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The primary objective of the project was to recover, digitize, and assess validity of the 11-day magnetic tape record from the CHURCH OPAL Exercise.

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LONG-TERM GOALS

CHURCH OPAL was among a series of classified ocean acoustic measurements done in the seventies to support development of undersea surveillance systems. The long-term goal of the current ONR project was to demonstrate that midwater acoustic data recorded on magnetic tape during these Fleet exercises is recoverable with original accuracy and fidelity. A companion goal was to declassify related documentation and promulgate information to enhance general accessibility and technical value to the scientific community.

OBJECTIVES

The primary objective of the project initiated in 2003 was to recover, digitize, and assess validity of the 11-day magnetic tape record from the CHURCH OPAL Exercise. Expanded objectives extending through 2004 were: (a) to declassify all documentation related to CHURCH OPAL; (b) to advise and assist ARL:UT in the process of data recovery; and (c) to assess utility of the CHURCH OPAL data as a baseline for determining long-term trends of ambient noise; and (d) to initiate research using the recovered database.

APPROACH

The CHURCH OPAL Exercise in early September 1975 included an acoustic measurements site in the Northeast Pacific (27.7°N; 137.8°W) in a water depth of 4,880 meters. This data set was selected as a test case for assessment of the utility and viability of creating a modernized digital database from major undersea field exercises done by the Long Range Acoustic Propagation Project (LRAPP) in the seventies. The submerged buoy systems generated acoustic signals from 13 suspended hydrophones that were recorded *in situ* on a 14-inch reel of magnetic tape. An independent project, funded by ONR in 2003, at the Applied Physics Laboratory of the University of Texas (ARL:UT) implemented a reconstituted capability for recovery, conversion, and processing of the hydrophone data. Advice, recall, and cooperative research was done with Dr. David Knobles, Jack Shooter, and their colleagues at ARL:UT. Classified and unclassified reports issued under the original project were sighted, referenced, annotated, and identified as to source(s) preparatory to submission of a request for approval to declassify. The declassification of CHURCH OPAL documentation was accomplished with assistance of K. W. Lackie and Peggy Lambert at ONR. Lackie, Shooter, and other individuals involved were participants in LRAPP sponsored ocean acoustic projects during the seventies.

WORK COMPLETED

Recovery and digitization of the CHURCH OPAL magnetic tape recording was accomplished by ARL:UT. An acoustic spectrum, calculated in 1975 for nearfield passage of a commercial ship, was used as the reference case for comparison of original and recovered digital data. Figure 1 shows the ship noise (upper spectrum) from the hydrophone at a depth of 4,850 meters. Also shown is noise in the absence of nearfield ships when the sea surface was nearly calm (lower spectrum). Spectral integration time was ten minutes; frequency resolution was 0.1 Hz for the CPA and 0.2 Hz for the low noise event. The characteristics of these spectra were reproduced in the analysis of the recovered data to assure targeted system accuracy within one dB and preservation of frequency response.

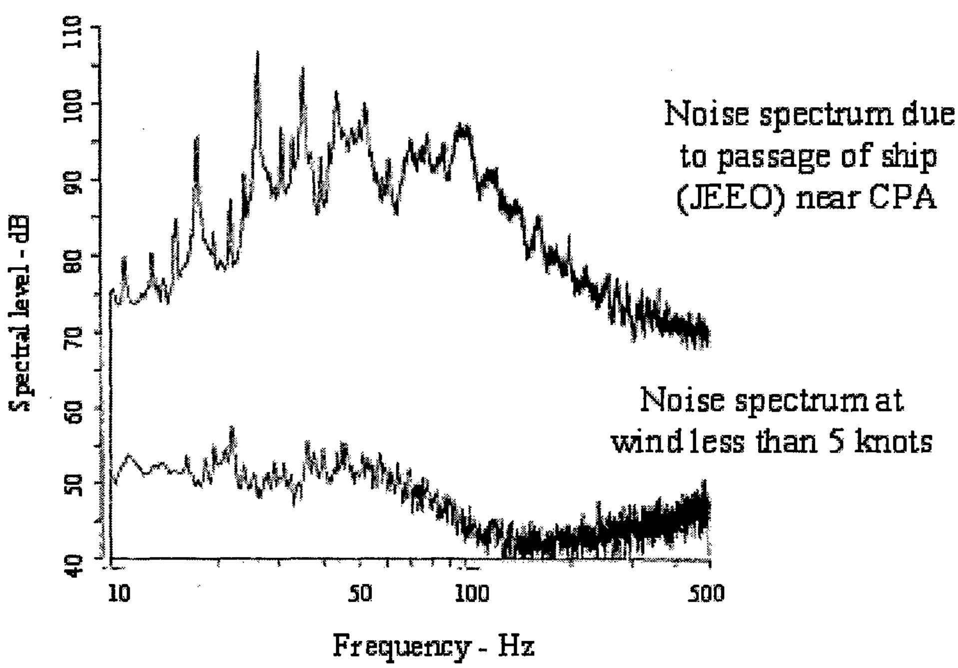

Figure 1. Two spectra from deepest hydrophone

Authority was granted to ONR by CNO (N774) for declassification and unlimited distribution of all documentation related to the CHURCH OPAL Fleet Exercise. Analysis of the recovered data was done to confirm and/or refine results obtained in the seventies. The original analysis spectrum of 10-500 Hz was broadened to a lower limit of 5 Hz. Results were presented in May 2004 at the meeting of the Acoustical Society of America in New York City.

RESULTS

The 11-day time history at the CHURCH OPAL site of spectral level for 50 Hz, using an integration time of ten minutes, is shown in Figure 2. The upper curve is for the hydrophone that is a few hundred meters above "conjugate depth", *i.e.,* the conventional definition for the bottom of the deep sound channel. The lower curve is for the hydrophone suspended 30 meters above the seafloor. The beginning of the record until the middle of Julian day 249 (September 6th) is contaminated by the process of deploying the submerged taut-wire buoy system. Periods of sharply peaked elevated levels in days 250, 253, 257 and 258 are caused by individual passage of commercial ships within a range of 50 miles from the buoy site. Of particular significance is the contrast in SPL between the two hydrophone depths. Furthermore, the effect of wind is evident. Wind speed between days 249 and 253 ranged from about 7 knots to over 20 knots late on day 250. During days 254 to 257, wind speed ranged from calm to about 10 knots. Notably, the wind effect is detectable only with the deepest hydrophone. This carries the clear implication that the segments of the upper hydrophone record that are devoid of nearfield shipping give a good measure of ambient noise due to distant shipping. At 50 Hz the average SPL is about 75 dB. At 25 Hz the SPL is about 72 dB.

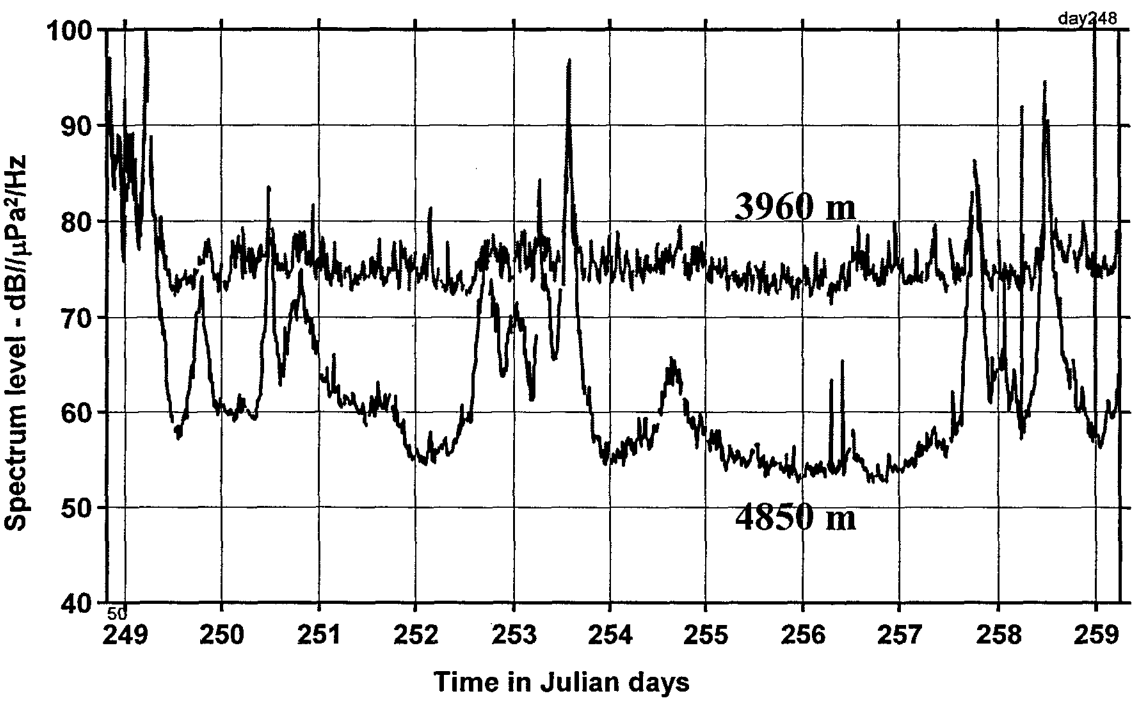

Figure 2. Ten day record of spectral level at 50 Hz for hydrophones in and below the deep sound channel.

The original analysis by Wittenborn (1976) of data from CHURCH OPAL and another exercise (CHURCH ANCHOR) in 1973 that was further to the west, provided the basis for modifying and extending the "Wenz Curves" (Wenz, 1962) to frequencies less that 1000 Hz. Table 1 shows wind and shipping dependence within the sound channel. The levels for distant shipping are sensitive to the geographic location; levels for local wind dependence are not. It is noteworthy that wind speed of 30 knots generates ambient noise comparable to distant shipping in the frequency band of 10-100 Hz. At 1000 Hz, wind dominates at speeds greater than 5-10 knots.

Table 1. Sound pressure levels due to shipping and wind.

	Frequency (Hz)				
	10	50	100	500	1000
Wind Speed:					
5 knots	25	33	38	46	48
10 knots	37	45	49	55	56
15 knots	57	59	61	63	62
30 knots	66	67	67	68	68
Distant Shipping:					
Minimum	65	72	67	55	40
Maximum	75	79	75	57	50

Analysis of the data recovered from CHURCH OPAL enabled extension of the low frequency band to 5 Hz. Figure 3 displays spectra for the hydrophones in the sound channel (3960 m) and near the seafloor (4850 m). One pair of curves is for a period of wind less than 5 knots and the other pair

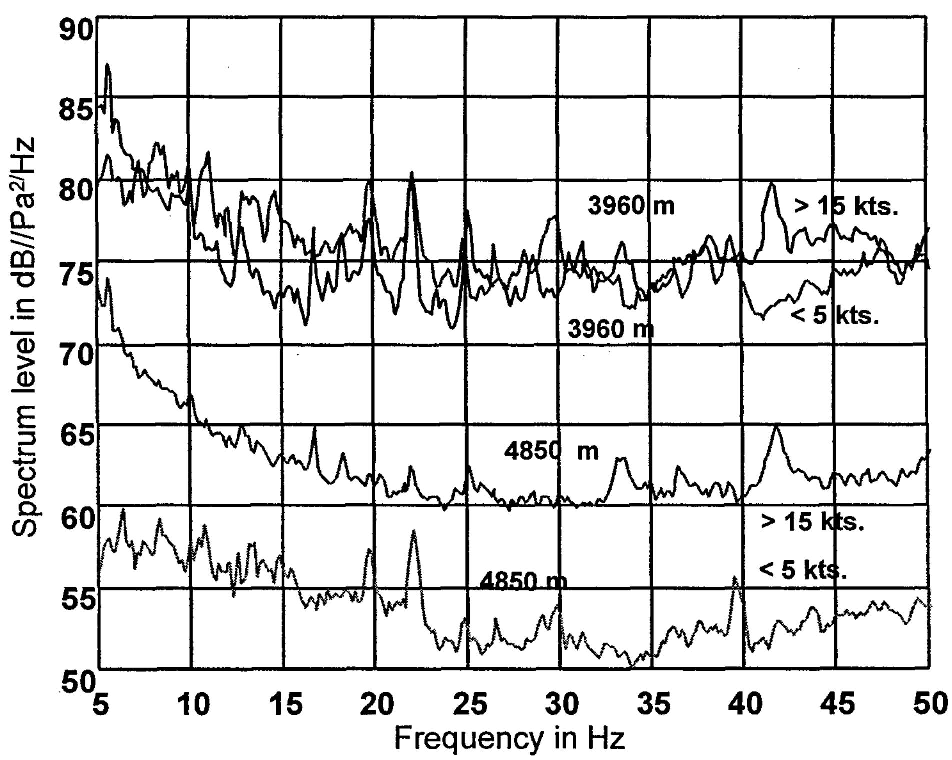

Figure 3. Ambient noise spectral characteristics in 5-50 Hz band.

applies to a period when wind speed was greater than 15 knots. The wind effect is clearly discernible at the deep phone but is masked by distant shipping noise in the sound channel. Of particular note is the low wind case. This shows a high level of correlation between the pair of phones indicating that the residual noise recorded from the lower phone is caused by distant shipping. Furthermore, these levels are remarkably low (less than 55 dB in the 20-50 Hz band) and less than 60 dB down to 5 Hz. It also is noteworthy that the doublet at 19.5 and 22 Hz has about the same signal-to-noise ratio at both hydrophones. This doublet is attributable to one or more blue whales.

IMPACT/APPLICATIONS

The very low frequency acoustic spectrum offers unexplored potential for a variety of Naval warfare, surveillance, and communication interests. Ambient noise at these frequencies is an important factor in evaluation of system concepts. The same applies to some critical issues pertinent to marine mammals. The calibrated acoustic data acquired in the seventies has considerable potential as a baseline for determining long-term trends in ambient noise related to commercial ship traffic.

REFERENCES

Wittenborn, A. F., "Ambient Noise and Associated Propagation Factors as a Function of Depth and Wind Speed in the Deep Ocean," Report No. T 76 RV 5060 C, Tracor, Inc., Rockville, Maryland, April 1976.

Wenz, G. M., "Acoustic Ambient Noise in the Ocean, Spectra and Sources," Journal of the Acoustical Society of America, 34, 1936-1956, 1962.