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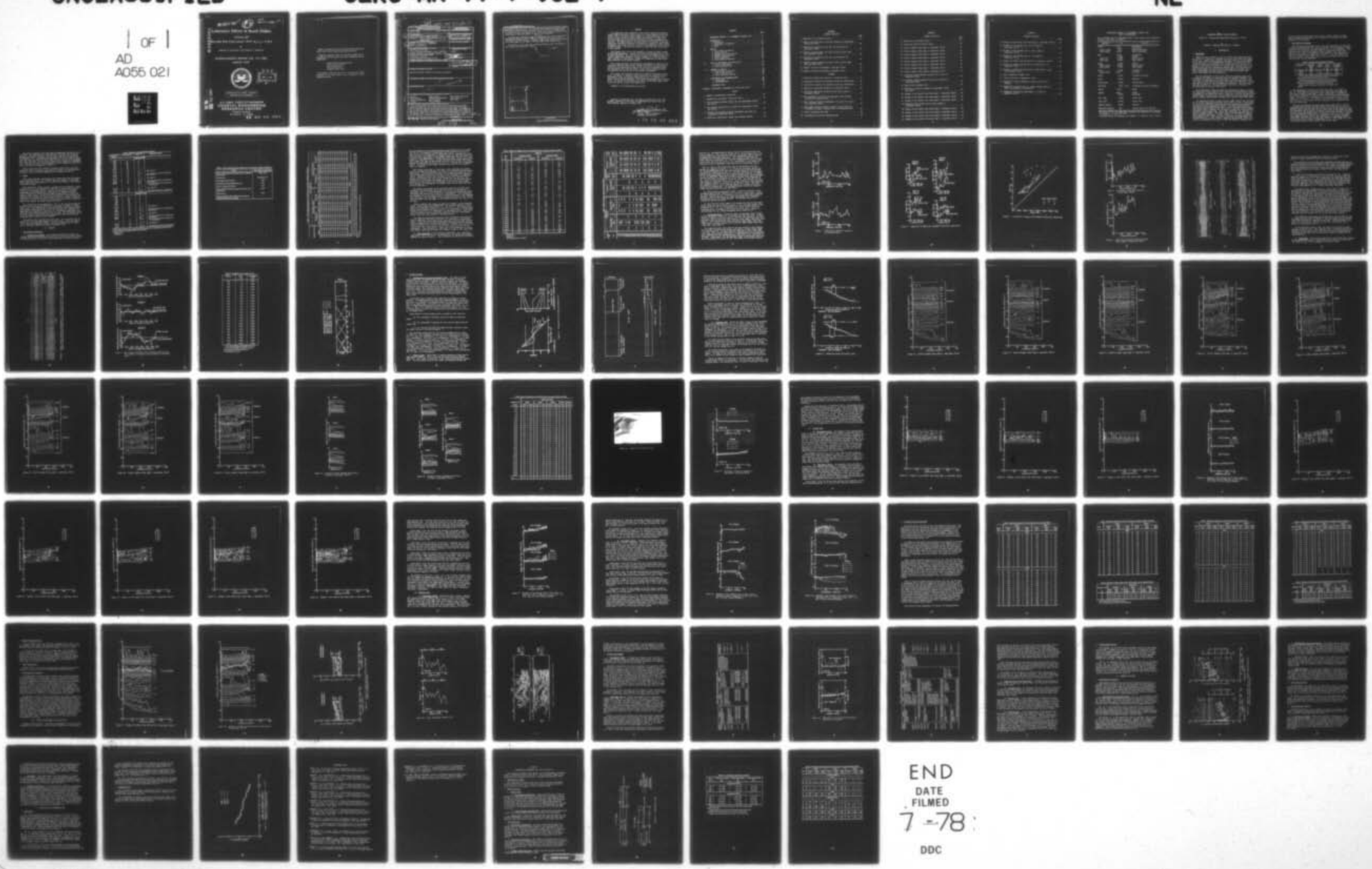

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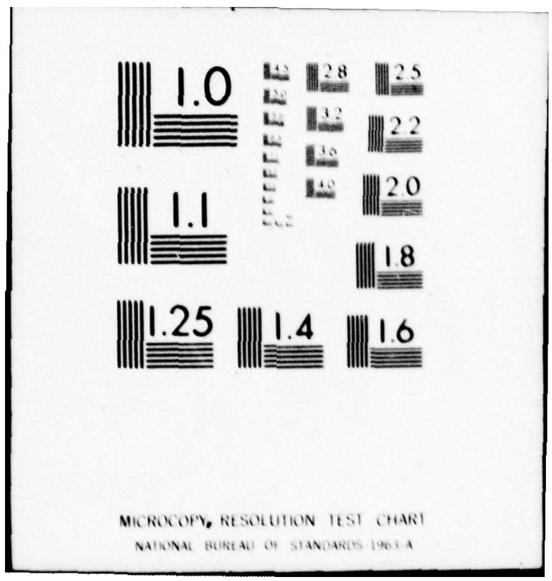

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MR 77-7 (VII)

Laboratory Effects in Beach Studies

Volume VII

Movable-Bed Experiments With $H_o/L_o = 0.013$

by

Charles B. Chesnutt and Robert P. Stafford

MISCELLANEOUS REPORT NO. 77-7 (VII)
MARCH 1978

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In two experiments with a wave period of 2.35 seconds on an initial movable-bed slope of 0.10 in tanks 6 and 10 feet wide, significant differences in profile shape and wave height variability developed. Secondary wave and re-reflection effects resulting from the 38.3-foot difference in distance from the wave generator to the profile toe caused differences in the shape of the offshore zone. The 0.15-foot gap at the end of the generator blade in the 10-foot tank and the critical combination of wavelength and tank width

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) generated a transverse wave. The transverse wave affected the profile shape--the shoreline became skewed, the depth over the shelf in the offshore zone increased laterally, and changes in the inshore zone progressed from one side of the tank to the other during the course of the experiment.

The reflection coefficient, K_R, varied from 0.03 to 0.14 in the 6-foot tank and the average in the 10-foot tank varied from 0.11 to 0.24, with considerable lateral variation. Changes in K_R in the 10-foot tank correlate well with changes in the shape of the upper part of the offshore zone.

The profile in the 6-foot tank reached equilibrium, while the profile in the 10-foot tank continued to change.

PREFACE

Ten experiments were conducted at the Coastal Engineering Research Center (CERC) from 1970 to 1972 as part of an investigation of the Laboratory Effects in Beach Studies (LEBS), to relate wave height variability to wave reflection from a movable-bed profile in a wave tank. The investigation also identified the effects of other laboratory constraints. The LEBS project is directed toward the solution of problems facing the laboratory researcher or engineer in charge of a model study; ultimately, the results will be of use to field engineers in the analysis of model studies. The work was carried out under the CERC coastal processes program.

This report (Vol. VII) is the seventh in a series of eight volumes on the LEBS experiments. Volume I describes the procedures used in the 10 LEBS experiments, and also serves as a guide for conducting realistic coastal engineering laboratory studies; Volumes II to VII are data reports covering all experiments; Volume VIII summarizes the LEBS experiments detailed in the earlier volumes.

This volume describes two movable-bed experiments in which the wave reflection variation and profile changes are shown to be affected by a transverse wave generated by gaps at the side of the generator blade. The experiments also show the effect of the initial distance between the generator and the profile on the profile development.

This report was prepared by Charles B. Chesnutt, principal investigator, and Robert P. Stafford, senior technician in charge of the two experiments, under the general supervision of Dr. C.J. Galvin, Jr., Chief, Coastal Processes Branch. The authors acknowledge the assistance of Dr. O.S. Madsen in identifying the sources of the wave height variability and for his review of the manuscript.

Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.

for Wilson P. Andrews LTC
JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.48	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1] To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: C = (5/9) (F -32).

To obtain Kelvin (K) readings, use formula: K = (5/9) (F -32) + 273.15.

LABORATORY EFFECTS IN BEACH STUDIES

Volume VII. Movable-Bed Experiments With $H_o/L_o = 0.013$

by
Charles B. Chesnutt and Robert P. Stafford

I. INTRODUCTION

1. Background.

Transverse waves caused by a gap at the end of the generator blade can affect the transport of sediment and create significant wave height variability. Madsen (1974) defined transverse waves in his development of the theory for a three-dimensional wavemaker. He pointed out that transverse waves can be generated for a water depth of 2.33 feet (0.71 meter), a tank width of 10 feet (3.0 meters), and a wave period of 2.35 seconds used in the two experiments reported here, and that transverse waves were probably the source of the considerable wave height variability observed by Fairchild (1970) for the same wave period, tank width, water depth, and wave generators.

The two experiments in this study offered an unplanned opportunity to quantify the effect of transverse waves on sediment transport. One experiment was conducted in a 6-foot-wide (1.8 meters) wave tank without a gap at either end of the blade, which made it essentially a control tank against which the other experiment was measured. The other experiment was conducted in a 10-foot-wide wave tank with a 0.15-foot (4.6 centimeter gap at one end of the blade.

These experiments (when designed) were conducted primarily to relate the variation of wave heights to the variation of wave reflection caused by changes in the movable-bed profile; and also, to define the equilibrium profile shape, at which point it was assumed that the wave height variability would be significantly reduced, and to identify tank width effects.

The Laboratory Effects in Beach Studies (LEBS) project was initiated at the Coastal Engineering Research Center (CERC) in 1966 to investigate the cause of wave height variability and other problems associated with movable-bed coastal engineering studies. Ten movable-bed laboratory experiments were conducted from 1970 to 1972 in the CERC Shore Processes Test Basin (SPTB) to measure the variation in reflection as the profile developed toward equilibrium. These LEBS experiments are reported in a series of eight volumes. This report (Vol. VII) describes two experiments conducted with $H_o/L_o = 0.013$. Volumes II, III, and IV (Chesnutt and Stafford, 1977a, 1977b, and 1977c) discussed five experiments conducted with $H_o/L_o = 0.021$; Volume V (Chesnutt and Stafford, 1977d) discussed one experiment with $H_o/L_o = 0.039$; and Volume VI (Chesnutt and

Stafford, 1978) two experiments with $H_o/L_o = 0.004$. Volume I of the series (Stafford and Chesnutt, 1977) discusses the contents and primary purposes of these reports.

2. Experimental Procedures.

The experimental procedures used in the LEBS experiments are described in Volume I which provides the necessary details on the equipment, quality control, data collection, and data reduction for all 10 experiments. Data collection and reduction procedures unique to experiments 72B-06 and 72B-10 in this study are documented in the Appendix. The conditions of these two experiments are summarized in Table 1. The table shows that the initial slope, water depth, wave period, wave height, and sand size were the same in both experiments.

Table 1. Summary of experimental conditions.

Experiment[1]	Initial test length (ft)	Initial slope	Wave period (s)	Generated wave height[2] (ft)
72B-06	93.0	0.10	2.35	0.34
72B-10	54.7	0.10	2.35	0.34

[1] Refer to Volume I (Stafford and Chesnutt, 1977) for relation between these experiments and the other eight LEBS experiments.

[2] Determined for the given wave period and constant water depth of 2.33 feet so that the generated-wave energy flux, computed from linear theory, had a constant value of 5.8 foot-pounds per second-foot.

NOTE.–Constant: initial d_{50} of sand (by dry sieve analysis) = 0.22 millimeter.

Two experimental facilities were used (see Figs. 3, 4, and 5 in Vol. I). Each facility consisted of two side-by-side wave tanks, one with a 0.10 concrete slope and the other a sand slope. A generator was common to each pair of tanks so that each had identical wave energy input. The operation of the generators is described in Section IV and Appendix B of Volume I. The concrete slope provided a control (benchmark value) for the varying reflection measured in the neighboring tank with the movable bed.

Two basic differences existed between the two facilities: (a) The tank width, where one pair of tanks (each 6 feet wide) was used for experiment 72B-06, and the other pair of tanks (each 10 feet wide) was used for experiment 72B-10; and (b) the gap at the ends of the generator blades of the 10-foot tank generator but not the 6-foot tank generator. (The gap, which was measured in March 1975, is discussed in Vol. I.) The initial test length (distance from the wave generator to the initial stillwater level (SWL) intercept) was 93 feet (28.3 meters) in experiment 72B-06 and 54.7 feet (16.7 meters) in experiment 72B-10. This length was 7 feet (2.1 meters) greater on the concrete side in both tanks.

The initial grading of the sand slope in experiment 72B-06 was on 12 July 1972. The first run was on 20 July 1972, the last run was on 20 September 1972 after 150 hours, and the data collection was completed 22 September 1972. Preparation for experiment 72B-10 was begun 14 July 1972, the first run was on 19 July 1972, the last run was on 21 September 1972 after 150 hours, and the data collection was completed 26 September 1972. The major events of each experiment and the cumulative time at the end of each run are summarized in Table 2.

Table 3 gives the data collection schedule within each 5-hour run. During the first 5 hours when runs varied in length, the same data were collected, with the schedule depending on the length of the run.

3. Scope.

This report describes and analyzes the reduced data from LEBS experiments 72B-06 and 72B-10. The original data are available in an unpublished laboratory memorandum (No. 6) (Leffler and Chesnutt, 1978) filed in the CERC library.

Wave reflection, profile surveys, sediment-size distribution, breaker characteristics, water temperatures, and current observations are discussed in the following section. Section III discusses (a) profile development, which examines the interrelation of changes in profile shape, sediment-size distribution, breaker characteristics, water temperature, and currents; and (b) profile reflectivity, which examines the interrelation of changes in profile shape, breakers, currents, and wave reflection. Section IV discusses the results of wave height variability, profile equilibrium, and other laboratory effects.

The conclusions and recommendations (Sec. V) are directed toward the problems of the laboratory researcher or engineer in charge of a model study. This study demonstrates a laboratory effect only recently identified (Madsen, 1974) and points out to the researcher the importance of measuring and recording all conditions in a laboratory experiment, even those which may appear insignificant at the time. Field engineers should be aware of these conclusions and recommendations when discussing and analyzing model studies of their projects.

The data in this study may have other uses. The researcher can use these short- and long-term changes in profile shape. After an analysis of the scale and laboratory effects, the field engineer may use these data to determine generalized profile adjustment rates.

II. RESULTS

1. Wave Height Variability.

a. Incident Wave Heights. Wave height measurements from the continuous recording of water surface elevation at the center range, station +25 during the first 10 minutes of each experiment are shown in Table 4.

Table 2. Schedule for experiments 72B-06 and 72B-10.

Cumulative time[1] (hr:min)	Wave record No.	Survey No.	Special data collected
		Experiment 72B-06	
0:00		1	
0:10	32	2	
0:40	33	3	
1:30	34	4	
3:00	35	5	
5:00	36	6	
10:00	37	7	
......[2]	...[3]	......[3]	
30:00	41	11	Wave reflection
......[2]	...[3]	......[3]	
50:00	45	15, S1	Sand samples, profile surveys, ripple photos
55:00	46	16	Wave reflection
......[2]	...[3]	......[3]	
80:00	51	21	Wave reflection
......[2]	...[3]	......[3]	
100:00	55	25, S2	Sand samples, profile surveys, ripple photos
105:00	56	26	Wave reflection
		26, S2	Sand samples, profile surveys, ripple photos, wave reflection
......[2]	...[3]	......[3]	
130:00	61	31	Wave reflection
......[2]	...[3]	......[3]	
150:00	65	35, S3	Sand samples, profile surveys, ripple photos
		Experiment 72B-10	
0:00		1	
0:10	21	2	
0:40	22	3	
1:30	23	4	
3:00	24	5	
5:00	25	6	
10:00	26	7	
......[2]	...[3]	......[3]	
30:00	30	11	Wave reflection
......[2]	...[3]	......[3]	
50:00	34	15, S1	Sand samples, profile surveys, ripple photos
55:00	35	16	Wave reflection
......[2]	...[3]	......[3]	
80:00	40	21	Wave reflection
......[2]	...[3]	......[3]	
100:00		25, S2	Sand samples, profile surveys, ripple photos
105:00		26	Wave reflection
	45	26, S2	Sand samples, profile surveys, ripple photos, wave reflection
......[2]	...[3]	......[3]	
130:00	50	31	Wave reflection
......[2]	...[3]	......[3]	
150:00	54	35, S3	Sand samples, profile surveys, ripple photos

[1]Wave records were taken *during* run ending at cumulative time shown; surveys, sand samples, and ripple photos were taken *after* run ending at the cumulative time shown (see also Table 3).

[2]Increments of 5.

[3]Increments of 1.

Table 3. Data collection schedule within runs for experiments 72B-06 and 72B-10.

Event	Time within runs (hr:min)
Photo of SWL intercept and upper slope, if damaged since last run	Before start
Current data	Throughout run
Recording of wave envelope	4:40
Preparation of visual observation form	4:55
Photos of runup and breaker	4:59
Photo of SWL intercept and upper slope, after water had calmed	5:00
Profile survey	5:00
Water temperature data collected in morning and afternoon of each day of testing.	

Table 4. Wave heights during first 10 minutes for experiments 72B-06 and 72B-10.

Cumulative time	Wave height (ft)											
	Experiment 72B-06						Experiment 72B-10					
	Movable bed			Fixed bed			Movable bed			Fixed bed		
(min:s)	(avg)	(max)	(min)	(avg)	(max)	(min)	(avg)	(max)	(min)	(avg)	(max)	(min)
0:00 to 0:20	0.332[1]	0.360	0.312	0.336	0.364	0.309	0.312[1]	0.336	0.294	0.315	0.339	0.280
0:20 to 0:40	0.357[2]	0.350	0.321	0.348	0.396	0.315	0.344[2]	0.376	0.315	0.311	0.328	0.284
0:40 to 1:20	0.375	0.400	0.359	0.360	0.387	0.344	0.380	0.406	0.351	0.291	0.309	0.274
1:40 to 2:20	0.386	0.410	0.356	0.350	0.357	0.340	0.356	0.376	0.326	0.284	0.304	0.267
2:40 to 3:20	0.401	0.416	0.387	0.351	0.388	0.326	0.366	0.375	0.345	0.291	0.328	0.258
3:40 to 4:20	0.410	0.418	0.384	0.359	0.384	0.327	0.376	0.392	0.363	0.290	0.303	0.276
4:40 to 5:20	0.408	0.435	0.386	0.351	0.375	0.324	0.355	0.363	0.338	0.300	0.286	0.269
5:40 to 6:20	0.405	0.441	0.421	0.341	0.374	0.314	0.333	0.342	0.324	0.291	0.304	0.274
6:40 to 7:20	0.404	0.422	0.380	0.351	0.375	0.318	0.349	0.369	0.320	0.292	0.308	0.280
7:40 to 8:20	0.419	0.447	0.400	0.345	0.386	0.321	0.350	0.360	0.334	0.293	0.322	0.280
8:40 to 9:20	0.432	0.450	0.412	0.357	0.378	0.328	0.345	0.362	0.326	0.307	0.336	0.279
9:20 to 10:00	0.419	0.442	0.390	0.341	0.358	0.304	0.343	0.356	0.333	0.317	0.342	0.286
Avg[3]	0.406			0.351			0.355			0.296		

[1]Waves 3 to 8 with some distortion and reflection from beach slope, which appears near crest on waves affected (both channels).

[2]Waves 10 to 18. Distortion appears as in first waves, but more randomly throughout the wave (both channels); distortion continues rather slight, nearly always on back side of wave in sand channel. Waves much smaller in concrete channel, with both trough and crest of many waves cut out by distortion.

[3]Excludes averages for cumulative times 0:00 to 0:20 and 0:20 to 0:40.

The wave heights in the movable-bed tanks varied from 0.31 to 0.45 foot (9.4 to 13.7 centimeters) in experiment 72B-06 and from 0.29 to 0.41 foot (8.8 to 12.5 centimeters) in experiment 72B-10. Ignoring the first group of waves, the range of wave heights within the first 10 minutes was 0.13 foot (4.0 centimeters) in experiment 72B-06 and 0.09 foot (2.7 centimeters) in experiment 72B-10. In the fixed-bed tanks, again ignoring the first group, the range of wave height variation was 0.10 foot (3.0 centimeters) in experiment 72B-06 and 0.07 foot (2.1 centimeters) in experiment 72B-10. The range of wave height variation was lower in the fixed-bed tanks, as expected.

The average wave height in each tank of each experiment was determined by averaging the average of 10 waves in a 40-second interval during each minute. In the movable-bed tank, the average wave height was 0.41 foot in experiment 72B-06 and 0.36 foot (11.0 centimeters) in experiment 72B-10. Because the waves were recorded at the same distance from the profile and assuming that the initial reflectivity was the same, the difference in the average wave height was not due to reflection from the profile, but likely due to the difference in the initial test length, which affects the development of secondary waves and re-reflection from the wave generator.

The average wave height in the fixed-bed tanks was 0.35 foot (10.7 centimeters) in experiment 72B-06 and 0.30 foot (9.1 centimeters) in experiment 72B-10. In each experiment, the difference between the fixed- and movable-bed tanks was 0.06 foot (1.8 centimeters). This difference was probably due to the gage position at different points in the standing wave envelope, since the gages in the fixed-bed tanks were 7 feet farther from the profile than the gages in the movable-bed tanks (see Fig. A-1 in the App.).

Table 5 presents the average incident wave heights in both fixed-bed tanks. These heights were determined by the automated method for determining the reflection coefficient, K_R (see Vol. I). The range of variation in the fixed-bed tank was 0.05 foot (1.5 centimeters) in experiment 72B-06 and 0.04 foot (1.2 centimeters) in experiment 72B-10. This variation was probably caused by generator operation variation, measurement errors, and errors not caused by a changing profile.

The range of wave height variation in the movable-bed tank was 0.06 foot in experiment 72B-06 and 0.03 foot (0.9 centimeter) in experiment 72B-10. There was little significant difference in wave heights between fixed and movable bed of either experiment, indicating that the changing profile accounted for little of the variation. However, there was significant difference in the average incident wave heights between the two experiments. This difference is likely due to the difference in initial test length, which was 38.3 feet (11.7 meters) longer in the 6-foot tank.

b. Wave Reflection. The reflection coefficient, K_R, data from experiments 72B-06 and 72B-10, as determined by the manual and automated methods, are given in Table 6. The two methods are described in Volume I.

Table 5. Incident wave heights in fixed- and movable-bed tanks for experiments 72B-06 and 72B-10.

Time	Height (ft)			
	Experiment 72B-06[1]		Experiment 72B-10[2]	
(hr)	Movable bed	Fixed bed	Movable bed	Fixed bed
0.66	------[3]	------	------	------
1.50	------	------	0.32	0.32
3.00	------	------	0.31	0.32
5.00	0.37	0.35	------	------
10.00	0.39	0.37	0.32	0.33
15.00	------	------	0.33	0.34
20.00	0.37	0.34	0.32	0.32
25.00	0.38	0.34	0.32	0.33
30.00	0.35	0.37	------	------
35.00	------	------	------	------
40.00	0.38	0.37	0.31	0.34
45.00	0.39	0.37	------	------
50.00	------	------	0.32	0.33
55.00	0.38	0.39	0.31	0.35
60.00	------	------	------	------
65.00	------	------	0.31	------
70.00	0.37	0.35	0.31	0.35
75.00	------	------	------	------
80.00	0.38	------	------	------
85.00	------	------	0.31	------
90.00	0.39	0.36	0.32	0.35
95.00	------	------	0.31	0.34
100.00	------	------	------	------
105.00	0.36	0.37	0.32	0.36
110.00	0.40	0.36	0.32	0.36
115.00	0.40	0.37	------	------
120.00	0.39	0.35	0.31	0.34
125.00	0.40	0.39	0.33	------
130.00	0.40	0.36	0.30	0.35
135.00	0.41	0.39	------	------
140.00	0.39	0.36	0.30	0.34
145.00	0.39	------	0.31	0.34
150.00	0.38	0.35	0.30	0.33
Avg	0.38	0.36	0.31	0.34

[1]Range 3 only.
[2]Range 5 only.
[3]Data for these times were not reduced.

Table 6. Reflection coefficients, manual and automated methods.

Cumulative time	Manual method						Automated method							
	Movable bed						Movable bed			Fixed bed	Movable bed			Fixed bed
	Experiment 72B-6			Experiment 72B-10			Experiment 72B-06				Experiment 72B-10			
(hr)	Range			Range			Range			Range	Range			Range
	1	3	5	1	5	9	1	3	5	3	1	5	9	5
0:16														
0:66		0.219		0.405	0.203	0.279								
1:50		0.133									0.086	0.147	0.166	0.050
3:00		0.189		0.281		0.298					0.103	0.153	0.082	0.024
5:00								0.043		0.031				
10:00				0.308		0.286		0.078		0.027	0.096	0.177	0.137	0.056
15:00		0.135									0.098	0.122	0.158	0.055
20:00								0.057		0.035	0.057	0.121	0.156	0.050
25:00	0.153	0.133	0.155					0.041		0.034	0.080	0.120	0.160	0.045
30:00		0.163		0.220	0.204	0.246	0.082	0.043	0.088	0.064				
35:00											0.103	0.131	0.153	0.049
40:00								0.087		0.029	0.138	0.202	0.196	0.046
45:00				0.325	0.225	0.286		0.074		0.034				
50:00		0.169									0.117	0.155	0.192	0.039
55:00	0.144	0.144	0.158	0.187	0.207	0.276	0.082	0.065	0.073	0.058	0.128	0.144	0.172	0.066
60:00		0.159		0.276	0.256	0.346								
65:00		0.157									0.113	0.145	0.177	
70:00				0.327	0.234	0.244		0.080		0.040	0.112	0.152	0.187	0.057
75:00		0.170		0.254	0.252	0.340								
80:00	0.147	0.142	0.144	0.273	0.214	0.286	0.075	0.110	0.073					
85:00		0.191									0.112	0.173	0.178	
90:00								0.100		0.040	0.117	0.161	0.178	0.085
95:00		0.161									0.185	0.202	0.151	0.050
100:00		0.184		0.328	0.312	0.353								
105:00	0.153	0.180	0.174	0.256	0.250	0.256	0.097	0.128	0.094	0.035	0.187	0.197	0.157	0.054
110:00								0.093		0.039	0.170	0.213	0.128	0.039
115:00								0.090		0.054	0.221		0.196	
120:00					0.304			0.075		0.052	0.219	0.202	0.147	0.046
125:00				0.298	0.297	0.321		0.137		0.039				
130:00	0.186	0.175	0.173	0.347	0.282	0.290	0.114	0.094	0.106	0.034	0.237	0.208	0.135	0.049
135:00				0.340	0.303	0.346		0.104		0.060				
140:00								0.136		0.034	0.223	0.213	0.194	0.070
145:00				0.356		0.338		0.103		0.049	0.184	0.183	0.144	0.056
150:00				0.418		0.327		0.112		0.029				0.046

Plots of K_R (automated method) versus time in the fixed-bed tanks are shown in Figure 1. The fixed-bed values of K_R varied from 0.03 to 0.06 in experiment 72B-06 and from 0.02 to 0.09 in experiment 72B-10, with no long-term drift in either experiment. This variation represents all errors involved in measuring K_R from the changing profile in the neighboring tanks, and thus the error in K_R measurements in the movable-bed tanks was ±0.015 in experiment 72B-06 and ±0.035 in experiment 72B-10.

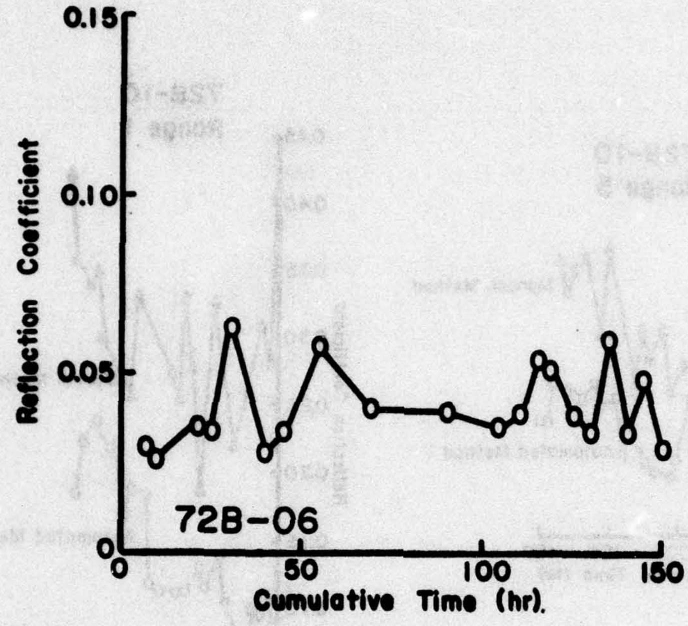
The K_R data in the movable-bed tanks as determined by the two methods are compared in Figure 2. K_R values for the manual method versus the automated method for those wave records reduced by both methods are shown in a scatter plot (Fig. 3). The plot indicates that the manual method values were higher than the automated method values by an average of 0.07 in experiment 72B-06 and in range 5 of experiment 72B-10 (enclosed points), and that the difference was not a function of the magnitude of K_R, since the data are parallel to the 45° line. The data for the outside ranges in experiment 72B-10 show a larger difference between methods and a greater scatter, as a result of the transverse wave. The effect of the transverse wave on a wave envelope appears as a longer wave superposed on the standing wave. The automated method removes any long wave effect and thus would have been much lower.

K_R versus time for experiment 72B-06 is plotted in Figure 4, with the manual method values reduced by 0.07 to give a single curve. During the first 30 hours the K_R fluctuated, but the maximum values gradually declined. After 30 hours the K_R began increasing, with continuing fluctuations about the increasing mean. The maximum value of 0.14 occurred at 125 and 140 hours.

K_R data from the center range of the movable-bed tank of experiment 72B-10 versus time are plotted in Figure 5, with the manual method values reduced by 0.07. The K_R increased for the first 10 hours and then fluctuated about an average 0.16 between 10 and 90 hours. During the last 60 hours the K_R values fluctuated about a mean of 0.21.

c. Transverse Waves. Transverse waves in experiment 72B-10 caused the wave to appear to wobble as it traveled down the wave tank. At about station 40 (about 15 feet (4.6 meters) from the wave generator) the crest was higher than the generated wave (range 5) along range 1 and lower along range 9. Near station 25 the crest was higher along range 9 and lower along range 1 and near station 10 the crest was again higher along range 1 and lower along range 9.

The transverse wave can be seen in the wave records of the standing wave envelope recorded by the moving wave gage at 55 hours along ranges 1, 5, and 9 (Fig. 6). Assuming that the variation is due to the transverse wave, the envelope along range 5 is representative of the generated wave, unaffected by the transverse wave, since this is the centerline of the tank. Along range 1 the maximum wave height occurred near station 25 and the minimum near station 39, and along range 9 the maximum occurred



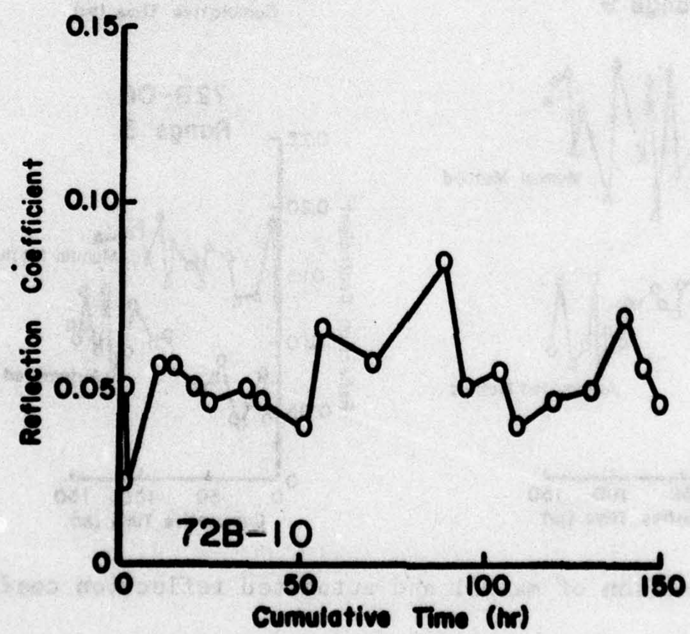


Figure 1. Reflection coefficient variation in fixed-bed tanks.

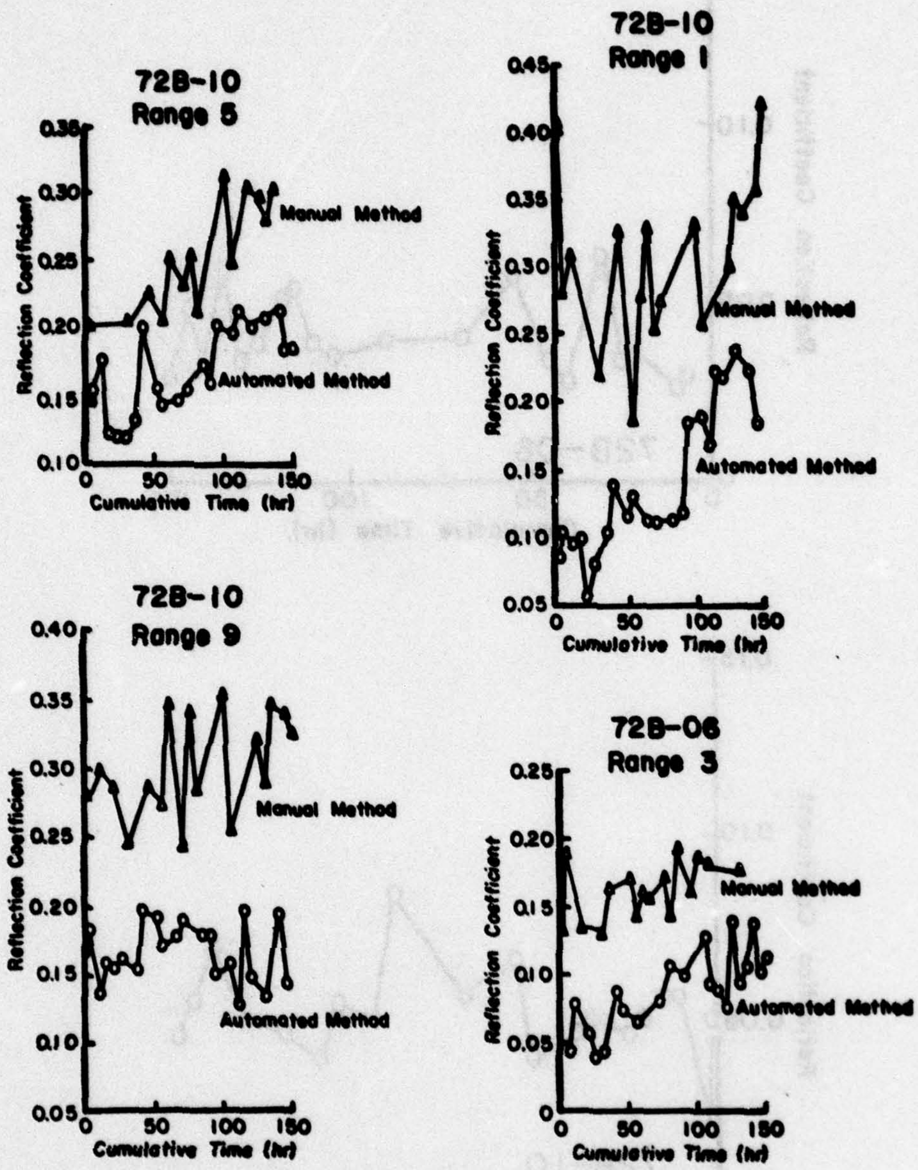


Figure 2. Comparison of manual and automated reflection coefficients.

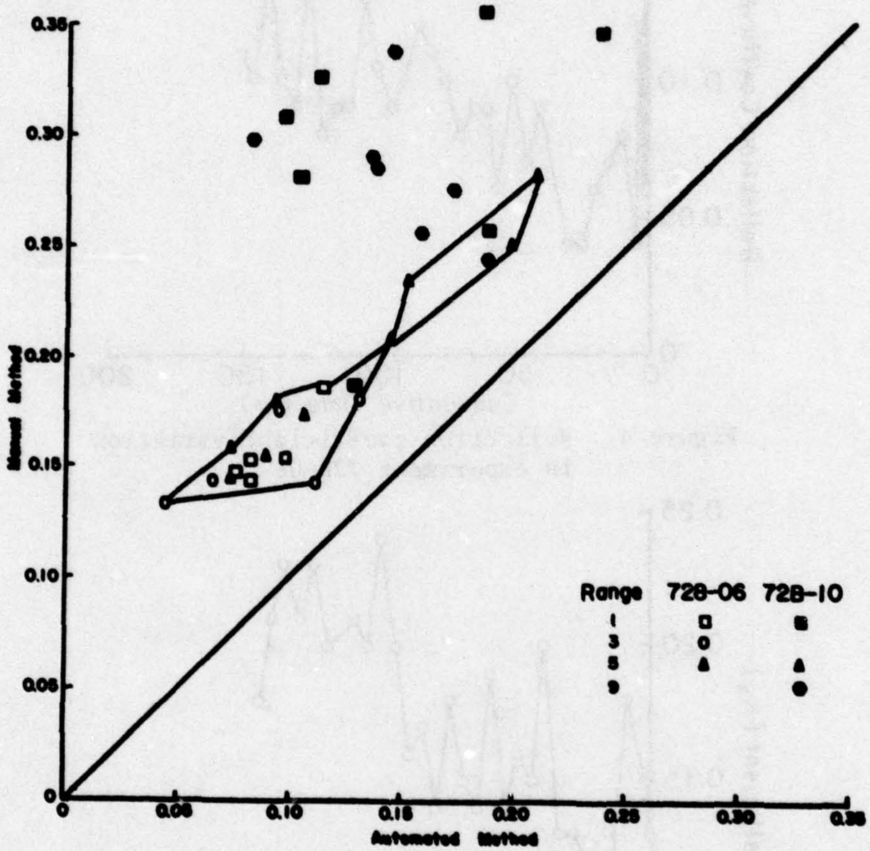


Figure 3. Correlation of manual and automated reflection coefficients.

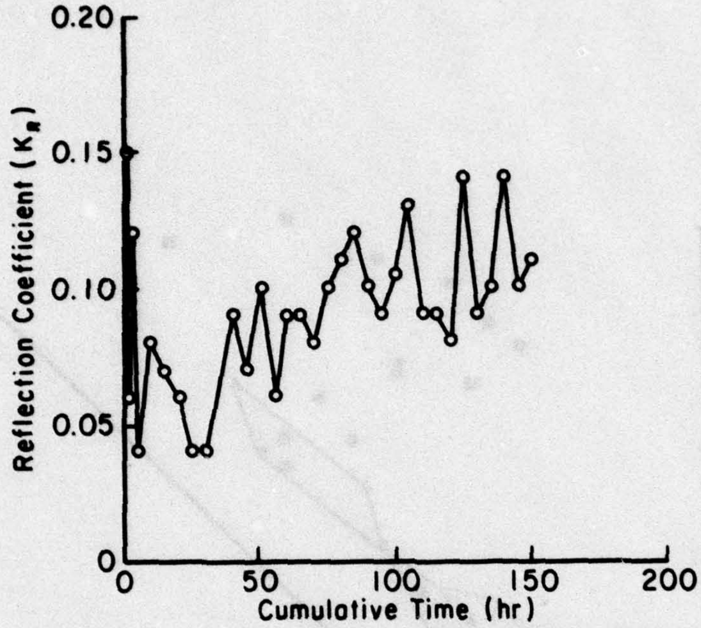


Figure 4. Reflection coefficient variation in experiment 72B-06.

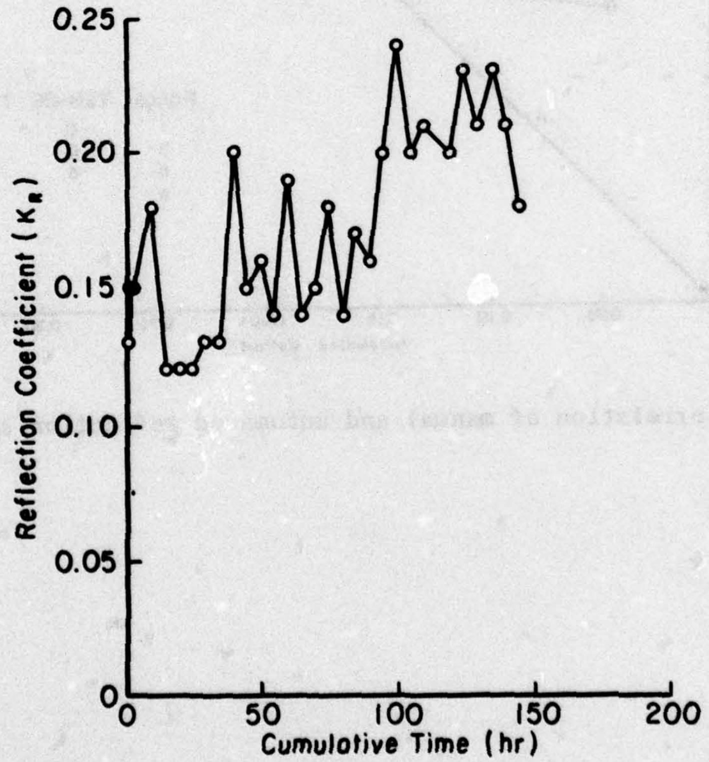


Figure 5. Reflection coefficient variation along center range in experiment 72B-10.

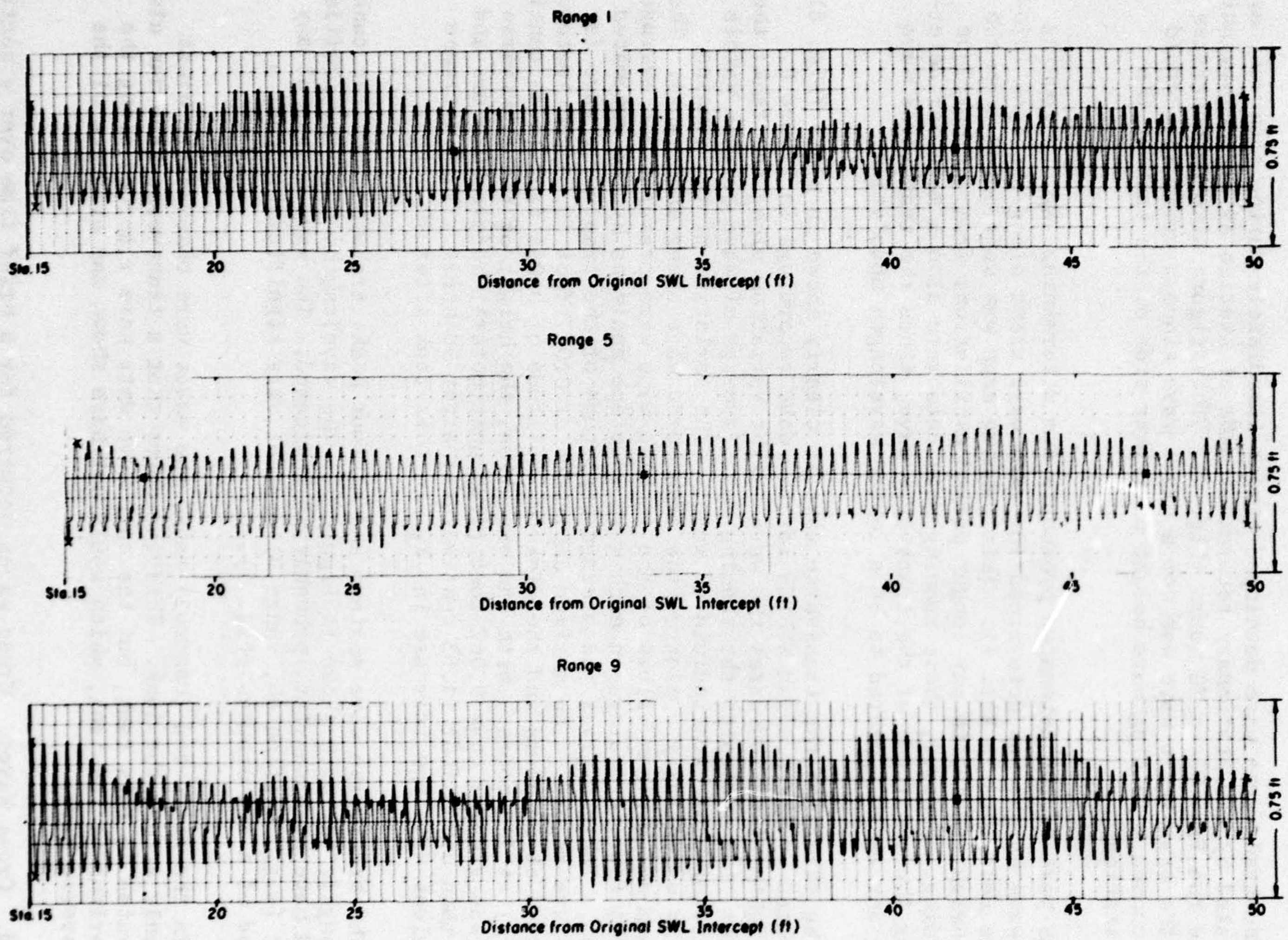


Figure 6. Wave envelopes at 55 hours in experiment 72B-10 showing existence of transverse wave (chart speed, 2 millimeters per second; carriage speed, 3 millimeters per second).

near station 40 and the minimum near station 25 (a depression in what would be a higher antinode without the transverse wave).

The transverse wave developed almost immediately during each run, as indicated by the stationary recordings made at station 40 at the beginning of the run from 65 to 70 hours (Fig. 7). This figure also demonstrates that the transverse wave was not a cross wave since a cross wave would have caused a varying wave height on either side of the tank at the same station.

As part of the automated procedure for determining K_R, a running mean wave height was determined for each wave crest along the tank (procedure described in Vol. I). This running mean was subtracted from the wave height to smooth any longer period oscillations from the envelope recording. However, these running mean data were also a means of determining the amplitude of the transverse wave, since the transverse wave along any range appeared to be a longer wavelength modulation.

The effect of the transverse wave is clearly shown in plots (Fig. 8) generated by the program WVHTCN for the wave recordings in Figure 6. The lighter line indicates the wave height variation along the tank; the heavier line indicates the running mean (average of wave heights within a wavelength of each individual wave). The variation of the running mean is essentially a plot of the transverse wave along each range. The maximum and minimum values of the running mean were measured and averaged for the four recordings on each wave envelope analyzed by the automated method. Table 7 gives the average amplitude of the transverse wave for each wave record. The maximum amplitude of 0.077 foot (2.35 centimeters) occurred at 50 hours and the minimum amplitude of 0.038 foot (1.16 centimeters) at 140 hours. With one exception, the height of the transverse wave was greater than 0.062 foot (1.89 centimeters) before 90 hours and less than 0.060 foot (1.83 centimeters) after 90 hours. This decrease coincides with the increase in K_R in this tank after 90 hours.

The transverse wave maximum and minimum peaks traveled down the tank in roughly the path shown in Figure 9. The wavelengths over the profile would have been shorter, probably as indicated. The wave height at any point (e.g., station 40, range 9) did not vary significantly over a period of a few minutes (Fig. 7).

In the fixed-bed (control) tank, the waves were observed to break unevenly across the tank. This indicates that a transverse wave was also generated in this tank, but the only wave data were recorded along the centerline of the tank, which would not have shown any evidence of the transverse wave.

d. Cross Waves. Cross waves occurred for a brief time over a section of the movable-bed profile in experiment 72B-06, but were not measured. The effect, if any, was not apparent in the profile data.

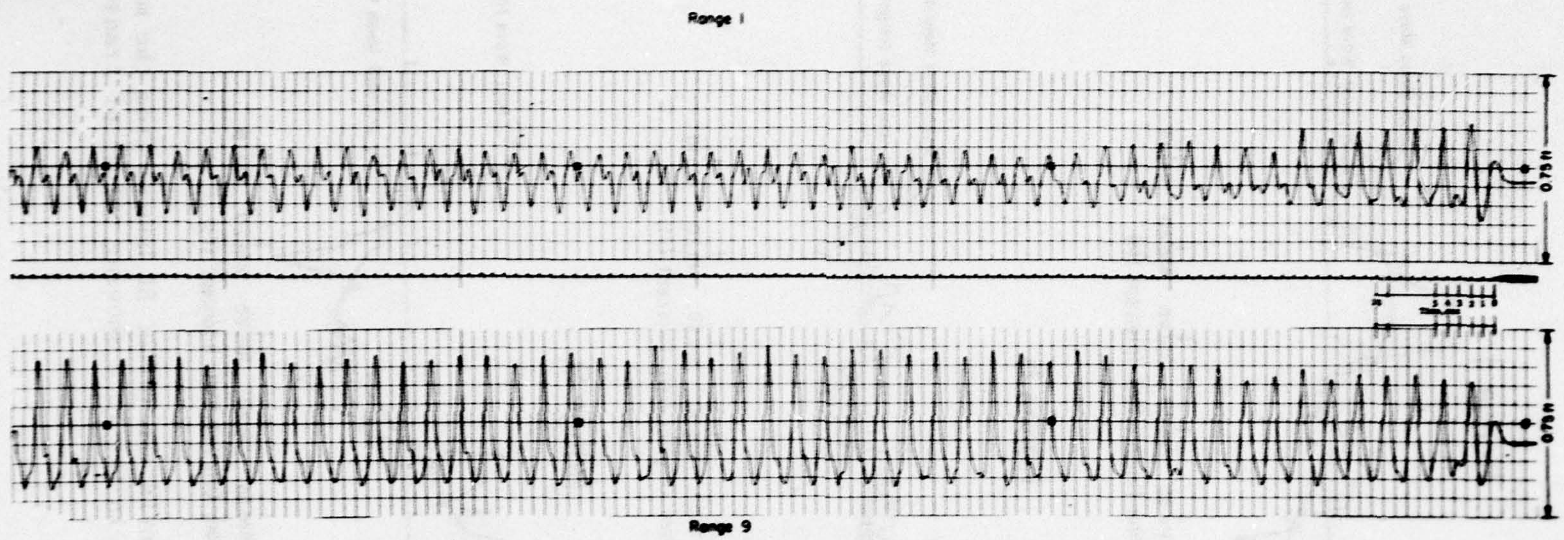


Figure 7. Water surface elevation recordings at 65 hours for station 40, experiment 72B-10, showing lateral variation in wave height caused by transverse wave (carriage speed stationary).

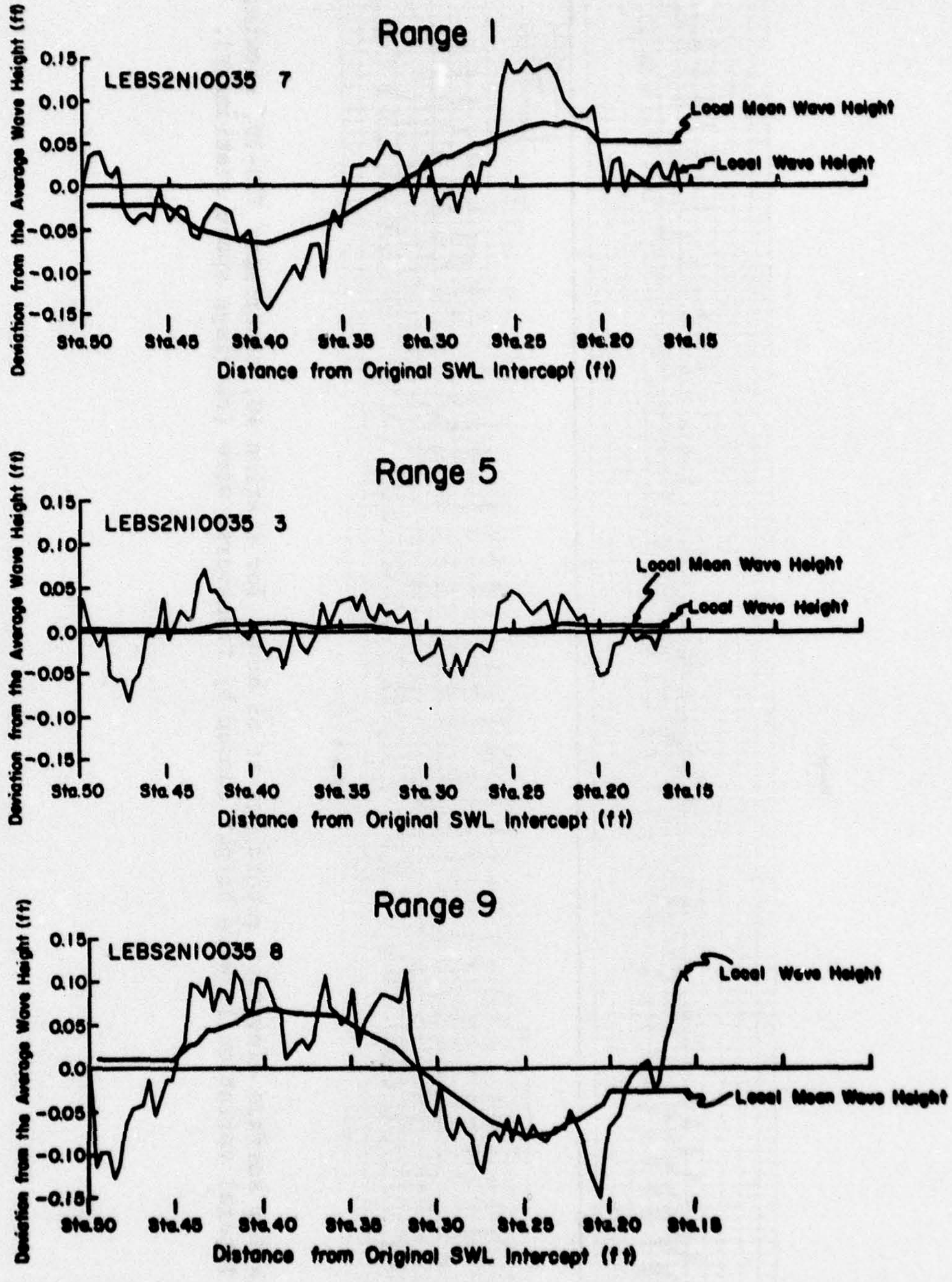


Figure 8. Wave height deviation (after 55 hours) from the mean for envelopes in Figure 6 showing effect of transverse waves.

Table 7. Amplitude of the transverse wave.

Roll No.	Time (hr)	Avg height (ft)
023	1.5	0.063
024	3.0	0.048
026	10.0	0.066
027	15.0	0.075
028	20.0	0.071
029	25.0	0.068
031	35.0	0.062
032	40.0	0.070
034	50.0	0.077
035	55.0	0.067
037	65.0	0.070
038	70.0	0.065
041	85.0	0.063
042	90.0	0.071
043	95.0	0.052
044	100.0	0.042
045	105.0	0.059
046	110.0	0.039
047	115.0	0.048
048	120.0	0.043
050	130.0	0.044
052	140.0	0.038
053	145.0	0.060

Note.—Values determined at amplitude of the curve of local mean wave height versus distance along the tank, as part of the automated method for determining K_R (see Vol. I).

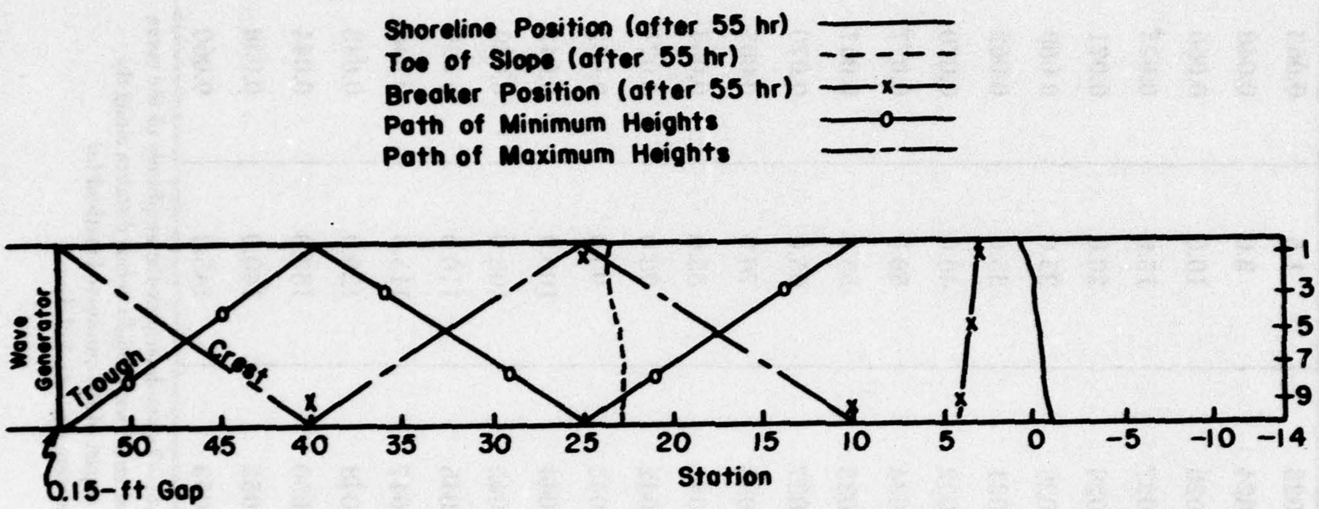


Figure 9. Path of transverse wave peak.

2. Profile Surveys.

a. Interpretation of Contour Movement Plots. The profile surveys (discussed in Vol. I) measured the three space variables of onshore-offshore distance (station), longshore distance (range), and elevation at fixed times (indicated in Table 2) during the experiment. The CONPLT method (see Vol. I) for presenting the data involves fixing the longshore distance by selecting data from a given range and analyzing the surveys along that range. The surveyed distance-elevation pairs along that range are used to obtain the interpolated position of equally spaced depths; e.g., -0.1, -0.2, and -0.3 on the hypothetical profile in Figure 10(a). These contour positions from each survey are then plotted against time (Fig. 10,b).

A horizontal line in Figure 10(b) represents no change in contour position. An upward-sloping line indicates landward movement of contour position (i.e., erosion); a downward-sloping line indicates seaward movement (i.e., deposition). The slope of a line indicates the rate of erosion or deposition (horizontally) at that elevation. The three x's at time t_2 (Fig. 10,b) indicate multiple contour positions at -0.2-foot elevation which is shown by the intersection of the dashline with profile t_2 in Figure 10(a).

Three types of contour movement plots included in this study are:

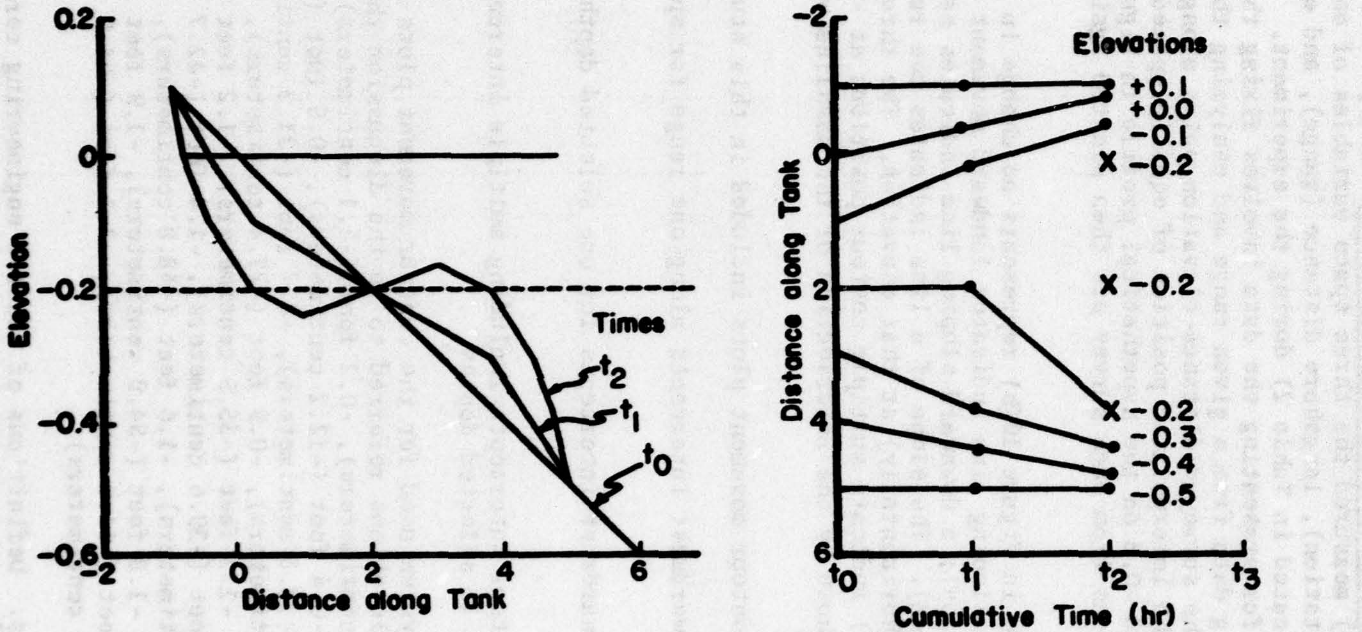
(a) The seawardmost intercepts along one range for specified depths;

(b) the seawardmost intercepts for one selected depth along all ranges; and

(c) all contour intercepts including multiple intercepts along one range, for up to 12 selected depths.

The coordinate system used for the contour movement plots is shown in Figure 11. The elevations referred to in the discussion that follows are: 0.1 foot (3.0 centimeters), -0.2 foot (-6.1 centimeters), -0.3 foot (-9.1 centimeters), -0.4 foot (-12.2 centimeters), -0.5 foot (-15.2 centimeters), -0.6 foot (-18.3 centimeters), -0.7 foot (-21.3 centimeters), -0.8 foot (-24.4 centimeters), -0.9 foot (-27.4 centimeters), -1.0 foot (-30.5 centimeters), -1.1 feet (-35.5 centimeters), -1.2 feet (-36.6 centimeters), -1.3 feet (-39.6 centimeters), -1.4 feet (-42.7 centimeters), -1.5 feet (-45.7 centimeters), -1.6 feet (-48.8 centimeters), -1.7 feet (-51.8 centimeters), -1.8 feet (-54.9 centimeters), -1.9 feet (-59.9 centimeters), -2.0 feet (-61.0 centimeters), -2.1 feet (-64.0 centimeters), and -2.2 feet (-67.1 centimeters).

b. Profile Zones. Definitions of coastal engineering terms used in LEBS reports conform to Allen (1972) and the Shore Protection Manual (SPM) (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1977). For the profile zones in this study, the boundary between the



a. Profile Line

b. Movement of Contour Position

Figure 10. Interpretation of contour movement plots.

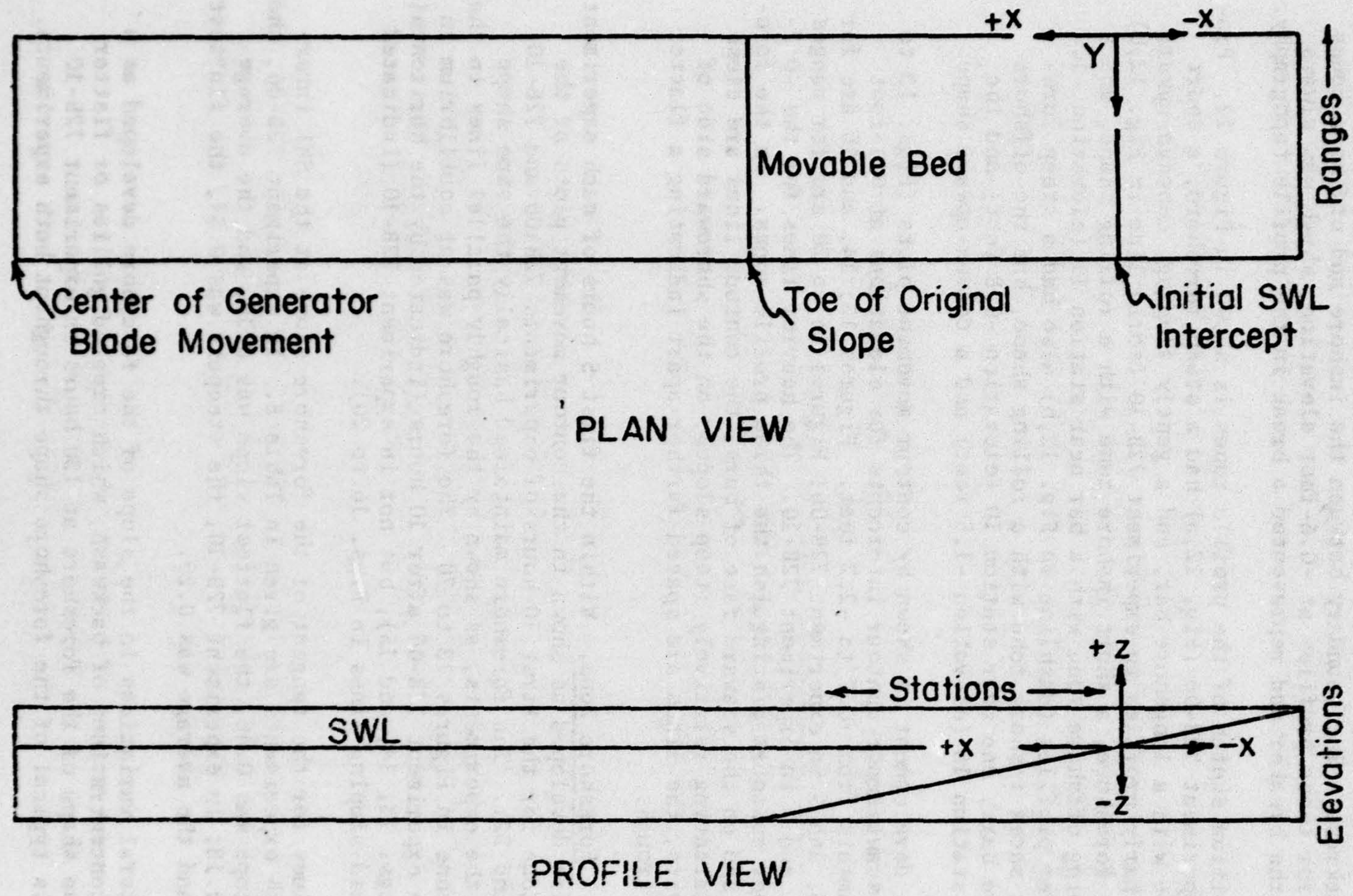


Figure 11. Definition of coordinate system.

foreshore and inshore zone occurred at elevation -0.2 foot, the lower limit of backrush. The boundary between the inshore and offshore zones is defined for these profiles at -0.6-foot elevation, which was always seaward of the breaker and represented a break in the profile topography.

A definition sketch of the profile zones is shown in Figure 12. Profiles in experiment 72B-06 (Fig. 12,a) had a steep foreshore, a short inshore zone with a longshore bar, and a gently sloping, concave-upward offshore. Early profiles in experiment 72B-10 (solid line in Fig. 12,b) had a steep foreshore, a short inshore zone with a rolling shape, and a gently sloping offshore zone with a bar near station 11 (elevation -1.0 foot). Later profiles (dashline in Fig. 12,b) also had a steep foreshore and a short inshore zone with a rolling shape, but the offshore zone had two bars, one near station 10 (elevation -0.8 foot) and the other near station 18 (elevation -1.5 feet) and a convex-upward shape.

Profile development is shown by contour movement plots (Figs. 13 to 20) of the seawardmost contour intercepts for elevations at 0.1-foot depth increments from +0.7 to -2.2 feet. Figures 13, 14, and 15 are for ranges 1, 3, and 5 in experiment 72B-06; Figures 16 to 20 are for ranges 1, 3, 5, 7, and 9 in experiment 72B-10. The heavier lines for the -0.2- and -0.6-foot contours distinguish the three profile zones. In the foreshore zone and on the seaward face of bars, the contour lines are close together indicating relatively steep slopes; on the shoreward side of the bar crests, the lines are spaced farther apart indicating a flatter slope or a trough.

(1) Foreshore Zone. Within the first 5 hours of each experiment the foreshore developed as shown in the contour movement plots of the foreshore zone for the first 10 hours of experiments 72B-06 and 72B-10 (Figs. 21 and 22). The foreshore maintained basically the same shape throughout the experiments, as shown by the roughly parallel lines in the foreshore zone in Figures 13 to 20. The foreshore was at equilibrium in position in experiment 72B-06 after 10 hours (indicated by the horizontal lines in Figs. 13, 14, and 15), but not in experiment 72B-10 (indicated by the upward-sloping lines in Figs. 16 to 20).

The values for the tangent of the foreshore slope at the SWL intercept in both experiments are given in Table 8. In experiment 72B-06, the steepest slope was 0.46, the flattest slope was 0.10, and the average slope was 0.18; in experiment 72B-10, the steepest was 0.54, the flattest was 0.10, and the average was 0.20.

The lateral variations in the slope of the foreshore developed as a result of concentrations of backwash, which created gullies or flatter slopes. The shape of the foreshore at 130 hours in experiment 72B-10 (Fig. 23) is typical of the foreshore shape throughout both experiments.

Figure 24 compares the shoreline (0 contour) movement along the several ranges of the two experiments. The shoreline (and foreshore zone) prograded about 1 foot during the first 10 hours in experiment 72B-06 and

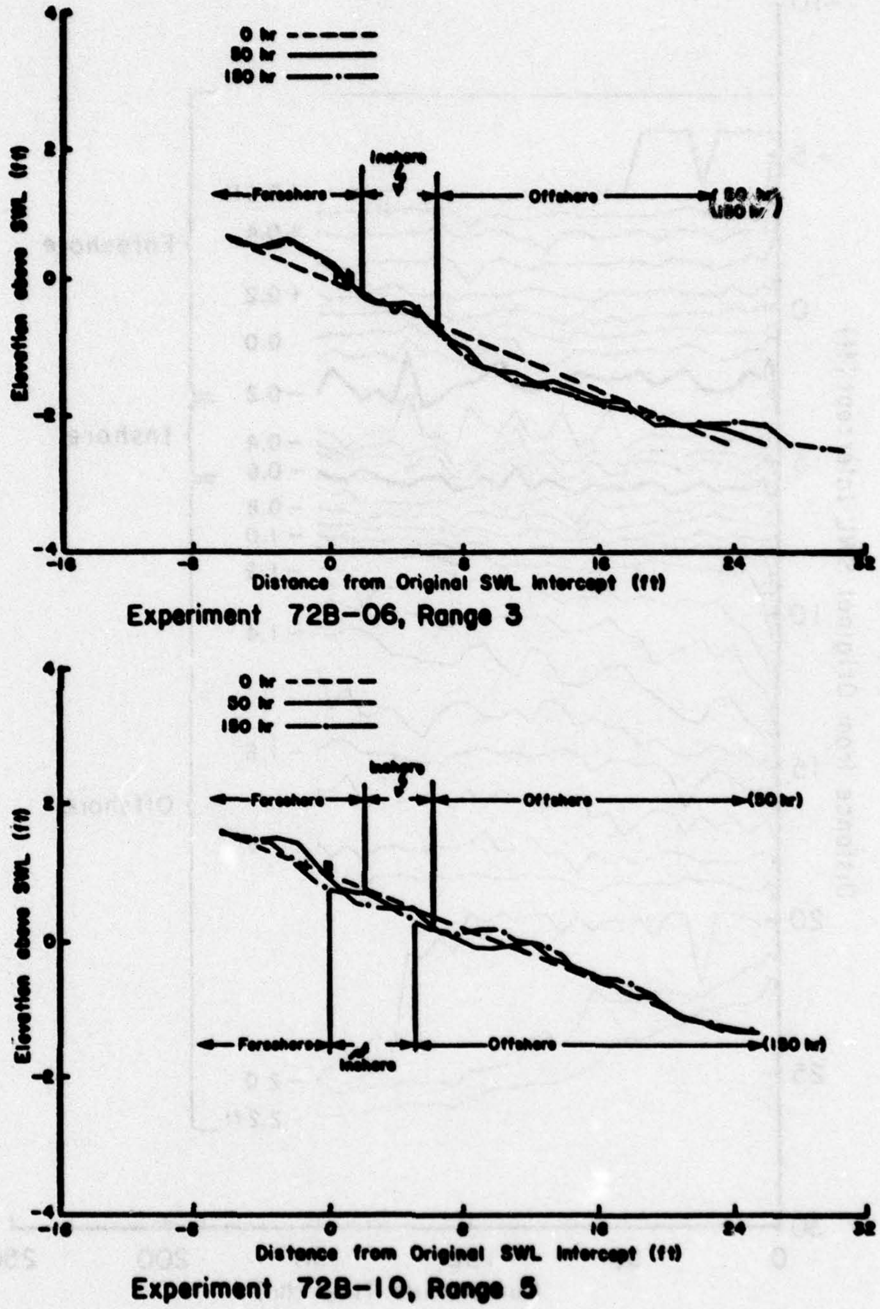


Figure 12. Definition sketch of profile zones.

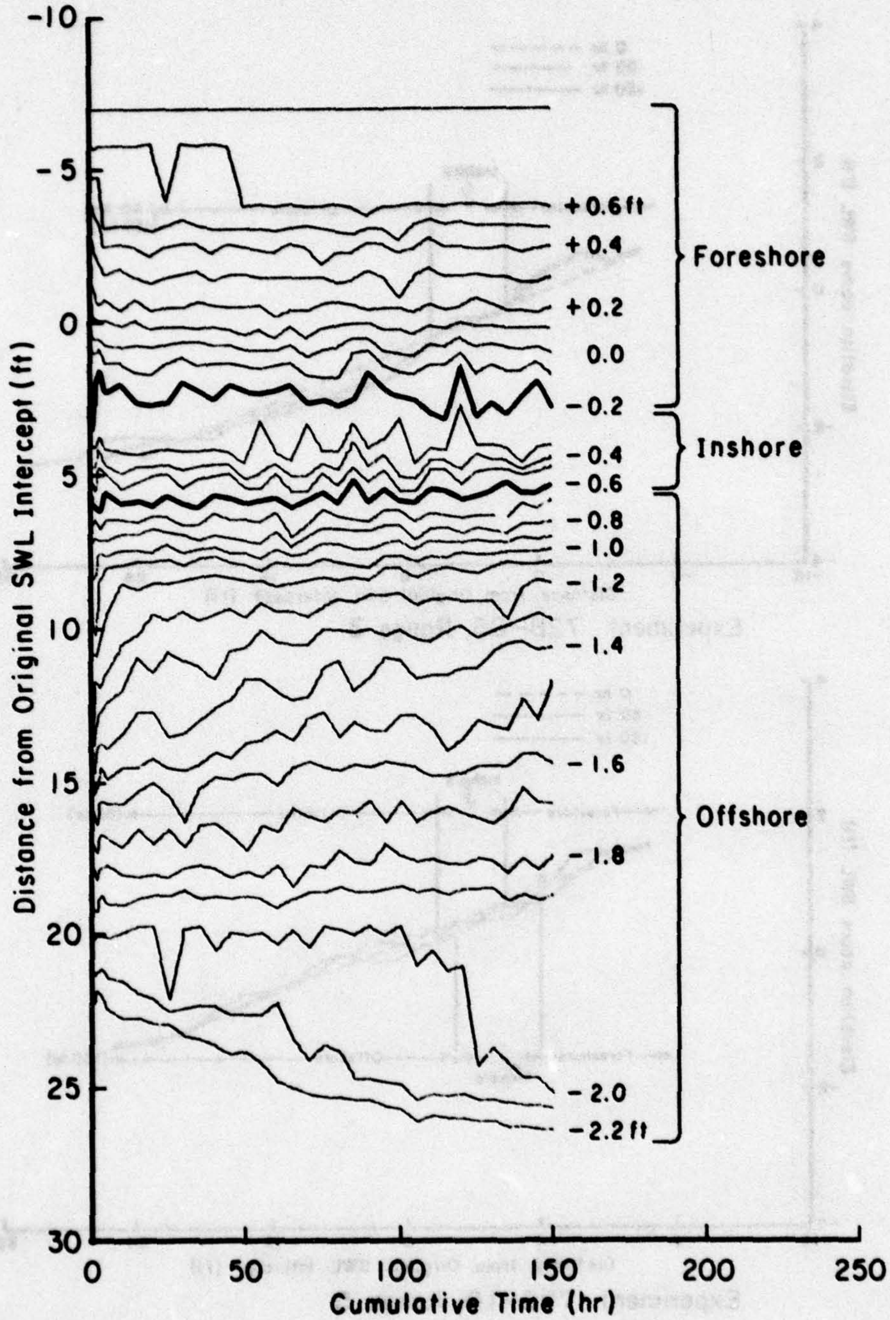


Figure 13. Profile changes along range 1, experiment 72B-06.

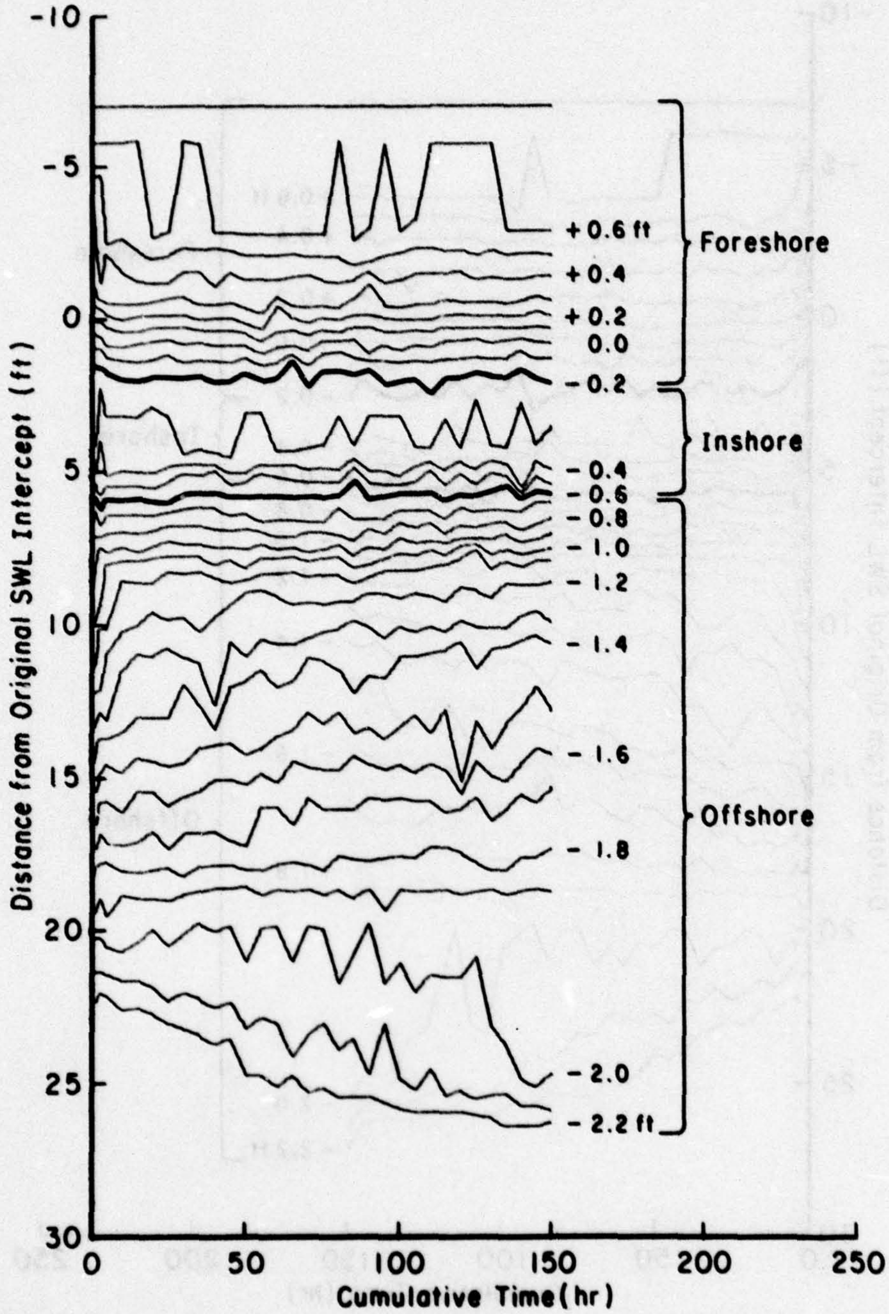


Figure 14. Profile changes along range 3, experiment 72B-06.

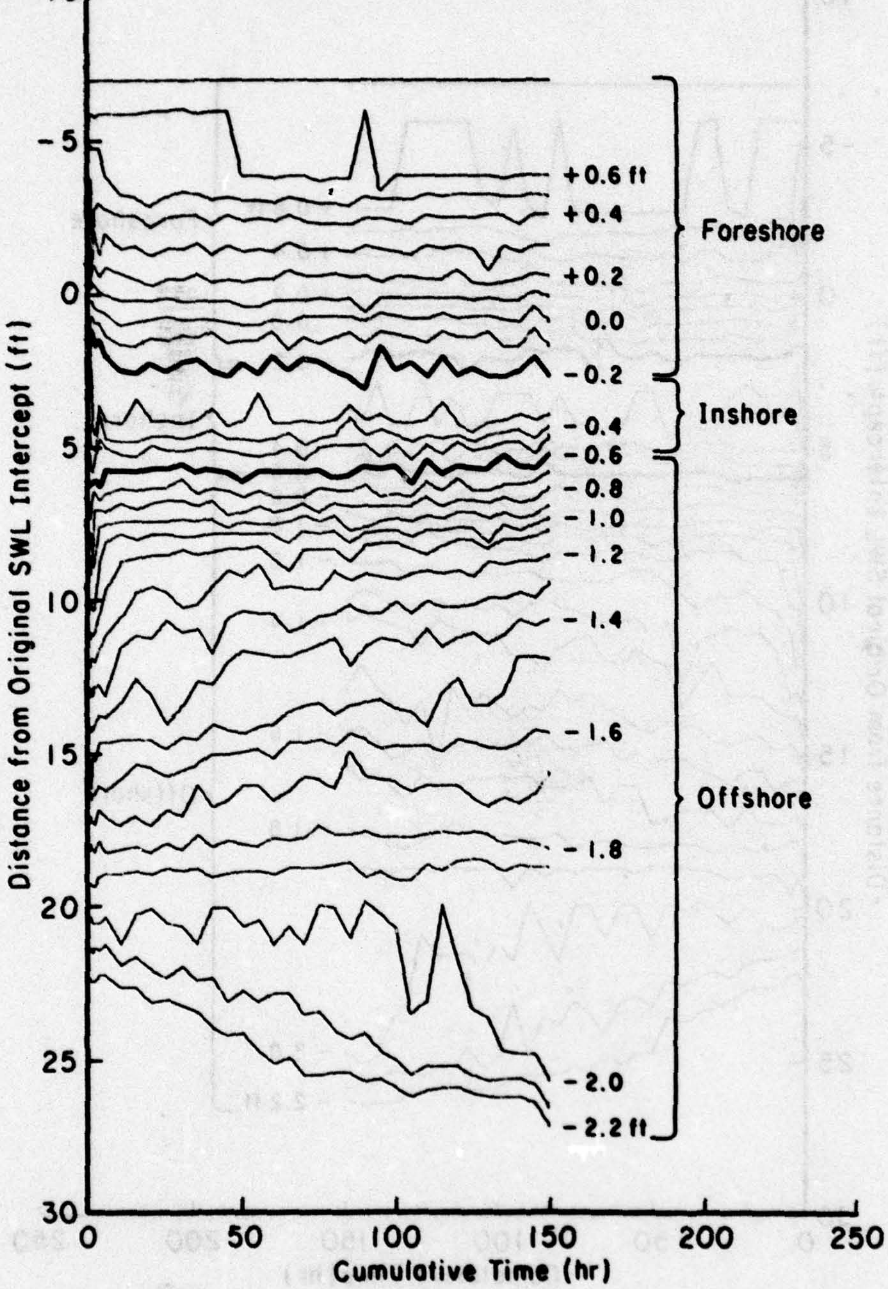


Figure 15. Profile changes along range 5, experiment 72B-06.

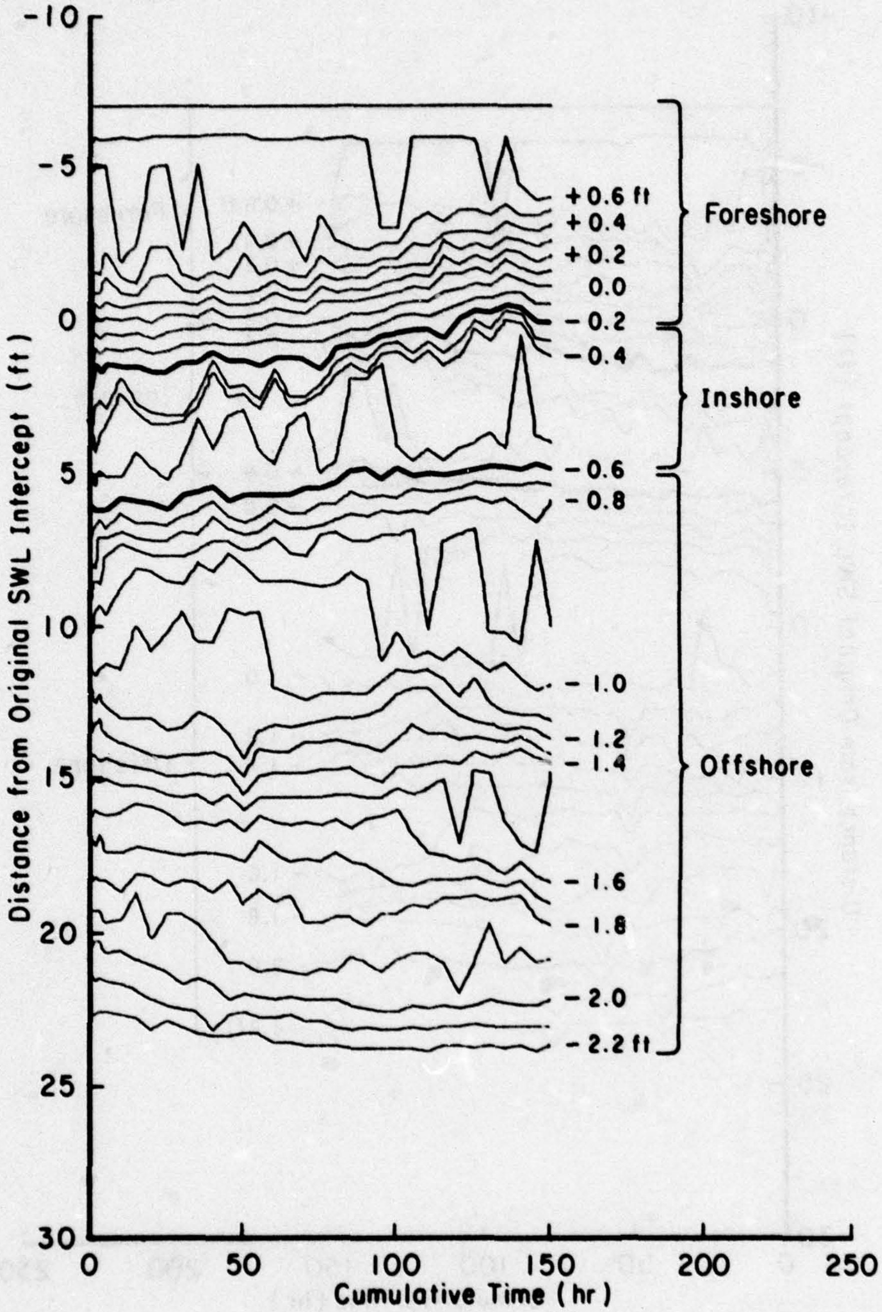


Figure 16. Profile changes along range 1, experiment 72B-10.

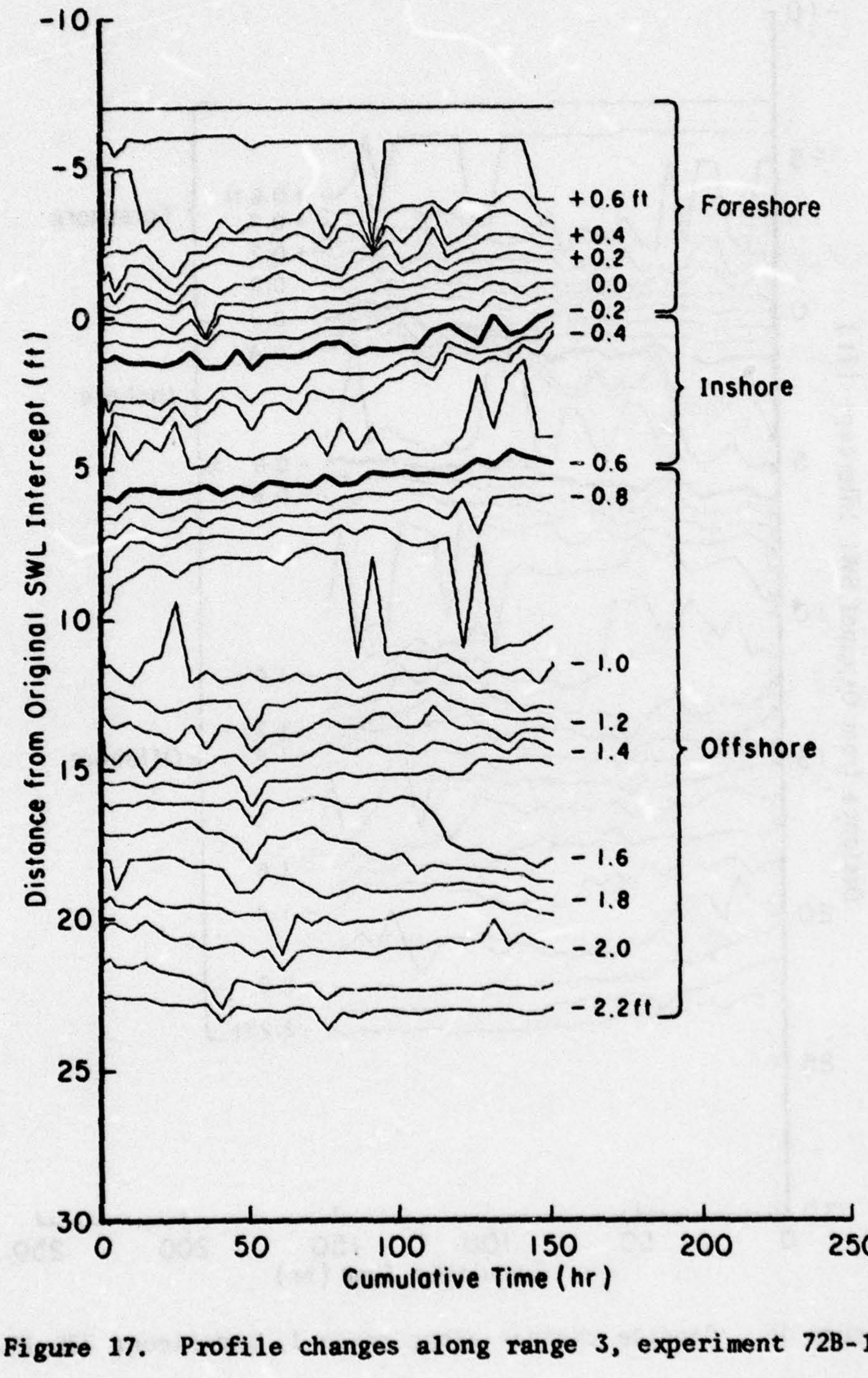


Figure 17. Profile changes along range 3, experiment 72B-10.

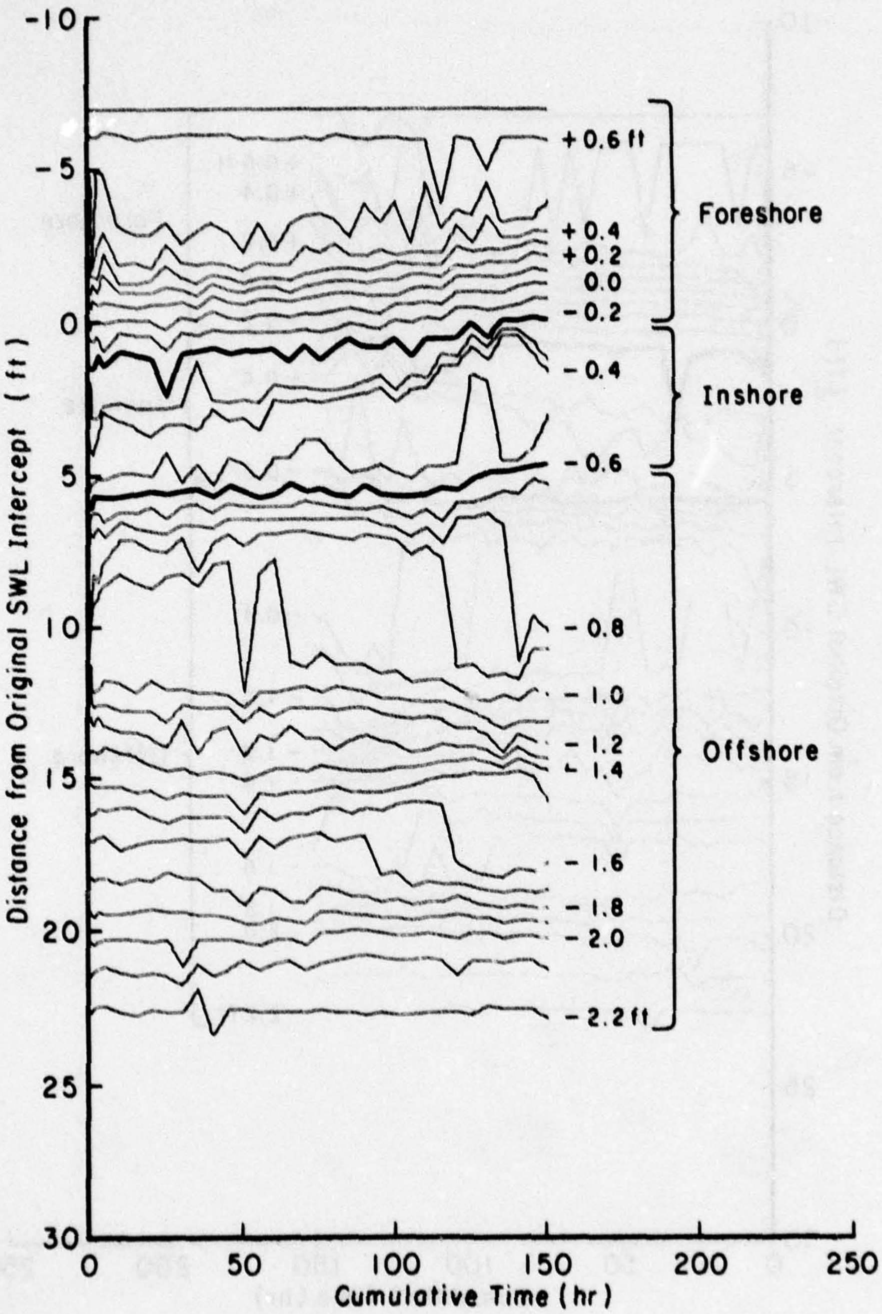


Figure 18. Profile changes along range 5, experiment 72B-10.

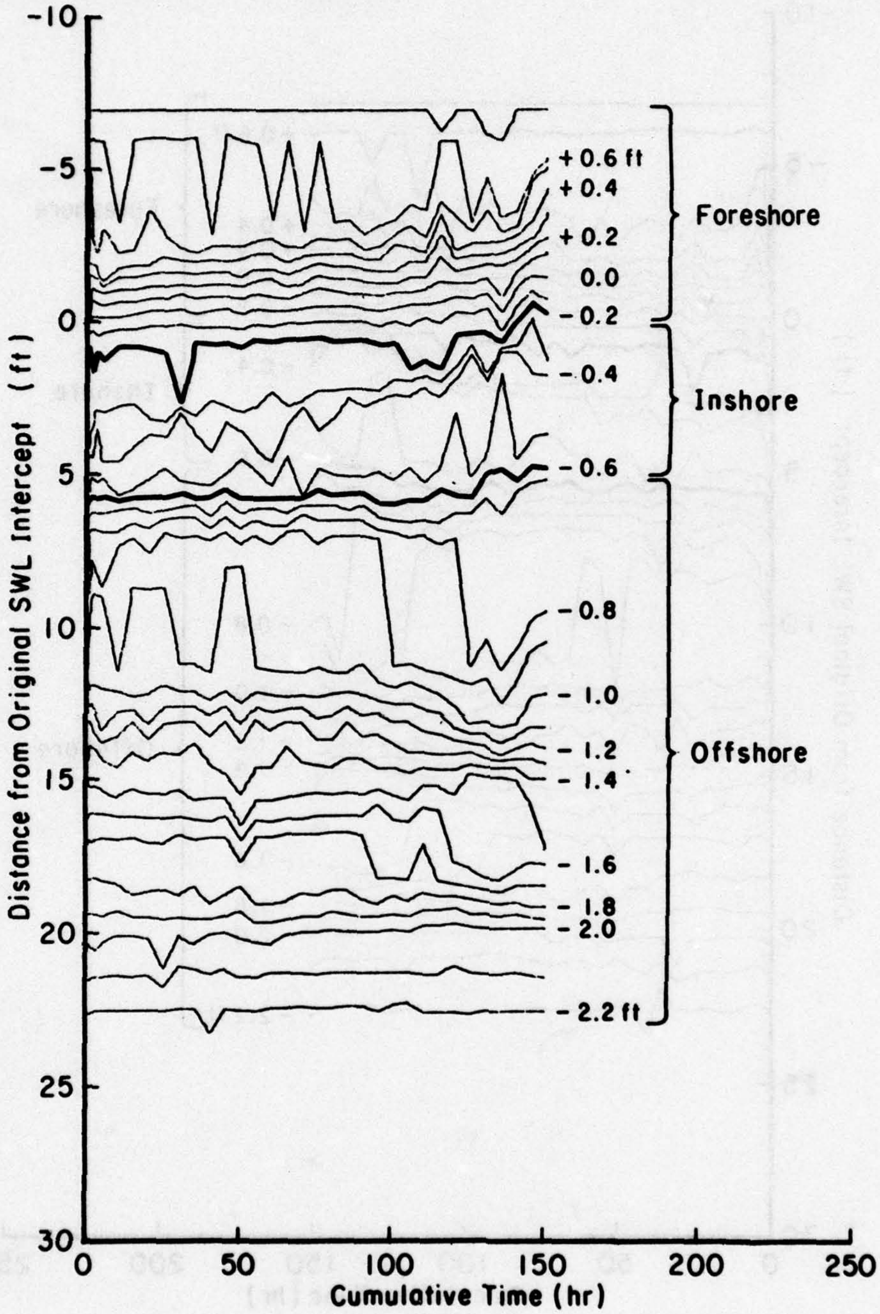


Figure 19. Profile changes along range 7, experiment 72B-10.

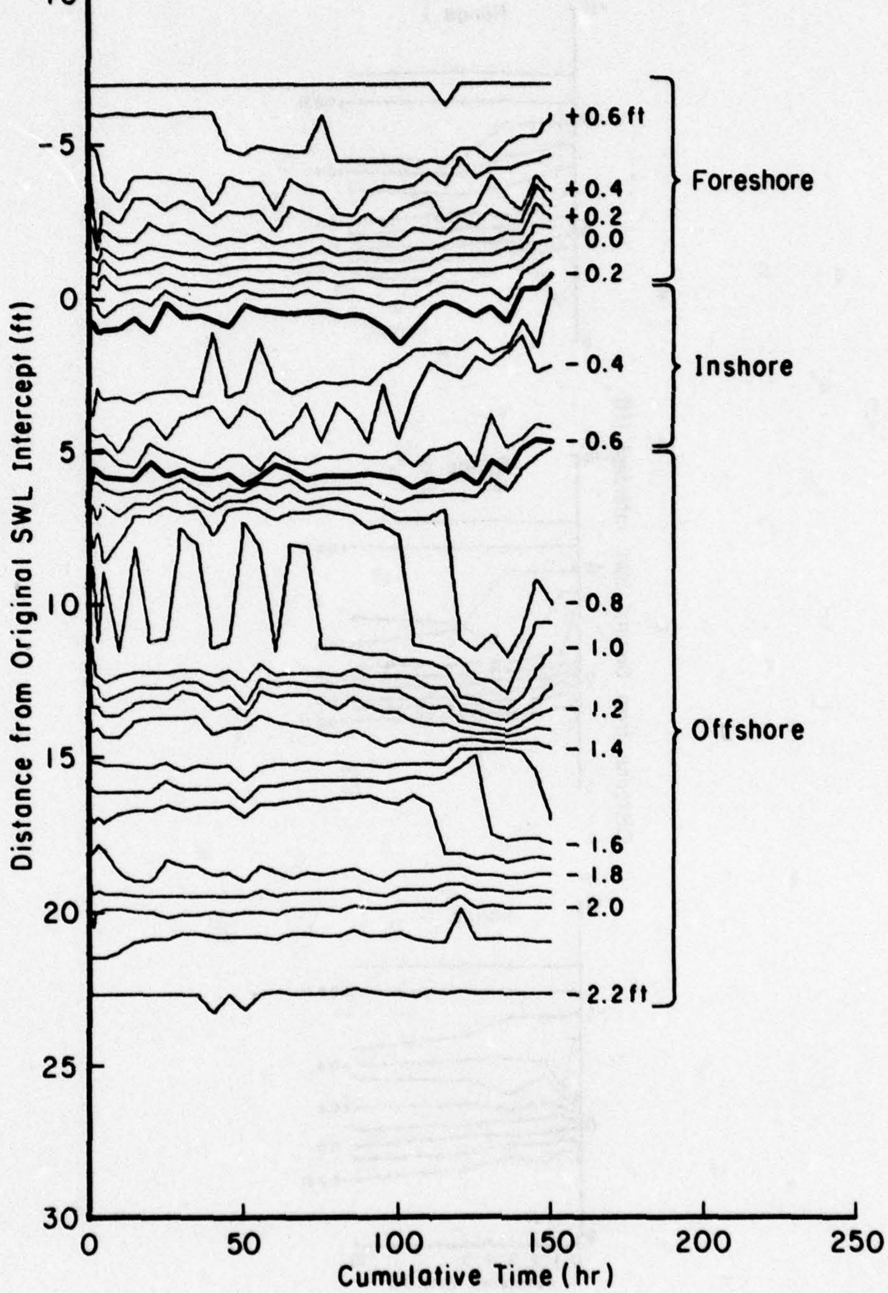


Figure 20. Profile changes along range 9, experiment 72B-10.

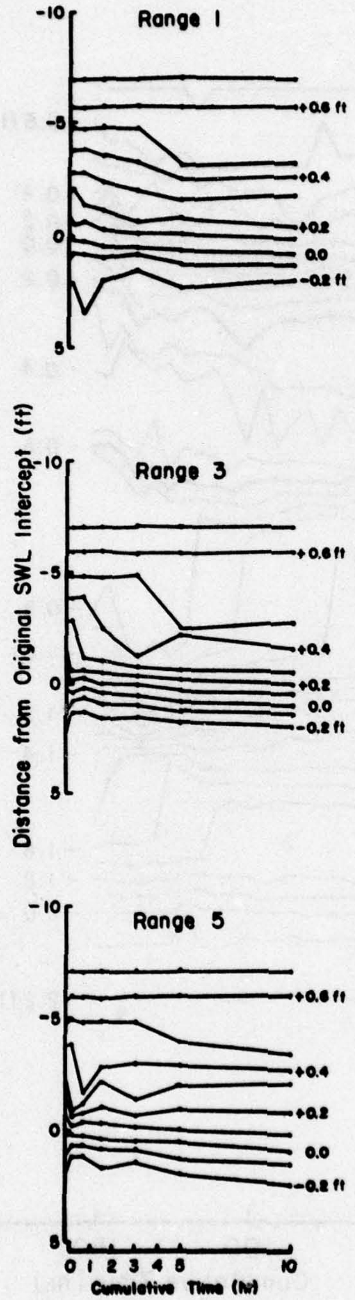


Figure 21. Foreshore contour movement during first 10 hours of experiment 72B-06.

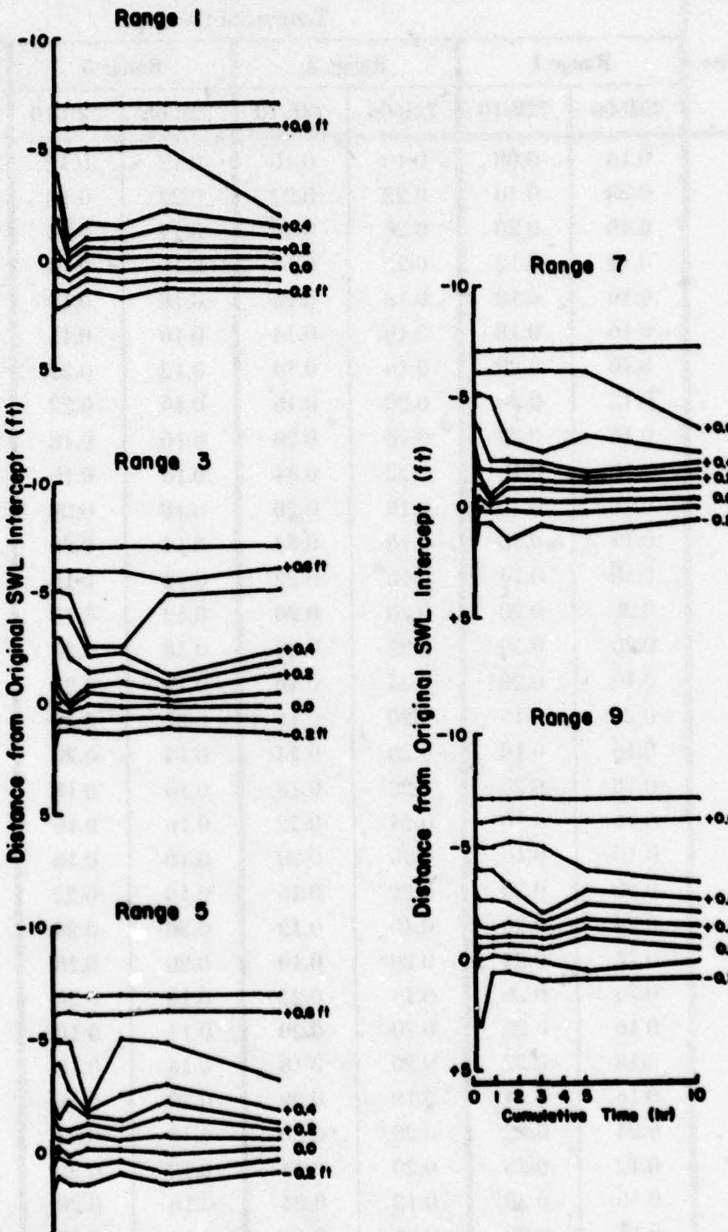


Figure 22. Foreshore contour movement during first 10 hours of experiment 72B-10.

Table 8. Slope of the beach face at the SWL intercept in experiments 72B-06 and 72B-10.

Cumulative time	Tangent of the slope							
	Range 1		Range 3		Range 5		Range 7	Range 9
(hr:min)	72B-06	72B-10	72B-06	72B-10	72B-06	72B-10	72B-10	72B-10
0:00	0.16	0.08	0.10	0.10	0.12	0.12	0.10	0.16
0:10	0.20	0.16	0.22	0.22	0.22	0.18	0.14	0.22
0:40	0.18	0.22	0.20	0.50	0.14	0.34	0.48	0.28
1:30	0.14	0.12	0.20	0.14	0.16	0.14	0.06	0.20
3:00	0.16	0.18	0.18	0.16	0.18	0.18	0.16	0.22
5:00	0.16	0.18	0.16	0.14	0.16	0.16	0.20	0.20
10:00	0.16	0.20	0.16	0.14	0.12	0.22	0.20	0.22
15:00	0.12	0.20	0.20	0.16	0.16	0.22	0.20	0.22
20:00	0.16	0.20	0.18	0.20	0.16	0.18	0.24	0.16
25:00	0.18	0.16	0.22	0.34	0.16	0.16	0.24	0.22
30:00	0.20	0.18	0.16	0.20	0.18	0.20	0.24	0.20
35:00	0.14	0.18	0.16	0.54	0.14	0.20	0.24	0.20
40:00	0.18	0.14	0.18	0.22	0.18	0.16	0.22	0.22
45:00	0.20	0.20	0.20	0.20	0.12	0.18	0.20	0.20
50:00	0.20	0.20	0.22	0.20	0.18	0.20	0.24	0.22
55:00	0.16	0.20	0.24	0.18	0.16	0.20	0.20	0.16
60:00	0.26	0.16	0.20	0.16	0.22	0.20	0.24	0.18
65:00	0.16	0.18	0.20	0.14	0.14	0.20	0.22	0.22
70:00	0.18	0.20	0.22	0.18	0.16	0.18	0.22	0.24
75:00	0.16	0.16	0.24	0.22	0.16	0.16	0.16	0.20
80:00	0.10	0.16	0.36	0.20	0.16	0.16	0.18	0.22
85:00	0.20	0.20	0.22	0.16	0.18	0.22	0.20	0.22
90:00	0.24	0.20	0.46	0.12	0.30	0.20	0.22	0.24
95:00	0.18	0.24	0.20	0.18	0.20	0.18	0.20	0.20
100:00	0.14	0.26	0.14	0.22	0.16	0.28	0.24	0.20
105:00	0.16	0.20	0.20	0.20	0.14	0.18	0.22	0.16
110:00	0.18	0.22	0.20	0.18	0.14	0.18	0.22	0.22
115:00	0.16	0.14	0.18	0.20	0.20	0.18	0.14	0.18
120:00	0.24	0.22	0.20	0.20	0.16	0.22	0.24	0.20
125:00	0.12	0.20	0.20	0.14	0.18	0.22	0.16	0.16
130:00	0.16	0.20	0.18	0.24	0.18	0.20	0.24	0.18
135:00	0.14	0.20	0.20	0.14	0.12	0.18	0.18	0.18
140:00	0.14	0.24	0.28	0.34	0.14	0.20	0.18	0.22
145:00	0.18	0.20	0.18	0.18	0.18	0.18	0.18	0.16
150:00	0.12	0.18	0.20	0.22	0.14	0.20	0.10	0.22
Avg	0.17	0.19	0.21	0.21	0.17	0.19	0.20	0.20

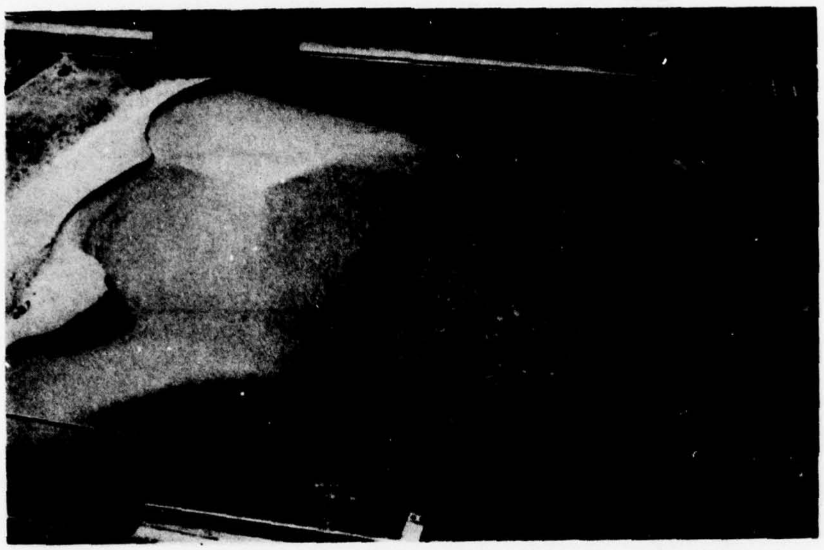


Figure 23. Shape of the foreshore zone.

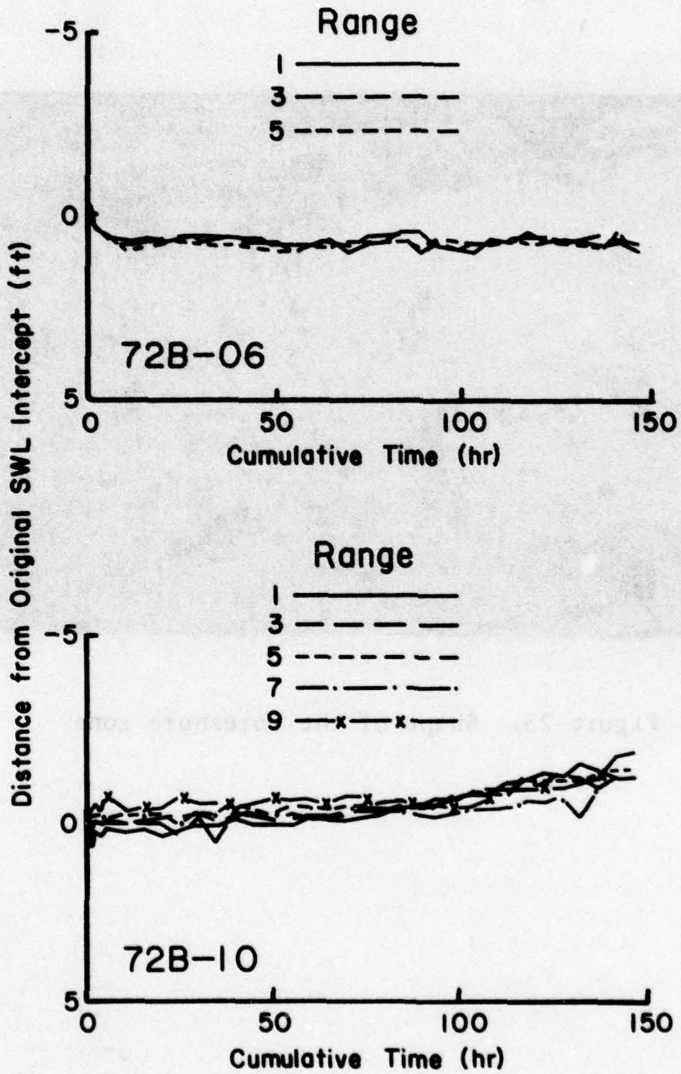


Figure 24. Shoreline (0 contour) movement in experiments 72B-06 and 72B-10.

then remained essentially stable for the remainder of the experiment. The position of the shoreline varied across the tank (as indicated by the wider spacings at times), but there was never more than a 0.5-foot difference.

During the first 100 hours of experiment 72B-10, considerable lateral variation occurred in shoreline position. The shoreline was skewed across the tank; the shoreline retreated along ranges 7 and 9 and advanced along ranges 1 and 3. There was a 1.2-foot difference across the 10-foot tank in the position of the shoreline. By 100 hours the 0 contours had coalesced, with a net recession of 0.4 foot. Between 100 and 150 hours the shoreline receded at a rate of 0.018 foot per hour (0.55 centimeter per hour). During the last 20 hours, considerable lateral variation again occurred in the position of the shoreline. Because the backshore slope was 0.10 (and not flat) the volume rate of erosion was not constant and increased at a rate proportional to the square of the shoreline recession rate.

(2) Inshore Zone.

(a) Experiment 72B-06. The movement of all contour intercepts in the inshore zone along the three ranges in experiment 72B-06 is shown in Figures 25, 26, and 27. In the first 10 minutes a longshore bar formed by the plunging breaker near station 4 with a crest elevation of -0.3 to -0.4 foot, as indicated by the multiple intercepts (Figs. 25, 26, and 27). The inshore zone remained stationary throughout the experiment, as indicated by the essentially horizontal lines for the -0.2-, -0.4-, -0.5-, and -0.6-foot contours. The absence of multiple intercepts for the -0.2- to -0.4-foot contours indicated that at times the bar became essentially a flat region. The movement of the -0.3-foot contour and appearance of the -0.4-foot multiple intercepts indicate that the bar crest elevation varied between -0.3 and -0.4 foot.

The movements of the -0.3-, -0.4-, -0.5-, and -0.6-foot contours along the three ranges are compared in Figure 28. Little lateral variation occurred at -0.6 foot and only small variations at -0.4 and -0.5 foot. The considerable lateral variation in the -0.3-foot contour indicates that the bar crest reached the -0.3-foot elevation at different times along the different ranges.

(b) Experiment 72B-10. The movement of all contours in the inshore zone along the five ranges in experiment 72B-10 is shown in Figures 29 to 33. In the first 10 minutes a longshore bar formed by the plunging breaker near station 2 between the -0.2- and -0.3-foot contours and a flat region also developed near station 5 between the -0.4- and -0.5-foot contours. The bar later became just a flat area and then eroded completely. The flat region between the -0.4- and -0.5-foot contours eventually developed into a bar. These changes occurred along all ranges, but at different times and to different extents.

Along range 1 (Fig. 29) the bar near station 2 was eroded by 5 hours and the area between the -0.2- and -0.3-foot contours varied between

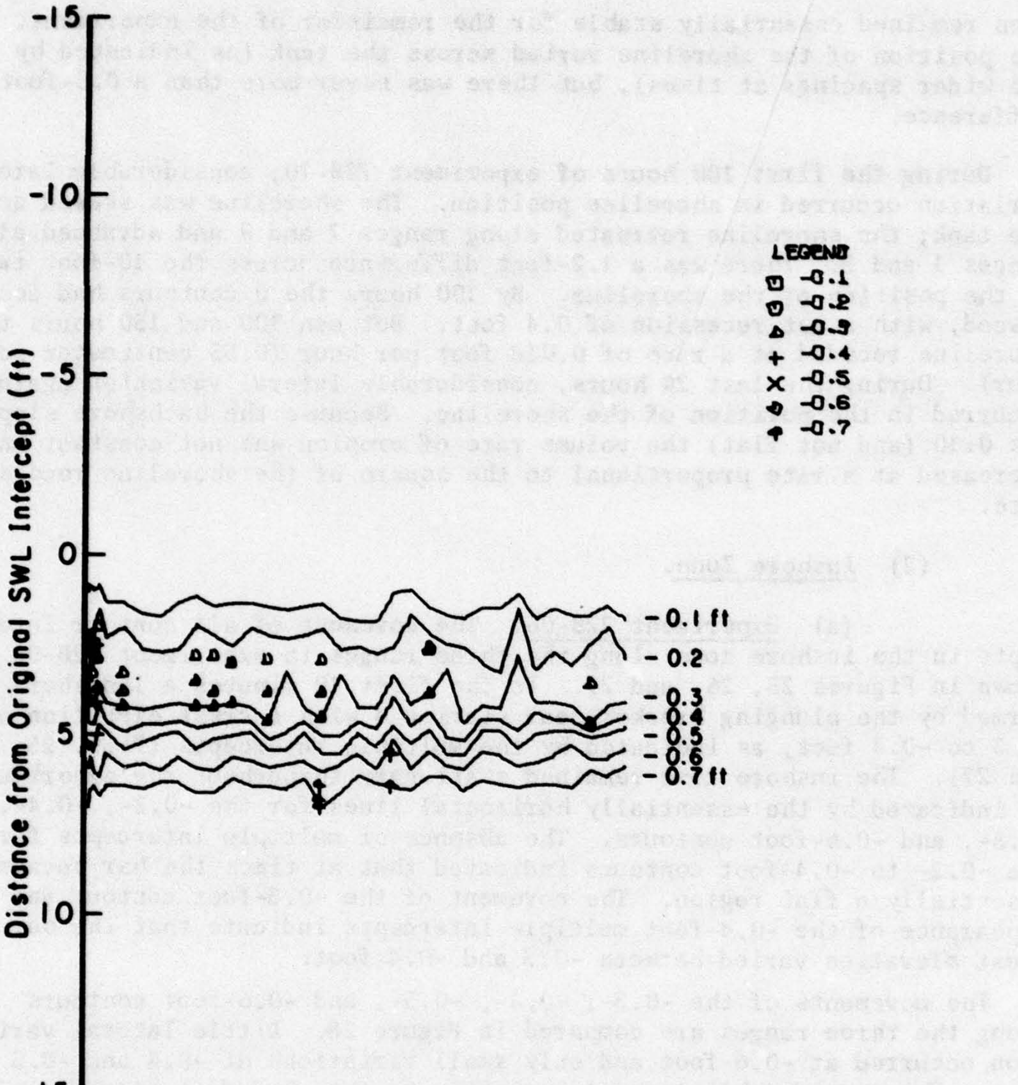


Figure 25. Changes in the inshore zone along range 1, experiment 72B-06.

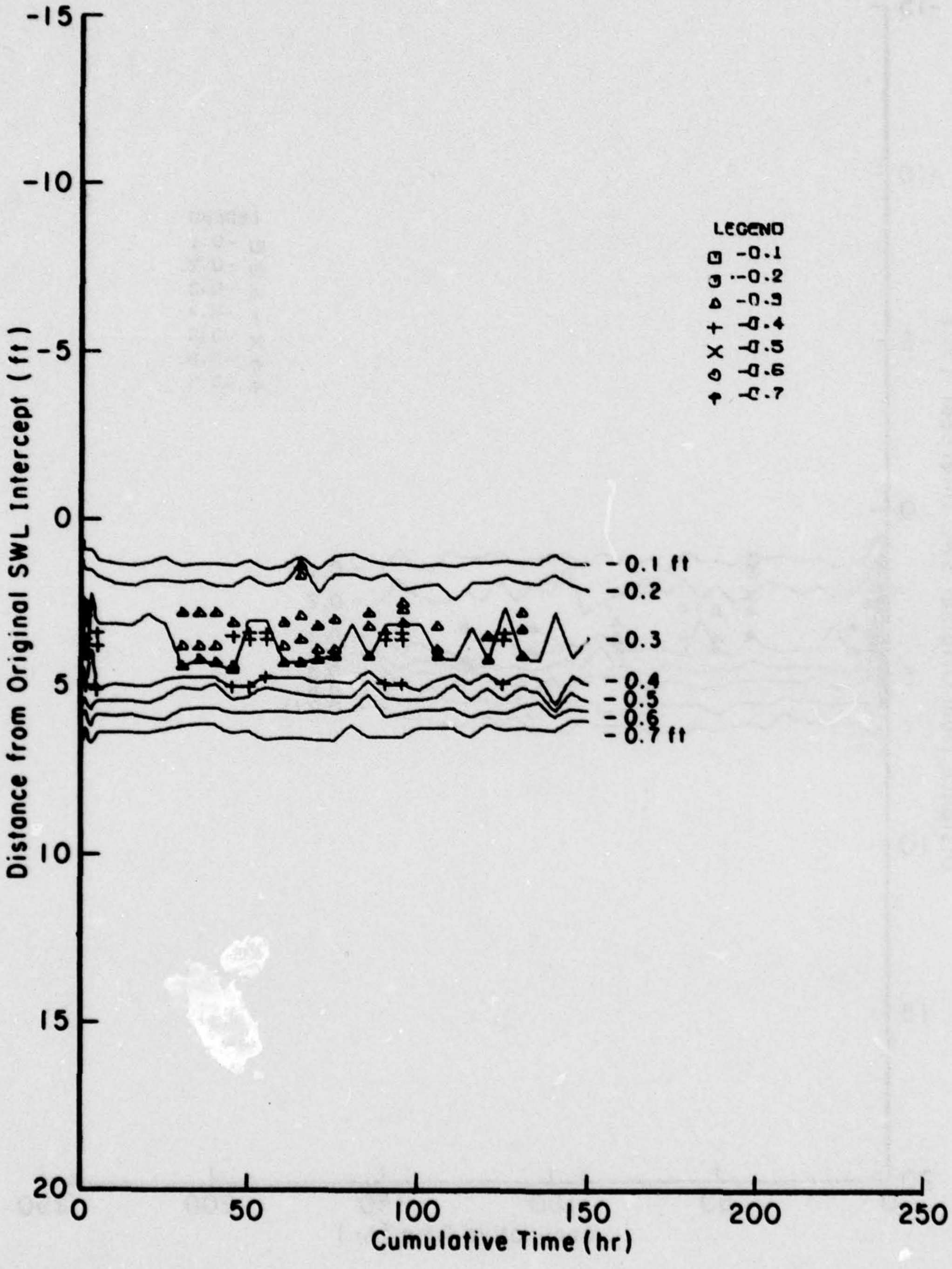


Figure 26. Changes in the inshore zone along range 3, experiment 72B-06.

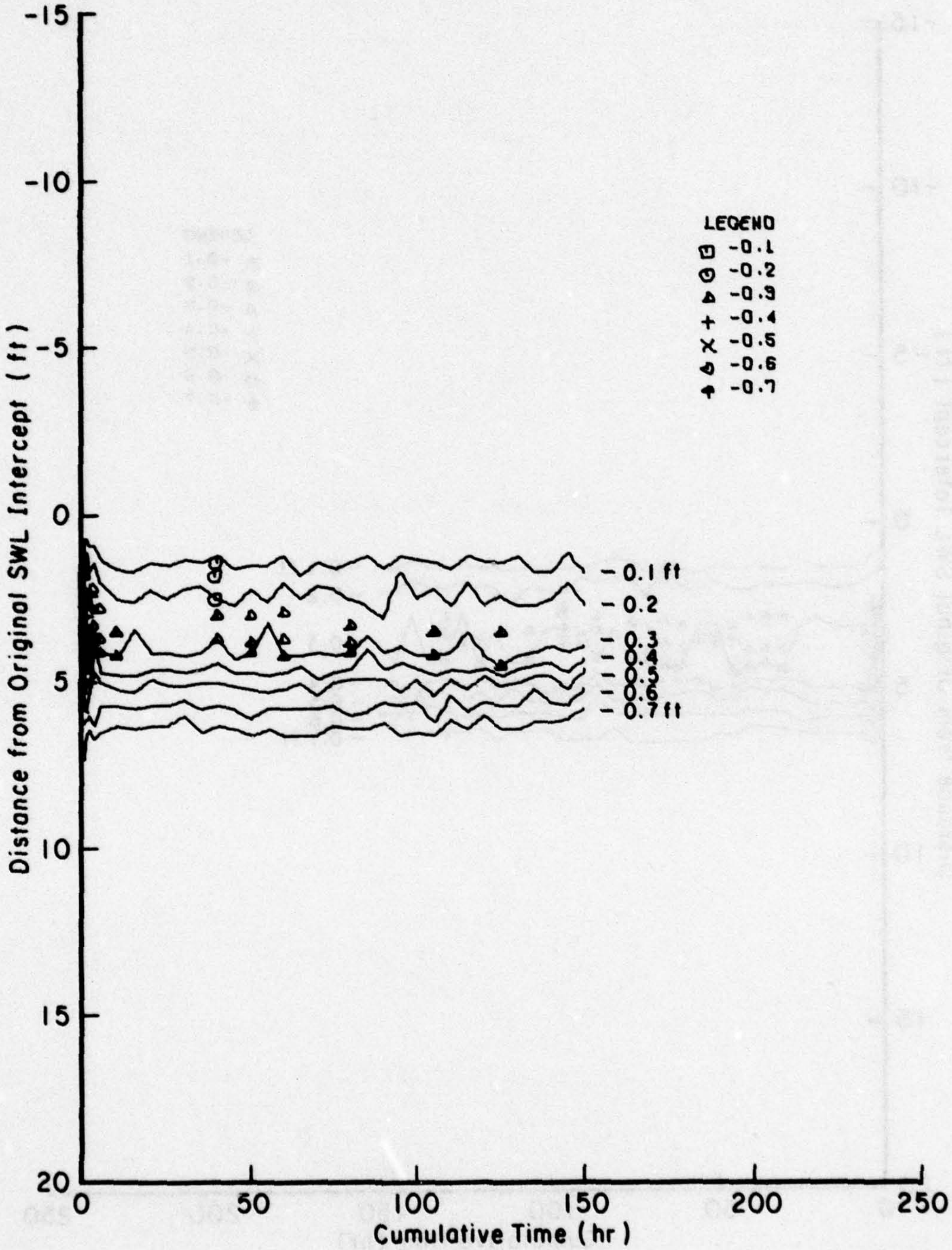


Figure 27. Changes in the inshore zone along range 5, experiment 72B-06.

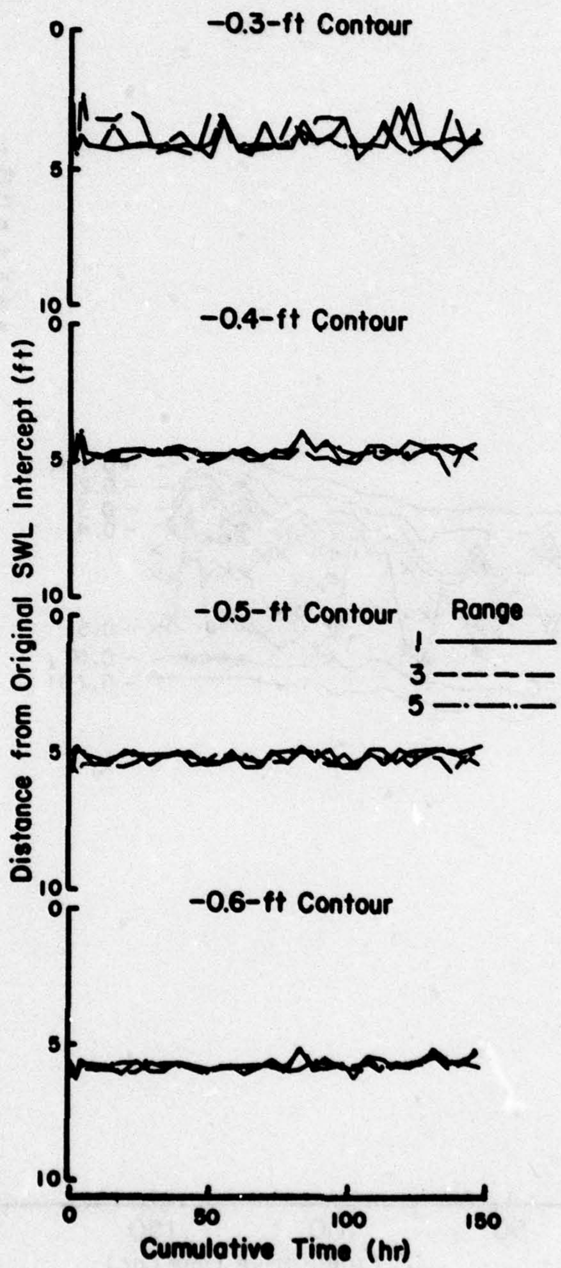


Figure 28. Movement of the inshore zone at three ranges in experiment 72B-06; comparison of the -0.3-, -0.4-, -0.5-, and -0.6-foot contour movements.

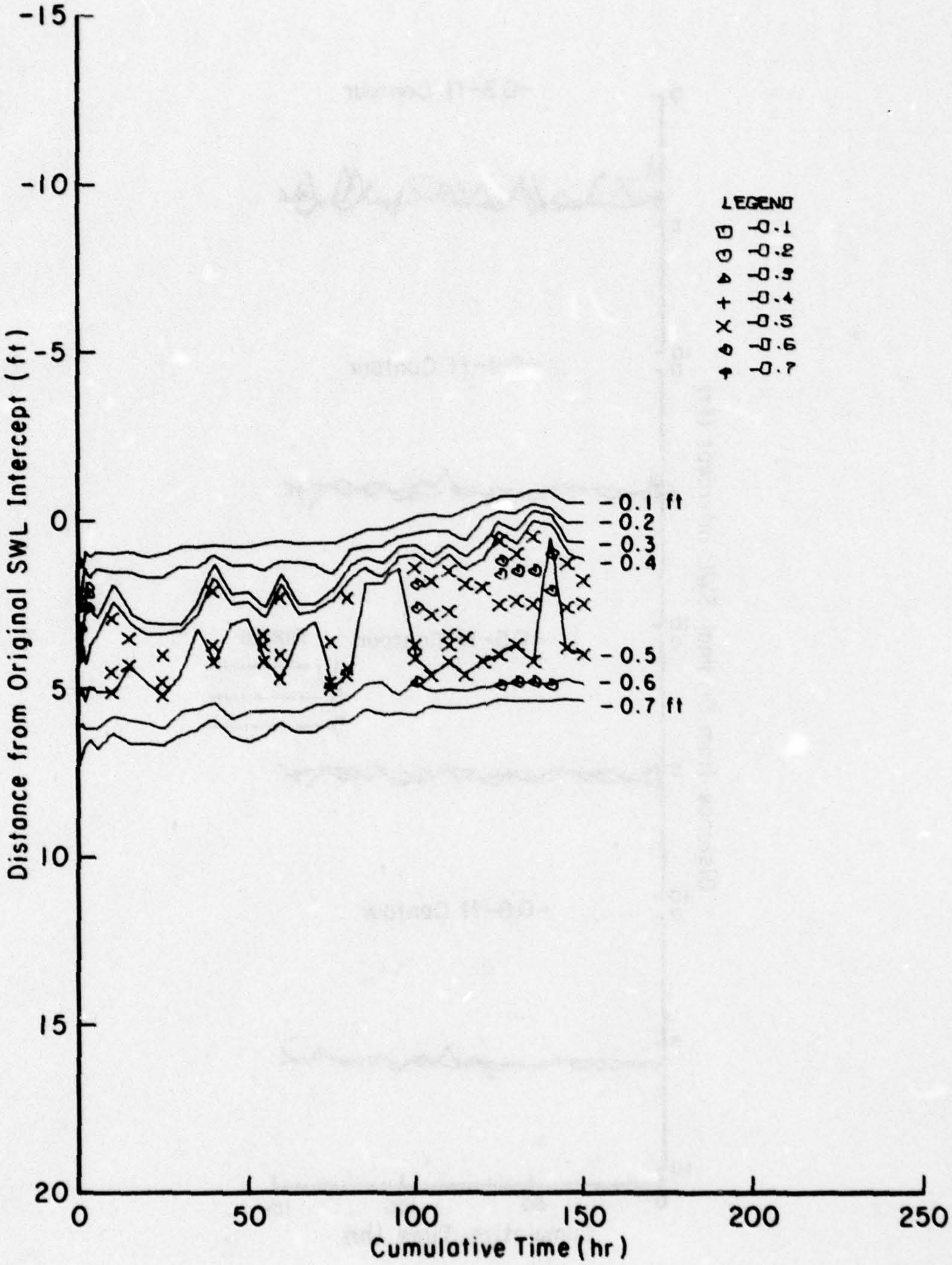


Figure 29. Changes in the inshore zone along range 1, experiment 72B-10.

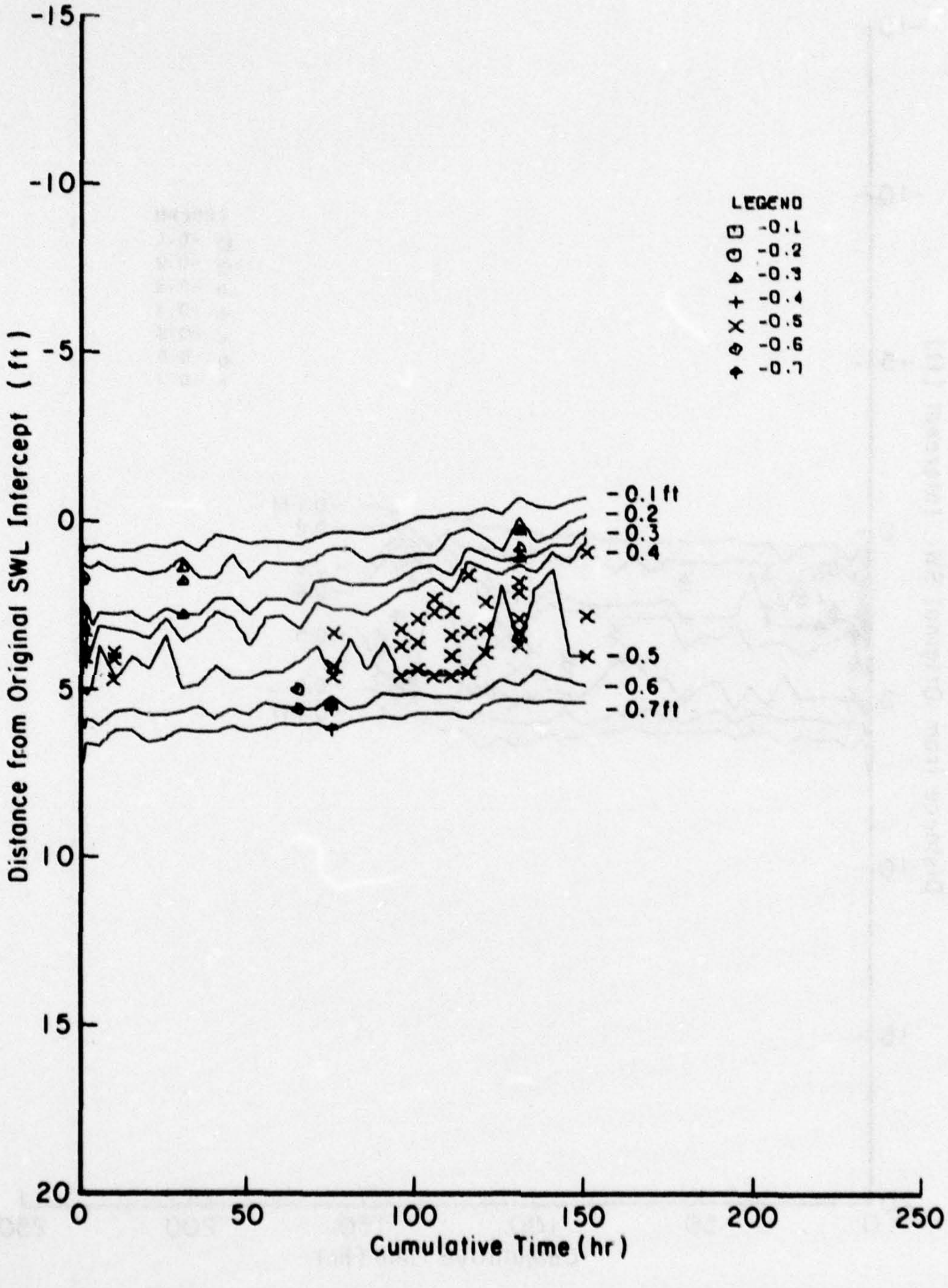


Figure 30. Changes in the inshore zone along range 3, experiment 72B-10.

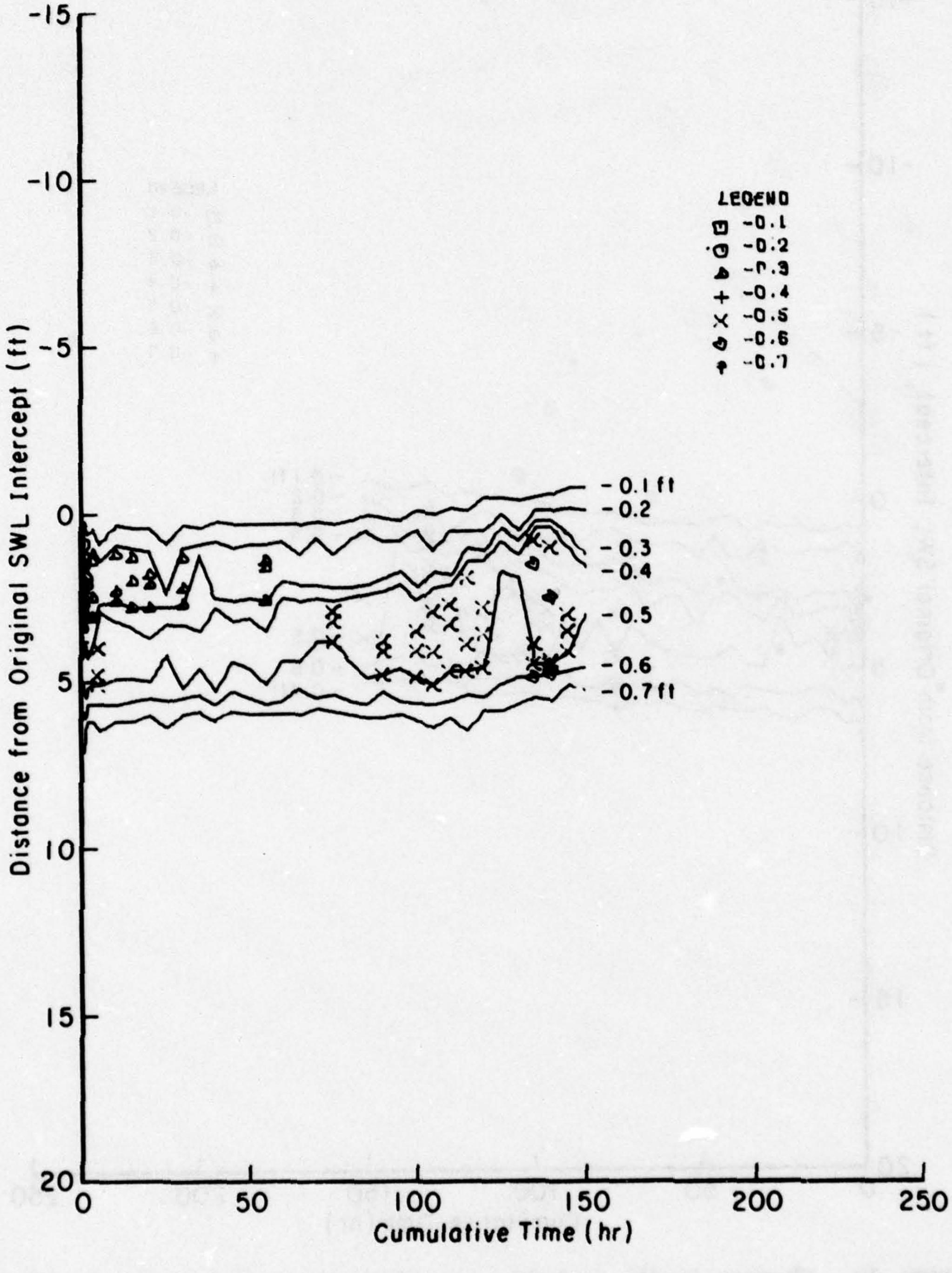


Figure 31. Changes in the inshore zone along range 5, experiment 72B-10.

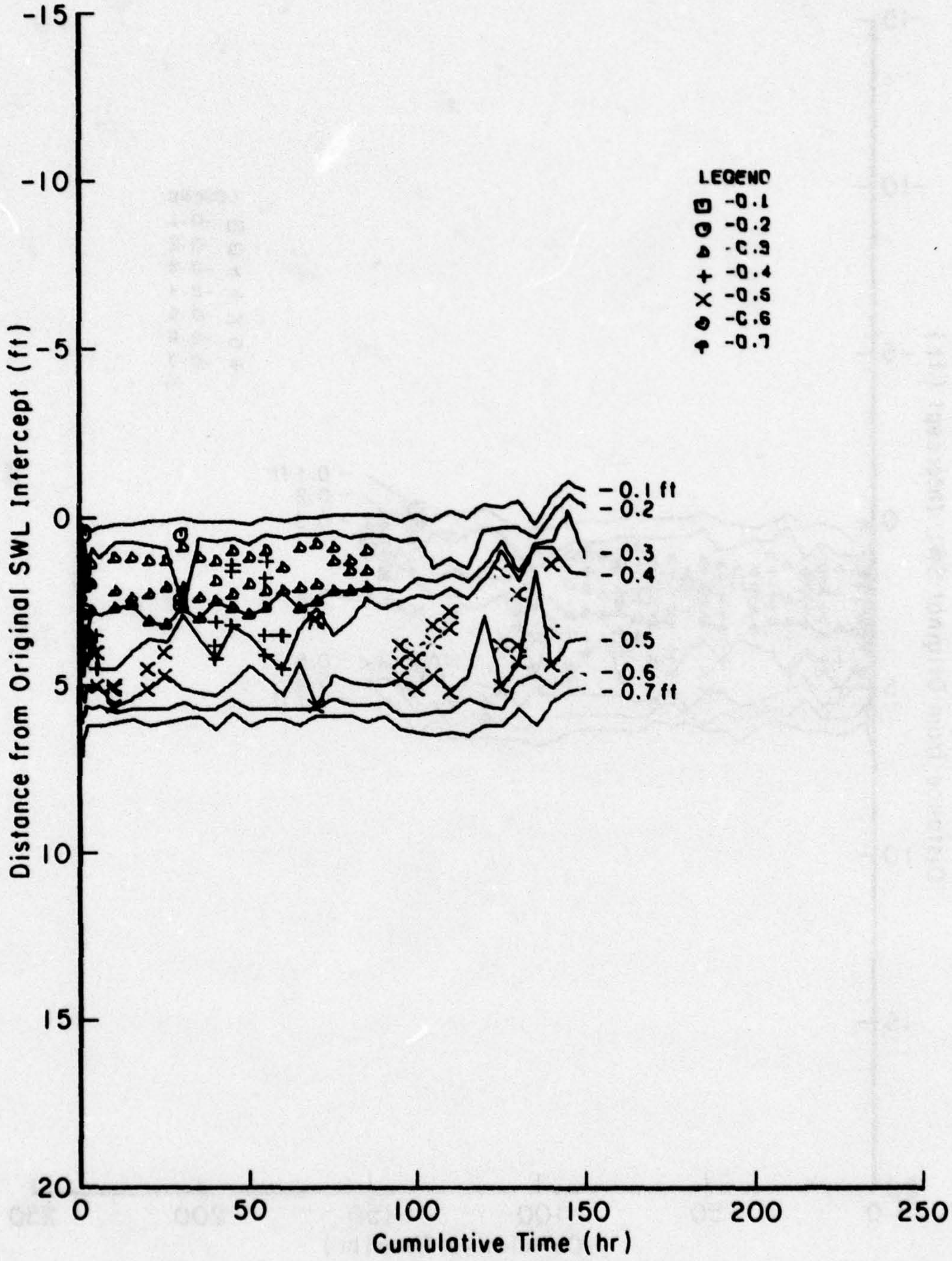


Figure 32. Changes in the inshore zone along range 7, experiment 72B-10.

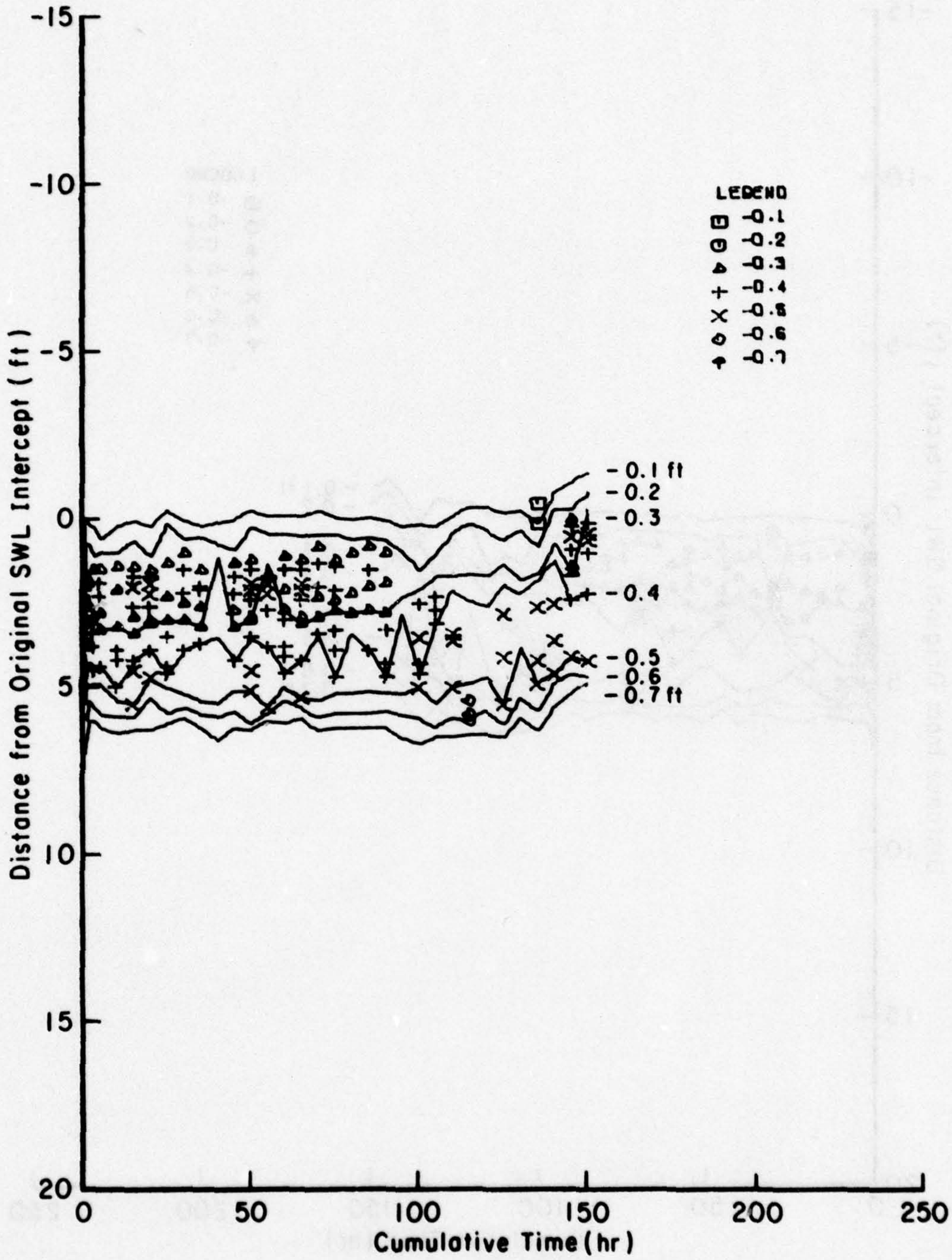


Figure 33. Changes in the inshore zone along range 9, experiment 72B-10.

steep and flat until 75 hours; after 75 hours the area was eroded and then remained steep. The flat area between the -0.4- and -0.5-foot contours oscillated between barred and flat until 100 hours and then became a fully developed bar and trough for the remainder of the experiment. The bar crest reached -0.5 foot and the bar trough reached -0.6 foot.

Along range 3 (Fig. 30) the bar near station 2 developed, eroded quickly, and then the area around station 2 remained mostly unchanged until 85 hours, when this area began eroding and became steep. For the first 95 hours the area around station 5 was gently sloping and after 95 hours became flatter and slightly barred, but with the depth variation only a little over 0.1 foot.

Along range 5 (Fig. 31) the bar near station 2 remained for the first 30 hours; this area started eroding at 100 hours. The area near station 5 was flat for most of the first 90 hours and then a bar and trough developed, with the bar crest elevation reaching -0.5 foot and the bar trough elevation reaching -0.6 foot twice.

Along range 7 (Fig. 32) the bar near station 2 remained for the first 85 hours and the trough shoreward of the bar occasionally reached an elevation of -0.4 foot. This area began eroding at 120 hours. The area around station 5 was gently sloping until 65 hours, and then became flat. However, a bar never actually developed as this flat area widened.

Along range 9 (Fig. 33) the bar near station 2 remained for the first 90 hours and the trough shoreward of the bar occasionally reached an elevation of -0.5 foot. This area began eroding at 95 hours, but never became as steep as along the other ranges. A bar developed near station 5 almost immediately, with a crest elevation of -0.4 foot. After 100 hours the bar crest elevation eroded to -0.5 foot.

The movements of the -0.3-, -0.4-, -0.5-, and -0.6-foot contours along the five ranges are compared in Figure 34. At -0.6 foot the lateral variation was minimal during the first 65 hours and the last 10 hours, but from 65 to 140 hours the position varied as much as 1 foot, with the position seawardmost along range 9 and landwardmost along range 1. Lateral variation at -0.5 foot was more confused, but range 9 was generally seawardmost and range 1 generally landwardmost. The largest and most consistent variations occurred at -0.3 and -0.4 foot, also with range 9 seawardmost and range 1 landwardmost.

(3) Offshore Zone.

(a) Experiment 72B-06. During the first 10 hours, considerable erosion occurred at depths from -0.7 to -1.3 feet, which along with the deposition at the outer edge of the inshore (-0.4 to -0.6 foot), formed a steep slope at the upper edge of the offshore zone (see Figs. 13 to 15). The area between the -0.4- and -1.1-foot contours remained steep (0.23) throughout the remainder of the experiment. The area between the -1.2- and -1.9-foot contours was more gently sloping (0.07) and did

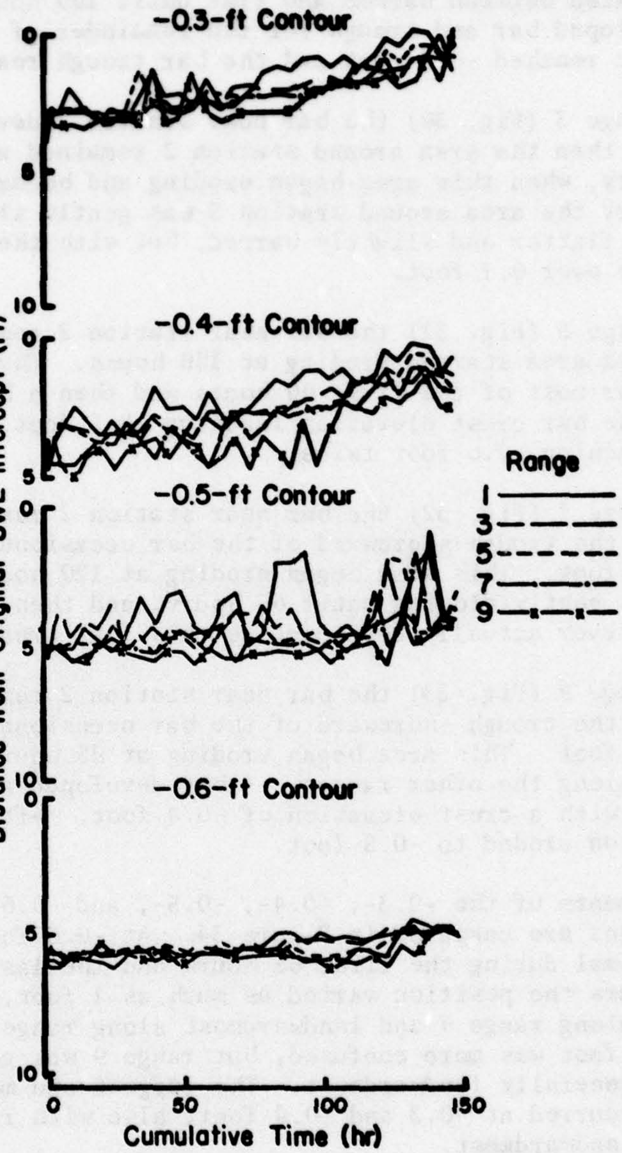


Figure 34. Movement of the inshore zone at five ranges in experiment 72B-10; comparison of the -0.3-, -0.4-, -0.5-, and -0.6-foot contour movements.

change significantly. Sand was continuously deposited at depths of -2.1 and -2.2 feet and after 90 hours at -2.0 feet. After 125 hours a flat area developed to a width of 6.5 feet (1.98 meters) between the -1.9- and -2.0-foot contours.

The movements of the -1.0-, -1.5-, and -2.0-foot contours along the three ranges are compared in Figure 35. No significant lateral variation occurred at -1.0 foot and the variations at -1.5 feet were large at only one time and no pattern developed (i.e., one range was not always seaward of the others). At -2.0 feet the variations on the flattest part of the profile were large, but again there was no consistent pattern.

(b) <u>Experiment 72B-10</u>. Changes in the offshore zone are shown in Figures 16 to 20. Initially, considerable erosion occurred along range 5 (Fig. 18) at elevations -0.8 to -1.0 foot, which formed a steep slope at the upper part of the offshore and, along with deposition at -1.1 and -1.2 feet, a flat area between the -1.0- and -1.1-foot contours (around station 10). The -1.0-foot contour later moved seaward, and then the -0.9- and -0.8-foot contours progressively crossed to the seaward edge of the flat area, indicating a widening of that area. The -1.7- and -1.8-foot contours gradually separated and formed a flat area near station 16; these contours then moved seaward, further widening this flat area. These changes occurred along the other ranges, but at different times and to different extents.

Along range 1 (Fig. 16) the area near station 10 became flat at a lower elevation (-1.1 feet), and the -0.8-foot contour never moved seaward. The area near station 16 became flat near the end of the experiment between the -1.4- and -1.6-foot contours.

Along range 3 (Fig. 17) the area near station 10 developed into a flat area as along range 5, but the -0.8-foot contour never moved seaward. Near station 16 the flat area developed between -1.5 and -1.6 feet.

Along range 7 (Fig. 19) the area near station 10 developed in a manner similar to range 5, but the flat area near station 16 first developed between the -1.8- and -1.7-foot contours near station 18 and then grew toward station 16 with deposition at the -1.7-, -1.6-, and -1.5-foot elevations.

Along range 9 (Fig. 20) the changes in the flat areas occurred as along range 7. However, a steeper slope developed between the two flat regions from 120 to 140 hours.

The movements of the -1.0-, -1.5-, and -2.0-foot contours along the five ranges are compared in Figure 36. There was considerable variation in the seaward movement of the -1.0-foot contour, which began and ended first along range 9 and began and ended last along range 1. The -1.5-foot contour was generally more seaward along range 1 with little difference along the other ranges. Seaward of station 20 was an area of deposition along ranges 1 and 3, but not along the other ranges.

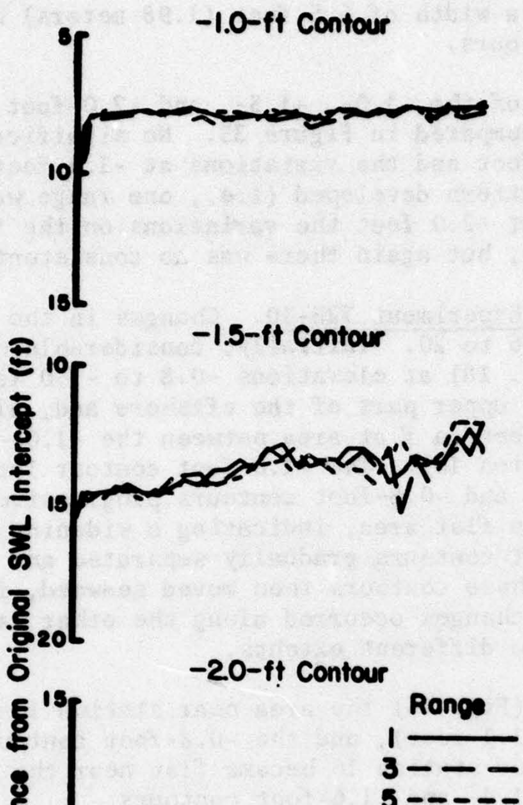


Figure 35. Movement of the offshore zone at three ranges in experiment 72B-06; comparison of the -1.0-, -1.5-, and -2.0-foot contour movements.

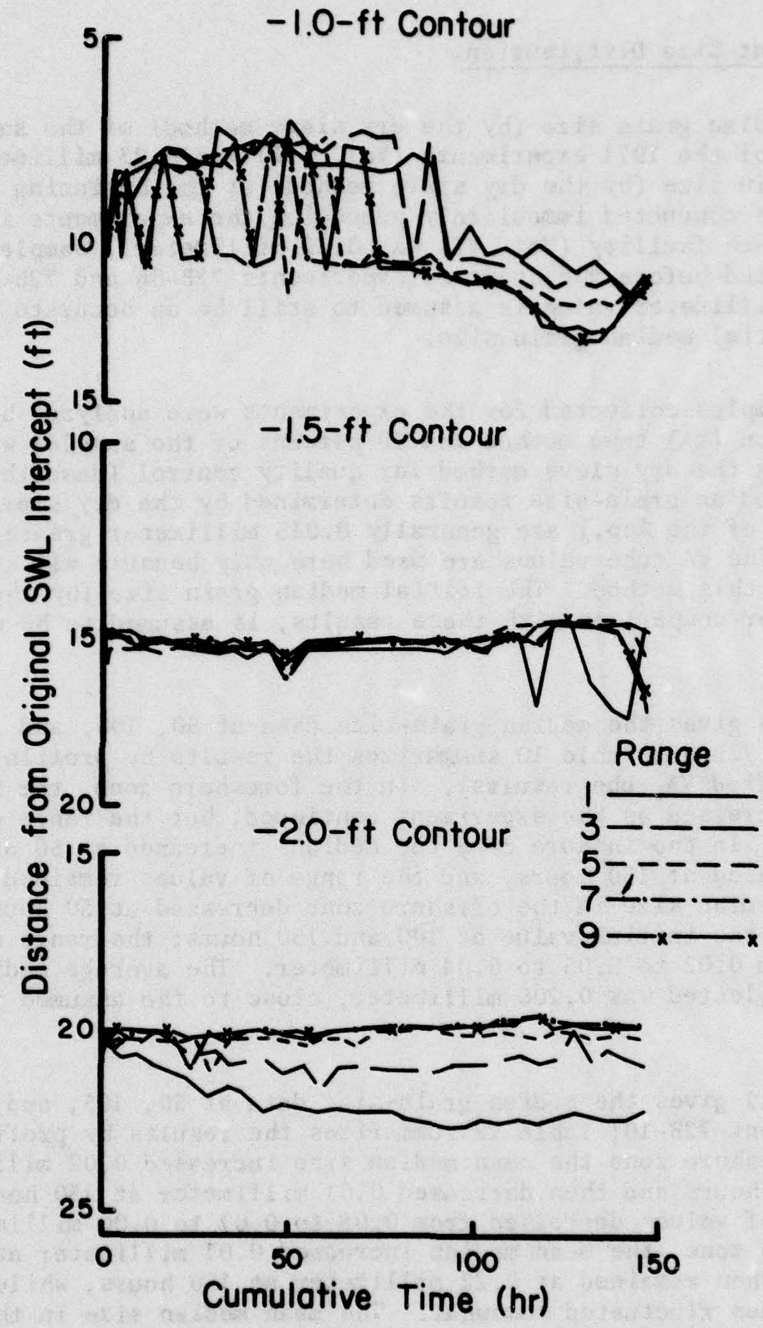


Figure 36. Movement of the offshore zone at five ranges in experiment 72B-10; comparison of the -1.0-, -1.5-, and -2.0-foot contour movements.

3. Sediment-Size Distribution.

The median grain size (by the dry sieve method) of the sand at the beginning of the 1971 experiments (Vol. III) was 0.23 millimeter. The median grain size (by the dry sieve method) at the beginning of the experiments conducted immediately preceding the experiments in this study in each facility (Vol. VI) was 0.22 millimeter. Samples were not collected before the start of experiments 72B-06 and 72B-10, but the 0.22-millimeter value is assumed to still be an accurate estimate of the initial median grain size.

All samples collected for the experiments were analyzed by the Visual Accumulation (VA) tube method and 10 percent of the samples were also analyzed by the dry sieve method for quality control (described in Vol. I). The median grain-size results determined by the dry sieve method (Table A-2 of the App.) are generally 0.015 millimeter greater than the VA tube. The VA tube values are used here only because all samples were reduced by this method. The initial median grain size (by the VA tube method), for comparison with these results, is assumed to be 0.205 millimeter.

Table 9 gives the median grain-size data at 50, 100, and 150 hours in experiment 72B-06; Table 10 summarizes the results by profile zone (data are unmodified VA tube results). In the foreshore zone, the mean of the medians increased as the experiment continued, but the range of medians decreased. In the inshore zone the medians increased at 50 and 100 hours, then decreased at 150 hours, and the range of values remained quite small. The mean median size in the offshore zone decreased at 50 hours, then increased to the initial value at 100 and 150 hours; the range of values varied from 0.02 to 0.05 to 0.04 millimeter. The average median of all samples collected was 0.206 millimeter, close to the assumed initial median.

Table 11 gives the median grain-size data at 50, 105, and 150 hours in experiment 72B-10; Table 12 summarizes the results by profile zone. In the foreshore zone the mean median size increased 0.02 millimeter at 50 and 105 hours and then decreased 0.01 millimeter at 150 hours, while the range of values decreased from 0.08 to 0.07 to 0.06 millimeter. In the inshore zone, the mean median increased 0.01 millimeter at 50 and 105 hours and then remained at 0.22 millimeter at 150 hours, while the limits of the values fluctuated somewhat. The mean median size in the offshore zone decreased 0.02 millimeter at 50 hours, increased 0.01 millimeter at 105 hours, and remained constant at 150 hours; the range increased slightly, then increased greatly, and finally decreased greatly. The average median of all samples collected was 0.200 millimeter, fairly close to the assumed initial median.

The results of both experiments are typical of eroding profiles.

Table 9. Sediment-size analysis at 50, 100, and 150 hours for experiment 72B-06.

Station (ft)	Range 1 Elevation (ft)	Range 1 Median (mm)	Range 1 Median (phi)	Range 5 Elevation (ft)	Range 5 Median (mm)	Range 5 Median (phi)
			50 hr			
–6	0.60	0.20	2.32	0.60	0.20	2.32
–4	0.60	0.21	2.26	0.60	0.21	2.26
–2	0.30	0.18	2.46	0.35	0.19	2.39
0	0.12	0.22	2.18	0.15	0.21	2.29
2	–0.15	0.25	2.00	–0.19	0.24	2.09
4	–0.30	0.23	2.15	–0.30	0.23	2.13
6	–0.62	0.20	2.32	–0.60	0.21	2.28
8	–1.00	0.20	2.32	–1.00	0.20	2.33
10	–1.24	0.19	2.37	–1.25	0.19	2.40
12	–1.35	0.19	2.40	–1.42	0.20	2.32
14	–1.49	0.19	2.40	–1.46	0.20	2.32
16	–1.70	0.19	2.40	–1.68	0.19	2.38
18	–1.75	0.19	2.41	–1.82	0.20	2.33
20	–1.99	0.18	2.47	–1.97	0.18	2.52
22	–2.07	0.18	2.47	–2.05	0.19	2.38
24	–2.23	0.19	2.40	–2.19	0.19	2.37
			100 hr			
–6	0.62	0.21	2.26	0.60	0.21	2.28
–4	0.60	0.22	2.18	0.60	0.23	2.15
–2	0.32	0.21	2.26	0.34	0.20	2.32
0	0.12	0.24	2.05	0.13	0.21	2.24
2	–0.11	0.26	1.97	–0.12	0.25	2.00
4	–0.28	0.25	2.00	–0.24	0.23	2.11
6	–0.65	0.23	2.15	–0.60	0.23	2.13
8	–1.05	0.20	2.31	–0.98	0.21	2.27
10	–1.28	0.20	2.36	–1.27	0.19	2.37
12	–1.38	0.19	2.39	–1.43	0.19	2.41
14	–1.54	0.19	2.37	–1.50	0.21	2.26
16	–1.67	0.19	2.38	–1.68	0.20	2.34
18	–1.80	0.19	2.38	–1.82	0.19	2.39
20	–1.96	0.19	2.41	–2.00	0.18	2.44
22	–2.03	0.20	2.34	–2.00	0.19	2.40
24	–2.08	0.19	2.39	–2.04	0.19	2.39
26	–2.23	0.20	2.34	–2.20	0.20	2.32

Table 9. Sediment-size analysis at 50, 100, and 150 hours for experiment 72B-06.—Continued

Station	Range 1 Elevation (ft)	Range 1 Median (mm)	Range 1 Median (phi)	Range 5 Elevation (ft)	Range 5 Median (mm)	Range 5 Median (phi)
			150 hr			
–6	0.62	0.21	2.28	0.60	0.20	2.29
–4	0.60	0.23	2.15	0.60	0.23	2.12
–2	0.32	0.21	2.29	0.32	0.20	2.31
0	0.10	0.22	2.21	0.13	0.23	2.12
–2	–0.13	0.24	2.07	–0.18	0.24	2.07
4	–0.38	0.21	2.22	–0.25	0.22	2.18
6	–0.71	0.21	2.24	–0.69	0.22	2.20
8	–1.10	0.20	2.29	–1.05	0.21	2.28
10	–1.30	0.20	2.36	–1.31	0.20	2.34
12	–1.44	0.20	2.32	–1.49	0.19	2.41
14	–1.57	0.20	2.34	–1.54	0.20	2.34
16	–1.71	0.20	2.33	–1.70	0.19	2.43
18	–1.81	0.20	2.34	–1.80	0.18	2.44
20	–1.95	0.18	2.44	–2.00	0.19	2.41
22	–2.00	0.19	2.40	–2.00	0.19	2.38
24	–2.00	0.19	2.37	–2.00	0.20	2.35
26	–2.20	0.19	2.38	–2.09	0.19	2.38
28	–2.30	0.20	2.33	–2.28	0.19	2.40
30	–2.33	0.20	2.30	–2.33	0.21	2.22

Table 10. Summary of median grain-size values within profile zones for experiment 72B-06.

Cumulative time	Profile zones								
	Foreshore[1]			Inshore			Offshore		
(hr)	Mean (mm)	Range (mm)	No.	Mean (mm)	Range (mm)	No.	Mean (mm)	Range (mm)	No.
50	0.21	0.25 to 0.18	8	0.22	0.23 to 0.21	3	0.19	0.20 to 0.18	19
100	0.23	0.26 to 0.20	8	0.24	0.25 to 0.23	3	0.20	0.23 to 0.18	21
150	0.23	0.24 to 0.20	8	0.22	0.22 to 0.21	2	0.20	0.22 to 0.18	26

[1] Samples collected from the backshore not included.

Note.—Initial median grain size is assumed to be 0.205 millimeter.

Table 11. Sediment-size analysis at 50, 105, and 150 hours for experiment 72B-10.

Station	Range 1			Range 5			Range 9		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
50 hr									
–6	0.60	0.20	2.31	0.60	0.21	2.29	0.60	0.21	2.24
–4	0.50	0.22	2.18	0.53	0.23	2.12	0.50	0.27	1.88
–2	0.40	0.20	2.34	0.40	0.19	2.38	0.30	0.21	2.29
0	0.10	0.21	2.26	–0.03	0.22	2.22	–0.12	0.27	1.90
2	–0.23	0.20	2.36	–0.27	0.20	2.36	–0.40	0.24	2.06
4	–0.53	0.21	2.24	–0.44	0.20	2.34	–0.40	0.23	2.15
6	–0.60	0.19	2.39	–0.69	0.18	2.47	–0.60	0.20	2.32
8	–0.95	0.18	2.47	–1.00	0.18	2.49	–1.02	0.19	2.41
10	–1.11	0.18	2.47	–1.00	0.18	2.49	–1.05	0.19	2.38
12	–1.15	0.18	2.44	–1.00	0.18	2.46	–1.08	0.18	2.47
14	–1.20	0.18	2.46	–1.32	0.17	2.54	–1.41	0.17	2.56
16	–1.50	0.19	2.43	–1.50	0.17	2.59	–1.58	0.18	2.44
18	–1.76	0.19	2.40	–1.74	0.19	2.40	–1.77	0.17	2.56
20	–1.85	0.18	2.46	–1.94	0.19	2.37	–2.00	0.18	2.45
22	–2.05	0.18	2.52	–2.18	0.19	2.40	–2.14	0.17	2.51
105 hr									
–6	0.60	0.20	2.32	0.60	0.21	2.23	0.60	0.21	2.24
–4	0.53	0.24	2.09	0.52	0.23	2.15	0.50	0.21	2.24
–2	0.35	0.21	2.26	0.28	0.21	2.25	0.27	0.22	2.22
0	–0.05	0.24	2.05	–0.17	0.28	1.86	–0.09	0.28	1.84
2	–0.50	0.20	2.31	–0.30	0.21	2.20	–0.25	0.25	2.03
4	–0.50	0.20	2.34	–0.50	0.21	2.26	–0.50	0.23	2.13
6	–0.70	0.19	2.40	–0.65	0.20	2.31	–0.60	0.22	2.19
8	–0.95	0.19	2.41	–1.00	0.19	2.38	–0.90	0.20	2.30
10	–1.00	0.19	2.37	–1.00	0.20	2.33	–1.00	0.20	2.31
12	–1.12	0.19	2.39	–1.00	0.20	2.32	–1.00	0.20	2.31
14	–1.31	0.18	2.47	–1.38	0.18	2.51	–1.35	0.19	2.43
16	–1.58	0.18	2.45	–1.55	0.19	2.40	–1.62	0.19	2.38
18	–1.71	0.19	1.37	–1.70	0.20	2.33	–1.78	0.20	2.34
20	–1.85	0.19	2.43	–1.95	0.18	2.45	–2.00	0.19	2.43
22	–2.00	0.19	2.40	–2.18	0.19	2.41	–2.15	0.10	3.32

Table 11. Sediment-size analysis at 50, 105, and 150 hours for experiment 72B-10.–Continued

Station	Range 1 Elevation (ft)	Range 1 Median (mm)	Range 1 Median (phi)	Range 5 Elevation (ft)	Range 5 Median (mm)	Range 5 Median (phi)	Range 9 Elevation (ft)	Range 9 Median (mm)	Range 9 Median (phi)
	150 hr								
–6	0.60	0.22	2.20	0.60	0.21	2.27	0.60	0.24	2.09
–4	0.60	0.22	2.22	0.50	0.21	2.25	0.40	0.24	2.06
–2	0.20	0.20	2.33	0.15	0.24	2.09	0.05	0.26	1.90
0	–0.10	0.24	2.07	–0.15	0.26	1.92	–0.30	0.26	1.94
2	–0.50	0.21	2.28	–0.42	0.22	2.18	–0.40	0.24	2.07
4	–0.50	0.19	2.39	–0.53	0.21	2.24	–0.47	0.20	2.29
6	–0.74	0.19	2.40	–0.75	0.19	2.40	–0.80	0.20	2.32
8	–0.90	0.18	2.45	–0.80	0.20	2.32	–0.80	0.21	2.27
10	–0.90	0.21	2.26	–0.80	0.21	2.26	–0.80	0.20	2.31
12	–1.00	0.20	2.29	–0.97	0.20	2.36	–1.02	0.19	2.38
14	–1.26	0.21	2.25	–1.34	0.19	2.38	–1.30	0.20	2.35
16	–1.53	0.19	2.40	–1.50	0.20	2.33	–1.47	0.20	2.34
18	–1.65	0.20	2.34	–1.68	0.20	2.32	–1.70	0.21	2.29
20	–1.84	0.19	2.38	–1.92	0.19	2.40	–2.00	0.16	2.61
22	–2.01	0.19	2.43	–2.17	0.20	2.33	–2.15	0.18	2.47
24	–2.21	0.18	2.51	–2.25	0.19	2.40	–2.25	0.17	2.59
26	–2.33	0.18	2.46						
28	–2.33	0.19	2.38						
30	–2.33	0.21	2.17						

Table 12. Summary of median grain-size values within profile zones for experiment 72B-10.

Cumulative time (hr)	Foreshore[1] Mean (mm)	Foreshore[1] Range (mm)	Foreshore[1] No.	Inshore Mean (mm)	Inshore Range (mm)	Inshore No.	Offshore Mean (mm)	Offshore Range (mm)	Offshore No.
50	0.22	0.27 to 0.19	9	0.21	0.24 to 0.19	8	0.18	0.19 to 0.17	25
105	0.24	0.28 to 0.21	9	0.22	0.25 to 0.20	7	0.19	0.20 to 0.10	26
150	0.23	0.26 to 0.20	8	0.22	0.26 to 0.19	7	0.19	0.21 to 0.18	33

[1]Samples collected from the backshore not included.

Note.–Initial median grain size is assumed to be 0.20 millimeter.

4. Breaker Characteristics.

A plot of breaker position (dashline) superimposed on a plot of contour movement along range 3 for experiment 72B-06 is shown in Figure 37. The waves broke by plunging and mainly at depths of 0.3 to 0.4 foot.

A similar plot of breaker position along range 5 for experiment 72B-10 is shown in Figure 38. The waves broke by plunging before 115 hours and by spilling after 115 hours, at depths of 0.2 to 0.4 foot. A plot (Fig. 39) of breaker position superimposed on a plot of contour movement in the inshore zone along ranges 1 and 9 of experiment 72B-10 shows that the waves broke by plunging (except at 110 and 140 hours along range 1) at depths of 0.3 to 0.5 foot.

5. Water Temperature.

Figure 40 gives data on daily average water temperature versus both cumulative test time and dates for experiments 72B-06 and 72B-10.

6. Wave-Generated Currents.

Wave-generated bottom and surface currents were observed throughout the two experiments. In experiment 72B-06, no discernible pattern of circulation developed in the surface currents; however, if a bob moved inside the breaker zone it stayed between the breaker and the shoreline. Although no apparent pattern of bottom currents was observed, all neutrally buoyant bobs eventually moved offshore to the area between stations 30 and 32, even if the bobs started inside the breaker zone. The pathlines of surface current bobs indicate as many pathlines in one direction as in the opposite direction (Fig. 41). Although surface currents were observed throughout, no regular pattern ever developed. The average velocity was 0.037 foot (1.128 centimeters) per second.

No apparent circulation pattern developed in the surface currents of experiment 72B-10; however, surface bobs dropped shoreward of station +15 moved shoreward, and any bob that moved into the breaker zone stayed between the breaker and the shoreline. The area between stations +7 and +9 was the dividing line for bottom currents; a bob went either direction from within this area, and a bob placed seaward or shoreward of the area moved away from the area. The current bobs and organic matter (leaves, debris) accumulated in the area bounded by ranges 0 and 1 and stations 0 and +3 and in the area bounded by ranges 0 and 10 (the tank walls) and stations +19 and +22. Other than the limits of general directions discussed, no patterns or regular pathlines of circulation developed in this experiment either. The average velocity was 0.046 foot (1.402 centimeters) per second.

III. PROFILE DEVELOPMENT AND REFLECTIVITY

Results are analyzed by: (a) Profile development, in which the interdependence of the changes in profile shape, sediment-size distribution,

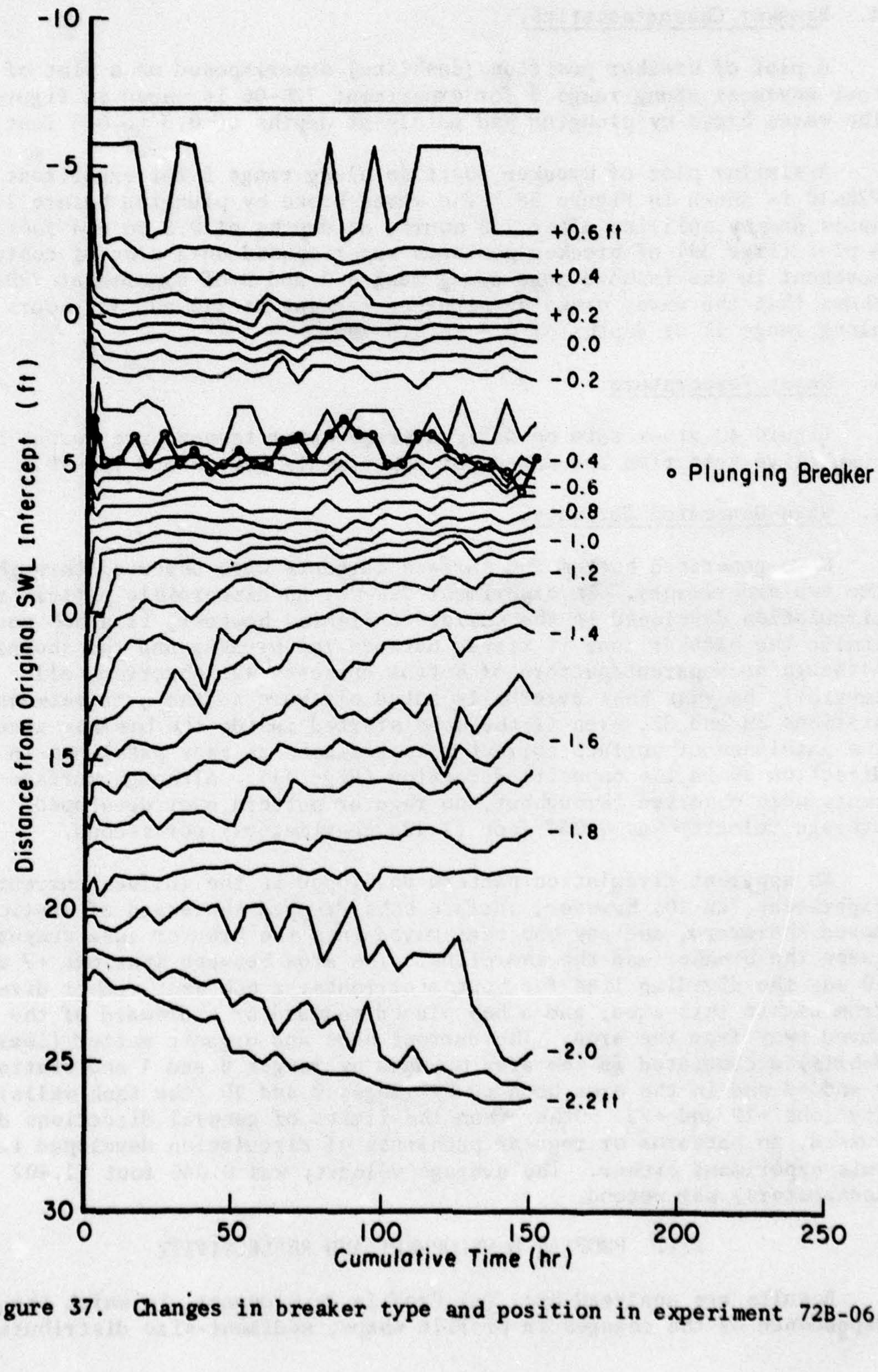


Figure 37. Changes in breaker type and position in experiment 72B-06.

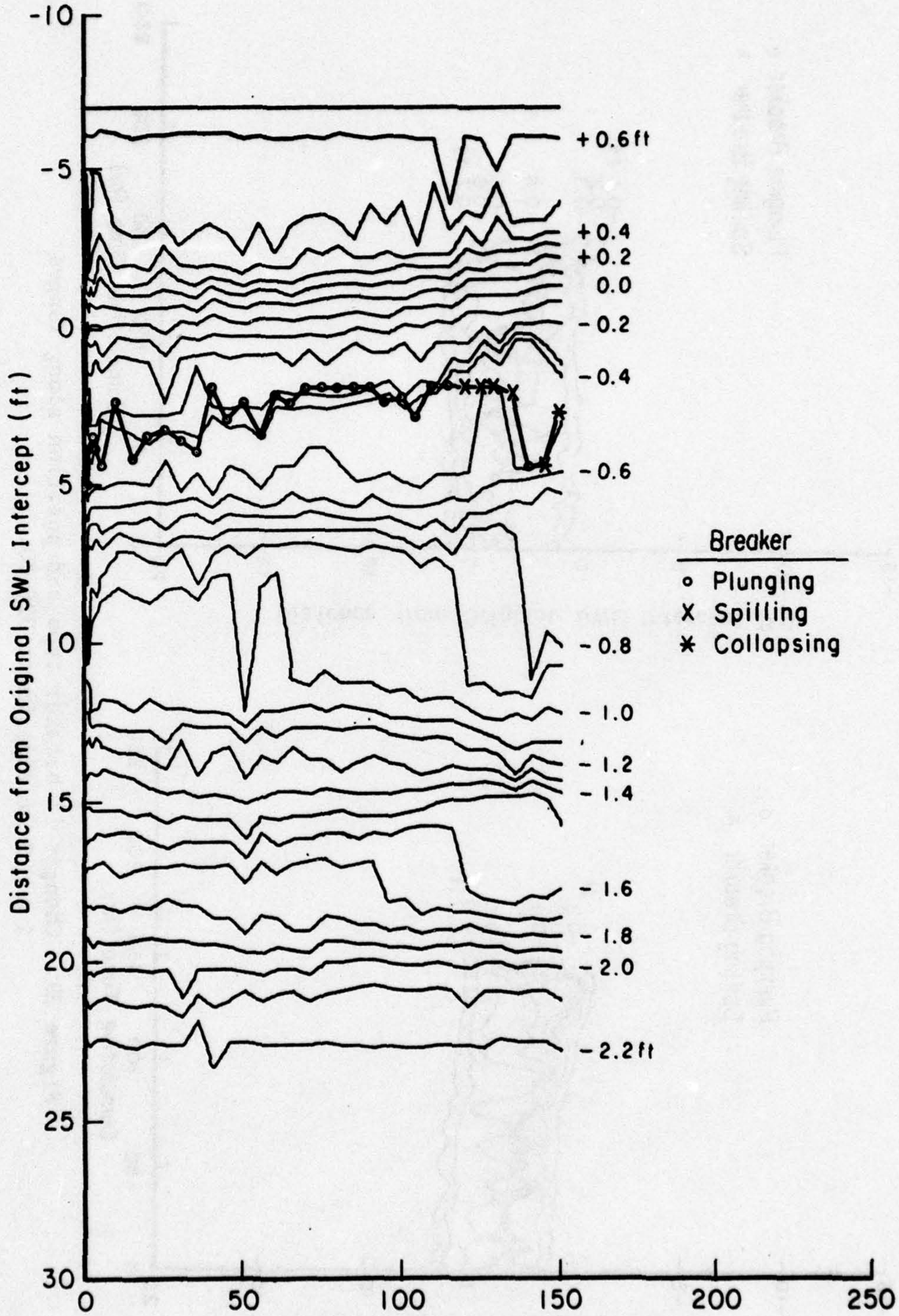


Figure 38. Changes in breaker type and position along range 5 of experiment 72B-10.

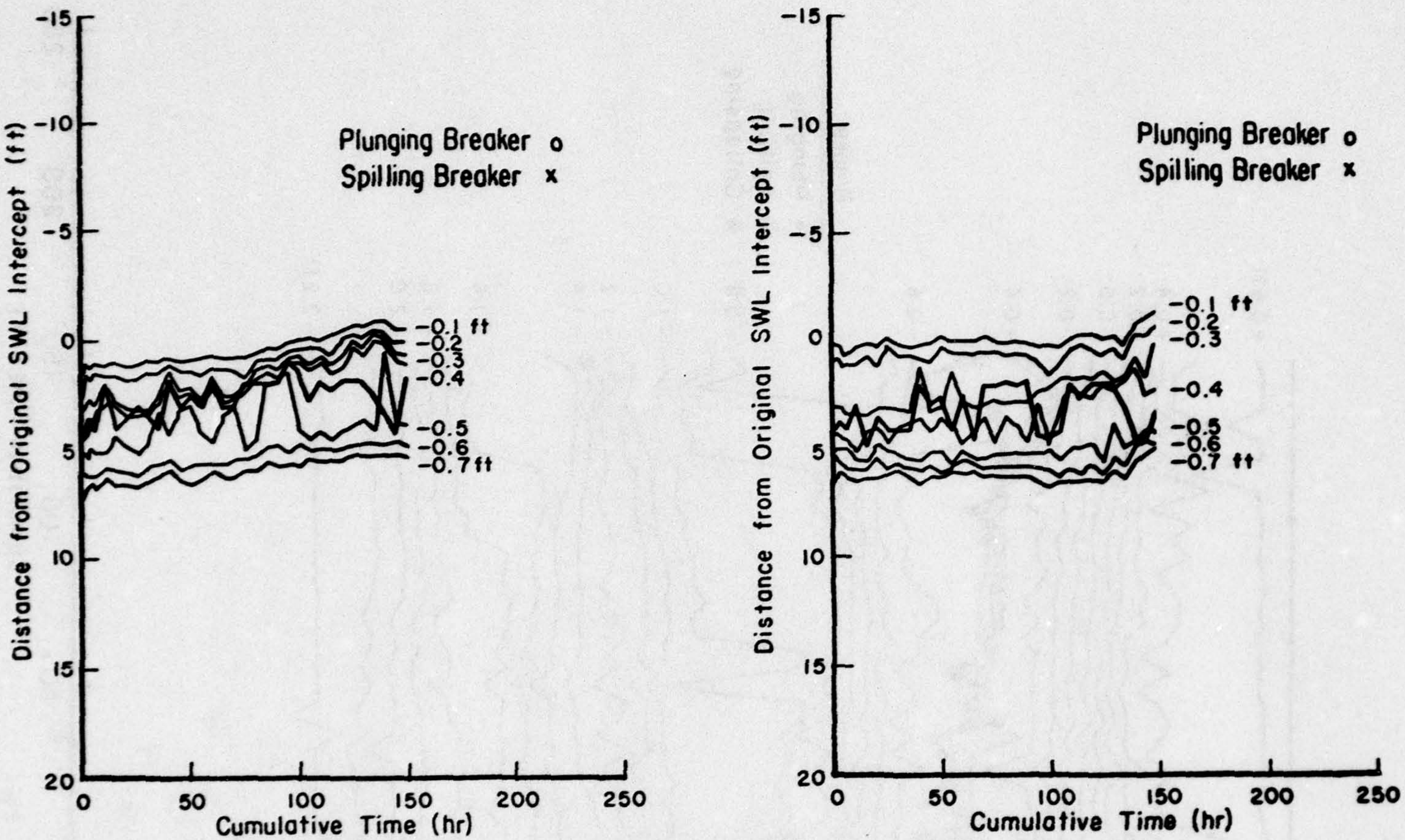


Figure 39. Changes in breaker type and position along ranges 1 and 9 of experiment 72B-10.

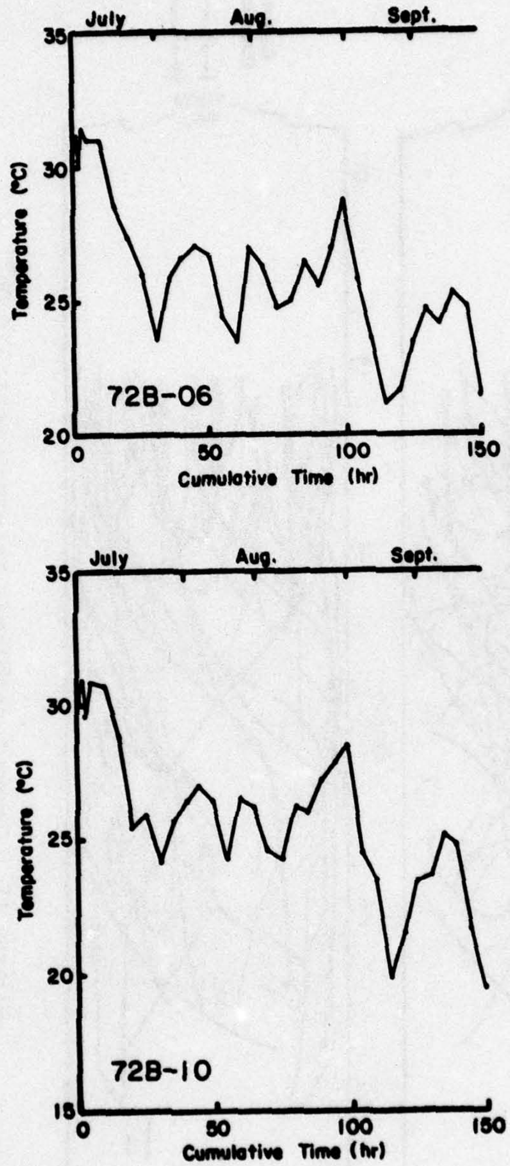


Figure 40. Water temperature changes, 1972.

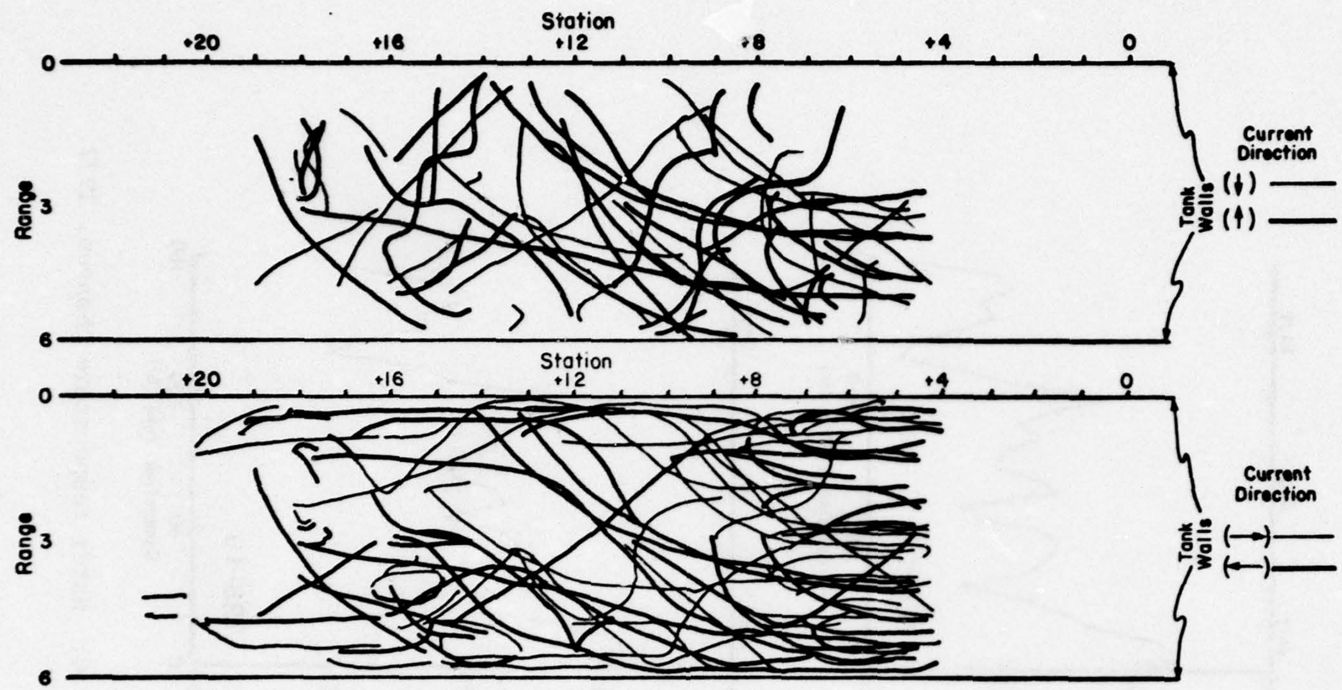


Figure 41. Current pathlines in experiment 72B-06.

breaker characteristics, water temperature, and wave-generated currents is analyzed; and (b) profile reflectivity, in which changes in profile shape and breaker characteristics are related to the variability of the reflection coefficient. Profile development provides an introduction to the profile reflectivity discussion.

1. Profile Development.

a. Experiment 72B-06. The important changes in the foreshore, inshore, and offshore zones, the median grain size, breaker and current conditions, and water temperature during this experiment are summarized and tabulated as a function of time in Table 13.

The profile development discussed previously and condensed in Table 13 occurred as follows. In the first 10 minutes a longshore bar was formed by the plunging breaker in the inshore zone, which remained stable in position and varied slightly in crest elevation throughout the experiment. During the first 10 hours, the foreshore developed an equilibrium shape and position and the offshore zone developed a steep slope just below the inshore zone. After 10 hours the only profile changes occurred in the offshore zone, with erosion from elevations -1.3 to -1.7 feet gradually steepening the upper offshore zone and deposition at -2.1 to -2.2 feet before 90 hours and at -2.0 to -2.2 feet after 90 hours. The profile appeared to be quite close to equilibrium. The sediment became coarser in the foreshore and inshore zones and remained about the same in the offshore zone.

The movement of the shoreline with the change in water temperature is compared in Figure 42. The shoreline was stable in position even though the water temperature dropped several times during the experiment.

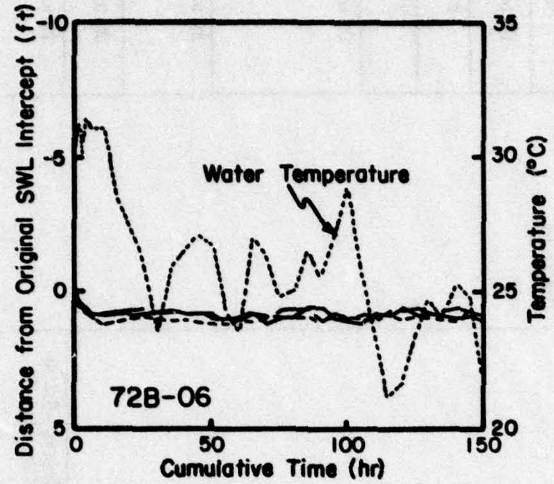
b. Experiment 72B-10. Profile development in this experiment is summarized in Table 14. During the first 10 minutes a longshore bar formed in the inshore zone near station 2 by the plunging breaker; at station 5 a flat area developed along ranges 1, 3, and 5 and a bar along range 9. In the first 5 hours the foreshore developed an equilibrium shape, with the shoreline along range 1 farther seaward and along range 9 farther landward; in the first 10 hours a steep slope formed at the upper edge of the offshore zone and a flat area near station 10. Sand was also deposited seaward of the -1.8-foot contour, but only along range 1.

From 5 to 10 hours the foreshore was stable, but almost immediately after the formation of the bar at station 2 the bar began eroding first along range 3, then range 1, and then range 5. The eroded sand was deposited in the offshore zone near station 10 all across the tank and seaward of the -1.8-foot contour along ranges 1 and 3. A flat area began developing near station 5 along range 7 at 65 hours.

From 70 to 100 hours the foreshore adjusted by eroding along ranges 1, 3, and 5 so that the shoreline was again normal to the tank walls.

Table 13. Summary of profile development, experiment 72B-06.

Time (hr)	Foreshore	Inshore	Offshore	Breakers and currents	Temperature (°C)
0 to 0.16	Developed equilibrium shape; shoreline prograded	Longshore bar formed	Erosion at −0.7 to −1.3 ft, formed steep slope just below inshore; deposition at −2.1 and −2.2 ft	Breakers plunging at depths of 0.3 to 0.4 ft; no discernible circulation patterns; bobs inside breaker zone never moved outside breakers	30
0.16 to 5		No change; bar crest elevation varied between −0.3 and −0.4 ft at different times along different ranges			30 to 31
5 to 10	Reached equilibrium position after total advance of 1 ft				31
10 to 90	No change		Erosion at −1.3 to −1.7 ft; deposition at −2.1 and −2.2 ft		23 to 29
50 hr	Mean d_{50} = 0.21 mm	Mean d_{50} = 0.22 mm	Mean d_{50} = 0.19 mm		
100 hr	Mean d_{50} = 0.23 mm	Mean d_{50} = 0.24 mm	Mean d_{50} = 0.20 mm		
90 to 150			Erosion at −1.3 to −1.7 ft; deposition at −2.0 to −2.2 ft		21 to 29
150 hr	Mean d_{50} = 0.23 mm	Mean d_{50} = 0.22 mm	Mean d_{50} = 0.20 mm		



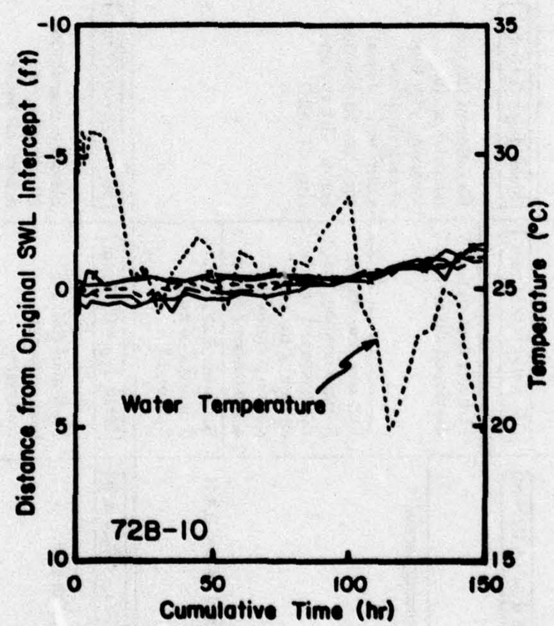


Figure 42. Comparison of water temperature changes and shoreline movement.

Table 14. Summary of profile development, experiment 72B-10.

Time (hr)	Foreshore	Inshore	Offshore	Breakers	Currents	Temperature (°C)
0 to 0.16	Developed stable shape; Shoreline not normal to tank walls	Longshore bar formed near station 2, and at range 9, station 5; flat region formed near station 5, ranges 1, 3, and 5	Steep slope developed at upper edge, and flat area at station 10; deposition along range 1 below −1.8 ft	Plunging at −0.2 to −0.4 ft (range 5) Plunging at −0.3 to −0.5 ft (ranges 1 and 9)	No circulation pattern observed; surface bobs moved shoreward from station +15 and stayed if moved into breaker zone; bottom bobs moved shoreward from station +7 and seaward from station +9	29
0.16 to 5		Bar at station 2 began eroding in order of ranges 3, 1, and 5				30 to 31
5 to 10	No change					31
10 to 65	50 hr Mean d_{50} = 0.22 mm	Mean d_{50} = 0.21 mm	Mean d_{50} = 0.18 mm			24 to 29
65 to 70		Flat area near station 5 developed along range 7	Elevation of flat area near station 10 increased with time at each range and varied with range at each time; deposition below −1.8 ft along ranges 1 and 3			25
70 to 75	Shoreline becoming normal to tank walls.					24
75 to 90		Flat area near station 2 began eroding, first along ranges 1 and 3; erosion of bar near station 2 completed along ranges 7 and 9				26 to 27
90 to 100	Net recession at 100 hrs: 0.4 ft	Bar formed at station 5 in order of ranges 5, 3, and 1				28 to 29
100 to 115	105 hr Mean d_{50} = 0.24 mm	Mean d_{50} = 0.22 mm	Mean d_{50} = 0.19 mm			20 to 25
115 to 130	Shoreline recession rate: 0.018 ft/hr	Erosion of flat area near station 2 continuing	Elevation near station 10 still rising; no deposition below −1.8 ft	Spilling at −0.2 to −0.4 ft (range 5) Plunging at −0.3 to −0.5 ft (ranges 1 and 9)		22 to 24
130 to 150	Recession continuing; large lateral variations in position					19 to 25
	150 hr Mean d_{50} = 0.23 mm	Mean d_{50} = 0.22 mm	Mean d_{50} = 0.19 mm			

After 75 hours at station 2 the erosion of the bar along ranges 7 and 9 was completed and the flat area along ranges 1 and 3 began eroding. Between 90 and 100 hours a bar formed at station 5, first along range 5, then along range 3, and finally along range 1. The sand eroded from the foreshore and inshore zones was deposited seaward of the -1.8-foot contour along ranges 1 and 3 and in the flat area near station 10. The area near station 10, when formed, was lower along the range 1 side and the area remained tilted as sand was then deposited apparently equally across the tank.

After 100 hours the foreshore began eroding and the flat area near station 2 continued eroding. Most of the sand was deposited on the flat area around station 10; none was deposited seaward of the -1.8-foot contour. Near the end of the experiment, lateral variations again occurred in the position of the receding shoreline.

The movement of the shoreline and change in water temperature for this experiment are also compared in Figure 42. The drop in temperature at 10 hours did not appear to affect the foreshore erosion, but the drop at 100 hours coincided with the initiation of shoreline recession.

c. Comparison of the Two Experiments. Although the general profile shapes in the two tanks were similar, there were significant differences in all profile zones.

(1) Foreshore Zone. In experiment 72B-06 the foreshore developed an equilibrium shape and position (normal to the tank walls) during the first 10 hours; in experiment 72B-10 an initially stable foreshore shape developed (shoreline not normal to the tank walls) and then later, the foreshore began eroding.

(2) Inshore Zone. In both experiments a longshore bar formed during the first 10 minutes by the plunging breaker. However, in experiment 72B-06 the bar remained stable except for some variation in the crest elevation; in experiment 72B-10 the bar near station 2 eroded, starting first along the range 1 side of the tank and progressing across the tank to range 9. The second bar (near station 5) formed first along the range 9 side and moved in the opposite direction across the tank to range 1.

(3) Offshore Zone. In both experiments a steep slope at the upper edge of the offshore zone was formed by erosion at the -0.7- to -1.0-foot elevations during the first 10 hours. However, differences in the shape of the lower offshore zone developed. In experiment 72B-06, the profile became concave upward. Sand was eroded at -1.1 to -1.7 feet along all ranges and deposited at -2.1 and -2.2 feet, and later at -2.0 feet along all ranges forming a flat area between stations 20 and 25 (elevation -2.0 feet). In experiment 72B-10 the profile became convex upward. Sand was deposited at elevations -0.9 to -1.7 feet along all ranges and at elevations -1.9 to -2.2 feet along ranges 1 and 3, forming flat areas near stations 10 (elevations -0.8 to -1.1 feet) and 16 (elevations -1.5 to -1.8 feet).

2. Profile Reflectivity.

The changing K_R with the contour movements along the center ranges of each tank is compared in Figure 43. The K_R in experiment 72B-06 (Fig. 43) fluctuated considerably during the first 5 hours as the major profile adjustments occurred. From 5 to 150 hours the mean K_R gradually rose, with fluctuations about the rising mean; the only profile changes were a gradual steepening of the upper part of the offshore between the -0.6- and -1.7-foot contours.

The K_R in experiment 72B-10 (Fig. 43) was higher than in experiment 72B-06. The K_R increased during the initial profile development (0 to 10 hours) and then fluctuated about an average 0.16 from 10 to 80 hours during a period when profile changes were minimal. The K_R increased from 0.16 to 0.24 between 90 and 100 hours and then fluctuated about an average 0.21; the offshore zone developed steeper slopes between stations 12 and 15 and between stations 18 and 20.

IV. SUMMARY OF RESULTS

1. Wave Height Variability.

Four probable causes of the wave height variability measured in experiments 72B-06 and 72B-10 are (a) wave reflection from the changing profile, (b) re-reflection from the wave generator, (c) secondary waves, and (d) transverse waves. These experiments were designed primarily to quantify the amount of variability due to reflection from the profile, but the data were reduced in a manner which also allowed the quantification of the variability due to the transverse wave.

a. Wave Reflection From the Profile. The K_R in the fixed-bed tanks did not vary greatly and there was no long-term increase or decrease in K_R in these tanks. The slight variation is a measure of the accuracy of the reflection measurements in the movable-bed tanks; the range of variation was ±0.015 in experiment 72B-06 and ±0.035 in experiment 72B-10.

The K_R in the movable-bed tank of experiment 72B-06 varied from 0.03 to 0.14. During the first 30 hours the K_R fluctuated greatly, but the maximum values declined. After 30 hours the K_R again increased with continuing fluctuations about the increasing mean. These variations were not caused by any apparent change in profile shape.

The average K_R in the movable-bed tank of experiment 72B-10 varied 0.11 to 0.24 with a similar time variation. However, the increases in K_R in this tank coincided with increasing steepness of the offshore slope between stations 10 and 15. As the height of the top of this steeply sloped section increased from -1.0 to -0.8 foot, the K_R increased. The variation of this critical elevation across the tank apparently caused corresponding variations in K_R.

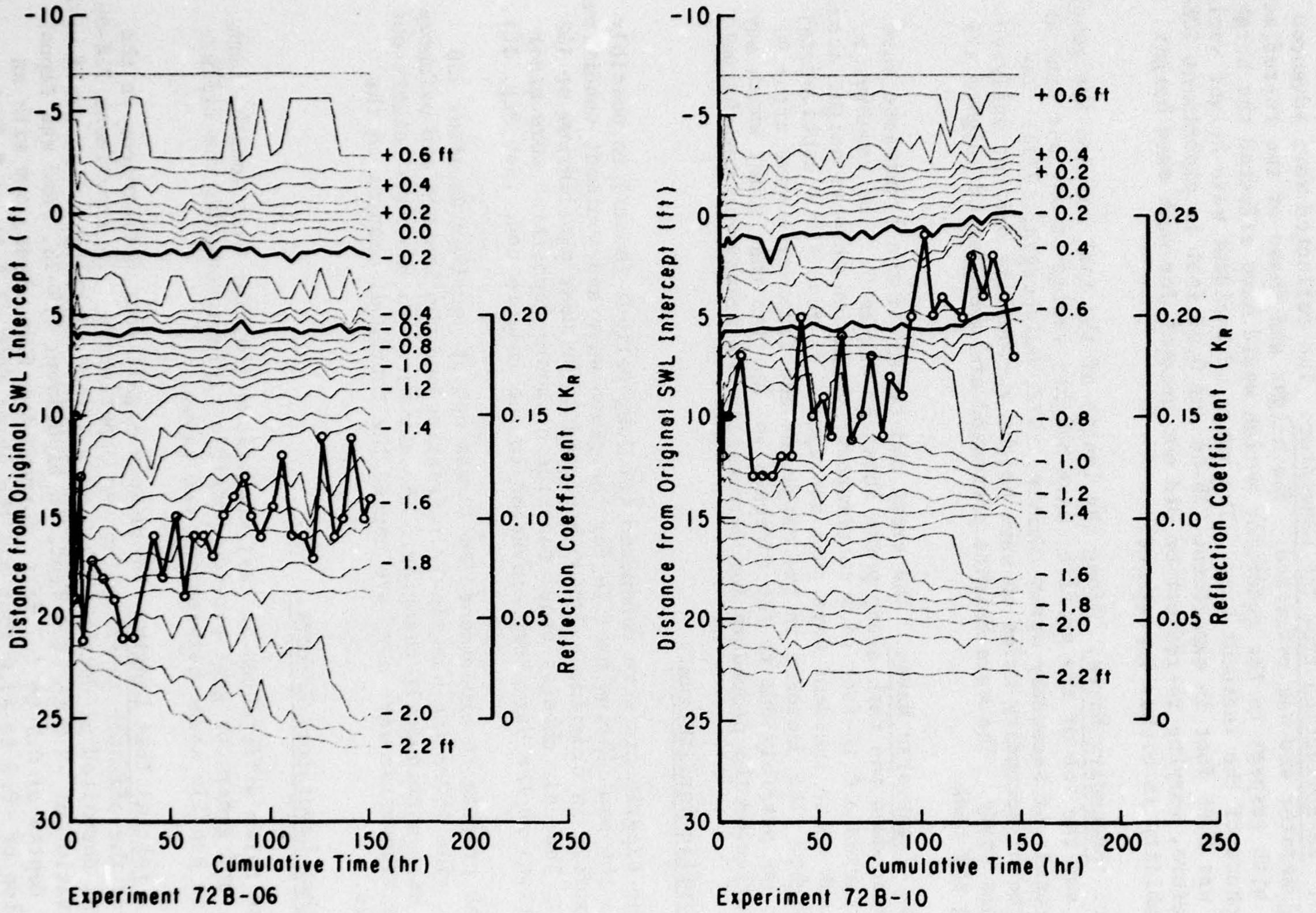


Figure 43. Comparison of profile and K_R changes showing effect of profile adjustments on reflection.

b. **Re-Reflection from the Generator**. The reflected wave advanced to the generator and was reflected. The height and phase of the re-reflected wave with respect to the generator motion would have affected the height and phase of the incident wave. The range of incident wave height variation was 0.06 foot in experiment 72B-06 and 0.03 foot in experiment 72B-10. Therefore, varying re-reflection did not account for much wave height variability in either experiment.

c. Secondary Waves. Along the length of the tank between the generator and the toe of the profile, wave heights varied at any one time as the result of secondary waves (Galvin, 1972; Hulsbergen, 1974). The effects of secondary waves on wave height variability are not analyzed in this study. The wave heights presented are averages of heights all along the tank.

d. Transverse Waves. The crest and trough of the transverse wave traveled down the tank along paths shown in Figure 9. The transverse wave caused a 0.16-foot (4.9 centimeters) variation in wave height across the tank on an incident wave that averaged 0.34 foot (10.4 centimeters) in height. The decrease in the height of the transverse wave after 90 hours was possibly due to the increase in K_R (at that time) which may have affected the procedure for determining the transverse wave height.

2. Profile Equilibrium.

The experiments were conducted for long periods (hours) to possibly define the equilibrium profile for the given wave and sediment conditions. The profile in experiment 72B-06 appeared to be near equilibrium at 150 hours. The only changes other than the offshore deposition were minor variations in the bar crest elevation in the inshore zone (see Fig. 12).

The profile in experiment 72B-10 was not at equilibrium after 150 hours. The shoreline was slowly retreating and the inshore and offshore zones were continuously changing. The asymmetry in the wave heights due to the transverse wave may have caused the continual changes to the profile.

3. Other Laboratory Effects.

The three differences in test conditions (initial test length, tank width, and generator gap) provide possible explanations for the differences in profile shape between the two tanks.

a. Initial Test Length. There were significant differences in the shape of the offshore zones in the two experiments. In experiment 72B-06, sand was deposited at depths of 2.0 to 2.2 feet, forming a flat shelf with an elevation of -2.0 to -2.1 feet; in experiment 72B-10, sand was deposited at depths of 0.9 to 1.7 feet, forming two flat areas, one with an elevation of -0.8 to -1.0 foot and the other from -1.5 to -1.8 feet. These differences were likely caused by the differences in itital test length.

Two phenomena are affected by differences between the generator and the profile: re-reflection and secondary waves. The average incident wave height in the movable-bed tanks was 0.38 foot (11.6 centimeters) in experiment 72B-06 and 0.31 foot in experiment 72B-10; therefore, re-reflection differences may have caused some differences. Secondary waves were observed on the wave recordings.

b. <u>Tank Width</u>. Tank width effects have been reported in Volumes II, III, V, and VI of the LEBS series. The overshadowing effects of the generator gap differences in this study precludes a separate analysis of tank width effects. However, the critical combination of tank width and wavelength caused the transverse wave condition.

c. <u>Generator Gap Effect</u>. The transverse wave observed in experiment 72B-10 was generated by the gap at the end of the generator blade and resulted in the following differences in profile shape between the two tanks. The wave heights over the profile in experiment 72B-10 were obviously confused as a result of the transverse wave. This may have caused the shoreline to become skewed, with range 9 landwardmost and range 1 seawardmost. The flat area near station 10 in the 10-foot tank was lower in elevation along range 1 than along range 9. The erosion and formation of the bars in the inshore zone of the 10-foot tank were unique and the erosion progressed from range 1 to 9 and the formation from 9 to 1. Figure 43 compares the profiles along ranges 1, 5, and 9, and shows the lateral variations caused by the transverse wave.

V. CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions.

(a) In two experiments with a water depth of 2.33 feet, a wave period of 2.35 seconds, and a generator stroke of 0.24 foot (7.3 centimeters) (generated-wave height of 0.34 foot), the average incident wave height was 0.38 foot in experiment 72B-06 and 0.31 foot in experiment 72B-10 (Table 5). Reflection measurements in the control tanks with a fixed-bed profile varied from 0.03 to 0.06 in experiment 72B-06 and from 0.02 to 0.09 in experiment 72B-10, indicating that the measurement error in determining K_R from the changing profile was ±0.015 in experiment 72B-06 and ±0.035 in experiment 72B-10 (Table 6).

(b) K_R varied from 0.03 to 0.14 in experiment 72B-06 and the average K_R in experiment 72B-10 varied from 0.11 to 0.24. The K_R in the 10-foot tank varied considerably across the tank. Increases in K_R in experiment 72B-10 correlate well with changes in the upper part of the offshore slope. The K_R changes in experiment 72B-06 were not caused by any apparent change in profile shape (Fig. 43).

(c) The profile in the 6-foot tank developed an equilibrium shape during the first 30 hours (Fig. 14). The profile in the wider tank was [illegible], [illegible] continuously, changing, and never reached equilibrium (Fig. 18).

(d) Differences in the shape of the offshore zone between the two tanks were apparently the result of re-reflection and secondary wave effects caused by the difference in initial test length (Fig. 12).

(e) The gap at the end of the generator blade in experiment 72B-10 and the critical combination of wavelength and tank width caused a transverse wave. This accounted for a 0.16-foot lateral variation in wave height (Figs. 6, 7, and 8 and Table 7).

(f) The transverse wave affected the shape of the profile: the shoreline became skewed, the depth of the shelf in the offshore zone increased laterally, and changes in the inshore zone progressed from one side of the tank to the other during the experiment (Fig. 44).

2. Recommendations.

(a) The final profile shape in experiment 72B-06 could be used as an approximation to an equilibrium profile for these wave, sediment, and initial slope conditions (Fig. 12).

(b) Researchers and modelers using wave generators with gaps at the end of the blade should consult Madsen (1974) to determine critical wave periods for each water depth used in testing.

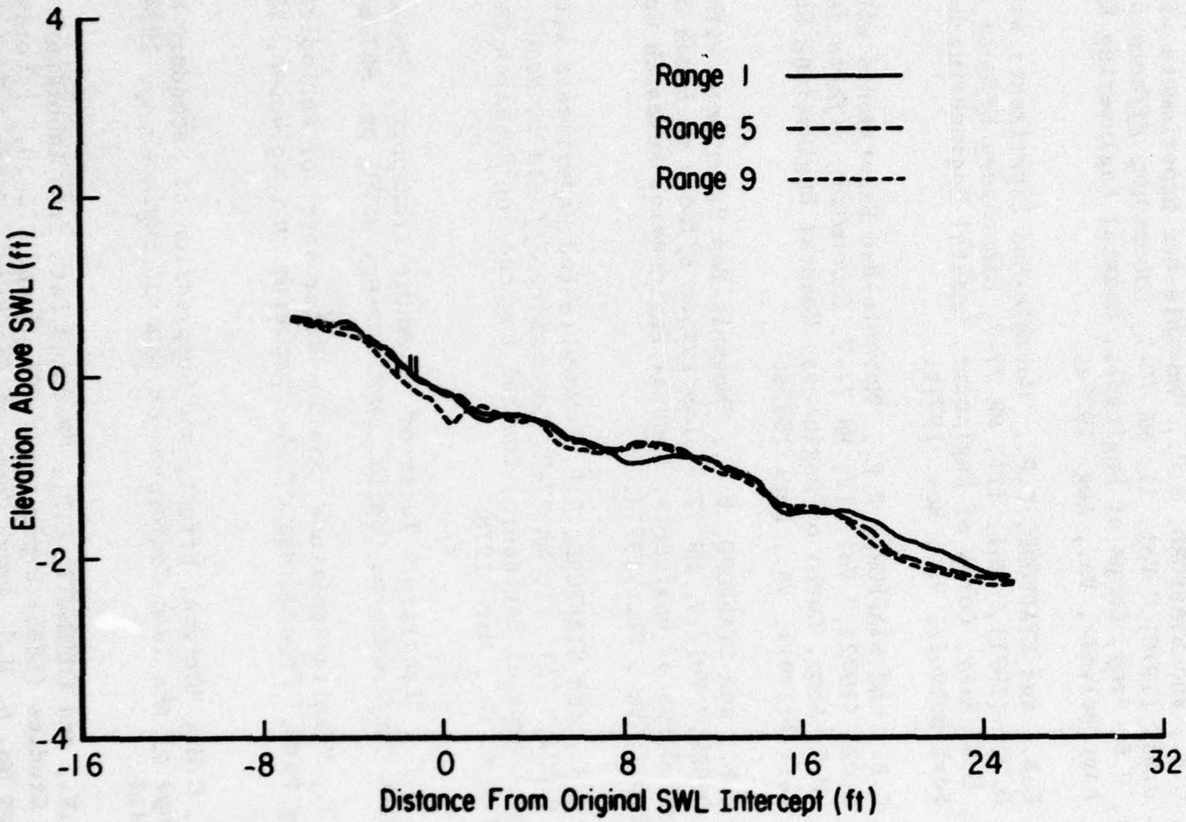


Figure 44. Comparison of profiles along ranges 1, 5, and 9 at 150 hours in experiment 72B-10.

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APPENDIX

EXPERIMENTAL PROCEDURES FOR 72B-6 AND 72B-10

This appendix documents those aspects of the experimental procedures unique to experiments 72B-06 and 72B-10. The procedures common to all experiments are documented in Volume I (Stafford and Chesnutt, 1977).

1. Experimental Layout.

The experimental layout was the same as that used for experiments 71Y-06 and 71Y-10 (Vol. III). Figure A-1 shows the position of the initial profiles with respect to the coordinate system.

2. Data Collection.

a. Regular Data.

(1) Wave Height Variability. During the first run in each experiment, a continuous water surface elevation was recorded at station +25 near the toe of the movable-bed profiles and 7 feet offshore of the toe of the fixed-bed slope. During all subsequent runs, wave envelopes in experiment 72B-06 were recorded with wave gages moving along the center of the two tanks from station +15 to +85 and from +85 to +15, and in experiment 72B-10 along the center of the fixed-bed tank and ranges 1, 5, and 9 in the movable-bed tank from station +15 to +50 and from +50 to +15.

(2) Wave-Generated Current Data. Observations of wave-generated surface and bottom currents were made throughout both experiments.

b. Special Data. Four types of special data were collected at less frequent intervals, and Table A-1 indicates the times when each type of data was collected and the spacings and limits of the data collected.

3. Data Reduction.

a. Wave Height Variability. The wave reflection envelopes were divided into two groups for data reduction. The automated method for determining K_R was used with the grade I data, which had no quality control problems. The manual method for determining K_R was used with the grade II data, which had problems of (a) pen skips, (b) highly variable carriage speed, or (c) off-scale values. Some of the grade I envelopes were reduced manually to provide a comparison of the two methods.

b. Sand-Size Distribution. All samples were analyzed using the VA tube method by the U.S. Army Engineer Division, Missouri River, laboratory. Approximately 10 percent of the samples were also analyzed by project personnel in the CERC Petrology Laboratory using the dry sieve method as a quality control measure. Table A-2 gives the results from the dry sieve method.

c. Breaker Characteristics. Breaker type and position were determined from the visual observation forms.

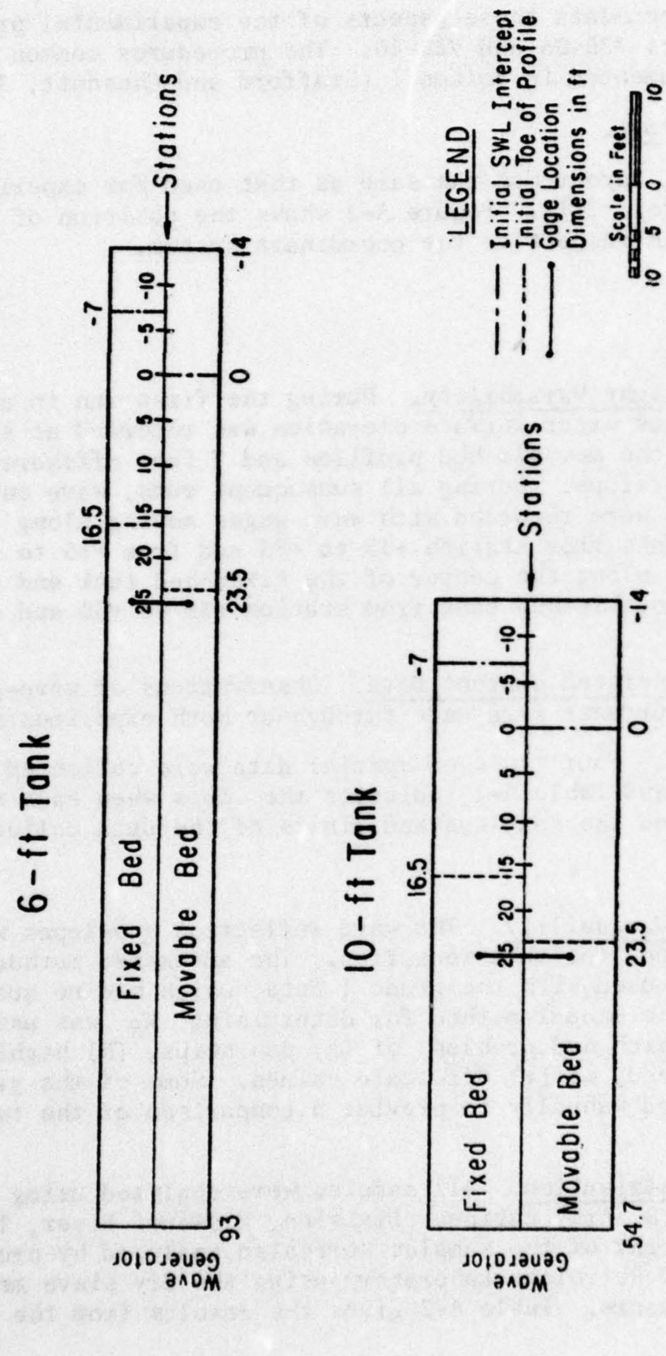

Figure A-1. Experimental setup.

Table A-1. Summary of special data collection

Time (hr)	Profile survey limits[1] (ft)	Photo survey limits (ft)	Sand sample limits[2] (ft)
Experiment 72B-06			
50	−7 to +26	−7 to +27	−6 to +24
100	−7 to +28	−7 to +31	−6 to +26
150	−7 to +33	−7 to +31	−6 to +30
Experiment 72B-10			
50	−7 to +27	−10 to +26	−6 to +22
100	−7 to +30	Not taken	Not taken
105	Not taken	−7 to +26	−6 to +22
150	−7 to +31	−7 to +29	−6 to +30[3]

[1] Elevations measured at 0.5-foot intervals between the given stations along ranges 0.5 foot apart.

[2] Samples collected at 2-foot intervals between given stations along ranges 1 and 5 in the 6-foot tank, and ranges 1, 5, and 9 in the 10-foot tank.

[3] Samples collected along range 1 only at stations +26, +28, and +30.

Table A-2. Sediment-size analysis (dry sieve method) at various hours for experiments 72B-06 and 72B-10.

Station	Range 1			Range 5			Range 9		
	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)	Elevation (ft)	Median (mm)	Median (phi)
Experiment 72B-06									
50 hr									
–2	——	——	——	–0.19	0.25	2.03	——	——	——
12	——	——	——	–1.42	0.21	2.27			
20	–1.99	0.20	2.32	——	——	——	——	——	——
105 hr									
–2	——	——	——	–0.12	0.24	2.05	——	——	——
12	——	——	——	–1.43	0.20	2.32	——	——	——
22	——	——	——	–2.00	0.20	2.34	——	——	——
150 hr									
–2	0.32	0.21	2.22	0.32	0.22	2.20	——	——	——
18	–1.81	0.20	2.32	–1.80	0.20	2.34	——	——	——
Experiment 72B-10									
50 hr									
0	0.10	0.23	2.15	——	——	——	——	——	——
6	——	——	——	–0.69	0.20	2.32	——	——	——
12	——	——	——	——	——	——	–1.08	0.19	2.40
14	–1.20	0.20	2.35	——	——	——	——	——	——
20	–1.85	0.19	2.38	——	——	——	——	——	——
100 hr									
–2	0.35	0.21	2.22	0.28	0.22	2.16	0.27	0.23	2.13
18	–1.71	0.19	2.43	–1.70	0.21	2.25	–1.78	0.20	2.29
150 hr									
–2	0.20	0.21	2.24	0.15	0.25	1.99	0.05	0.28	1.86
18	–1.65	0.20	2.32	–1.68	0.22	2.20	–1.70	0.22	2.20