters are state of the art and provide incredible dynamic range and extremely low distortion.

Direct Calibration

The input channels provide 4 fixed gain steps. This allows SpectraPLUS to be calibrated directly to volts, millivolts or to the transducer sensitivity providing quick and accurate calibration for microphones, accelerometers and other sensors.

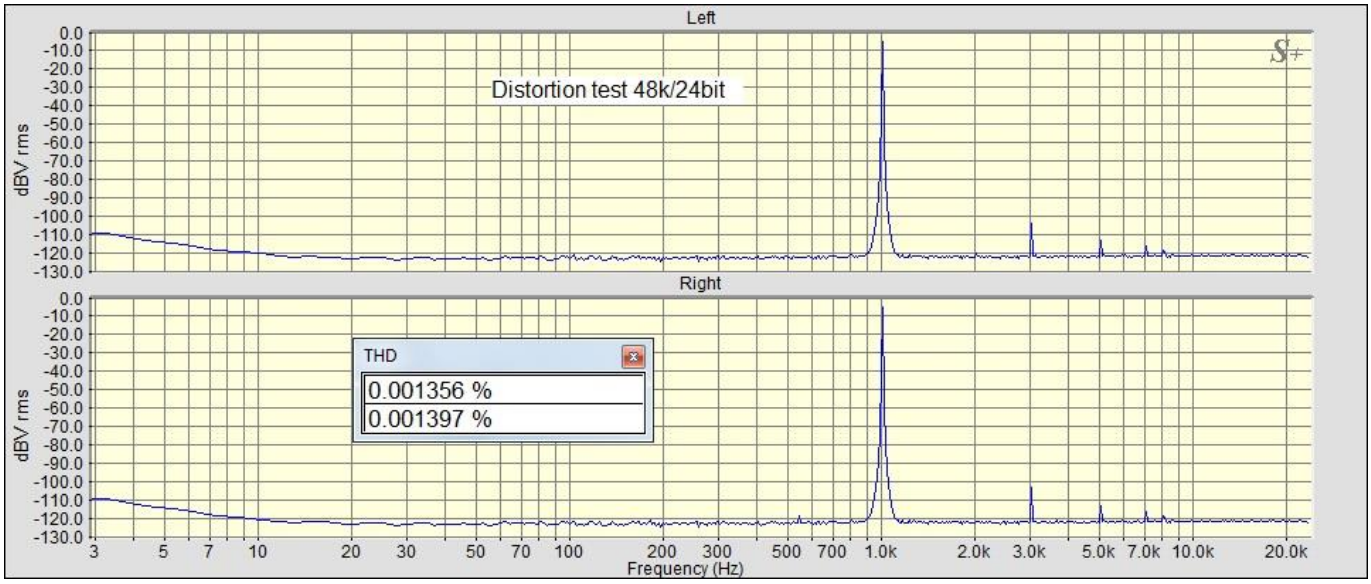
IEPE Power

Accelerometers, microphones and hydrophones often use IEPE powered sensors; IEPE power is a 4ma constant current supply that is built-in to the input circuitry of the module. It is enabled via the SpectraPLUS software. IEPE is also known as ICP (trademarked by PCB electronics).

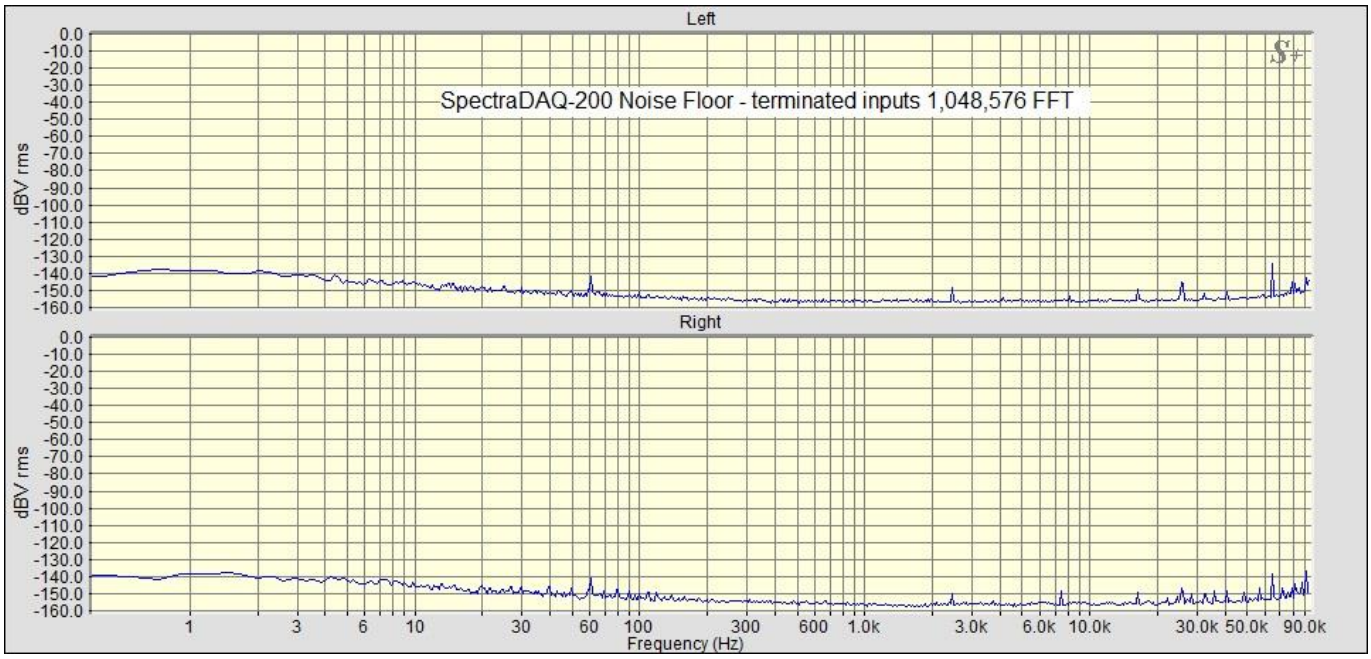
Input Voltage Ranges (software selectable)	+/-10V, +/-2.5, +/-625mV, +/-156mV
Sampling Rate	Up to 192kHz
Sampling Precision	24 bit
Input Channels	2
Input Impedance	0.5 Meg Ohm
IEPE power (software selectable)	4ma constant current
Frequency Response	4 Hz to 92 kHz (-1dB)
Low Frequency cutoff	2 Hz (-3dB)
Total Harmonic Distortion (THD)	< 0.002% (0.5 Vrms signal level, 2.5 V gain)
Spurious Free Dynamic Range	> 95 dB
Noise Floor (terminated inputs)	< -130 dBVrms
Channel Separation	> 90 dB
Input Connectors	2 BNC (single ended)
Output Voltage	+/-1.4 V (1 Vrms)
Output Channels	2
Output Connectors	1 BNC, 3.5 mm stereo
Digital I/O	3 Input, 3 Output (RJ45 connectors)
Drivers (Vista/Win7/8/10, x32 and x64)	MME (Windows Multimedia Extensions) ASIO (Steinberg Audio Stream Input/Output)
PC Interface	USB 3.0 (cable included)
Operating Temperature range	0 to 50 C
Dimensions	5.5 x 3 x 1 in (140 x 77 x 26 mm)
Weight	9 oz (250 grams)
Warranty	I year

Pricing, availability and specifications are subject to change without notice

Distortion measurement with the output looped back to the inputs



Noise floor measured with terminated inputs



Transducers
Hydrophones

VP2000 Voltage preamplifier

The VP2000 is a 1 MHz bandwith voltage preamplifier designed for uses in conjunction with piezoelectric hydrophones.

VP2000 offers excellent low-noise performance over the entire frequency range; - gain selections in 6 levels from 0 to 50 dB.

A range of 12 high-pass and 12 low-pass filters are available, - these allow ideal band pass filter settings.

The VP2000 has a high input impedance which allow the measurements at frequencies below 1 Hz with even very small hydrophones sensor capacities.

FEATURES

- **1 Hz to 1 MHz bandwidth**
- **Gain selection From 0 to 50 dB**
- **Options of 12 high-pass filters and 12 low-pass filters**
- **Excellent low-noise characteristic**

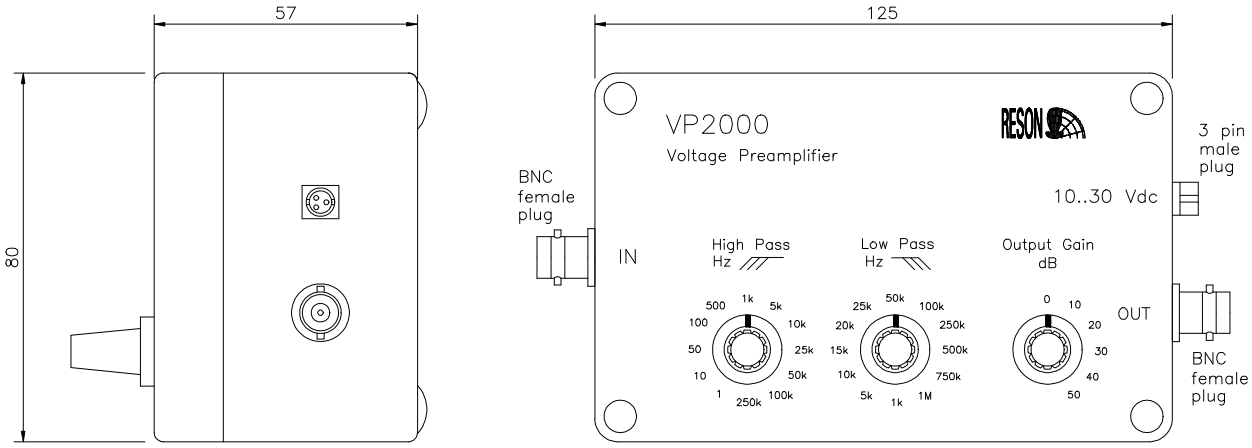
TECHNICAL SPECIFICATIONS

Input:	
Impedance:	>100 M-Ohm´s
Max. input level:	1 Vrms at 12 V supply
Output:	
Impedance:	10 Ohm//100µF
Max. level:	3 Vrms at 24 V supply
Max. load:	10 nF (100 m cable)
Gain:	
Gain settings, 6 steps dB::	0–10–20–30–40-50
Bandwidth	
Frequency range with 20 dB gain:	-3 dB 0.5 Hz to 0.5 MHz -6 dB 1 MHz)
Noise:	
Power spectrum density noise at 1kHz:	20 nV/√Hz

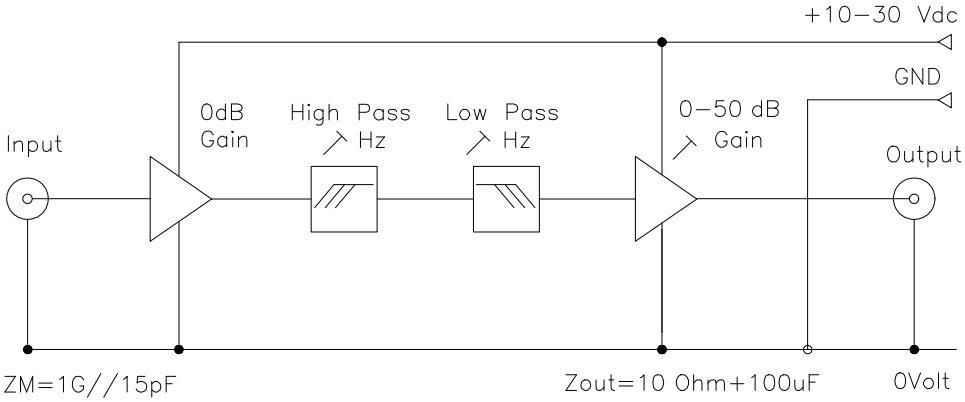
Hi-Pass Filters:	
-3 dB @ Hz:	1-10-50-100-500-1k-5k
(6 dB/oct)	10k-25k-50k-100k-250k
Lo-Pass Filters:	
-3 dB @ Hz:	1k-5k-10k-20k-25k-50k
(6 dB/oct)	100k-250-500k-750-1M
Power supply:	
Voltage nominal:	12 Vdc (min 10Vdc, max 30Vdc)
Current quiescent:	15mA @ 12 Vdc 20mA @ 24 Vdc
Enclosure case: Dimensions:	Splash proof aluminum box. L: 125 mm, W:80 mm, H: 60 mm.
Accessory included:	Supply cable TL8088 for Laboratory. DC Supply.
Accessory available:	See page 5

RESON

VP2000 outline dimensions and layout



Functional Block Diagram



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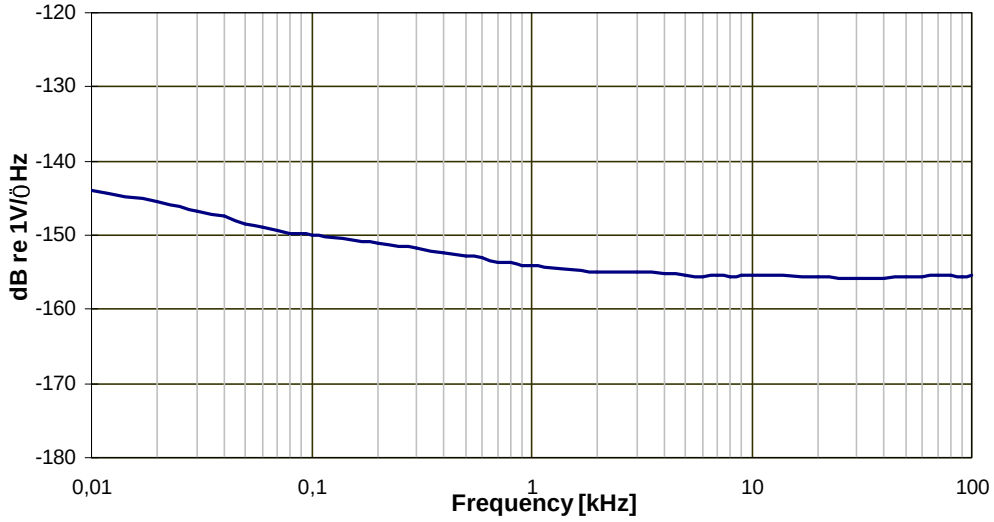
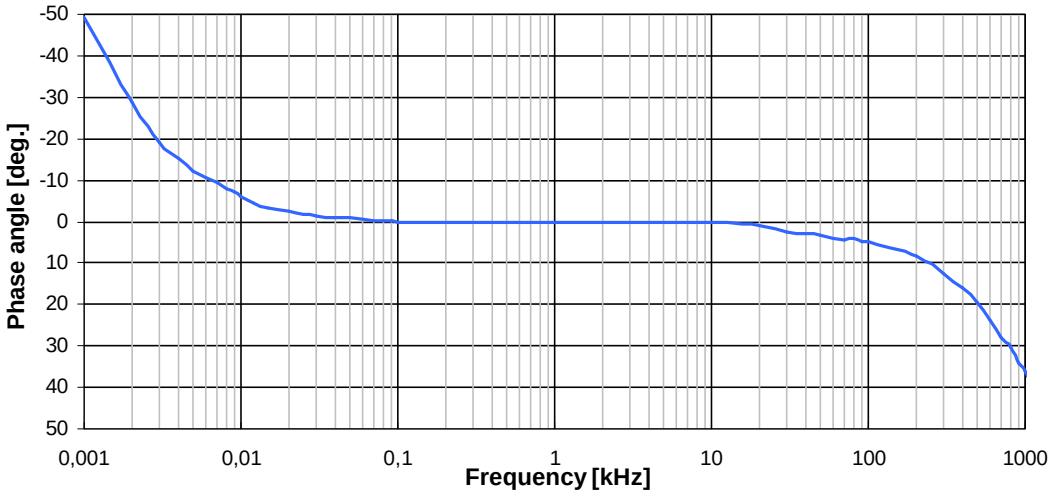
Noise power density spectrum re input
Input load 1nF, gain 0dB, 1Hz filter



Phase shift
With 1 Hz filter at 0dB and 0dB gain



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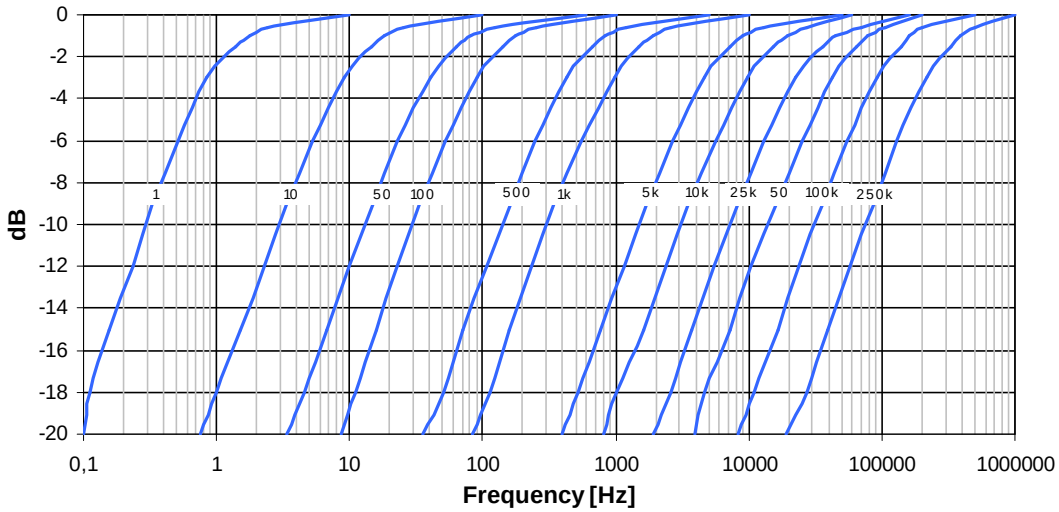
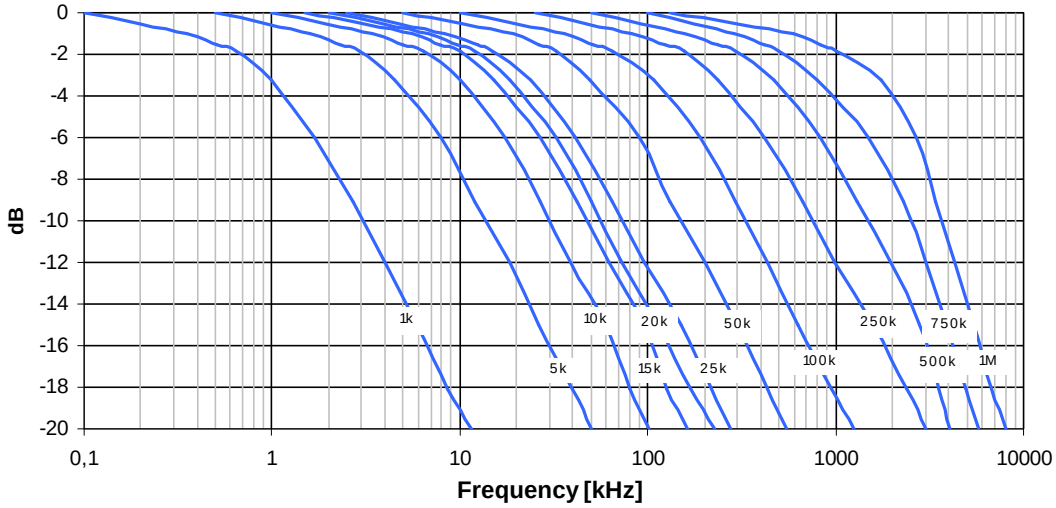
Fax: +65 6 872 1334
E-mail: telenav@mbox2singnet.com.sg

High Pass filter characteristics



Low Pass filter characteristics



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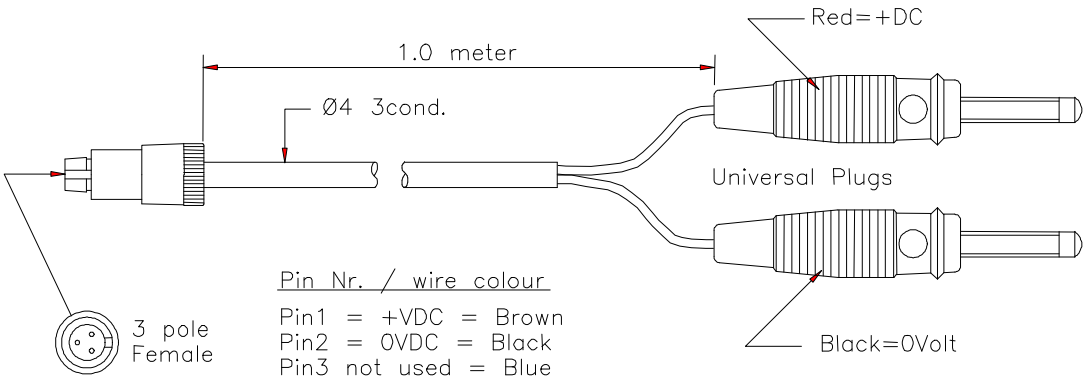
TL 8088 Supply cable



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New Products

Hydrophones
overview of all models

SQ26-H1B Hydrophone
CR1 Hydrophones
CR2 Hydrophone
CR3 Hydrophone
C55 Hydrophones
C56 Hydrophone
C57 Hydrophones
C75 Hydrophone
C305 Hydrophone

SQ26-08 Hydrophone

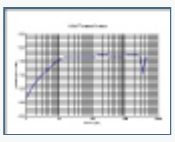
The Sensor Technology SQ26-08 has a very slick, compact design, and is a component in several Cetacean Research™ hydrophone systems, and is also sold separately.

The SQ26-08 is a general purpose hydrophone ideal for whale watching, full audio-band signal detection, and mobile underwater recording; except that it can NOT be used as a stand-alone hydrophone.

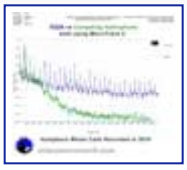
The SQ26-08 hydrophone **must be used with a recording device or preamplifier** that has a bias powered (a.k.a. plug-in powered) microphone input, and thus is included in the following Cetacean Research™ underwater recording systems:

- **SQ26-H1** compact portable hydrophone system
- **µRUDAR-mk2™** autonomous underwater recording system





The SQ26-08 Hydrophone is a component. It can not be used as a stand alone hydrophone.



View frequency spectra plots and listen to humpback whale recordings .

SQ26-08 Hydrophone specifications	
Frequency Range [kHz]	0.020 to 50
Transducer Sensitivity* [dB, re 1V/µPa]	-194
Preamplifier Gain [dB]	25
Effective Sensitivity* [dB, re 1V/µPa]	-169
SPL Equiv. Self Noise at 1kHz [dB, re 1µPa/√Hz]	44
Power Requirement [Vdc]	2 to 5
RMS Overload Acoustic Pressure [dB, re 1µPa]	154
Maximum Operating Depth [m]	100
Operating Temperature Range [°C]	-25 to 60
Dimensions [mm]	70 L x 32 dia.
Shielded Cable Length [m] cable includes 3.5mm stereo phone plug	10 or 30
Directionality	omnidirectional below 10kHz
Battery / Connector box	N/A **

* Transducer Sensitivity + Preamplifier Gain = Effective Sensitivity.

** powered by most of the plug-in powered microphone inputs, such as the Zoom H1n digital flash recorder

Directly compare our hydrophone to the competition:
View and Listen

The SQ26-08 **must be used with a recording device or preamplifier** that has a bias powered (a.k.a. plug-in powered) microphone input, such as the Zoom H1 used in our **SQ26-H1 system** or it's **SQ26-H1B** base.

Tools for Science, Education, Art and Conservation since 1994

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