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NORDA Report 34

ADC034017

The Acoustic Model Evaluation Committee (AMEC) Reports

Volume 1A

Summary of Range Independent Environment Acoustic Propagation Data Sets (U)

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Foreword (U)

(U) The Acoustic Model Evaluation Committee (AMEC) has been chartered to serve as an advisory group to the Director, ASW Program (OP-095), on matters dealing with model evaluation. In fulfillment of its charter AMEC will produce a series of volumes detailing the methodology taken and the results of specific model evaluations. This volume presents a summary of acoustic propagation loss experimental data for use as reference in assessing the accuracy of range independent propagation loss models. Each data set was submitted to criteria which assure suitability to propagation loss model evaluation for a range independent environment. Twelve data sets were found suitable and are summarized: SUDS, GOA, FASOR, LORAD, PARKA II, WHOI Hays-Murphy, Bearing Stake, IOMEDEX, JOAST III, JOAST IV, ATOE, and JAGUAR.

G. T. Phelps

G.T. Phelps, Captain, USN
Commanding Officer, NORDA

Executive Summary (U)

(U) The Acoustic Model Evaluation Committee (AMEC) has examined propagation loss experimental results to determine their applicability to the evaluation of propagation loss computer models for which the environmental inputs are independent of range. Twelve data sets were found suitable for this purpose, meeting criteria of range independence and environmental data available in sufficient quantities for model input requirements. The twelve data sets are: (1) Surface Duct Sonar (SUDS) Measurements, (2) Gulf of Alaska, (3) Forward Area Sonar Research (FASOR), (4) PARKA III (Pacific Acoustic Research Kanehoe-Alaska), (5) Long Range Acoustic Detection (LORAD), (6) BEARING STAKE, (7) Mediterranean Sound Transmission (WHOI Hayes-Murphy), (8) Ionian Mediterranean Exercise (IOMEDEX) (9) JOAST III (Joint Oceanographic and Acoustic System Tests), (10) JOAST IV, (11) Acoustic Transmission and Oceanographic Experiment (ATOE), (12) Joint Americas Geophysics Underwater Acoustics Research (JAGUAR). These experimental results and their supporting environmental data are reviewed in this volume. Any factors associated with these data that would affect model evaluation are carefully set forth.

Preface (U)

(U) This report was prepared under the joint sponsorship of the Naval Sea Systems Command, Program Manager, P. R. Tiedeman (SEA 63D3), PE 63708N; the Surveillance Environmental Acoustic Support Project, Program Manager Dr. Robert A. Gardner (NORDA Code 520), PE 63795N; the Tactical ASW Environmental Acoustic Support Project, Program Manager, E. Chaika (NORDA Code 530), PE 63795N; via the Acoustic Model Evaluation Committee under the auspices of OP-952D (Capt. J. Harlett).

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The Acoustic Model Evaluation Committee (AMEC) Reports

Volume IA. Summary of Range Independent Environment Acoustic Propagation Data Sets (U)

Introduction (U)

(U) The overall objectives of Acoustic Model Evaluation have been addressed in companion volumes to this report and will not be dwelled on here except to the extent necessary to put this effort into proper perspective. The thrust of the effort described in this volume is to provide identification, assessment, and summarization of environmental and acoustical propagation data sets for use by the Model Evaluator. Only data obtained in range independent environments are discussed herein.

Background (U)

(U) Acoustical models are developed as components of prediction systems. While they may be ultimately a part of these larger systems, the acoustical models in turn require environmental inputs as their basis for computation. To determine the accuracy of a prediction system result, it is necessary to have an assessment of the accuracy of the acoustical model. Appropriate references for evaluation of a model are measured data sets covering the parametric range of the model's applicability. It is not expected that any one experiment covers the range of applicability of a given acoustical model; however, many different acoustical measurements with concurrent environmental data have been made and reported, which, taken together, form a valid basis for evaluation. This task is to identify candidate acoustic data; to assess their utility as a function of experiment geometry and parameters, as well as concurrently collected environmental data; and to summarize them to provide model evaluators with an easily accessible but concise and complete description of relevant data sets.

(U) Literally hundreds of propagation loss experiments have been conducted over the past 40 years. Three major bibliographies of reported measurements [1, 2, 3] have been reviewed in the process of selecting the data sets described in this report. The Navy Data Bank (NAVDAB) [1] developed a concise description of acoustic data sets and selected specific sets for digitization and implementation into a computerized software system. These data come principally from NAVSEA supported experiments (See Appendix 1A). Most Navy laboratories have the systems on their computers and have added data sets of local interest. The official version of NAVDAB resides at the Naval Ocean Systems Center (NOSC), San Diego. The SEAS (Surveillance Environmental Acoustic Support) project, formerly LRAPP, has developed a separate data bank for results of exercises described in reference [2] (See Appendix 1B.). On request to the SEAS project manager, data taken in a particular exercise can be installed in the data bank (if not already available) and accessed by analysts. These data are typically low frequency, <500 Hz, taken in deep ocean basins. The Acoustic Reference Service of OMIS (Oceanographic Management Information System) [3] contains a listing of hundreds of experiments and their measurement parameters as obtained from laboratory reports and open and classified journals. Appendix 1C is a partial listing of experiment names only from OMIS.

(U) In selecting data, the evaluation process [Reference 4], as well as the characteristics of models to be evaluated (initially FACT and RAYMODE [5, 6] were reviewed to identify ranges of parameters treated by the models. Basically, the models purported to treat such a large range of conditions that practically any reported data set would be appropriate for use. Therefore, the problem reduced to selecting data sets which, together, provided a wide range of parameters (e.g., frequency, range, deep water, shallow water, surface ducts, bottom interaction, environmental conditions, etc.), were reasonably accessible, had adequate data density, and had accuracies which could be assessed.

Approach (U)

(U) Scientists were selected who had long experience as participants in field experiments to assist with the data set selections and summarizations. The four who performed the actual work are identified as preparers of this report and in the appendices with the data set each summarized.

(U) Data sets were identified, reviewed, and assessed by each participant in association with R. Martin. Once it was agreed that it warranted summarization as a range independent data set, the scientist assigned conducted the summarization and submitted it. Each data set was assessed on the basis of:

- Accessibility of the processed data
- Adequate concurrent environmental support data to assess the range independent environment assumption
- The prevailing environmental conditions (e.g., sound velocity profile type, bottom depth)
- The source and receiver geometry and operating parameters, frequency, type of propagation (CZ, BB, etc.)
- Acceptable navigation accuracy
- Data density

Summarization includes:

- Exercise description
- Exercise acoustic parameters
- Processing and analysis parameters and description
- Navigational system description
- Exercise environmental measurements listing and synopsis
- Location of processed data
- Plots, graphs and/or tabulations of relevant environmental data
- Plots of all propagation loss curves recommended for use in evaluations
- References

(U) Assessment of data quality depended on information contained in the reports, personal experiences and, at times, discussions with exercise personnel. Reports typically described the calibration procedures (source and receiver), source levels used for explosives, tow depth determination methods and navigation techniques used. From personal experience and specific analyses [7], for example, it is known that acoustic travel time multiplied by appropriate group velocity estimates yield by far the best estimate of range of any techniques in general use. Detonation depth variability impact on source band level variability for SUS (signals, underwater sound) which are pressure detonated and contain a 1.8 lb TNT charge is well known [8]. These charges may detonate at ± 10% of selected depth and result in as much as 2 dB error in 1/3 octave band levels. Also different experimenters often used different estimates of source level; recently the estimates given in Reference [8] have been generally accepted and, where possible, the difference between level used and those of Reference [8] are identified. Analyses of bubble pulses [9] show that detonation depths are typically within ±10% of design. Other methods used include fuse cut to length and charges floated from the surface. Finally it is noted that towed CW sources might vary in depth with maneuvers and sea state, but this typically has little or no impact on source level and is sensitive to source receiver geometry only near strong changes in sound velocity with depth.

Overview of Data Sets (U)

(U) Table 1 lists exercise parameters of Appendices 2 thru 13. It is noted that receiver depths span the entire water column while source depths are typically relatively close to the surface; ATOE (1220 m) and GOA (1067 m) are exceptions. Frequencies range from 0.025 kHz to 5.0 kHz and both CW and explosive sources are used. Ranges are as long as 500 nm and navigation typically involves the use of absolute acoustic travel times. Also a wide range of propagation types, both as isolated and as composite phenomena, were obtained reflecting a considerable range of sound velocity, bottom depths and source receiver geometries.

(U) Figure 1 displays the location of each of the exercises together with a characterization of the experiment track. Other exercises are also identified in this figure, some of which will be summarized in a follow-on effort for evaluation of range dependent models. Some of the exercises (e.g., BEARING STAKE, SUDS) summarized as range independent had some events which displayed range dependent environments; these events also will be considered for the follow-on report. Many other exercises listed in Appendices 1A through 1C, would have been suitable for model evaluation, but it was not possible to make a complete assessment of all of them for this purpose; nor would it have been practicable to summarize many more than included in this report from the point of view of that effort per se and because the model evaluation process itself is labor intensive and can only cope with relatively little of what's available.

(U) Some experiments were reviewed but not used. JAGUAR-Argentina, for example, has anomalously shaped propagation loss curves which were patently inexplicable with respect to the reported environment. TRANSLANT IV was a source-depth dependence propagation study of extremely low data density with range. With respect to AMOS, adequate reported information in sufficient detail as to be useful in the evaluation process could not be located [10]. Many other data sets dealt principally with reverberation or noise and may be useful if models of that type are evaluated.

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[1] NAVSEA Ocean Environmental Acoustic Data Bank, SEA-06H1/036 - EVA/MOST #2-#6, 1 Jan 1976.

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[4] A Methodology for Comparison of Models for Sonar System Applications, Vol. 1 of 9 Dec 1976, NAVSEA Report SEA 06H1/036 - EVA/MOST 10.

[5] The FACT Model, Vol. 1, C.W. Spofford, Maury Center Report 109, Nov 1974.

[6] Criteria for Propagation Loss Model Assessment for APP Application, Gustave P. Leibiger, NUSC Tech Memo 771245 of 7 Dec 1977.

[7] PARKA II-A Range Determination, Nai Yen, NUSC Tech Memo TA 11-98-75.

[8] Source Levels of Shallow Underwater Explosives, J.B. Gaspin and V.K. Shuler, Naval Ordinance Lab (NSWC) Report 71-160 of 13 Oct 1971.

[9] Analysis of the Distribution of Measured Bubble Pulse Periods of Explosive Sources, R.J. Hecht, OCEANS '78 Proceedings of Fourth Annual Combined Conference of MTS and IEEE, 6-8 Sep 1978.

[10] Data Summarization for Propagation Loss Model Evaluation (U), Analysis and Technology, Inc., Report #P-826-01-80 dtd 17 July 1980. Prepared by F. Friedel and R. Bessette. CONFIDENTIAL

(U) Table 1. Summary of Range Independent Data Set Parameters

App. #	Exercise	Source Type	Source Depths (m)	Rcvr Depths (m)	Analyzed Frequencies (kHz)	Ranges (nm)	Range Determ.	Bottom Interaction	Type Propagation
2	SUDS	CW Pulses	45	4 to 180	0.4,1.0,1.5 2.5,3.5,5.0	0-18	Radio Tone	No	SD,CD
3	Gulf of Alaska	CW Pulses	30.5,305, 1067	15-305	1.5,2.5	0-21	Absolute Time Diff.	No	CZ
4	FASOR	CW Pulses	6.1,23	37	1.5	0-13	X-ponder Travel Time	Yes	DP,BB,S.W,SD
5	LORAD	CW Pulses	15,34, 47,55	30,90 300	0.53,1.03	0-240	Radio Tone	Yes	DP,BB,CZ
6	PARKA II	TNT	18,152	91,760 3290	0.025,0.050,0.100 0.180,0.400	0-500	Radio Tone	Yes	DP,BB,CZ
7	MED Sound Xmssn (HAYES & MURPHY)	TNT	24,99	107,137, 305	0.035,0.0675, 0.1,0.2	0-240	Radio Tone	Yes	DP,BB,CZ
8	BEARING STAKE	CW TNT	18,91, 18,91,244	400,1900, 500,1700, 3300 On Bottom	0.14,0.29,0.025, 0.039,0.02,0.05, 0.125,0.140,0.3, 0.315,0.5	0-182	SATNAV Dead Reck.	Yes	DP,BB
9	IOMEDEX	CW	152	137,613 1116,2377, 2650	0.125	8-138	SATNAV Dead Reck.	Yes	DP,RSR,BB
10	JOAST III	CW Pulses	6	18-160	3.0 to 3.9	36-55	Radio Tone	No	CZ
11	JOAST IV	TNT	91,244	18,106, 244	0.025-1.0 1/3 Oct	5-300	Radio Tone	Yes	SC,RSR,BB
12	ATOE	TNT	1220	1265,1417	0.025,0.05, 0.1,0.2,0.4, 0.8,1.6	25-400	SATNAV Dead Reck.	No	SC
13	JAGUAR	CW TNT	18	20,40	1.6,2.6, 0.1 to 5.0 1/3 Oct	0-28	Radio Tone Radar	Yes	SW

Legend:
SD Surface Duct
CD Cross Duct
CZ Convergence Zone or RSR
DP Direct Path
BB Bottom Bounce
SW Shallow Water
SC Sofar Channel
RSR Deep Refracted Surf. Reflected

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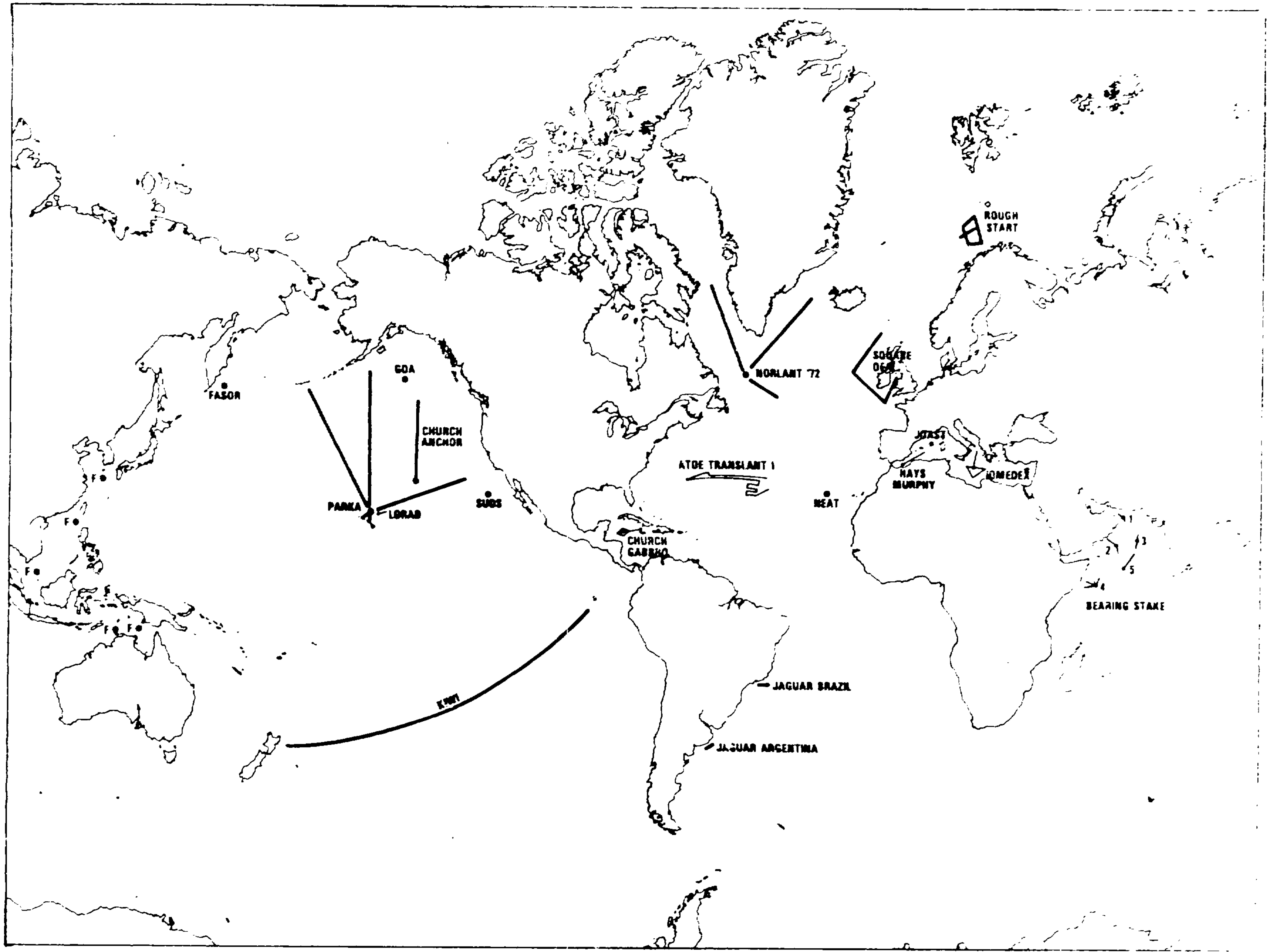

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(U) Figure 1. Exercise location

Appendix 1. (U) Partial Listing of Candidate Data Sets

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APPENDIX 1A

NAVDAB DATA BASE SUMMARY
(03/23/77)

DATA BASE NAME: OFFICIAL NAVDAB
DATE OF LAST UPDATE: 03/23/77
TEXT AVAILABLE SECTOR: 45507

NAVDAB EXP. NO.	EXPERIMENT NAME	NO. OF CRUISES	NO. OF STATIONS	NO. OF ACO. RUNS	NO. OF ENV. RUNS	SIZE (IN WORDS)	PERCENT OF TOTAL
1	FASOR I	1	19	252	698	69888	5.5
2	FASOR II	1	29	391	368	55356	4.3
3	AMOS	9	161	8065	2756	617008	48.4
4	LORAD, HAWAII	1	1	17	3	5544	.4
5	LORAD, ALASKA	1	2	2	23	3304	.3
6	JOAST III	1	5	127	141	121212	9.5
7	JOAST IV	1	3	24	18	7112	.6
8	FASOR III	1	34	603	413	87528	6.9
9	GULF OF ALASKA	1	1	37	53	36288	2.8
10	SUDS I	1	4	34	492	159712	12.5
11	WHOI MED. EXP. 1968	1	1	2	2	5096	.4
12	SQUARE DEAL (AMB. NOISE)	1	6	48	32	11144	.9
13	TASMAN TWO	1	6	6	69	9044	.7
14	DREA SCATTERING	12	285	489	305	61012	4.8
300	NUC OFF SAN DIEGO	5	10	116	14	12096	.9
301	WESTFALL SEAMOUNT	4	6	122	15	12824	1.0
	TOTALS	42	573	10335	5402	1274168	100.0

	SIZE (IN WORDS)	PERCENT OF TOTAL
NON-DELETED RECORDS SIZE:	1274168	100.0
DELETED RECORDS SIZE	0	.0
TOTAL DATA BASE SIZE:	1274168	100.0

APPENDIX 1B

LISTING OF SEAS SPONSORED EXERCISES 1968-1977

PARKA I, II-A & II-B

NEAT I & II

TESTBED

INTEGRATED MEDITERRANEAN PROGRAM (IMP)

IOMEDEX

TRANSLANT I, II, III, & IV

SURFACE-DUCT SONAR MEASUREMENTS (SUDS)

NORLANT '72

EASTLANT II

TASSRAP

BAJA I & II

BERMUDA NOISE

CHURCH GABBRO

BLAKE TEST

SQUARE DEAL/RIDGE ACOUSTICS

CHURCH ANCHOR

RIMPAC '73

MSS BASELINE TEST

MEDITERRANEAN AUGMENTATION PROGRAM - TASKS I - V & TASK IV EXTENDEX

CAPER

WESTLANT '74

CHURCH OPAL/KENT BEACON

CHURCH STROKE

APPENDIX 1C

PARTIAL LISTING OF 195 EXERCISES WITH PARAMETER SUMMARIZATION IN OMIS ACOUSTIC REFERENCE SERVICE

72 GMEX
73 GRAVEL 67
74 GRAVEL 68
75 GULF
76 HAWAII
77 HIAWATHA
78 IMP
79 IOMEDEX
80 IXWEX
81 II-2
82 13-4
83 I.O.
84 JAGUAR ARGENTINA
85 JAGUAR BRAZIL
86 JAPN
87 JASA V60 N2
88 JOAST IV
89 KAMA
90 KOK
91 LAMBDA ARRAY FIELD TRIAL
92 LAPE
93 LOLA
94 LORAD
95 LORAD ALASKA
96 MED
97 MED ASW I
98 MED ASW IV
99 MED ASW IV ENTENDEX
100 MED ASW V
101 MEDEA
102 MEDL
103 MEDWIN
104 MESS
105 MICHAEL
106 MILOCSURVNORLANT
107 MINOX 3
108 MIZPAC 71
109 MODE
110 MOSES
111 MOVORD 001
112 MSS BASELINE
113 MSS FVT
114 NA-1
115 NEAT
116 NEAT I
117 NEAT II
118 NEPTUNE
119 NORL
120 NORLANT 72
121 NP07
122 NPSA
123 NP-9
124 NUC OFF SAN DIEGO
125 OCEAN ACRE
126 OKHK
127 OPEX I
128 PARKA II A

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Appendix 2. (U) SUDS (Surface Duct Sonar Measurements)

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APPENDIX 2

SURFACE DUCT SONAR MEASUREMENTS (SUDS)

Summarized by Kenneth V. Mackenzie

RATIONALE

The purpose of this report is to recommend to model evaluators data sets suitable for evaluating FACT and RAYMODE X models. Two limitations of these models are requirements of a single range-independent sound speed profile and a flat bottom.

Initial efforts are directed toward selecting optimum sets of data in NAVDAB to test model accuracy, because NAVDAB exists at NUSC and contains quality acoustic data sets with sufficient supporting environmental data.

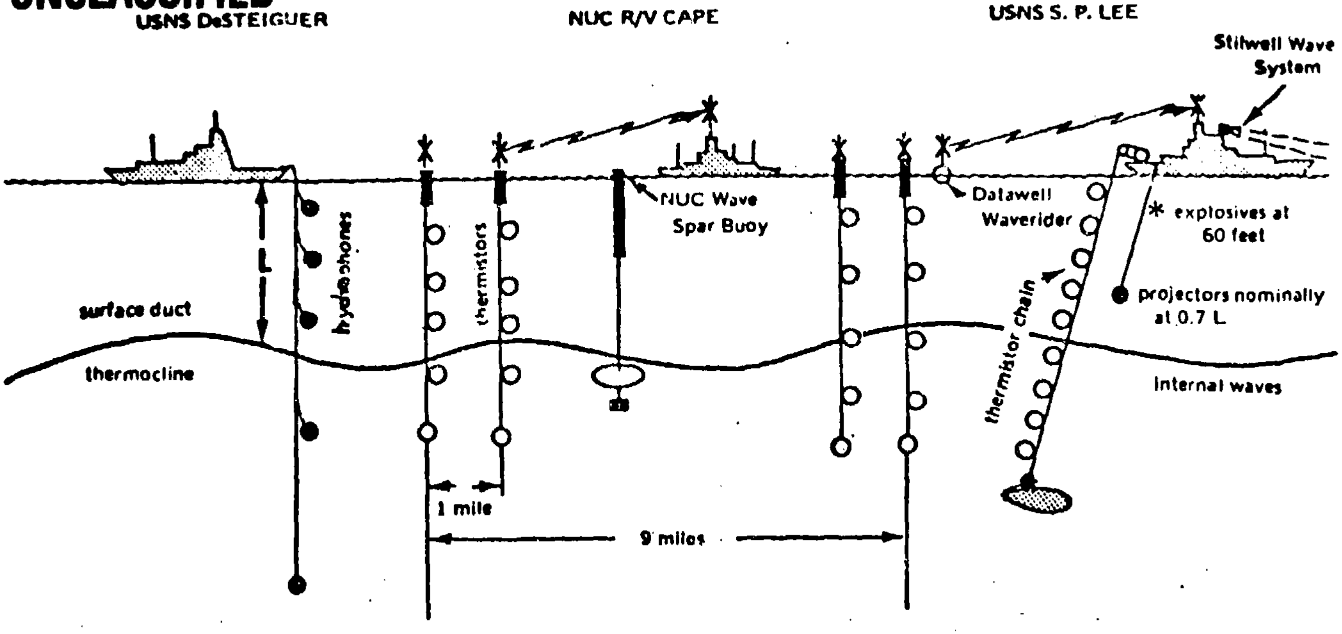
The Naval Undersea Center, San Diego, conducted a series of 18 surface duct propagation loss experiments in three deepwater areas, at four acoustic stations off the west coast of Southern California from 9 to 24 February 1972, during the program known as SUrface Duct Sonar Measurements (SUDS 1).

Of the 18 acoustic runs, eight were selected that met the criteria for a profile sufficiently range-independent to evaluate the simplistic FACT and RAYMODE X models (see Table 1).

Complete information is published in NUC TP-463, 464, and 465 totalling 979 pages. The present report is a stand-alone synopsis with a number of errors/inconsistencies corrected.

SUDS 1 EXPERIMENT

A chief feature of SUDS was the copious sampling of the oceanographic environment. The experiment utilized three ships to obtain both acoustical and supporting environmental data simultaneously. Each of the 18 runs produced approximately 4000 data points per channel per frequency or about 40,000 data points per run. Figure 1 illustrates deployment of the ships and sensors.



USNS DeSTEIGUER

Records acoustic signals received by 5 hydrophones at depths of 20 feet and 0.4L, 0.8L, 1.3L, and 2.0L, where L is layer depth.

Nansen casts, STD-SV, XBT's.

NUC R/V CAPE

Records data telemetered from 10 thermistor buoys spaced 1 mile apart.

NUC Wave Spar Buoy, XBT's.

USNS S. P. LEE

Tows thermistor chain and projectors at depths of 20 to 200 feet, with frequencies of 0.4, 1.0, 1.5, 2.5, 3.5, and 5.0 kHz.

MK-61 SUS charges at 60 feet, Datawell Waverider System, Stilwell Wave System, Nansen casts, STD-SV, XBT's.

Figure 1. SUDS Experiment.

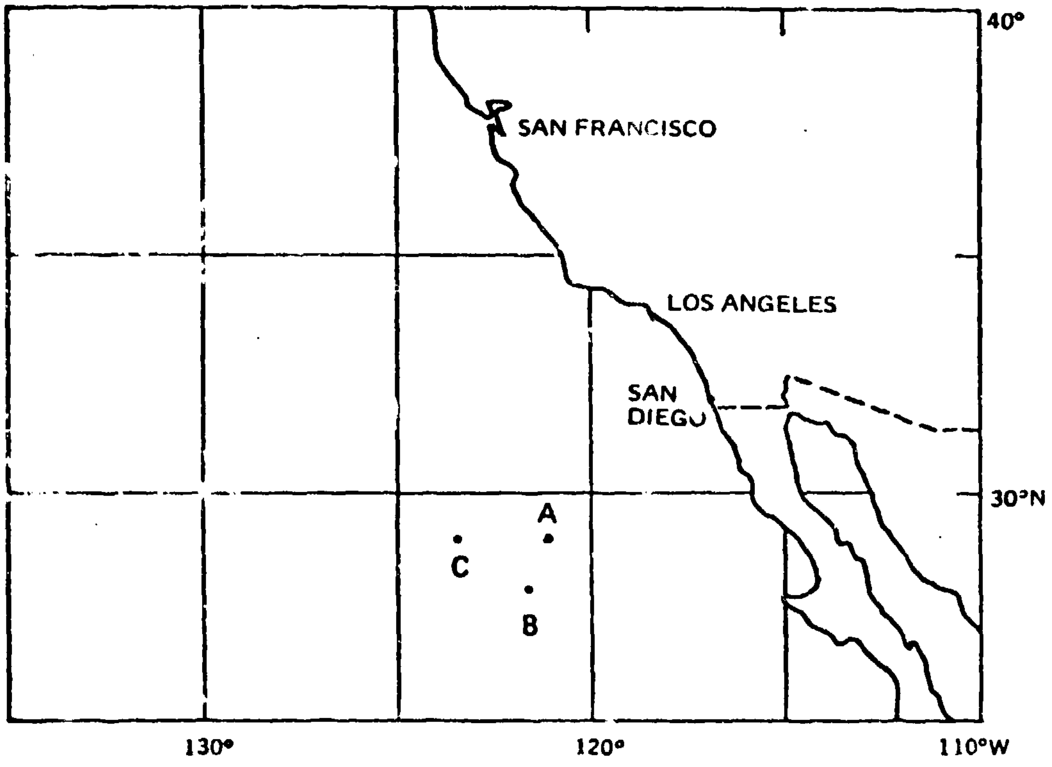


Figure 2. Location of Experimental Areas.

TABLE 1. SUDS I PARAMETERS

Appendix Station Run	A 1 2	B 1 3	C 3 2	D 3 3	E 1 1	F 4 1	G 4 3	H 4 4
Layer depth (m)	68	79	6	11	20	17	0	10
Depressed channel axis (m)	-	-	20	20	200	-	-	-
Max. sound speed depth (m)	68	79	90	79	250	17	0	10
Axis depth (m)	900	900	700	700	900	700	700	700
Source depths (m)	42,45	42,45	42	42	41	43,46	43	43
Receiver depths (m)	4,17,43, 72,112	4,17,43, 72,112	6,37,73, 119,182	6,34,69, 112,173	6,24,59, 98,148	6,36,73, 118,181	6,36,72, 117,180	6,36,72, 117,180
Frequencies (kHz)	0.4,1.0	3.5,5.0	1.5,2.5	0.4,1.0	1.5,2.5	3.5,5.0	1.5,2.5	1.5,2.5
Min. range (kyd)	2.2	0.1	3.9	0.1	0.5	0.1	2.3	2.6
Max. range (kyd)	26.6	27.5	31.4	34.6	27.1	33.3	35.1	33.4

Bottom depth - only non-bottom reflected signals were processed. Model should assume infinite bottom loss.

Navigation - Radio tones to measure acoustic travel times accuracy ±15 m.

Figure 2 defines locations of the experimental areas. Station 1 was conducted in Area A, Station 2 in Area B, and Stations 3 and 4 in Area C. At each acoustic station either four or five propagation loss runs were carried out. Propagation losses in near-surface propagation paths (direct, surface channel, and depressed channel) were measured as a function of range.

Acoustic Measurements

Pulsed CW propagation loss measurements were conducted on 15 of the acoustic runs, and SUS charges were sources for three runs. Three pairs of frequencies were transmitted for each run: three employed 0.4 and 1.0 kHz sources, five 1.5 and 2.5 kHz, and six 3.5 and 5.0 kHz sources, with one run at 1 kHz only.

Source depths were 0.7 of the measured surface layer depth or 15 m whichever was deeper, for 12 runs and 6 m for 3 runs. During each experiment a series of 500 msec pulses, at a 12 sec repetition rate for each frequency, were transmitted as the source ship opened or closed range at 3 knots from the receiver ship.

Transmissions were received on five transducers suspended from the recording ship, which was hove to and drifting. From initial BTS, receiver depths were rigged for 6 m and 0.4, 0.8, 1.3, and 2.0 times the measured surface layer depth.

Surface duct signals were clearly time-separated from 1st and 2nd bottom reflected sound. Propagation runs did not reach the convergence zone, consequently the data sets are for pure surface duct propagation. A large bottom loss can be assumed for evaluations of surface duct components of a particular model. Data were noise-corrected whenever received sound was within 10 dB of the noise. Simultaneous transmission of radio and acoustic pulses enabled range accuracies of ± 15 m.

Details of the eight selected runs and plots of propagation loss vs range are presented in Appendices A through H.

Environmental Measurements

The following oceanographic parameters were measured: temperature, salinity, and sound speed as a function of depth; surface roughness and wind speed as a function of time. Hydrographic casts measured temperature and salinity at discrete depths from the surface to bottom. A Plessey STD/SV profiling system simultaneously measured temperature, salinity, and sound speed as continuous functions of depth from the surface to bottom. A Sippican XBT system obtained temperature as a continuous function of depth from the surface to 450 m. A thermistor chain, consisting of 44 thermistors spaced 5.6 m apart, acquired a vertical temperature profile every 10 sec from the surface to 242 m along the track of the source ship. A Lockheed Teletherm buoy line consisting of 10 buoys tethered 1 nmi apart simultaneously collected 10 temperature profiles at 10 equally spaced depths from the surface to 125 m every 10 sec. Surface roughness was determined by a Datawell Waverider buoy, with supplementary data from a wave staff and stereo photographs of the sea surface. Ship logs recorded wind speed and direction as well as sea state.

Both temporal and spatial variability were encountered; results are discussed in the References. Tables and figures in the appendices supply details to a depth of 1500 meters. For greater depths the profiles were the same for all stations and are presented in Table 2.

Table 2. Sound Speed vs Depth in SUDS Area

Depth (m)	Sound Speed (m/s)
2000	1491.7
2500	1498.9
3000	1506.9
4000	1524.3

Sound speed profiles for the upper 200 meters are plotted in Figure 3. Profiles 3a and b exhibited bi-linear profiles. Profiles 3c and d possessed a shallow surface duct overlaying a weak depressed channel (hereby designated a "pseudo surface duct") which might well have simulated a true surface duct except for the complications of mode-trapping. Profiles 3e and f had a shallow surface duct with the sources below the ducts. Finally 3g indicated a negative gradient, and 3h a negative gradient beneath a shallow surface duct.

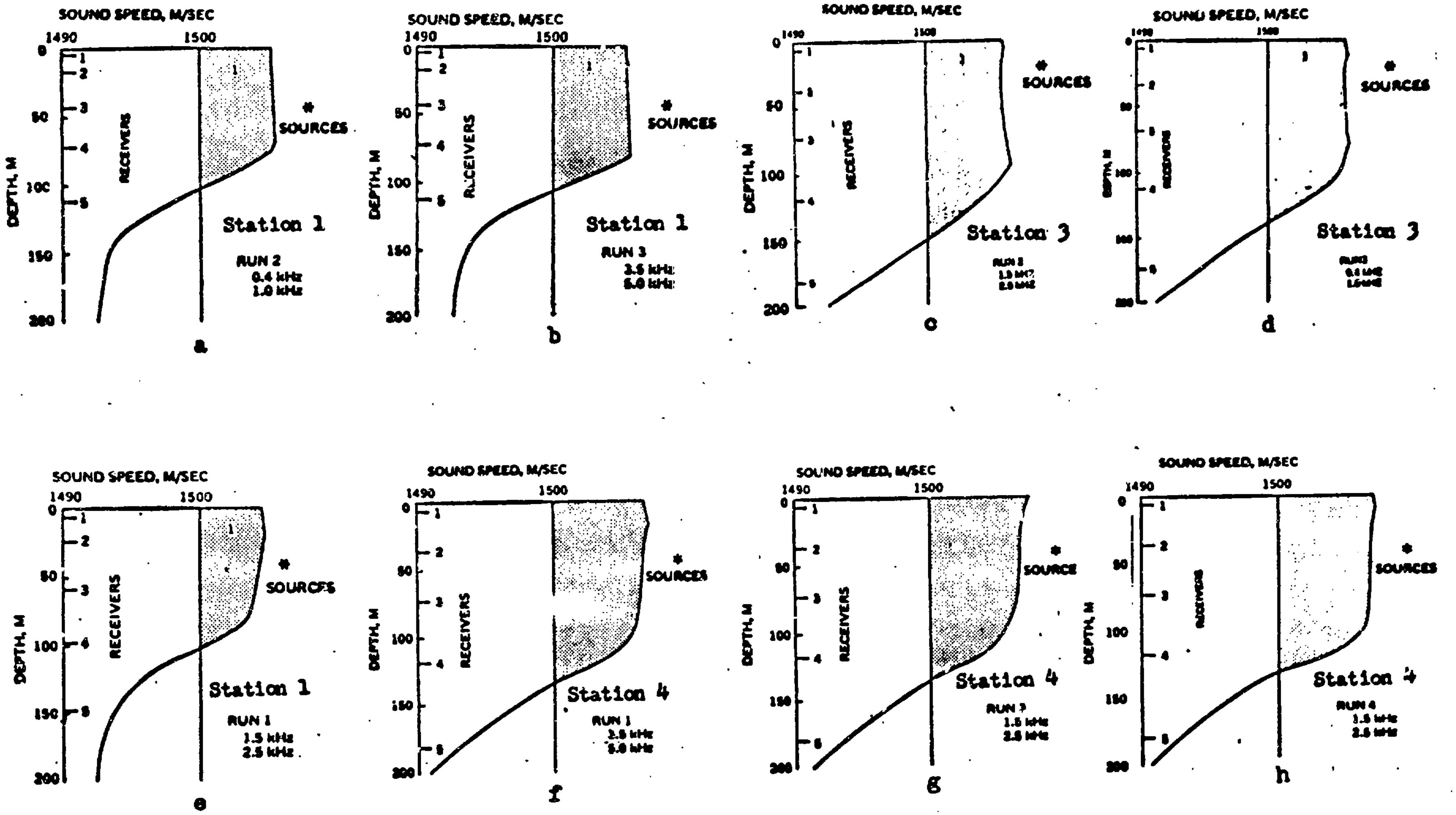


Figure 3. Average Sound Speed Profiles in [illegible] 200 Meters.

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Naval Undersea Center, NUC TP 463, Surface Duct Sonar Measurements (SUDS I - 1972) by E.R. Anderson and M.A. Pederson, November 1976.

APPENDIX A

Station 1, Run 2—11 February 1972 (Closing)

During this run 0.4 and 1.0 kHz propagation losses were detected over acoustic ranges from 2.2 to 26.6 kyd. The plane of the propagation paths was a changing function of time and never coincided with the plane of the source ship measurements. Hence, environmental data gathered by the source ship are not necessarily descriptive of conditions in the propagation path planes.

Average Sound Speed Profile

Individual sound speed profiles reflected the presence of transient surface channels varying in depth from 10 to 80 m, small depressed channels at 20 to 50 m depths, and refractive channels from 190 m to 250 m. No coherent sound speed profile boundaries were apparent.

Figure A-1 is a plot of the average sound speeds listed in Table A-1. Details of the average sound speed distribution in the upper 200 m appear in Figure 3a. No persistent features of importance existed. The data were averaged to obtain a single average sound speed profile applicable to the complete run. The average profile was characterized by a 68 m surface channel and an isospeed layer from 200 to 300 m. Transient depressed channels in the individual profiles are not retained in the average profile. Individual spectra did not indicate a change with time.

During the experiment the source ship reported 10 knot winds, 2 ft waves, and 5 ft swell; the receiver ship 12 knot winds, 1 ft waves, and 3 to 4 ft swell. Sea surface roughness data were obtained by the Waverider buoy for the complete run. Spectral analysis revealed two trains of swell centered at about 11.0 and 15.7 sec wave periods, causing surface roughness associated with the 3 to 5 ft swell reported by both ships. Also present were 1.5 to

2.5 sec wind waves resulting from local 10 to [illegible] knot winds encountered by both ships. Receivers 1, 2, and 3 were in the surface sound channel, receiver 4 was just below the surface channel, and receiver 5 in the thermocline.

AMOS Parameters

The AMOS propagation loss model assumes that sources and receivers are in the same water volume, in which single layers of the AMOS parameters are applicable. Average values of AMOS parameters, derived from the thermistor chain temperature measurements and applicable to the Run 2 experiment, were

isothermal layer depth	223 ft
surface water temperature	58.8°F
sea state	3

Discussion

Propagation loss measurements are plotted in Figures A-2. through A-6. Visual comparison suggests the following:

- A small variability in propagation loss was observed at both frequencies for the receivers in the sound channel and at 0.4 kHz for the two deeper receivers. At 1.0 kHz the two deep receivers displayed a marked change in propagation loss variability at about 8.0 kyd. For greater ranges the pulse-to-pulse propagation loss exhibits a random variability of about ±5 dB.

- A limited maximum range of arrivals was observed at 0.4 kHz. The maximum possible range was 26.6 [illegible] For each receiver all, or the majority of the arrivals were below noise for ranges greater than the following:

4 m	19.7 kyd	72 m	19.0 kyd
17 m	23.8 kyd	112 m	17.1 kyd
43 m	22.0 kyd		

- At 0.4 kHz propagation loss at the 112 m receiver was 10 to 20 dB greater than on the 17 m receiver; at 1.0 kHz for ranges greater than 9.0 kyd, losses on the 112 m receiver were a nominal 25 dB greater.
- At 0.4 kHz the 4 m propagation losses were consistently greater than the other two receivers located in the sound channel. This was not observed at 1.0 kHz.
- At either frequency, little difference in propagation loss was noted for the two receivers below the surface channel.

Table A-1. Station 1, Run 2 (11 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Number of Observations	Average Speed	Standard Deviation
0	1350	1505.29	0.13
10	1350	05.41	0.13
20	1350	05.44	0.16
30	1350	05.46	0.16
50	1350	05.47	0.26
75	1350	05.25	0.57
100	1350	00.61	0.94
125	1350	1495.80	0.50
150	1350	93.38	0.32
200	1350	92.48	0.25
250	1350	92.37	0.19
300	22	92.45	0.72
400	20	89.79	0.90
500	4	87.54	0.68
600	4	85.79	0.75
800	6	83.59	0.29
1000	5	83.54	0.19
1200	5	84.57	0.13
1500	5	86.66	0.09
68		1505.48	SC
900		1483.40	AXIS

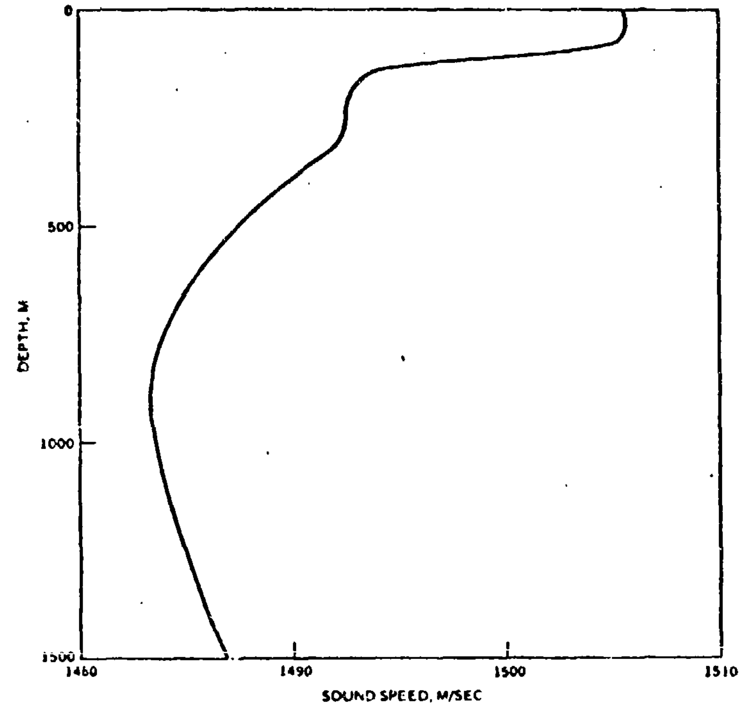
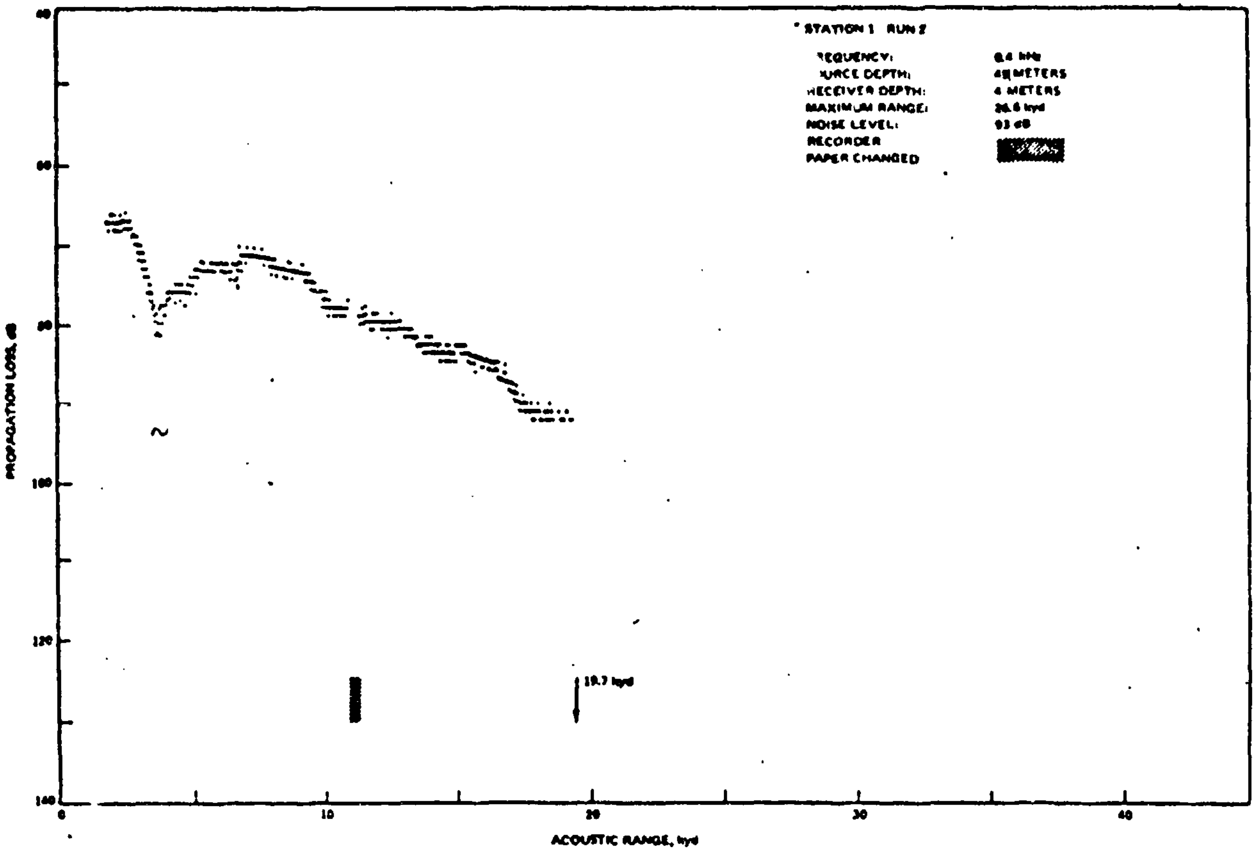


Figure A-1. Station 1, Run 2
Average Sound Speed Profile.


STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 93 dB
RECORDER PAPER CHANGED
19.7 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

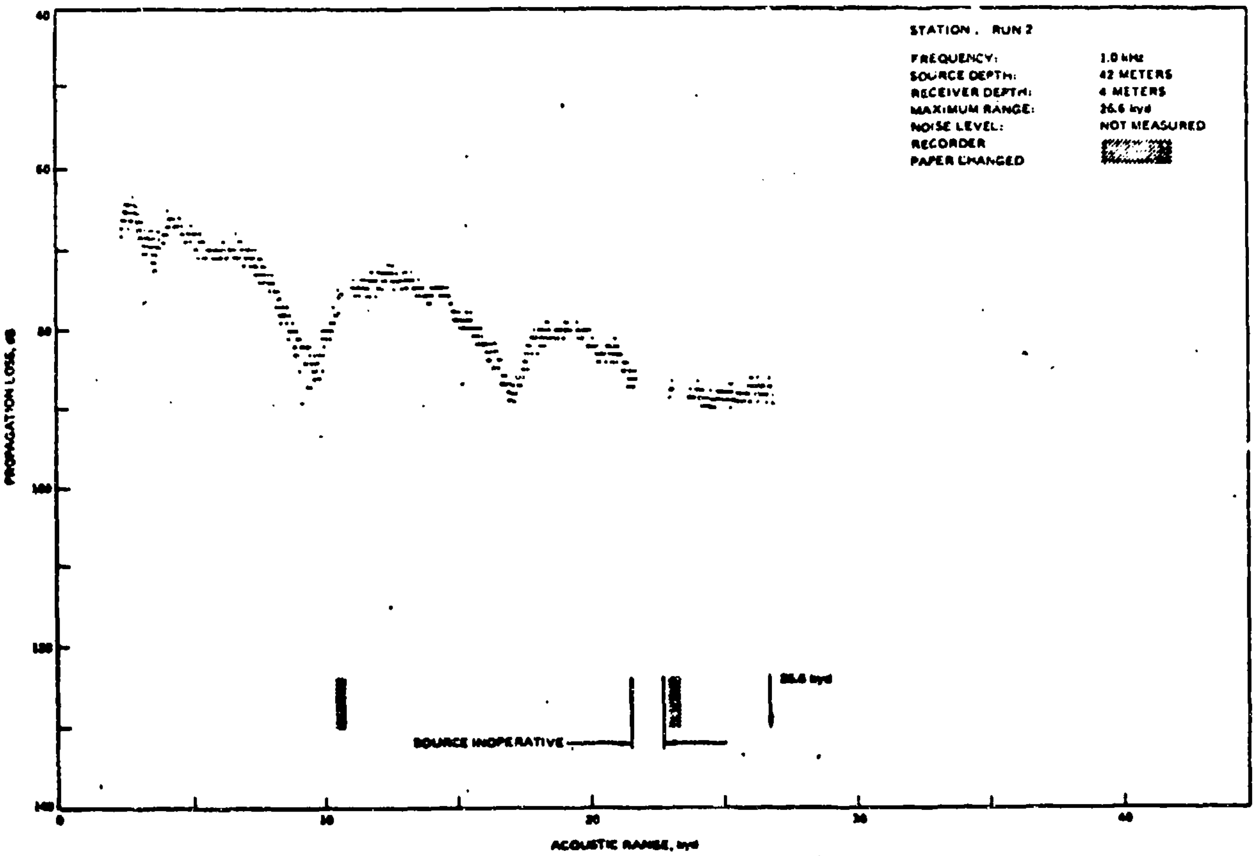

STATION . RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
26.6 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. A-2

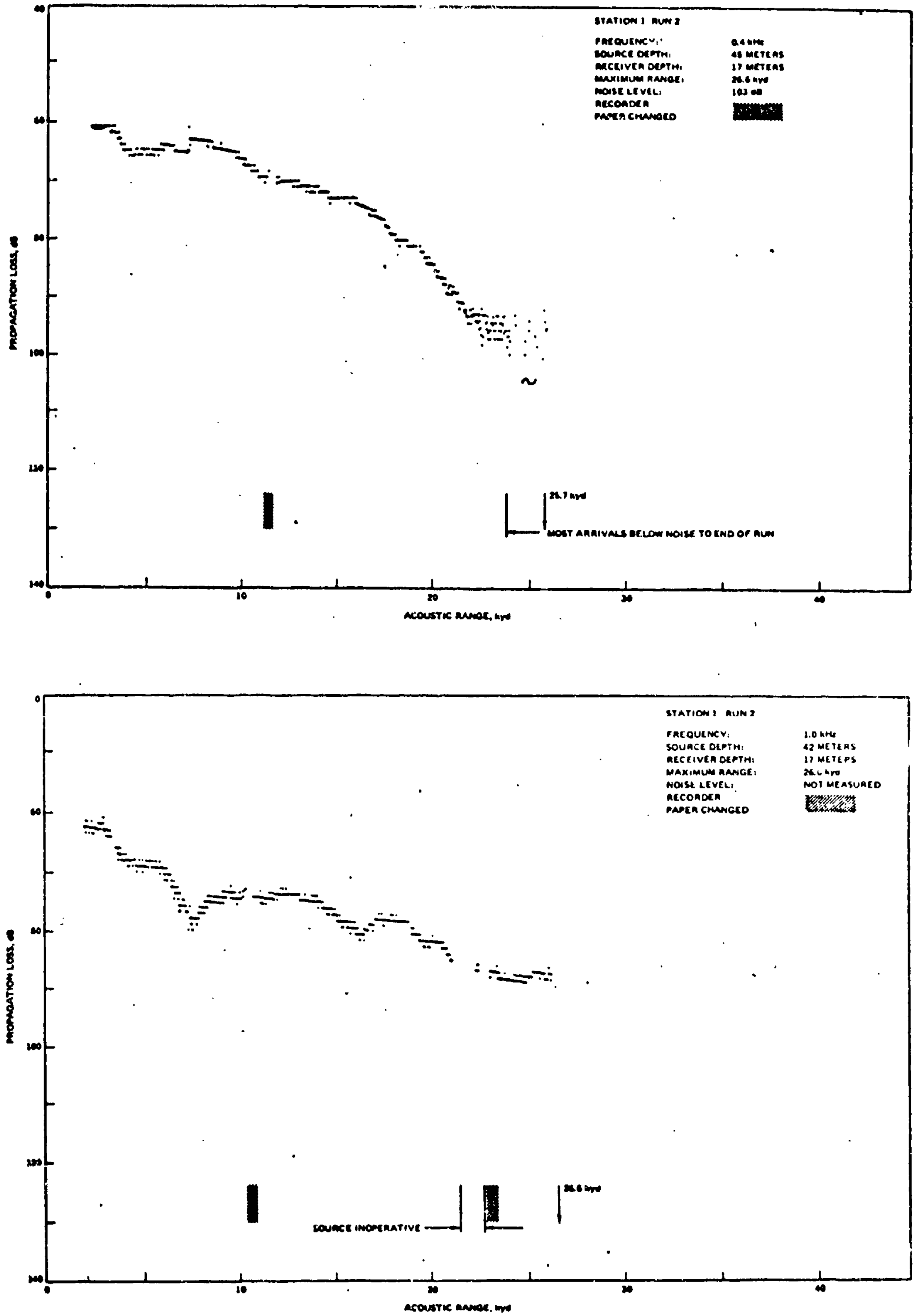

STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 48 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 103 dB
RECORDER PAPER CHANGED ▨
25.7 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 17 METEPS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
26.6 kyd
PROPAGATION LOSS, dB
0
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. A-3

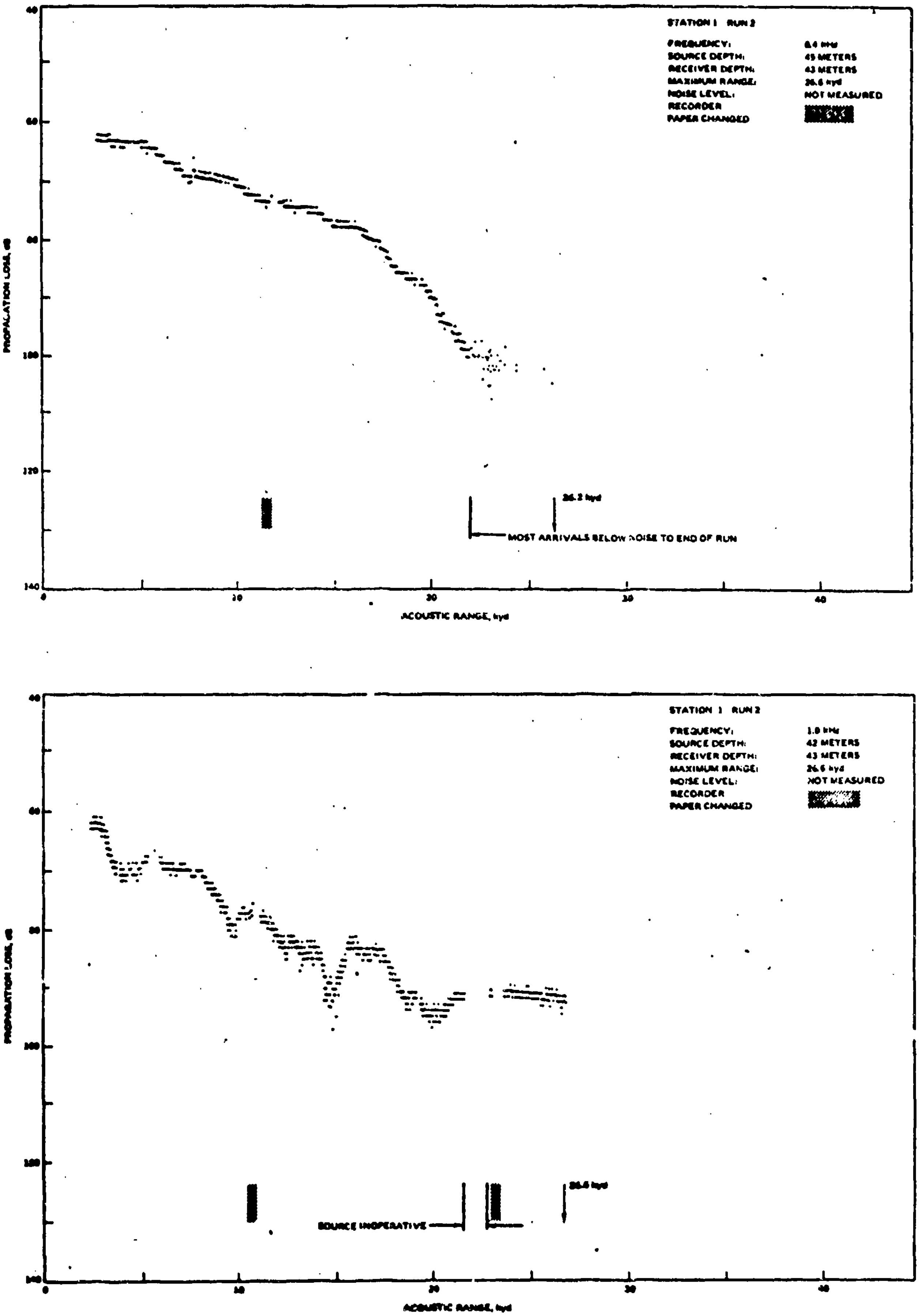

STATION 1 RUN 2
FREQUENCY: 8.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
26.2 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
SOURCE INOPERATIVE
26.6 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. A-4

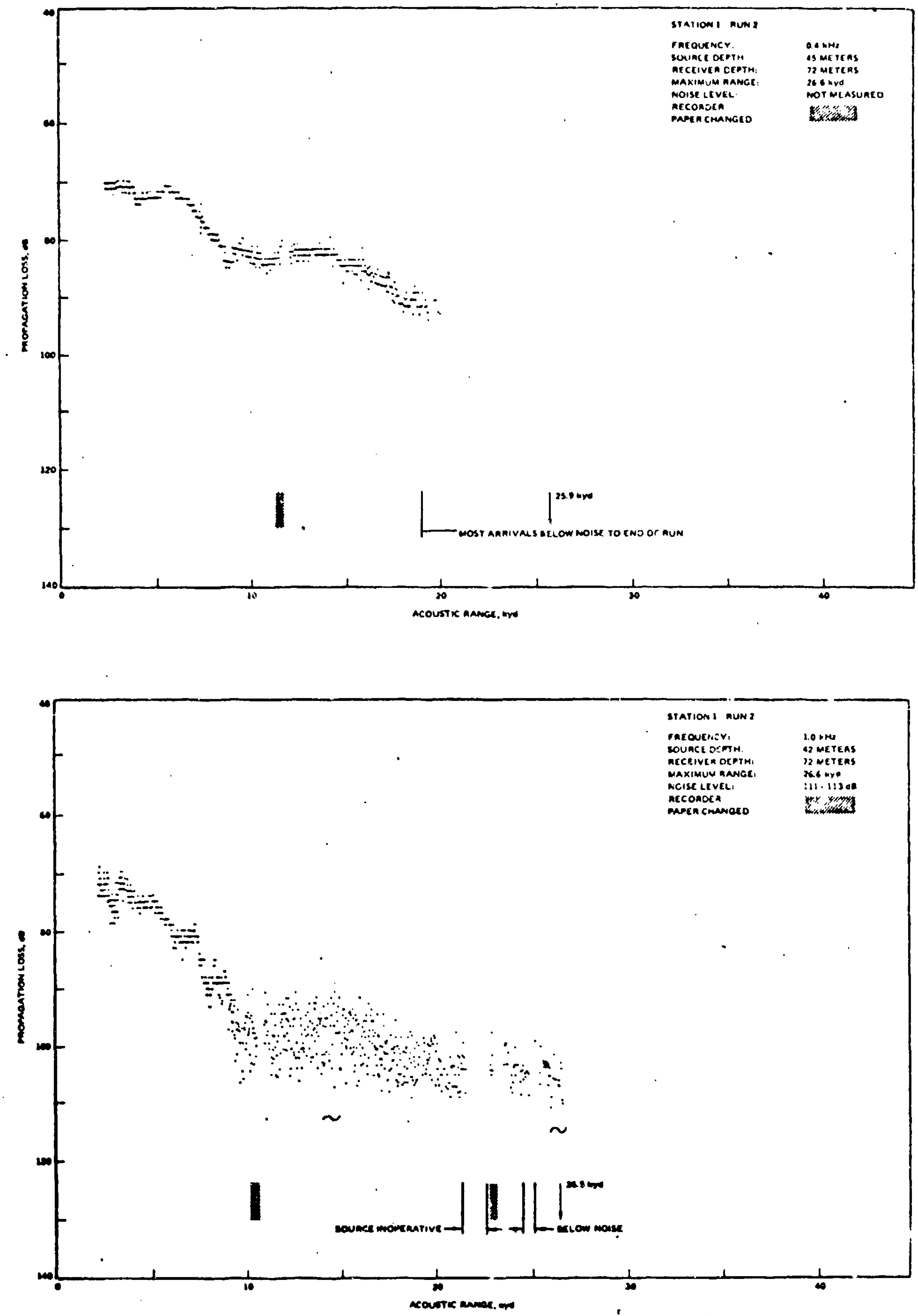

STATION 1 RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
25.9 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 111 - 113 dB
RECORDER PAPER CHANGED
26.5 kyd
SOURCE INOPERATIVE
BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. A-5

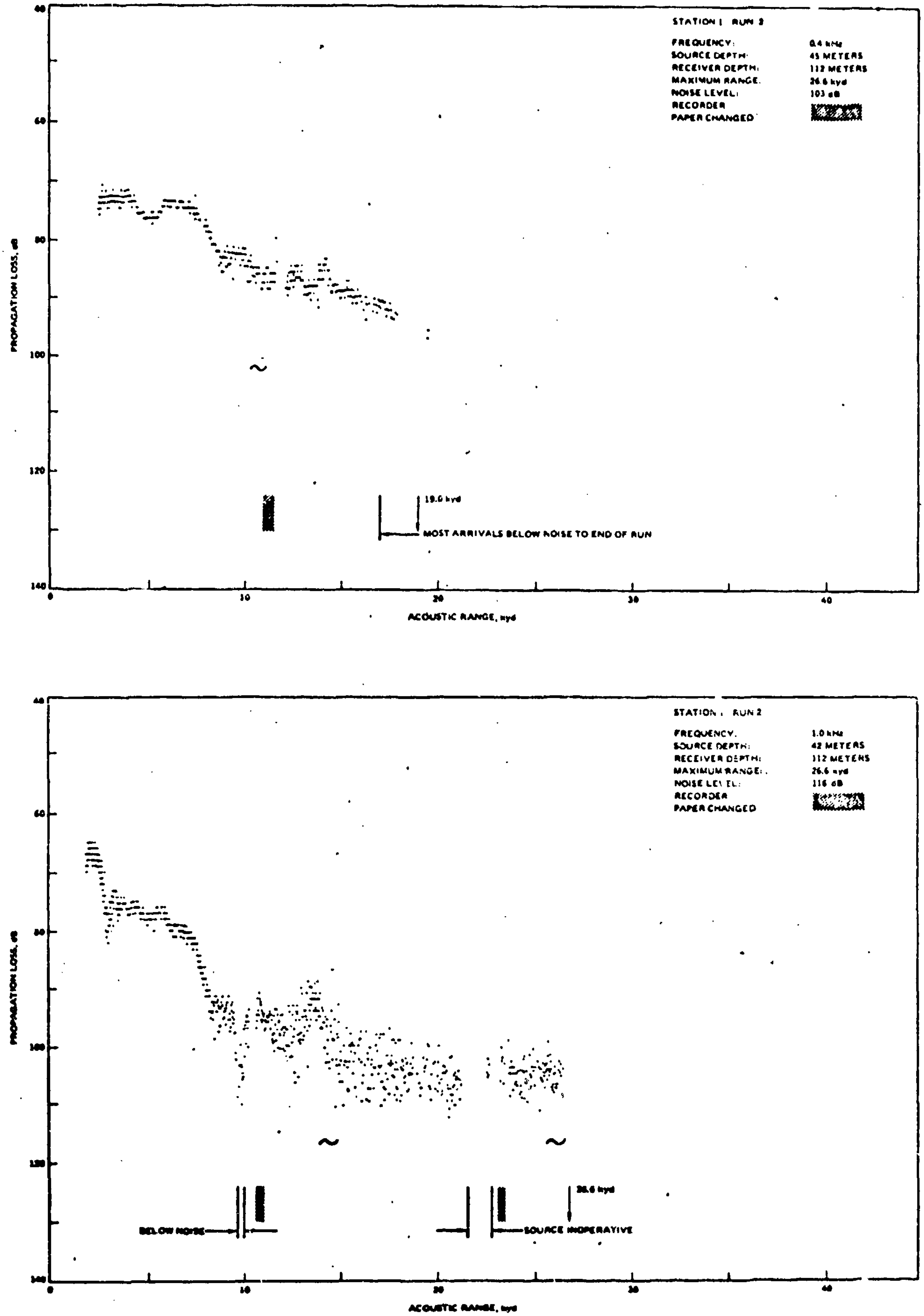

STATION I RUN 2
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 103 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
19.0 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION I RUN 2
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 26.6 kyd
NOISE LEVEL: 116 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
26.6 kyd
BELOW NOISE
SOURCE INOPERATIVE
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. A-6

APPENDIX B

Station 1, Run 3—11 February 1972 (Opening)

During this run, 3.5 and 5.0 kHz propagation losses were measured over acoustic ranges from 53 yd to 27.5 kyd (Figure B-1, Profile 1). The propagation paths coincide closely with the track of the source ship.

Average Sound Speed Profiles

An inspection of profiles in each water volume indicated little horizontal variability in profile shape. Figure 3b is a plot of Profile 1. Both sources and receivers were in a water volume characterized by a 79 m surface channel. Both source and receiver ships reported 4 to 8 knot winds, 1 ft waves and 3 ft swell. Sea surface roughness data were obtained by the Waverider buoy for the complete run. Spectral analysis revealed swell centered at a 9.5 sec wave period. Also present were 1.5 to 3.5 sec wind waves. Most sea surface roughness was associated with the 9.5 sec swell. Receivers 1, 2, 3, and 4 were in the surface sound channel and receiver 5 was in the thermocline.

AMOS Parameters

During this run, sources and receivers were in the same water volume out to the range of 27.5 kyd. Average values of AMOS parameters, derived from the thermistor chain temperature measurements and applicable to the Run 3 experiment include:

isothermal layer depth	259 ft
surface water temperature	58.8^{0}F
sea state	2

Discussion

The propagation loss measurements are plotted in Figures B-2 through B-6. The vertical lines on the individual propagation loss plots indicate the acoustic range from the receivers of the sound speed profile boundary. A visual comparison of these plots suggests the following:

- Disappearance of the 79 m surface channel at an acoustic range of 27.5 kyd exerted no observable effect on the propagation loss measured by the three shallowest receivers.

- For the three shallowest receivers, arrivals were recorded at both frequencies out to the maximum range of the experiment. For the 72 m receiver, most of the arrivals were below noise for ranges greater than 34.8 and 35.7 kyd at 3.5 and 5.0 kHz, respectively. For the 112 m receiver, most arrivals at 3.5 kHz were below noise for ranges between 18.6 and 25.3 kyd and for those greater than 34.6 kyd, with the last arrival being recorded at a range of 38.0 kyd. For the same receiver, all 5.0 kHz arrivals between 32.0 and at a range of 38.0 kyd. For the same receiver, all 5.0 kHz arrivals between 32.0 and 34.5 kyd were below noise, with the last arrival received for a range of 37.0 kyd. Also most arrivals were below noise between 20.8 and 25.6 kyd.

- At both frequencies, little difference was noted in propagation loss for the three shallowest and two deepest receivers. For the two deep receivers, the 3.5 kHz propagation loss for ranges greater than about 12 kyd was 10 to 20 dB greater than the three shallow receivers. At 5.0 kHz, this was also true for ranges greater than about 6.0 kyd.

- At all receiver depths and all ranges, the propagation loss at 5.0 kHz was greater than the propagation loss at 3.5 kHz, as exemplified by the 17 m receiver.

Table B-1. Station 1, Run 3 (11 February 1972)
Average Sound Speed Profile (m/sec).

Depth,	Profile 1 0720–1130		
m	n	$\overline{C}$	σ
0	1503	1505.35	0.16
10	1503	05.38	0.13
20	1503	05.44	0.13
30	1503	05.49	0.16
50	1503	05.50	0.10
75	1503	05.61	0.47
100	1503	01.37	1.62
125	1503	1496.22	0.74
150	1503	93.66	0.28
200	1503	92.73	0.15
250	1503	92.03	0.31
300	21	91.59	0.82
400	19	89.20	0.85
500	4	87.54	0.68
600	4	85.79	0.75
800	6	83.59	0.29
1000	5	83.54	0.13
1200	5	84.57	0.13
1500	5	86.66	0.09
79		1505.63	SC
900		1483.35	AXIS

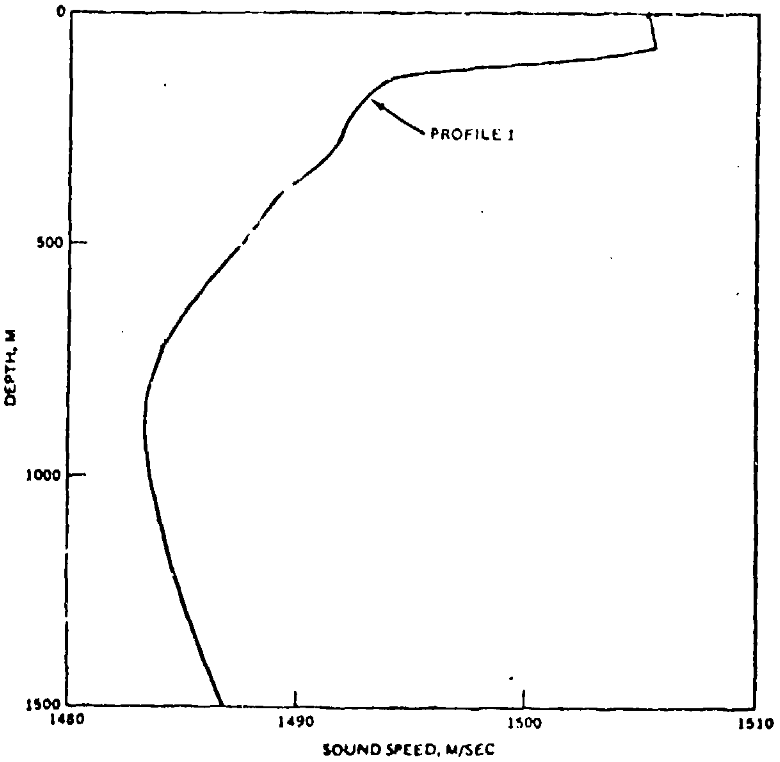
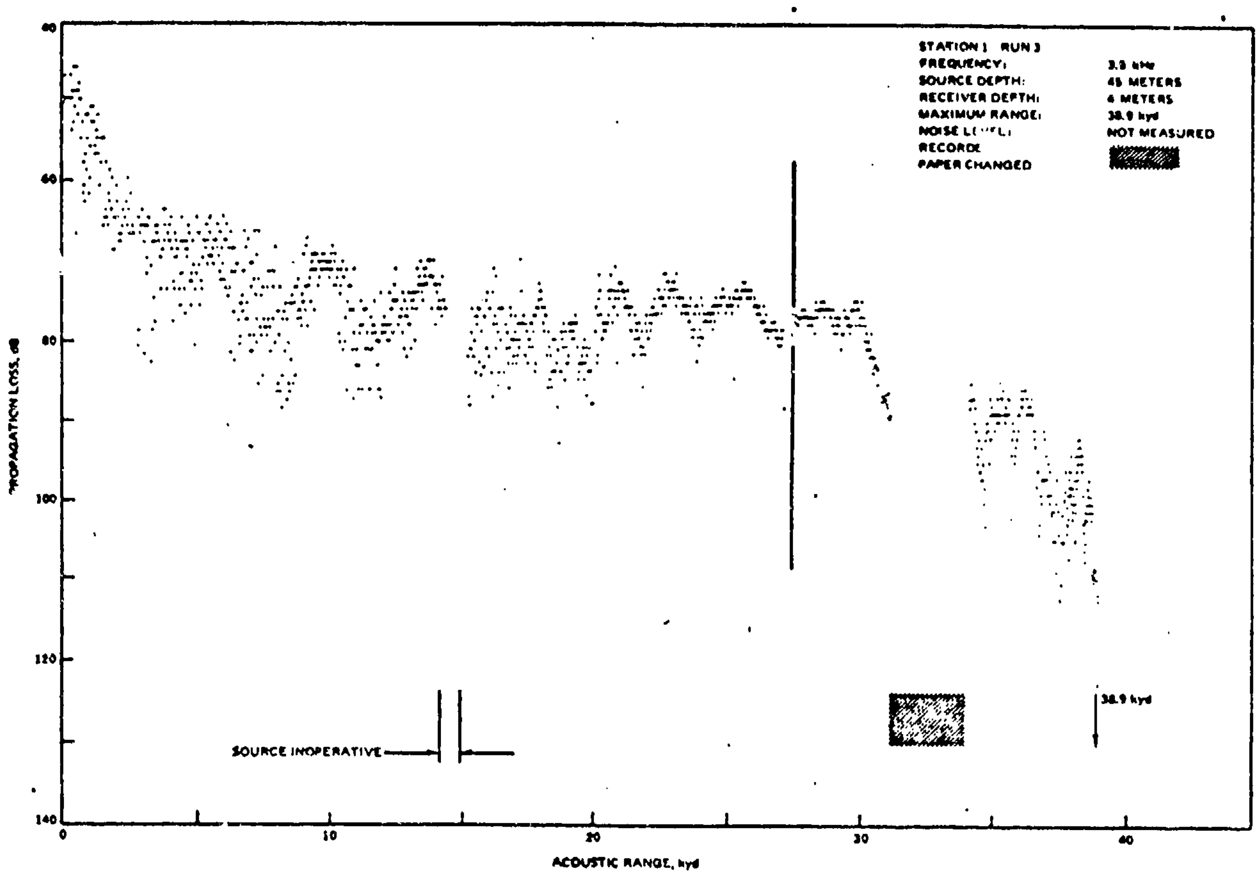


Figure B-1. Station 1, Run 3
Average Sound Speed Profile.


STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

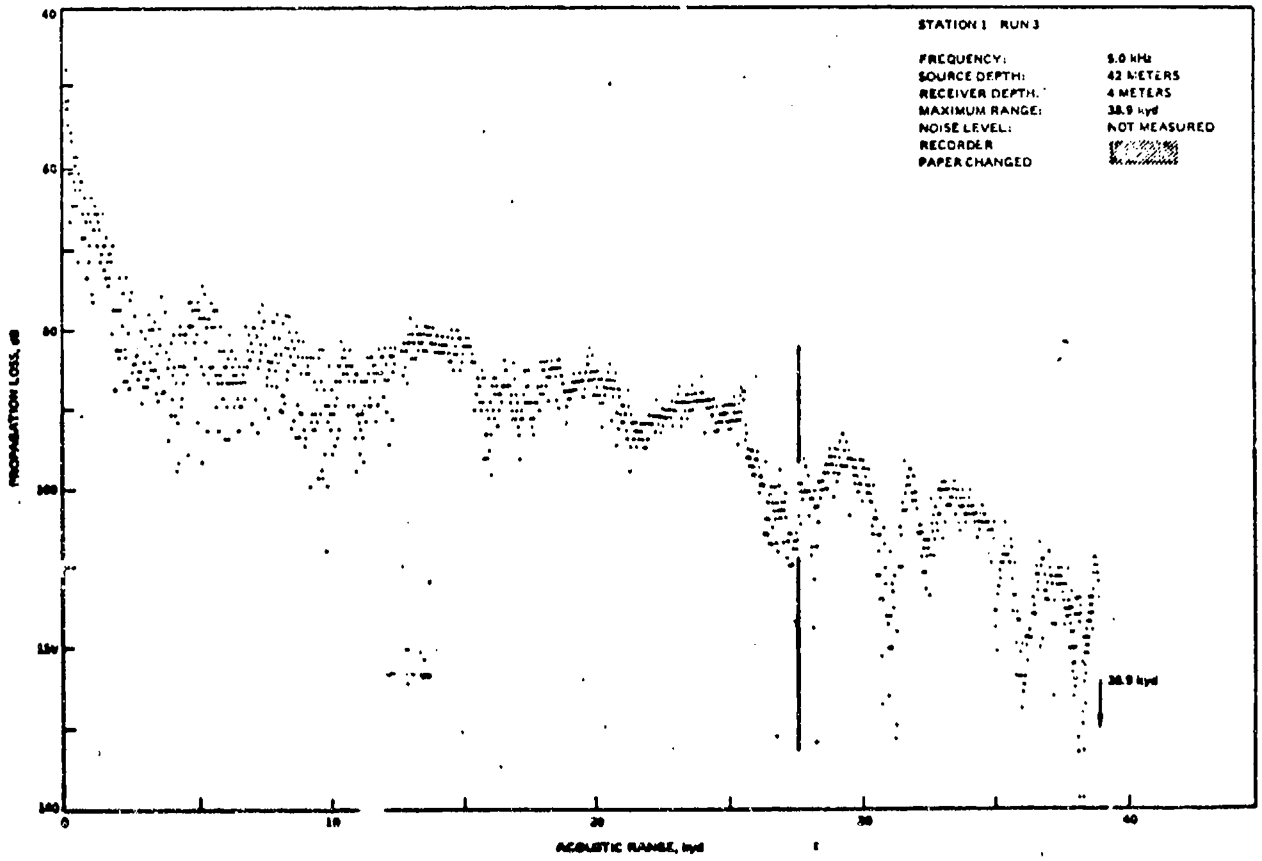

STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-2

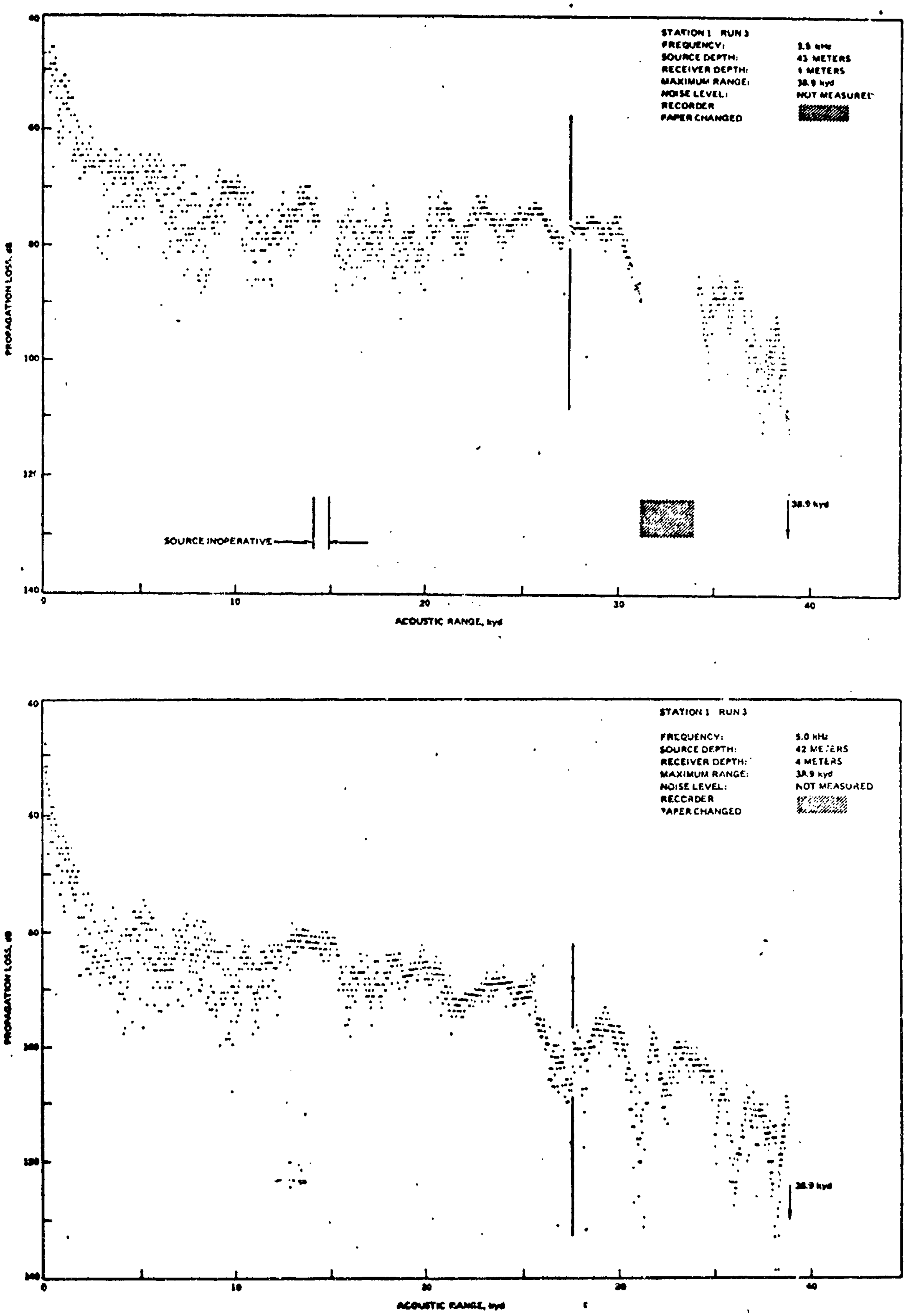

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
SOURCE INOPERATIVE
38.9 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 4 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
38.9 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-2

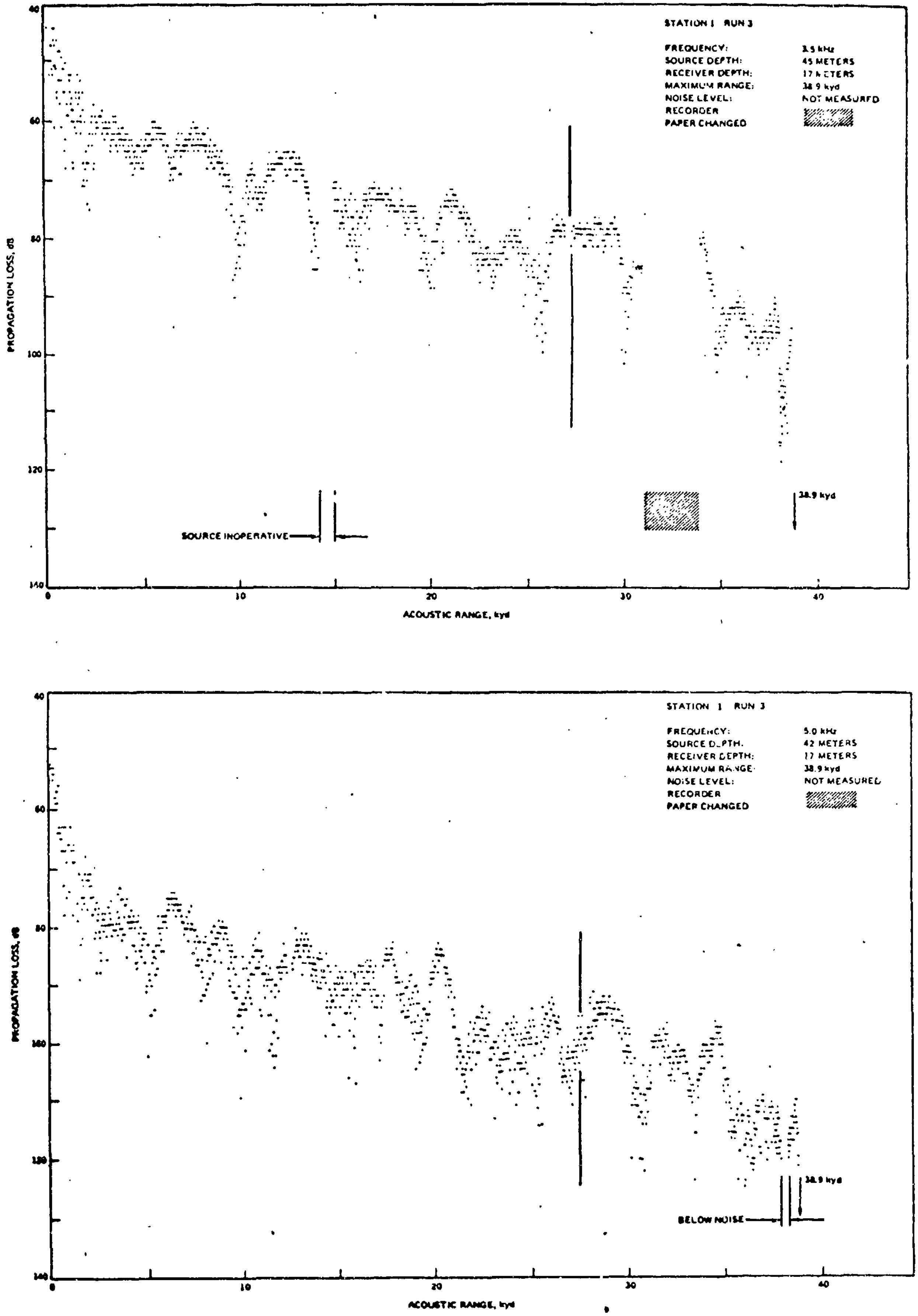

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 17 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
BELOW NOISE
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-3

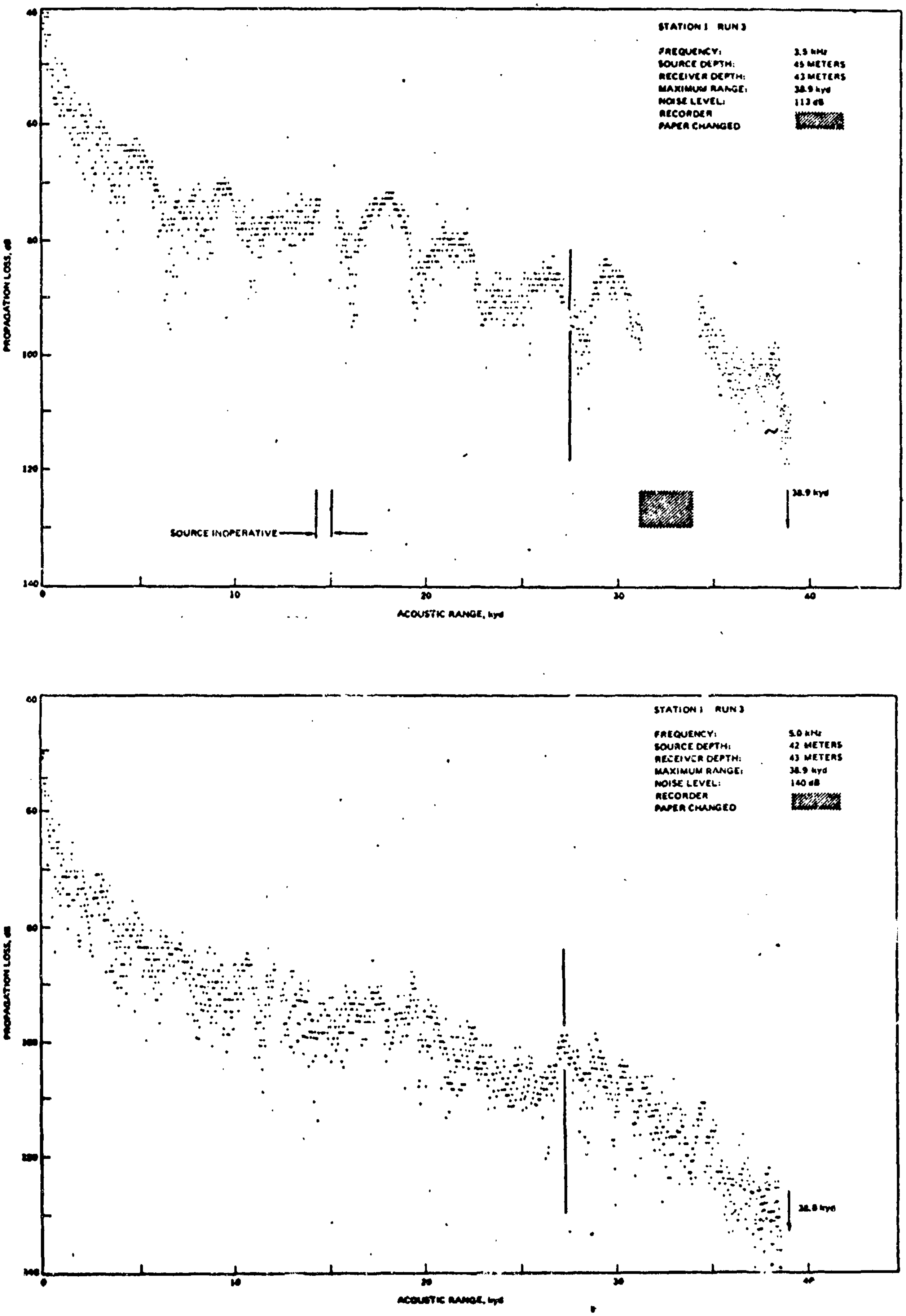

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 113 dB
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 43 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 140 dB
RECORDER PAPER CHANGED ▨
38.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-4

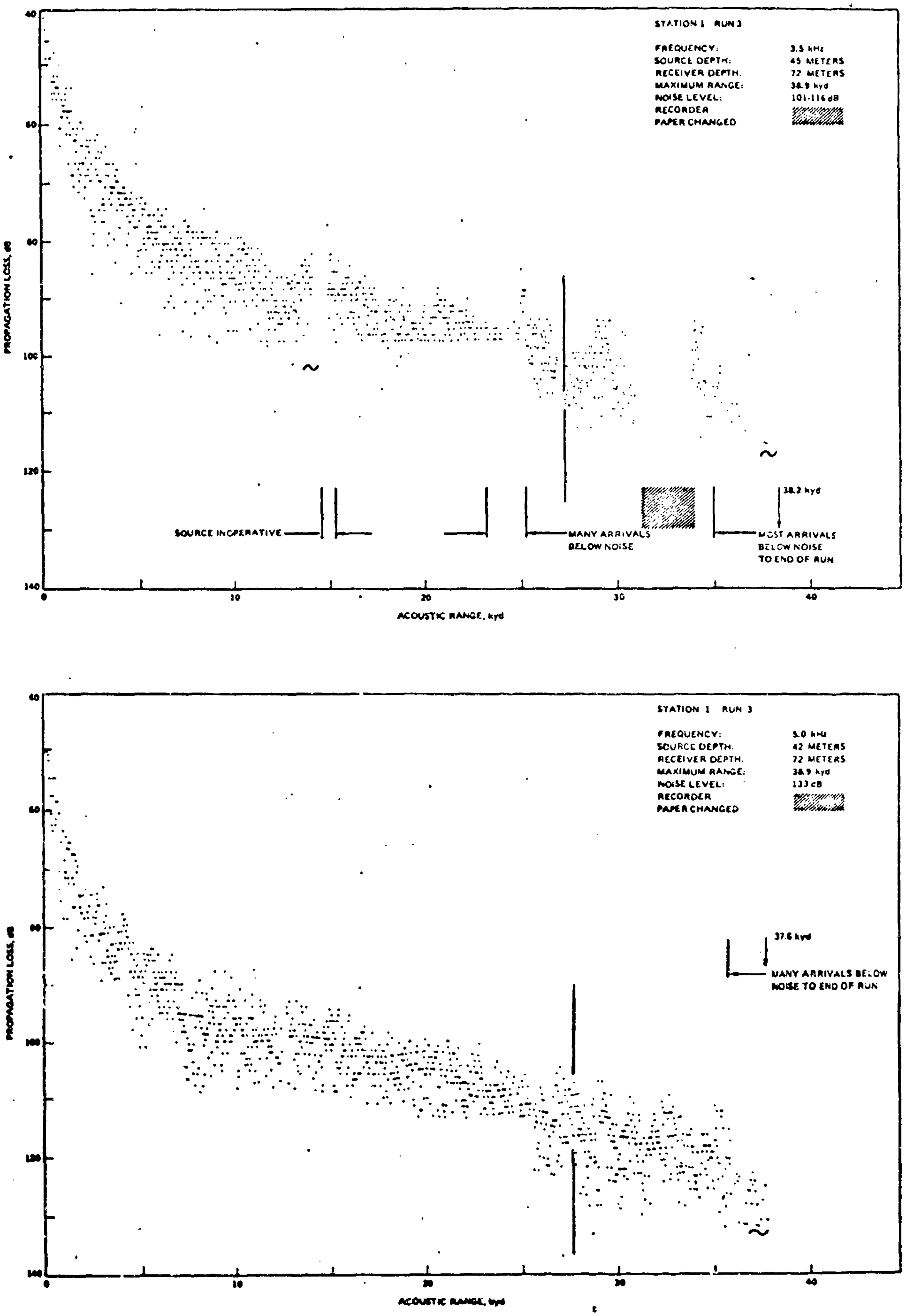

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 101-116 dB
RECORDER PAPER CHANGED
38.2 kyd
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 133 dB
RECORDER PAPER CHANGED
37.6 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-5

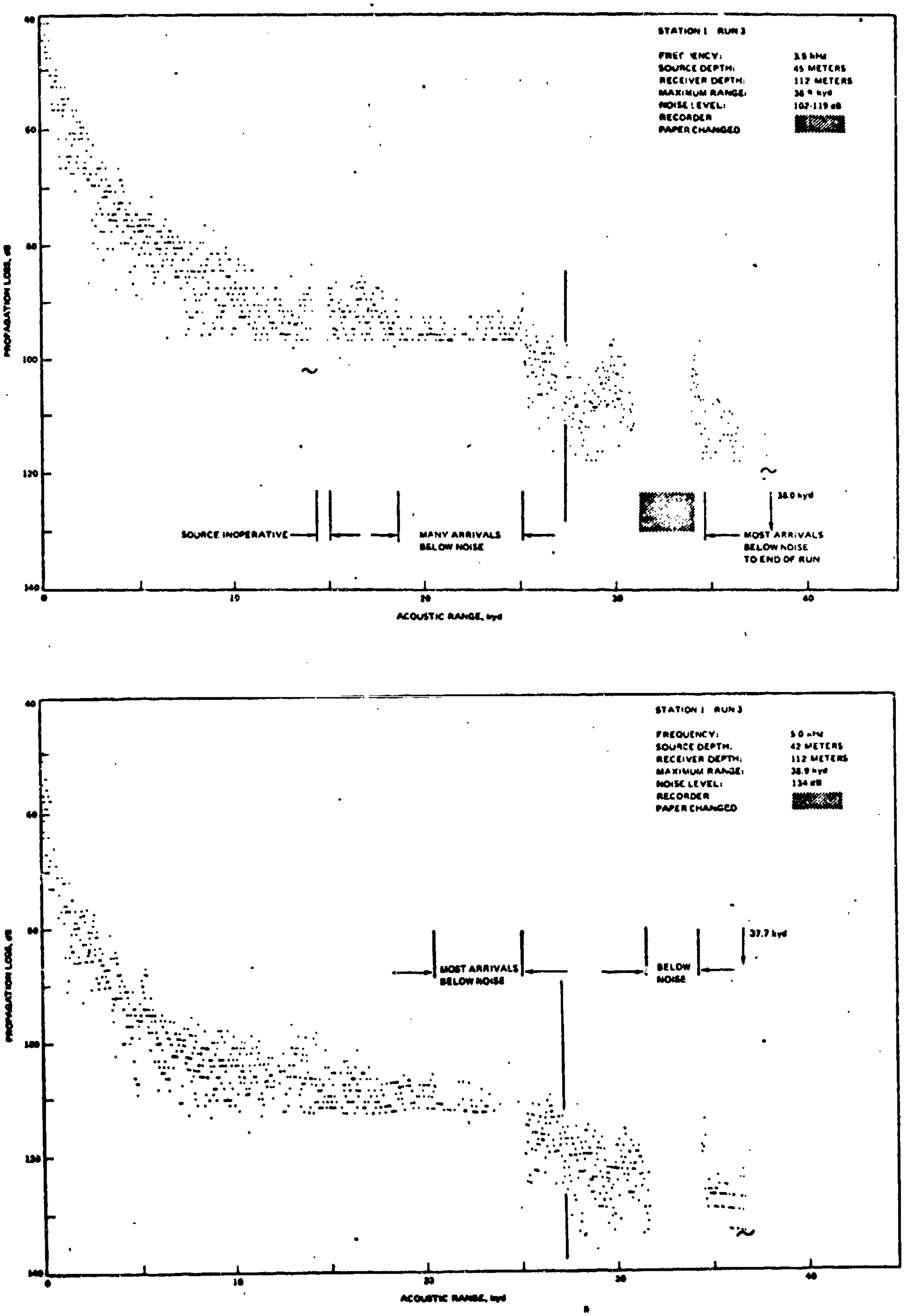

STATION 1 RUN 3
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 45 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 102-119 dB
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
38.0 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 3
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 38.9 kyd
NOISE LEVEL: 134 dB
RECORDER PAPER CHANGED ▨
MOST ARRIVALS BELOW NOISE
BELOW NOISE
37.7 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. B-6

APPENDIX C

Station 3, Run 2—20 February 1972 (Opening)

During the run, measurements indicated a temperature change from 0.5 to 1.0°C between 85 and 107 m, which resulted in the formation of a depressed channel.

Figure C-1 is a plot of the Profile 3 sound speeds listed in Table C-1; details are presented in Figure 3. As a result of nighttime cooling of surface water the profile shows a 6 m surface channel. Profile 3 has a 54 m depressed channel with the minimum sound speed at 20 m.

Average Sound Speed Profiles

Propagation losses of 1.5 and 2.5 kHz were measured over acoustic ranges from 3.9 to 33.6 kyd. Both the source and receiver ships reported winds less than 5 knots at the beginning of the run, increasing to about 10 knots, waves less than 1 ft, and 3 to 4 ft swell. Sea surface roughness data were obtained by the Waverider buoy for all but the first 5 min of the run; spectral analysis revealed that most of the roughness was contained in the 12.0 to 15.0 sec wave period band of swell. Receiver 1 was at the same depth as the surface sound channel, receivers 2 and 3 were in the depressed channel, and receivers 4 and 5 in the main thermocline.

AMOS Parameters

Sources and receivers were in the same water volume out to a range of 31.4 kyd. Average values of parameters derived from the thermistor chain temperature measurements, and applicable to the Run 2 experiment were:

isothermal layer depth	20 ft
depressed channel axis	66 ft
surface water temperature	59.2°F
sea state	2

Discussion

Propagation loss measurements are summarized in Figures C-2 through C-6. Vertical lines on individual propagation loss plots indicate the acoustic range from the receivers of the sound speed profile boundaries; visual comparison suggests the following:

- The most pronounced feature is the regular modal patterns observed at all depths for both frequencies. The complexity of the pattern and the random variability is greater at the higher frequency.
- In general, the propagation loss is smallest for the receivers in the depressed channel and greatest for those in the main thermocline.

Table C-1. Station 3, Run 2 (20 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Profile 3 0105-0506 n	C̄	σ
0	1809	1505.90	0.29
10	1809	05.80	0.26
20	1809	05.70	0.29
30	1809	05.78	0.29
50	1809	05.76	0.26
75	1809	06.08	0.24
100	1809	05.97	0.84
125	1809	03.48	1.20
150	1809	1499.96	1.40
200	1809	92.31	0.57
250	1809	89.35	0.38
300	11	86.10	0.36
400	11	83.15	0.65
500	9	81.81	0.29
600	5	81.36	0.36
800	4	81.25	0.15
1000	4	82.17	0.22
1200	4	83.47	0.22
1500	4	86.06	0.22
6		1506.05	SC
20		1505.70	DC
90		1506.40	MAX
700		1481.20	AXIS

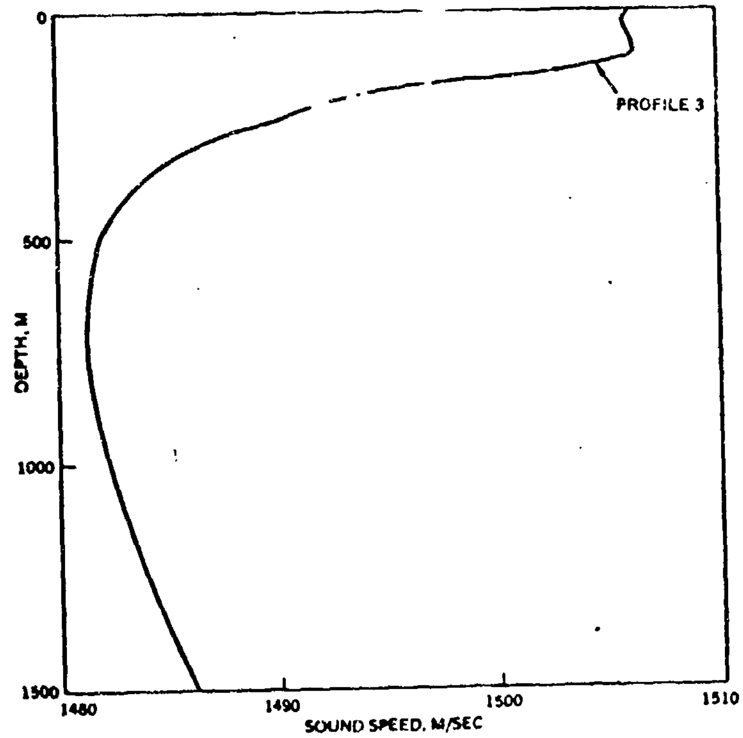


Figure C-1 Station 3, Run 2
Average Sound Speed Profile

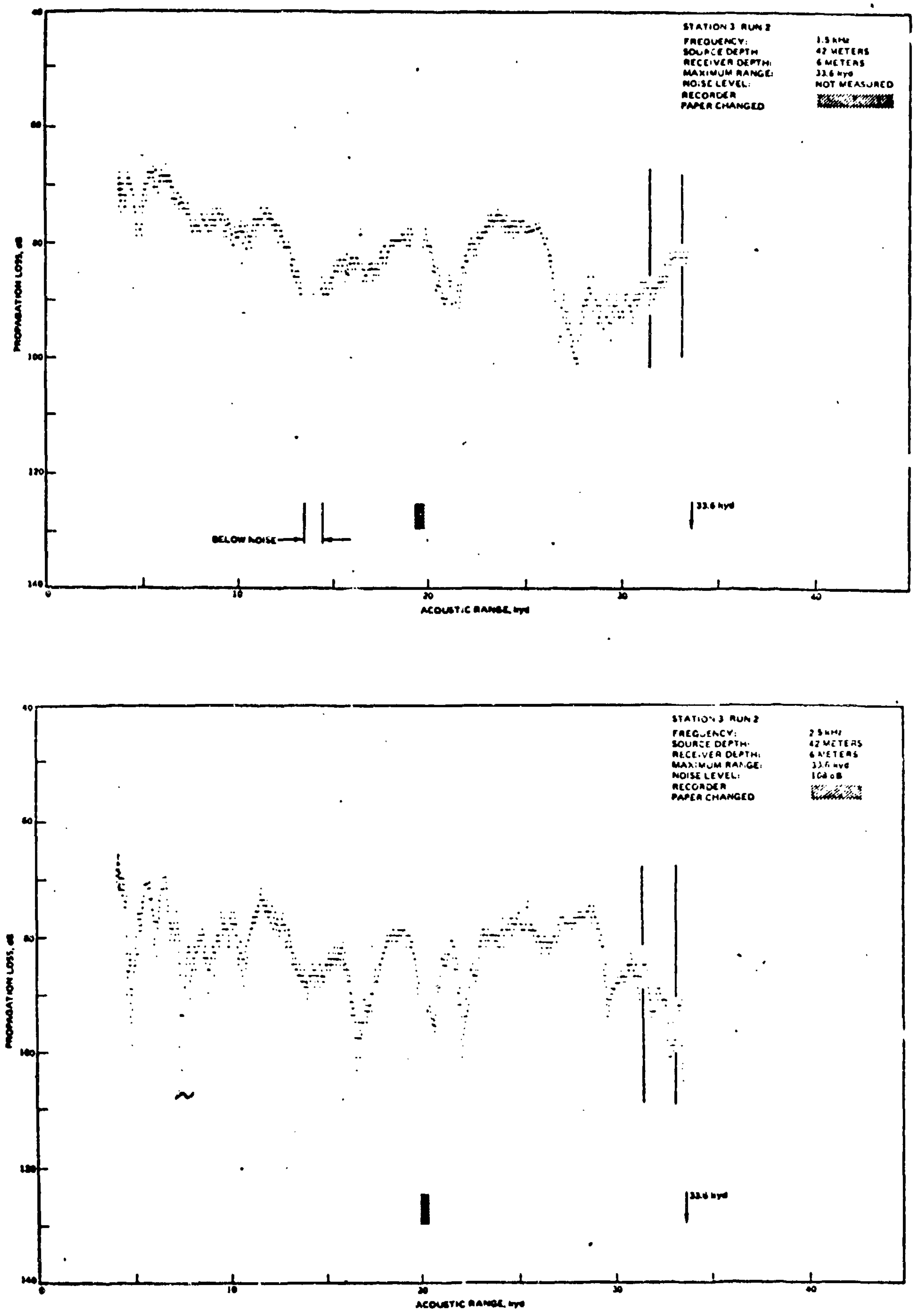

STATION 3 RUN 2
FREQUENCY: 1.5 kHz
SOURCE DEPTH 42 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
BELOW NOISE
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 2
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: 108 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. C-2

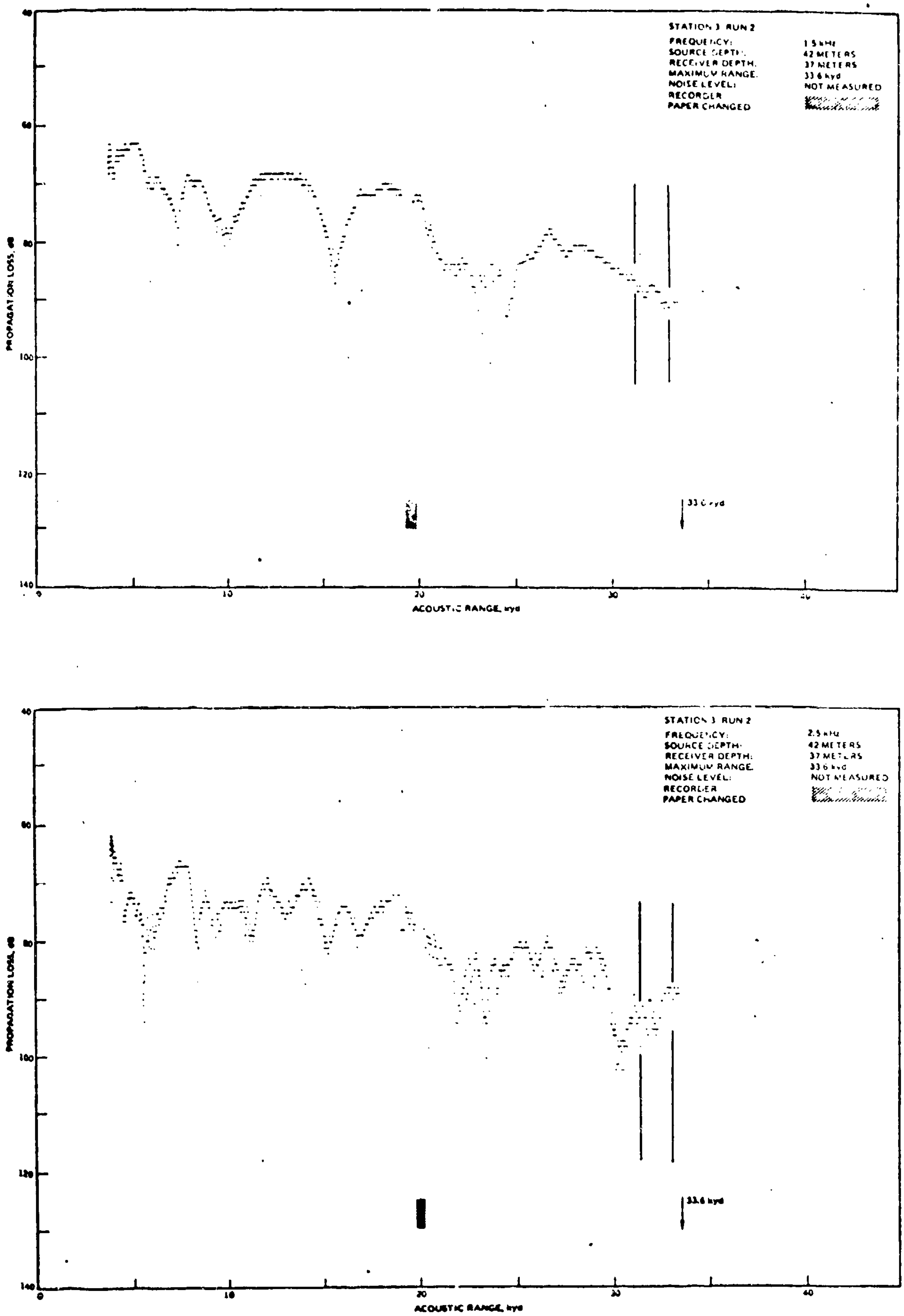

STATION 3 RUN 2
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 37 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER
PAPER CHANGED
33.6 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 2
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 37 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER
PAPER CHANGED
33.6 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. C-3

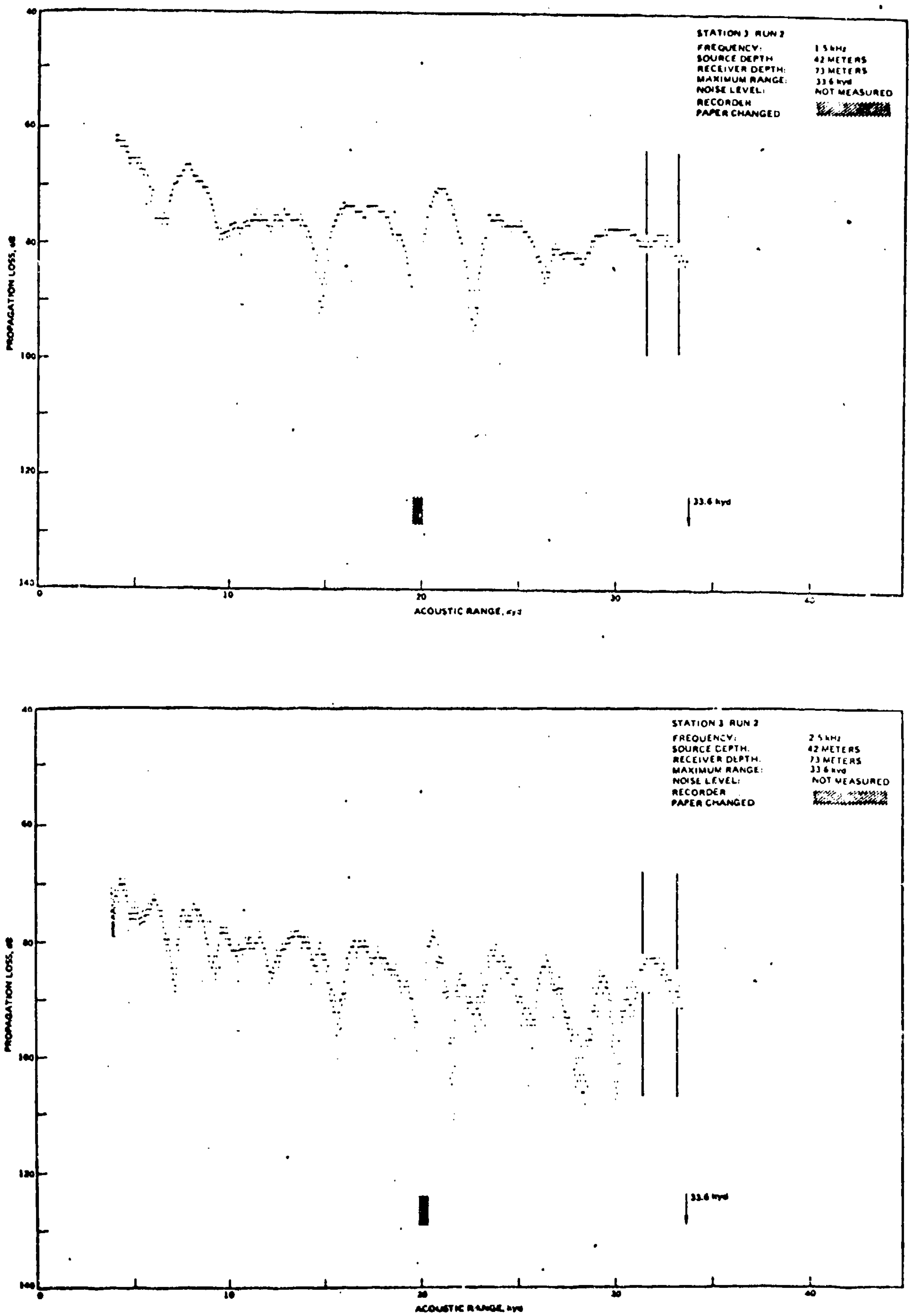

STATION 3 RUN 2
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
33.6 kyd
STATION 3 RUN 2
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
33.6 kyd

Fig. C-4

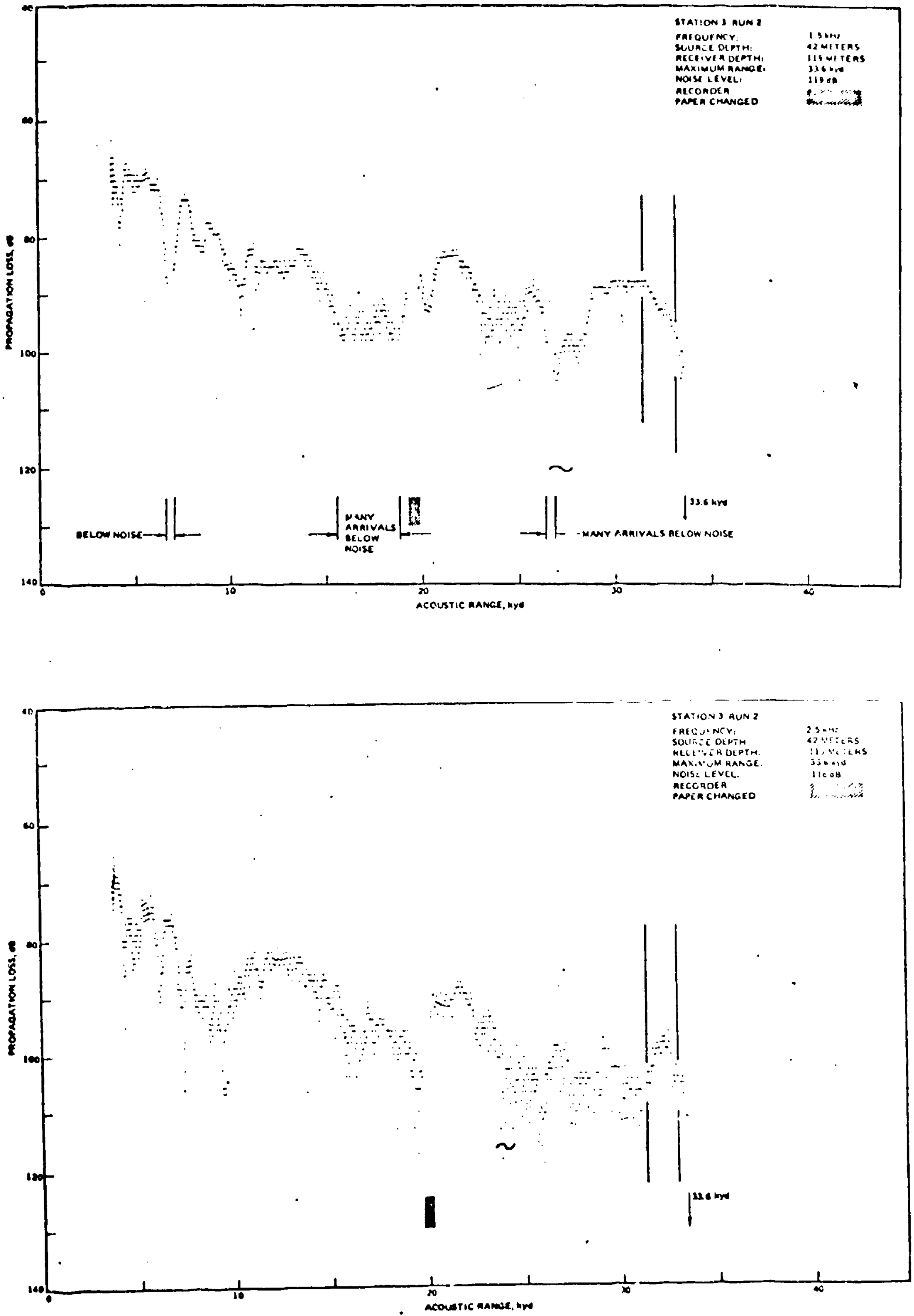

STATION 3 RUN 2
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 119 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: 119 dB
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
BELOW NOISE
MANY ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 2
FREQUENCY: 2.5 kHz
SOURCE DEPTH 42 METERS
RECEIVER DEPTH. 119 METERS
MAXIMUM RANGE. 33.6 kyd
NOISE LEVEL. 116 dB
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. C-5

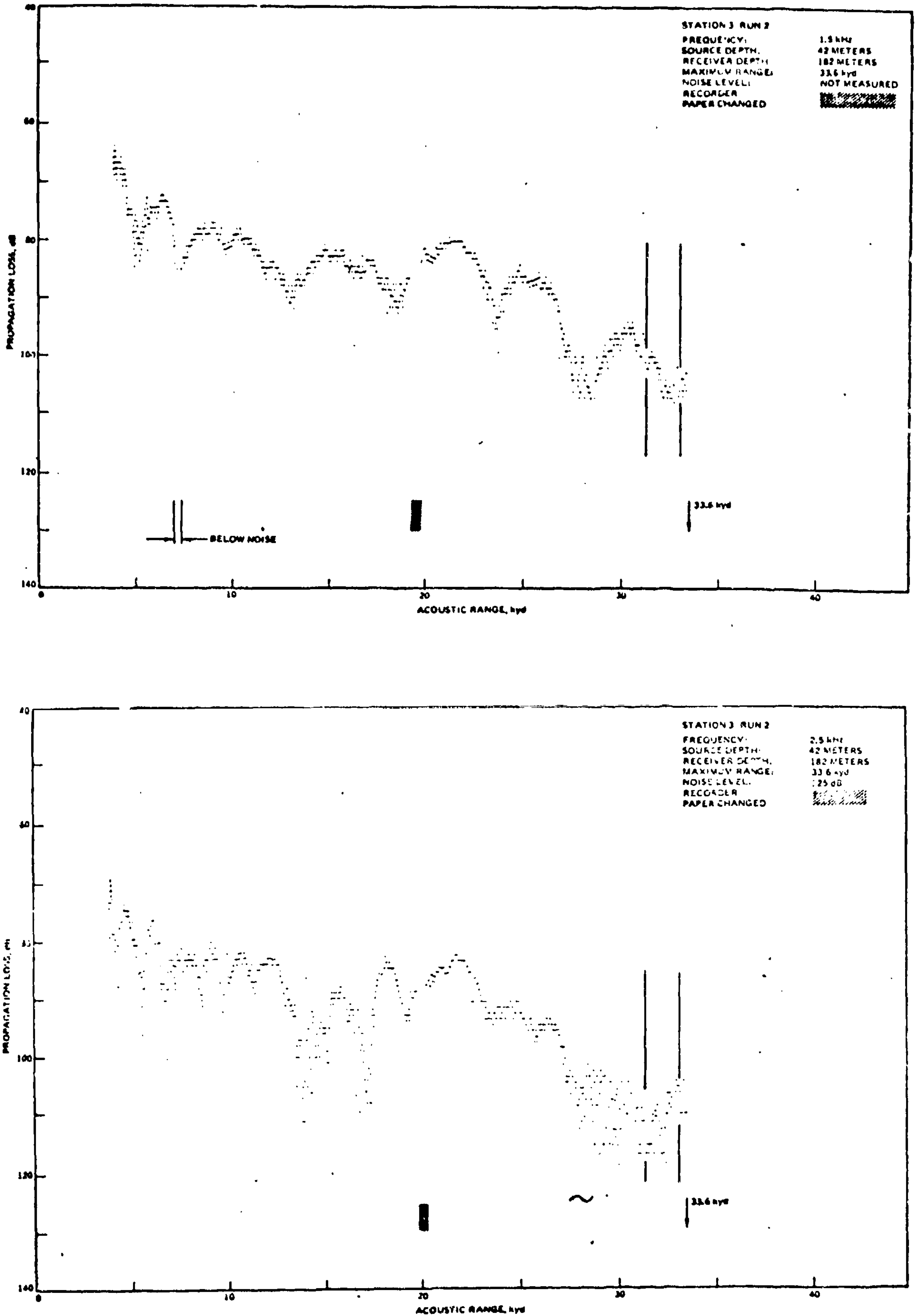

STATION 3 RUN 2
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 182 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: NOT MEASURED
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
BELOW NOISE
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 2
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 182 METERS
MAXIMUM RANGE: 33.6 kyd
NOISE LEVEL: 125 dB
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
33.6 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. C-6

APPENDIX D

Station 3, Run 3—20 February 1972 (Closing)

During this run 0.4 and 1.0 kHz propagation losses were measured over acoustic ranges from 100 yd to 37.5 kyd. Profile 3 (Figure 3) applied out to 34.6 kyd.

Average Sound Speed Profile

Profile 3 contained a depressed channel with a minimum sound speed at 20 m and a maximum sound speed at 79 m. The source ship reported 10 to 12 knot winds, 2 ft waves and 3 ft swell; the receiver ship 8 to 10 knot winds, 1 ft waves, and 3 to 5 ft swell. No Waverider buoy measurements were obtained during this run. Receiver 1 was in the surface channel, receivers 2 and 3 were in the depressed channel, and receivers 4 and 5 in the main thermocline.

AMOS Parameters

Sources and receivers were in the same water volume out to a range of 34.6 kyd. Average values of parameters, derived from the thermistor chain temperature measurements, and applicable to the Run 3 experiment were:

isothermal layer depth	36 ft
depressed channel axis	66 ft
surface water temperature	59.4°F
sea state	2

Discussion

The propagation loss measurements are plotted in Figures D-2 through D-6. Between 5.7 and 7.9 kyd both sources malfunctioned. Hence, no arrivals were recorded over this range interval. A visual comparison of the plots suggest the following:

- The most obvious feature was the rapid increase in 0.4 kHz propagation loss out to a range that was a function of receiver depth. These ranges were:

receiver 1	6 kyd	receiver 4	12 kyd
receiver 2	8 kyd	receiver 5	12 kyd
receiver 3	10 kyd		

  From the above ranges to the maximum range, the average propagation loss was almost independent of range for all receivers.
- At 0.4 kHz, the greatest propagation losses were recorded by the 6 m receiver. An inspection of this plot reveals many below-noise missing arrivals for range greater than about 13 kyd.
- The 1.0 kHz propagation loss pattern recorded, for ranges greater than about 15 kyd (receivers 1, 2, and 3) and 7 kyd (receivers 4 and 5), was completely different from that recorded at 0.4 kHz. The 1.0 kHz propagation loss exhibits a systematic pattern typical of modal interference.

Table D-1. Station 3, Run 3 (20 February 1972) Average Sound Speed Profile (m/sec).

Depth,	Profile 3 0731-1418		
m	n	$\overline{C}$	σ
0	2248	1506.06	0.46
10	2248	06.12	0.45
20	2248	06.06	0.49
30	2248	06.07	0.49
50	2248	06.12	0.56
75	2248	06.24	0.30
100	2248	05.53	0.64
125	2248	02.38	0.76
150	2248	1498.14	0.94
200	2248	91.45	0.47
250	2248	88.79	0.38
300	15	85.62	0.59
400	15	83.02	0.63
500	9	81.81	0.29
600	5	81.36	0.36
800	4	81.25	0.15
1000	4	82.17	0.22
1200	4	83.47	0.22
1500	4	86.06	0.22
11		1506.14	SC
20		1506.06	DC
79		1506.30	MAX
700		1481.20	AXIS

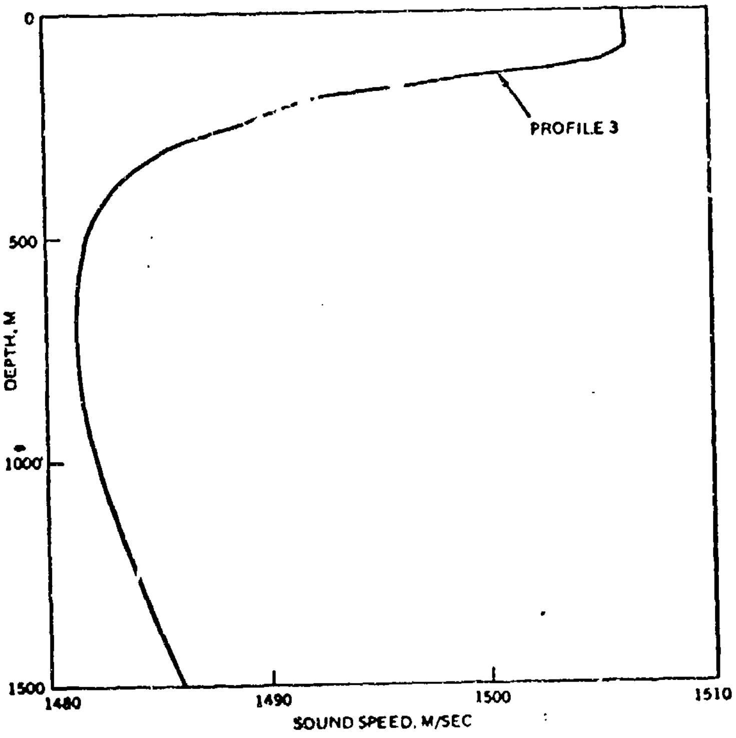


Figure D-1. Station 3, Run 3 Average Sound Speed Profile.

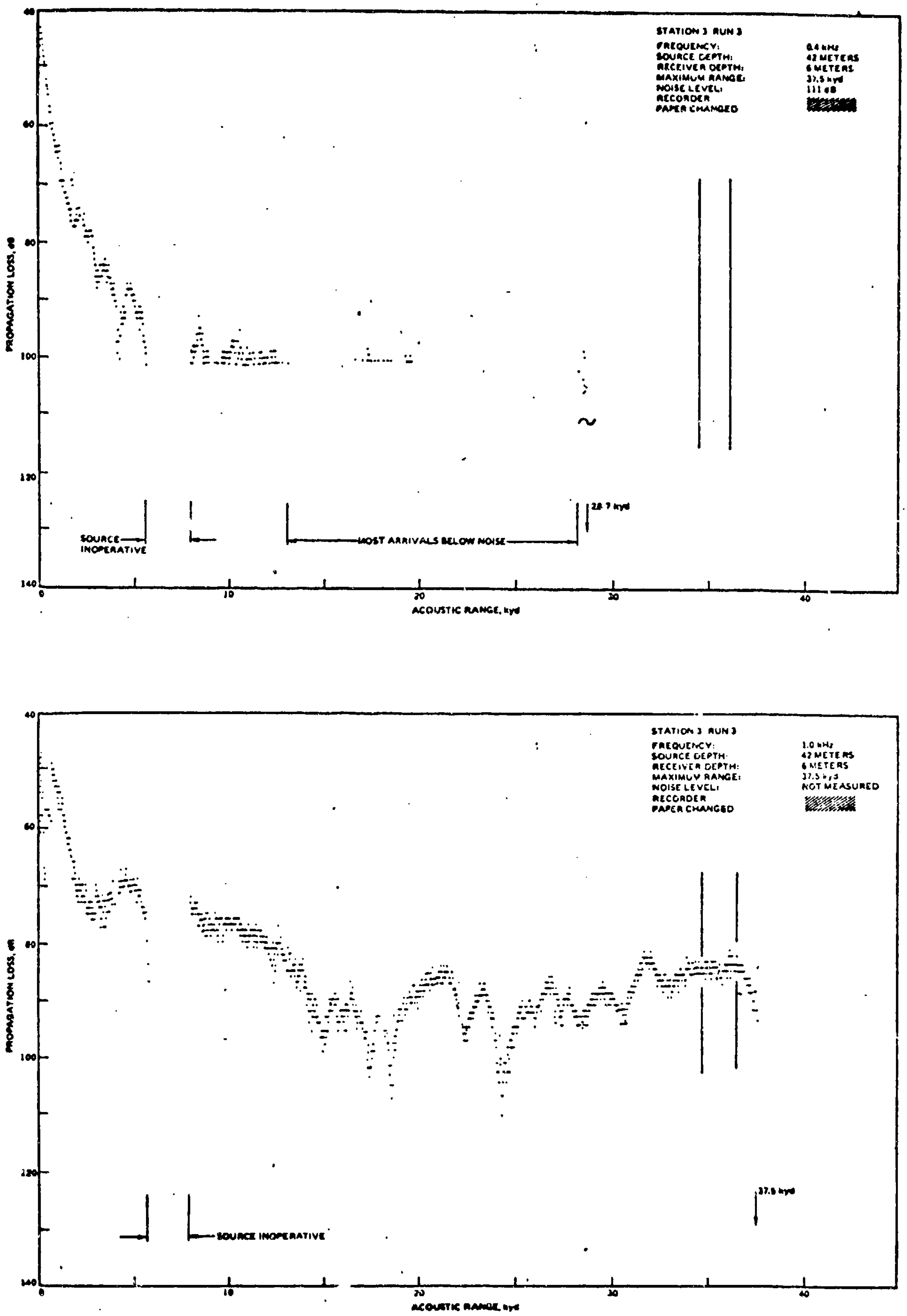

STATION 3 RUN 3
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: 111 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
28.7 kyd
STATION 3 RUN 3
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
SOURCE INOPERATIVE
37.5 kyd

Fig. D-2

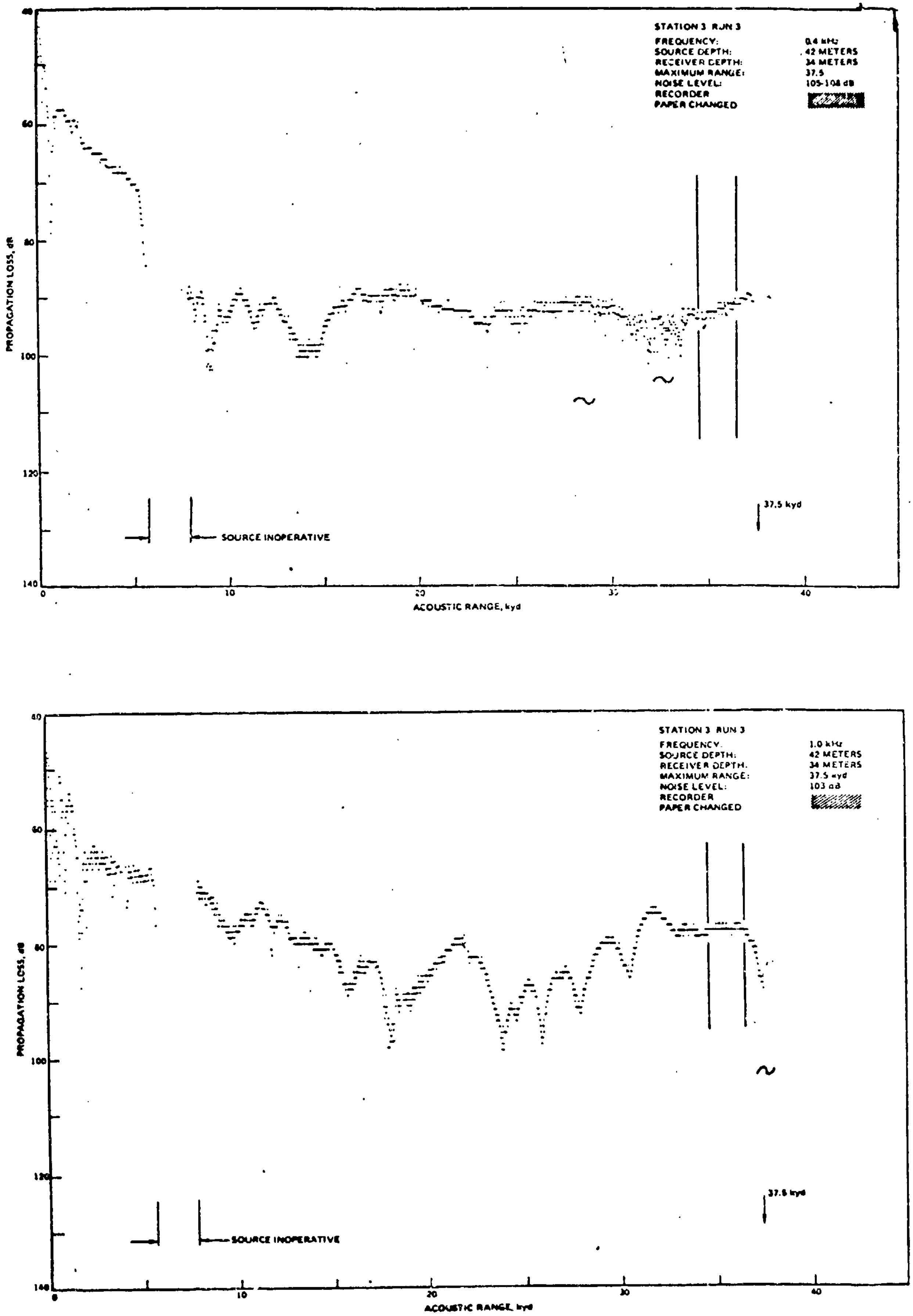
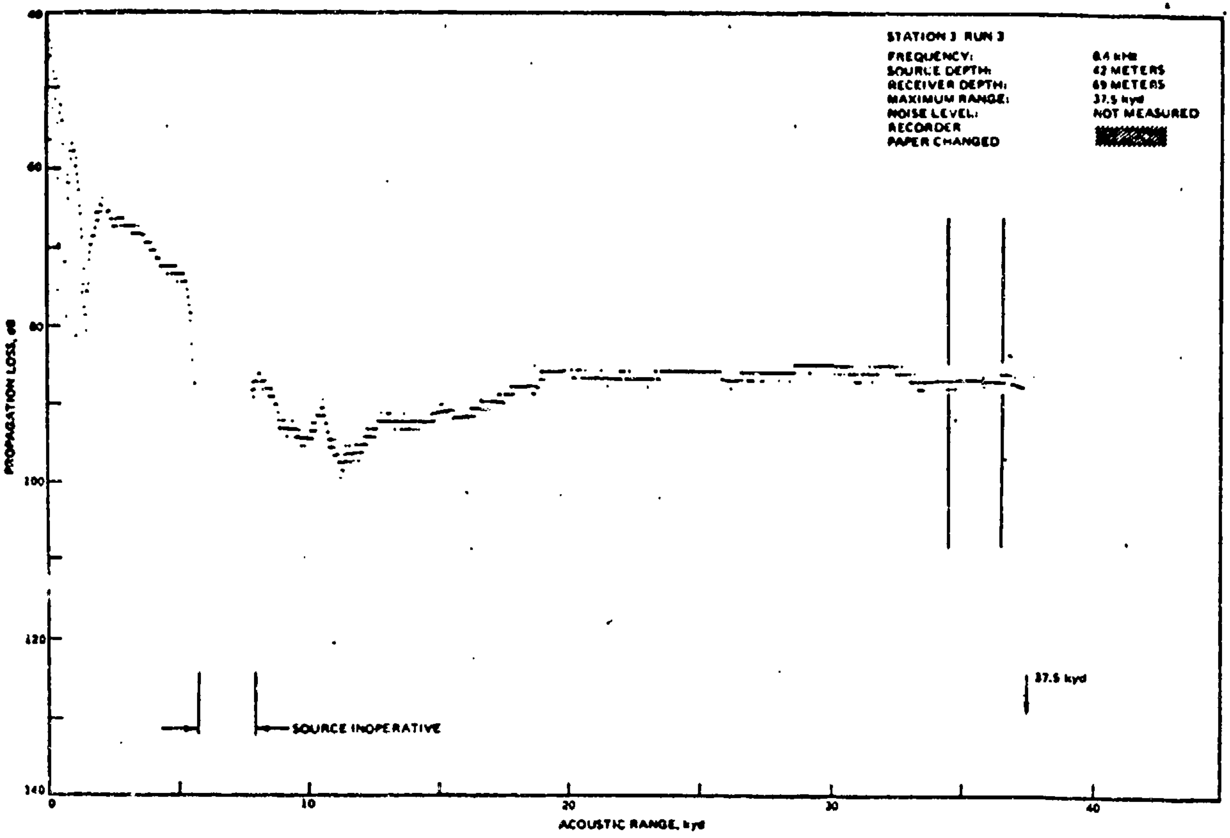

STATION 3 RUN 3
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 34 METERS
MAXIMUM RANGE: 37.5
NOISE LEVEL: 105-108 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
SOURCE INOPERATIVE
37.5 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 3
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 34 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: 103 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
SOURCE INOPERATIVE
37.5 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. D-3


STATION 3 RUN 3
FREQUENCY: 8.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 69 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
SOURCE INOPERATIVE
37.5 kyd

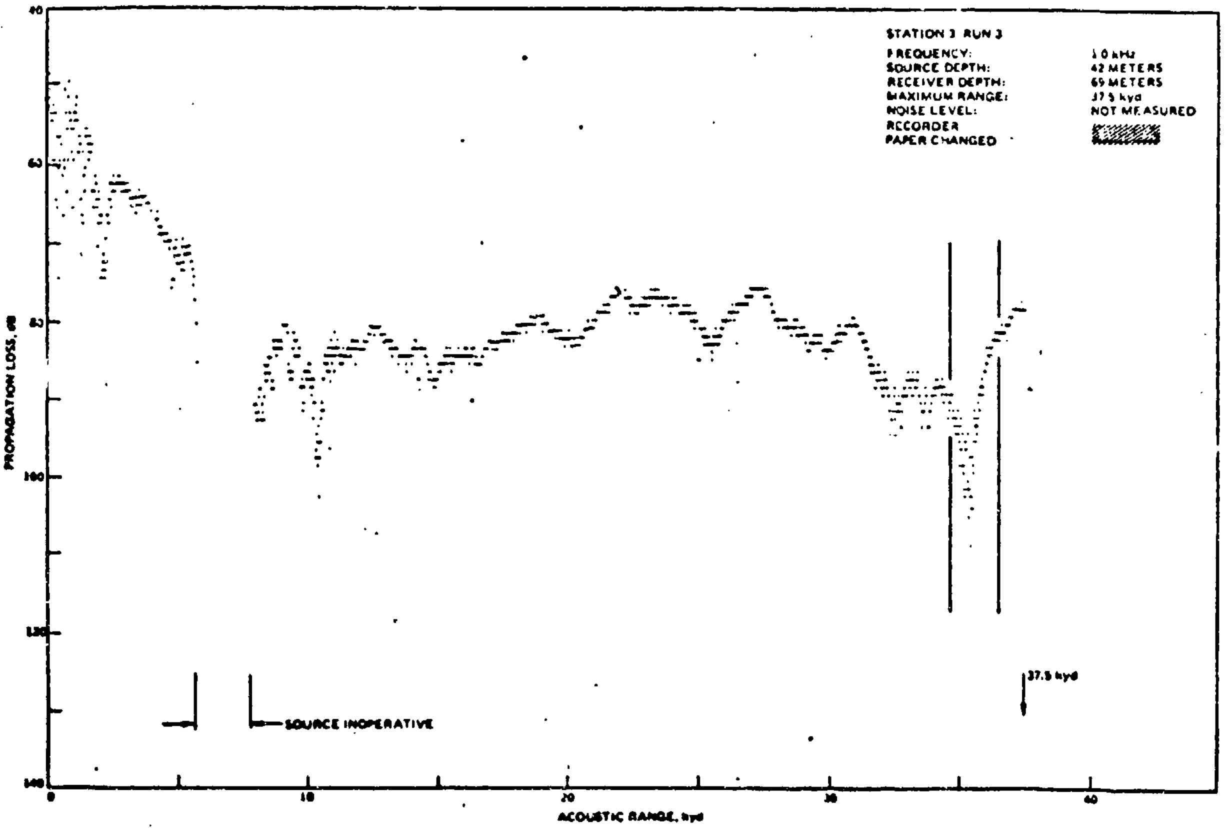

STATION 3 RUN 3
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 69 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
SOURCE INOPERATIVE
37.5 kyd

Fig. D-4

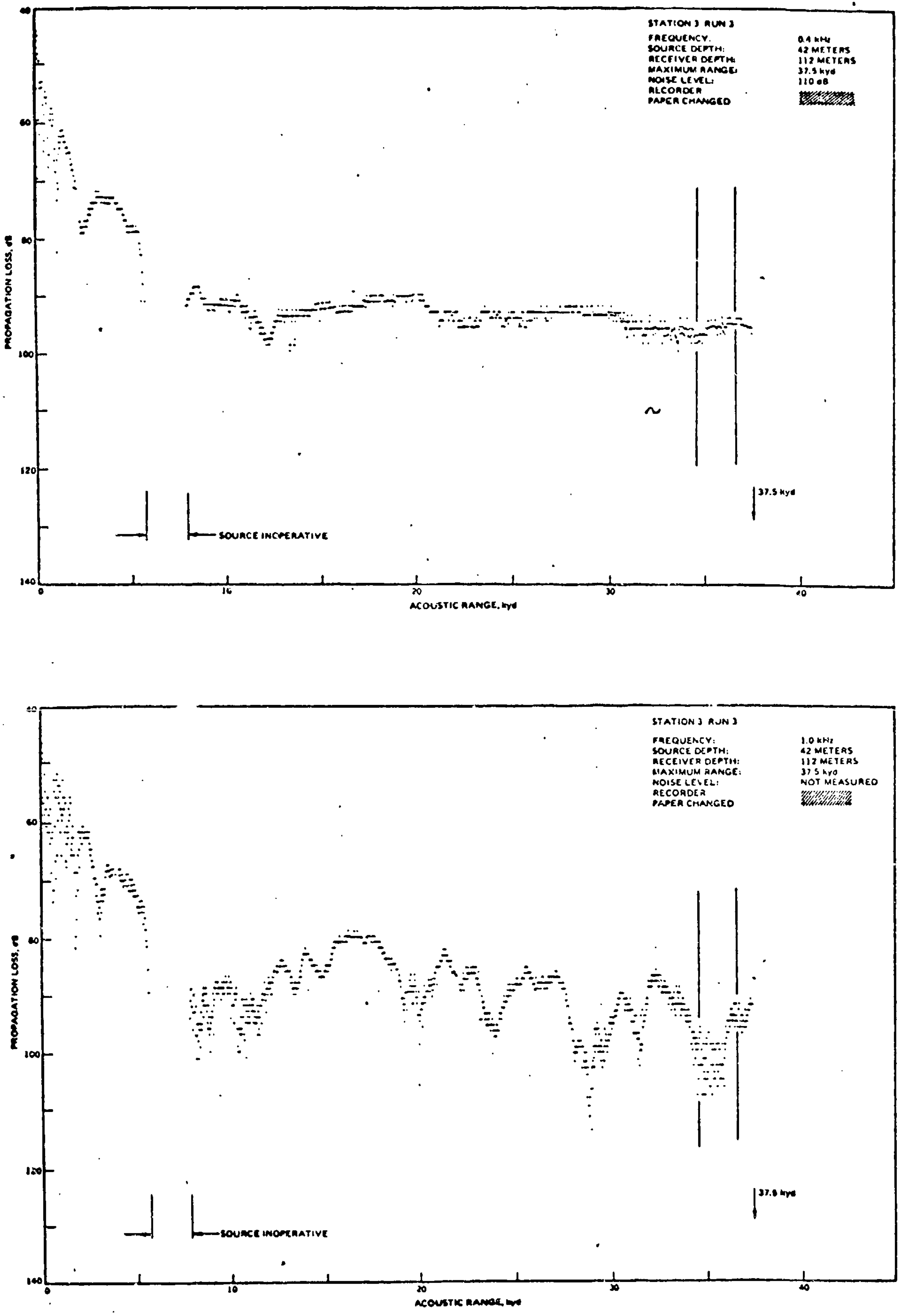
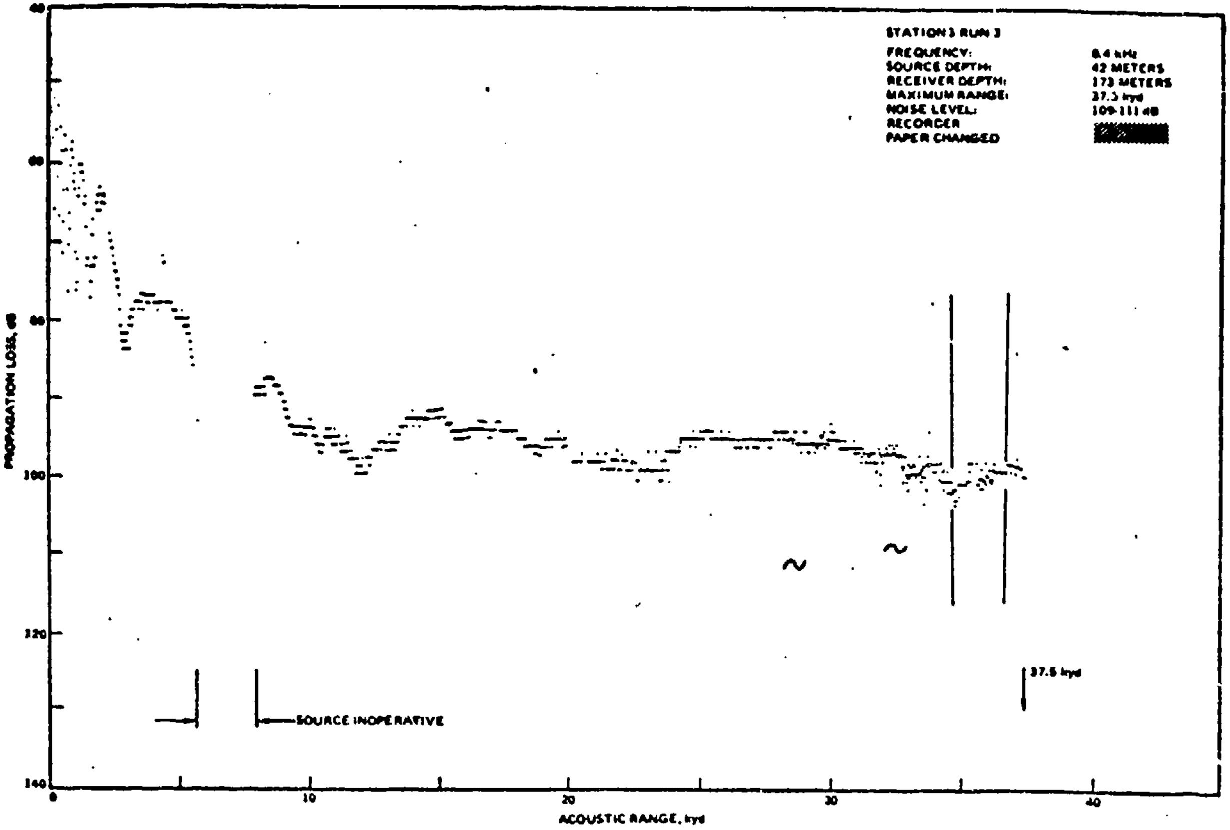

STATION 3 RUN 3
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: 110 dB
RECORDER PAPER CHANGED ▨
37.5 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 3 RUN 3
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 112 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
37.5 kyd
SOURCE INOPERATIVE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. D-5


STATION 3 RUN 3
FREQUENCY: 0.4 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 173 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: 109-111 dB
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
37.5 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

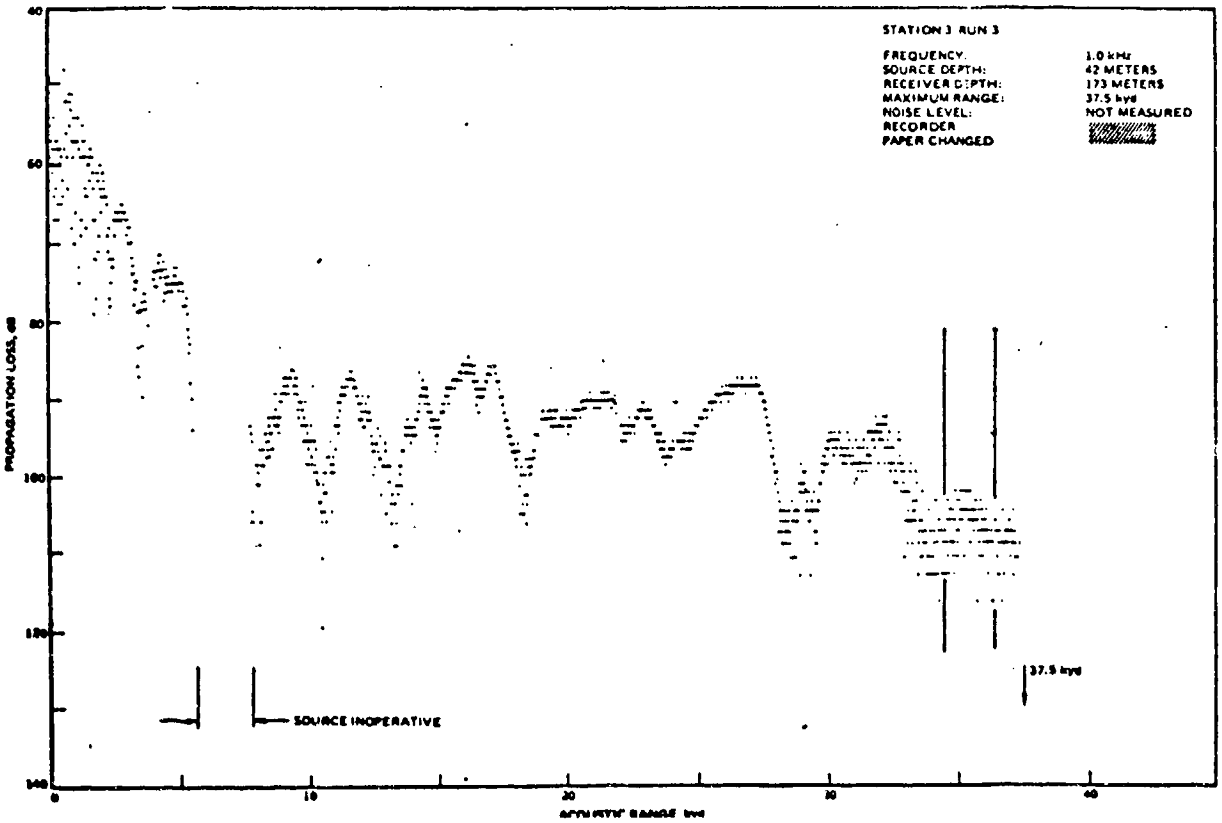

STATION 3 RUN 3
FREQUENCY: 1.0 kHz
SOURCE DEPTH: 42 METERS
RECEIVER DEPTH: 173 METERS
MAXIMUM RANGE: 37.5 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
SOURCE INOPERATIVE
37.5 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. D-6

APPENDIX E

Station 1, Run 1 — 10 February 1972 (Opening)

During this run 1.5 and 2.5 kHz propagation losses were measured over acoustic ranges from 480 yd to 27.1 kyd.

Average Sound Speed Profile

Individual sound speed profiles reflected the presense of transient surface channels varying in depth from 6 to 50 m and small depressed channels from 20 to 50 m depths. No persistent features of importance existed. The data were averaged to obtain a single average sound speed profile applicable to the complete run as plotted in Figure 3. The average profile was characterized by a 20 m surface channel and a 70 m refractive channel, with the minimum sound speed at 200 m. The transient depressed channels, illustrated in individual profiles, were not retained in the average profile. The average thermistor chain data displayed a depressed channel with axis at 50 m. The source ship reported light airs to 3 knot winds, 1 ft waves, and 3 ft swell; the receiver ship 4 to 5 knot winds, ripples, and 2 ft swell. No Waverider buoy measurements of sea surface roughness were obtained during this experiment. Receiver 1 was located in the surface layer, receivers 2 and 3 below the layer, receiver 4 in the thermocline, and receiver 5 just above the refractive channel.

AMOS Parameters

Average values of parameters, derived from the thermistor chain temperature measurements, and applicable to the Run 1 were:

isothermal layer depth	66 ft
depressed channel axis	656 ft
surface water temperature	58.6°F
sea state	1

Discussion

The propagation loss measurements are plotted in Figures E-2 through E-6. A visual comparison suggests the following:

- A consistent minimum of low propagation loss was observed over the range interval from 22.8 kyd to 23.6 kyd for both frequencies and all receiver depths except for the 98 m receiver at 1.5 kHz which may have been masked by a noise level about 10 dB higher than the other receivers noise levels. The three deepest receivers lacked depth dependence. Propagation loss for these receivers is greater than that observed on the shallowest receiver.

- No difference existed between receivers out to 13.0 kyd at 1.5 kHz and 15.0 kHz at 2.5 kHz. At greater ranges, the 148 m receiver recorded a propagation loss about 15 dB greater than the 6 receiver.

- Out to ranges of about 19.0 kyd (1.5 kHz) and 25.0 kyd (2.5 kHz) little difference was noted in propagation loss versus range for the three deepest receivers and at 1.5 kHz, no difference between the shallowest receivers.

- Out ot 5.0 kyd no depth dependence was observed at either frequency.
- The propagation loss at 2.5 kHz was a nominal 10 dB greater than the 1.5 kHz propagation loss.
- Arrivals were received from the maximum range of the run (27.1 kyd) on the three shallowest receivers at 2.5 kHz and from 26.8 kyd and 27.0 kyd on the 98 m and 148 m receivers, respectively. At 1.5 kHz, arrivals were received from the maximum range on the 24 and 59 m receivers and from 26.9, 24.0, and 24.9 kyd on the 6, 98, and 148 m receivers, respectively.

Table E-1. Station 1, Run 1 (10 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Number of Observations	Average Speed	Standard Deviation
0	1431	1504.51	0.52
10	1431	04.66	0.52
20	1431	04.66	0.46
30	1431	04.61	0.46
50	1431	04.29	0.49
75	1431	03.77	0.46
100	1431	00.33	1.22
125	1431	1495.80	0.86
150	1431	93.73	0.42
200	1431	92.41	0.15
250	1431	92.71	0.19
300	12	92.33	0.69
400	10	89.69	1.04
500	4	87.54	0.68
600	4	85.79	0.75
800	6	83.59	0.29
1000	5	83.54	0.19
1200	5	84.57	0.13
1500	5	86.66	0.09
20		1504.66	SC
200		1492.41	RC
250		1492.71	MAX
900		1483.40	AXIS

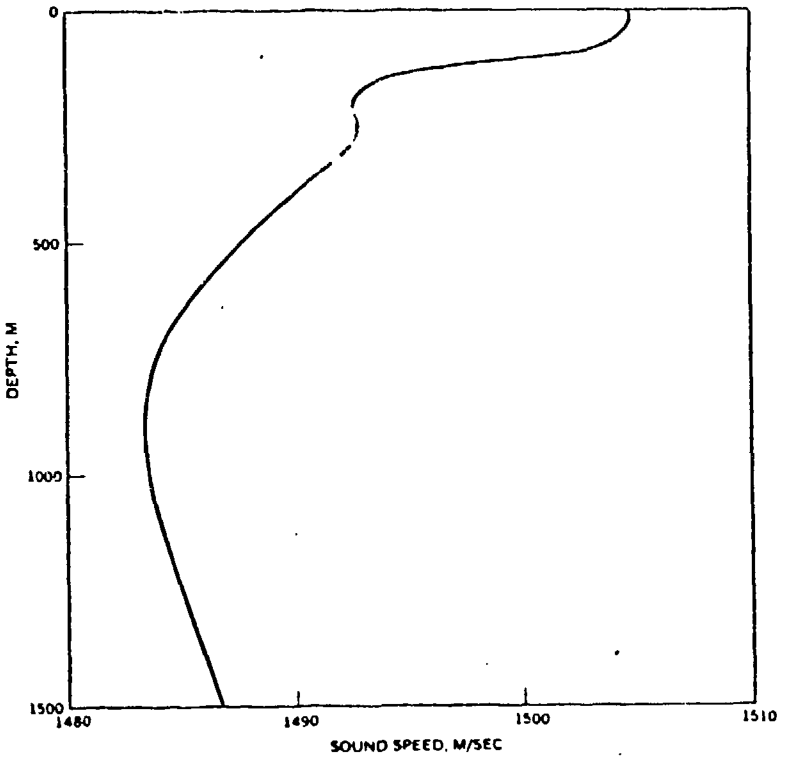


Figure E-1. Station 1, Run 1
Average Sound Speed Profile.

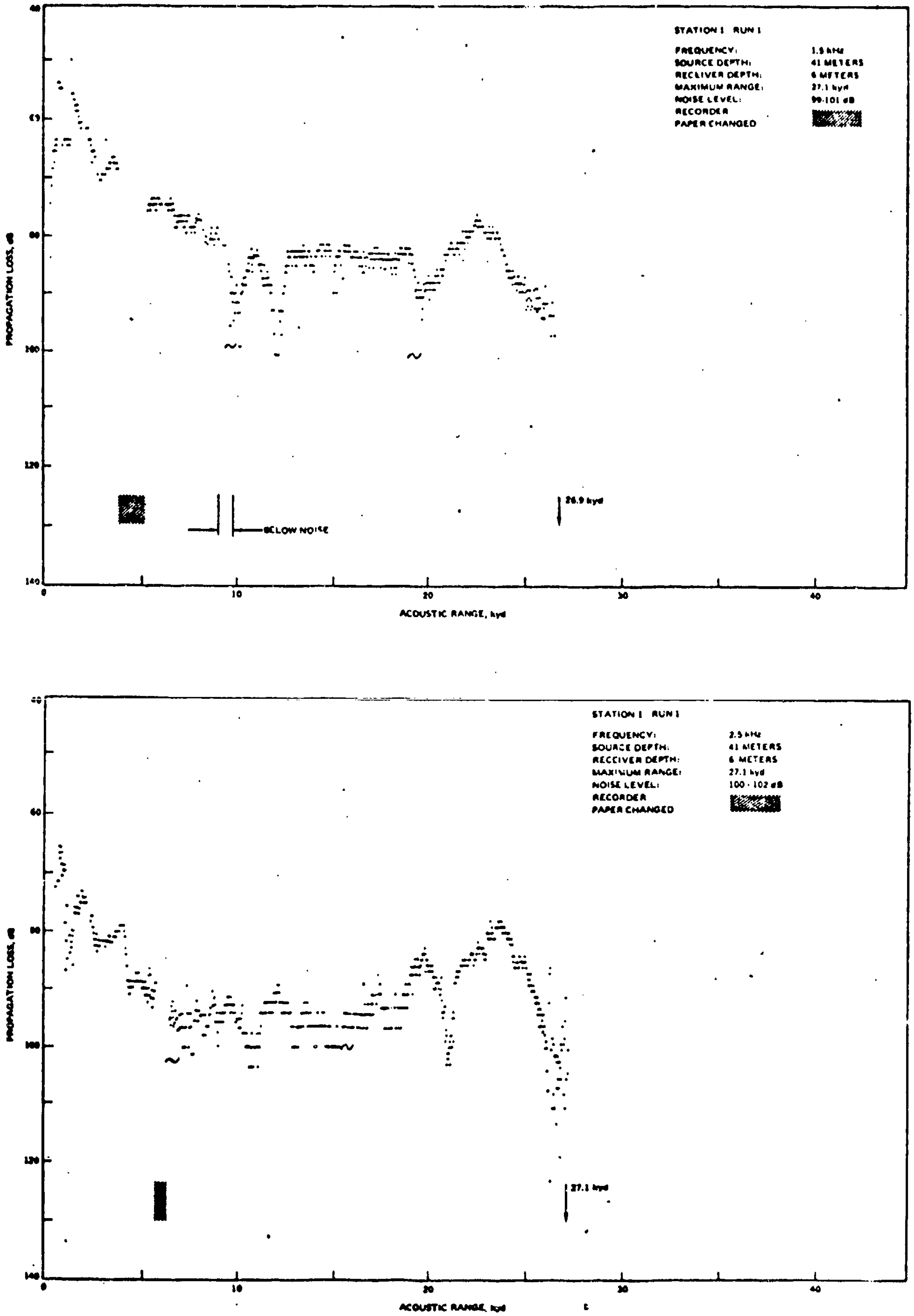

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 99-101 dB
RECORDER PAPER CHANGED ▨
BELOW NOISE
26.9 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 100 - 102 dB
RECORDER PAPER CHANGED ▨
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. E-2

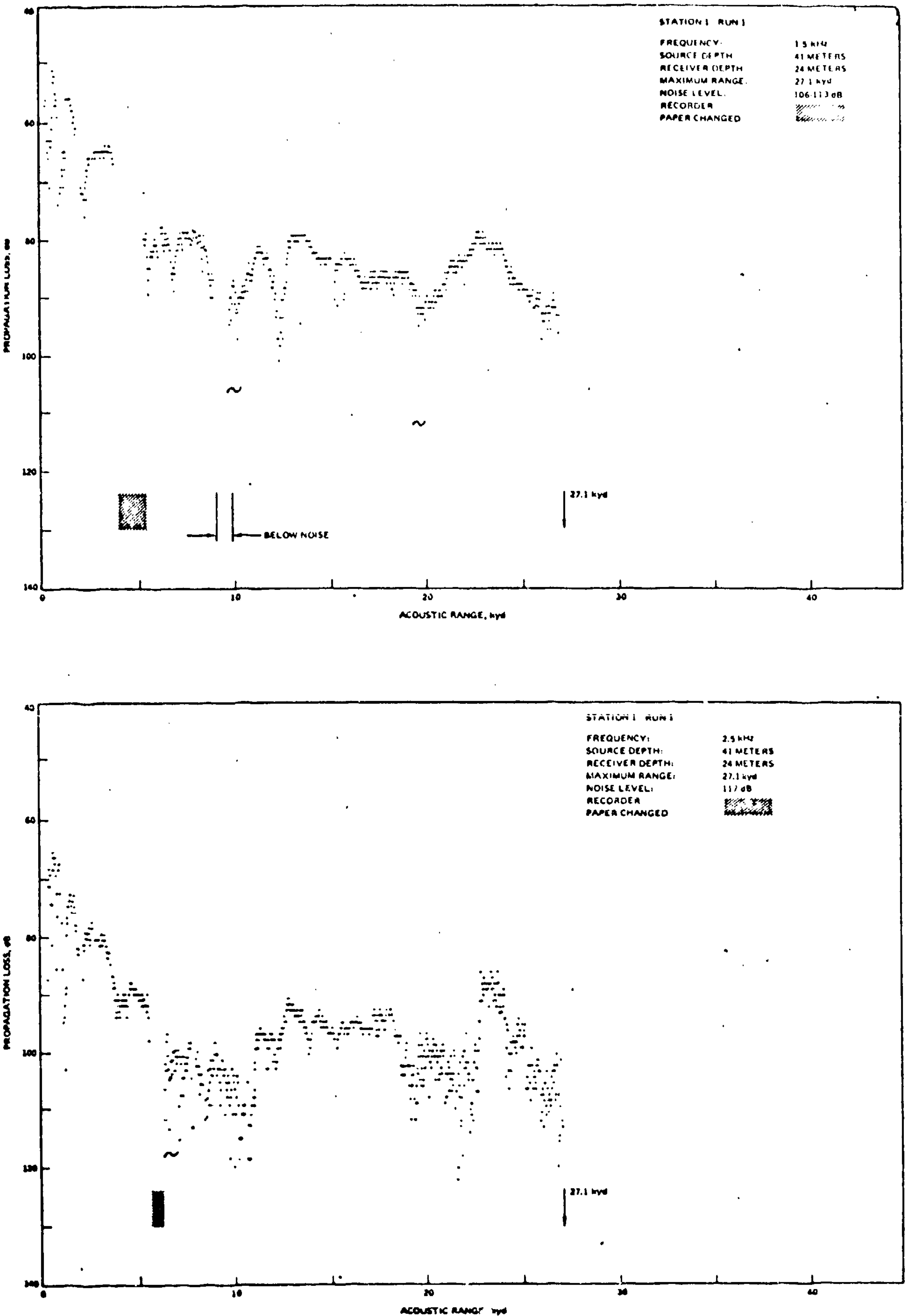

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 24 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 106-113 dB
RECORDER
PAPER CHANGED
27.1 kyd
BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 24 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 117 dB
RECORDER
PAPER CHANGED
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

Fig. E-3

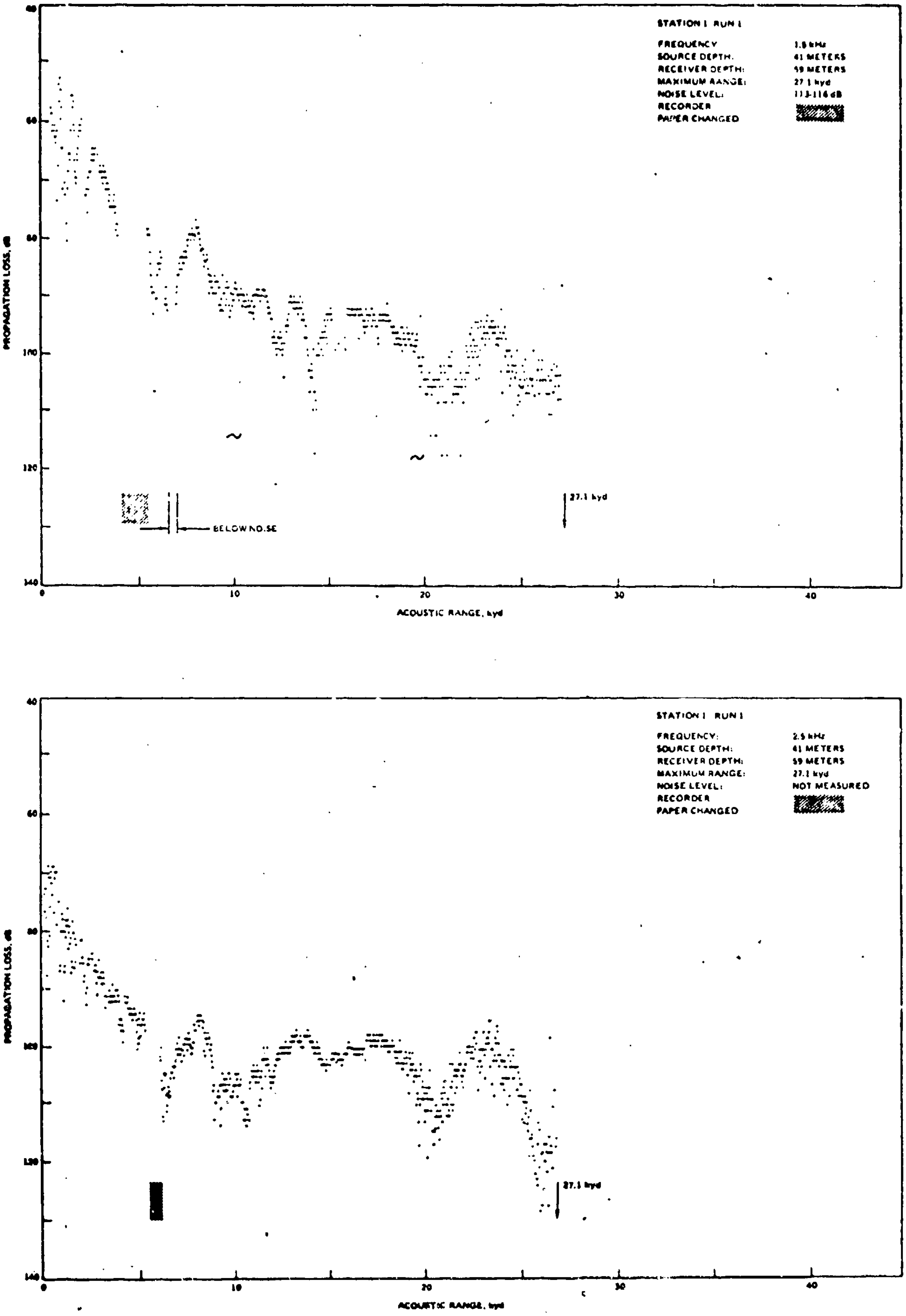

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 59 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 113-116 dB
RECORDER PAPER CHANGED ▨
BELOW NOISE
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 59 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
27.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

Fig. E-4

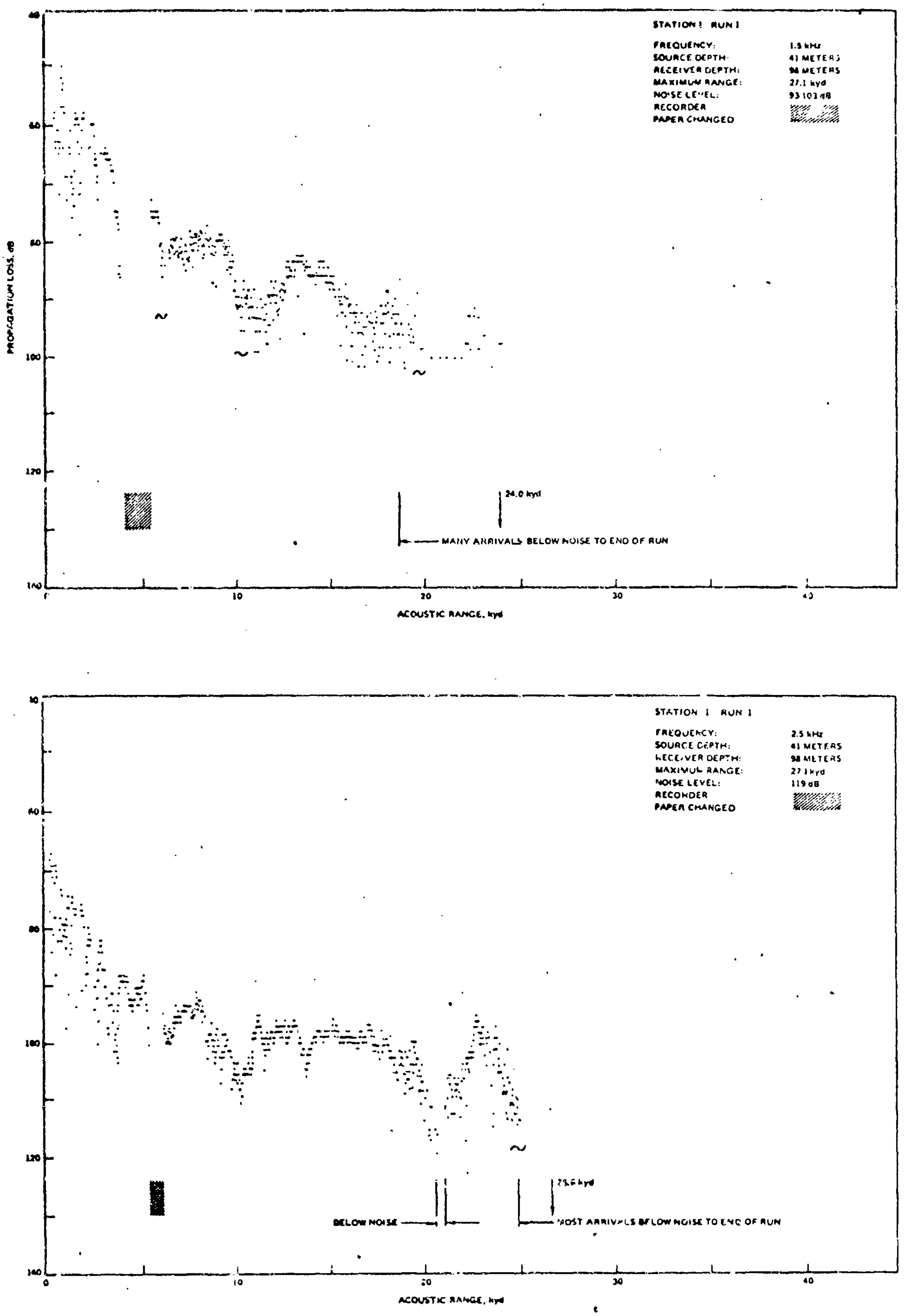

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 98 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 93 103 dB
RECORDER PAPER CHANGED
24.0 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 98 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 119 dB
RECORDER PAPER CHANGED
25.6 kyd
BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. E-5

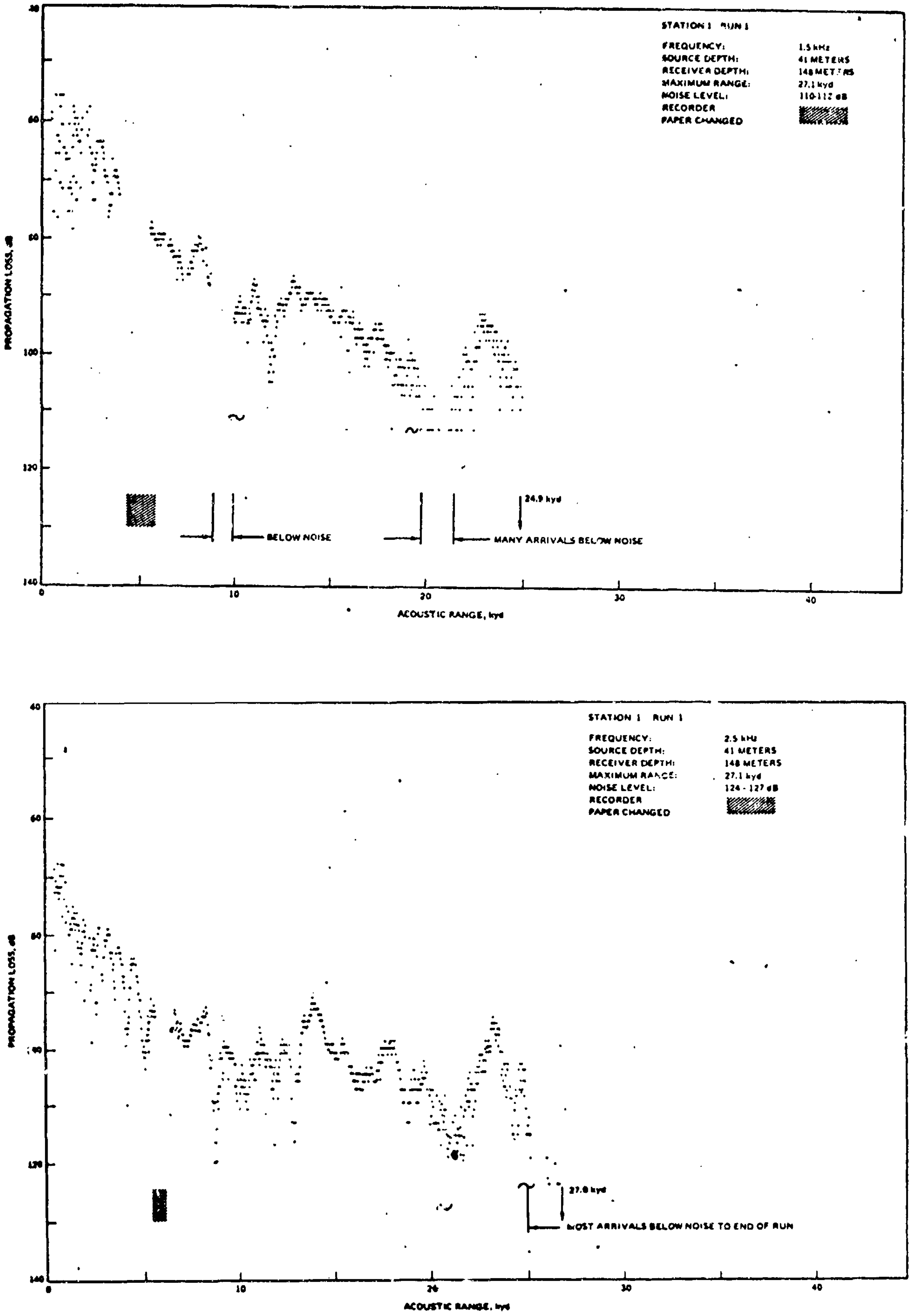

STATION 1 RUN 1
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 148 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 110-112 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
BELOW NOISE
24.9 kyd
MANY ARRIVALS BELOW NOISE
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 1 RUN 1
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 41 METERS
RECEIVER DEPTH: 148 METERS
MAXIMUM RANGE: 27.1 kyd
NOISE LEVEL: 124 - 127 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
27.0 kyd
MOST ARRIVALS BELOW NOISE TO END OF RUN
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. E-6

APPENDIX F

Station 4, Run 1—21-22 February 1972 (Closing)

During this run 3.5 and 5.0 propagation losses were measured over acoustic ranges from 100 yd to 33.3 kyd.

Average Sound Speed Profile

Individual profiles revealed transient surface channels to varying depth and intermittent small depressed channels. Figure 3 contains a plot of these average data, as well as source and receiver depths. The average sound speed profile is characterized by a 17 m surface channel with a small negative sound speed gradient underlaying to a depth of 80 m. During this experiment the source ship reported 5 to 6 knot winds, 1 ft waves, and 8 to 10 ft swell, while the receiver ship reported light airs to 5 knot winds, calm to ripples, and 4 ft swell. Sea surface roughness measurements were obtained by the Waverider buoy. Spectral analysis of these measurements indicated a change in spectrum time. Receiver 1 was located in the surface channel, receivers 2 and 3 in the small negative sound speed gradient layer, and receivers 4 and 5 in the thermocline.

AMOS Parameters

Average values of these parameters, derived from the themistor chain measurements and applicable to the Run 1 experiments were:

isothermal layer depths	56 ft
surface water temperature	59.7^{0}F
sea state	1

Discussion

The propagation loss measurements are summarized in Figures F-2 through

F-6. A visual comparison of the plots suggests the following:

- The 5.0 kHz propagation losses recorded on all receivers were slightly greater than the 3.5 kHz propagation losses. The 3.5 kHz propagation loss recorded on the 6 m receiver, located in the 17 m surface sound channel, was slightly, but not markedly, less than that recorded on the four deep receivers. At 5.0 kHz the propagation loss recorded on the 6 m receiver at ranges greater than about 20 kyd was a nominal 10 dB less than that recorded on the four deepest receivers.

- The maximum range for Run 1 was 33.2 kyd. For the three deep receivers, many of the 3.5 kHz arrivals were below the noise level for ranges greater than about 21 kyd. For the two deep receivers many of the 5.0 kHz arrivals were below noise level for ranges greater than 26 kyd.

Table F-1. Station 4, Run 1 (21-22 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Number of Observations	Average Speed	Standard Deviation
0	2421	1506.67	0.23
10	2421	06.79	0.19
20	2421	06.79	0.21
30	2421	06.69	0.33
50	2421	06.48	0.23
75	2421	06.44	0.27
100	2421	05.66	0.78
125	2421	01.94	1.72
150	2421	1497.16	0.95
200	2421	90.78	0.68
250	2421	88.03	0.53
300	12	86.01	0.32
400	11	83.02	0.45
500	9	81.81	0.29
600	5	81.36	0.36
800	4	81.25	0.15
1000	4	82.17	0.22
1200	4	83.47	0.22
1500	4	86.06	0.22
17		1506.87	SC
700		1481.20	AXIS

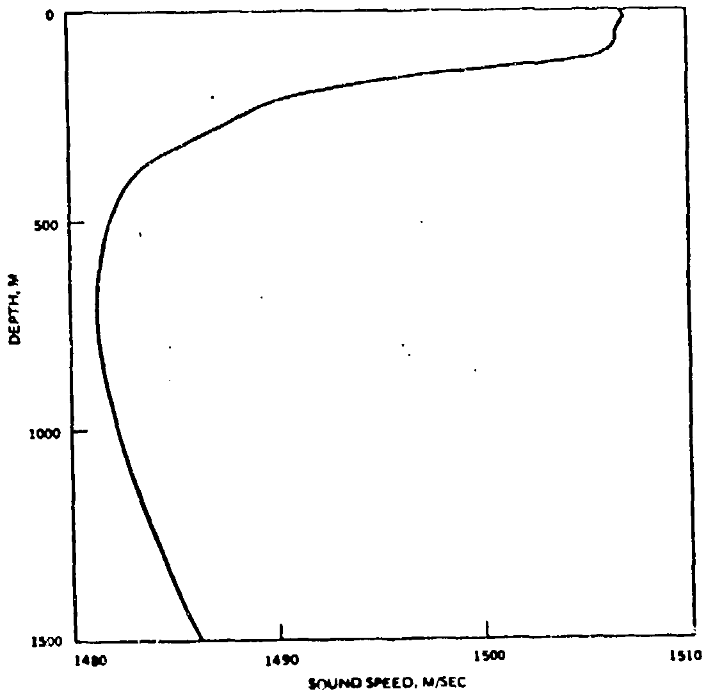


Figure F-1. Station 4, Run 1.
Average Sound Speed Profile.

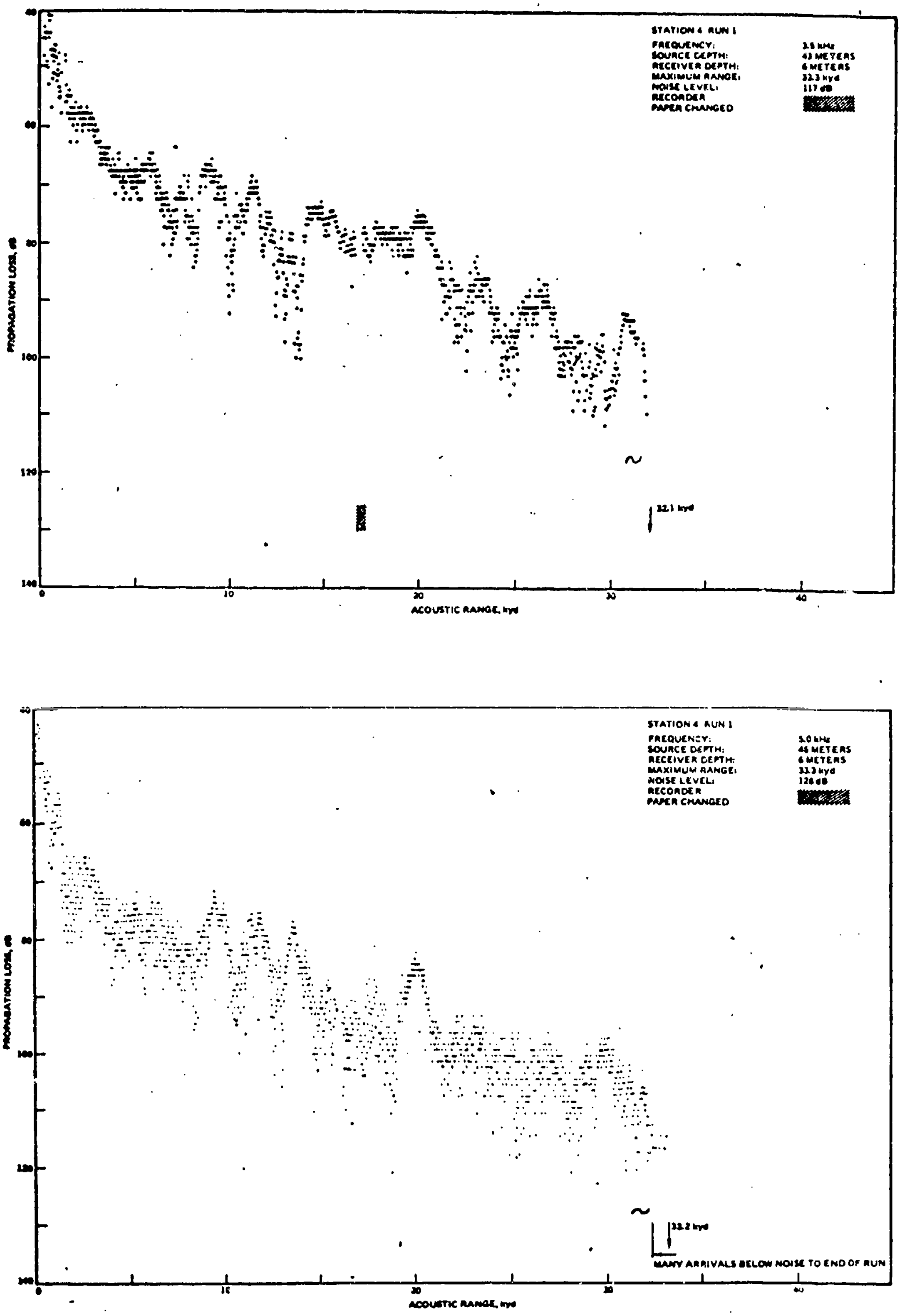

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED ▨
32.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 126 dB
RECORDER PAPER CHANGED ▨
33.2 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. F-2

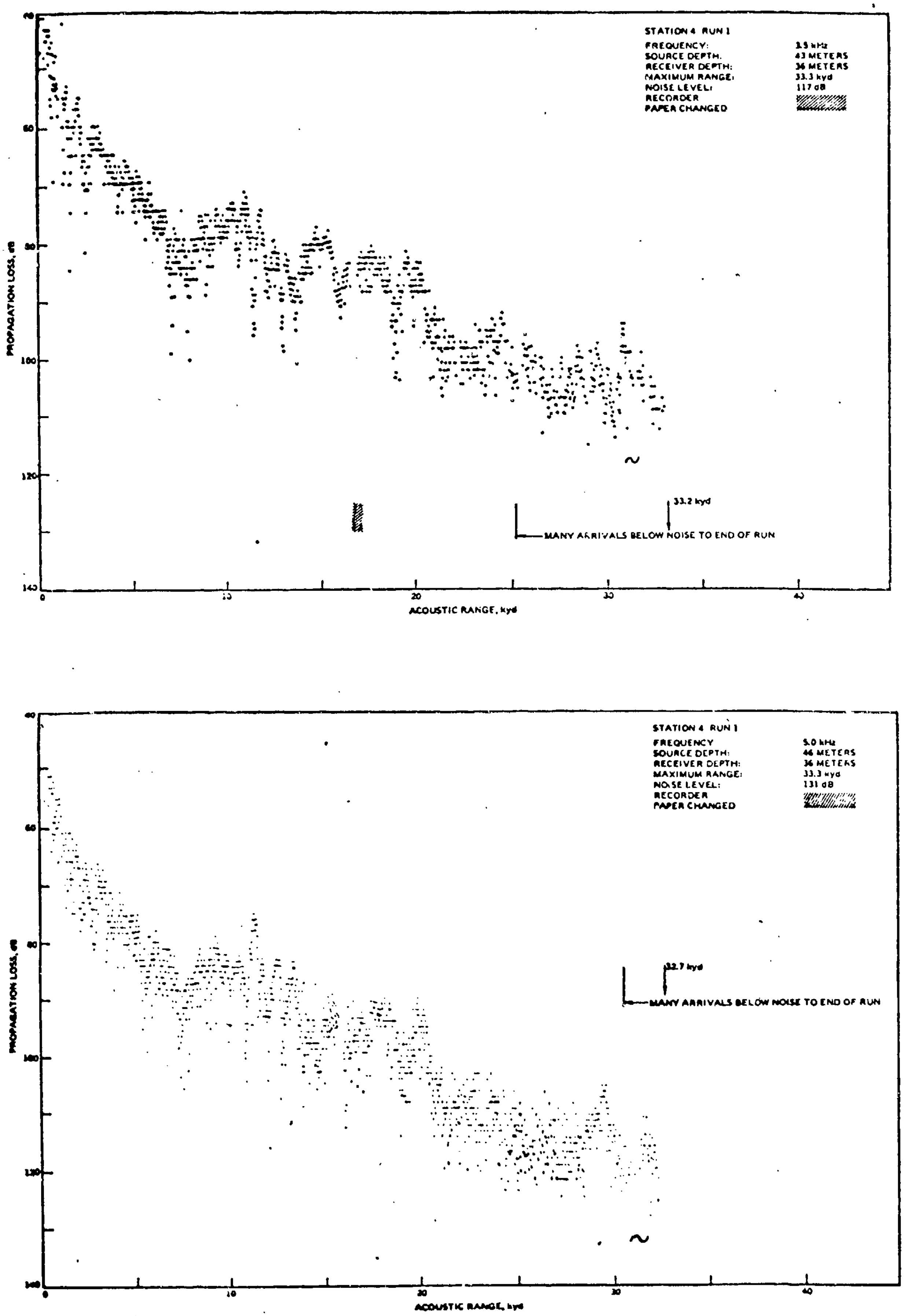
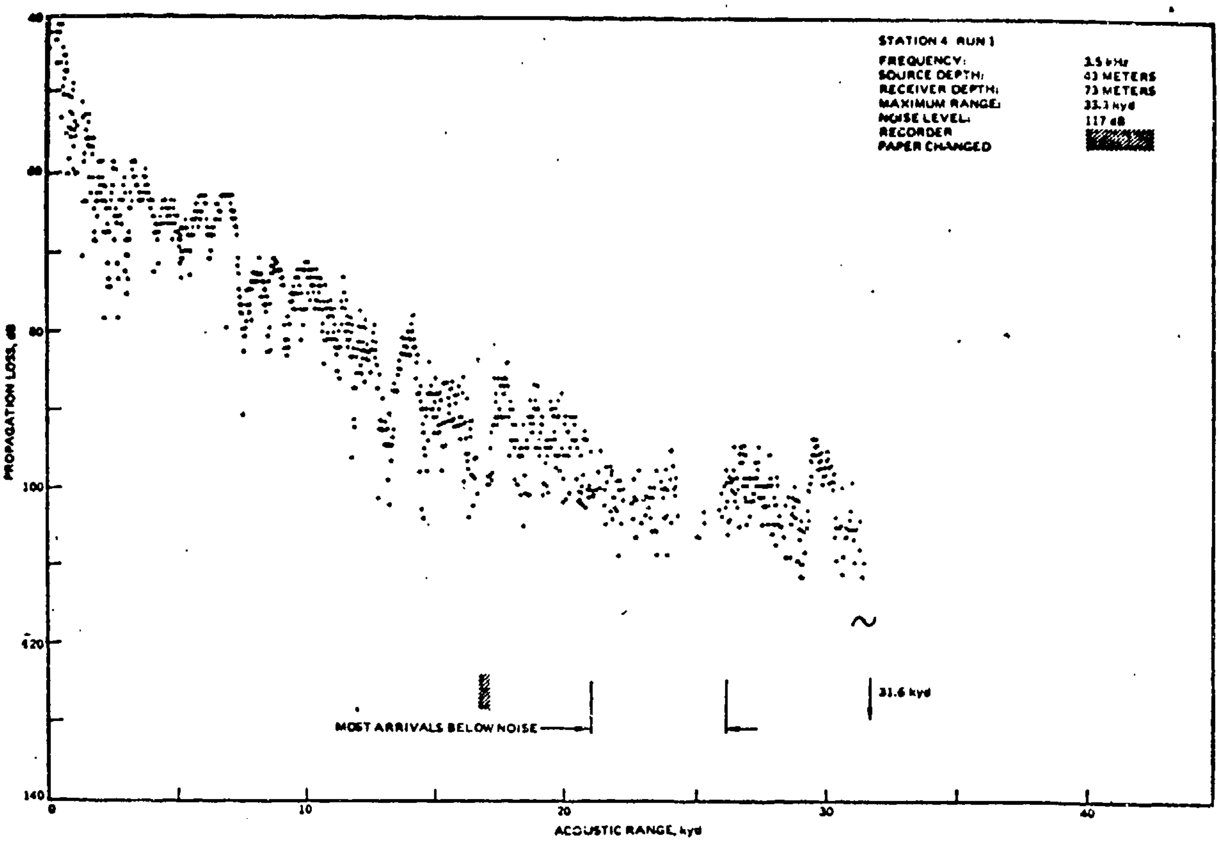

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED ▨
33.2 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 1
FREQUENCY 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER PAPER CHANGED ▨
32.7 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. F-3


STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 117 dB
RECORDER PAPER CHANGED ▨
31.6 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

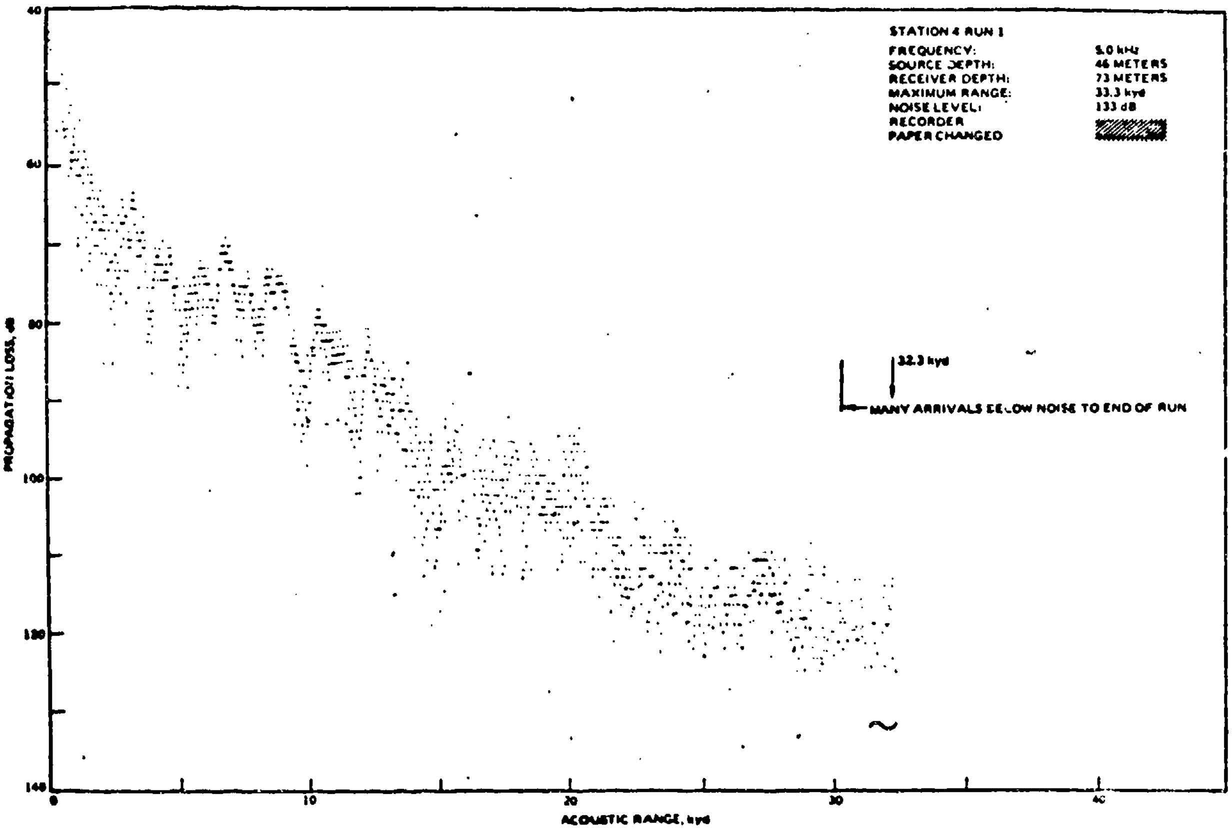

STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 73 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 133 dB
RECORDER PAPER CHANGED ▨
32.3 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. F-4

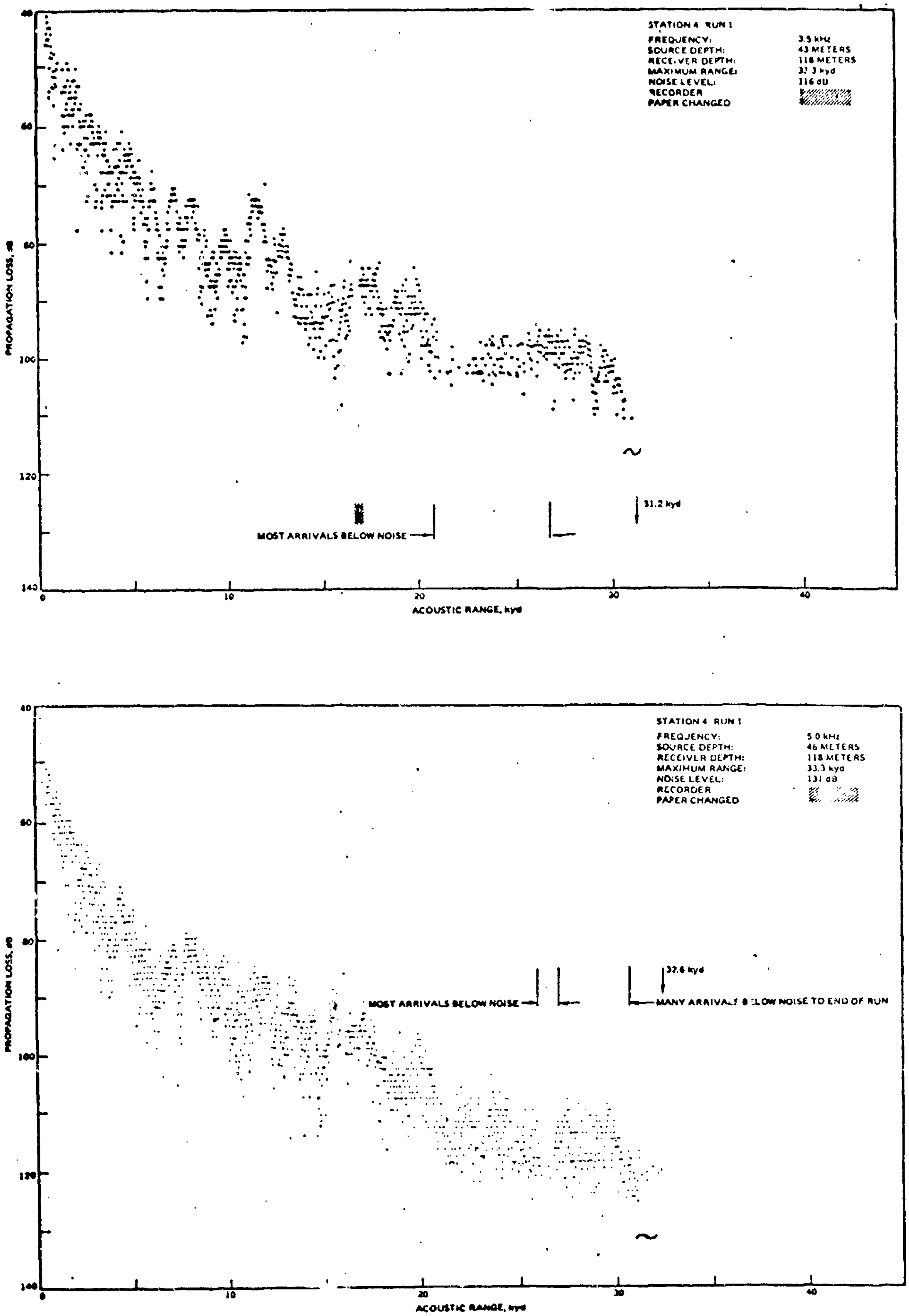
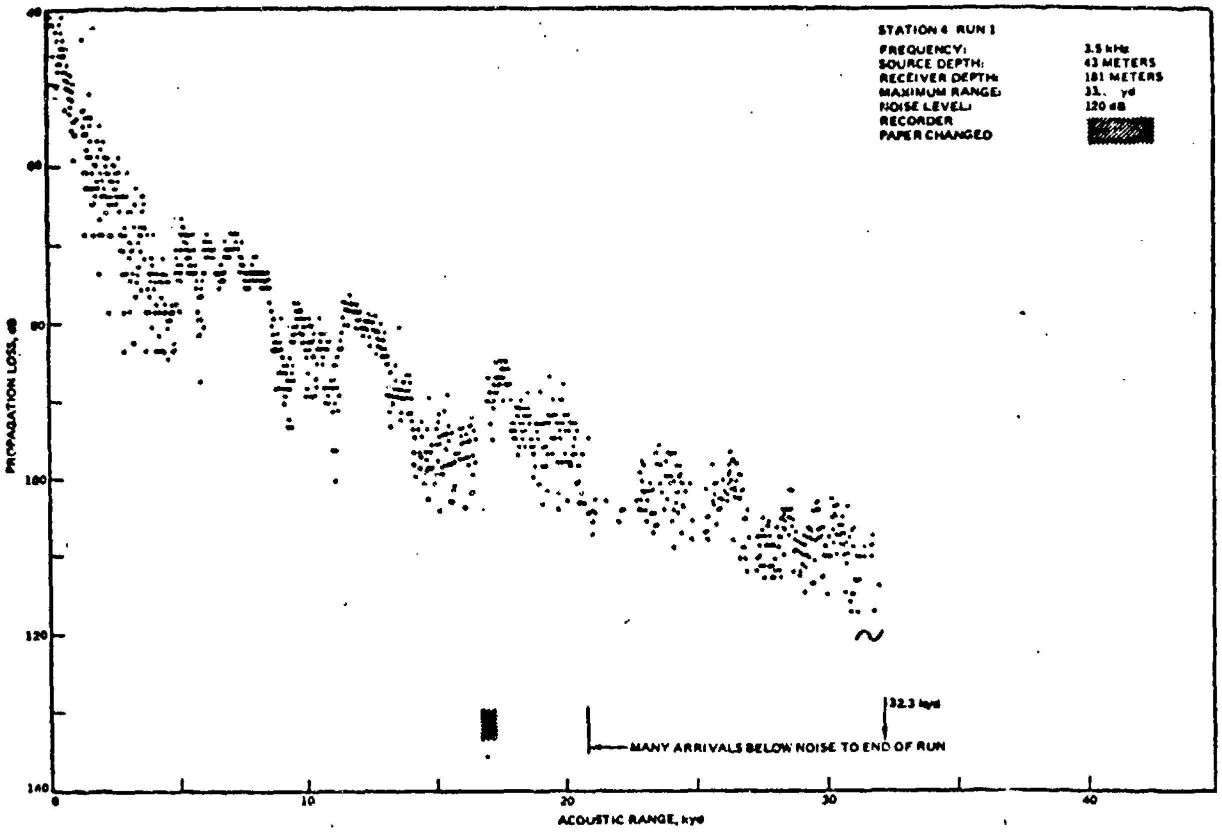

STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 118 METERS
MAXIMUM RANGE: 32.3 kyd
NOISE LEVEL: 116 dB
RECORDER PAPER CHANGED
31.2 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 118 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER PAPER CHANGED
32.6 kyd
MOST ARRIVALS BELOW NOISE
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40

Fig. F-5


STATION 4 RUN 1
FREQUENCY: 3.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 181 METERS
MAXIMUM RANGE: 33. yd
NOISE LEVEL: 120 dB
RECORDER
PAPER CHANGED
32.3 kyd
MANY ARRIVALS BELOW NOISE TO END OF RUN
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

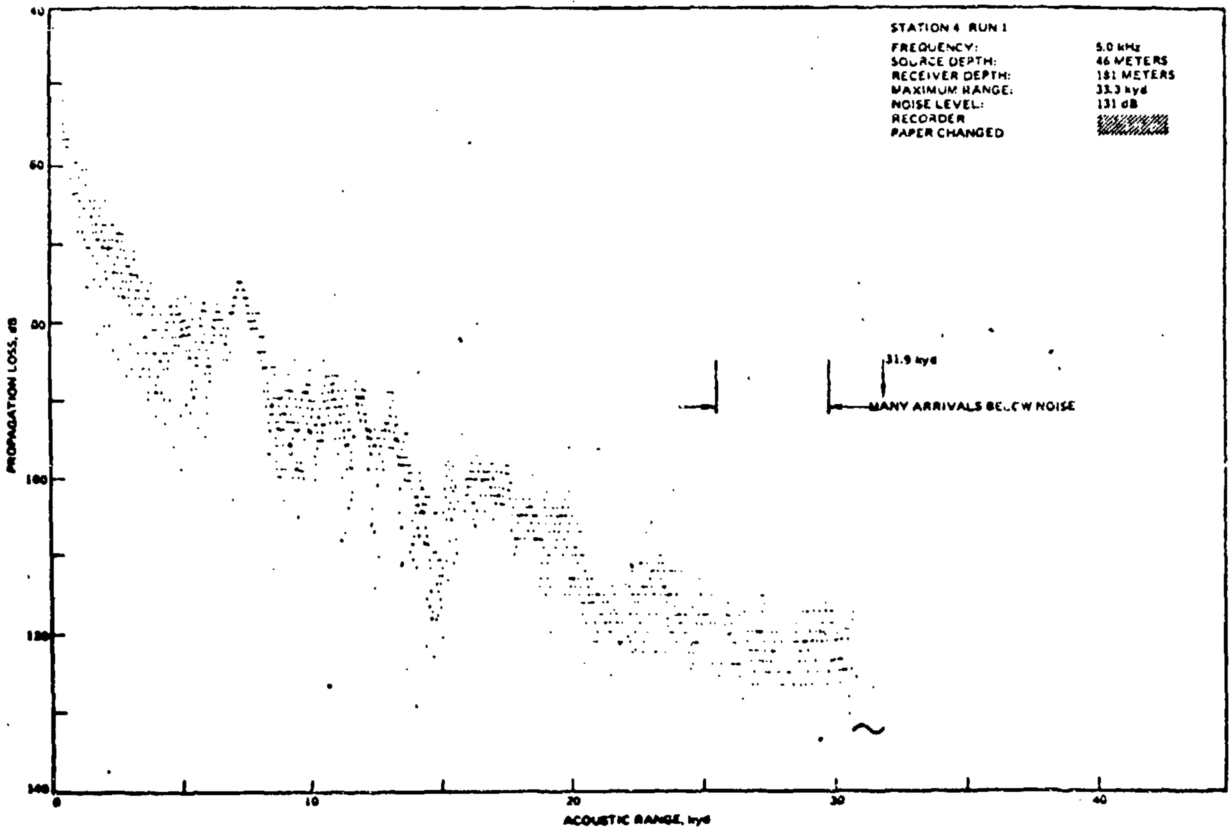

STATION 4 RUN 1
FREQUENCY: 5.0 kHz
SOURCE DEPTH: 46 METERS
RECEIVER DEPTH: 181 METERS
MAXIMUM RANGE: 33.3 kyd
NOISE LEVEL: 131 dB
RECORDER
PAPER CHANGED
31.9 kyd
MANY ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. F-6

APPENDIX G

Station 4, Run 3 — 22-23 February 1972 (Closing)

During this run 1.5 and 2.5 kHz propagation losses were measured over acoustic ranges from 213 to 35.1 kyd.

Average Sound Speed Profile

Individual sound speed profiles suggested that the experiment was conducted in a single sound speed profile volume. Profiles revealed transient surface channels at various depths to 67 m. Figure 3 contains a plot of the average sound speeds. The average profile is characterized by a negative sound speed gradient from the surface to 700 m, the depth of the deep sound speed minimum. Surface and depressed channels in the individual profiles were not retained in the average profile. The source ship reported 4 to 8 knot winds, 1 ft waves, and 7 to 8 ft swell; the receiver ship 7 to 8 knot winds, 1 ft waves, and 3 to 4 ft swell. Sea surface roughness measurements were obtained by the Waverider buoy. Spectral analysis of the Waverider buoy measurements indicated that most of the variance was in a wave period band centered at 12.6 sec, with a secondary peak at 7.8 sec. All receivers were in a negative sound speed gradient.

AMOS Parameters

Average values of the parameters, derived from the thermistor chain temperature measurements, and applicable to the Run 3 experiments were:

isothermal layer depth	0 ft
surface water temperature	59.5°F
sea state	2

Discussion

The propagation loss measurements are summarized in Figures G-2 through G-6.

The missing arrivals in the 27 to 29 kyd range interval were due to a malfunction of the sources. A visual comparison of plots suggests the following:

- At both frequencies the propagation loss recorded on the 6 and 36 m receivers was slightly less than that recorded on the 72, 117, and 180 m receivers.
- For any given receiver depth, no frequency dependence occurred in the propagation loss patterns.
- Although the average sound speed profile did not display a surface or depressed channel, the propagation loss patterns exhibited a well developed modal pattern, especially for the propagation losses recorded on the shallower receivers.
- The maximum range for Run 3 was 35.1 kyd. The maximum range was recorded for both frequencies at all receiver depths.

Table G-1. Station 4, Run 3 (22-23 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Number of Observations	Average Speed	Standard Deviation
0	2493	1507.15	0.26
10	2493	06.89	0.35
20	2493	06.70	0.39
30	2493	06.59	0.42
50	2493	06.51	0.42
75	2493	06.31	0.83
100	2493	05.46	1.42
125	2493	01.97	1.20
150	2493	1497.55	1.01
200	2493	91.31	0.43
250	2493	88.75	0.64
300	16	86.41	0.44
400	16	83.27	0.52
500	9	81.81	0.29
600	5	81.36	0.36
800	4	81.25	0.15
1000	4	82.17	0.22
1200	4	83.47	0.22
1500	4	86.06	0.22
700		1481.20	AXIS

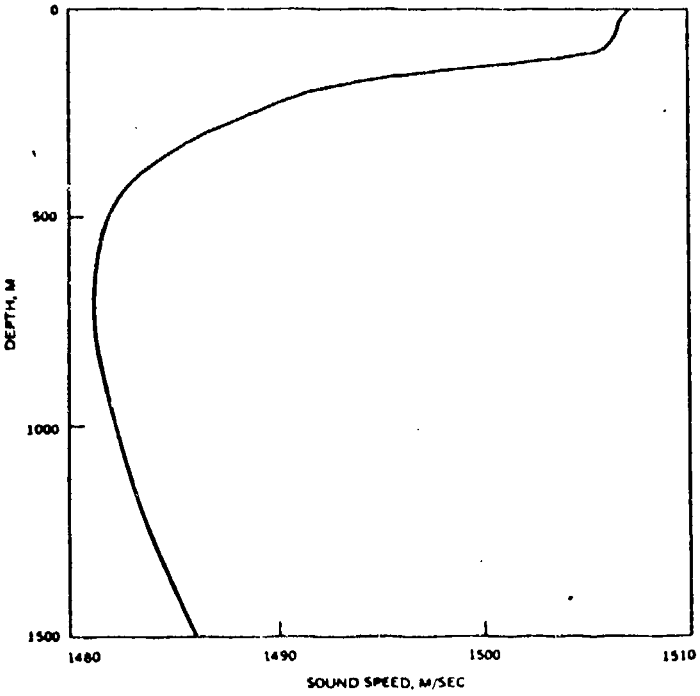


Figure G-1. Station 4, Run 3
Average Sound Speed Profile.

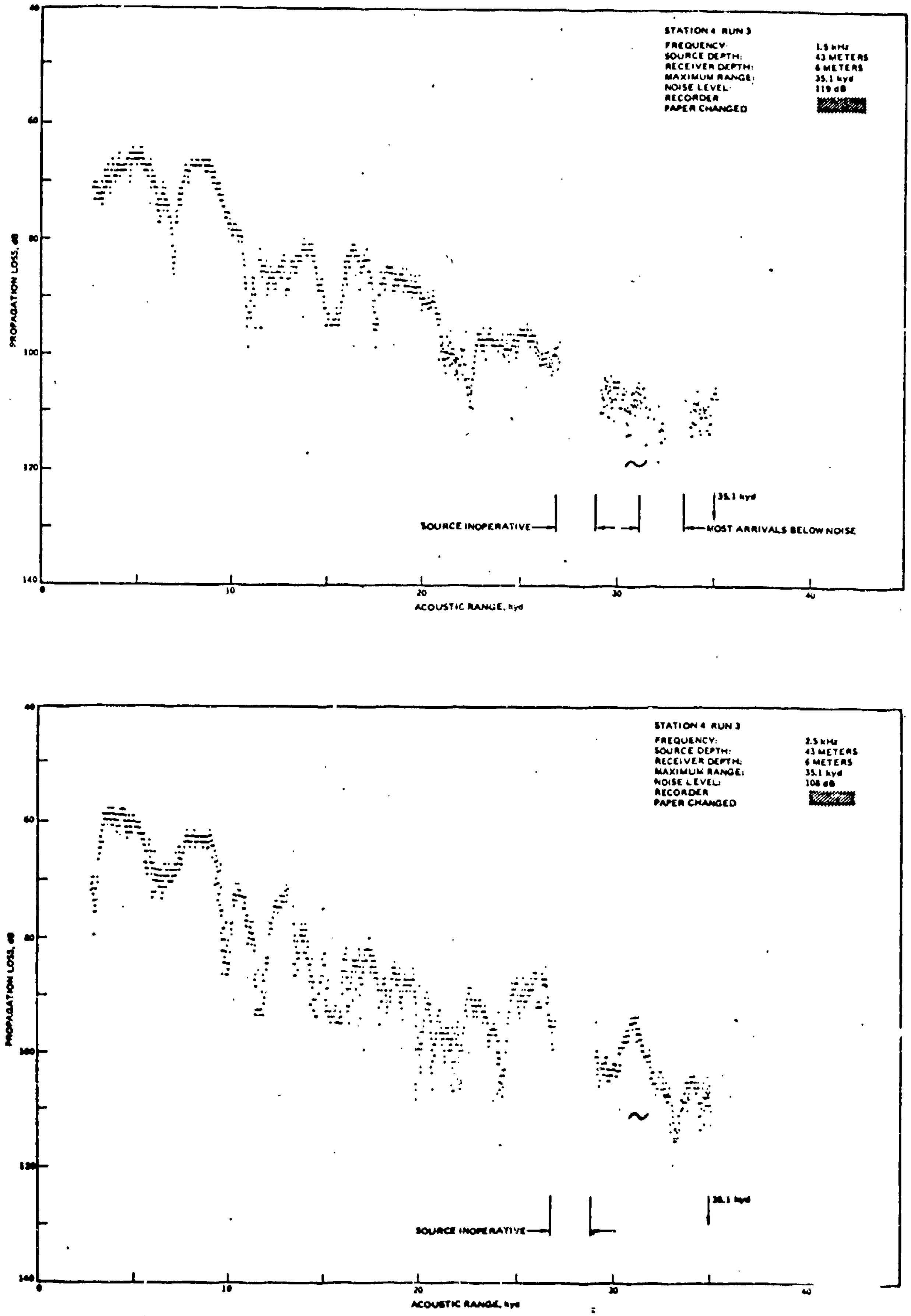

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 119 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
SOURCE INOPERATIVE
35.1 kyd
MOST ARRIVALS BELOW NOISE
STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 108 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
ACOUSTIC RANGE, kyd
0
10
20
30
40
SOURCE INOPERATIVE
35.1 kyd

Fig. G-2

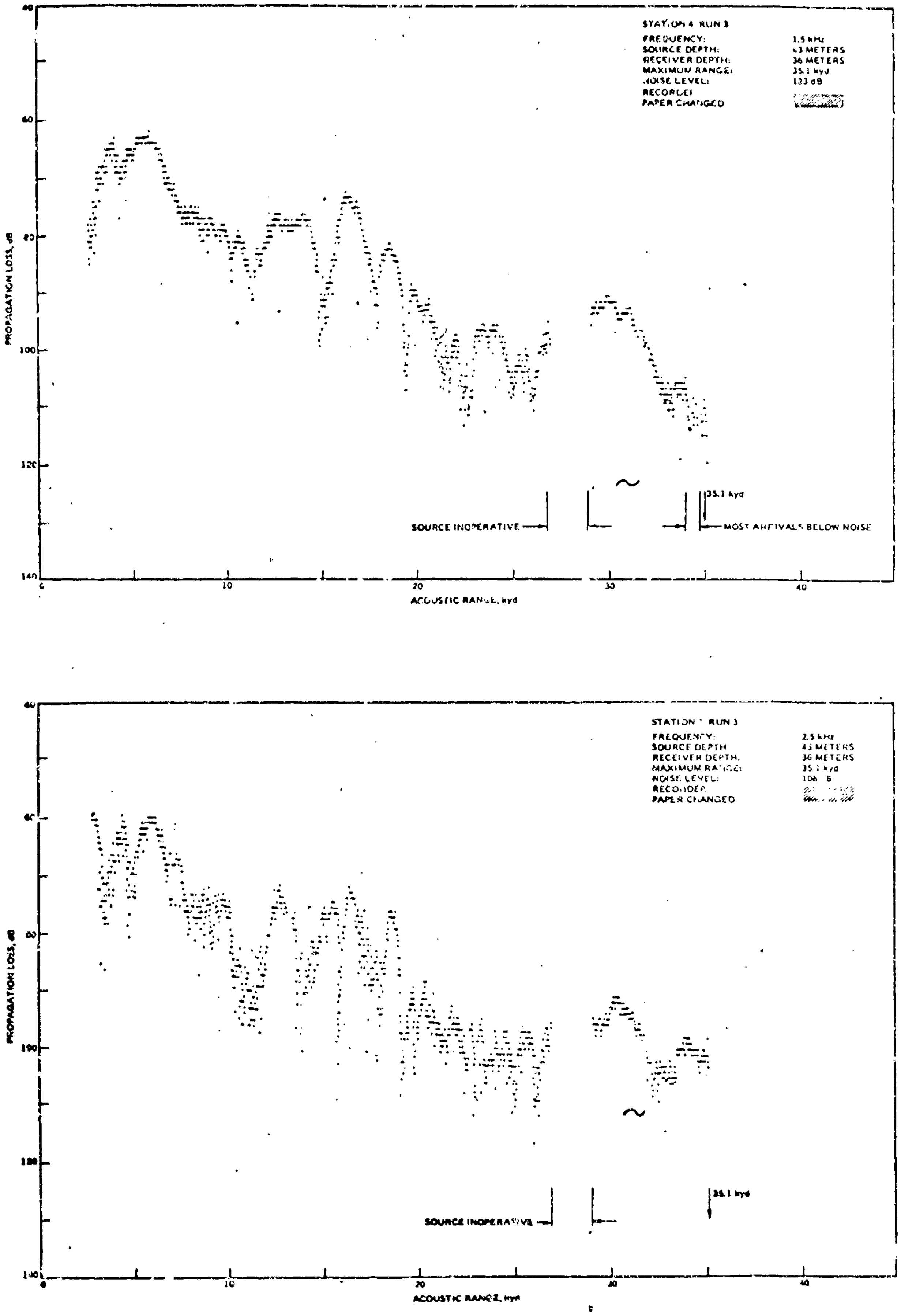

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 123 dB
RECORDER
PAPER CHANGED
SOURCE INOPERATIVE
35.1 kyd
MOST ARRIVALS BELOW NOISE
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 106 dB
RECORDER
PAPER CHANGED
SOURCE INOPERATIVE
35.1 kyd
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. G-3

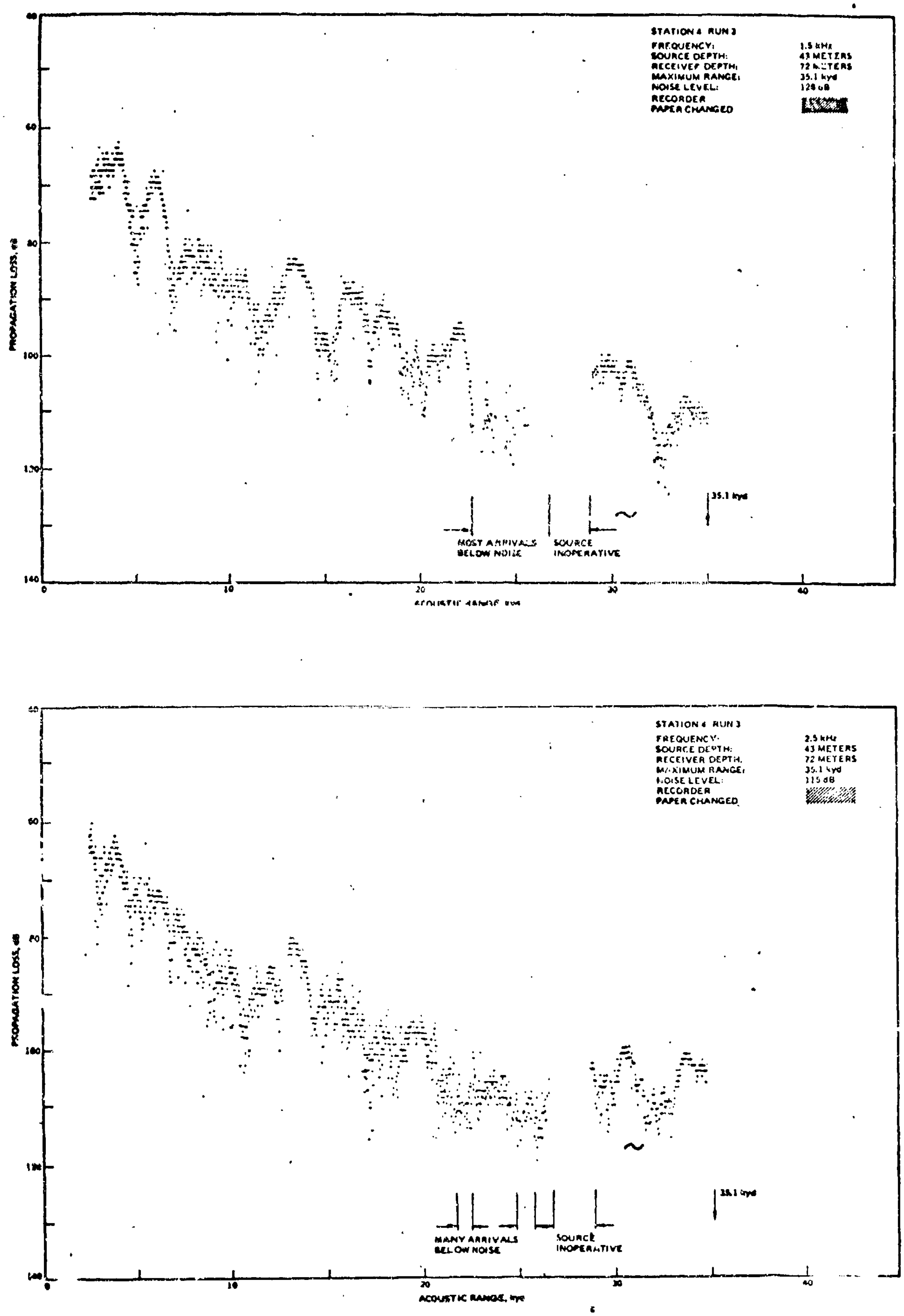

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 120 dB
RECORDER PAPER CHANGED
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
35.1 kyd
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd
40
60
80
100
120
140
0
10
20
30
40
STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 115 dB
RECORDER PAPER CHANGED
MANY ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
35.1 kyd
PROPAGATION LOSS, dB
ACOUSTIC RANGE, kyd

Fig. G-4

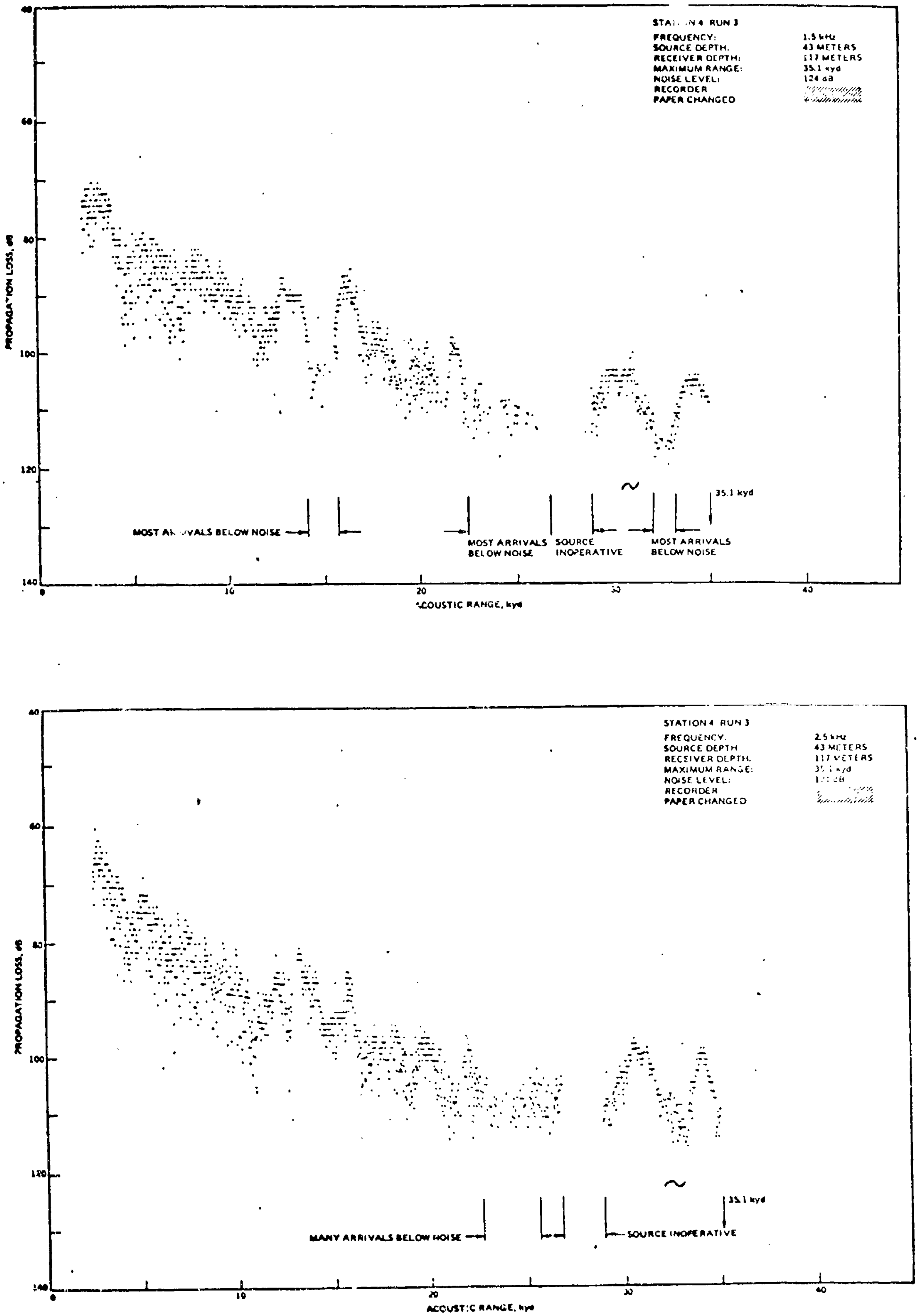

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH. 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 124 dB
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
MOST ARRIVALS BELOW NOISE
35.1 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 3
FREQUENCY. 2.5 kHz
SOURCE DEPTH 43 METERS
RECEIVER DEPTH. 117 METERS
MAXIMUM RANGE:
NOISE LEVEL:
RECORDER
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
MANY ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
35.1 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. G-5

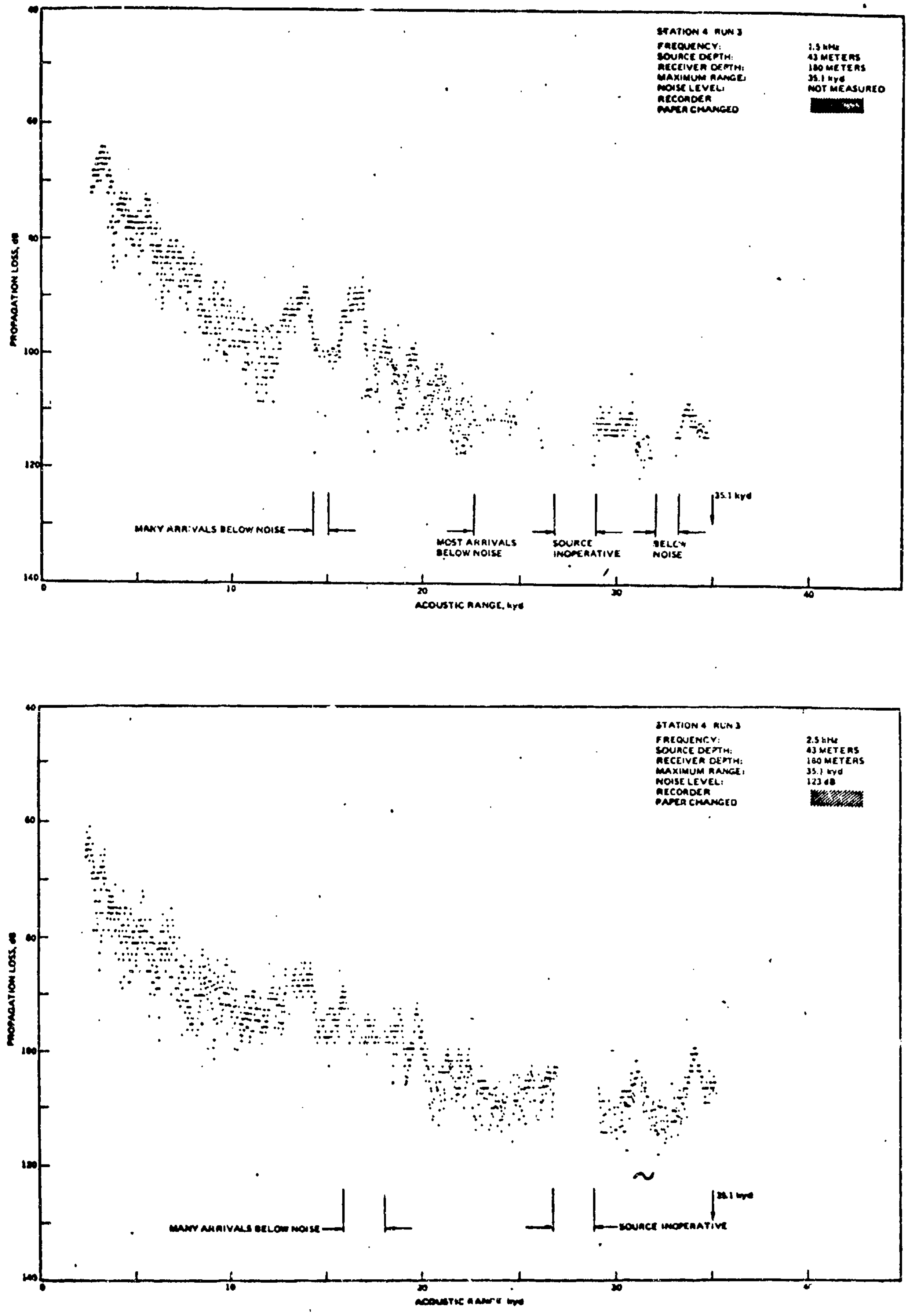

STATION 4 RUN 3
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
BELOW NOISE
35.1 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 3
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 180 METERS
MAXIMUM RANGE: 35.1 kyd
NOISE LEVEL: 123 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
MANY ARRIVALS BELOW NOISE
SOURCE INOPERATIVE
35.1 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. G-6

APPENDIX H

Station H, Run 4—23 February 1972 (Opening)

During this run, 1.5 and 2.5 kHz propagation losses were measured over acoustic ranges from 2.6 to 33.4 kyd.

Average Sound Speed Profiles

Individual sound speed profiles suggested that the experiment was conducted in a single sound speed profile volume. The profiles exhibited transient surface channels to varying depths and intermittent small depressed channels. Figure 3 contains a plot of the average sound speed profile. The average profile is characterized by a 10 m surface channel. The transient depressed channels observed in individual profiles were not preserved in the average profile. Sea surface roughness measurements were obtained by the Waverider buoy for the complete run. The source ship reported 8 to 10 knot winds, 1 ft waves, and 8 ft swell; the receiving ship 8 to 10 knot winds, 1 ft waves, and 3 to 4 ft swell. Receiver 1 was located in the surface channel, receivers 2 and 3 in a small negative sound speed gradient layer, and receivers 4 and 5 in the main thermocline.

AMOS Parameters

The average values of parameters, derived from the thermistor chain temperature measurements, and applicable to the Run 4 experiment were:

number of observations	1854
isothermal layer depth	33 ft
surface water temperature	59.9^{0}F
sea state	2

Discussion

The propagation loss measurements are summarized in Figures D-2 through D-6.

A visual comparison suggests the following:

- Although the average sound speed profile was characterized by a 10 m surface channel, the 6 m receiver recorded all transmitted pulses out to only 4.6 kyd (1.5 kHz) and 5.1 kyd (2.5 kHz). At greater ranges there were many intervals in which many, most, or all of the transmitted pulses were below the noise level. It is somewhat paradoxical that at 2.5 kHz, all 6 m pulses were received from 30.1 kyd to the end of the run at 33.4 kyd.

- At both frequencies and for the four deepest receivers, the propagation loss plots displayed modal patterns that were best developed at 1.5 kHz.

Table H-1. Station 4, Run 4 (23 February 1972)
Average Sound Speed Profile (m/sec).

Depth, m	Number of Observations	Average Speed	Standard Deviation
0	1854	1507.05	0.22
10	1854	07.08	0.22
20	1854	06.99	0.23
30	1854	06.94	0.26
50	1854	06.80	0.46
75	1854	06.81	0.20
100	1854	06.20	0.64
125	1854	01.87	0.79
150	1854	1496.89	1.09
200	1854	90.71	0.36
250	1854	88.07	0.34
300	12	85.94	0.50
400	12	82.77	0.58
500	9	81.81	0.29
600	5	81.36	0.36
800	4	81.25	0.15
1000	4	82.17	0.22
1200	4	83.47	0.22
1500	4	86.06	0.22
10		1507.08	SC
700		1481.20	AXIS

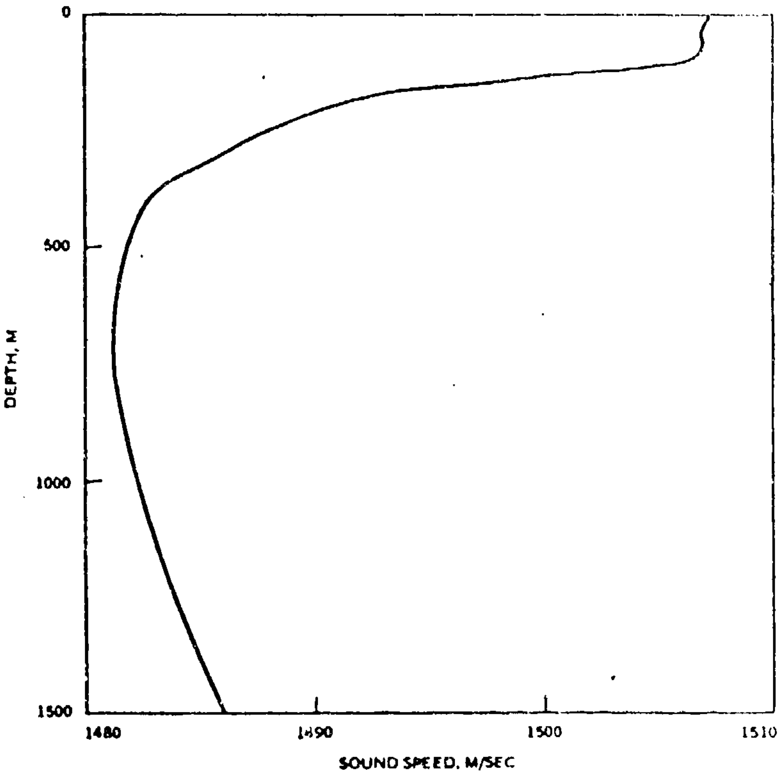


Figure H-1. Station 4, Run 4
Average Sound Speed Profile.

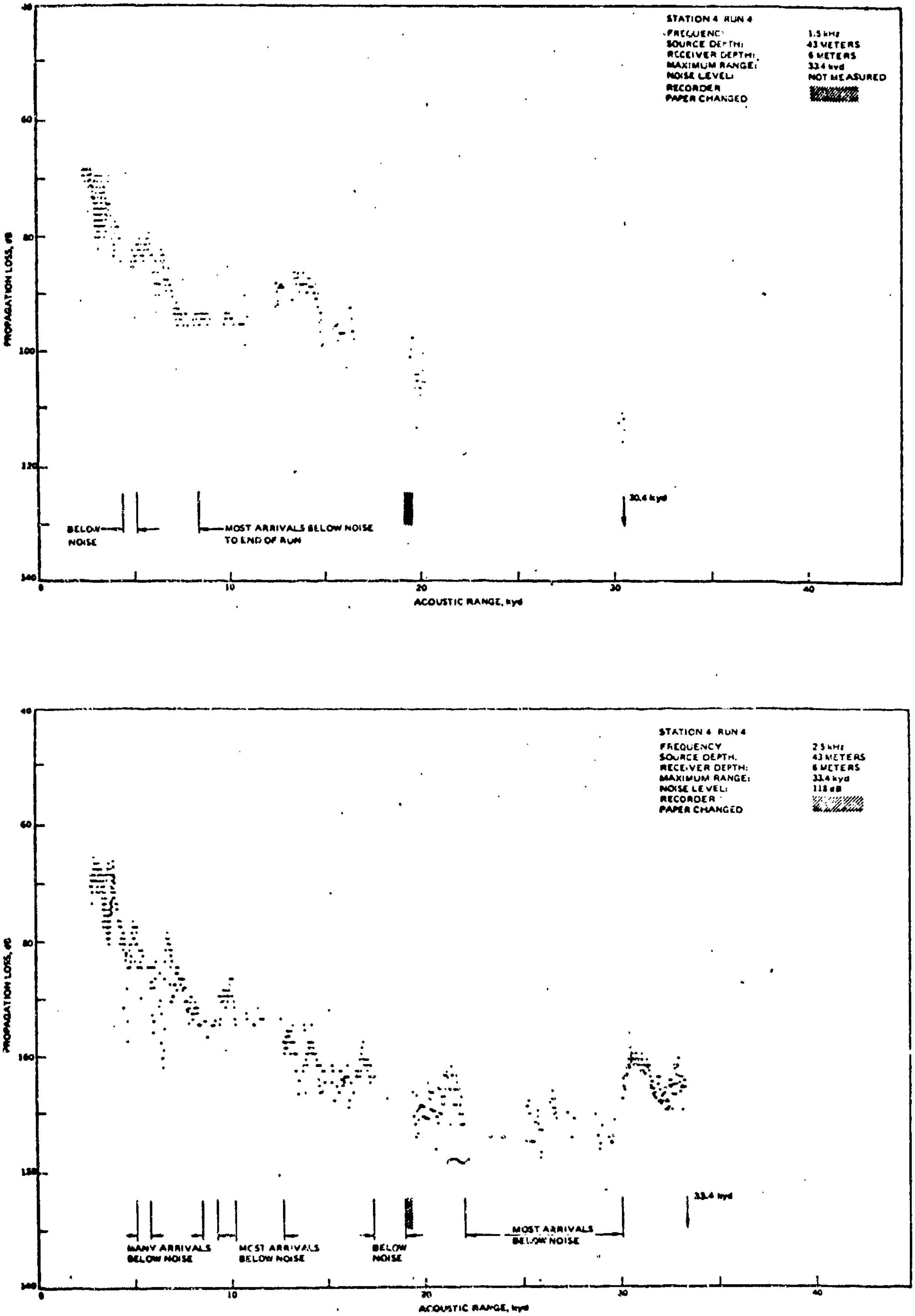

STATION 4 RUN 4
FREQUENCY 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: NOT MEASURED
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
30.4 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd
STATION 4 RUN 4
FREQUENCY 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 6 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 118 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
BELOW NOISE
MOST ARRIVALS BELOW NOISE
33.4 kyd
0
10
20
30
40
ACOUSTIC RANGE, kyd

Fig. H-2

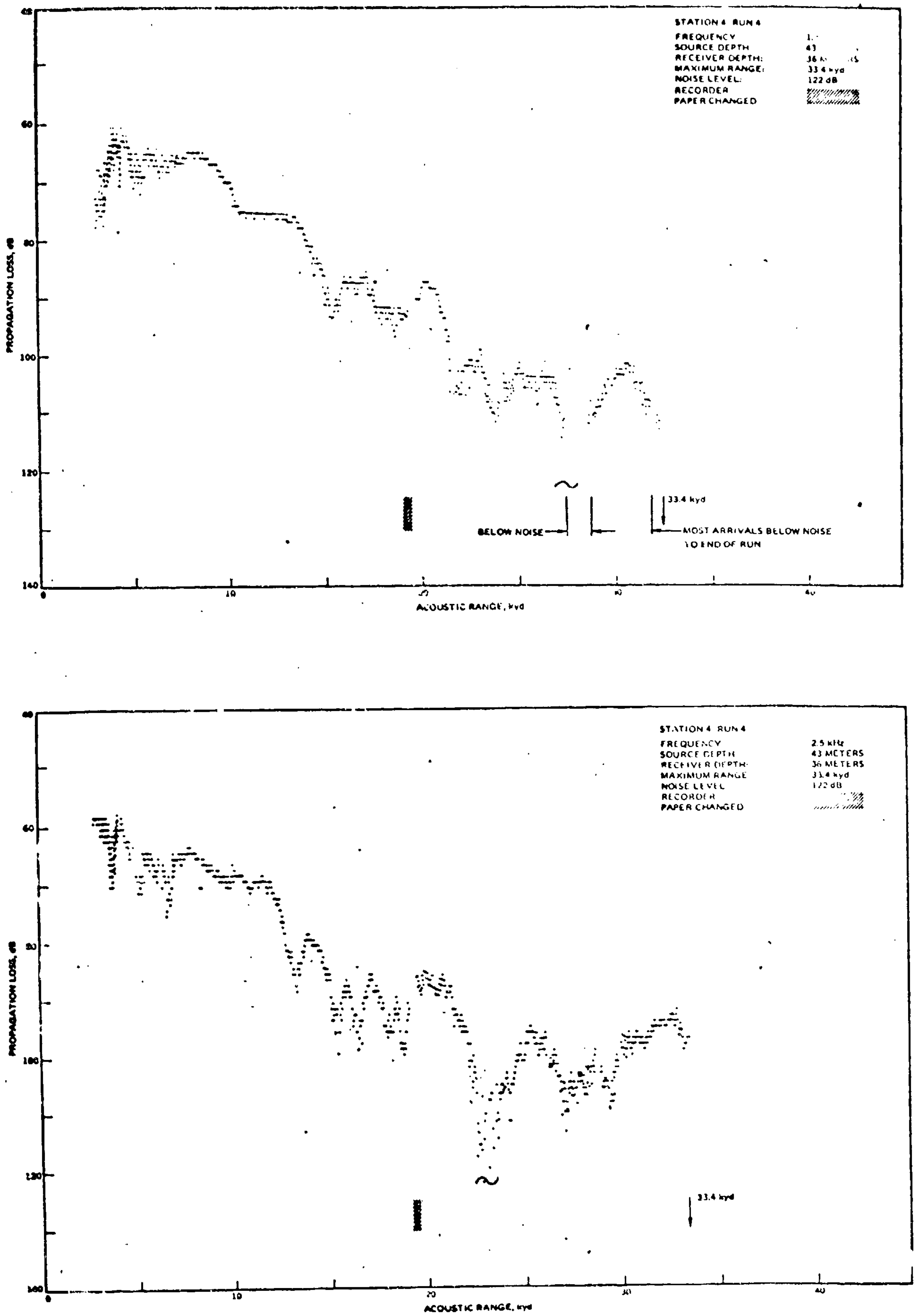

STATION 4 RUN 4
FREQUENCY 1.
SOURCE DEPTH 43
RECEIVER DEPTH: 36 M RS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 122 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
33.4 kyd
BELOW NOISE
MOST ARRIVALS BELOW NOISE TO END OF RUN
STATION 4 RUN 4
FREQUENCY 2.5 kHz
SOURCE DEPTH 43 METERS
RECEIVER DEPTH: 36 METERS
MAXIMUM RANGE 33.4 kyd
NOISE LEVEL 122 dB
RECORDER PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
33.4 kyd

Fig. H-3

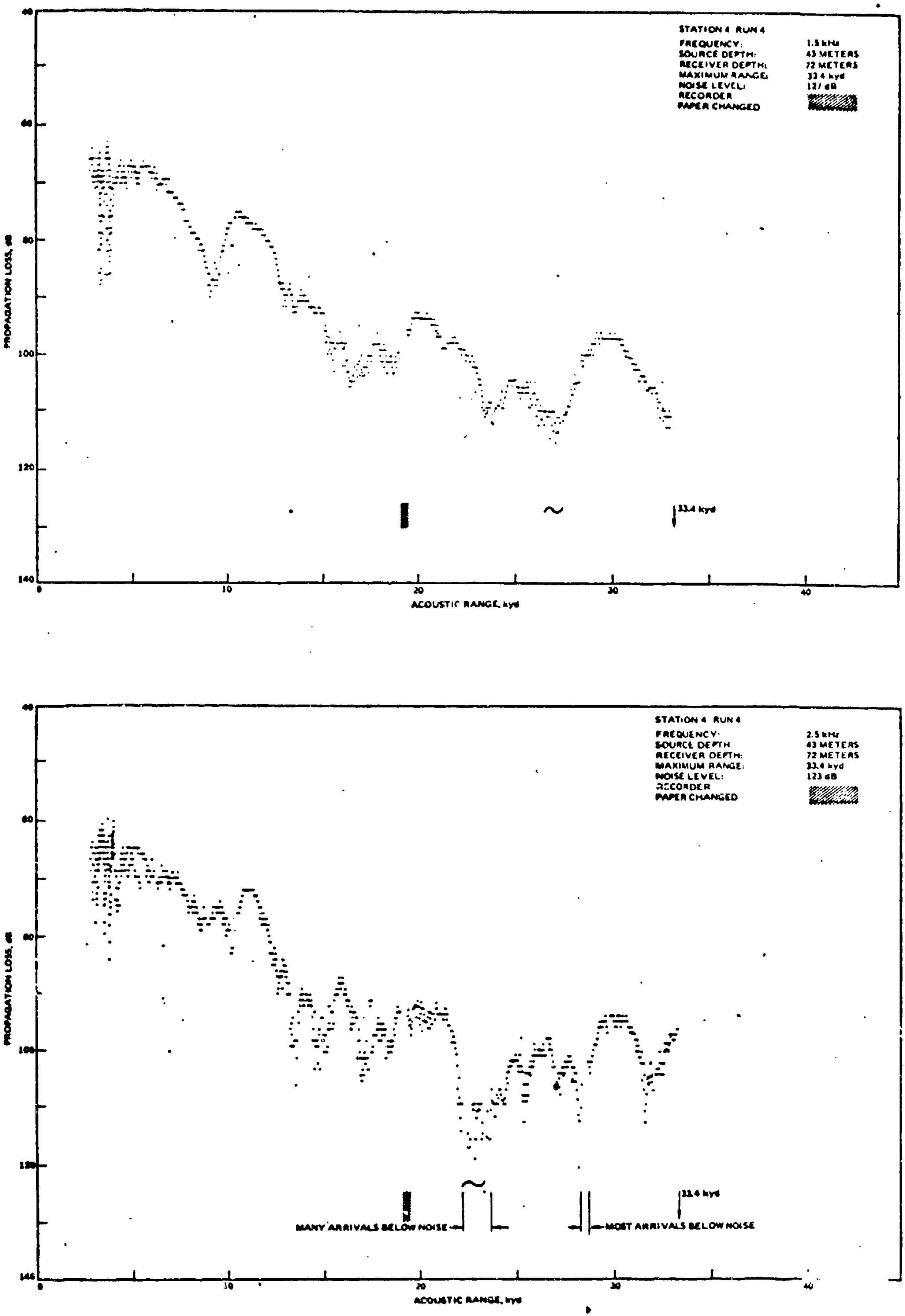

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 127 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
33.4 kyd
STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH 43 METERS
RECEIVER DEPTH: 72 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 123 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
33.4 kyd
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE

Fig. H-4

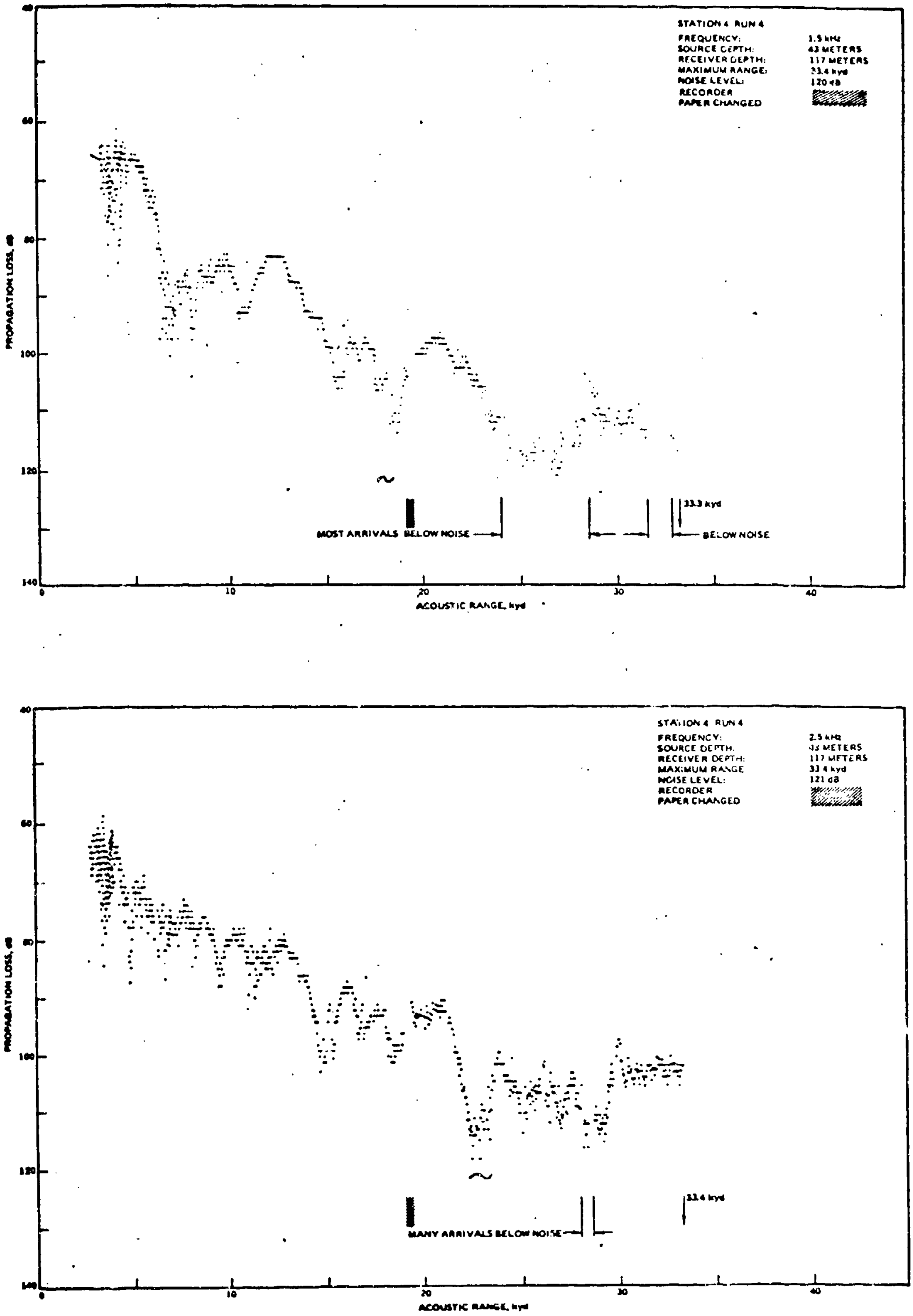

STATION 4 RUN 4
FREQUENCY: 1.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE: 33.4 kyd
NOISE LEVEL: 120 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
MOST ARRIVALS BELOW NOISE
33.3 kyd
BELOW NOISE
STATION 4 RUN 4
FREQUENCY: 2.5 kHz
SOURCE DEPTH: 43 METERS
RECEIVER DEPTH: 117 METERS
MAXIMUM RANGE 33.4 kyd
NOISE LEVEL: 121 dB
RECORDER PAPER CHANGED ▨
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
MANY ARRIVALS BELOW NOISE
33.4 kyd

Fig. H-5

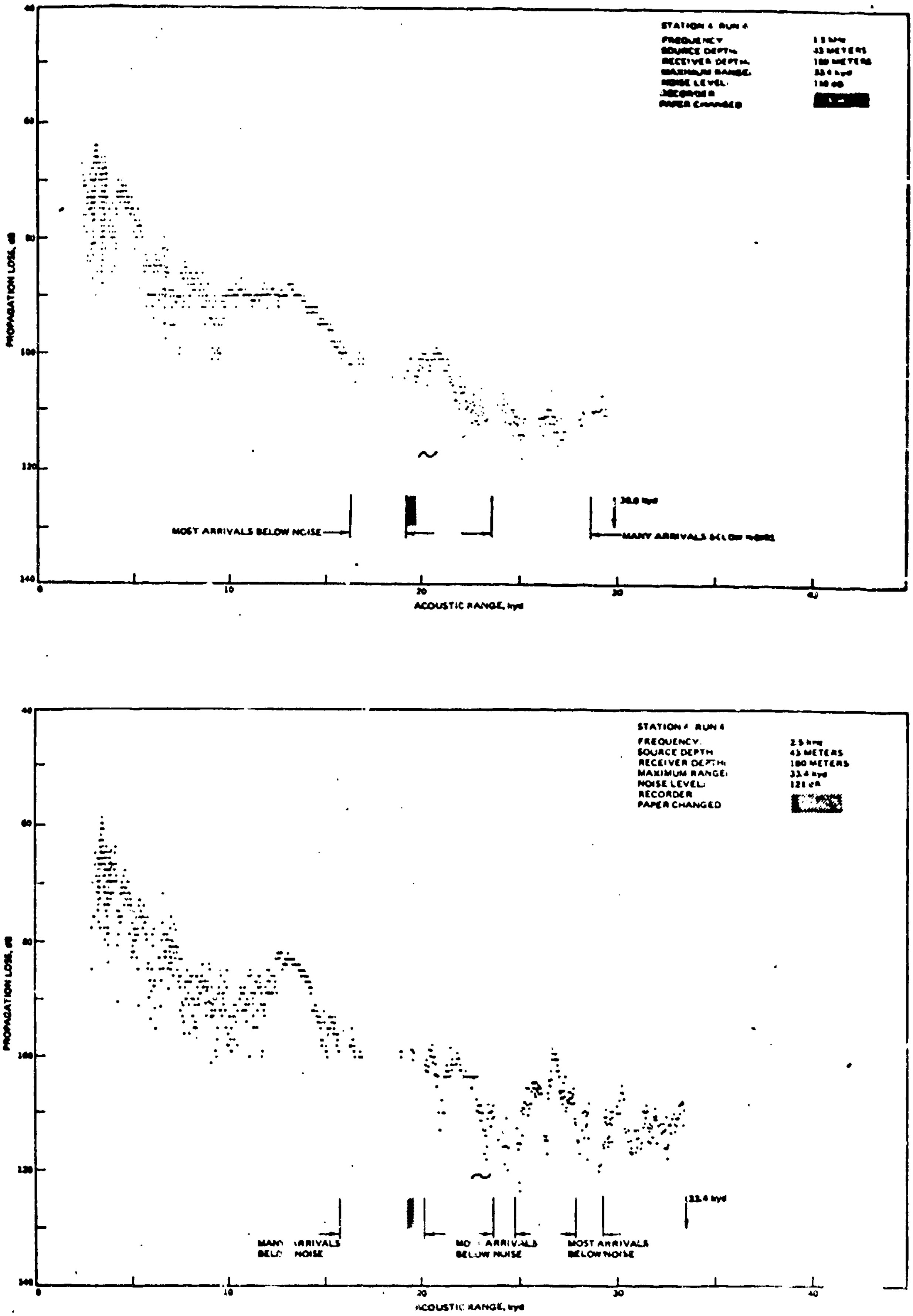

STATION 4 RUN 4
FREQUENCY 1.5 kHz
SOURCE DEPTH 43 METERS
RECEIVER DEPTH 180 METERS
MAXIMUM RANGE 33.4 kyd
NOISE LEVEL
RECORDER [redacted]
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
MOST ARRIVALS BELOW NOISE
30.0 kyd
MANY ARRIVALS BELOW NOISE
STATION 4 RUN 4
FREQUENCY 2.5 kHz
SOURCE DEPTH 43 METERS
RECEIVER DEPTH 180 METERS
MAXIMUM RANGE 33.4 kyd
NOISE LEVEL 121 dB
RECORDER [redacted]
PAPER CHANGED
PROPAGATION LOSS, dB
40
60
80
100
120
140
0
10
20
30
40
ACOUSTIC RANGE, kyd
MANY ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
MOST ARRIVALS BELOW NOISE
33.4 kyd

Fig. G-6

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Appendix 3. (U) GOA (Gulf of Alaska)

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APPENDIX 3

GULF OF ALASKA DATA SET (U)

Summarized by James A. Whitney

(U) The Naval Ocean Systems Center (formerly the Naval Undersea Center (NUC)) conducted deep-water acoustic experiments in the Gulf of Alaska (GOA) approximately 200 miles southeast of Kodiak, Alaska from April to August, 1971. This summary describes data from the test series ABLE-4 as reported in NUC TP 301, Vol IV.[1] Propagation loss data from ABLE-4 consist of 35 plots containing a total of 82,698 data points. This summary will present a limited sampling of these plots for purposes of illustration.

(U) Data concerning the water column including sound speeds are to be found in NUC TP 301, Vols II and III.[2,3] Sediment data and Sea Floor Studies are in reference (4).

(U) The data is available in NAVDAB (Exp 9, Cruise 1, Runs 1-35). However, it should be emphasized that the apparent propagation loss is reported. Apparent propagation loss is calculated from the axial source level and the effect of vertical directivity is not included. Since the sources used in the GOA experiments were directive these data can be used to evaluate the RAYMODE X propagation loss model. Any or all of the data presented in reference (1) should be suitable for model evaluation. The data do not include bottom bounce propagation.

(C) The purpose of the GOA tests were to determine the magnitude of improved sonar performance vs depth to be gained by utilizing the Reliable Acoustic Path (RAP), and to compare convergence zone propagation for a shallow source with RAP propagation for a deep source.

EXPERIMENT PROCEDURES (U)

(U) ABLE 4 experiments were conducted at the site labeled A3,4 in Figure 1. All propagation runs were conducted with the source ship closing on a nominal

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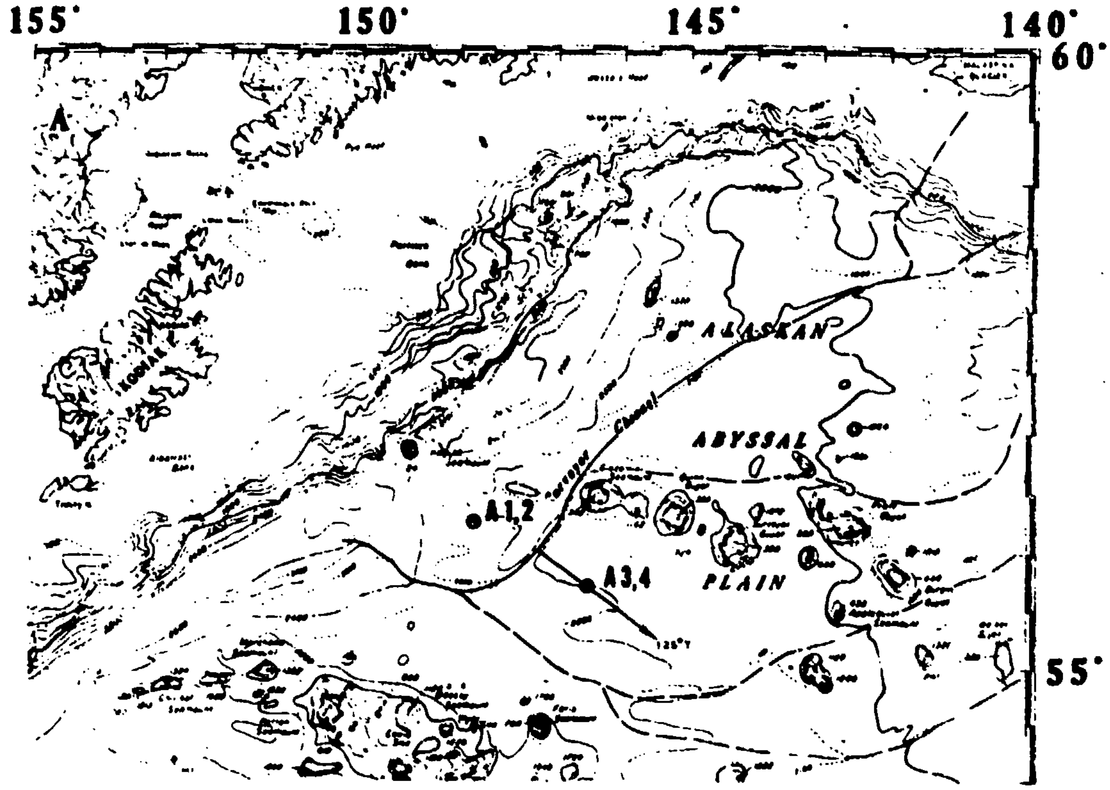

(U) Figure 1a Chart (from Chase, Scripps Institution) showing locations of Stations A1, 2 and A3, 4. Contour interval is 100 fathoms (uncorrected) in deep-water areas.

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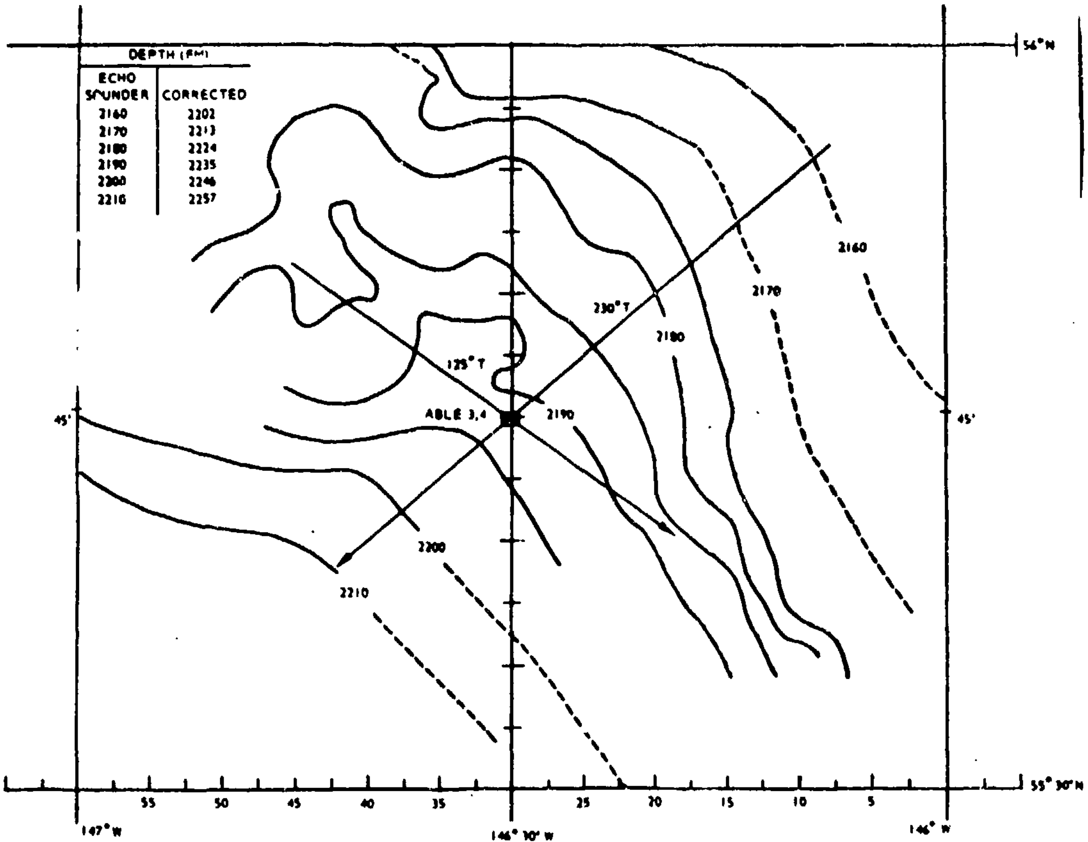

DEPTH (FM)	
ECHO SOUNDER	CORRECTED
2160	2202
2170	2213
2180	2224
2190	2235
2200	2246
2210	2257

(U) Figure 1b Bathymetric chart for Station ABLE 3 and 4.

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bearing of 251°T (see Figure 1B). This course was run to minimize reflections from the two chains of seamounts shown in Figure 1A.

(C) The geometry of the acoustic experiments is shown in Figure 2. The USNS S. P. LEE was hove to and drifted with five hydrophones and a stationkeeping source rigged over the side. The USS DOLPHIN or USS BAYA served as a source ship and closed range on LEE. Pulsed CW propagation loss was measured on seven runs, three at 1.5 kHz and four at 2.5 kHz. Parameters for these runs are given in Table 1.

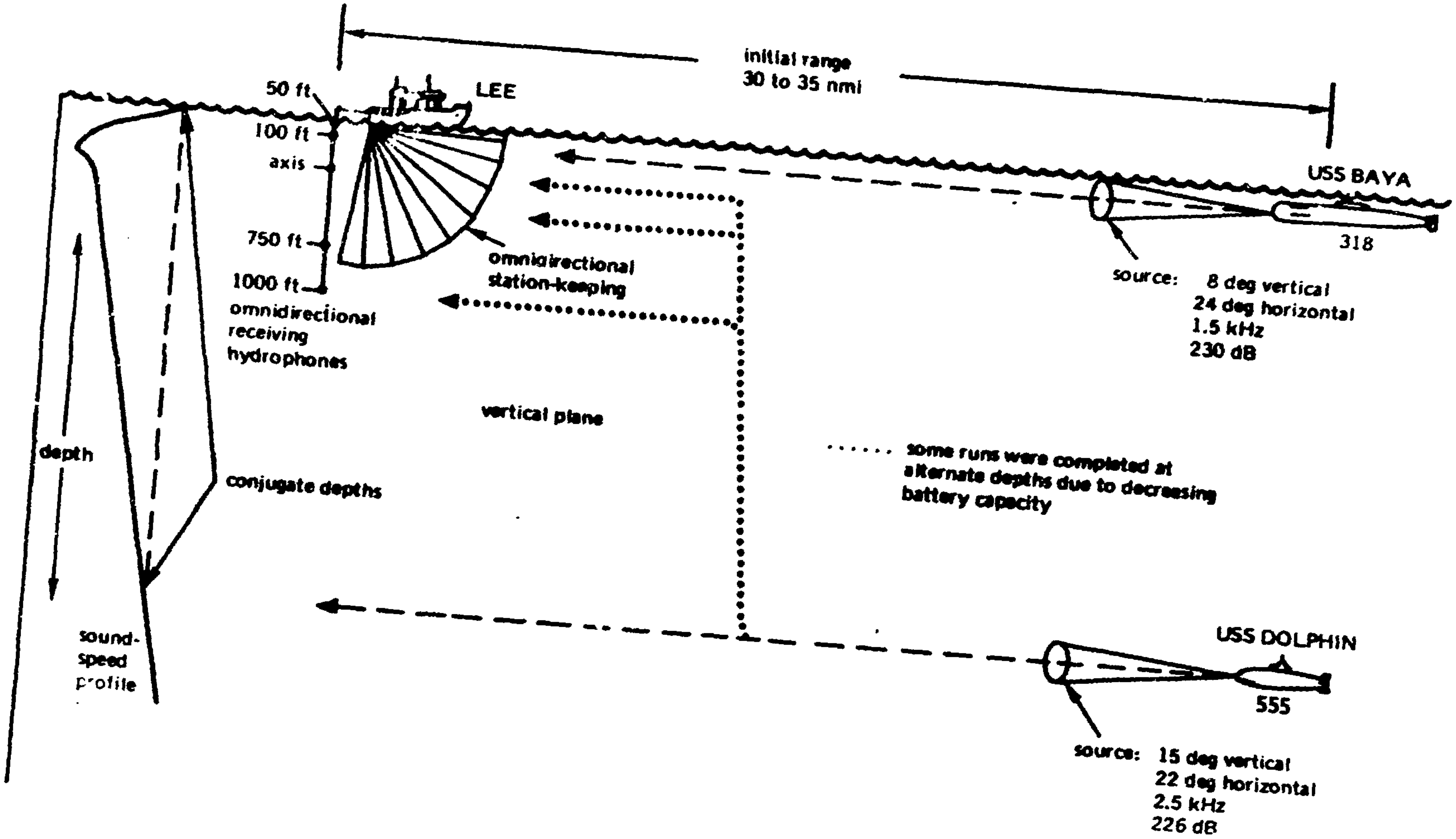
RANGE DETERMINATION (U)

(U) For the GOA tests, the heart of the ranging system were accurate master clocks aboard each of the three ships. Prior to submergence of the DOLPHIN and BAYA these clocks were synchronized with WWV. The acoustic pulses, transmitted from any of the three ships, were sequenced by the master clock aboard, which also provided the time ticks on the acoustic records. Travel times were measured by subtracting the time of transmission (known from a definite schedule) from the time of reception as measured on the received acoustic pulse recorder.

DOLPHIN SOURCE SYSTEM (U)

(C) The general characteristics of DOLPHIN's source are given in NUC TP 301, Vol 1.[5] The measured vertical directivity pattern at 2.5 kHz is given in Figure 3. The vertical beamwidth is about 15°. Table 2 lists the angles corresponding to half-decibel points. Down angles are given to include angles up to 16.5°, slightly more than that source angle for rays which graze the bottom. Up angles are continued to -41° to include the case of transmitting to short range.

(C) Horizontal beamwidth of 22° was used on ABLE-4 tests. The source level was between 224.5 and 226.5 dB re one micro-pascal at one yard.



(C) Figure 2. Geometry of typical fine-grain Reliable Acoustic Path (RAP) propagation loss experiments.

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TABLE I. (U) Gulf of Alaska Parameters

Run Number	140	143	124	108	107	112A	112B
Frequency (kHz)	1.5	1.5	1.5	2.5	2.5	2.5	2.5
Source Depth (m)	30.5	30.5	30.5	1067	1067	305	305
Receiver Depths (m)	15,30.5 90,229,305	Same	Same	Same	Same	Same	Same
Minimum Range (kyd)	40.6	9.5	3.1	2.8	32.9	16.6	2.1
Maximum Range (kyd)	69.3	58	12.1	30.9	73.5	63.9	20.3
Bottom Depth (m)	4078	4042	4042	4060	4060	4060	4042
S. Speed (m/s)	1525.4	1524.7	1524.7	1525.0	1525.0	1525.0	1524.7
Layer Depth (m)	10	10	10	0	10	10	10
S. Speed (m/s)	1476.7	1476.8	1476.5	1477.6	1476.6	1479.1	1479.2
S. Speed Minima (m/s)	1461.9	1462.5	1461.9	1462.5	1462.5	1462.0	1461.9
Depth (m)	75	90	75	85	85	75	75
NAVDAB EXP. 9 RUN NO.	1-5	11-15	31-35	6-10	16-20	21-25	26-30

NAVIGATION - Range determined by clock differences times sound speed: Accuracy 100 yds.

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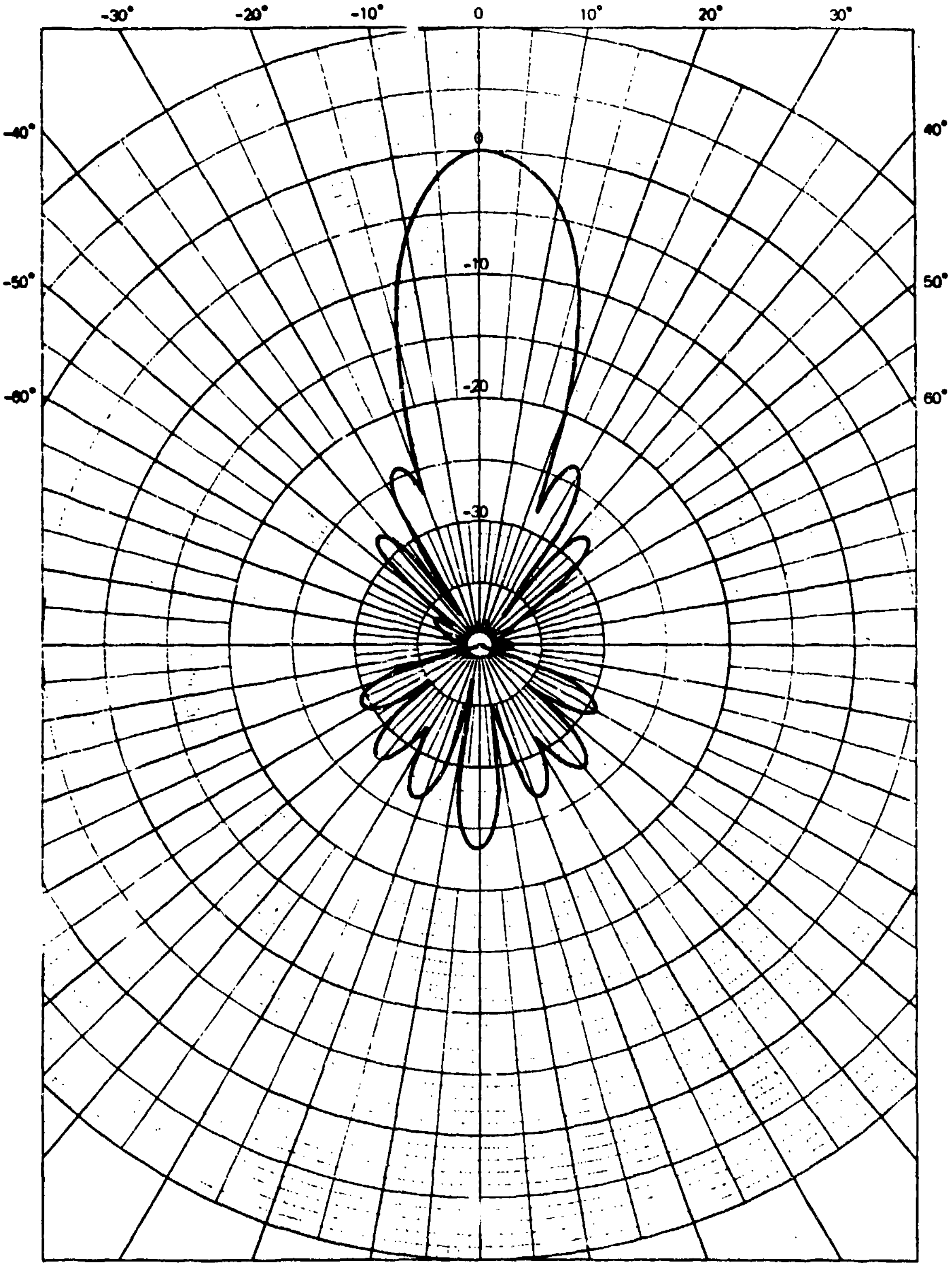

(C) Figure 3. Vertical directivity pattern of DOLPHIN source at 2.5 kHz.

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(C) Table 2 Vertical directivity pattern of DOLPHIN source at 2.5 kHz.

dB Down	Down Angle	Up Angle	dB Down	Down Angle	Up Angle
0.0	0.0	0.0	24.5		-19.3
0.5	4.0	-2.3	25.5		-19.5
1.5	6.3	-4.2	26.5		-20.0
2.5	8.4	-5.8	25.5		-22.5
3.5	9.8	-7.1	24.5		-25.0
4.5	11.1	-8.1	25.5		-27.3
5.5	11.9	-8.9	26.5		-28.3
6.5	12.4	-9.7	27.5		-28.9
7.5	13.4	-10.6	28.5		-29.5
8.5	14.0	-11.2	29.5		-30.0
9.5	14.8	-12.0	30.5		-31.0
10.5	15.4	-12.8	31.5		-32.0
11.5	15.7	-13.4	32.5		-33.0
12.5	16.3	-14.0	33.5		-34.0
13.5	17.0	-14.7	34.5		-34.5
14.5	–	-15.1	35.5		-35.0
15.5		-15.6	36.5		-35.5
16.5		-16.2	35.5		-35.7
17.5		-16.7	34.5		-36.0
18.5		-17.1	33.5		-36.5
19.5		-17.6	32.5		-37.0
20.5		-18.2	31.5		-37.5
21.5		-18.5	30.5		-38.0
22.5		-18.8	29.5		-39.0
23.5		-19.0	28.5		-41.0

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(C Table 3 Vertical directivity pattern of BAYA source at 1.5 kHz.

dB Down	Down or Up Angle	dB Down	Down or Up Angle
0.0	0.0	24.5	9.9
0.5	1.8	25.5	9.95
1.5	3.0	26.0	10.0
2.5	3.7	24.5	10.05
3.5	4.4	23.5	10.1
4.5	5.0	22.5	10.25
5.5	5.4	21.5	10.4
6.5	5.75	20.5	10.6
7.5	6.1	19.5	10.7
8.5	6.4	18.5	10.9
9.5	6.7	17.5	11.1
10.5	7.0	16.5	11.35
11.5	7.3	15.5	11.6
12.5	7.6	14.5	11.9
13.5	7.85	13.5	12.4
14.5	8.1	13.0	13.5
15.5	8.3	13.5	14.6
16.5	8.5	14.5	15.1
17.5	8.7	15.5	15.4
18.5	8.9	16.5	15.65
19.5	9.10	17.5	15.9
20.5	9.30	18.5	16.1
21.5	9.48	19.5	16.3
22.5	9.64	20.5	16.4
23.5	9.78	21.5	16.6

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(U) Half-second pulses were transmitted at 2.5 kHz on a schedule of 12/min or one every five seconds. Every 12th pulse, on the exact minute, was skipped to aid in the data analysis. The 5-sec spacing between pulses was sufficient so that the bottom reflected returns from previous pulses seldom interfered with the desired return.

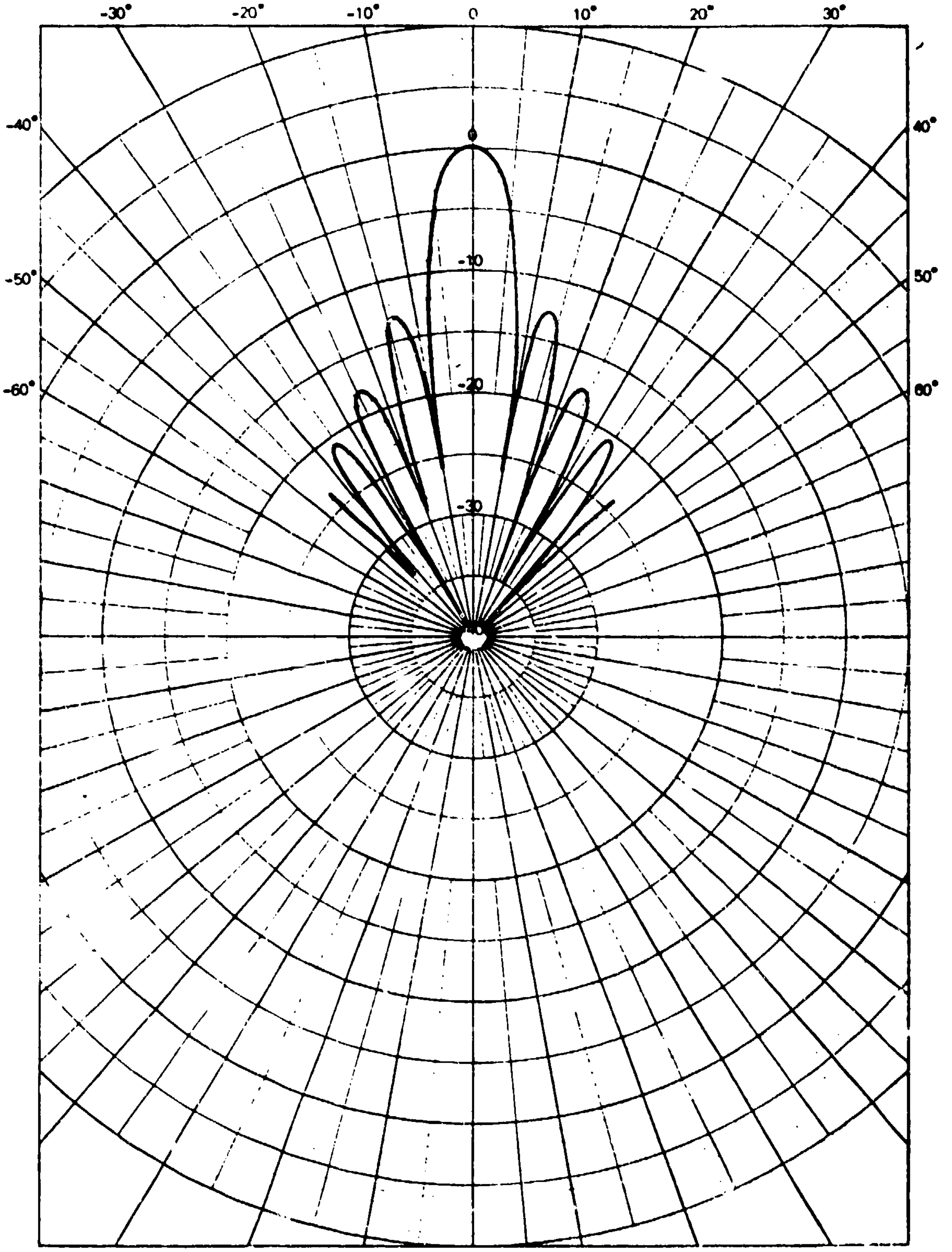
BAYA SOURCE SYSTEM (U)

(C) The theoretical vertical beam pattern is given in Figure 4. Vertical beamwidth is about 8°. Table 3 lists the angles for this vertical pattern. Up angles are not continued beyond that required to graze the ocean bottom. The BAYA's source depth was 100' and an angle of -16.6° is more than adequate to include the shortest range of the experiment. The source was operated at 1.5 kHz with a nominal source level of 230 dB re one micro-Pascal at one yard. The horizontal beamwidth was 24°.

(U) Half-second pulses were transmitted at the rate of 6/min or one every ten sec. Every sixth pulse, the one which would occur ten sec after the minute, was skipped. With few exceptions, returns from the previous pulse did not interfere with the desired return. The background was, as in the DOLPHIN Runs, bistatic reverberation.

LEE RECEIVING SYSTEM (U)

(U) The five receiving hydrophones were at depths of 50, 100, 396, 750 and 1000 ft or 15, 30.5, 90, 229 and 305 meters respectively. The two deepest hydrophones were rigged over the fantail of the LEE. The three shallowest were suspended from a buoy which was floated away from the LEE.



(C) Figure 4. Vertical directivity pattern of BAYA source at 1.5 kHz.

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(U) Stationkeeping pulses of 1/2 sec at 2.5 kHz were transmitted from 30-ft source overside from LEE and used by BAYA or DOLPHIN to determine range and bearing.

(U) The receiving system contained filters to reduce noise. At 1.5 kHz the filter bandwidth was 40 Hz at the 3-dB downpoints. For DOLPHIN runs the filters were centered at 2.5 kHz with 80-Hz bandwidth at the 3-dB down points.

(U) Logarithmic amplifiers were used in the final recording stage. To compensate for the drift of these amplifiers, quick calibrates of the receiving systems were made every half-hour throughout each run in addition to the regular complete calibrates at the beginning and end of each run. The main recorder was a six channel Brush strip chart with a magnetic tape backup.

ENVIRONMENTAL FEATURES (U)

(U) All of the raw data pertaining to sound speed for the GOA tests are given in reference (2). The data were collected by four different instrument systems: (1) a Sippican expendable bathythermograph (XBT) to 450 meters measured temperature vs depth; (2) a Plessey Environmental System STD/SV to measure salinity, temperature and sound speed versus depth; (3) a Ramsey Engineering Company SVTP profiling system to measure sound speed and temperature versus pressure; and (4) hydrographic casts to measure temperature, salinity and depth.

(U) Table 4 contains sound speed data that is the best estimate for the conditions applying to Run 108. All sound speeds given in this report are calculated from the temperature, salinity and depth data from the STD/SV equipment and E. R. Anderson's sound speed equation. Table 4 data are plotted in Figure 5 and for purposes of illustration and discussion is considered the profile typical of ABLE-4. The bottom depth for this profile is 4060 meters.

(U) Table 4 Typical sound-speed profile for ABLE 4.

Depth (meters)	Sound Speed (meter/sec)	Source of Data
0	1477.6	STD Number 78
10	1477.0	
20	1476.7	
30	1471.2	
50	1466.3	
75	1463.9	
100	1463.3	
150	1467.2	STD Number 77
200	1468.0	Subtype-2 STD
250	1468.7	
300	1469.4	
400	1470.6	
500	1471.7	
600	1472.8	
800	1474.9	
1000	1477.1	
1200	1479.4	
1500	1483.2	
2000	1490.4	All STD on GOA
2500	1498.3	
3000	1506.4	
3500	1515.0	
4000	1523.9	

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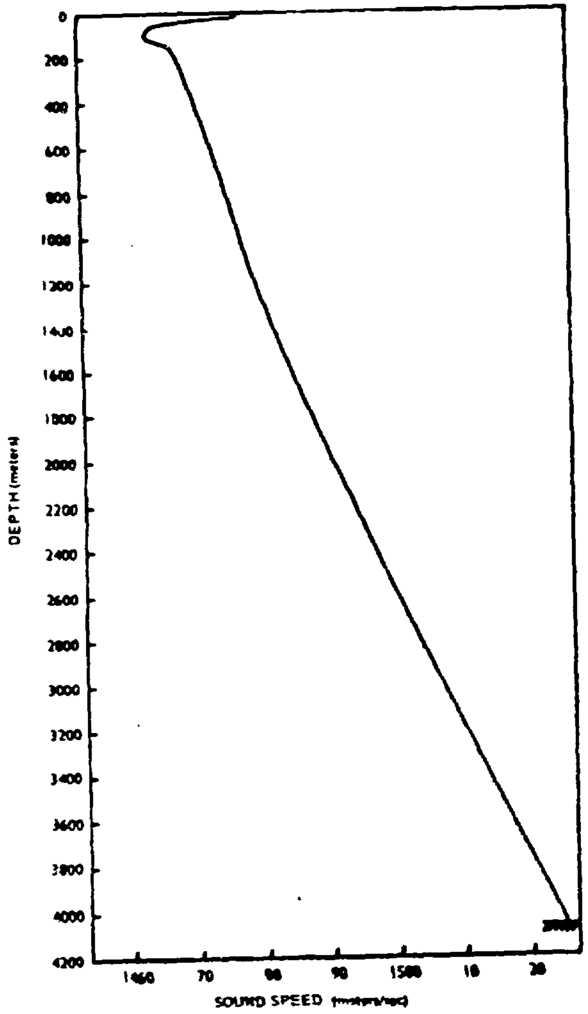

(U) Figure 5 Typical sound speed profile for ABLE 4.

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(U) The data (Table 4) from 200-1500 meters is the average of all STD/SV data taken in sub-type 2 water in GOA tests and the data from 2000-4000 m is the average from all GOA data. From 2000 meters to the bottom there was no significant temporal or spatial variation. Dr. E. R. Anderson[2] has established that all ABLE-4 tests were conducted in a water volume that produces a single-minimum type of sound speed profile designated as sub-type 2. In the data presented in this report and for the profiles given for each acoustic run it will be assumed that all sound speeds at 250 meters and below are equal to the data in Table 4.

(U) Since no bottom reflected propagation was obtained the ocean bottom discussion will be very limited. A complete description of the ocean bottom may be found in reference (4). The effect of bottom slope on the acoustic runs was minimal. Since the nominal direction of the runs was 125°T and mostly along the contours the bottom depth changes only slightly throughout each run. Maximum downward slope of approximately 0.115 degrees was on a course of 230°T.

(U) A geoacoustic model of the bottom is given in reference (4). The upper two meters of sediment is classified very fine silt with grain size of .005 mm mean diameter.

(U) Observations of wave and weather conditions were recorded in ship's log. In general, these conditions on ABLE-4 were quite mild and favorable. Sea states were 1-2 with wind speeds of 7 knots or less. Table 5 contains these and other pertinent data.

3 ACOUSTIC RESULTS (U)

(C) The salient acoustic parameters for the propagation loss runs are given in Table 1. BAYA runs at 1.5 kHz were Runs 140, 143 and 124. DOLPHIN runs at 2.5 kHz were Runs 107 and 108 (3500 ft source depth) and 112A and 112B (1000 ft). These

(C) Table 5. Salient features of the propagation loss runs.

Run Number	Frequency (Hz)	Source Depth (ft)	Range (kyd)		July 1971 Day of Run	Time		Source Ship Position				Receiver Ship Position				Bottom Depth (fm)	Bottom Sound Speed (yd/sec)	Wind			Wave			Sea State	Swell Height (ft)	Weather Code
								Start		End		Start		End												
			Start	End		Start	End	Longitude W	Latitude N	Longitude W	Latitude N	Longitude W	Latitude N	Longitude W	Latitude W			Direction (deg T)	Speed (kt)	Force Code	Direction (deg T)	Height (ft)	Period (sec)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
140	1.5	100	69.3	40.6	2	0842	1500	146°51'	55°55'	146°30'	55°48'	146°05'	55°38'	146°01'	55°36'	2230	1668.2	*	1	01	*	1.00	0.8	02	4	50
108	2.5	3500	30.9	2.8	2	1725	2100	146°24'	55°41'	146°00'	55°35'	146°00'	55°34'	145°56'	55°35'	2220	1667.8	315	5	02	*	0.33	1.4	01	3	03
143	1.5	100	58.0	9.5	3	0448	1441	146°27'	55°49'	145°52'	55°33'	145°48'	55°33'	145°40'	55°33'	2210	1667.4	270	6	02	270	1.00	1.7	02	3	03
107	2.5	3500	73.5	32.9	3	1615	2201	146°32'	55°52'	145°59'	55°38'	145°40'	55°33'	145°34'	55°28'	2220	1667.8	310	7	03	310	1.00	2.0	02	2	03
112A	2.5	1000	63.9	16.6	5	0435	1100	146°49'	55°50'	146°08'	55°38'	146°02'	55°34'	145°55'	55°35'	2220	1667.8	260	7	03	260	1.00	2.0	01	1.5	03
112B	2.5	1000	20.3	2.1	5	•2136	2400	146°07'	55°38'	145°54'	55°32'	145°52'	55°32'	145°52'	55°31'	2210	1667.4	255	6	02	240	0.33	1.7	02	2	03
124	1.5	100	12.1	3.1	6	0323	0630	145°59'	55°34'	145°49'	55°31'	145°48'	55°31'	145°46'	55°30'	2210	1667.4	285	6	02	285	1.00	1.7	02	2	03

*Variable

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runs will be described in more detail in following sections of this report. Sample plots of propagation loss vs range will be given. Five plots of data are given in reference (1) for each run, one for each receiver depth. Any or all plots should be suitable for model evaluation. The results for Runs 140 and 143 are very similar. Only seven of those plots are chosen for illustration purposes in this summary.

(U) The sound speed profile data of Table 4 can be used to illustrate the source and receiver depth configurations. An understanding of this configuration is necessary for a meaningful interpretation of the propagation loss plots. Table 6 presents the conjugate depths to the source and receiver depths and to the surface. The conjugate depth to a given depth has the same sound speed as the given depth. Thus the given depth and its conjugate depth lie on opposite sides of the sound channel axis.

Table 6. (C) Conjugate Depths

	Depth (ft)	Conjugate Depth (ft)
Source depths	100	1361
	1000	106
	3500	
Receiver depths	50	3141
	100	1361
	296	335
	750	123
	1000	106
Surface	0	3338

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(C) The importance of conjugate depth is that is provides a simple qualitative guide to propagation conditions. For example, if the source is below the axis of the sound channel, there will be near-surface shadow zones above its conjugate depth. Similarly, if the source is above the axis there would be shadow zones above the conjugate depth to the source depth. This feature is discussed in reference (5), pages 18-20. The 3500-ft depth for DOLPHIN was selected at sea on the basis of the sound speed profile. It was chosen to be deeper than the conjugate depth of the surface to ensure that there are no near-surface shadow zones at closer ranges. The 50 and 100 ft receiver depths were chosen to delineate the near-surface shadow zone. The receiver depth of 296 ft (90 m) was chosen to be near the axis of minimum sound speed.

(C) To summarize the important features of Table 6: For the 100-ft source there will be (ray theory) shadow zones for all five receivers since all receivers are shallower than 1361 ft. For the 1000-ft source there will be a small shadow zone for the 100-ft receiver and a much larger shadow zone for the 50-ft receiver. For the 3500 ft source no shadow zones exist for any of the five receivers. The experimental data generally agree well with this summary. Exceptions are the three deep receivers for the 100-ft source, which do not appear to have shadow zones.

RUN 108 (U)

(C) This was a DOLPHIN run with source depth of 3500 ft (1067 meters). Start and end times were 1725 and 2100, 2 July, respectively. Propagation losses at 2.5 kHz were measured at ranges 30.9 to 2.8 kyd. NAVDAB, Exp. 9, Cruise 1, Runs 6-10 (receiver depths 50, 100, 296, 750 and 1000 ft respectively) contain these data.

(U) The sound speed profile given in Figure 5 and Table 4 is the best estimate for that applicable for Run 108. The top 200 meters is repeated here in Table 7 and Figure 6 and includes the minima at 85 meters* as reported in reference (2). The average water depth is 4060 meters and the bottom water sound speed is 1525 m/s.

(U) Average wind speed was five knots with average wave and swell heights 0.5 and 3 ft respectively.

(C) Apparent propagation loss vs range for the 100 ft (30.5 m) receiver depth is given in Figure 7. The plot represents only a portion of the entire run.

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* A profile curve "fitted" to Table 4 data will have a minimum at about 90 m.

Fig.6 (U) Sound speed vs depth, RUN 108

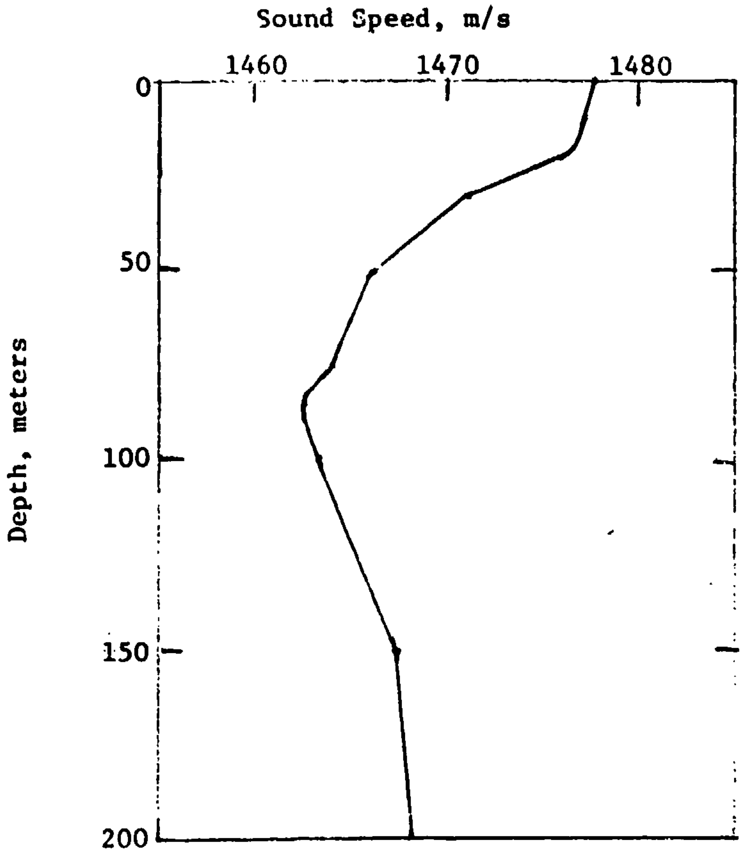

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Table 7 (U) Sound Speed Profile

RUN 108

Depth (m)	Sound Speed (m/s)
0	1477.6
10	1477.0
20	1476.7
30	1471.2
50	1466.3
75	1463.9
100	1463.3
150	1467.2
200	1468.0
85	1462.5 minima
4060	1525.0 Bottom

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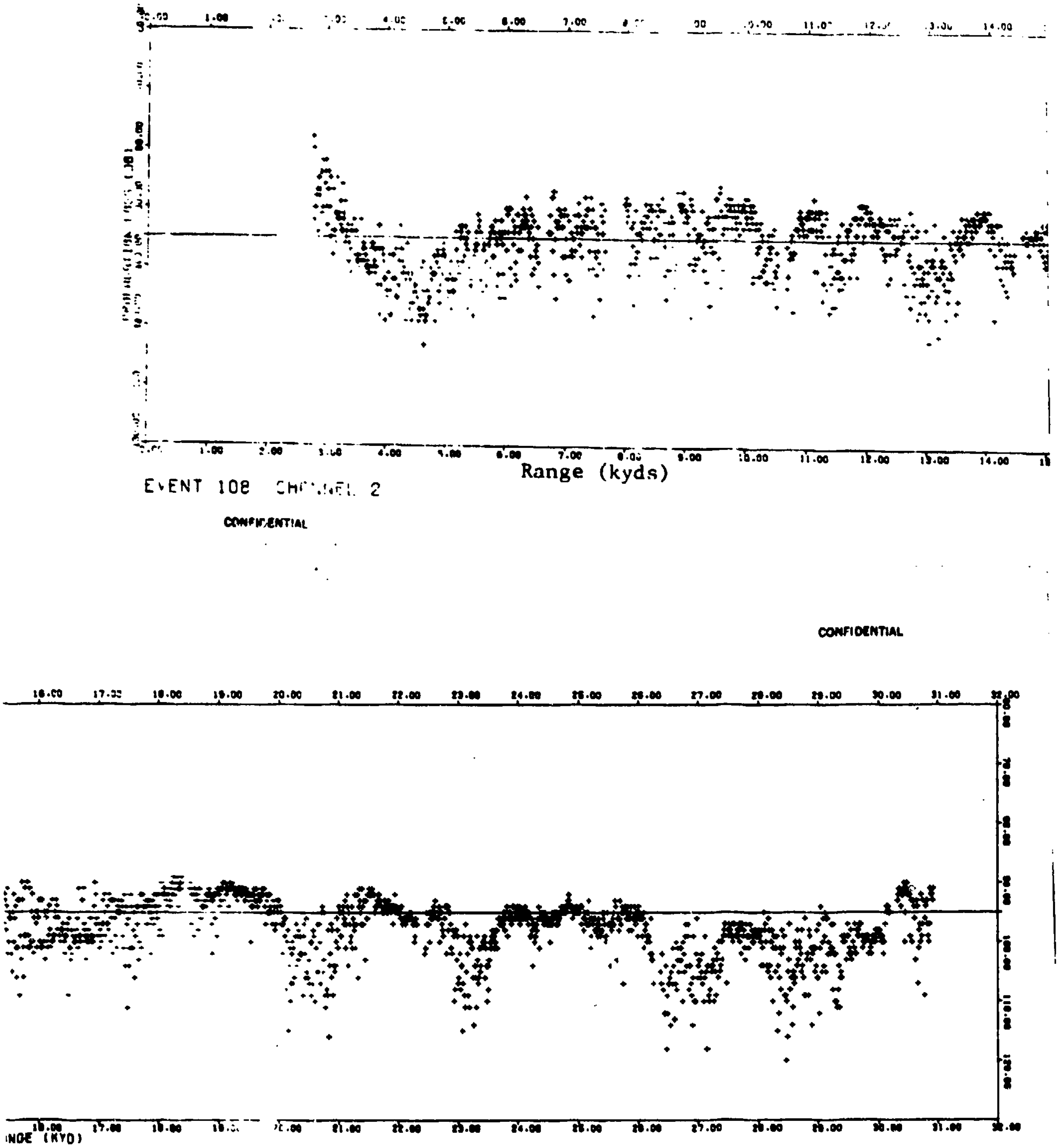

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(C) Figure 7 Propagation Loss at 2.5 kHz for 3500-ft source & 100-ft receiver.

RUN 140 (U)

(C) Run 140 was a BAYA run with source depth of 100 ft (30.5 m). The run was made from 0842 to 1500, 2 July. Propagation losses at 1.5 kHz were measured at ranges 69.3 to 40.6 kyds. These data are found in NAVDAB, Exp. 9, Cruise 1, Runs 1-5, for the five receiver depths 50 ft (15 m), 100' (30.5 m), 296' (90 m), 750' (229 m) and 1000' (305 m) respectively. Plots of the data are to be found in reference (1) and are not repeated here so as to conserve space.

(U) The best estimate of the sound speed profile for this run is given in Figure 8 and Table 8 (first 200 meters). The sound speed minima is at 75 meters. The water depth is 4078 meters and the bottom water sound speed is 1525.4 m/s. The average wind speed was three knots and the wave and swell heights averaged 1.0 and 4 ft respectively.

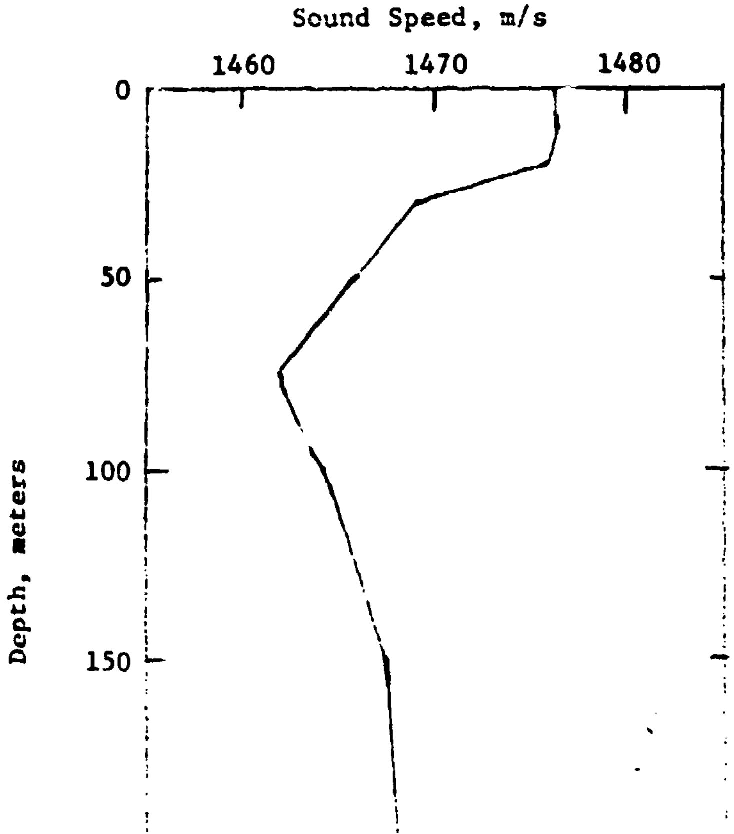

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Fig.8 (U) Sound speed vs depth, RUN 140

Table 8 (U) Sound Speed Profile
RUN 140

Depth (m)	Sound Speed (m/s)
0	1476.2
10	1476.3
20	1475.8
30	1469.2
50	1465.9
75	1461.9
100	1464.2
150	1467.3
200	1468.0
75	1461.9 minima
4078	1525.4 Bottom

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RUN 143 (U)

(C) BAYA's source depth was 100 ft for Run 143. Start and end times were 0448 and 1441, 3 July, respectively. Propagation losses at 1.5 kHz were measured at ranges 58 to 9.5 kyds. These data are listed in NAVDAB Exp. 9, Runs 11-15 for the five receiver depths, Run 11 is receiver depth 50 ft, etc. Plots of these data are to be found in reference (1) but are not repeated here. The results from Runs 143 and 140 agree to a remarkable extent: differences in average losses lying between -0.5 and 1.2 dB.

(U) The sound speed profile for Run 143 is given in Figure 9 and Table 9 for the first 200 meters. The sound speed minima is at 90 meters. Bottom depth averaged 4042 meters with sound speed ≈ 1524.7 m/s. The average wind speed was six knots and wave and swell heights averaged 1.0 and 3 ft respectively.

Fig.9 (U) Sound speed vs depth, RUN 143

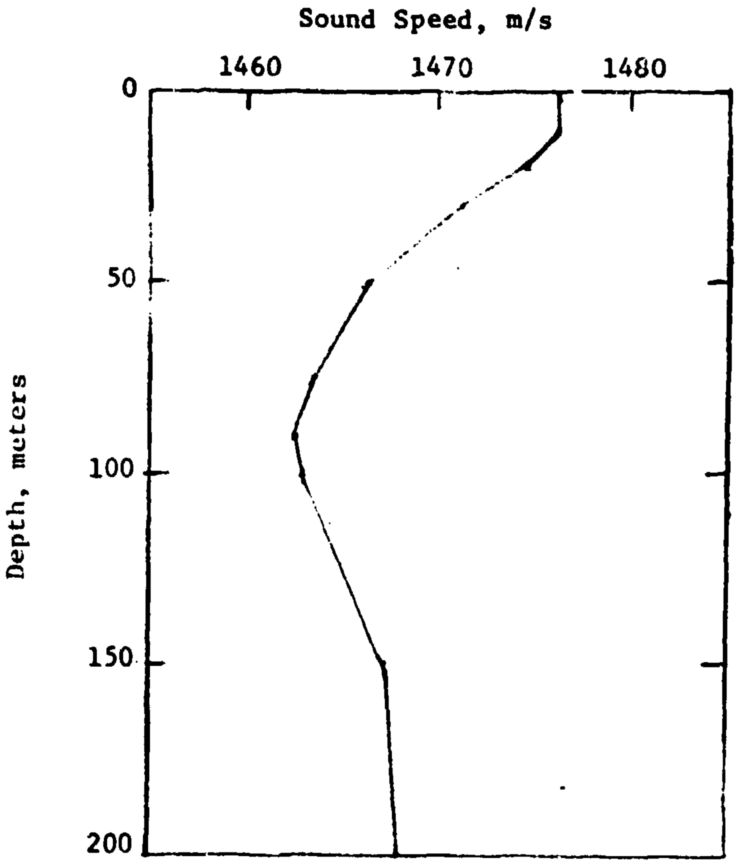

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Table 9 (U) Sound Speed Profile
RUN 143

Depth (m)	Sound Speed (m/s)
0	1476.3
10	1476.3
20	1474.5
30	1471.4
50	1466.4
75	1463.5
100	1462.9
150	1467.3
200	1468.0
90	1462.5 minima
4042	1524.7 Bottom

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RUN 107 (U)

(C) Run 107 was a DOLPHIN Run with source depth of 3500 ft (1067 meters). Start and end times were 1615 and 2201, 3 July, respectively. Propagation losses were measured at 2.5 kHz for ranges of 73.5 to 32.9 kyds. These data are contained in NAVDAB, Exp. 9, Runs 16-20 for the five receiver depths. Plots of these data are Figures 14A-14E of reference (1). They are not repeated here for lack of space.

(U) The sound speed profile shown in Figure 10 and Table 10 is the best estimate for the time of this Run. The sound speed minima is at 90 meters. Bottom depth was 4060 m with sound speed = 1525.0 m/s.

(U) The average wind speed was seven knots. Wave and swell heights were 1.0 and 2 ft respectively.

Fig. 10 (U) Sound speed vs depth, RUN 107

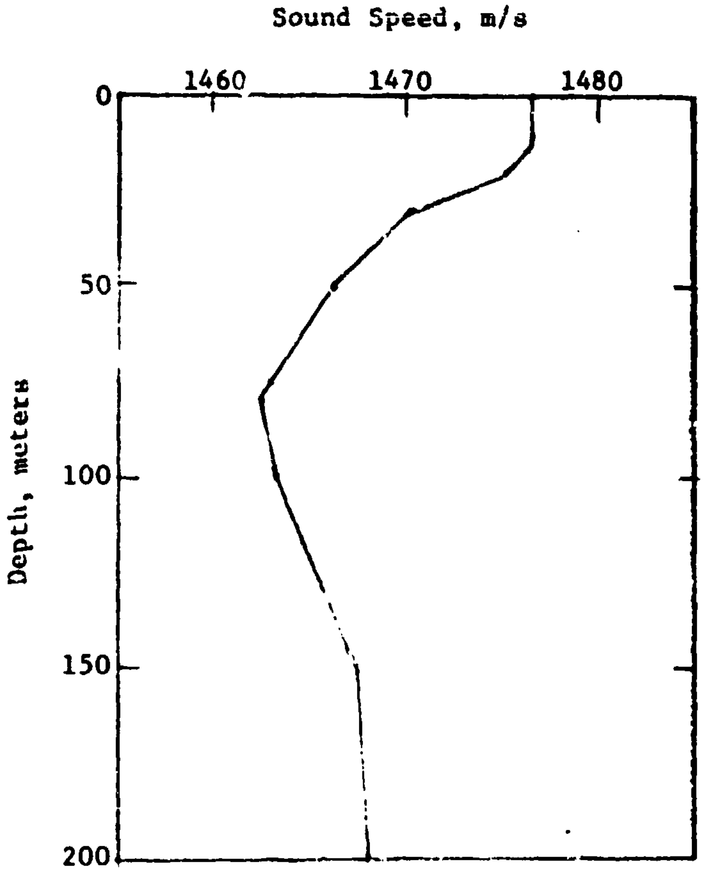

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Table 10 (U) Sound Speed Profile
RUN 107

Depth (m)	Sound Speed (m/s)
0	1476.5
10	1476.5
20	1475.1
30	1470.1
50	1466.2
75	1463.0
100	1463.2
150	1467.5
200	1468.1
80	1462.5 minima
4060	1525.0 Bottom

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RUN 112A (U)

(C) This Run was conducted from 0435 to 1100, 5 July, with DOLPHIN's source at a depth of 1000 ft (305 meters). Propagation losses were measured at 2.5 kHz for ranges of 63.9 to 16.6 kyds. Plots of the data are in Figures 15A-15E in reference (1) and are not repeated here. NAVDAB, Exp. 9, Runs 21-25 correspond to Run 112A, receiver depths 50, 100, 296, 750 and 1000 ft respectively.

(U) The sound speed profile given in Figure 11 and Table 11 (0-200 meters) applies for this run. The sound speed minima is at 80 meters. Average water depth is 4060 m and the sound speed is 1525.0 m/s.

(U) Average wind speed, wave and swell heights were seven knots, 1.0 ft and 1.5 ft respectively.

Fig.11 (U) Sound speed vs depth, RUN 112A

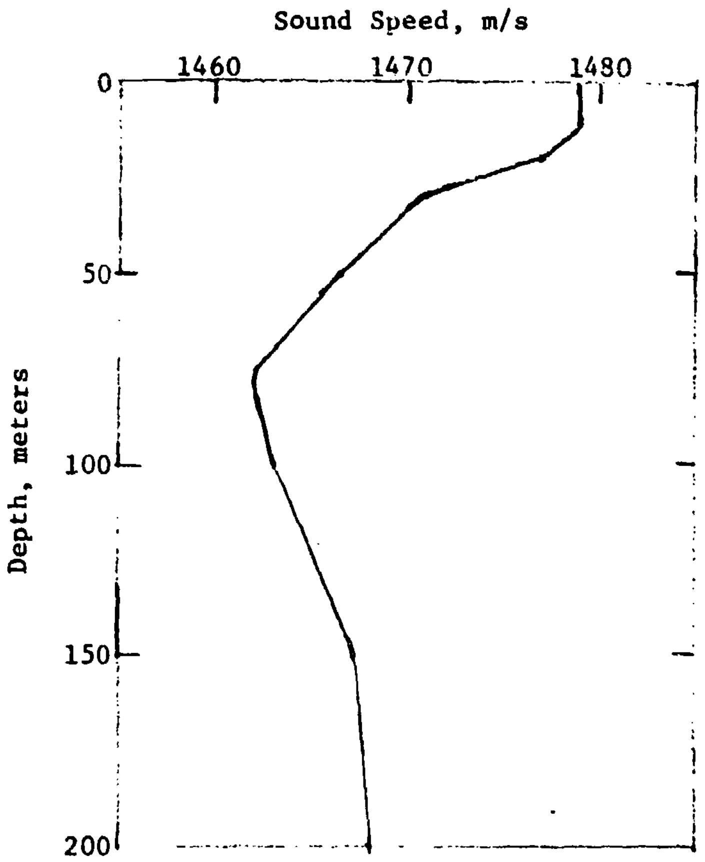

Table 11 (U) Sound Speed Profile
RUN 112A

Dep (..	Sound Speed (m/s)
0	1478.9
10	1479.0
20	1477.0
30	1470.7
50	1466.5
75	1462.2
100	1463.0
150	1467.2
200	1468.0
80	1462.0 minima
4060	1525.0 Bottom

RUN 112B (U`

(C) This was a DOLPHIN Run with source depth of 1000 ft (305 m). The Run was conducted from 2136 to 2400, 5 July. Propagation losses at 2.5 kHz were measured at ranges of 20.3 to 2.1 kyd.

(U) The best estimate for the sound speed profiles for this Run is given in Figure 12 and Table 12. The sound speed minima is at 75 meters. From Table 5, wind speed averaged six knots with 1/3 ft wave height and 2-ft swells.

(C) NAVDAB Runs 26-30 correspond to Run 112B for the five receiver depths. Figures 13-15 show results for this run: Figure 13 is for the 100 ft receiver and Figures 14 and 15 are for the 296' (90 m) and 750' (229 m) receiver depths respectively. Data for the 50 and 1000 ft receiver depths are not shown here.

Fig 12 (U)Sound speed vs depth, RUN 112B

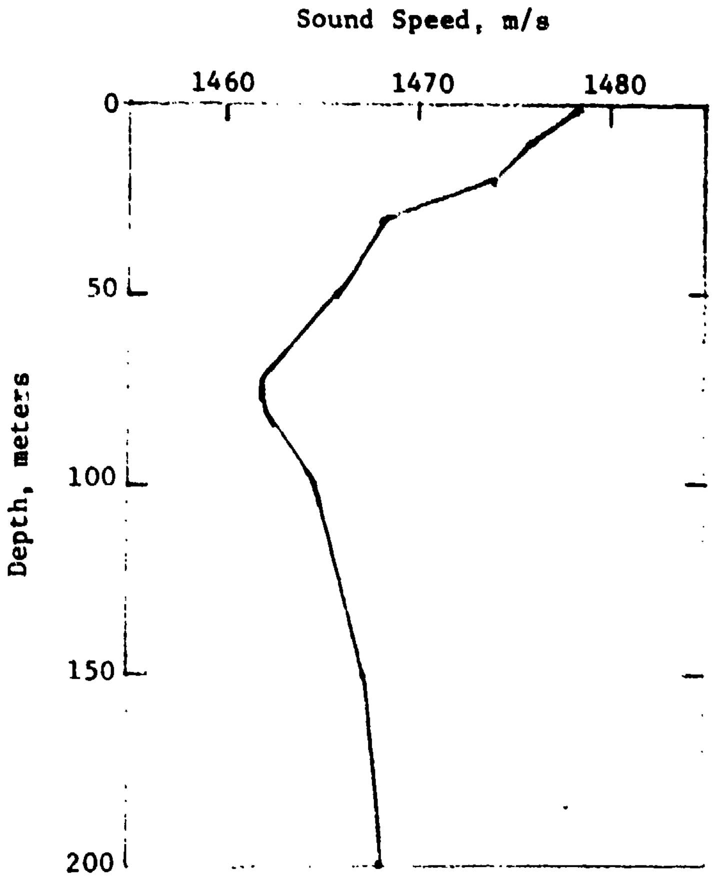

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Table 12 (U) Sound Speed Profile
RUN 112B

Depth (m)	Sound Speed (m/s)
0	1478.5
10	1475.9
20	1474.0
30	1468.2
50	1465.8
75	1461.9
100	1464.7
150	1467.2
200	1468.1
75	1461.9 minima
4042	[illegible] Bottom

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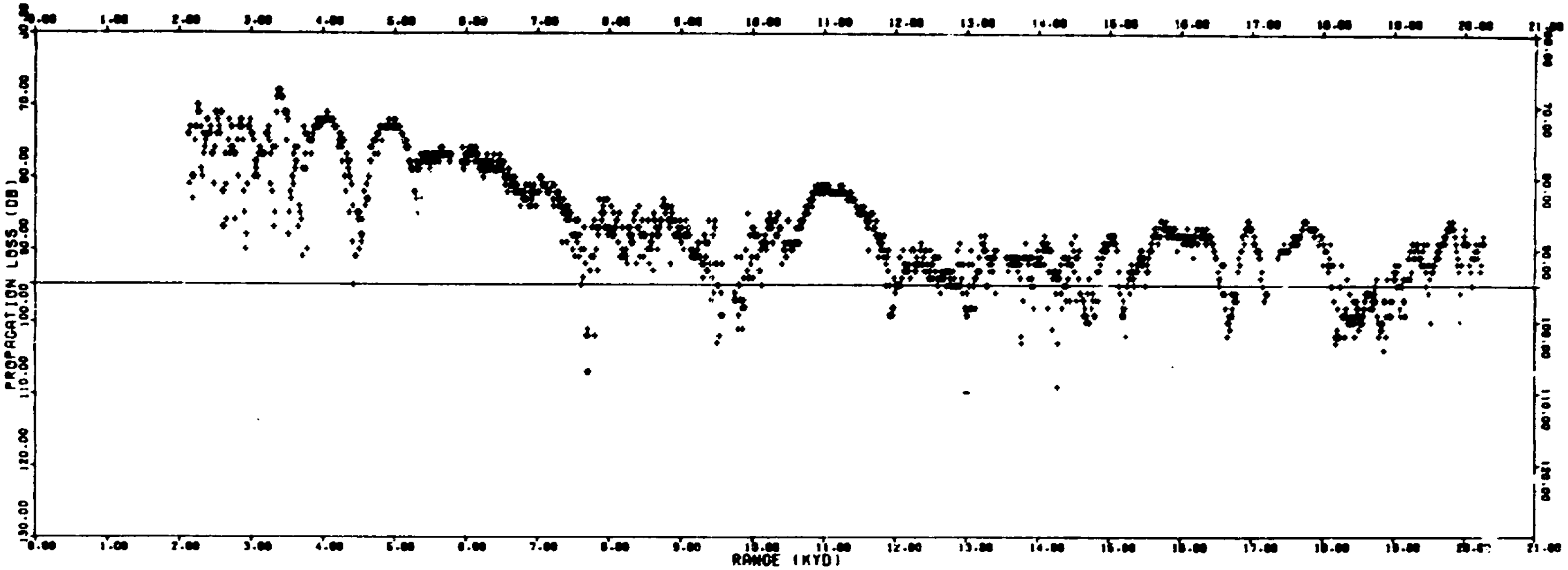

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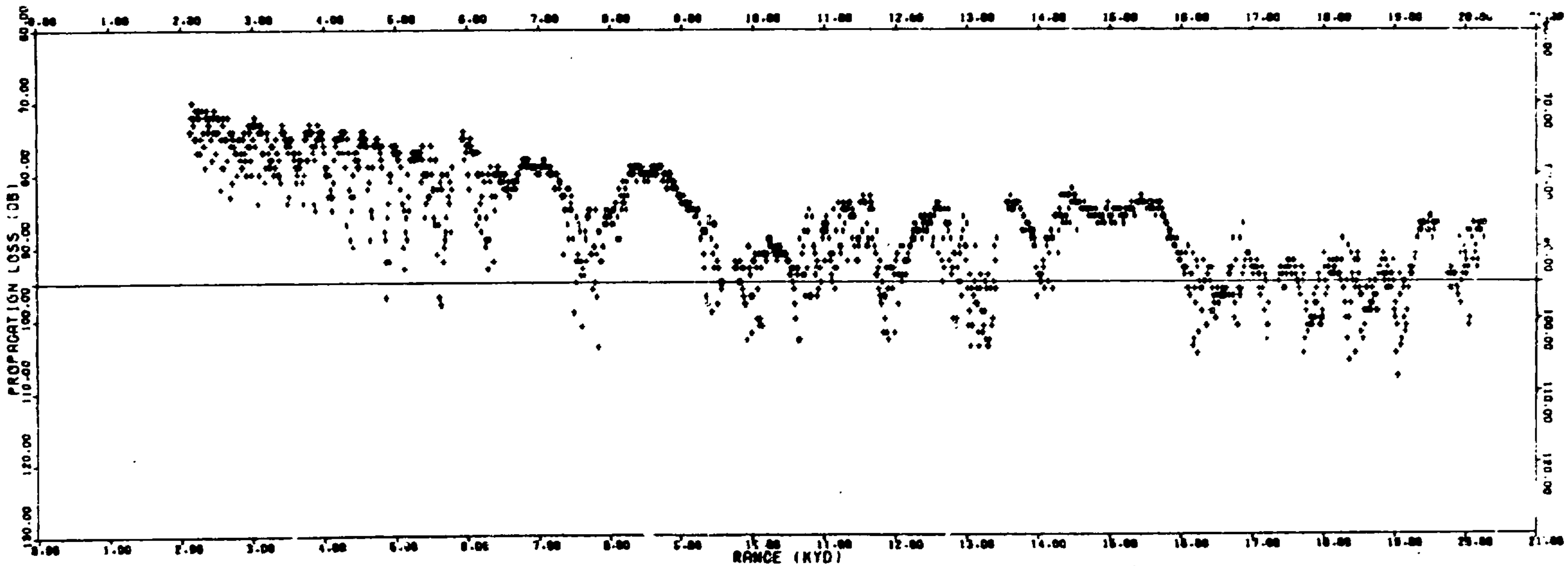
(C) Figure 13 Propagation loss at 2.5 kHz for 1000-ft source & 100-ft receiver.



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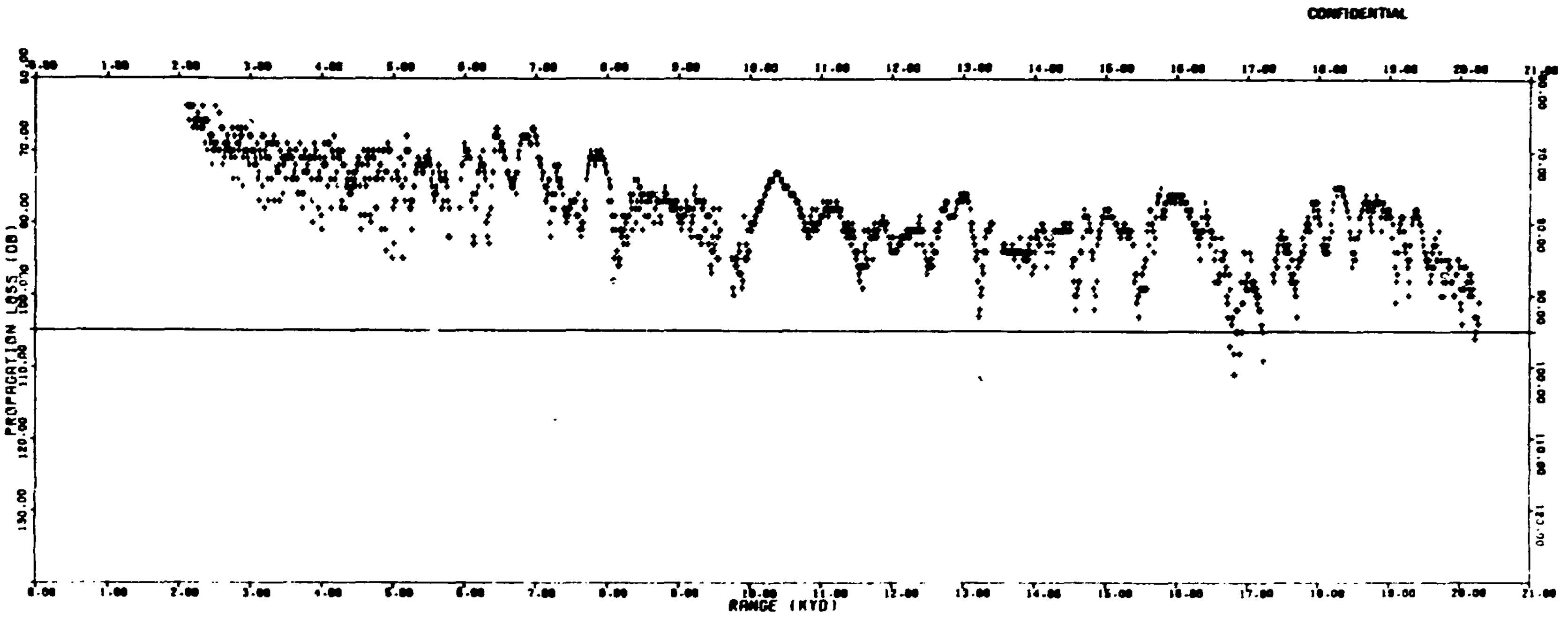
(C) Figure 14 Propagation loss at 2.5 kHz, 1000-ft source, 296-ft receiver.



EVENT 112 B CHANNEL 4

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(C) Figure 15 Propagation loss at 2.5 kHz, 1000-ft source, 750-ft receiver.

RUN 124 (U)

(C) This run was conducted from 0323 to 0630, 6 July. BAYA's source depth was 100' (30.5 m). Propagation losses were measured at 1.5 kHz for ranges of 30.9 to 2.8 kyd.

(U) The sound speed profile given in Figure 16 and Table 13 (the first 200 meters) applies for this run. The minima sound speed axis is at 75 m. Wind speed averaged six knots. Wave and swell heights averaged 1.0 and 2 ft respectively.

(C) NAVDAB Run numbers 31-35 are listings for receiver depths 50, 100, 296, 750 and 1000 ft. Propagation loss vs range is given in Figures 17-20, receiver depths 30.5 m (100'), 90 m (296'), 229 m (750') and 305 m (1000') respectively.

Fig.16 (U) Sound speed vs depth, RUN 124

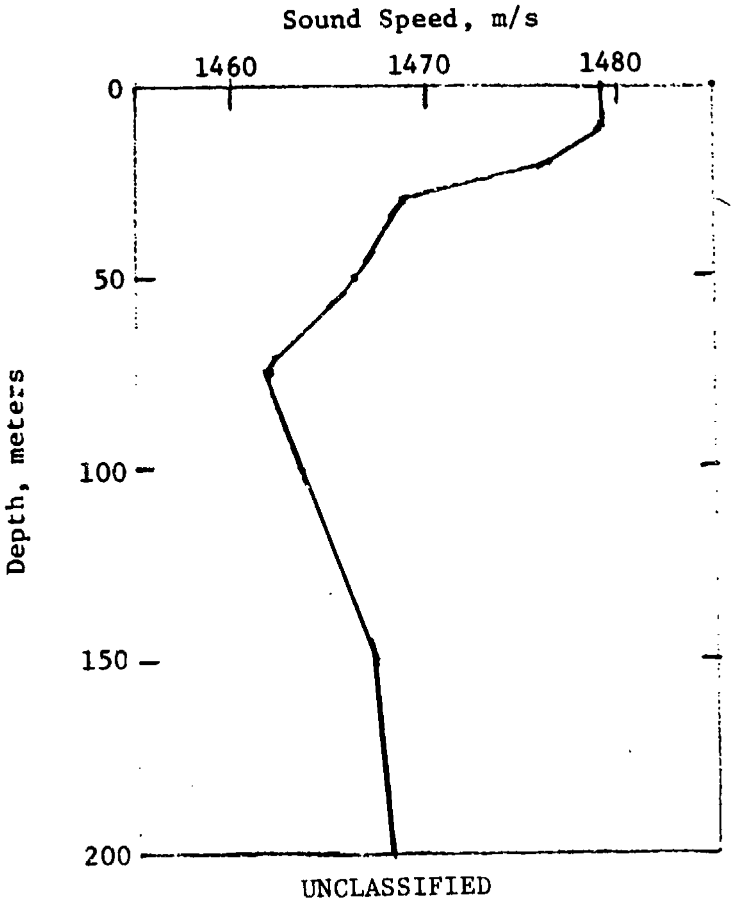

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Table 13 (U) Sound Speed Profile
RUN 124

Depth (m)	Sound Speed (m/s)
0	1479.1
10	1479.2
20	1476.5
30	1468.7
50	1466.3
75	1461.9
100	1463.5
150	1467.2
200	1468.0
75	1461.9 minima
4042	1524.7 Bottom

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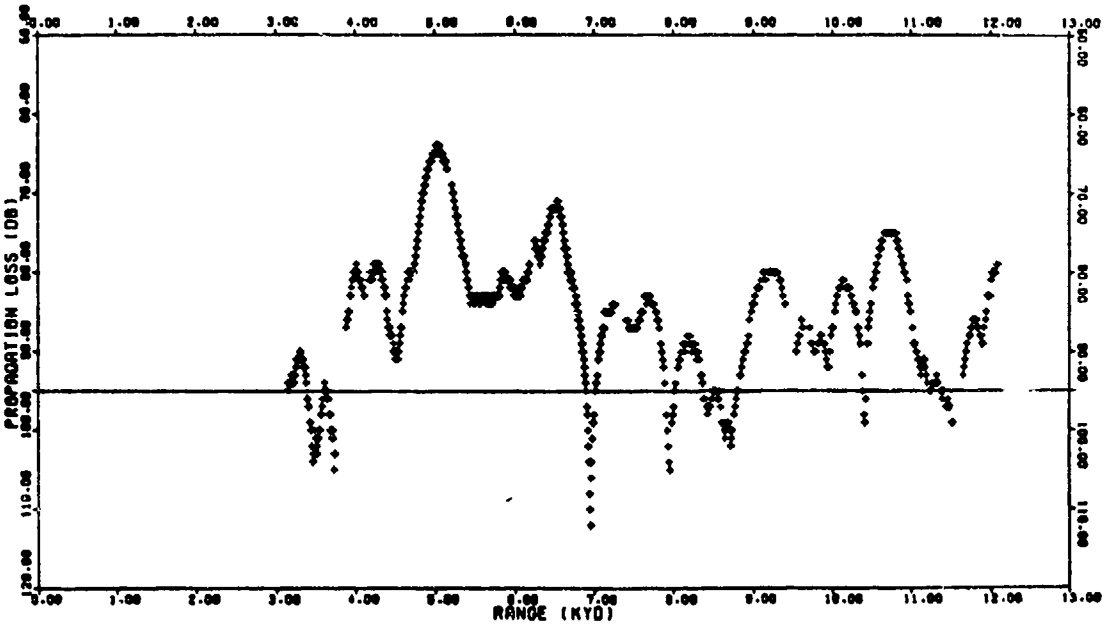

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EVENT 124 CHANNEL 2

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(C) Figure 17 Propagation loss at 1.5 kHz, 100-ft source, 100-ft receiver.

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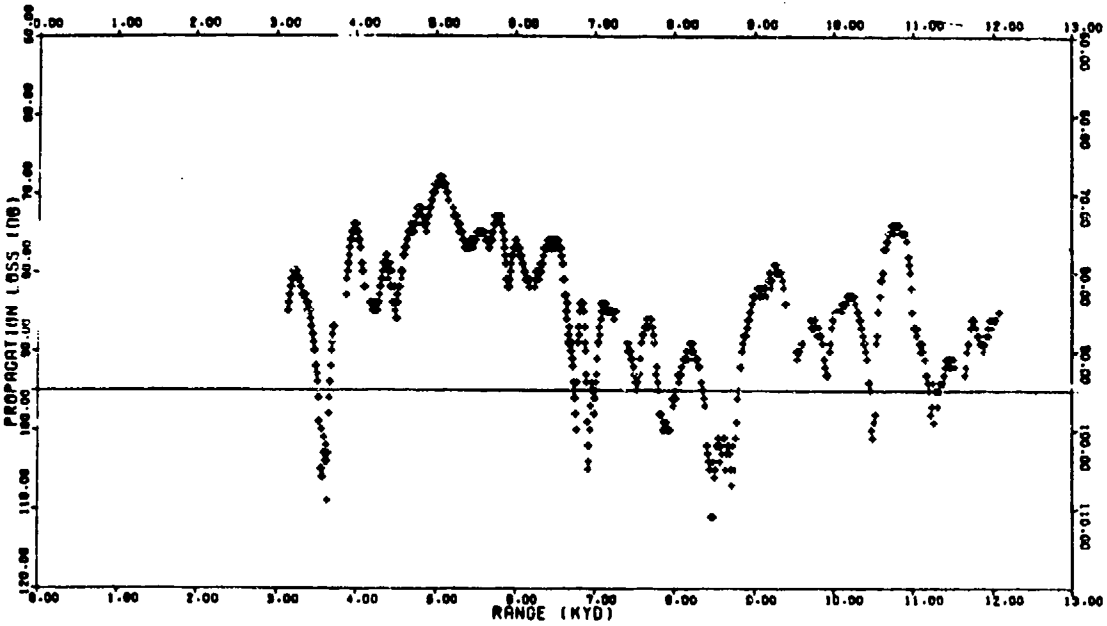

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EVENT 124 CHANNEL 3

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(C) Figure 18 Propagation loss at 1.5 kHz, 100-ft source, 296-ft receiver.

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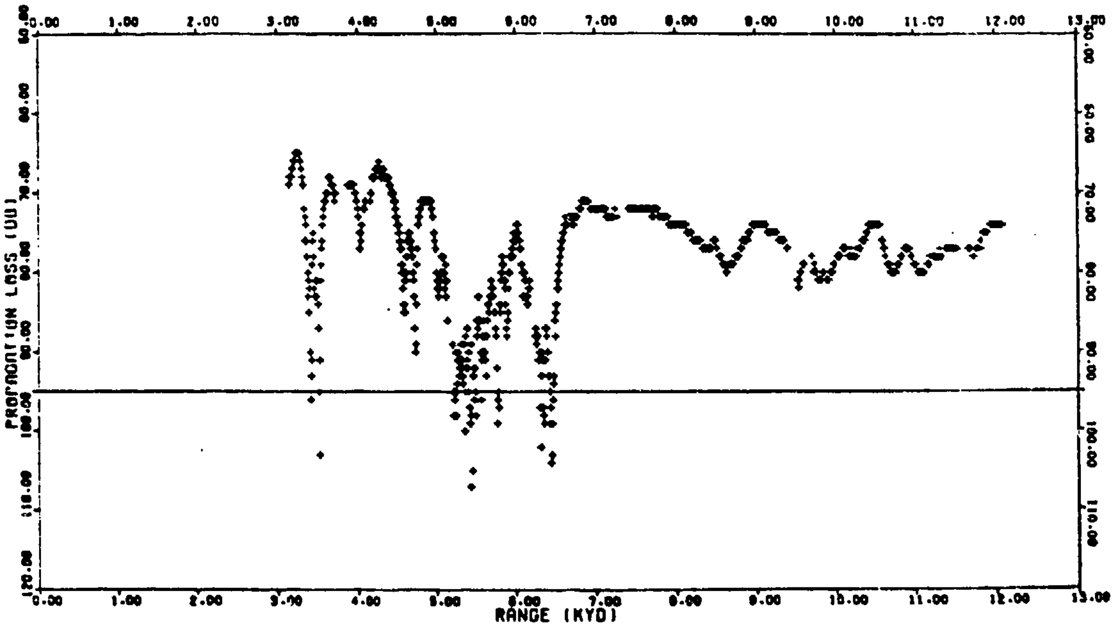

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EVENT 124 CHANNEL 5

(C) Figure 20 Propagation loss at 1.5 kHz, 100-ft source, 1000-ft receiver.

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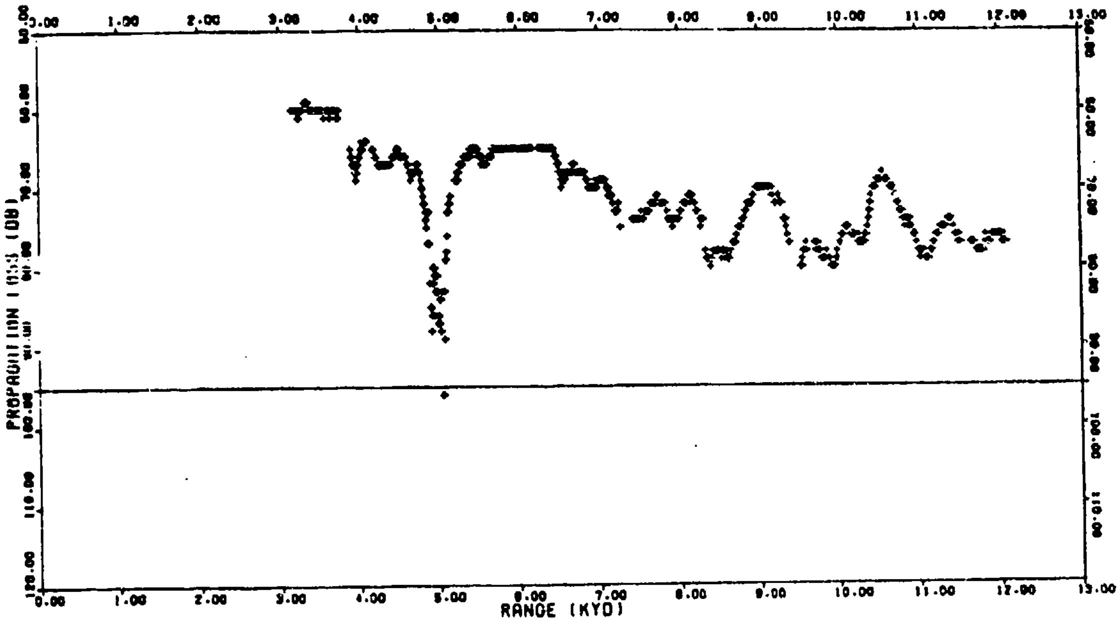

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EVENT 124 CHANNEL 4

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(C) Figure 19 Propagation loss at 1.5 kHz, 100-ft source, 750-ft receiver.

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1. Naval Undersea Center. NUC TP 301, "Gulf of Alaska Sonar Tests April-August 1971, Volume IV: Acoustic Propagation Los Data Report and Initial Analysis (U)," by M. A. Pedersen and D. White, December 1973. (CONFIDENTIAL).

2. Naval Undersea Center. NUC TP 301, "Gulf of Alaska Sonar Tests April-August 1971, Volume II: STD/SV, SVTP, and XBT Data Report," by E. R. Anderson and J. R. Lovett, August 1972.

3. Naval Undersea Center. NUC TP 301, "Gulf of Alaska Sonar Tests April-August 1971, Volume III: Comparison of Measured and Computed Sound Speeds," by E. R. Anderson, December 1972.

4. Naval Undersea Research and Development Center. NUC TN 679, "Gulf of Alaska Cruise 1971 Sea Floor Studies at Station ABLE," by R. T. Bachman, H. L. C. Hascall, and E. L. Hamilton, January 1972.

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Appendix 4. (U) FASOR (Forward Area Sonar Research)

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APPENDIX 4

DATA SETS FOR MODEL EVALUATION: SELECTED FASOR STATIONS

Summarized by James A. Whitney

INTRODUCTION:

The purpose of the Forward Area Research Program (FASOR) was to obtain the data necessary for sonar performance prediction from Forward areas of strategic importance. Stations were selected to meet both scientific objectives and fleet requirements. The objectives of this selection process was to sample areas that exhibited stable sound-speed profiles (reference 1) and to center stations in areas with smooth ocean floors and uniform properties.

FASOR covered three cruises. FASOR I consisted of 19 stations in the Northwestern Pacific proceeding west from Hawaii in a route which contained the Philippine Basin in both the southern and northern parts of the Philippine Sea, the closed basin of the Sulu Sea, South and East China Seas, the Sea of Japan, the Kurile Trench and stations in the main Pacific Ocean enroute back to Hawaii. FASOR II was conducted along the northern rim of the Pacific Ocean skirting the Aleutian Islands, entered the Sea of Japan and then proceeded south to the South China Sea and Borneo, including 21 stations between San Diego and Manila. FASOR III proceeded from Hawaii and took stations in the South Pacific, conducted experiments near the east and north coasts of Australia, continued through to the Indian Ocean and the Bay of Bengal and terminated at Singapore. In all acoustical and environmental measurements were made at 59 stations, ten of which were in shallow water.

The USS BAYA, a research submarine, and USNS CHARLES H. DAVIS, an oceanographic surface ship participated in each FASOR cruise. On FASOR III two Australian ships made cooperative studies while on FASOR stations near that continent but no RAN data will be discussed here. The results of the FASOR cruises are given in references 2-9. References 2-4 give both acoustic and environmental data for FASOR I, II and III. References 5 and 6 are sea floor studies while references 7-11 discuss acoustic propagation and echo-ranging in the FASOR areas.

Data sets chosen for use in model evaluation are from the following stations: FIG and REDWOOD are deep water stations from FASOR II; and 4 shallow water stations, OAK and THORN from FASOR II and FASOR III stations INDIA and JULIETT.

Table 1 lists the salient features of those propagation loss runs. Note that FASOR II is NAVDAB Experiment 2 while FASOR III is NAVDAB Experiment 8. Station FIG has a positive gradient profile from surface to bottom, hence no axis depth. Data for the surface conditions are given since these conditions can be important in shallow water propagation. Other data including sound speed profiles are discussed later in this report.

MEASUREMENTS:

In the measurement of propagation loss there were normally three runs. The first, called the bomb run, used explosive sources (SUS MK 61), and measured loss over a broad frequency band and with adequate resolution of signal arrivals. The USNS DAVIS dropped charges while opening range and (on FASOR II) transmitting 1.5 kHz pulsed CW signals, and the USS BAYA at submerged keel depth of 150 ft received and recorded the signals on both narrowband and broadband analog systems.

The second run was combined with echo ranging and began at the extreme range of the SUS measurements. USS BAYA closed range to an echo-repeater and transponder unit (see references 10 and 11) that was deployed from DAVIS, suspended from a buoy and anchored in shallow-water. During rough weather this unit was either tethered to DAVIS or substituted with the sonar dome unit. BAYA's signals activated the acoustic repeater and interrogated a delayed transponder

Table 1. Parameters for FASOR Stations

FASOR Station		FIG	REDWOOD	OAK	THORN	INDIA	JULIETT
NAVDAB:	Exp.	2	2	2	2	8	8
	Station	6	18	15	20	10	11
	Run	3	3	1,2	1,2	1,2	1,2
Frequency (kHz)		1.5	1.5	1.5	1.5	1.5	1.5
Source Depth (m)		6.1	6.1	23	23	23	23
Receiver Depth (m)		37	37	37	37	37	37
Min. Range (kyds)		6.5	1.0	13.8	13.4	25	14.7
Max. Range (kyds)		57.1	39.0	47.5	37.0	47.9	57.0
Layer Depth (m)		0	19	30	55	50	75
Axis Depth (m)		NA	1200	NA	NA	NA	NA
Wind Speed (knots)		18	8	6-12	5-6	14-15	8-9
Wave Height (ft)		4	1	4	1	4	2
Swell Height (ft)		6	4	8	3-5	6	3
Bottom Depth (m)		7648	3282	120	104	50	124

Navigation - Round trip acoustic travel time from xponder acc. ± 15 m whose source level was set to exceed the repeater's level and to thus provide one-way loss when the repeated signal was below interference levels.

The third run was similar to the second but usually over a different range interval. This run pattern was varied on certain stations due to limits of weather and time.

Signals were received on BAYA's array and auxiliary hydrophones, filtered and rectified before display on an analog recorder or fed to the on-board computer via an A-D converter and recorded on magnetic tape. The AN/USQ computer was programmed to sum and average over the pulse-length (usually 1/2 sec) and other time intervals. Signal levels, travel times and other ancillary information was listed. Signals that were overloaded on the array beams could normally be read from an auxiliary hydrophone channel.

Propagation loss (only one-way loss is discussed in this report) was obtained from the transponder signal which was delayed 10 sec to avoid any interference with echoes or repeater signals. Low speeds were used to avoid Doppler complications and to diminish self noise. An echo-ranging run usually continued for 4-5 hours and covered a range interval of about 15 kyds.

EQUIPMENT

Sonar equipment used in FASOR is described in references 11-14. The main echo-repeater with delayed transponder was a modification of the "artificial target" described in reference 12. The use of the computer in real-time analysis is discussed in reference 14.

Table 2 lists the characteristics of the sonar equipments used to obtain the propagation loss data discussed here. A block diagram of the receiving equipment is shown in Fig. 1.

Table II. Summary of Sonar Equipments

Equipment	Location	Beamwidth, 1.5 kHz Horizontal (degrees)	Beamwidth, 1.5 kHz Vertical (degrees)	Nominal Depth Ft
Hydrophone array	Forward deck, USS BAYA	2	200	120
Repeater with delayed transponder	Buoy Suspended Vertical line hydrophones	360	32	150
	Cylindrical sources	360	40	75
	Sonar dome, USNS DAVIS			
	Hydrophone	360	360	150
	Source	120	20	20
Transducer	Bow Tank USS BAYA	30	15	135

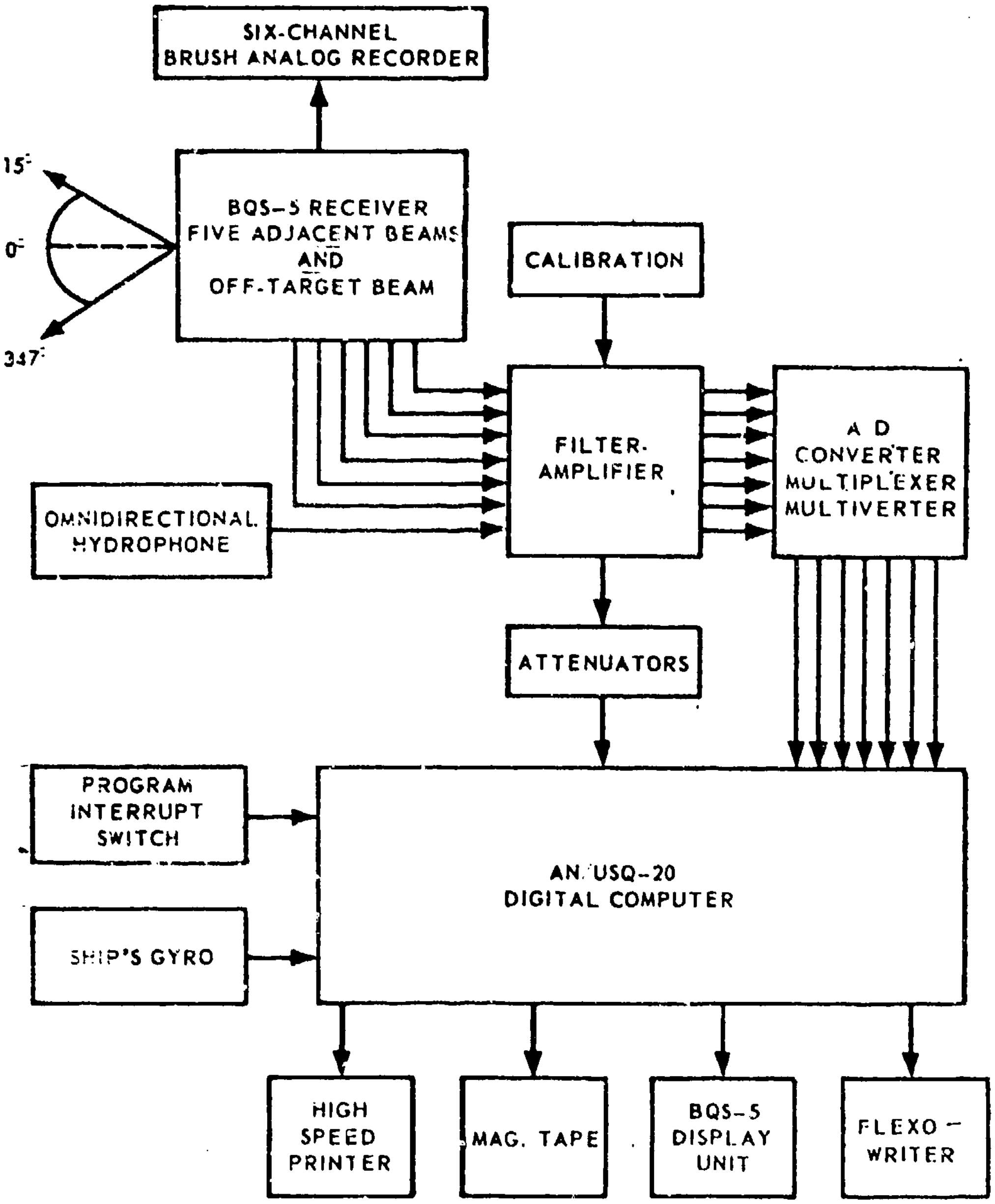

Figure 1. Block diagram of the tone-pulse sonar data receiving system aboard the USS BAYA.

The receiving system obtains signals from five adjacent preformed beams of the delay lines. Each beam is 2 degrees wide with adjacent beams 2 degrees apart. The signals from each of the five adjacent beams, from an "off-target" beam, and from an omnidirectional hydrophone are all inputs to a seven-channel filter-amplifier which has a 5-Hz bandwidth centered optionally at either 1.5 kHz or 4.3 kHz.

Signals go from the filter-amplifier to an analog-to-digital converter - sampling rate is 10 per sec per channel. Each channel sampled simultaneously and the multiverter digitizes the samples in sequential order. The digitized data enter the AN/USQ-20 computer for reduction and analysis.

Most signal levels, classified as echo, target, transponder or reverberation are taken from the computer listings. At computer down times and at other problem times such as overloads, the levels could be read from the six-channel recorder which monitored the incoming analog signals.

Since the delay-time of the delayed transponder signal is accurately known through calibrations and resettings, the transmitted travel time is accurately established for that run type. Travel times during the bomb run was established by signal arrival and transmitted time differences which were carefully logged from very accurate clocks on each ship. Range was obtained from the product of the travel time and the group velocity.

RESULTS:

Station FIG. Station FIG was located in the Kurile Trench and was occupied 5-7 March 1966. True bottom depth is given as 7648 meters (reference 5). The terrain along the bomb run was about 200 fathoms (366 m) relief. No sediment sample was taken but the sediment type is predicted to be deep sea clay-silt.

The bottom material is not likely to be of importance since the sound speed profile is positive gradient from surface to bottom. Infinite bottom loss should be used in model evaluation.

Data from 1.5 kHz pulsed (.5 sec) CW received during the progress of the bomb run is Acoustic Run 3 of NAVDAB Station 6. Range coverage is from 6.5 to 57.1 kyd. This run contains the only propagation loss recommended for use in model evaluation from this station. Figure 2 is a plot of the propagation loss vs range in kyds.

Figure 3 is a plot of the sound speed profile with depth in meters and sound speed in m/s Table 3 is a tabulation of the profile in Figure 3.

Wind speed was variable during this run averaging 18 knots. Wave and swell heights were four and six ft respectively.

Station REDWOOD. Station REDWOOD was located on the South China Sea Abyssal Plain and was occupied 12-14 May 1966. Relief along the bomb run was about 180 fathoms (330 m), excluding a small hill of about 60 fathoms (110 m). The sediment type is turbidite with an indicated sediment thickness over rock of 500 m (reference 5). True depth of water is 3282 m with a density of 1.037 gm/cm^3. Properties of the sediment are given in Table 4. Sound velocities are given for the top of the layer.

The sound speed profile for station REDWOOD is shown in Fig. 4 and listed in Table 5. The layer depth is about 19 m and the axis of minimum sound speed is 1200 m. This station is bottom-limited and bottom bounce propagation was observed.

The bomb run extended to 39 kyds. Propagation loss data obtained at 1.5 kHz from pulses transmitted between the explosive charges is shown in Fig. 5. This

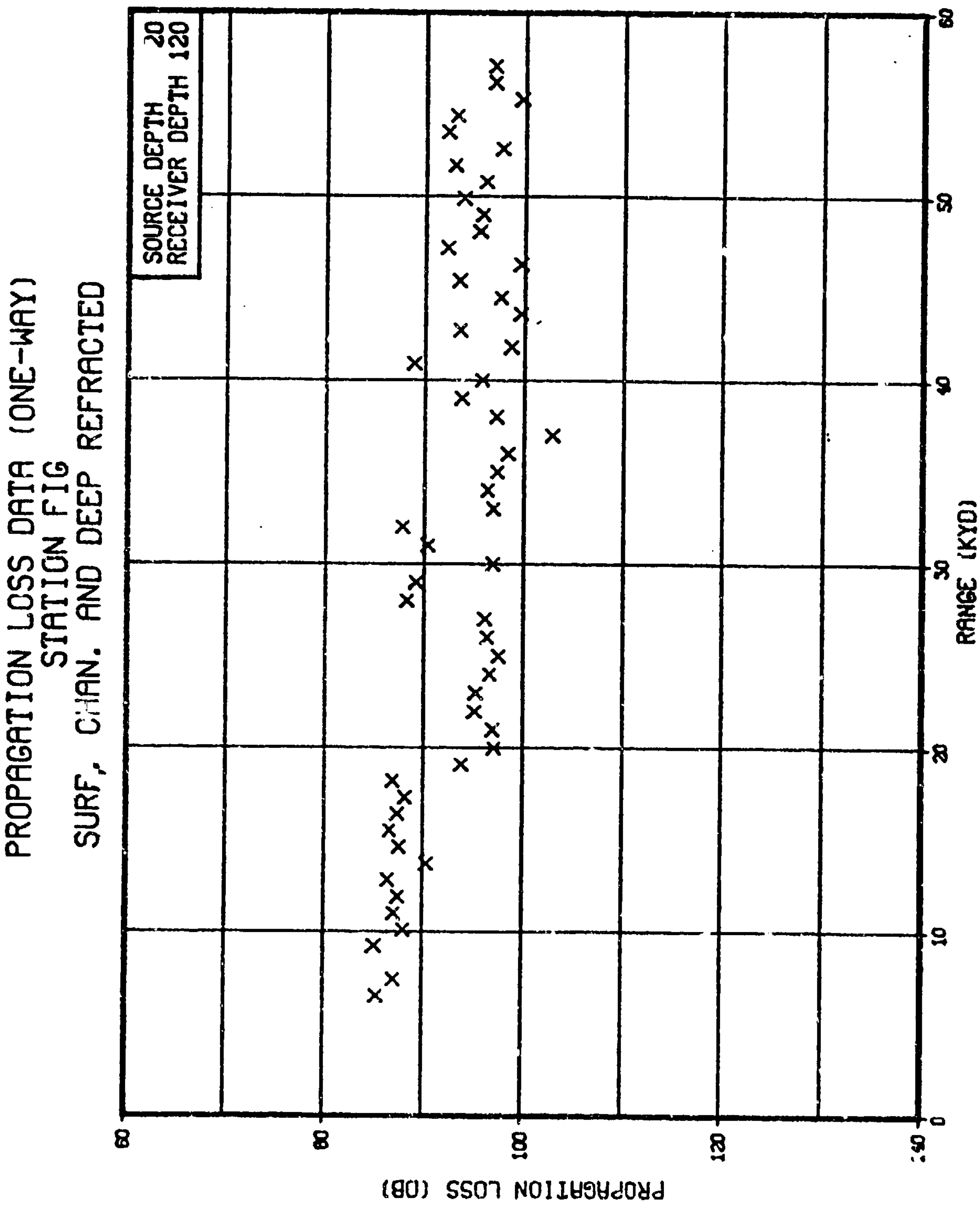

Fig. 2 Propagation Loss vs Range, Station FIG

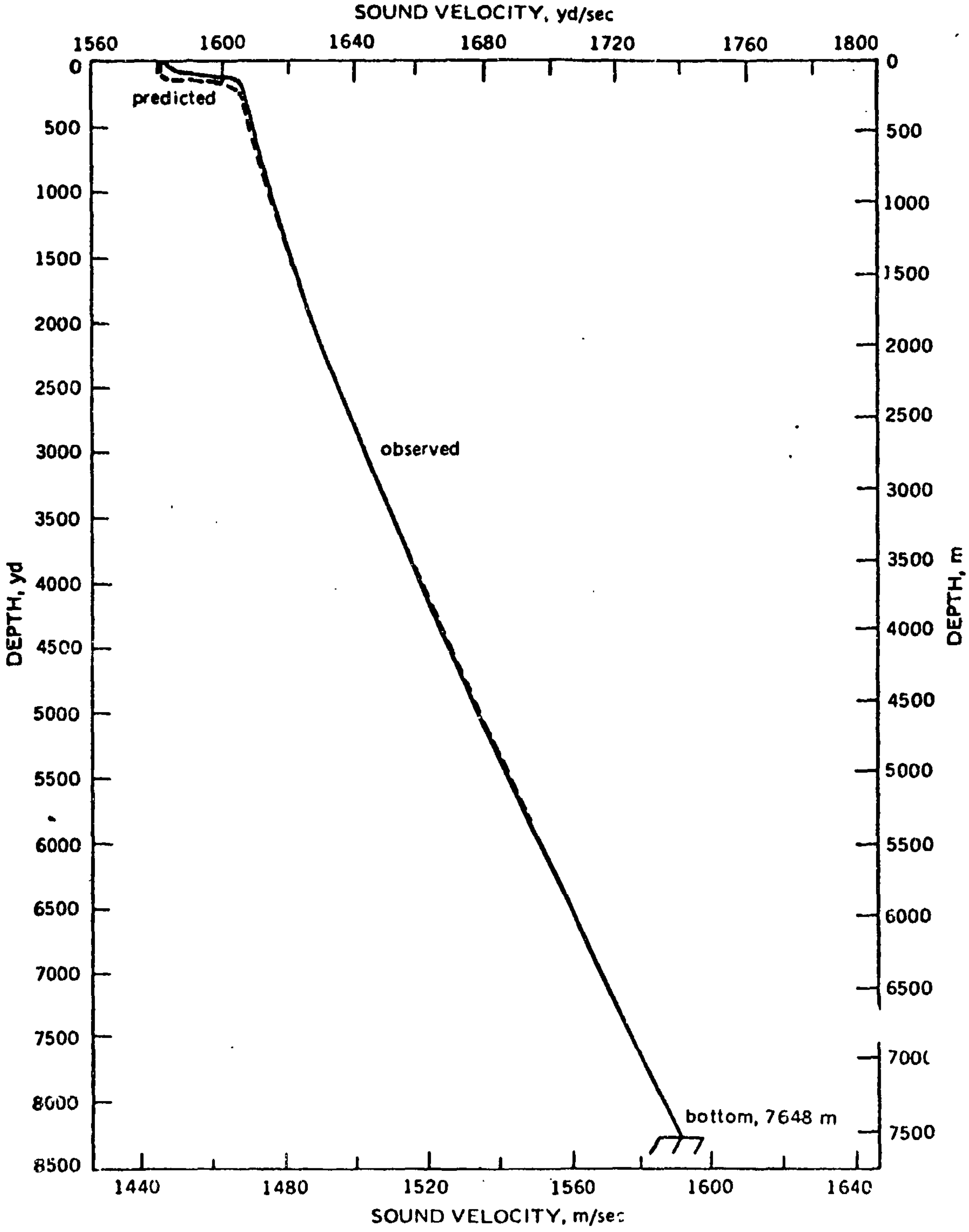

Fig. 3 Sound Speed vs Depth, Station FIG

Table 3. Sound Speed Profile, Station FIG

Depth (m)	Sound Speed (m/s)
0	1447.3
5	1447.4
10	1447.5
20	1447.6
50	1447.9
75	1448.6
100	1457.3
125	1463.4
150	1466.0
200	1467.3
250	1467.7
300	1468.4
400	1469.5
500	1470.6
600	147[illegible].7
700	1[illegible].8
800	1473.9
1000	1476.2
1200	1478.6
1500	1482.6
2000	1490.2
2500	1498.1
3000	1506.3
4000	1523.5
5000	1541.8
7648	1591.3

Table 4. In-Situ Properties of the Sediment, Station REDWOOD

Layer Number	Thickness m	Sediment Type	Porosity %	Sound Velocity m/s	Velocity Gradient Sec^{-1}	Density g/cm^3
1	4.5	Silty-clay	73.5	1484	1.98	1.49
2	0.1	(Volcanic ash)	(68.0)	(1575)	-	(1.57)
3	1.5	(Silty-clay)	(73.0)	(1485)	-	(1.49)
4	0.1	(Volcanic ash)	(68.0)	(1575)	-	(1.57)

Notes:

1. Values in parenthesis are assumed.
2. For a complete geophysical model, assume alternation of layers 3 and 4 to full thickness of the sediments.

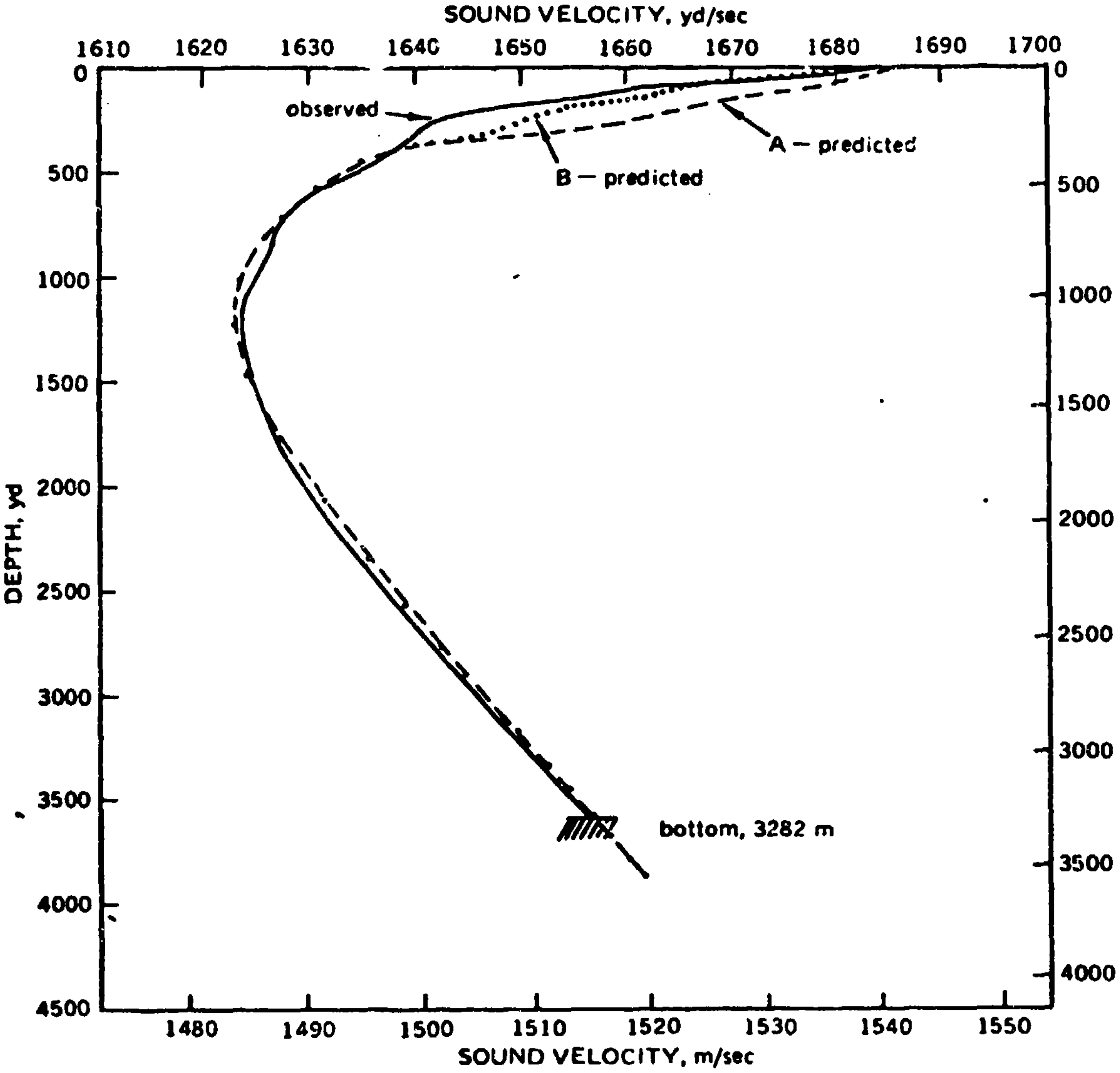

Fig. 4 Sound Speed as a function of Depth, Station REDWOOD

Table 5. Sound Speed Profile, Station REDWOOD

Depth	Sound Speed
0	1542.3
10	1540.0
19	1540.1
20	1539.7
30	1537.1
50	1533.6
75	1527.3
100	1521.4
125	1517.3
150	1515.1
200	1509.4
250	1504.6
300	1499.3
400	1496.8
500	1492.3
600	1489.0
700	1488.5
800	1487.3
900	1485.6
1000	1484.9
1100	1484.7
1200	1484.6
1300	1484.8
1400	1485.1
1500	1485.8
1750	1489.1
2000	1492.7
2500	1501.1
3000	1509.7
3282	1514.0

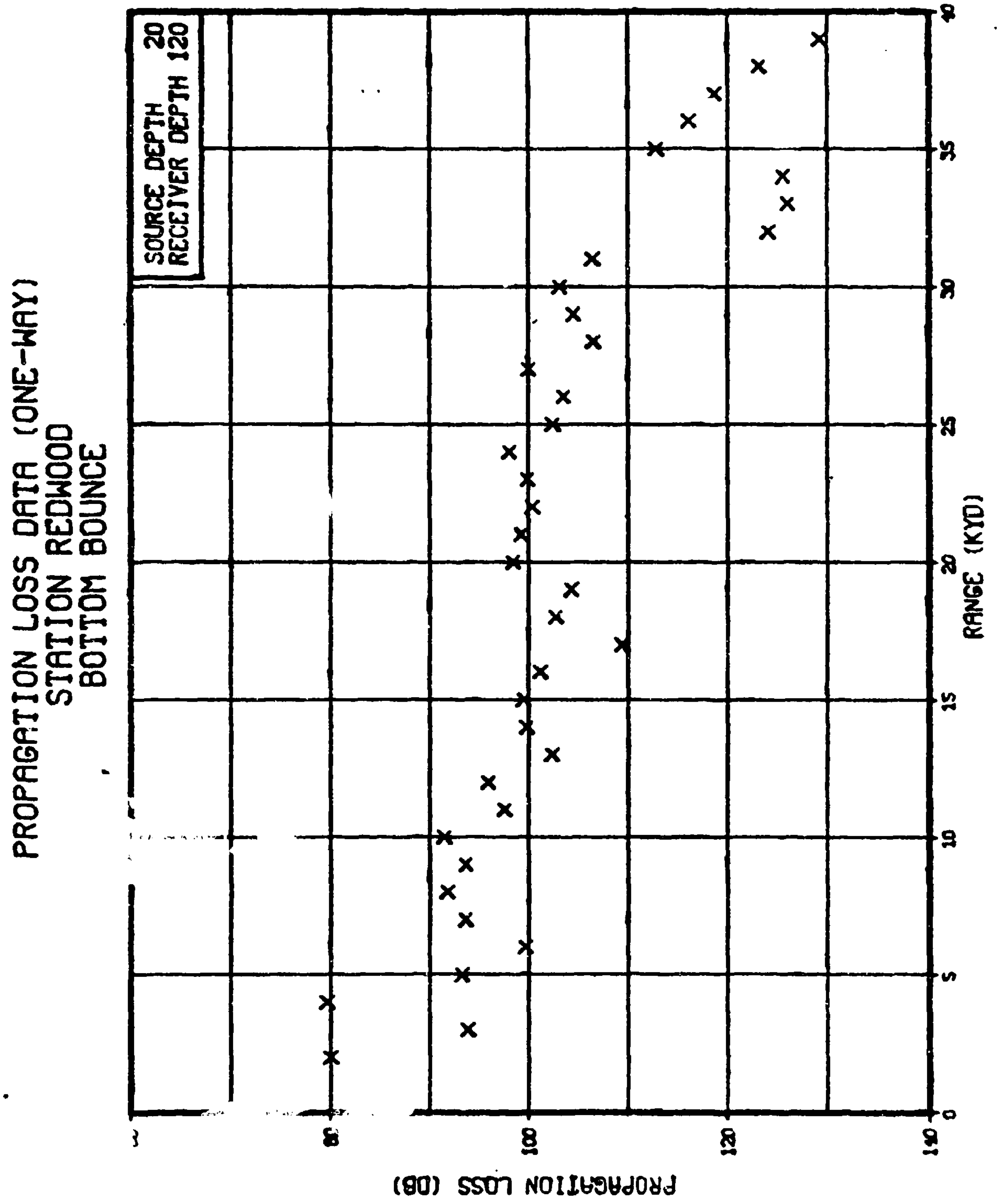

Fig. 5 Propagation Loss vs Range, Station REDWOOD

The appropriate sound speed profile is shown in Fig. 7 and listed in Table 7. There exists a modest surface layer to 30 meters.

Table 6. In Situ Properties for Station OAK

Layer No.	Depth (m)	Material	Sound Speed (m/s)	Gradient m/s/m	Attenuation dB/m/kHz	Density g/cm^3
1	0	Water	1514.6		0	1.02
2	30	Water	1514.9	.01	0	1.02
3	120	Water	1508.7	-.069	0	1.026
4	120	Fine sand	1762	(1.0)	.51	1.9
5	121	(Silty-Sand)	(1600)	-	(.56)	(1.74)
6	124	(Silty-Sand)	(1660)	-	(.75)	(1.81)
7	125	(Silty-Sand)	(1600)	-	(.56)	(1.74)
8	575		(6000)		(.10)	(2.6)

Station THORN - Station THORN is located in shallow water in the western Pacific Ocean. Propagation loss runs were made on 26 May 1966. The sea floor was smooth along the test tracks and sloped gradually to the west from about 75 m to 116 m (in approximately 40 n miles) with a mean depth of approximate 104 m over sand sediments of unknown thickness. The water column and sediments are modeled as in Table 8 (see references 5, 10 and 15).

The two runs, NAVDAB Exp. 2, station 20, Runs 1 and 2 should be combined and a constant depth of 104 m assumed for model evaluation. Figure 8 is a plot of this run. The transponder source was at 75 ft (23 m) and BAYA's receivers were at 120 ft (37 m), each pulse a data sample.

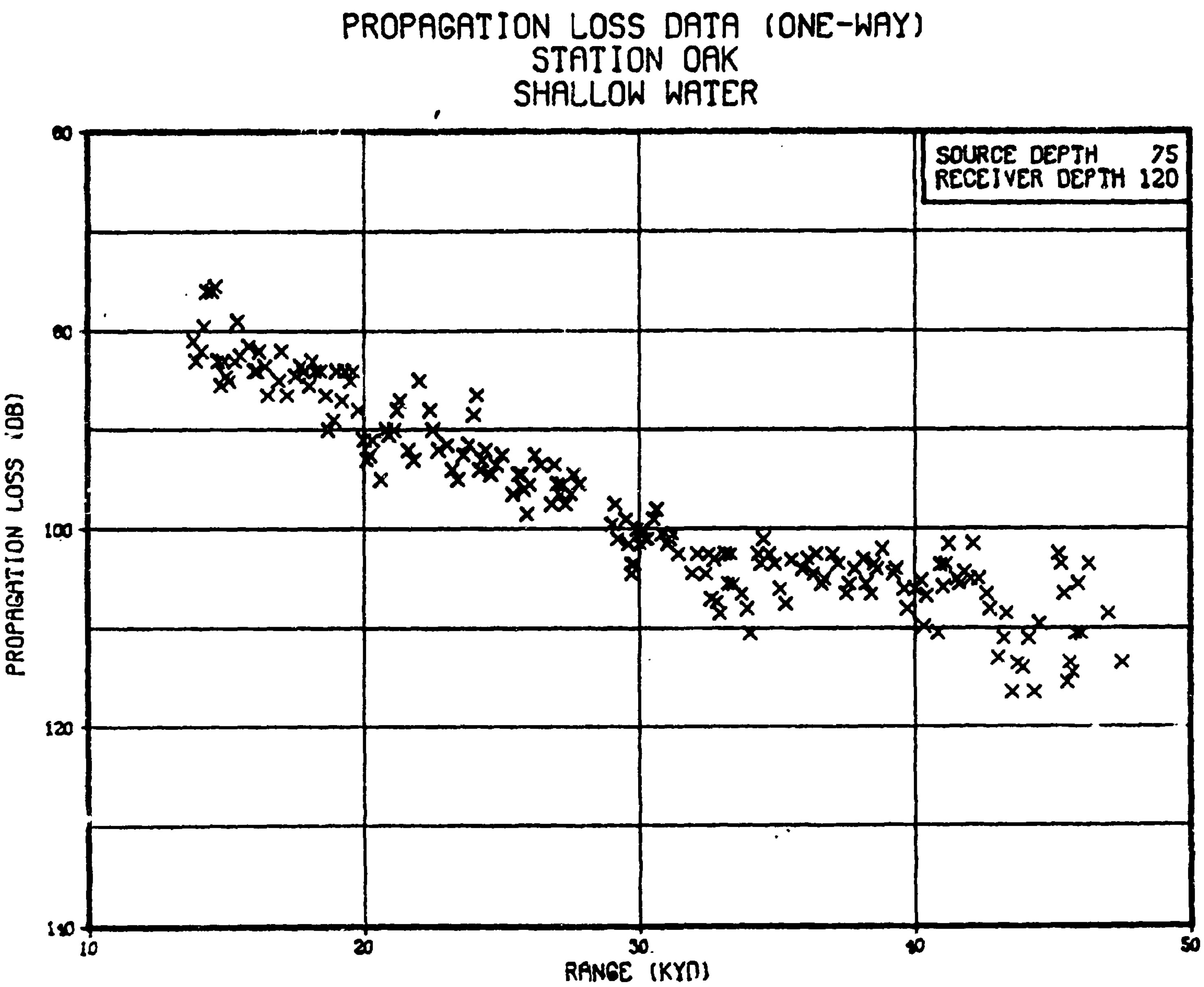

Fig. 6 Propagation Loss vs Range, Station OAK

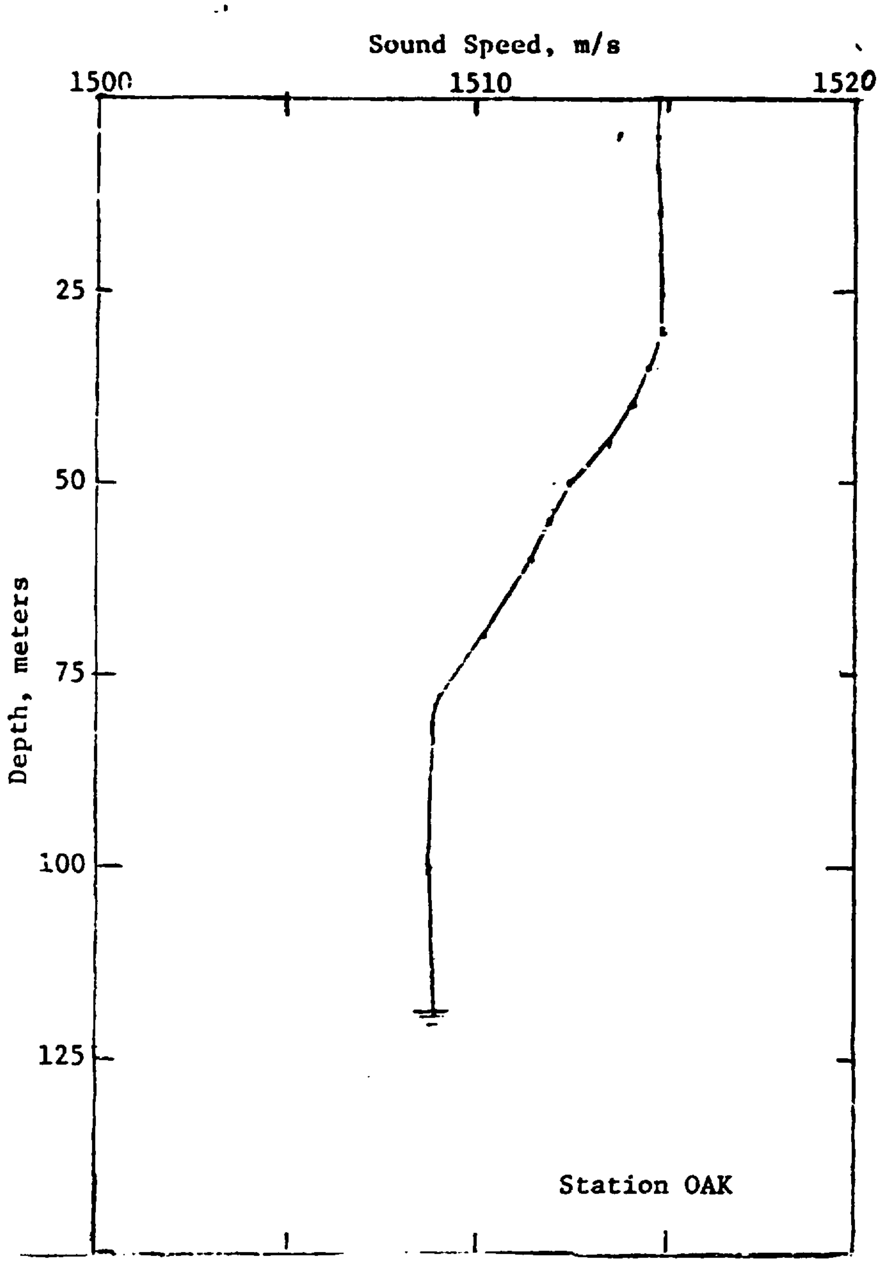

Fig. 7 Sound Speed Profile,Station OAK

TABLE 7 Sound Speed Profile, station OAK

Depth (m)	Sound Speed (m/s)
0	1514.6
10	1514.7
20	1514.8
30	1514.9
40	1514.2
50	1512.4
60	1511.5
70	1510.4
80	1508.9
100	1508.4
120	1508.7

Table 8. In Situ Properties for Station THORN

Layer No.	Depth (m)	Material	Sound Speed (m/s)	Gradient m/s/m	Attenuation dB/m/kHz	Density g/cm^3
1	0	Water	1542.4	.033	0	1.02
2	55		1544.2	-.35	0	1.02
3	75		1537.2	-.317	0	1.02
4	104	Water	1528.0	-	0	1.024
5	104	Sand	1809.	.74	(.51)	1.95
6	114	Sand	1883	.20	(.51)	1.95
7	124	(Sand)	(1903)	(.10)	(.49)	(1.95)
8	375	Rock	2265	(-.1)	(.49)	(1.95)

The sound profile appropriate for this run is given in Fig. 9 and listed in Table 9. Layer depth is about 55 m. Wind speeds were light at 5-6 knots. Wave and swell heights averaged one and four ft respectively.

Station INDIA - Station INDIA is in shallow water on the continental shelf of the Arafura Sea north of Australia. The sea floor in the area is flat (relief of about two fathoms) with sediments ranging from sand to fine grained mud. The water column was near iso-velocity. The water and sediment model for this station is given in Table 10 (see references 6 and 15). Sediment thickness is unknown but is estimated to be at least 50 meters.

Two propagation loss runs were made on 8-9 May 1969, with the transponder source at 75 ft (23 m) and BAYA's receivers at 37 m. These runs (NAVDAB Exp. 8, station 10, Runs 1, 2) are combined and plotted in Fig. 10, each pulse a data sample. It is recommended that this combined run be used in model evaluation.

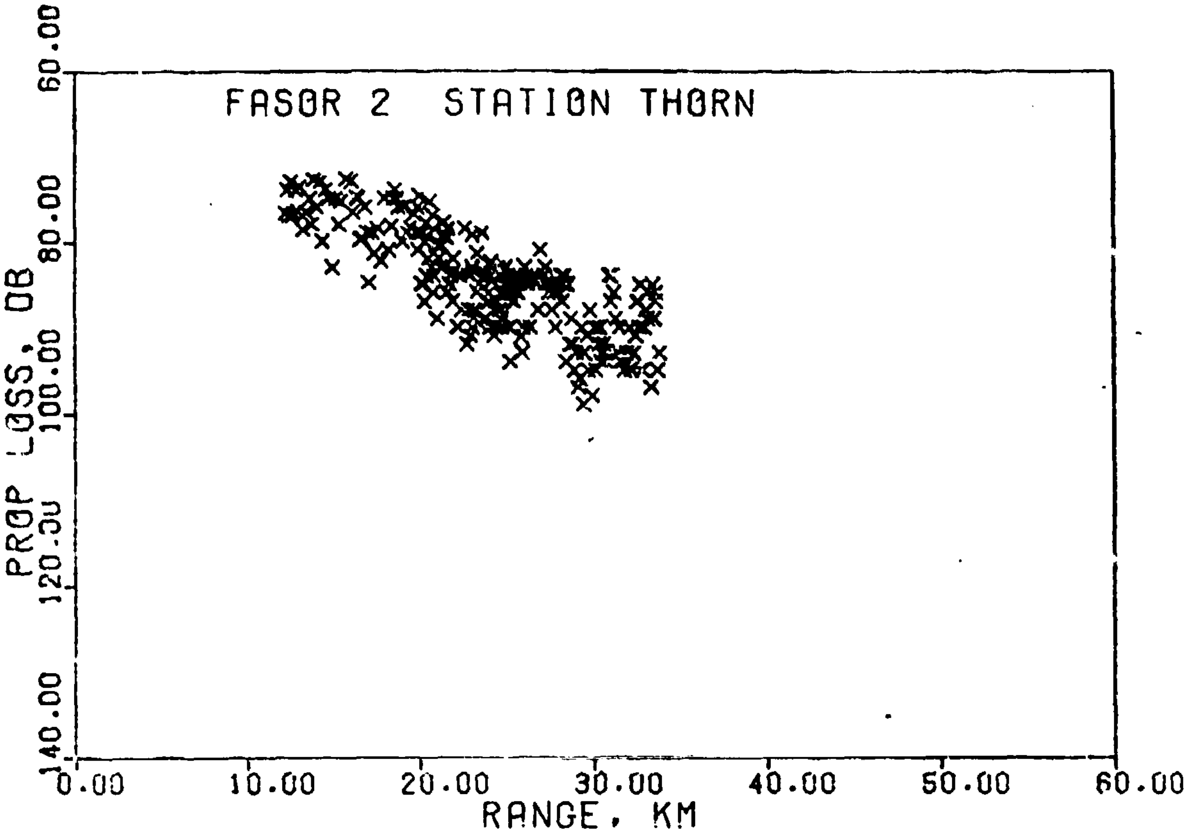

Fig. 8 Propagation Loss vs Range, Station THORN

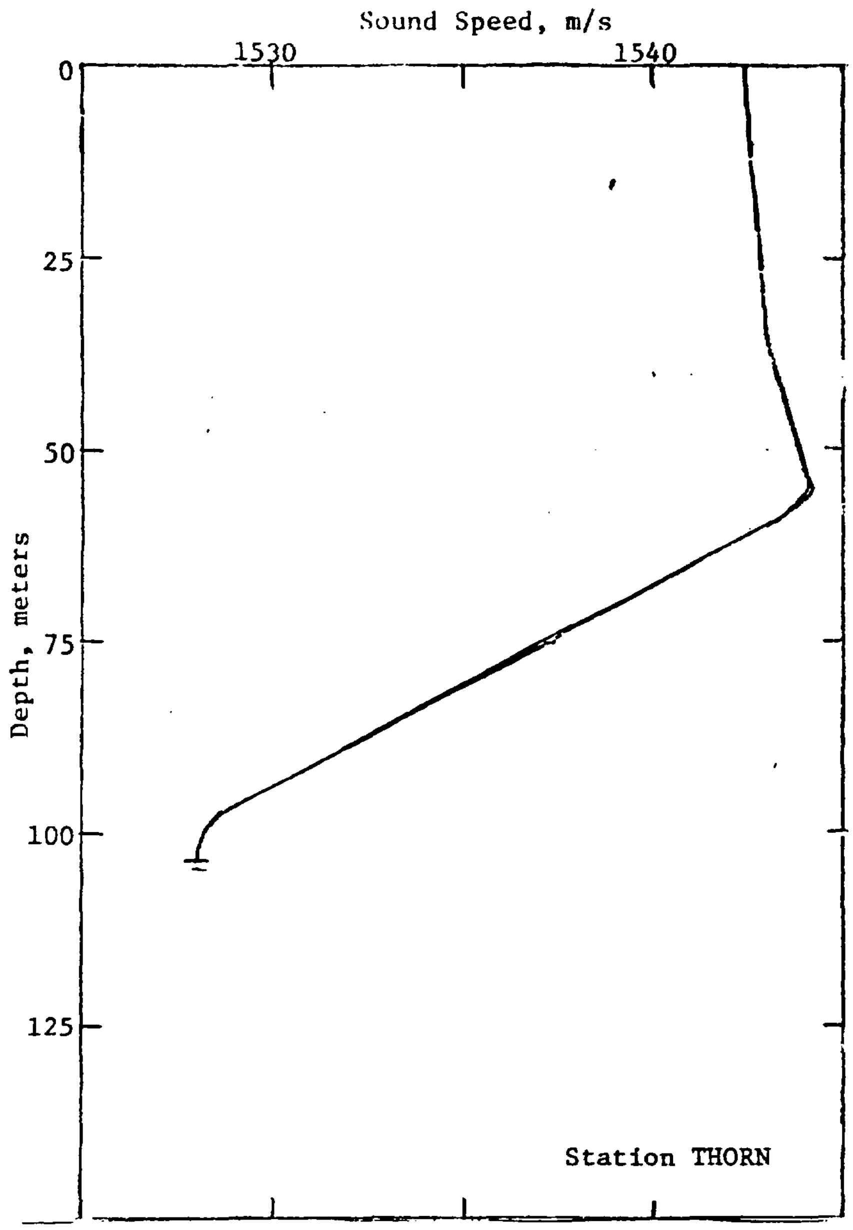

Fig.9 Sound Speed Profile, Station THORN

TABLE 9 Sound Speed Profile,Station THORN

Depth (m)	Sound Speed (m/s)
0	1542.4
10	1542.6
20	1542.7
30	1542.9
40	1543.4
50	1543.8
55	1544.2
60	1543.1
75	1537.2
100	1528.2
104	1528.0

Table 10. In Situ Properties for Station INDIA

Layer No.	Depth (m)	Material	Sound Speed (m/s)	Gradient m/s/m	Attenuation dB/m/kHz	Density g/cm^3
1	0	Water	1541.6	.02	0	1.02
2	30		1542.2	-.01	0	1.02
3	50	Water	1542.0	-	0	1.023
4	50	Clayey Sand	1593	(1.0)	.15	1.6
5	52	(Silty-Sand)	(1650)	-	.65	(1.8)
6	52.1	(Clayey Sand)	(1600)	-	(.15)	(1.6)
7	54.1	(Silty-Sand)	(1650)	-	(.65)	(1.8)
8	54.3	-	(1600)	-		(1.6)
9	354.3	-	2024	-	(.15)	(1.6)

The sound speed profile which applies for this run is shown in Fig. 11 and tabulated in Table 11. The layer depth is considered to be the same as the water depth at 50 m. Wind speeds were 14-15 knots. Wave and swell heights were observed to be four and six ft respectively.

Station JULIETT - This station is on the continental shelf northwest of Darwin, Australia. Average depth was about 124 meters with maximum relief of 12 fathoms (22 m). In the station area the sediment is mostly calcareous silty sand with flat bank tops covered by foraminiferal and coralline algal sands. Sediment thickness is about 130 m. The water and sediment model for this station (reference 6 and 15) is given in Table 12.

At the times of the propagation runs (12-13 May 1969) wind speeds varied between six and 10 knots, averaging about nine knots. Wave height was constant at

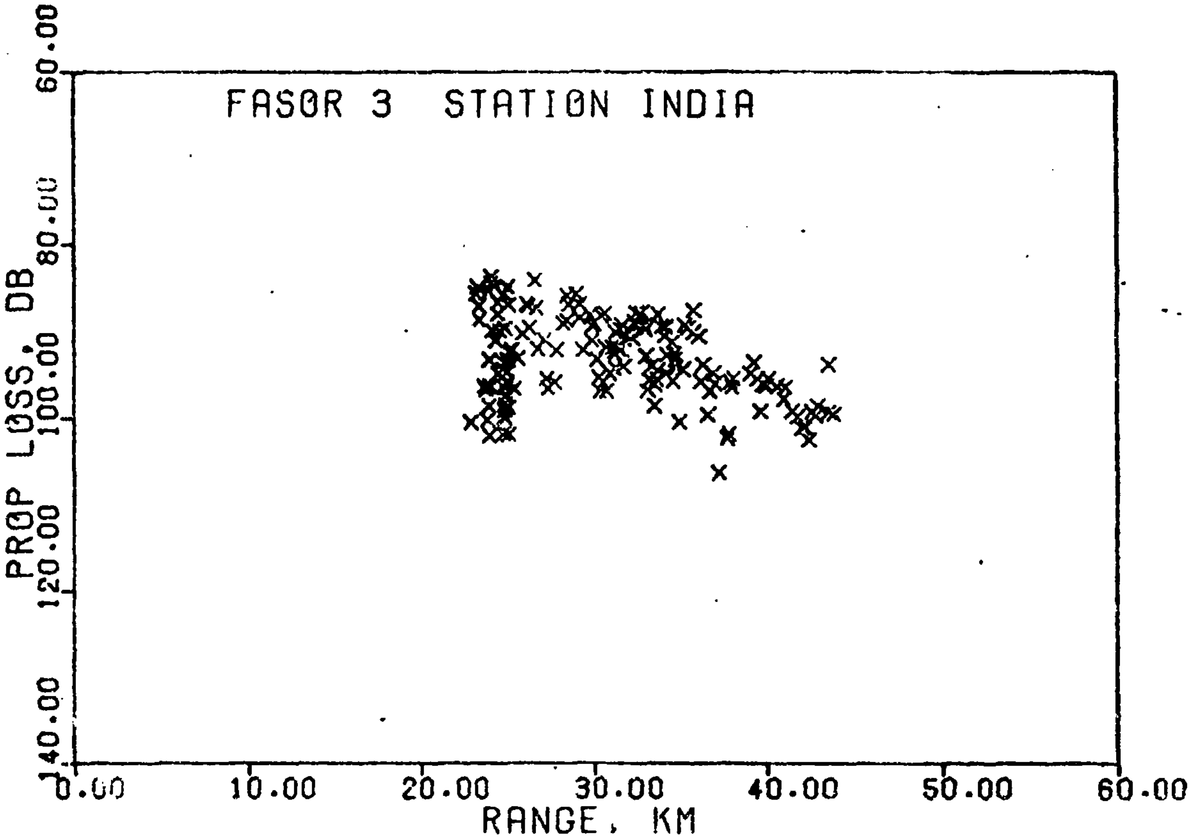

Fig. 10 Propagation Loss vs Range, Station INDIA

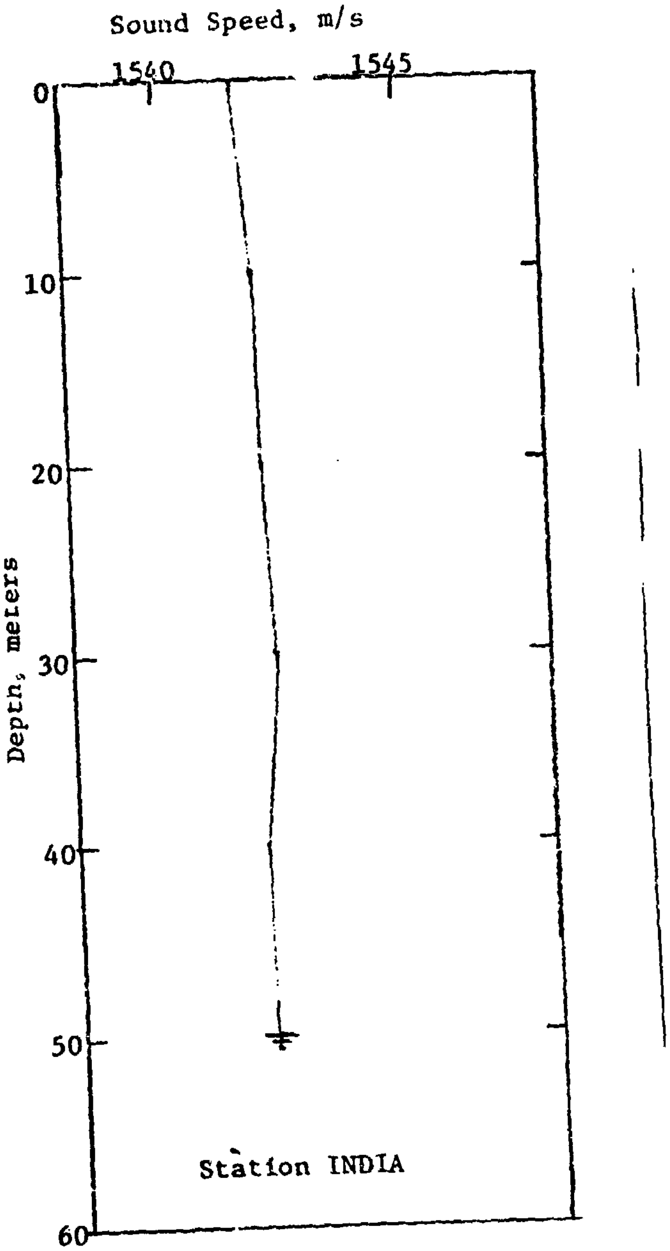

Fig. 11 Sound Speed Profile,

TABLE 11 Sound Speed Profile, Station

Depth (m)	Sound Speed (m/s)
0	1541.6
10	1541.9
20	1542.0
30	1542.2
40	1541.9
50	1542.0

two ft with three-ft swells. For use in model evaluation the two runs (NAVDAB Exp. 8, station 11, Runs 1-2) are combined as shown in Fig. 12. The range coverage is from 14.7 to 57.0 kyds. The transponder source depth was 75 ft (23 m) and the BAYA's receivers were at 37 meters.

Table 12. In Situ Properties of Station JULIETT

Layer No.	Depth (m)	Material	Sound Speed (m/s)	Gradient m/s/m	Attenuation dB/m/kHz	Density g/cm^3
1	0	Water	1542.7	.016	0	1.02
2	75		1543.9	-.25	0	1.02
3	124	Water	1531.7		0	1.024
4	124	Silty-Sand	1581	(1.5)	(.15)	1.58
5	254	Limestone	(2500)	(-.1)	(.1)	(2.2)

The sound speed profile which applies for this run is shown in Fig. 13 and tabulated in Table 13. The layer depth was 75 m and the bottom depth averaged 124 meters.

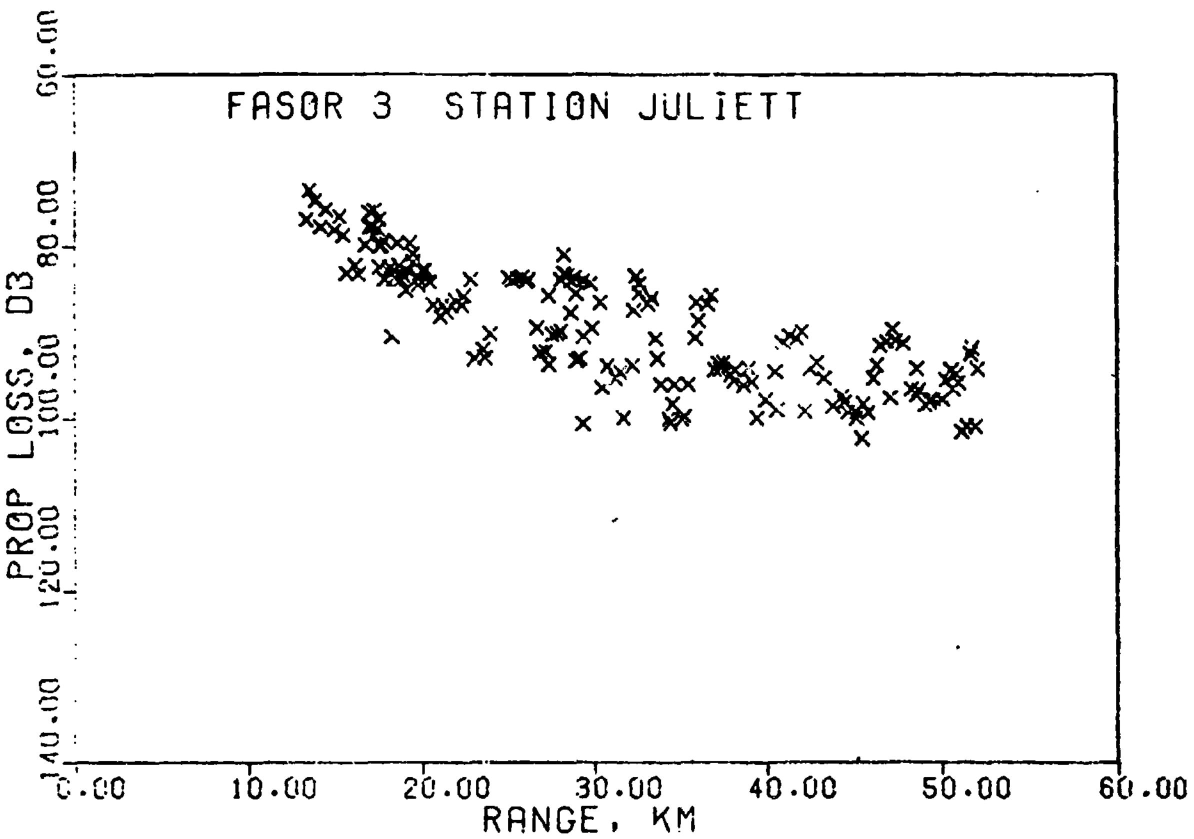

Fig. 12 Propagation Loss vs Range, Station JULIETT

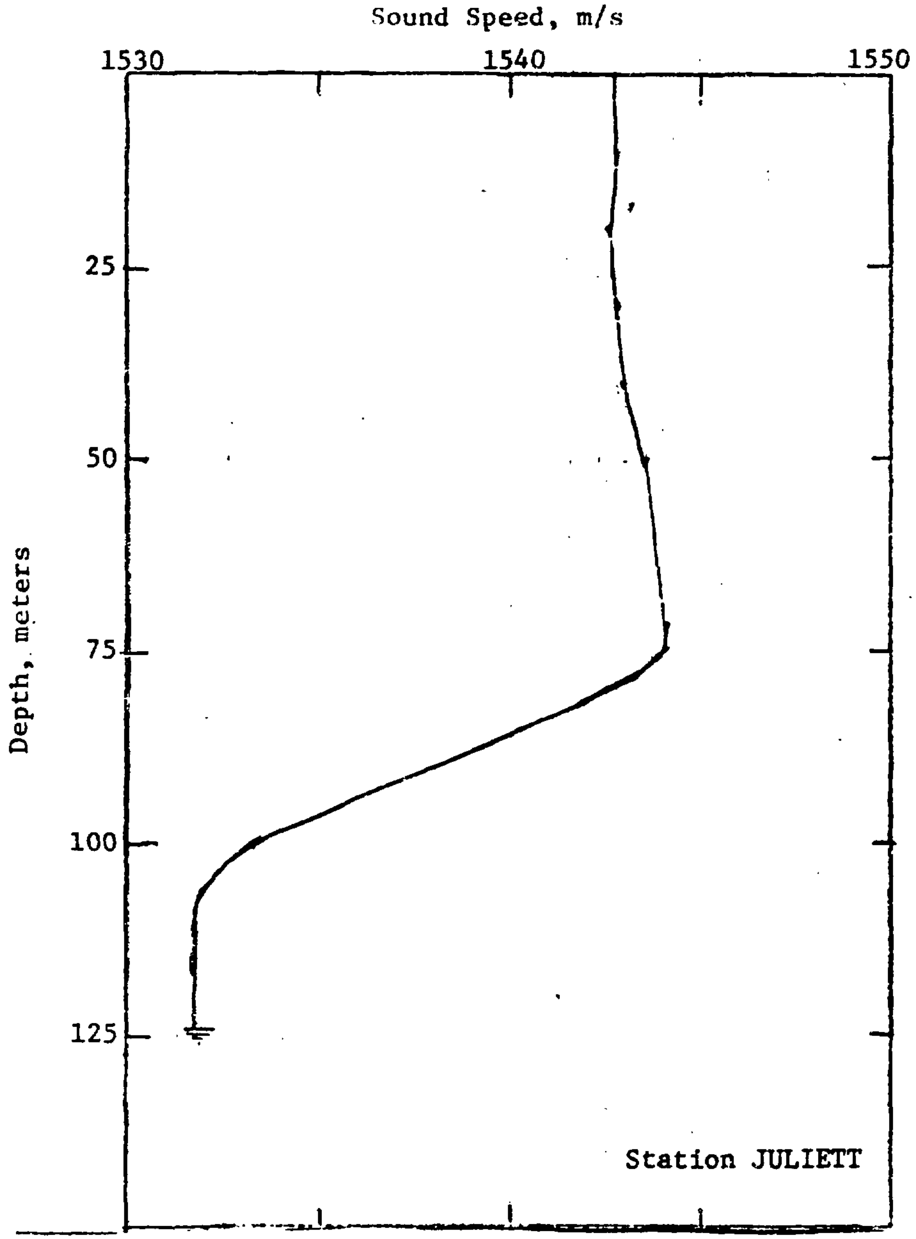

Fig. 13 Sound Speed Profile, Station JULIETT

TABLE 13 Sound Speed Profile,
Station JULIETT

Depth (m)	Sound Speed (m/s)
0	1542.7
10	1542.8
20	1542.6
30	1542.8
40	1542.9
50	1543.6
75	1543.9
100	1533.2
112	1531.8
124	1531.7

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14. Navy Electronics Laboratory Report 1363, (C) "Sonar Data Reduction and Analysis in Real time at Sea ," by G. S. Yee, Mar 1966.

15. Naval Ocean Systems Center TR ___, "Shallow-Water Sound Propagation: A Normal Mode Model," by D. White and D. F. Gordon (in publication).

Appendix 5. (U) LORAD (Long Range Acoustic Detection)

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APPENDIX 5

DATA SETS FOR MODEL EVALUATION: THE LORAD/HAWAII DATA SET

Summarized by James A. Whitney

INTRODUCTION

This report will summarize the data obtained in a long-range acoustic transmission experiment conducted in September, 1953 in 3100 fathom water northeast of Hawaii (see reference (1)).

The propagation loss data is available in NAVDAB, Experiment 4 (Cruise 1, Station 1). There the data have been assigned to 17 runs with the frequency alternating with Run No. and the receiver depths delineated by data set(s) within each run. This is detailed in Table 1.

THE EXPERIMENT

A surface ship, the USS MOCTOBI, towed two sound sources that were alternately driven by 500-msec pulses. Figure 1 shows the location of the experimental track and the bottom topography of the area. The receiving ship, the USS SABALO, a submarine, lay to and drifted to the northwest while monitoring signals on hydrophones at depths of 100, 300 and 1000 ft. Drift rate was about 0.7 knot.

The acoustic sources were 530-Hz and 1030-Hz Fessenden transducers at depths of 50 ft (15.24 m) and 110 ft (33.5 m) respectively, towed on course 073° at a speed of about 3 knots. Sources were pulsed alternately by groups of three 500-msec pulses. There were 3- and 2- sec intervals between individual pulses and 5 seconds between groups.

The test was scheduled to exceed 500 n miles but terminated after 241 miles. At that point the MOCTOBI was sent on an emergency call to aid a disabled ship.

EQUIPMENT

The instrumentation was similar to that of previous experiments and is more completely described in reference (2). On the receiving ship, two hydrophones were

Table 1. Range, depth and frequency parameters for the LORAD/HAWAII data set

NAVDAB Run No. Data Set Figure	1 1 4	1 2 4	2 1 5	2 2 5	3 1 6	3 2 6	4 1 7	4 2 7	5 1 8	6 1 -	6 2 -	6 3 -
Source Depth (ft)	50	50	180	180	50	50	180,* 155	180,* 155	110	50	50	50
Receiver Depths (ft)	1000	100	1000	100	1000	100	1000	100	100	1000	300	100
Frequency (kHz)	0.530	.530	1.03	1.03	.53	.53	1.03	1.03	1.03	.53	.53	.53
Min. Range (kyd)	.38	.74	.46	.44	3.04	1.96	1.92	1.88	89	45	90.4	45
Max. Range (kyd)	9.14	9.2	9.0	20.5	76.2	79	22	21.9	100.9	143	142.8	143
Layer Depth (m)	37	37	37	37	Approximately 33 meters →							

Sound Axis The axis of minimum sound speed is about 750 meters.

Bottom Depth Depth to bottom is assumed constant at 3100 fm (5670 m).

Navigation Range was established by a radio link between source and receiving ships.

*Source depth was 155 ft from 9 to 22 kyds.

Table 1. Range, depth and frequency parameters for the LORAD/HAWAII data set (continued)

NAVDAB Run No.	7	8	9	10	11	12	13	14	15	16	17
Data Set	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3
Figure	9	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B
Source Depth (ft)	110	50	110	50	110	50	110	50	110	50	110
Receiver Depths (ft)	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100	1000, 300, 100
Frequency (kHz)	1.03	0.53	1.030	0.530	1.030	0.53	1.030	0.53	1.03	0.53	1.030
Min. Range (kyd)	88.2	182.	186.	250.	250.	313.3	317.	375.6	375.5	440.	446.
Max. Range (kyd)	160.9	216.2	217.8	274.2	267.6	350.	330.	416.	407.	478.	471.
Layer Depth (m)	Approximately 33 meters										
Sound Axis	The axis of minimum sound speed is about 750 meters.										
Bottom Depth	Depth to bottom is assumed constant at 3100 fm (5670 m)										
Navigation	Range was established by a radio link between source and receiving ships.										

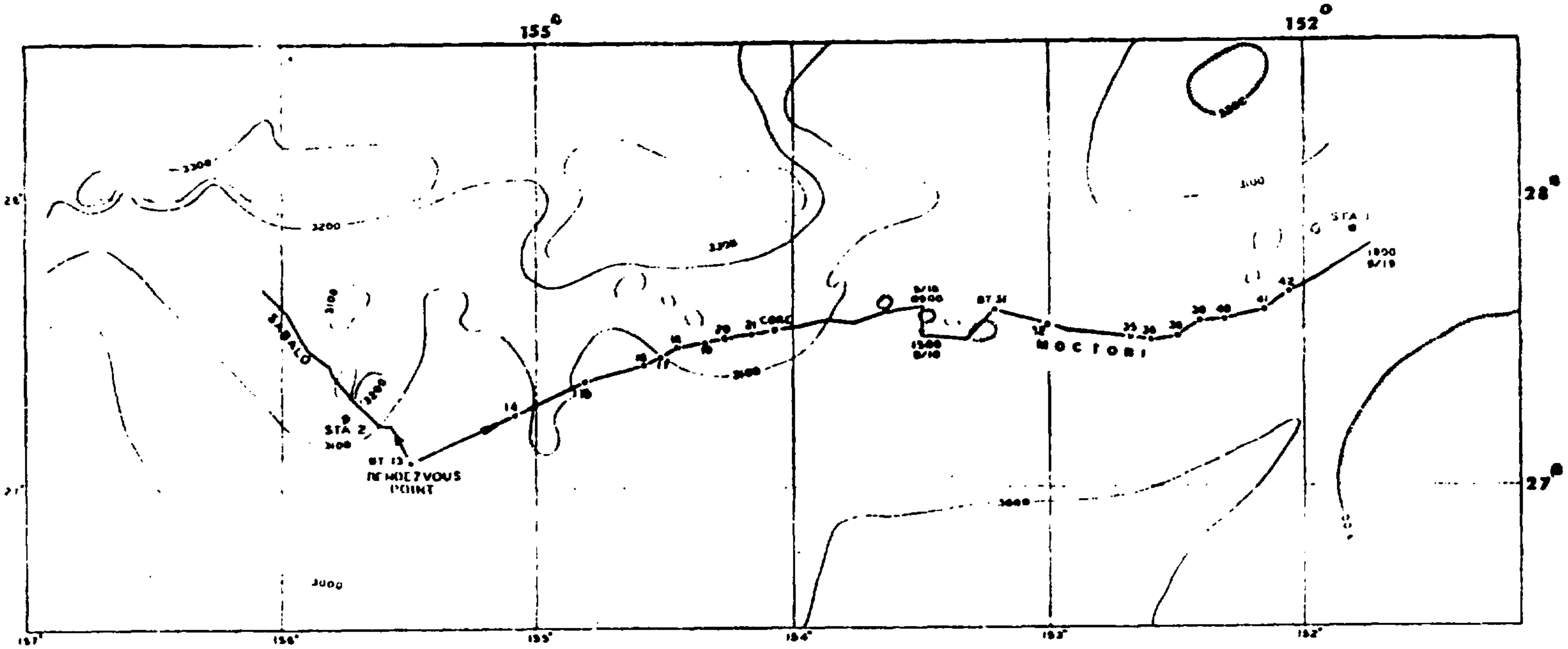

Figure 1   Bottom topographic map showing the location of the experimental track.

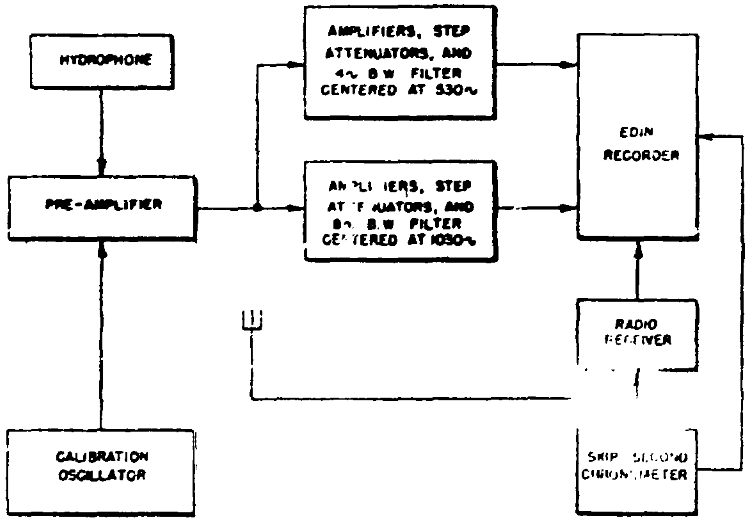

Figure 2.   Block diagram of the receiving equipment for one hydrophone.

floated out 600 ft with buoyed suspension at depths of 100 ft (30.5 m) and 300 ft (91.4 m) to reduce ship noise. Receiving hydrophones at depths of 300 ft and 1000 ft (305 m) were directly suspended from the submarine. The latter 300-ft hydrophone was used for the first half of the run and the buoyed hydrophone was used for the remainder of the run.

Figure 2 is a block diagram of the receiving equipment for one hydrophone. The sound pulses at the two frequencies were separated by means of two parallel-T feedback filters with bandwidth of 4 Hz centered at 530 Hz and 8 Hz centered at 1030 Hz. Signals were recorded on a EDIN ink recorder.

A radio link was established between ships to ensure range accuracy. A radio pulse was keyed simultaneously with the acoustic pulse on the source ship. Received-signal time differences (acoustic-radio) multiplied by the acoustic group velocity generally results in accurate ranges.

Table 2 gives the average noise both in narrow bands and spectrum levels. All values except those for 530 Hz at the 300-ft hydrophone agree with spectrum levels measured in other experiments.

Table 2. Average noise readings (dB re 1μb)

	530 Hz		1030 Hz	
Hydrophone depth (ft)	Band Level	Spectrum Level	Band Level	Spectrum Level
100	-24	-30	-19	-28
300 (buoyed)	-18	-24	-16	-25
300	-18	-24	-17	-26
1000	-23	-29	-22	-31

Source levels were checked by monitor hydrophones. A depth gauge was employed and secured to the support cable near the 1030 Hz source.

ENVIRONMENTAL FEATURES

Bathythermograms (BT's) were taken by the source ship at the locations indicated in Figure 1 by the numbered black dots. The average sea conditions observed at the receiving ship was sea state 2.

From October 6 to 8, 1953, less than a month after the acoustic test, extensive oceanographic measurements were made in this area. The mean water depth was 3100 fathoms while the sea floor relief was less than 100 fathoms. A bottom core taken in the area was composed of red clay. The results of the sediment analysis of this core is given in Table 3.

Table 3. Sediment sample data (from reference (3))

Location	27°32'N, 154°06'W
True Depth	3120 fathoms (5706 m)
Gr. Diameter	0.002 mm
Porosity	71.7 per cent
Wet Density	1.46 gm/cc
Sound Speed:	
Sediment	5320 ft/sec (1621.5 m/s)
Bottom Water	5110 ft/sec (1557.5 m/s)
Absorption Loss	7.9 dB/ft at 30 kHz
Sediment Type	Red clay
Sand	1.0 %
Silt	13.0 %
Clay	86.0 %

SOUND SPEED PROFILES

There was little difference between the sound speed profiles determined from oceanographic stations 1 and 2, which were taken at locations near the extremes of the test track (see Figure 1). There was also only slight variation in the BT's taken along the track by the source ship.

Figure 3 illustrates the sound speed profile used by Pedersen and Keith (reference (4)), to compute transmission losses for comparison to experimental losses from reference (1). This profile results from the combination of the average near-surface profile (to 150 meters) and the October Nansen cast data. The upper 150 meters are based on three BT's - one taken at the start of the run and two taken at the range of the first convergence zone. It was felt that it was desirable to have the most reliable calculations for the first zone (reference (4)).

Table 4 lists the depths and sound speeds (2) in meters and m/s respectively for the profile shown in Figure 3. The layer depth* is 33.0 m (107 ft) and the sound axis depth is 750 m. Prior to the development and wide-spread use of Wilson's equations (reference (5)) NEL and the Hydrographic Office had been computing sound speeds by equations fit by Mackenzie (reference (6)) to the tables of Kuwahara (reference (7)). Since the original temperatures and salinity profiles are not available a correction of column 2 sound speeds to Wilson's equation (column 3 of Table 4), was considered necessary.

E. R. Anderson of NEL selected 23 oceanographic stations taken throughout the Pacific Ocean and sound velocities were computed by both methods. The differences, Wilson's less Kuwahara's sound velocities, are plotted as a function of depth in reference (8). Del Grosso has published tables of sound-speed differences of several equations from his 1974 equation (reference (9)). The author of this report has combined those results with differences calculated from Nansen cast data from three FASOR stations having nearly the same conditions of latitude and temperature range as LORAD/Hawaii. The resulting sound-speed difference vs depth was used to correct the Kuwahara sound speeds (2) to Wilson sound speeds (3) in Table 4. It is recommended that the sound speed profile (3) be used in calculations for model evaluation.

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*Table 1 shows a greater layer depth for the first part of the run since the first BT indicated a surface layer of greater than 120 ft.

Table 4. Sound Speed Profile

(1) Depth (m)	(2) Sound Speed (m/s)	(3) Sound Speed (m/s)
0	1532.75	1536.2
15.24	1533.07	1536.5
30.5	1533.39	1536.8
32.6	1533.45	1536.8
33.5	1533.29	1536.7
50	1530.22	1533.6
75	1522.96	1526.3
100	1520.25	1523.6
150	1517.60	1520.8
200	1511.93	1515.1
250	1501.23	1504.3
305	1496.30	1499.4
500	1483.16	1485.9
600	1479.77	1482.3
700	1477.67	1480.1
750	1477.58	1479.9
800	1477.83	1480.0
1000	1479.07	1481.1
1500	1484.16	1485.6
2000	1490.50	1491.3
3000	1506.78	1506.8
4000	1524.21	1523.9
5670	1554.75	1554.7

(2) Sound speed from reference 4 in m/s.

(3) Sound speed corrected to Wilson's equation.

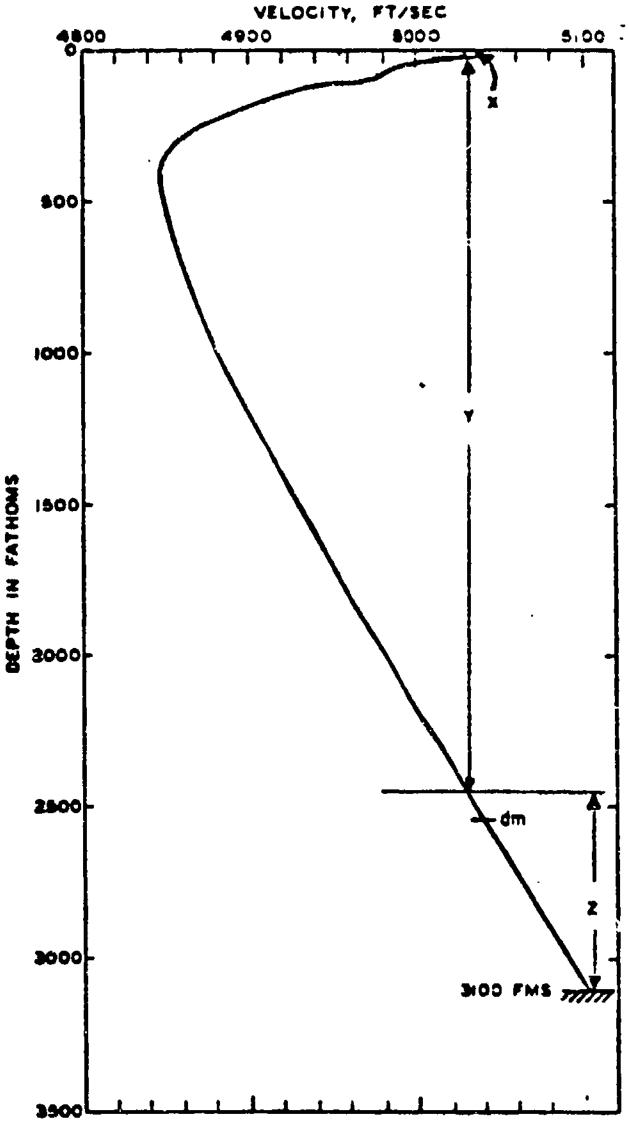

Figure 3. Sound Speed Profile for Lorad/Hawaii.

RESULTS

The original data was reduced by averaging the mean pressure amplitude of six consecutive pulses corresponding to each minute of transmission (without regard to path type) and converting to dB loss. Exceptions are Figures 5, 7 and 8 at 1030 Hz and Figures 4 and 6 at 530 Hz where the paths were distinctly separate. An average transmission loss was thus obtained for every 100 yards of range increment. The data in NAVDAB was taken from the propagation loss plots in reference (1). Points were read in such a manner as to reproduce those plots.

Figures 4-14 are direct reproductions of the propagation loss plots of reference (1). During the first 4.5 miles (9 kyds) of the transmission run the 1030-Hz source was at a depth of 180 ft, from 4.5 to 11 miles (9 to 22 kyds) it was at 155 ft and from 11 miles outward the 1030-Hz source depth was maintained at 110 ft. However, this source was inoperative from 11 to 44.5 miles (22 to 89 kyds).

The depth of the 530-Hz source was 50 ft throughout the experiment. The 530-Hz source and the 100-ft receiver were in the surface channel with the 1030-Hz source and the 1000-ft receiver below it. The 300-ft hydrophone was inoperative until 45 miles (90 kyds).

The propagation losses for direct and surface-channel transmission are shown in Figure 4 (530 Hz) and Figure 5 (1030 Hz). Figures 6-14 present the propagation loss for convergence zone transmission. Gaps in the data indicate equipment failure. The dashed line at or near the lower edge of the figures is the level corresponding to signal-to-noise. Losses beginning or terminating at this level indicate regions where all or nearly all signals were below noise. Since no noise correction was applied, the losses for signals near noise levels are only qualitative.

Once-bottom reflected and first-zone signals are combined in Figure 6 and Figure 9 results from twice-bottom-reflected and second-zone signals, since it is not possible to distinguish where the bottom-reflection signals merge with the corresponding zone. Figure 8 (an exception) results from signals determined to be 1st zone refractive signals. In general, the dominant signal was processed and errors may be present at the crossover ranges.

The experiment was halted for five hours at zone 4 (Figure 11) while the receiving submarine charged batteries and the transmitting ship lay to, drifted, and closed range somewhat. This accounts for the overlaps in Figure 11. Also when the test was resumed the submarine was still on charge with one engine, increasing the noise level to the point of obscuring the trailing edge of zone 4.

The experiment was terminated at 240.7 miles, just beyond the apparent end of zone 7.

CONCLUDING REMARKS

Header information in NAVDAB is partly in error. For example, the 1030-Hz source depth is listed as 180 ft for all runs. The correct depths are given in Table 1.

The model evaluator might consider NAVDAB Runs 3, 6, 8, 10, 12, 14 and 16 as one set of three runs at 530 Hz and 7, 9, 11, 13, 15 and 17 as one set of three runs at 1030 Hz. Run numbers 1, 2, 4 and 5 should be treated independently of other data.

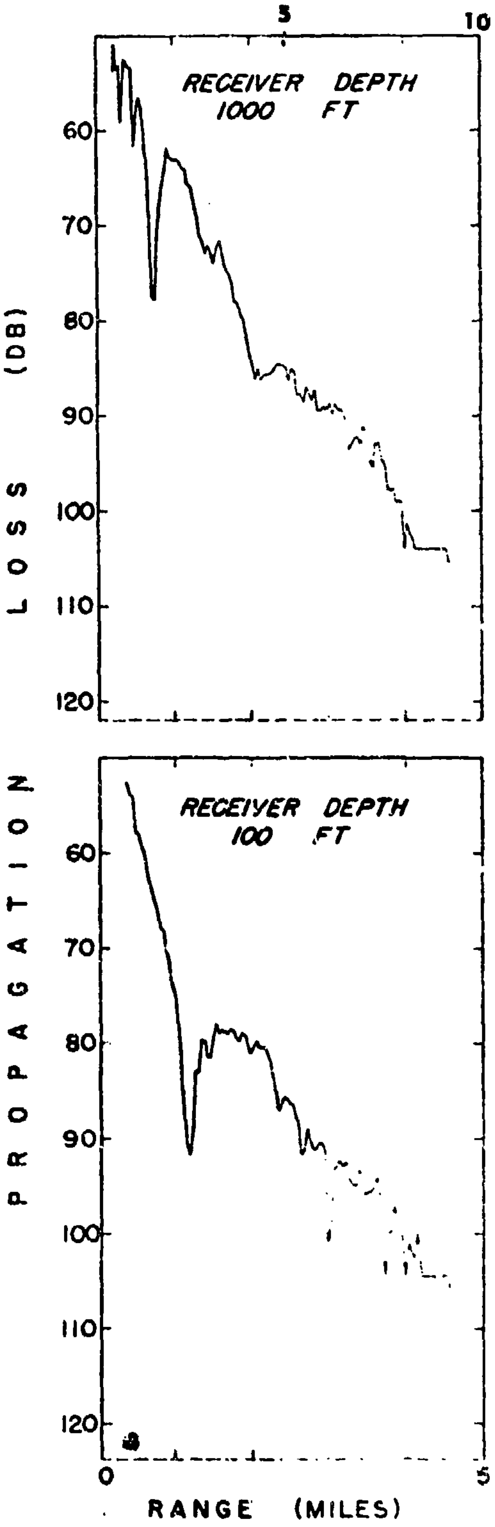

Figure 4 Propagation loss of direct signals (530 cps).

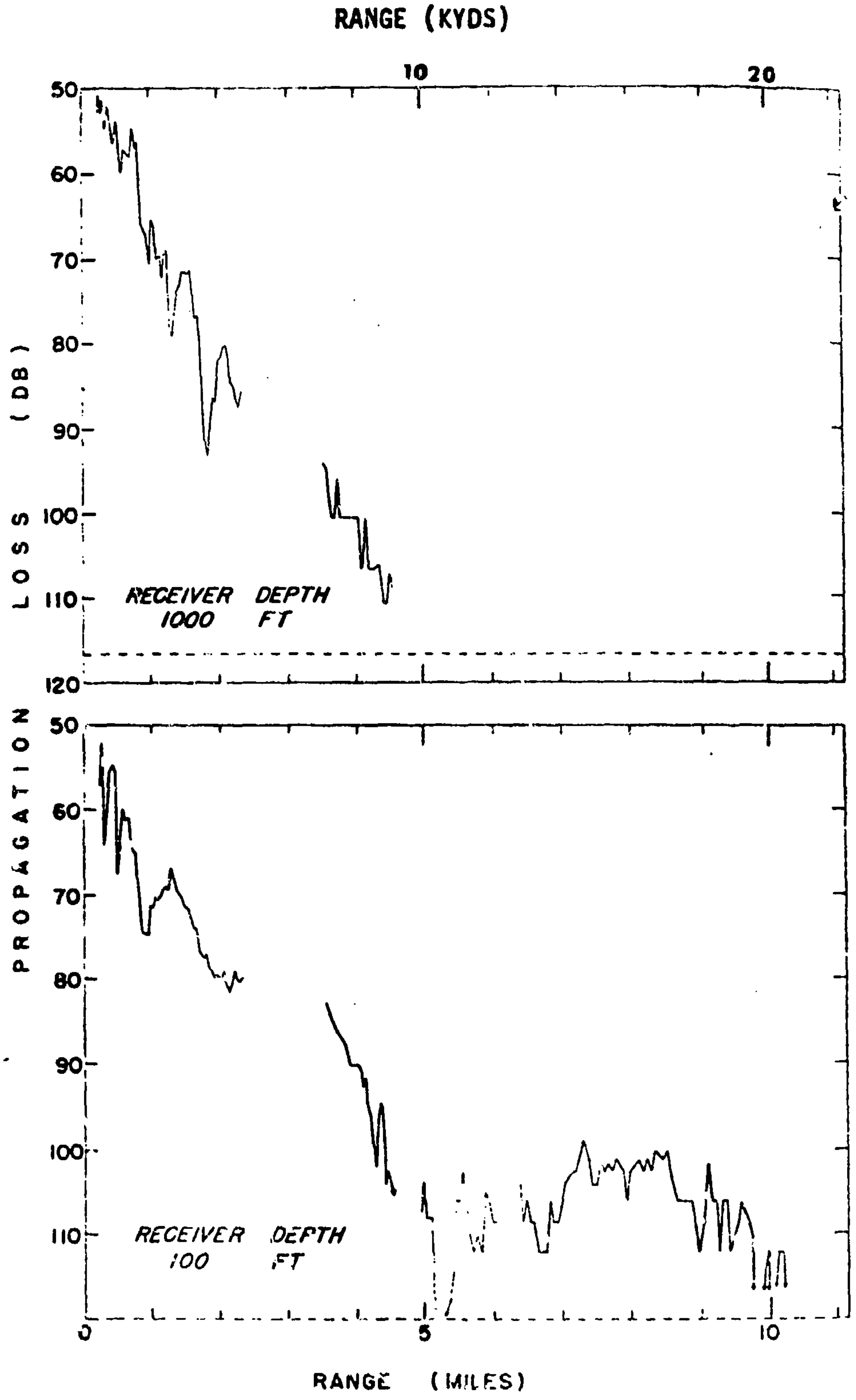

Figure 5 Propagation loss of direct and surface-channel signals (1030 cps).

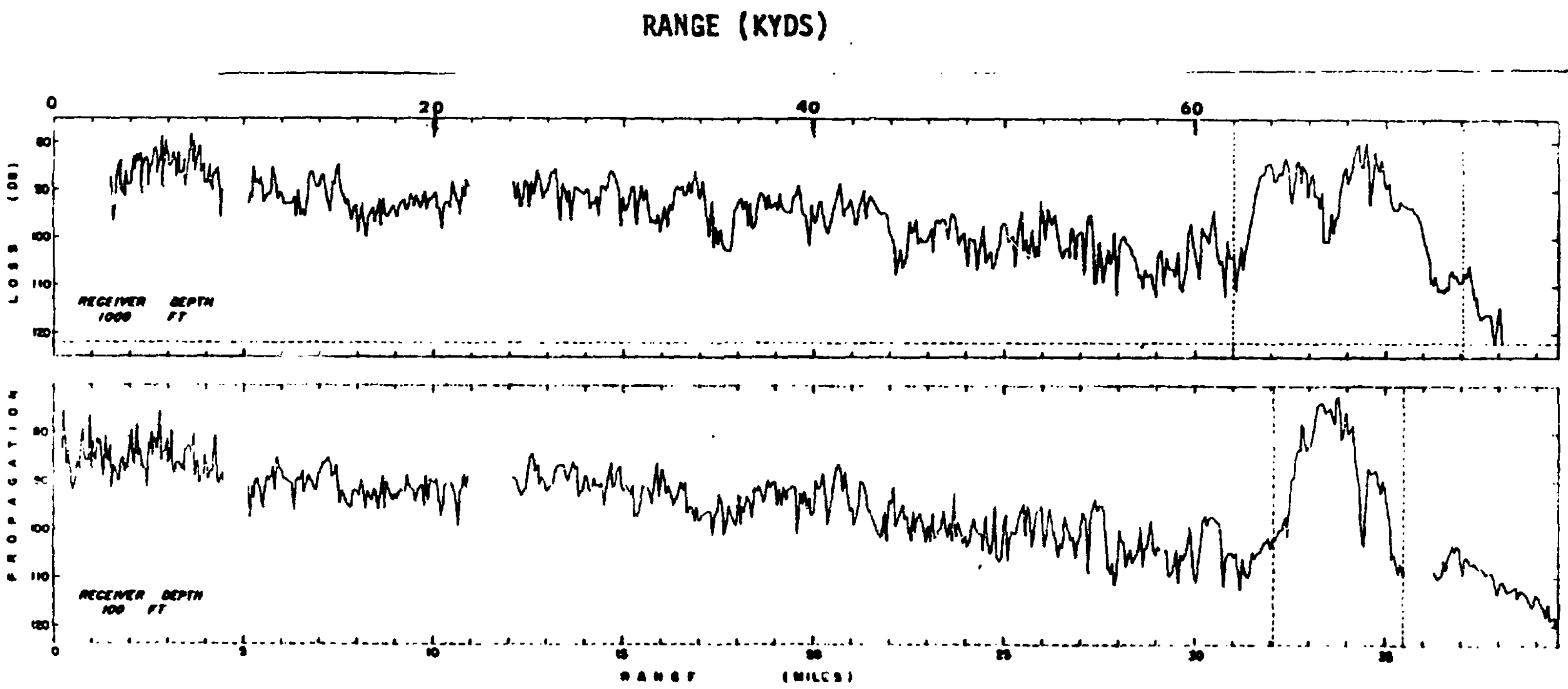

Figure 6 Propagation loss of once-bottom-reflected and first-zone signals (530 cps).

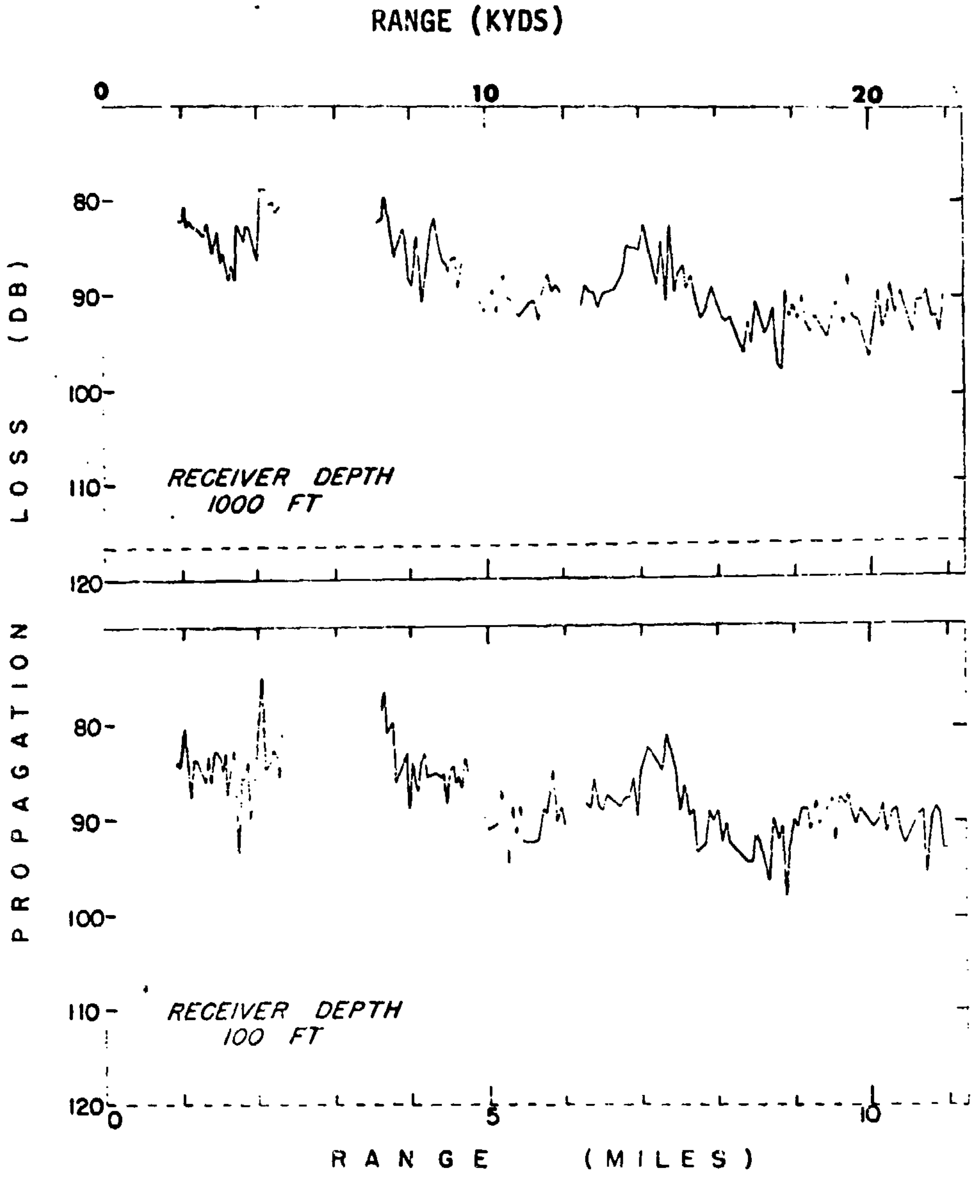

Figure 7. Propagation loss of once-bottom-reflected signals (1030 cps).

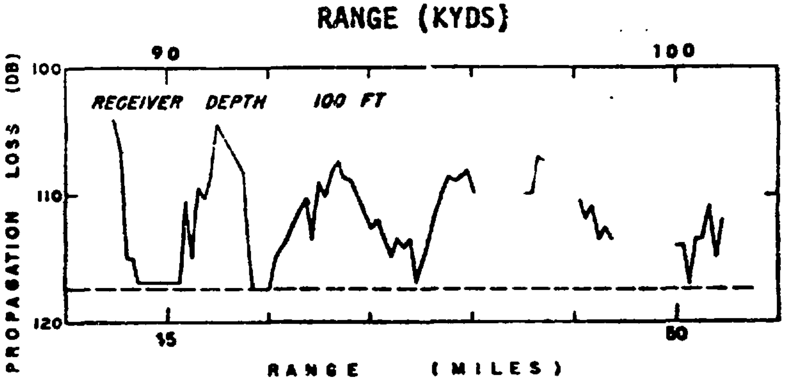

Figure 8. Propagation loss for a portion of the first zone (1030 cps).

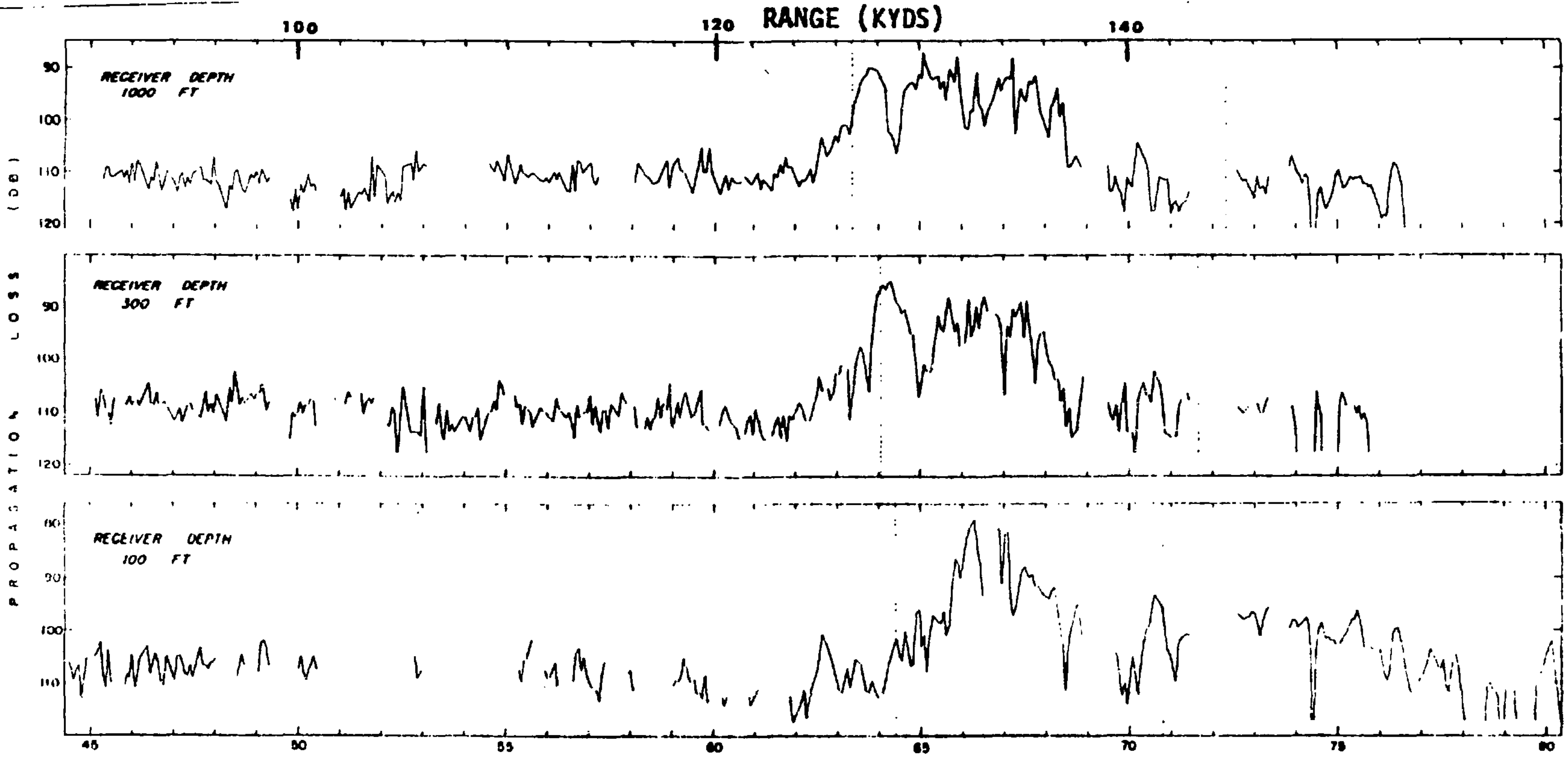

Figure 9 Propagation loss of twice-bottom-reflected and second-zone signals (1030 cps).

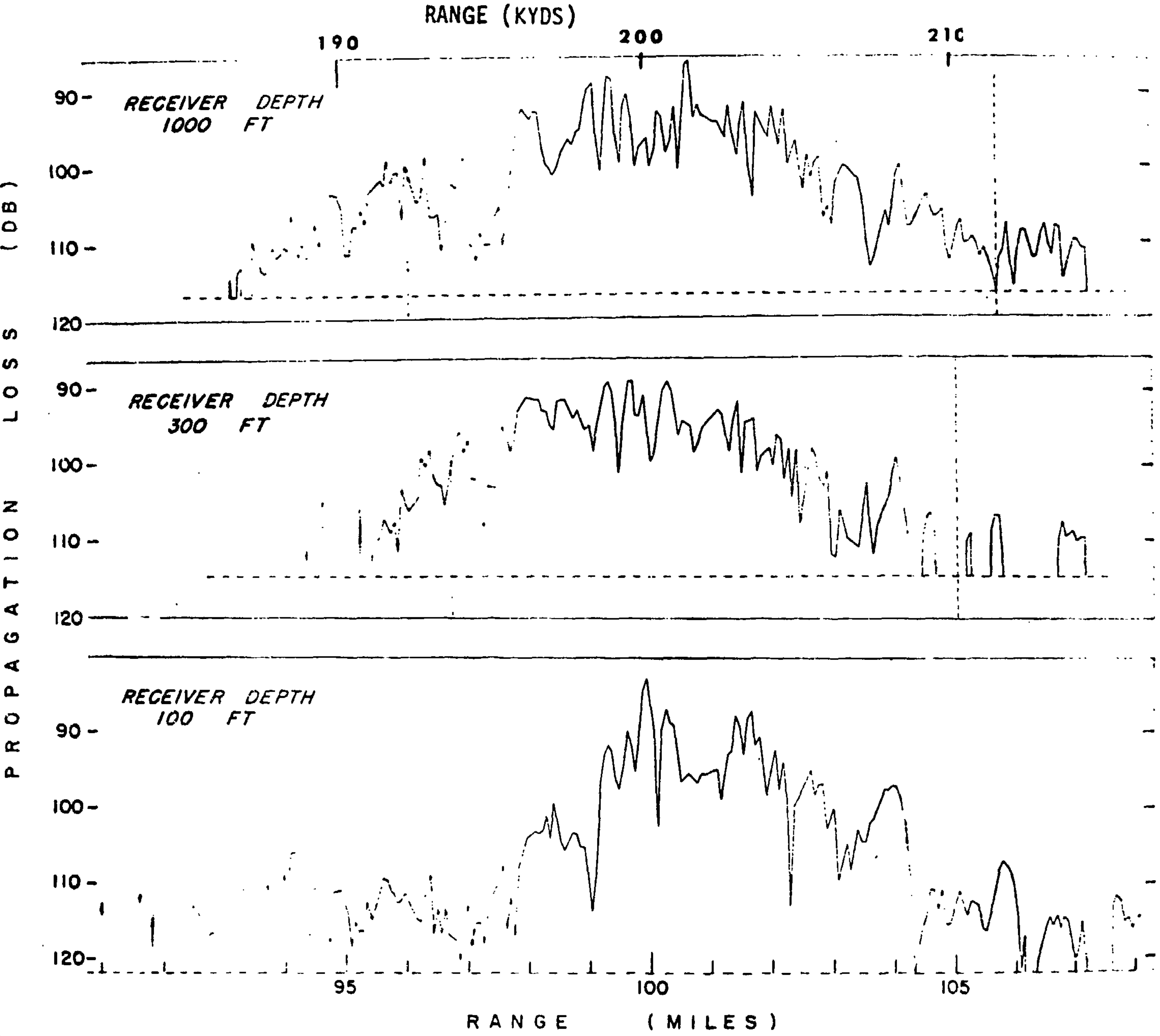

Figure 10A. Propagation loss at Zone 3 (530 cps).

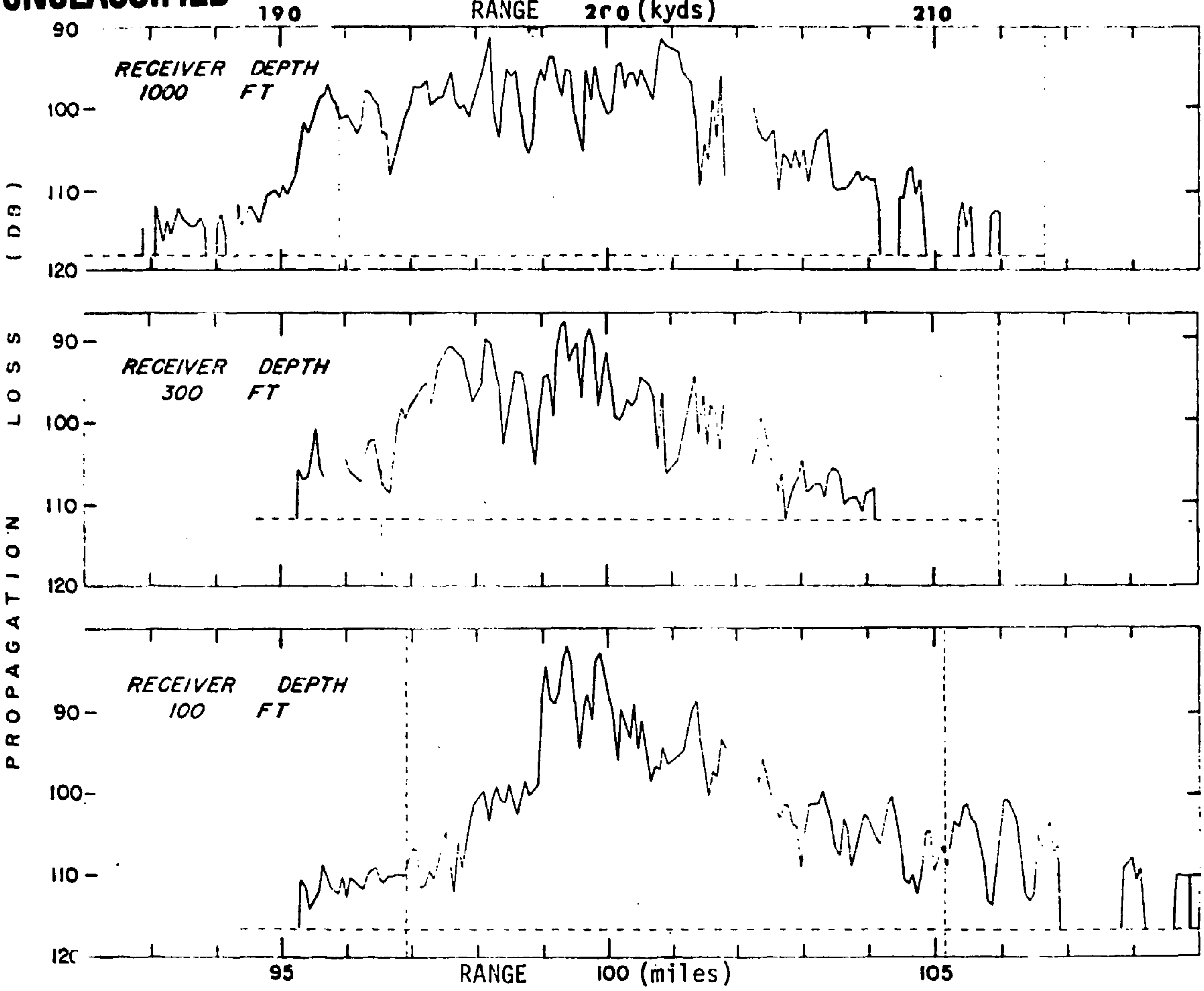

Figure 10B. Propagation loss at Zone 3 (1030 cps).

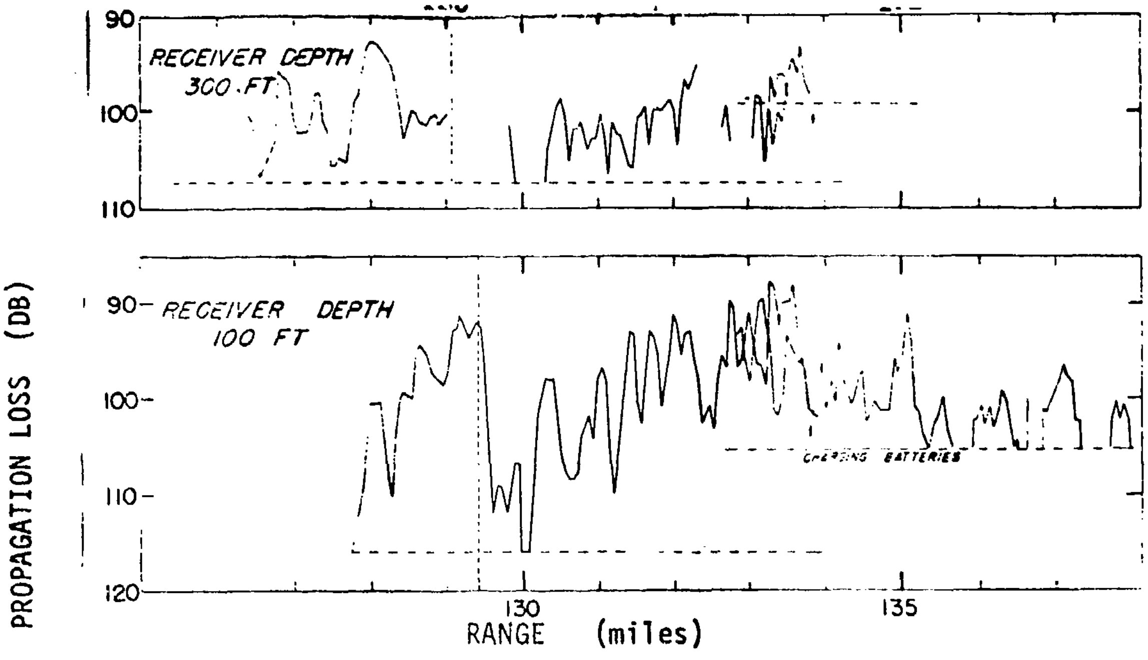

Figure 11B. Propagation loss at Zone 4 (1030 cps).

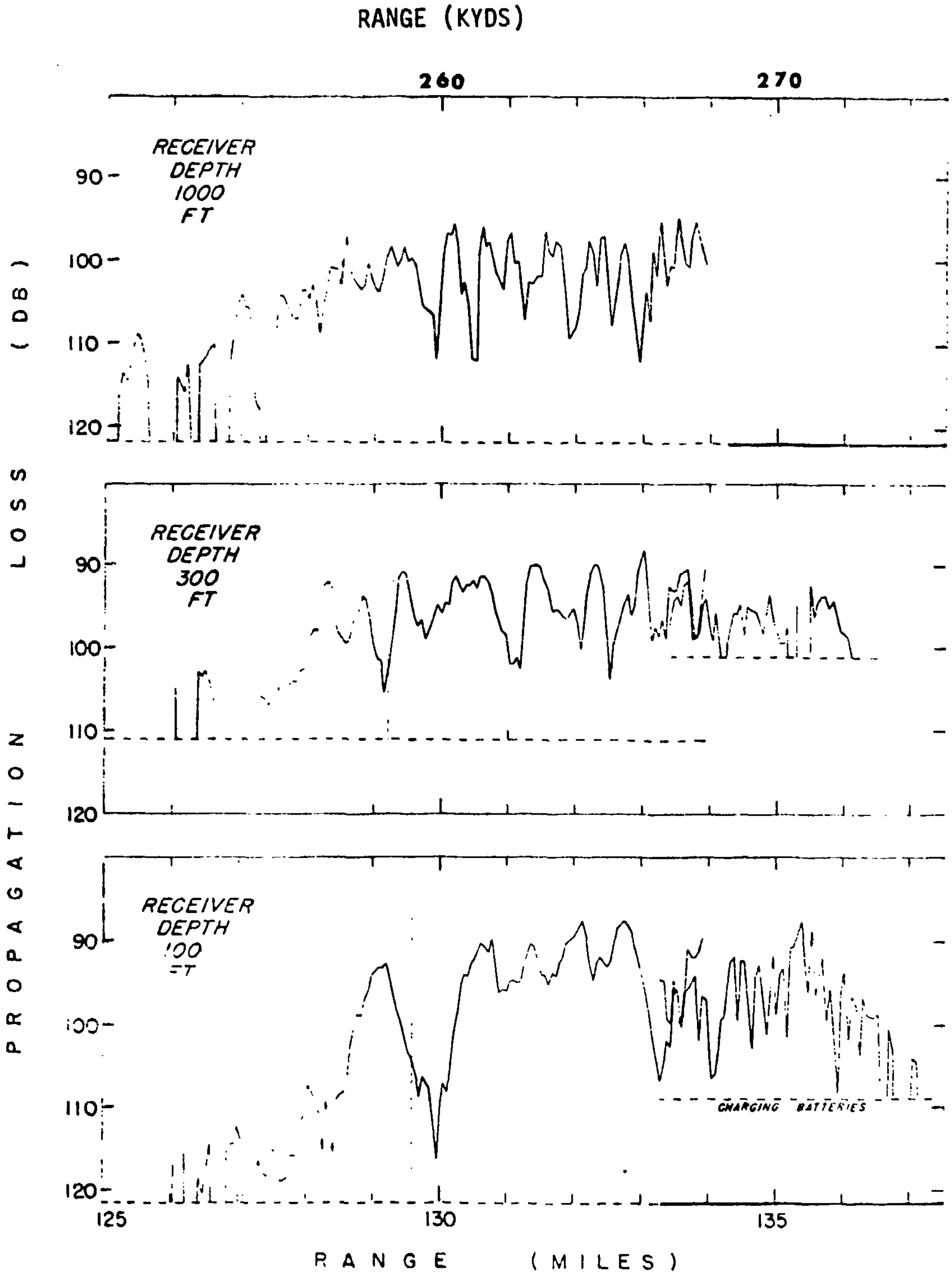

Figure 11A. Propagation loss at Zone 4 (530 cps).

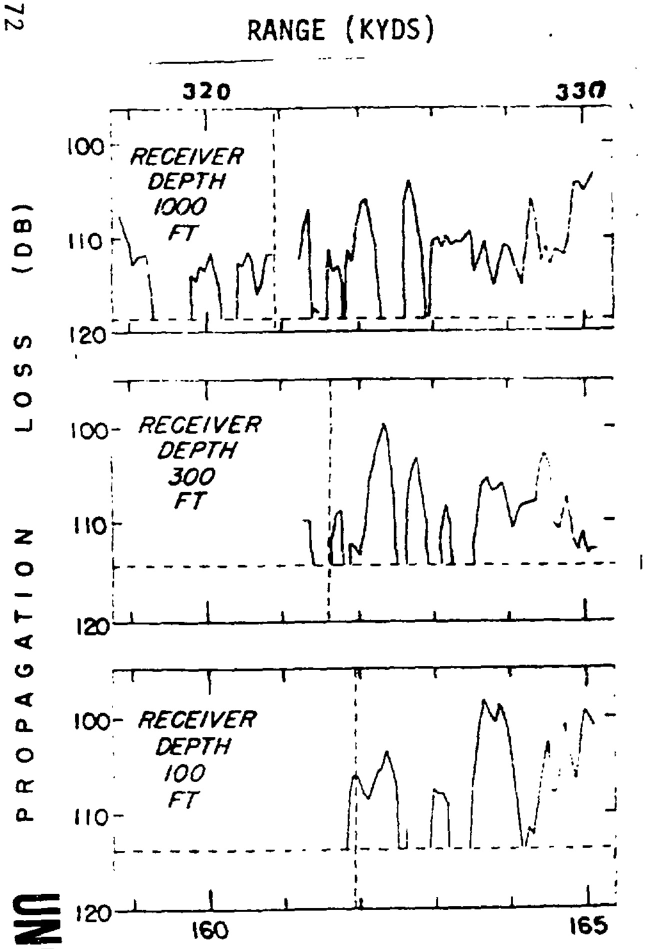

Figure 12B. Propagation loss at Zone 5 (1030 cps).

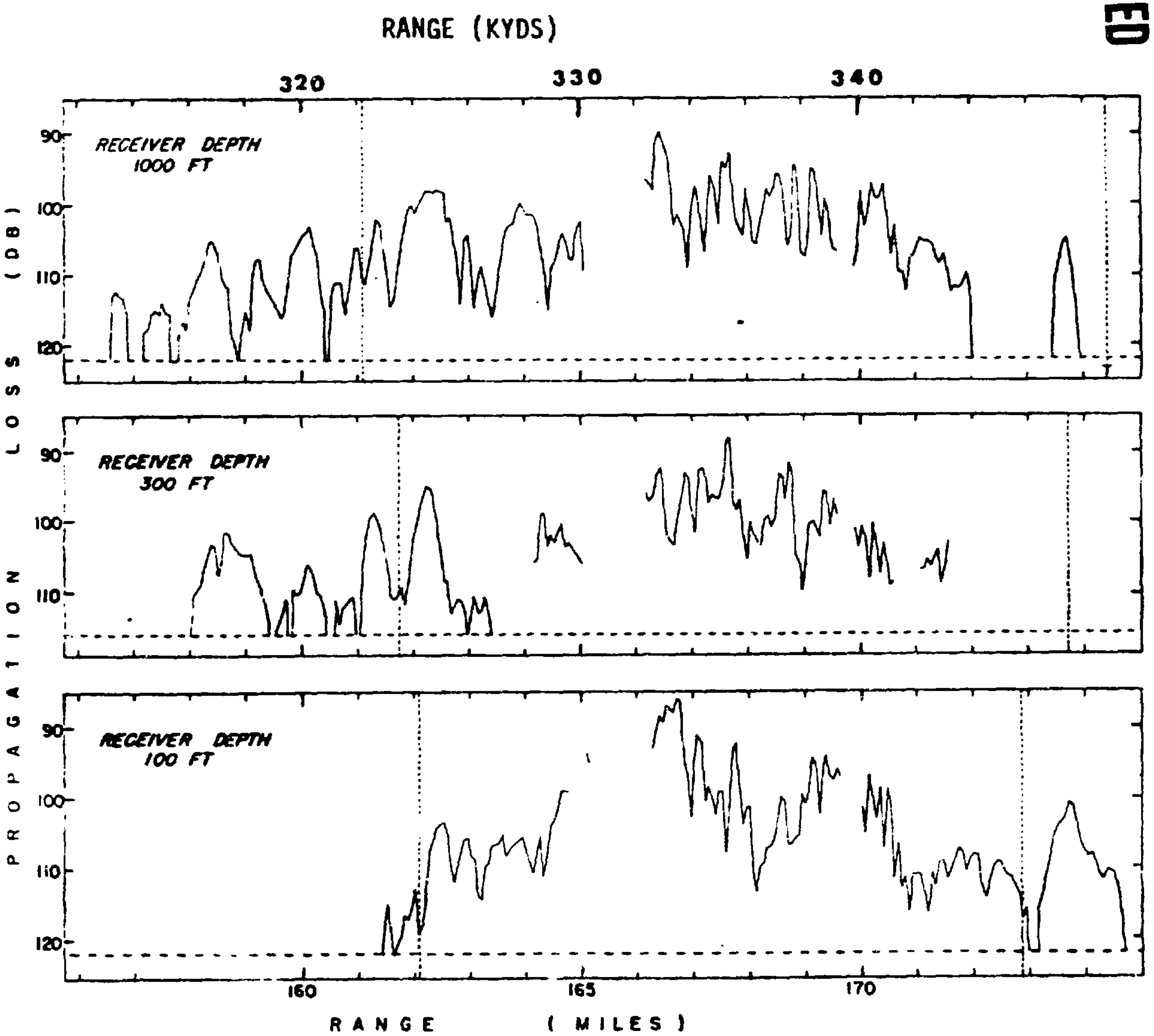

Figure 12A. Propagation loss at Zone 5 (530 cps).

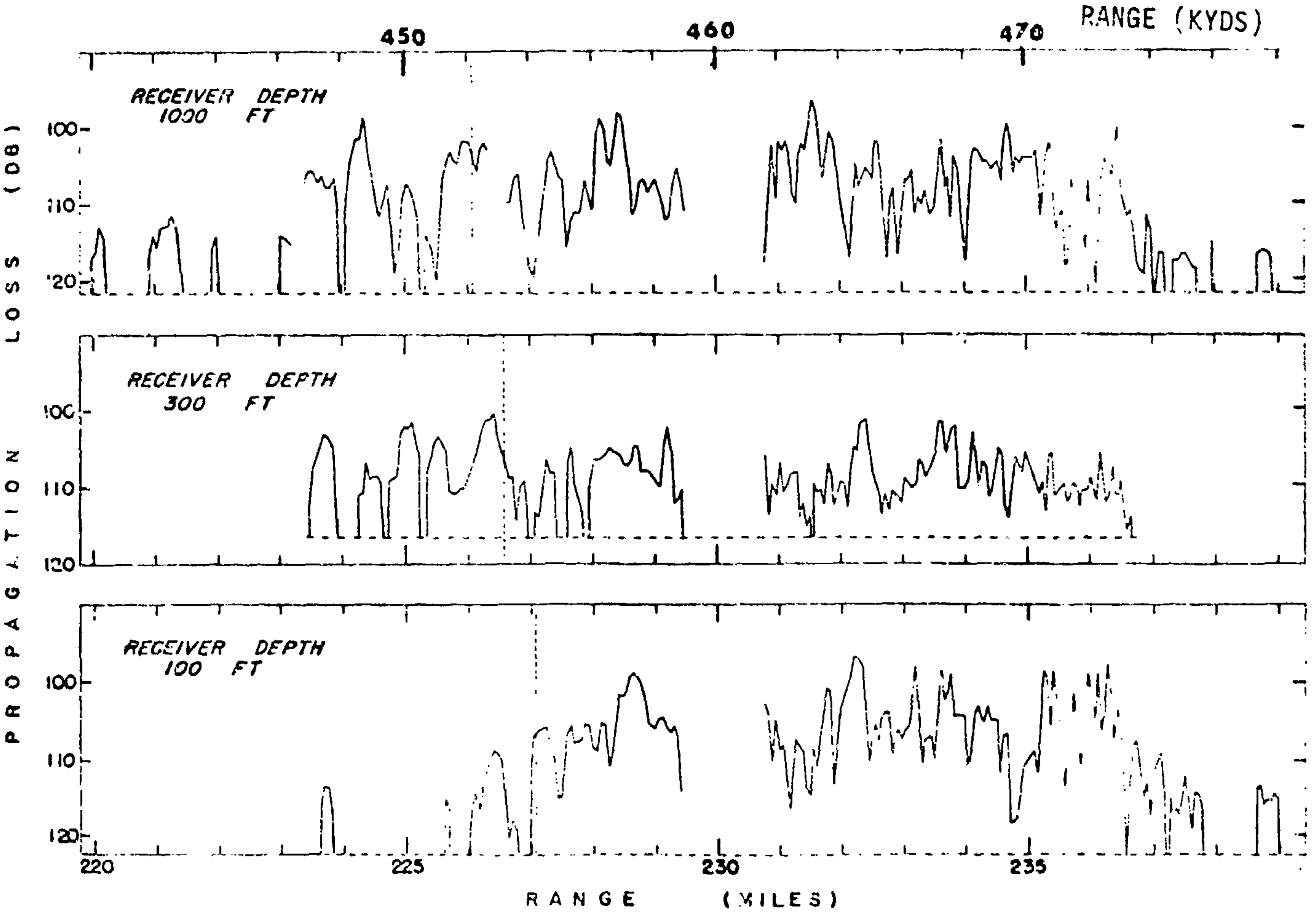

Figure 14A. Propagation loss at Zone 7 (530 cps).

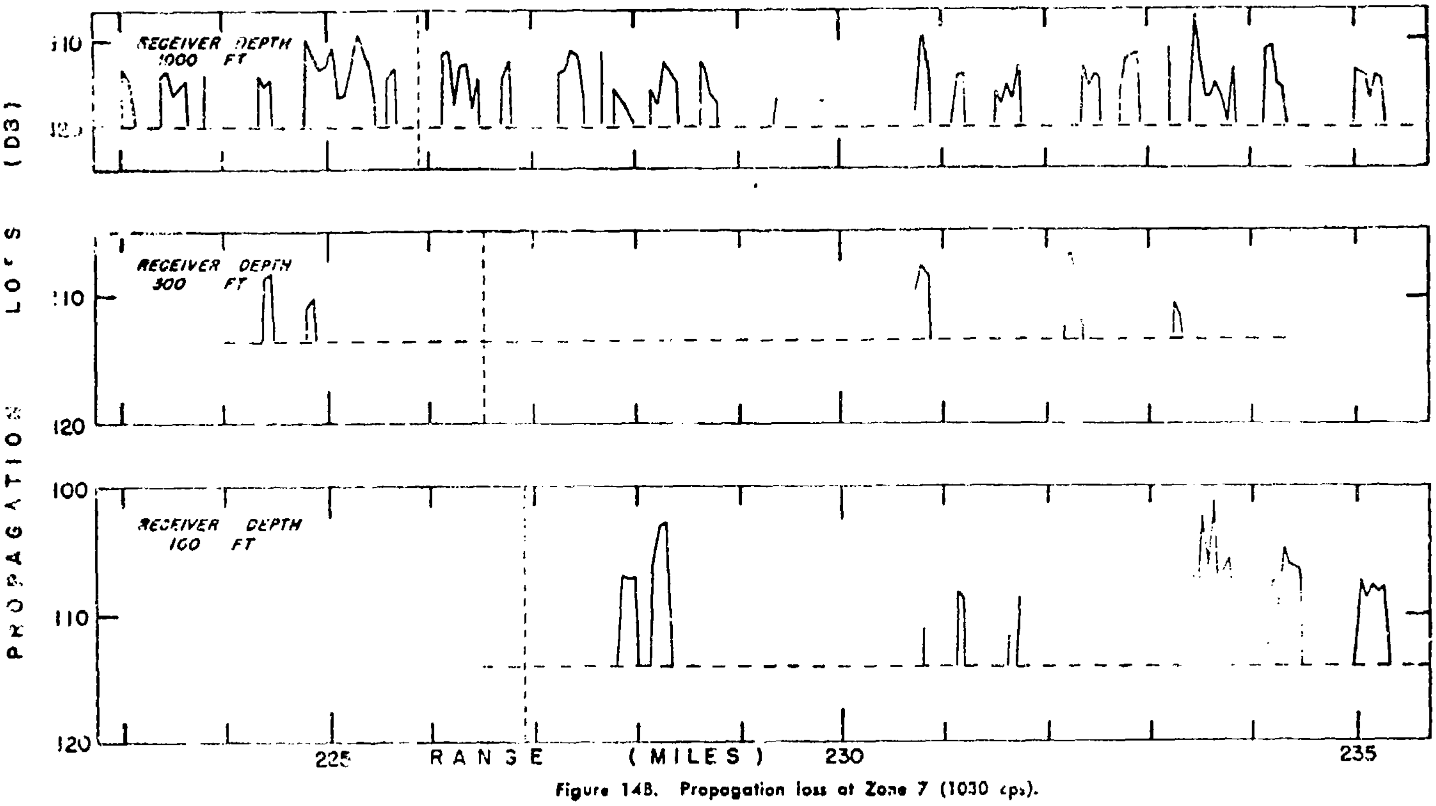

Figure 14B. Propagation loss at Zone 7 (1030 cps).

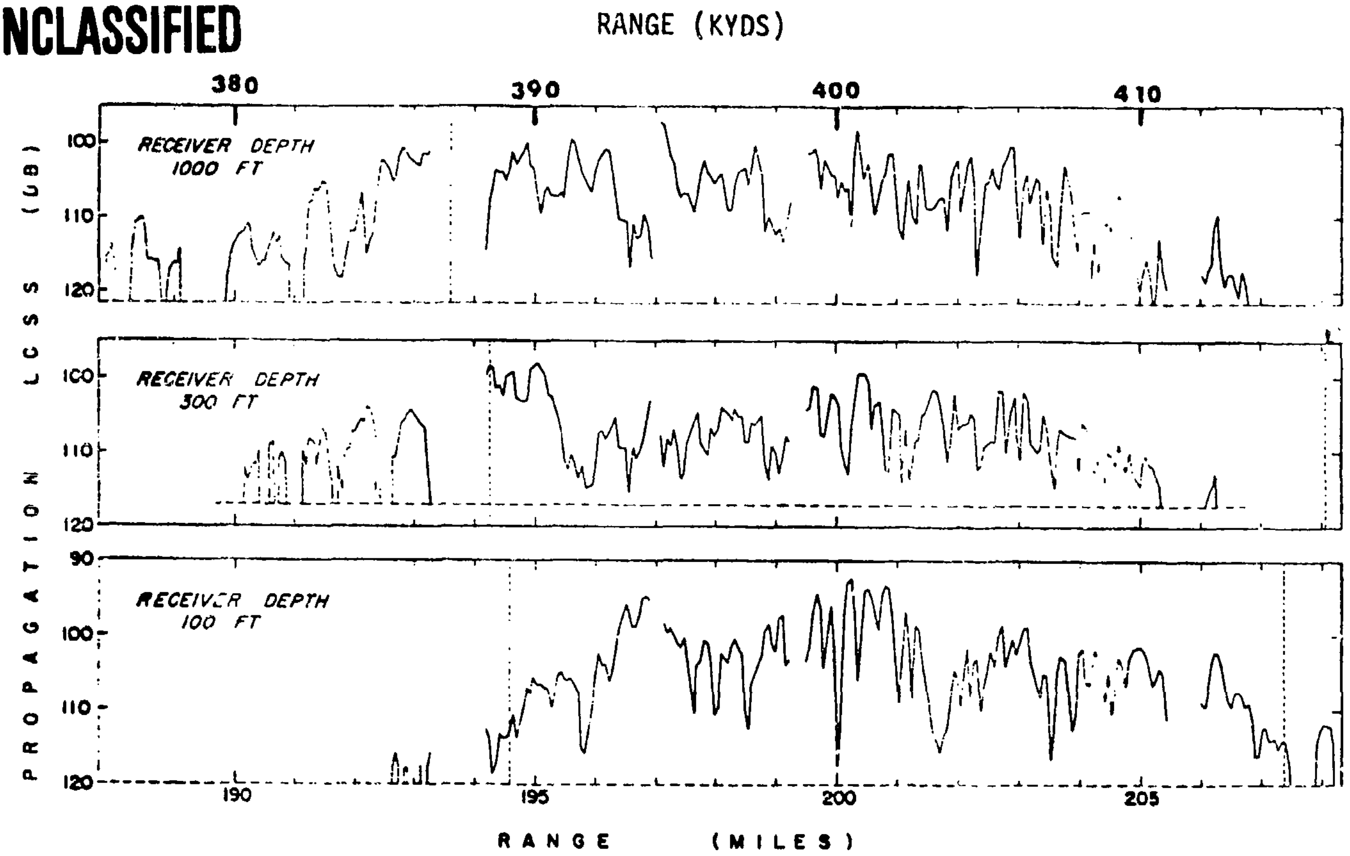

Figure 13A. Propagation loss at Zone 6 (530 cps).

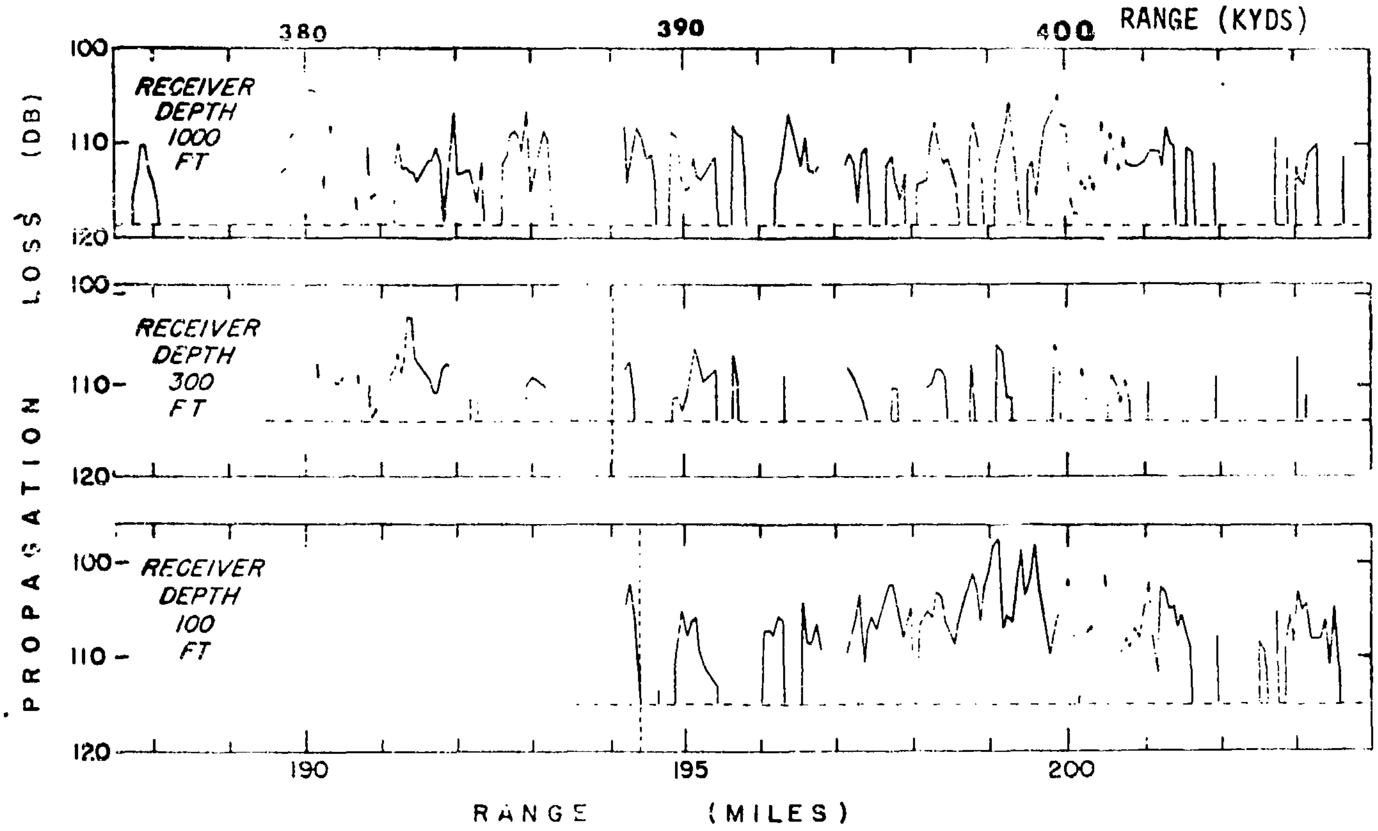

Figure 13B. Propagation loss at Zone 6 (1030 cps).

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2. U.S. Navy Electronics Laboratory Rept 559, "Results of a Long-Range 530-cps – Underwater Sound Transmission Experiment," by M. A. Pedersen, et al, 17 Jan 1955.

3. U.S. Navy Electronics Laboratory Rept 763, "Oceanographic and Geological Factors Influencing Low-Frequency Acoustic Transmission off Northeast OAHU, Hawaii," by E. R. Anderson, E. L. Hamilton and R. M. Lesser, 5 Mar 1957.

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5. W. Wilson, "Equation for the Speed of Sound in Sea Water," J. Acoust. Soc. Am., Vol 32, p. 1357L (1960).

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7. S. Kuwahara, "Velocity of Sound in Sea Water and Calculation of the Velocity for use in Sonic Sounding," Hydrographic Review, Vol 16, 123 (1939).

8. U.S. Navy Laboratory Report 1105, "A New Ray Intensity Procedure for Underwater Sound Based on a Profile Consisting of Curvilinear Segments," by M. A. Pedersen, D. F. Gordon, and A. J. Keith, Mar 1962.

9. V. A. Del Grosso, "New Equation for the Speed of Sound in Natural Waters (with Comparisons to other Equations)," J. Acoust. Soc. Am., Vol 56, p. 1084 (Oct 1974).

APPENDIX: Bottom Reflection Loss

An analysis of bottom loss was made in reference 4 for these data. An average bottom loss was obtained by subtracting the appropriate theoretical spreading and absorption loss from the average experiment propagation loss for each kyd range interval. The results are summarized in Table A-1.

Table A-1 Bottom Reflection Loss

RANGE OF GRAZING ANGLES (DEGREES)	AVERAGE BOTTOM REFLECTION LOSS (dB/refl)	
	530 Hz	1030 Hz
2 - 10	5.9 to 7.3 ± 1.0	4. to7.5 ± 1.0
10 - 24	6.4 ± 2.1	NO DATA
10 - 24(twice reflected)	7.0 ± 0.6	
27 - 60	10.1 ± 2.2	8.8 ± 2.5
60 - 85	6.7 ± 2.1	6.4 ± 1.8

For sediment conditions of Table 4; $C_2/C_1 = 1.05$, $\rho_2/\rho_1 = 1.425$, and $k = .864$ dB/m/kHz, values of bottom reflection loss as calculated from formulas given by L. M. Brekhovskikh, "Waves in Layed Media," page 20, are given in Table A-2.

TABLE A-2. Theoretical Bottom Reflection Loss

GRAZING ANGLE (degrees)	Bottom Reflection Loss (dB/refl)	
	α = .016	α = 0.10
5	1.0	2.5
10	1.9	4.7
15	3.1	6.7
20	6.3	8.4
25	9.3	9.8
30	10.9	10.9
40	12.5	12.4
50	13.3	13.2
60	13.7	13.6
80	14.0	14.0

The value of k = 0.864 dB/m/kHz is obtained from α_s= 7.9 dB/ft @ 30 kHz (reference 3) where $\alpha_s = kf^n$ dB/m/kHz, f is the frequency in kHz and n is takened to be 1. The coefficient α used in the calulations becomes $\alpha = (\alpha_s/8.7)(\lambda/2\pi)$ = 0.016. The value of $\alpha = 0.10$ is a probable maximum for this sediment. The assumption that n=1 makes α, and hence the bottom reflection loss, independent of frequency and the reflection loss at 530 Hz would be equal to that at 1030 Hz.

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Appendix 6. (U) PARKA II (Pacific Acoustic Research Kaneohe-Alaska)

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APPENDIX 6 (U)

PARKA IIA SUMMARY (U)

Summarized by Robert L. Martin

PURPOSE:

(U) To summarize the PARKA IIA data set for use by the Model Evaluator.

GENERAL:

(C) PARKA IIA was conducted North of Oahu, Hawaii in November 1969, references 1 and 2. The Exercise parameters are summarized in Table 1. The receiving site (R/V FLIP) was located at 27°33'N, 157°40'W with hydrophones at nominal depths of 300 ft., 2500 ft. and 10,800 ft. The frequency range of interest was 25 to 400 Hz. Only radial shot events were conducted. The source ship deployed 3 lb. TNT shots alternately at 60 and 500 ft. approximately every mile along three different radial tracks to ranges of 500 n mi (see Figure 1). Aircraft deployed 1.8 lb. SUS MK61 at either 60 ft. or at 800 ft. (depending on the run direction to or away) along three different radial tracks to ranges of 2000 n mi.; these aircraft events will not be summarized. No CW events (while planned) were conducted due to heavy storms and equipment damage.

(C) All data were processed in 1/3 octave bands centered at 25, 50, 100, 180 and 400 Hz. The SUS source levels originally used for the center frequency of each band are listed in Table 3 and discussed in that section. These reference source levels were changed and a new data tape was generated; these new source levels are also identified in Table 3; the NUSC data tape identified in Table 1 used these source levels as reference. The curves used in this summary had the original source levels for reference. However, since PARKA, the measurement community has generally accepted levels derived from GASPIN and Shuler, see table 3, and the NUSC PARKA tapes should be corrected to these source levels for use in model evaluation.

Classified by multiple sources
Review on 1 Oct 1994

Encl (3) to NORDA ltr
115:RLM:vfc Ser 115/015

(C) TABLE 1

PARKA IIA PARAMETERS (C)

Comment: PARKA Events 9-2 and 9-3 are the only ones with nearly range independent environments over the entire tracks. These events resulted in nearly identical propagation loss levels vs. range and therefore only Event 9-2 is recommended for evaluation

Event #	9-2
Source type	3 lb. TNT blocks
Detonation depth control	Fuze cut to length
Source depths (ft)	60 and 500
Receiver depths (ft)	300/2500/10,800
Analysis frequency (Hz)	25/50/100/180/400
Analysis bandwidth/type	1/3 octave/total energy
Min range (n mi)	~2
Max range (n mi)	~500
Surface sound speed (ft/sec)	5022.16
Layer depth (ft)/sound speed (ft/sec)	262.5/5026.49
Sound axis depth (ft)/sound speed (ft/sec)	3280.8/4857.19
Bottom depth (ft)	18,600
Navigation	Radio tone ~0.1 nmi accuracy

Data location - NUSC digital tape stored with others at Federal Records Center, Waltham, MA. Rec. Group #181, Accession #75-A-342 FRC Box #425582 or 425583. Reel with label P2RR3 (Box 5 of Aug 74 shipment to Waltham), NUSC point-of-contact - Stan Jackson.

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(U) Environmental data (SVP, XBTs, Bathymetry) were obtained along each track. Bottom properties (cores) and normal incidence, 3.5 kHz, echo sounding data were obtained which shows the sediment depth.

(U) Bottom loss, 100-800 Hz and 15° - 85°, was measured at the receiving site.

(U) Navigation (ranging) was accomplished with radio tone cut-off at shot detonation and an assumed group velocity. Satellite positioning fixes agreed with these ranges to within 0.1 n mi.

(C) The total exercise is summarized in Table 2 below:

TABLE 2 (C)

PARKA Acoustic Parameters

Events	Hyd. depth (ft)	Source depths (ft)	Frequencies (Hz)	Ranges
9-1	300,2500,10,800	60,500 ft.	25,50,100,180,400	320 n mi
9-2/3	"	"	"	500 n mi
9-4/5	"	"	"	450 n mi

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(U) Only the northern track (Event 9-2) is recommended for processing because it's essentially identical to Event 9-3 and both the southwest and south tracks result very quickly in range dependent bathymetry and also because the short range (less than 100 n mi) character of the propagation loss is the same for all tracks (see Figures 2 and 3).

ENVIRONMENTAL DATA (U)

(U) Bottom structure near FLIP was obtained using a 3.5 kHz echo sounder. It shows a 48 to 72 ft. sediment layer overlying a thin layer of chert. In the general area sediment layers 170 to 320 ft. thick overlie a strongly reflecting sub-bottom of high sound velocity (~15000 ft/sec). 30 ft. cores taken show the upper sediment to be red clay with an estimated sound speed of 4900 ft/sec.

(U) Bottom loss was also measured at the PARKA site from 15 to 85° grazing at 100, 180, 400 and 800 Hz. This information is in Figure 4.

(U) The oceanographic data collected during PARKA II-A was obtained by two dedicated vessels (MARYSVILLE and REXBURG) and by the receiving ships (SANDS) and the source ship (CONRAD) (Figures 5-8 . The receiving ship collected XBT's (750m) and SVP's periodically throughout the exercise at one site. The source ship collected bathymetry and XBT's along the full length of each track; at the end points of each track it took STD's. One of the dedicated vessels, MARYSVILLE, took XBT's and SVP's on a track between the source ship and FLIP; because it had to stop to take the SVP's it could only travel approximately half each track. The other dedicated vessel, REXBURG, towed a thermistor chain (surface to 220m) to half the range on the northern track and the full track for the southwest and south events. This provided continuous temperature contouring along each track.

ACOUSTIC EVENT 9-2 (U)

(U) The attached Figures 9-18 display all the event 9-2 data processed (3 hyd. depths, 2 source depths and 5 frequencies) for this event. Some of the short range shots were overloaded but in the early analyses this appeared to have no significant impact on the propagation results. In the PARKA II-A report the overloaded data were identified with little circles as noted on the 9-3 event at 100 Hz, attached as Figure 19. In an analysis of propagation loss using peak levels and energy (NUSC Document 6001, reference 3) it is noted that overloaded shots (close range) had significantly higher peak propagation loss associated with them relative to the energy values than when the shots were not overloaded. This indicates that only the peak loss is affected significantly on overload.

(U) The receiver depths as measured acoustically during the exercise were different than the nominal; same for the 300 ft. hydrophone, as deep as 2700 ft. for the axis unit and as shallow as 10,300 ft. for the deep hydrophone.

(C) Finally, the source levels used for the attached propagation loss curves were too high by about 9 dB at 25 Hz and 5 dB at 50 Hz for the 60 ft. sources. The recommended source levels as derived from Gaspin and Shuler are compared with the ones used for these curves in Table 3 below. If the NUSC tapes are used then the reference source level is given in the middle column.

TABLE 3 (U)

(C) Source Levels for 3#TNT Charges (dB//1 erg/CM^2-sec/Hz)

	60 ft.				500 ft.			
Freq. (Hz)	Orig. Level	NUSC Tape Level+	G&S* Level	Diff	Orig. Level	NUSC Tape Level	G&S Level	Diff
25	68	54	59	9	63	60	59	4
50	60	52	55	5	60	57	57	3
100	55	50	53	2	56	54	54	2
180	52	49	52	0	53	51	53	0
400	49	46	49	0	50	48	50	0

+ to get source level in NUSC LOG, add 10 log ρc + 10 log BW = 52 dB + 10 log BW

*G&S - derived from Gaspin & Shuler

SOUND SPEED PROFILE AND BOTTOM DEPTH FOR EVALUATION (U)

(U) The recommended profile is attached as Figure 20. Analysis by AESD, reference 4, found little difference between using 3 profiles or 18 profiles over the 500 n mi range of event 9-2. In a separate discussion with John Hanna, he stated that a single profile would be adequate for the first 100 n mi. The profile he used is essentially the same as the one recommended and is tabulated in Table 4 and compared on Figure 20 with that used by the Panel on Sonar System Modeling (POSSM), reference 5.

(U) The bottom depth for the range independent model is 18,600 ft. Detailed bathymetry north from the PARKA site is given in Table 5.

TABLE 4 (U)

1st PARKA PROFILE (U)

z (m) (ft)	c (m/s) (ft/s)	z	c	z	c	z	c
0.00	1532.10 5026.8	67.05 220	1532.30 5028.1	88.39 290	1525.80 5006.1	118.87 390	1521.60 4992.4
158.49 520	1518.20 4981.2	237.73 780	1509.90 4954	356.60 1170	1499.70 4920.5	390.12 1280	1495.60 4910.3
456.32 1530	1491.10 4892.3	502.90 1650	1488.70 4884.4	612.62 2010	1483.50 4867.4	643.10 2110	1482.50 4864.1
725.39 2380	1481.10 4859.5	853.40 2800	1481.20 4859.8	899.12 2950	1481.50 4860.8	999.70 3280	1482.10 4862.8
1200.85 3940	1483.00 4865.7	1398.96 4590	1484.90 4872	1600.12 5250	1486.70 4877.9	1795.23 5890	1488.70 4884.4
1999.39 6560	1491.10 4892.3	2499.24 8200	1498.10 4915.3	2999.09 9840	1505.90 4927.7	3453.22 11330	1513.70 4966.4
6000.00 19686	1896.80 5238.4						

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TABLE 5 (U)
Uncorrected Fathoms

Correction is ~100 fm at 3000 fm

```
ETMY IS IN FATHOMS FOR  CHARTINO2
THE   501 PAIRS OF PROFILE POINTS (RANGE,DEPTH) OUT TO  500 NAUTICAL MILES.
   0.       2951.       1.      2962.       2.      2957.       3.      2941.
   4.       2918.       5.      2992.       6.      2870.       7.      2893.
   8.       2955.       9.      2974.      10.      2911.      11.      2955.
  12.       2958.      13.      3025.      14.      3037.      15.      3032.
  16.       3019.      17.      3006.      18.      3001.      19.      3004.
  20.       3009.      21.      3010.      22.      3011.      23.      2977.
  24.       2950.      25.      2922.      26.      2901.      27.      2899.
  28.       2902.      29.      2917.      30.      2933.      31.      2951.
  32.       2966.      33.      2973.      34.      2960.      35.      2987.
  36.       2994.      37.      3001.      38.      3004.      39.      3004.
  40.       2997.      41.      2983.      42.      2995.      43.      2953.
  44.       2939.      45.      2929.      46.      2924.      47.      2924.
  48.       2932.      49.      2946.      50.      2977.      51.      2985.
  52.       3002.      53.      3012.      54.      3014.      55.      3011.
  56.       3005.      57.      2999.      58.      2945.      59.      2995.
  60.       2996.      61.      2994.      62.      3001.      63.      3004.
  64.       3008.      65.      3004.      66.      3005.      67.      2995.
  68.       2992.      69.      3000.      70.      3024.      71.      3071.
  72.       3132.      73.      3196.      74.      3248.      75.      3275.
  76.       3271.      77.      3244.      78.      3203.      79.      3157.
  80.       3114.      81.      3076.      82.      3044.      83.      3019.
  84.       3001.      85.      2969.      86.      2977.      87.      2962.
  88.       2937.      89.      2902.      90.      2866.      91.      2840.
  92.       2835.      93.      2860.      94.      2903.      95.      2955.
  96.       2994.      97.      2894.      98.      2953.      99.      2892.
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 116.       3144.     117.      3150.     118.      3101.     119.      3172.
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 124.       3044.     125.      3025.     126.      2958.     127.      2925.
 128.       2908.     129.      2918.     130.      2946.     131.      2980.
 132.       3009.     133.      3025.     134.      3030.     135.      3027.
 136.       3020.     137.      3014.     138.      3010.     139.      3007.
 140.       3005.     141.      3007.     142.      3010.     143.      3014.
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 152.       3037.     153.      3042.     154.      3044.     155.      3041.
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 184.       3000.     185.      3000.     186.      3001.     187.      3003.
 188.       3005.     189.      3007.     190.      3009.     191.      3011.
 192.       3011.     193.      3011.     194.      3009.     195.      3007.
 196.       3005.     197.      3003.     198.      3001.     199.      3000.
 200.       3009.     201.      3000.     202.      3000.     203.      3001.
 204.       3003.     205.      3004.     206.      3004.     207.      3005.
 208.       3004.     209.      3004.     210.      3003.     211.      3003.
 212.       3092.     213.      3001.     214.      3001.     215.      3000.
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 224.       3008.     225.      3006.     226.      3003.     227.      3001.
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 236.       3171.     237.      3186.     238.      3144.     239.      3196.
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 272.       3194.     273.      3184.     274.      3162.     275.      3132.
 276.       3090.     277.      3065.     278.      3039.     279.      3022.
 280.       3013.     281.      3015.     282.      3026.     283.      3046.
 284.       3073.     285.      3102.     286.      3131.     287.      3157.
 288.       3177.     289.      3193.     290.      3203.     291.      3208.
 292.       3206.     293.      3197.     294.      3179.     295.      3153.
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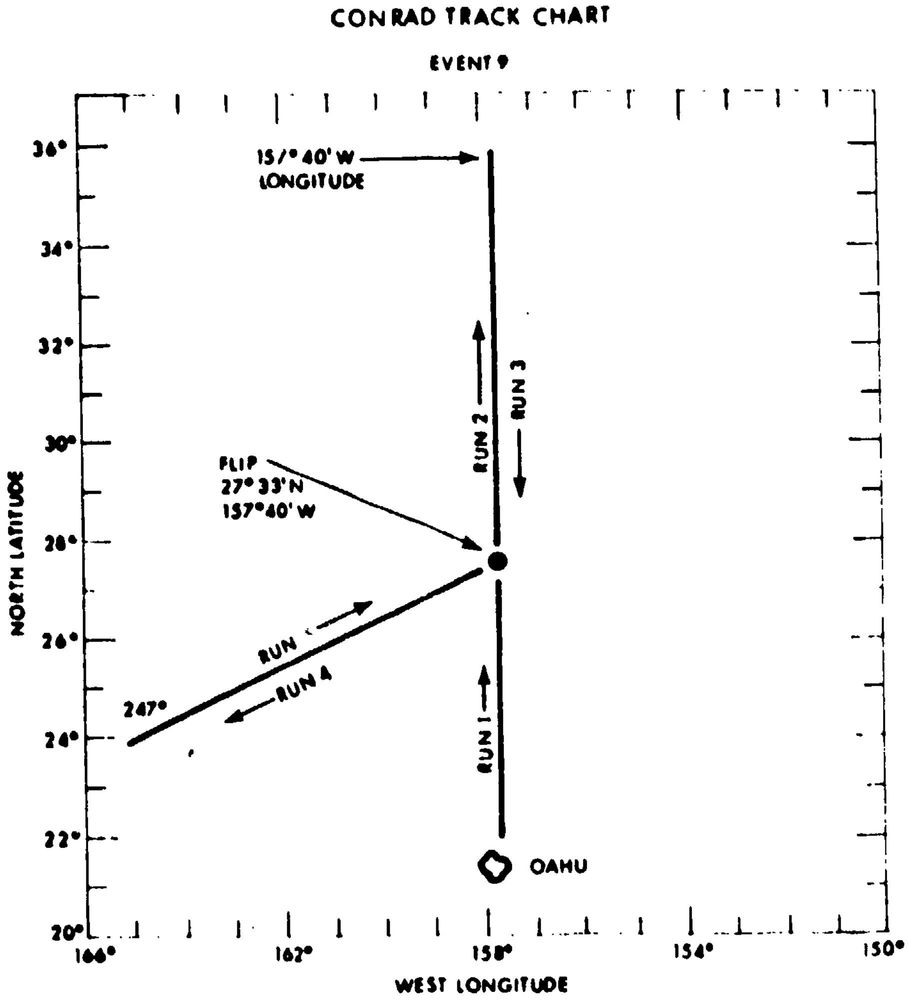
2

(U) REFERENCES:

1. PARKA II-A: The Acoustic Measurements(U): Maury Center for Ocean Science, MC Report 006, Vol 1. UNCLASSIFIED
2. PARKA II-A: The Oceanographic Measurements(U): Maury Center for Ocean Science MC Report 006 Vol 2. Feb 1972. CONFIDENTIAL.
3. PARKA II-A: Acoustic Data Summary(U), NUSC Document 6001. December 1969. UNCLASSIFIED
4. Personal communication R. Martin, NORDA, with Dr. J. H na, SAI (formerly AESD). UNCLASSIFIED
5. A Methodology for the Comparison of Models for Sonar System Application: Volume 1(U). NAVSEA Report SEA06H1/036-EVA/MOST-10. 9 December 1976. UNCLASSIFIED

PARKA II-A EXPERIMENT PLAN



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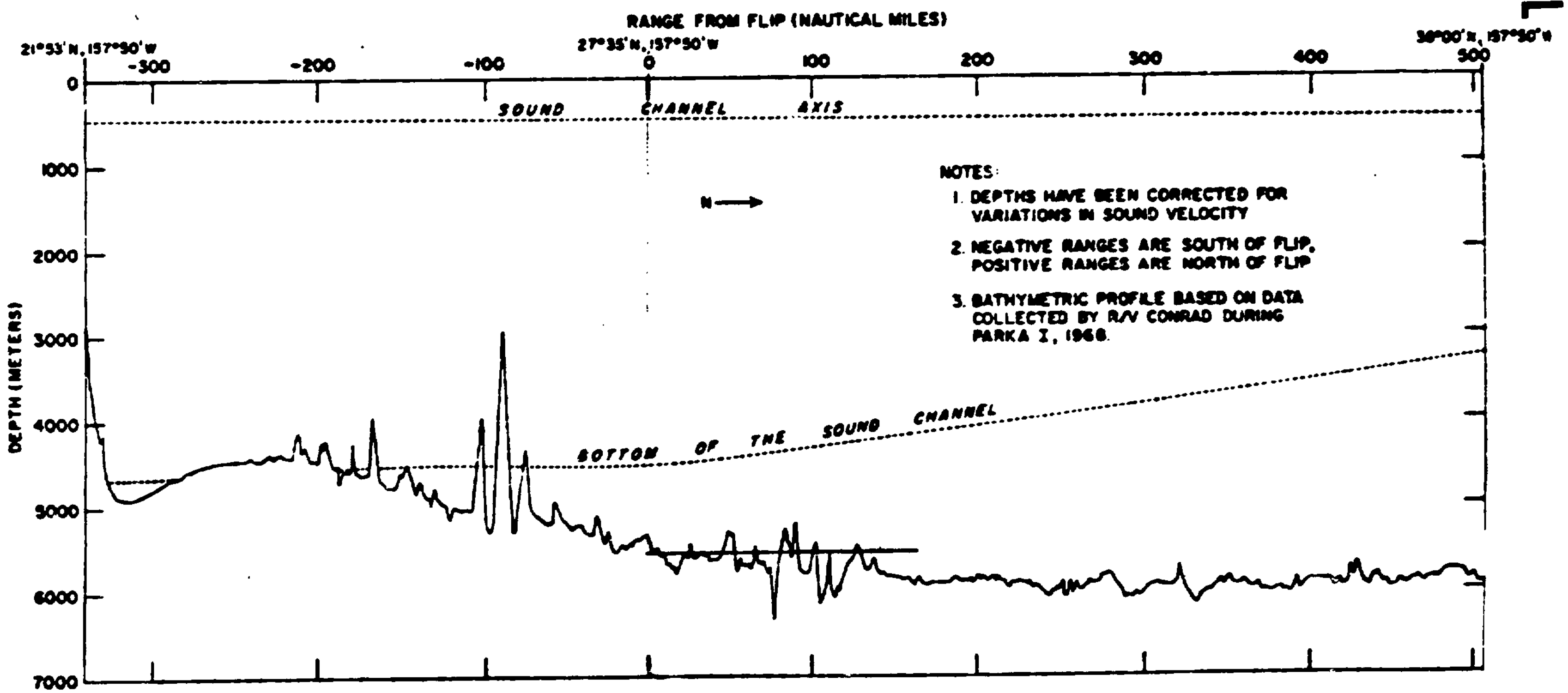
NOTES:

RUN 1: 330 MILES LONG

RUN 2 - 5: 500 MILES LONG

– Tracks covered by source ship (C) MC Report 006, Vol

FIGURE 1 (U)



(U) — Bathymetric Profile, PARKA North-South Track MC Report 006, Vol 2

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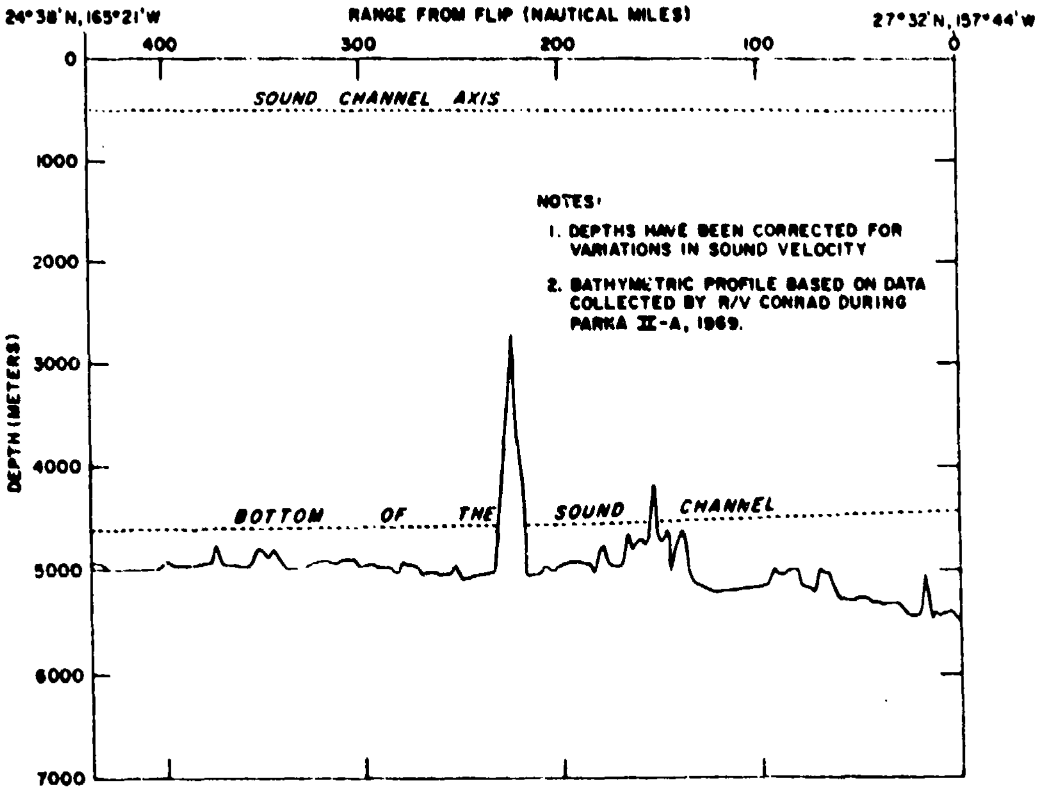
FIGURE 2 (U)

SOUND VELOCITY STRUCTURE



NOTES:

1. DEPTHS HAVE BEEN CORRECTED FOR VARIATIONS IN SOUND VELOCITY
2. BATHYMETRIC PROFILE BASED ON DATA COLLECTED BY R/V CONRAD DURING PARKA II-A, 1969.

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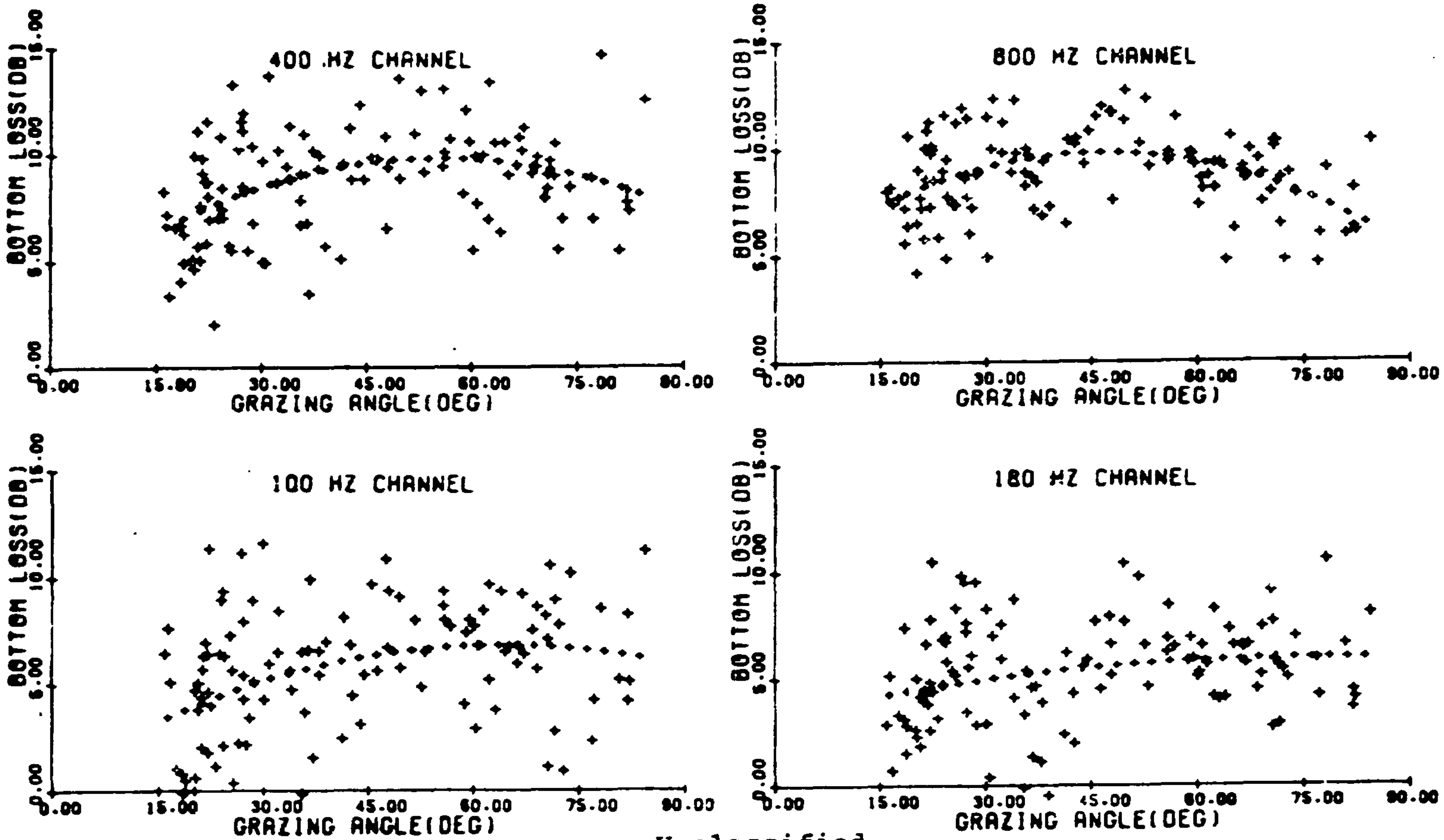
— Bathymetric Profile, PARKA II-A Southwest Track

MC Report 006, Vol 2

FIGURE 3 (U)

BOTTOM LOSS MEASUREMENTS

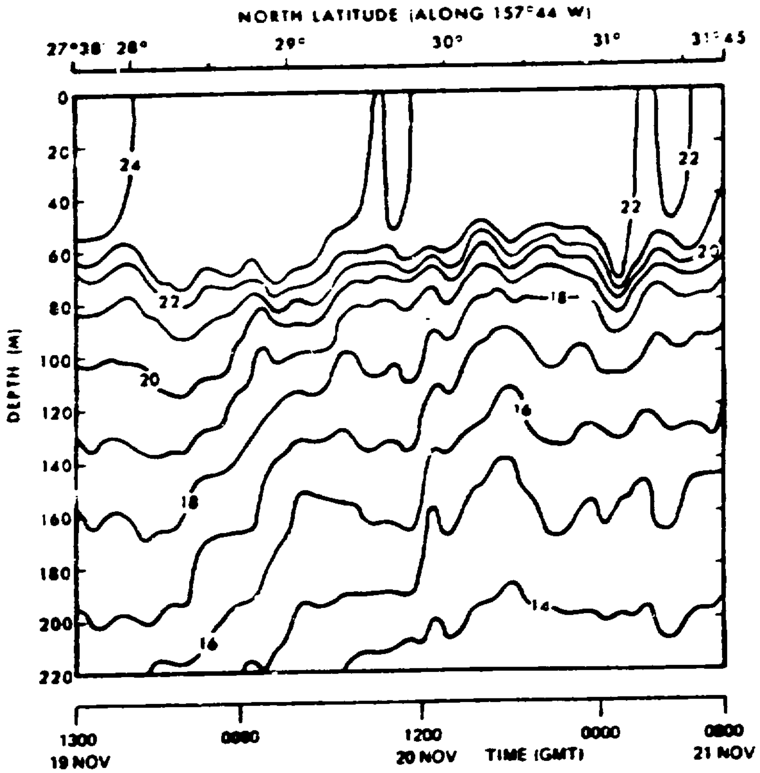


Unclassified

– Bottom reflection loss as a function of grazing angle for four frequencies: 100, 180, 400, and 800 Hz (U)

MC Report 006, Vol 2

FIGURE 4 (U)



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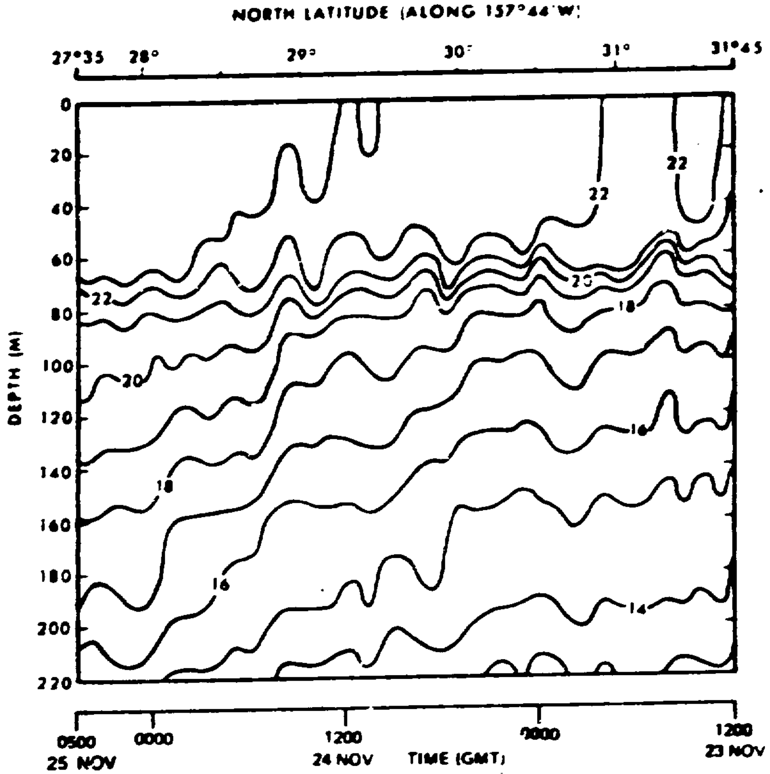
— Temperature Structure (°C), REXBURG Event 9-2 (FLIP to 31°45'N)

MC Rept 006, Vol 2

FIGURE 5 (U)



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— Temperature Structure (°C), REXBURG Event 9-3 (31°45'N to FLIP)

MC Rept 006, Vol 2

FIGURE 6 (U)

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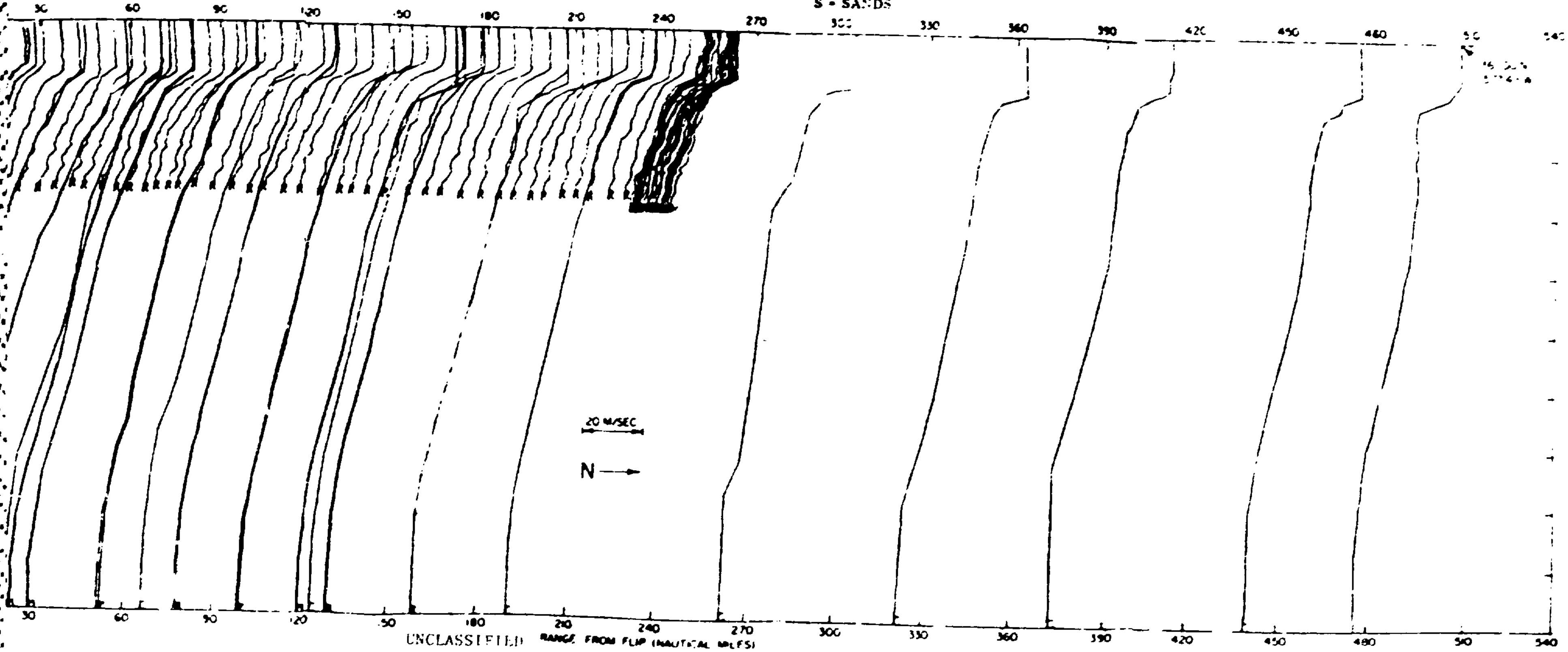
1. Nominal FLIP position 27°35'N,157°44'W
2. Observations are plotted at actual range from FLIP along top scale
3. Letter at bottom of profile indicates source of data

C = CONRAD
M = MARYSVILLE
R = REXBURG
S = SANDS



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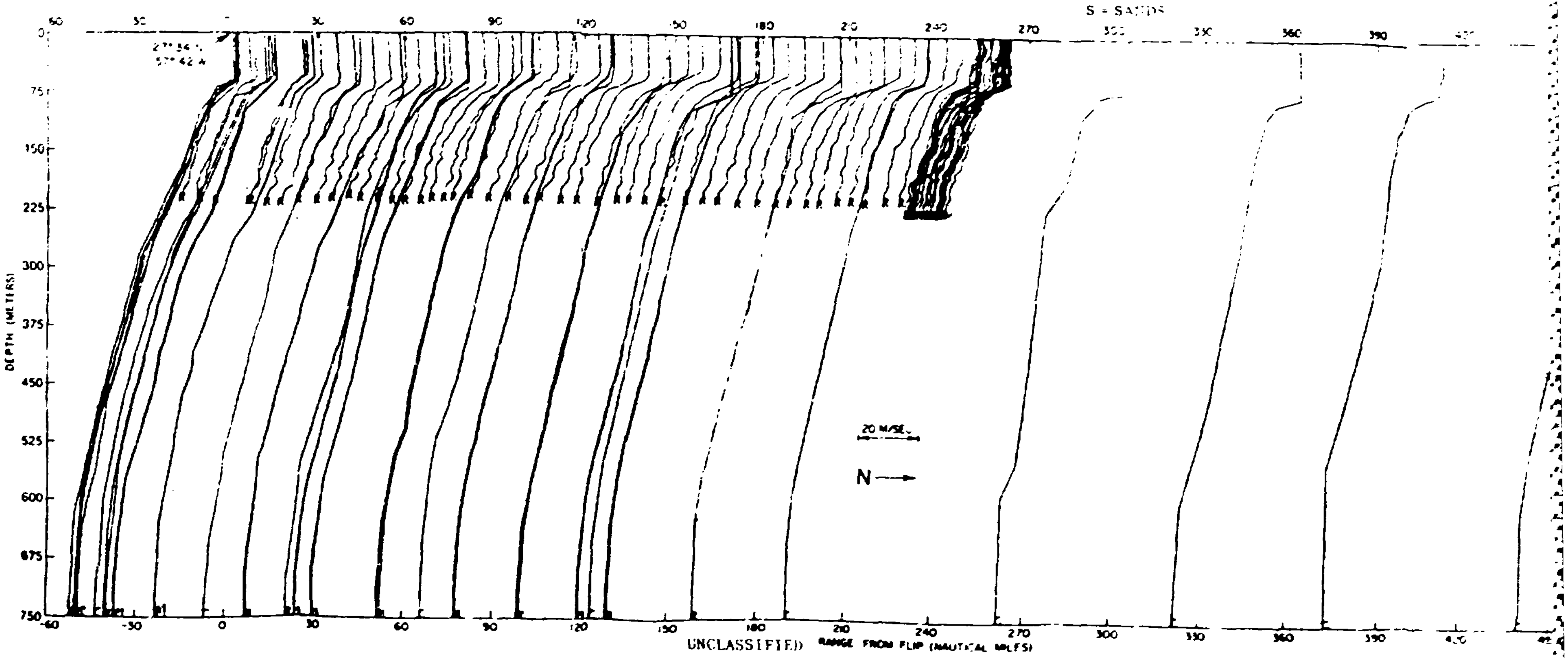
— Shallow Sound Velocity Profiles, Event 9-2 (Propagation Loss and Arrival Structure), FLIP to 36°N

FIGURE 7 (U)

1. Nominal FLIP position 27°35'N,157°44'W
2. Observations are plotted at actual range from FLIP along top scale
3. Letter at bottom of profile indicates source of data

C = CONRAD
M = MARYSVILLE
R = REXBURG
S = SANDS



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— Shallow Sound Velocity Profiles, Event 9-2 (Propagation Loss and Arrival Structure), FLIP to 36°N

FIGURE 7 (U)

MC Report 0(, Vo

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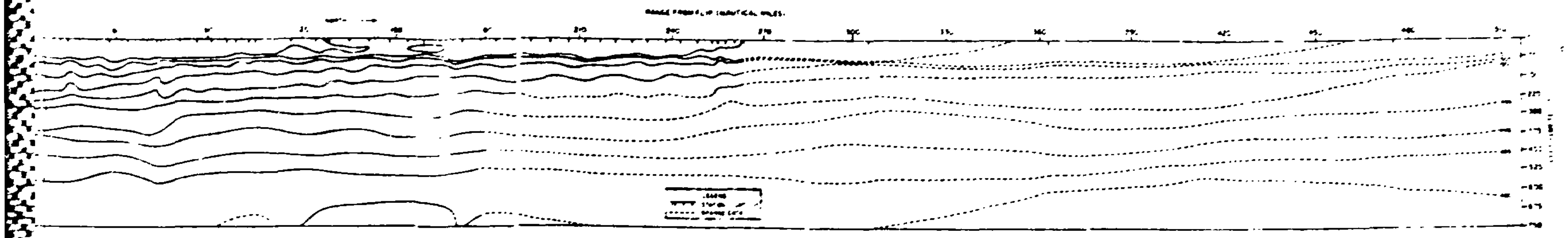

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(U) Contoured shallow cross section of sound velocity, Event 902 (propagation loss arrival structure), FLIP to 36°N, MC Report 006, Vol 2

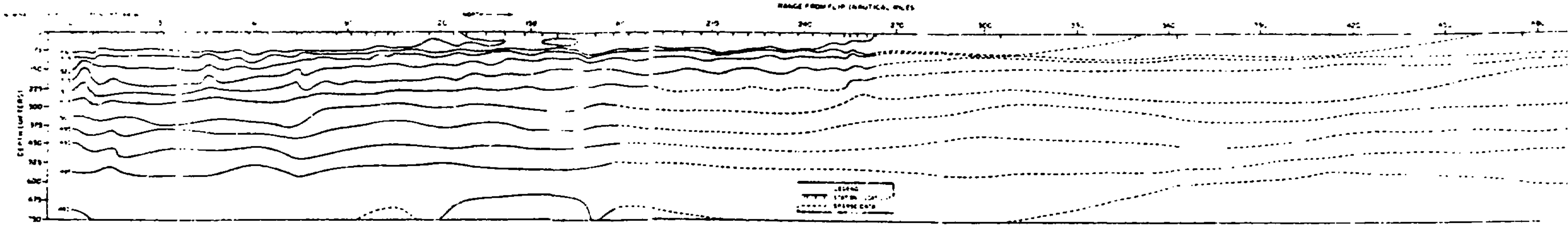

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Figure 8. (U) Contoured shallow cross section of sound velocity, Event 902 (propagation loss arrival structure), FLIP to 36°N, MC Report 006,

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ACOUSTIC DATA PLOTS

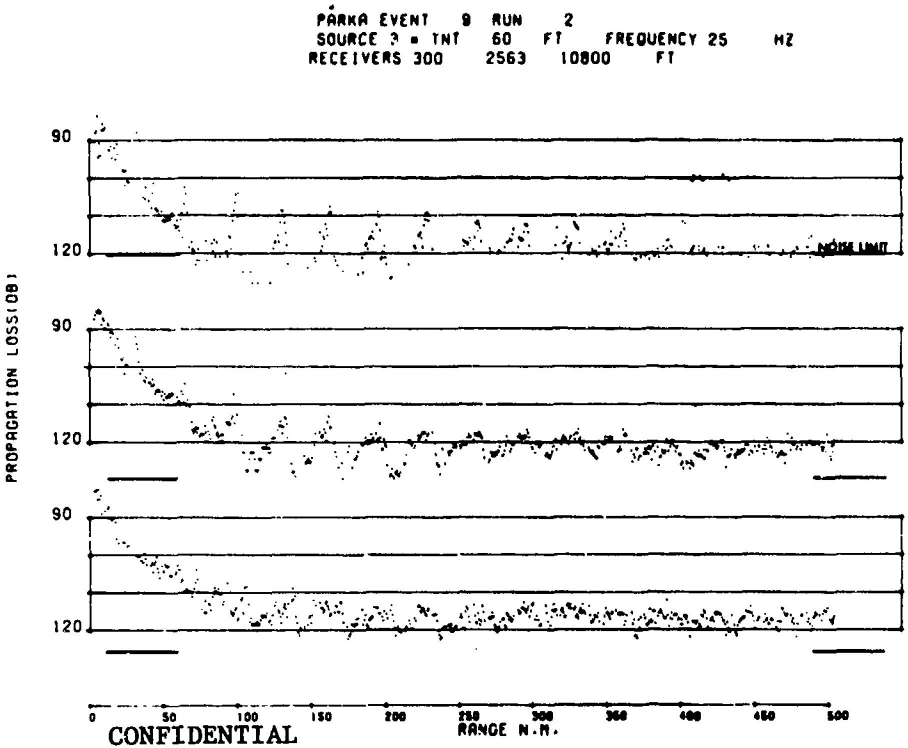
PARKA EVENT 9 RUN 2
SOURCE 3 = TNT 60 FT FREQUENCY 25 HZ
RECEIVERS 300 2563 10800 FT

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Figure 9 (U) Ship run north of FLIP, outgoing MC Report 006, Vol 1

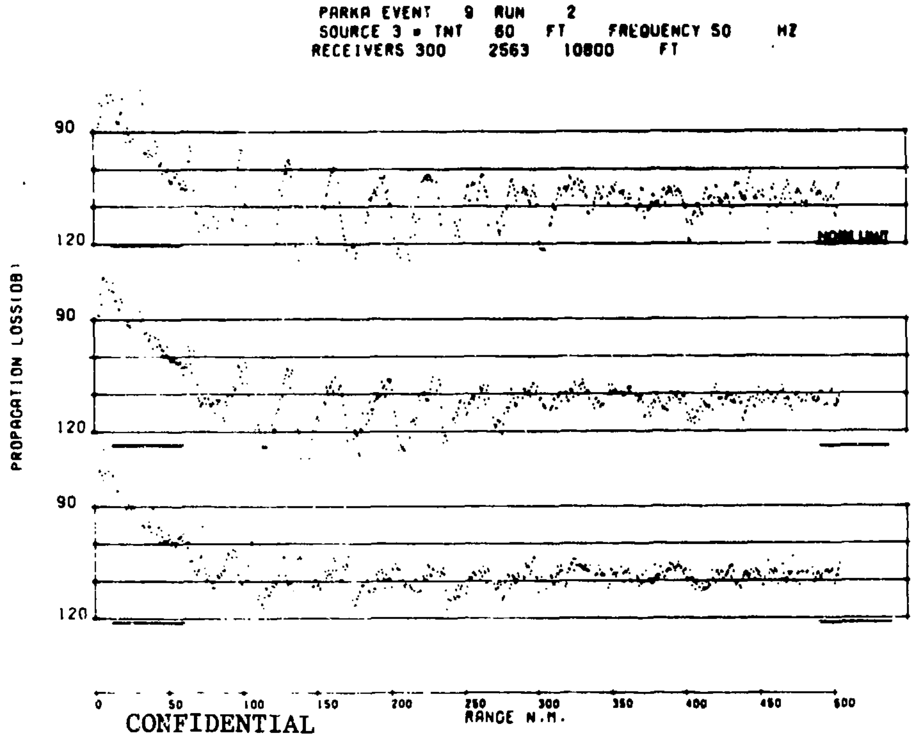
PARKA EVENT 9 RUN 2
SOURCE 3 = TNT 60 FT FREQUENCY 50 HZ
RECEIVERS 300 2563 10800 FT

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Figure 10 (U) Ship run north of FLIP, outgoing MC Report 006, Vol 1

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ACOUSTIC DATA PLOTS

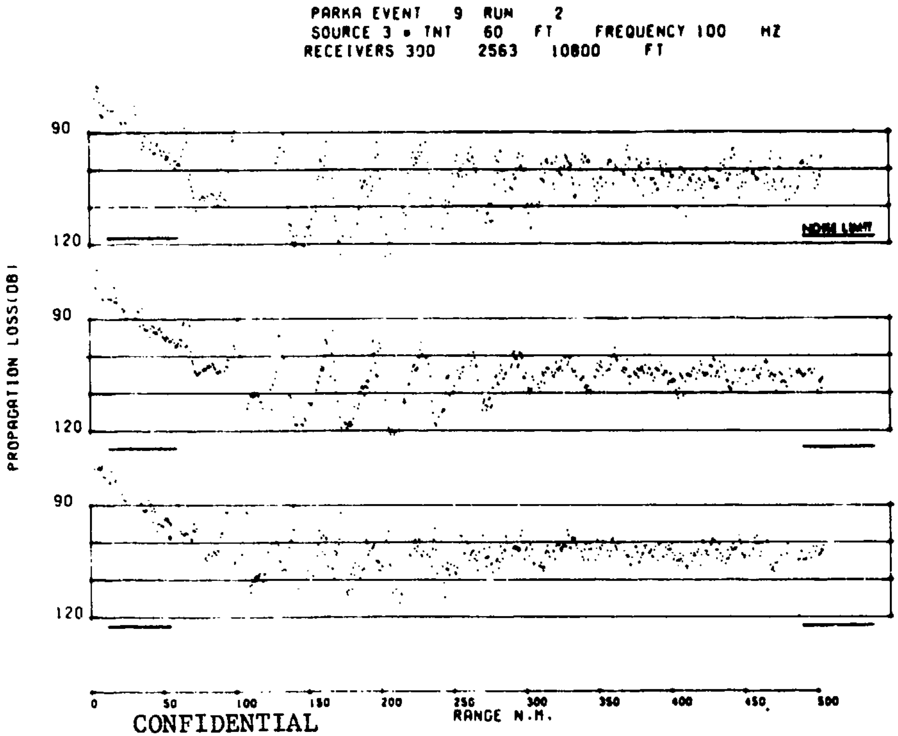

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FIGURE 11 (U) **Ship run north of FLIP, outgoing** MC Report 006, Vol 1

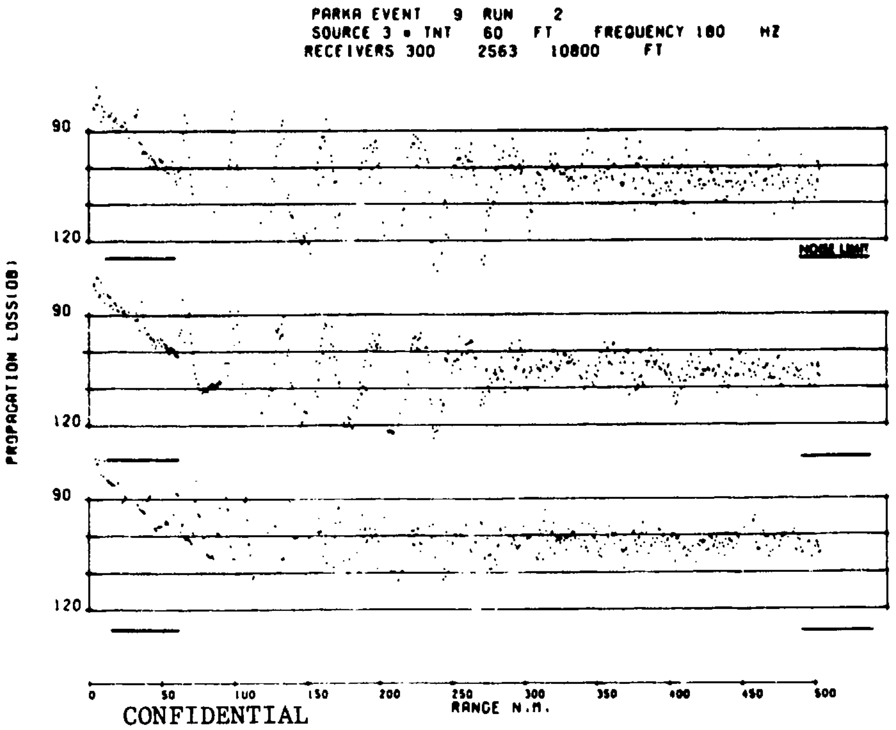

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FIGURE 12 (U) **Ship run north of FLIP, outgoing** MC Report 006, Vol 1

ACOUSTIC DATA PLOTS

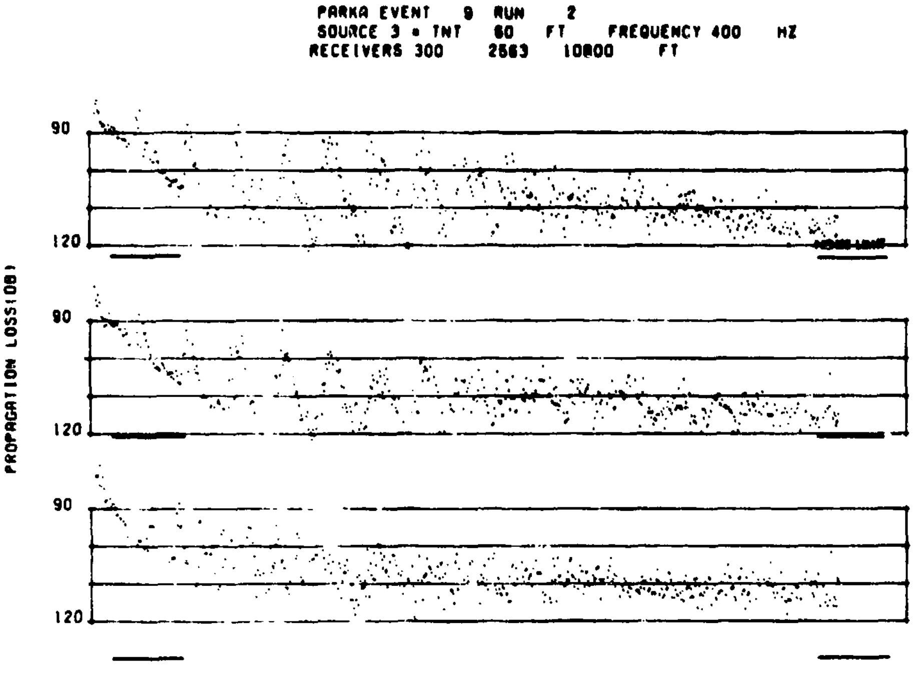

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FIGURE 13 (U) **Ship run north of FLIP, outgoing** MC Report 006, Vol 1

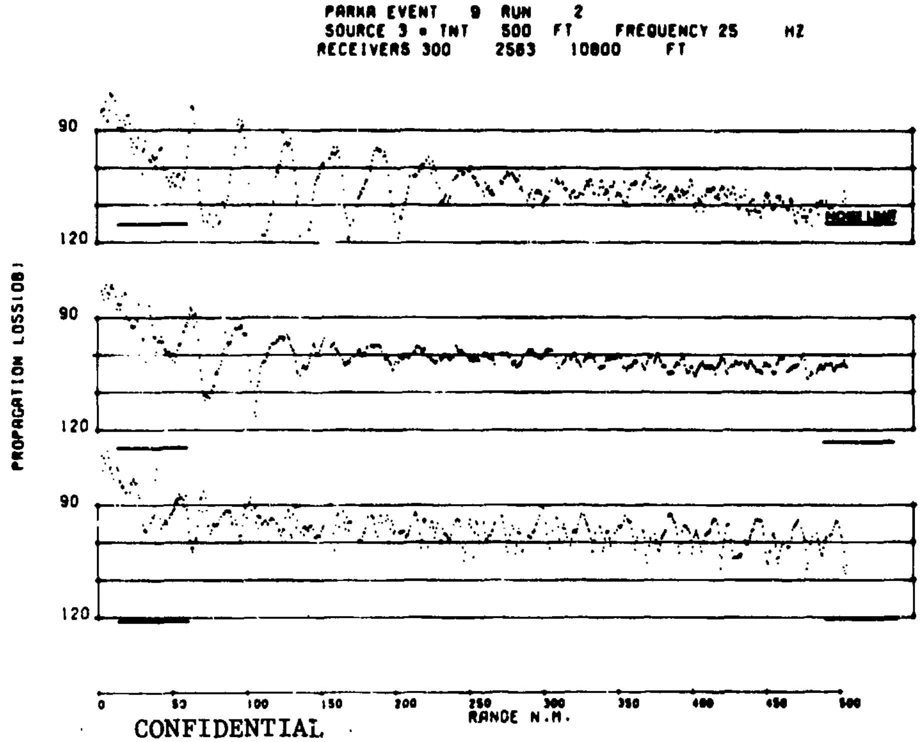

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FIGURE 14 (U) **Ship run north of FLIP, outgoing** MC Report 006, Vol 1

ACOUSTIC DATA PLOTS

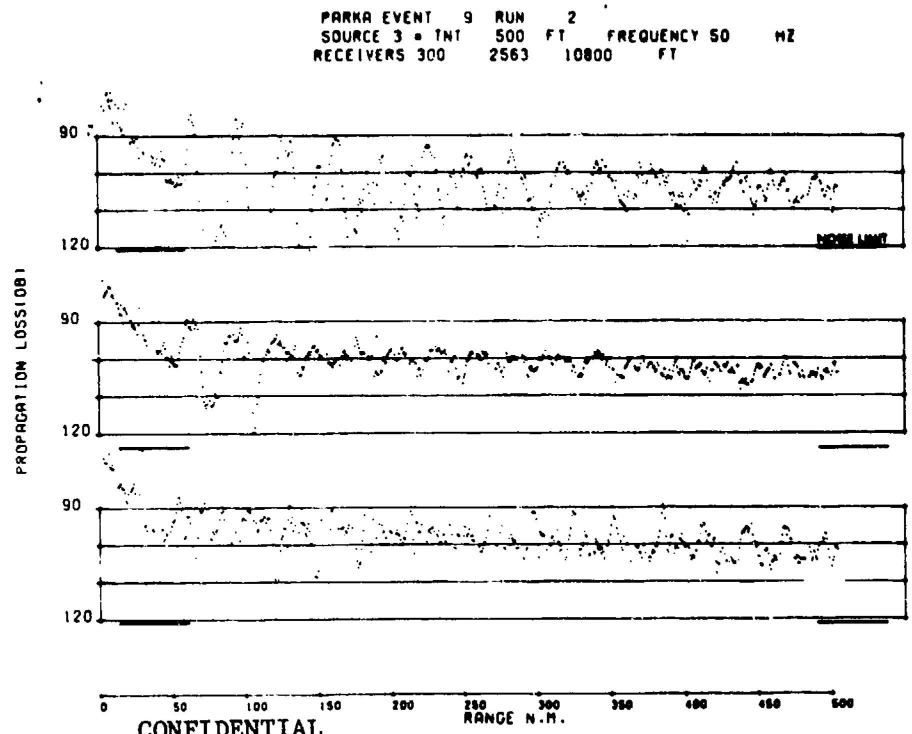

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FIGURE 15 (U) Ship run north of FLIP, outgoing MC Report 006, Vol 1

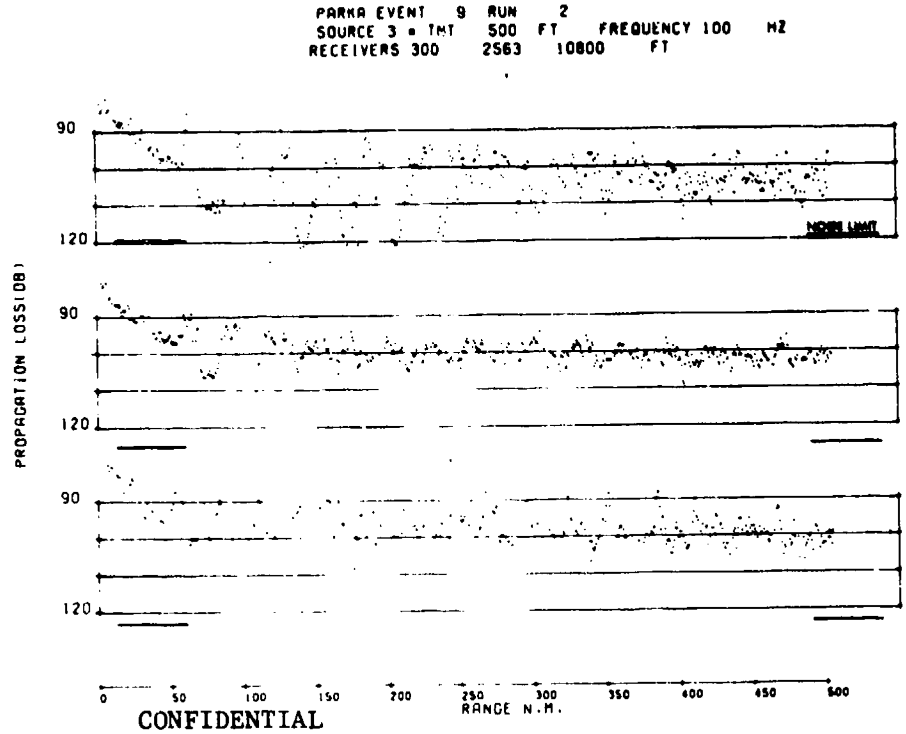

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FIGURE 16 (U) Ship run north of FLIP, outgoing MC Report 006, Vol 1

ACOUSTIC DATA PLOTS

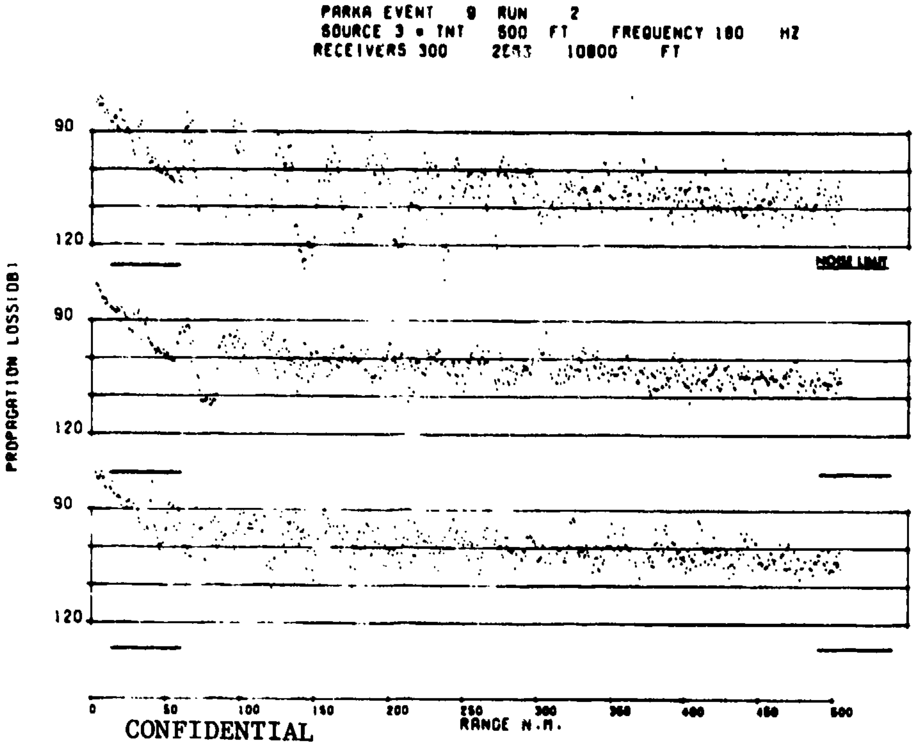

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FIGURE 17 (C) **Ship run north of FLIP, outgoing** **MC Report 006, Vol 1**

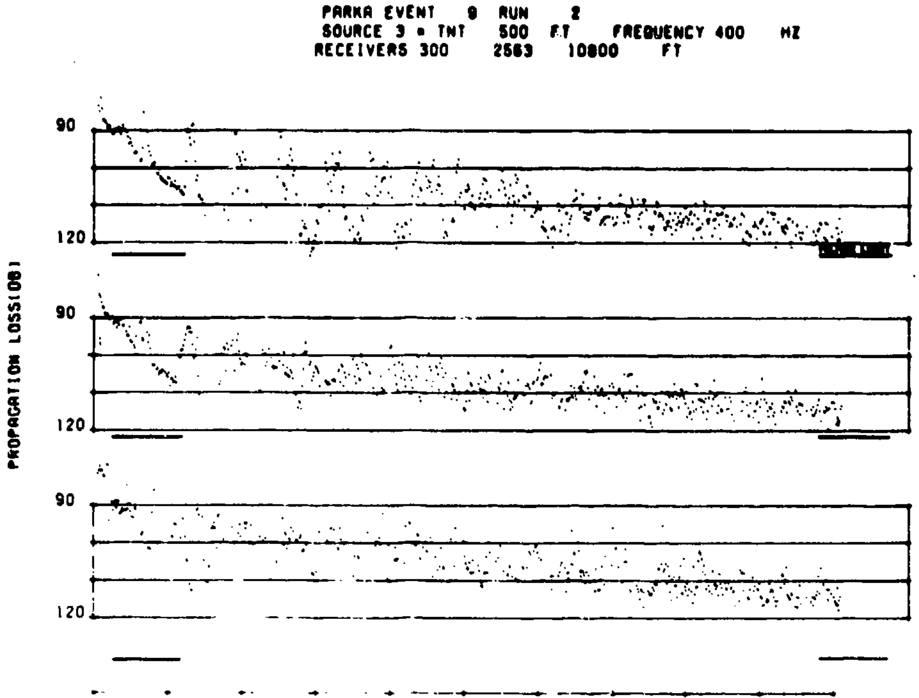

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FIGURE 18 (C) **Ship run north of FLIP, outgoing** **MC Report 006, Vol 1**

ACOUSTIC DATA PLOTS

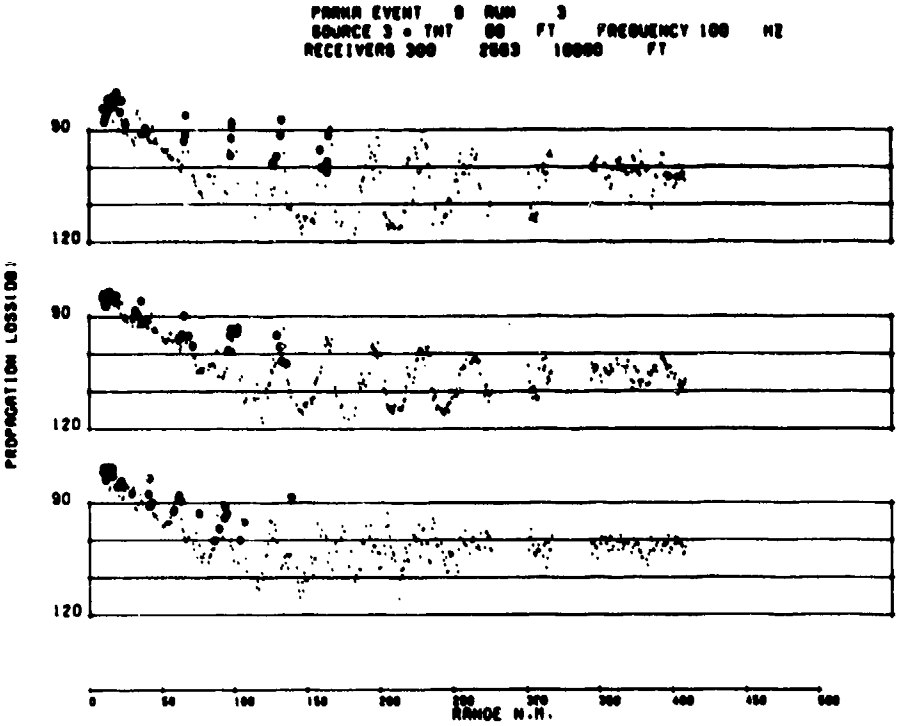
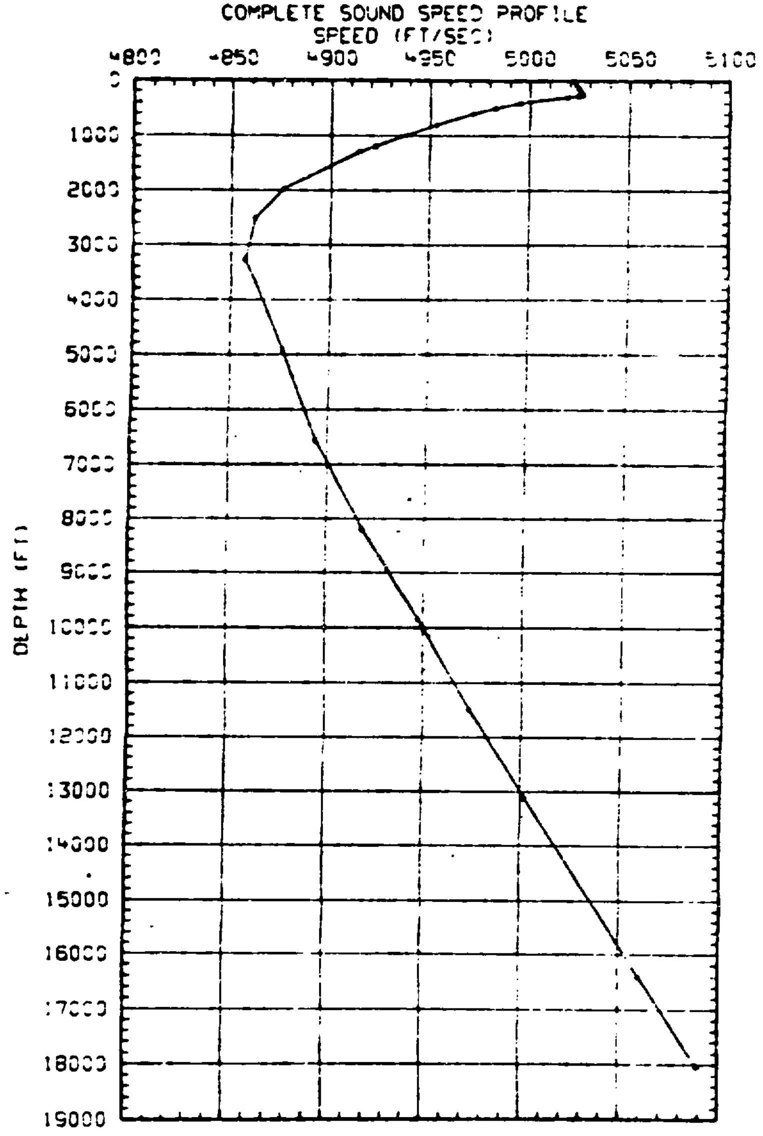


FIGURE 19 (C) Ship run north of FLIP, incoming MC Report 006, Vol 1



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DEPTH	SPEED
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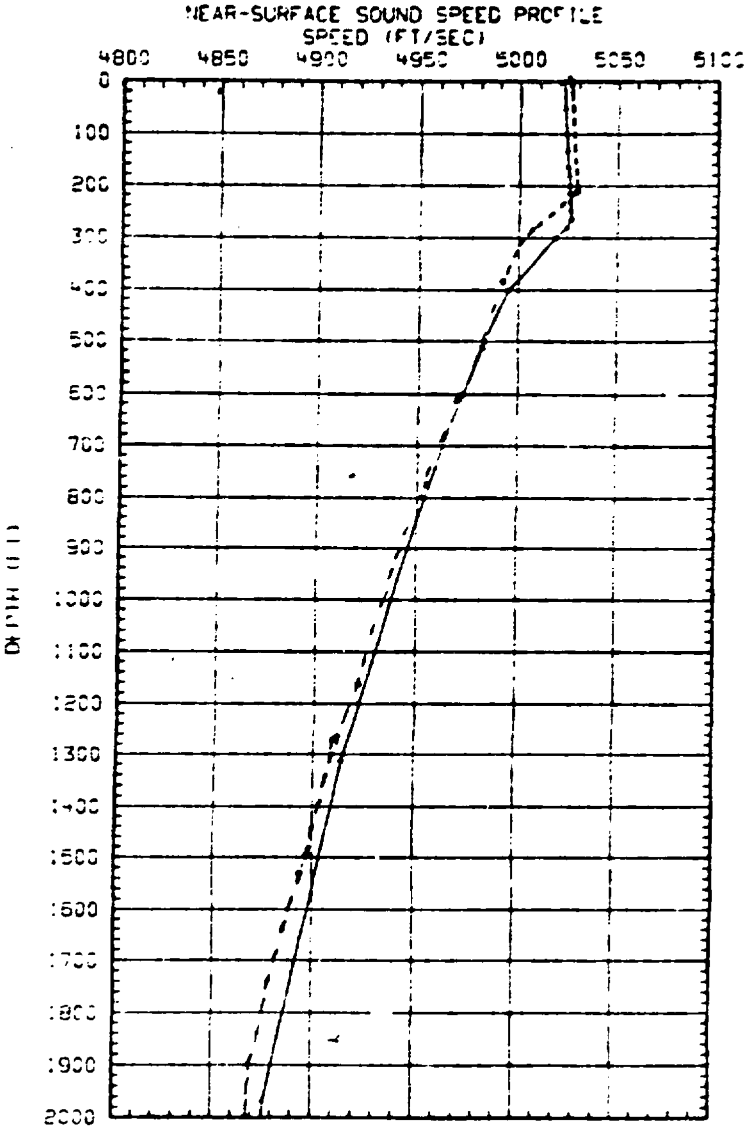
50.0	5022.98
100.0	5023.80
131.2	5024.32
164.0	5024.66
196.5	5025.13
200.0	5025.45
229.7	5025.94
246.1	5026.21
262.5	5026.49
278.9	5024.31
300.0	5018.86
400.0	4995.15
500.0	4983.04
600.0	4971.64
800.0	4953.36
1200.0	4922.25
1312.3	4913.92
1968.5	4876.22
2500.0	4861.85
3280.8	4857.19
4921.2	4876.77
6561.7	4894.17
8202.1	4918.46
9842.5	4947.25
11482.5	4973.59
13123.3	5002.03
16404.2	5060.11
18044.6	5085.60



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29-Point PARKA Sound Speed Profile (U)

FIGURE 20 (U)

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Appendix 7. (U) Mediterranean Sound Transmission (WHOI Hays-Murphy)

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Appendix 7 (U)

Mediterranean Sound Transmission (1968) (U)

(Hayes Murphy Data)

Summarized by Robert L. Martin

INTRODUCTION (U)

(U) In July 1968 R/V CHAIN completed twelve sound transmission runs in the Mediterranean Basins (reference (1)). The purpose of the series was to observe transmission loss at low frequencies (mainly 100 and 35 Hz) from deep water to shallow water receivers in all the basins, and to measure the transmission loss for a completely deep water transmission run. The run with both source and receiver in deep water was ship-to-ship; ST. MARGARETS (U.K.) shooting to R/V CHAIN in the Algiers-Provencal Basin. The other runs in the Mediterranean Sea were performed with airplanes shooting to the ship (R/V CHAIN) and are not discussed in this summary. Sound velocity profiles and/or STD lowerings were made at several locations. At the receiving locations echo sounding traverses were made along the shallow portions and down the slope of the planned tracks. ST. MARGARETS obtained bathythermograph dips periodically, and echo sounded for bathymetry along the track of the ship-to-ship run. A summary of the exercise parameters is contained in Table 1. The exercise tracks are shown in Figure 1.

EXERCISE DESCRIPTION (U)

ST. MARGARETS Run (U)

(C) CHAIN hove to at 38°17'N, 03°53'E and ST. MARGARETS proceeded to 36°21'N, 2°W firing one pound charges every two minutes. The usual charge depth was 80 feet; a charge was also fired at 325 feet every hour. Three

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Review on : 28 August 1989

TABLE 1 (U)

Exercise:	Mediterranean Sound Transmission (1968)
Event:	ST. MARGARETS
Source Type:	1 lb. TNT
Source Depths:	80 and 325 ft
Receiver depths:	350, 450 and 1000 ft
Acoustic Analysis:	1/3 octave total energy
Frequencies:	35, 67.5, 100 and 200 Hz
Data Density:	80 ft source, 3 shots per nm 350 ft source, 1 shot per 10 nm
Range over which environment is Range Independent:	0-240 nm
Water Depth:	1500 fathoms max (2750 m) 1420 fathoms min (2600 m)
Environmental data:	Sound velocity profiles and water depth vs range
Navigation:	Not addressed in report as such
Range Determination:	Radio link time difference
Range Accuracy:	Less than 1.5% of range -- probably better than 0.5% of range
Data Location:	Each plotted value tabulated vs range in reference (1)
Comments:	(1) Source level accuracy is 3dB or better (2) Depth excess is 1500 m or more. Bottom reflected energy may dominate below 67.5 Hz but probably contribute little above 100 Hz.

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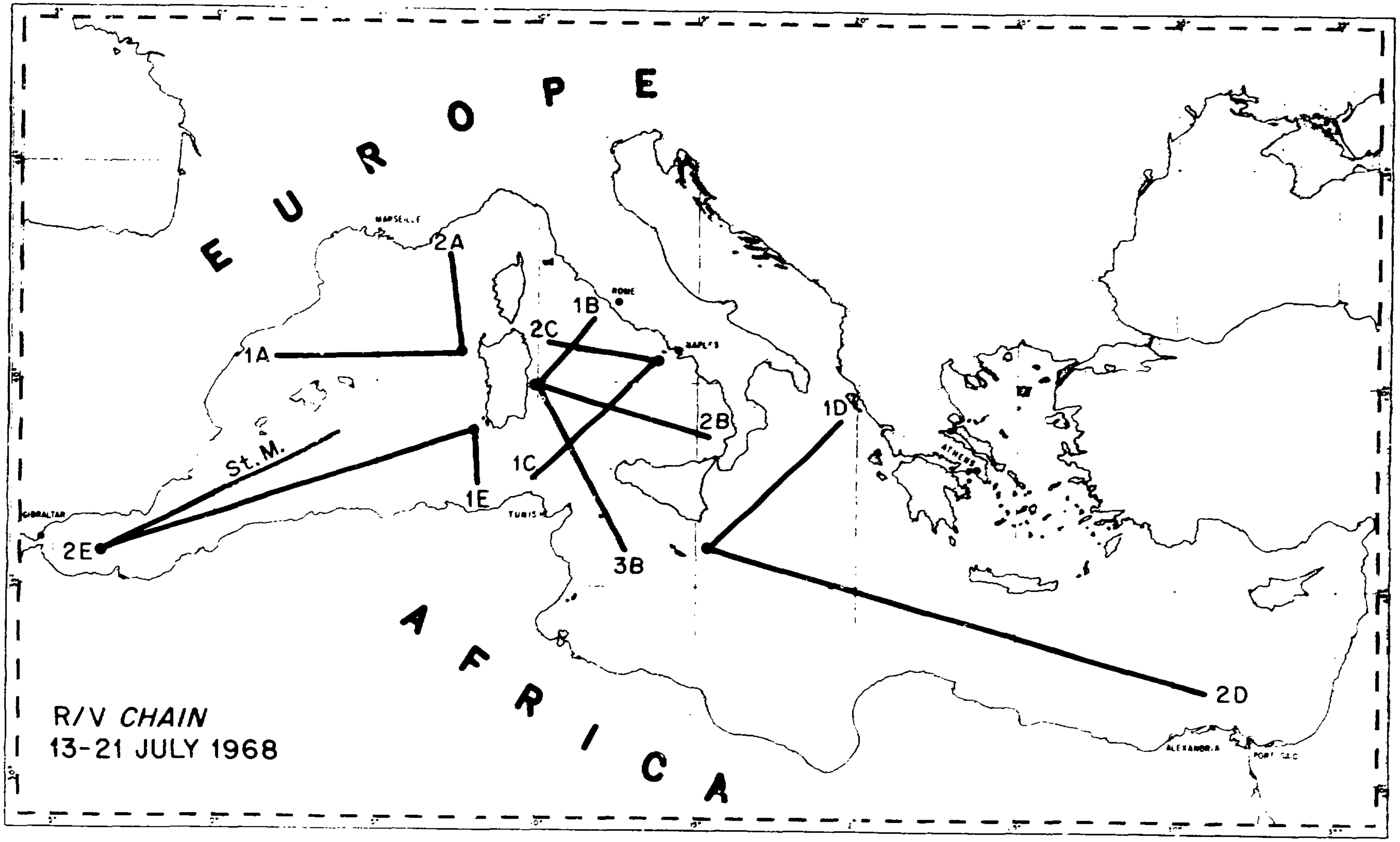

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Figure 1. (U)R/V CHAIN 13 - 21 July 1968.

hydrophones were floated away from CHAIN, on separate cables, at nominal depths of 350, 450 and 1000 feet. The actual depths as measured during the run for the two shallow hydrophones are given in Table 2. It is assumed that the depth of the third hydrophone behaved similarly. Depth differences greater than 100 ft are assumed erroneous but smaller depth differences may be associated with current drag tilting the array in the vertical.

(U) The signals came through a preamplifier, with sufficient dynamic range to handle the input levels, up to amplifiers aboard the ship. These had variable gains so that the signals could be put on the tape recorders at optimum levels. The level of each shot was monitored by peak level signal lights and gains were changed as needed during the run. Since wave and pulse calibrations were placed on each reel of tape through a calibration resistor at the hydrophone input to the preamplifier.

(U) The shot instants were detected aboard ST. MARGARETS and transmitted to CHAIN and recorded on the same reel as the shots. Voice announcements, time ticks, and a standard frequency were combined on the same channel with the shot instants. While not stated, this method of ranging implies a maximum range error of 1.5% of range and more likely the error is considerably less than that. Considering the variability in the loss curves (Figures 4-6) this appears adequate. As this was a rather long run and CHAIN was on silent ship during shot reception, hour breaks were taken after meal time and at mdinight to take care of housekeeping duties aboard CHAIN. These breaks account for the discontinuities in the shot separations along the run.

TABLE 2 (U)

St. Margarett's Run

Actual Hydrophone Depths/fathoms

Range n.m.	Shot #	350 ft Hydrophone	450 ft Hydrophone	(450-350)
9.1	30	365	460	95
12.6	40	360	480	120
62.2	188	380	490	110
147.5	450	300	375	75
150.8	461	290	380	90
155.0	476	305	390	85
158.3	486	300	400	100
163.0	499	310	375	65
171.9	528	300	380	80
174.9	539	320	400	80
178.4	554	325	420	95
183.0	572	330	415	85
189.0	591	350	445	95
236.8	753	350	425	75
262.4	840	290	365	75
274.2	885	280	355	75
277.1	896	280	360	80
285.7	935	285	355	70
290.2	952	300	365	65

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SOURCE DEPTHS AND SOURCE LEVELS (U)

(U) The calculated source levels were determined from the information in the JASA papers of Christian (1967) and Weston (1960). It is assumed that 80 ft levels are from Weston and the 325 ft levels from Christian. Standard levels are currently derived from Gaspin and Shuler (reference 2); differences between G&S, Weston ahd Christian are discussed in reference 3. 300 ft G&S source levels are typically 2-3dB greater than Christian and 60 ft G&S levels are 3dB greater than Weston at 25 Hz, approximately the same at 50 and 100 Hz and 2dB less at 160 Hz.

(C) ST. MARGARET' shots were at depths of 80' and 325' and were one pound explosives fired by Engineers special cap. Source levels used were $(\text{dynes/cm}^2)^2$ sec/Hz):

	35 Hz	67.5 Hz	100 Hz	200 Hz
80 ft.	102.5	101.5	100.5	98.5
325 ft.	104.8	100.8	99.3	97.3

HYDROPHONE DEPTHS AND CALIBRATIONS (U)

(U) The hydrophone depths were nominally at 350, 450 and 1000 ft. The control of the two shallower hydrophones was somewhat better than that on the deep hydrophone. The two shallow hydrophones were calibrated at Orlando in April 1968 and were within one dB of previous calibrations. Corrections were made for temperature and depth effects. Sine waves (35 and 100 Hz) and exponential pulses were sent through the system (calibration resistance input) on every reel of tape and played back during analysis. The deep hydrophone has built-in exponential calibration pulse but this did not prove satisfactory. Sine wave calibrations were run through the entire system at Majorca at the end of the exercise. The hydrophone was calibrated at Orlando after the cruise and the sensitivity was within one dB of the manufacturer's specifications. The preamplifier gain as measured after the cruise agreed with that measured before the cruise. A partial failure occurred in a transistor in an emitter follower circuit during the exercise. Examination of the effect of this showed it to be important only when the signal level was above a certain value which occurred only at shorter ranges.

SOURCE/RECEIVER HORIZONTAL RANGES (U)

(U) The ship-to-ship ranges were based on a mixture of ST. MARGARETS' navigation and shot travel times. The shot time transmitted by radio was not always received. The expected range error using this technique is less than 1.5% of range and could be ~ 0.1% of range depending on the care used in selecting the group velocity and identifying it with the correct signal arrival.

(U) During the ST. MARGARETS' run the deep hydrophone was not completely turned on until shot #207. Also, towards the end of the run at shots #772 to #824, power problems aboard ship resulted in poor data.

ACOUSTIC LEVEL MEASUREMENTS (U)

(U) Part of the analysis was done aboard CHAIN and the rest in the laboratory: two different set-ups were used for analysis in the laboratory. Cross checks of measurements indicate that the systems agree with one dB. As mentioned previously, peak voltage indicator lights were used to monitor signal levels for input into the tape recorder, with the intention of maintaining a level within the limits of 1 volt to 10 dB below 1 volt. All shots were plotted on the graphs, as no obvious correlation with overload/underload was seen.

(U) The tape recordings were played back on the same recorder used in the runs, through emitter followers, Allison filters set at one-third octave bands and an analog $\int p^2 dt$ computer, and read out on a paper recorder. The logarithm of the deflection was measured and the signal level calculated. Source levels were then used to obtain the transmission loss. Calibration signals were run from each tape for the two shallower hydrophones and analyzed the same way.

(C) The 35 Hz long-range shot wave trains carried measurable energy for a considerable length of time (about 10 seconds). When the signal levels were low, it was possible to visually correlate successive shots and determine the termination of energy associated with the shot.

ENVIRONMENTAL DATA (U)

(U) The depth of water along the ST. MARGARETS' run is given in Figure 6. Sound velocity profiles measured directly and those derived from the XBT's of ST. MARGARETS are given in Figures 2 and 3 respectively. Depth excess for an 80 ft. source in this environment is on the order of 1500 m with a bottom limiting ray emanating from the source at approximately 10°. At 35 Hz the surface image effect results in a source pattern with a major lobe directed 30° with respect to the vertical; at 67.5, 100 and 200 Hz this angle is 15, 10 and 5° respectively. For a low loss bottom, bottom reflected energy may well be dominant along the entire transmission path at 35 Hz becoming less so as frequency is increased because of this image effect. The 325 ft. source, however, is at the sound channel axis and waterborn energy will dominate with some contribution from the bottom if it is highly reflective.

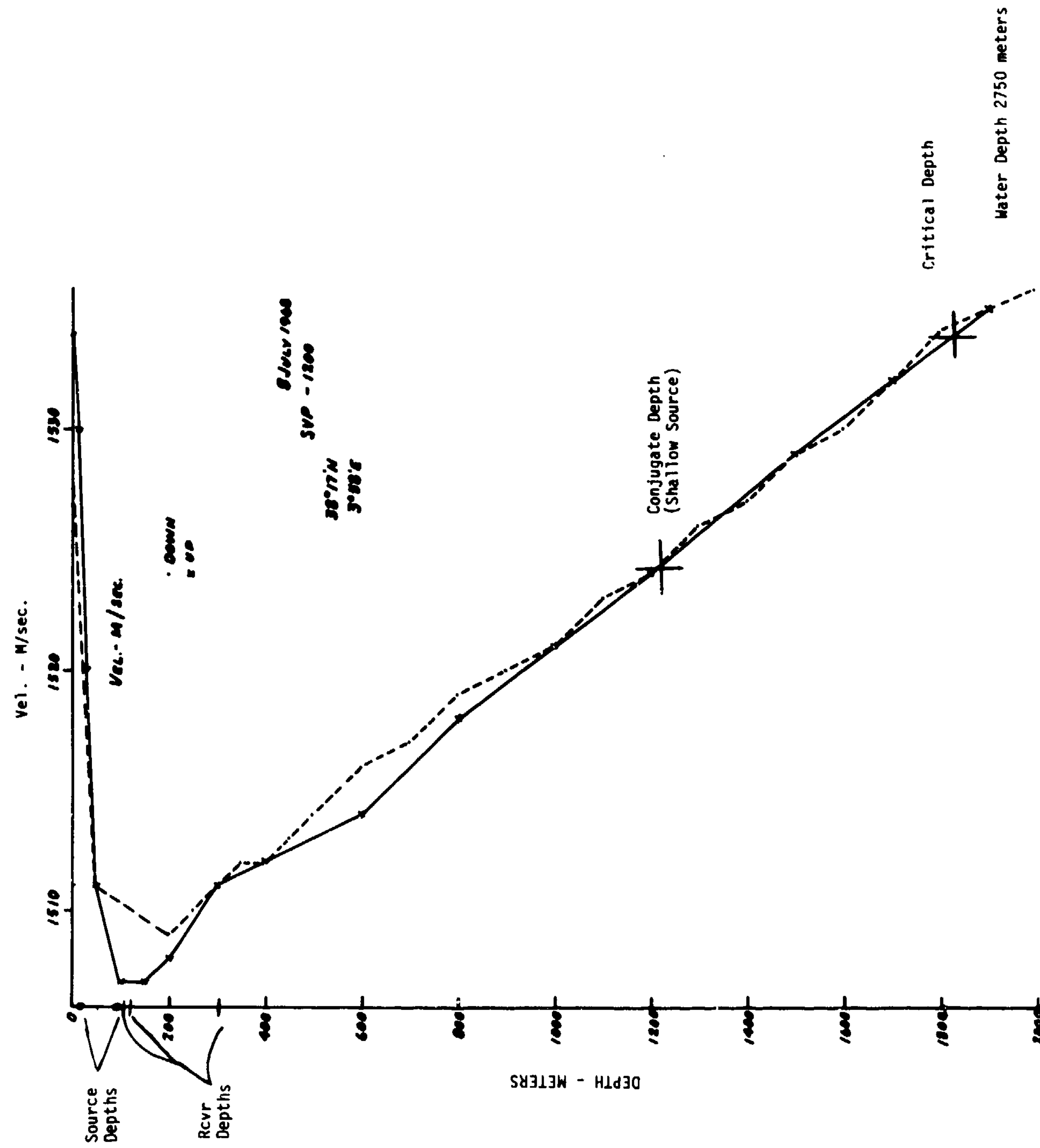

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Figure 2. (C) Sound Velocity Profile - ST. MARGARETS.

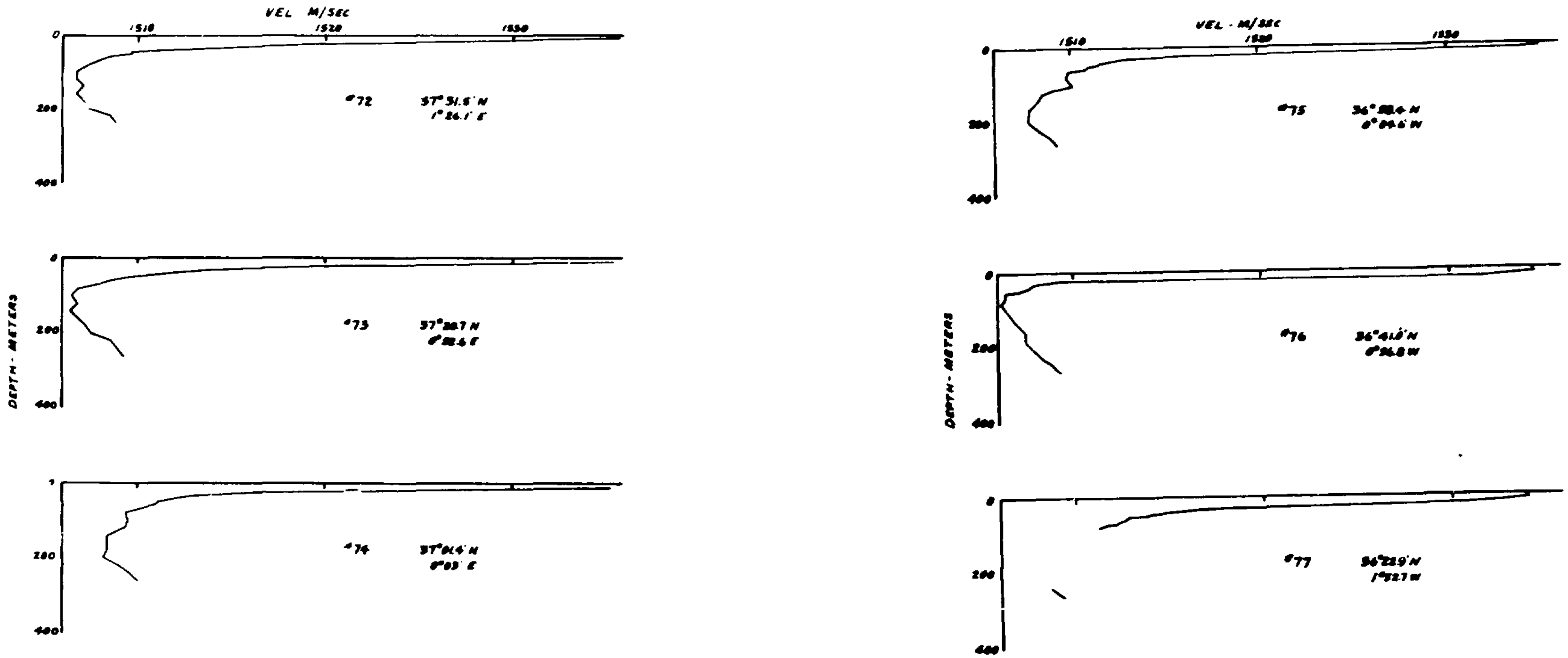

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Figure 3. (U) Velocity Profiles Derived from ST. MARGARET's BT's

(U) Because the thermocline is so steep and repeatable and depth excess so large, the small variations of the sound velocity profiles (Figure 3) with location are not expected to affect the range independent environment assumption.

RESULTS (U)

(C) The locations of the transmission runs as planned are shown in Figure 1. For the run marked ST. MARGARETS, R/V CHAIN hove to at 38°17'N, 03°53'E and ST. MARGARETS steamed toward Gibraltar firing charges. Charges were at 80' except for hourly shots at 325'. At the location of CHAIN for the ST. MARGARETS' run the water depth was approximately 1400 fathoms.

(C) The measured transmission loss is presented in graphical form in Figures 4 through 6. The 35 Hz graphical data (Figure 4) for three hydrophones for each run are presented on a single page as are the 100 Hz data (Figure 5). We have also included data at 67.5 Hz and 200 Hz for the ST. MARGARETS' run (Figure 6); included in this figure is the ST. MARGARETS' echo sounding along the track.

(C) Of interest is the somewhat higher level shown for the ST. MARGARETS' run at 100 Hz by the deep hydrophone compared with the results from the two shallower ones. No explanation is given but there was no particular reason to suspect equipment shortcomings.

REFERENCES (U)

1. "Mediterranean Sound Transmission: (U), E.E. Hayes and E.L. Murphy, July 1968. Woods Hole Oceanographic Institution, Ref #69.69. Unclassified

2. "Source Levels of Shallow Underwater Explosions" (U), by J.B. Gaspin and V.K. Shuler. Naval Ordnance Laboratory Technical Report 71-160 of 13 Oct 1971. Unclassified

3. "SUS Source Level Committee Report" (U), Maury Center Report #112, Nov 1975. Unclassified

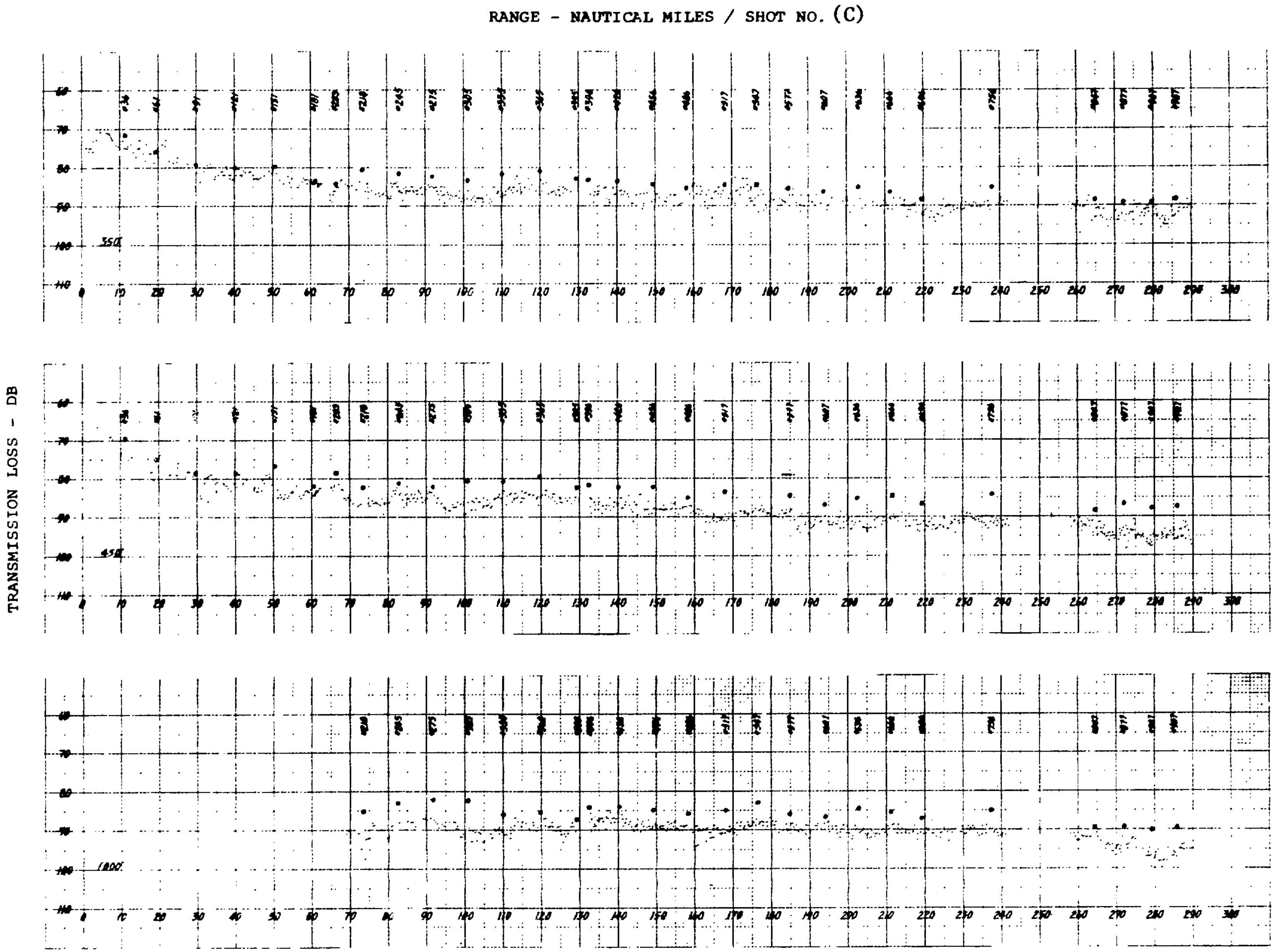

Figure 4. (C)35 Hz ST. MARGARETS-CHAIN, July 1968. (TABLE I)
80' and 325' (O) Deep Shots.

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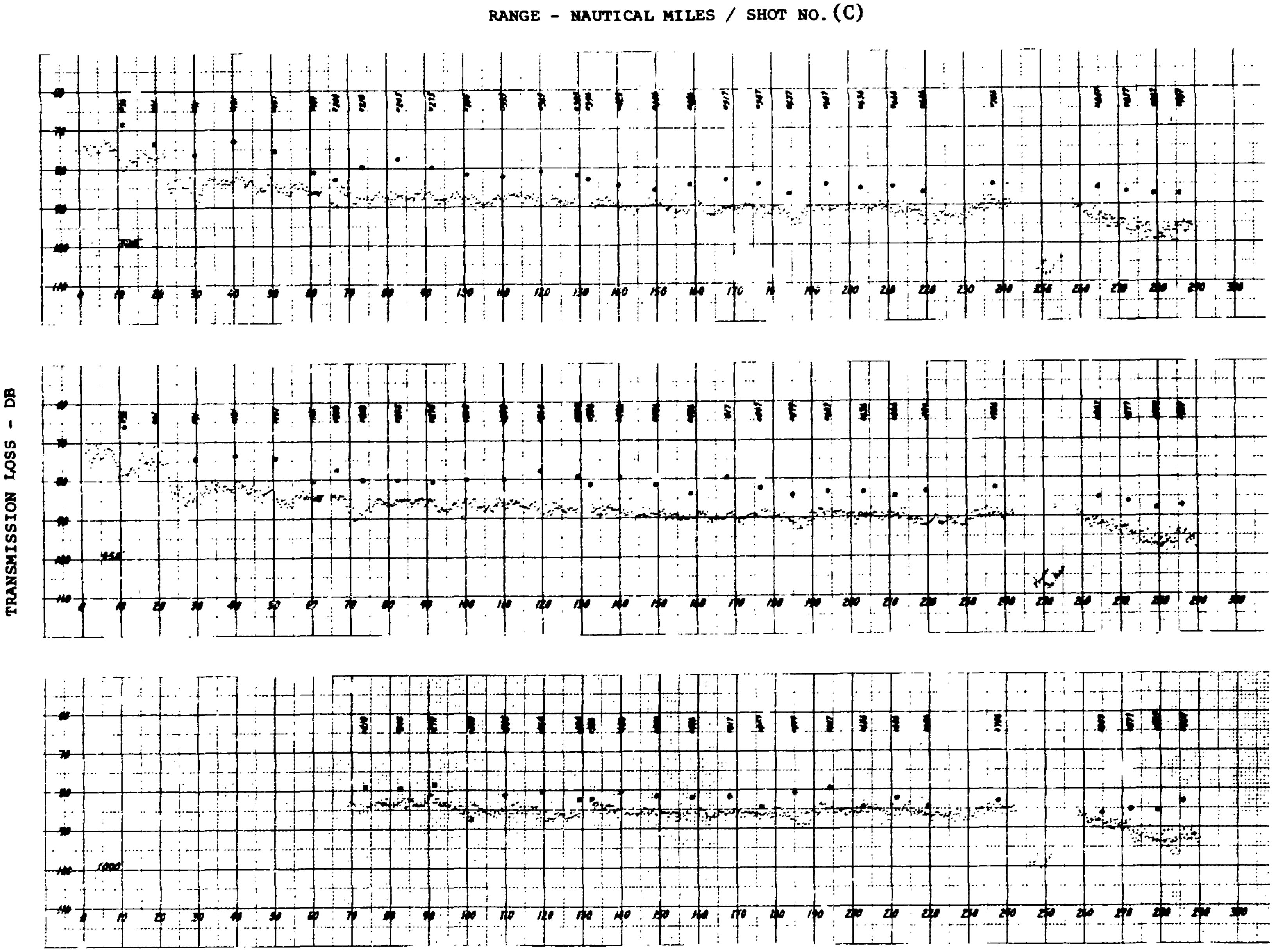

Figure 5.(C)100 Hz ST. MARGARETS-CHAIN, July 1968. (TABLE I)
80' and 325' (O) Shots.

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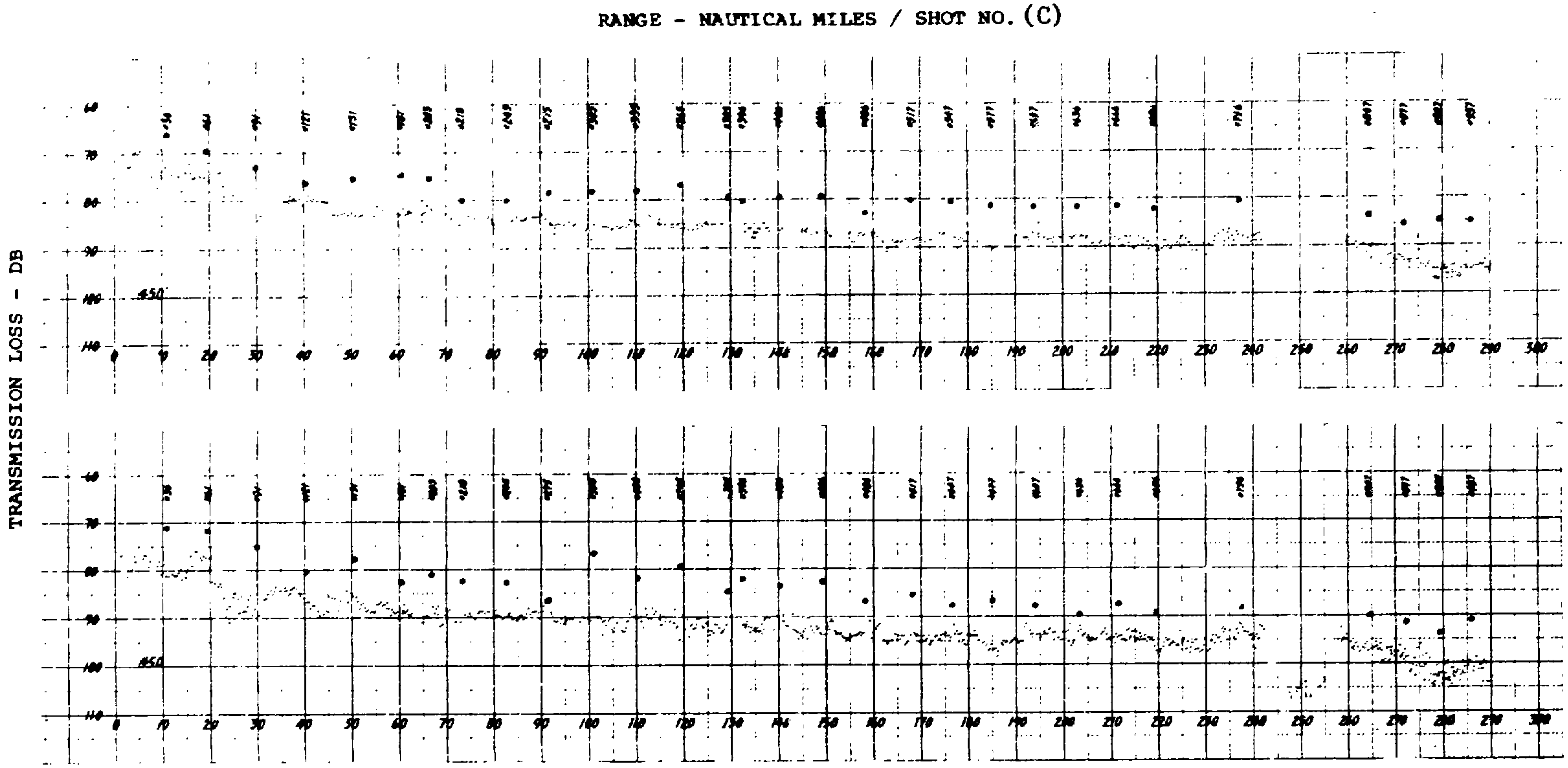

Figure 4.(C)(1) 67.5 and 200 Hz ST. MARGARETS-CHAIN, July 1968. (TABLE I)

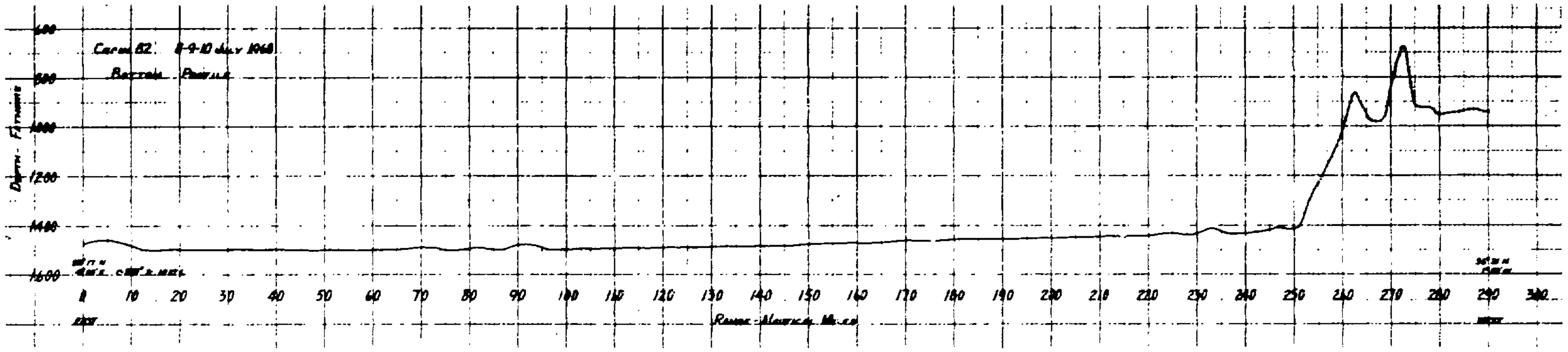

Figure 6(C)(2) ST. MARGARETS - CHAIN, July 1968. Bottom Contour.

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Appendix 8. (U) BEARING STAKE (Indian Ocean Experiment)

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Appendix 8

DATA SETS FOR MODEL EVALUATION
BEARING STAKE EXERCISE (U)

Summarized by James A. Whitney

INTRODUCTION (U)

(C) The BEARING STAKE Exercise was conducted at five (5) selected sites in the Northwestern Indian Ocean from 13 January to 4 May 1977. Figure 1 gives the locations of those sites. The purpose of this report is to summarize data for the RAYMODE X and FACT propagation loss model evaluation. SITE 1B (Gulf of Oman) and SITE 4 (Northern Solami Basin) have reasonably flat bottoms. Propagation loss data was obtained from hydrophones at various depths at both sites and will be considered for range-independent model evaluation. The sea floor at SITE 3 was flat but only acoustic data from bottom-mounted hydrophones was available. Data from SITES 2 and 5 as well as that from certain events for SITE 4 may be considered for range-dependent model evaluation. Table 1A summarizes the BEARING STAKE Exercise parameters.

(U) Table 1B summarizes oceanographic and meteorological data collected at each major acoustic site. Oceanographic data consisted of expendable bathythermograph (XBT) observations and sound velocity/salinity-temperature-depth (SV/STD) stations. XBTs are summarized by the maximum depth to which each trace was acceptable. Meteorological data included observations of wind speed, wind direction and sea and swell heights. In addition to Table 1B data, sea surface temperature was measured continuously by WILKES at SITES 1A, 1B, 3 and 4, and bathymetric data were collected by KINGSPORT, WILKES and MIZER throughout the exercise area. Bathymetric data along KINGSPORT acoustic tracks were depth corrected using Mathew's tables.

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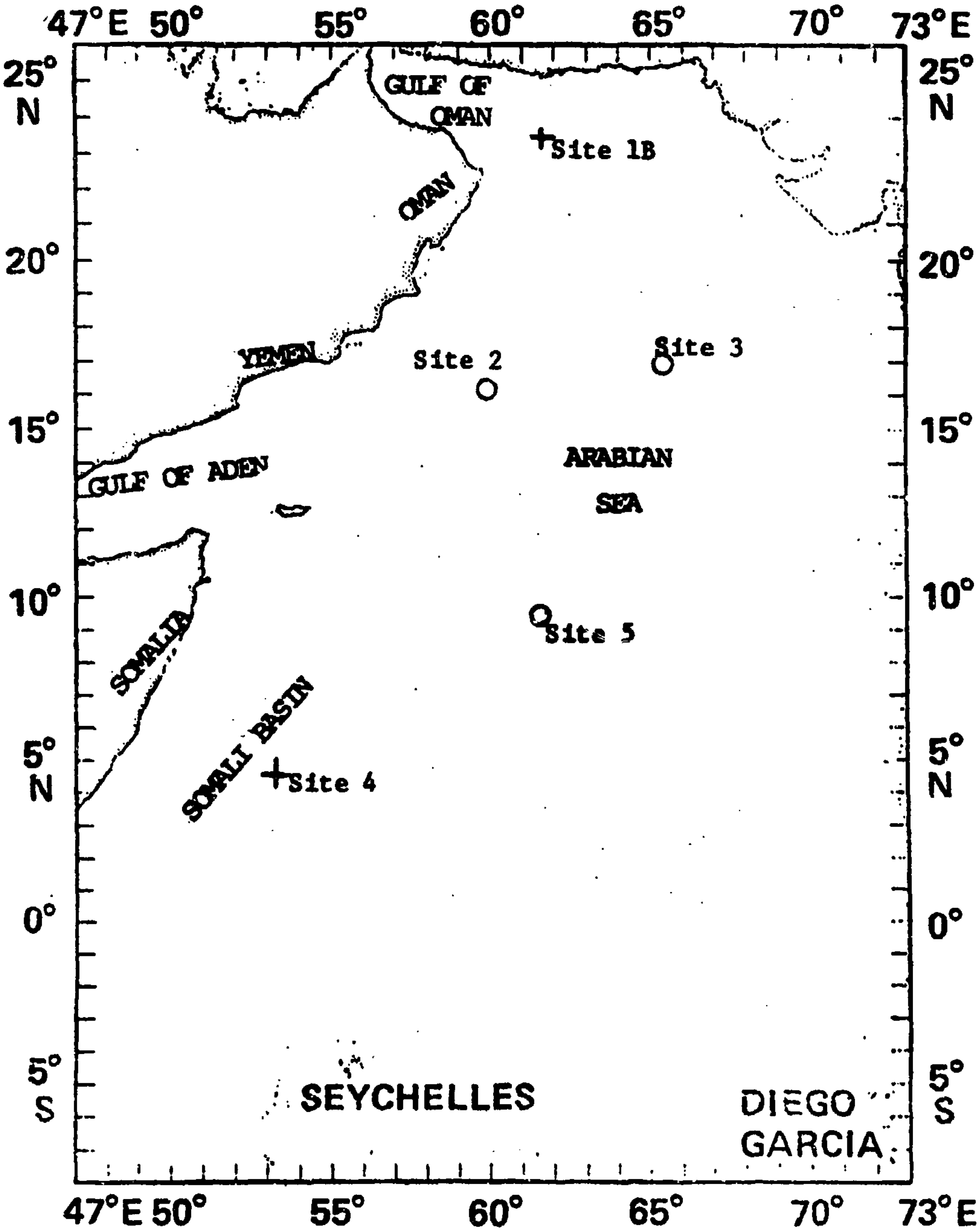

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Fig. 1 (C) Location of BEARING STAKE Exercise Sites

Table 1A

BEARING STAKE Exercise Parameters

Site	1B	1B	1B	1B	1B	1B	4	4	4
Array	BMA*	BMA	BMA	VAC	VAC	VAC	BMA	BMA	VAC
Event	S1	P1	P4	S1	P1	P4	S1	P1	P1
Freq (Hz)	20,50 140,300	25,140 290	39,140 290	20,50,125 315,500	25,140 290	39,140 290	20,50 140,300	25,140 290	25,140 290
Source depths (m)	18,91, 244	18,91	18,102	18,91,244	18,91	18,102	18,91, 244	18,91	18,91
Rec. Depths	Bottom	Bottom	Bottom	496,1685, 3321	496,1685, 3321,3351	496,1685, 3321,3351	4048, 4485, 4725	4048, 4485, 4725	400,1916 5076,5106
Min Range (km)	1.9, 11.3	2.0	4.0	6	6	12	0	16	6
Max Range (km)	292,280	296	130	288	288	122	333	324	308
Layer depth (m)	75	10	10	75	10	10	0	0	0
Depth Min. Sound Speed (m)	1676	1725	1725	1676	1725	1715	1785	1785	1785
Bottom Depth (m)	3350	3350	3350	3353	3351	3351	5105	5105	5106

Navigation - Satellite navigation with reconciled dead reckoning was used for vertical array data. Accuracy should be better than 1 nm.

The dead reckoning was not reconciled for the bottom mounted array data and range errors could accumulate to 3 nm between satellite fixes (reference 10).

CW Source Calibration - Over-the-side using calibrated hydrophone

SUS Source Levels - Gaspin and Shuler levels used (reference 4).

Environment - Propagation is typically bottom limited. See appendix 1.

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BMA - Bottom Mounted Array

VAC - Vertical ACODAC (array)

TABLE 1B.(U)Summary of BEARING STAKE Oceanographic Data

		No. of XBTs to Depth				
Ship	Site	200-600m	600-1500m	1500m	SV/STDs	Weather Observations
USNS KINGSPORT	1A	4	-	24	4	132
	1B	10	-	1	12	840
	2	1	10	0	1	108
	3	4	7	21	12	168
	4	2	25	25	13	288
	5	2	16	4	4	132
USNS MYER	1A	4	9	9	0	240
	1B	0	4	8	0	158
	2	1	3	9	0	192
	3	3	2	13	0	321
	4	0	4	14	0	332
	5	2	11	3	0	253
USNS WILKES	1A	1	4	1	5	0
	1B	3	4	13	5	0
	2	-	-	-	-	-
	3	9	12	36	6	0
	4	13	20	36	4	0
USNS MIZER	1B	7	6	6	2	96
	2	9	10	1	1	156
	3	20	10	2	5	96
	4	6	18	4	3	264
	5	2	4	0	3	156
HMAS DIAMANTIA	1B	20	0	0	0	13
	2	0	0	0	0	25
	3	12	0	0	0	13
	4	32	8	0	0	44
	5	21	4	0	0	29
TOTAL		188	202	230	80	

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(U) All XBT traces were machine digitized and converted to sound speed using Wilson's (Oct 1960) equation and a salinity field derived mainly from exercise SV/STD data. Generally, sound speeds calculated from XBT temperatures were up to 1.0 m/s higher than those measured directly and up to 0.5 m/s higher than those calculated from SV/STD data. Most of this error is attributable to XBT probe and recorder inaccuracies compounded by inaccuracies in Wilson's equation. However, measured and calculated sound speed gradients were nearly identical throughout the upper 2000-2500 m of the water column. Below about 3000 m depth, measured sound speeds were used to extend profiles used in all analyses. Data collection periods at SITE 1B and SITE 4 were 16-26 February and 9-26 March respectively. A summary of the sound speed and other environmental variability for the BEARING STAKE Exercise is reported in reference (1).

(C) Propagation loss data of interest at this time are the results of CW-and-SUS-charge source transmission runs (denoted as EVENTS P1, P4 and S1 respectively) received at the Bottom-Mounted Array (BMA) and the Vertical ACODAC Array (VAC). Acoustic results obtained at the BMA are reported in reference (2) while results from the VAC systems are reported in reference (3). Reference (3) also discusses bottom interaction and gives results for bottom-reflection loss. BMA data was obtained at all SITES and while the VAC was deployed at 1B, 3 and 4, useful data was obtained only at SITES 1B and 4.

(C) Propagation loss data from SITES 1B and 4 that are resident at NOSC (Code 724) were sent to NUSC (R. Lauer, Code 3122) via magnetic tape in June 1979. The element table for that tape (a computer listing accompanied the tape) was frequency and source-depth coded. The following will explain that code:

EVENT S1

ARRAY	VAC(V)	BMA(B)
Frequency #1	30 Hz	20 Hz
2	50	50
3	125	140
4	315	300
5	500	-

Source depths were 18, 91 and 244 meters

	Freq Code	Freq (Hz)	Source Depth
EVENT P1	LOW	25	91 m
	MED	140	18
	HI	290	18
EVENT P4	LOW	39	91 m
	MED	140	18
	HI	290	18

(C) Each file element (on the computer listing) has an assigned sequence number. The parameter tables (see RESULT section) will refer to the appropriate sequence number rather than the file element. For example: sequence #50 is element 1BKBS15FR209 which is the data run for SITE 1B, Array BMA, EVENT S1, Hydrophone #5, Frequency 2 (50 Hz), and source depth 91 meters. There are 139 propagation loss runs to be summarized. A limited number of these runs will be presented for illustration of propagation loss vs range.

GENERAL (U)

TRANSMISSION EVENTS (U)

(C) Western Electric Company (WeCo) conducted long-range transmission events from USNS KINGSPORT (T-AG-164) at each site. Two CW-projectors were used: a Honeywell H-29 transducer towed at 18 m was used at the higher frequencies (140 and 290 Hz) while a MK-6 projector towed at 91 m was used at frequencies 25 and 39. Sources were calibrated over-the-side utilizing a calibrated hydrophone. The CW EVENTS P1 and P4 were along radial tracks from the SITE position. The projector schedule was eight (8) minutes on and two (2) minutes off. Source levels used in computing propagation loss are given below.

Projector output levels (U)

Site	Freq (Hz)	Depth (m)	Level (dB//μPa @ 1 m)
1B	25	91	190.0
1B	140	18	183.0
1B	290	18	182.0
4	25	91	190.0
4	39	91	193.5
4	140	18	186.5
4	290	18	182.0

(C) Explosive charges (SUS) were launched from KINGSPORT and detonated at depths of 18 m (60 ft), 91 m (300 ft) and 244 m (800 ft). The track of this EVENT S1 was along the same radial (but in the opposite direction) as EVENT P1. The output levels used in computing propagation loss in dB re 1 erg/cm^2/HZ @ 1 yd are those derived by Gaspin and Schuler (reference 4) and are currently assumed to be the best available estimates.

RECEIVING SYSTEMS: Bottom Mounted Array

(C) The bottom mounted array contains eight hydrophones and was installed at each site by USNS MYER (T-ARG-6). Hydrophone grouping and positioning varied at each site. Broadband signals from the hydrophones were transmitted to MYER via a 12-15 mile length of quadded cable and were immediately amplified and recorded on magnetic tape records in analog format.

(U) A simplified block diagram of the data recording systems aboard MYER is given in Figure 2. Signals received from the acoustic projectors were passed through wave analyzers with a nominal 1.0 Hz bandwidth and disolayed on graphic recorders having 8 second integration time. Eight data channels were processed simultaneously in this manner. Ambient noise displayed during the off periods (2 minutes out of every 10) was used to establish the signal-to-noise ratio of the data points. The eight (8) graphic recorder channels were read manually every 2 minutes and propagation losses are calculated for 1-Hz bandwidths centered on each of the four (4) frequencies for each CW projector event.

(C) The SUS signals were passed through a shot processor and displayed on graphic recorders. The shot processor contains eight (8) filters each having a fixed bandwidth of 18% of the center frequency (at 20 Hz the bandwidth is 40% of the center frequency). After filtering, the signals are squared and integrated to provide a measure of the total received energy. The output of each channel and associated attenuator settings are recorded on magnetic tape in digital format for subsequent data processing operations.

(U) Magnetic tape records of the shot processor outputs are reduced with an HP 2100 computer and associated peripherals. WECo software calculates propagtion losses for each SUS charge detonation, referenced to a 1-Hz bandwidth. Outputs from the computations include

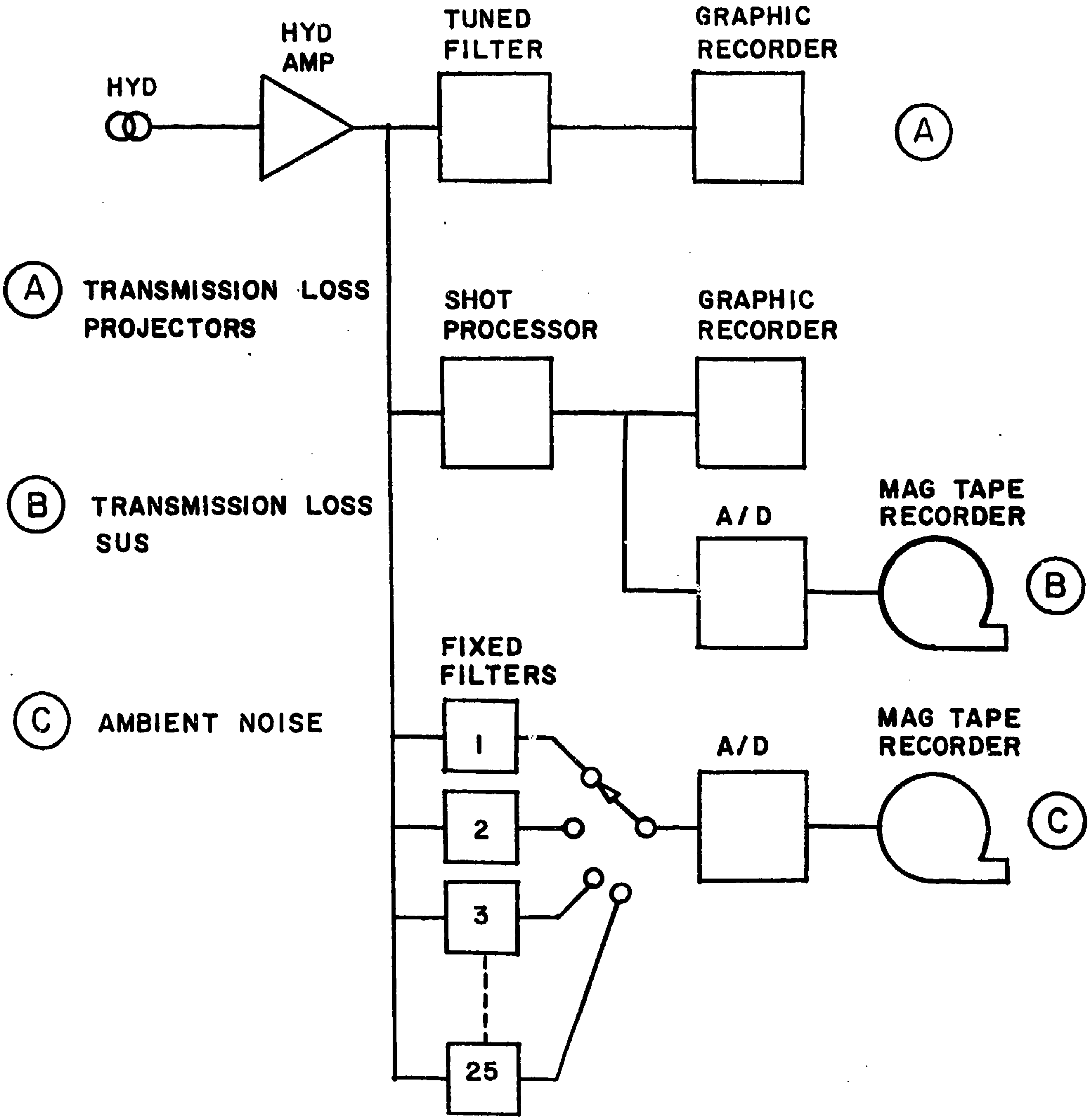


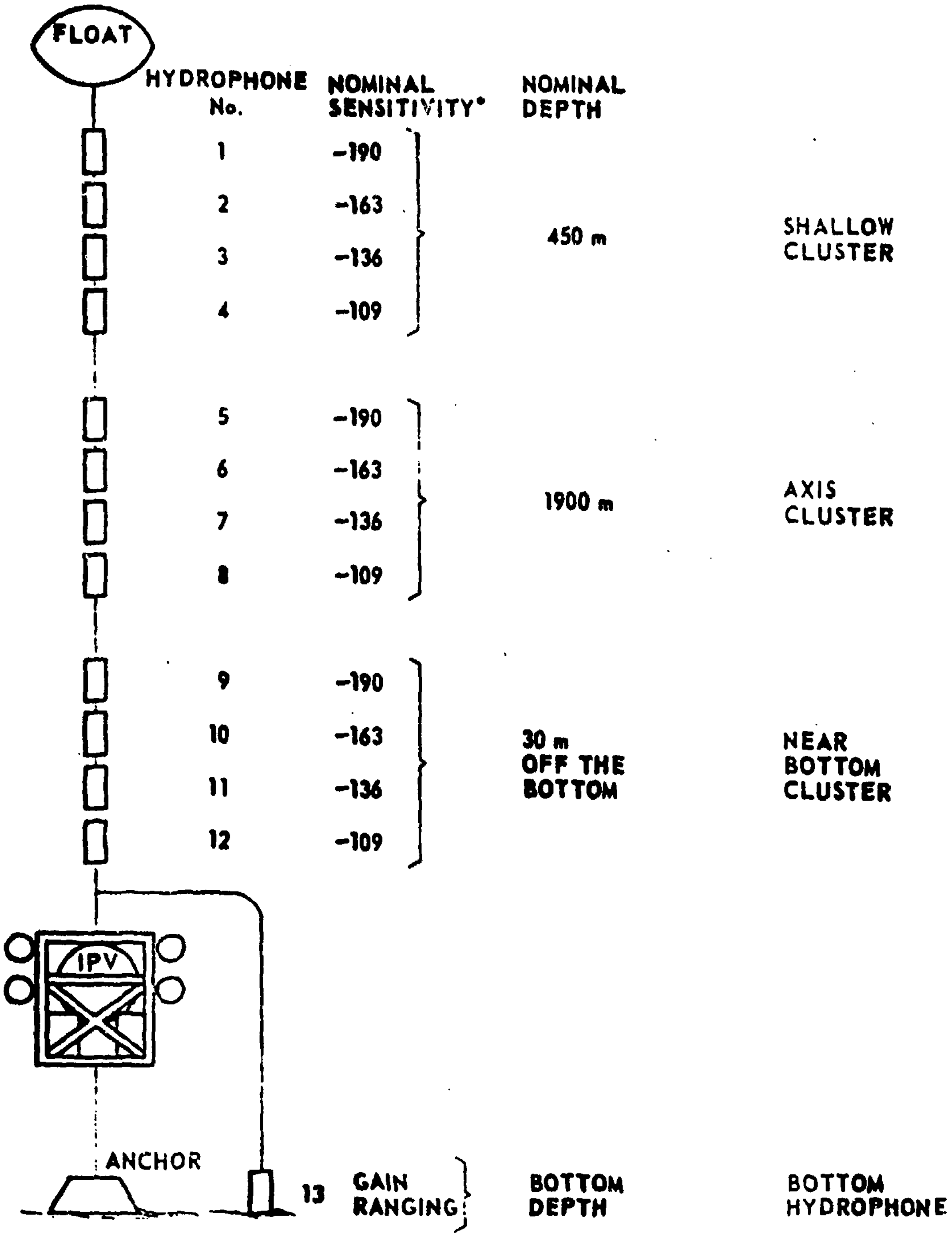
Figure 2 (U) Data Recording System, USNS MYER

a tabular listing of the individual propagation loss values, smoothed prop loss results (5 point running averages), source/receiver geometry descriptors and sequential shot number.

RECEIVING SYSTEMS: Vertical ACODAC (U)

(U) The Acoustic Data Capsule (ACODAC) System has been designed to make long term unattended recordings of ambient noise and signals in the ocean. ACODAC is an analog system. It can record up to 13.6 days in a continuous mode or up to several months by time selection. Typically, ACODAC consists of a hydrophone array, a sub-surface float that supports the array, a 40-inch diameter instrument pressure vessel (IPV) and battery power module in a main frame, acoustic releases and anchors.

(U) The BEARING STAKE configuration with 13 hydrophones employed in clusters at four (4) depths in the water column is shown in Figure 3. Nominal depths and hydrophone sensitivities are given. At three (3) depths, a wide dynamic range for recording was planned. The bottom hydrophone (located within 1 meter of the bottom is used exclusively for omnidirectional ambient noise measurements and is rigged to release to the bottom and is not recoverable. Each hydrophone (ITC 1010A) together with its associated preamplifier and lithium battery module is connected to a Kelvar electromechanical cable, which is the main structural member between all components. Minimum vertical separation was maintained between the four (4) hydrophones in each cluster. Cross talk between hydrophones was substantially reduced through the use of individual shielded pairs between the IPV ard each hydrophone.



*dB 1 V/μPa

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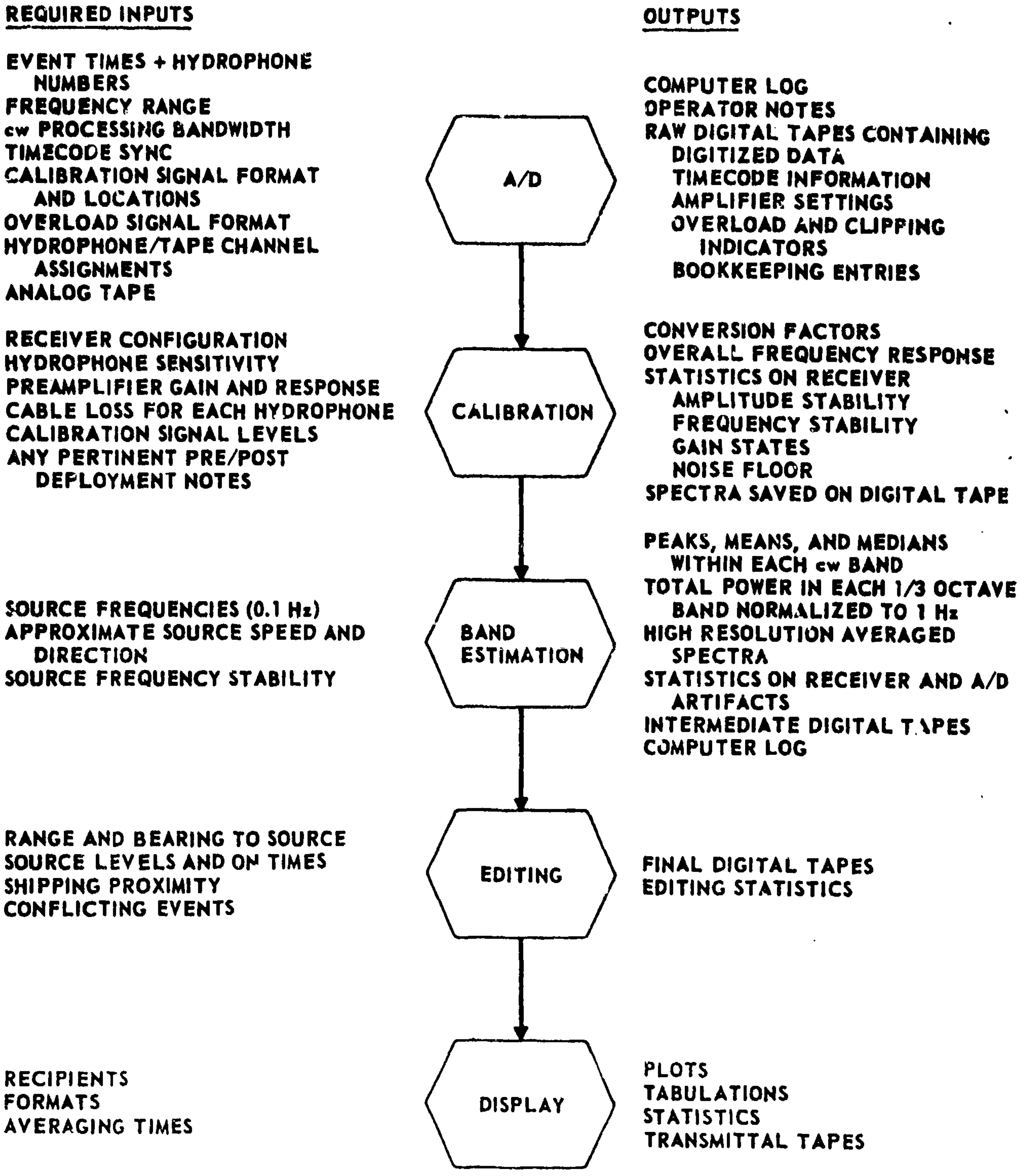
FIGURE 3.
VAC HYDROPHONE LOCATIONS AND THEIR SENSITIVITIES (U)

Detailed information concerning the VAC system including the criteria used to select the hydrophone depths and the data processing techniques and data products are found in reference 5. A discussion of the planning for bottom interaction measurements - VAC sensor placement, source depths, source patterns, etc. - are given in reference 6. Details of the VAC deployments and the acoustic source events are described in reference 7.

(C) The recorded data from the SUS charges undergo an analog-to-digital conversion followed by fast Fourier transform analysis (0.16 Hz resolution) of appropriate portions of the digitized data. The total propagation loss from each SUS charge to the receiving hydrophone is determined as a function of the separation distance (range). The signal from each SUS was reduced to propagation loss in one-third octave bands in 20 frequency bands. Shot arrival times and duration of the signals are also determined. Basic raw data will be contained on the VAC tape recordings during all KINGSPORT SUS events. Other data requirements include the shot deployment times (to +- 5.0 sec), navigation data (source-to-receiver range or position vs time) and representative SVP and bathymetry data along the propagation paths.

(U) The processing flow for the ARL/UT, AN/CW system is shown in Figure 4. The basic signal processing task of the system is to compute and calibrate a narrowband spectrum from contiguous time increments throughout the data period analysis. Currently, an 8192 pint FFT is used to provide a frequency resolution of 0.147 Hz for the frequency range of 10 to 600 Hz. The CW analysis is achieved



REQUIRED INPUTS		OUTPUTS
EVENT TIMES + HYDROPHONE NUMBERS FREQUENCY RANGE cw PROCESSING BANDWIDTH TIMECODE SYNC CALIBRATION SIGNAL FORMAT AND LOCATIONS OVERLOAD SIGNAL FORMAT HYDROPHONE/TAPE CHANNEL ASSIGNMENTS ANALOG TAPE	A/D	COMPUTER LOG OPERATOR NOTES RAW DIGITAL TAPES CONTAINING DIGITIZED DATA TIMECODE INFORMATION AMPLIFIER SETTINGS OVERLOAD AND CLIPPING INDICATORS BOOKKEEPING ENTRIES
RECEIVER CONFIGURATION HYDROPHONE SENSITIVITY PREAMPLIFIER GAIN AND RESPONSE CABLE LOSS FOR EACH HYDROPHONE CALIBRATION SIGNAL LEVELS ANY PERTINENT PRE/POST DEPLOYMENT NOTES	CALIBRATION	CONVERSION FACTORS OVERALL FREQUENCY RESPONSE STATISTICS ON RECEIVER AMPLITUDE STABILITY FREQUENCY STABILITY GAIN STATES NOISE FLOOR SPECTRA SAVED ON DIGITAL TAPE
SOURCE FREQUENCIES (0.1 Hz) APPROXIMATE SOURCE SPEED AND DIRECTION SOURCE FREQUENCY STABILITY	BAND ESTIMATION	PEAKS, MEANS, AND MEDIANS WITHIN EACH cw BAND TOTAL POWER IN EACH 1/3 OCTAVE BAND NORMALIZED TO 1 Hz HIGH RESOLUTION AVERAGED SPECTRA STATISTICS ON RECEIVER AND A/D ARTIFACTS INTERMEDIATE DIGITAL TAPES COMPUTER LOG
RANGE AND BEARING TO SOURCE SOURCE LEVELS AND ON TIMES SHIPPING PROXIMITY CONFLICTING EVENTS	EDITING	FINAL DIGITAL TAPES EDITING STATISTICS
RECIPIENTS FORMATS AVERAGING TIMES	DISPLAY	PLOTS TABULATIONS STATISTICS TRANSMITTAL TAPES

FIGURE 4
ARL/UT AN/cw PROCESSOR FUNCTIONS

ARL - UT
AS-76-792
GEE - DR
7 - 14 - 76

by using the calibrated narrowband spectra to estimate the signal power in a given frequency band. For the low frequency data the following processing was used: The spectra are first averaged for a specified period. From these averages, two types of band estimates are obtained. For each CW signal, a narrowband (+- 0.5 Hz) centered about the source frequency is searched for its spectral peak line. The signal power in a narrowband (.22 Hz) centered about this peak is then determined. Peak tracking is used to compensate for any DOPPLER variation in source frequency which might occur. The second type of band estimate determines the ambient noise power in a wider band (4 Hz) associated with each source frequency. In computing propagation loss, the signal power is corrected for the noise power component. For the high frequency (140 and 290 Hz) data, the power in a 5-Hz band centered about the source frequency is used to estimate the signal power, while the power in a 20-Hz band is used to estimate the ambient noise level.

(U) The following outputs of the processor are available for analysis:

1. ambient noise spectra in narrow/or octave bands

2. CW signal power, noise power, and signal-to-noise estimation narrow frequency bands, and

3. propagation loss, noise power estimates, and signal-to-noise estimates vs range and/or time.

(U) Nominally five (5) independent spectra are averaged prior to output and computation of total propagation loss.

SOURCE-TO-RECEIVER RANGES (U)

(U) Source-to-receiver ranges for the CW EVENTS will be obtained from a magnetic tape that gives source-to-receiver range and bearing as a function of time (reference 5). This information is the result of a program which calculates the range and bearing between two platforms when one or both of them are moving. The program assumes a great circle course at constant speed and heading between satellite fixes. Satellite fixes occurred every 100 n mi on the average. The difference between the dead reckoned position and the new satellite position over this range could be as much as 3 n mi. Results of the position time history reconstructions are required as inputs to the range and bearing computation. Output data consist of:

1. names and positions of source and receiver,
2. bearing and range between them, and
3. event identification, including date and time.

(U) Navigation information collected during KINGSPORT SUS runs will be checked as described in the Data Analysis Plan (reference 5). After the data have been reconciled they are used as an input to a dead reckoning program. This program computes the geographical position of each SUS detonation from the reconciled ship navigational data and the SUS drop times. The positions calculated by this program are dead reckoned along a great circle path between each pair of navigational points assuming no source or speed changes. The outputs from the dead reckoning SUS program are a tape that presents detonation times and positions for both ships and aircraft. Source-to-receiver ranges are thus obtained.

RESULTS (U)

SITE 1B (U)

(C) SITE 1B was located at the mouth of the Gulf of Oman where the water depth was about 3300 m. The nominal position of the site, 23°33'N, 61°09'E, and the direction of the EVENTS P1, P4 and S1 are shown in Figure 5. The bottom along the radial track (EVENTS S1 outward and P1 inward bound) was fairly flat to a range of about 250 km into the Gulf (see Figure 6). The track of EVENT P4 was over a flat bottom into the Oman Basin. The depths of the eight (8) BMA hydrophones (taken from reference 2) and of the VAC hydrophones (from reference 3) are given in Table 2.

Table 2 (C) SITE 1B hydrophone depths

Hyd No.	Depth, BMA (m)	Depth, VAC (m)
1	3348	
2	3349	496
3	3350	
4	3350	
5	3350	
6	3351	
7	3351	1685
8	3351	
9 - 12	-	3321
13	-	3351

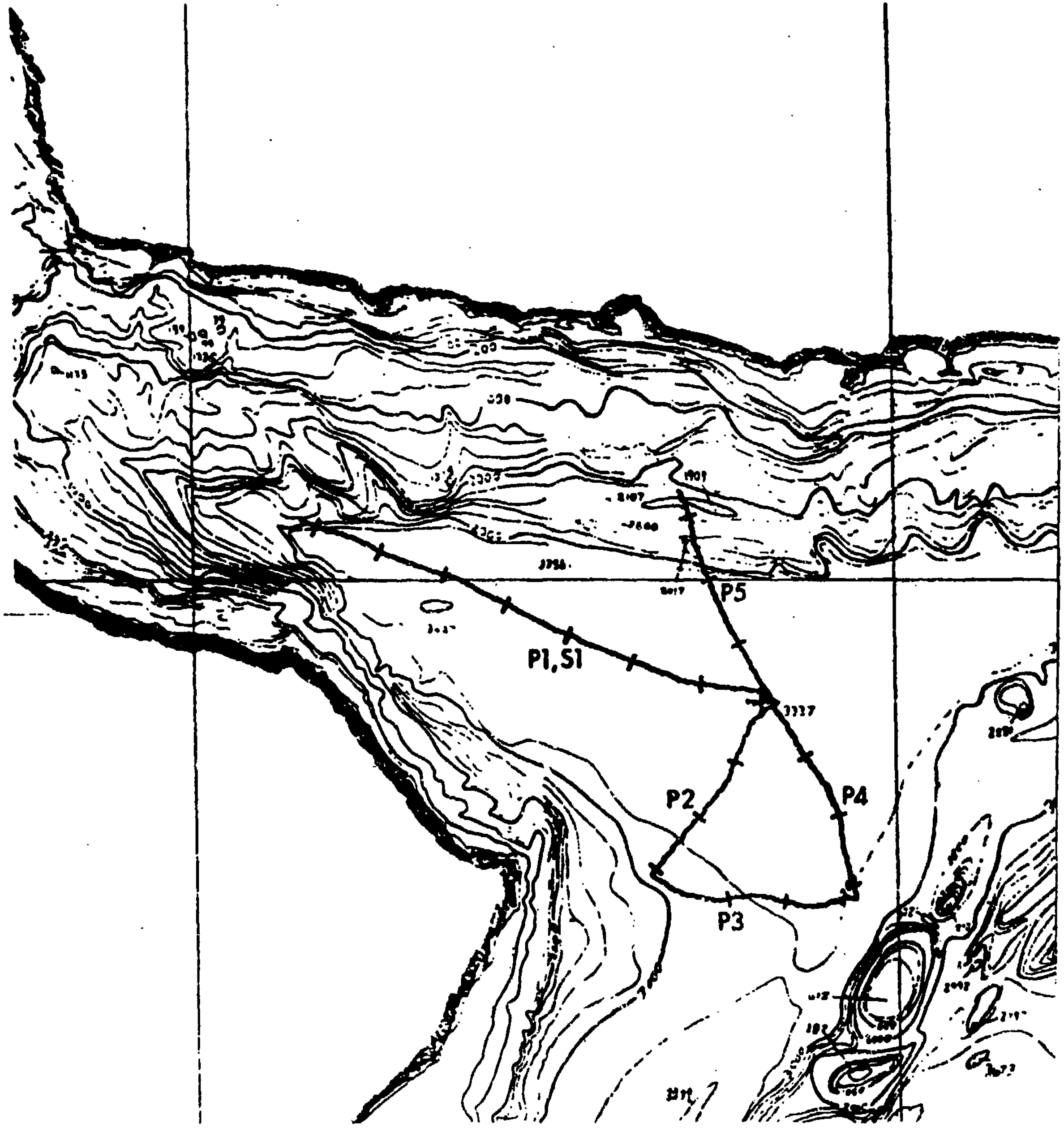


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FIGURE 5
KINGSPORT SOURCE TRACKS – SITE 1B (U)
TICK MARKS EACH 40 km FROM 1B

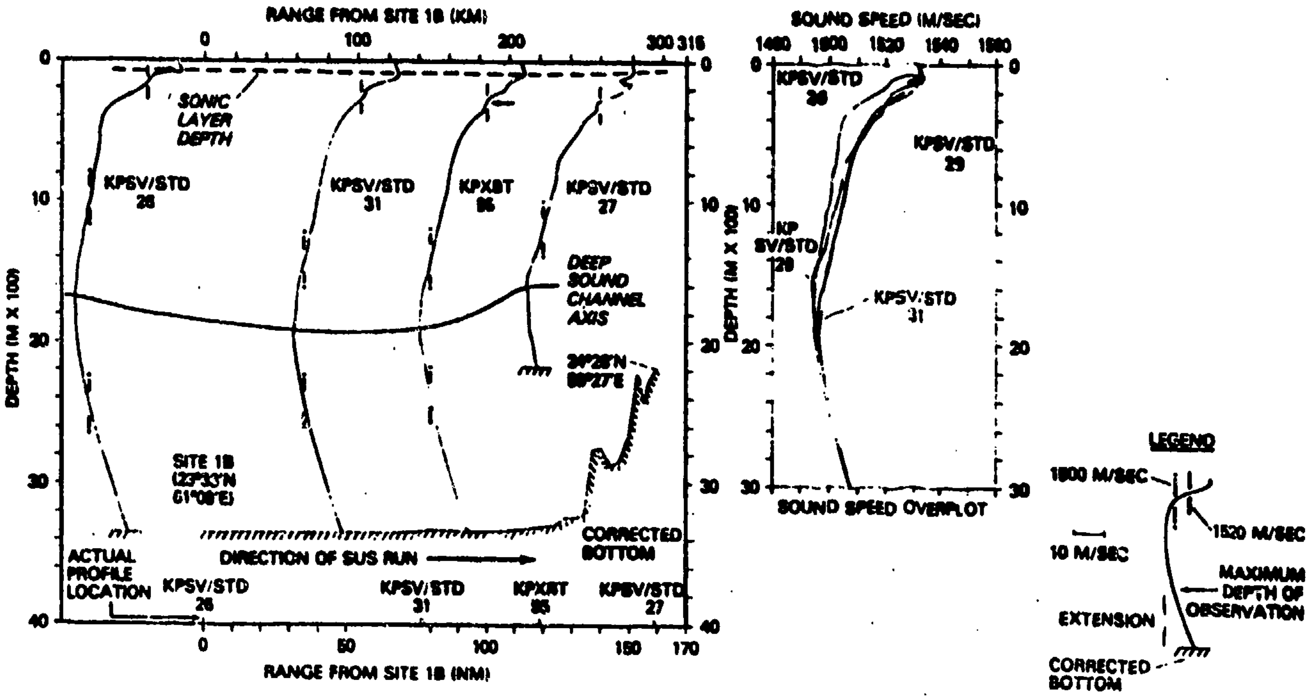

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Figure 6. (U) Sound speed structure along KINGSPORT S1 track at site 1B

(U) The representative sound speed profile for SITE 1B (from reference 1) is illustrated in Figure 7 and listed in Table 3. A surface layer depth (SLD) of about ten (10) meters was found and the deep sound channel axis (DSC) is at 1725 m. The corrected bottom depth is 3350 m. This sound speed profile is one taken near the site and should be used for EVENTS P1 and P4. This site was bottom-limited for both the near-surface (18-25 m) and sub-surface (91-102 m) sources. The critical depth deficiency was at least 1000 m. EVENT P1 was conducted from Feb 19/1030 to Feb 20/1000 to a maximum range of 200 km. EVENT P4 was conducted Feb 20, 1115 to 2130, maximum range 120 km.

(U) For the time of EVENT S1 (Feb 18/1600, to Feb 19/0530) the sound speed profile shown in Figure 8 and listed in Table 4 is typical. This profile has a SLD of 75 m with the DSC at 1676 m and bottom depth of 3353 m.

(U) Environmental survey data taken within a 37 km radius of SITE 1B on Feb 18-20 indicates wind speed variable from 4-7 knots, direction nearly 180°T, sea or wave height of 1 m with 2-m swells (this data obtained from Figure 4, reference 1).

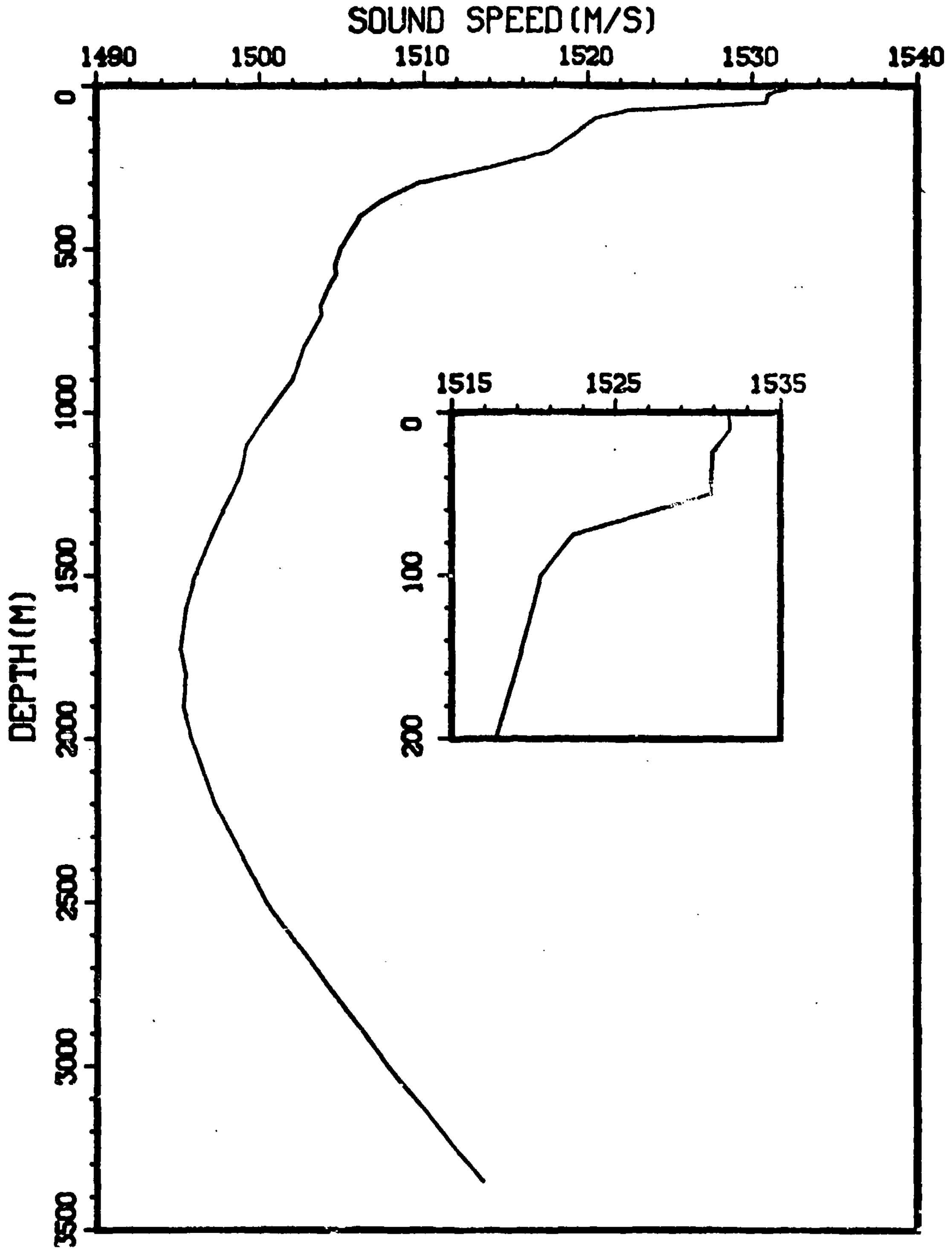

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Figure 7.(U) Representative Exercise Sound Speed Profile, SITE 1B.

(U) Table 3. Representative Exercise sound speed profile for SITE 1B, EVENTS P1 and P4 (U)

Depth (m)	Sound Speed (m/s)	Depth (m)	Sound Speed (m/s)
0	1531.9	700	1503.7
10	1532.0	800	1502.6
25	1530.9	900	1501.9
50	1530.8	1000	1500.5
75	1522.4	1100	1499.1
100	1520.4	1200	1498.6
150	1519.1	1300	1497.7
200	1517.7	1400	1496.8
250	1514.0	1500	1495.9
300	1509.5	1600	1495.3
350	1507.4	1725	1495.0
400	1506.0	1800	1495.3
500	1504.8	1901	1495.2
550	1504.5	2000	1495.7
575	1504.6	2200	1497.2
625	1504.0	2500	1500.3
675	1503.6	3000	1507.7
		3350	1513.5

UNCLASSIFIED

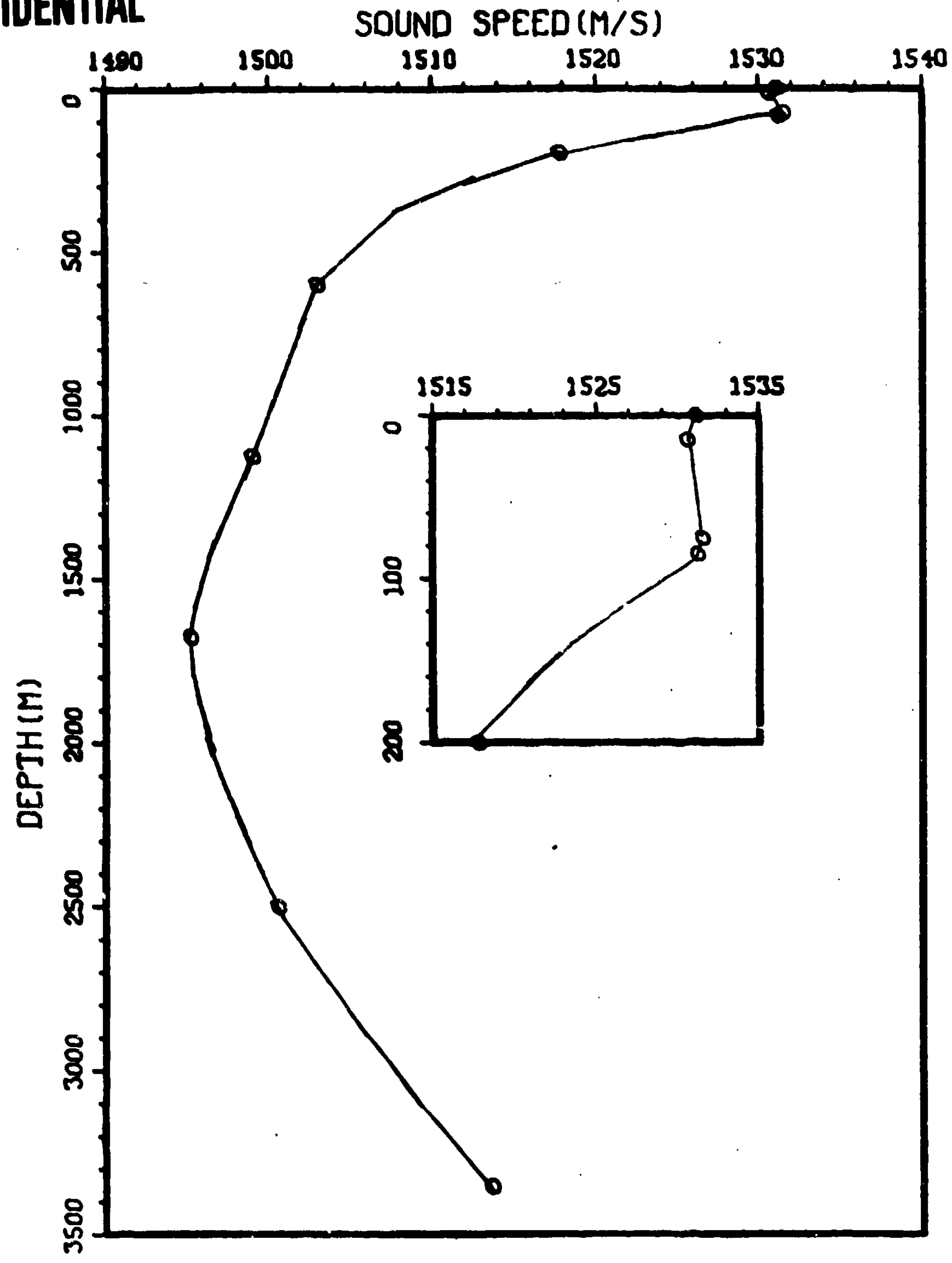

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Figure 8.(U) Typical Sound Speed Profile for Event S1, SITE 1B.

(U) Table 4. Sound speed profile for
EVENT S1, SITE 1B (U)

Depth (m)	Sound Speed (m/s)
0	1531.1
15	1530.6
75	1531.5
85	1531.3
120	1521.1
200	1517.8
600	1503.0
1125	1499.9
1676	1495.2
2500	1500.6
3353	1513.6

UNCLASSIFIED

SITE 4

(C) SITE 4 was located on the Chain Ridge in the Northern Somali Basin. The site, nominally 4°42'N, 53°10'E, and ridge structure is shown in Figure 9. Water depths on this northeast slope of the ridge were 4000-5000 meters. The bottom is reasonably flat at a depth of about 5100 m along the course (~ 275°T) of EVENT P1 to approximately 290 km at the continental rise (see Figure 10 which is Figure 26 of reference 1). The ACODAC receivers were located about 75 km from the foot of the slope along the track of EVENT P1 with hydrophone #13 on the floor of the basin (reference 7). The depth of the 8 BMA hydrophones (see reference 2) and of the 13 ACODAC hydrophones (from reference 3) are given in Table 5.

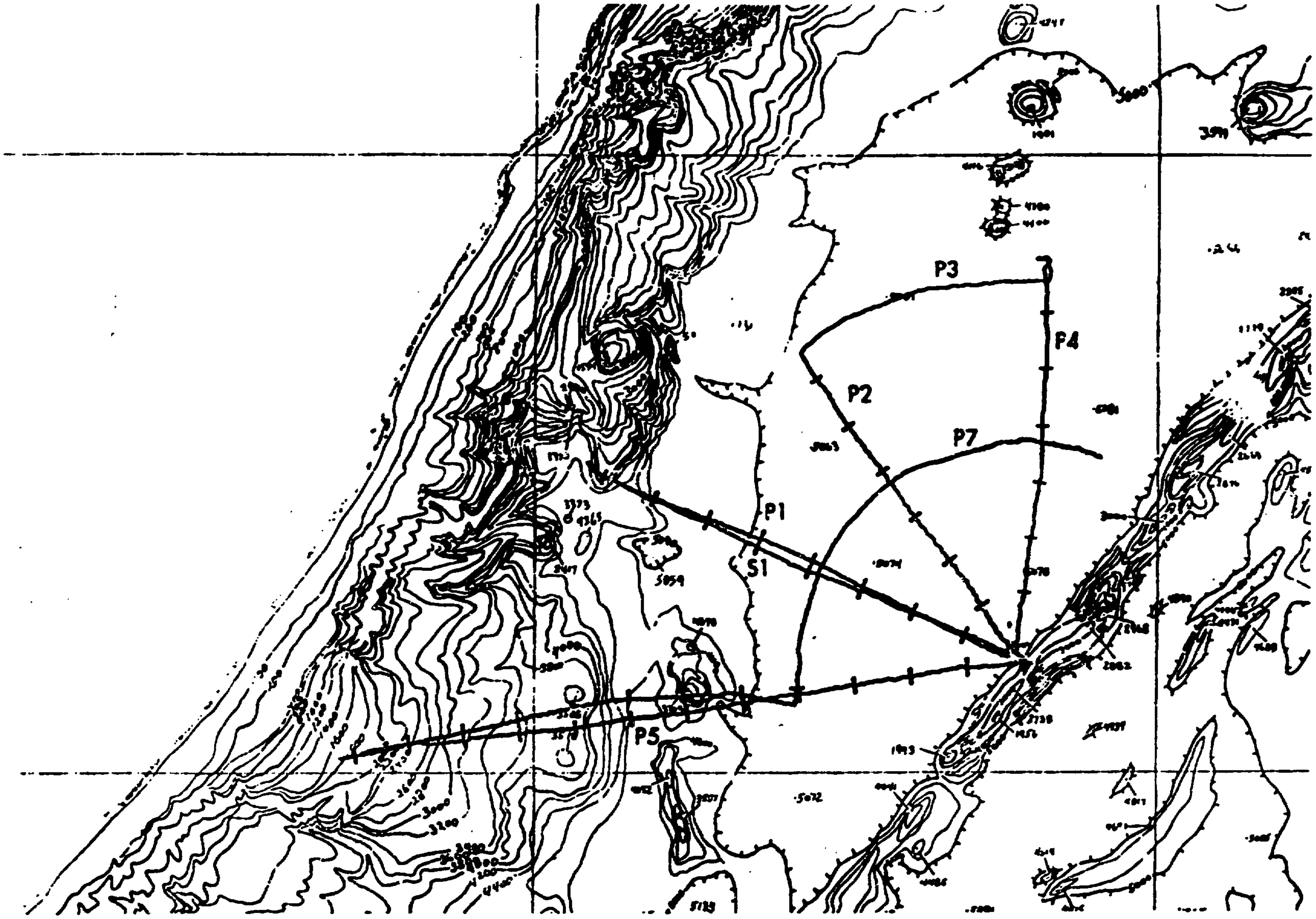

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FIGURE 9

KINGSPORT SOURCE TRACKS – SITE 4 (U)

TICK MARKS EACH 40 km FROM 4

ARL:UT
AS-78-102
KCF-GA
1-19-78

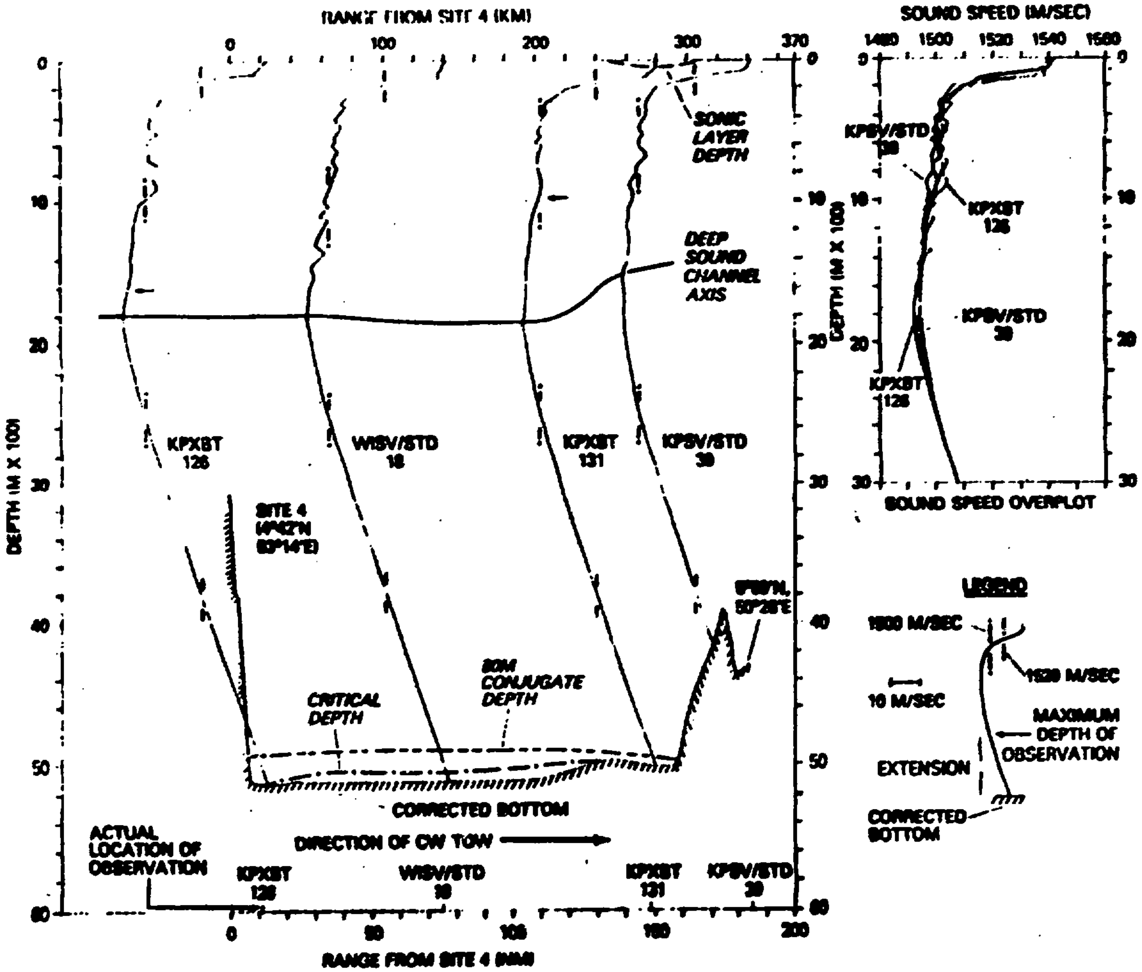

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Figure 10. (U) Sound speed structure along KINGSPORT P1 track at site 4

Table 5. (U)SITE 4 hydrophone depths

Hyd No.	Depth, BMA (m)	Depth, VAC (m)
1	4725	
2	4506	
3	4486	400
4	4468	
5	4464	
6	4235	1916
7	4048	
8	3778	
9 - 12	-	5076
13	-	5106

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(U) The representative sound speed profile for SITE 4 as given in reference 1 is shown in Figure 11 and listed in Table 6. EVENT P1 was conducted from Mar 13/0930 to Mar 14/1000 (maximum range 310 km) and EVENT S1 was conducted Mar 14/1510 to Mar 15/0630. For this limited time interval the sound speed profile shown in Figure 12 and Table 7 is a typical profile. This profile was taken about 140 km from the site along the track of EVENT P1. No surface layer was observed. The deep sound channel axis is at 1785 m and the corrected bottom depth is 5105 m. This bottom is near the critical depth: depth excess is about 60 m for the Table 7 profile. The 91 m conjugate depth was about 180 m shallower than the bottom. The underlined sound speeds are suggested for use in calculating propagation losses.

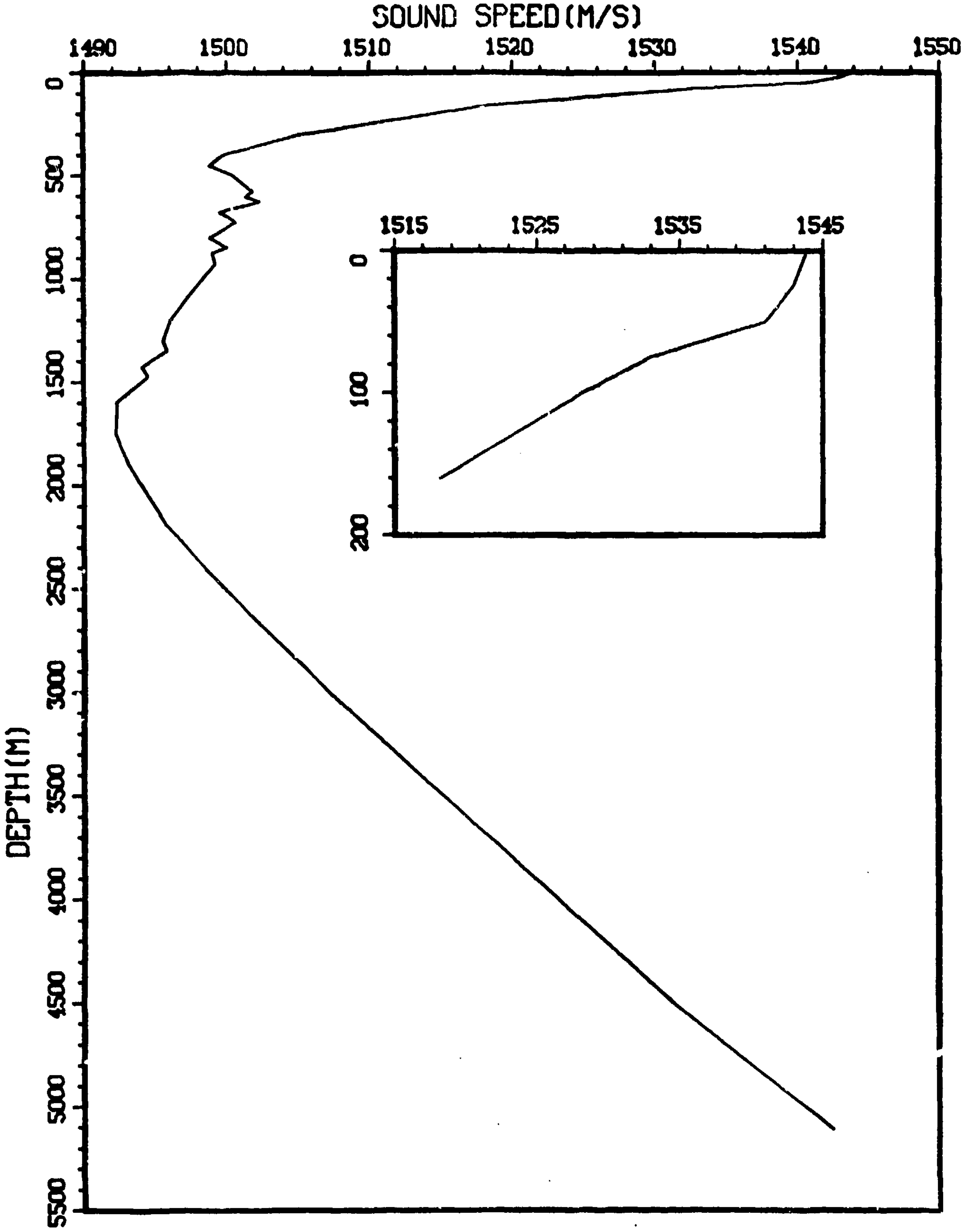

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Figure 11.(U) Representative Exercise Sound Speed Profile, SITE 4.

(U) Table 6. Representative exercise sound speed profile for SITE 4

Depth (m)	Sound Speed (m/s)	Depth (m)	Sound Speed (m/s)
0	1543.9	925	1499.3
25	1543.0	999	1498.4
50	1541.0	1098	1497.2
75	1532.9	1197	1496.1
100	1528.2	1297	1495.6
160	1518.2	1346	1495.9
201	1514.3	1421	1494.2
250	1509.4	1470	1494.6
300	1505.1	1595	1492.4
400	1499.3	1743	1492.3 DSC
450	1498.9	1892	1493.2
500	1500.5	1991	1494.1
575	1501.9	2189	1495.8
600	1501.4	2511	1500.1
625	1502.4	3004	1507.3
675	1499.6	3498	1515.2
726	1500.7	4012	1523.5
799	1498.9	4501	1531.4
849	1501.1	5106	1542.5 CBD
874	1499.1		

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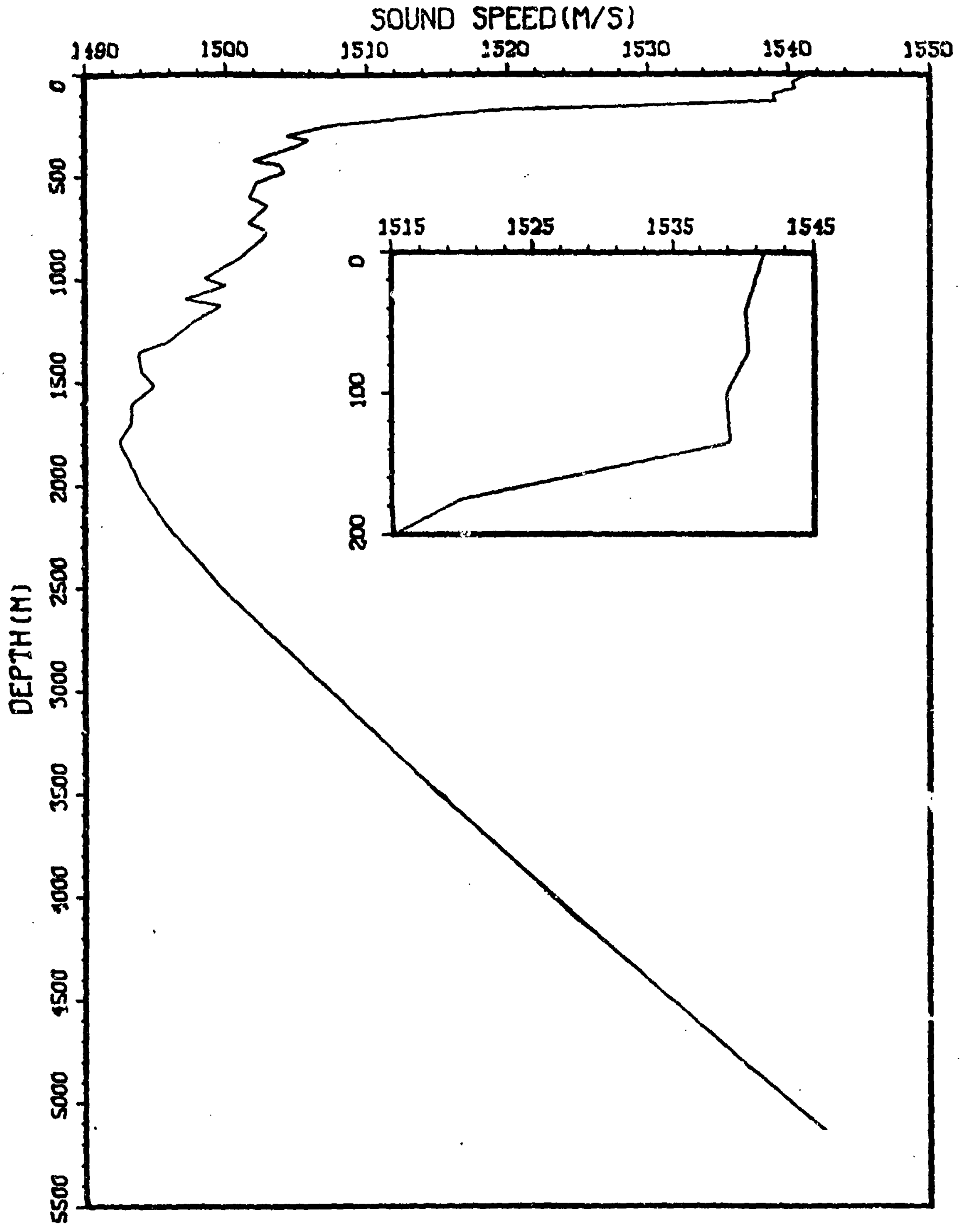

Figure 12.(U) Typical Sound Speed Profile for SITE 4.

(U) Table 7. Sound speed profile for EVENT P1 and EVENT S1, SITE 4

Depth (m)	Sound Speed (m/s)	Depth (m)	Sound Speed (m/s)
0	1541.5	990	1498.4
40	1540.3	1026	1500.0
70	1540.5	1092	1497.0
100	1538.9	1125	1499.6
135	1539.2	1200	1497.6
175	1519.9	1300	1495.8
200	1515.1	1350	1493.7
250	1507.2	1450	1494.0
300	1504.3	1510	1494.9
320	1505.9	1600	1493.2
350	1504.9	1700	1493.1
419	1501.9	1785	1492.3
441	1503.9	1900	1493.2
472	1504.2	2000	1493.9
527	1502.1	2200	1495.9
595	1501.6	2500	1499.7
635	1503.0	3000	1507.5
710	1501.5	3500	1515.2
760	1503.0	4000	1523.5
800	1502.5	4501	1532.1
900	1500.7	5105	1542.5

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(U) Throughout SITE 4 occupation, sound speed profiles showed extremely variable microstructure between about 300 and 1800 m (reference 1). This microstructure was caused by mixing of the following water masses:

1. High salinity Persian Gulf Intermediate Water (PGIW) with a core at 250 - 400 m.

2. Low salinity Subtropical Subsurface Water (SSW) at 400 - 500 m.

3. High salinity Red Sea Intermediate Water (RSIW) at 500 - 900 m.

4. Low salinity Antarctic Intermediate Water (AAIW) at 700 - 800 m,

and by sinking of RSIW as a result of this intermixing. A sporadic sonar layer frequently was present but was not a feature for EVENTS P1 and S1. Wind speeds averaged 5 m/s, direction about 190°T with 1 m seas and 2 m swells.

The Sea Floor (U)

(C) Geoacoustic models of the sea floor in these areas are given in reference 8. Most of the necessary environmental data were collected from the USNS WILKES (T-AGS-33). The Geoacoustic models for SITES 1B and 4 are given in the tables in the Appendix.

Bottom Reflection Loss (U)

(C) Bottom loss was measured along the SUS source tracks (EVENT S1) at SITES 1B and 4. The bottom loss was measured using multiple-reflection arrivals from sources at all ranges along the tracks: most measurements were made from arrivals reflecting three (3) or more times from the bottom. First and second bottom arrivals were often overloaded. The measurements from arrivals with different number of reflections were consistent at each site. The data processing uses both the propagation loss in shot arrivals and ray theory predictions of the arrival structure and propagation loss (reference 3). Figures 13 and 14 show representative bottom loss (per reflection) vs grazing angle for SITES 1B and 4 respectively. These curves are the averages of the results from the different receiver (ACODAC) and source depths used at each site. The bottom loss measurements were averaged over 2° grazing angle windows. At SITE 1B, there is a considerable depth deficiency (1000 m or greater) so that there is a minimum bottom reflection angle (depending on source depth). Note that there are higher bottom losses at SITE 4 than at SITE 1B, especially at the higher ? frequencies.

PROPAGATION LOSS RESULTS (U)

(C) The propagation loss results from EVENTS S1, P1 and P4 at SITE 1B are summarized in Tables 9, 10 and 11. Tables 12 and 13 summarize the propagation loss results for SITE 4. These tables give the significant parameters of frequency, source and receiver depths as well as minimum and maximum ranges and bottom depth for the appropriate

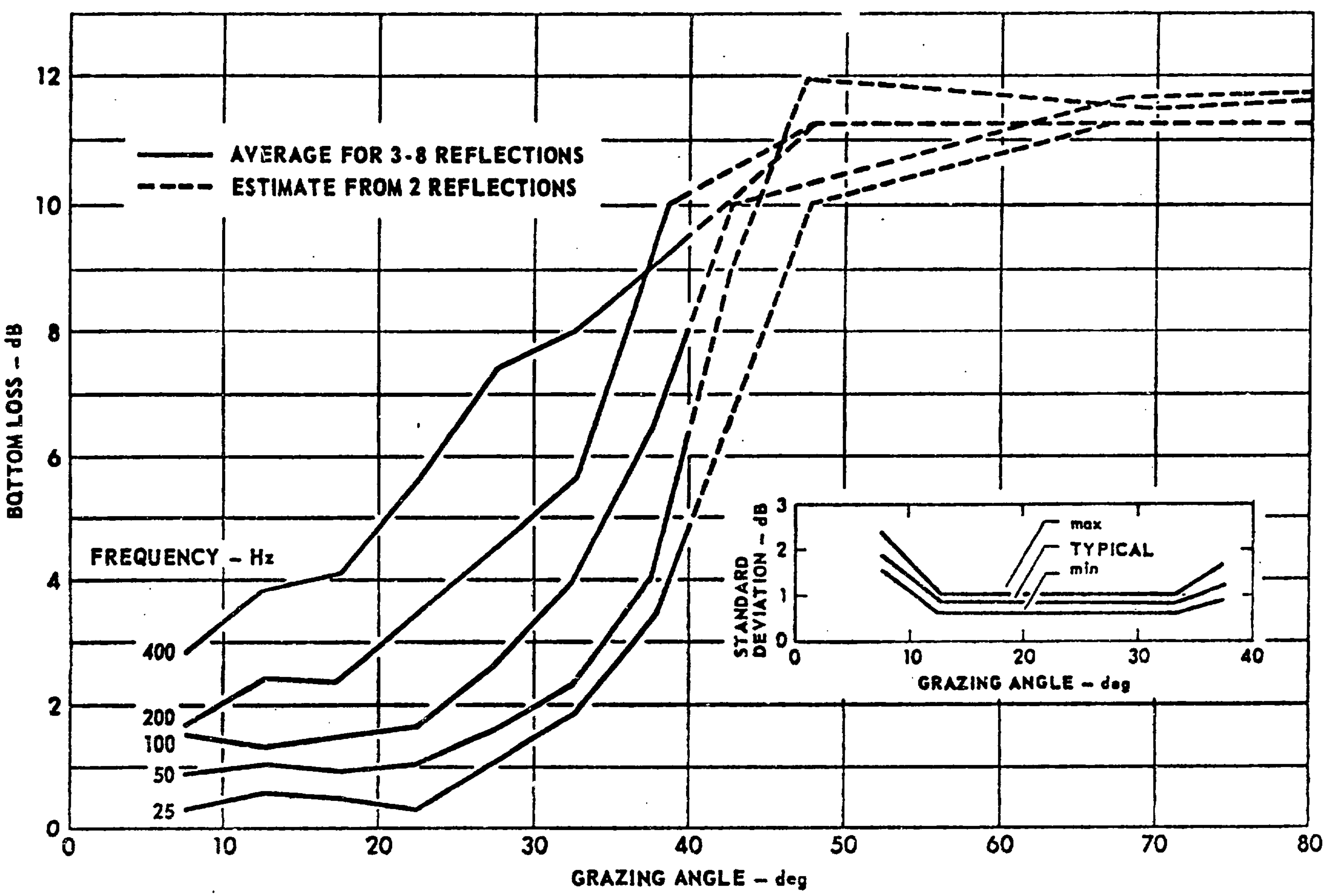

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FIGURE 13, (U)
REPRESENTATIVE BOTTOM LOSS – SITE 1B

ARL:UT
AS-78-57
SKM-GA
5-8-78

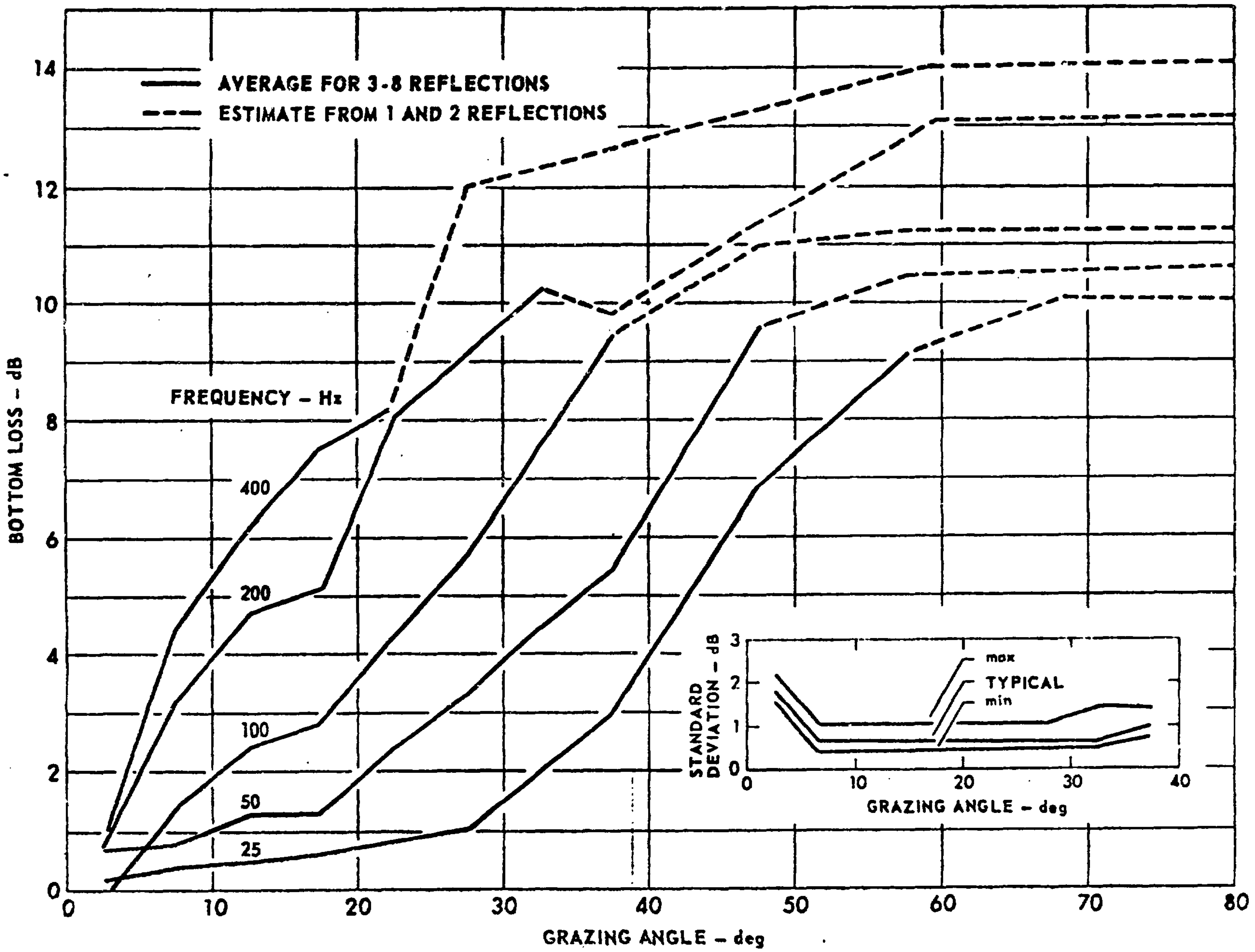

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FIGURE 14. (U) REPRESENTATIVE BOTTOM LOSS - SITE 4

Table 9. (U) BEARING STAKE Parameters, SITE 1B, Bottom Mounted Array

EVENT	S1	S1	S1	S1	S1	S1	S1	S1	P1	P1	P1	P4	P4	P4
Seq No.**	46-47	48	49-50	51	52-53	54	55-56	57	133	134	135	136	137	138
Fig.	-	-	15a,b	17a	-	-	16a,b	17b	18a	18b	18c	-	19a	19b
Freq (Hz)	20	20	50	50	140	140	300	300	25	140	290	39	140	290
Source Depths (m)	244, 91	18	244 91	18	244 91	18	244 91	18	91	18	18	102	18	18
Rec Depths (m)	3350*	*	*	*	*	*	*	3350*	3350*	*	*	*	*	3350*
Min Range (km)	1.9	11.3	1.9	11.3	1.9	11.3	1.9	11.3	2.0	2.0	2.0	4.0	4.0	4.0
Max Range (km)	292	280	292	280	292	280	292	270	296	296	296	130	130	130
Layer Depth (m)	75	→	→	→	→	→	→	75	10	10	10	10	10	10
Depth of Min Sound Speed (m)	1676	→	→	→	→	→	→	1676	1725	1725	1725	1725	1725	1725
Bottom Depth (m)	3350 meters	→	→	→	→	→	→	→	→	→	→	→	→	3350

**Refer to the element table correspondent to the taped runs
*Receiving hydrophones on the bottom.

(C) Table 10. (U) Parameters for BEARING STAKE Exercise, SITE 1B, VAC

EVENT	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Seq No.	1-3	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28-30	31-33	34-36	37-39	40-42	43-45
Fig.	-	20a	20b	20c	-	-	21a	-	21b	-	-	22	-	-	-
Freq (Hz)	20	50	125	315	500	20	50	125	315	500	20	50	125	315	500
Source Depths (m)	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244	18,91 244
Rec Depths (m)	496	496	496	496	496	1685	1685	1685	1685	1685	3321	3321	3321	3321	3321
Min Range (km)	8	8	6	6	6	8	8	8	6	6	8	8	6	6	6
Max Range (km)	284	284	288	288	284	284	284	284	288	288	288	288	284	284	284
Layer Depth (m)	A layer depth of 75 meters was observed for EVENT S1														
Depth of Min Sound Speed (m)	1676 →														1676
Bottom Depth (m)	Depth to bottom is assumed to be constant at 3353 meters.														

Table 11. (U) Parameters for BEARING STAKE Exercise, SITE 1B, VAC

EVENT	P4	P4	P4	P4	P4	P4	P1	P1	P1	P1	P1	P1
Seq No.	131-122	123-124	125-126	127-128	129-130	131-132	109-110	111-112	113-114	115-116	117-118	119-120
Fig.	24	25	-	-	-	-	-	-	23a,b	-	-	-
Freq ((Hz)	39	39	140	140	290	290	25	25	140	140	290	290
Source Depths (m)	102	102	18	18	18	18	91	91	18	18	18	18
Rec Depths (m)	496, 1685	3321, 3351	496, 1685	3321, 3351	496, 1685	3321, 3351	496, 1685	3321, 3351	496, 1685	3321, 3351	496, 1685	3321, 3351
Min Range (km)	12.0	12.0	12.0	12.0	12.0	12.0	6.0	6.0	6.0	12.0	12.0	12.0
Max Range (km)	122.0	122.0	122	122	122	122	288	288	286	288	288	280
Layer Depth (m)	10 ⟶					⟶	10	10	10	10	10	10
Depth of Min Sound Speed (m)	1725 ⟶					⟶	1725	1725	1725	1725	1725	1725
Bottom Depth (m)	Depth to bottom is assumed constant at 3350 meters											

Table 12. (U) BEARING STAKE Parameters, SITE 4, Bottom Mounted Array

EVENT	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	P1	P1	P1
Seq No.	58-60	61-63	64-66	67-69	70-72	73-75	76-78	79-81	82-84	85-87	88-90	91-93	94-96
Fig.	-	-	-	-	-	-	-	-	-	-	26	27	28
Freq (Hz)	20	50	140	20	50	140	300	20	50	140	25	140	290
Source Depths (m)	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	244, 91, 18	91	18	18
Rec* Depths (m)	4725	4725	4725	4485	4485	4485	4485	4048	4048	4048	4725 4485 4048	4725 4485 4048	4725 4485 4048
Min Range (km)	0	0	0	0	0	0	0	0	0	0	16	16	16
Max Range (km)	333	333	333	333	333	333	333	333	333	333	324	324	324
Layer Depth (m)	No consistent layer depth was observed at SITE 4.												
Depth of Min Sound Speed (m)	The sound axis depth for the representative sound speed profile for SITE 4 was 1785 meters.												
Bottom Depth (m)	Bottom depth is approximately 5105 meters to about 295 km along track.												

*Receiving hydrophones on ridge at SITE 4 location.

Table 13. (U) BEARING STAKE Parameters, SITE 4, VAC

EVENT	P1	P1	P1	P1	P1	P1
Seq No.	97-98	99-100	101-102	103-104	105-106	107-108
Fig.	0	29,30	31	-	-	-
Freq (Hz)	25	25	140	140	290	290
Source Depths (m)	91	91	18	18	18	18
Rec Depths (m)	400, 1916	5076, 5106	400, 1916	5076, 5106	400, 1916	5076, 5106
Min Range (km)	10	10	6	6	6	6
Max Range (km)	308	308	308	308	305	285
Layer Depth (m)	0	0	0	0	0	0
Depth of Min Sound Speed (m)	1785 →					1785
Bottom Depth (m)	Bottom depth is approximately 5105 meters to about 295 km along the track.					

SITE and EVENT. Reference to the data tape element (sequence number) and illustration (if any in this report) are also given. ACODAC data from EVENT S1, SITE 4 are not included since most receivers were overloaded by the first and second arrivals.

(C) Propagation loss data for the CW tows (EVENTS P1, P4), have been (pressure squared) averaged in 2 km bins, usually five (5) data points. The CW projectors were towed at 8 knots or 247 m/min and the data (BMA) was read every two minutes. Range accuracy is not discussed in the references and a rough estimate for the CW events might be 1 km. Data for the SUS runs (EVENT S1) is given at the rate of 1 per shot reception. The ranges here would be less accurate.

(C) Figures 15, 16, and 17 show propagation loss vs range for EVENT S1, SITE 1B and the Bottom Mounted Array (BMA), hydrophone No. 5. Figure 15a and 15b show 50 Hz propagation from two source depths, 244 m vs 91 m. Figures 16a and 16b show 300 Hz propagation for the same source depths. The 300 Hz data are considerably more variable and greater losses with the greater variability are shown for the 91 m source. Figures 17a and 17b compare 50 Hz data with 300 Hz data for the 18 m source depth.

(C) Figures 18 and 19 present propagation loss vs range for EVENTS P1 and P4 respectively at SITE 1B and hydrophone No. 5, BMA. Figures 18a, 18b and 18c contrast the data at the three frequencies for EVENT P1. Figures 19a and 19b show the propagation at 140 Hz and 290 Hz for EVENT P4.

(C) Figures 20-22 show propagation loss data obtained at the VAC receivers for EVENT S1 at SITE 1B, source depth 91 m. Figures 20a, 20b and 20c show the propagation losses for 50, 125 and 315 Hz respectively as received at Hydrophone 2 (496 m). Figures 21a and 21b compare losses at Hydrophone 6 (1685 m) for frequencies of 50 and 315 Hz respectively while Figure 22 shows 50 Hz propagation losses received at 3321 m, 30 m from the bottom. The propagation losses shown in Figure 15b (50 Hz, 91 m source to a bottomed receiver) show a greater range dependence than Figure 22 losses.

(C) Figures 23-25 will illustrate propagation loss vs range for EVENTS P1 and P4 for VAC receivers at SITE 1B. Figures 23a and 23b contrast propagation losses at 140 Hz as received at two (2) different hydrophone depths, 496 m and 1685 m respectively. Propagation losses at 39 Hz, EVENT P4, are shown in Figure 24 for the axis receiver (1685 m) and in Figure 25 for the receiver at 3321 m, 30 meters from the bottom.

(C) Figures 26 - 31 give propagation losses vs range for EVENT P1 at SITE 4. This site showed a small depth excess for EVENT P1 and convergence zone propagation is seen at the two higher frequencies 140 Hz (Figure 27) and 290 Hz (Figure 28) but is not so evident in Figure 26 at 25 Hz. Propagation losses at 25 Hz as seen at the VAC receivers are shown in Figure 29 (5076 m receiver depths) and Figure 30 (receiver depth is within 1 m of the bottom). Note the absence of convergent zones. Figure 31 shows 140 Hz propagation losses to an axis receiver at 1916 m.

(U) In general the SUS data (EVENT S1) for all sites has slightly greater propagation losses than the corresponding CW data. Site 1B showed generally lower losses than the other locations. Detailed discussion of propagation loss for the BEARING STAKE SITES is found in reference 9 as well as references 2 and 3.

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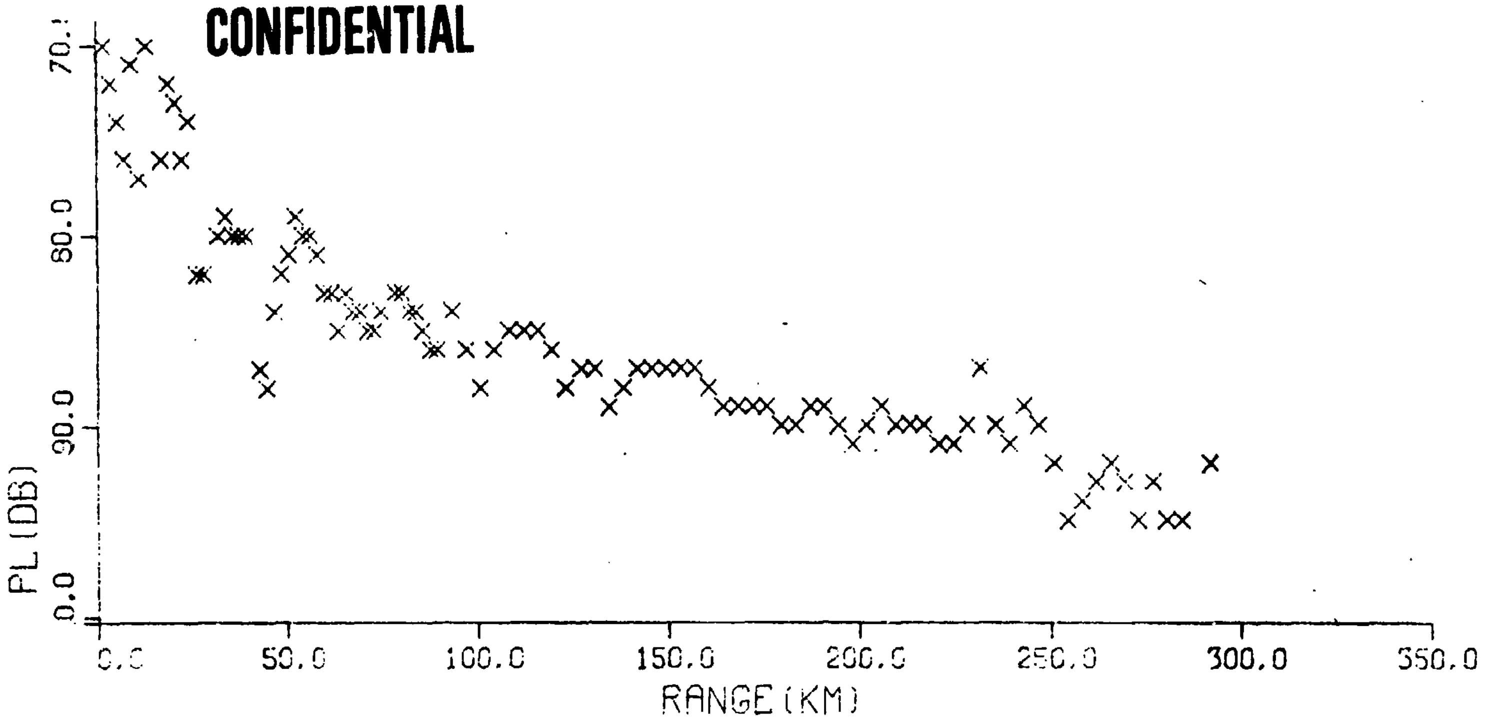

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Figure 15b.(C) Propagation Loss vs Range at 50 Hz, Event S1, Site 1B, Source depth 91 m and Bottomed receiver. Tape Sequence #50

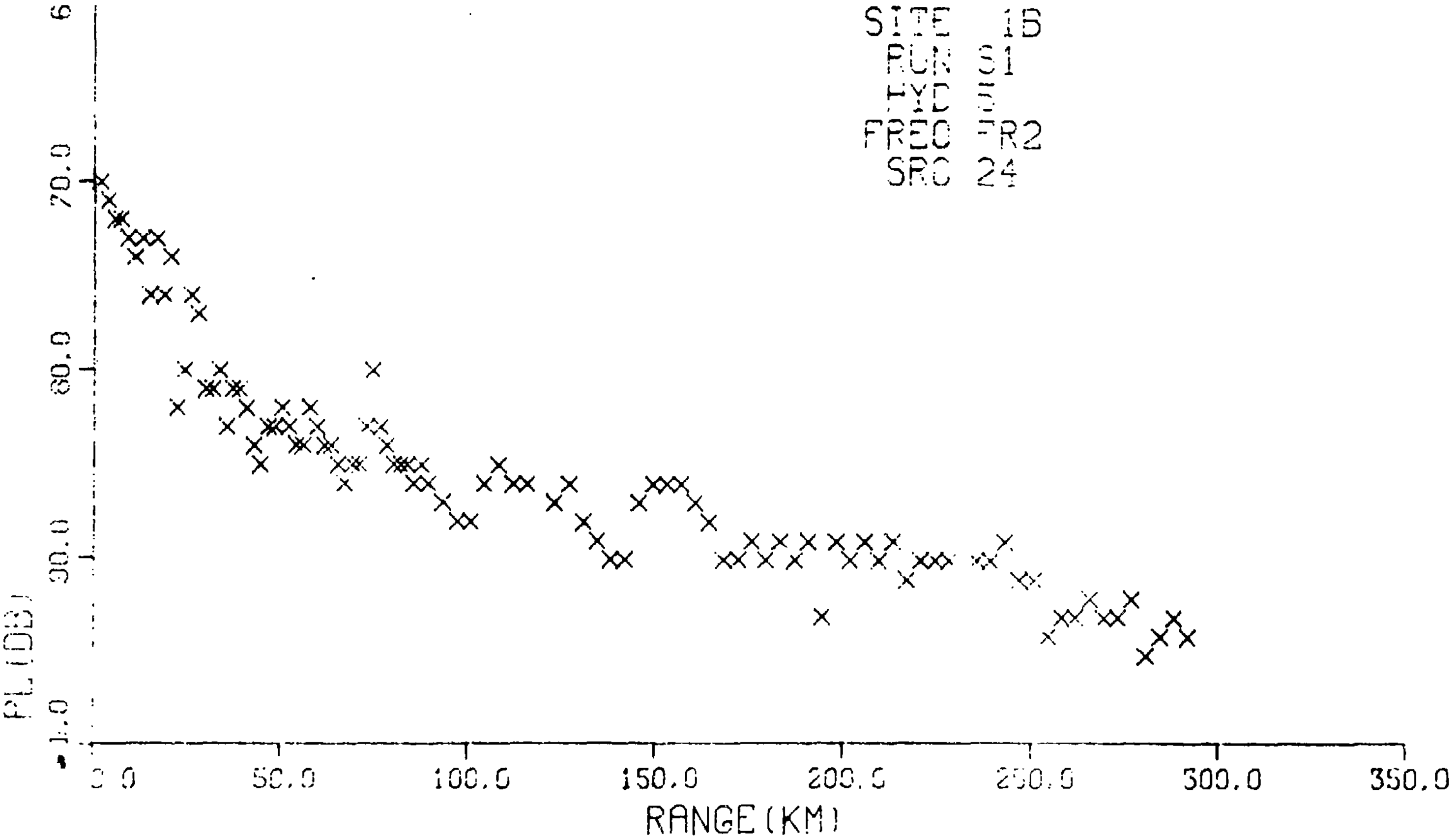

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Figure 15a.(C) Propagation Loss vs Range at 50 Hz for Event S1, Site 1B, Source depth 244 m & Bottomed receiver. Tape Sequence #49

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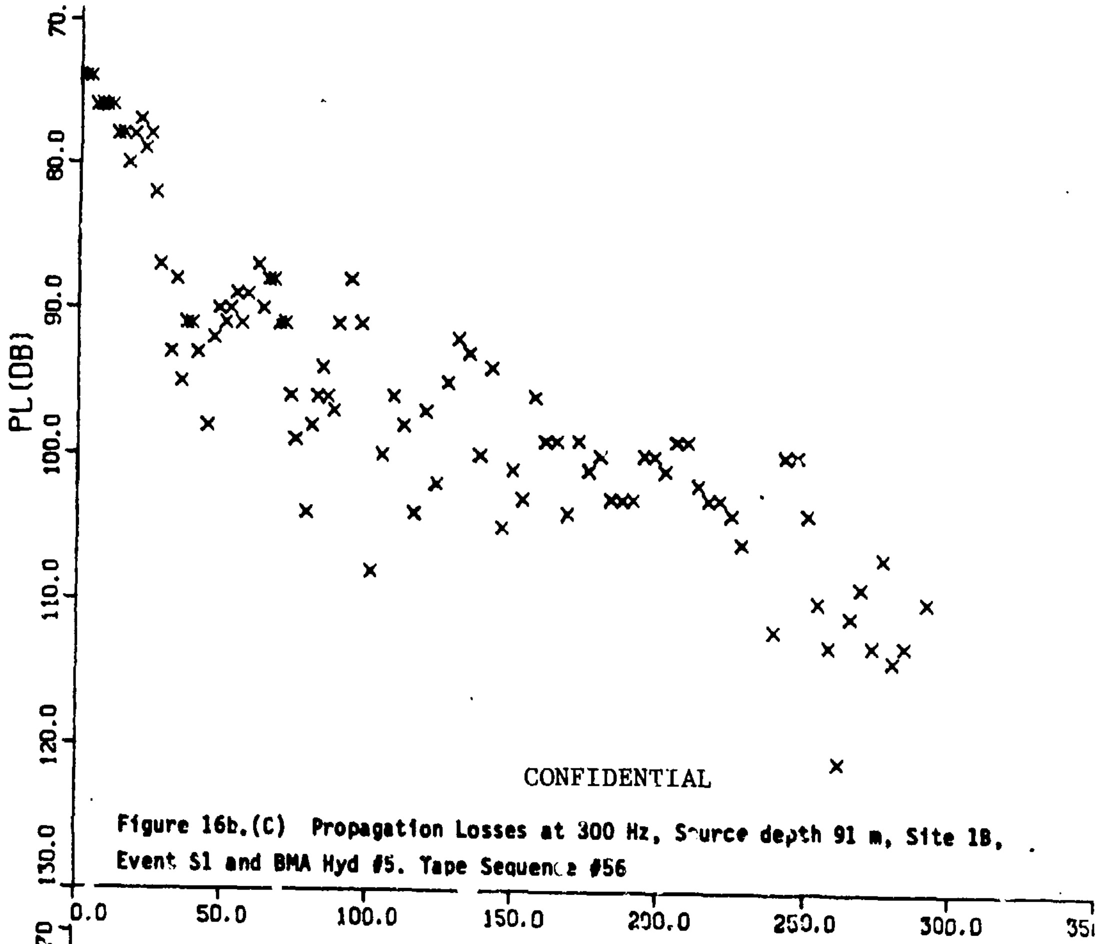

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Figure 16b.(C) Propagation Losses at 300 Hz, Source depth 91 m, Site 1B, Event S1 and BMA Hyd #5. Tape Sequence #56

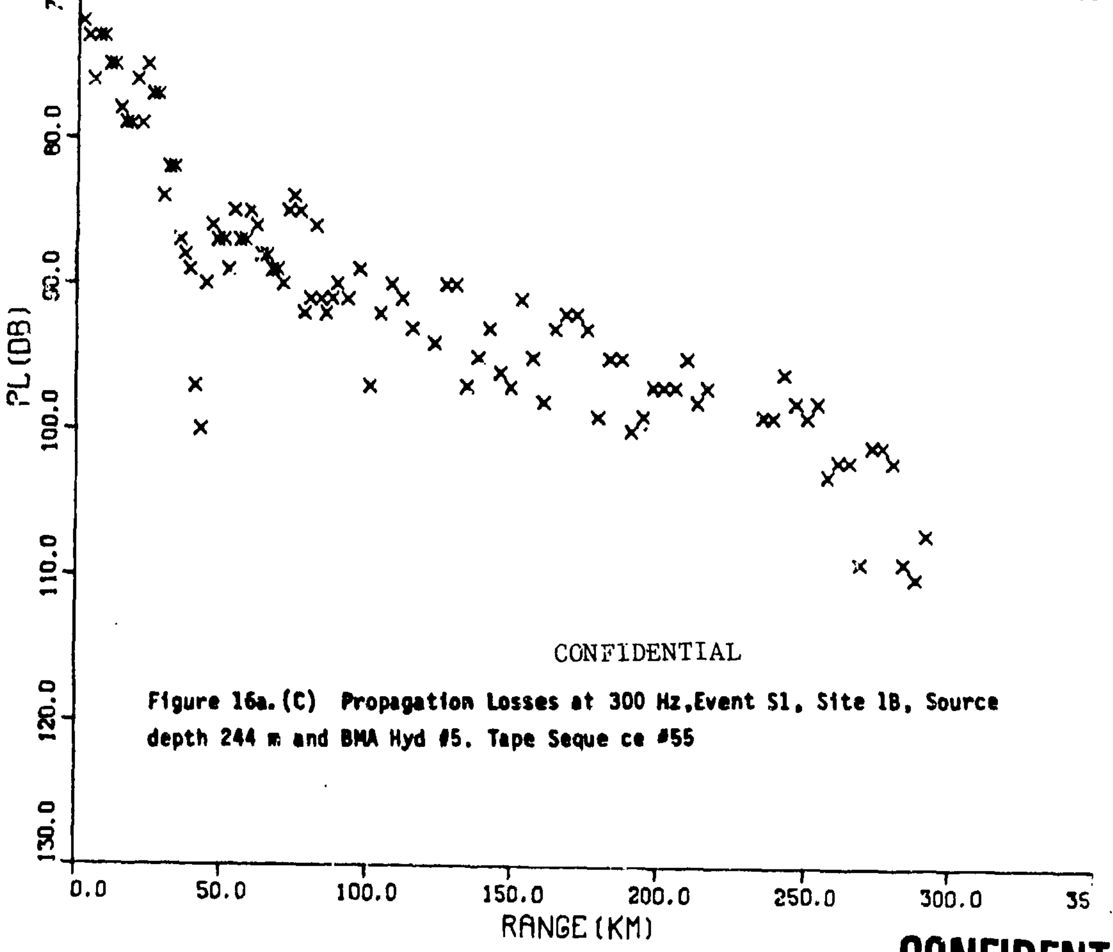

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Figure 16a.(C) Propagation Losses at 300 Hz, Event S1, Site 1B, Source depth 244 m and BMA Hyd #5. Tape Sequence #55

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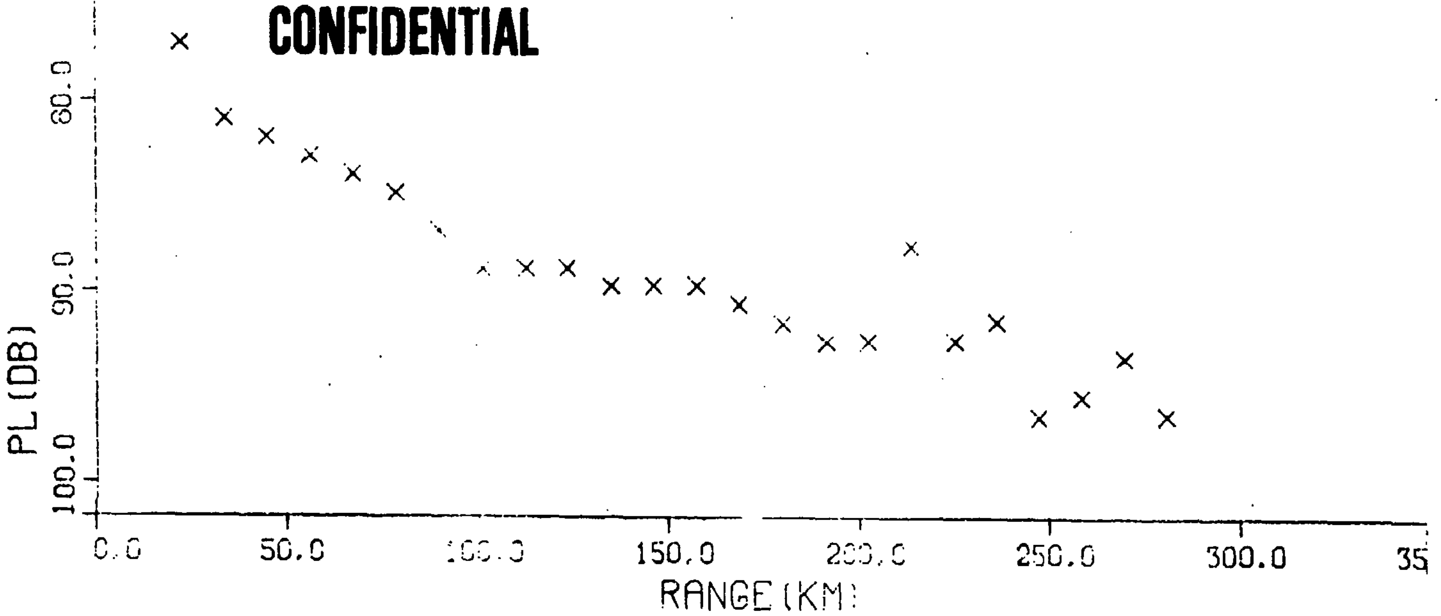

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Figure 17a. (C) Propagation Losses at 50 Hz, Source depth 18 m, Event S1, Site 1B and BMA Hyd #5. Tape Sequence #51

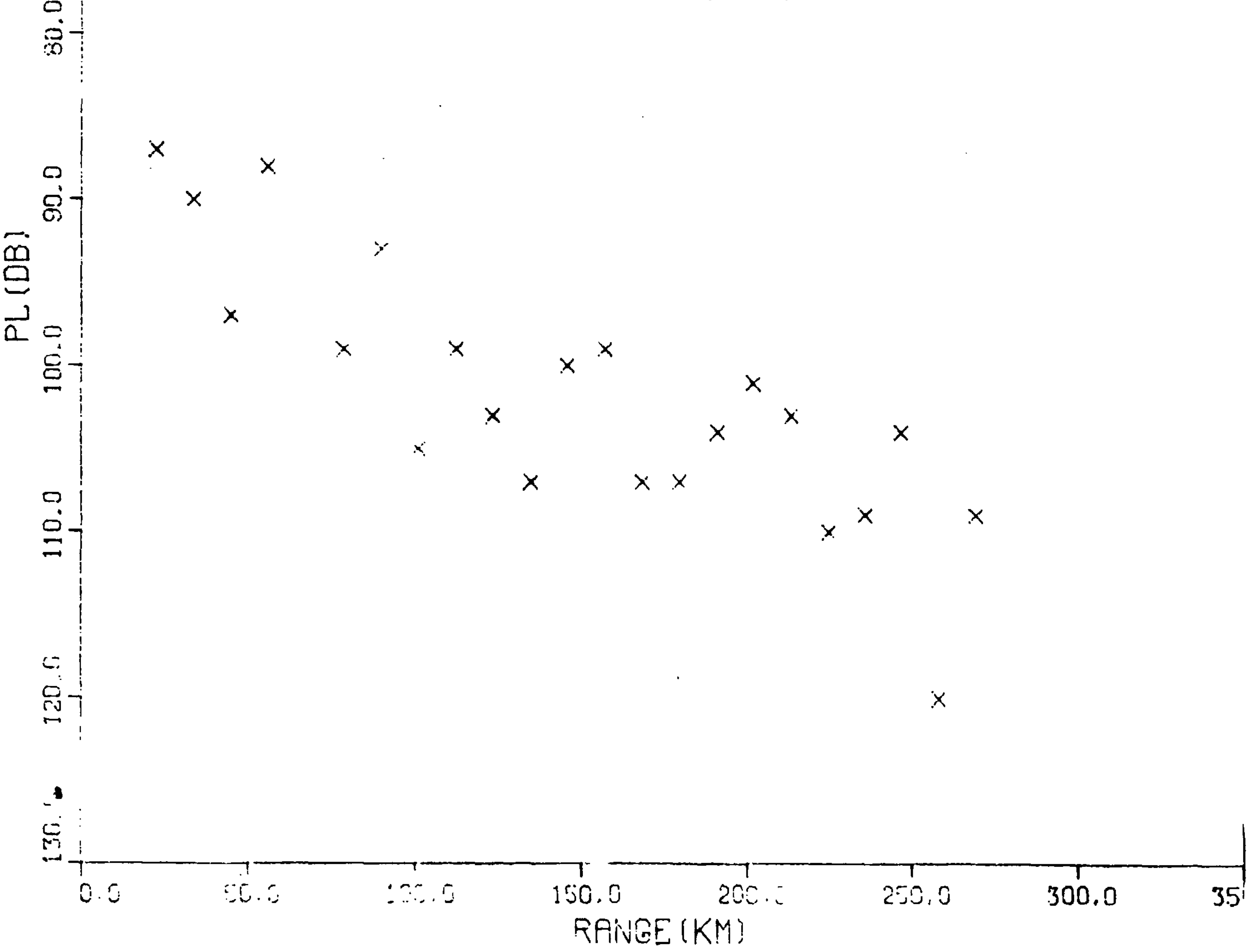

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Figure 17b. (C) Propagation Losses at 300 Hz, Source depth 18 m, Event S1, Site 1B and BMA Hyd #5. Tape Sequence #57

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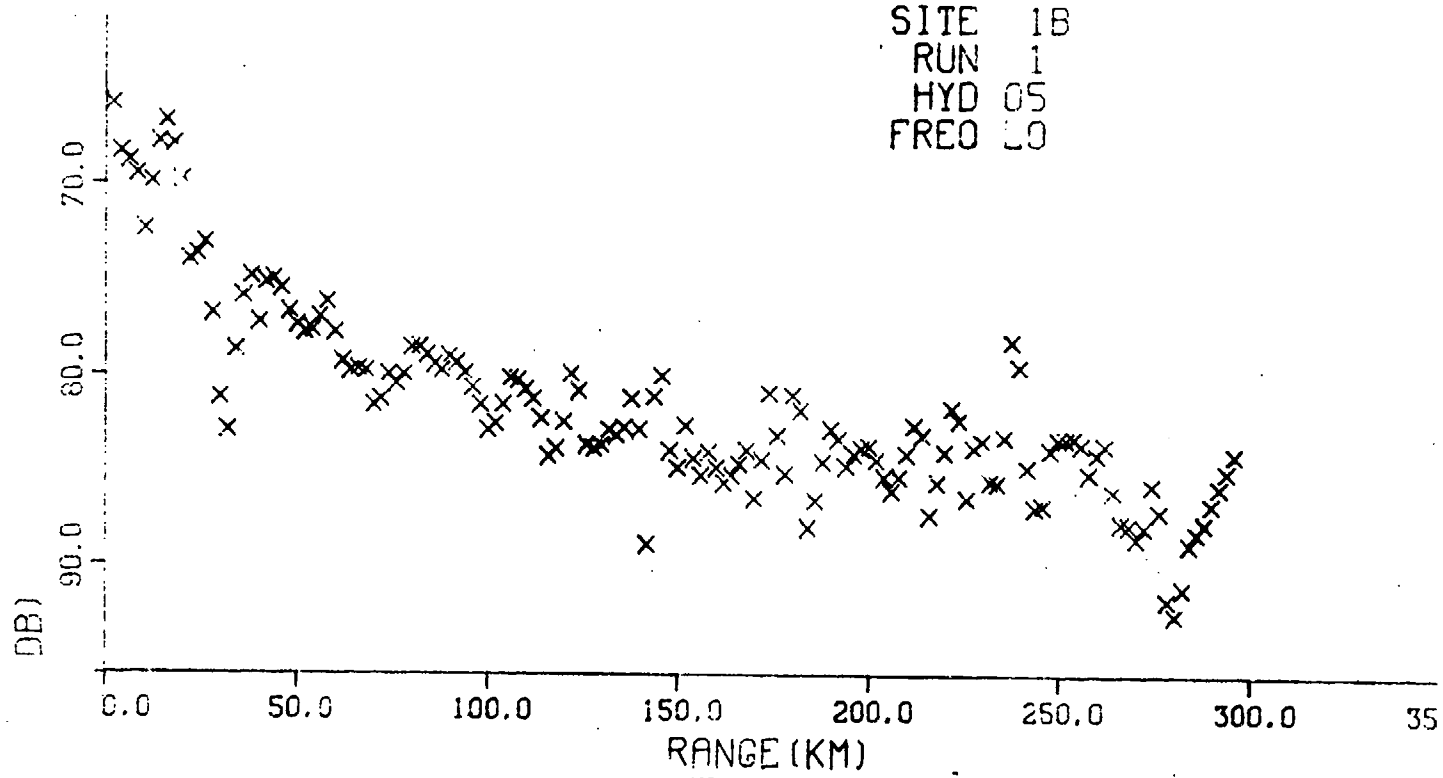

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Figure 18a.(C) Propagation Loss at 25 Hz, Source depth 91 m. Event P1, Site 1B and BMA Hyd #5. Tape Sequence #133

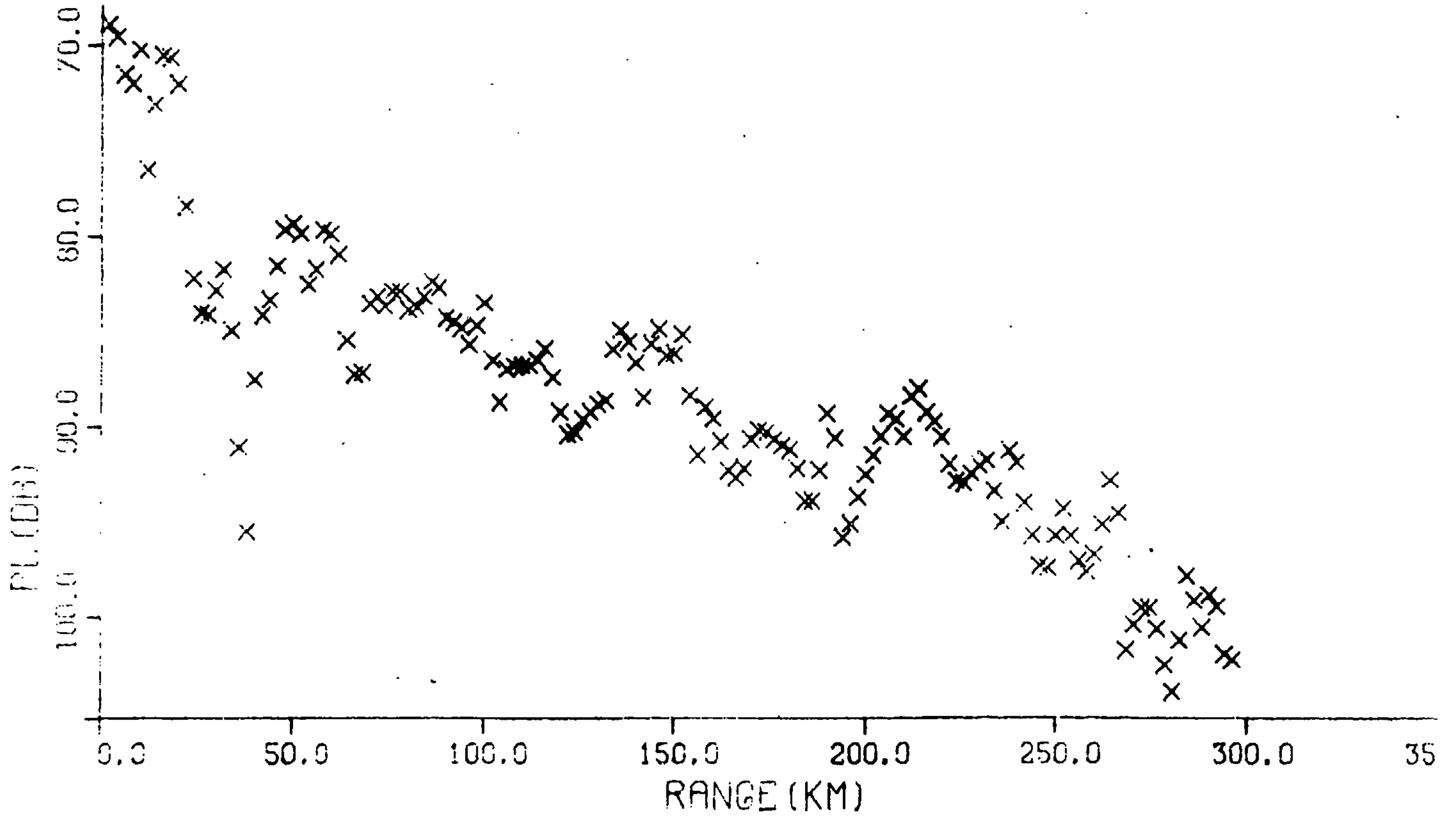

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Figure 18b.(C) Propagation Loss at 140 Hz, Source depth 18 m. Event P1, Site 1B and BMA Hyd #5. Tape Sequence #134

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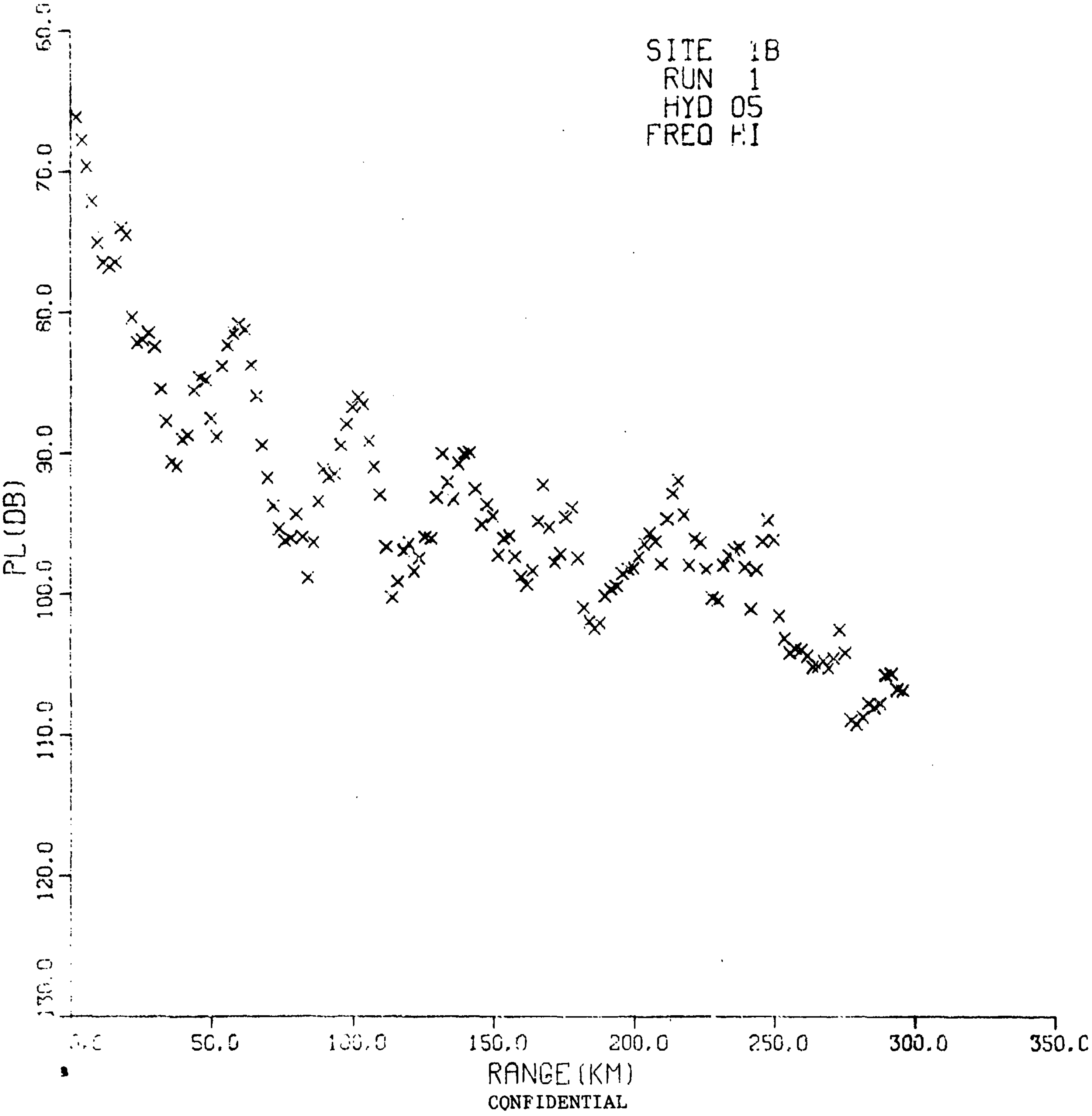

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Figure 18c.(C) Propagation Loss at 290 Hz, Source depth 18 m. Event P1, Site 1B and BMA Hyd #5. Tape Sequence #135

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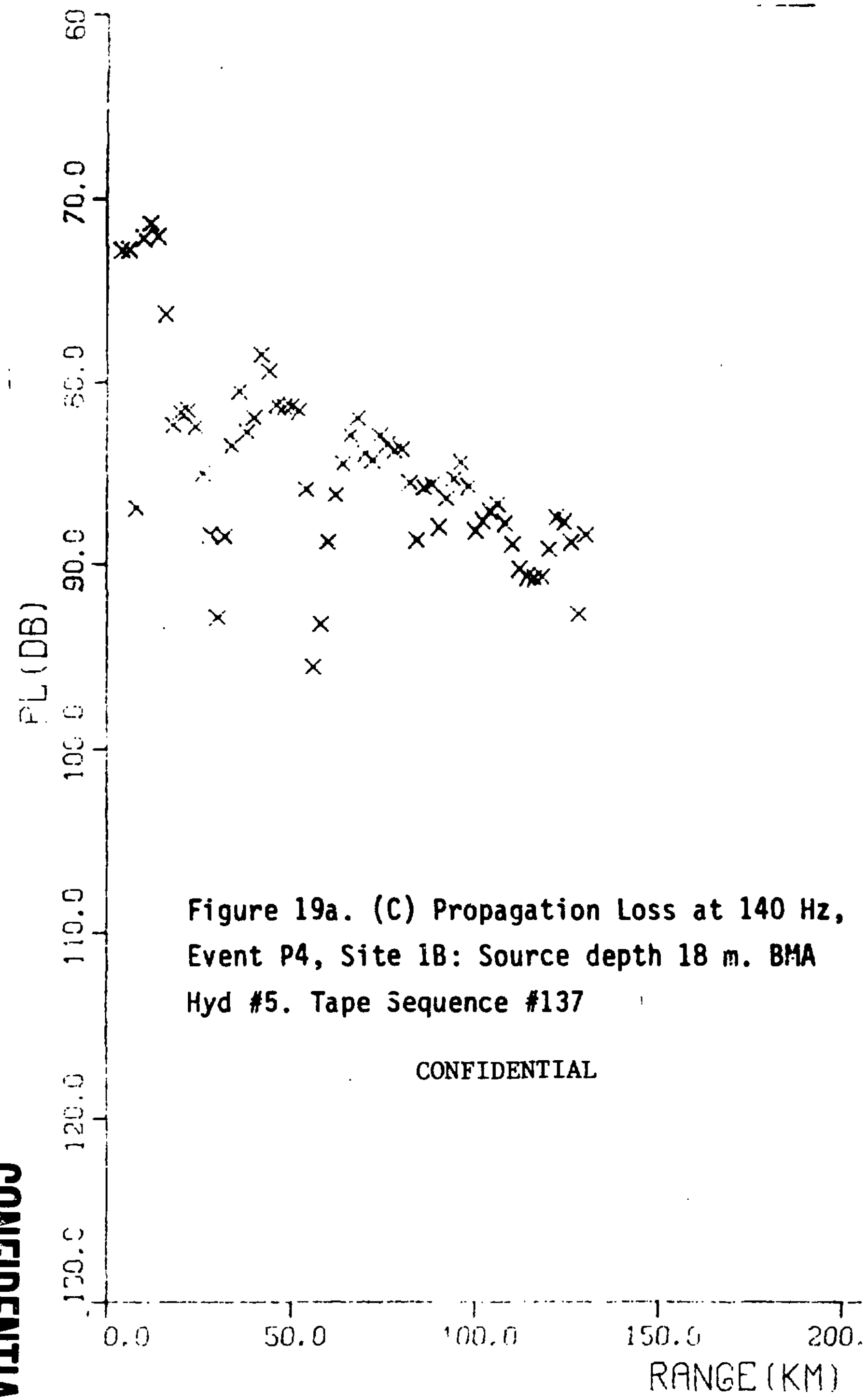

Figure 19a. (C) Propagation Loss at 140 Hz, Event P4, Site 1B: Source depth 18 m. BMA Hyd #5. Tape Sequence #137

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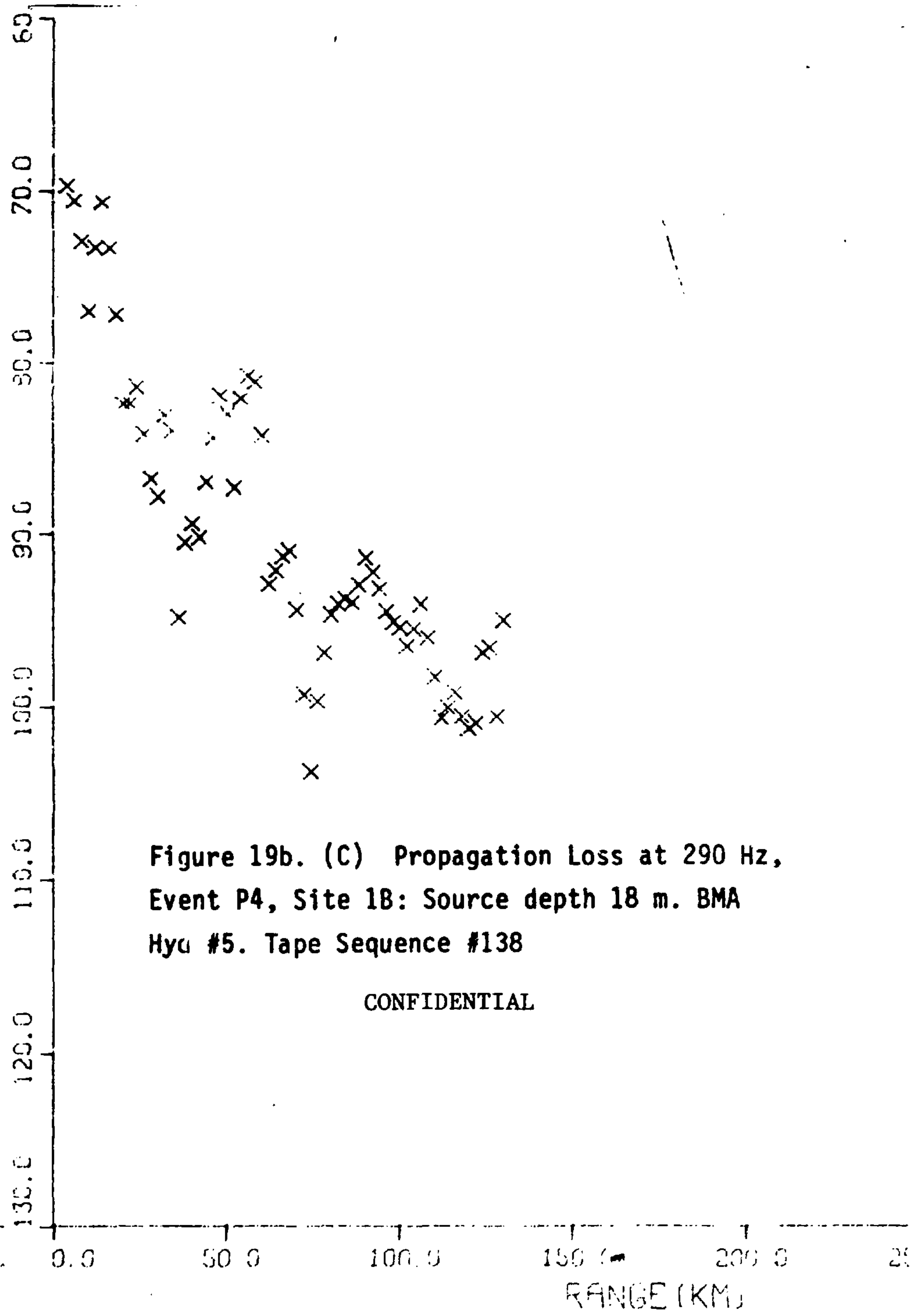

Figure 19b. (C) Propagation Loss at 290 Hz, Event P4, Site 1B: Source depth 18 m. BMA Hyd #5. Tape Sequence #138

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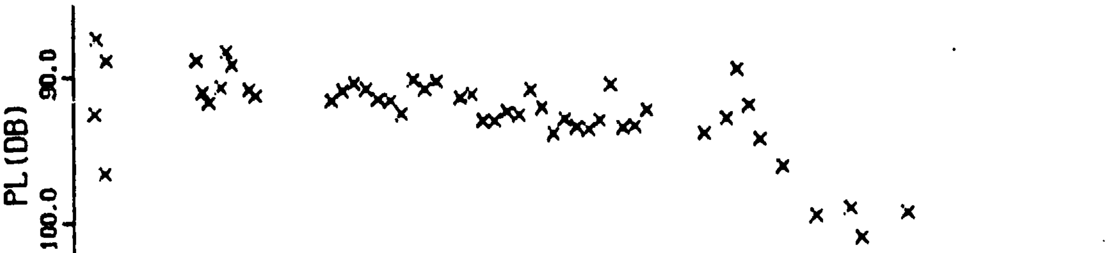

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Figure 20a.(C) Propagation Loss at 50 Hz, Event S1, Site 1B. Source depth 91 m, Receiver depth 496 m. Tape Sequence #5

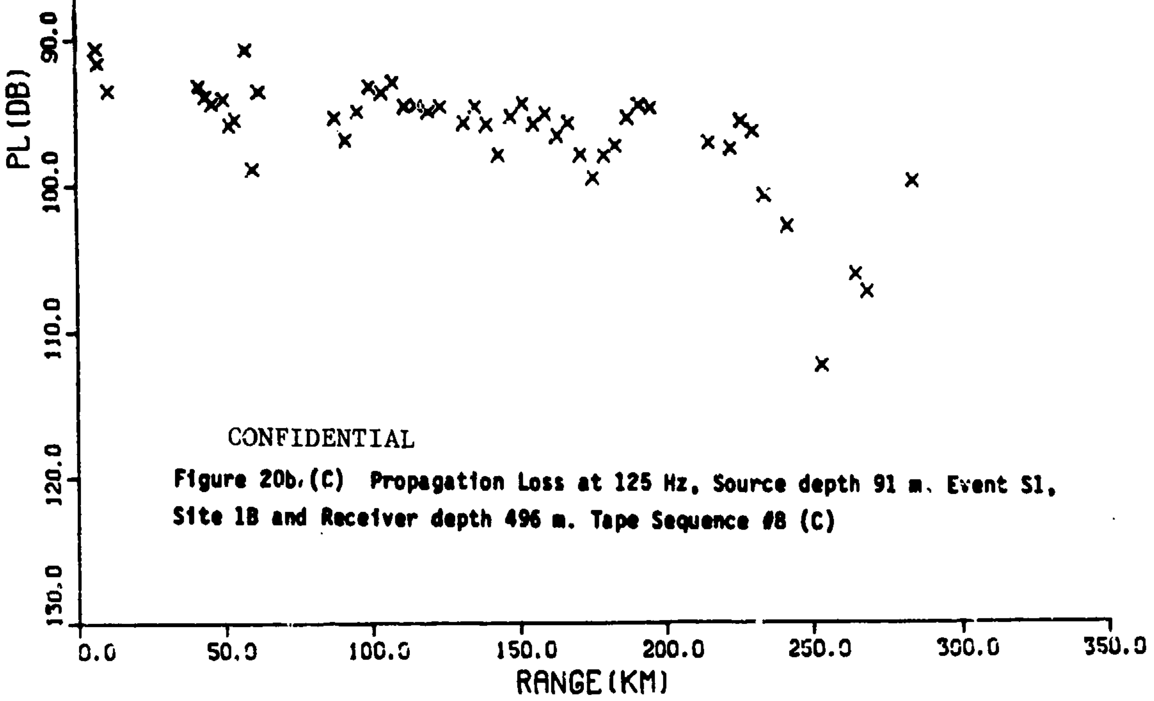

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Figure 20b.(C) Propagation Loss at 125 Hz, Source depth 91 m. Event S1, Site 1B and Receiver depth 496 m. Tape Sequence #8 (C)

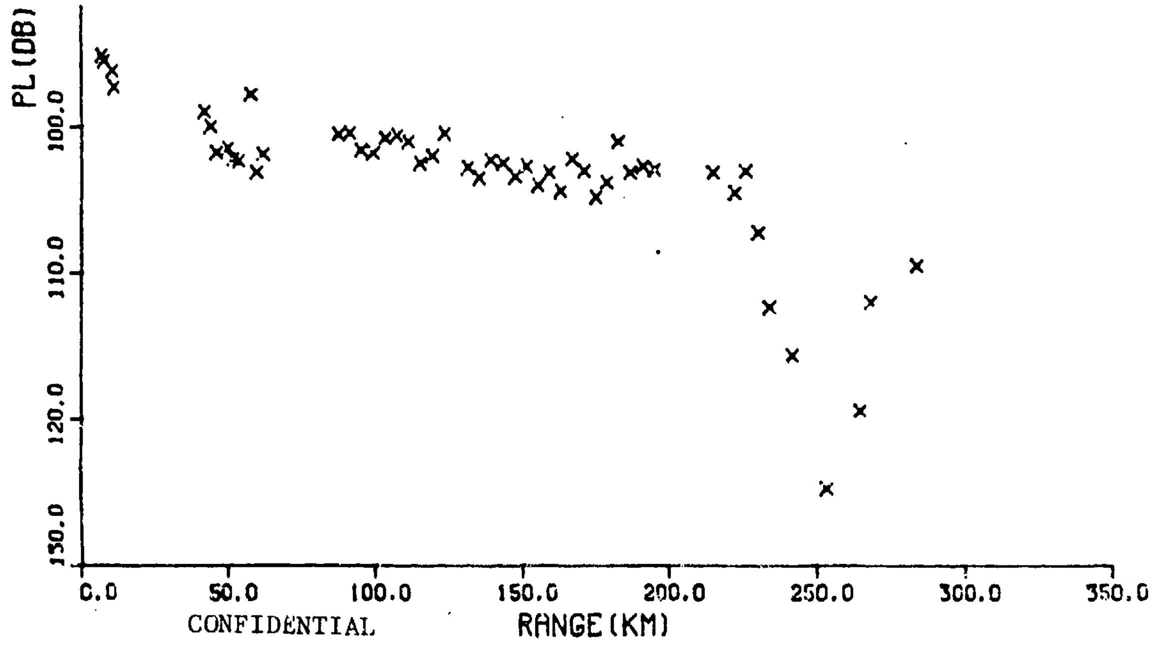

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Figure 20c.(C) Propagation Loss at 315 Hz, Source depth 91 m. Event S1, Site 1B and Receiver depth 496 m. Tape Sequence #11

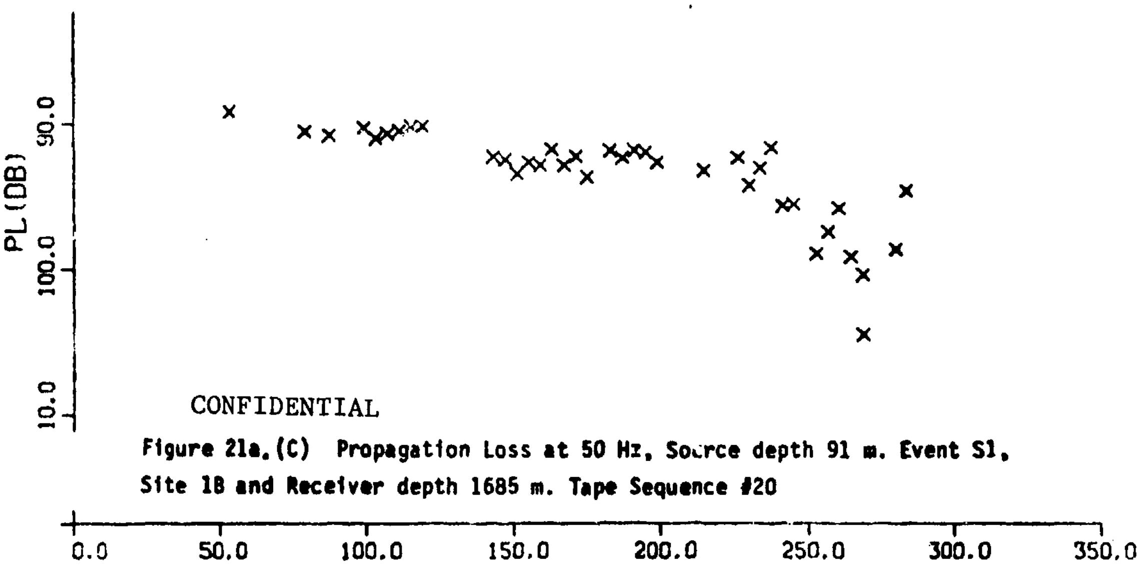

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Figure 21a. (C) Propagation Loss at 50 Hz, Source depth 91 m. Event S1, Site 18 and Receiver depth 1685 m. Tape Sequence #20

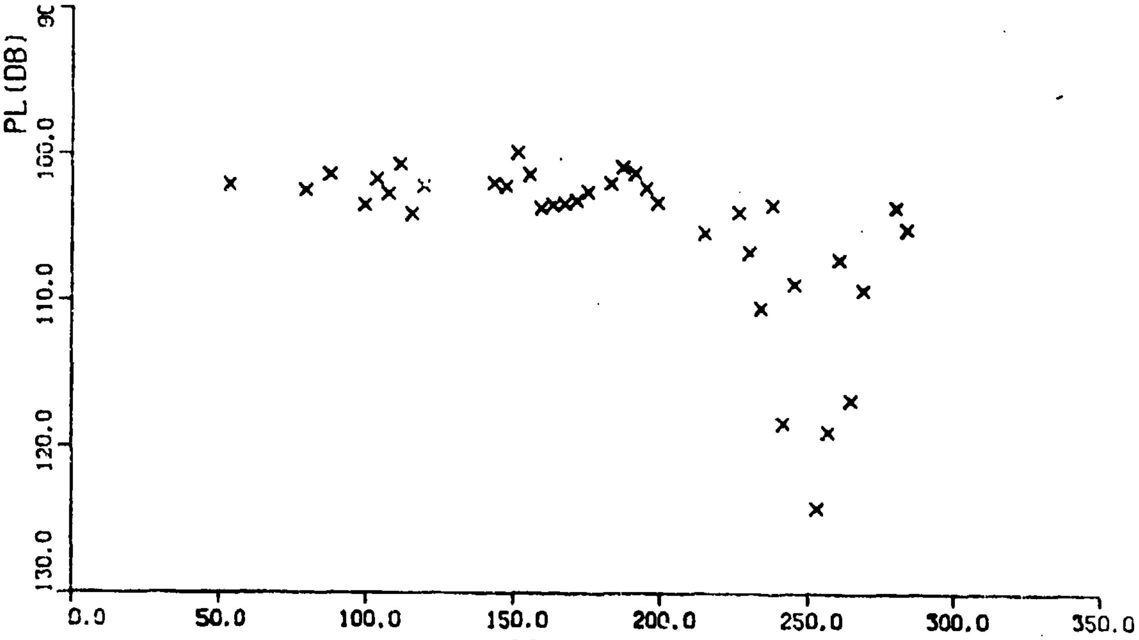

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Figure 21b. (C) Propagation Loss at 315 Hz, Source depth 91 m. Event S1, Site 18 and Receiver depth 1685 m. Tape Sequence #26

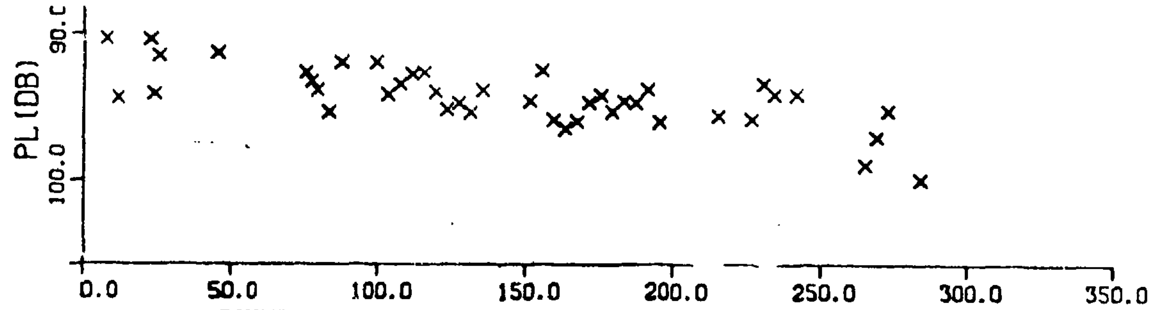

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Figure 22. (C) Propagation Loss at 50 Hz, Source depth 91 m. Event S1, Site 1B and receiver depth 3321 m. Tape Sequence #35

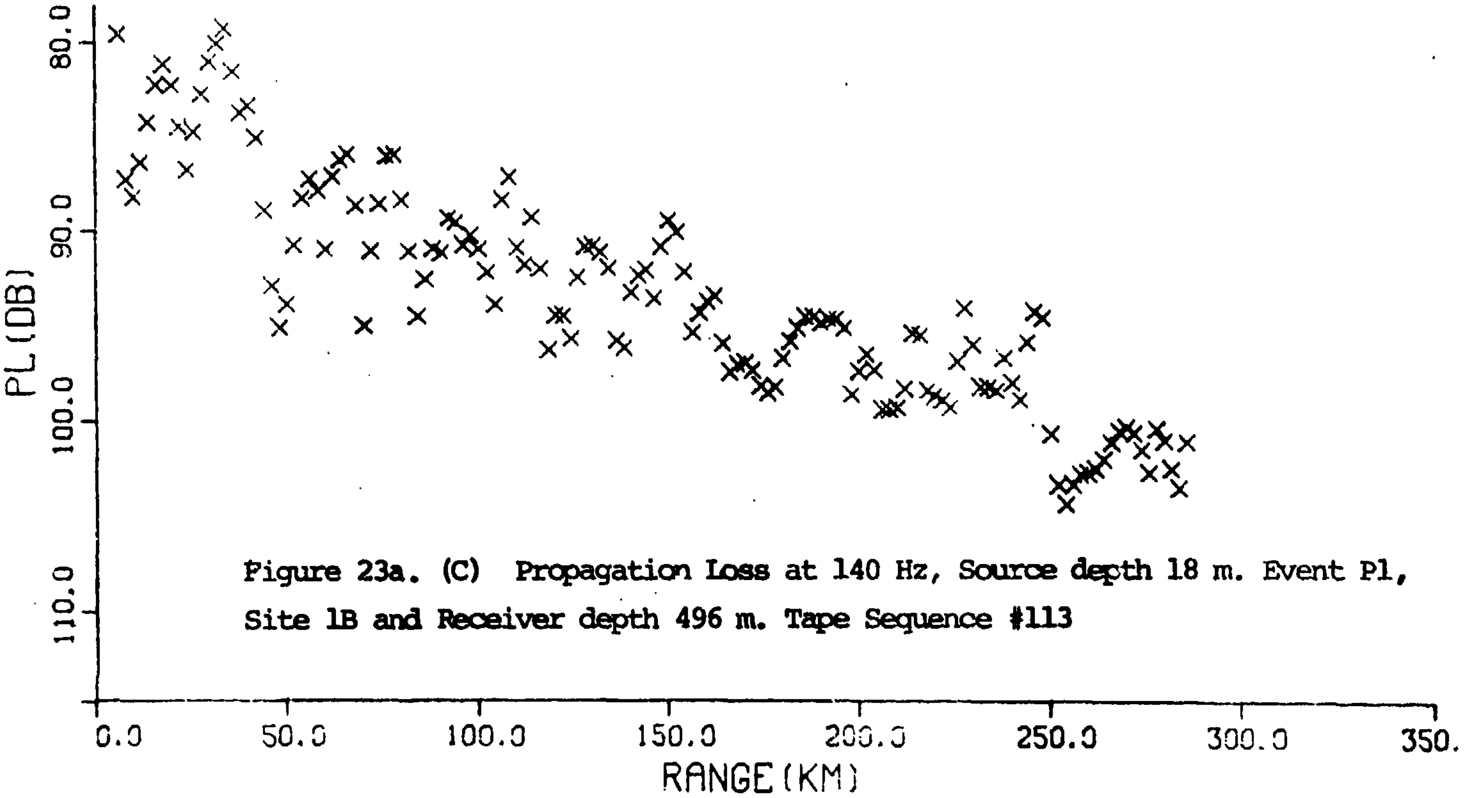

Figure 23a. (C) Propagation Loss at 140 Hz, Source depth 18 m. Event P1, Site 1B and Receiver depth 496 m. Tape Sequence #113

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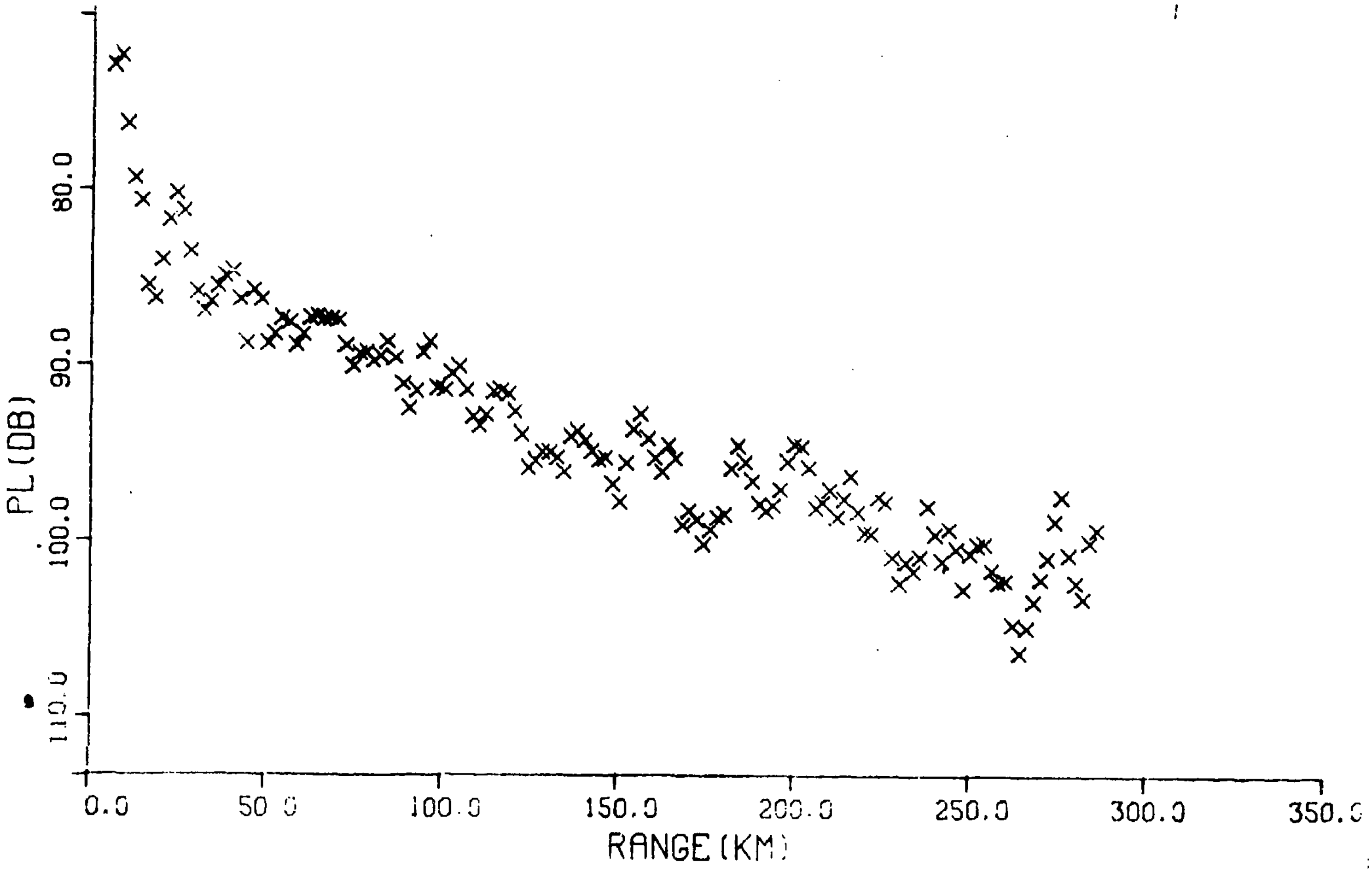

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Figure 23b. (C) Propagation Loss at 140 Hz, Source depth 18 m, Receiver depth 1685 m, Site 1B, Event P1. Tape Sequence #114

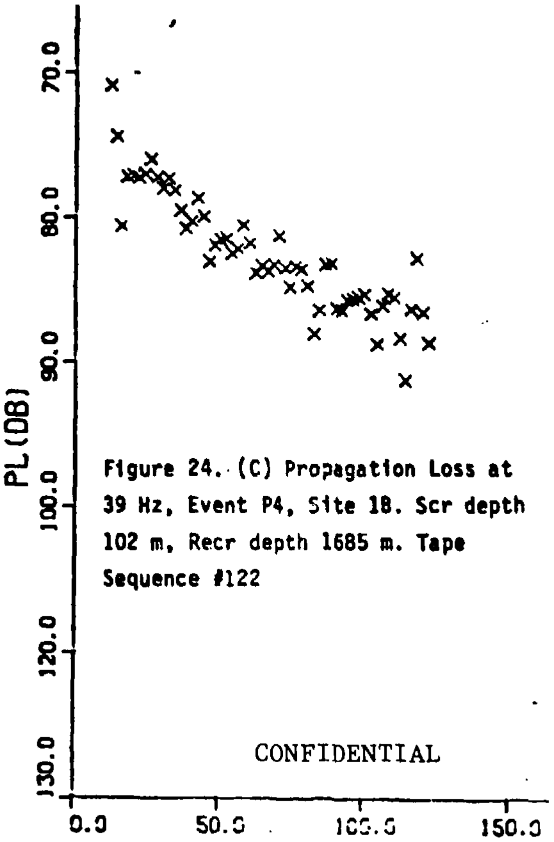

Figure 24. (C) Propagation Loss at 39 Hz, Event P4, Site 18. Scr depth 102 m, Recr depth 1685 m. Tape Sequence #122

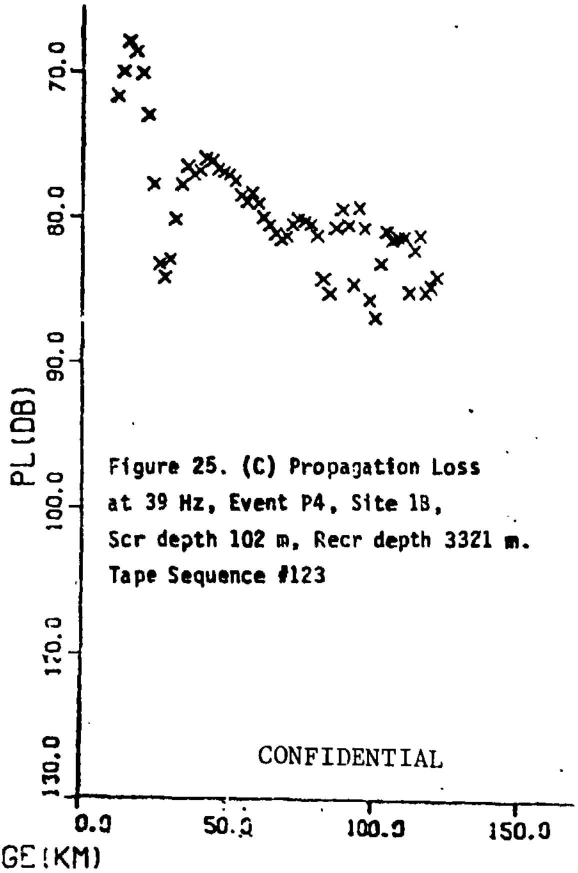

Figure 25. (C) Propagation Loss at 39 Hz, Event P4, Site 18, Scr depth 102 m, Recr depth 3321 m. Tape Sequence #123

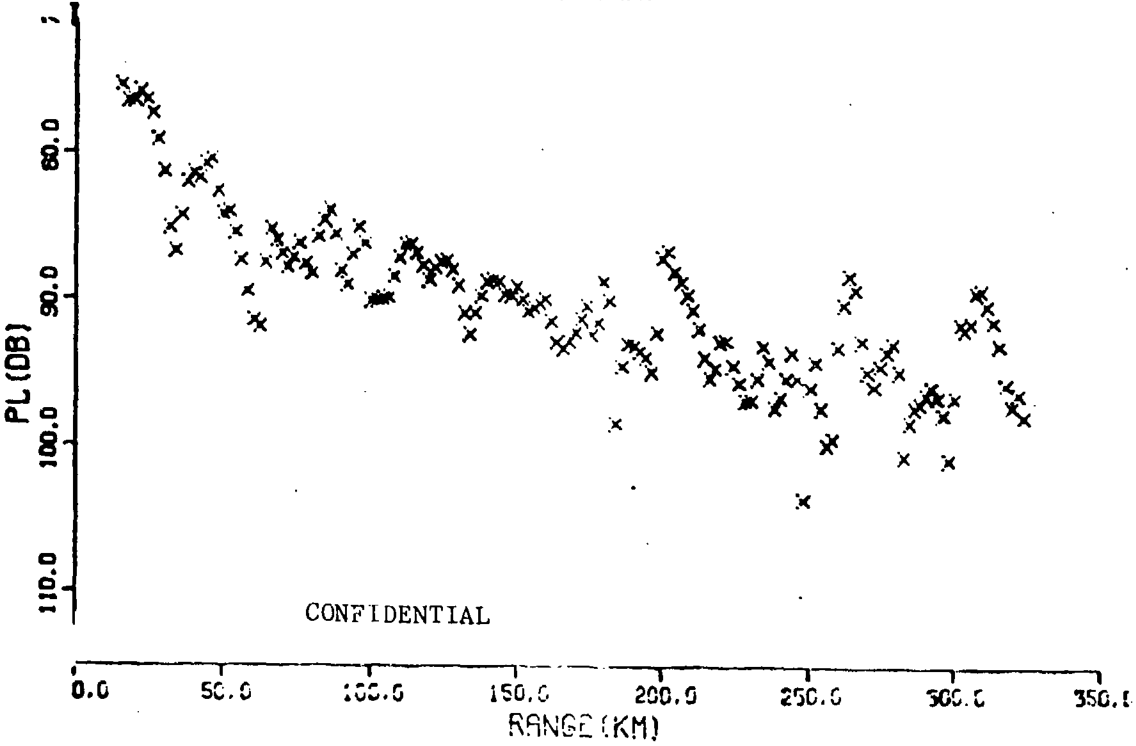

Figure 26. (C) Propagation Loss at 25 Hz, Source depth 91 m, BMA Hyd #3. Event P1, Site 4, Tape Sequence #89

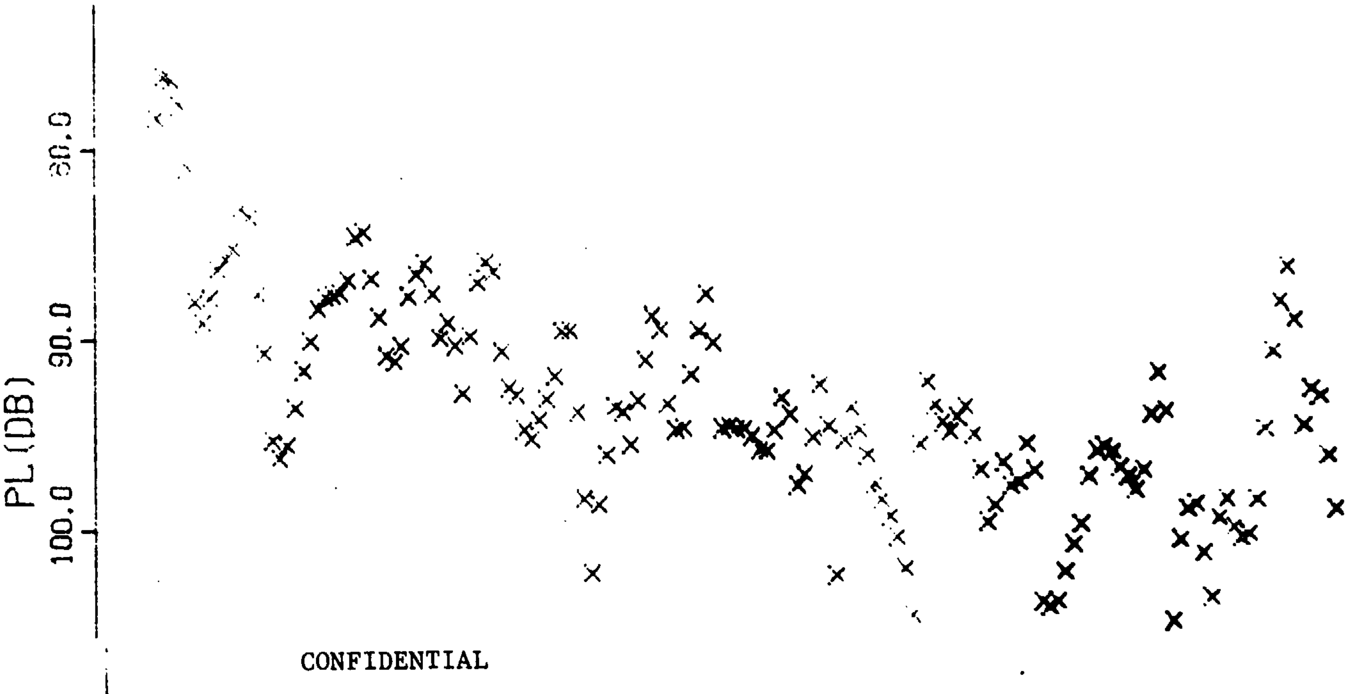

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Figure 27. (C) Propagation Loss at 140 Hz, Source depth 18 m, BMA Hyd #3. Event P1, Site 4. Tape Sequence #92

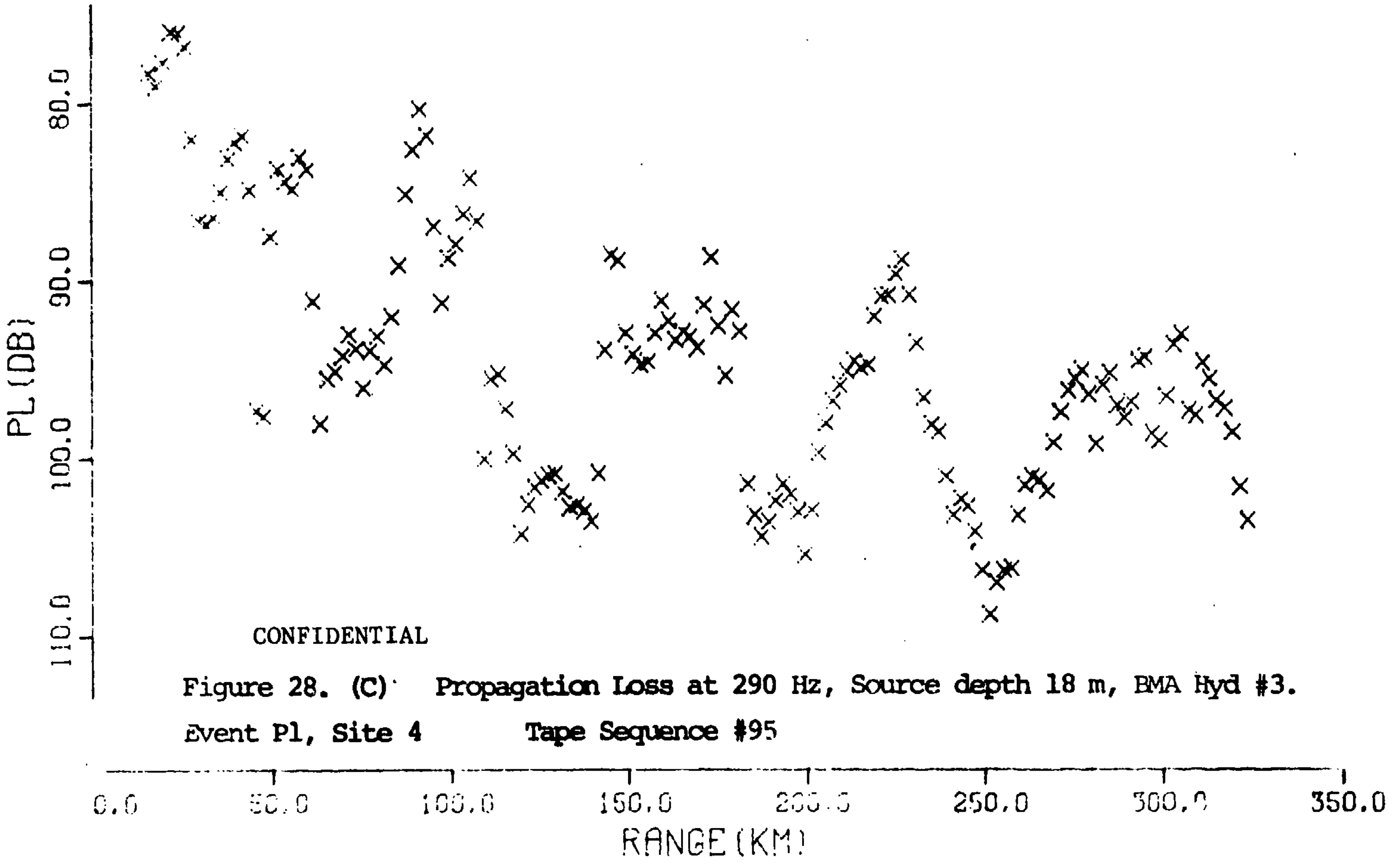

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Figure 28. (C) Propagation Loss at 290 Hz, Source depth 18 m, BMA Hyd #3. Event P1, Site 4 Tape Sequence #95

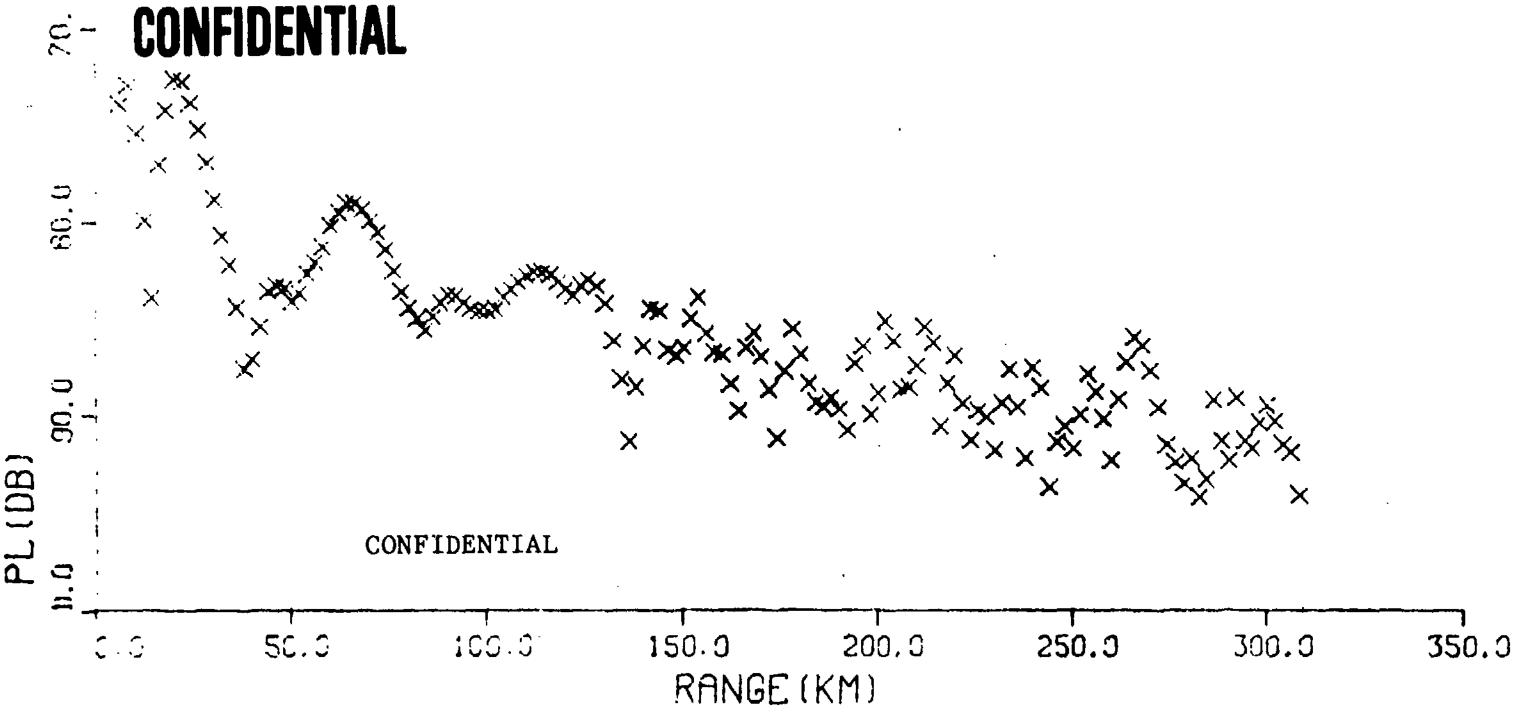

Figure 29. (C) Propagation Loss at 25 Hz, Source depth 91 m, Receiver depth 5076 m. Event P1, Site 4. Tape Sequence #99

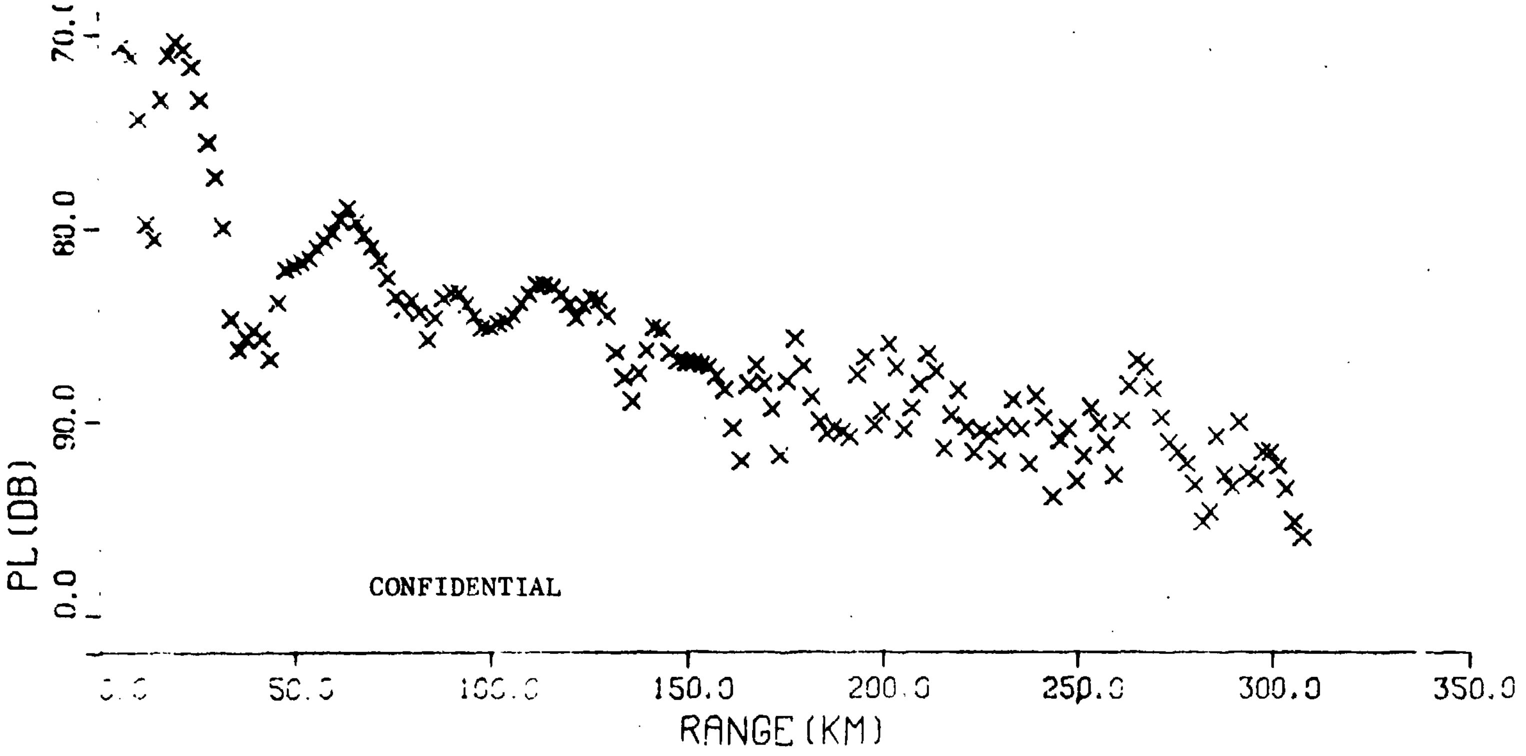

Figure 30. (C) Propagation Loss at 25 Hz, Source depth 91 m, Receiver depth 5106 m. Event P1, Site 4. Tape Sequence #100

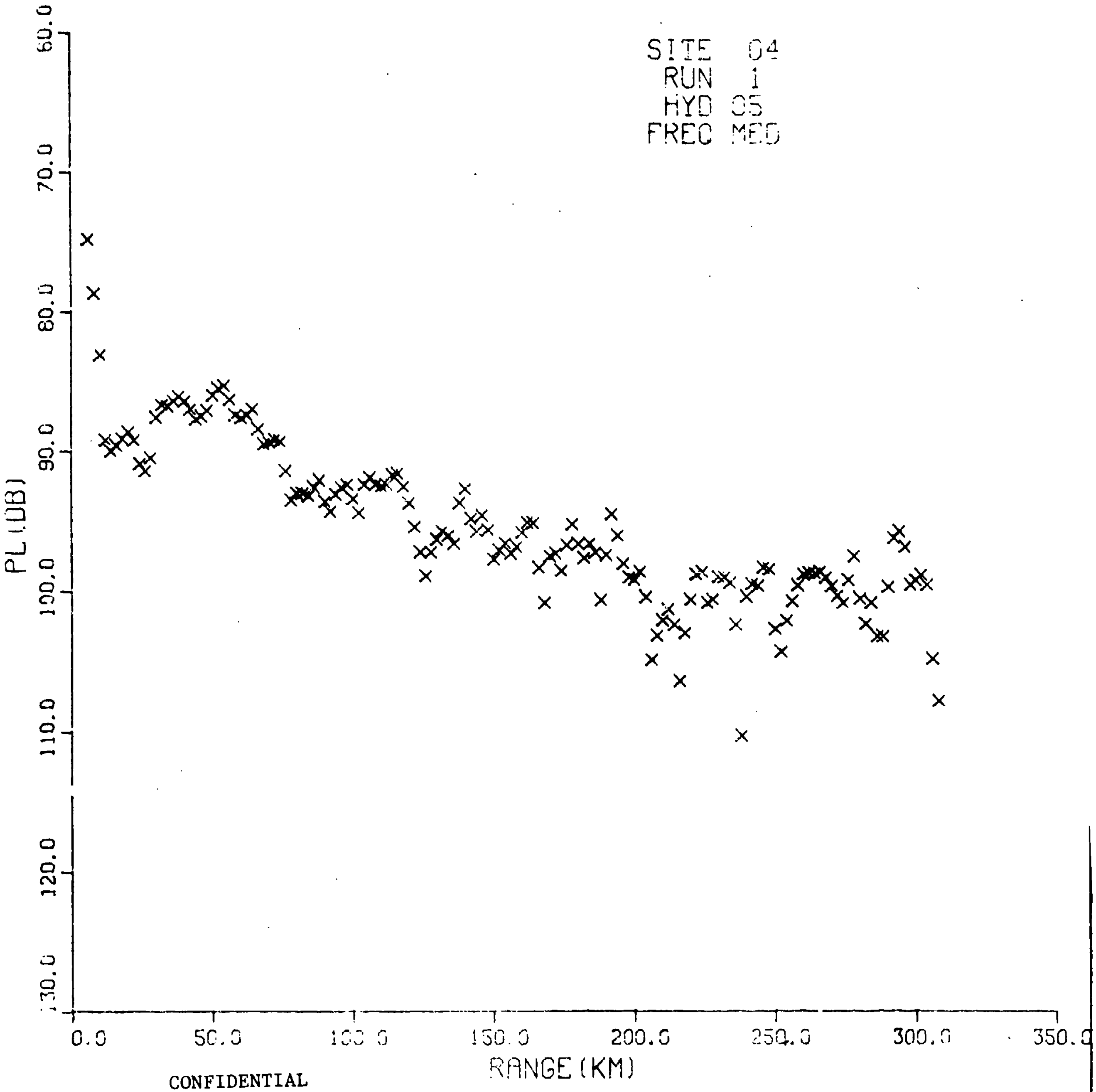

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Figure 31. (C) Propagatin Loss at 140 Hz, Source depth 18 m, Receiver depth 1916 m. Event P1, Site 4. Tape Sequence #102

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9. Naval Ocean Systems Center Technical Report 467, "BEARING STAKE Propagation Loss Assessment (U)," by M. A. Pedersen and G. S. Yee, Oct 1979. CONFIDENTIAL
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APPENDIX

BEARING STAKE GEOACOUSTIC MODELS (U)

INTRODUCTION (U)

(U) The following geoacoustic models of the sea floor are along the tracks of the USNS KINGSPORT during BEARING STAKE. They are primarily intended for use in reconciling experimental bottom-loss measurements with theory and secondarily for use with the other models extrapolating measurements and predictions to other adjacent areas.

(U) The geologic setting of the geoacoustic models and the methods used to derive the values in the tables were discussed in Part II of reference 8.

(U) In the following tables, values are usually not rounded off, but are shown as computed (to indicate trends and gradients). There is no intent to indicate accuracy or probable errors. All values must be considered as generalizations and estimates, especially when one model is extrapolated over a general area or along an insonified line along the sea floor.

GEOACOUSTIC MODEL 1a (U)

Geoacoustic model: 1a **Area:** Gulf of Oman (areas 1A and 1B)

Location: 23°33'N latitude; 61°09'E longitude

Water depth: Echo sounder: 1826 fathoms; 3340 m; set at 1500 m/s
Corrected: 1831 fathoms; 3348 m (from station data)

Province and description of the sea floor: Abyssal Plain Province. The sea floor is composed of a first layer of flat-lying turbidites overlying two other sedimentary rock layers which dip to the north. The acoustic basement is probably basalt.

Layer Material	Thickness, s(1)	m(2)		Depth, m	Velocity, m/s V_p(3)	V_s(4)	Attenuation, k_p(5)	k_s(6)	Density, g/cm^3(7)
Bottom Water					1514.5				1.04306
Sea Floor									
1 Sediment and Sedimentary Rock	0.62	1250		Sfc(8)	1515	120	0.05-0.10-0.20	15.0	1.58
				100	1638	377	0.07-0.11-0.19	16.5	1.67
				200	1750	442	0.10-0.12-0.17	18.0	1.80
				300	1851	499	0.12-0.13-0.16	19.5	1.91
				400	1943	558	0.14	21.0	2.02
				500	2026	619	0.14	21.0	2.10
				600	2101	679	0.12	18.0	2.13
				700	2168	730	0.11	16.5	2.15
				800	2230	780	0.10	15.0	2.18
				900	2286	820	0.08	12.0	2.20
				1000	2337	860	0.07	10.5	2.22
				1100	2385	900	0.06	9.0	2.24
				1200	2429	935	0.05	7.5	2.25
				1250-	2450	950	0.05	7.5	2.26
2 Sedimentary Rock	0.34	986	493	1250+	2565	1040	0.05	7.5	2.30
				1743	2900	1300	0.03	4.5	2.40
				2236-	3235	1560	0.02	3.0	2.49
3 Sedimentary Rock	0.30	1104	552	2236+	3400	1700	0.02	3.0	2.52
				2788	3685	1843	0.02	3.0	2.57
				3340-	3975	1988	0.02	3.0	2.61
4 Basalt				3340+	4600	2270	0.02	0.07	2.50

(U) Notes (for further derivation of values and discussions see Part II, "Methods and Results")

1. Thickness, s (in seconds of one-way sound travel time) from reflection records.
2. Thickness, m, from one-way travel time and layer mean velocity.
3. V_p (compressional wave (sound) velocity):
    a. First layer:

    $$V_p = 1.515 + 1.292D - 0.611D^2 + 0.141D^3,$$

    where V_p is in km/s and depth in the sea floor (D) is in km.

    b. Lower layers: V_ps from literature.
4. V_s (shear wave velocity): From unpublished study by Hamilton of V_p/V_s ratios in marine sediments and rocks. Basalt V_s from Christensen and Salisbury (1975).
5. k_p (constant in attenuation of compressional waves (α_p) in dB/m = $k_p f$, where f is frequency in kHz). The three values to 300 m are probable minimum value, recommended value for first trial in bottom-loss modeling, and probable maximum value. From Hamilton (1972, 1974, 1976a).
6. k_s (constant in attenuation of shear waves (α_s) in dB/m = $k_s f$, where f is frequency in kHz). Based on Hamilton (1976c) at surface; proportional to k_p at depth.
7. Density (saturated bulk density in situ). Surface density computed from core data. Density at depth from Hamilton (1978, 1976b). Basalt density from Christensen and Salisbury (1975).
8. Sfc values are a composite for the 0- to 1-m depth interval. For a detailed model of this interval see the diagram and the following data.

Detail of First Meter (U)

Layer Material	Thickness, s	m	Depth, m	Velocity, m/s V_p	V_s	Attenuation, k_p	k_s	Density, g/cm^3
Bottom Water				1514.5				1.04306
Sea Floor								
			Sfc	1485	115	0.05-0.10-0.20	1.50	1.53
1a Silt-clay		0.8						
			0.8-	1486	119	0.05-0.10-0.20	15.0	1.53
			0.8+					
1b Silt		0.2		1620	130	0.45-0.60-0.85	13.0	1.80
			1.0-					

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(U) Notes

1. The geoacoustic models (such as in the main table) showing thick sediment and sedimentary rock sections over acoustic basement, e.g., basalt, are generalized and do not account for the multiple reflectors usually seen at high frequencies, e.g., in the 3.5-kHz records or in cores.

2. If a detailed, multireflector model is desired, the above sequence of a thicker silt-clay layer and a thinner silt (or other) layer can be alternated to any desired depth. If so, the property values can be corrected for depth as follows:

   a. For the silt-clay layer:

      (1) For V_p: increase V_p using gradients computed from the equation for V_p as a function of depth.

      (2) Other properties: vary the value of the property with depth using the appropriate gradient from the values listed in the main table.

   b. For the silt (or other layer):

      (1) For V_p: increase V_p as above for silt-clay.

      (2) For k_p: vary k_p along lines b and c (figure 17).

      (3) Other properties: as above for silt clay.

3. It should be noted that in areas where turbidites form abyssal plains or fans (such as in the Oman Basin, Arabian Fan, and Somali Basin) the reflectors usually represent coarser sediments spilling discontinuously from leveed channels. These reflectors cannot usually be followed over very great distances or correlated from area to area. Any detail, as above, is a gross generalization of widely varying layers (in thickness and properties).

4. The values listed in the main table for Sfc are composite proportional values for the first 1 m of sediment. Other properties in three cores for the 0- to 1-m depth are as follows (silt-clay porosity was salt-corrected from core 4 in center of basin; silt porosity from velocity-porosity relations of other data):

Property	Silt-clay		Silt
Velocity ratio	0.98		1.07
		composite: 1.00	
Porosity, %	71		55
		composite: 68	
Mean grain size, ϕ	8.39		6.09
(number in sample)	(46)		(6)
Grain density, g/cm^3		Average of all samples:	2.73
(number in sample)			(56)

5. Although these generalized data indicate a sharp top boundary between the silt-clay and silt layers, it is more apt to be gradational in all properties.

In Situ Properties of Bottom Water (U)

True Depth, m	T, °C	S, ppt	P, kg/cm^2	Sound Speed, m/sec	Density, g/cm^3	Impedance, g/cm^2 sec X 10^5
3348	1.83	34.74	346.7	1514.5	1.04306	1.57971

GEOACOUSTIC MODEL 4a (U)

Geoacoustic model: 4a **Area:** Somali Basin, off northeast Africa

Location: 05°08'N latitude; 52°16'E longitude

Water depth: Echo sounder: 2769 fathoms; 5064 m; set at 1500 m/s
Corrected: 2789 fathoms; 5100 m (from station data)

Provinc and description of the sea floor: Abyssal plain province. The northern Somali Basin, between the east African continental rise and Chain Ridge, is composed of a thick layer of flat-lying turbidite sediments and sedimentary rocks overlying basalt.

Layer Material	Thickness, s(1)	Thickness, m(2)	Depth, m	Velocity, m/s $V_p(3)$	Velocity, m/s $V_s(4)$	Attenuation, $k_p(5)$	Attenuation, $k_s(6)$	Density, g/cm^3(7)
Bottom Water				1543.8				1.05065
Sea Floor								
1 Sediment and Sedimentary Rock	0.76	1580	Sfc(8)	1528	125	0.04-0.08-0.18	15.0	1.42
			100	1649	390	0.06-0.09-0.17	19.3	1.68
			200	1760	448	0.09-0.11-0.16	23.5	1.81
			300	1864	507	0.11-0.12-0.15	25.7	1.93
			400	1960	570	0.14	30.0	2.03
			500	2048	636	0.14	30.0	2.11
			600	2128	702	0.12	25.7	2.14
			700	2202	755	0.11	23.5	2.17
			800	2269	810	0.10	21.4	2.19
			900	2330	855	0.08	17.1	2.22
			1000	2385	900	0.07	15.0	2.24
			1500	2582	1050	0.04	8.6	2.30
			1595-	2607	1070	0.03	6.4	2.31
2 Sedimentary Rock	0.25	940 470	1595+	3500	1750	0.03	3.0	2.54
			2065	3750	1875	0.02	3.0	2.58
			2535-	4000	2000	0.02	3.0	2.61
3 Basalt			2535+	5300	2680	0.02	0.07	2.70

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(U) **Notes** (for further derivation of values and discussions see)

1. Thickness, s (in seconds of one-way sound travel time) from reflection records.
2. Thickness, m, from one-way travel time and layer mean velocity.
3. V_p (compressional wave (sound) velocity):

   a. First layer:

   $$V_p = 1.528 + 1.25D - 0.45D^2 + 0.0568D^3,$$

   where V_p is in km/s and depth in the sea floor (D) is in km.

   b. Lower layers: V_ps from literature.

4. V_s (shear wave velocity): From unpublished study by Hamilton of V_p/V_s ratios in marine sediments and rocks. Basalt V_s from Christensen and Salisbury (1975).

5. k_p (constant in attenuation of compressional waves (α_p) in dB/m = k_pf, where f is frequency in kHz). The three values to 300 m are probable minimum value, recommended value for first trial in bottom-loss modeling, and probable maximum value. From Hamilton (1972, 1974, 1976a).

6. k_s (constant in attenuation of shear waves (α_s) in dB/m = k_sf, where f is frequency in kHz). Based on Hamilton (1976c) at surface; proportional to k_p at depth.

7. Density (saturated bulk density in situ). Surface density computed from core data. Density at depth from Hamilton (1978, 1976b). Basalt density from Christensen and Salisbury (1975).

8. In the above model, the Sfc values are a composite for the 0- to 3-m depth interval. For a detailed model of this interval see the diagram and notes below.

Detail of First 3 Meters (U)

Layer Material	Thickness, s	Thickness, m	Depth, m	Velocity, m/s V_p	Velocity, m/s V_s	Attenuation, k_p	Attenuation, k_s	Density, g/cm^3
Bottom Water				1543.8				1.05065
Sea Floor								
			Sfc	1513	115	0.03-0.07-0.17	15.0	1.39
1a Silt-Clay		2.8						
			2.8-	1517	128	0.03-0.07-0.17	15.0	1.39
			2.8+					
1b Sand-Silt-Clay		0.2		1635	175	0.45-0.06-0.85	13.0	1.78
			3.0-					

(U) Notes

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1. The geoacoustic models (such as in the main table) showing thick sediment and sedimentary rock sections over acoustic basement, e.g., basalt, are generalized and do not account for the multiple reflectors usually seen at high frequencies, e.g., in the 3.5-kHz records or in cores.

2. If a detailed, multireflector model is desired, the above sequence of a thicker silt-clay layer and a thinner silt (or other) layer can be alternated to any desired depth. If so, the property values can be corrected for depth as follows:

   a. For the silt-clay layer:

      (1) For V_p: increase V_p using gradients computed from the equation for V_p a function of depth.

      (2) Other properties: vary the value of the property with depth using the appropriate gradient from the values listed in the main table.

b. For the silt (or other layer):

(1) For V_p: increase V_p as above for silt-clay.

(2) For k_p: vary k_p along lines b and c (figure 17).

(3) Other properties: as above for silt-clay.

3. It should be noted that in areas where turbidites form abyssal plains or fans (such as in the Oman Basin, Arabian Fan, and Somali Basin), the reflectors usually represent coarser sediments spilling discontinuously from leveed channels. These reflectors cannot usually be followed over very great distances or correlated from area to area. Any detail, as above, is a gross generalization of widely varying layers (in thickness and properties).

4. The values listed in the main table for Sfc are composite values for the depth interval of 0 to 3 m (illustrated above). Some averaged properties in four cores for this interval, other than those listed above, are as follows (porosity in silt-clay (0 to 100 cm) is salt corrected; porosity in sand-silt-clay based on velocity-porosity relations from other data):

Property	Silt-clay	Sand-silt-clay
Velocity ratio	0.98	1.06
	composite: 0.99	
Porosity, %	79	55
	composite: 77	
Mean grain size, ϕ	8.95	5.48
(number in sample)	(182)	(2)
Grain density, g/cm^3	Average of all samples:	2.66
(number in sample)		(179)

5. Although these generalized data indicate a sharp top boundary between the silt-clay and sand-silt-clay layers, it is more apt to be gradational in all properties.

<u>In Situ</u> Properties of Bottom Water (U)

True Depth, m	T, °C	S, ppt	P, kg/cm^2	Sound Speed, m/sec	Density, g/cm^3	Impedance, g/cm^2 sec X 10^5
5100	1.38	34.69	529.6	1543.8	1.05065	1.62199

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GEOACOUSTIC MODEL 4b (U)

Geoacoustic model: 4b Area: Chain Ridge, Somali Basin Area

Location: 04°44'N latitude; 53°10'E longitude

Water depth: Echo sounder: 2180 fathoms; 3987 m; set at 1500 m/s
Corrected: 2187 fathoms; 4000 m; (from station data)

Province and description of the sea floor: Hill, seamount, ridge province. Chain Ridge runs northeast-southwest and is the eastern boundary of the Somali Basin (as used herein). The ridge is about 2100 m high (2900- to 5000-m depth). This model at middepth represents the west side and top of the ridge.

Layer Material	Thickness, s(1)	Thickness, m(2)	Depth, m	Velocity, m/s V_p(3)	Velocity, m/s V_s(4)	Attenuation, k_p(5)	Attenuation, k_s(6)	Density, g/cm^3(7)
Bottom Water				1524.3				1.04594
Sea Floor								
1 Sediment	0.13	217	Sfc(8)	1540	118	0.05-0.09-0.20	15.0	1.50
			100	1660	400	0.07-0.10-0.19	16.7	1.69
			200	1772	454	0.10-0.12-0.17	20.0	1.82
			217-	1790	463	0.10-0.12-0.17	20.0	1.84
2 Basalt			217+	5300	2680	0.02	0.07	2.70

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(U) Notes (for further derivation of values and discussions see "Methods and Results")

1. Thickness, s (in seconds of one-way sound travel time) from reflection records.
2. Thickness, m, from one-way travel time and layer mean velocity.
3. V_p (compressional wave (sound) velocity):
   a. First layer:

      $$V_p = 1.540 + 1.25D - 0.45D^2 + 0.0568D^3,$$

      where V_p is in km/s and depth in the sea floor (D) is in km.

   b. Lower layers: V_p: from literature.
4. V_s (shear wave velocity): From unpublished study by Hamilton of V_p/V_s ratios in marine sediments and rocks. Basalt V_s from Christensen and Salisbury (1975).

No cores were taken at this location. Properties were predicted from files, assuming the sediment was a calcareous (foraminiferal) ooze with a velocity ratio of 1.01, porosity of 72%, and a grain density of 2.67 g/cm^3.

(U) In Situ Properties of Bottom Water (U)

True Depth, m	T, °C	S, ppt	P, kg/cm^2	Sound Speed, m/sec	Density, g/cm^3	Impedance, g/cm^2 sec X 10^5
4000	1.45	34.71	414.6	1524.3	1.04594	1.59433

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GEOACOUSTIC MODEL 4c (U)

Geoacoustic model: 4c **Area**: Continental Terrace, west of Somali Basin

Location: 05°53'N latitude; 50°36'E longitude

Water depth: Echo sounder: 2180 fathoms; 3987 m; set at 1500 m/s
Corrected: 2187 fathoms; 4000 m (from station data)

Province and description of the sea floor: Continental terrace province. Geoacoustic model 4c is on the lower slopes of the continental rise off East Africa and west of the Somali Basin.

Layer Material	Thickness,		Depth,	Velocity, m/s		Attenuation,		Density,
	s(1)	m(2)	m	V_p(3)	V_s(4)	k_p(5)	k_s(6)	g/cm^3(7)
Bottom Water				1524.3				1.04594
Sea Floor								
1 Sediment and Sedimentary Rock	0.50	970	Sfc(8)	1510	125	0.04-0.07-0.18	15.0	1.42
			100	1631	370	0.06-0.09-0.17	18.8	1.66
			200	1742	438	0.09-0.11-0.16	20.6	1.79
			300	1846	496	0.11-0.12-0.15	24.4	1.91
			400	1942	557	0.14	26.3	2.01
			500	2030	622	0.14	26.3	2.10
			600	2110	687	0.12	22.5	2.13
			700	2184	740	0.11	20.6	2.16
			800	2251	795	0.10	18.8	2.19
			900	2312	840	0.08	15.0	2.21
			970-	2351	870	0.07	13.1	2.22
2 Sedimentary Rock	0.25	940 470	970+	3500	1750	0.03	3.0	2.54
			1400	3750	1875	0.02	3.0	2.58
			1910-	4000	2000	0.02	3.0	2.61
3 Basalt			1910+	5300	2680	0.02	0.07	2.70

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(U) **Notes** (for further derivation of values and discussions see)

1. Thickness, s (in seconds of one-way sound travel time) from reflection records.
2. Thickness, m, from one-way travel time and layer mean velocity.
3. V_p (compressional wave (sound) velocity):
   a. First layer:

$$V_p = 1.510 + 1.25D - 0.45D^2 + 0.0568D^3,$$

   where V_p is in km/s and depth in the sea floor (D) is in km.

   b. Lower layers: V_ps from literature.
4. V_s (shear wave velocity): From unpublished study by Hamilton of V_p/V_s ratios in marine sediments and rocks. Basalt V_s from Christensen and Salisbury (1975).

5. k_p (constant in attenuation of compressional waves (α_p) in dB/m = $k_p f$, where f is frequency in kHz). The three values to 300 m are probable minimum value, recommended value for first trial in bottom-loss modeling, and probable maximum value. From Hamilton (1972, 1974, 1976a).

6. k_s (constant in attenuation of shear waves (α_s) in dB/m = $k_s f$, where f is frequency in kHz). Based on Hamilton (1976c) at surface; proportional to k_p at depth.

7. Density (saturated bulk density in situ). Surface density computed from core data. Density at depth from Hamilton (1978, 1976b). Basalt density from Christensen and Salisbury (1975).

8. In the above model, the Sfc values are a composite for the 0- to 3-m depth interval. For a detailed model of this interval see the diagram and notes below.

Detail of First 3 Meters (U)

Layer Material	Thickness, s	Thickness, m	Depth, m	Velocity, m/s V_p	Velocity, m/s V_s	Attenuation, k_p	Attenuation, k_s	Density, g/cm^3
Bottom Water				1524.3				1.04594
Sea Floor								
1a Silt-Clay		2.8	Sfc	1495	115	0.04-0.07-0.18	15.0	1.38
			2.8-	1499	128	0.04-0.07-0.18	15.0	1.38
1b Sand-Silt-Clay		0.2	2.8+	1615	175	0.45-0.60-0.85	13.0	1.78
			3.0-					

(U) <u>Notes</u>

1. No cores were taken at this location. It is assumed that the sediment properties are essentially the same here as at the site of model 4a.

2. Notes 1 through 5 for the detailed diagram of geoacoustic model 4a apply.

(U) <u>In Situ</u> Properties of Bottom Water (U)

True Depth, m	T, °C	S, ppt	P, kg/cm^2	Sound Speed m/sec	Density, g/cm^3	Impedance, g/cm^2 sec X 10^5
4000	1.45	34.71	414.6	1524.3	1.04594	1.59433

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Appendix 9. (U) IOMEDEX (Ionian Mediterranean Exercise)

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APPENDIX 9

DATA SETS FOR MODEL EVALUATION: THE IOMEDEX EXERCISE (U)

Summarized by James A. Whitney

INTRODUCTION (U)

(U) This report summarizes acoustic and environmental data from the IOMEDEX Exercise, in particular that data which are recommended for use in the evaluation of range-independent propagation loss models.

(C) The Ionian Mediterranean Exercise (IOMEDEX) was conducted 30 October to 25 November 1971 in the Ionian Basin of the Mediterranean Sea. The objective of the exercise was to acquire the environmental and acoustic data necessary for concept formulation and advanced development of passive ASW systems. Acoustic data acquired were omnidirectional noise spectral levels at two locations and transmission loss as a function of receiver depth, range and location. The range, depth and frequency parameters for the range-independent propagation loss data are given in Table 1. A summary of IOMEDEX is given in reference 1.

(C) Figure 1 identifies points of interest in the operating area and the track of the R/V NORTH SEAL. During the period 6 - 24 November 1971, fixed and mobile acoustic measurement recording systems and towed acoustic sources were deployed in accordance with the Operations Order. Also during this period, at specified locations and time intervals, measurements were taken of the sound velocity, bathymetry, and current structure, and observations were made of the surface environment and geographical distribution of shipping.

(C) Ships participating in the exercise were the USNS SANDS, R/V KNORR, R/V NORTH SEAL, USS HAMMERBERG, USS COURTNEY and USS LESTER. Acoustic measurement systems included the Ambient Noise Buoy (ANB), Moored Acoustic

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REVIEW ON: 8 Oct 1994

Table 1. Parameters for the IOMEDEX Data Set (U)

Figure 6	A	B	C	D	E	F
Frequency (Hz)	125	125	125	125	125	125
Source Depth (m)	152	152	152	152	152	152
Receiver depths (m)	137	613	1113	1116	2377	2650
Min Range (N. Mi)	8	8	8	8	8	8
Max Range (N. Mi)	128	135	138	135	120	120
Layer Depth (m)	42	42	42	42	42	42
Sound Axis (m)	The axis of min sound speed is about 130 m					
Critical Depth	The mean critical depth is 1000 m					
Bottom Depth	Assumed contant at 3000 m.					
Navigation	Range accuracy was ± .2 N. Mi (see reference 2)					
Data Location	Data can be accessed through the "LRAPP Acoustic Data Bank" by request to NORDA Code 520 SEAS Project, NSTL Station, MS 39529					

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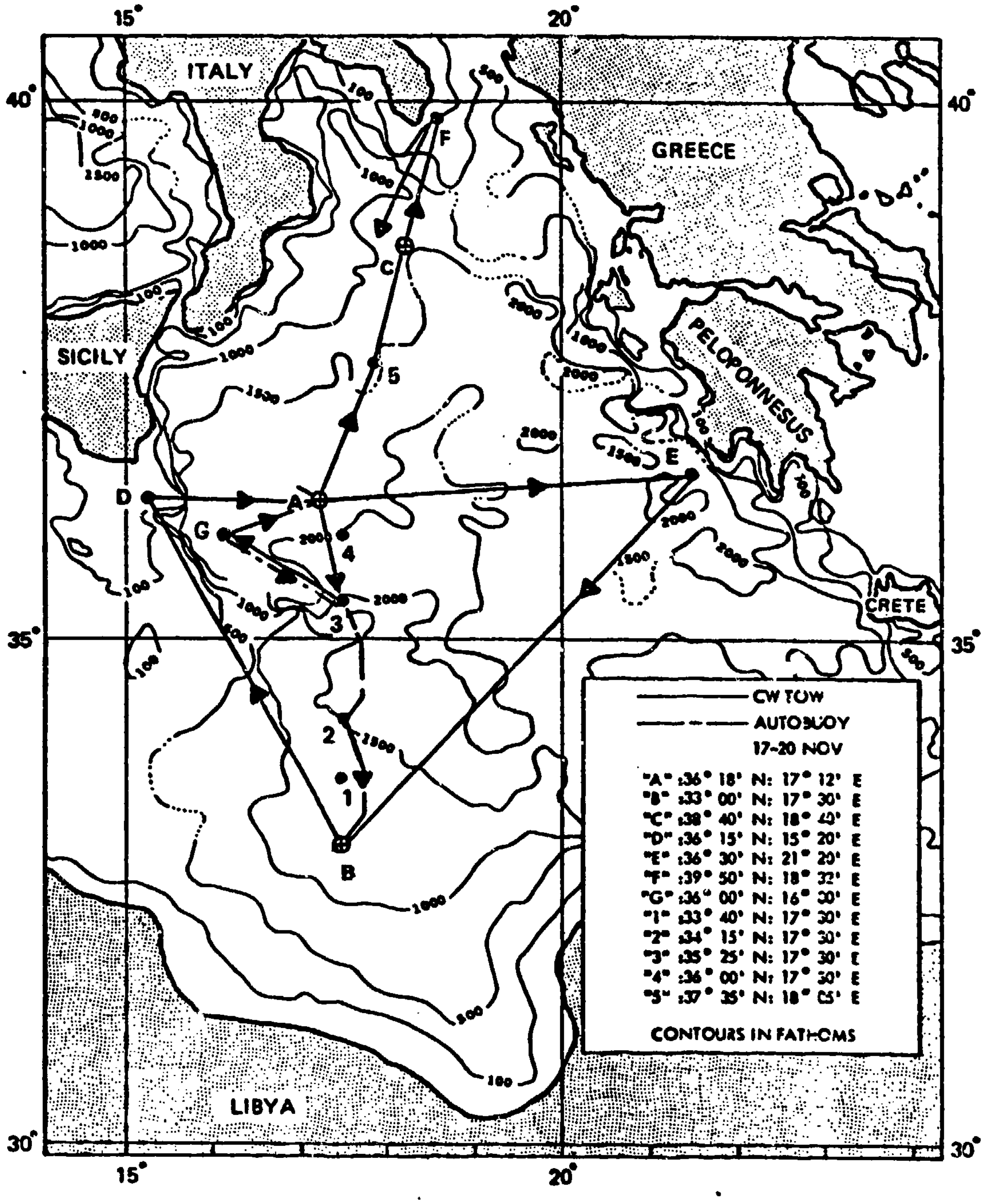

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Figure 1. (C). IOMEDEX Area Illustrating Points of Interest and the Track of the R/V NORTH SEAL

Buoy System (MABS), SONODIVER, AUTOBUOY, SPARBUOY and SONOBUOYS. The schedule of data acquisition from each of these systems is summarized in Figure 2. The system characteristics are given in Table 2.

(C) Oceanographic data were collected from all six ships and from various aircraft for use in determining environment effects on acoustic propagation. Results of the oceanographic data analysis are given in reference 3.

MEASUREMENT SYSTEMS: Acoustic (U)

(C) MABS is a moored, self-contained programmable acoustic acquisition system for sampling a deep-water acoustic field in the frequency range 10 - 5000 Hz. An instrumentation capsule sequentially samples and records the output of five hydrophones spaced along a 1770 ft cable. Total recording time varies from 42 hours to 30 days depending on the sampling rate. The MABS data were acquired at Site A during the two periods shown in Figure 2.

(C) The Ambient Noise Buoy (ANB) is a bottom anchored, nonattended buoy system for monitoring acoustic signal in the ocean over the frequency range of 20 - 600 Hz. Received signals are simultaneously and continuously analog-recorded on a four channel magnetic tape recorder. One ANB was deployed at Site A where data from a 3119 meter deep hydrophone were recorded during the period 6 - 14 November. Three ANB's were anchored near one another at Site C, and data was recorded continuously from hydrophones at depths of 137, 613, 1113, 1116, 2377 and 2650 meters, during the period 8 - 16 November.

(U) SPARBUOY was deployed once and recorded less than six hours of data. The other systems, AUTOBUOY, SONODIVER and SONOBUOYS, were deployed at various times, depth and positions (see Fig. 2).

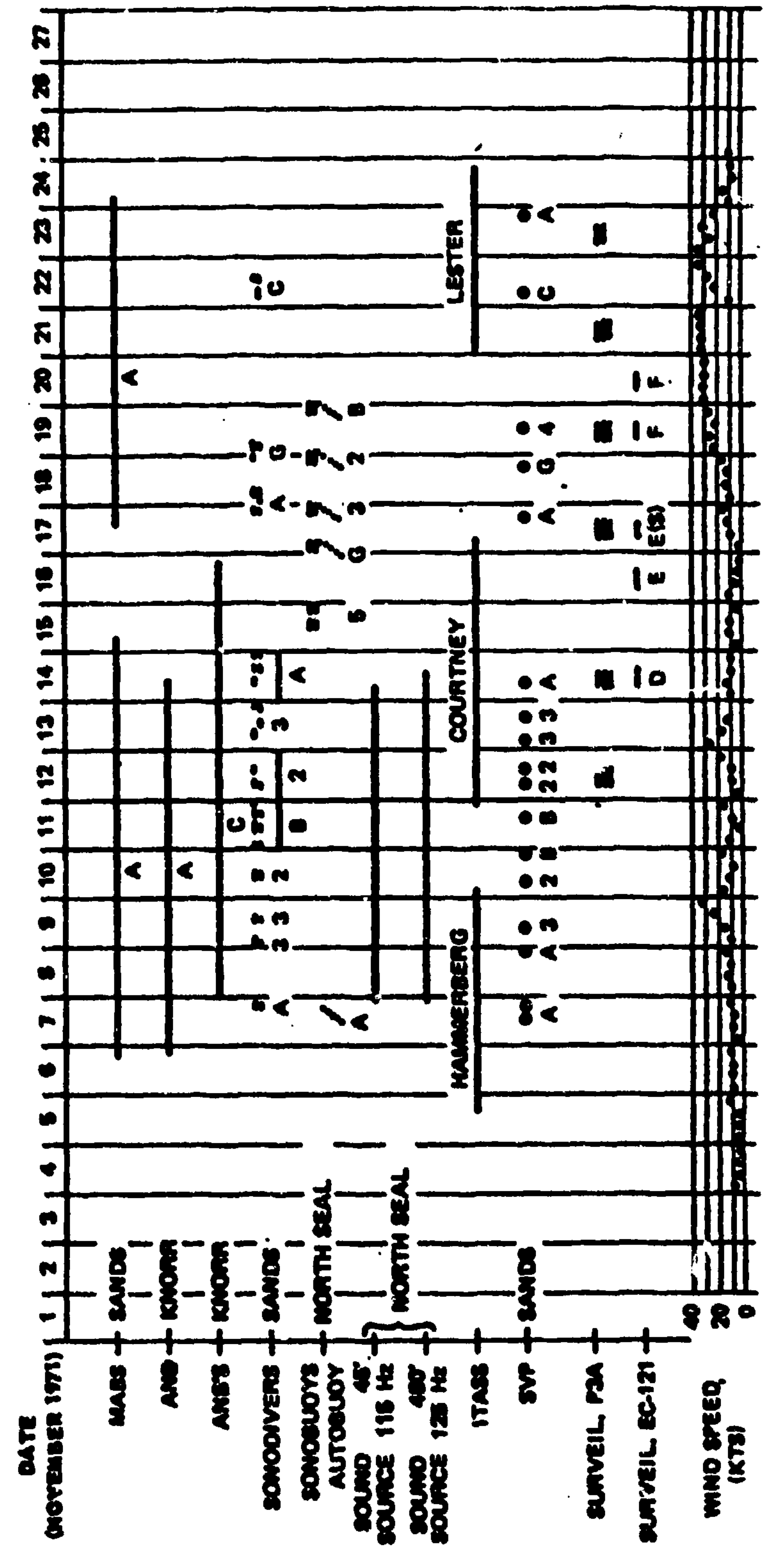

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Figure 2. (U) Overview of IOMEDEX measurement schedule.

(U) Table II

MEASUREMENT SYSTEM CHARACTERISTICS

Equipment	Frequency Band	Maximum Data Acquisition Capability	IOMEDEX Sampling Interval	Sample Lengths	Number of Hydrophones
MABS	10-2500 Hz	42 Hours	30 Min; 6-15 Nov 20 Min; 17-24 Nov	25 Sec per Hydrophone	5
ANB	20-600 Hz	187 Hours	Continuous	187 Hours	2 per Unit
SONODIVER	8-6000 Hz	50 Min	One Depth per Dive	20 Min	1 per Unit
SONOBUOY	10-3000 Hz	8 Hours	Continuous	4-6 Hours	1 per Unit
AUTOBUOY	8-2500 Hz	160 Min	Five Depths per Dive	20 Min Each Depth	2

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(C) Two CW acoustic sources were towed by the NORTH SEAL: a WT-4 operated at 115 Hz and an HX 37 operating at 125 Hz and a source level of 90 dB//μb at 1 yd. No data was reduced at 115 Hz due to problems resulting in unreliable source levels. The HX-37 was successfully operated at a source depth of 152 meters. This source depth was estimated from the cable length and angle since the depth gauge failed.

(C) Propagation loss data summarized in this report will be that data obtained at Site C and during the tow from A to C. The density of the data recorded by the ANB's was much greater than that from the MABS. Also the range coverage from A to C is greatest.

(U) Satellite navigation was used throughout the exercise. R/V KNORR and NORTH SEAL used the Magnavox MX706 system, while USNS SANDS used the Navy AN/SRN-9 system. System accuracies are 200 yds or better (reference 4).

(U) Continuous bathymetric profiles were recorded by each ship whenever underway on an IOMEDEX track. Bottom depths have been corrected for variations from the standard 1500 m/s by using Matthew's depth correction tables.

ENVIRONMENTAL SUMMARY (U)

(U) Between 26 October and 27 November, 82 T-5 (1830 m) and 231 T-7 (760 m) XBT traces were collected by SANDS, KNORR and NORTH SEAL. During this same period 91 T-4 (460 m) XBT traces were collected by the HAMMERBERG, COURTNEY AND LESTER. Also 204 AXBTs were dropped, of which 153 (73%) produced useable traces, usually to 330 m. These did not give useable sea surface temperatures due to a variable offset but AXBTs did give accurate values of mixed layer depth. In addition SANDS occupied 19 sound velocimeter stations during IOMEDEX.

(U) The major data collection effort was to support acoustic measurements. Thus, XBT and SVP data were collected at various reference points, near A, B or C and along various tracks only during acoustic test periods. Also the IOMEDEX area was under the influence of a large storm during the period 19 - 23 November. This depression markedly changed near-surface characteristics and consequently divides IOMEDEX into two time periods. The environmental data base before the storm (1 - 19 Nov) is considerably larger and better distributed than after the storm (23 - 31 Nov).

(U) Sound velocity profiles were calculated from XBT temperatures and historical salinity values (references 5 and 6) using the October 1960 Wilson's equation. Salinities were taken from data collected by the USNS LEE during October and November 1970 as part of the Integrated Mediterranean Project (IMP) (reference 6).

(U) Current measurements were made at points near Site A in the Period of 6 - 26 November and near Site C for 8 - 25 November and near Site C for 8 - 25 November. Data were processed to produce a listing of hourly current speed averages in 5 cm/sec intervals vs direction at certain depths referred to magnetic north in 15 degree intervals. These data are summarized in reference 3 and are given in detail in Appendix B of reference 3.

(U) Figure 3 summarizes measurements of wind force and direction and sea state and swell height observations made during IOMEDEX by SANDS, NORTH SEAL, and KNORR. Many of the individual data points are based on an average of three observations made by different ships at disparate locations. However, this figure accurately depicts predominant conditions in the area on the dates indicated. Wind speeds were high on 9, 13, 21 and 22 November and low on 4, 11 and 16 November. High wind speeds observed after 19 November mark the passage of the large depression that had significant effects on near-

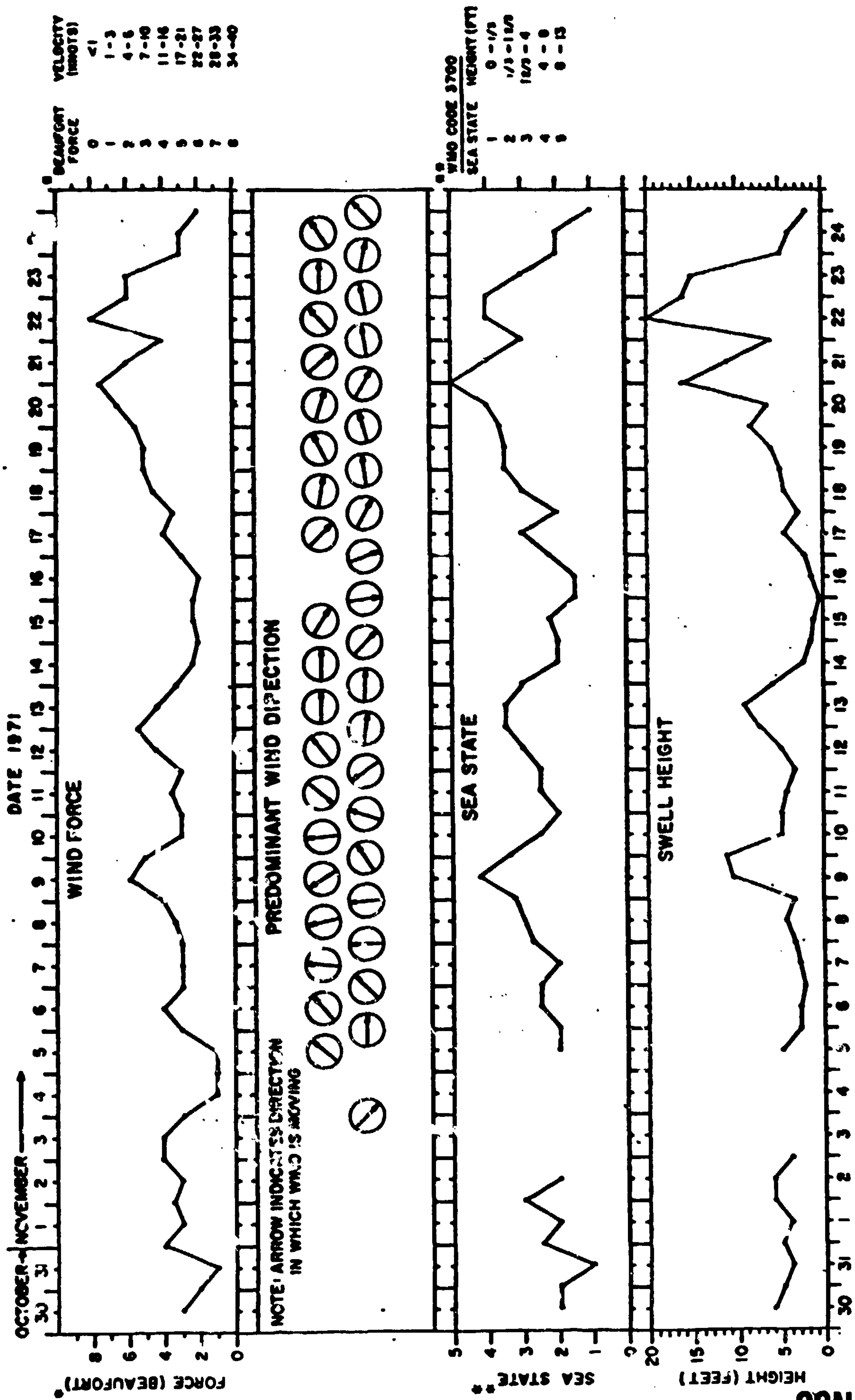

Figure 3 (U) Wind Force, Wind Direction, Sea State, and Swell Height Summary

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surface oceanographic conditions. The CW tow from near Site A toward Site C was on 13 - 14 November. On those dates wind speed was decreasing from about 20 to 16 knots with 10 - 5 ft swells and a sea state of 3 - 4.

SOUND VELOCITY STRUCTURE (U)

(C) Relatively shallow critical depths found at Sites A, B and C allowed uninterrupted convergence zone propagation from a near-surface source at all times during IOMEDEX. The deep sound channel axis (DSC) varied between about 50 and 300 m at the three sites and averaged about 150 m.

(C) Figure 4 shows 12 sound velocity profiles along a north-northwest track from Site A to Site C. Data used to obtain the sound speed profiles in this figure were collected between 7 and 15 November when most acoustic receivers were operational at A and C. The bathymetric profile was taken from KNORR data.

(U) Surface sound speeds along track A - C varied from 1526.5 m/s near point A to 1522.1 m/s near point C. A sporadic mixed layer occurred at depths of between 40 and 60 m for most profiles. The DSC axis varied between about 90 m and 200 m along the track while the sound speed at the axis varied between 1512 and 1516.1 m/s. Maxima of DSC sound velocity and axis depth roughly correspond to a preferential flow of the LIW (Levantine Intermediate Water), high salinity water mass. Mixing in this LIW layer sometimes produced secondary sound channels.

(C) The CW run of interest occurred between 1000 z and 2000 z on 13 November. Thus the actual profiles of interest would be NORTH SEAL XBT's 56, 57 and 59 and possibly SANDS SVP #1. XBT's 56 and 59 show layer depths of 42 and 55 m respectively. The DSC axis varies between 105 and 160 m with a mean depth of 135 m. The critical depth was about 1000 m at Site A and about 900 m at C. Depth excess along track A - C was never less than 1400 m.

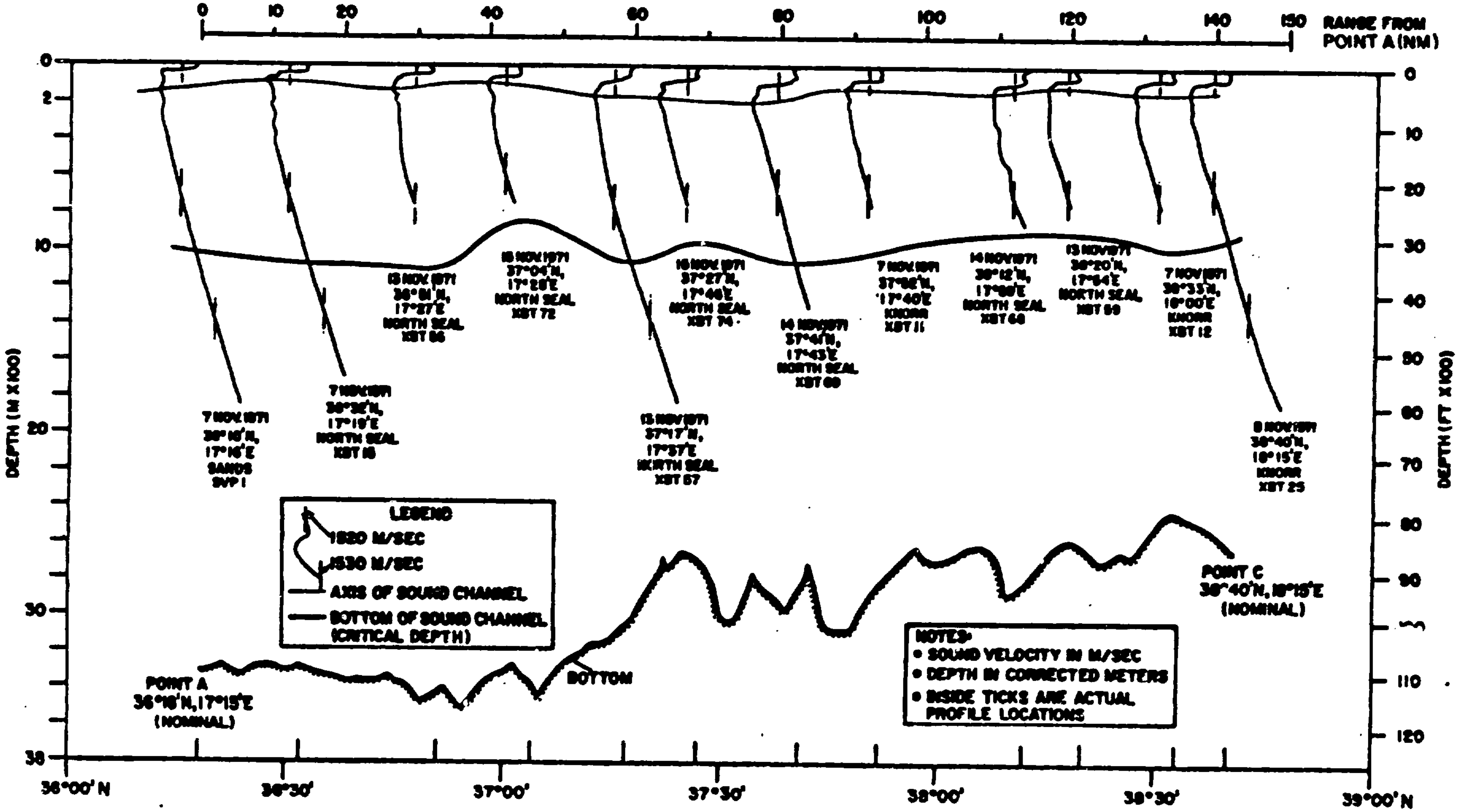

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Figure 4 (U) Sound Velocity Profiles from Point A to Point C (7-15 Nov)

(U) Since the majority of the sound speed profiles given in Figure 4 show surface sound speed layers the profile given by XBT 56 was chosen to represent this run (XBT 57 does not have a surface layer). This profile is illustrated in Figure 5 and listed in Table 3. This profile has been extended to a bottom depth of 3000 m with sound velocity data from reference 6. Layer depth is 42 meters with the DSC axis 130 m and a critical depth of 1050 m.

PROPAGATION LOSS RESULTS (U)

(U) Throughout the CW tow data from the five MABS hydrophones were only recorded every ½-hour sequentially for 25 sec each and the two ½-hourly recordings alternated between the on-and-off periods of the CW sources. Conversely the data from the ANB hydrophones were recorded continuously. Thus the ANB hydrophone data is preferred for model evaluation.

(C) Figure 6 gives propagation loss versus range in nautical miles (nm) as measured at Site C by ANB hydrophones. The frequency was 125 Hz at a source depth of 152 m. The receiver depths are 137 m (top, Figure 6a), 613, 1113, 1116, 2377 and 2652 m, respectively. The minimum range was about 8 nm and the maximum range was about 138 nm. The accuracy of these data is reported to be ±1.0 dB, ±2 minutes and ±0.2 nm (reference 2). Figure 6 is Figure 3-4 of reference 1.

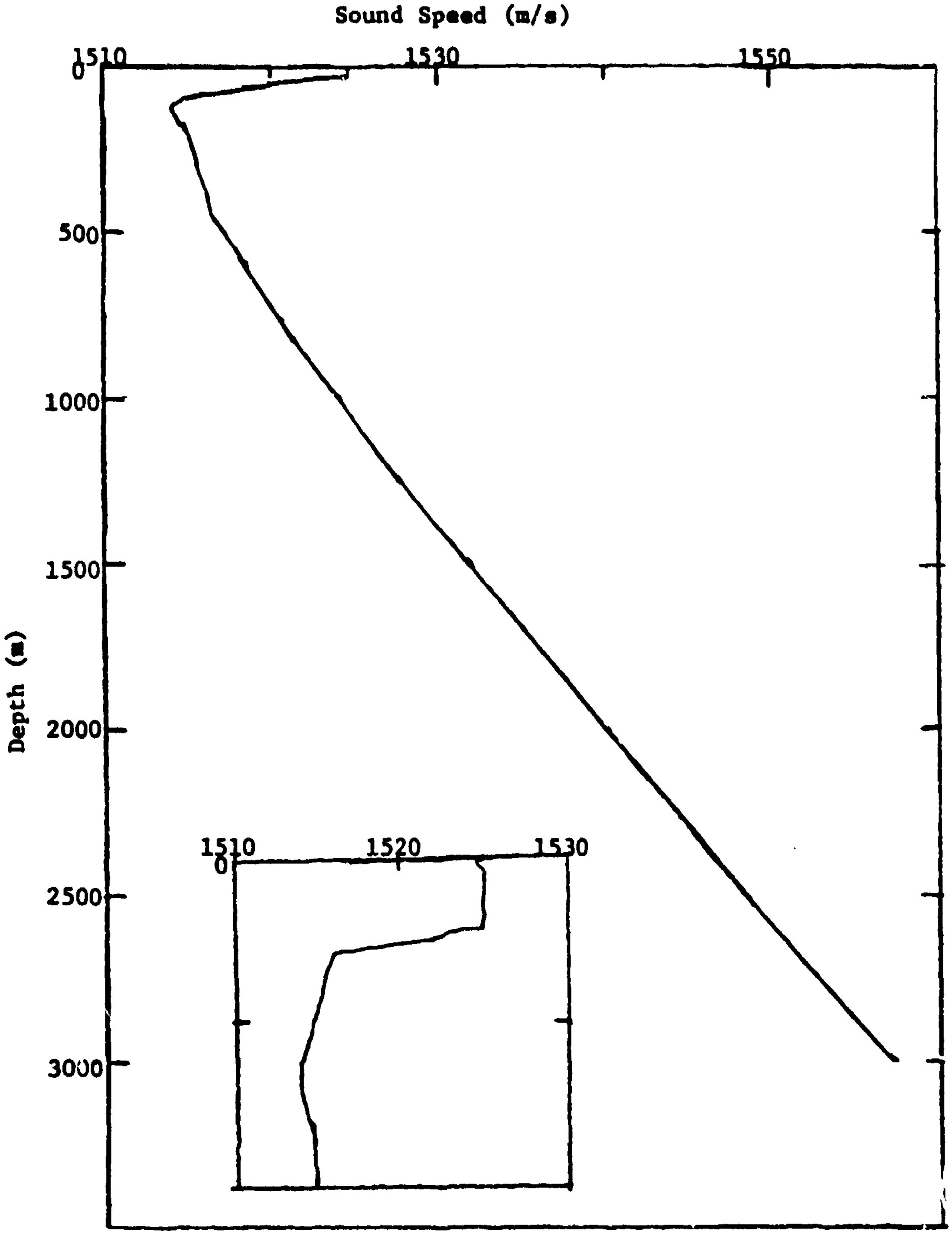

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Figure 5 (U). Sound Speed Profile for 13 Nov.

Table 3.(U) Sound Speed Profile for 13 Nov.

Depth (m)	Sound Speed (m/s)	Depth (m)	Sound Speed (m/s)
0	1524.8	215	1515.0
5	1524.5	300	1515.7
10	1524.9	400	1516.3
40	1524.9	450	1516.5
42	1524.9	500	1517.3
45	1524.8	600	1518.4
50	1521.5	700	1519.6
60	1516.0	750	1520.3
70	1515.6	800	1521.2
75	1515.5	1000	1524.1
90	1515.2	1200	1527.0
100	1514.9	1500	1531.8
120	1514.2	2000	1540.0
130	1514.0	2500	1548.3
150	1514.2	3000	1557.1
160	1514.7		
170	1515.2		
180	1514.6		
200	1514.9		

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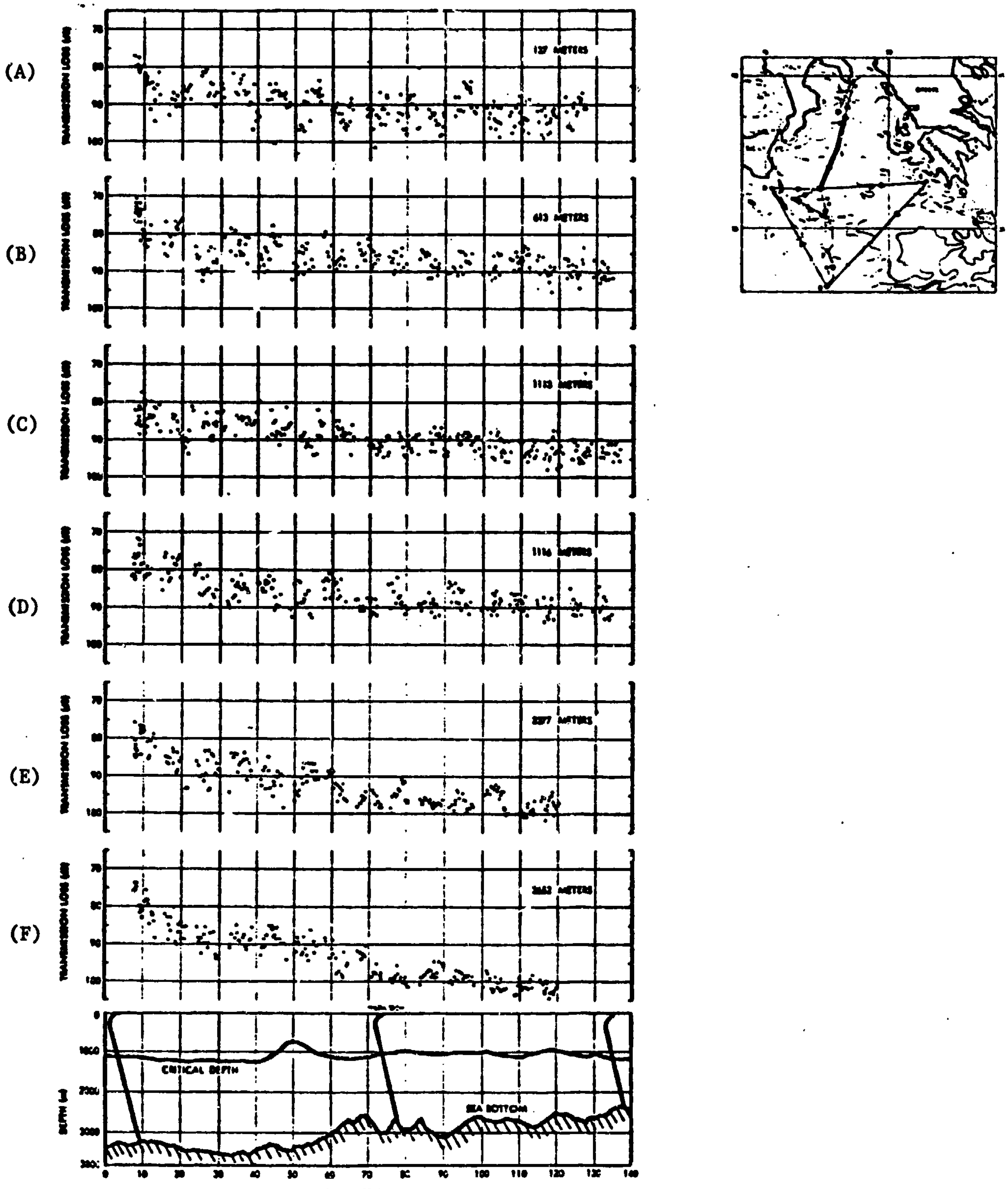

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Figure 6 (C). Transmission Loss versus Range Measured at Site C by ANB's (Track A to C)

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Appendix 10. (U) JOAST III (Joint Oceanographic Acoustic and System Tests)

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Appendix 10

Joint Oceanographic Acoustic and System Tests (JOAST III)(U)

Summarized by Frederic C. Friedel

(C) The Joint Oceanographic Acoustic and System Tests (JOAST) consisted of a set of experiments conducted principally at 5 locations in the Mediterranean Sea during the summer of 1970. The purpose of the JOAST program was to provide data on a number of critical problems associated with present (AN/SQS-26) and future mobile sonar systems in order to improve the ASW effectiveness of our Naval forces in the Mediterranean Sea. This section summarizes the results obtained from that portion of JOAST designated as Phase III as reported in "JOAST Mediterranean Convergence Zone Studies For AN/SQS-26 Performance Prediction (C)," Parts I and II, NUSC Reports 4121-I and 4121-II. The basic objectives of this phase were twofold: (1) to determine the limitations imposed by the scattering layer on the performance of the AN/SQS-26 operating in the convergence zone (CZ) mode in the summer environment, and (2) to make detailed propagation loss measurements as well as acoustic and biological measurements of the scattering layer, to be used for the development of a prediction model for loss and reverberation in the CZ mode. This summary focuses on the propagation loss obtained in the convergences zone for the purpose of model evaluation.

(U) A total of thirty convergence zone propagation loss runs as a function of range and depth were conducted. Significant sampling of the oceanographic environment for each measurement was made. The measurements results are well documented and of high density (7 to 8 experimental values of propagation loss per 1000 yd). Twenty-one convergence propagation loss curves as a function of range and depth were available for each run. The effects of source depression angle (0 or 5°) pulse type (LFM & CW) and frequency dependence are measured. It seems justified that the medium for these transmissions for any one run can be considered independent of range and that it can be modeled from a single velocity structure taken for the run. These data sets are recommended for evaluating FACT and RAYMODE X models. Only data sets at Station 3 and 5 are summarized because they are representative of the two major type of velocity profiles encountered and, therefore, are considered representative of the measurements made. A set of parameters for the measurements at Station 3 and 5 are listed in Table 3-1. The data set of JOAST III is listed as being available at the local NAVDAB at NUSC/NL.

3.1 (U) JOAST III EXPERIMENT DESCRIPTION

(U) The details of the experiment presented here are those concerned only with propagation loss measurements (reverberation was also measured). The measurements were made at the stations in the Mediterranean Sea indicated in Figure 3-1. Referring to Figure 3-2 the SANDS was the receiving platform at the station and maintained positions using a bow thruster to a spar buoy hydrophone array (CZ array), floating from the SANDS. This CZ array consisted of 20 hydrophones linearly spaced at 25 ft. intervals from 60 ft. to 535 ft. Three depth sensors were placed on the string located at top (60 ft.) middle (285 ft.) and bottom (535 ft.). These sensors were monitored to determined vertical orientation and stability of this CZ array. In addition a single hydrophone was used at 25 ft. or 1000 ft. deep as conditions warranted.

(U) XBT casts were made at the SANDS at 6 hour intervals. Deep sound velocity profiles were taken by SANDS at each station.

(C) The source ship was the USS GLOVER using the AN/SQS-26 AXR sonar as the acoustic source. The GLOVER started at a range in excess of that of the convergence zone and slowly approached the SANDS, thereby, effectively moving the convergence zone past the SANDS CZ array. The SQS-26 sonar was normally operated

(U) Table 3-1. JOAST III Parameters

	APPENDIX 3A-11 thru 21	APPENDIX 3A-24 thru 27A
STATION	3	5
RUNS	1-12	1-4
LAYER DEPTH (ft)	80 ft nominal	420 ft nominal
MAX SOUND SPEED DEPTH (ft)	8500	8200
AXIS DEPTH (ft)	260	1300
DEEP SOUND CHANNEL DEPTH (ft)	6600	6200
SOUND VELOCITY PROFILE	See Fig 3-6 & Table 3-7	See Fig 3-7
SOURCE DEPTHS (ft)	20	20
RECEIVER DEPTHS (ft)	60, 85, 110, 135, 160, 185, 210, 235, 260, 285, 310, 335, 360, 385, 410, 435, 460, 485, 510, 535	Same as for Station 3
FREQUENCY (kHz)	3.050-3.150, 3,250 3.350-3.450, 3.550 3.650-3.750, 3.850	Same as for Station 3
DATA DENSITY	14 values/nm in CZ	14 values/nm in CZ
MIN RANGE (kyd)	36	40
MAX RANGE (kyd)	53	55
BOTTOM DEPTH (ft)	8500 plus	8200 plus
	Model should assume infinite bottom loss since only refracted paths are important.	
NAVIGATION	Radio Tone - measure acoustical travel time, range accuracy - within 100 yds.	
DATA LOCATION	NAVDAB UNCLASSIFIED	

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(U) Fig 3-1 JOAST Phase III Mediterranean stations

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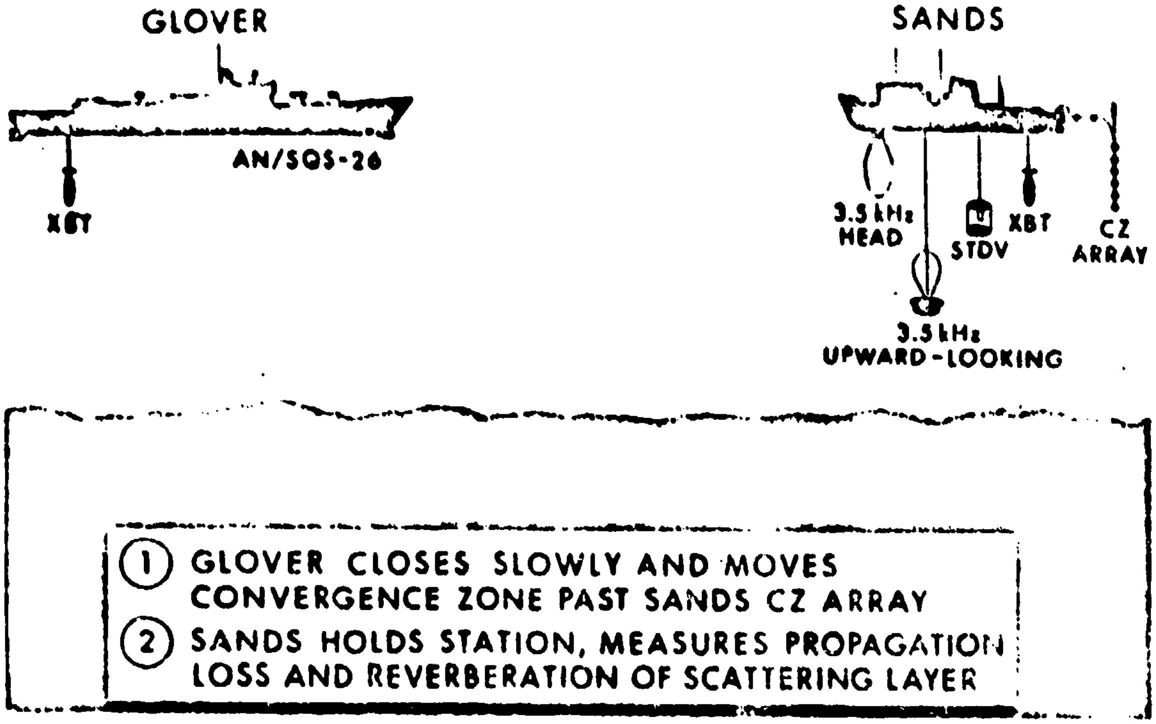

(U) Fig 3-2 Experimental operation for JOAST Phase III in a modified 1/3 CZ mode. Under the normal 1/3 CZ mode, 500 msec LFM (linear frequency modulation), 500 msec CW (continuous frequency) and 30 msec ODT (omni directional transmission) pulses are transmitted with a dead time between pulses of 10 msec. In the modified 1/3 CZ mode the dead time was increased to 300 msec and the ODT transmission was suppressed. This allowed sufficient time between the LFM and CW receptions at the SANDS to permit processing of the received signals for convergence zone propagation loss (CZPL). The sequencing of frequencies used in the 1/3 CZ mode for normal SQS-26 functioning was maintained for most runs. Under the modified 1/3 CZ function, one pulse at one of three LFM frequency bands and one pulse at one of the CW frequencies are transmitted as a doublet (i.e., two 500 msec pulses with 300 msec dead time between pulses) at each repetition time and repeated every third transmission. Table 3-2 lists these doublet frequencies along with a frequency identifier. Additional modifications were made in the transmitting schedule where the CW pulse was shortened to 14 msec or a wide band (400 Hz) 800 msec LFM pulse was transmitted for one frequency band (3300-3700) at each repetition time. Table 3-3 lists the coded signal events and in conjunction with Table 3-4 completes the list of Operational Data for each run. All 500 msec LFM pulses had a nominal 100 Hz bandwidth. Only the data for Stations 3 and 5 are of concern here. In 1/3 CZ transmission the vertical beamwidth (3 dB down) is 16° and the sector coverages is 120°, however for the transmissions of Station 5 the sector coverage was 40°, (BB search mode). The modified 1/3 CZ mode of transmission is depicted in Figure 3-3. The timing indicated in the sequence is that of a radio signal t_o transmitted to the SANDS for computation of acoustical travel time. At the time t_o the frequency of the radio transmitted CW tone was changed.

(U) During the runs the GLOVER made XBT casts at 1 hour intervals.

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(U) TABLE 3-2

DOUBLET-PULSE FREQUENCIES

Identifier	LFM Frequencies (Hz)	CW Frequencies (Hz)
F_1	3050-3150	3250
F_2	3350-3450	3550
F_3	3650-3750	3850

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(U) TABLE 3-3

CODED SIGNAL EVENTS

Event No.	LFM Duration (msec)	CW Duration (msec)	Three Frequency (1/3 CZ)	Single Frequency
C150	500	500	X	
C101	500	14	X	
C201	500	14		F_3
C300	800	--		F_2
C410	--	100	X	
C500	500	--	X	

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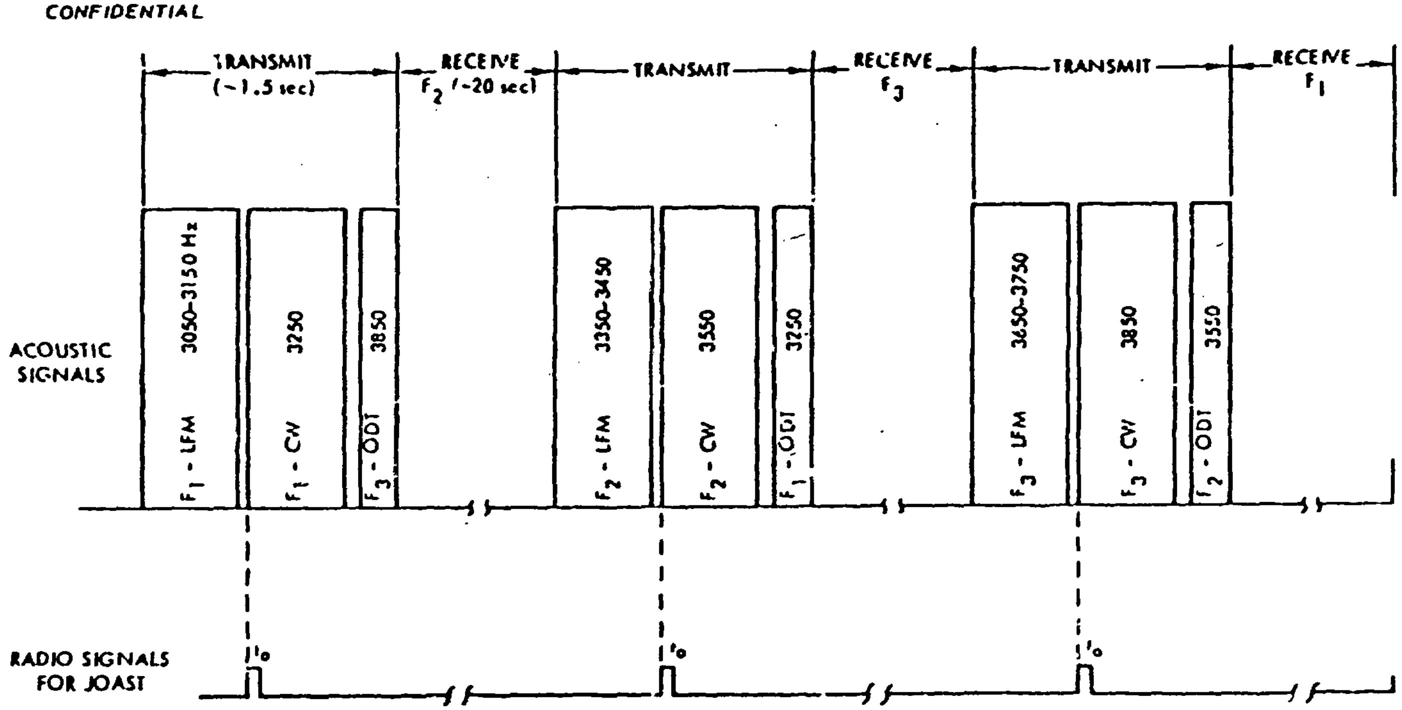
(U) TABLE 3-4

OPERATIONS DATA FOR EACH RUN OF JOAST PHASE III

Run	Date	Start Time (Local)	Position		GLOVER SOA (knots)	Depression Angle (deg)	Event
			Latitude	Longitude			
Station 1 - 37°16'N, 01°15'E							
2	8-22	0037	37°23'N	01°26'E	3	0	C500
3	8-22	1521	37°29'N	01°27'E	5	0	C500
4	8-22	2346	37°27'N	01°11'E	5	5	C500
6	8-23	1652	37°22'N	01°06'E	8	5	C300
7	8-23	1949	37°22'N	01°06'E	5	0	C150
Station 2 - 41°20'N, 06°57'E							
1	8-28	2128	41°33'N	07°00'E	8	0	C150
2	8-29	0125	41°33'N	07°00'E	5	5	C150
3	8-29	1355	41°41'N	07°13'E	3	0	C410
4	8-29	2255	41°41'N	07°13'E	3	0	C150
5	8-30	1350	41°50'N	07°22'E	5	0	C300
6	8-30	2209	41°29'N	07°29'E	3	5	C150
7	8-31	1112	41°22'N	07°47'E	5	0	C101
Station 3 - 40°16'N, 13°00'E							
1	9-4	1557	40°24'N	12°42'E	5	0	C150
2	9-4	2201	40°24'N	12°42'E	4	0	C150
3	9-5	0139	40°24'N	12°42'E	5	5	C150
4	9-5	1409	40°22'N	12°46'E	4	0	C150
5	9-6	0100	40°26'N	12°52'E	4	0	C150
6	9-6	1326	40°22'N	12°53'E	4	0	C300
7	9-6	2120	40°22'N	12°54'E	4	0	C150
8	9-7	0033	40°22'N	12°54'E	4	5	C150
9	9-7	0951	40°24'N	12°59'E	4	0	C101
10	9-7	1916	40°24'N	12°59'E	4	0	C101
11	9-7	2253	40°26'N	12°58'E	5	0	C201
12	9-8	1005	40°30'N	13°01'E	4	0	C150
Station 4 - 36°31'N, 18°30'E							
1	9-20	2320	36°21'N	18°30'E	4	0	C150
2	9-21	2010	36°30'N	18°28'E	4	5	C150
Station 5 - 34°02'N, 26°30'E							
1	9-27	2107	34°03'N	26°20'E	4	0	C150
2	9-27	2348	34°03'N	26°20'E	4	5	C500
3	9-28	1021	34°06'N	26°36'E	4	5	C500
4	9-28	1351	34°06'N	26°36'E	4	5	C500



(U) Fig. 3-3. AN/SQS-26 transmitting and receiving acoustic frequency sequence (1/3 CZ mode) with JOAST t_0 radio pulse transmission timing.

3.2 (U) DATA ACQUISITION AND PROCESSING

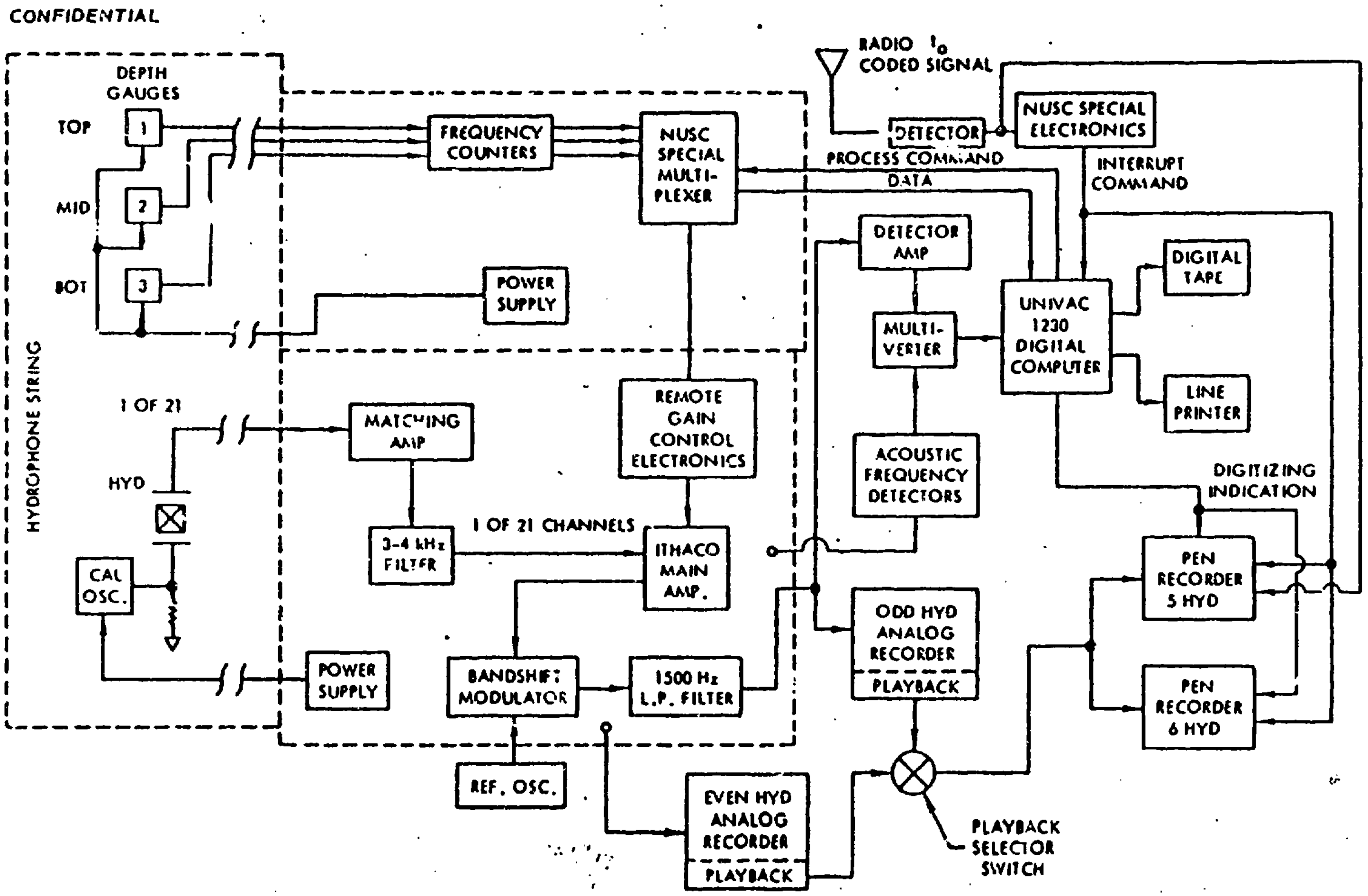
(U) The data processing block diagram for the convergence zone propagation loss is in Figure 3-4. Although the diagram is mostly self explanatory a simplified explanation of the data flow and entry follows.

3.2.1 (U) Depth Gages

(U) These gages were low impedance pressure to frequency converters. The frequency output of the sensors were measured by a frequency counter. The BCD output of the counter were fed to a special multiplexer and then to an input buffer of the UNIVAC 1230 computer. The computer was programmed to cycle the multiplexer and sample all the inputs, (separate hydrophone depth gage and coded value of remote gains control amplifiers). Cycling of the multiplexer occurred after each set of receptions were stored in the computer but before computations. The computer was programmed to compute the equivalent depth of the gages using the coded depth gage frequency. Interpolation was then used to determine the hydrophone depths from the measured depth gages and their proximity to the designed location of each hydrophone.

3.2.2 (U) Travel Time Measurement

(U) The radio t_o transmission was detected with special electronics and used to generate an interrupt to the computer which then records the time of the interrupt. The computer then senses the time for the acoustical arrival. The elapsed time between interrupt and acoustical arrival is the acoustical travel time. Each travel time was stored on digital tape and printed out by a high speed printer for immediate verification by the operating personnel.



(U) Fig. 3-4. JOAST Phase III data processing block diagram for convergence zone propagation loss measurements

(U) The horizontal range for the propagation loss was based on the travel time for each GLOVER's transmission, and an effective average sound speed determined from on-site velocimeter data. An error analysis concluded that the acoustically determined horizontal range measurement should be accurate to within 100 yds for all results presented.

3.2.3 (U) Acoustic Signal Processing

(U) The output of the hydrophones for the acoustical signals was fed to a matching amplifier, band passed (3-4 kHz), amplified (operator controlled automatically adjustable gain amplifiers) and then band shifted to a band between 250 and 1250 Hz by use of a stable 2750 Hz carrier. The band shifted signals were then fed to the digital and analog processing systems. The envelope of the band shifted signal was developed with a linear detector and amplified for computer processing. The integration time constant for the detection was 1 msec and a digital sample was obtained every 5 msec when the 500 msec acoustic pulses were being processed. As a backup for the digital system the band shifted signals were recorded on analog FM tape recorders. As the signals were recorded, the reproduced tape outputs were fed to two 8-channel pen recorders for visual observations of the hydrophones output. One channel of the pen recorder was used to indicate the period of time over which digitization of the acoustical signals occurred. The signals from one hydrophone after band shifting were fed to three filters whose bandwidths were chosen to pass the bandshifted F_1, F_2, or F_3 LFM signals. The filter outputs were envelope detected and fed to three preassigned multiverter channels which were searched by the computer to sense the highest level during the time of the acoustic reception. This permitted the assignment of the frequency identifier of the LFM and CW data being processed. The system was calibrated by injecting sine wave electrical signals in series with the hydrophone elements. In conjunction with the hydrophone calibration curves[1], the acoustical pressure levels for the sine wave signals are established and serve as a basis for determining the acoustical level of the received signals for the experiments.

3.2.4 (U) Propagation Loss Measurements

(U) A computer program was developed to calculate the received acoustic levels for each transmission. This process was synchronized after the first t_0 commands and the first acoustic arrival was received, because the repetition rate of the GLOVER transmissions was known and fixed for a run. Once an acoustic signal was detected it was known that another reception would occur within a certain time limit. The computer would count to time equal to 2 secs less than the anticipated acoustic arrival and then become ready for processing. At this time the computer determined the mean square level estimate of 1 sec noise sample before the acoustic reception. A threshold level of between 3 and 10 times this noise level was then set by the operator. These threshold levels were determined for five hydrophones of the string (hydro 1, 5, 10, 15 and 20). Once the signal levels at any two of the 5 hydrophones for five consecutive digital samples exceeded the threshold level, the time at which the first digital sample exceeded the threshold level was recorded as the time of arrival for the reception. Travel time was then calculated.

(U) When the GLOVER transmissions arrived at the vertical string, 2 seconds, (400 digital samples) were stored in computer memory. These 2 seconds of data included 100 msec (20 samples) of noise history before the signal exceeded the threshold and 1.9 secs (380 samples) of signal data. This time aperture was sufficient to capture the signal doublet-pulse arrivals. The received levels were calculated by the computer using the following three methods.

1. (U) The digitized detected signals were squared and averaged over a time interval equivalent to the transmitted pulse length. This value was used to obtain an average propagation loss designated APL.

2. (U) The digitized detected signals were summed over a time interval of 1½ times the pulse length. The computer then determined the sample at which 95 percent of this extended level summation had occurred. This value was considered as the time over which 95 percent of the received energy had arrived and was used to develop another average propagation loss value designated APL'.

3. (U) During the APL processing the peak detected level was used to determine the peak propagation loss, designated PPL.

(U) To determine propagation loss the sonar level of the AN/SQS-26 had to be known. This was determined for signal type (LFM or CW) beamwidth, and depression angle (0° or 5°) by use of the techniques specified in the AN/SQS-26 (AXR) certification manual.[2] The near field results were checked before the operations at each station. The GLOVER starting at 3,000 yds would approach the CZ array buoy to 500 yds at an SOA of 3 knots using the CZ mode of transmission and radio timing signals. The computer determined ranges, received acoustic levels, and then determined a propagation loss based on inverse square spreading. The later two values were added to give a source level. All source levels determined at the GLOVER by near field techniques were confirmed. Convergence propagation loss is, therefore, computered as the source level minus the received levels in the convergence zone.

(U) After each run, the digital processed data tapes were edited to correct erroneous travel times, and rearranged to produce a CALCOMP plotting tape. This tape was then used to produce plotted results from a CALCOMP printer aboard the SANDS. Either of two types of plots were available.

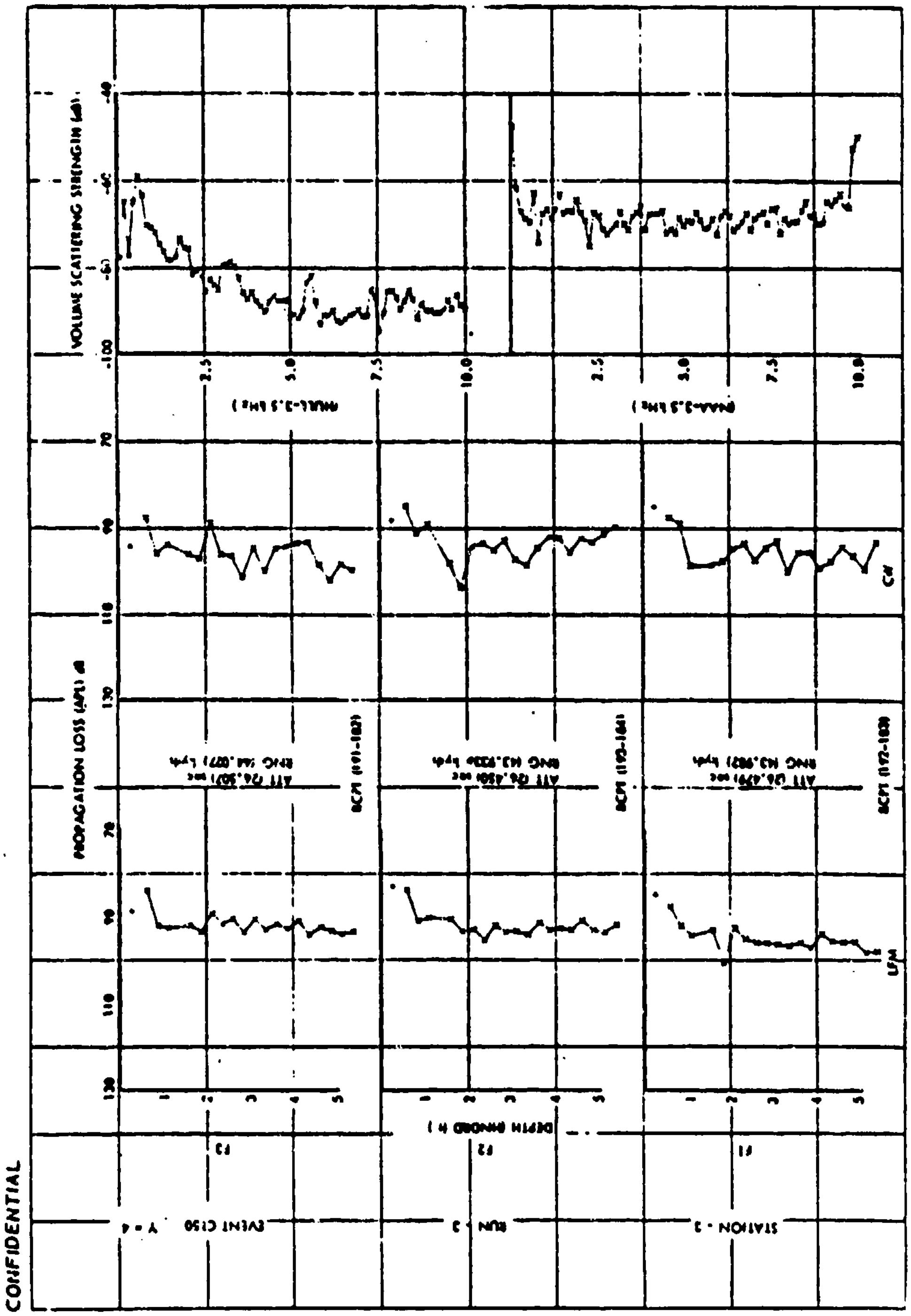
1. (U) A plot containing three CZPL curves as a function of range (for three hydrophones), pulse type, frequency (F_1, F_2, or F_3), and processing method (APL, APL' or PPL). This type of presentation is typical of the results in Appendix A of this report.

2. (U) A set of six propagation loss profiles (CZPL as a function of depth to 535 ft.) occurring at different ranges throughout the convergence zone, for LFM & CW CZPL results for the three frequencies associated with the doublet pulses (Figure 5). The plotting program could develop the average of a number of CZPL profiles; usually four to eight were averaged as a function of pulse type and frequency.

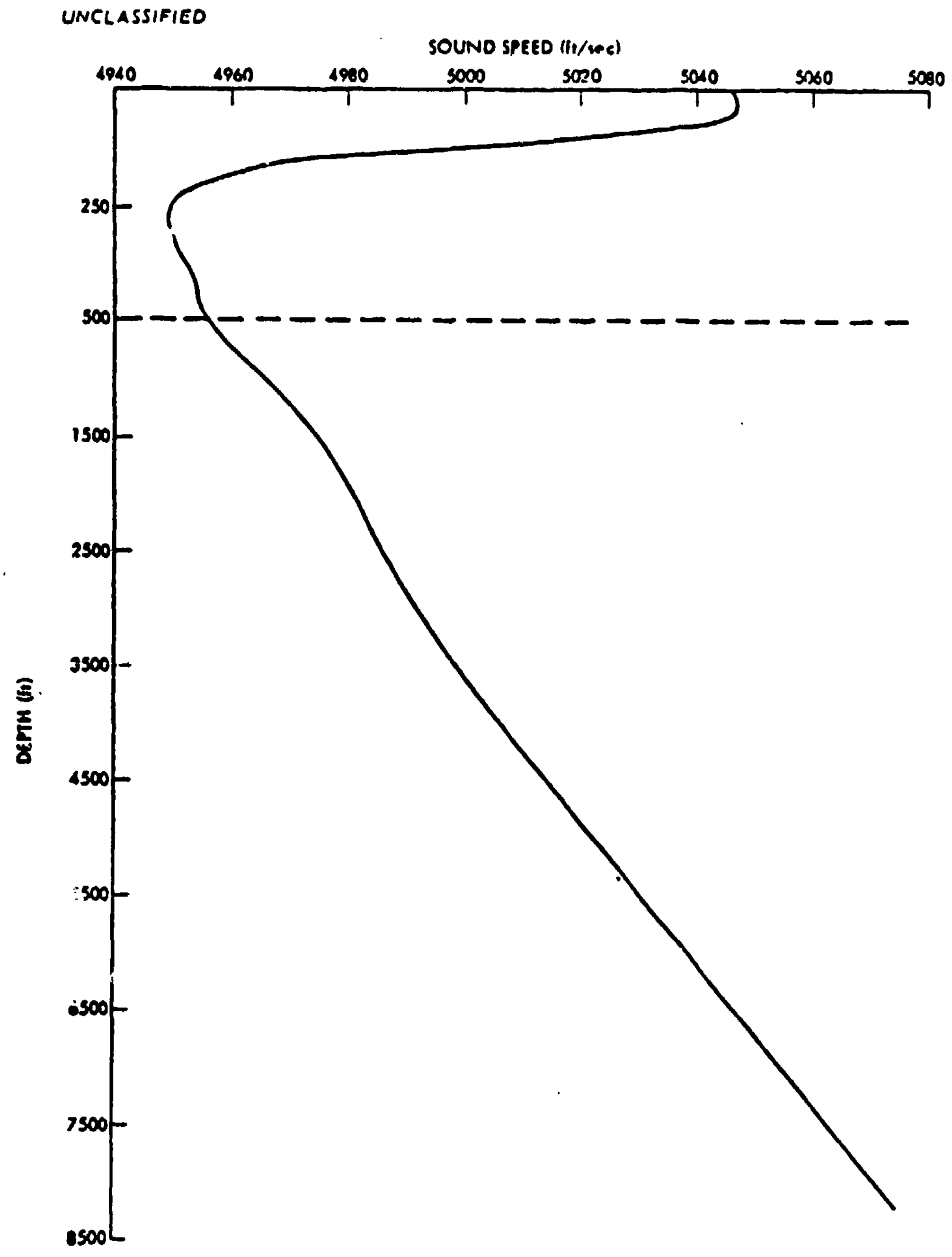
3.3 (U) ENVIRONMENTAL FACTORS

(U) The sound speed profiles as taken by the SANDS at Stations 3 and 5 are shown in Figures 3-6 and 3-7. They show the surface half channel, thermocline, minimum velocity (deep sound channel axis), and the positive speed gradient due to increasing pressure. Depth excess for convergence zone propagation is at least 2,000 ft.

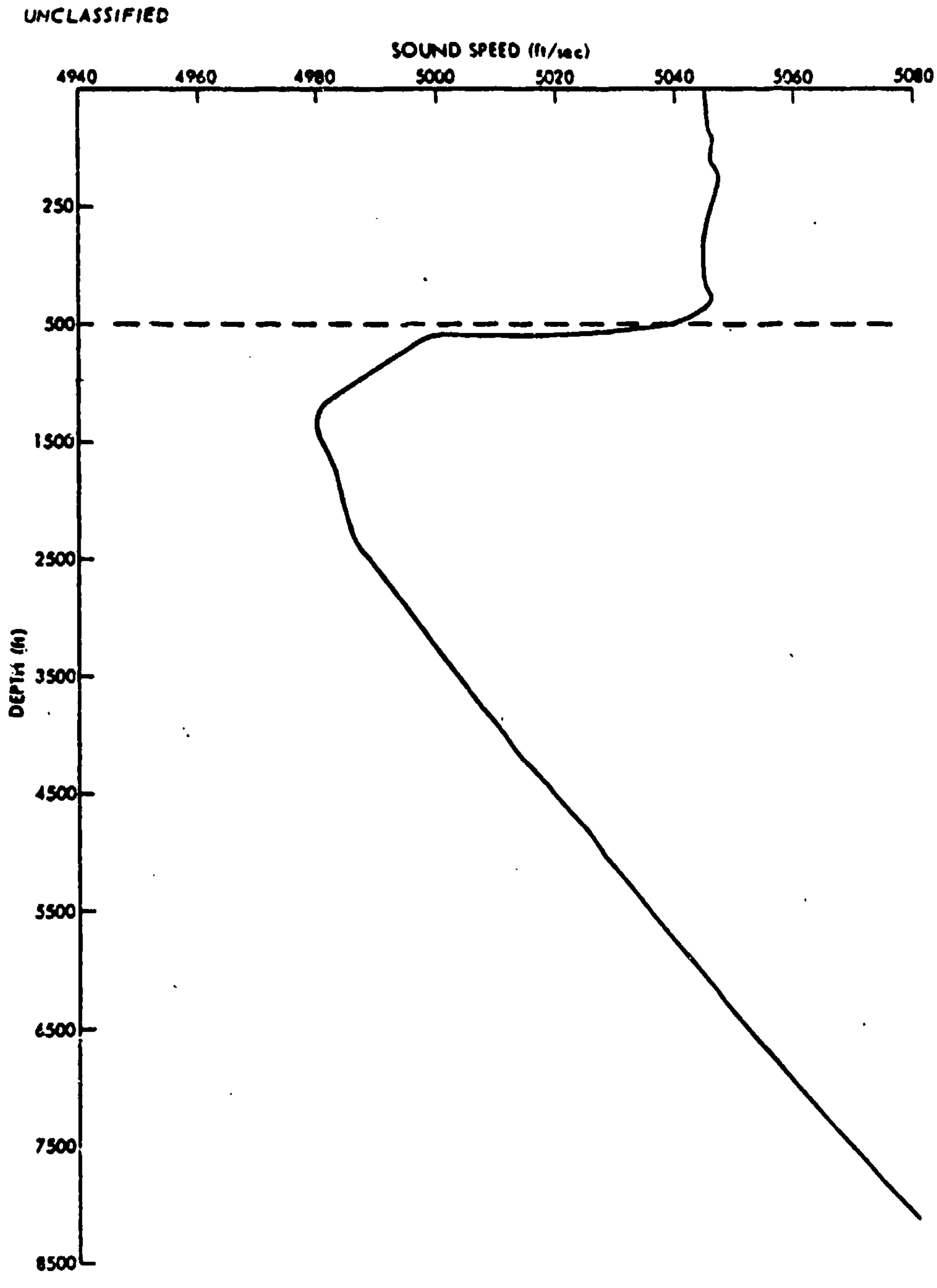
(U) The weather and sea conditions from the SANDS log are listed for each Station in Table 3-5.



(U) Fig. 3-5. Typical CALCOMP output generated aboard the USNS SANDS during JOAST Phase III operations. Shown are (1) convergence zone propagation loss depth profiles for each frequency and pulse type generated by AN/SQS-26 aboard the GLOVER for 1/3 CZ mode of transmission and (2) scattering strength depth profiles obtained with downward- and upward-looking fathometer systems aboard the SANDS.



(U) Fig. 3-[illegible] Sound speed profile for JOAST Phase III Station 3



(U) Fig. 3-7. Sound speed profile for JOAST Phase III Station 5

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(U) TABLE 3-5

JOAST PHASE III WEATHER AND SEA INFORMATION

Date	Position		Wind		Sea			Swell			Barometer Reading (in. Hg)
	Latitude	Longitude	Direction (deg)	Speed (knots)	Direction (deg)	Height (ft)	Period (sec)	Direction (deg)	Height (ft)	Period (sec)	
Station 1											
8-22	37°29'N	01°27'E	110	8	110	2	3	090	4	4	29.93
8-23	37°29'N	01°09'E	070	14	070	3	5	070	6	7	29.89
Station 2											
8-28	41°28'N	07°00'E	170	8	170	1	2	100	2	3	30.02
8-29	41°41'N	07°13'E	330	20	330	3	4	170	6	8	29.85
8-30	41°30'N	07°22'E	300	15	330	3	3	320	5	6	30.03
8-31	41°22'N	07°47'E	290	20	290	5	7	290	12	14	30.00
Station 3											
9-4	40°21'N	12°39'E	300	3	300	3	--	190	1	4	30.07
9-5	40°22'N	12°46'E	Calm		Calm		--	280	6	6	30.06
9-6	40°22'N	12°53'E	290	8	291	1	1	290	4	5	30.05
9-7	40°24'N	12°59'E	Calm		Calm		--	310	1	2	30.05
9-8	40°30'N	13°01'E	130	4	Calm		--	210	2	3	30.09
Station 4											
9-20	36°45'N	18°26'E	Calm		Calm		--	240	4	6	29.93
9-21	36°24'N	18°19'E	070	18	070	4	4	090	8	6	29.81
Station 5											
9-27	33°58'N	26°34'~~N~~E	300	6	Calm		--	025	6	9	30.04
9-28	33°59'N	26°31'~~N~~E	360	24	360	6	--	025	12	10	30.05

3.4 (U) PROPAGATION LOSS RESULTS

3.4.1 (U) Analysis of Processing Methods (APL, APL', PPL)

(U) The difference in CZPL for the two different processing methods (APL and APL') were found to be insignificant for receptions over the central range of the convergence zone (the range over which the CZPL values remain consistently less than 100 dB). This indicates that time spreading for the 500 msec pulse length is insignificant over this range. A comparison of the two methods is shown in Table 3-6 and as a result the processed data reported are those based over a time equal to the transmitted pulse length (APL). Therefore, the data sets based on APL to be used in the model comparison for propagation loss and start of convergence zone are shown at the end of this section. For the runs of Station 3 the measured CZPL versus range curves with frequency, LFM source pulse, and hydrophone depth as additional parameter are in Figures 3-18 through 3-28. Similarly, the runs of Station 5 are in Figures 3-29 through 3-36.

(U) The CZPL results for average propagation loss (APL) and peak propagation loss (PPL) processing show that the loss based on the latter were lower in value. For LFM pulses the PPL values were consistenly lower (2 - 4 dB) than the APL. This is graphically depicted for the data for Station 3, Run 8, for F_2 - LFM, (3350 - 3450 Hz) in Figure 3-8. Corresponding rsults for CW as shown in Figure 3-9 indicate the PPL is also lower than APL ranging on the average from 0 to 10 dB less. These differences can be explained in terms of the interference effect as applied to the LFM or CW acoustic pulses and the differences may be expected.

3.4.2 (U) LFM vs CW Analysis

(U) An analysis of the LFM and CW CZPL results from processing the data for total energy over the transmitted pulse length (APL) showed that CZPL for the LFM signals were slightly lower

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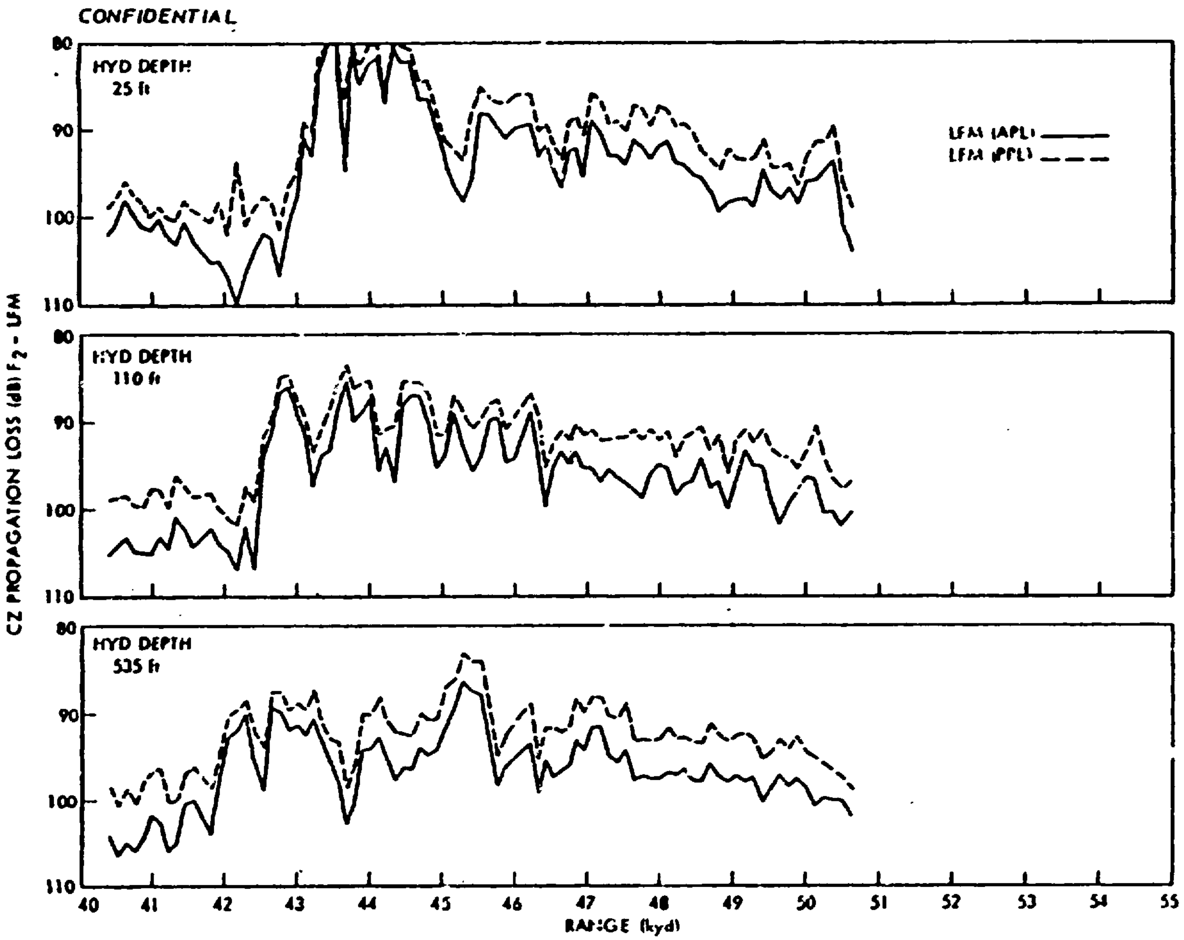
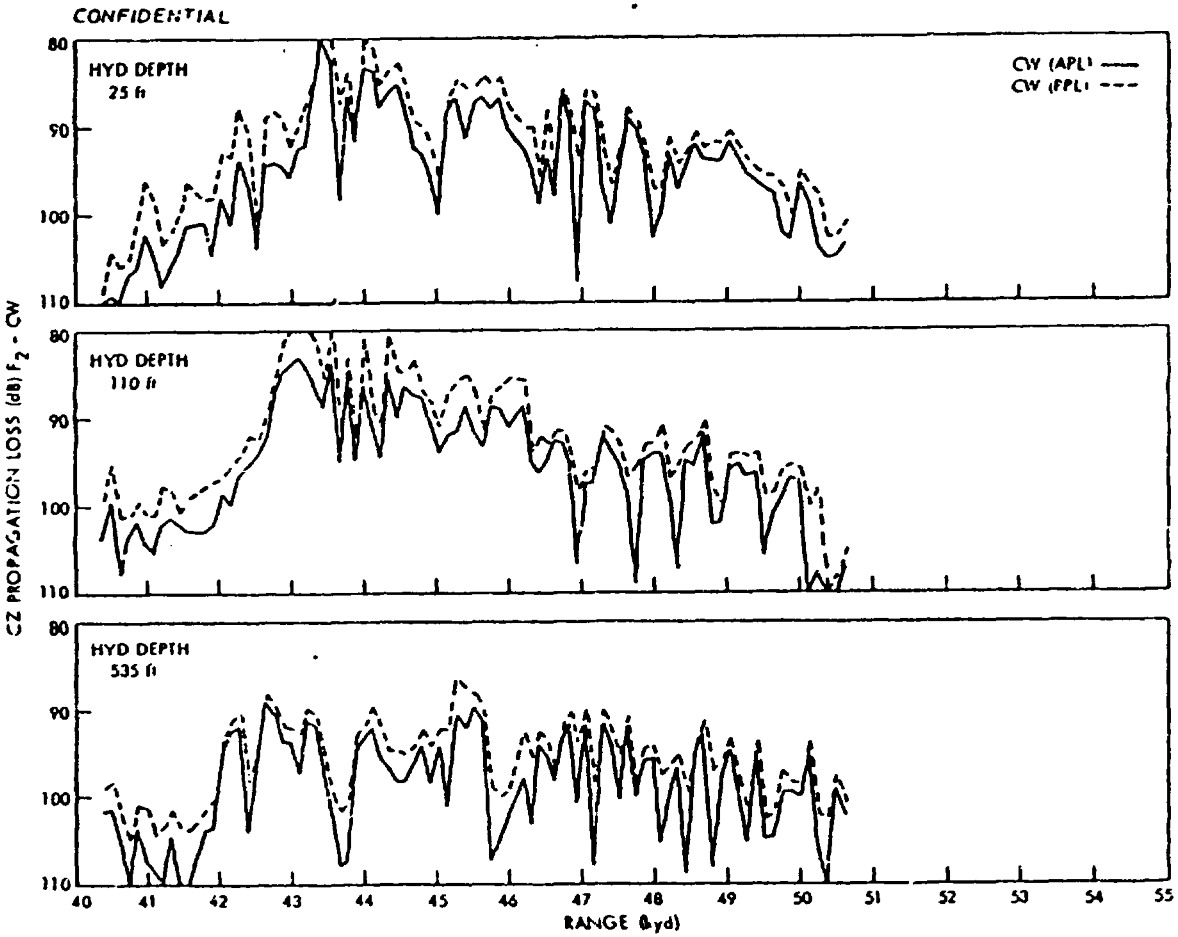
(U) TABLE 3-6

COMPARISON OF APL AND APL' RESULTS

Range (kyd)	Hydrophone No. 1 (Depth: 60 ft)		Hydrophone No. 2 (Depth: 160 ft)		Hydrophone No. 19 (Depth: 510 ft)	
	APL (dB)	APL' (dB)	APL (dB)	APL' (dB)	APL (dB)	APL' (dB)
48.631	98.25	98.25	100.75	100.75	105.00	104.62
48.498	103.37	103.37	100.62	100.62	104.87	104.87
48.349	100.25	100.25	100.25	100.25	95.62	95.50
48.237	95.12	95.12	97.25	97.25	103.00	102.87
48.107	93.00	93.00	102.00	102.00	103.62	103.62
47.997	99.25	99.25	98.00	98.00	101.75	101.75
47.874	91.87	91.87	90.12	90.12	103.12	103.12
47.755	96.25	96.25	95.50	95.50	93.00	92.87
47.635	92.50	92.50	97.62	97.62	100.62	100.62
47.517	93.00	93.00	100.37	100.37	103.87	103.87
47.397	94.12	94.12	92.75	92.75	99.87	99.87
47.278	94.62	94.62	96.12	96.12	99.37	99.37
47.158	96.25	96.25	98.62	98.62	98.75	98.62
47.040	89.25	89.25	93.87	93.87	97.25	97.12
46.920	90.50	90.50	94.37	94.37	93.50	93.50
46.801	95.25	95.25	92.37	92.37	95.75	95.75
46.683	92.37	92.37	92.12	92.12	94.75	94.75
46.564	88.87	88.87	95.25	95.25	94.12	94.12
46.456	84.75	84.75	93.62	93.62	96.00	96.00
46.347	87.75	87.75	100.87	100.87	94.50	94.00
46.238	86.25	86.25	90.25	90.25	92.00	91.87
46.131	83.75	83.75	93.12	93.12	96.25	96.25
46.023	87.50	87.50	91.50	91.50	93.37	93.37
45.914	93.62	93.62	92.87	92.87	93.00	93.00
45.805	94.87	94.87	92.50	92.50	92.75	92.75
45.696	96.12	96.12	92.37	92.37	89.37	89.37
45.588	88.12	88.12	87.87	87.87	89.87	89.87
45.479	88.25	88.25	91.62	91.62	92.37	92.37
45.226	82.12	82.12	90.25	90.25	90.25	90.25
45.119	87.50	87.50	91.62	91.62	91.37	91.37
45.010	86.62	86.62	92.25	92.25	93.00	93.00
44.901	90.25	90.25	92.00	92.00	89.50	89.50
44.793	87.75	87.75	93.75	93.75	90.50	90.50
44.684	86.25	85.25	90.87	90.87	88.00	88.00



(U) Fig. 3-8. Total energy (APL) and peak energy (PPL) convergence zone propagation loss results obtained for three hydrophone depths. F_2-LFM (3350-3450 Hz) data acquired at Station 3, Run 8. Data processed for period equal to transmitted pulse length to determine APL, with PPL determined from peak level over the same period.



(U) Fig. 3-9. Total energy (APL) and peak energy (PPL) convergence zone propagation loss results obtained for three hydrophone depths. F_2-CW (3550 Hz) data acquired at Station 3, Run 8. Data processed for period equal to transmitted pulse length to determine APL, with PPL determined from peak level over the same period.

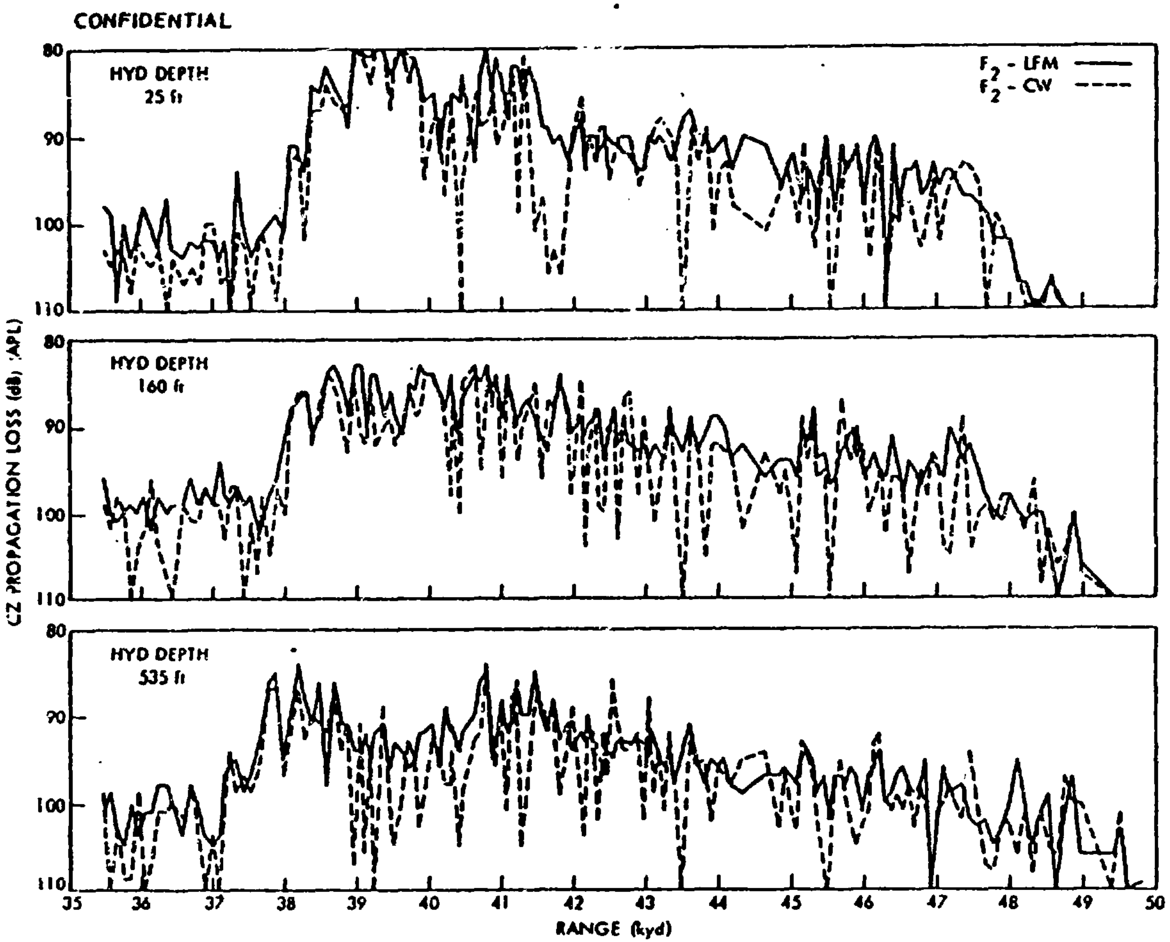
in loss on the average, and that the variability of CW CZPL results are greater. Figure 3-10 presents a comparison of the LFM and CW data as a function of range and hydrophone depth at Station 2, Run 6. Since it is felt that the differences can be logically explained only LFM-APL CZPL curves are presented in Part II of the JOAST III report.

3.4.3 (U) Attentuation Analysis

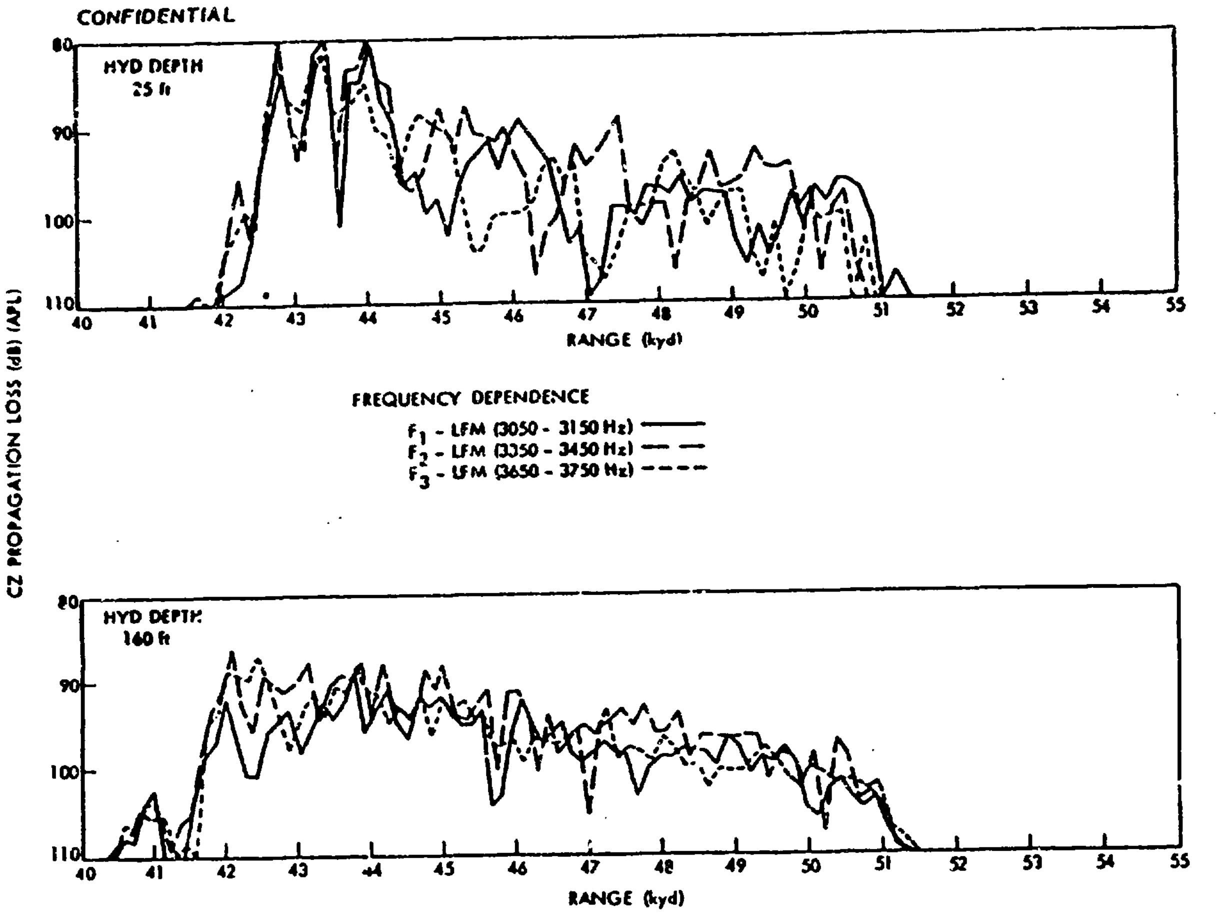
(U) Because of attenuation it would be expected that a one-way propagation loss between F_1 and F_3 frequency bands would be in the neighborhood of 2 dB.[3] Analysis of the CZPL results did not reveal any obvious frequency dependence over the frequency band used for the AN/SQS-26. This is illustrated in Figure 3-11 where the CZPL is shown for two hydrophone depths and the three frequency bands. The top hydrophone (25 ft.) is in the thermal layer and the 160 ft. hydrophone is in the steep negative sound speed gradient. A similar comparison is in Figure 3-12 for the curves from Station 3, Run 3, hydrophone at 25 ft., and Station 5, Run 2, hydrophone at 60 ft. For the lower set of curves in Figure 3-12 no discernable frequency dependence is shown. In the upper set at the front of the zone the frequency dependence is negligible. With increasing range the expected systematic frequency dependence (CZPL for $F_1 < F_2 < F_3$) is observed except that the difference approaches 6 dB. The results indicate that the difference cannot be due to simple attenuation associated with absorption.

3.4.4 (U) Depth Dependence

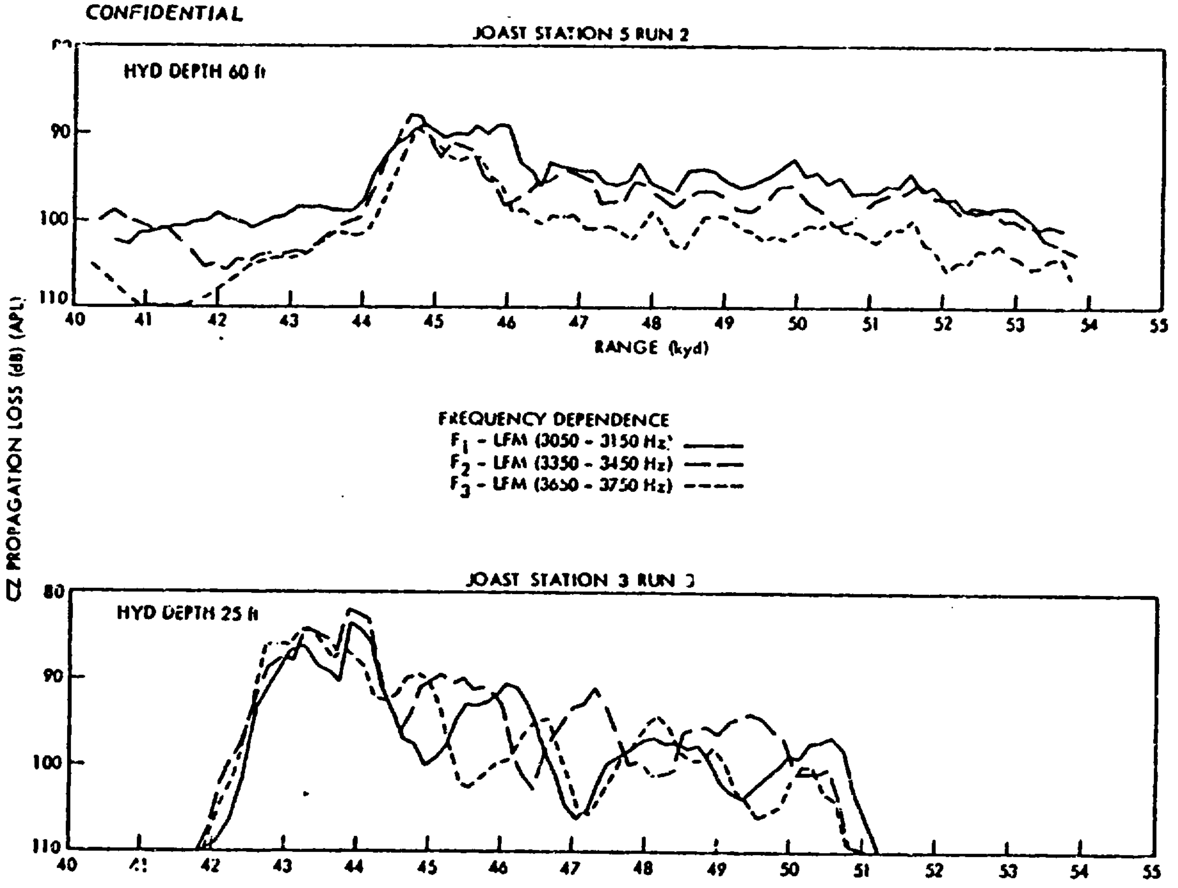
(U) For the Western Mediterranean (Stations 1, 2, & 3) a typical late summertime temperature profile gives a well defined warm surface layer with average temperatures above 70°F. The layer extends to approximately 80 ft. Between 80 and 100 ft.



(U) Fig. 3-10. Convergence zone propagation loss results obtained for three hydrophone depths. F_2-LFM (3350-3450 Hz) and F_2-CW (3550 Hz) data acquired at Station 2, Run 6. Data processed for period equal to transmitted pulse length to determine CZPL based on total energy (APL).



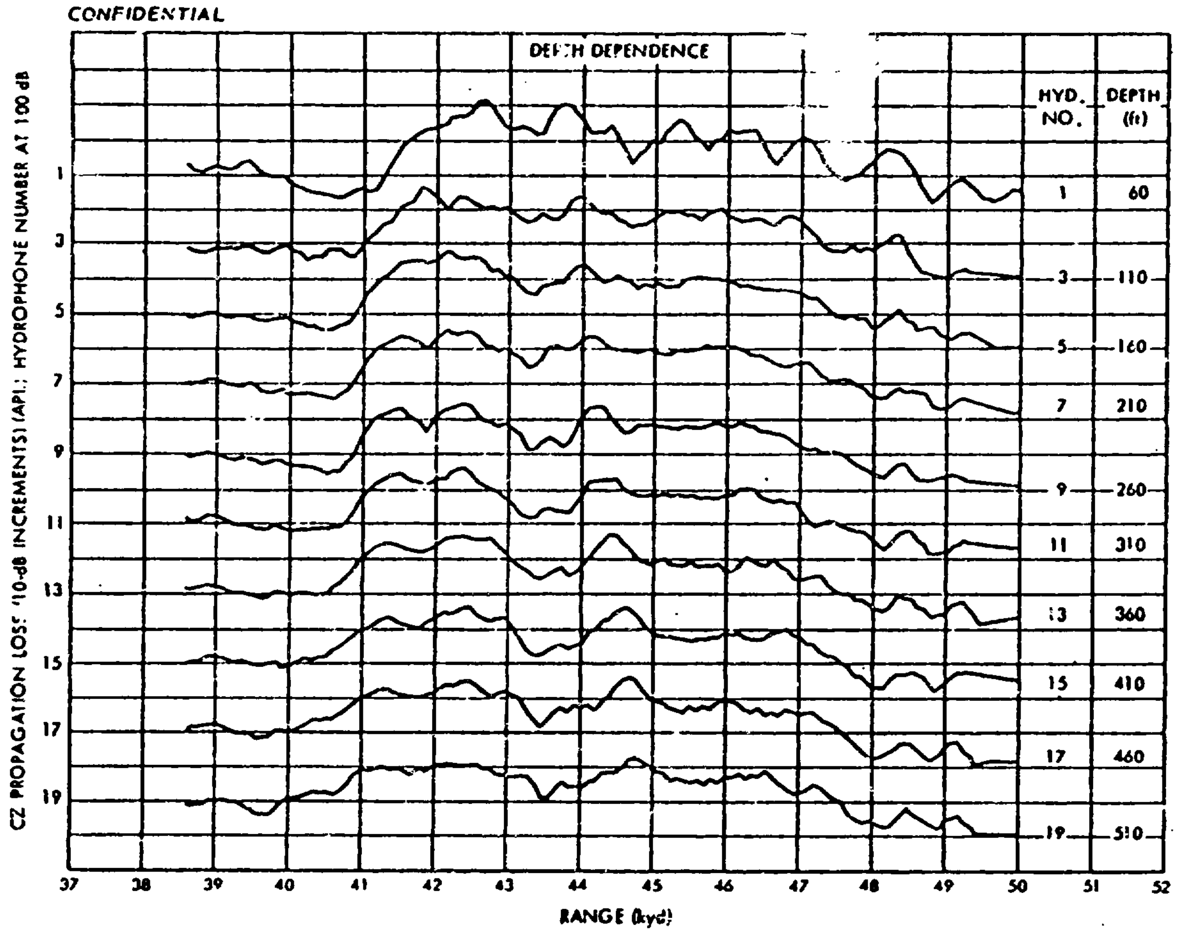
(U) Fig. 3-11. Detailed frequency dependence of convergence zone propagation loss for two hydrophone depths. F1-LFM (3050-3150 Hz). F2-LFM (3350-3450 Hz). and F3-LFM (3650-3750 Hz) data acquired at Station 3, Run 3. Data processed for period equal to transmitted pulse length to determine CZPL based on total energy (APL).



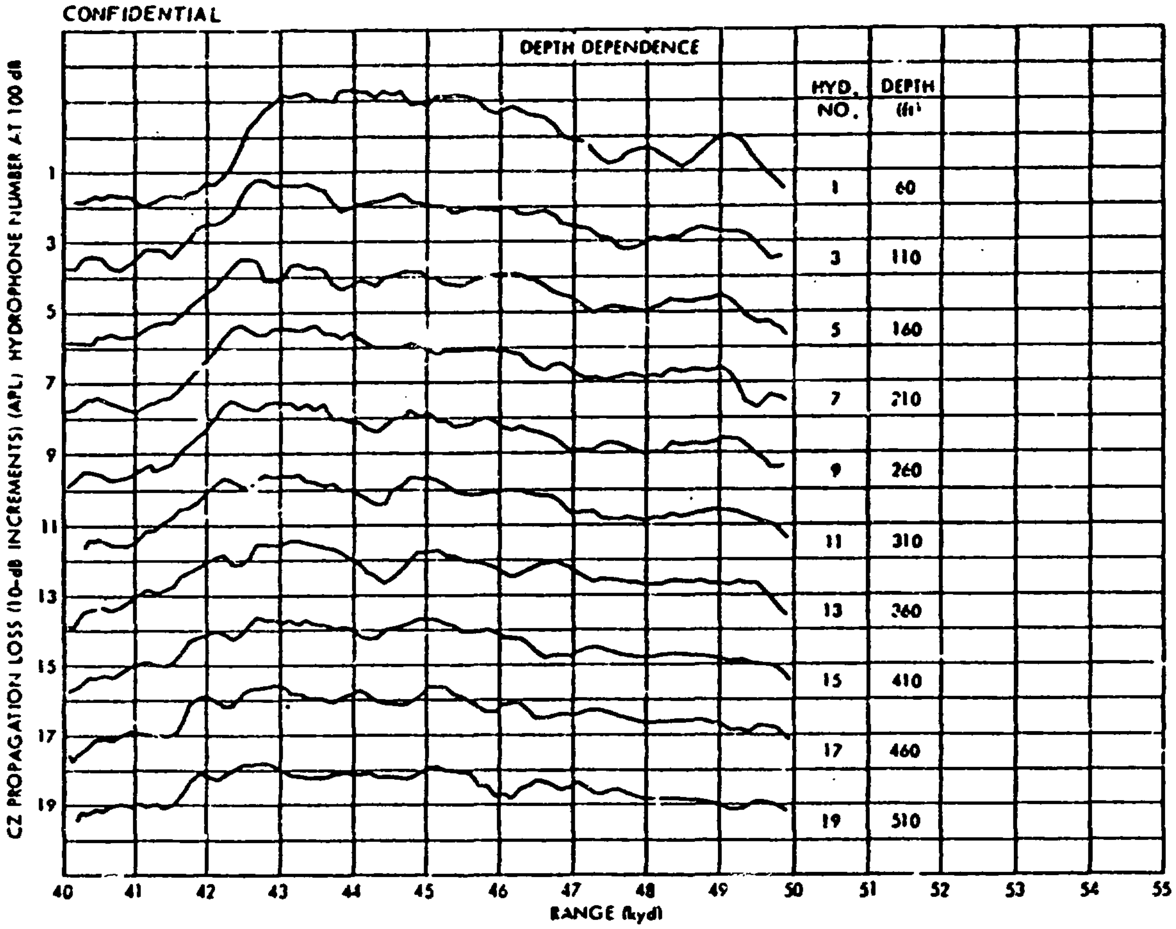
(U) Fig. 3-12. Frequency dependence of convergence zone propagation loss for three frequencies (F_1-LFM (3050-3150 Hz), F_2-LFM (3350-3450 Hz), and F_3-LFM (3650-3750 Hz)) for one hydrophone depth at Station 3, Run 3 (bottom) and Station 5, Run 2 (top). Data processed for period equal to transmitted pulse length (APL) and curves smoothed by using three-value moving average.

a sharp negative thermocline exists in which temperature gradients approach 1°F/ft. in magnitude. Below 125 ft., the rate of temperature change starts to decrease as a function of depth and at near 300 ft. the temperature remains relatively constant.

(U) The measurements indicate that for these stations the magnitude of loss is primarily a function of hydrophone position relative to the thermocline. Typical CZPL curves versus range show two minima (maxima in signal intensity) separated by several thousand yards. These signal maxima result from the upward propagation of rays that form a caustic at the beginning of the CZ and the downward propagation of rays that have reflected from the surface and form a caustic farther in the zone. This effect is observed in Figure 3-13 for data acquired at Station 1, Run 2, and in Figure 3-14 for the data of Station 3, Run 5. Here the propagation loss can be determined by associating the curve for a particular hydrophone with the number on the left hand axis. The hydrophone number is located on the 100 dB grid line for the curve and the spacing between grid lines is 10 dB. The minimum CZPL value varies from around 90 dB at 500 ft. to about 85 dB for the hydrophone just below the thermocline at 200 ft. In general, the entire CZPL curve is slightly greater in loss, on the average, as the depth increases from 200 to 500 ft. At 60 ft. the minimum CZPL is about 78 dB or about 7 dB lower than that at 200 ft. The two minimum loss regions are seen to form a single minimum loss region as the hydrophone depth decreases from deep to shallow depths. This latter tendency can be related to the water temperature profile. As the sound rays propagate from deep water toward the surface to form the convergence zone, they pass through the thermocline and refract towards the horizontal. This has the effect of concentrating more rays in a given volume and thus increases the intensity. This increase in intensity is experienced primarily by hydrophones above the thermocline (here 60 ft. and 25 ft. when used). The proximity of the hydrophone to the water surface



(U) Fig. 3-13. Depth dependence (three-value moving average) of convergence zone propagation loss for all odd-numbered hydrophones of array. F_2-LFM (3350-3450 Hz) data acquired at Station 1. Run 2. Data processed for period equal to transmitted pulse length (APL).



(U) **Fig. 3-14.** Depth dependence (three-value moving average) of convergence zone propagation loss for all odd-numbered hydrophones of array. F_2-LFM (3350-3450 Hz) data acquired at Station 3. Run 5. Data processed for period equal to transmitted pulse length (APL).

results in a reduction in range between the upward and downward-moving caustics. This difference in range decreases (as depth decreases) to such a point where the two maxima (min CZPL) for the curves become indistinguishable and tend to form one broad maximum.

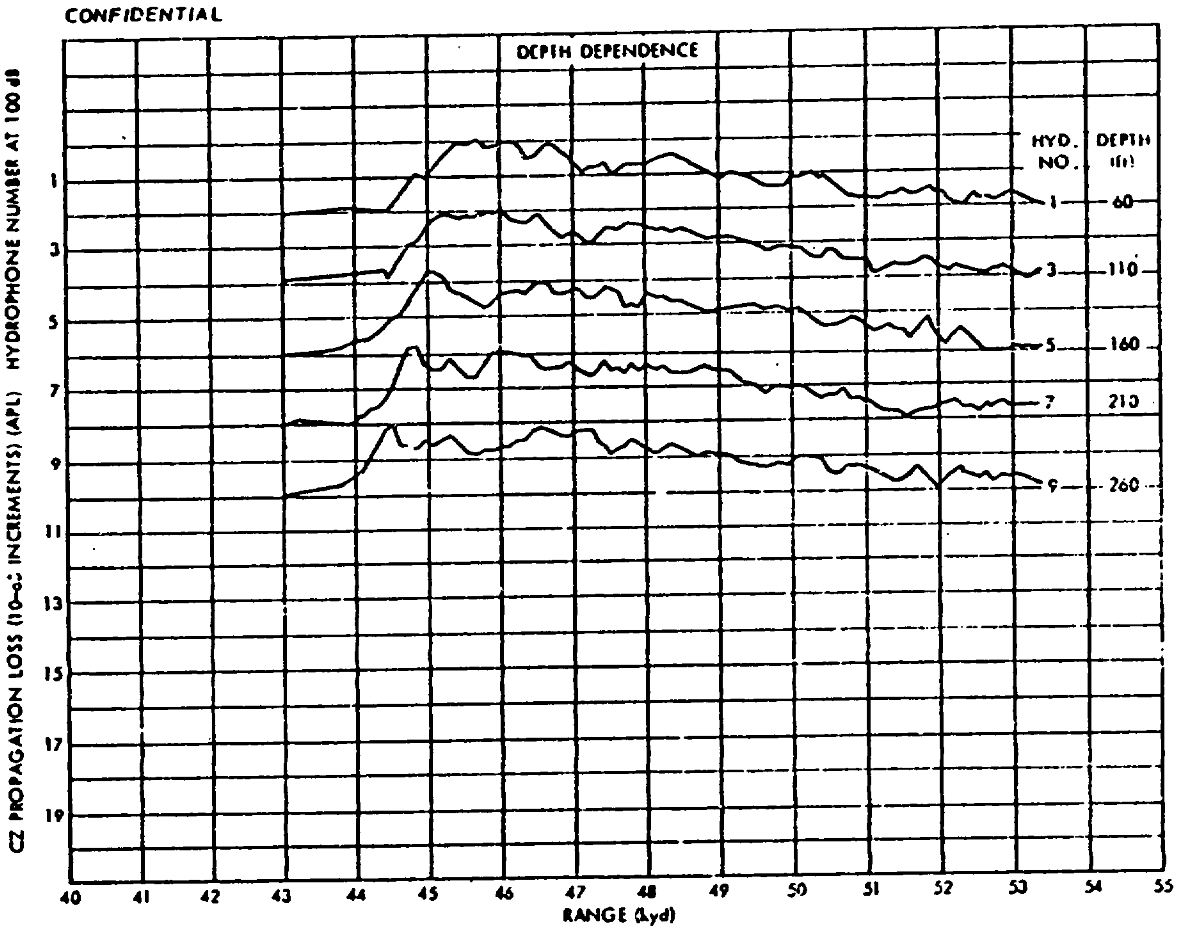
For Station 5, the CZPL results (Figure 15) differ from those of the other three stations. This was expected since the sound speed profile is quite different (Figure 3-9). The thermal layer extends to a depth near 500 ft. This condition affects the degree of focusing of acoustic rays at the convergence zone and produces higher CZPL values with minimum values in the order of 90 dB.

3.4.5 (U) DEPRESSION ANGLE EFFECTS

(U) For 10 of the 30 runs conducted for the Joast Phase III convergence zone measurements were made at a depression angle of 5° for the AN/SQS-26. All the other runs were at 0° depression angle. The variability of the CZPL curves as a function of range and run is large. It is impractical, therefore to compare CZPL results for a run with 0° depression angle with those for a depression angle of 5°. Model prediction may show the effects of depression angle, however, since most of the deep refracted energy which contributes to the caustic region is centered about the 0° horizontal angle at the source. Depressing the beam, modified the power relationship at these small angles and reduces the caustic gain.

3.4.6 (U) ZONE START RANGE

(U) For the shallow hydrophones (25 and 60 ft.) the start range of the CZ varied from a minimum of 37 kyds to a maximum of 45 kyds over the five Joast III stations. The measured results show that the range to the start of the zone is depth dependent.



(U) Fig. 3-15. Depth dependence (three-value moving average) of convergence zone propagation loss for all odd-numbered hydrophones of modified array. F_2-LFM (3350-3450 Hz) data acquired at Station 5, Run 4. Data processed for a period equal to transmitted pulse length (APL).

Over the upper 500 ft. the zone start range decreases in the order of 1,500 yds. The decrease is greatest above the thermocline, approximately 6 yds per foot of depth. Below the thermocline the start range decreases at approximately 2 yards per foot. The zone width also varies as a function of depth at the convergence zone. The zone width increases as depth increases from surface to 500 ft.

3.5 (U) FACTORS THAT MAY INFLUENCE RESULTS

(U) Bottom depth - no bottom topography is presented over the measurement courses. However, excess depth of about 2,000 ft. is indicated in the velocity profiles (to 8,500 ft.) which in themselves were not bottom limited. This excess depth should result in a strongly defined convergence zone with no contribution from bottom reflection. Therefore, infinite bottom loss can be assumed for the model.

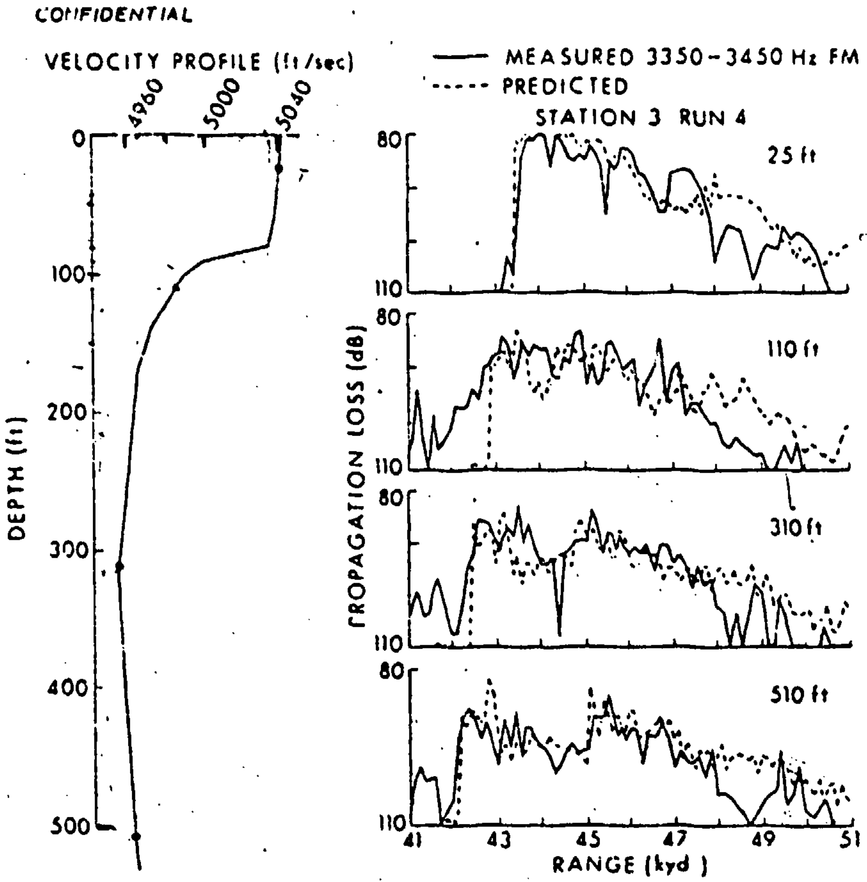
(U) Velocity profiles - velocity profiles were taken at the receiving point at the beginning of each station. The measurements at Station 3 were made over a time period of 4 days while those at Station 5 took two days. Below about 2,000 ft. the velocity profiles at any one station can be considered time independent over these time frames (positive velocity gradient essentially pressure or depth dependent). The velocity structure above 2,000 ft. can be subject both temporal and spatial effects. In addition, scaling of the velocity profile result in poorer reading accuracy in the first 100 ft. of depth. It is thought that the velocity at the source would be the more important factor in determining the start of the convergence zone. Although 1,000 ft. XBT's were taken by SANDS and GLOVER they are not available in the report. These may be available but would have to be dug out. (Private conversation with authors.)

(U) One sound speed profile derived from on-site environmental data (XBT, Nansen casts) at the source is at the left in Figure 3-16. The adjusted temperature profile was converted to velocity by using Wilson's formula. This upper depth speed profile can then be fitted to the deeper portion of the measured velocity profile (here Figure 6) to obtain a composite total velocity profile at the source (see Table 3-7). This profile can be used initially in the modeling instead of Figure 3-6 to determine if the start range is better verified and is to be applicable to results of Station 3, Run 4.

3.5.1 (U) Model Comparisons

(U) It is important that if the results of the model and measured propagation loss are to be compared that the output of the model be selected to compare with the type and processing of the received signal in the experiment. The signal types are pulsed LFM and were processed on the basis of the energy of the arrivals. On the basis of inputs for the Fact and Raymode model programs, only single frequency (CW) predictions can be made. One possibility presents itself, if available from the output of the model, is that of determining the propagation loss from the peak signal amplitude for the arrivals computed as a function of time from coherent addition of the direct and multipath signals (i.e., phase taken into account). In Figure 3-17 the measured LFM-APL CZPL results are compared with the CW-PPL CZPL results for F_2 at Station 3, Run 4 for justification in using CW peak processing in the model prediction. The curves are similar but not identical and the same type of results should be expected for the model comparison if peak processing is used.

(U) It is possible that a single velocity profile used in modeling may not be sufficient to accurately predict the convergence zone propagation loss. The indications are that the velocity at the source and the velocity depth profile are fundamental



(U) Fig. 3-16. Measured and predicted convergence zone propagation loss for four hydrophones. F_2-LFM (3350-3450 Hz) measured data acquired at Station 3, Run 4. Data processed for period equal to transmitted pulse length. Sound speed profile derived from on-site environmental data and used for model prediction.

(U) Table 3-7. Composite Velocity Profile Station 3, Run 4

DEPTH (ft)	VELOCITY (ft/sec)
0	5041.5
20	5040.0
80	5032.0
90	4999.0
110	4983.0
165	4960.0
320	4954.0
505	4962.0
1000	4967.0
2000	4982.0
5000	5023.0
8000	5070.0
8300	5076.0

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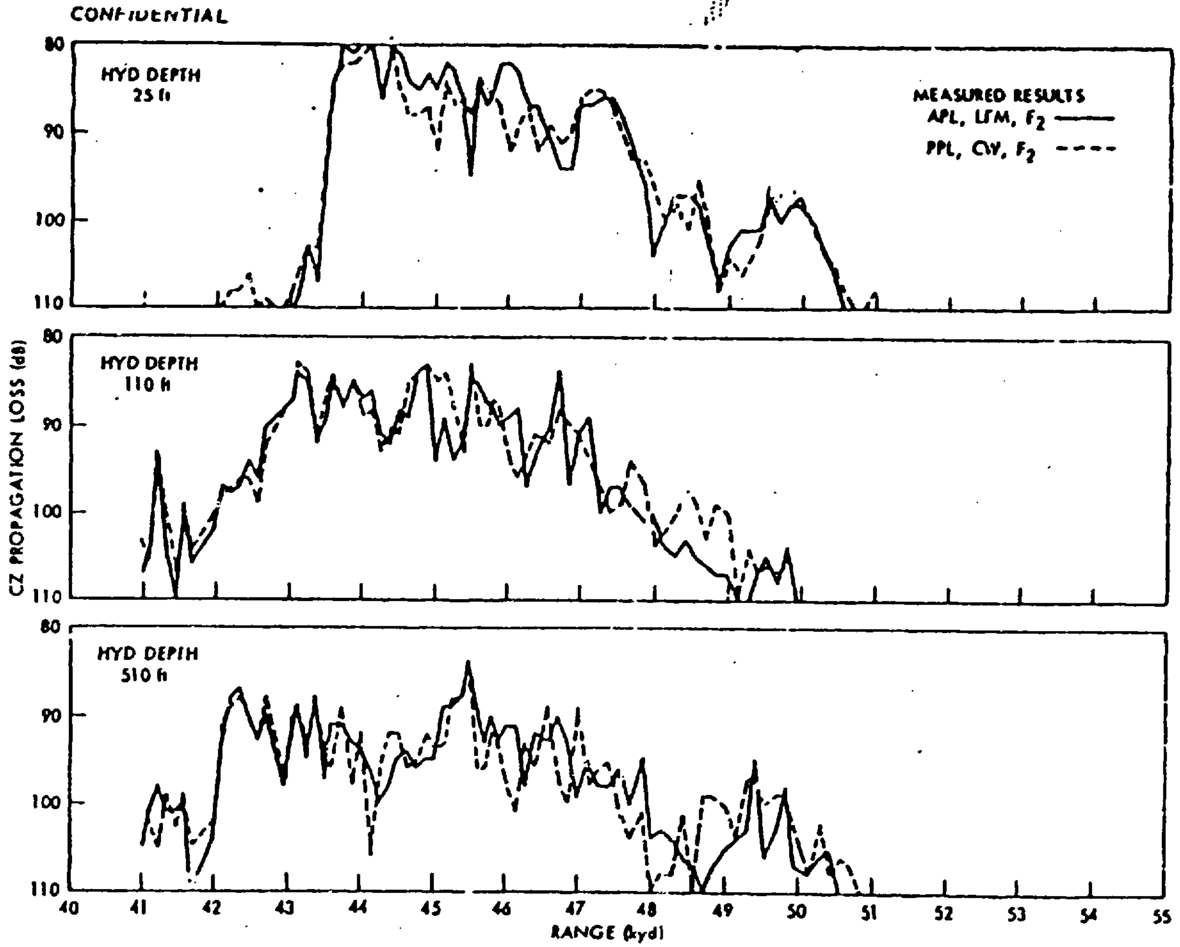

(U) Fig. 3-17. Measured LFM-APL CZPL results and measured CW-PPL CZPL results for F_2 at Station 3, Run 4 for justification of comparison between convergence zone propagation loss CW model predictions and measured LFM results.

in determining the start range of the convergence zone, but the upper portion of the velocity depth profile at the receiving point will be more important in determining the magnitude and shape of the propagation loss versus range at the depths above the deep sound channel axis (see Propagation Loss Results). The largest differences in XBT temperature profiles on the GLOVER and SANDS occurred at Station 5. The profile at SANDS consistently showed a sharp thermocline between 500 and 600 ft., whereas, the GLOVER's profile showed a more gradual thermocline occurring between 200 and 400 ft. The GLOVER's profile also showed considerable variability (1 hr intervals). The SANDS was more exposed to the colder waters of the Agean Sea and, therefore consistently show lower temperatures than at the GLOVER. Conceivably, the start of the CZ or the CZPL as a function of range will be more affected by the profile used than the start of the CZ at Station 3.

(U) Table 3-8. Cross References of Figures and Tables

Chapter 3	JOAST III, Part I
Figure 3-1	Figure 2-1; Page 2-2
Figure 3-2	Figure 2-2; Page 2-3
Figure 3-3	Figure 5-1; Page 5-3
Figure 3-4	Figure 4-1; Page 4-2
Figure 3-5	Figure 4-2; Page 4-14
Figure 3-6	Figure 2-5; Page 2-7
Figure 3-7	Figure 2-7; Page 2-9
Figure 3-8	Figure 4-3; Page 4-18
Figure 3-9	Figure 4-4; Page 4-19
Figure 3-10	Figure 4-5; Page 4-21
Figure 3-11	Figure 4-6; Page 4-23
Figure 3-12	Figure 4-8; Page 4-25
Figure 3-13	Figure 4-10; Page 4-30
Figure 3-14	Figure 4-12; Page 4-32
Figure 3-15	Figure 4-13; Page 4-33
Figure 3-16	Figure 4-14; Page 4-36
Figure 3-17	Figure 7-3; Page 7-7

APPENDIX A

	JOAST III, Part II
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3-29a thru 32b	A24 thru 27a; Pages A-27 thru 34

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Cross Reference for Tables (U)

Chapter 3	JOAST III
Table 3-1	-
Table 3-2	Table 2-2; Page 2-12
Table 3-3	Table 2-3; Page 2-13
Table 3-4	Table 2-4; Page 2-15
Table 3-5	Table 2-1; Page 2-11
Table 3-6	Table 4-1; Page 4-16
Table 3-7	-

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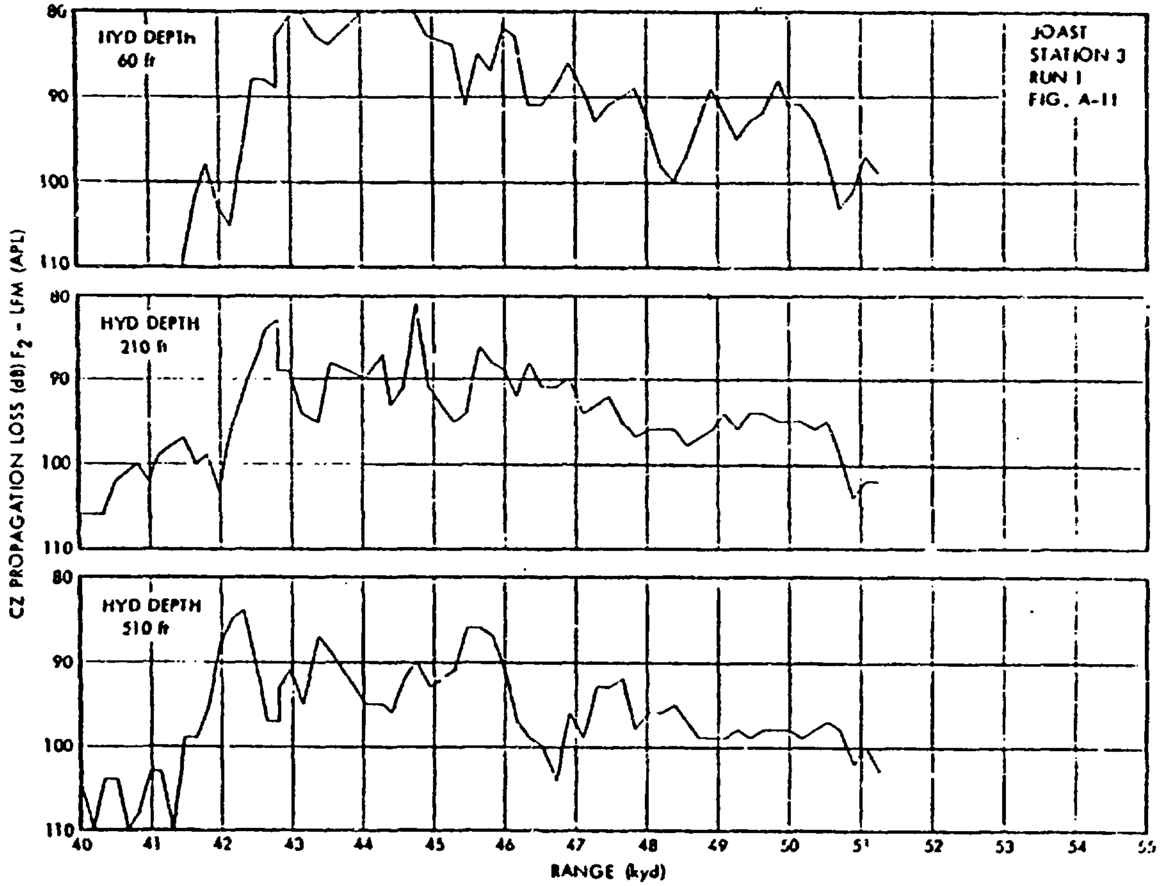

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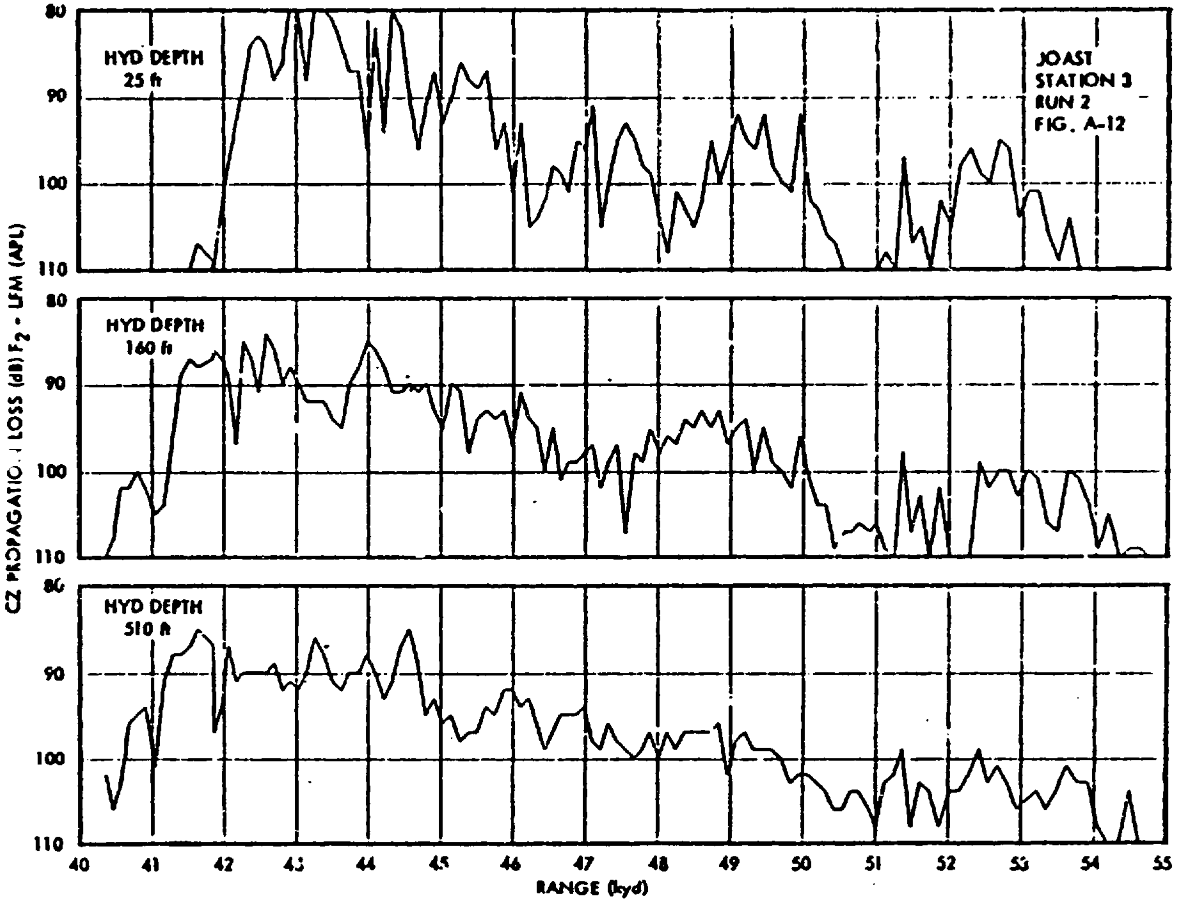
(U) Fig. 3-18.



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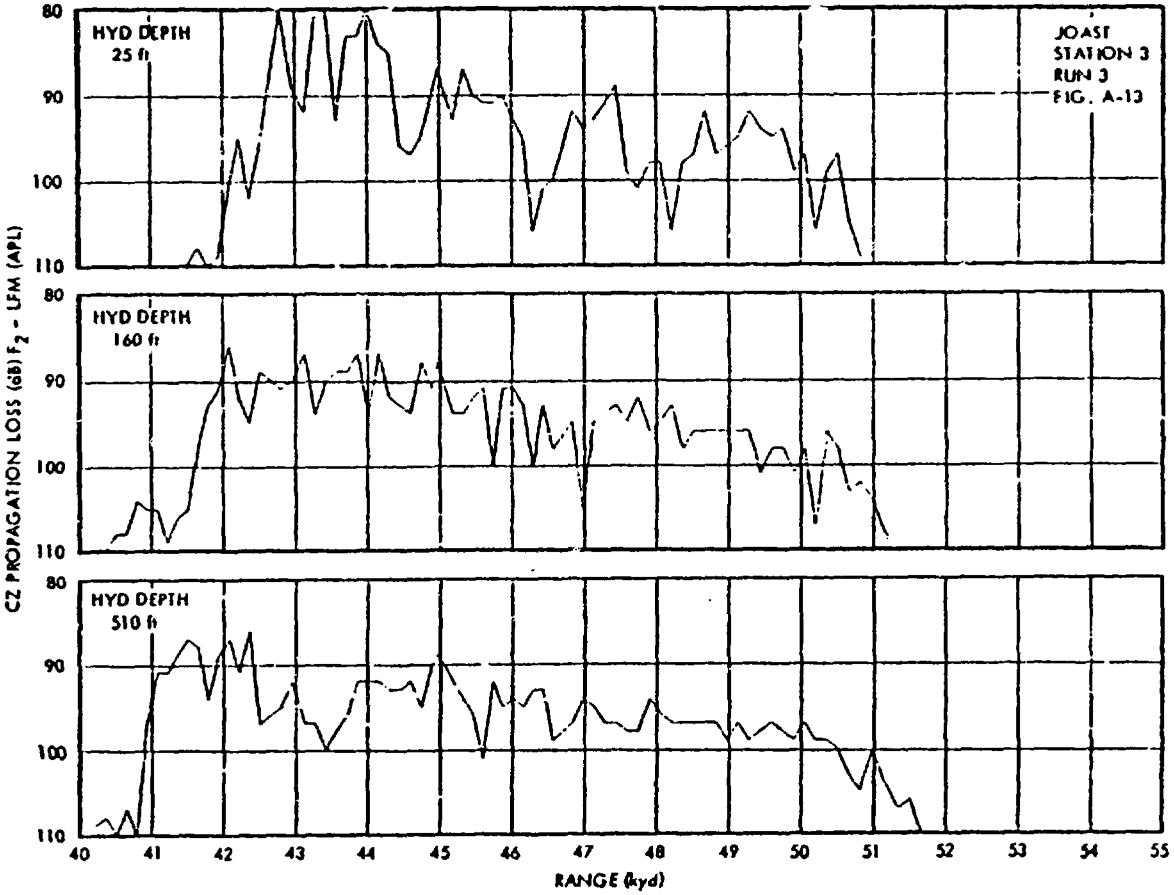
(U) Fig. 3-19



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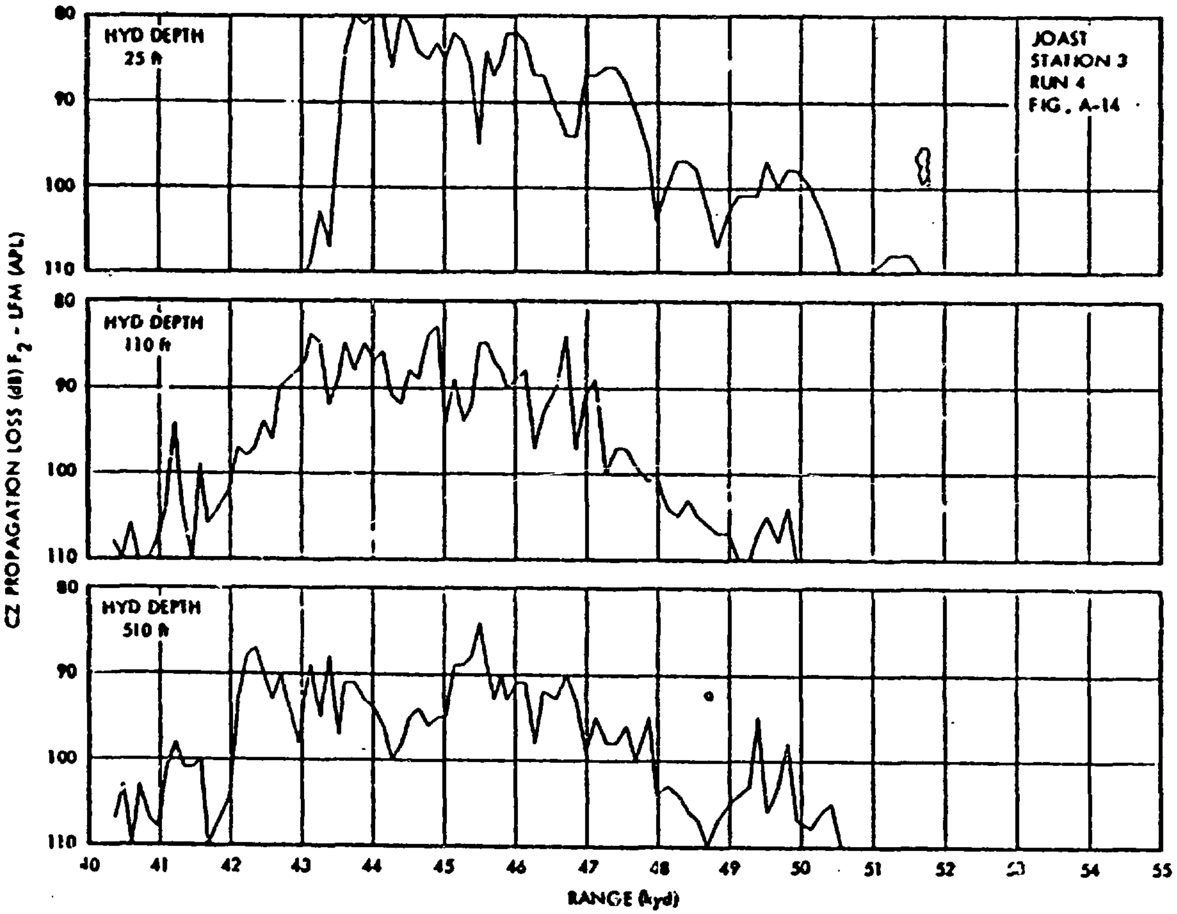

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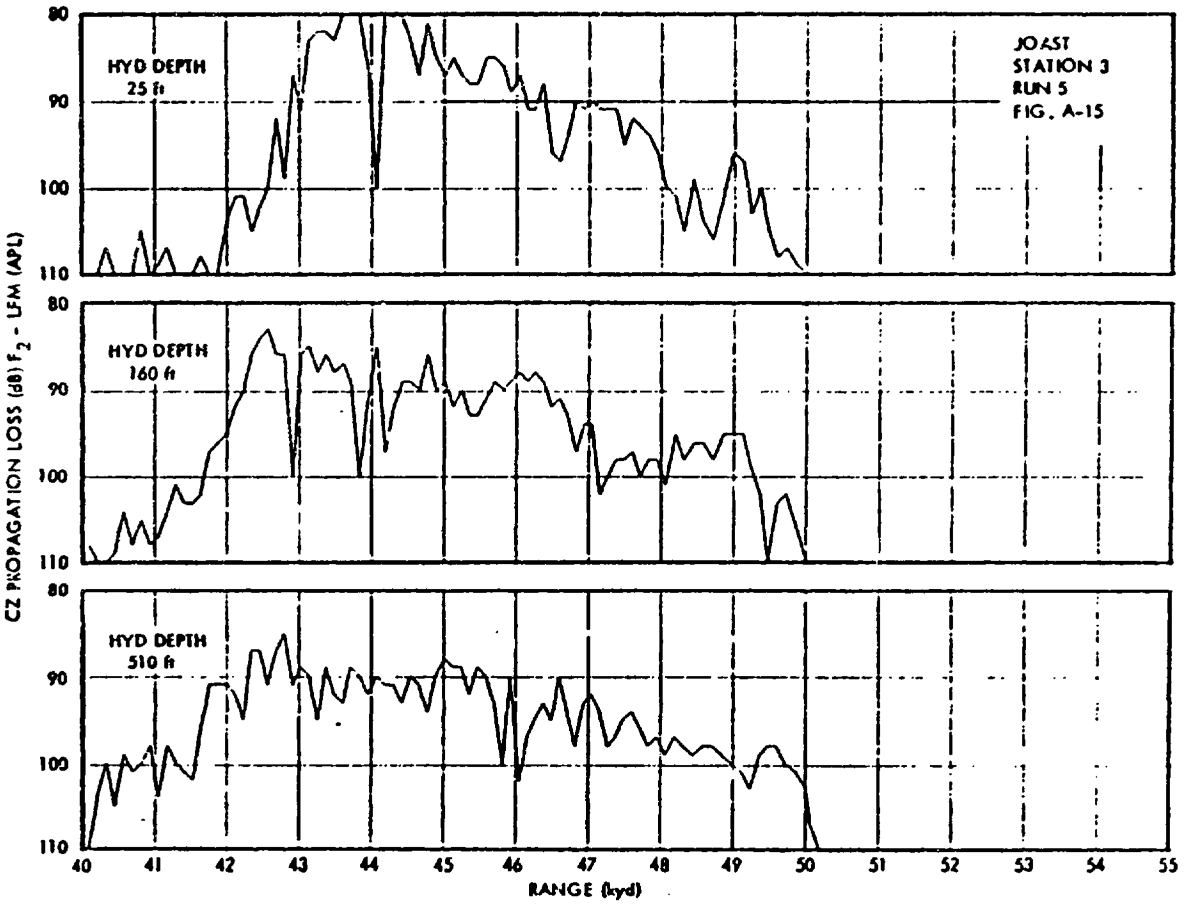
(U) Fig. 3-21.



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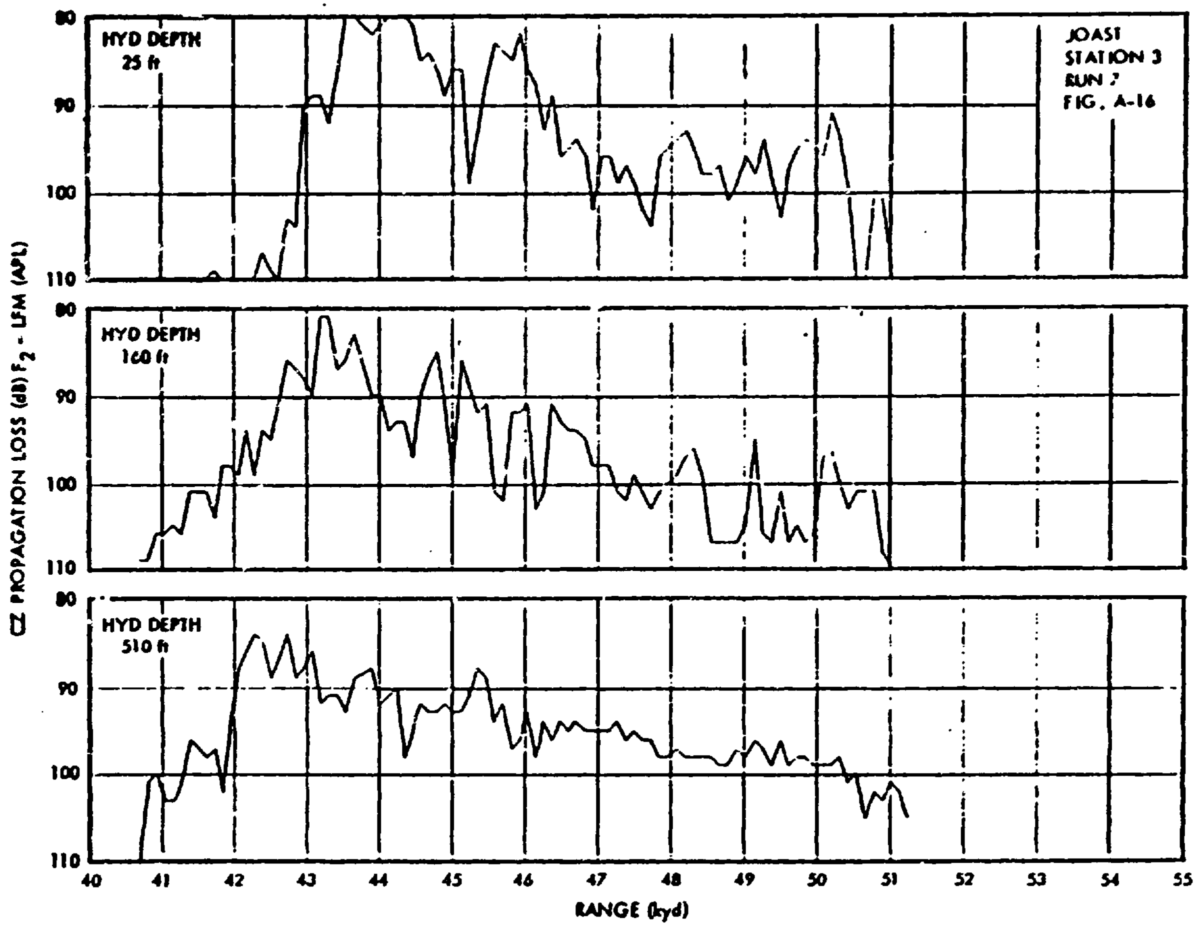
(U) Fig. 3-22.



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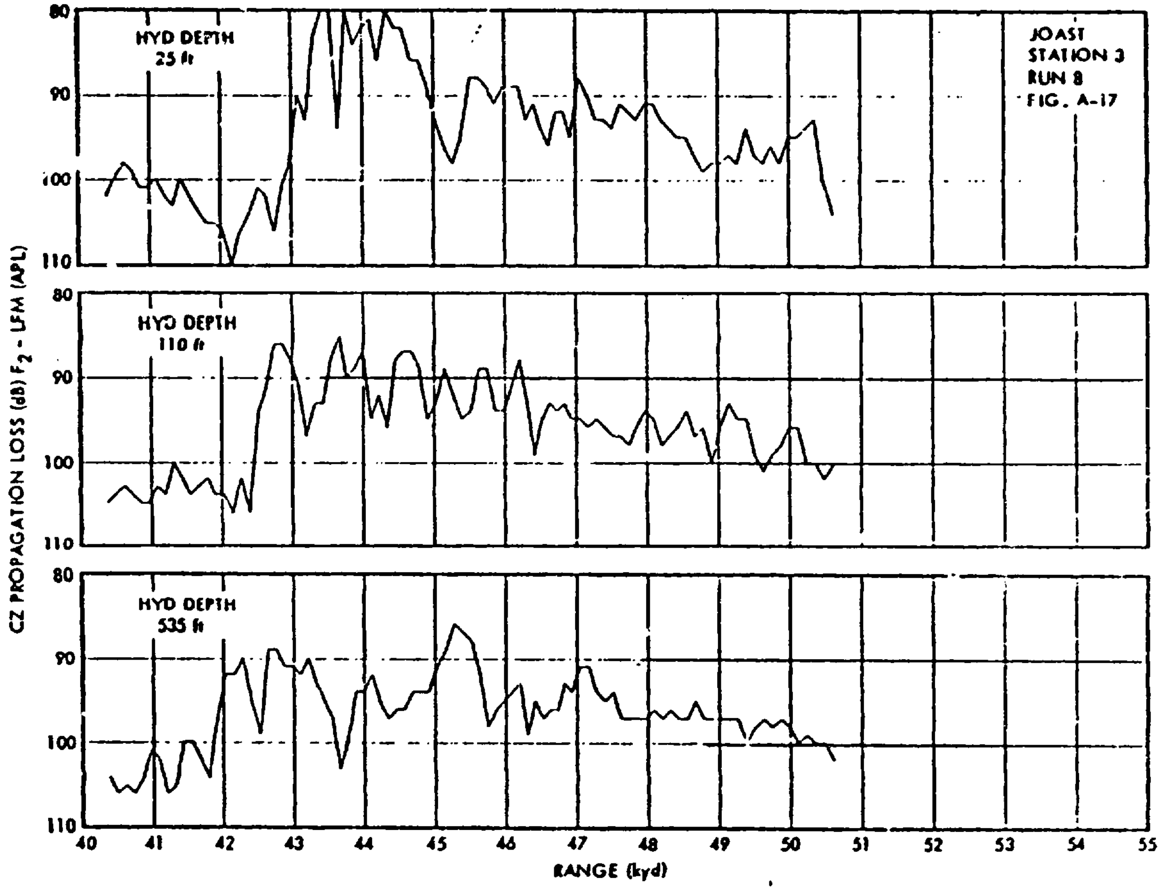

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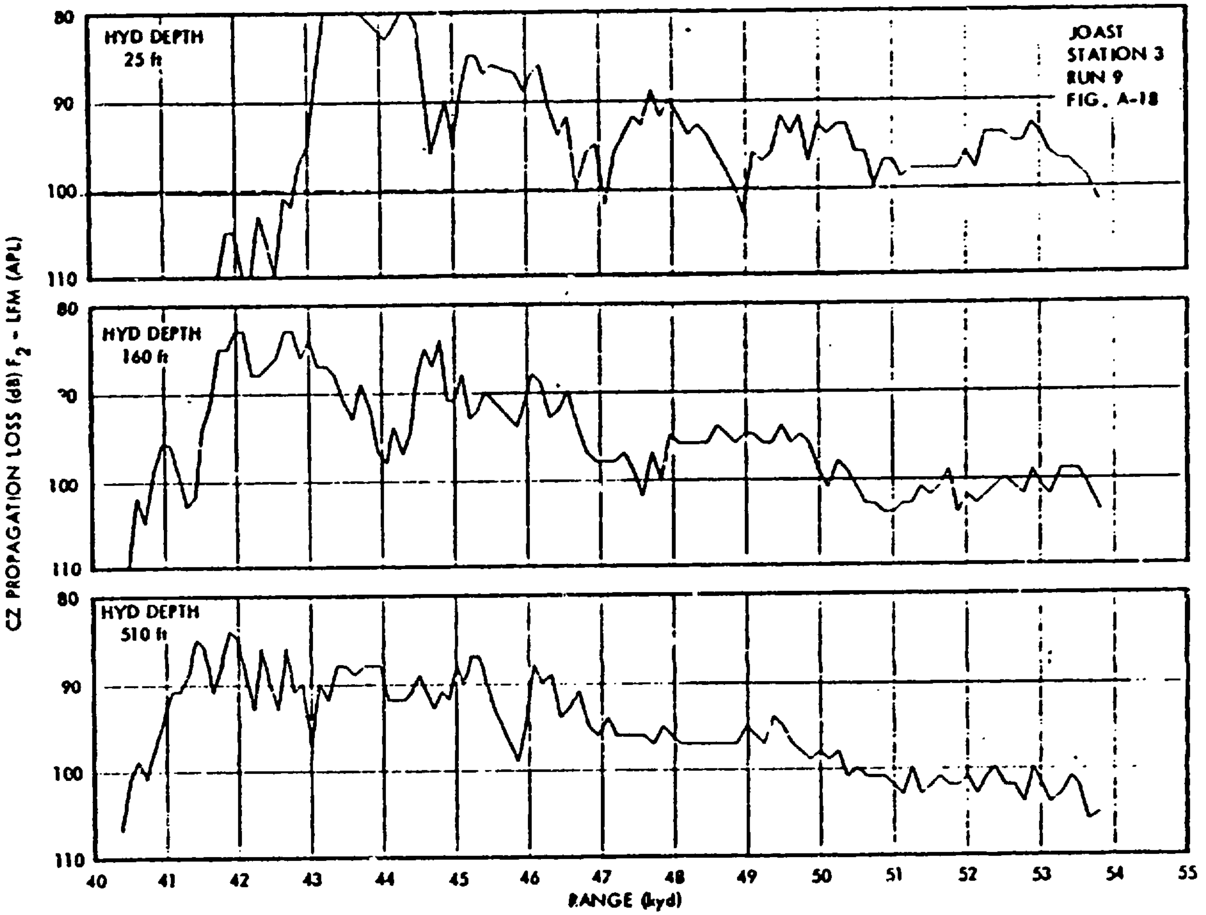
(U) Fig. 3-24.



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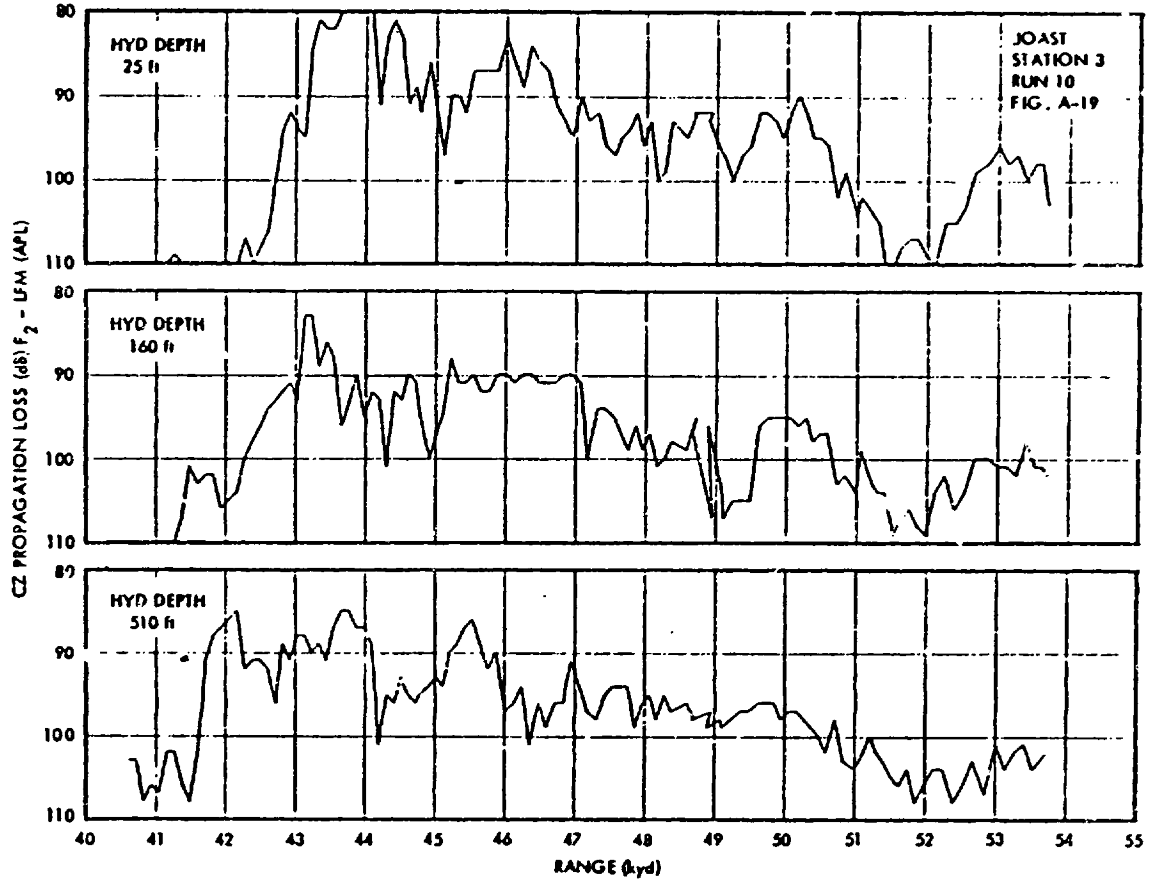
(U) Fig. 3-25.



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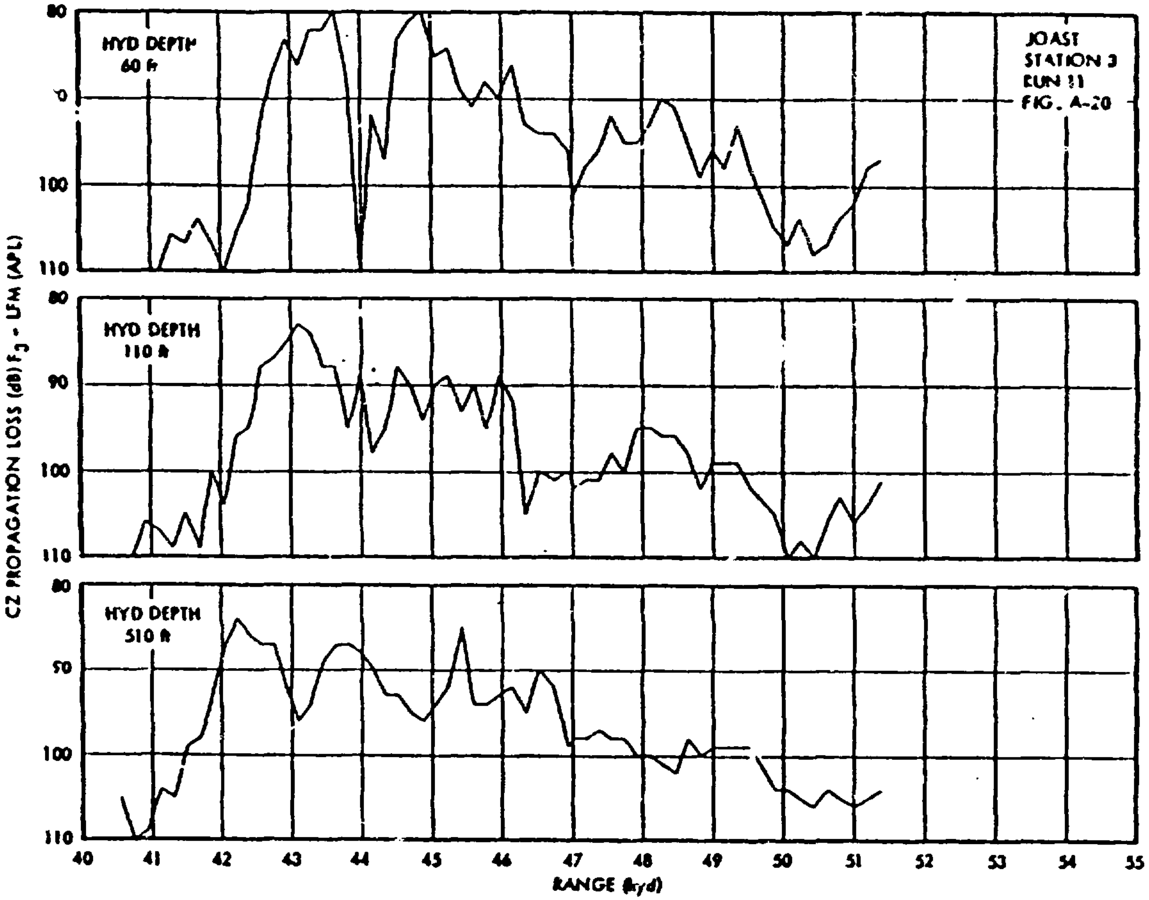
(U) Fig. 3-26.



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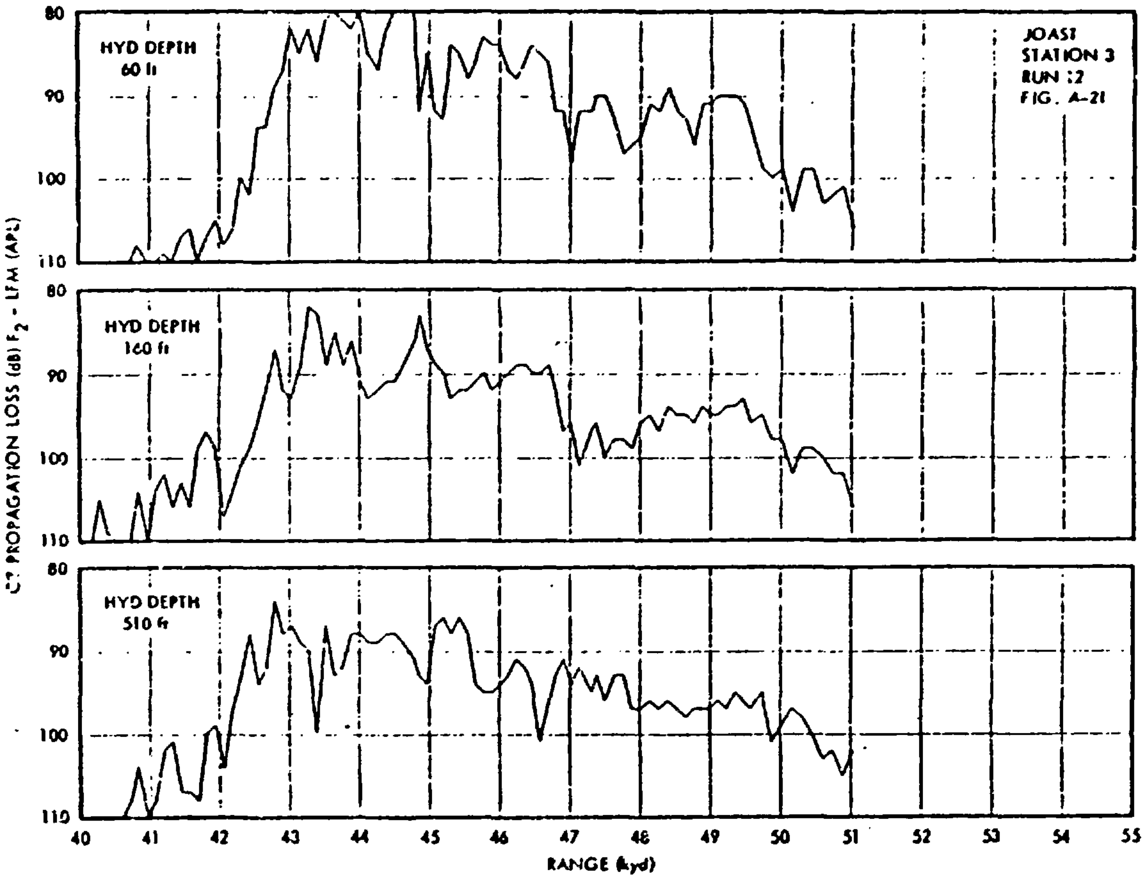
(U) Fig. 3-27.



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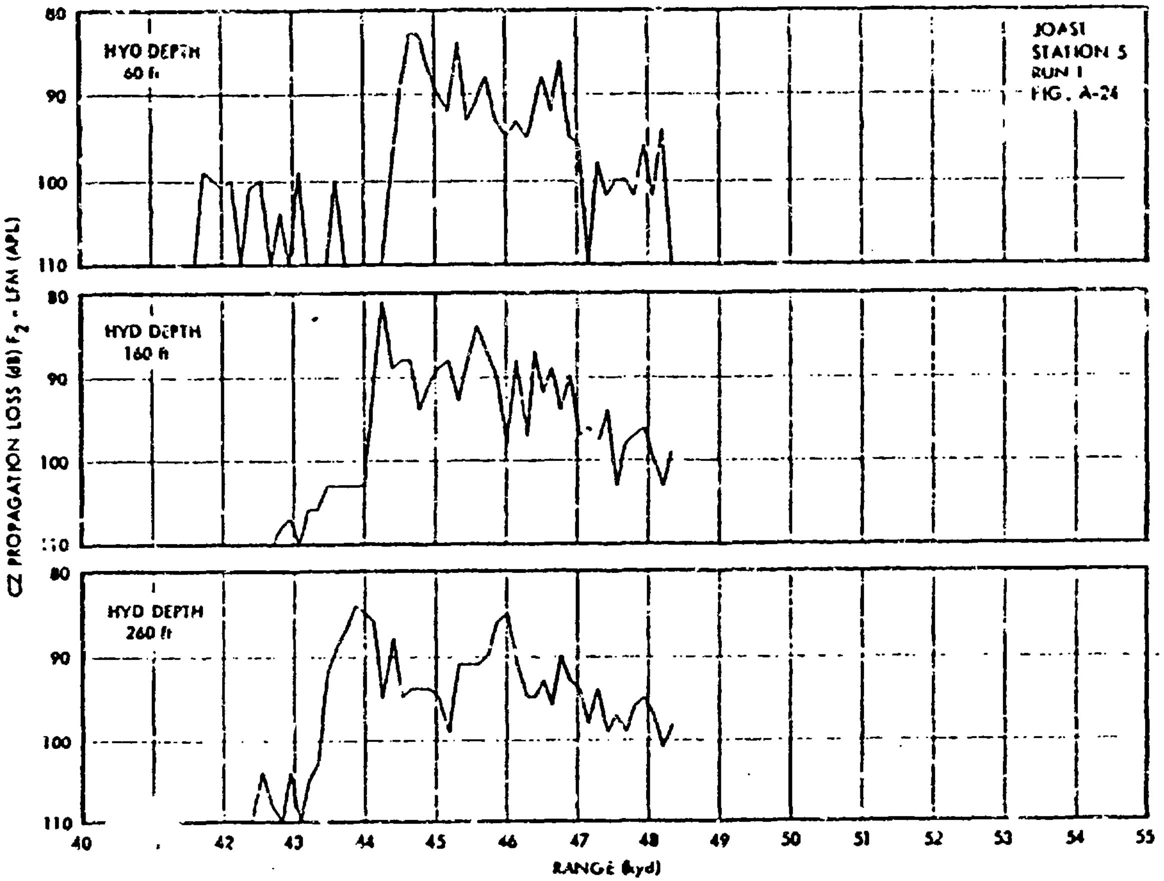
(U) Fig. 3-28.



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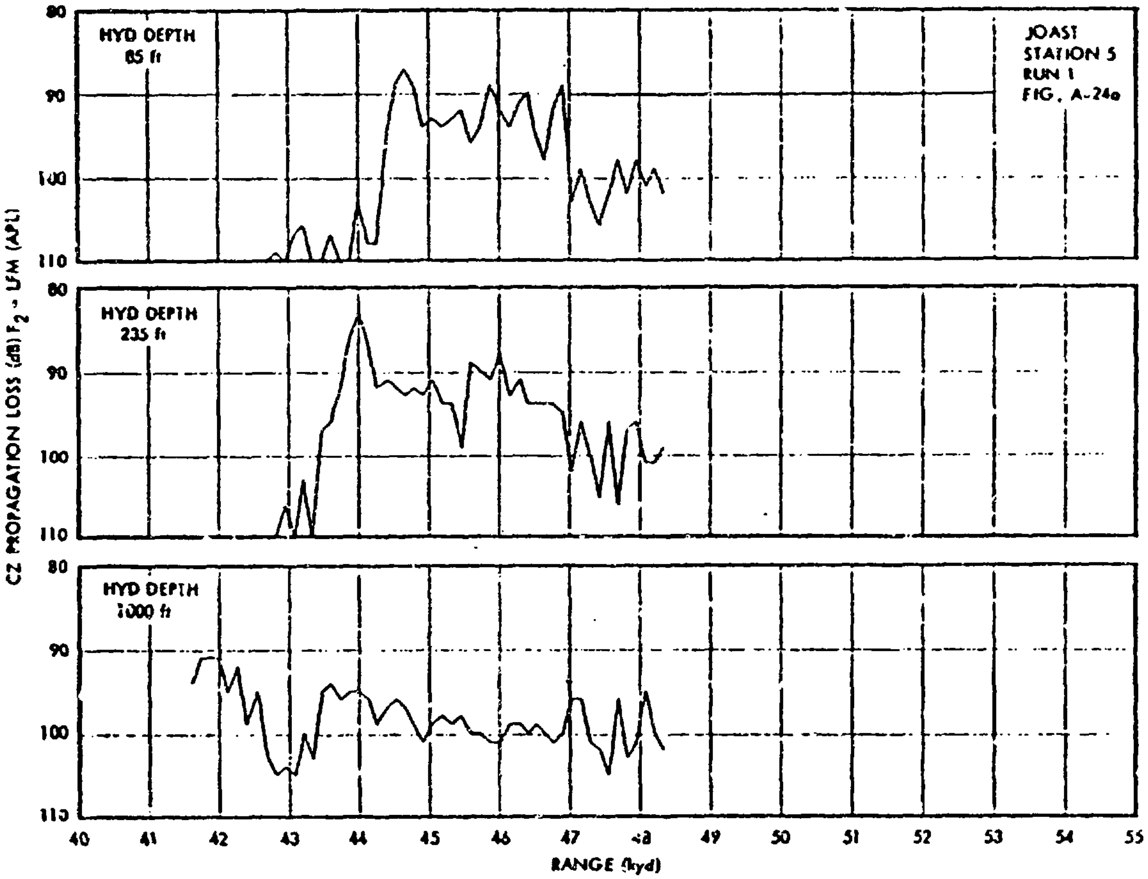
(U) Fig. 3-29a.



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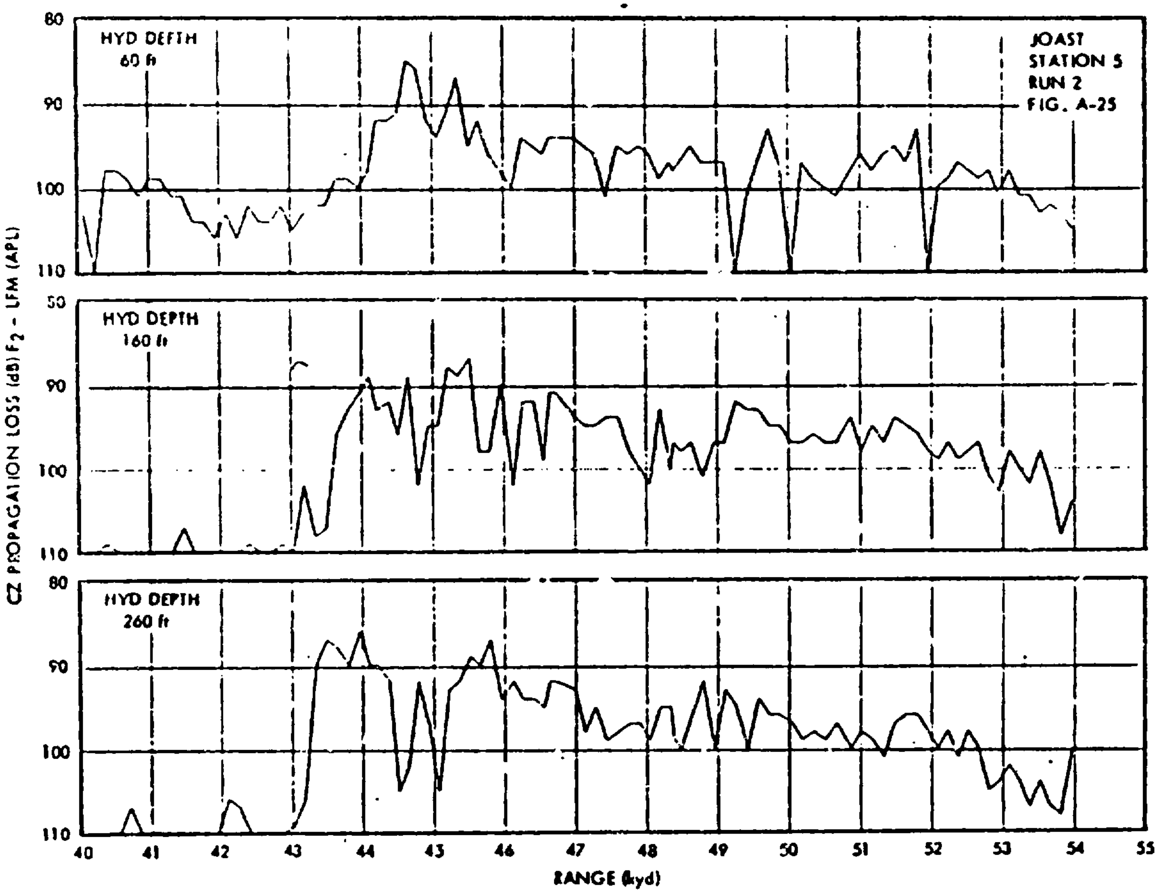
(U) Fig. 3-29b.



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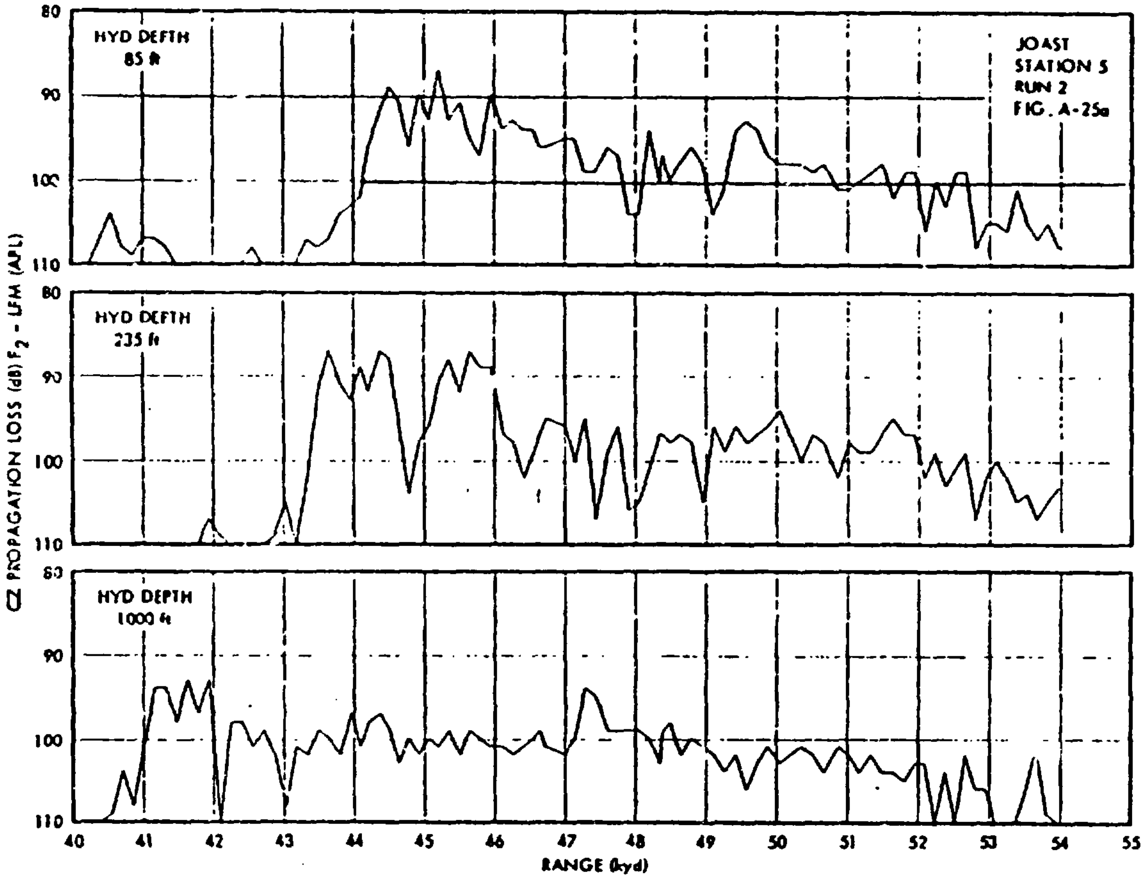
(U) Fig. 3-30a.



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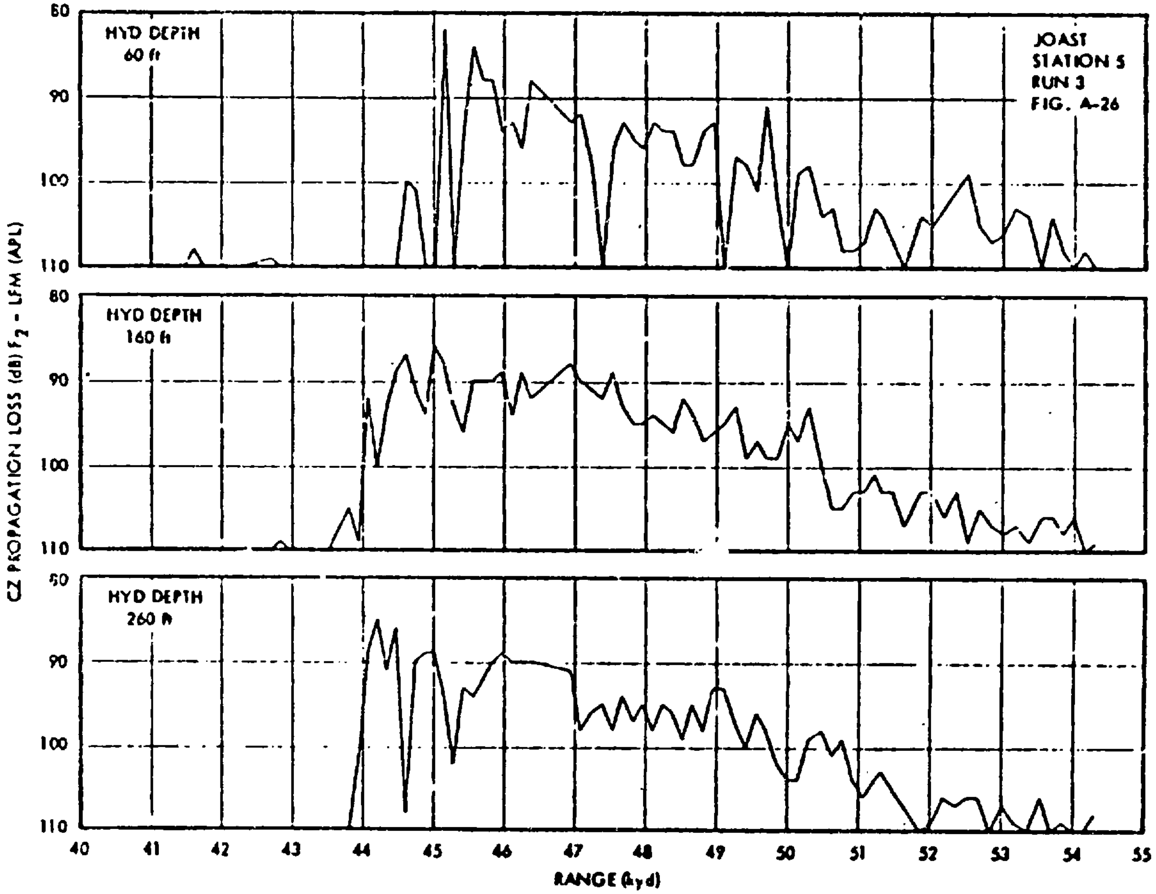
(U) Fig. 3-30b.



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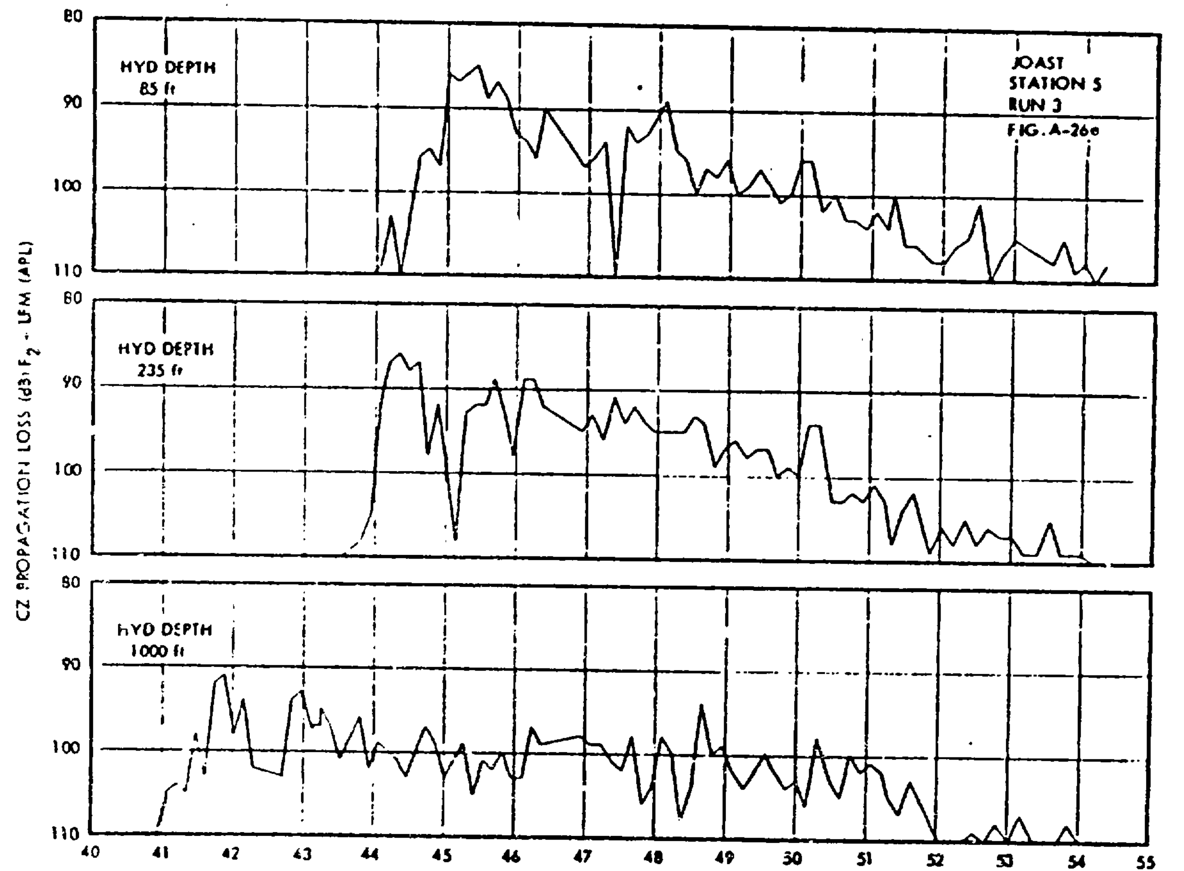
(U) Fig. 3-31a.



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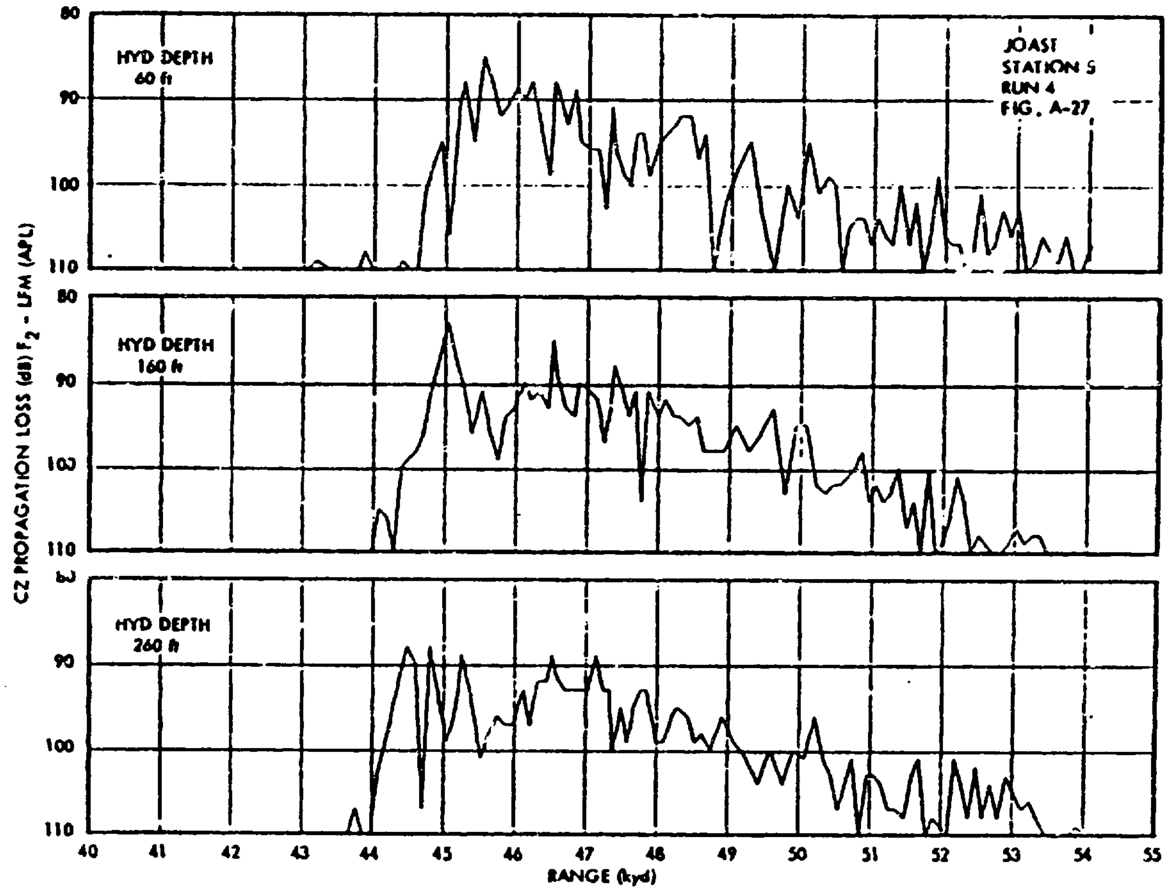

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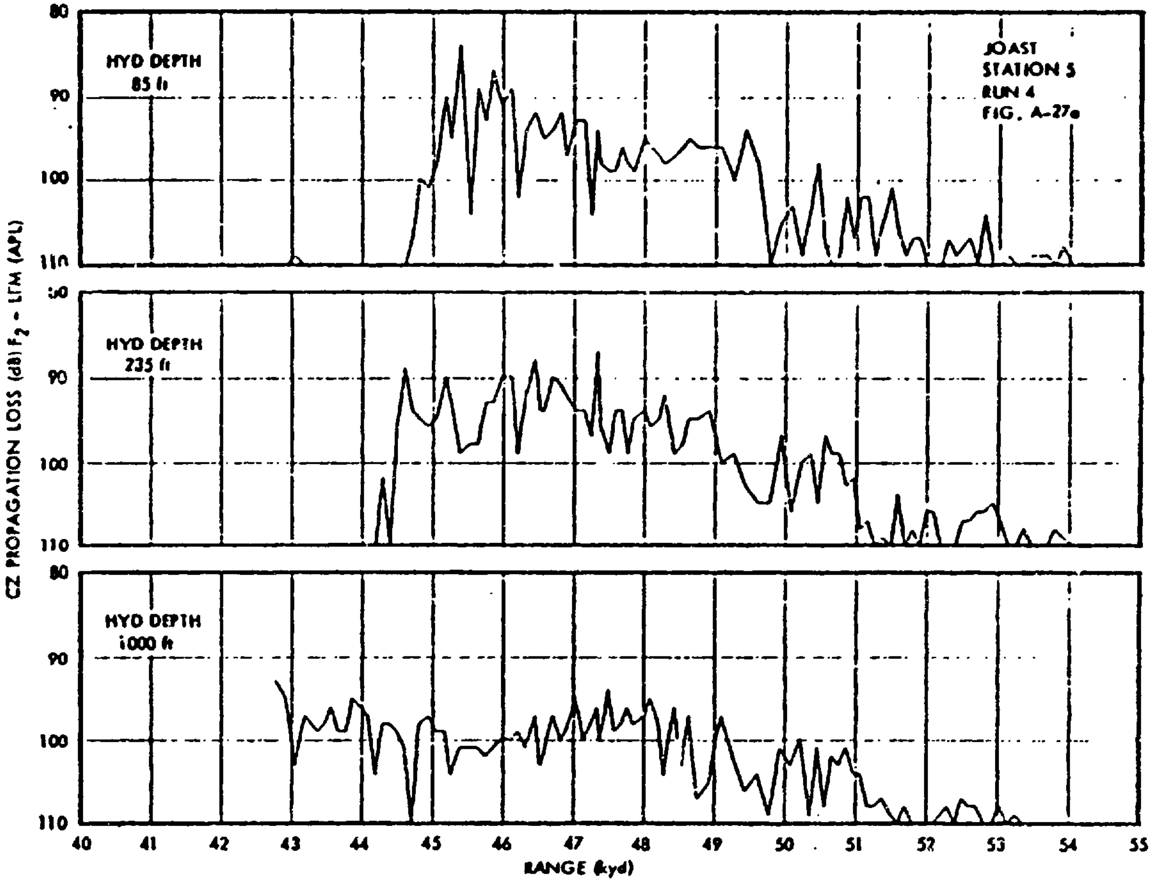
(U) Fig. 3-32a.



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(U) Fig. 3-32b.

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2. H. R. D'Amelia, R. S. Fogleman, L. W. Messerey, and T. G. O'Hara, "AN/SQS-26AXR Certification Test Procedures (U)," NUSL Pub. No. 863, 12 Oct 1967, (CONFIDENTIAL).

3. W. H. Thorp, "Analytic Description of the Low Frequency Attenuation Coefficient," Journal of Acoustical Society of America, Vol. 42 No. 1, July 1967, Page 270 (U).

4. JOAST Mediterranean Convergence Zone Studies for AN/SQS-26 Performance Prediction, Parts I and II, NUSC Reports 4121-I and 4121-II. CONFIDENTIAL.

Appendix 11. (U) JOAST IV

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APPENDIX 11

Joint Oceanographic Acoustic and System Tests (JOAST IV)

Summarized by Frederick C. Friedel

(U) This data set is reported in "Low Frequency Propagation Loss Experiment in the Mediterranean Seas - Results of Phase IV of Joint Oceanographic Acoustic System Tests (JOAST)," NUSC Report No. 4203, 5 November 1971. This report describes the low frequency propagation loss measurements conducted in October 1970 in the Mediterranean Sea as Phase IV of the JOAST experiments. The purpose was to provide acoustic and environmental data in four of the principal basins for acoustic modeling applications and for guidance in the deployment of the Interim Towed Array Surveillance System (ITASS). This set was examined to determine if any data could be modeled with a flat bottom and range independent sound speed profile in order to meet the initial limitations for evaluating the FACT and RAYMODE X models. Of the 18 measurement runs only four appear to meet the criteria and are reported here (see parameter Table 4-1). The data sets of this report were intended to be entered in NAVDAB. However, it is not certain if the entry were successfully completed and can be reclaimed.

4.1 (U) EXPERIMENT DETAILS

(U) The measurements reported were here made at Stations 7 and 9 (Figure 4-1) in three of the major basins of the Mediterranean Sea. The propagation loss measurements were made along two or more radial tracks from the station location as indicated in the figure. U. S. Navy P3B aircraft were used as source vehicles traversing the paths at a speed of 240 knots. Mk 61 or Mk 82 SUS signals were used at detonation depths of 60, 300, and 800 ft. Only one detonation depth was used per pass along the track. A run commenced when the aircraft passed over the receiving platform (USNS SANDS) and the first detonation was scheduled at a range of 5 nmi. Detonations were then scheduled every two minutes thereafter (8 nmi in range) during the run. Explosives are considered as omnidirectional sources over the frequency range

(U) Table 4-1. **JOAST IV Parameters**

	FIGURES 4-9 to 4-27	**FIGURES 4-28 to 4-39**
STATION	9	7
RUNS	D2C and D2B	B1B and B1C
FREQUENCIES (kHz)	.025 - 1.0, 1/3 Octave	.025 - 1.0, 1/3 octave
LAYER DEPTH (ft)	100-140	110 nominal
MAX SOUND SPEED DEPTH (ft)	9000	1200
AXIS DEPTH (ft)	450	520
DEEP SOUND CHANNEL DEPTH (ft)	4750	5500
SOURCE DEPTHS (ft)	800, 300	300, 800
RECEIVER DEPTHS (ft)	60, 350, 800	60, 350, 800
MIN RANGE (nmi)	5	5
MAX RANGE (nmi)	300	90
BOTTOM DEPTH (ft)	8400	8400

Model should use bottom depth of 8400 ft, bottom loss from archival files.

NAVIGATION - Radio Tone - acoustic travel time average speed, range update, radar, dead reckoning plots - range errors not given.

DATA LOCATION - NAVDAB

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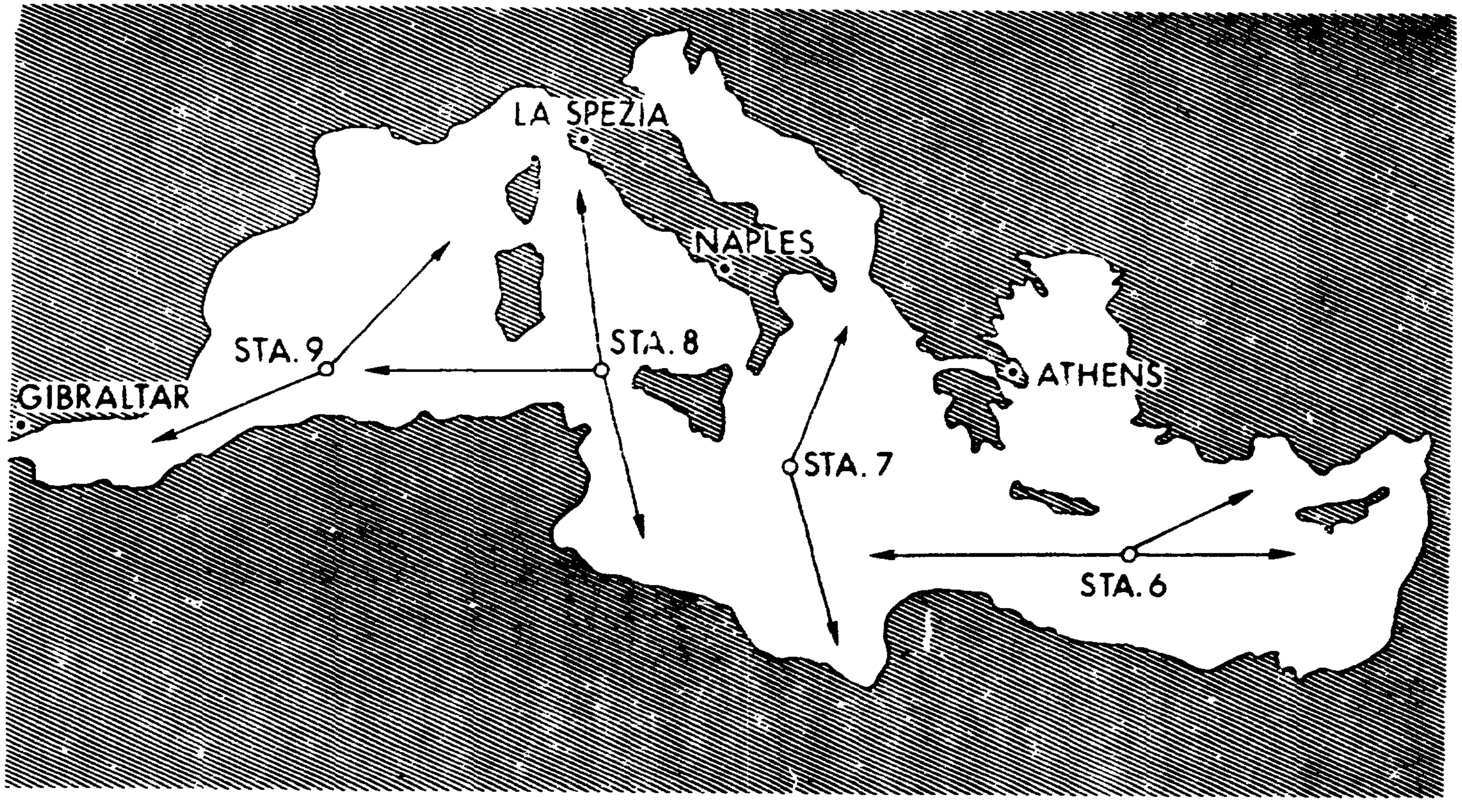

Fig. 4-1(U)Geographical Location of Low-Frequency Propagation Loss Measurements considered here. On one pass of the track, the aircraft made 1000 ft. AXBT casts every 24 nmi. The aircraft also transmitted a coded radio signal (cessation of a CW tone) for the receiving station to indicate the time of a SUS charge drop so that with the time of arrival of the explosive sound, travel time could be calculated. Range to the receiving station for each drop was also computed on the aircraft based on dead reckoning navigation and radar fixes when possible. The summary of the scheduled aircraft runs are presented in Table 4-2. Table 4-3(a) lists the test parameters for runs accomplished. As can be seen the runs accomplished are less than the number planned. This was a result of severity of the weather and insufficient data to warrant their inclusion mainly because of noise limitations. For our purpose here, only Runs B1B/B1C and D2B/D2C are considered due to the initial limitations of FACT and RAYMODE X.

(U) At the receiving station (USNS SANDS), hydrophones were deployed at nominal depths of 60 ft., 350 ft. and 800 ft. The latter two hydrophones were a two element array suspended from a surface buoy and position to the array buoys was maintained using the bow thruster of the SANDS. The hydrophones used in the measurements were calibrated at NUSC Dodge Pond Field Station before the cruise.

4.2 (U) DATA ACQUISITION AND PROCESSING

(U) A ship board processing system designed for the experiment made possible real-time data reduction; i.e., all necessary acoustic information is extracted from the shot before the next s received. A simplified block diagram for one hydrophone s shown in Figure 4-2. The signal from the hydrophone is fed o adjustable gain amplifiers and then to a set of 1/3 octave ilters with GMF's as indicated. The filter output is enveloped etected, and passed to the multiverter which multiplexes the ignals, samples and holds, and converts the analog signal to

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(U) TABLE 4-2

SUMMARY OF SCHEDULED AIRCRAFT RUNS

USNS SANDS STATION LOCATION	RUN DESIGNATION	AIRCRAFT BASE COURSE (°T)	SOURCE DEPTH (ft)	APPROXIMATE LENGTH OF RUN (nmi)
33° 15'N, 27° 30'E	A1A	090	60	250
	A1B	270	300	250
	A1C	270	800	250
	A2A	055	60	180
	A2B	235	300	180
	A2C	055	800	180
	A3A	282	60	465
	A3B	102	300	465
	A3C	282	800	465
35° 00'N, 17° 00'E	B1A	020	60	240
	B1B	200	300	240
	B1C	020	800	240
	B2A	157	60	180
	B2B	337	300	180
	B2C	157	800	180
38° 15'N, 11° 00'E	C1A	143	60	300
	C1B	323	300	300
	C2A	270	60	415
	C2B	090	300	415
	C2C	270	800	415
	C3A	354	60	220
	C3B	174	300	220
	C3C	174	800	220
38° 45'N, 04° [illegible]0'E	D1A	040	60	240
	D1B	220	300	240
	D1C	040	800	240
	D2A	245	60	300
	D2B	065	300	300
	D2C	245	800	300

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(U) TABLE 4-3a

TEST PARAMETERS FOR RUNS ACCOMPLISHED

RUN	DATE (1970)	TIME (START-FINISH)	RECEIVING SITE (LAT./LONG.)	SOURCE DEPTH(S) (ft)	HYDROPHONE DEPTHS (ft)
B1B-B1C	16 OCT.	1206Z-1430Z	35° 15' N. 16° 37' E.	300 800	60 350 800
B2B-B2C	16 OCT.	0824Z-1110Z	35° 15' N. 16° 37' E.	300 800	60 350 800
C1A/C1B	19 OCT.	0712Z-1008Z	36° 40' N. 11° 10' E.	60 300	60 350 800
C2A/C2B	19 OCT.	1014Z-1356Z	38° 31' N. 10° 52' E.	60 300	60 350 800
C3A/C3B	20 OCT.	0804Z-1014Z	38° 22' N. 11° 0' E.	60 300	60 350 800
C2C	20 OCT.	1026Z-1714Z	38° 14' N. 10° 58' E.	800	60 350 800
D2B/D2C	24 OCT.	1233Z-1537Z	38° 40' N. 04° 18' E.	300 800	60 350 800

(U) TABLE 4-3b

RUN	TRACK PARAMETERS					SURFACE CONDITIONS			
	MAX RANGE (nmi)	BRG FROM REC. SITE	BATHY. (FIG. NO.)	AXBT (FIG. NO.)	SALINITY (FIG. NO.)	SEA HT./DIR.	WIND SPEED/DIR.	SWELL HT./DIR./PER.	BAROM. in of Hg
B1B-B1C	170	020°T	3	-	17	6ft/160°T	16kt/160°T	12ft/170°T/7sec	29.85
B2B-B2C	190	157°T	7	8	17	6ft/160°T	16kt/160°T	12ft/170°T/7sec	29.85
C1A/C1B	170	165°T	7	9	17	4ft/340°T	8kt/340°T	4ft/360°T/5sec	30.06
C2A/C2B	415	270°T	7	10	17	4ft/340°T	8kt/340°T	4ft/360°T/5sec	30.06
C3A/C3B	220	351°T	7	11	17	4ft/270°T	18kt/260°T	8ft/270°T/6sec	29.80
C2C	405	270°T	7	-	17	4ft/270°T	18kt/260°T	8ft/270°T/6sec	29.80
D2B/D2C	290	245°T	7	12	17	8ft/360°T	25kt/360°T	20ft/360°T/10sec	30.33

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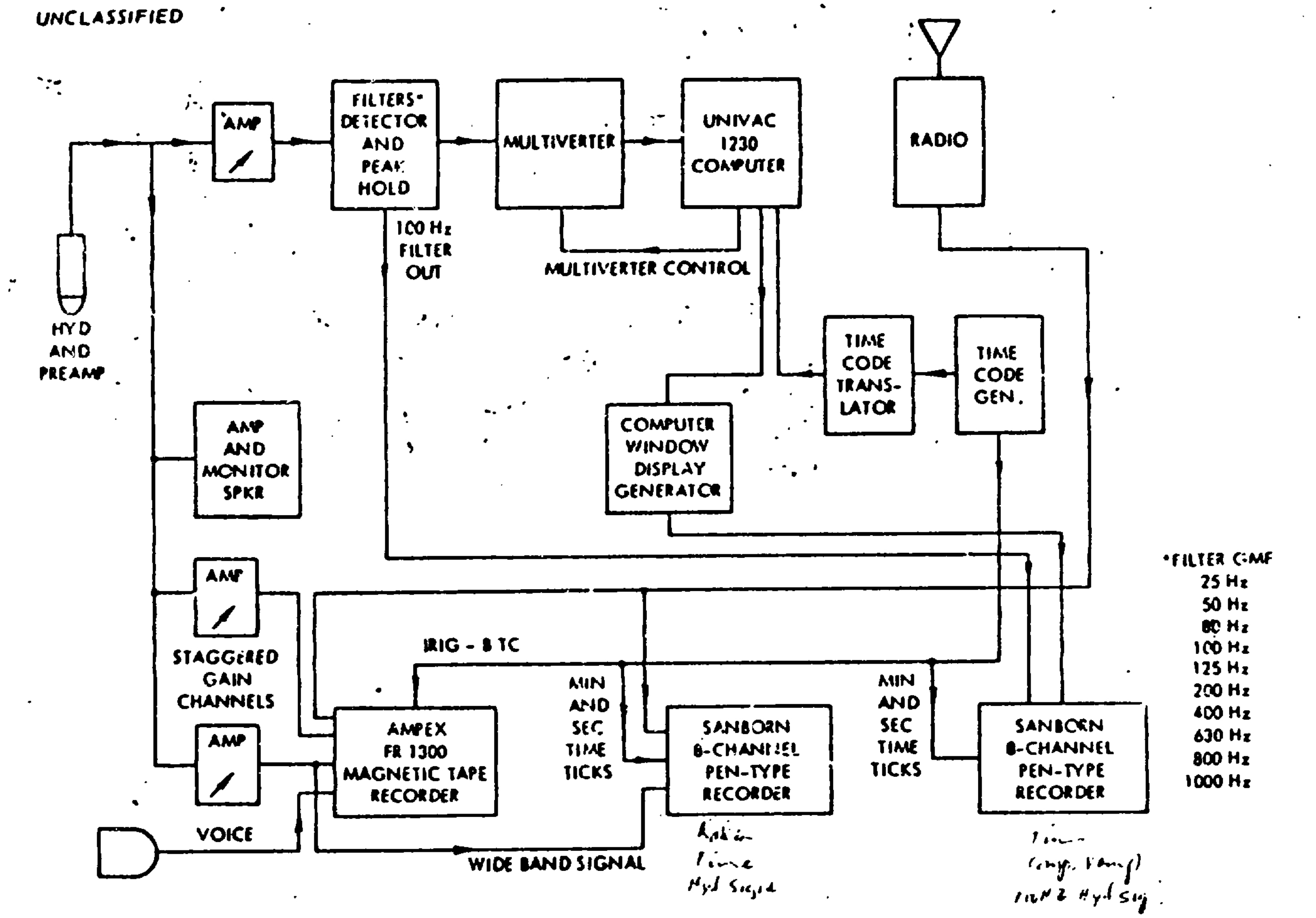

(U) Fig. 4-2. JOAST Phase IV Measurement System, Block Diagram computer formated digital equivalents. The sampled digital values are then input, on command from the computer, for processing at a rate equal to or greater than the Nyquist sampling criteria. Once two successive arrivals were received the computer could be set on an automatic mode of processing since a new arrival could be expected every two minutes. Previous to the expected signal arrival a sample of noise was processed to obtain the noise averaged mean squared value. This was stored and was also used with a multiplier, set by the operator, as a threshold value for determining if a signal had been received. A sample window was set so that the complete signal length was captured including part of the time history (up to 3 sec.) previous to the signal arrival. The summed squared values of the samples of the received signal plus noise was then adjusted by subtracting from it the averaged mean square value of noise adjusted for the window length. The use of continuous sine wave calibration signals at the GMF of the filters allowed the received squared signal samples to be converted to pressure levels and the estimated received signal analogous to $\int P^2 dt$ to be computed. The computer then outputed the propagation loss (source level - received level) where the source levels were constants stored in the computer as listed in Table 4-4 in addition to the received level, noise level, and signal-to-noise ratio. All the hydrophone analog signals were recorded along with voice identification and IRIG-B time code on a 14 channel Ampex FR 1300 magnetic tape recorder. The analog output of the 100 Hz filter was recorded on a Sanborn 8 channel pen type recorder with a computer window display of signal and minute and second time ticks. This permits visual observation of the time of arrival and the capture position in the computer window. A second pen type recorder recorded the radio signal, time ticks, and the wide band hydrophone signal. The drop time of the explosive was therefore visually determined. The computer calculated an acoustic travel for the received arrival from the time of arrival less the time of drop plus a drop to detonation time.

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(U) TABLE 4-4

EFFECTIVE SOURCE LEVELS

SUS MK-61 and MK-82 (or equivalent) Charges

FREQUENCY Hz	SOURCE DEPTH 60 ft MK-61		SOURCE DEPTH 300 ft MK-82		SOURCE DEPTH 800 ft MK-61	
	SPECTRUM LEVEL	1/3 OCTAVE BAND LEVEL	SPECTRUM LEVEL	1/3 OCTAVE BAND LEVEL	SPECTRUM LEVEL	1/3 OCTAVE BAND LEVEL
25	105.0 dB*	112.5 dB**	111.0 dB	118.5 dB	103.0 dB	110.5 dB
50	103.0	113.5	105.0	115.0	111.0	121.5
80	102.0	114.5	103.3	116.0	106.5	119.0
100	101.8	115.5	102.5	116.0	104.5	118.0
125	101.5	116.0	101.8	116.5	103.2	118.0
200	100.5	117.0	100.5	117.0	101.0	117.5
400	99.0	118.0	97.8	117.5	97.5	117.0
630	97.5	119.0	95.5	117.0	95.4	117.0
800	96.0	118.5	94.5	117.0	94.5	117.0
1000	94.5	118.0	93.8	117.5	93.9	117.5

* $dB//(1 \mu bar)^2 sec \cdot Hz^{-1}$

** 1/3 OCTAVE BAND LEVEL IS SPECTRUM LEVEL + 10 LOG BAND WIDTH TO NEAREST 0.5 dB

The latter was determined by actual measurements made before each run of the moment of release to time of detonation for each depth and at the altitude assigned to the aircraft for the runs. With an average horizontal sound velocity determined from the velocity profile taken at the stations the range was calculated for each detonation. The computer also routinely computed a range for each detonation using the initial range value updated every two minutes from the known aircraft speed. The aircraft independently recorded a range for each charge dropped by use of dead-reckoning trace plots or navigational fixes. The range finally assigned for each shot is the result of a review of all these range data. No mention is made of the range accuracy of the shot range. The wide band signal was also used on a storage scope which was calibration for system overload. This permitted system over loaded arrivals to be rejected.

4.3 (U) ENVIRONMENTAL DATA

4.3.1 (U) Bottom Topography

(U) The bottom topography along the measurement tracks are shown in Figure 4-3. These were read from chart H.O. 4300 and are uncorrected for actual sound speed. Since the vertical velocity is primarily determined by the positive pressure gradient (approximately 96% of the water depth) it is possible to compute an estimate of the error in the values from H.O. 4300. Calculations for Station 7, runs B1B/B1C and Station 9, runs D2B/D2C indicate an average error of 4.3 percent, that is the actual depth would be about 4.3 percent deeper than that read from the H.O. chart. (A true depth correction in fathoms for uncorrected fathometer and for the Mediterranean Sea is also given in a chart on the folder of "Convergence Zone Slide Rule" June 1973, NUSC/NL. For the depths here there is good agreement (less than 2 fm)).

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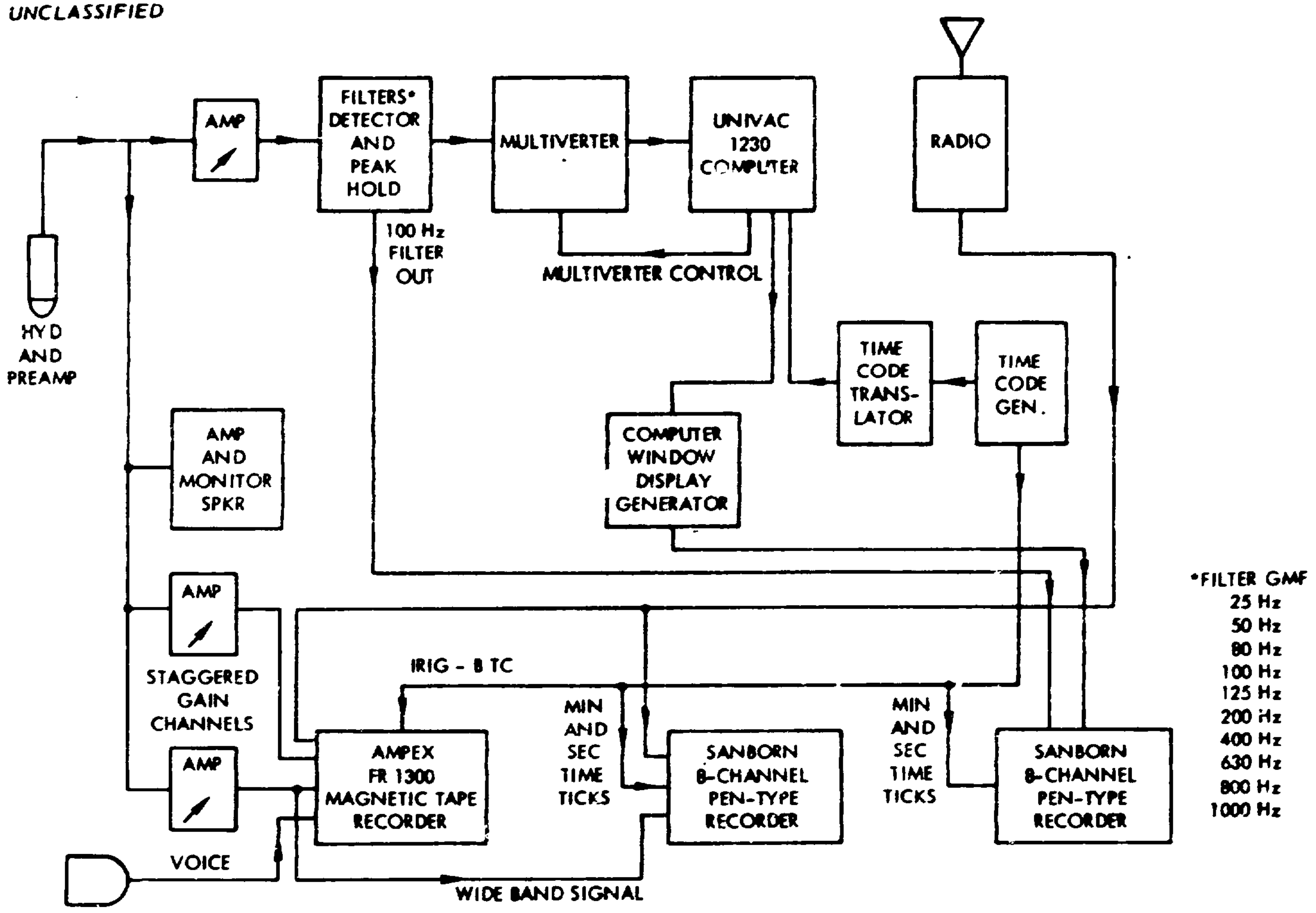

Fig. 4-2 (U)JOAST Phase IV Measurement System, Block Diagram

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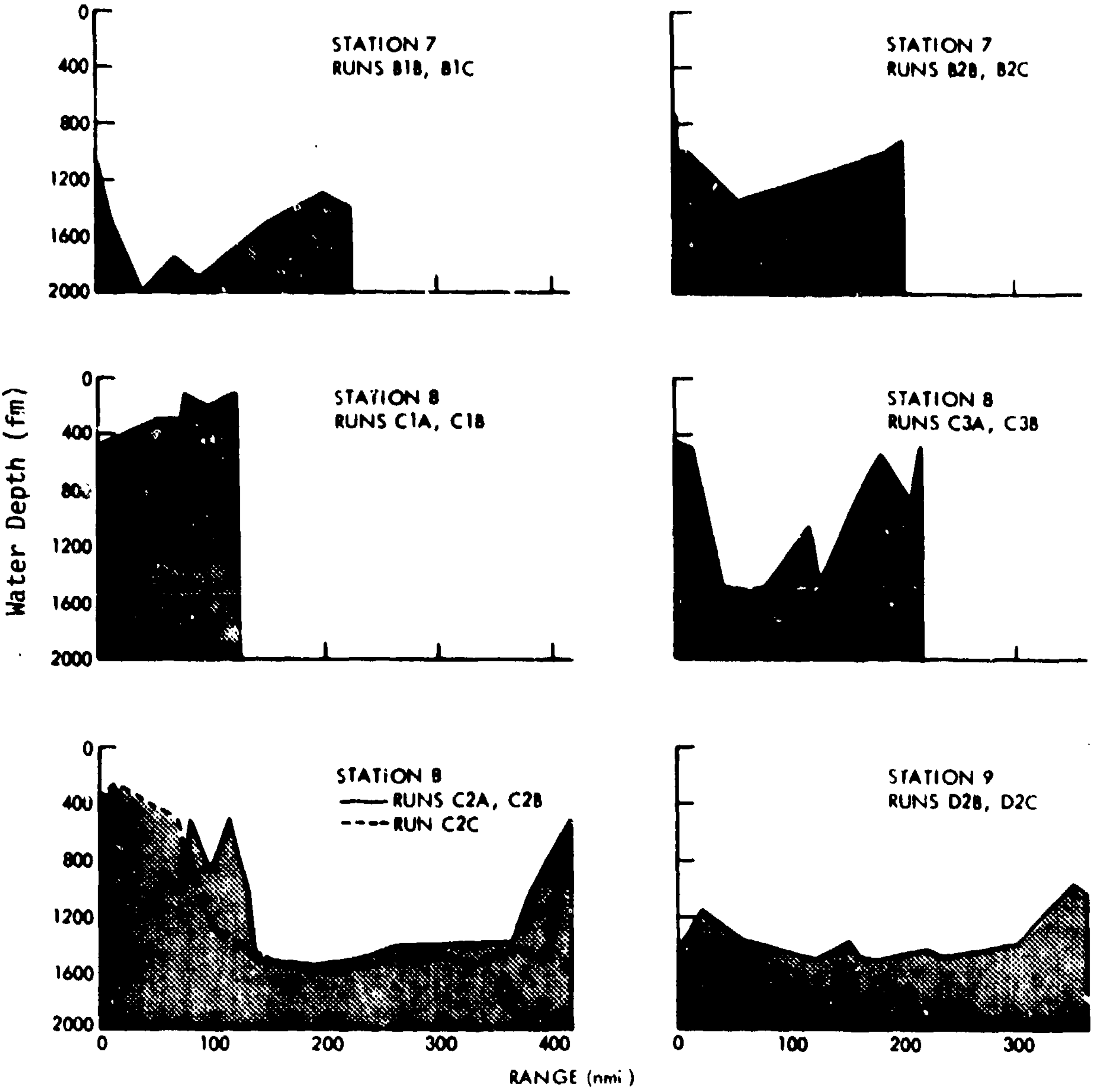

Fig. 4-3(U)Bottom Topography Along Measurement Tracks — Stations 7, 8, and 9

4.3.2 (U) Sound Velocity Profiles

(U) The sound velocity depth profiles for Station 7 and 9 are in Figure 4-4 and 4-5. A listing of these profiles is in Table 4-5. Temperature and salinity versus depth measurements are in Figure 4-6. Additional information in the form of the AXBT's along the track for the Stations 7 and 9 runs are presented in Figure 4-7 and 4-8. Examining this data indicates that a mixed layer occurs at the surface to 100-140 ft. deep. A depressed deep sound channel exists with the axis near 450 ft. and a channel depth of approximately 5500 ft. Transferring this information to Figure 4-3, we obtain a surface half channel of about 16-23 fathoms a deep sound channel axis near 83 fathom and a channel depth of 916 fathoms. Therefore, for runs B1B, B1C at Station 7 and D2B, D2C at Station 9 the bottom does not penetrate the deep sound channel and is at least 150 fathoms deeper at Station 7 and 300 fathoms at Station 9. Therefore it is concluded that for sources at 300 and 500 ft. to receivers at 350 and 500 ft the propagation would be essentially contained in the deep sound channel duct. Of the two possibilities here, the bottom depth for Station 9 (runs D2C and D2B) to 300 nmi is more constant than for Station 7. After 300 nmi the water depth decreases and eventually the bottom penetrates the deep sound channel so that the propagation loss would become range dependent. Similarly, at about 90 nmi for runs B1B and B1C the bottom may affect the propagation loss as it slopes upward toward the deep sound channel. The depth excess noted for each run would of course lend to convergence zone propagation since the source is omnidirectional. This would result in a variance about the average direct propagation loss but only about 25% of the scheduled explosion would occur at ranges where the zonal propagation would be effective (about 20 nmi increments in range). In addition, variability in the depths of the surface half channel would lead to sound channel leakage but they should be minimal for the data of Station 9 as the surface

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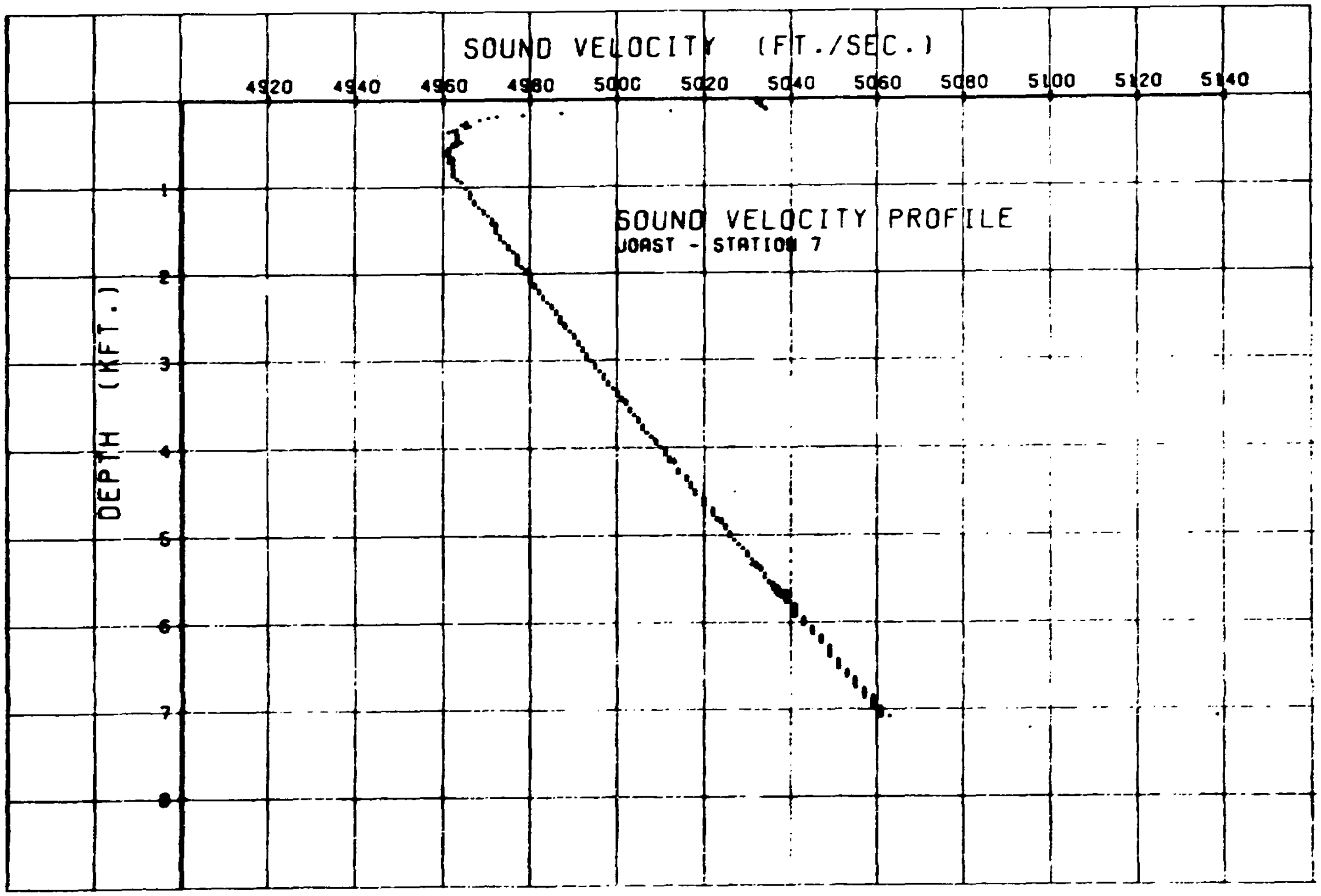

Fig. 4-4 (U) Sound Velocity Profile — Station 7

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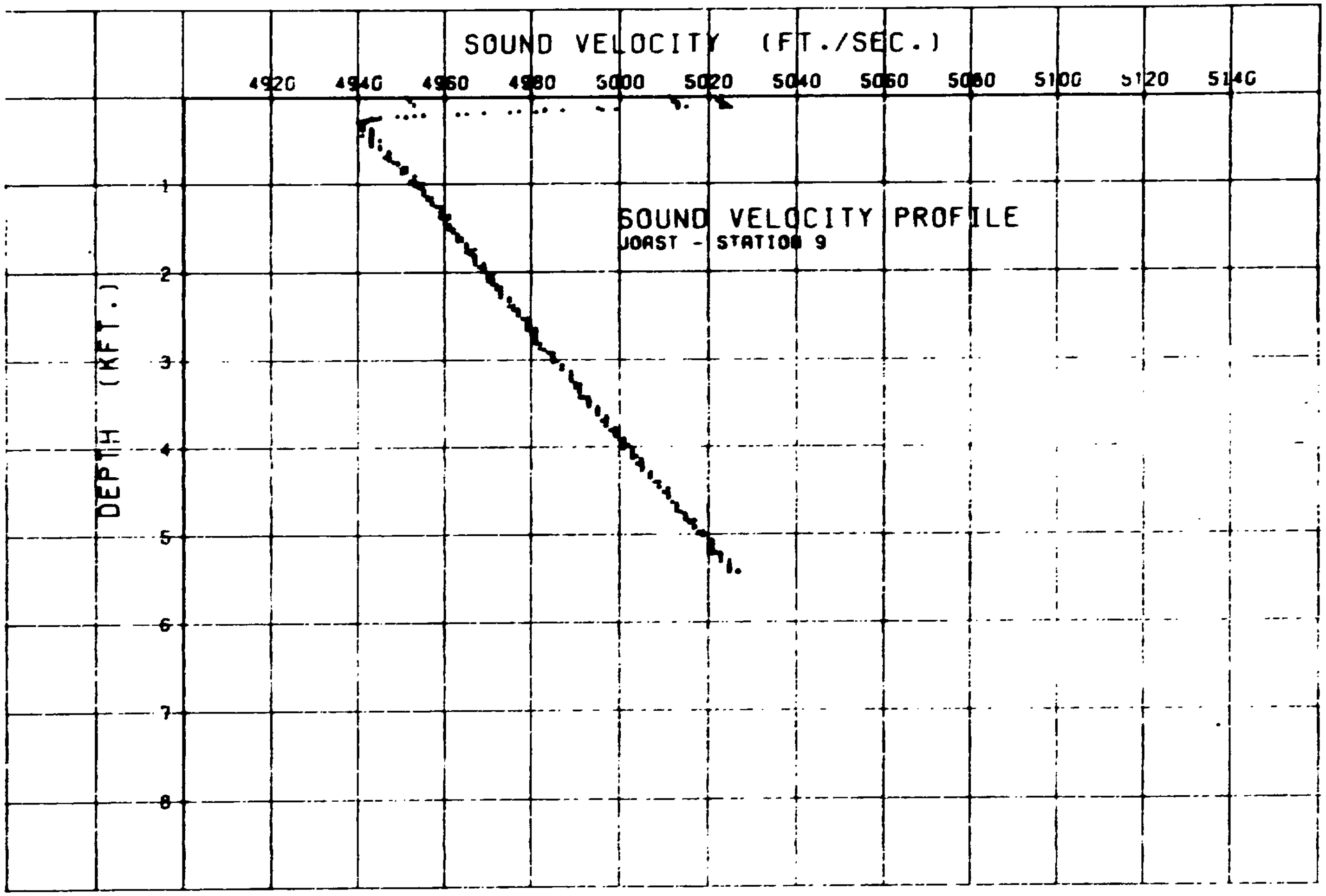

Fig. 4-5 Sound Velocity Profile — Station 9

(U) Table 4-5. Listing of Velocity-Depth Profiles for Station 9 and 7

Station 9 (Corrected for Surface Velocity)

DEPTH (ft)	VELOCITY (ft/sec)
0	5012
150	5014
185	4980
260	4960
400	4940
1400	4960
2650	4980
3800	5000
5175	5020
7000	5055 (Est)

Station 7

DEPTH (ft)	VELOCITY (ft/sec)
0	5032
130	5034
185	4980
520	4960
2000	4980
3390	5000
5695	5040
7000	5060

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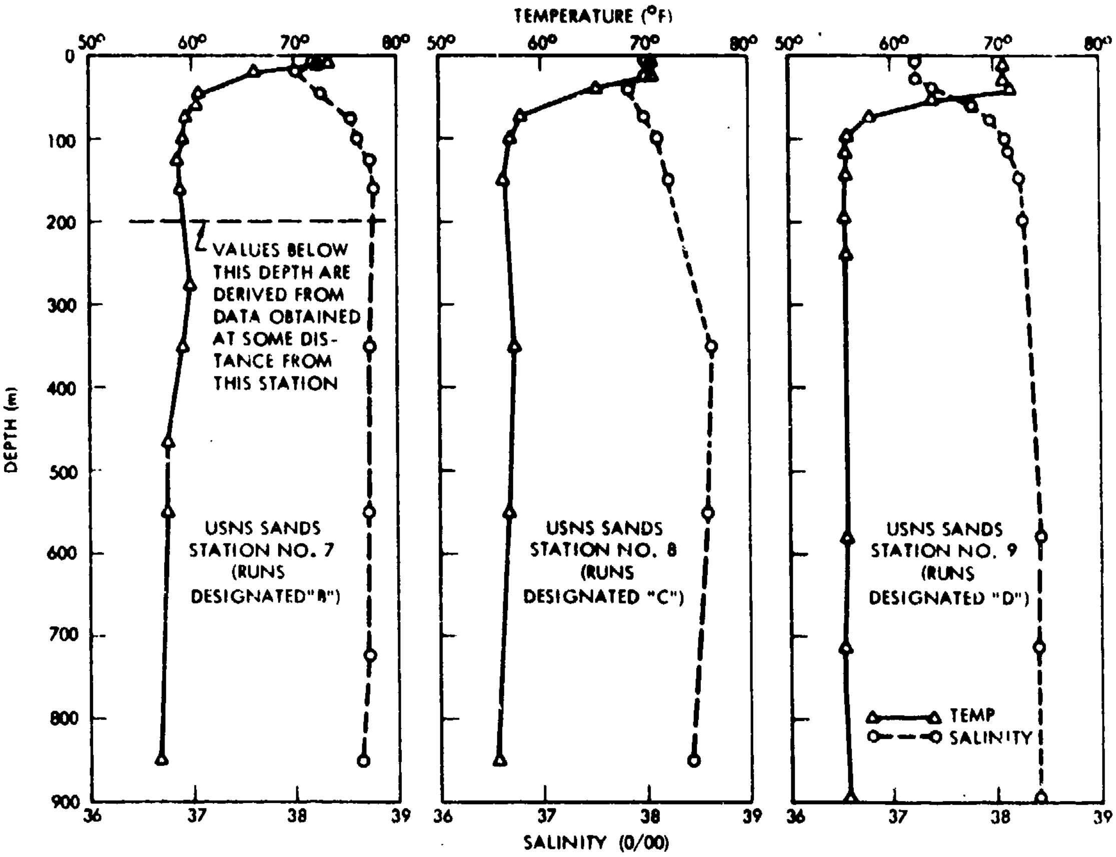

Fig. 4-6(U)Temperature and Salinity Data — Stations 7, 8, and 9

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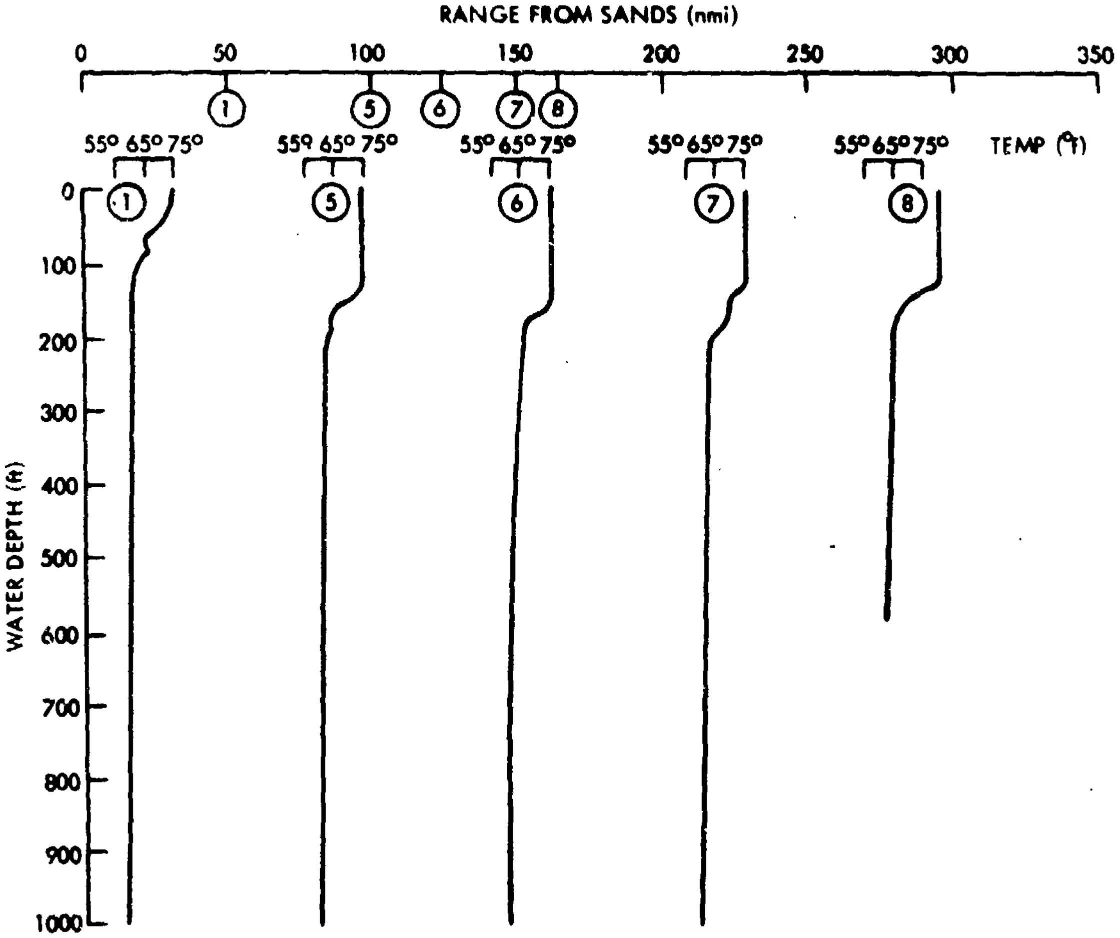

Fig. 4-7(U)AXBT Profiles vs Range — Run B2A, Station 7

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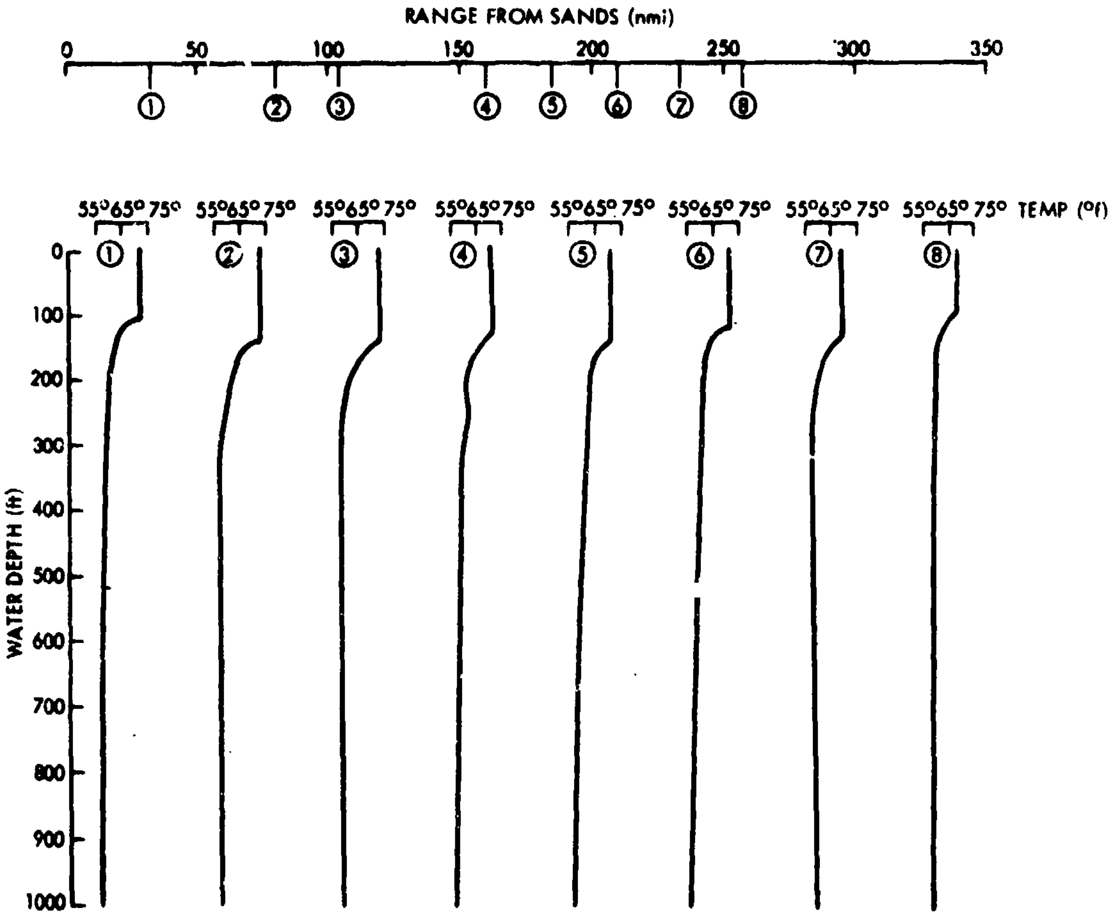

Fig. 4-8(U)AXBT Profiles vs Range — Run D2A, Station 9 half channel depth is relatively constant. With a channel axis of around 500 ft, the ducted sound propagation should be of interest in submarine sonar.

4.3.3 (U) Surface Conditions

(U) The recorded surface conditions for the runs are in Table 4-2(b). For Stations 7 and 9 the high seas, strong winds, and large swell existed. This adverse weather conditions strongly affected the measurement system hydrophones especially at 60 and 350 ft. resulting in high background noise (system) which contaminated the signal arrivals resulting in reduction of the data set. The calculated background levels routinely calculated are not reported since for the most part these levels represent platform noise and not sea ambient.

4.4 (U) PROPAGATION LOSS RESULTS

(U) The propagation loss data set for the D2C run at Station 9 (source at 800 ft) is the most complete to the 800 ft. hydrophone to a range of approximately 250 nmi and this run is recommended for the comparison of the models. The data set for this run is presented in Figures 4-9 through 4-17 as a function of range, hydrophone depth and frequency. In addition to the data set for the 800 ft. receiver, substantial data is indicated at the 350 ft. receiver in the frequency range above 100 Hz. For the D2B run (Figures 4-18 through 4-27) (source at 350 ft) the data set covers a range to about 100 nmi and is available only to the 800 ft. receiver. Since this requires only a source depth change in the model it should be considered. Here the 350 ft. receiver was inoperative due to a system failure. The sound velocity depth profile for the runs shows two surface sound speed values. From the temperature (AXBT) and temperature-salinity depth profiles it seems that the correct value of surface sound speed is about 5012 ft/sec. For the B1B/B1C run the data set for

B1C is the more complete and is in Figures 4-34 through 4-40. It is not intended that this set be modeled but used only as a fill into the data set of D2C since similar ducted sound transmission is implied.

4.5 (U) FACTORS THAT MAY INFLUENCE THE RESULTS

4.5.1 (U) Hydrophone Depth

(U) The depth of the hydrophones were monitored by remote readings from pressure gages mounted on each hydrophone unit.

4.5.2 (U) Bottom Topography

(U) Since the bottom topography was read from a map it may not be accurate enough to indicate the actual topography for a run. In addition, small changes in the location of the path made by the aircraft may alter the bottom topography. Of more possible importance are changes in the bottom contours. In the real world ideal flat bottoms are the exceptions rather than the norm over long ranges. When the bottom depth decreases with range, a condition exists that energy directed to the bottom can be reflected and then is trapped in the channel duct and adds to the received energy. This possibility could result in the reduction of propagation loss as noticed in the 90 to 150 nmi range in the data set for D2C at the 800 ft. hydrophone. Also, the data set for B1C appears to be affected by the bottom for ranges greater than about 90 nmi. If indeed this type of propagation exists then the simplistic models should be compared only with the data sets for frequencies (400 Hz and above) where the bottom loss is high and its effects are minimal. For bottom depths that decrease with range it would be expected that the reflected energy would be in the direction of the source and should have little effect at the receiving location.

4.5.3 (U) Bottom-Surface Reflections And Convergence Zone Propagation

(U) Although bottom cores were taken at the stations they were never reported. Bottom loss values from archival files should be used. Initially bottom-surface reflections are possible since the source is non-directional but they should not become important with increasing range because of the higher boundary losses. Convergence zone propagation is possible but should be of only minor importance in the duct. In addition, the data set covers only about 25% of the possible ranges for convergence zone propagation.

4.5.4 (U) Source Level

(U) The source levels used here were compared with the results of Gaspin & Schuler[1] and the changes in the propagation loss curves as a result of their source levels are listed in Table 4-6. In Table 4-7 the changes in source levels for the expected depth span for a nominal 800 burst (700-800 ft) are listed from ref 1 to be used as a guide in interpreting the propagation loss results.

4.5.5 (U) Possible Range Errors

(U) From an error analysis made in JOAST III, the travel time - average speed calculation of range indicated a range accuracy within 100 yds at 35-40 kyds. This error, about .25%, was due in part to average sound speed errors (about 5 ft/sec) and to time measurement errors. An error of this magnitude for the average sound speed should be determined for JOAST IV especially since we are concerned with only the sound channel. Considering a maximum possible error of .25% this would result in only .75 nmi range error at 300 nmi. However, besides the basic electronic system accuracy a more important additional error might result from

(U) Table 4-6 JOAST IV Adjustment in Propagation Loss for Gaspin & Shuler Source Levels

300 ft Source		800 ft Source	
1/3 Octave GMF (Hz)	Propagation Loss Adjustment (dB)	1/3 Octave GMF (Hz)	Propagation Loss Adjustment (dB)
25	+1.7	25	-1.5
50	+2.7	50	-0.4
80	+2.2	80	-1.2
100	+1.8	100	+1.7
125	+1.7	125	-0.1
200	+1.6	200	+0.5
400	+1.4	400	+2.1
630	+0.7	630	+1.9
800	+1.2	800	+1.6
1000	+0.7	1000	+1.1

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(U) TABLE 4-7

DEPTH VARIATION FOR AN 800-FOOT, 1.8-LB SOURCE

$\Delta E\ (E_d - E_{800})$ (db re 1 erg/cm^2/Hz)

Range 100 yds

1/3 Octave Band Center Frequency	Source Depth 700'	750'	850'	900'
12.5	1.8	.9	-.7	-1.4
16	2.9	1.3	-1.1	-2.0
20	3.3	1.5	-1.5	-2.9
25	2.8	1.4	-1.4	-2.7
31.5	2.2	1.1	-1.0	-2.0
40	2.4	1.2	-1.0	-1.8
50	1.2	.7	-.9	-1.7
63	1.2	-.4	-.1	0.0
80	2.0	-1.0	.1	0.5
100	0.0	.1	-.2	-.5
125	1.7	-1.3	.8	1.1
160	2.2	-.4	-.2	-1.2
200	1.0	-.5	-1.6	-2.3
250	1.2	.1	0.0	.3
315	1.6	1.7	.8	1.1
400	.5	.4	-.4	-.3
500	.4	.3	-.1	-.5
630	.6	.4	-.1	-.2
800	.8	.5	.2	-.1
1000	.7	.5	.2	0.0

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errors in the drop time of the charges from the aircraft to detonation in the ocean. The average time was measured previously to each run but many factors can possibly affect the actual drop such as air density, height and speed of aircraft, angle of penetration, and water density to name a few. In addition, since the data set is of graphical form, plotting errors (mechanical) can give range errors. The final range assigned to each slot was the result of the travel time - average speed calculations, computations using an initial range plus a value updated every two minutes using aircraft speed, and the independently recorded range for each shot by the aircraft from dead reckoning plots or navigational fixes. This procedure should inherently reduce the range errors.

References (U)

1. NUSC Report No. 4203 "Low Frequency Propagation Loss Experiment in the Mediterranean Sea" (U) of 5 Nov 1971 by Schumacher, William R.; Thorp, William H.; and Friedel, Frederick C. (CONFIDENTIAL)

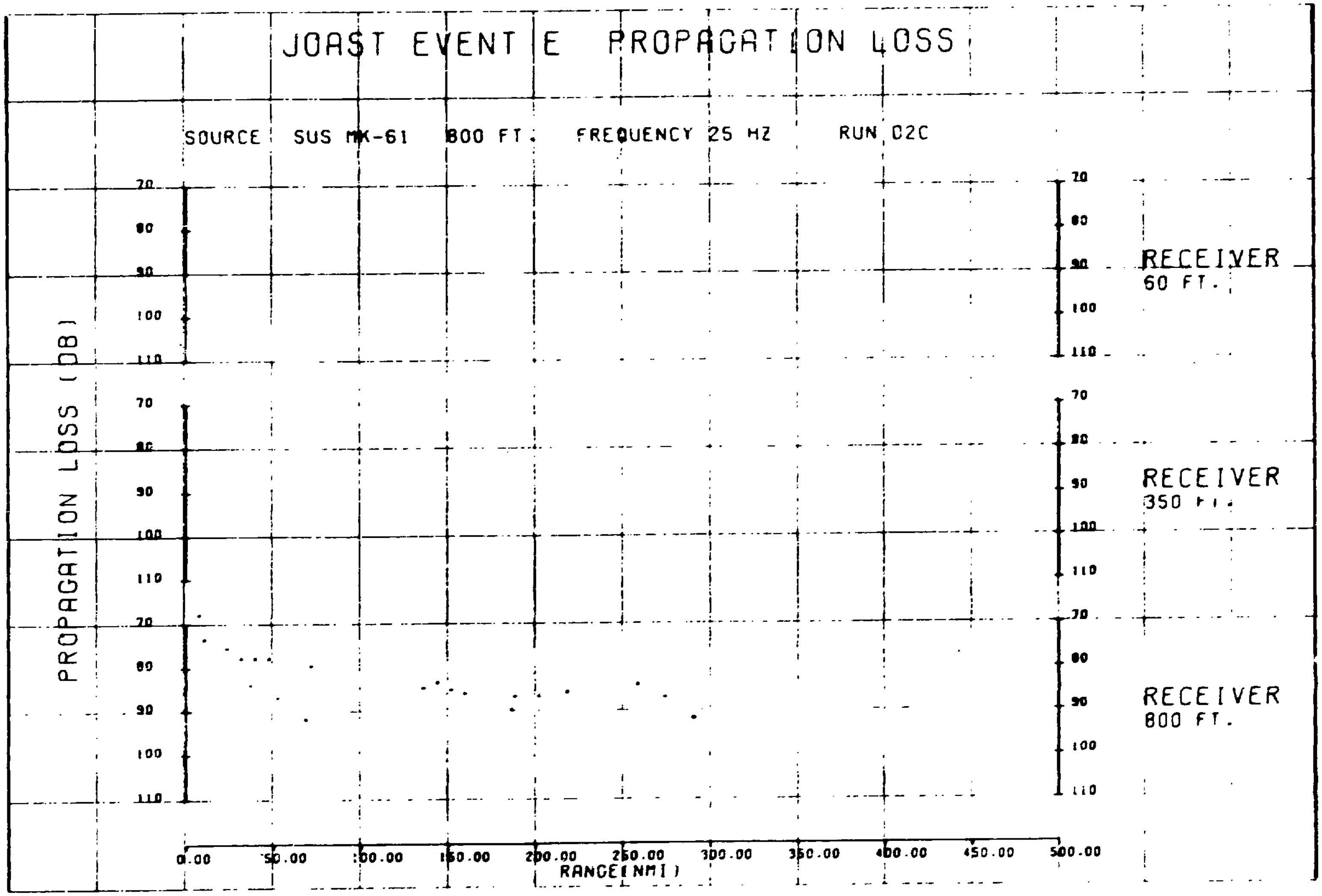

Fig. 4-9 (U) Run D2C Measured Propagation Loss — 25 Hz

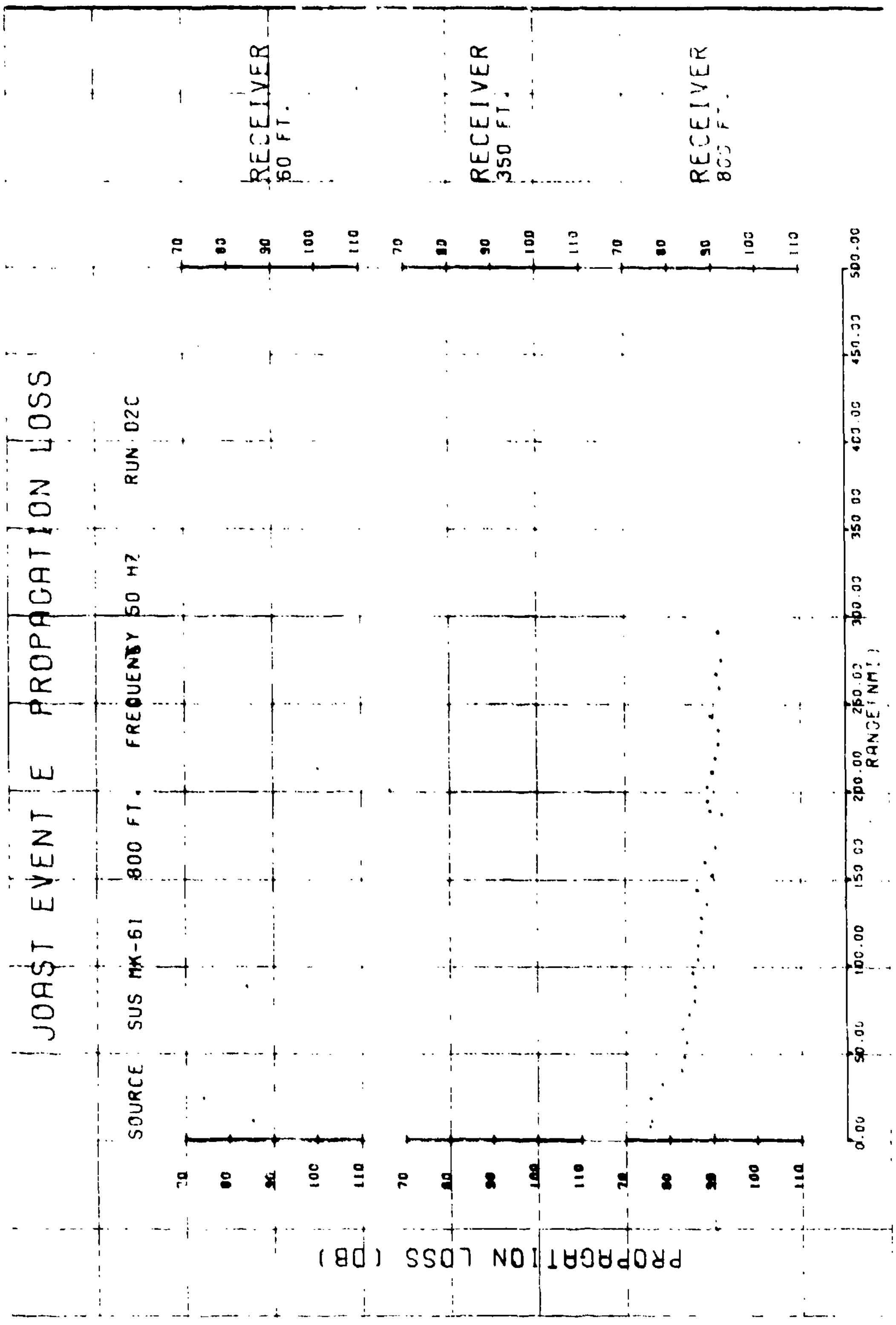

Fig. 4-10 (U) Run D2C Measured Propagation Loss — 50 Hz

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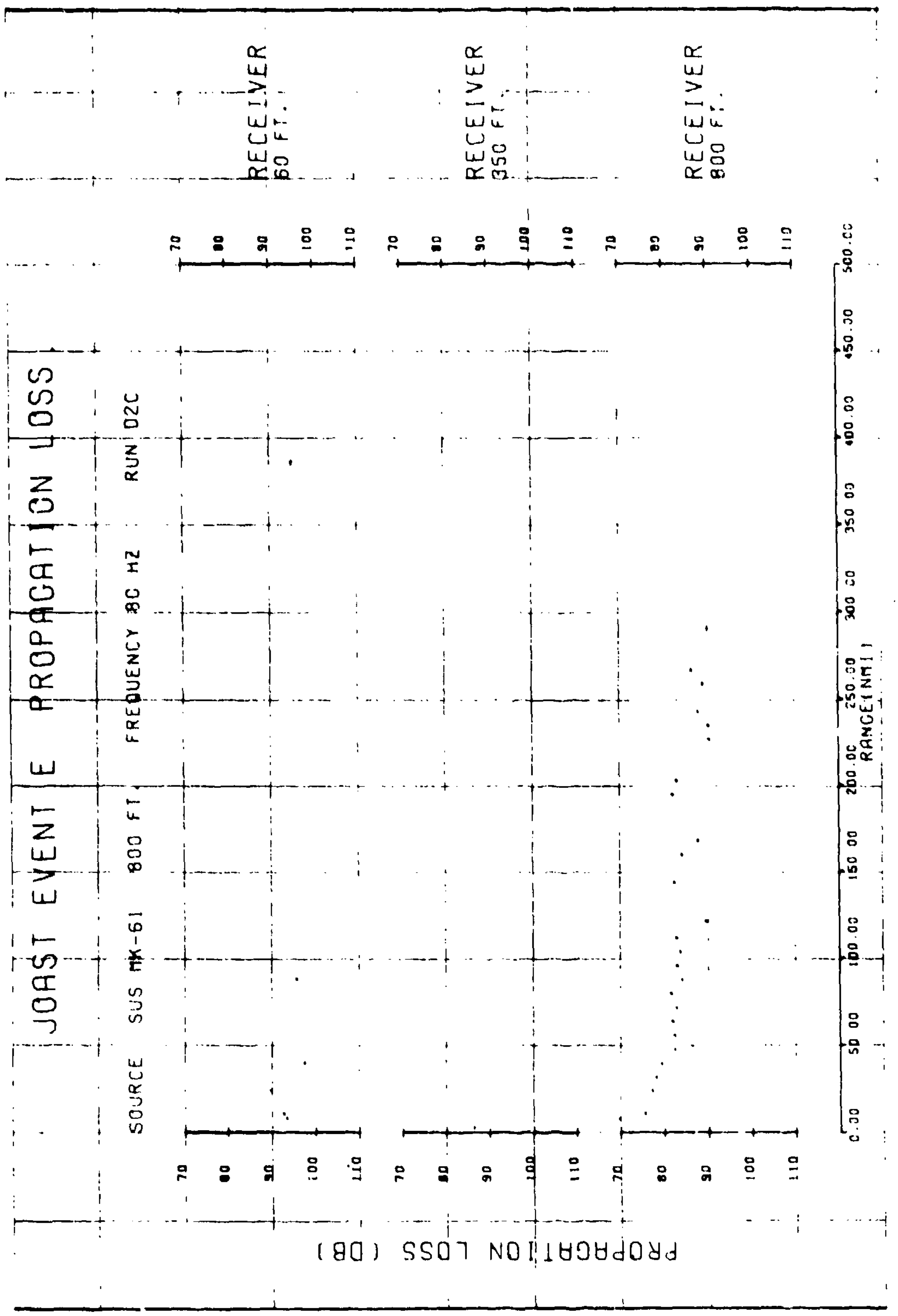

Fig. 4-11 (U) Run D2C Measured Propagation Loss — 80 Hz

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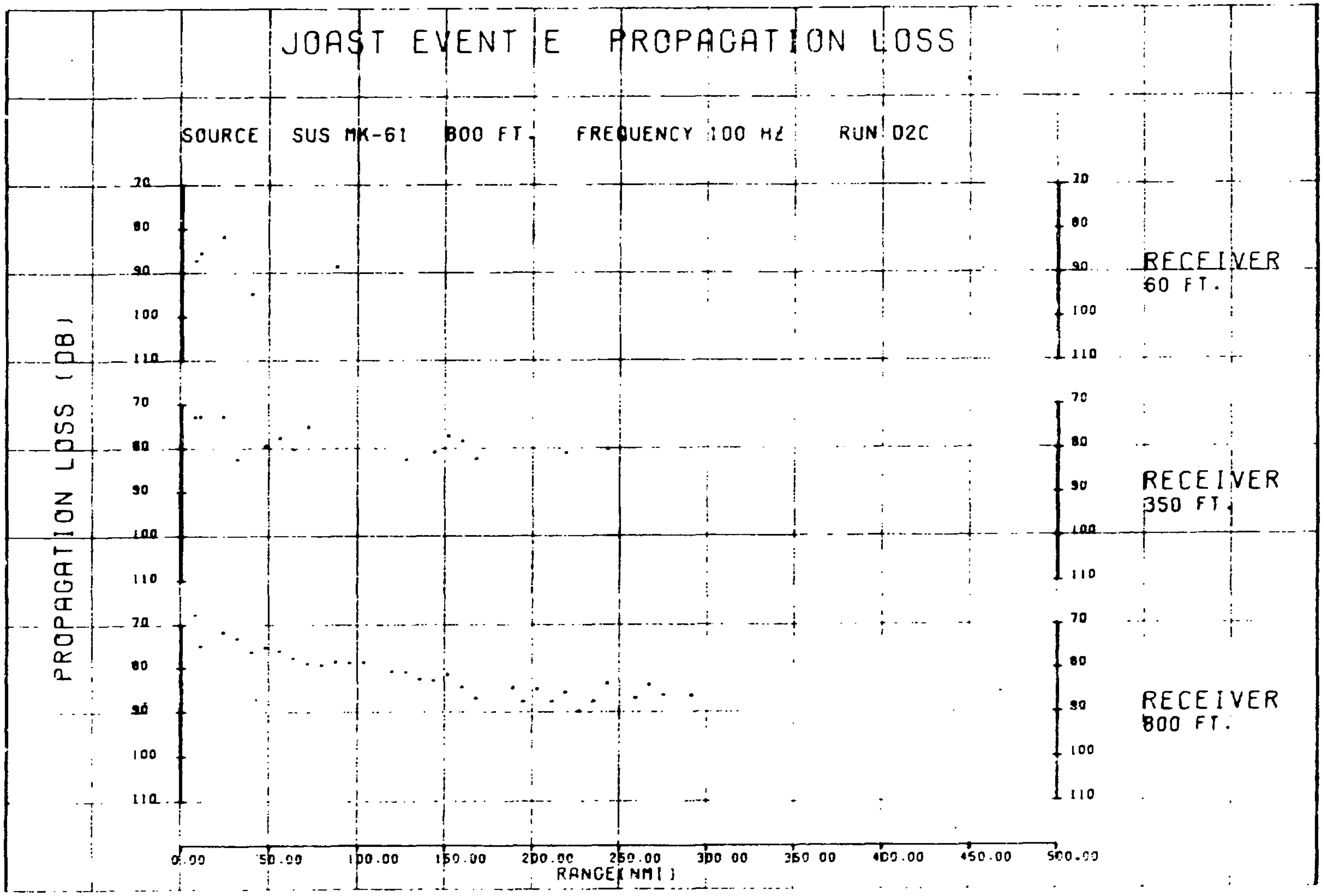

Fig. 4-12 (U) Run D2C Measured Propagation Loss — 100 Hz

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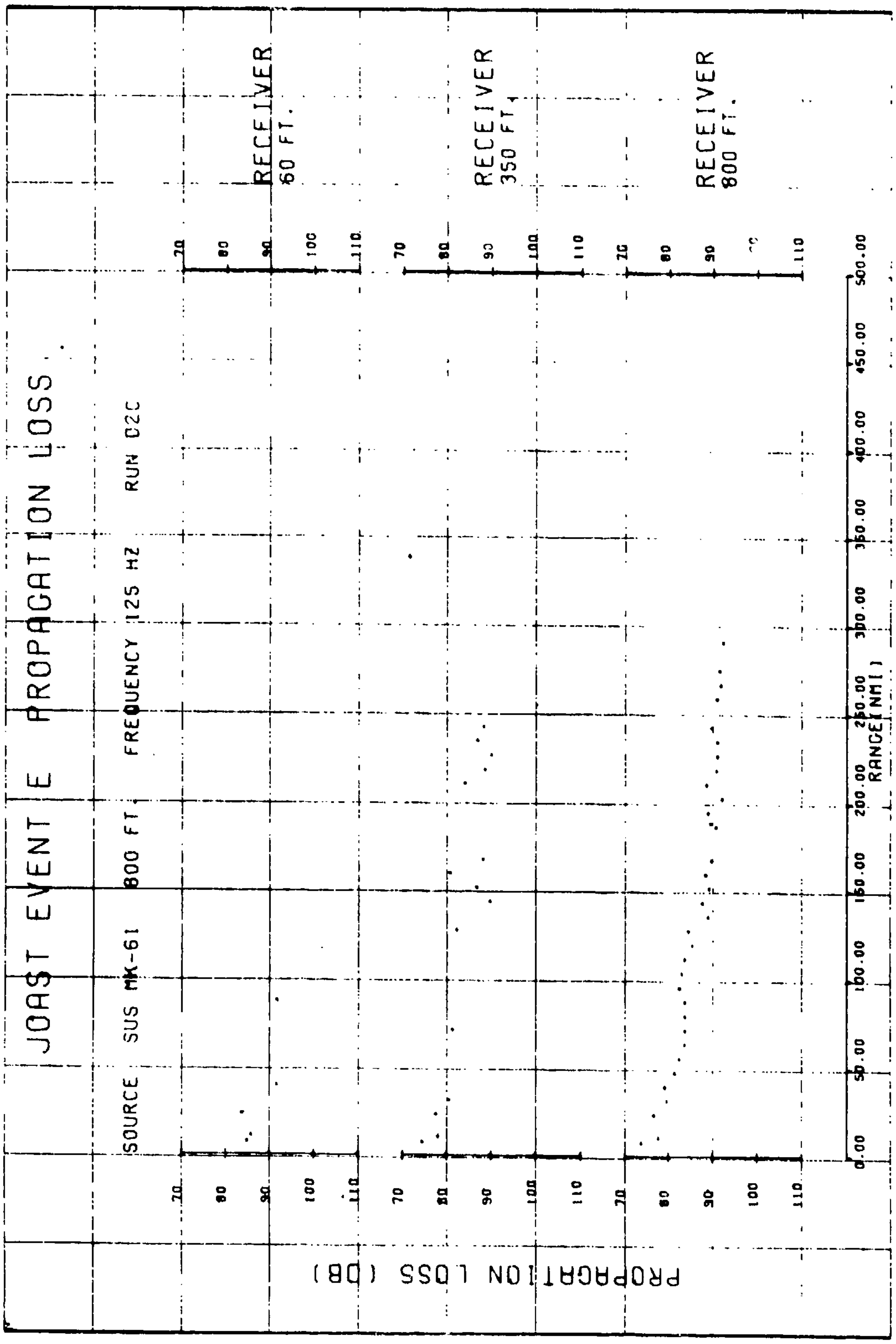

Fig. 4-13 (U) Run D2C Measured Propagation Loss — 125 Hz

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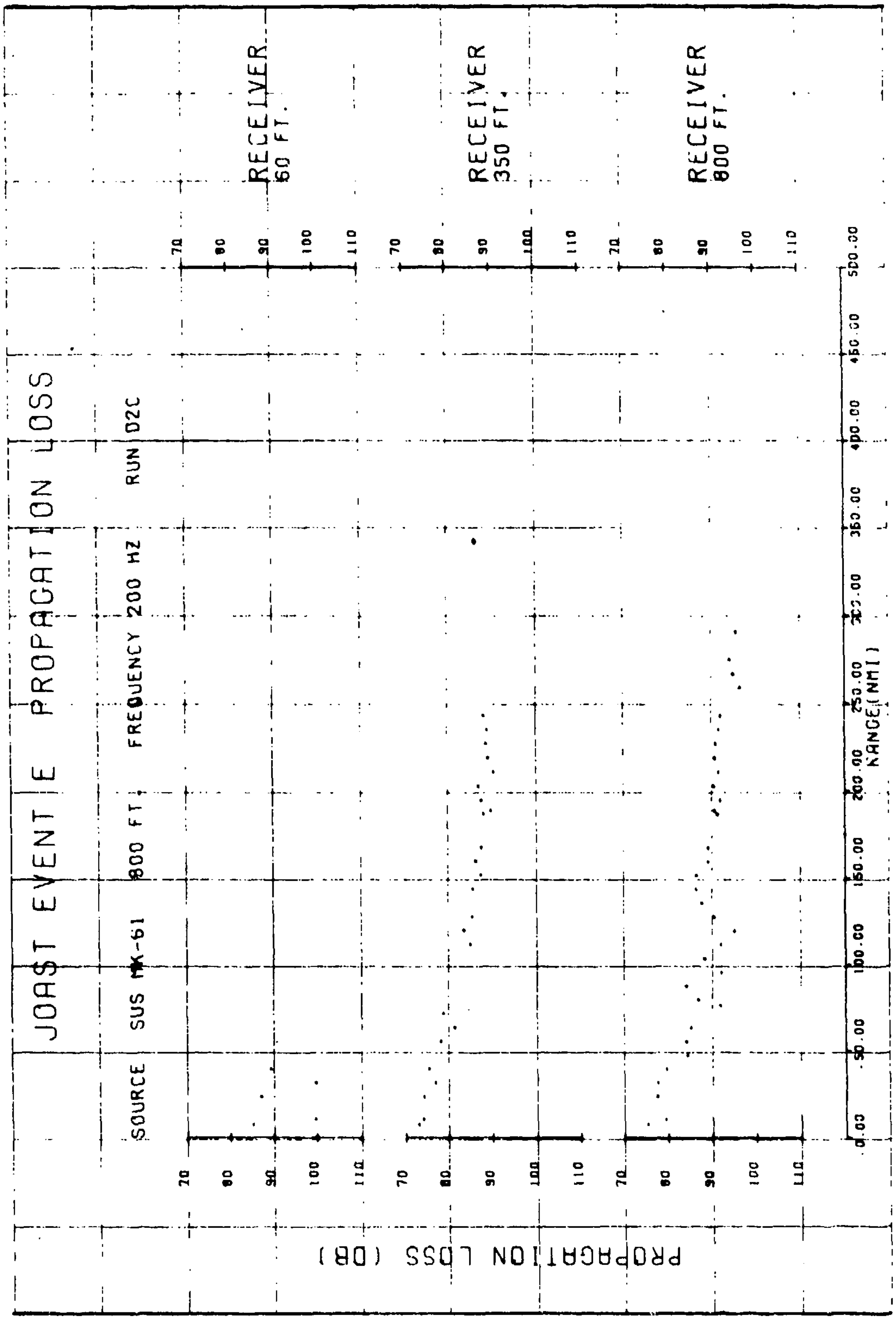

Fig. 4-14$^{(U)}$ Run D2C Measured Propagation Loss — 200 Hz

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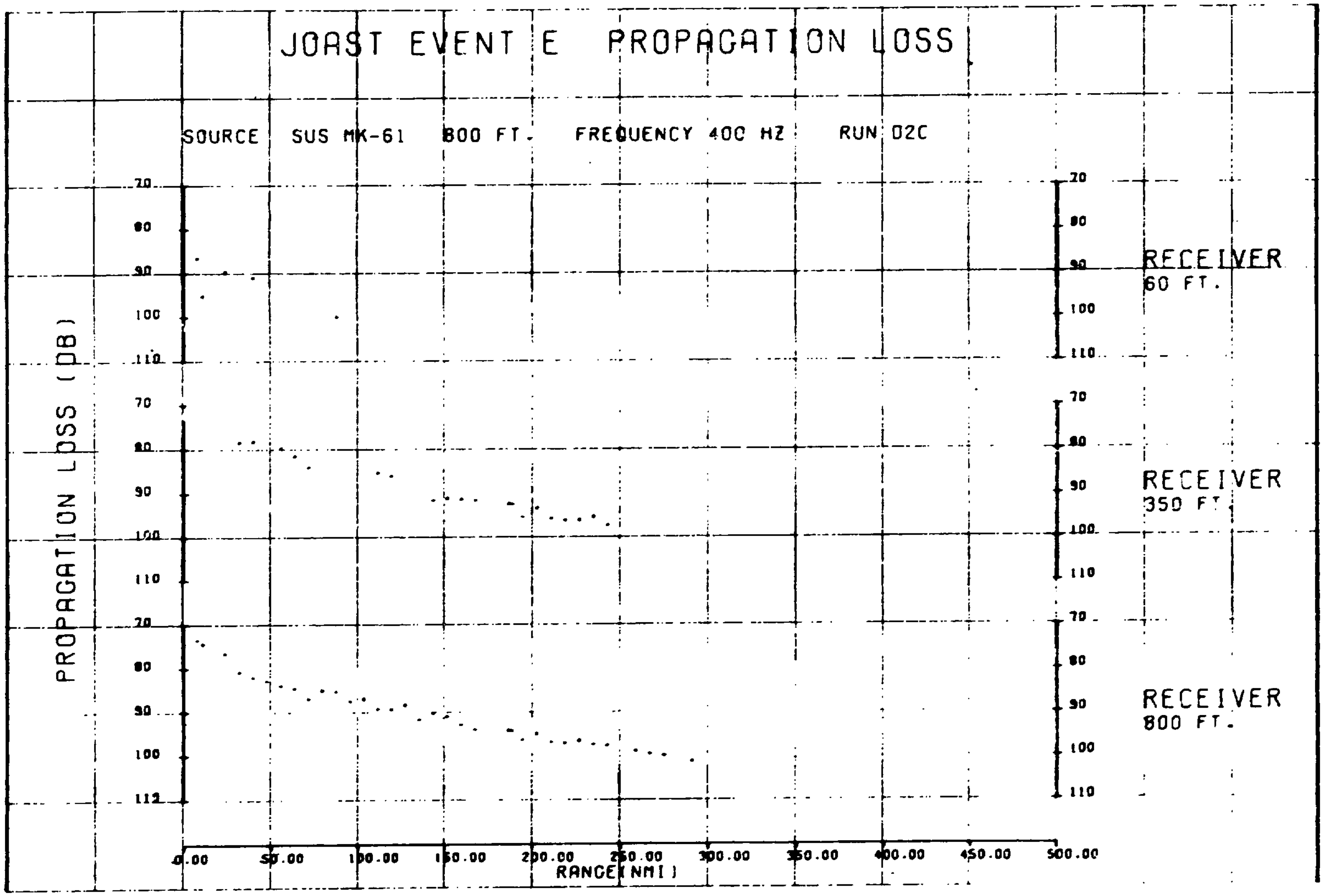

Fig. 4-15(U) Run D2C Measured Propagation Loss — 400 Hz

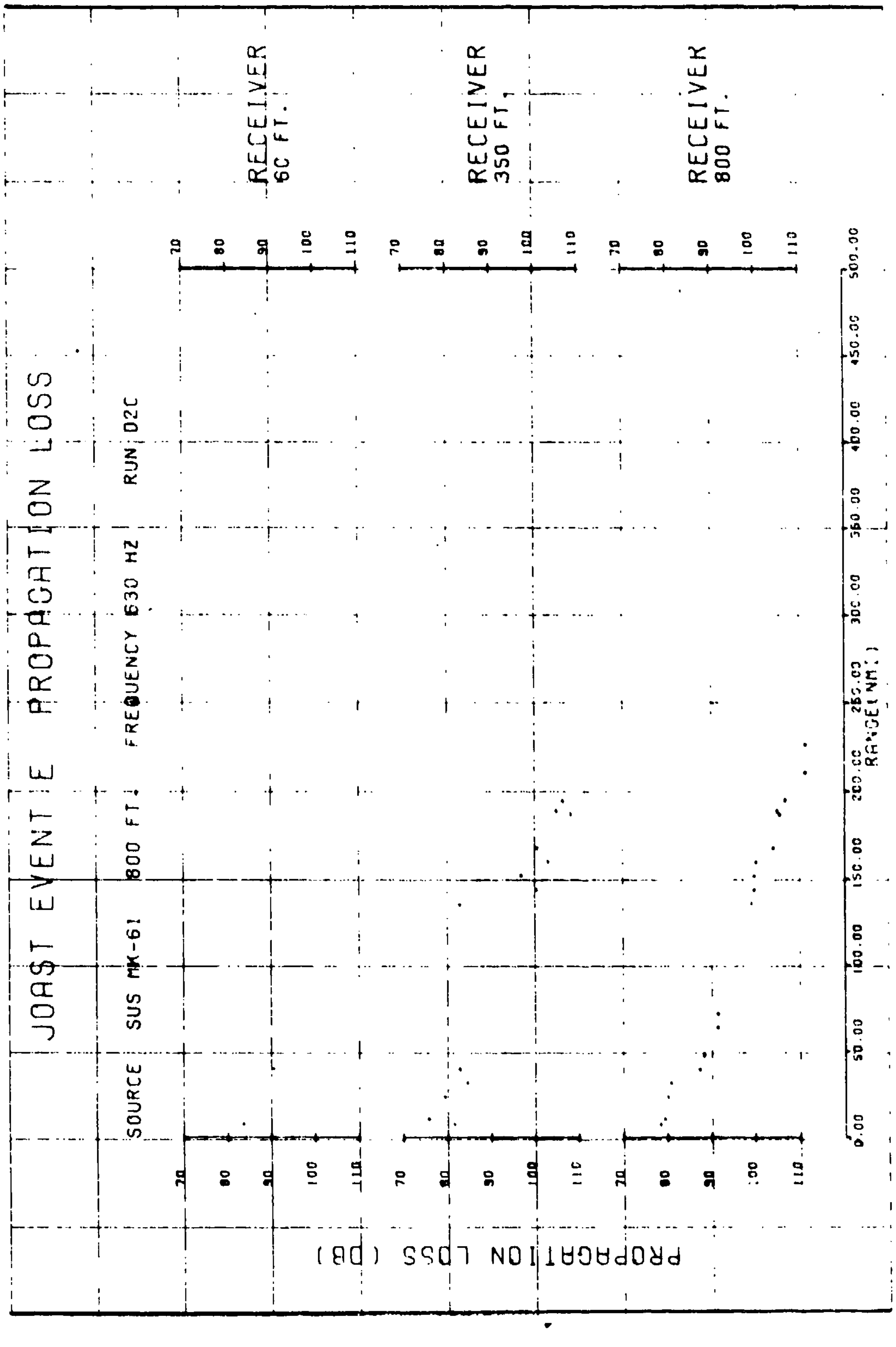

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Fig. 4-16(U) Run D2C Measured Propagation Loss — 630 Hz

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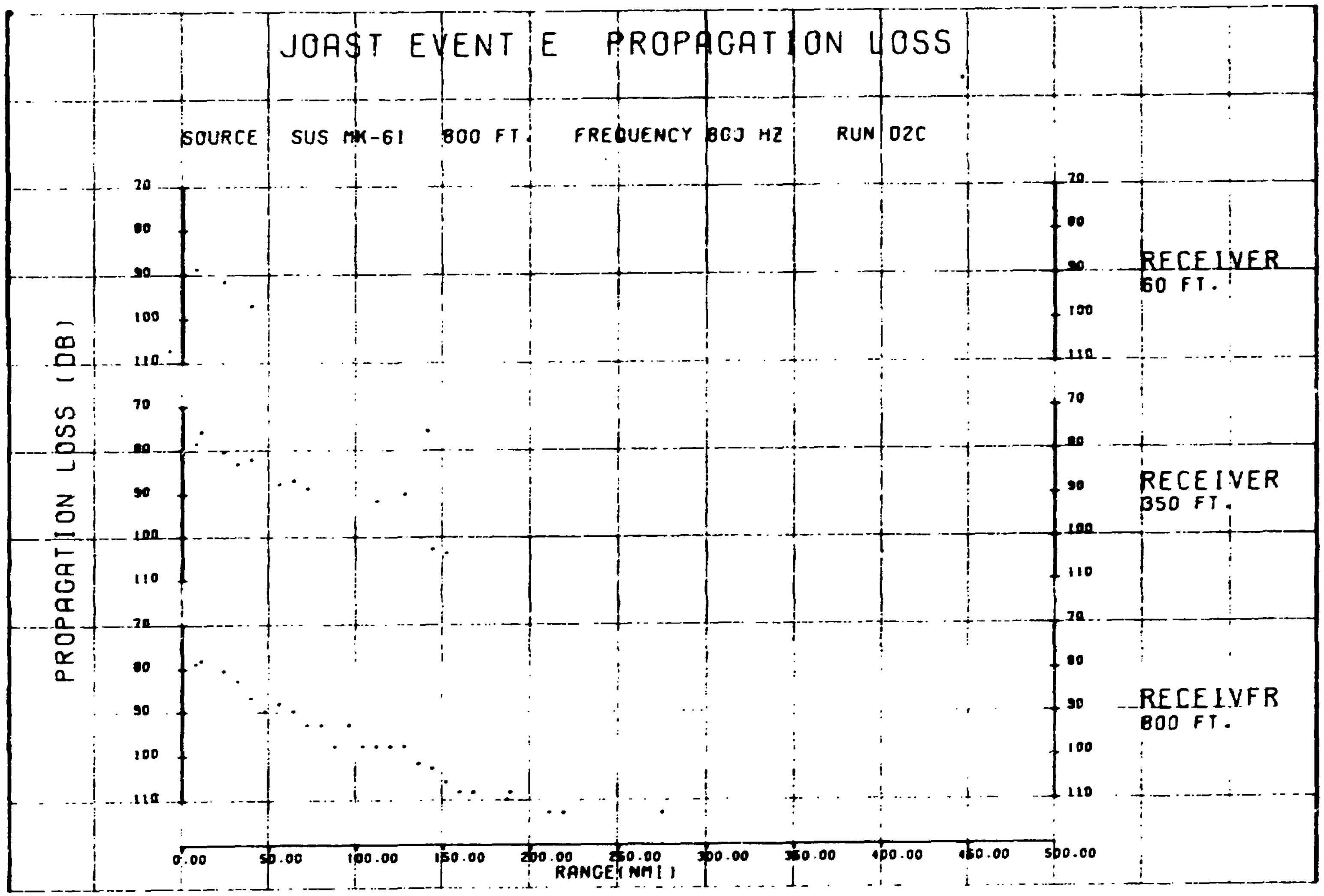

Fig. 4-17(U)Run D2C Measured Propagation Loss — 800 Hz

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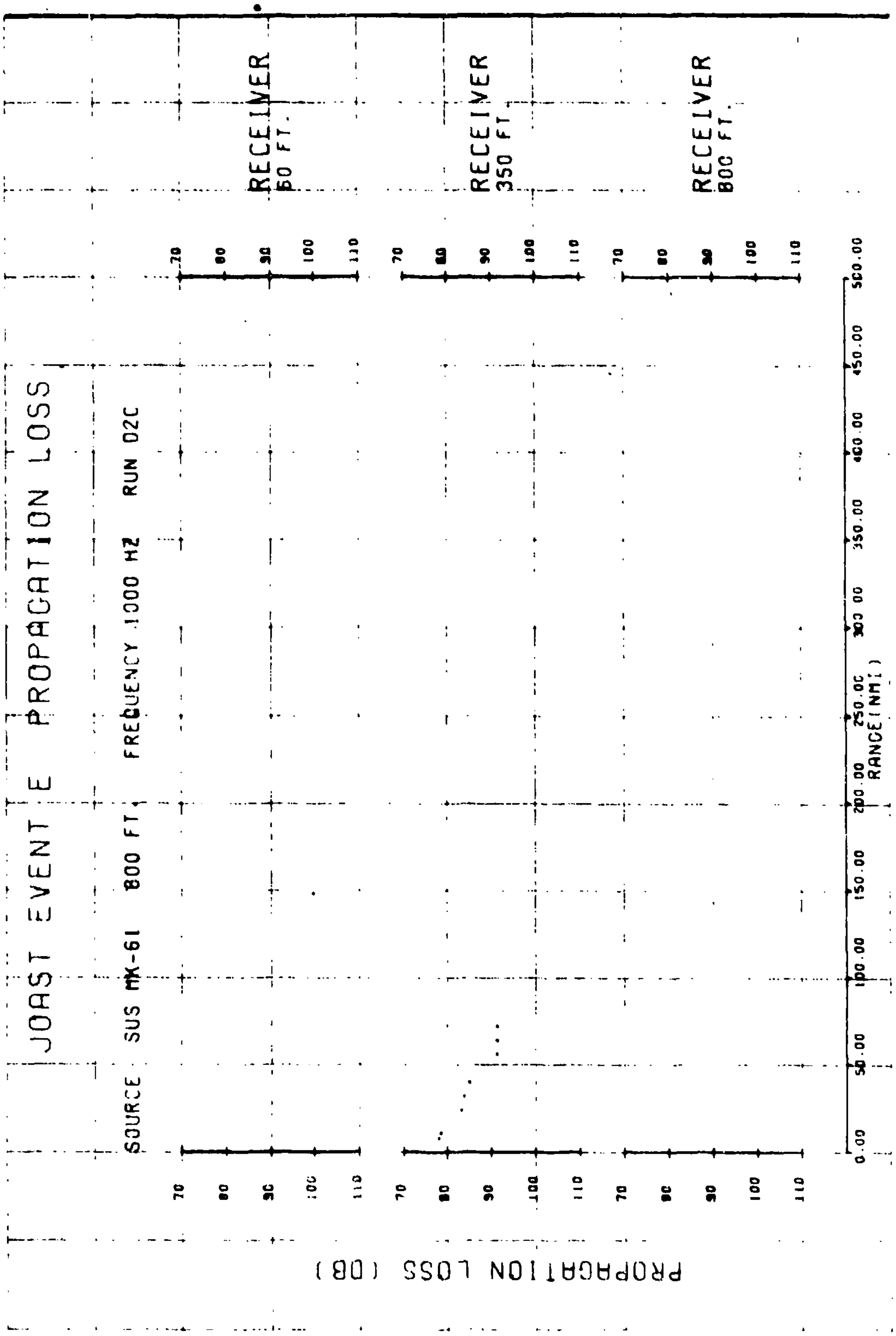

Fig. 4-18 (U)Run D2C Measured Propagation Loss — 1000 Hz

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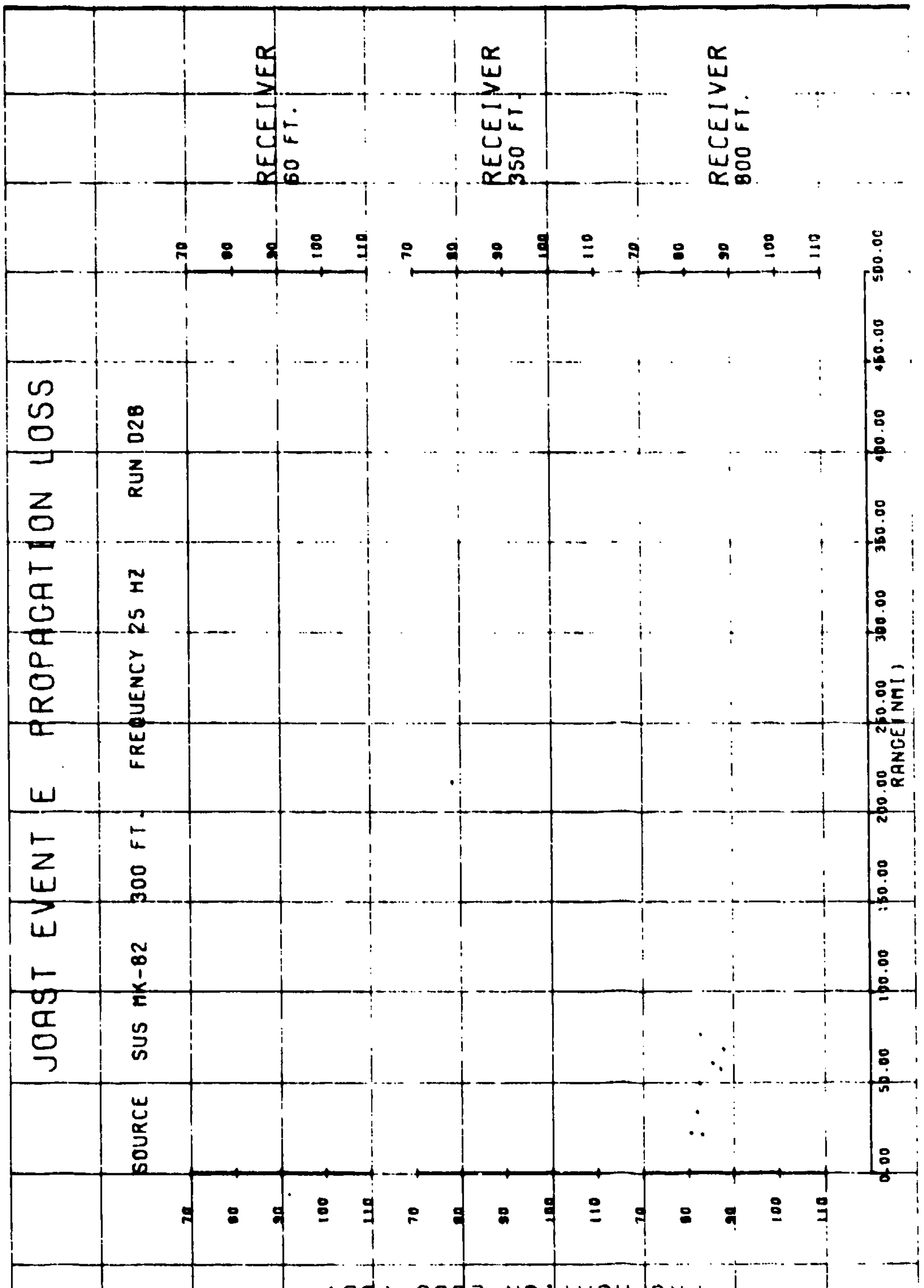

Fig. 4-19(U)Run D2B Measured Propagation Loss — 25 Hz

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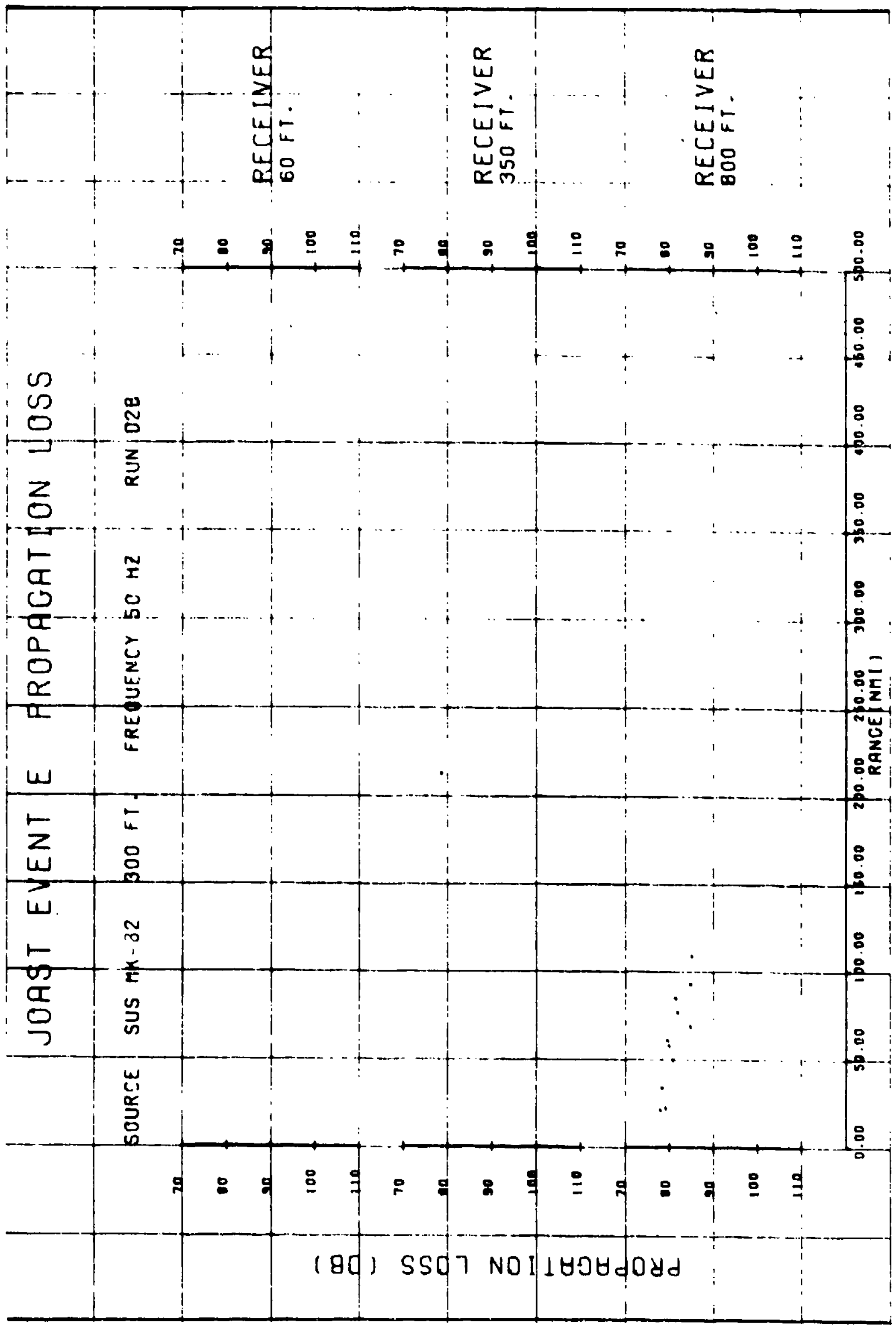

Fig. 4-20(U)Run D2B Measured Propagation Loss — 50 Hz

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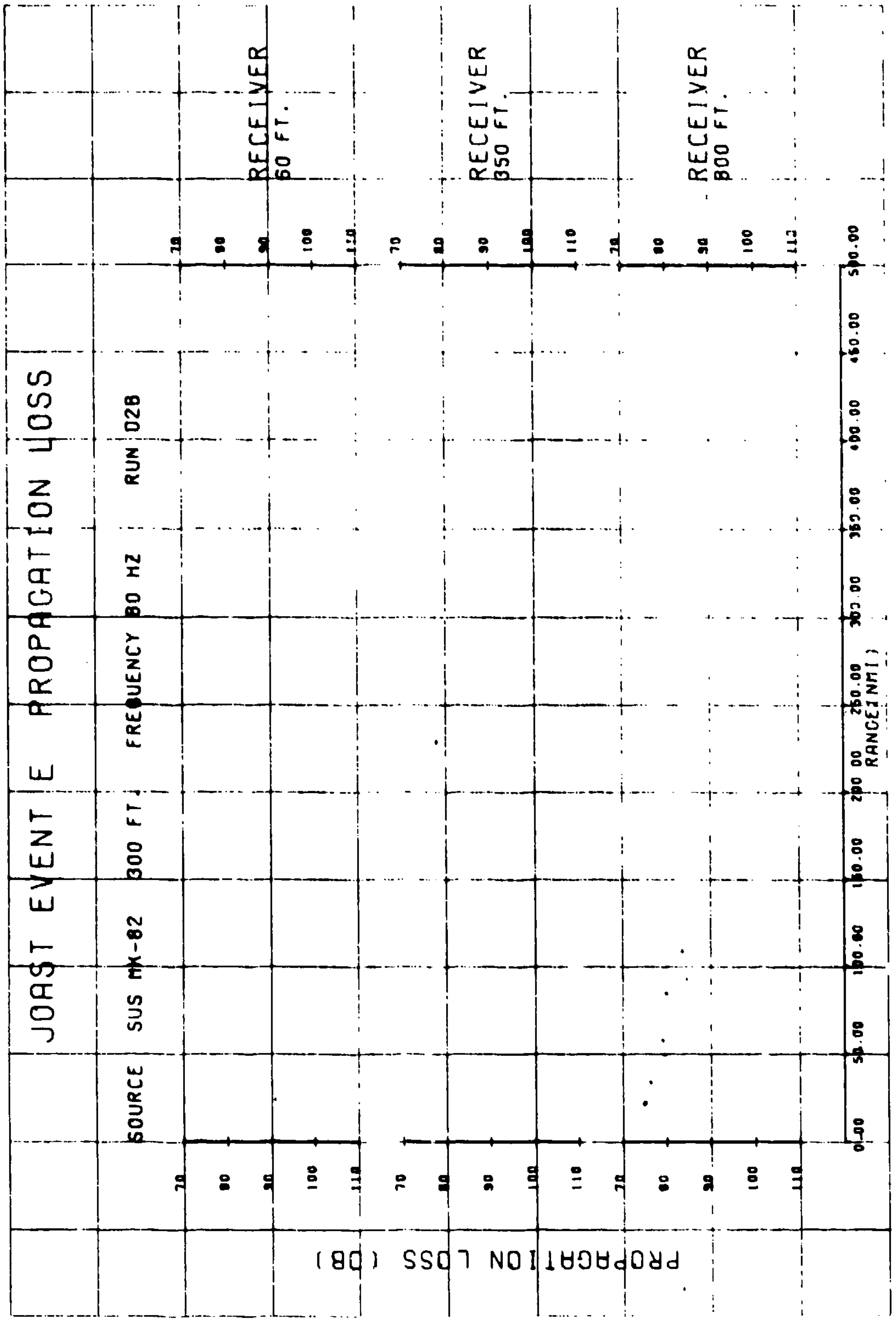

Fig. 4-21: (U) Run D2B Measured Propagation Loss — 80 Hz

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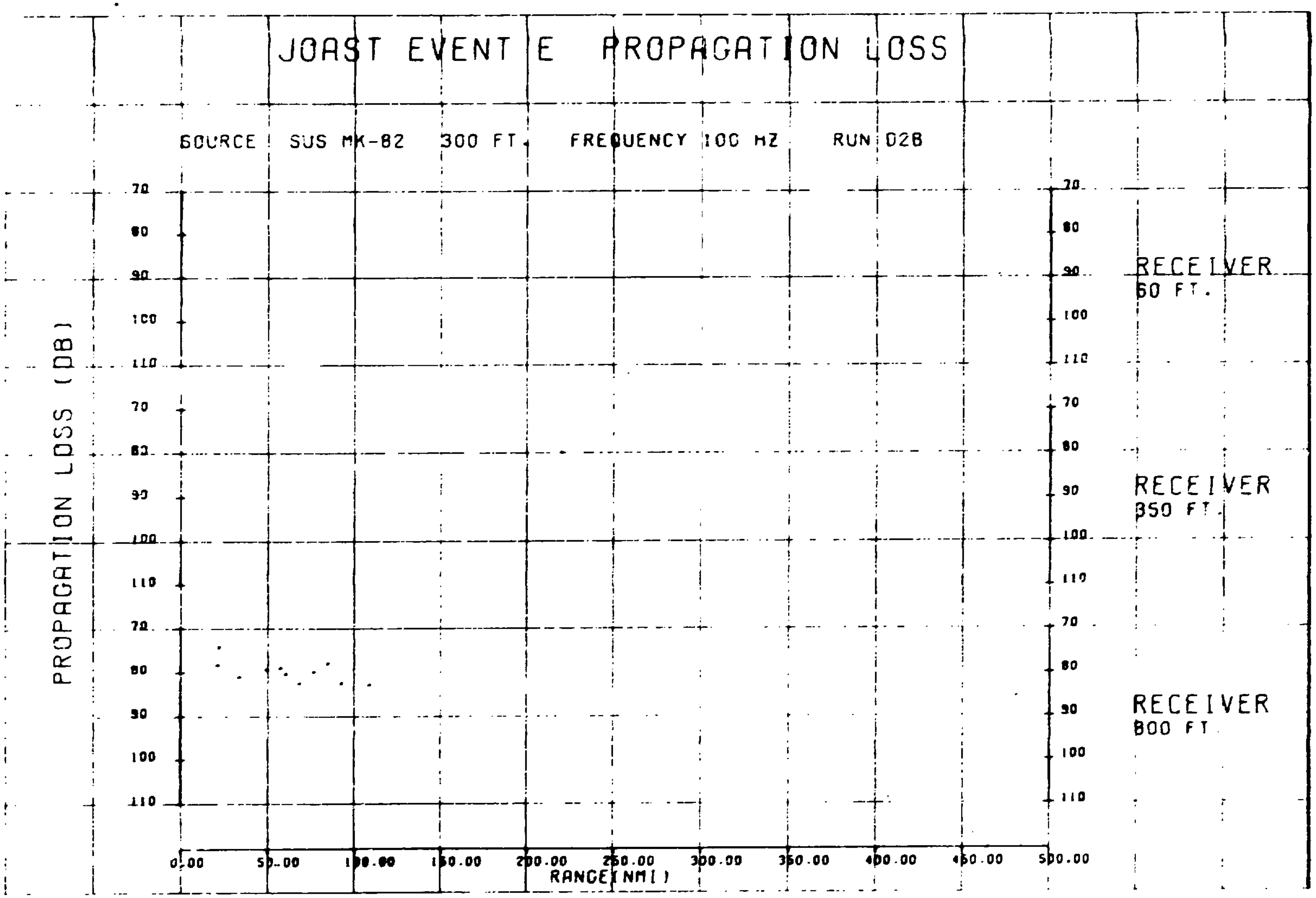

Fig. 4-22 (U)Run D2B Measured Propagation Loss — 100 Hz

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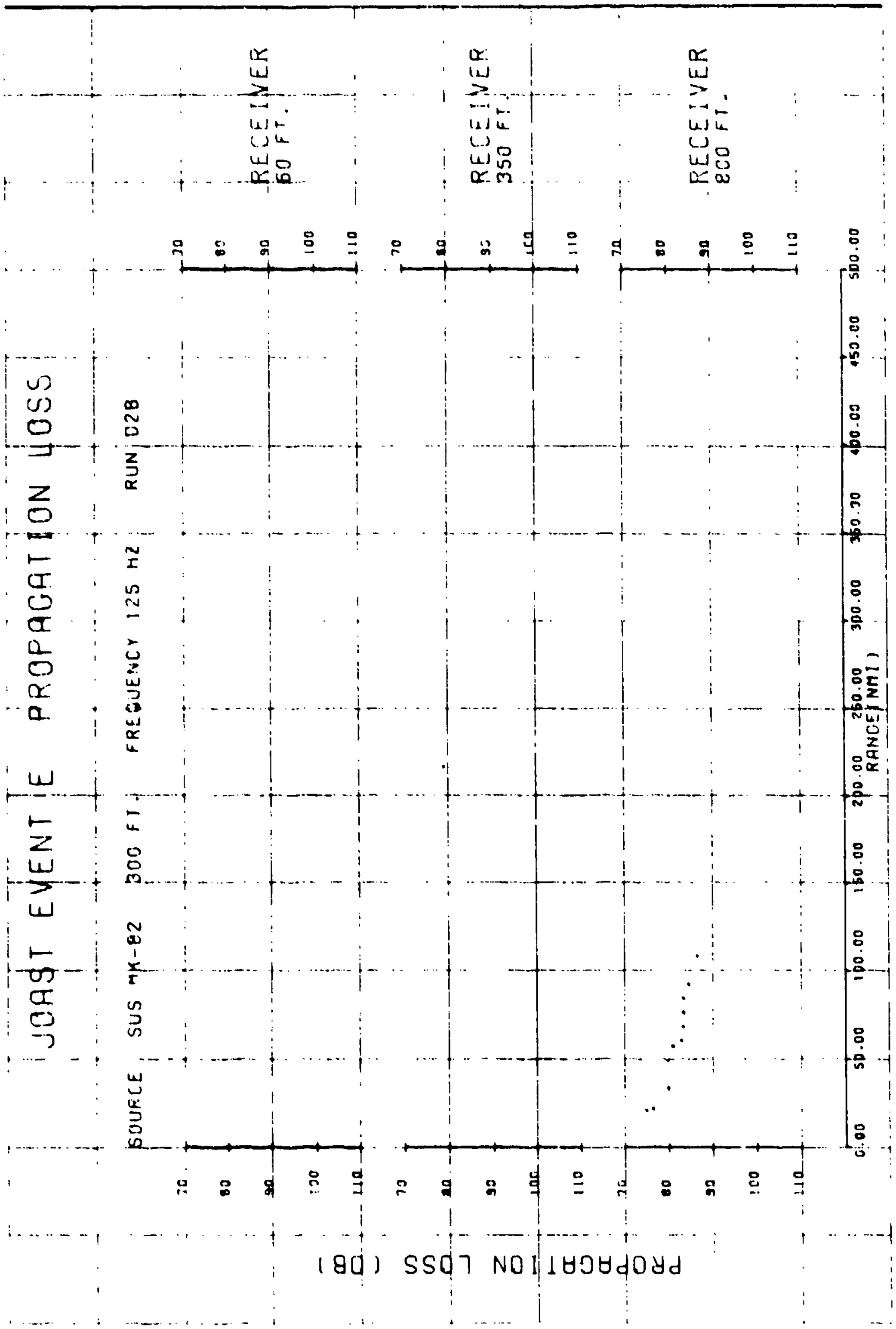

Fig. 4-23 (U)Run D2B Measured Propagation Loss — 125 Hz

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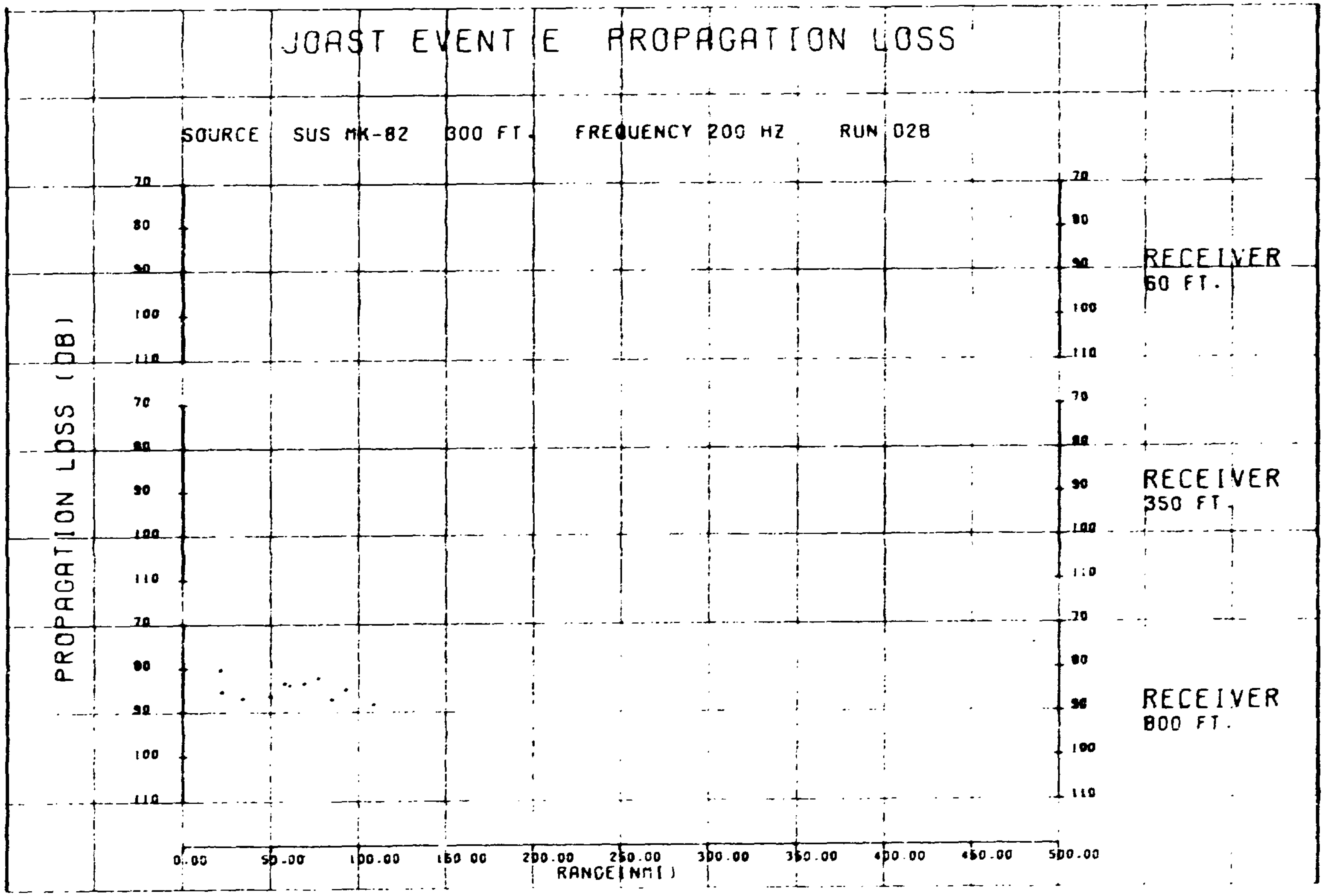

F'g. 4-24 (U)Run D2B Measured Propagation Loss — 200 Hz

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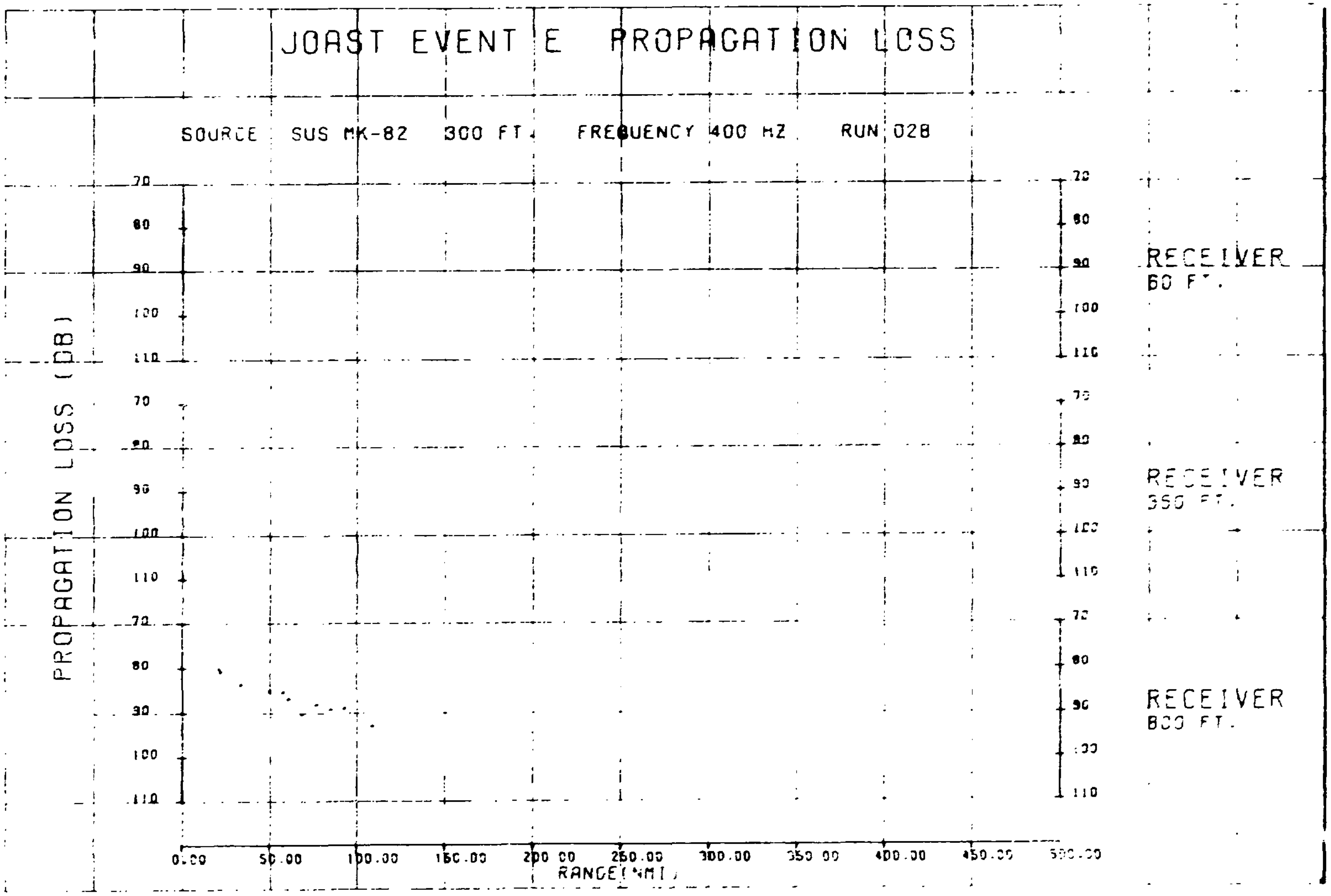

Fig. 4-25 (U)Run D2B Measured Propagation Loss — 400 Hz

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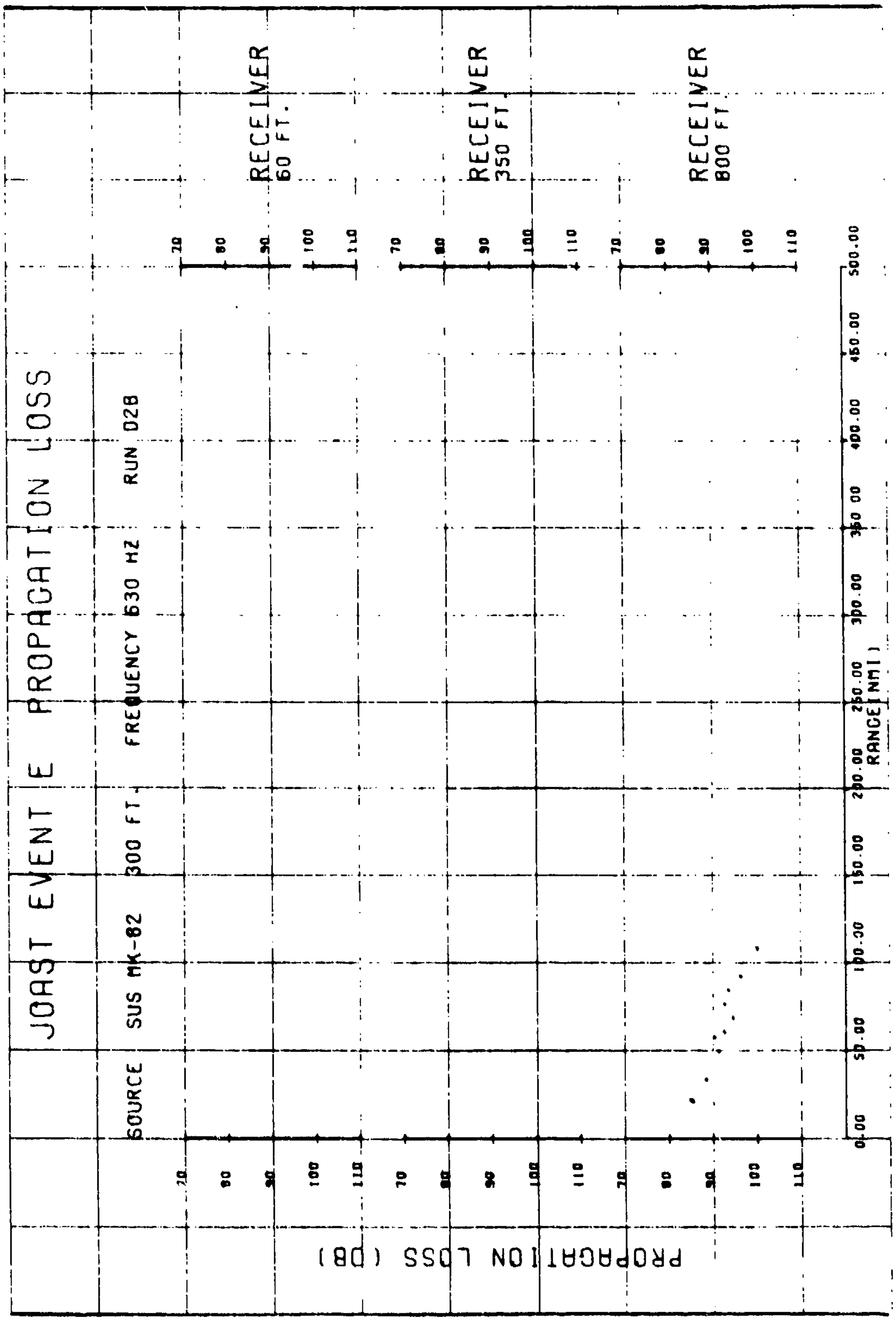

Fig. 4-26(U)Run D2B Measured Propagation Loss — 630 Hz

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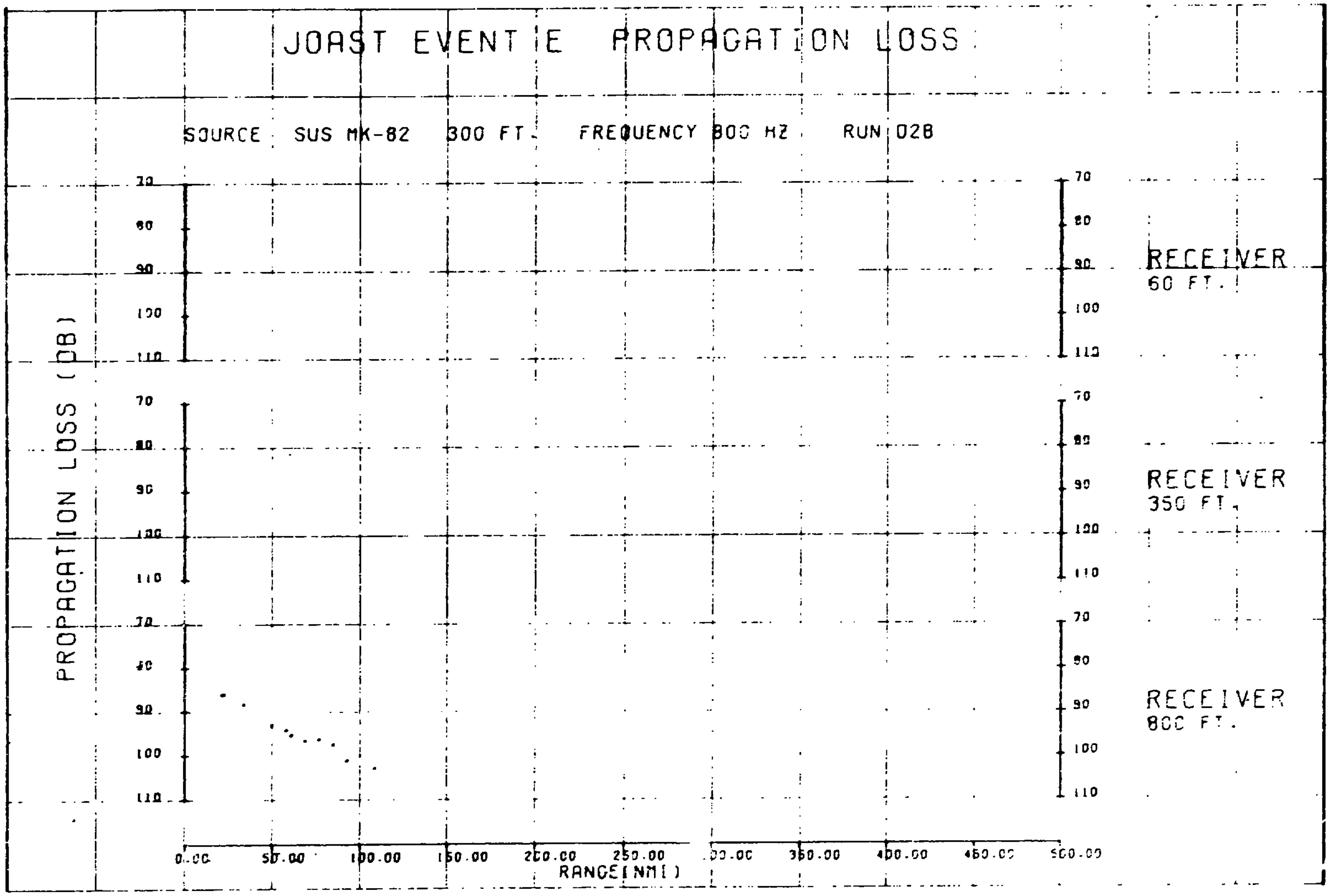

Fig. 4-27(U)Run D2B Measured Propagation Loss — 800 Hz

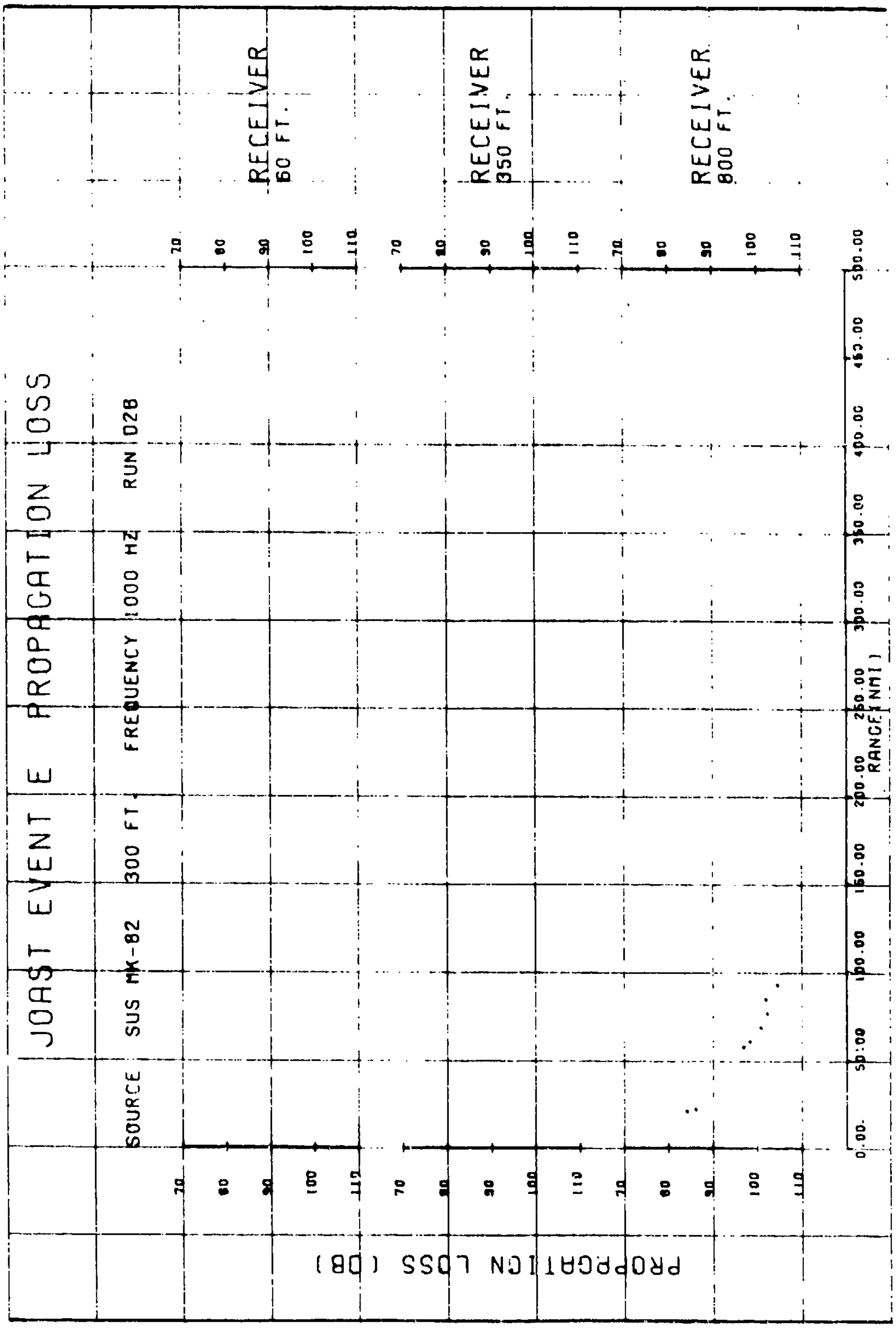

Fig. 4-28(U)Run D2B Measured Propagation Loss — 1000 Hz

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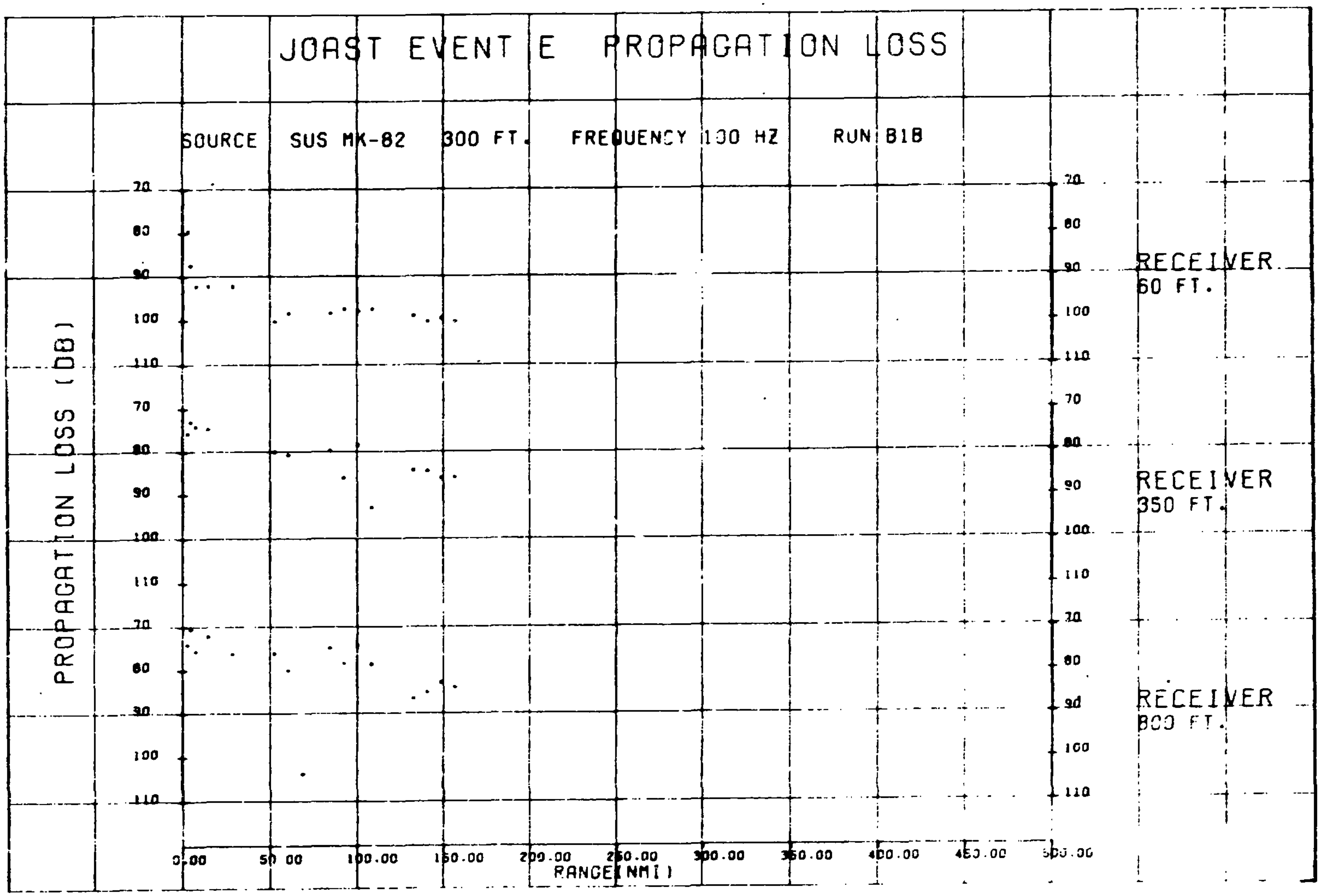

Fig. 4-29(U)Run B1B Measured Propagation Loss — 100 Hz

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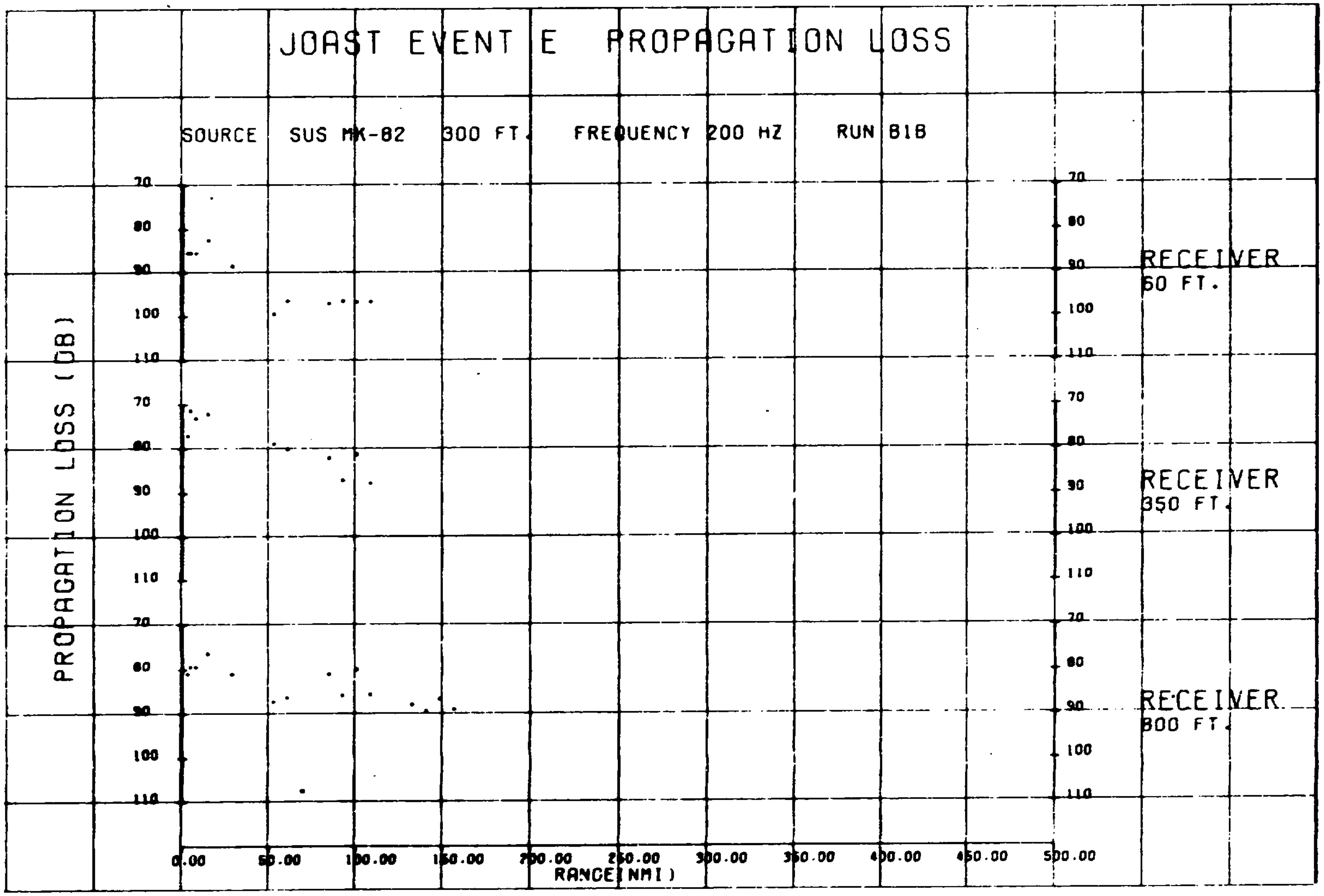

Fig. 4-30(U)Run B1B Measured Propagation Loss — 200 Hz

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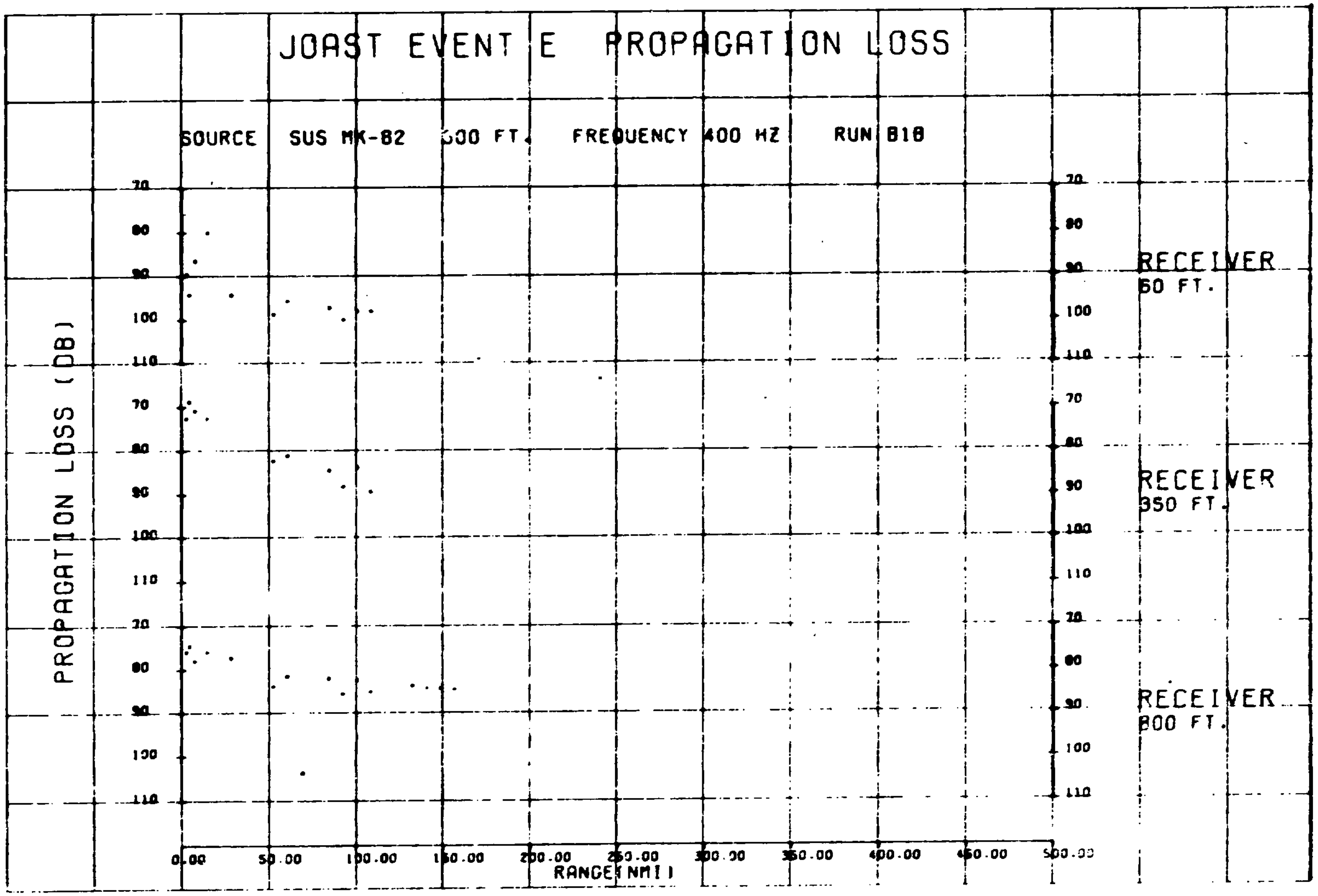

Fig. 4-31(U)Run B1B Measured Propagation Loss — 400 Hz

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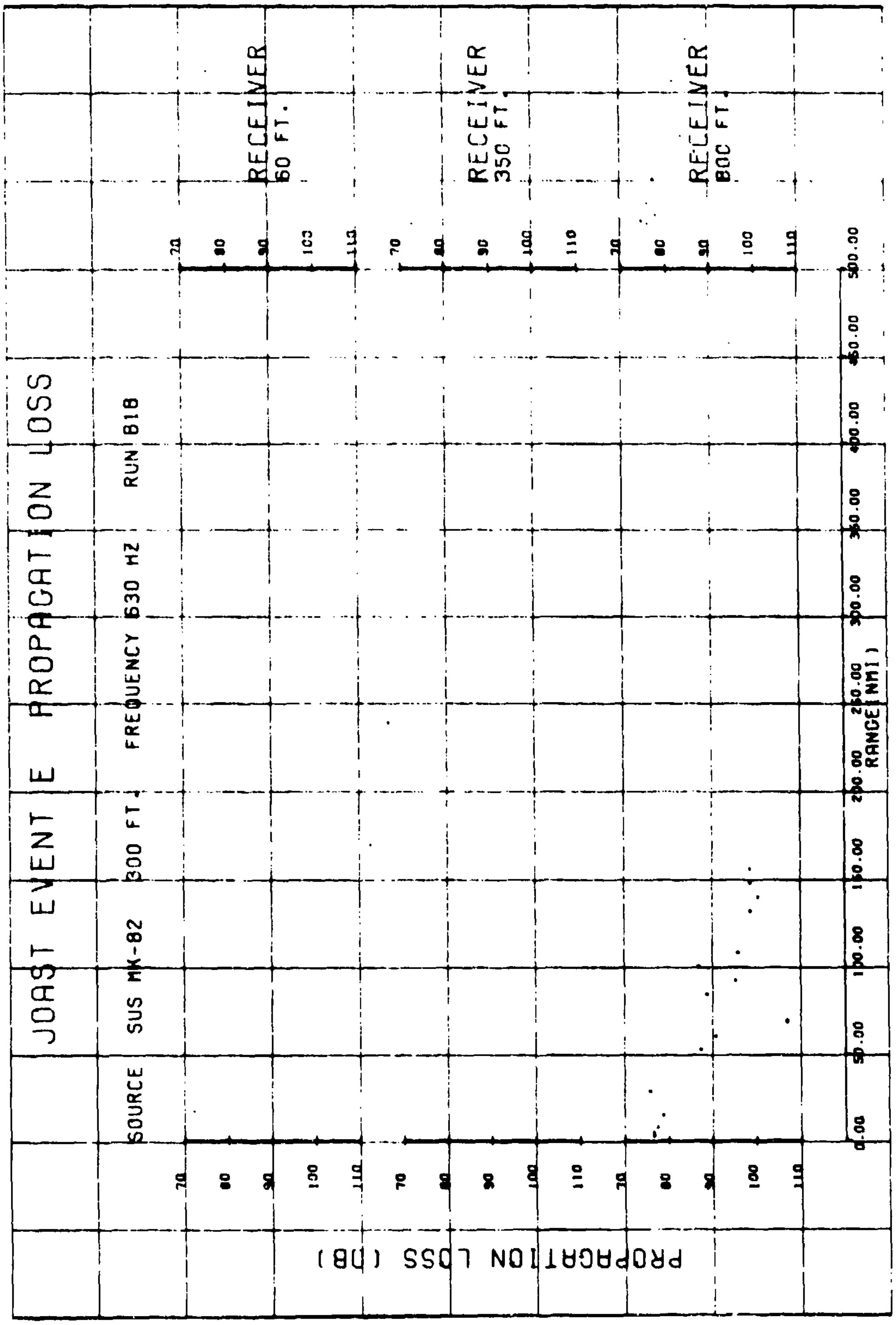

Fig. 4-32(U)Run B1B Measured Propagation Loss — 630 Hz

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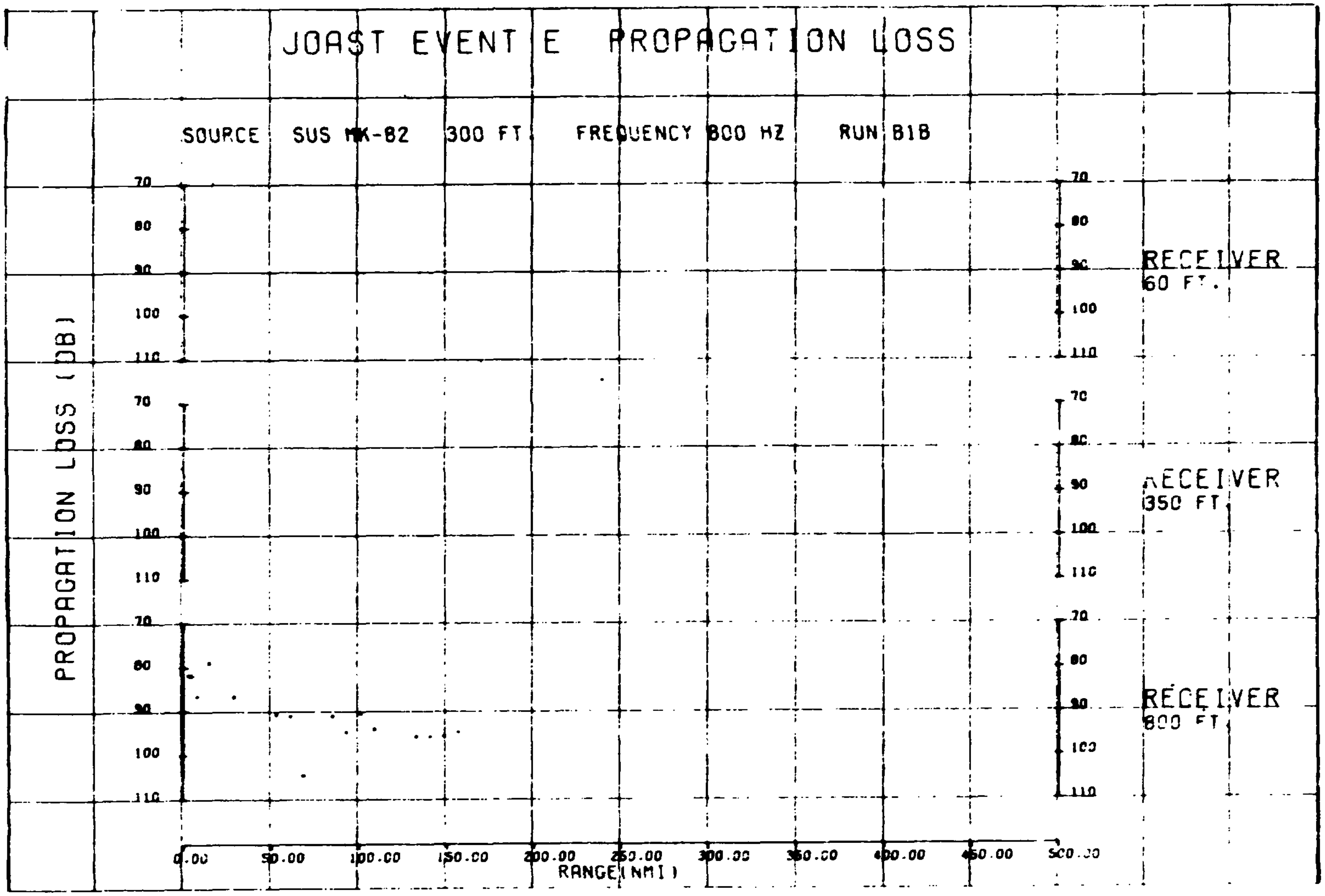

Fig. 4-33(U)Run B1B Measured Propagation Loss — 800 Hz

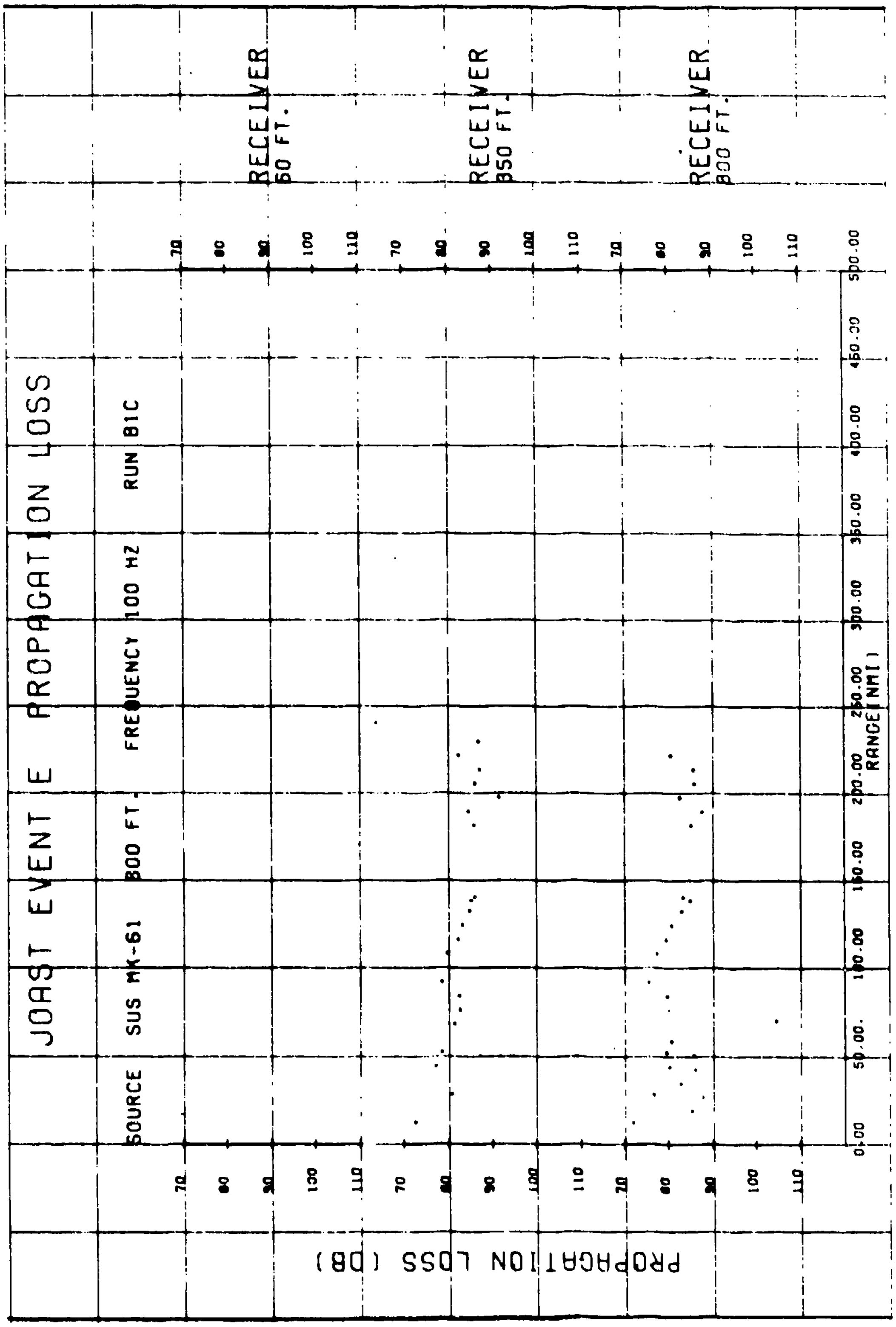

Fig. 4-34 (U)Run B1C Measured Propagation Loss — 100 Hz

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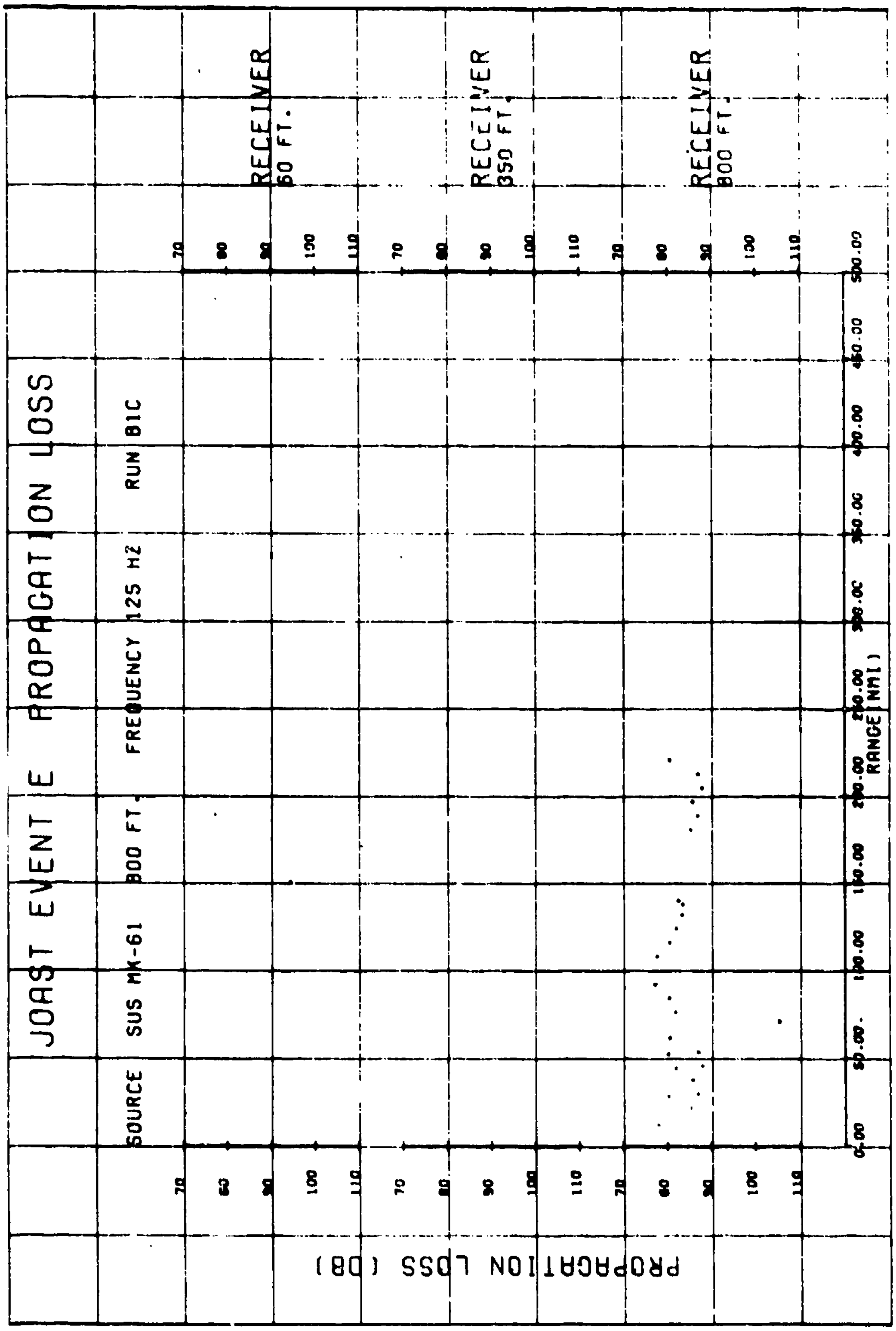

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Fig. 4-35 (U) Run B1C Measured Propagation Loss — 125 Hz

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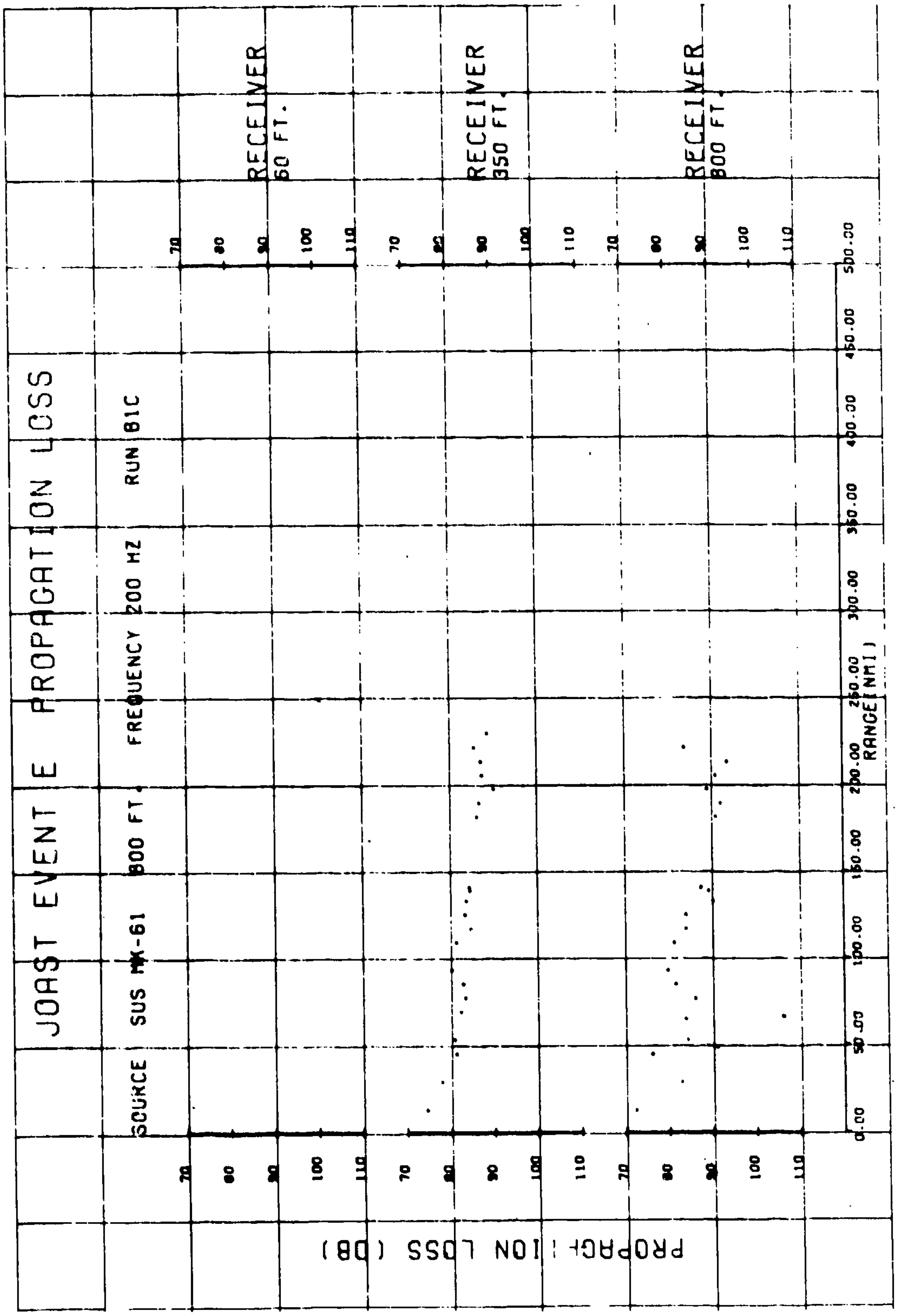

Fig. 4-36(U)Run B1C Measured Propagation Loss — 200 Hz

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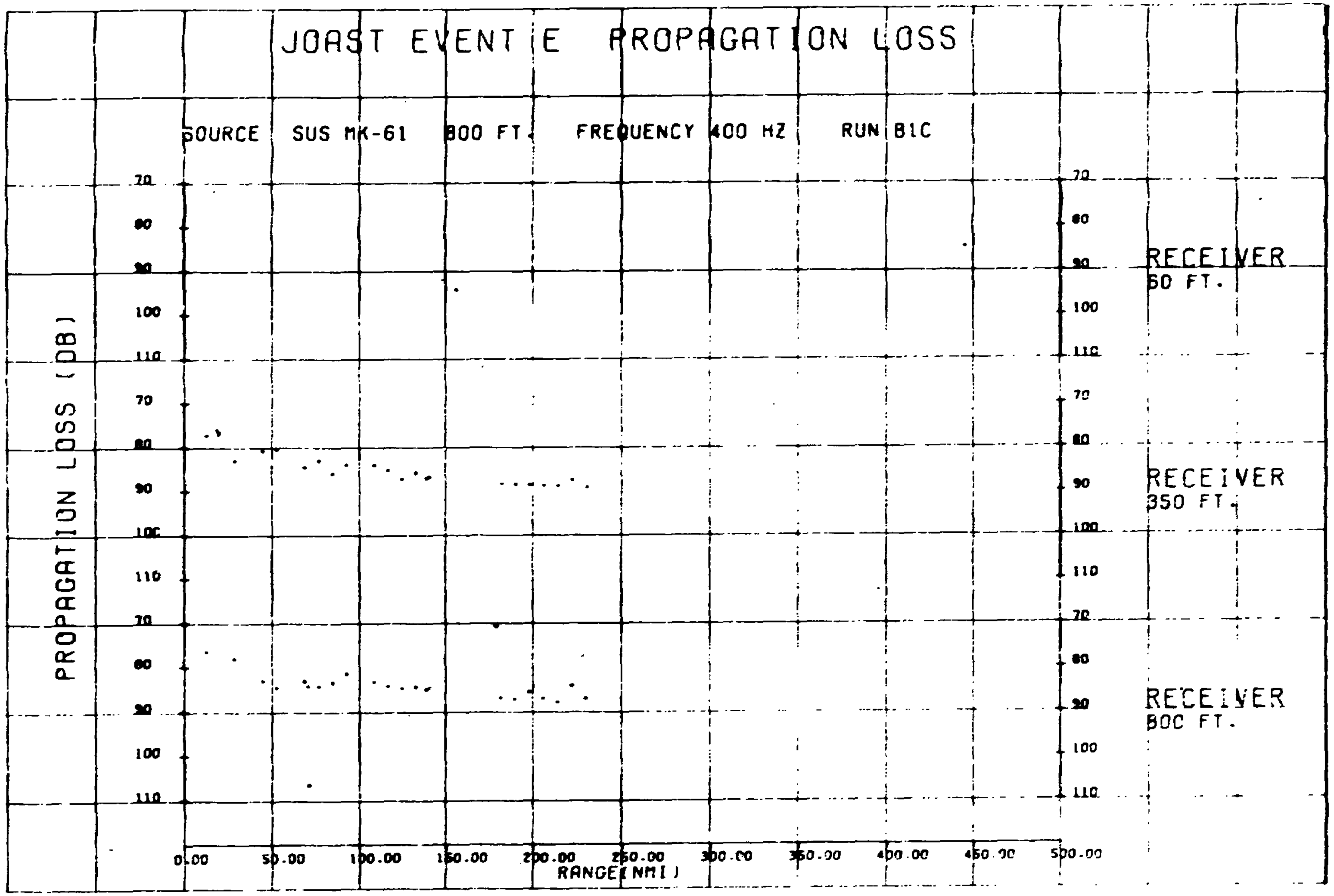

Fig. 4-37 (U) Run B1C Measured Propagation Loss — 400 Hz

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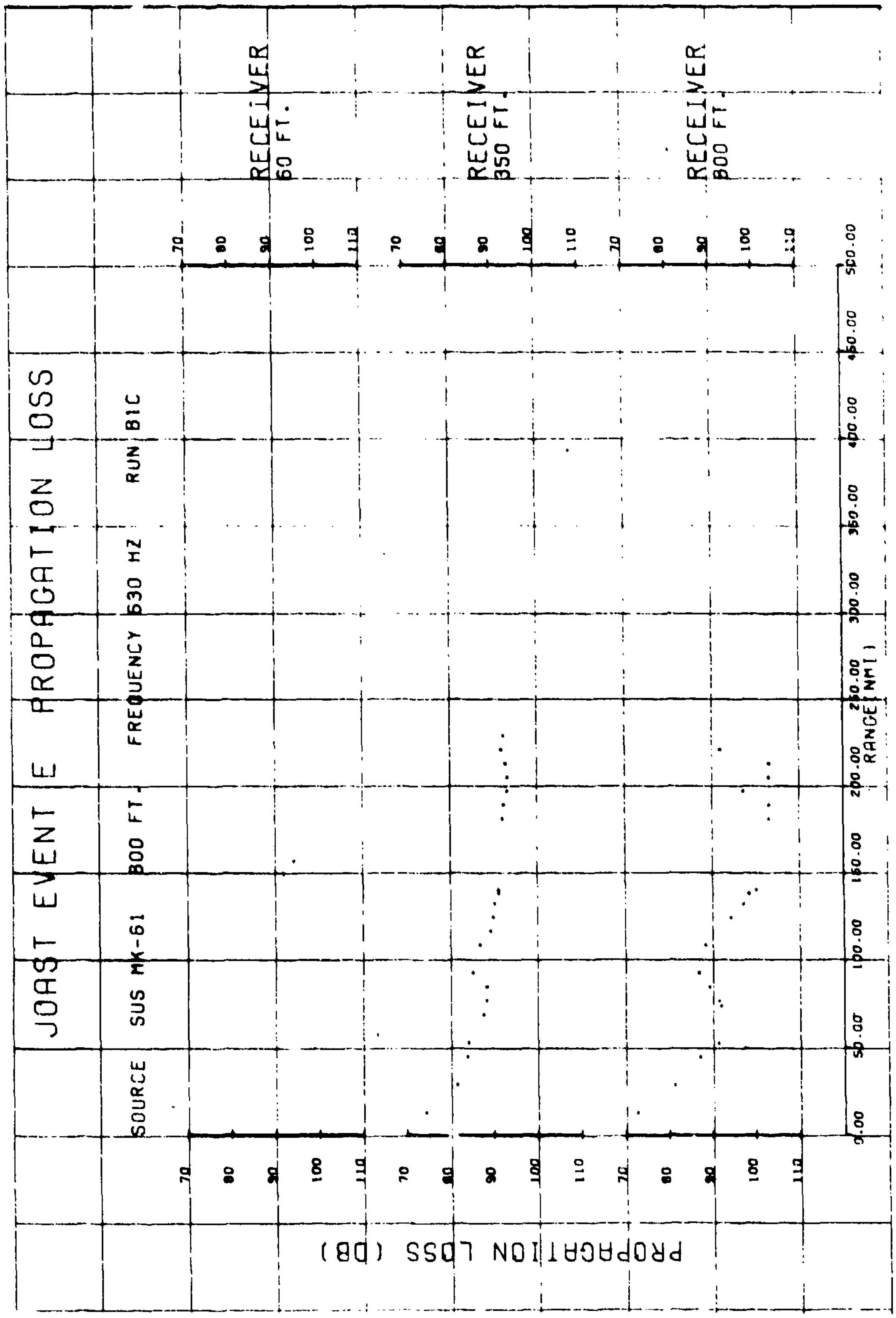

Fig. 4-38 (U) Run B1C Measured Propagation Loss — 630 Hz

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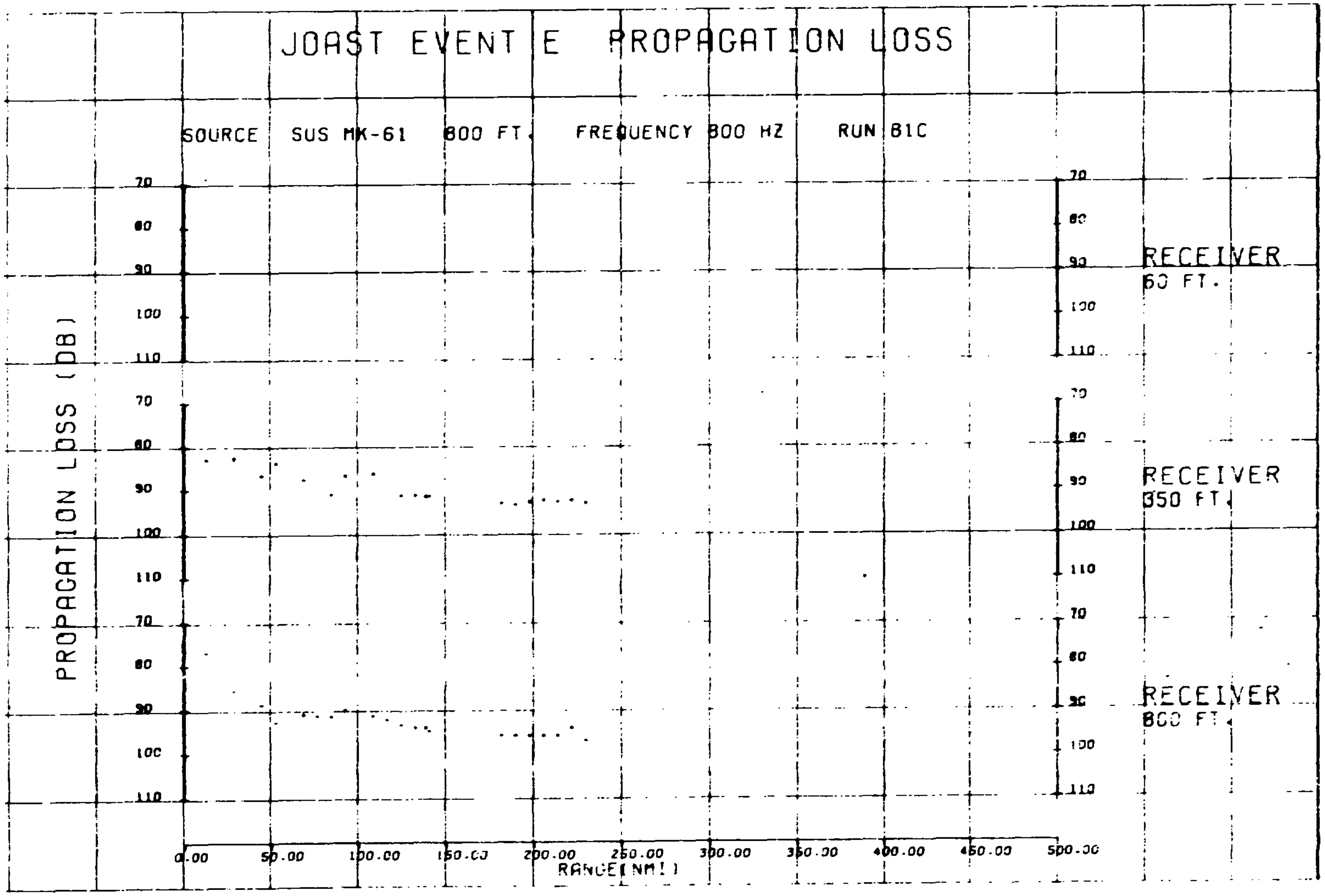

Fig. 4-39 (U) Run B1C Measured Propagation Loss — 800 Hz

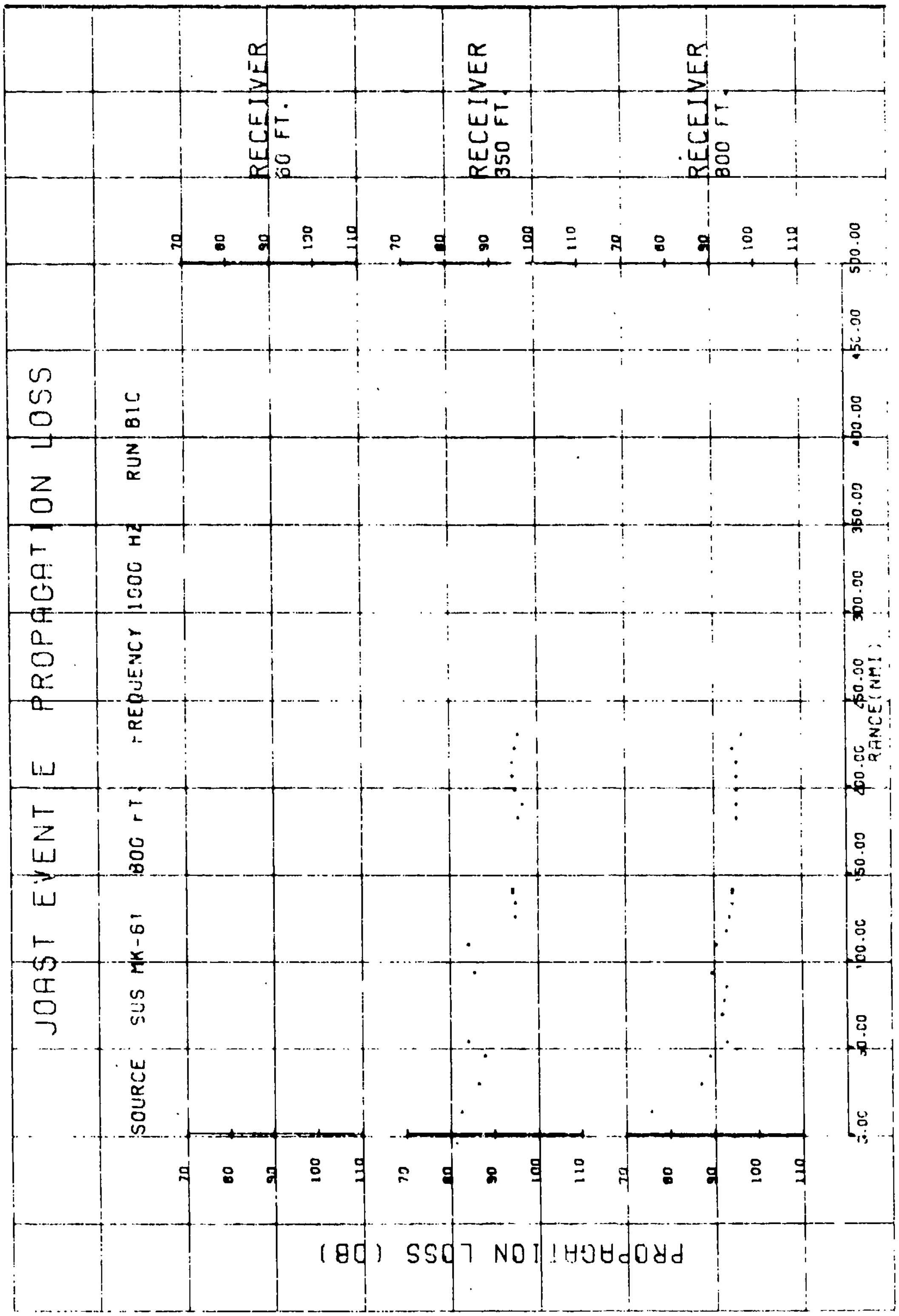

Fig. 4-40(U)Run B1C Measured Propagation Loss — 1000 Hz

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Appendix 12. (U) ATOE (Acoustic Transmission and Oceanographic Experiment)

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Appendix 12

Acoustic Transmission and Oceanographic Experiment (ATOE)(U)

Summarized by Frederick C. Friedel

(U) In January and February of 1971, long-range underwater acoustic propagation loss measurements were made between Bermuda and the Mid-Atlantic Ridge. The USNS SANDS (T-AGOR-6) served as the source ship detonating explosive sound signals at several depths between the near surface and the deep sound channel axis. These signals were received by five rather widely separated hydrophones situated at various depths in the vicinity of Bermuda and were recorded on magnetic tape at the Naval Underwater System Center's Tudor Hill Laboratory. The results of this experiment provide the basis for the study of comparative propagation loss on a seasonal basis and also will be used in the development of long-range acoustic propagation prediction models for the area.

(U) In addition to the standard meteorological data, supporting environmental information was obtained along the track by SANDS in the form of sound velocity profiles, bathythermograms, and depth recordings. Information on these measurements including the propagation loss data sets are in "Low-Frequency Propagation Loss Measurements of the Acoustic Transmission and Oceanographic Experiment (ATOE) in the Atlantic Ocean East of Bermuda (U)," NUSC Technical Report 4473. The data sets in this report were not entered in NAVDAB. However, the processed digital data tapes were sent for storage at the Federal Record Center, GSA: Waltham, Massachusetts 02154.

(U) Ninety-nine propagation loss curves as a function of range, source depth, receivers, and frequency are available in the report. Of these, the data sets for the source depth at 4,000 ft (1,219.5 m) and receivers at 4,150 ft (1,265.2 m) and 4,650 ft (1,417.6 m) in the range 25 nmi to 400 nmi appear to be able to be modeled by the simplistic requirements (single velocity profile and flat bottom) for the FACT and RAYMODE X models (see Table 6-1). This is based on the premise that since the source and receivers are close to the depressed sound channel axis, the major portion of the sound transmission will be contained near the axis and energy traveling at the extremes of the channel will not be significant.

6.1 (U) THE ATOE EXPERIMENT DESCRIPTION

6.1.1 (U) Source Ship

(U) The source ship, USNS SANDS, proceeded from point Alpha (Figure 6-1) in the neighborhood of a broadband hydrophone array on an easterly great circle route to point Bravo (B) (about 925 nmi distant). SANDS then steamed due south to point Charlie (C) in order to avoid local topographical features which practically eliminated sound reception. From point Charlie, the SANDS again proceeded on an easterly course to point Delta (D) in the mid Atlantic ridge at a range of 1,440 nmi. Bottom topography along the track (recorded every 2.5 nmi) as measured by SANDS fathometer (corrected for sound speed and fathometer depth) is in Figure 6-2. In conducting the experiment the SANDS advanced at 10 knots and detonated explosives on the following hourly schedule: A 3 lb TNT block set for 500 ft (152 m) was detonated every 10 minutes, followed by a similar charge two minutes later set for 60 ft (18.3 m). At the 15 and 45 minute mark, a 4 lb Mk 22-1 SUS charge set for 2,000 ft (609 m) was dropped and at the 25 and 55 minute marks, the SUS charges set for 4,000 ft (1,200 m) were dropped. Here we are concerned with source depth at 4,000 ft (1,220 m), so that the range spacing for the shots is nominally 5 nmi. Thermal measurements of the water column to 2,500 ft (762 m) were taken every four hours along the track. On the return from Point Delta to Bermuda, sound velocity profiles and 6000 ft (1829 m) bathythermograms were obtained each day. These velocity profiles and location of the measurements are shown in Figure 6-3.

(U) Table 6-1. ATOE Parameter Depressed Sound Channel surement

Layer Depth (m)	Depress Channel Axis (m)	Channel Depth (m)	Bottom Depth (m)	Source Depth (m)	Recvr. Depth (m)	Frequencies (kHZ)	Min Range (nmi)	Max Range (nmi)
150	1205	3658	4939*	1220	1265, 1417	.025,.05,.1, .2,.4,.8,1.6	25	400

Navigation - Satellite navigation employed with interpolated dead reckoning checked against travel time. ... accuracy ± 1 nm

Environmental Data: SVP's are summarized in report. XBT's collected every four hours but not reported.

Location of Data: Federal Record Center GSA Waltham, MA 02154. Box #4 ATOE 1-11, Box #5 ATOE 12-17.

*Averaged Value min 4390, max 5487. Since the source is omnidirectional and the received signal is integrated over all paths, bottom effects are initially effective in range. (See also, factors which may effect model comparison.)

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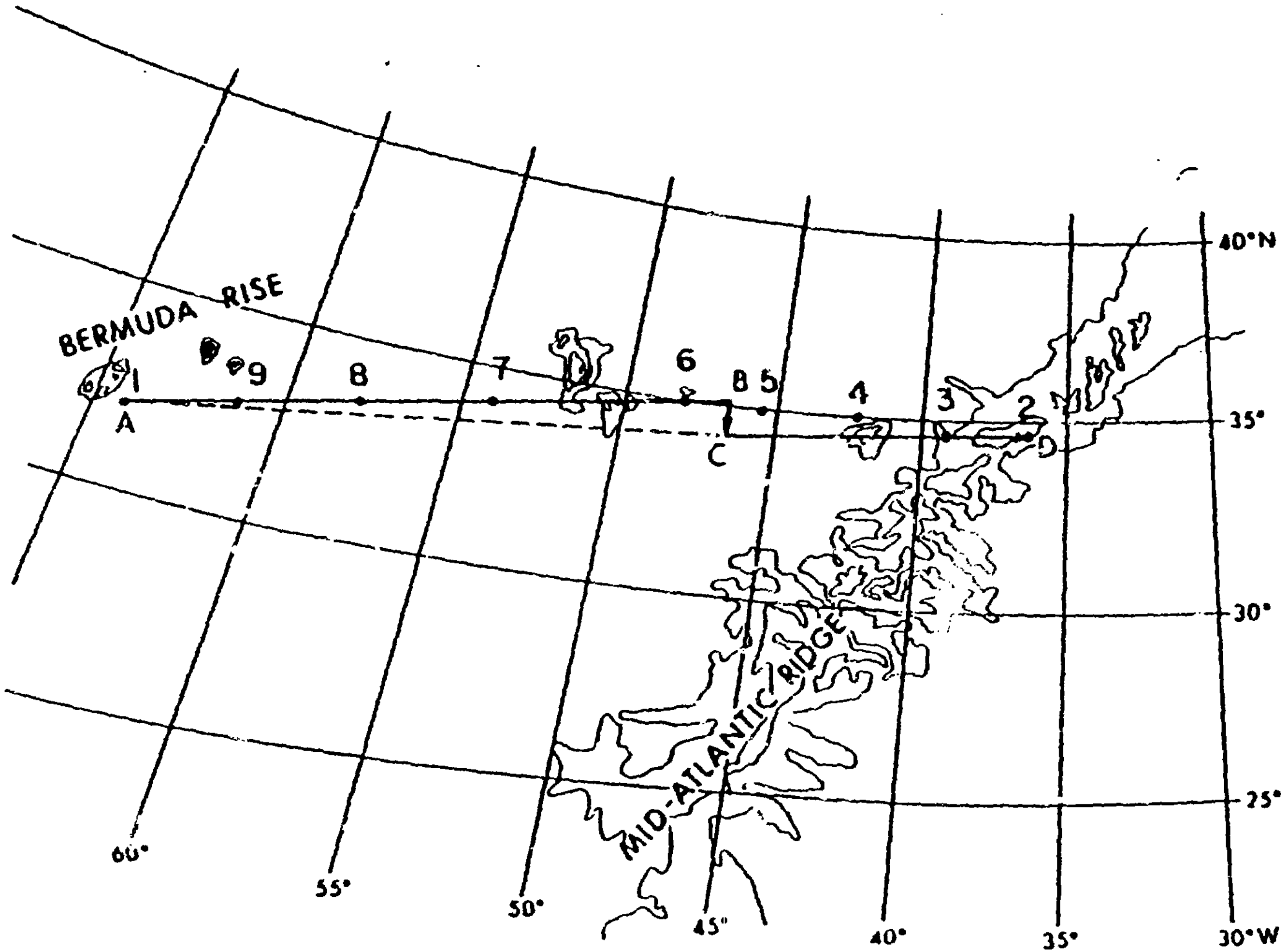

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(U) Fig. 6-1. Geographical Location of ATOE Propagation Measurements

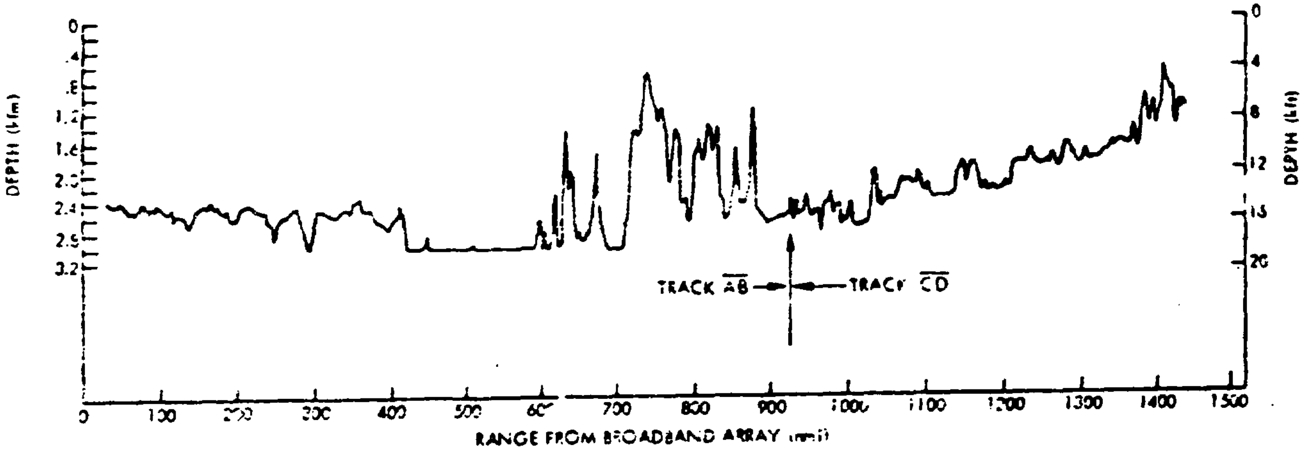
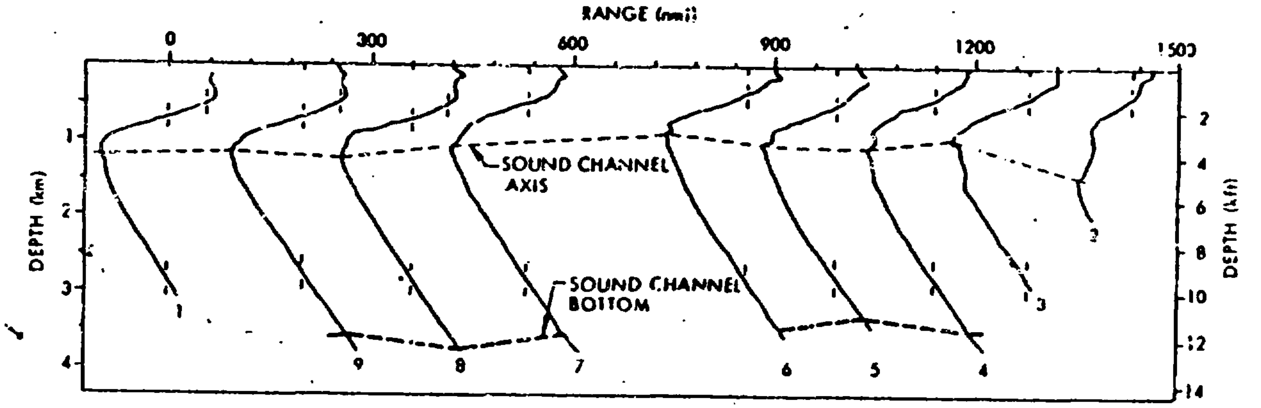
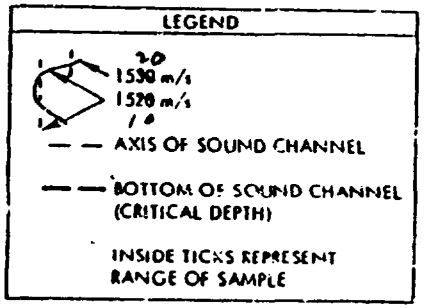


Fig 6-2 (U) Bottom Topography Along ATOE Measurement Track



CAST NO.	DATE 1971	TIME (ZULU)	LOCATION		RANGE (nmi)	WATER DEPTH (m)
			NORTH	WEST		
1	27 JAN	1330	32° 04.3'	64° 48.0'	5	3475
9	10 FEB	0030	32° 52.2'	60° 57.4'	201	5040
8	9 FEB	0100	33° 36.6'	57° 50.6'	364	4850
7	8 FEB	0130	34° 06.8'	54° 33.3'	530	5840
6	6 FEB	0820	34° 57.0'	46° 00.3'	858	4350
5	5 FEB	1200	34° 58.8'	45° 20.2'	988	4900
4	4 FEB	1530	35° 00.3'	42° 19.4'	1136	4540
3	3 FEB	1900	34° 48.8'	39° 17.4'	1285	3400
2	3 FEB	0030	34° 39.5'	36° 20.2'	1431	2170



(U) Fig. 6-3. Variation of Deep Sound Channel Axis Depth Along Test Track

(U) The primary navigational control for the operation was provided by a satellite navigator with an Omega system as back up.

6.1.2 (U) The Receiving Station

(U) The explosive signals were received on hydrophones associated with the arrays as located in Figure 6-4. In addition, hydrophones of an Easy II array not shown in the figure were used. The hydrophone depths and their relation to the bottom are depicted in Figure 6-5. For the array of concern here (broadband) two hydrophones located at 4,150 ft (1,265 m) (upper) and 4,650 ft (1,418 m) (lower) depths were used. The output of the hydrophones are cabled ashore to the NUSC Tudor Hill Laboratory where each hydrophone was assigned a high and low gain channel and then the unfiltered signals were recorded on 14-channel magnetic tape. IRIG-B time code and voice were also recorded. Calibration signals relating voltage output to a reference sound pressure of 1μPa @ 1 yd versus frequency (25, 50, 100, 200, 400, 800, 1600 and 3200 Hz) were periodically injected at the hydrophone terminals to calibrate the receiving amplifiers and tape recorder.

6.2 (U) DATA ACQUISITION AND PROCESSING

6.2.1 (U) Data Processing System

(U) To determine the propagation loss, wide band recorded signals from the hydrophones were reproduced and fed to 1/3 octave band filters with a geometric mean frequency (GMF) of 25, 50, 100, 200, and 400 Hz. In addition, the broadband upper hydrophone signal was processed through 1/3 octave band filters with a GMF of 800, 1600, and 3200 Hz. The filter outputs were then envelope detected and fed to a multiverter where they were serially sampled, multiplexed, and converted from analog values to 12-bit digital words.

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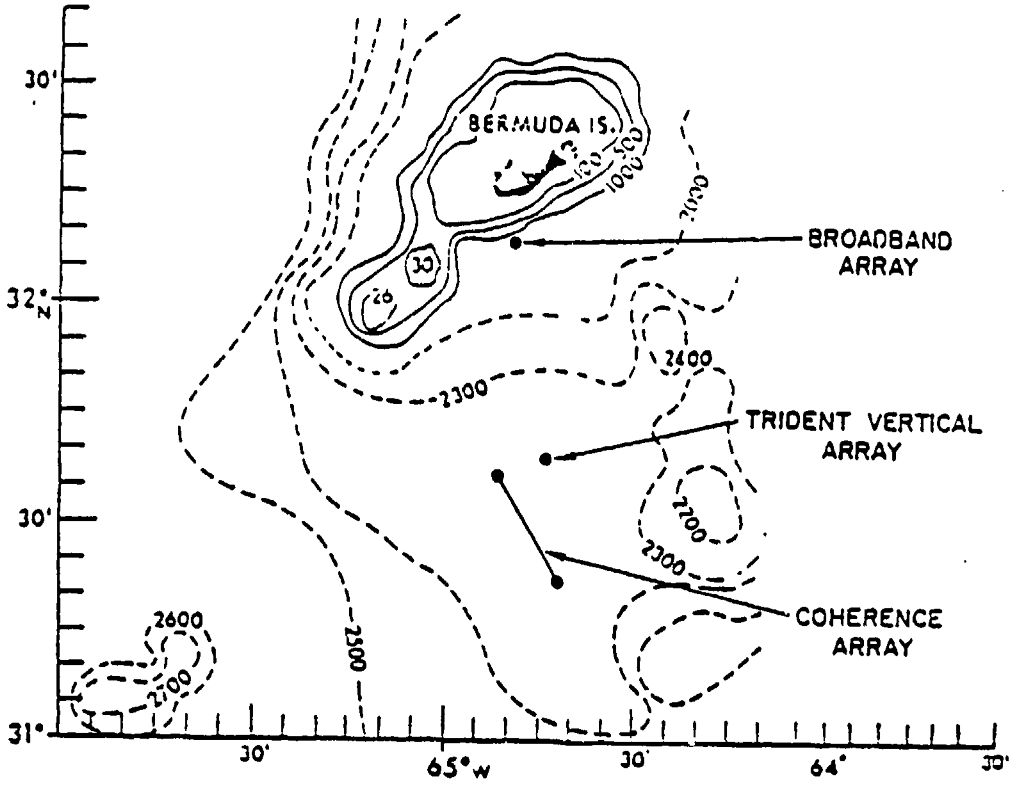
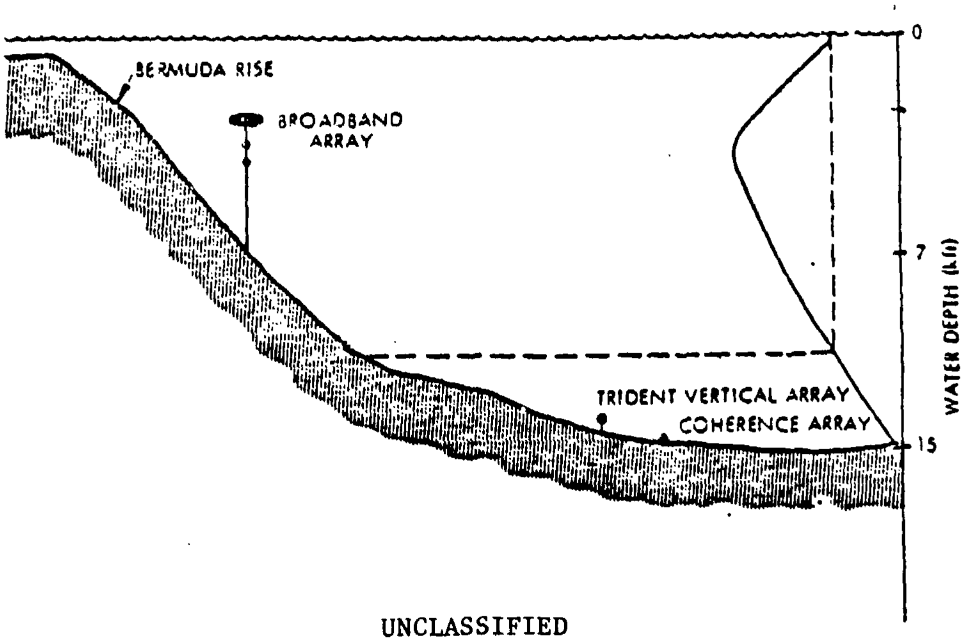


(U) Fig. 6-4. Hydrophone Array Locations for ATOE Measurements



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(U) Fig. 6-5. Hydrophone Depths

A Univac 1230 computer program utilized the digital samples to compute the acoustic background noise level, and received signal level, signal-to-noise ratio, and propagation loss (source level - received level). (See Table 6-2). The noise and received levels were based on estimates of the "energy" in the signal or an estimate of $\int^{T} p^2 dt$. No separation of path is made so that the contribution of all arrivals is measured. In order to ensure the proper alignment of the acquisition window with that of the received data a graphic recorder was used to monitor both the analog signal and the computer generated window. Overloaded signals were eliminated along with those contaminated by noise or otherwise unacceptable. Only those sets that resulted in a significant number of points were retained and presented in the report.

6.2.2 (U) Range Determination

(U) Great circle distances from the ship to each hydrophone were first calculated from all usable satellite fixes. From the recorded detonation instants and the range and times of successive satellite fixes, the range for each shot can be determined by interpolation. The range accuracy is not stated in the report, but for a high azimuth satellite reading, a navigational fix with an accuracy of 100 yards is possible. From the scientific data log maintained by SANDS, satellite navigational fixes were available every one to two hours and over 90% were at the azimuth angles between 15° and 80° required for high accuracy. In addition, course and speed of advance were logged every 15 minutes. Also, when radio communication with the receiving point existed, the travel time (receiving time minus the detonation time) was used with the average sound speed for the axis of the deep sound channel to calculate the range. All of these methods in combiantion should result in a high degree of accuracy for the range determination.

(U) Table 6-2. MK 22-1 Source Levels (1/3 Octave Band)
4000 ft Depth.

GMF	BAND LEVEL (dB//1μPa² @ 1 yd)*
25	200.8
50	210.1
100	220.2
200	223.7
400	221.5
800	219.1
1600	218.0
3200	215.5

*From unpublished work of L. C. Maple at NUSC.

For comparison the following source levels were computed from "Source Levels for Deep Underwater Explosion," Christian, Ermine A. JASA Vol. 42 No. 4, Oct 1967 p. 905-907.

25	200.9
50	208.5
100	219.0
200	222.5
400	220.5
800	217.6
1600	216.1
3200	213.5

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6.2.3 (U) Surface Conditions

(U) A summary of the daily sea state and wind conditions from the SANDS log is in Table 6-3. Here, only the data for Jan 27 and 28 is applicable. Only wind speed direction and barometric values are measured, all others are estimates of observations.

6.3 (U) PROPAGATION LOSS RESULTS

(U) The measured propagation loss determined on an energy basis is plotted against range, for the source depth of 4000 ft, receiver depths of 4,150 and 4,650 ft and frequency in Figures 6-6, through 6-15. The data set is plotted for the complete range of the experiment (about 1,420 nmi) but here we are interested in the first 400 nmi. Above this range the axis of the deep sound channel is seen to decrease in depth, and over 550 nmi the bottom contour is very jagged and penetrates the deep sound channel, resulting in range dependent propagation loss.

(U) The data set for broadband upper hydrophone (4,150 ft) is more complete and consistent than that for the lower hydrophone (4,650 ft) and should be used in model comparison. For the data set of the lower hydrophone a gap occurs from about 100 to 200 nmi as a result of a system failure. However, where the data sets for both hydrophones are comparable, the agreement on the average is very close, indicating almost the same results for both hydrophone depths.

6.4 (U) FACTORS THAT MAY INFLUENCE RESULTS

6.4.1 (U) Velocity Profiles

(U) The velocity profiles shown in Figure 6-3 were taken one to two weeks after the execution of the measurements. Since we are concerned only with the deep sound channel it is expected

(U) TABLE 6-[illegible]. Surface Conditions — From the Log of the USNS SANDS (T-AGOR-6)

Date (1971)	Sea		Wind		Swell		Barometer (inches of Hg) (Averages)
	Height (ft)	Direction (deg)	Speed (knots)	Direction (deg)	Height (ft)	Direction (deg)	
27 Jan	3-8	220-240	20-30	220-240	10-15	240-220	29.68 rising
28 Jan	8-12	260-220	40-18-26	260-220	25	260-220	29.8 rising
29 Jan	10-3	220-210-310	29-10	220-300	10-3	230-210-310	30.15 rising
30 Jan	4	310-000-120	14-4-15	310-000-120	10-20-10	310-260-300	30.35 rising
31 Jan	4-5	100-150-140	15-20-18	130-150-125	15-10	300	30.45 rising
1 Feb	5-3	140-90	18-15	140-090	10-6	300-120	30.50 steady
2 Feb	6-4	100-350-000	18-6-20	110-000	6-12	120-045	30.42 falling
3 Feb	4-0	300-230	20-8	000-030-325	12-8	045-000	30.18 falling
4 Feb	1-8-4	243-030	8-20-10-20	245-000-030	8-12	060-225-030	29.92 steady
5 Feb	5-12	030-060-000	20-25	030-060-060	12-25	315-015-000	29.95 steady
6 Feb	12-3	000-330-000	25-10	360-330-360	25-12	360-030-360	30.21 rising
7 Feb	3-1-4	000-210	10-6-15	360-210	12-6-12	000-030-270	30.38 rising
8 Feb	4-1-3	210-230-150	15-8-15	210-230-150	12-15-6	270-230	30.40 steady
9 Feb	3-6	180-160	15-22-20	150-180-160	6-12	230-190	30.35 falling

that the channel would remain essentially constant over this period. A representative velocity profile for modeling is listed in Table 6-4.

6.4.2 (U) Bottom Effects

(U) Referring to Figure 6-2, the bottom depth for the measurement for the range from about 25 nmi to 400 nmi is a minimum of 400 fathoms (732 m) below the deep sound channel bottom. A convergence zone mode of transmission would exist because of this excess depth, but its effects should be small in the sound channel at these ranges. The bottom is not ideally flat which is essential to the symplistic requirement of the models and the measured propagation loss will have some bottom effects. This results from the fact that the source is nondirectional so that bottom slopes increasing with range could direct energy into the sound channel towards the receiving point. Therefore, the closest agreement between the models and the measured propagation loss would be expected to be at the higher frequencies (400 Hz and above) where the bottom losses are sufficient to substantially reduce the bottom reflection contribution. Measured propagation values for the first 25 nmi are not available and therefore no comparison can be made with the models over this range. Within the first 25 nmi, the models should show contributions from the convergence zone mode and bottom reflections.

(U) At the hydrophone location, (Figure 6-5) the bottom depth is indicated as being about 7,000 ft (2,134 m) or 2,850 ft (869 m) below the broadband array upper hydrophone. The velocity profile 5 nmi along the measurement tract (east of the broadband array) indicates a bottom depth of 11,398 ft (3,475 m). With an average sound channel depth of about 12,135 ft (3,700 m) indicated from the velocity profiles, this channel depth is definitely bottom limited from the receiving point to about a range of 6 nmi (based on an average computed up slope of 8.3°). The

(U) Table 6-4. Sound Velocity (m/s) Vs Depth (m)
(From Cast 9, 10 Feb 1971, USNS SANDS)

DEPTH (m)	SOUND VELOCITY (m/sec)
0	1518.7
400	1521.0
700	1510.0
1000	1492.5
1200	1490.0
1500	1492.5
2800	1510.0
3500	1520.0
3800	1525.0

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channel energy will be reduced and the propagation loss increased. However, it is anticipated that the major energy flow will be confined to near the sound channel axis and probably less than 10% (1 dB) would be lost by reduction of the sound channel width. An additional possibility exists because of the Bermuda Rise with reference to the broadband array. The rise intercepts the hydrophone depth at an estimated distance of 19,500 ft (5,945 m) behind the hydrophone, (west) in line with the measurement tract. Referring to Figure 6-4, and the 1,000 fathom contour, the rise appears to intercept the hydrophone depth on the north at less than half the west distance. At frequencies where bottom loss is low, reflected energy from the bottom surroundings could result in a three dimensional effect on the hydrophone. What this effect would be, cannot be anticipated although for the 1/3 octave band at 25 Hz, (5.2 Hz BW) (Figure 6-11) possible focusing effects are indicated. Here again, consider the higher frequency propagation loss data set because of the increased boundary loss. In review, the selection of these data sets for symplistic model testing is based on the premise that the major portion of the energy flow will be contained near the deep sound channel axis. Bottom effects are anticipated from the physical details of the experiment but at the higher frequencies their effect should be minimized. In the practical case, it must be recognized that the symplistic model requirements generally would not exist over long range. If the bottom effects here are larger than anticipated, then the data sets must then be considered range dependent and are not subject to symplistic modeling.

6.4.3 (U) Model Output Selection

(U) Since the measured propagation loss is based on the total energy received at the hydrophone, the model output for propagation loss should reflect the measurement procedure. If available, the propagation loss should represent the summation of all arrivals (phase addition) at any range. This should closely approximate the measurement conditions.

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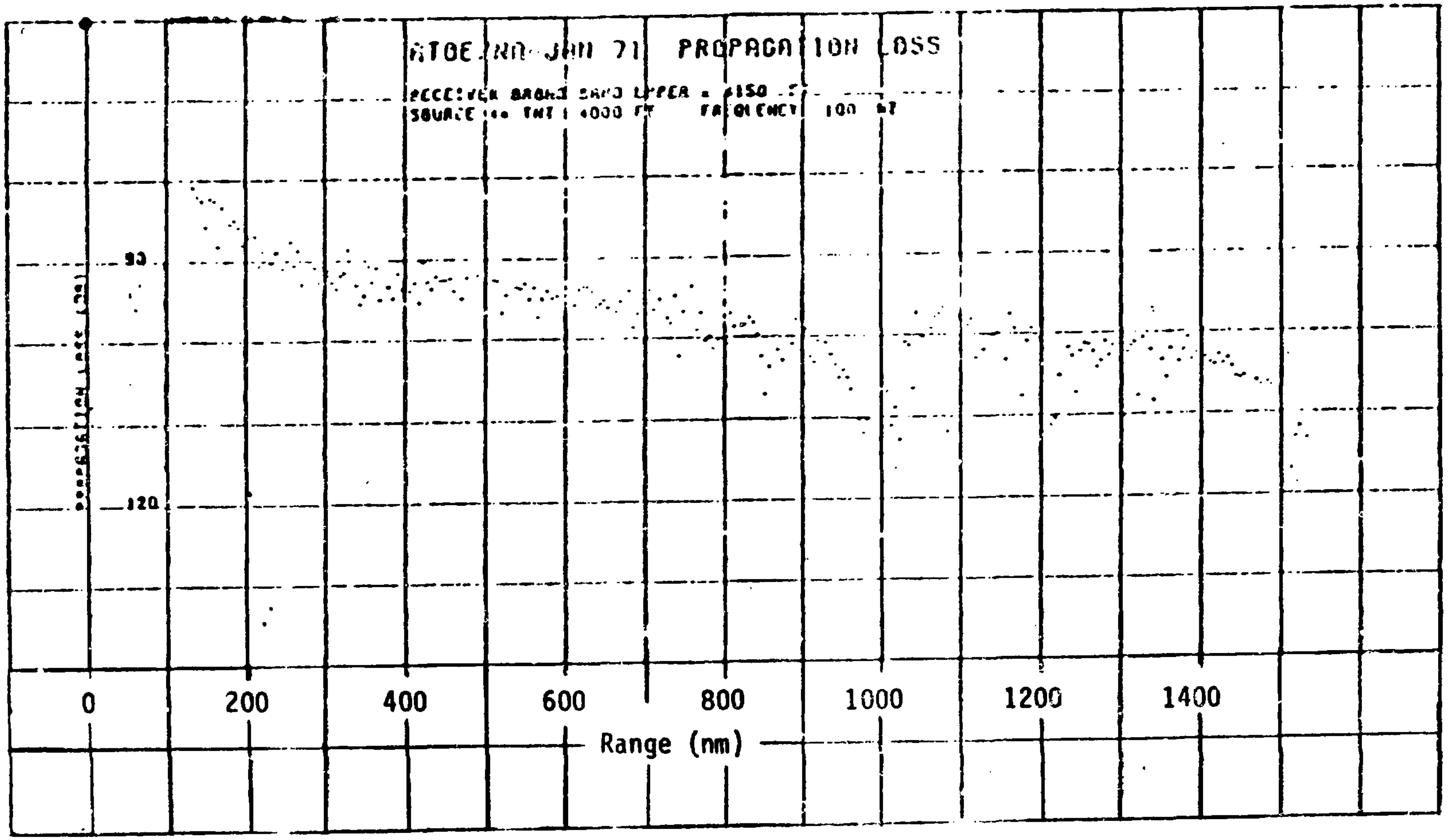

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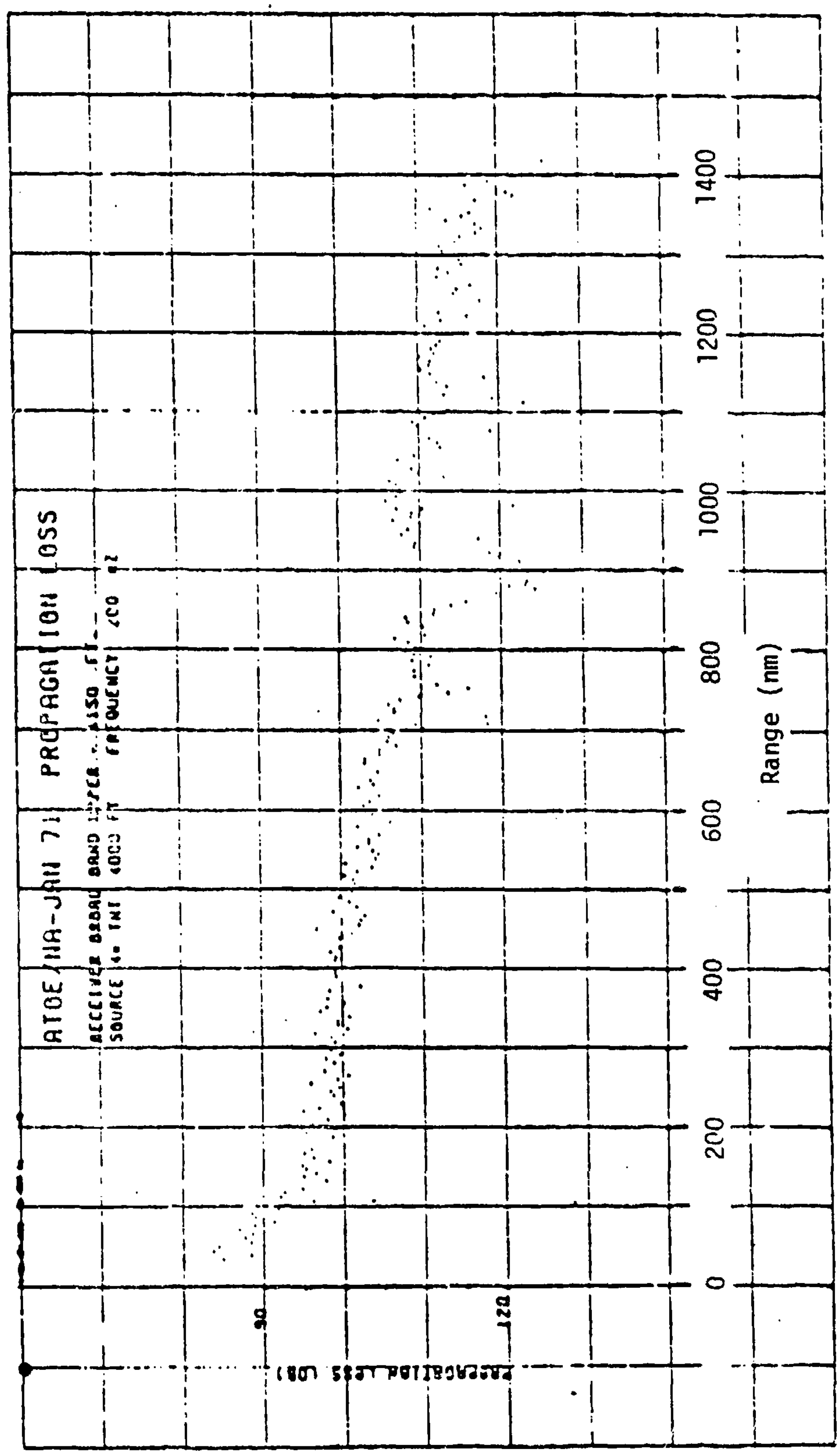

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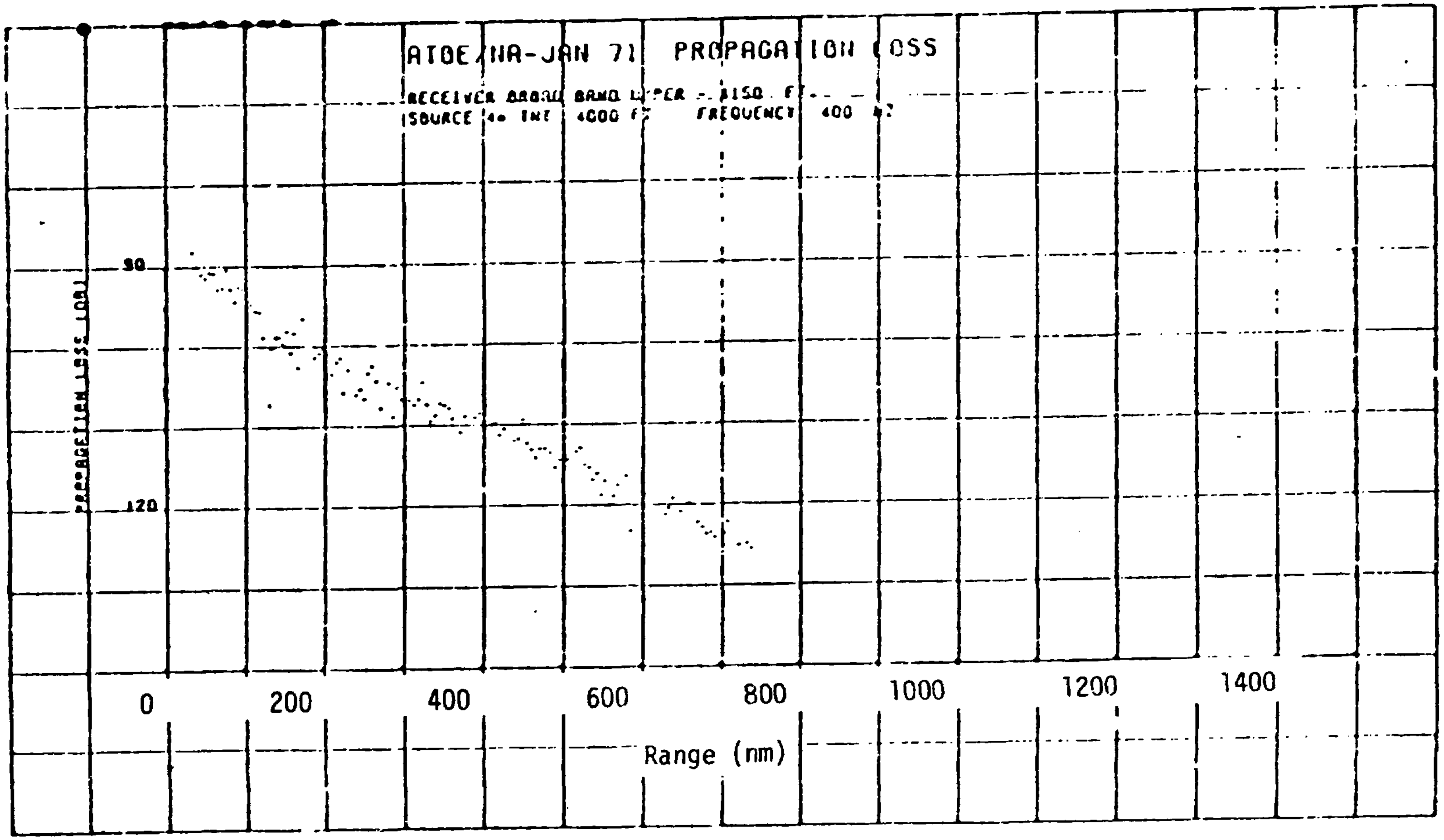

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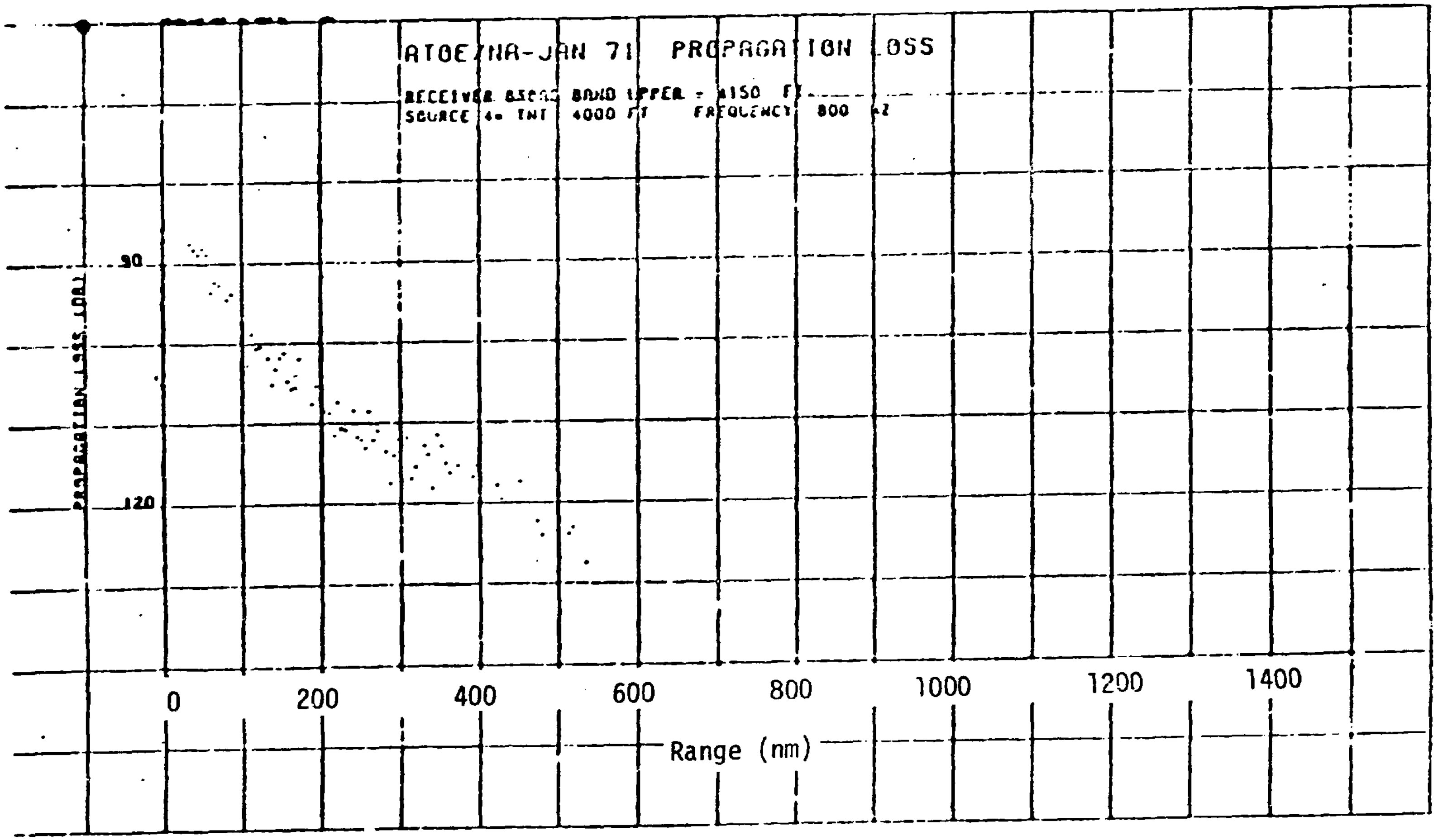

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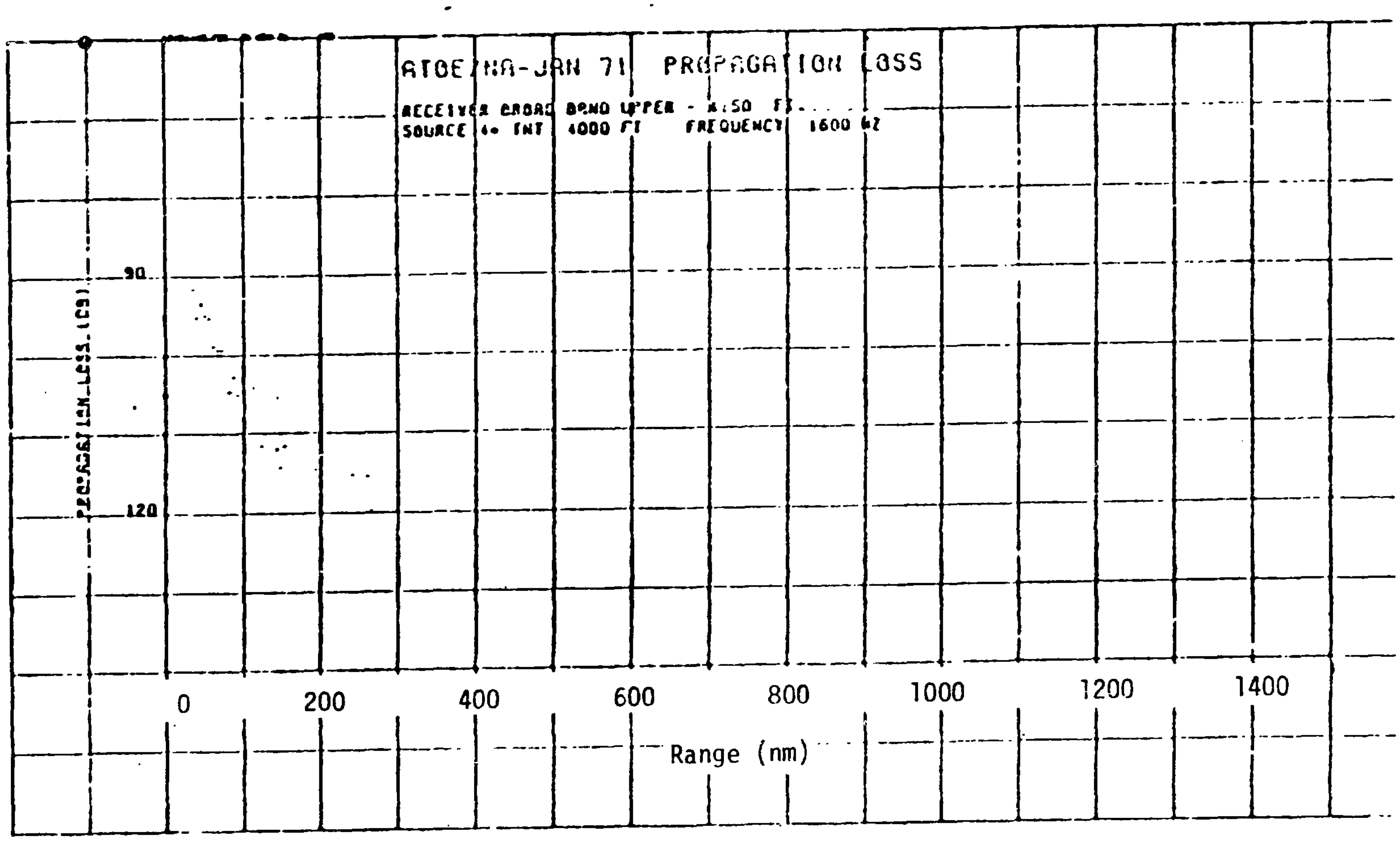

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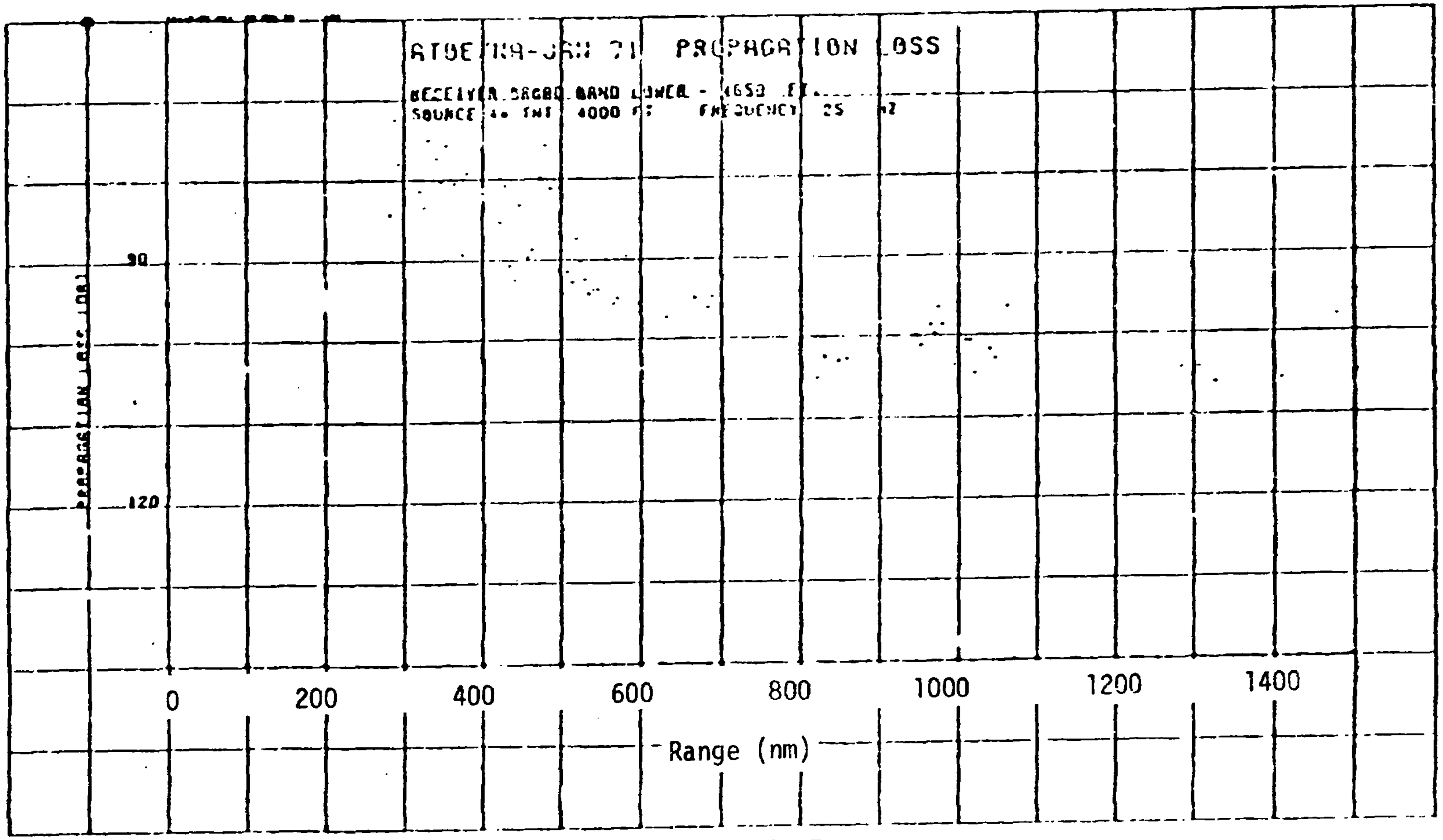

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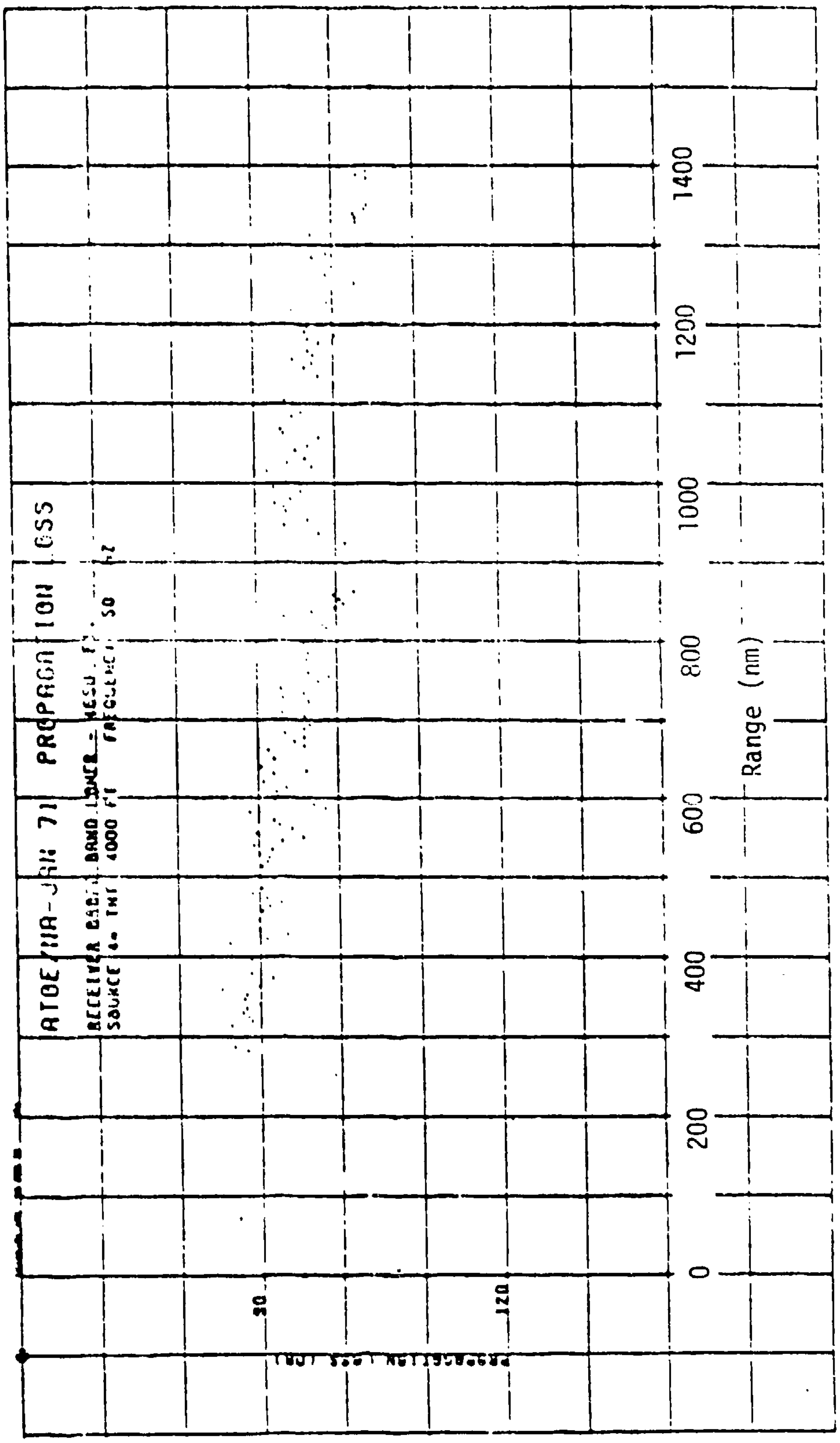

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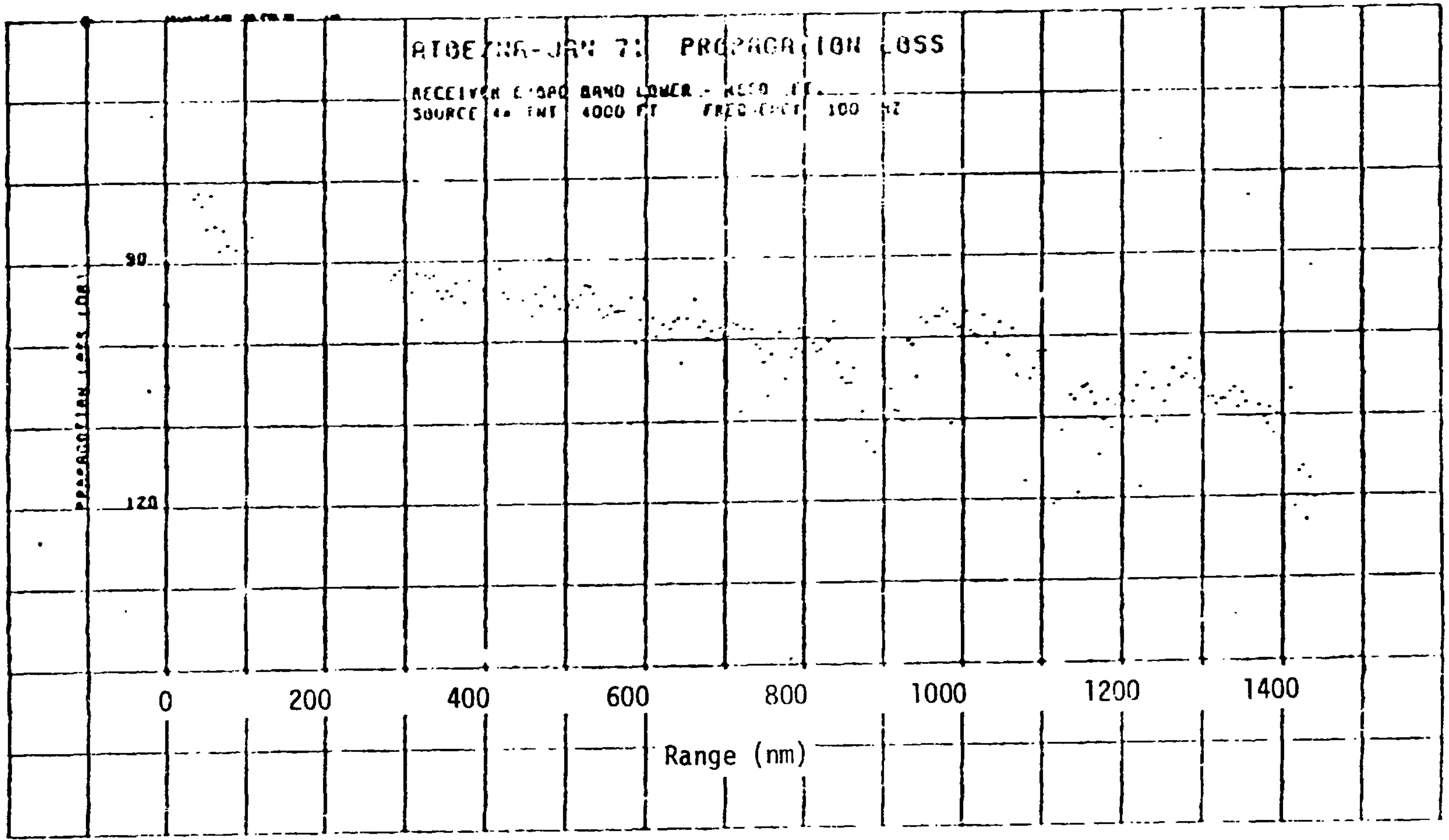

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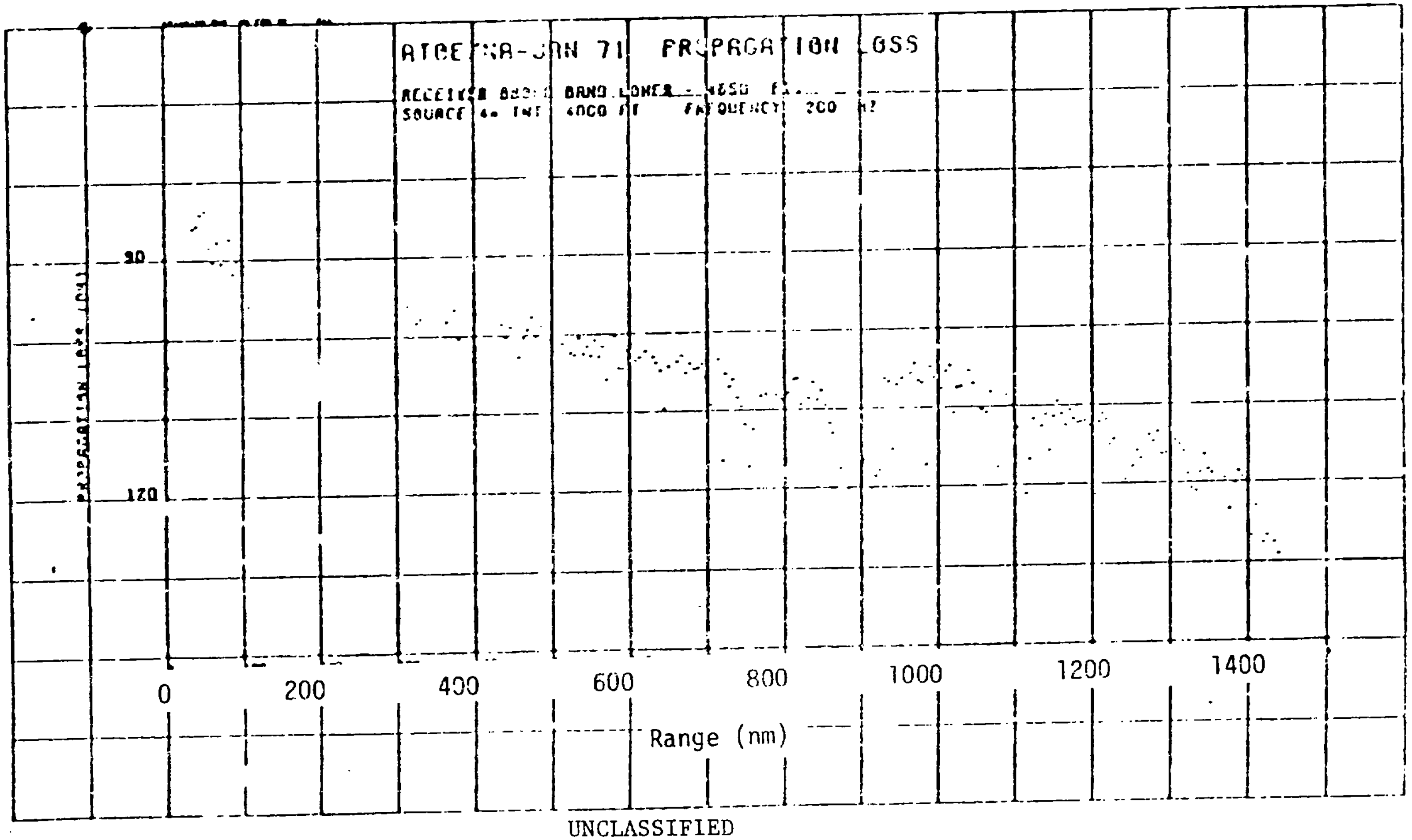

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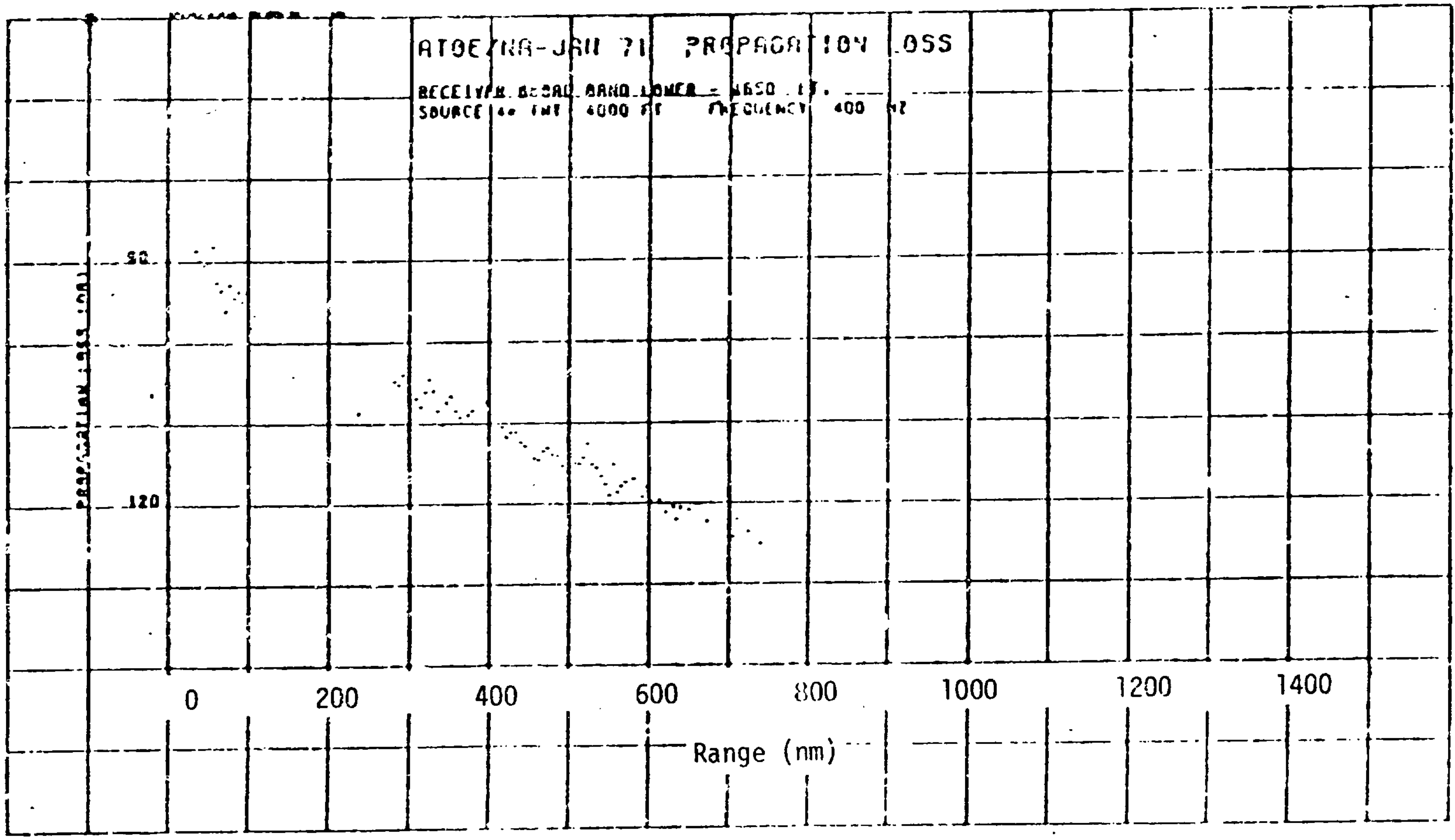

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APPENDIX 13

JAGUAR - BRAZIL

JOINT U.S./BRAZIL ACOUSTIC MEASUREMENT EXERCISE

Summarized by Robert L. Martin

INTRODUCTION

The purpose of the U.S./Brazil JAGUAR[1] (Joint Americas Geophysic Underwater Acoustic Research Program) acoustic measurement exercise was to evaluate shallow-water propagation-loss models for use in predicting acoustic transmission loss versus range in the frequency band 100 to 5000 Hz on the continental shelf of Brazil for late-summer conditions. The exercise consisted of measuring propagation loss and environmental parameters along a 50 km track in water depths of 60 m in an area off the coast of Rio de Janeiro, as shown in Figure 1. Two events were conducted. For the first event, explosives were detonated along the track at a depth of 18 m with range increments of 1 km to get a broad frequency coverage. For the second event, a CW source was towed along the track at a depth of 18 m, emitting a frequency of 1600 Hz while radially outgoing and 2600 Hz on the reciprocal path, to obtain continuous range coverage. Two hydrophones were suspended, one at a depth of 20 m and one at a depth of 40 m, cabled to a moored receiving ship, and used as receivers for both events. The acoustic data were processed to obtain propagation loss versus range. The environmental data were used as input to the Marsh-Shulkin shallow-water model[2] to determine the usefulness of that model for predicting propagation loss for this area. The results of the measurements and the model comparisons are presented in this report.

Table 1 summarizes the source, receiver and environment parameters for the exercise.

EXERCISE DESCRIPTION

The exercise was conducted as two events of one day each in an area south of Rio de Janeiro, as shown in Figure 1. The receiving ship, a Brazilian Navy

TABLE 1

JAGUAR Exercise Parameters Summary

	Shot Event	1.6 kHz Tow	2.6 kHz Tow
Source type	SUS 1.8#TNT$^+$	Scroll 190 dB//1μPA	Scroll 190 dB//1μPA
Source depth (m)	18	18	18
Receiver depths (m)	20, 40	20, 40	20, 40
Source freq (kHz)	0.1 to 5.0	1.6	2.6
Analysis bandwidth	1/3 oct	0.12 Hz	0.12 Hz
Min range (km)	2	0.5	1.5
Max range (km)	52	40	43
Surface soundspeed (m/s)	1532	1532	1532
Layer depth (m)	40*	40	40

+Source levels from ref 3 (Gaspin & Shuler).

*Typical sound speed profile is profile #3 of Figure 5.

Bottom depth: 58 m

Navigation: acoustic travel time and radar ranges (1% agreement) for shots. Radar ranges for CW events. Accuracy ≈50 m.

Processing shots: Total energy in 1/3 octave bands.
CW: Total energy in 0.12 Hz bands.

Data location - NUSC/New London, Mr. John Chester

Surface conditions - Wind speed 10 Kts, sea state 1, swell period 12 sec.

Environmental data - XBT & salinity vs. depth converted to sound speed
Bottom grab samples for sediment analysis
Sediment layer average sound speeds
Climatology
Bathymetry

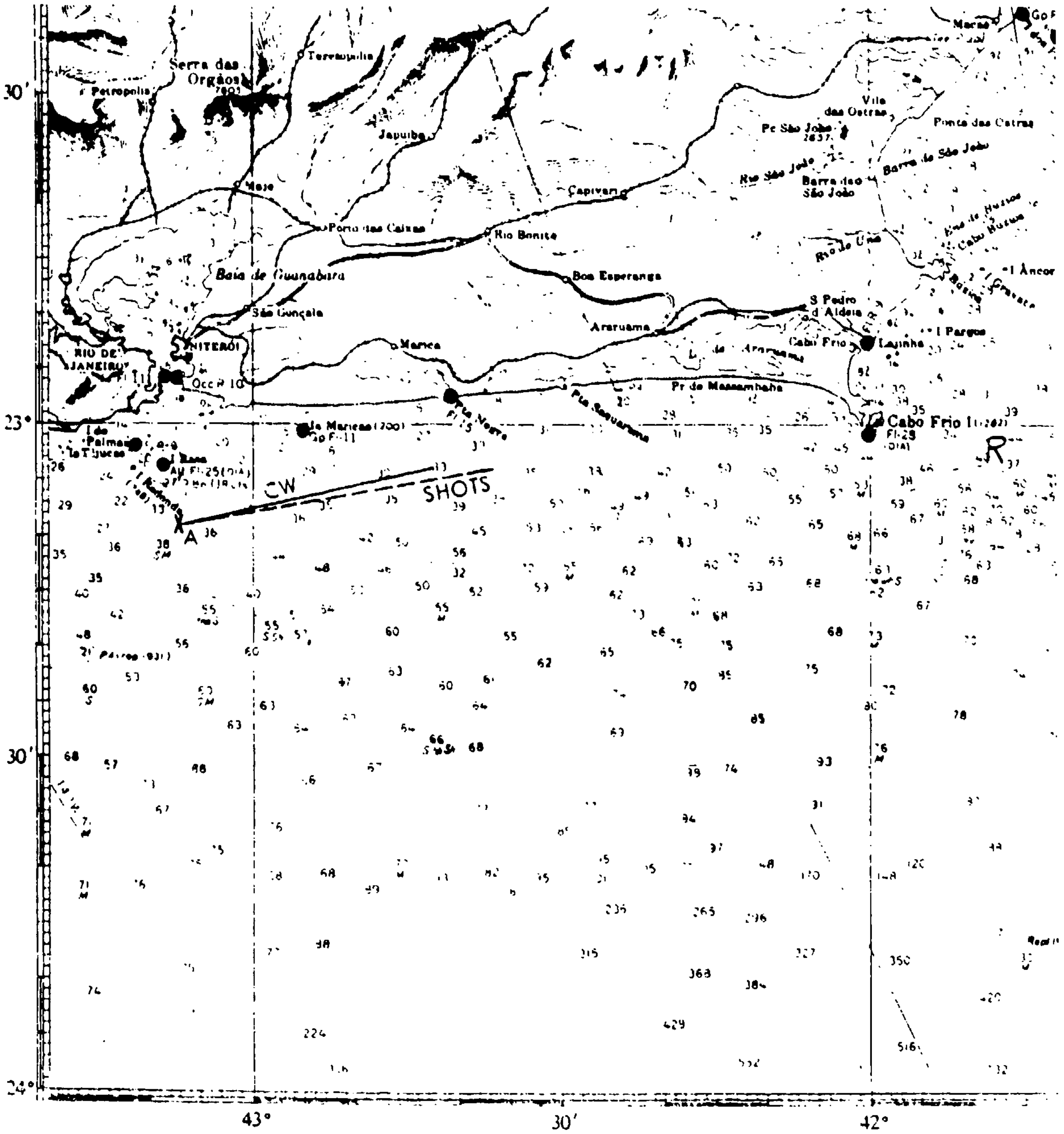

Figure 1. JAGUAR-Brazil Track Chart

rescue ship, K10 GASTAO MOUTINHO, was anchored at Point A (23°08.5'S, 43°0[illegible]5'W) with hydrophones deployed at 20 and 40 m (Figure 2). The source ship, a Brazilian Navy tugboat, R22 TRIDENTE, followed the 60 m (33 fathom) deep track shown in Figure 1.

For the first event, the source ship detonated SUS Mk 61 charges of 0.8 kg (1.8 lb.) TNT at 18 m depth every kilometer. Source-ship range versus time and shot number was maintained using radar on both ships, and by measuring shot travel time using a detonation instant-detection and transmitting technique.

For the second event, the source ship towed a CW source at a depth of 18 m (source level 190 dB//1μPa) excited with 1600 Hz on the outgoing track and 2600 Hz on the return track. The CW source consisted of a magnetostrictive scroll projector mounted in a tow body towed by the source ship with a double-armored faired cable. Tow depth was determined by amount of cable out and cable angle with the sea surface. Source frequency was monitored with a frequency counter on the source ship. Output level was determined by measuring drive voltage and comparing the measurements to calibration data obtained before the exercise. Radar range versus time logs from the receiving ship were used to plot CW propagation loss versus range.

Environmental data were collected by both ships. The source ship made XBT measurements along the track and took four bottom grab samples (Figure 3). The receiving ship took water samples and made conductivity-temperature profiles while anchored. In addition, information on the subbottom structure, potentially useful for interpreting low-frequency results, was obtained at two sites near the exercise tracks by Lamont Doherty Geophysical Observatory in 1974 as part of the International Decade of Oceanography Expeditions (IDOE).

ENVIRONMENTAL DESCRIPTION

On both days, a 24°C average layer, 30 m deep, overlaying a gentle thermocline (19 to 22°C at the bottom) existed. The average representative salinity used for

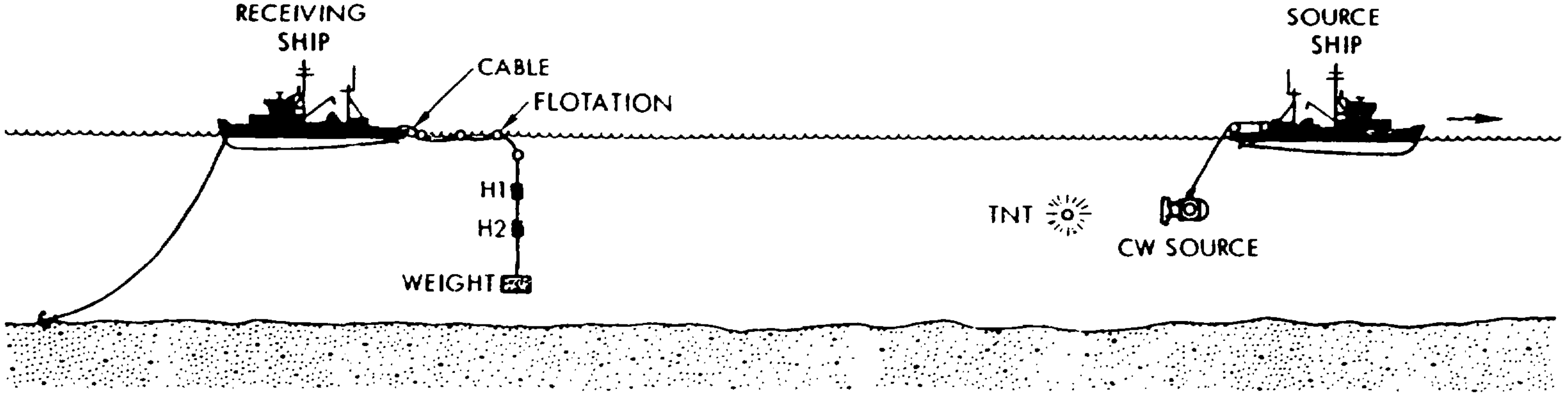

Figure 2. Exercise Geometry

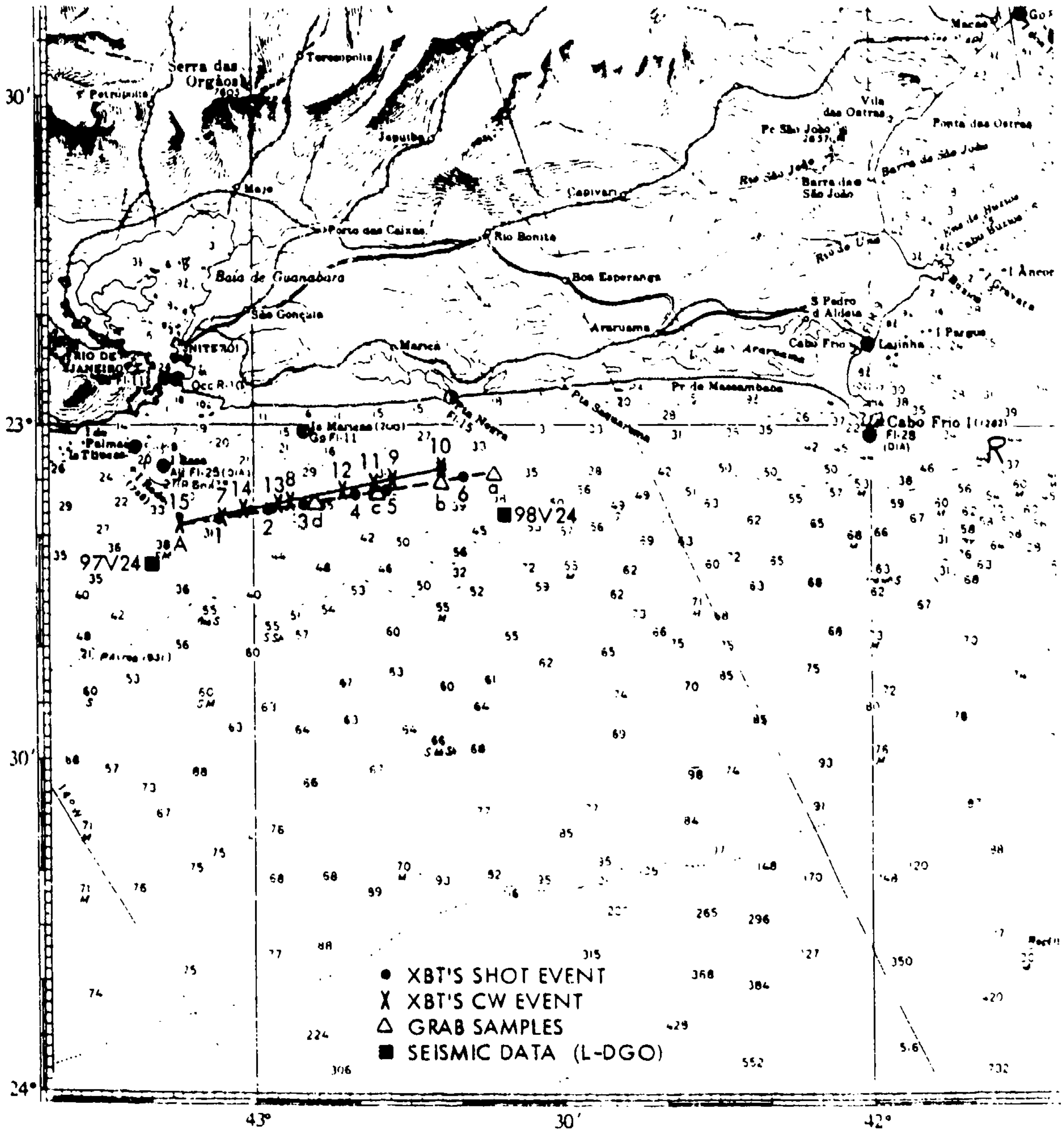

Figure 3. Environmental Data Locations

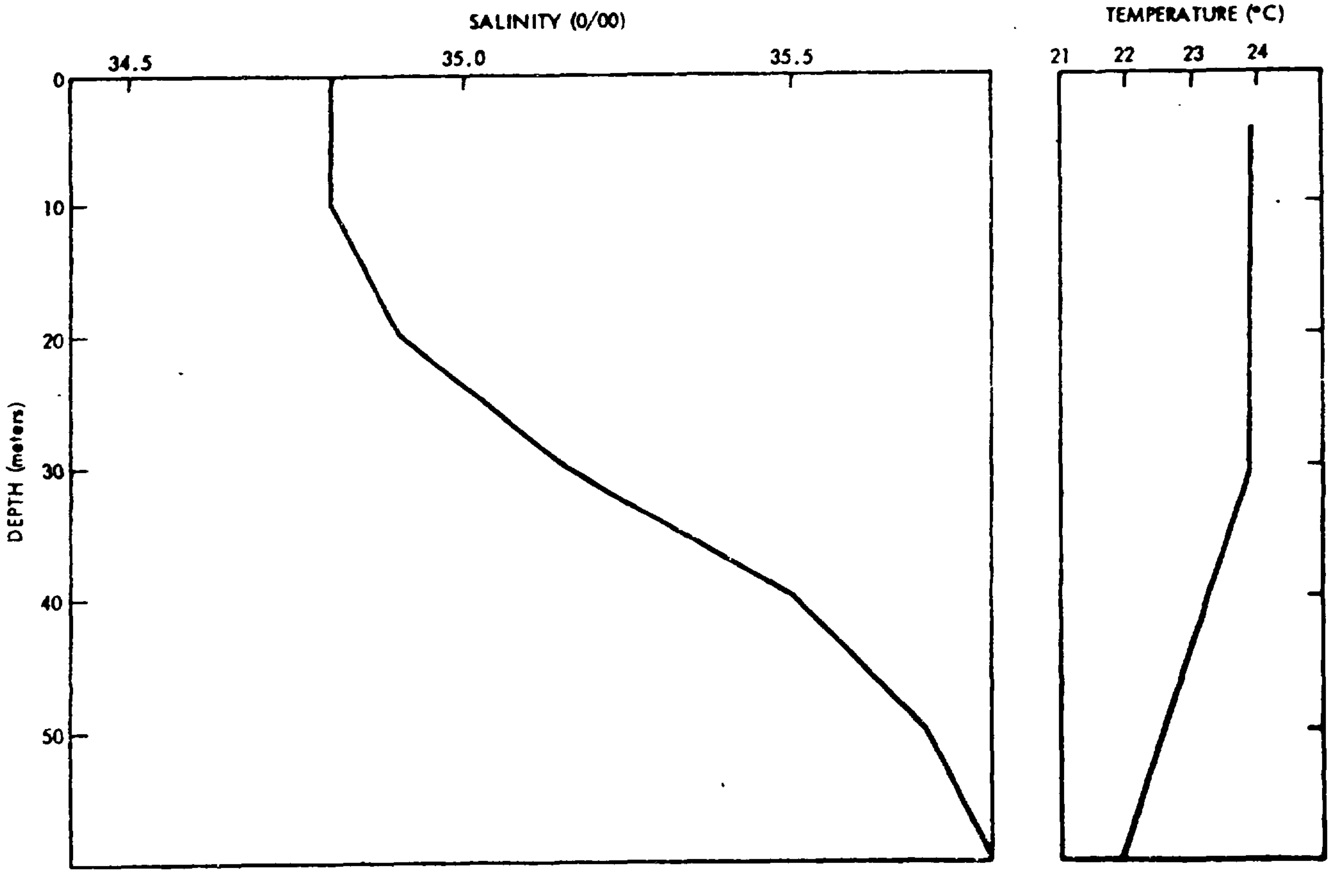

Figure 4. Representative Salinity and Temperature Profiles

sound-speed calculations is shown in Figure 4, together with a representative temperature profile. The calculated sound-speed profiles along the track are shown in Figures 5 and 6 numerically keyed to Figure 3. Water depth along the track is given in Figure 7.

The oceanographical-meteorological situation during the exercise can be explained in simple terms as the result of a cold front passing over Rio de Janeiro and a new polar air mass coming north with winds from the south. At that time, the prevailing northeast winds were inducing a very strong upwelling, resulting in very pronounced thermal gradients in the shelf. This upwelling situation exists more than 80 percent of the time in the Rio de Janeiro area. When the front came through, the situation changed abruptly. The cold water sank (downwelling), and the general trend was toward an isothermal layer over the shelf with some cold water close to the bottom.

On both days, the winds were gentle from the southwest averaging 10 knots. The swell was also from SW with an average period of 12 sec. For analysis and modeling purposes, sea state 1 was assumed. The grab samples revealed a sandy bottom.

SOUND SPEED DATA

XBT sections were taken by the source ship on both operating days. STD casts taken from the receiving platform cover the time span of the XBT sections on both days. The STD casts were made with a Martek electronic CTD. The receiving ship also took water samples and reversing thermometer casts (Nansen casts). Both Nansen and STD casts were taken at roughly the same time. Comparison of the T and S profiles and of the T versus S curves of the two casts indicates that Martek values were high by about 0.3^{o}C, low by about 0.15 parts per thousand, and deep by about 5 m as compared with the Nansen data.

Actual errors in extrapolating salinities over the XBT section, and to 60 m depth, are unknown.

The following average salinity values were used in computing sound speeds (according to the Del Grosso (1973) equation).

Depth (m)	Salinity ($^0/_{00}$)
0	34.80
10	34.80
20	34.90
30	35.15
40	35.50
50	35.70
60	35.80

Figures 5 and 6 show the sound-speed profiles from the shot and CW events, respectively, that were derived from the salinity and temperature data. The bulge in the profiles between 30 and 50 m depth is due to the downdwelling situation that existed during the exercise. Profile 3 of Figure 5 is considered typical for all events when using a range independent model; an increase of 2 dB in waterborn energy would be expected if profile 10 of Figure 6 were used instead. However, if significant energy were to arrive via bottom interacting paths there would be little discernible difference between total energy predictions using the different profiles.

SEDIMENT ANALYSIS

Table 2 describes the results of the sediment analysis from the four grab samples. Figure 3 identifies the location at which these samples were obtained. The calculations were used to provide an estimate of M_z = mean grain size, and Corr. V_p = the estimate of sediment velocity. Corr. V_p is arrived at by correcting a standard formula for V_p to compensate for actual-water sound speed, temperature and salinity at the water-sediment interface (in this case at 60 m water depth). Table 3 uses mean grain size to estimate the constant, K, needed to calculate sediment attenuation.

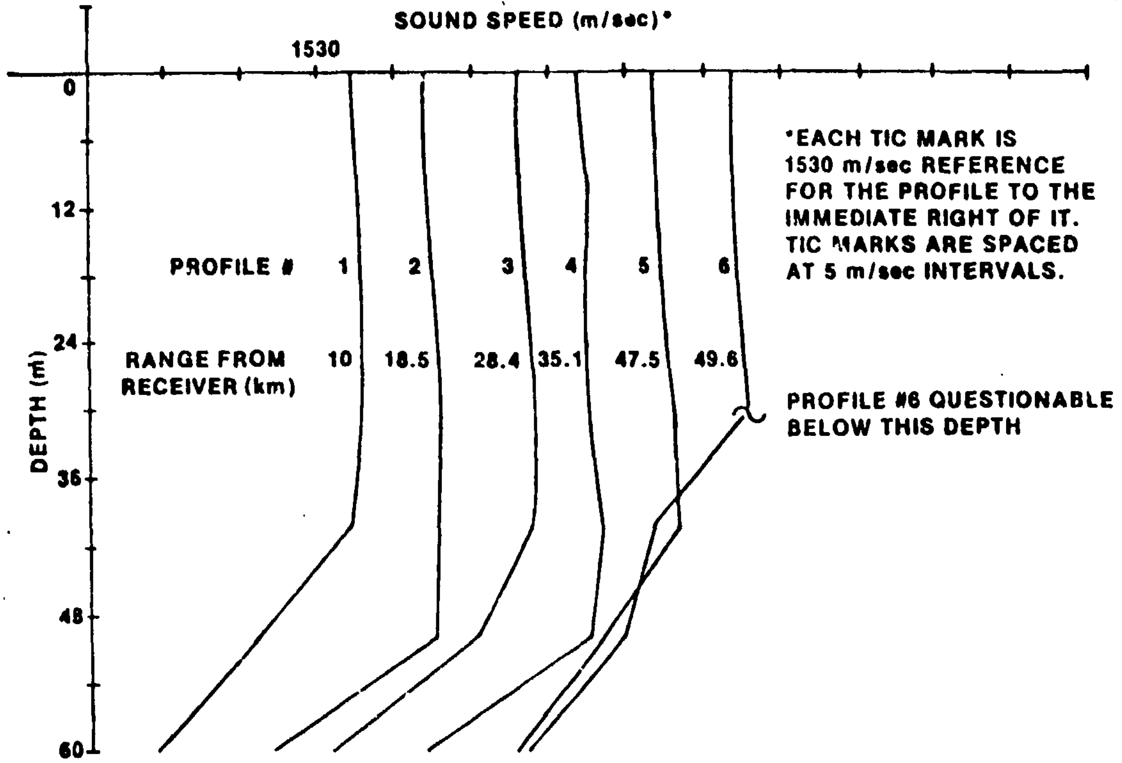

Figure 5. Sound-Speed Profiles, Shot Event, 12 May 1976

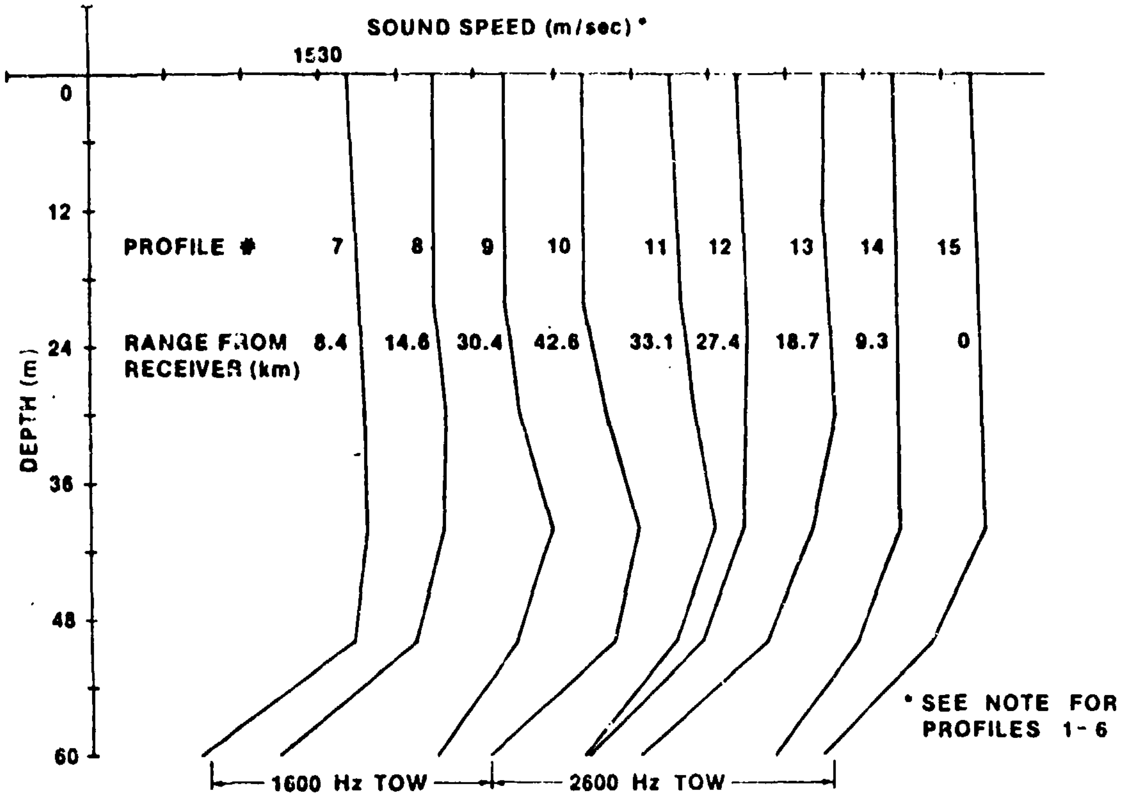

Figure 6. Sound-Speed Profiles, CW Events, 13 May 1976

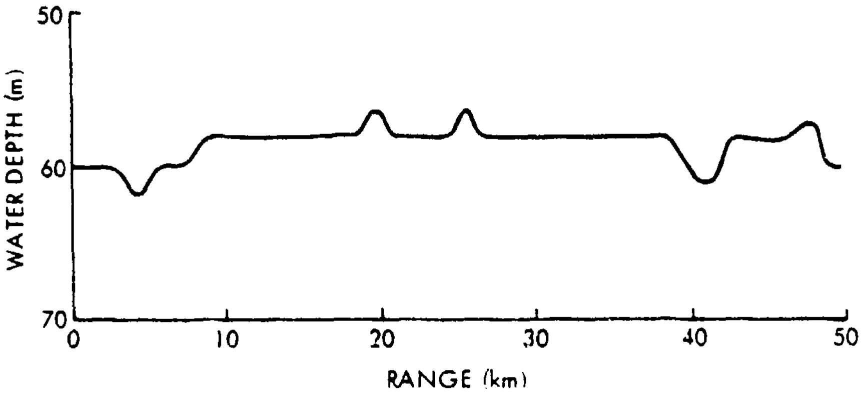

Figure 7. Water Depth Along Exercise Tracks

SUBBOTTOM STRUCTURE

The subbottom structure was obtained from Lamont Doherty Geophysical Observatory (LDGO). The location of the measurements which provided the data is shown in Figure 3 of the text and listed in table 4. The station designations are those used by LDGO in cataloging their measurements. The method of collecting and processing these data does not permit determining fine structure of the bottom nor of the interface-sediment sound speed. In this case, the 1800 m/sec sound speed identified with the first layer is an assumption. Also, while average sound speed is assigned to each layer, it is likely that a sound-speed gradient exists in each case.

ACOUSTIC RESULTS

CW-PROPAGATION LOSS

Figures 8a and 8b are plots of propagation loss versus range of the 1600 and 2600 Hz data, respectively, from the 20 m hydrophone. Each cross represents a 12.3 sec average for the 1600 Hz data and a 14.5 sec average for the 2600 Hz data derived from the local maximum of each FFT. The points at the furthest range of Figure 8a represent a condition of no-signal, and therefore yield the noise floor of the processing scheme. Superimposed on these data are the 5 minute averages obtained by summing over 21 frequency bins and averaging over 25 consecutive FFTs. The relatively high values shown in these plots are due to significant energy being contained in adjacent frequency bins.

In general, the 5 minute average, 40 m hydrophone results are within ±2 dB of the 20 m data for both frequencies. However, three highlights which appear at 14, 28, and 40 km range for the 20-m receiver are barely noticeable at the deeper depth.

Figure 9 is a plot of propagation loss versus range of the 1600 Hz data received on the 20 m hydrophone (upper curve) and on the 40 m hydrophone (lower

TABLE 2

Bottom Sediment Analysis

Grab Sample	Composition	Percent	Mean Grain Size (mm diameters) 84%	50%	16%
1	Sand	80	0.7	0.25	0.07
	Silt	13			
	Clay	7			
3.8% of $CaCO_3$ 10.9% Organic					
2	Sand	88	0.58	0.20	0.086
	Silt	8			
	Clay	4			
7.4% of $CaCO_3$ 4.8% Organic					
3	Sand	88	0.52	0.3	0.1
	Silt	6			
	Clay	6			
2.5% of $CaCO_3$ 9.8% Organic					
4	Sand	72	0.34	0.15	0.015
	Silt	26			
	Clay	2			
2.7% $CaCO_3$ 10.5% Organic					

TABLE 3

Attenuation

Sample No.	M_3 (mm)	k
1	0.34	0.5
2	0.28	0.45
3	0.30	0.5
4	0.16	0.15

where $\alpha = kf^2$, where $n \simeq 1$
f = frequency in kHz
α^2 = attenuation in dB/m
k = constant.

TABLE 4.

Subbottom Sound-Speed Structure

Station/Location	Depth Interval	Sound Speed (m/sec)
98 V 24/23°11.9'S	0 - 74 m (water)	1519
43°10.0'W	74 - 257 m	1800
	257 m	6150
98 V 24/23°07.9'S	0 - 83 m	1519
42°36.7'W	83 - 173 m	1800
	173 m - 481 m	5400
	481 m -	6250

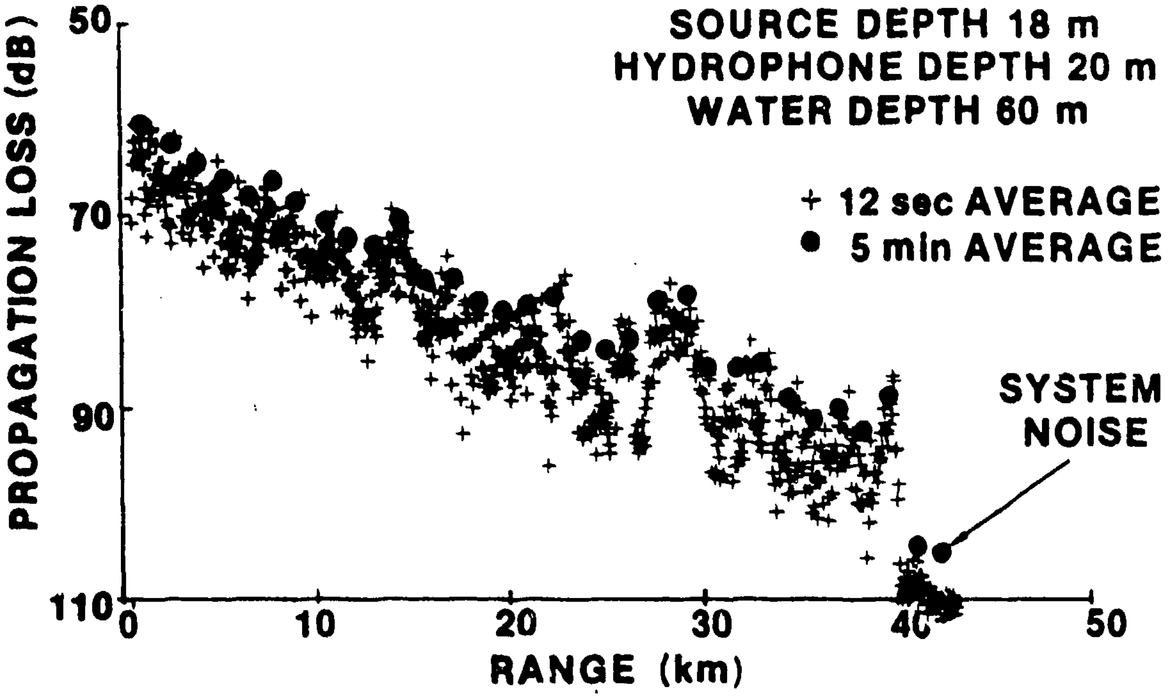

Figure 8a. 1600 Hz CW

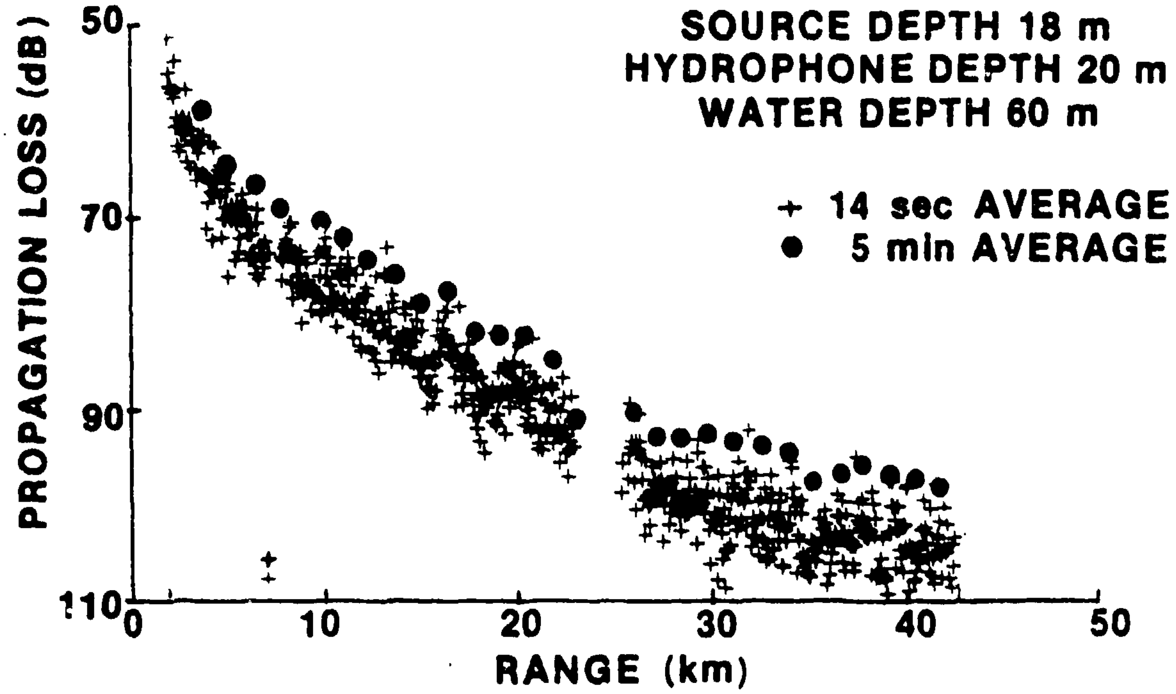

Figure 8b. 2600 Hz CW

Figure 8. CW Propagation Loss Versus Range

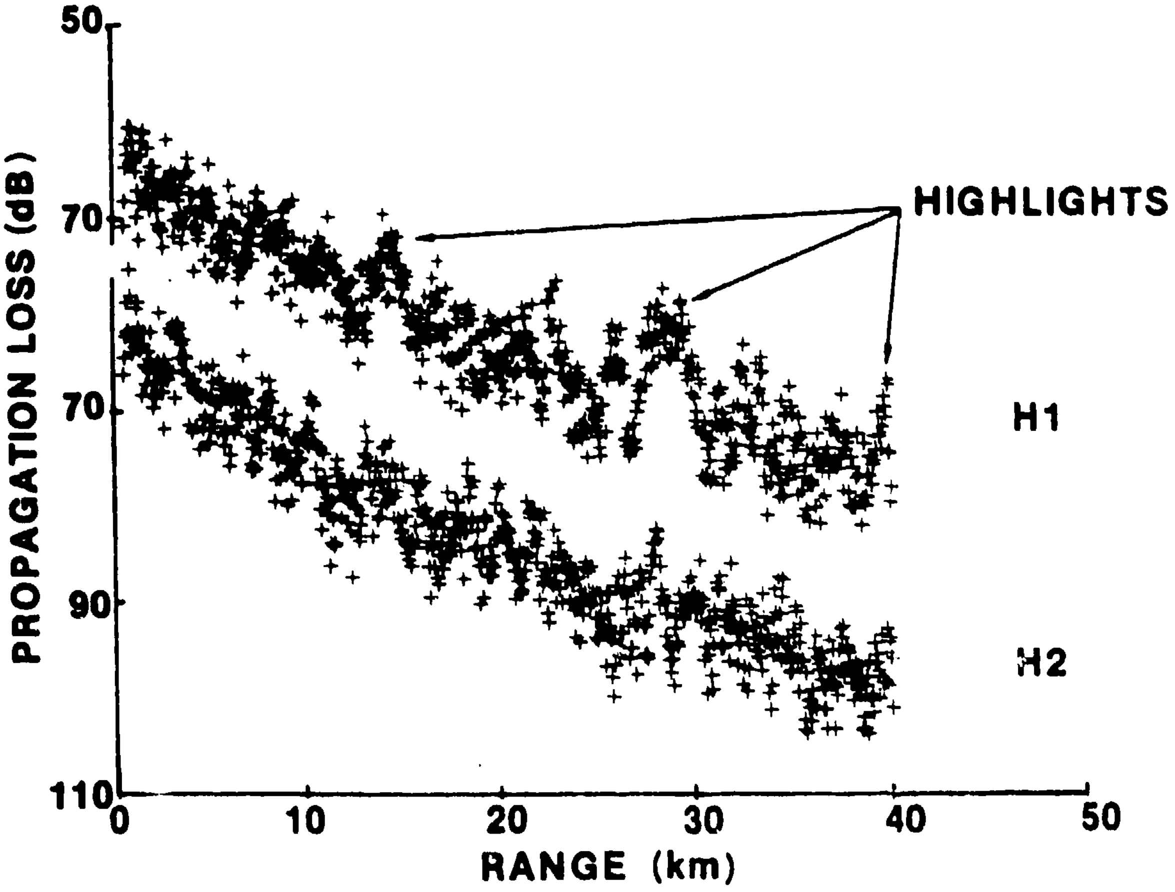

Figure 9. CW Propagation, 20 m Versus 40 m Comparison, 1600 Hz

curve). These two curves are purposely offset from one another by 20 dB. These highlights are also observable in the averaged data and demonstrate an acoustic-transmission enhancement of 3 to 6 dB for the shallow versus the deep hydrophone at those specific ranges.

SHOT-PROPAGATION LOSS AND COMPARISONS

Figures 10 to 13 show shot-propagation loss data versus range for each 1/3-octave frequency band from 100 to 5000 Hz for the 20 m hydrophone. The data for the 40 m unit are essentially identical and are not shown. The Marsh-Shulkin model prediction for a sand bottom, sea state 1, and a water depth plus duct depth of 100 m is shown as a dotted curve on each plot. The Marsh-Shulkin model forms a lower boundary to the measurements with differences that decrease with increasing frequency, going from a best-fit difference of approximately 8 dB below 1000 Hz to 2 dB above 2500 Hz; see table 2. The best fit was for ranges greater than 5 km, thereby eliminating the first three shots, which were overloaded. The difference between the model and measurements is probably due to the subbottom structure, which provides less loss to low-frequency transmission than to high-frequency transmission. However, while high-quality data on the subbottom structure and on the interface sediment from this exercise exist, information on the shallow subbottom structure does not. This gap in information will impact the accuracy with which any model can be used to quantitatively analyze these results as a function of frequency.

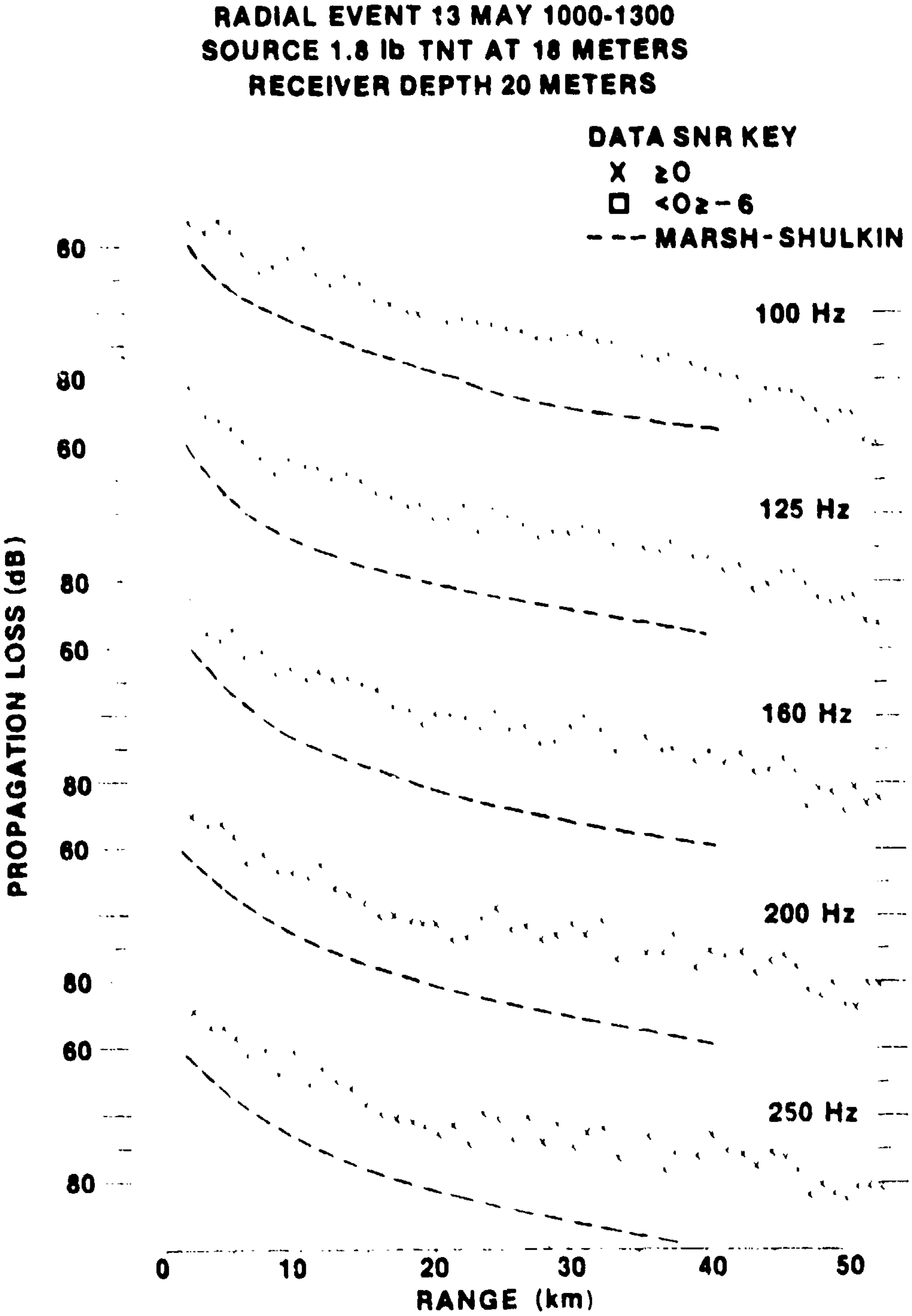

Figure 10. Shot Energy Propagation Loss, 100 Hz to 250 Hz

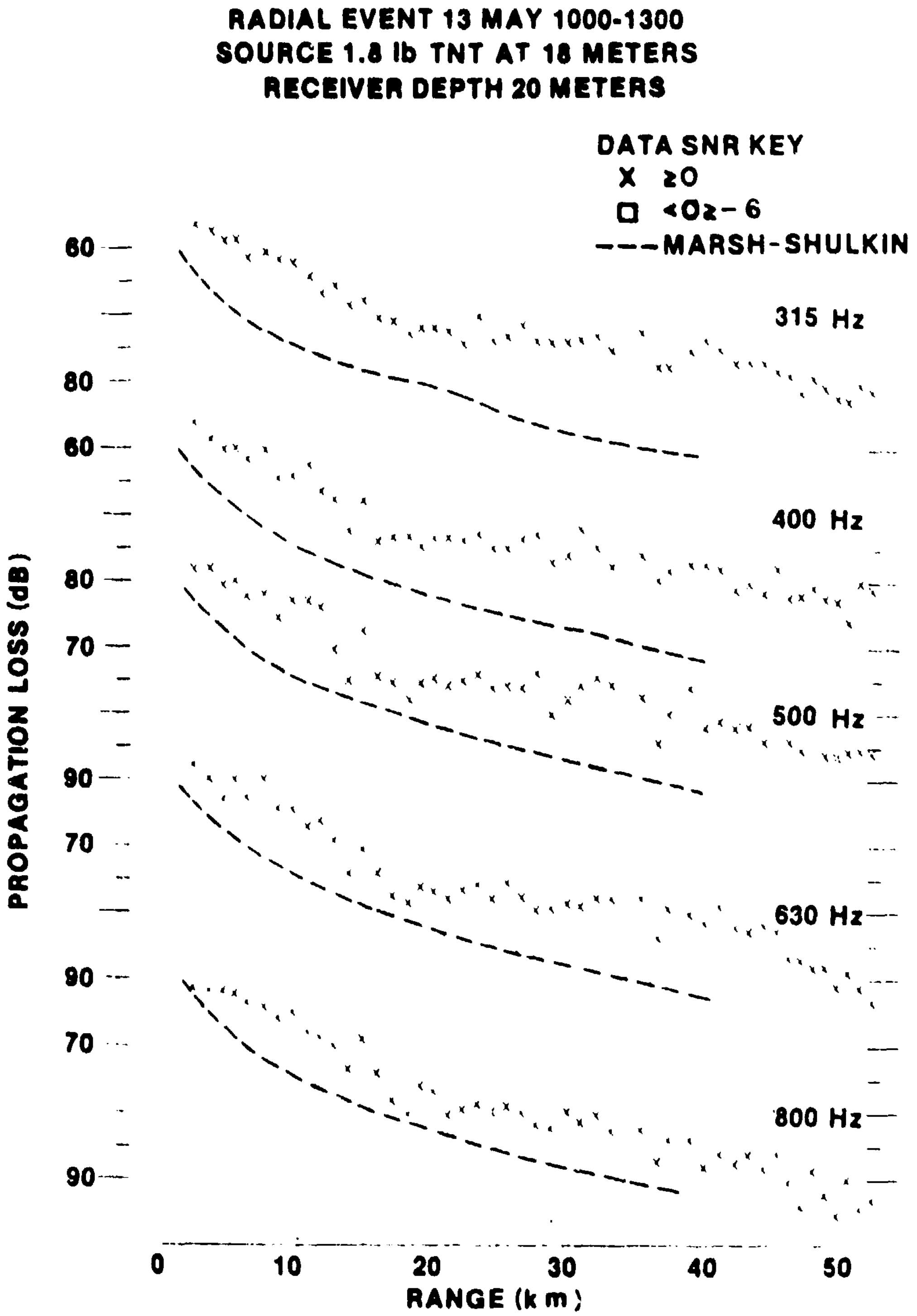

Figure 11. Shot Energy Propagation Loss, 315 Hz to 800 Hz

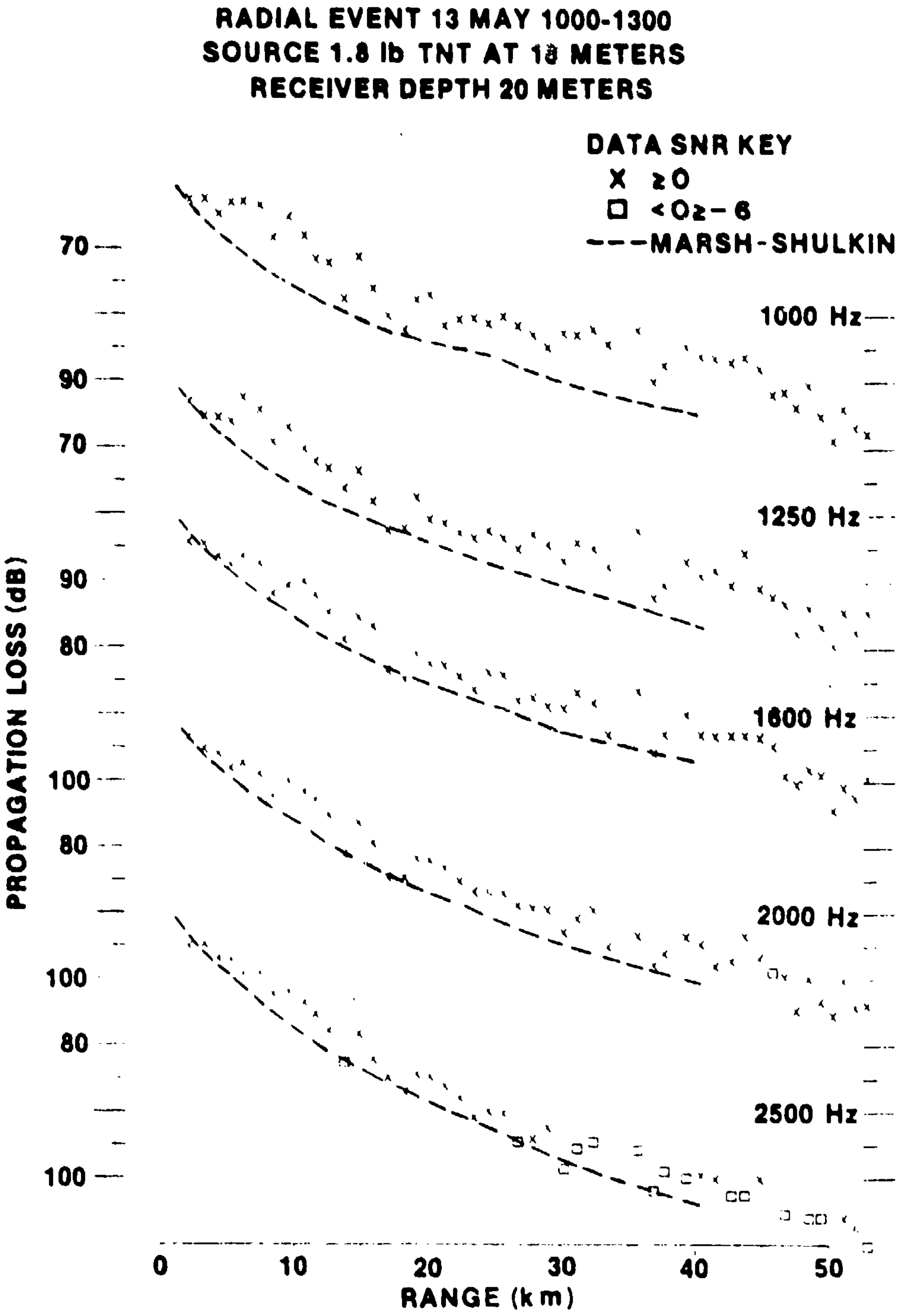

Figure 12. Shot Energy Propagation Loss, 1000 Hz to 2500 Hz

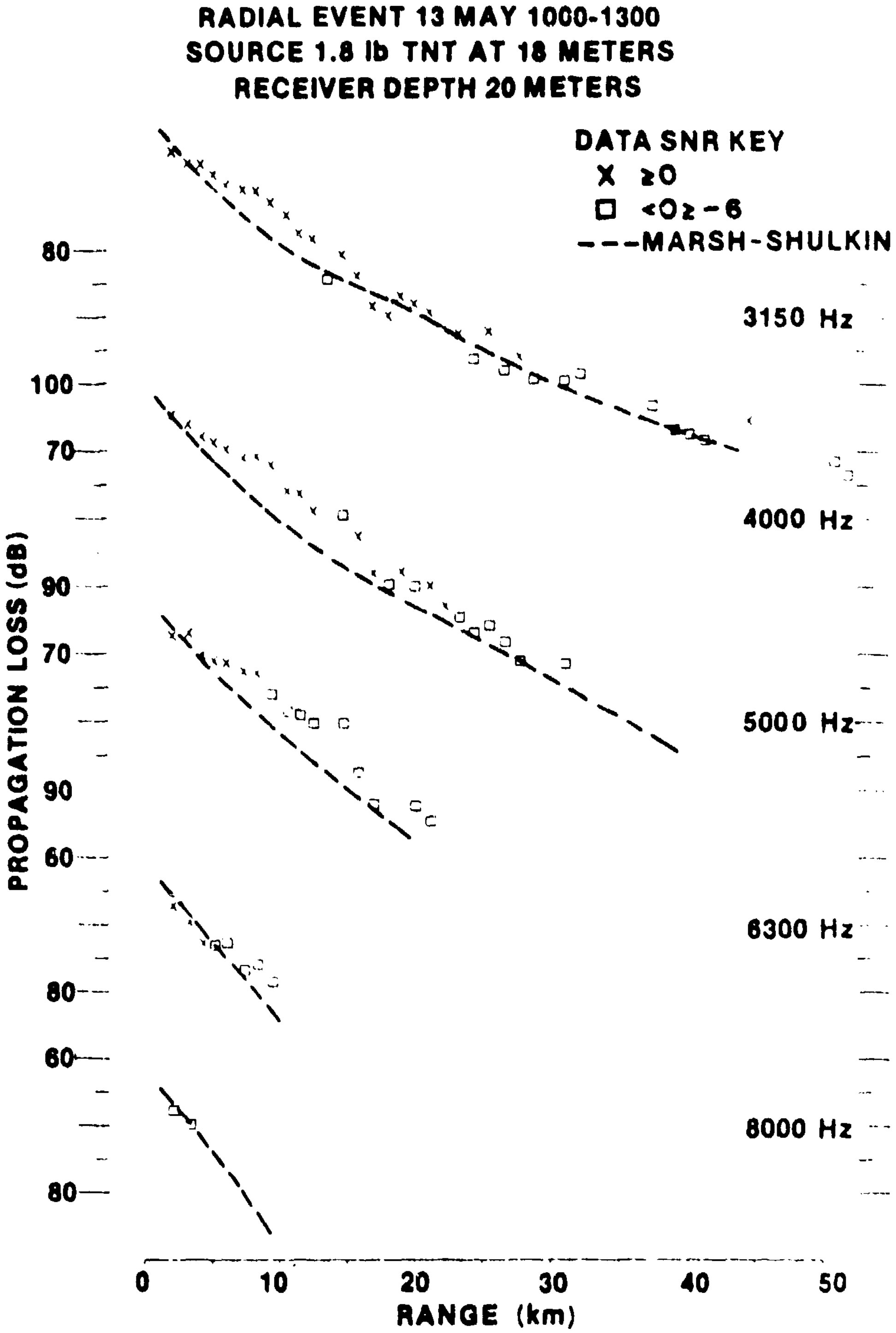

Figure 13. Shot Energy Propagation Loss, 3150 Hz to 8000 Hz

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2. H. W. Marsh and M. Shulkin, <u>Shallow Water Transmission</u>, Journal of the Acoustical Society of America, vol 34, p. 863, 1962.
3. J. B. Gaspin and V. K. Shuler, <u>Source Levels of Shallow Underwater Explosions</u>. Naval Ordnance Laboratory, NOLTR 71-160, 13 Oct 1971.

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Underwater acoustics
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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

(U) The overall objectives of Acoustic Model Evaluation have been addressed in companion volumes to this report and will not be dwelled on here except to put this effort into proper perspective. The thrust of the effort described in this volume is to provide identification, assessment, and summarization of environmental and acoustical propagation data sets for use by the Model Evaluator. Only data obtained in range independent environments are discussed herein.

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Ser 93/160
10 Mar 99

From: Chief of Naval Research
To: Commander, Naval Meteorology and Oceanography Command
1020 Balch Boulevard
Stennis Space Center MS 39529-5005

Subj: DECLASSIFICATION OF PARKA I AND PARKA II REPORTS

Ref: (a) CNMOC ltr 3140 Ser 5/110 of 12 Aug 97

Encl: (1) Listing of Known Classified PARKA Reports

1. In response to reference (a), the Chief of Naval Operations (N874) has reviewed a number of Pacific Acoustic Research Kaneohe-Alaska (PARKA) Experiment documents and has determined that all PARKA I and PARKA II reports may be declassified and marked as follows:

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3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

Peggy Lambert

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Continuation of LRAPP Final Report, February 1972, Contract N00014-71-C-0088, Bell Telephone Labs, Unknown # of pages
(NUSC NL Accession # 057708)

PARKA II-A, The Oceanographic Measurements, February 1972, MC Report 006, Volume 2, Maury Center for Ocean Science (ONR), 89 pages
(NUSC NL Accession # 059194) (NRL SSC Accession # 85007063)

Project Pacific Sea Spider - Technology Used in Developing A Deep-Ocean Ultrastable Platform, 12 April 1974, ONR-ACR-196, 55 pages
✓(DTIC # **529 945**)

LRAPP Program Review at the New London Laboratory, Naval Underwater Systems Center, 24 April 1975, NUSC-TD-4943, Unknown # of pages
(NUSC NL Accession # 004943)

An Analysis of PARKA IIA Data Using the AESD Parabolic Equation Model, December 1975, AESD Technical Note TN-75-09, Acoustic Environmental Support Detachment (ONR), 53 pages
(NRL SSC Accession # 85004613)

Bottom Loss Measurements in the Eastern Pacific Ocean, 26 January 1977, NADC-76320-20, 66 pages
✓(DTIC # **C009 224**)

PARKA I Oceanographic Data Compendium, November 1978, NORDA-TN-25, 579 pages
✓(DTIC # **B115 967**)

Sonar Surveillance Through A North Pacific Ocean Front, June 1981, NOSC-TR-682, 18 pages
✓(DTIC # **C026 529**)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 1, Model Evaluation Methodology and Implementation, September 1982, NORDA-33-VOL-1, 46 pages
✓(DTIC # **C034 016**)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 1A, Summary of Range Independent Environment Acoustic Propagation Data Sets, September 1982, NORDA-34-VOL-1A, 482 pages
✓(DTIC # **C034 017**)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 2, The Evaluation of the Fact PL9D Transmission Loss Model, Book 1, September 1982, NORDA-35-VOL-2-BK-1, 179 pages
(DTIC # **C034 018**)

The Acoustic Model Evaluation Committee (AMEC) Reports, Volume 2, The Evaluation of the Fact PL9D Transmission Loss Model, Book 2, Appendices A-D, September 1982, NORDA-35-VOL-2-BK-2, 318 pages
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1. In accordance with reference (a), a declassification review has been conducted on a number of classified LRAPP documents.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
NORDA35VOL.1BK 2OF3	Lauer, R.B.	THE ACOUSTIC MODEL EVALUATION COMMITTEE (AMEC) REPORTS, VOL. 2- APPENDICES A-D- EVALUATION OF THE FACT PL9D TRANSMISSION LOSS MODEL	Naval Ocean R&D Activity	810901	ND ADC034019	U
NORDA36VOL.3BK 2OF3	Lauer, R.B., et al.	THE ACOUSTIC MODEL EVALUATION COMMITTEE (AMEC) REPORTS, VOL. 3- APPENDICES A-D- EVALUATION OF THE RAYMODE X PROPAGATION LOSS MODEL (U)	Naval Ocean R&D Activity	810901	ND ADC034022	U
Unavailable	Hooper, M. W., et al.	MEASUREMENTS AND ANALYSIS OF ACOUSTIC BOTTOM INTERACTION IN THE NORTHWESTERN MEXICAN BASIN	University of Texas, Applied Research Laboratories	811005	ADA107551	U
Unavailable	Kirby, W. D.	FINAL REPORT FOR CONTRACT NUMBER N00014-78-C-0862	Science Applications Inc.	820201	ADA111000	U
Unavailable	Brunson, B. A., et al.	PHYSICAL SEDIMENT MODEL FOR THE PREDICTION OF SEAFLOOR GEOACOUSTIC PROPERTIES	Planning Systems Inc.	820701	ADA119445	U
Unavailable	Cavanagh, R. C., et al.	NORDA PARABOLIC EQUATION WORKSHOP, 31 MARCH - 3 APRIL 1981	Naval Ocean R&D Activity	820901	ADA121932	U
NORDA34VOL.1A	Martin, R. L., et al.	THE ACOUSTIC MODEL EVALUATION COMMITTEE (AMEC) REPORTS, VOL. 1A- SUMMARY OF RANGE INDEPENDENT ENVIRONMENT ACOUSTIC PROPAGATION DATA SETS	Naval Ocean R&D Activity	820901	ADC034017; ND	U
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Unavailable	Unavailable	1975-1982 SUMMARY REPORT	Analysis and Technology, Inc.	821217	ADA192591	U
Unavailable	DeChico, D.	ACOUSTIC EVALUATION OF SANDERS ASSOCIATES ACODAC SENSORS	Naval Air Development Center	830301	ADB073873	U
NRL-FR-8695; NRL-8695	Palmer, L. B., et al.	TRANSVERSE HORIZONTAL COHERENCE AND LOW-FREQUENCY ARRAY GAIN LIMITS IN THE DEEP OCEAN	Naval Research Laboratory	830809	ND	U
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