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AD NUMBER
AD527037
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; JUN 1973. Other requests shall be referred to Director, Naval Research Laboratory, Washington, DC 20375.
AUTHORITY
31 Dec 1988, per document marking; CNO [N772] ltr N772A/6U875630, 20 Jan 2006 and ONR ltr 31 Jan 2006

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NRL Memorandum Report 2638

Ambient Noise and Signal-to-Noise Profiles in IOMEDEX

[Unclassified Title]

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Sponsored by the Long Range Acoustic Propagation Project

June 1973

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ABSTRACT
[Unclassified]

Ambient noise vertical profiles in the Ionian Sea show temporal fluctuations in a few minutes at low, shipping-related frequencies to a few hours at higher, wind/sea-related frequencies. In the mean, ambient noise levels decrease with increasing depth over the frequency band of study: 20-300 Hz. Signal-to-noise profiles also show a fluctuation, depending on the range from source to receiver. These characteristics of deep-water ambient noise are discussed. The results and discussion bear directly on future sonar systems as to optional placement of sensors throughout the water column.

PROBLEM STATUS

This is a final report of these measurements; work on the problem is continuing.

AUTHORIZATION

NRL Problem 81S01-38
Project R2408

1. INTRODUCTION

(U) This report presents simultaneous measurements of ambient noise by five hydrophones placed throughout the 2700 m water column in the Ionian Sea. During part of the six-day period of continuous recording, a 125 Hz cw source was towed at a depth of 137 m radially in two directions from the hydrophones. This source provides a signal from which signal-to-noise (S/N) can be derived.

(C) The general trend of noise 20 Hz to 300 Hz is a decrease with increasing depth, as seen in Fig. 1-1. (A 90% confidence level, 5 to 95 percentile is depicted by bars through the data points.) At 50 Hz, the ambient noise profile is highly variable; at times there is little or no variation with depth, while at other times there is a local minimum near the critical depth. The shape of the 50 Hz profile may change drastically in times as short as 20 min. At 200 Hz, the ambient noise profile does not change so rapidly, and generally shows a continuously decreasing level as the hydrophone depth is increased.

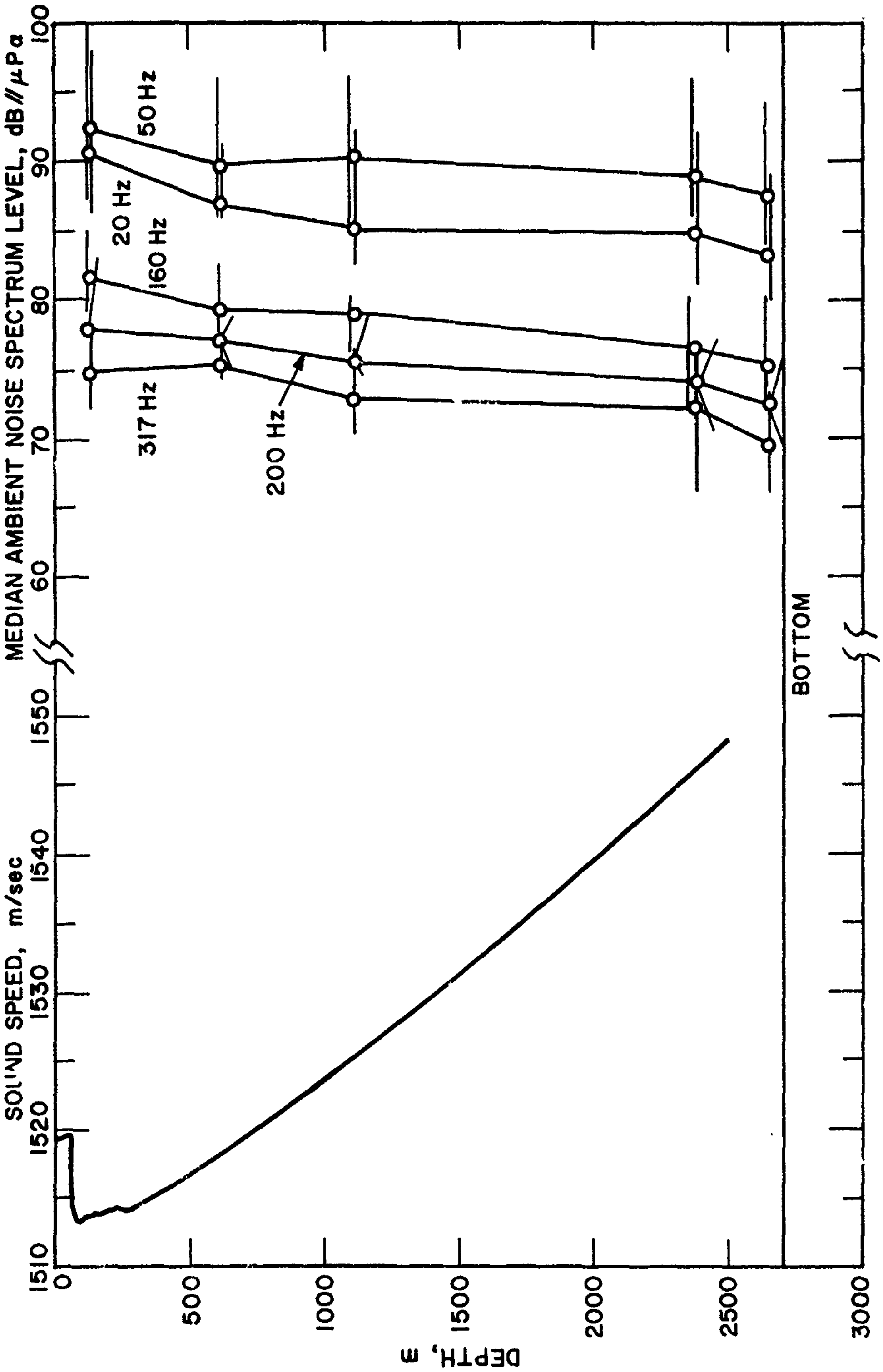
(C) S/N profiles were derived from the available cw signal (125 Hz) levels less the median 50-Hz noise levels during 6 and 10 hr towing periods. The S/N profiles out to 120 nm show a spatial variability deriving from the passage of the source through the convergence zones of the five receiving hydrophones. The local maximum in S/N near the bottom of the sound channel is due to both a relatively low noise level and good propagation to the hydrophone at that depth.

(U) As the integration time is increased to reduce the statistical uncertainty in the noise measurement, the signal level from a towed source is spatially averaged. Thus, experiments to measure S/N must be carefully designed to yield the desired results.

2. TEMPORAL VARIABILITY OF AMBIENT NOISE PROFILES

2.1. Experimental Approach

(C) Three ambient noise buoys (ANB) (Ref. 1, 2) deployed at Station CHARLIE in IOMEDEX (Fig. 2-1) provided continuous ambient noise



(C) Fig. 1-1 – IOMEDEX sound speed profile; median ambient noise spectral profiles at 20, 50, 160, 200, and 317 Hz derived from 1 min averages of 1/3 octave levels for 6 days.

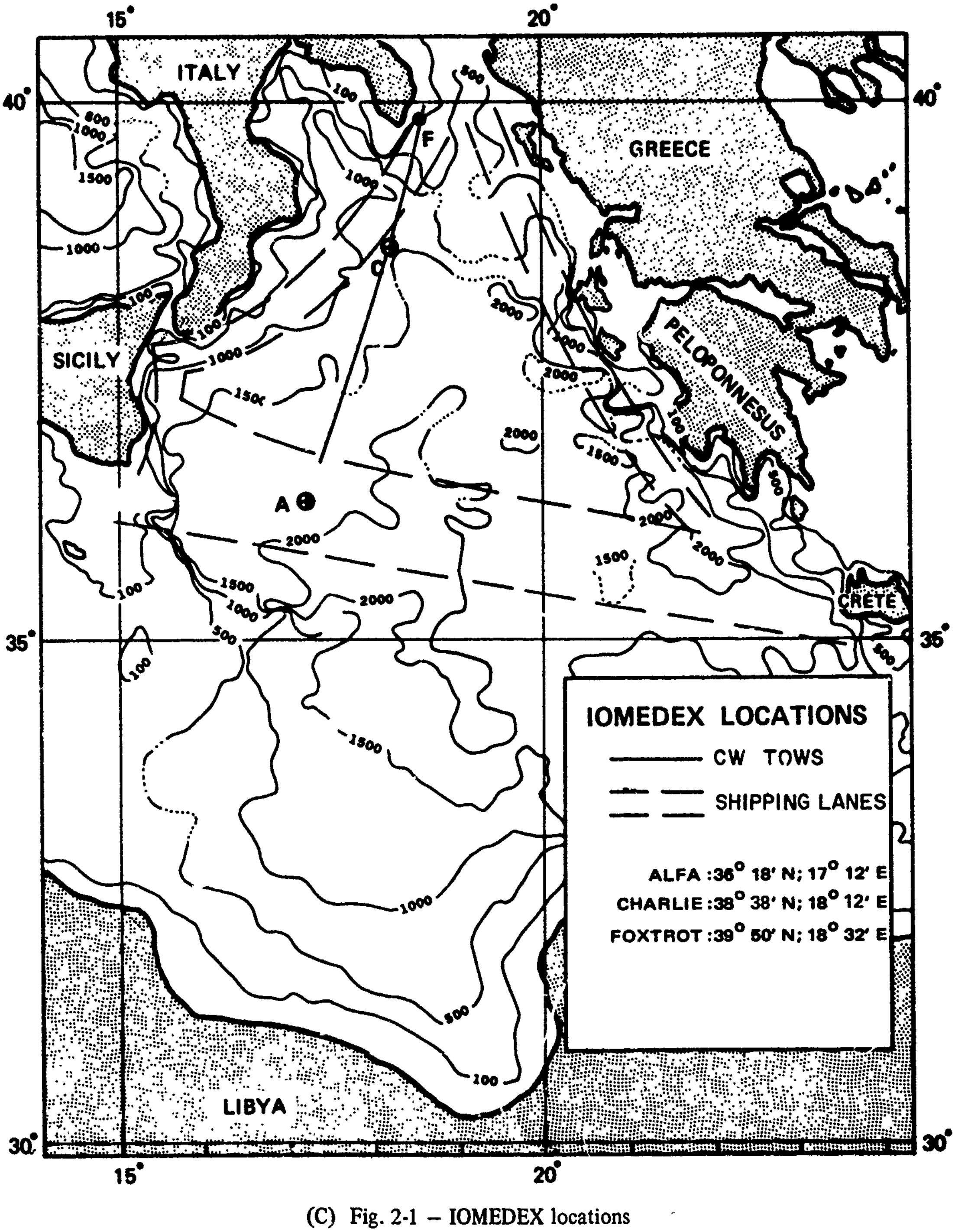
data for eight days at hydrophone depths ranging from 135 to 2650 meters. The critical depth was decreasing during the recording period from about 900 to 600 m. Each buoy recorded data from two hydrophones in a 20-600 Hz band. The three ANBs, electronically and mechanically similar, were horizontally displaced by 2.3 nm or less from each other. Because the buoys were deployed on successive days, they provided six days' simultaneous measurement of ambient noise. Synchronism of data from the buoys was achieved by observing recognizable events on each of the three buoy tapes.

(C) Station CHARLIE is 160 nm north of the principal shipping lane and is 50 nm southeast of most coastal traffic. Consequently, only one or two merchant ships per day were observed to pass very near the hydrophones. But elements of the Sixth Fleet were often nearby, so that ambient noise uncontaminated by nearby ships was obtained only for about 30-40% of the six-day measurement period. (See Figs. A-5 and A-9.) A shipping survey conducted on 14 Nov 1971 verified that the data presented herein are free of such contamination. A description of the overall experiment and some results are contained in References 3 and 4.

(C) The data from the three ANBs were processed digitally to yield 1-min averages of noise power in 1/3-octave bands 20-300 Hz. An averaging time of 10 min was selected for the post-processing analysis reported herein. The Appendix contains details of the experiment, ambient noise time series, spectra, and statistics, and a discussion of the processing used for IOMEDEX data.

2.2 Ambient Noise Profiles - 50 Hz

(C) Three time periods were selected during which ships were not near the recording hydrophones, as deduced from their records (Figs. A-5 to A-9). Ten minute averages of ambient noise at 50 Hz for five hydrophones during these periods are shown in Figs. 2-2 to 2-5. Marked changes in the noise profile are apparent and may occur over only a few successive profiles. Two features of the 50 Hz noise profile which appear to persist during the times of Figs. 2-2 to 2-5 are:



(C) Fig. 2-1 – IOMEDEX locations

1. Level decreases slightly with increasing depth;
2. The hydrophone nearest the bottom is consistently 2 dB quieter than the hydrophone 275 m above it.

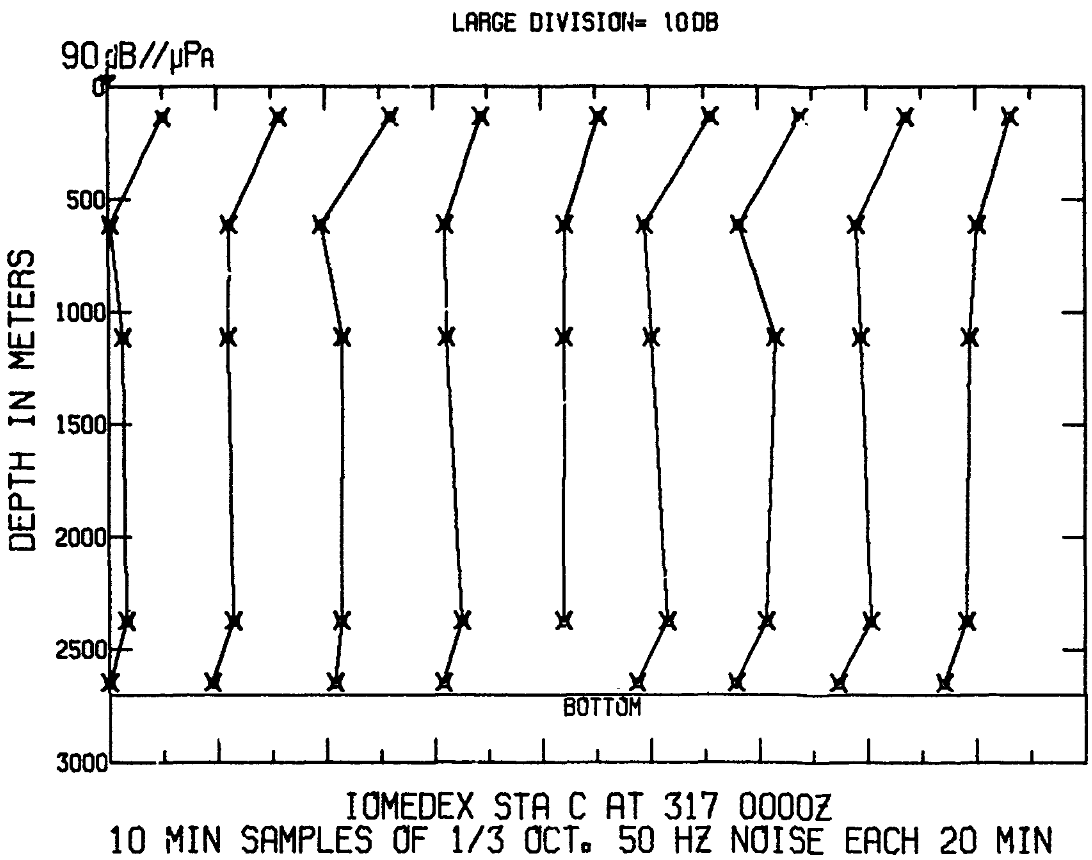
2.3 Ambient Noise Profiles - 200 Hz

(C) If 10-min averages of 200 Hz noise, each 20 min, are plotted as in Fig. 2-6, the results show little change. However, if we plot one 10-min average profile per hour for a few hours then the changes in the noise profile are as apparent at 200 Hz as in the case of the 50 Hz noise (Figs. 2-2 to 2-5). The same two features of the 200 Hz noise profiles are seen in the data in Figs. 2-7 to 2-9 as were seen at 50 Hz.

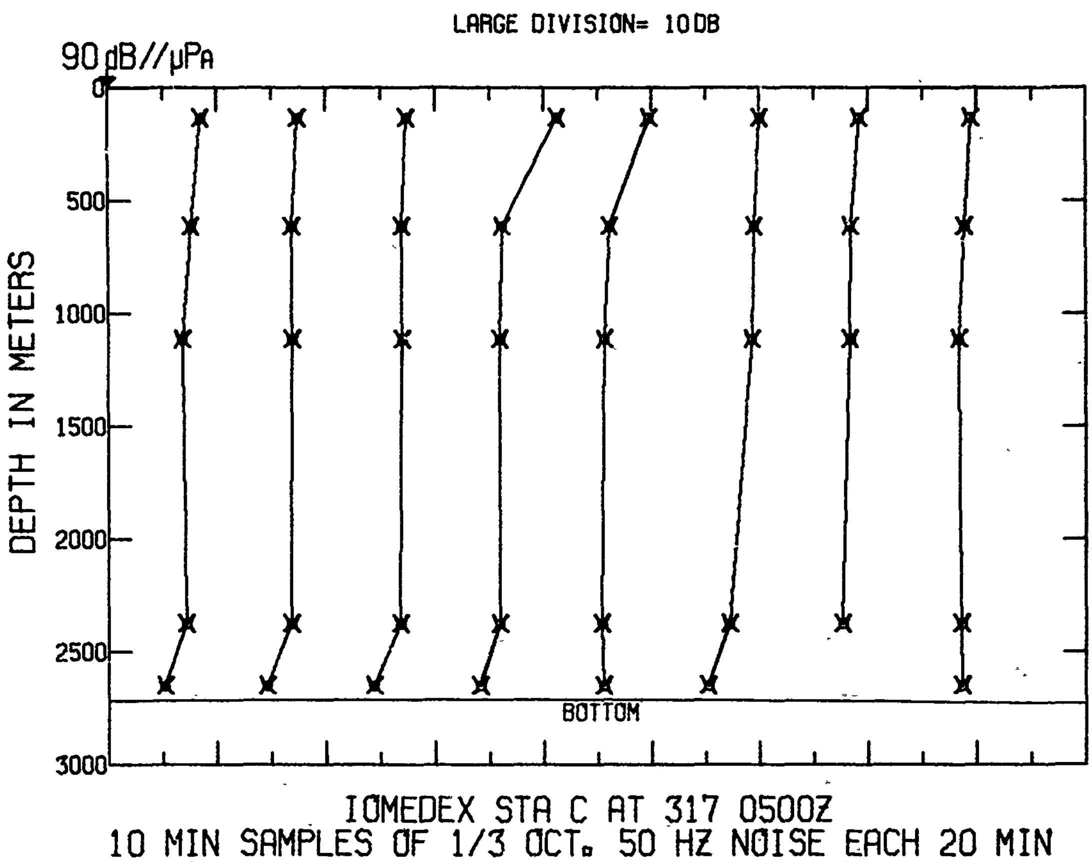
2.4 Discussion

(C) Noise at 50 Hz arises from discrete sources (ships) whereas noise at 200 Hz arises from ships and from distributed sources (wind waves). (Ref. 5) Propagation from the localized sources to a receiver depend strongly on the relative positions of the sources in the irregular transmission loss field of the receiver. A moving point source faithfully transforms the field's spatial irregularity to temporal irregularity at the hydrophone. On the other hand, the noise from a source distributed over a large area (a storm, for example) results from a spatial average of the source over a large part of the transmission loss field. Thus, even though the distributed source may move as fast as a ship, its contribution to the noise field is temporally smoothed by its spatial extent. Consequently, it is expected that the 50 Hz noise profile would change more rapidly than the 200 Hz noise profile, though absolute changes in the latter may be equally as great.

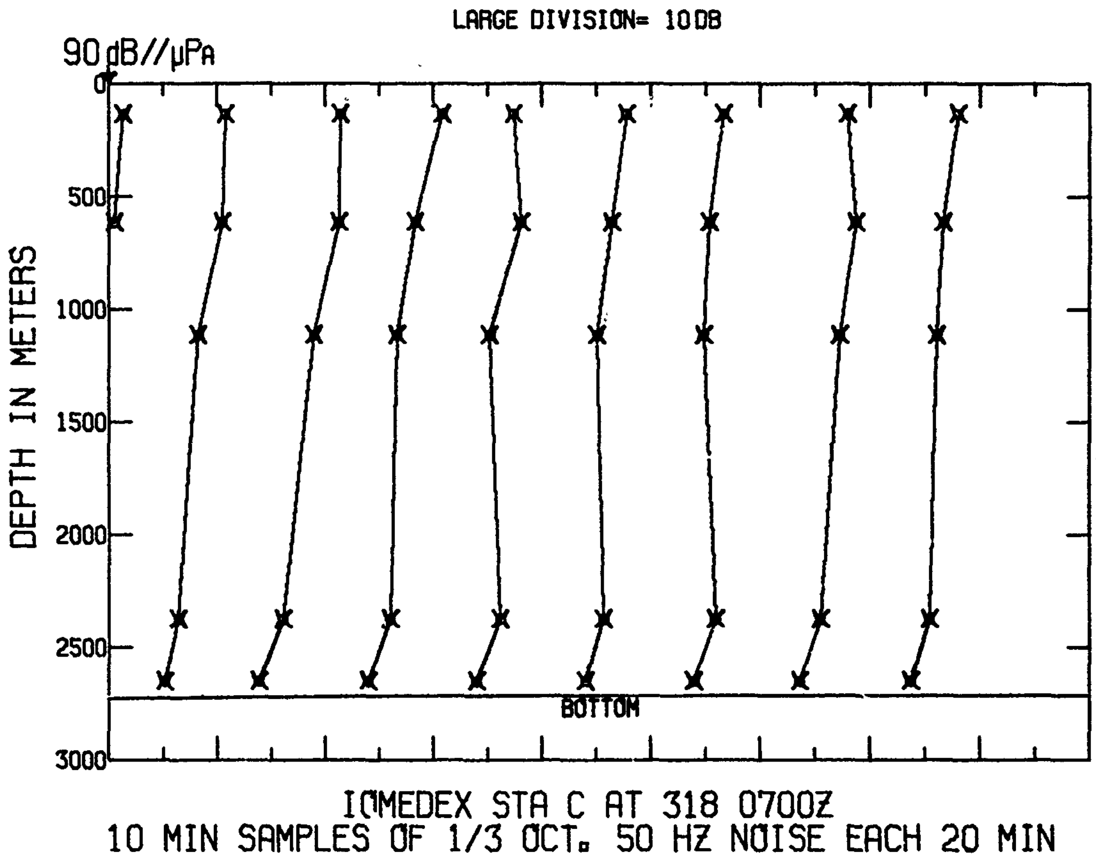
(U) The ambient noise measured by a hydrophone at any instant depends on the levels of the noise sources as well as their individual locations within the transmission loss field of that hydrophone. Because the transmission loss fields are different for hydrophones at different depths (See Section 3.), the instantaneous noise levels measured at depths differing by a few hundred meters are not correlated. This lack of covariance can result in rather large fluctuations in the shape of the ambient noise profile.



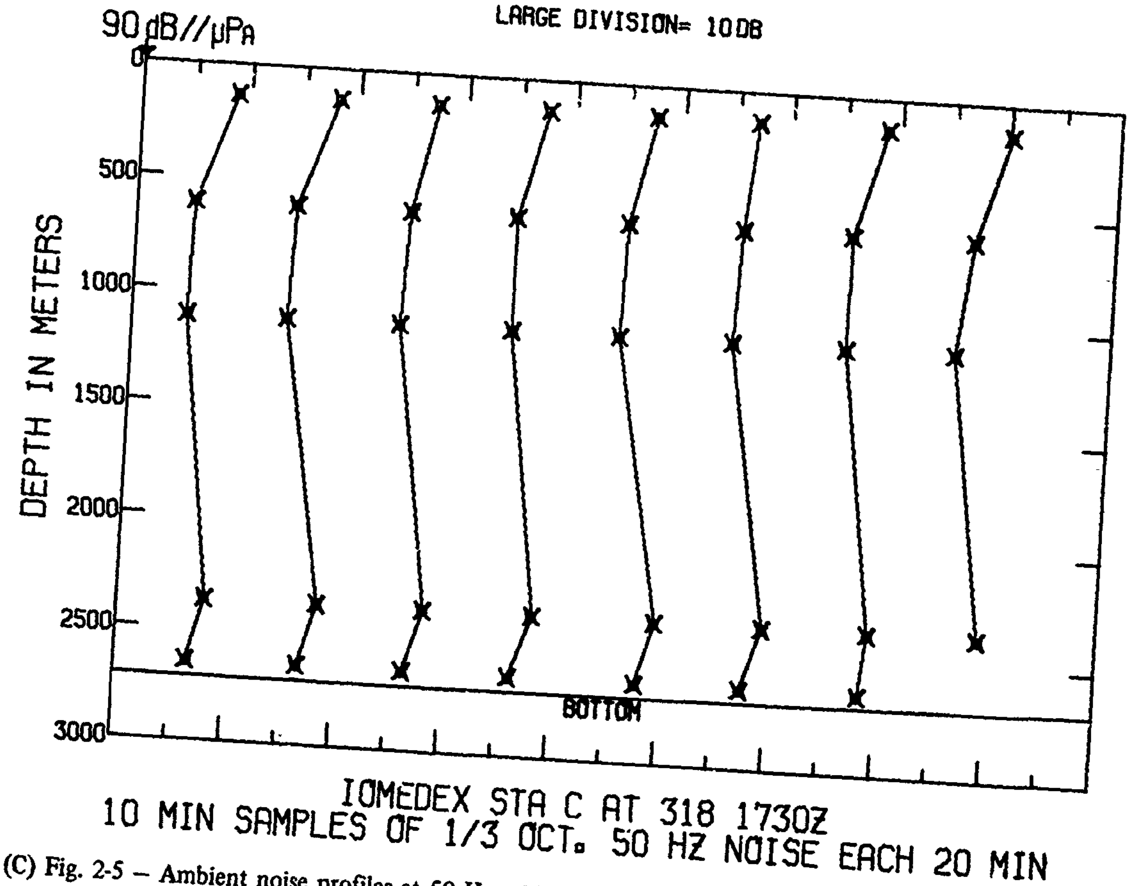
(C) Fig. 2-2 – Ambient noise profiles at 50 Hz: 10-min averages each 20 min beginning at 317 0000Z



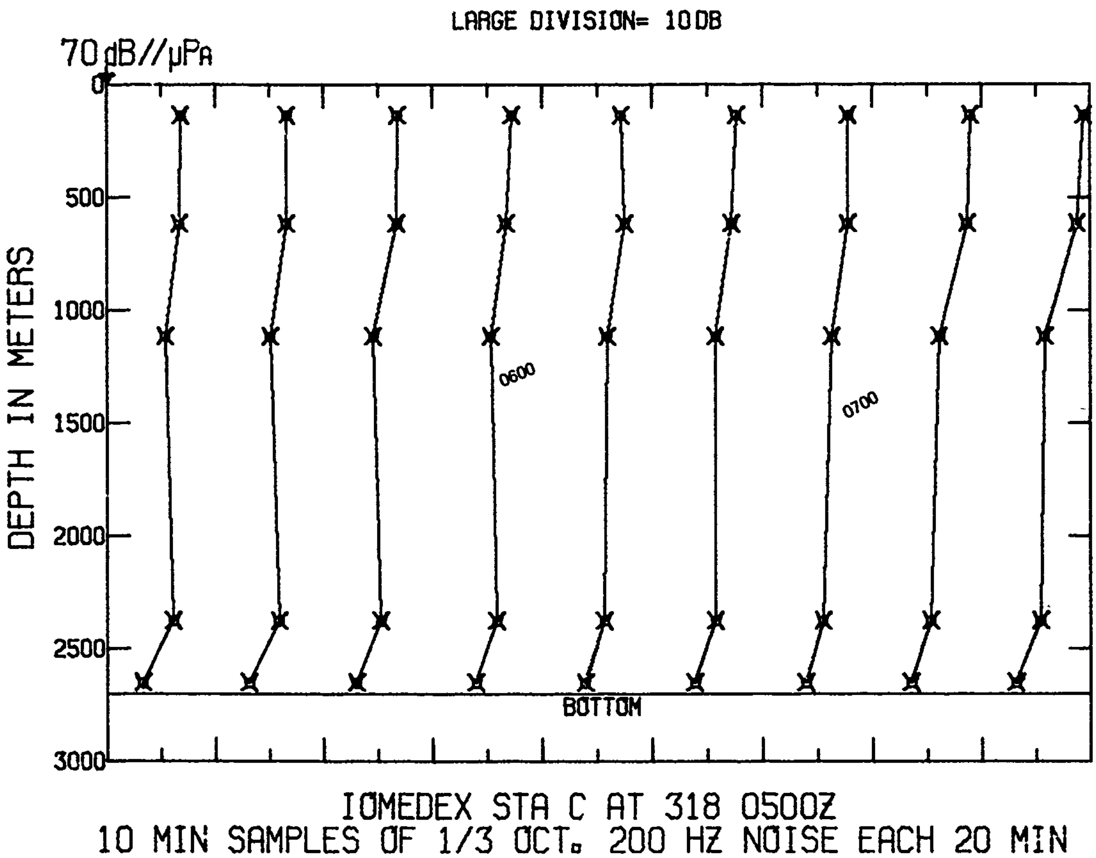
(C) Fig. 2-3 – Ambient noise profiles at 50 Hz: 10-min averages each 20 min beginning at 318 0500Z



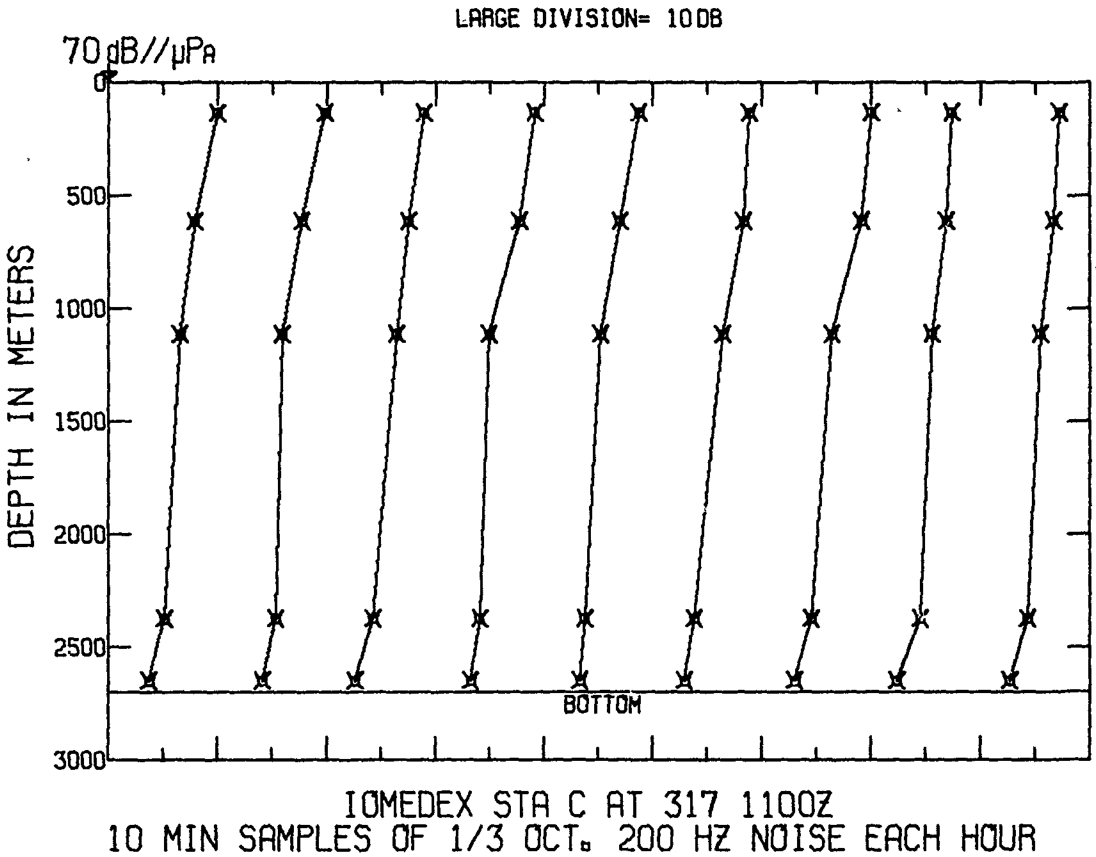
(C) Fig. 2-4 – Ambient noise profiles at 50 Hz: 10-min averages each 20 min beginning at 318 0700Z



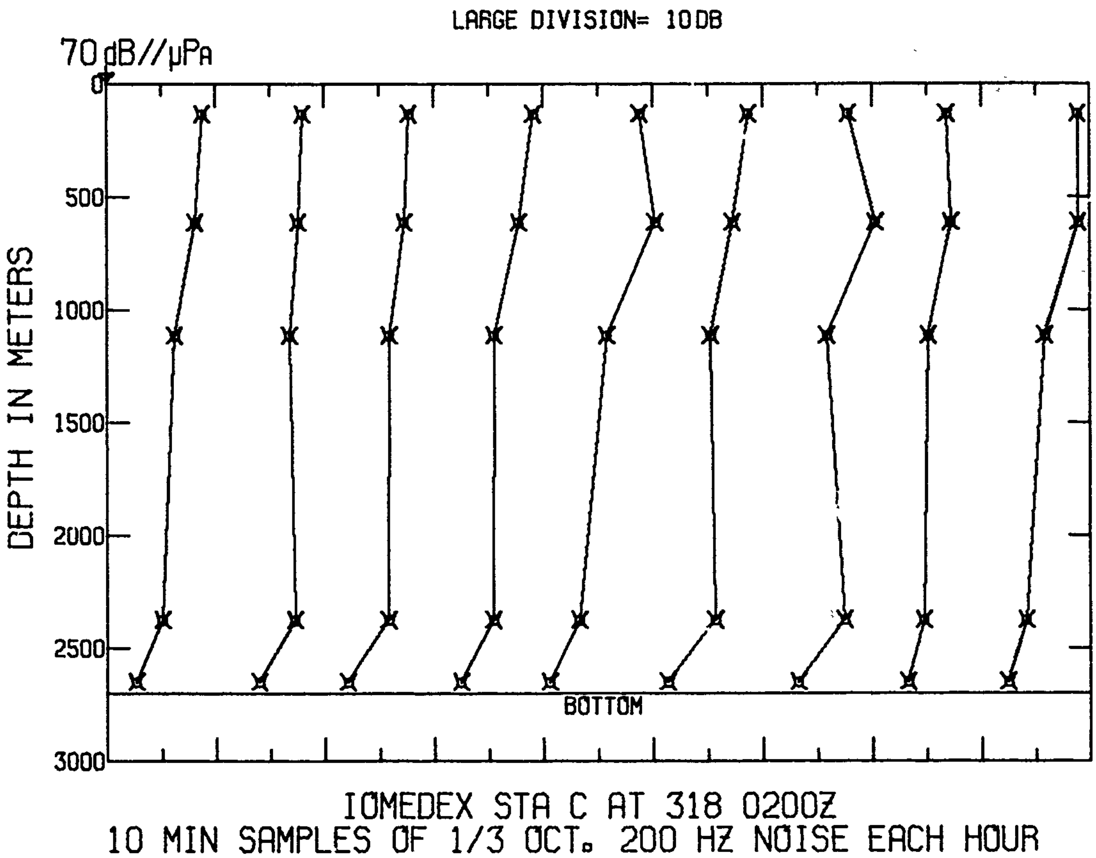
(C) Fig. 2-5 – Ambient noise profiles at 50 Hz: 10-min averages each 20 min beginning at 318 1730Z



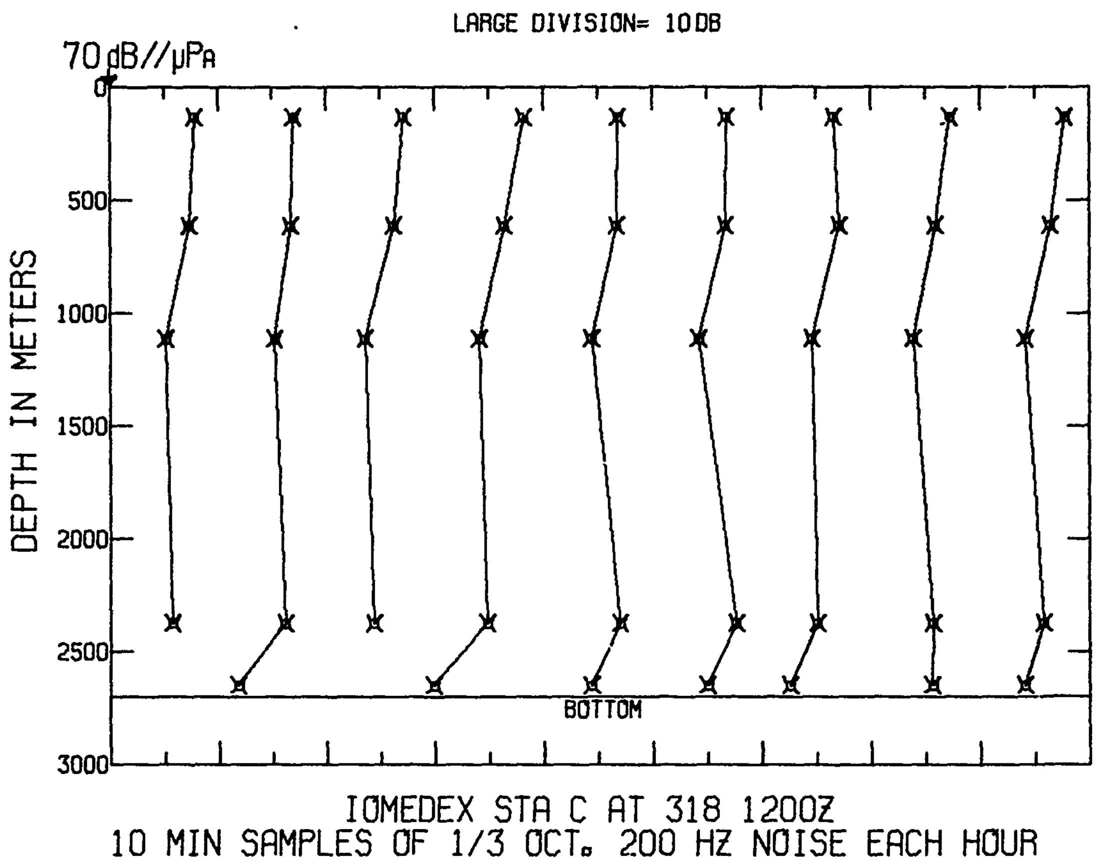
(C) Fig. 2-6 – Ambient noise profiles at 200 Hz: 10-min averages each 20 min beginning at 318 0500Z



(C) Fig. 2-7 – Ambient noise profiles at 200 Hz; 10-min averages each hr beginning at 317 1100Z



(C) Fig. 2-8 – Ambient noise profiles at 200 Hz: 10-min averages each hr beginning at 318 0200Z



(C) Fig. 2-9 – Ambient noise profiles at 200 Hz: 10-min averages each hr beginning at 318 1200Z

3. SIGNAL-TO-NOISE PROFILES

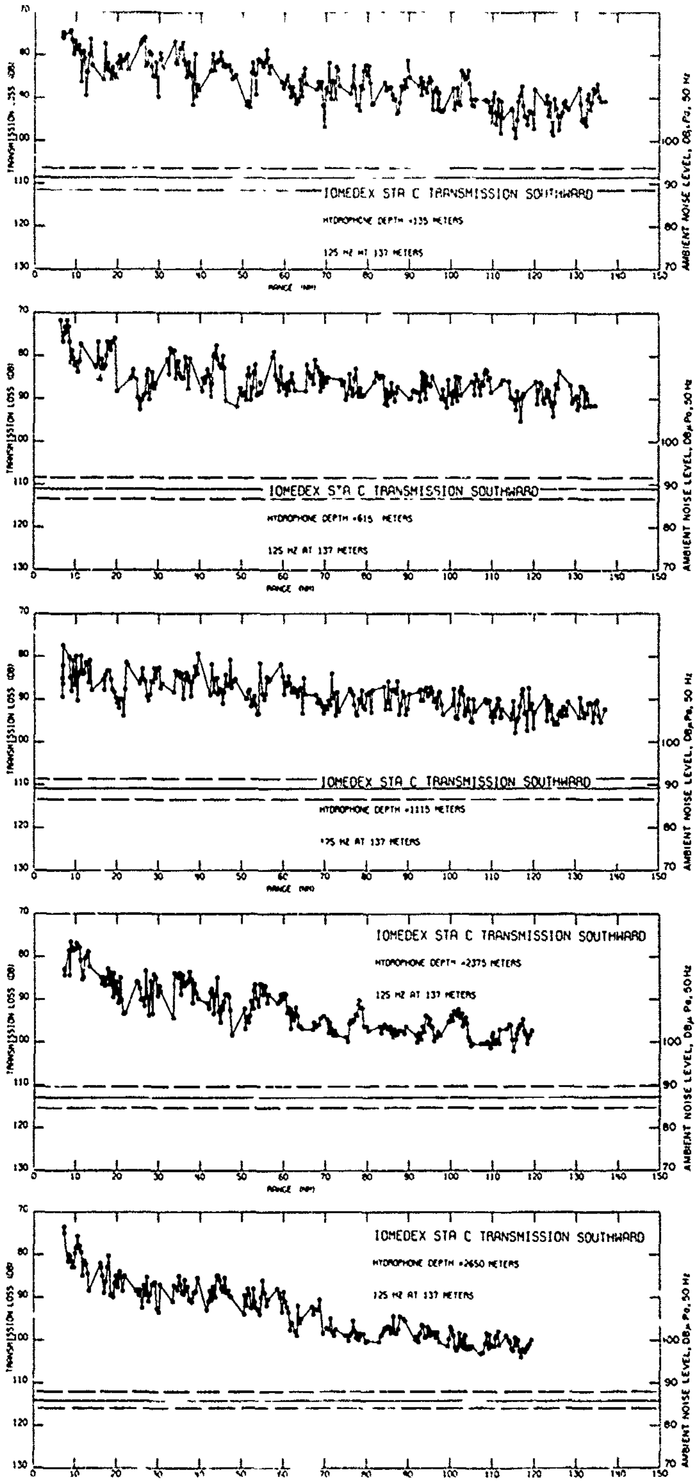
3.1 Results

(C) As discussed in Sec. 3.2 below, the S/N profiles (S at 125 Hz and N at 50 Hz) are indicative of S/N at 50 Hz. In this analysis S is the strength of a received cw signal at 125 Hz emitted from a source towed at 137 m along the tracks shown in Fig. 2-1. In accordance with IOMEDEX data processing guidelines, S was determined by processing in a 5 Hz band. Whenever the band level was less than 5 dB above the noise level in this band (as observed on a strip chart record), the level readings were corrected for noise (6); when this band level was less than 2 dB above the noise level in this band, signal levels were not assigned.

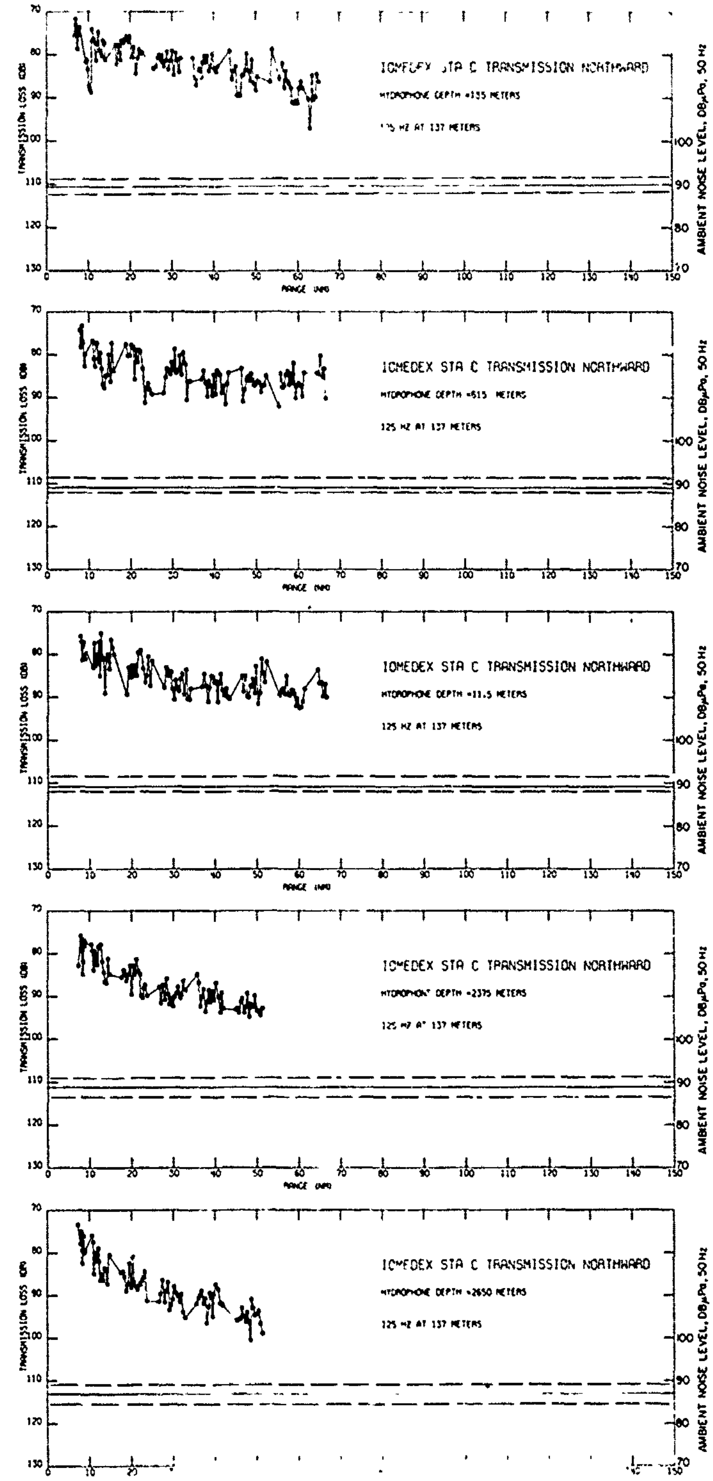
(C) Transmission loss is readily determined from the radiated level, 190 dB//μPa, less the 5 Hz band level. In Figs. 3-1 and 3-2 are shown the transmission loss data together with the median noise values; dashed lines indicate the 5 and 95 percentile levels. The noise values for comparison to this signal measured by the same hydrophones were the median values of 1 min samples detected through a 1/3-octave filter centered at 50 Hz for the tow periods. The times of observation were 10 and 6 hours for the two tracks south and north of Station CHARLIE, respectively.

(C) To obtain the resultant profiles shown in Fig. 3-3 the transmission loss curves of Fig. 3-1 and 3-2 were hand smoothed over a 5 nm range window centered about 10 nm range increments (1.2 hr at 8 kt). The profiles show a maximum near the bottom of the sound channel for ranges greater than 60 nm.

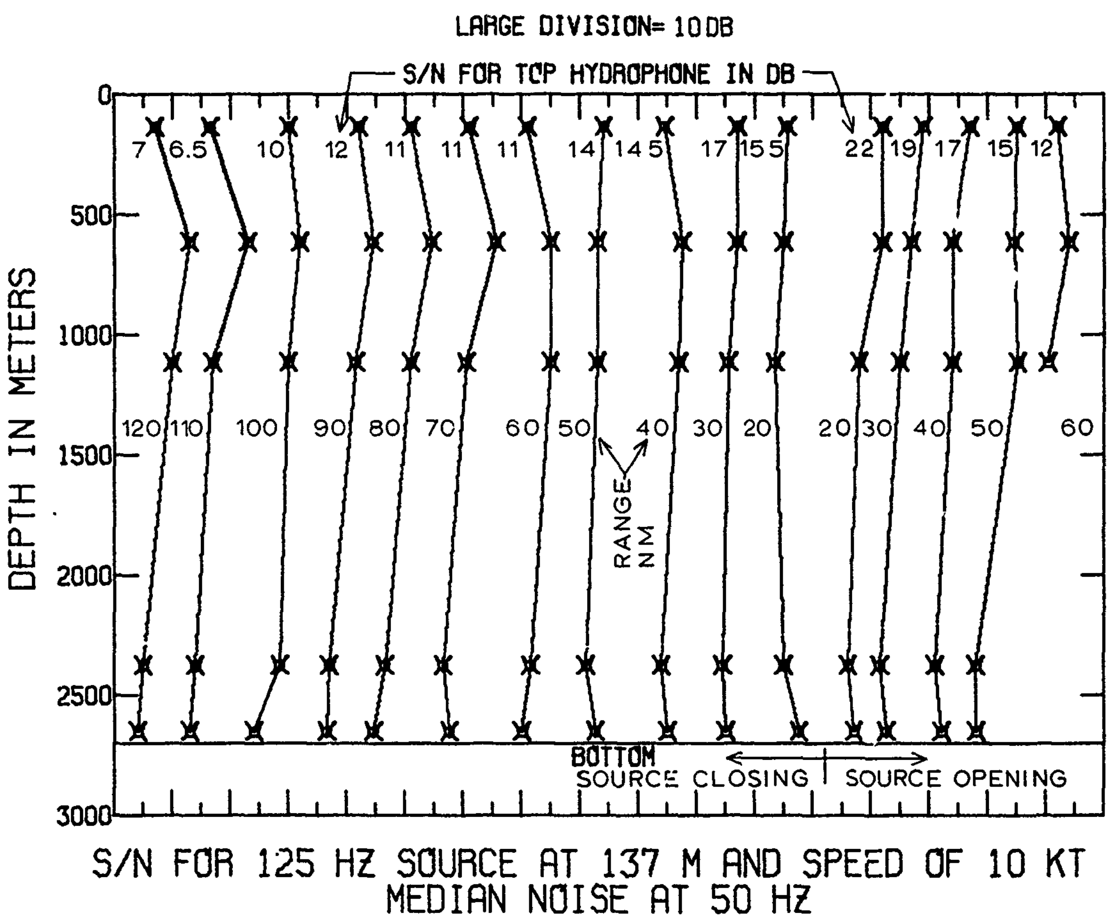
(C) Convergence zone propagation, evident in Figs. 3-1 and 3-2, is reflected in the variability of the S/N profiles. This variability is magnified by the fact that convergence zone boundaries at a given location depend on receiver depth; i.e., propagation maxima to the hydrophones at 135 and 615 m occur for the source at slightly different ranges. This lack of covariance of both transmission loss and ambient noise measured by hydrophones at different depths would further amplify the variation of the "instantaneous" S/N values over those obtained by using average noise values.



(C) Fig. 3-1 – Transmission loss north of Station C and 1/[illegible]ve ambient noise spectrum level at 50 Hz



(C) Fig. 3-2 – Transmission loss south of Station C and 1/3-octave ambient noise spectrum level at 50 Hz



(C) Fig. 3-3 – S/N profiles from data in Figs. 3-1 and 3-2

(U) Except for hydrophones near the bottom, propagation to the south of Station CHARLIE is not dominated by acoustic paths which reach the bottom. Propagation to the north of Station CHARLIE, on the other hand, becomes bottom-limited at ranges of 50-60 nm, as seen in Fig. 2-1. Thus, S/N in Fig. 3-3 could not be measured at ranges greater than 50-60 nm in the northerly direction.

3.2 Discussion

(C) IOMEDEX propagation data were not available at 50 Hz to produce S/N profiles with both S and N at 50 Hz. Because acoustic paths to hydrophones near the bottom result in a greater bottom interaction than for the upper hydrophones and because the bottom acts like a low pass filter, one might expect propagation at 50 Hz to be better for the lower two hydrophones than shown in Figs. 3-1 and 3-2. (Ref. 7) To test this notion transmission loss data are needed from sources in the sound channel for at least two frequencies and at two hydrophone depths (one near the bottom and one in the sound channel). The data should be derived fcrm the same experiment and should be processed in the same manner to preclude a systematic bias dueto source levels, integration times, etc. Accordingly, propagation data from PARKA II (Ref. 8) - events 9-2, 9-4, and 9-5 at 50, 100, and 180 Hz - were selected for 91 m explosive sources and for hydrophones at 781 and 3292 m; the conjugate depth near FLIP for a 91 m source was 4340 m. These data, sampled for ranges less than 200 nm, failed to show any significant trend of the frequency dependence of propagation with hydrophone depth. Thus, we conclude that the S/N profiles (both S and N at 50 Hz) would not differ significantly in shape from those in Fig. 3-3.

3.3 Precision of S/N

(U) The precision of S/N is determined by the precision of both the transmission loss and ambient noise measurements. As long as both measurements are made by the same acoustic system, errors in calibration cannot bias S/N. Thus, we are led to consider the precision of the measurement of a signal and noise, both of which fluctuate. Assuming that the noise in nearly Gaussian, a one minute sample measured through a 1/3 -octave filter at 50 Hz has a statistical uncertainty of 0.2 dB. (Ref. 9) (Assume 90% confidence level, 5 to 95 percentile.)

(C) Consider fluctuation of the signal from a towed cw source. If the medium is stationary, the fluctuation of the signal observed by the receiver is due solely to the source's transit through the receiver's transmission loss field. This fluctuation may be manifest as frequency modulation (because of the changing velocity of the source with respect to the receiver or from macroscopic motion at the receiver) or as amplitude modulation (because of the highly irregular transmission loss field). A tracking filter can be used to greatly reduce the frequency modulation, if necessary. To avoid smoothing the envelope of the amplitude modulation requires a processing filter whose bandwidth β is at least v/ℓ, where v is the tow speed and ℓ is the minimum spatial irregularity to be detected. Expressed in terms of the bandwidth for a given filter,

$$\ell_{min} = v/\beta.$$

In IOMEDEX, $\ell_{min} = (3\ m/sec)/(1\ Hz) = 3\ m$, so that there is no inadvertent filter smoothing of the transmission loss data. Thus, for "instantaneous" S/N values, the combined statistical uncertainty would be 0.2 dB.

(U) For Fig. 3-3, the signal is spatially averaged over 2 nm, whereas the noise is time averaged over the towing periods of 10 and 6 hrs. Processing of the signal resulted in a precision of $\pm$ 1 dB. (Ref. 6) Dashed lines representing the 5 and 95 percentile confidence limits of noise in Figs. 3-1 and 3-2 show that noise fluctuations are the dominant contributor to the variability in S/N. The mean of the standard deviations of the noise values for the five hydrophones during the towing period is 1.2 dB. Since the level of the bender bar source was constant to within 0.5 dB, the uncertainty in the S/N profiles of Fig. 3-3 is 1.3 dB.

4. CONCLUSIONS

4.1 Findings

(C) Ambient noise measured during IOMEDEX shows that noise generated by ship traffic (50 Hz) has a depth dependence which has large short term

(5–20 min) variability, whereas noise heavily influenced by weather (200 Hz) has a depth dependence whose variability is as large but over a longer time (1-2 hr). (Compare Figs. 2-2, 2-6, and 2-8.)

(C) The S/N profiles have maxima near the bottom of the sound channel, and they undergo relatively large fluctuations as the towed source is moved through different parts of the transmission loss fields at the five hydrophones.

4.2 Recommendations

(C) From the vertical profiles in Sec. 2 and 3, it is evident that both ambient noise and S/N must be sampled more densely in the water column than was the case in IOMEDEX in order to determine experimentally the depth dependence of these quantities. Ray tracing during the design of such experiments could provide estimates of vertical gradients in propagation loss which could be of use indicating both the number of sensors required and their distribution throughout the water column.

(C) Figure 1-1 shows the 5 to 95% cumulative probability of ambient noise at the five depths of measurement. Even though the total time of the statistical sample is six days, there is still seen to be a marked reduction in the variability of 1/3-octave ambient noise levels (at 20 and 317 Hz) near the bottom of the sound channel (615 m), compared to those at other depths. Generally, this also holds true at other frequencies not shown here. Low variability coupled with a high noise level points to a statistical convergence in the mean associated with a larger number of contributing sources. As the depth is increased below the critical depth, on the other hand, nearby sources, whose temporal density variation is greater than for distant sources, are increasingly more important to the noise field. The less variable nature of the ambient noise at and above the critical depth strongly suggests that it is more readily predictable than that for other depths. The predictability aspect of ambient noise and S/N vs. depth should be investigated for other sets of experimental data.

5. ACKNOWLEDGEMENT

(U) The experiment was sponsored by the Long Range Acoustic Propagation Project, ONR, and was conducted at sea in conjunction with the Woods Hole Oceanographic Institution. In particular the Captain and crew of R/V KNORR contributed significantly to the success of the experiment. Much computational assistance was rendered by R. A. O'Brien.

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Appendix A: IOMEDEX Data

A.1 The Experiment

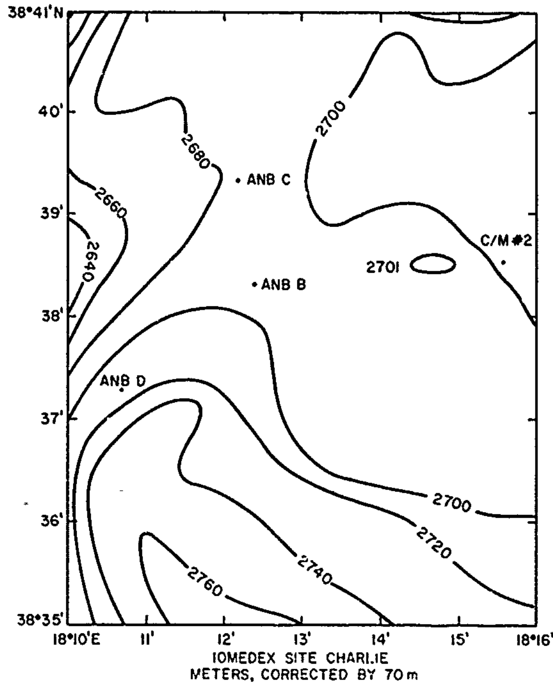
(U) The NRL IOMEDEX Summary Report (Ref. 3) contains ambient noise data obtained by NRL during the experiment. The present report contains that portion of the noise data best relating to ambient noise and S/N vs. depth, together with transmission loss data obtained using the same acoustic recording channels as were used for the ambient noise data acquisition. This Appendix contains ambient noise spectra and supporting information used in analysis for this report.

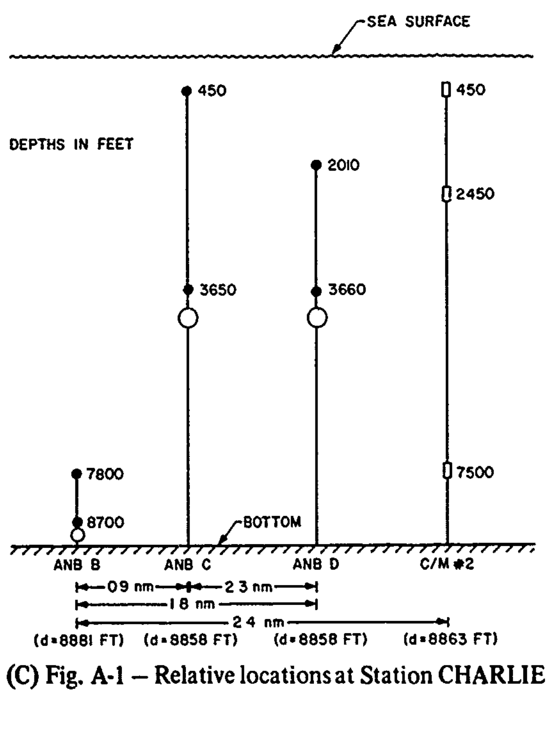
(U) Four ANBs and two current meter arrays were deployed at two locations (ALFA and CHARLIE, Fig. 2-1) for IOMEDEX. Seven hydrophones yielded good data for their time on station, and one hydrophone yielded only three hours of data because of failure of an operational amplifier in the buoy (the upper hydrophone of ANB A at Station ALFA).

(C) The positions of the sensors, both in depth and relative to each other, for Station CHARLIE are shown in Fig. A-1, where the numbers in parentheses indicate the water depths at each sensor location. At Station ALFA the two hydrophones of ANB A were 7000 feet and 10240 feet, and the current meters were located at depths of 450 feet, 2450 feet, and 7500 feet.*

(U) The ANBs used in IOMEDEX were adapted from a measurement system developed for the VELA UNIFORM project and are discussed in Ref. 1 and 2. The original tape recorders in these equipments were replaced by recorders developed for the NUTMEG Project. These recorders use 1/2-inch, 1/2 mil thick mylar tape and, at the recording speed of 0.2 inches per second (ips), are capable of recording for 187 hours. In IOMEDEX the recordings were continuous. Processing of the magnetic data tapes from the ANBs is discussed below.

* In this Appendix all depths are in feet (1 ft = 0.3048m) and all ambient noise levels are in dB//μbar (dB//μPa=dB//μbar+100).





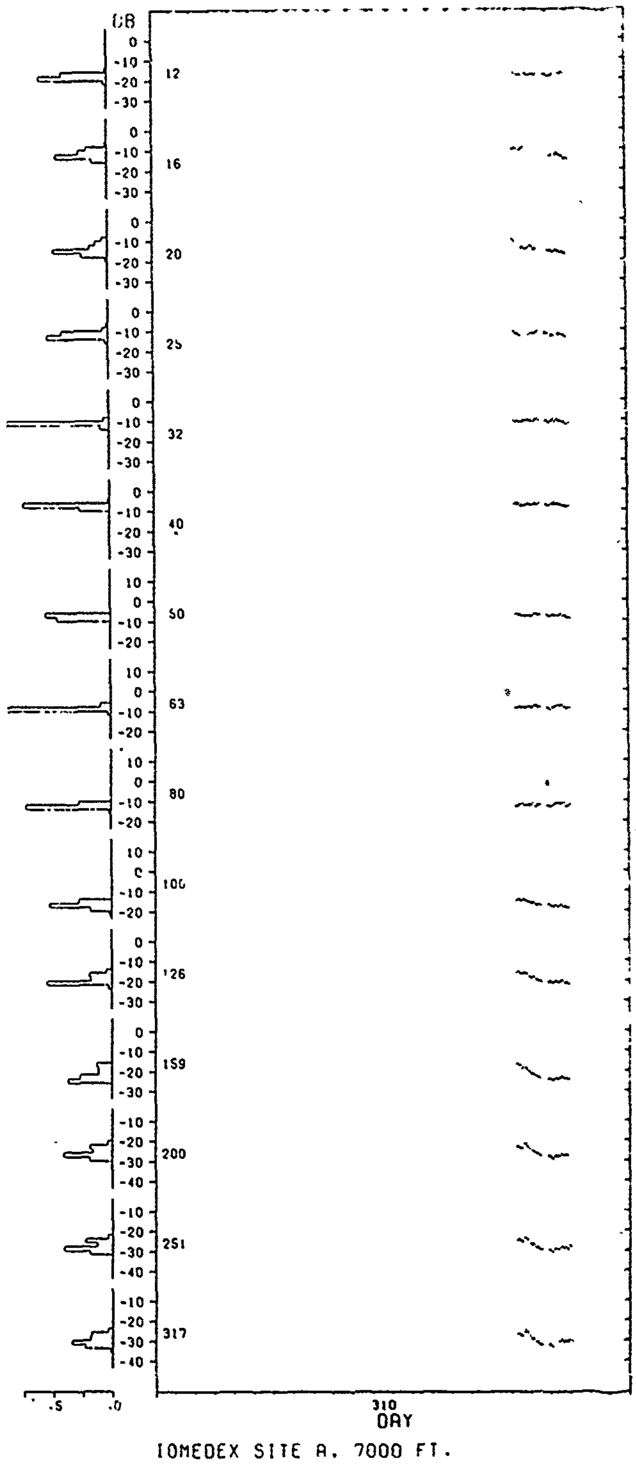
(C) Fig. A-1 – Relative locations at Station CHARLIE

(U) The original data tapes were removed from the ANBs and played back on an instrumentation tape recorder aboard R/V KNORR at a playback speed of 64:1 to another tape recorder containing 1/2-inch, 1 mil thick tape, run at 30 ips. These latter tapes were then played at 30 ips into a General Radio Model 1925 Multifilter. The outputs of sixteen, 1/3-octave filters of the Multifilter passed directly into a multiplexer and thence to an analog-to-digital converter, Hewlett-Packard Model 5610. The single output, in 10-bit digital form, was then fed into a Hewlett-Packard Model 2116B digital computer where data compaction was achieved. The data were stored as one-minute averages on digital magnetic tape. The digitizing rate, 13,653.3 Hz, controlled by a General Radio frequency synthesizer, permitted acquisition of 1.00 min data samples for 16 input channels at the speed up ratio of 64:1.

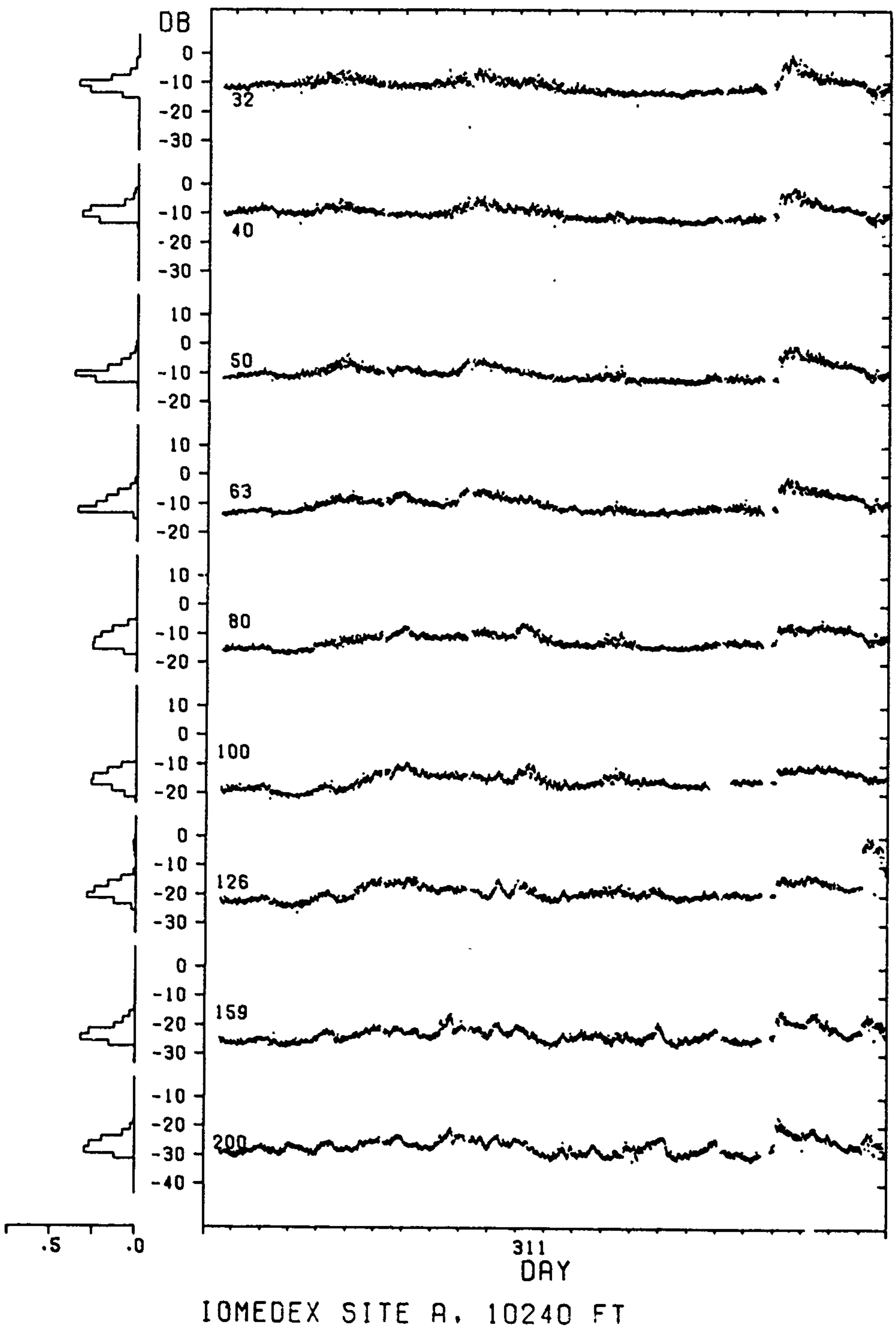
(C) The objectives of Project IOMEDEX dictated the requirements for time series of ambient noise at frequencies 20-300 Hz and frequency spectra in this band. Such processed data are presented in this Appendix.

A single ANB tape generated 11 dubbed tapes. During dubbing at 64:1, the start and stop time of the original tape and starting of the data inevitably produced a desynchronization of absolute clock time. By looking at events whose times of occurrence are known, it is felt that the time assignments to the ANB IOMEDEX data are accurate to $\pm$ 40 minutes throughout the entire 7-plus days of recording time for each hydrophone. In the time series records, Figs. A-2 and A-3, whose abscissa scale factors is one hour per tick, the error assignments in time are $\pm$ 4 minutes. In the other time series records, notably Figs. A-4 through A-9, whose time scale factor is 5 hours per tick, the time assignments are good to within $\pm$ 20 minutes. In all the IOMEDEX data presented herein all sound pressure levels and transmission loss values are accurate to $\pm$ 1dB.

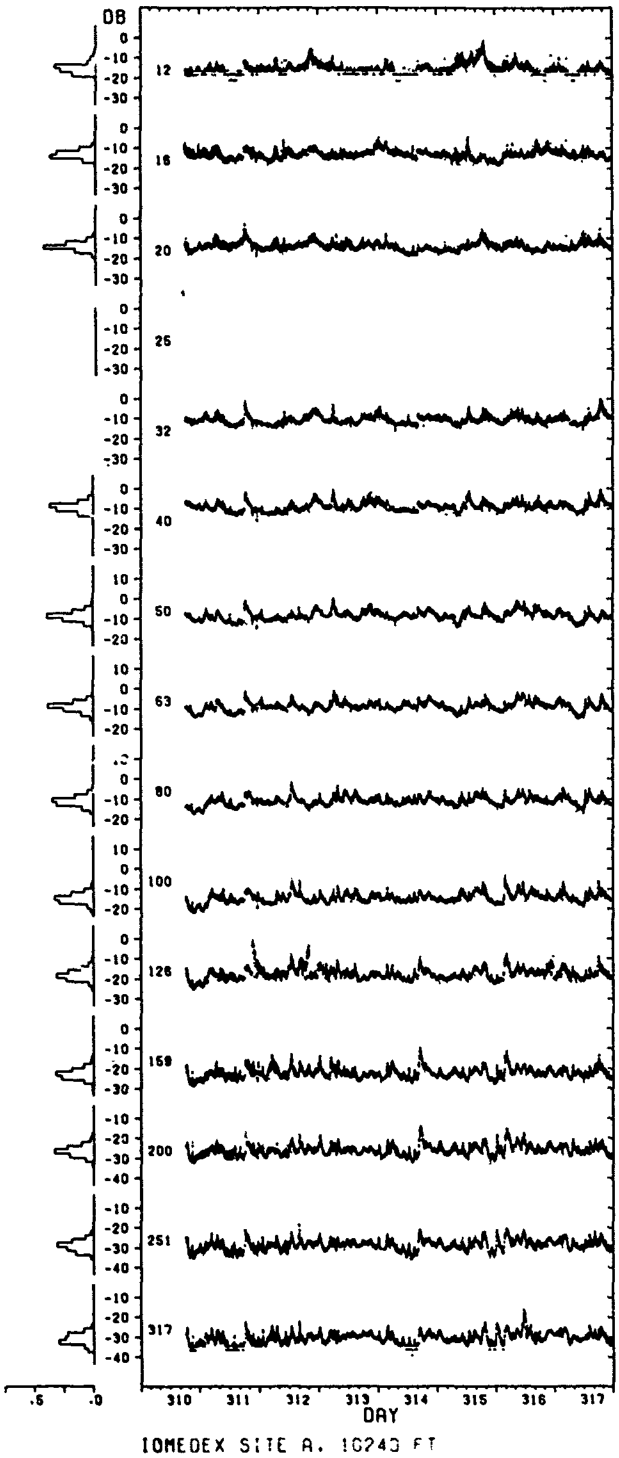
(U) The hydrophone systems employed with the ANBs were calibrated in accordance with standard procedures at NRL. Hydrophones were calibrated at Underwater Sound Reference Division (USRD), Orlando, Florida, before the exercise, and have been recalibrated following the measurement phase of



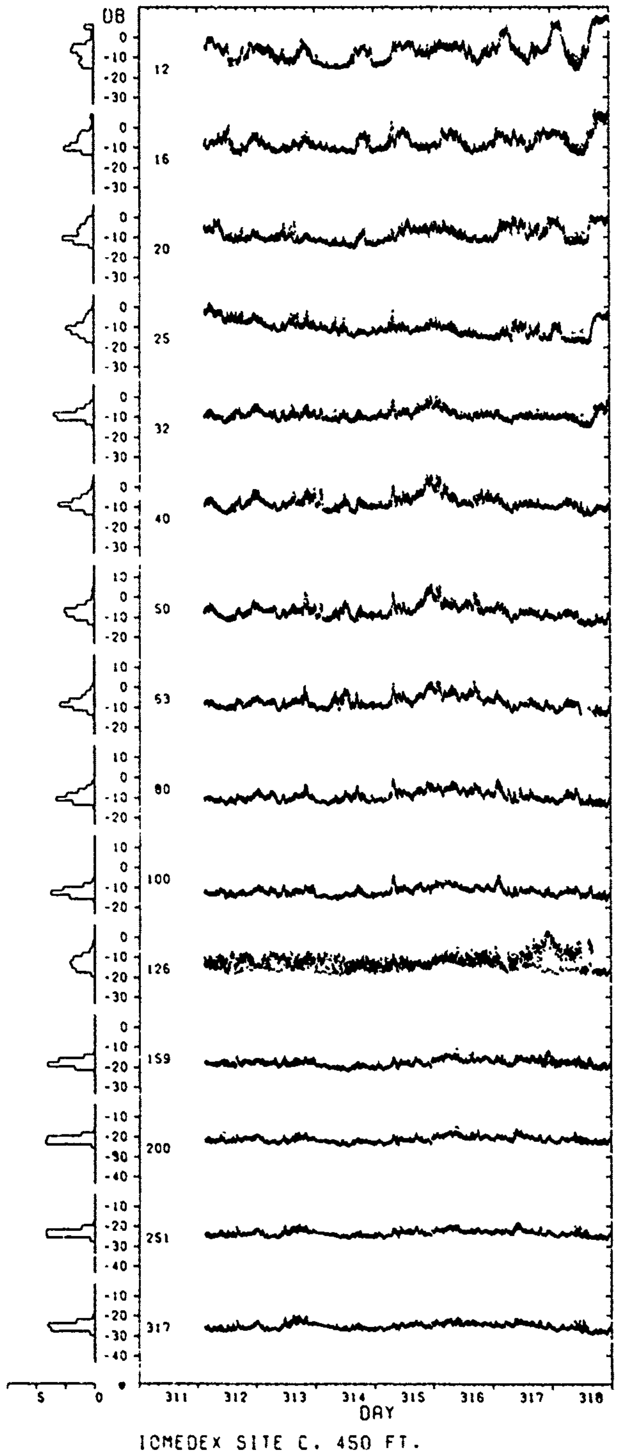
(C) Fig. A-2 – Ambient noise spectrum levels at Station ALFA, day 311, hydrophone depth = 7000 ft



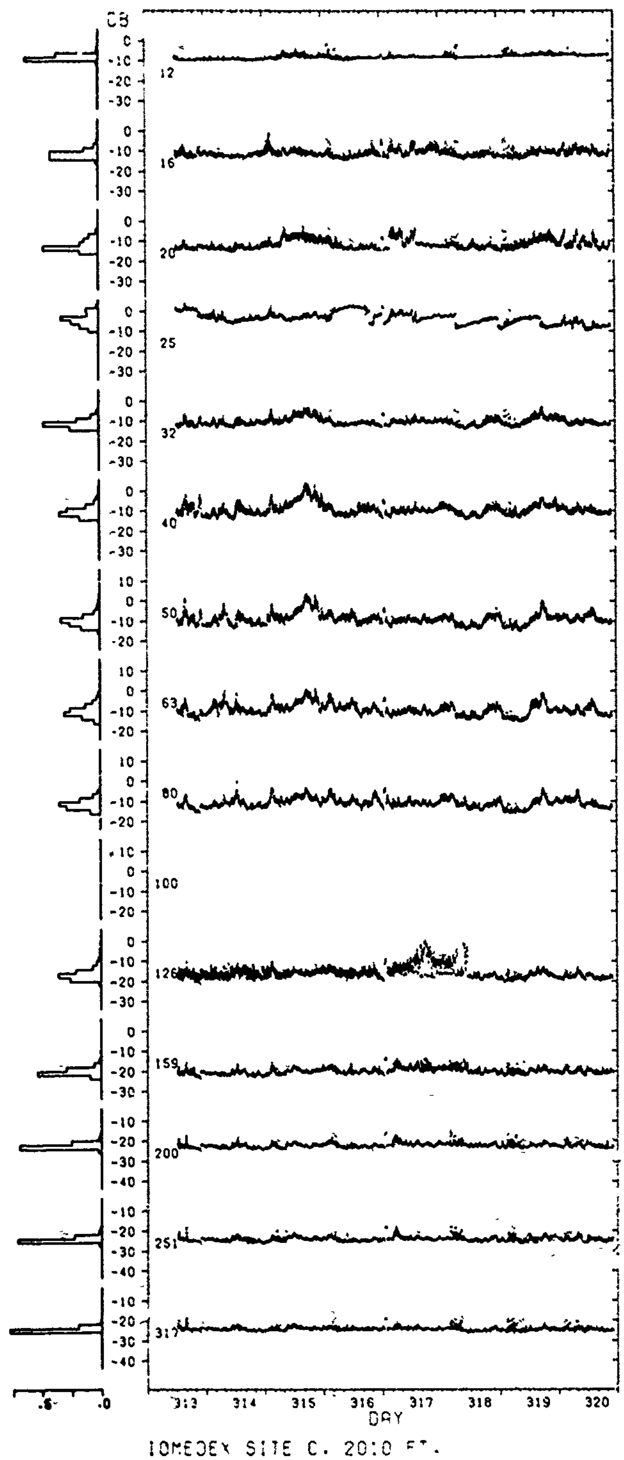
(C) Fig. A-3 – Ambient noise spectrum levels at Station ALFA, day 310, hydrophone depth = 10240 ft



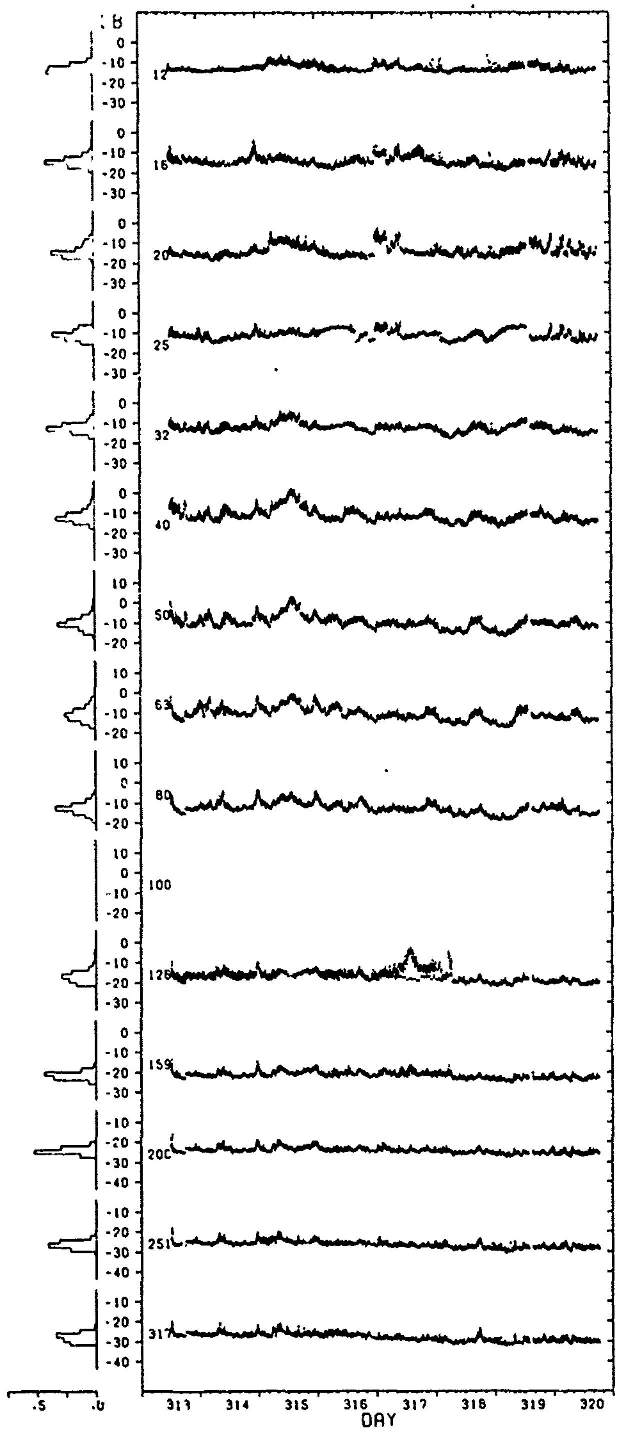
(C) Fig. A-4 — Ambient noise spectrum levels at Station ALFA, days 310-317, hydrophone depth = 10240 ft



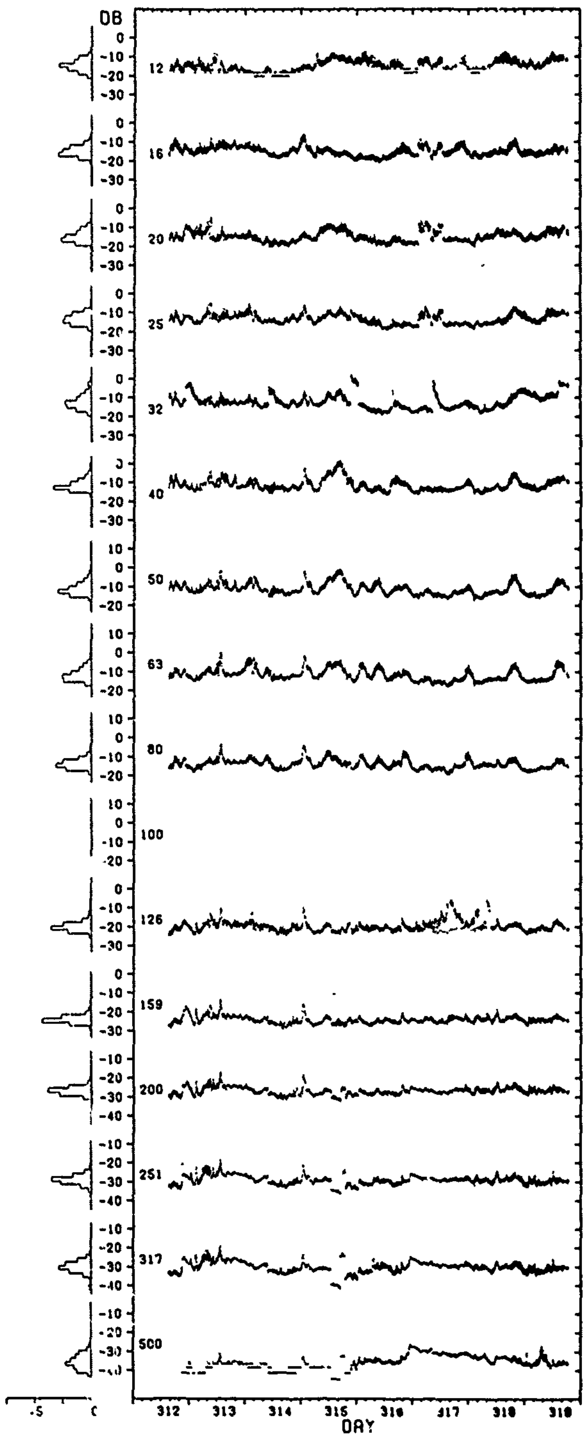
(C) Fig. A-5 – Ambient noise spectrum levels at Station CHARLIE, days 311-318, hydrophone depth = 450 ft



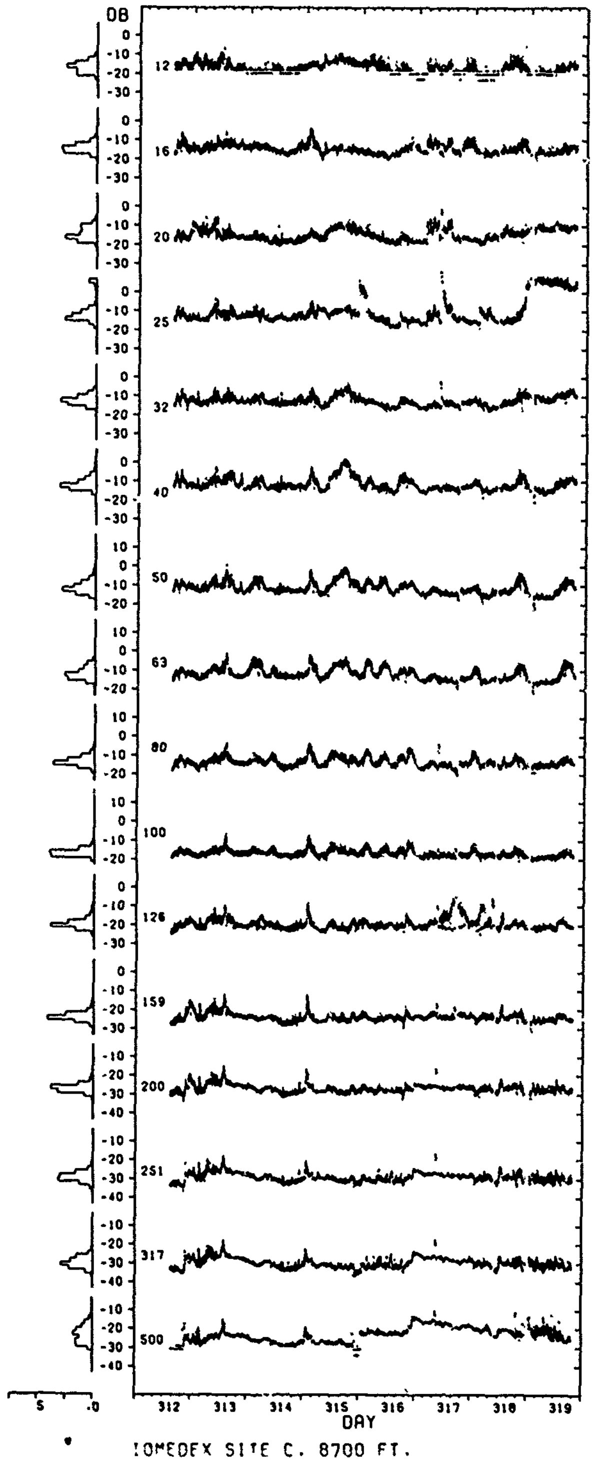
(C) Fig. A-6 – Ambient noise spectrum levels at Station CHARLIE, days 313-320, hydrophone depth = 2010 ft



(C) Fig. A-7 – Ambient noise spectrum levels at Station CHARLIE, days 313-320, hydrophone depth = 3650 ft



(C) Fig. A-8 – Ambient noise spectrum levels at Station CHARLIE, days 312-319, hydrophone depth = 7800 ft



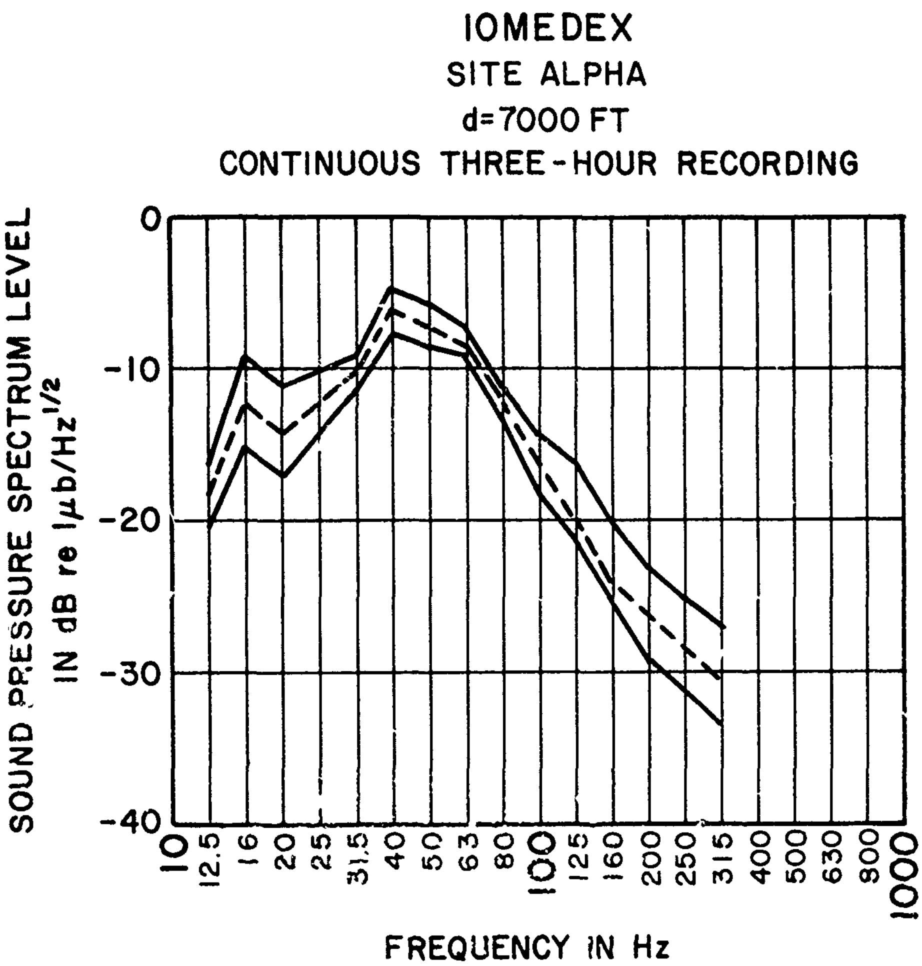
(C) Fig. A-9 – Ambient noise spectrum levels at Station CHARLIE, days 312-319, hydrophone depth = 8700 ft

IOMEDEX. The electronic and magnetic tape portions of the system were calibrated by injection of tones of known level and known frequency at each center frequency of IOMEDEX analysis. These injected calibration tones were recorded on the original data tapes inside the ANBs, which themselves were in the main laboratory of R/V KNORR, both before and after deployment. Electronic noise was at least 10 dB below measured values.

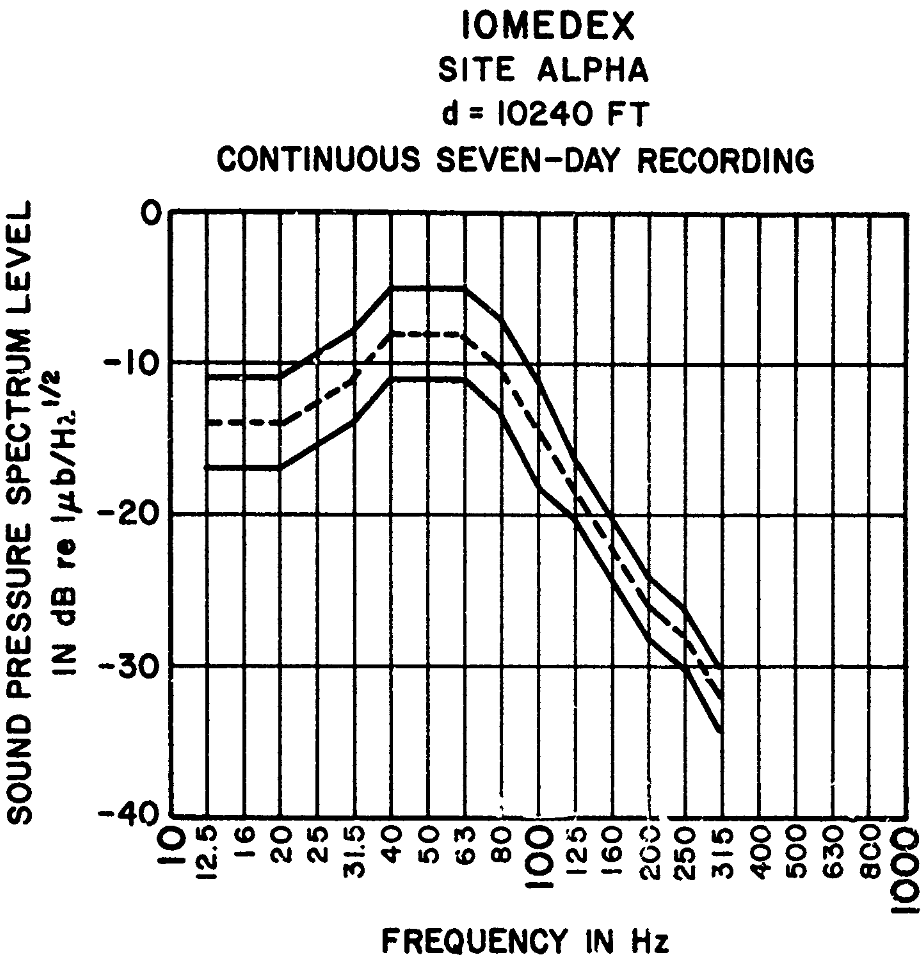
A.2 Results

(U) Time series plots of ambient noise level from Station ALFA for ANB A are shown in Figs. A-2 to A-4. Note that Fig. A-4 has a compressed time scale. Time series plots for ANBs B, C, and D at Station CHARLIE are shown in Figs. A-6 through A-9. The deep hydrophone from ANB C is very nearly at the same depth as the deep hydrophone of ANB D and consequently not been included. Each plotted point is a 2 minute average of the signal output from the 1/3-octave filter whose frequency is identified with each plot. Accompanying each time series is a histogram. Average 1/3-octave levels taken from those histograms and reduced to a 1 Hz bandwidth are shown in Figs. A-10 through A-16. In each case the center dashed curve represents the modes from the histograms associated with each 1/3-octave filter shown on the time-series plots. The two bracketing solid curves show the limits of 90% of the data for that curve.

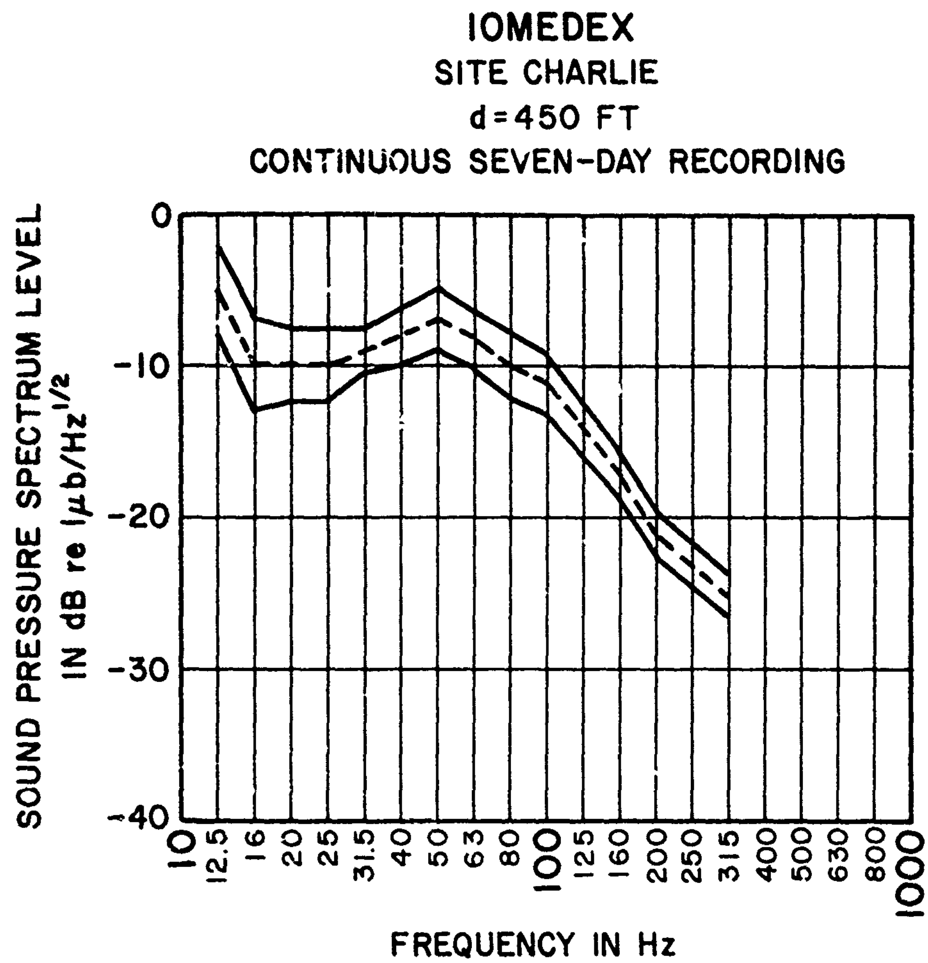
(C) Transmission loss data at 125 Hz were presented in Figs. 3-1 and 3-2 for radial tracks south and north from Station CHARLIE (r=0). The source was towed at 137 m by R/V NORTH SEAL. (Refer to Sec. 3) Values of transmission loss were determined in the following way: from an ANB recording a signal was passed through a filter with effective bandwidth of 4.9 Hz and then displayed on a Sanborn recorder. The data shown in Figs. 3-1 and 3-2 represents two-minute sight averages of the Sanborn record every 10 min and 40 sec. Successive points are connected by straight line segments. A signal-to-noise ratio of 2 dB was used for rejection of low level signals; levels recorded on the Sanborn recorder were corrected for ambient noise prior to assigning transmission loss values.



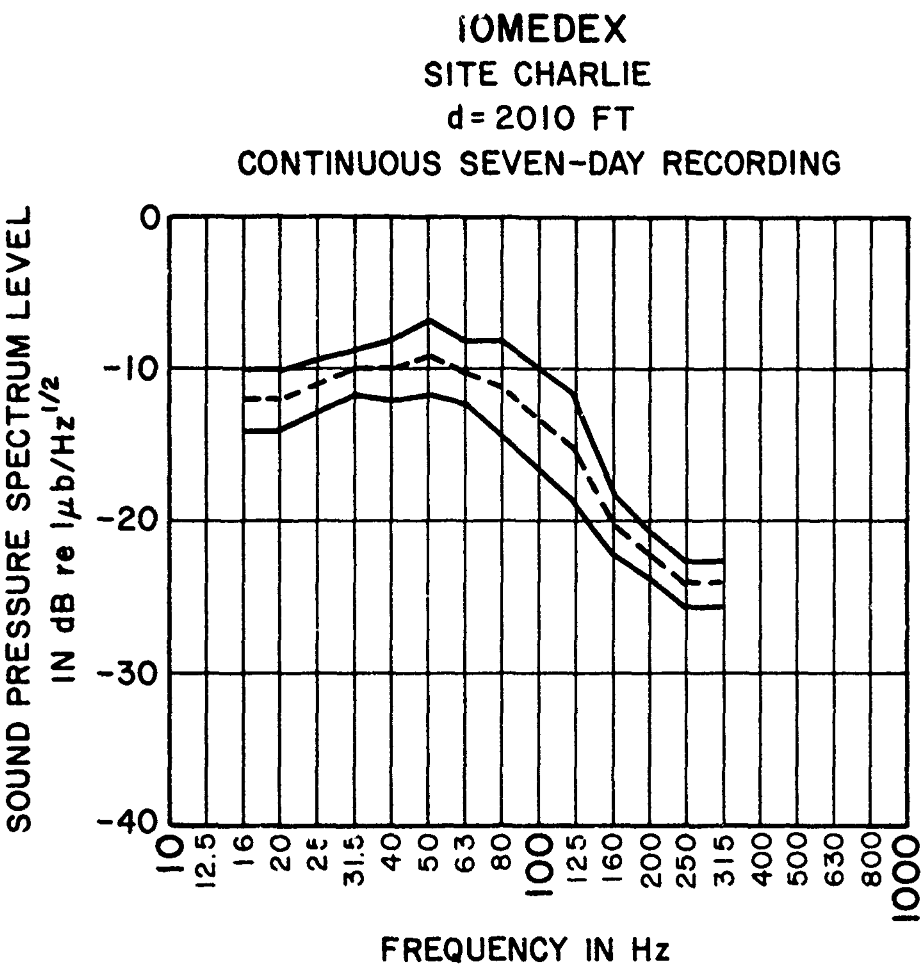
(C) Fig. A-10 – Ambient noise spectrum, Station ALFA, hydrophone depth = 7000 ft



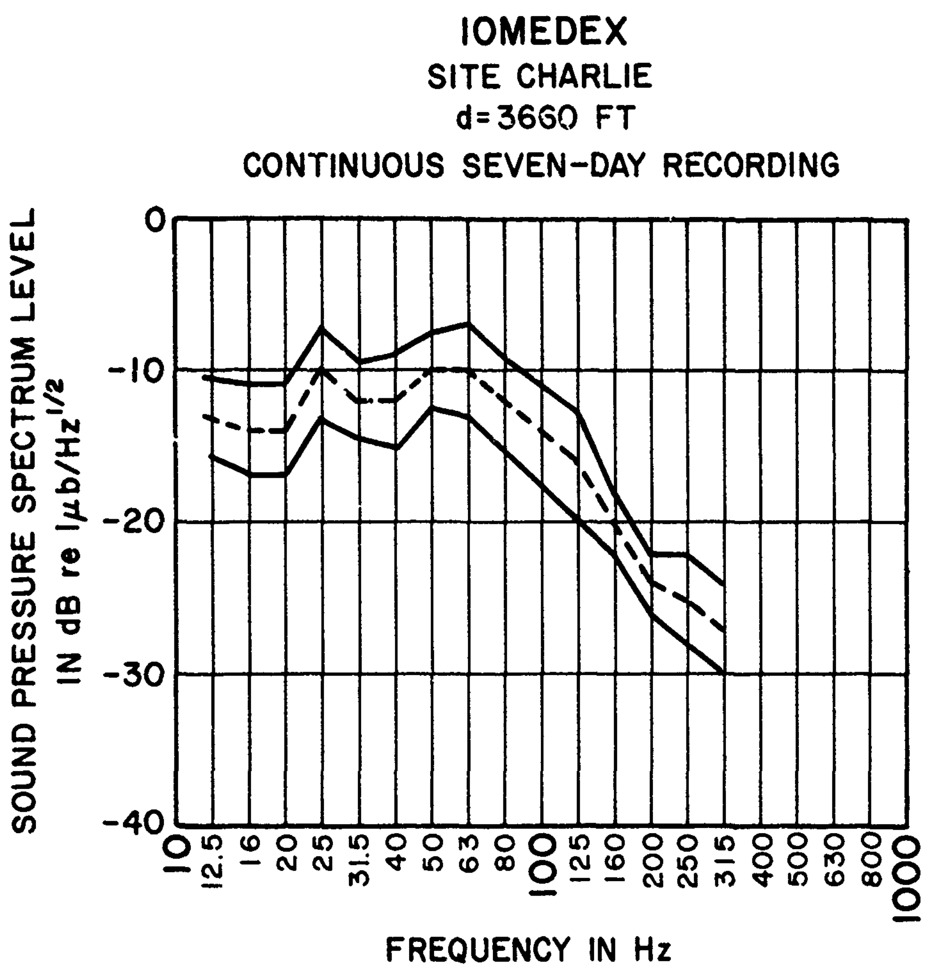
(C) Fig. A-11 – Ambient noise spectrum, Station ALFA, hydrophone depth – 10240 ft



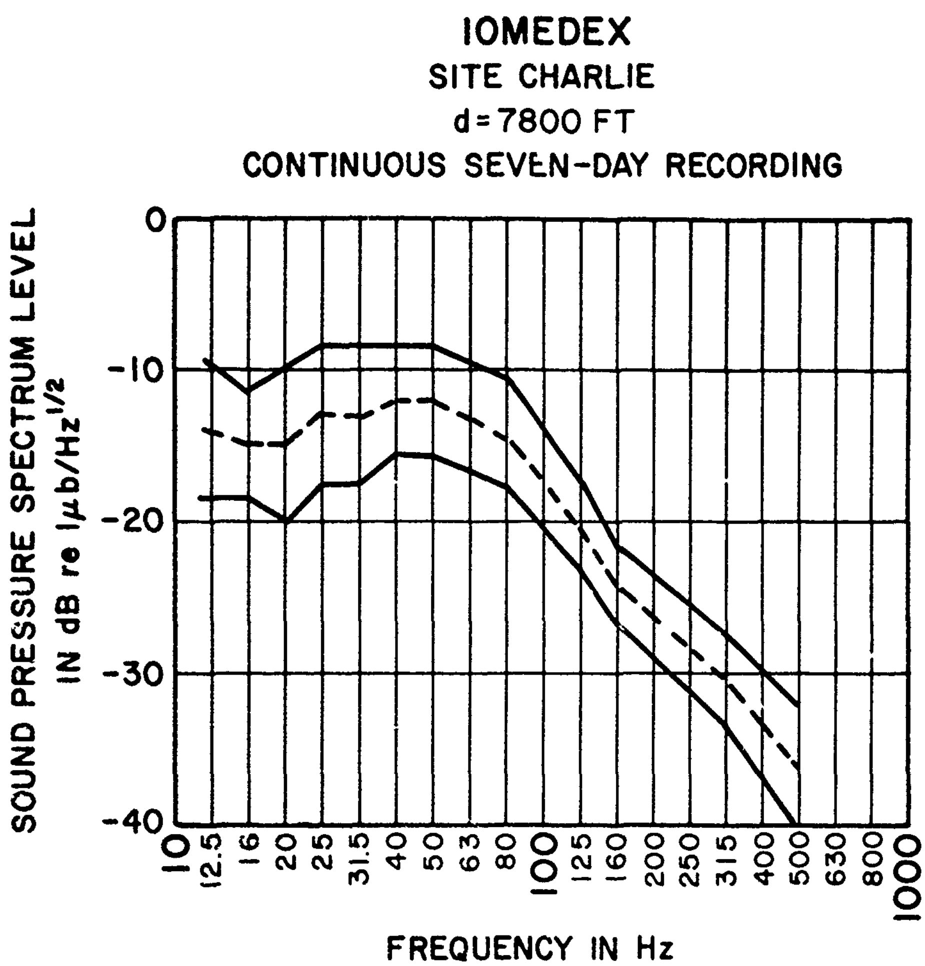
(C) Fig. A-12 – Ambient noise spectrum, Station CHARLIE, hydrophone depth = 450 ft



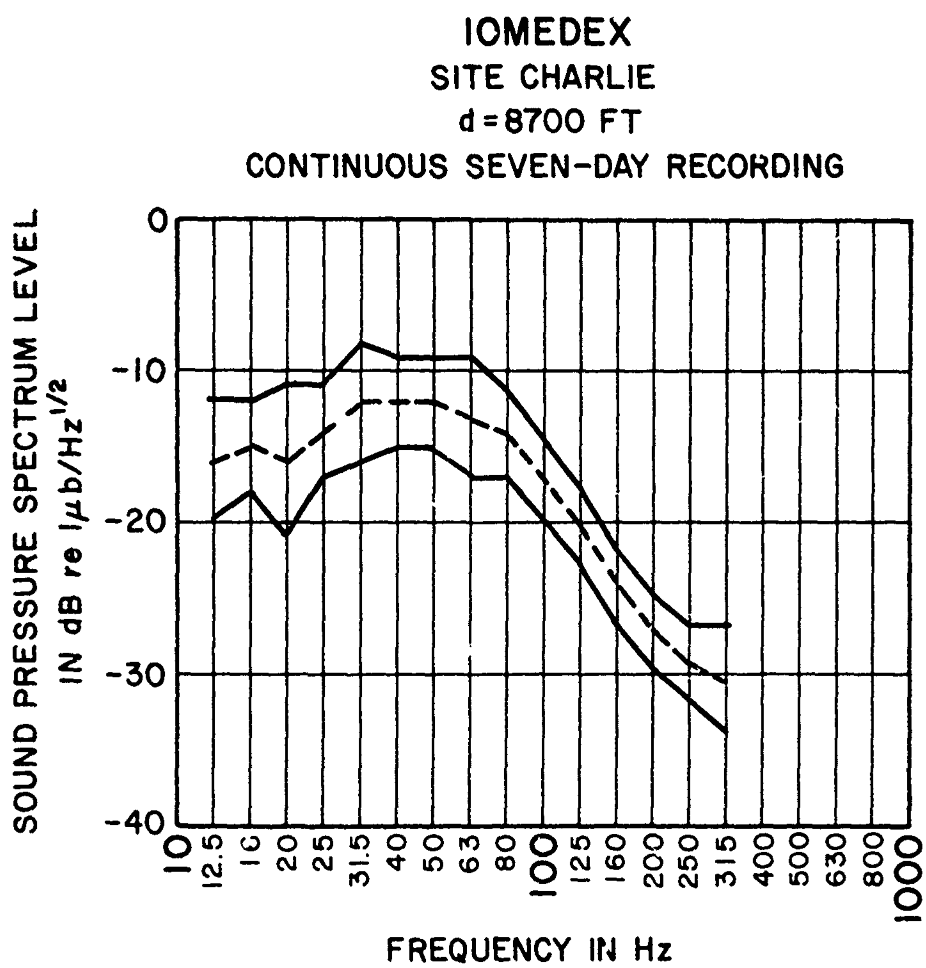
(C) Fig. A-13 – Ambient noise spectrum, Station CHARLIE, hydrophone depth = 2010 ft



(C) Fig. A-14 – Ambient noise spectrum, Station CHARLIE, hydrophone depth 3660 ft



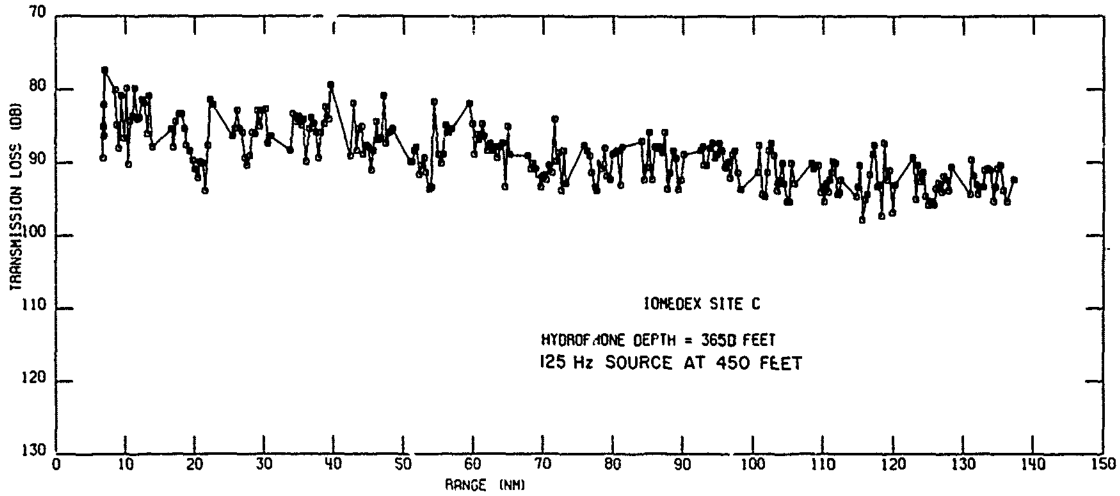
(C) Fig. A-15 – Ambient noise spectrum, Station CHARLIE, hydrophone depth 7800 ft

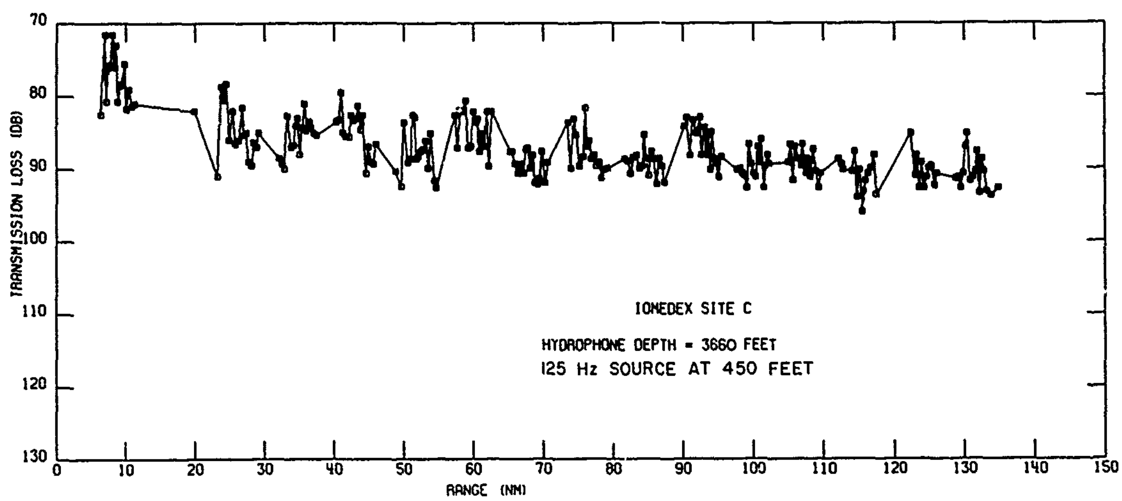


(C) Fig. A-16 – Ambient noise spectrum, Station CHARLIE, hydrophone depth 8700 ft

(U) Fig. A-17 shows transmission loss at two similar depths by hydrophones located 2.3 nm apart. The ranges in Figs. 3-1 and A-17 are measured from each buoy location. (Refer to Fig. 2-1 for their relative locations; the buoy locations and Station ALFA toward which the track is taken are practically colinear.) A comparison of the two transmission loss profiles in Fig. A-17 shows a pronounced local variability of the transmission loss field resulting from a combination of two principal factors in order of importance: spatial variation arising from the 2.3 nm separation; and, temporal variation arising from the transit time of R/V NORTH SEAL covering the 2.3 nm, roughly 18 min. The lack of bias in these two profiles attests to the consistency of the calibration method applied to the two ANBs.

(U) Details of other aspects of IOMEDEX may be found in the IOMEDEX Synopsis, Ref. 4. Additional transmission loss data will be found in the IOMEDEX data bank maintained by Tracor, Inc., and in the NRL IOMEDEX Summary Report, Ref. 3.





(C) Fig. A-17 – Transmission loss south of Station C for hydrophone depth = 3650 and 3660 ft

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1. ORIGINATING ACTIVITY *(Corporate author)* Naval Research Laboratory Washington, D.C. 20375	2a. REPORT SECURITY CLASSIFICATION Confidential	
	2b. GROUP XGDS-3-1988	
3 REPORT TITLE AMBIENT NOISE AND SIGNAL-TO-NOISE PROFILES IN IOMEDES (Unclassified Title)		
4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)* A final report on one phase of the problem; work is continuing.		
5. AUTHOR(S) *(First name, middle initial, last name)* S.W. Marshall		
6. REPORT DATE	7a. TOTAL NO. OF PAGES 49	7b. NO. OF REFS 9
8a. CONTRACT OR GRANT NO. NRL Problem S01-38	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Memorandum Report 2638	
b. PROJECT NO.		
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	
d.		
10. DISTRIBUTION STATEMENT Distribution limited to U.S. Government Agencies only; test and evaluation; June 1973. Other requests for this document must be referred to the Director, Naval Research Laboratory, Washington, D.C. 20375.		
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13. ABSTRACT

Ambient noise vertical provides in the Ionian Sea show temporal fluctuations in a few minutes at low, shipping-related frequencies to a few hours at higher, wind/sea-related frequencies. In the mean, ambient noise levels decrease with increasing depth over the frequency band of study: 20-300H z. Signal-to-noise profiles also show a fluctuation, depending on the range from source to receiver. These characteristics of deep-water ambient noise are discussed. The results and discussion bear directly on future sonar systems as to optional placement of sensors throughout the water column.

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DD FORM 1 NOV 65 1473 (PAGE 1)
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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Underwater acoustics						
Ambient noise						
IOMEDEX						
Mediterranean Sea						

DD FORM 1 NOV 65 1473 (BACK)
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