Data Report from an Experiment to Measure the Dispersion of a Hopper Dredge Discharge Plume at Kanmon Channel, Japan

1984

Marine Mining Panel

The United States - Japan Cooperative Program

in Natural Resources

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I. General Description of the Experiment

I-1. Objectives

The Marine Mining Panel of the United States - Japan Cooperative Program in Natural Resources, conducted a cooperative experiment involving the study of a technique for controlling surface turbidity and sediment dispersion associated with hopper dredge operations.

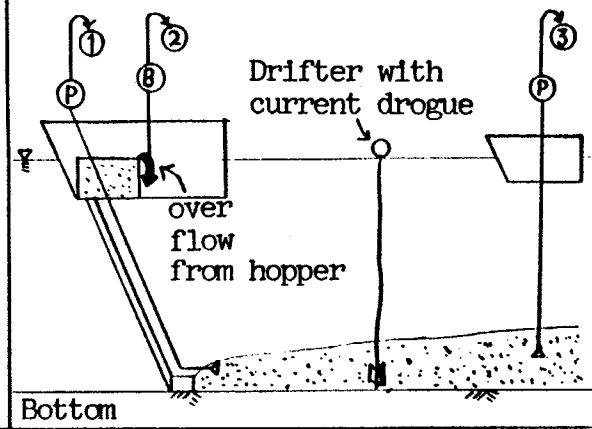
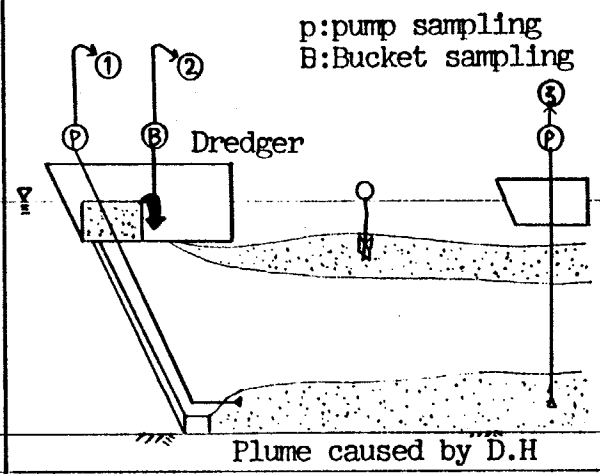
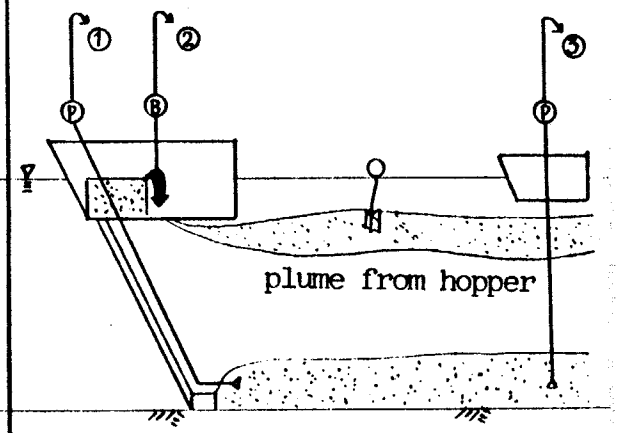
The principal objective of the experiment was to test a Japanese - developed Anti-Turbidity Overflow System (ATOS) at a typical dredge site off the coast of Japan and to determine its effectiveness in controlling surface turbidity and sediment dispersion associated with continental shelf dredge operations using a conventional drag suction hopper dredge Kaihomaru.

The ultimate goal of the panel is to detrmine the applicability of the ATOS to marine sand and gravel mining.

I-2. Constitution of the experiment

In order to evaluate change in turbidity dispersion, the experiment included three cases depending on the sources of the turbidity plume (Case I: plume caused by the drag head, Case II: plume discharged through ATOS, Case III : plume without ATOS, see Fig. I-1). Each case was observed twice with the following

Fig. I - 1 Schematic explanation for the three cases of the experiment
(Schematic representation of water sampling)

	Case I	Case II	Case III
Boats and plume			
Purpose	To observe dispersion process of the bottom turbidity plume caused by the drag head.	To observe dispersion process of the near surface turbidity plume discharged through ATOS.	To observe dispersion process of the near surface turbidity plume discharged without ATOS.
Marker current drogue depth	A drifter which has a drogue at a depth of the plume was put in to trace the turbid water mass.		
	2 m above the bottom	6 m below the sea surface	2 m below the sea surface
Water sampling	① Five times sampled from just behind the drag head during dredge operation. (see Fig.)		
	② Overflow water from the hopper weir was sampled three times : 5,15 and 25 minutes after overflow start.		
	③ Sea water sampling from six depths to determine vertical distribution of SS was made from three boats situated transverse to the plume direction. The sampling was repeated six times : 5,15,25 and 35 minutes after start of dredging, and 20 and 60 minutes after finish of dredging. To determine the background SS distribution the same type of sampling was made on station before the start of dredging.		

measurements and sampllings:

1. Continuous current measurements at four depths on a single station in the area.
2. Analyses of bottom sediment in the dredging site.
3. Water sampling for measuring SS concentration and particle size distribution.
4. Turbidity measurements with turbidimeters.
5. Pumping rate of slurry and other information on board the Kaihomaru.
6. Weather and sea conditions

To trace the center of the turbidity plume, one or two drifters with a surface-marker buoy were placed in the center of the plume. Five survey boats were lined up about 50 m apart in a cross plume direction to measure the cross sectional dispersion of the turbidity. The main boat (No. 2) followed the marker buoy so that it was always located at the plume center.

I-3. Location and period of the field experiment

The field experiments were carried out at Kanmon Channel in the western part of the Seto Inland Sea, Japan. The detailed location is shown in Fig. I-2.

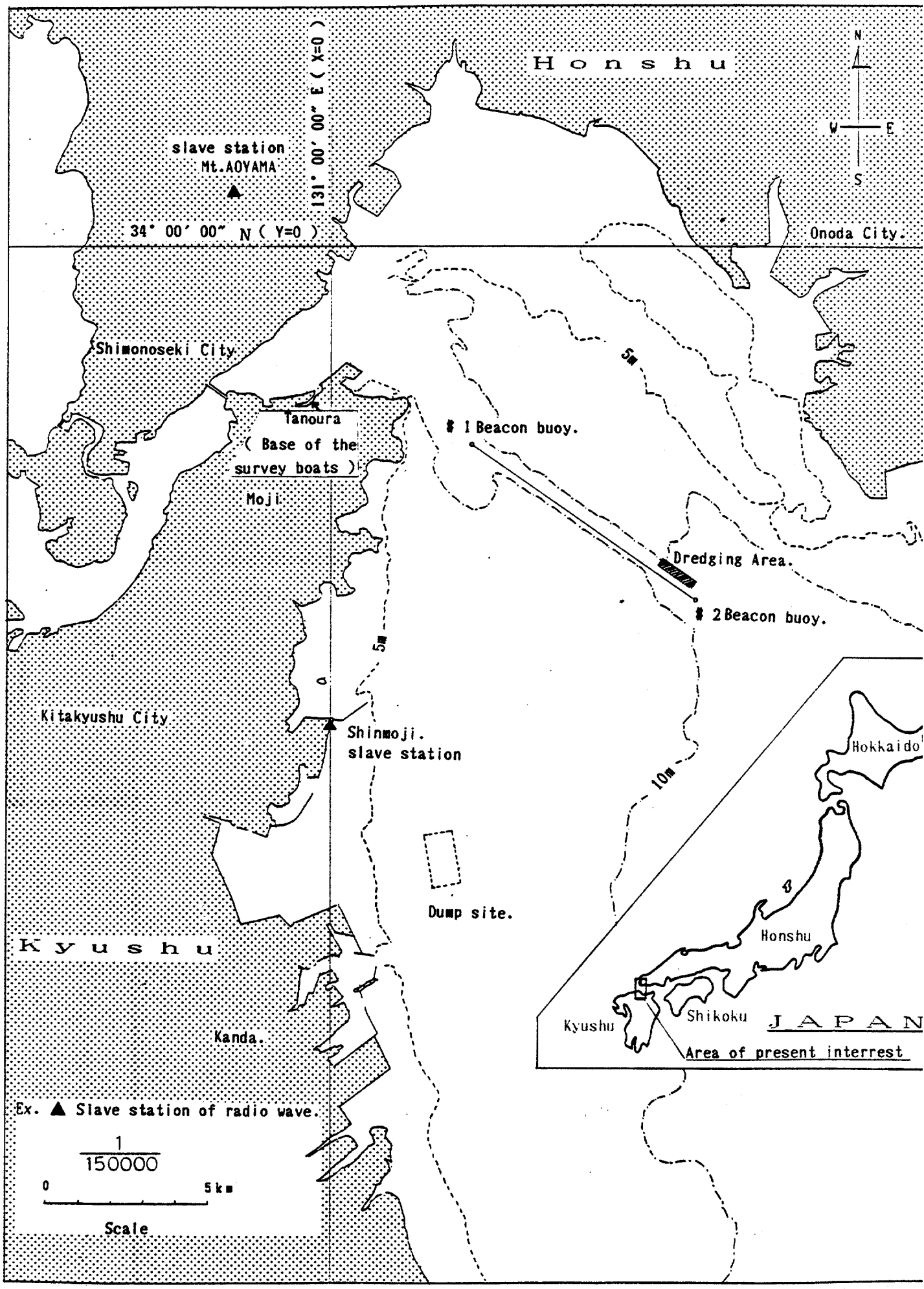


Fig. 1－2 Area of the experiment

The period of observation;

from July 22 through July 25, 1984.

The period, late July, was chosen because the most stable and good weather can be expected every year.

I-4. The hopper dredge, Kaihomaru and ATOS function

The Kaihomaru, which belongs to the Fourth Port and Harbor Construction Bureau, Ministry of Transport was served for the experiment.

The principal particulars of the Kaihomaru are as follows:

length	86.6 m
breadth	16.0 m
depth	7.0 m
draft (loaded)	5.8 m
gross tonnage	3,198 tons
speed	11.6 kts
dredging depth (max.)	17.0 m
hopper capacity	2,052 m^3
dredging pumps	5000 $m^3/h \times 2$

Fig. I-3 shows the general arrangements of the Kaihomaru.

Previous studies have shown that allowing a hopper to overflow in the conventional manner can have serious effects upon the environment through development of a near-surface sediment plume

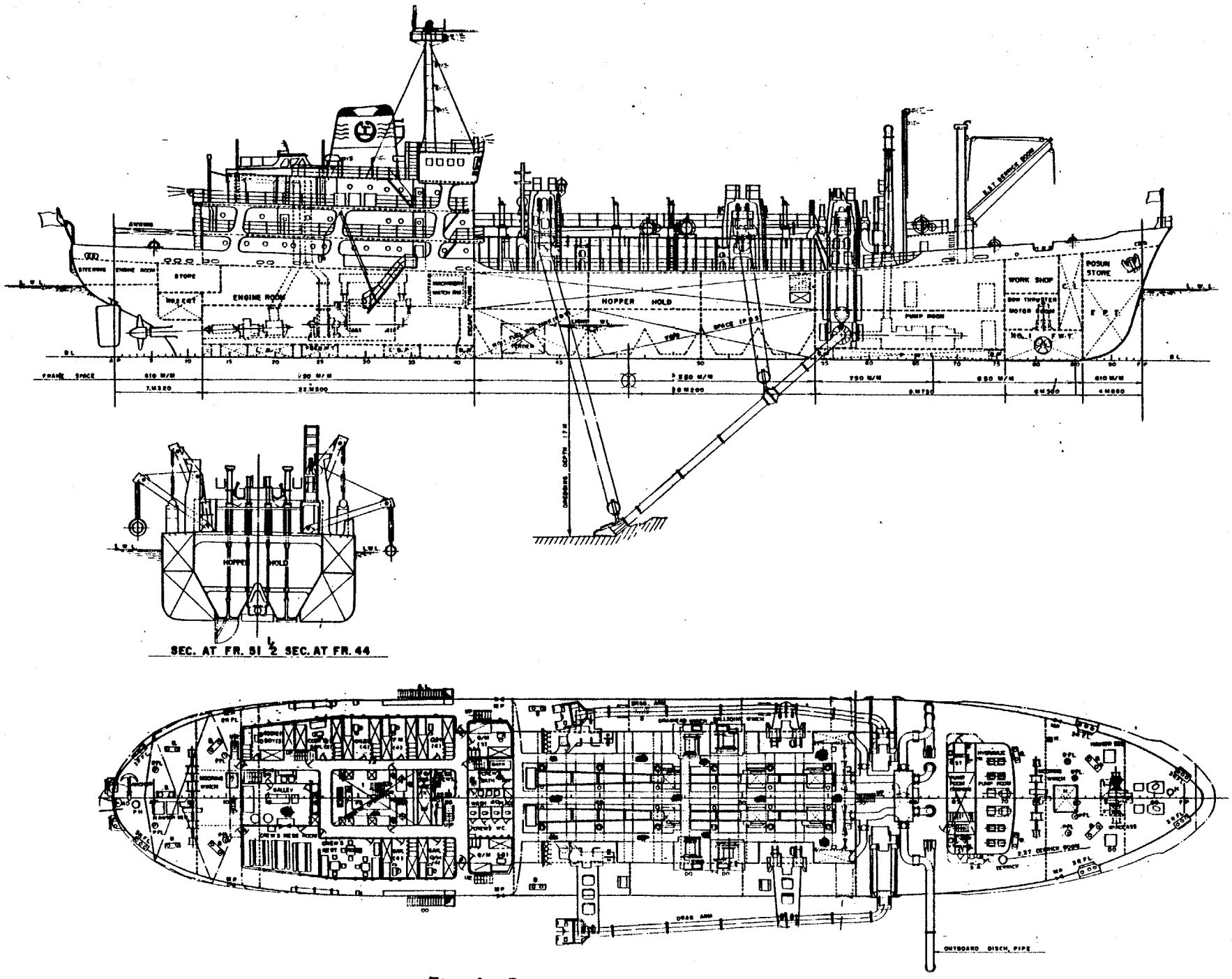
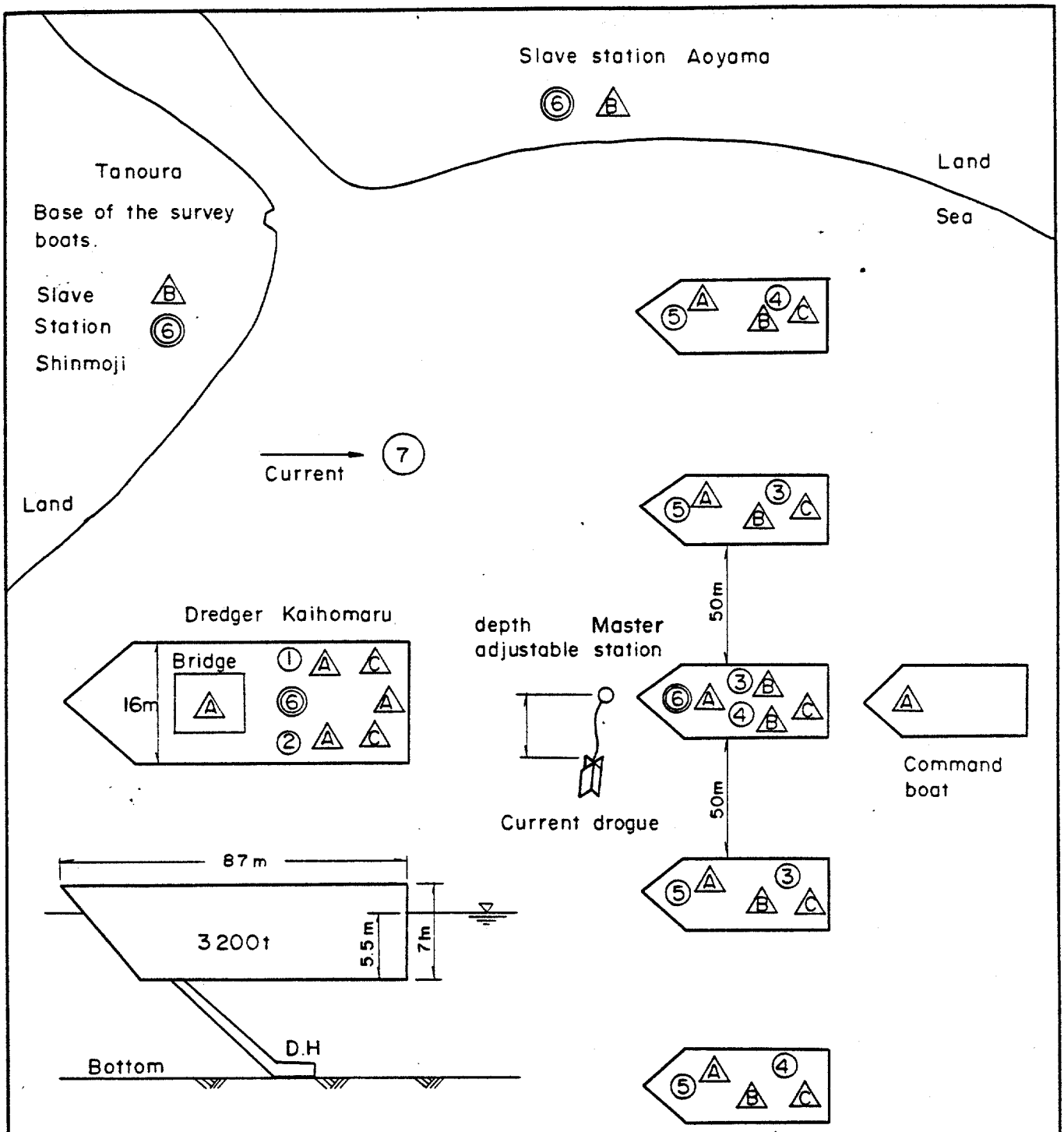


Fig. I-3 The Kaihomaru

No. 2	* Precise fixing with a radio wave distance meter * Water sampling for SS with a pump * Vertical turbidity profile measurement * Drifter tracking * Bottom sediment sampling
No. 4 No. 5	* Vertical and cross plume turbidity profile measurement * Depth sounding * Mooring and retrieval of current meters
No. 6	* Command boat

Boats, the dredge, instruments and staff arrangement is shown in Fig. I-4.



① Water sampling from the drag head.

② Overflow water sampling.

③ Water sampling from 6 depths (1, 3, 5, 7, 10, 12 m from surface)

④ Turbidimeter and Electric pen recorder

⑤ Positioning with a hand bearing compass and a portable distance meter

⑥ Positioning with auto distance meters by radio wave

⑦ Current observation at 4 depths

Fig. I-4 Boats, Instruments and Staff arrangements

I-6. Geological and oceanographic features of the region

The area of the experiment is located in the western end of the Seto Inland Sea, which is often called the Suhonada Sea. Fig. I-5 shows a bathymetic chart of the region. Bottom sediments around the dredge site are mud or mud with shells.

Currents are generally weak except for narrow channel parts. Current patterns and speeds of the maximum flood and ebb currents in a mean spring tide period are shown in Figs. I-6 and I-7, respectively.

Figs. I-8, I-9, and I-10 show a five-years (1976 - 1980) average of the sea surface temperature, salinity and transparency (measured with a Secchi disk, 30 cm in diameter) in July, respectively. Those observations were made once a month by three prefectural fisheries experimental stations.

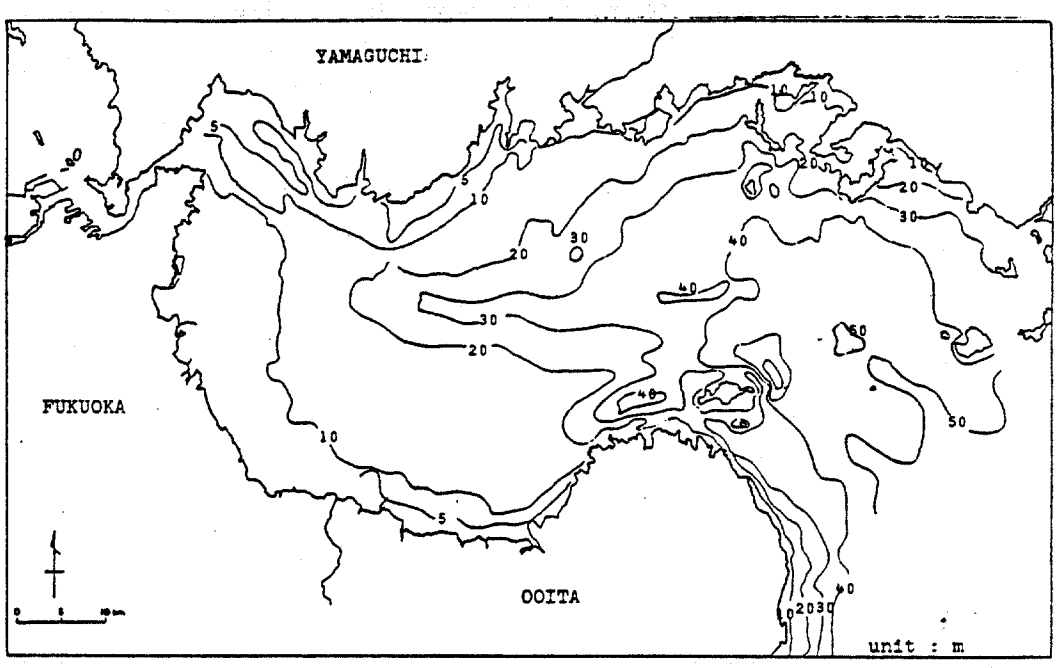


Fig. I - 5 Bathymetry of the Suhonada Sea

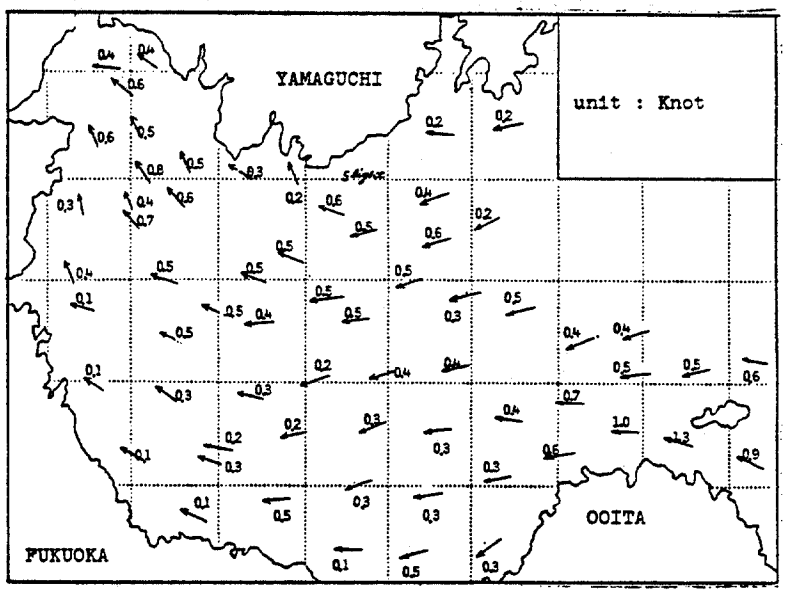


Fig. I - 6 Flow pattern and speeds of the maximum flood current

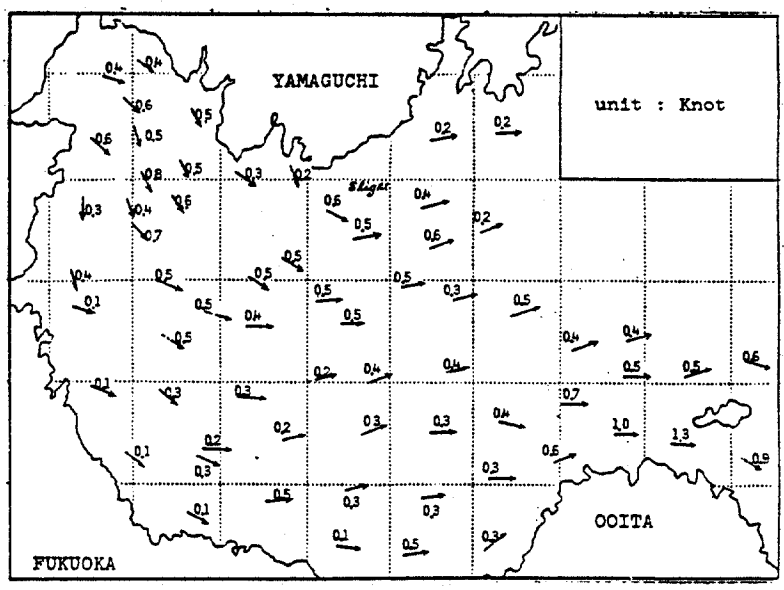


Fig. I - 7 Flow pattern and speeds of the maximum ebb current

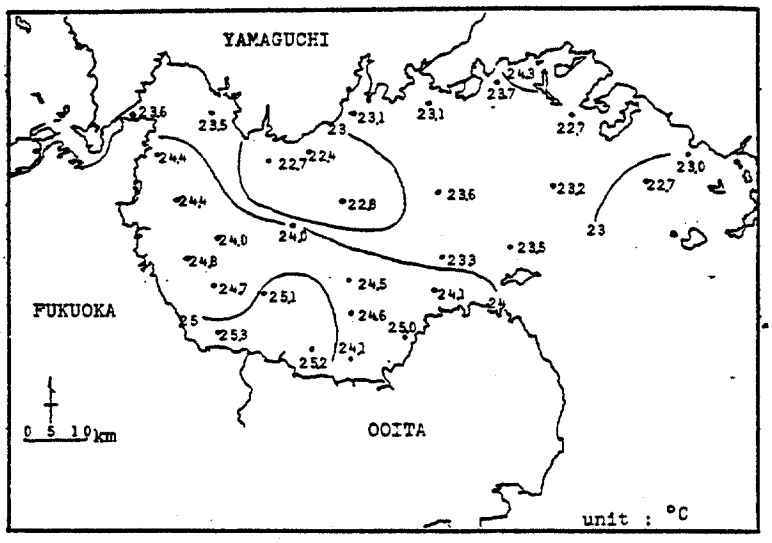


Fig. I - 8 Sea surface temperature in July (a five years average)

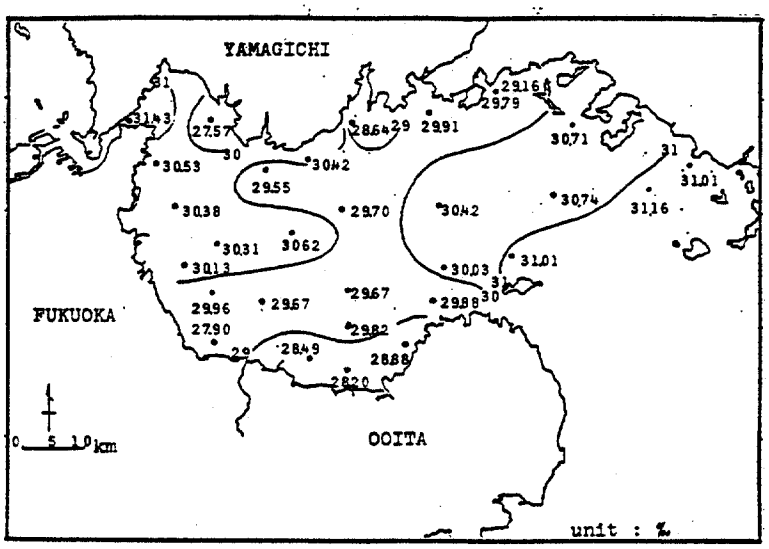


Fig. I - 9 Sea surface salinity in July (a five years average)

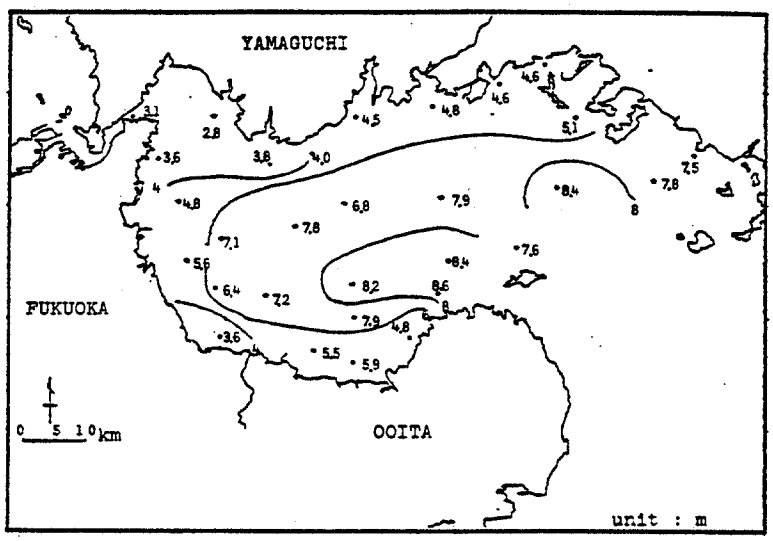


Fig. I - 10 Transparency in July (a five years average)

II Methods of observation and sampling

II-1. Positioning methods

To determine the positions of the boats, two methods were applied. The dredge Kaihomaru and the main survey boat (No. 2), located at the center of the turbidity plume, were equipped with a system for measuring distance at sea by means of radio waves (AUDISTER). The basic system consists of fixed slave stations on land, and a master station installed aboard the survey boat. The location of the boat can be determined by measuring the distance between the boat and each slave stations. This equipment measures distance quickly and accurately. For example, the measurement time at a range of 50 km is about 1 second and the measurement error is ± 1.0 m. Further explanation of the system is given in the Appendix -27. Locations of the master and slave stasions are shown in TableII-1 and Fig. II-1.

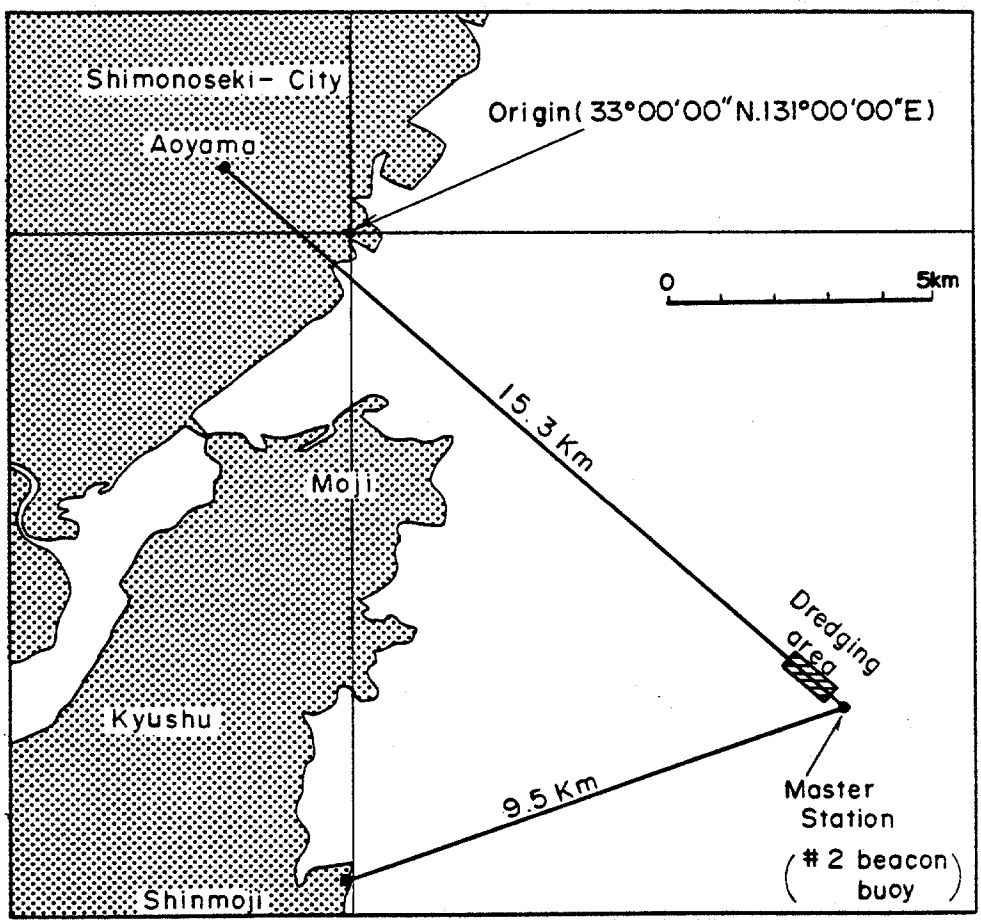
In the second method for position fixing, a hand bearing compass (Fig.II-2) and a portable distance meter (Fig.II-3) were used to measure distance and direction. These devices were installed on the boats, Nos. 1 and 3, to determine their position relative to the main boat of which the location was determined accurately by the first method.

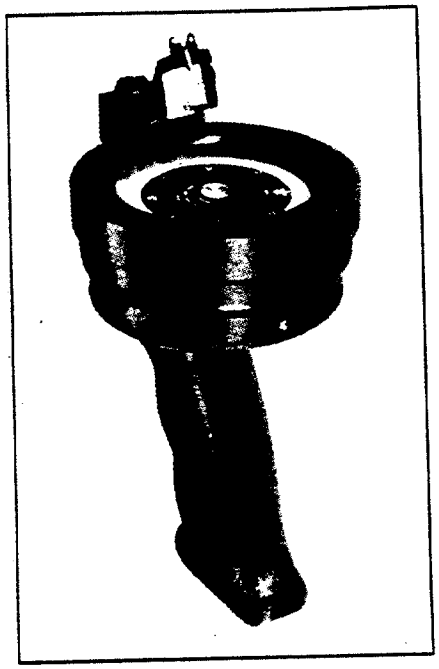
Table. Ⅱ−1 Locations of the AUDISTER (slave station)

Item		Boat	kaihomaru	# 2 boat
Slave station (Ⅱ)	Aoyama	X (m)	112788	112787
		Y (m)	− 3007	− 2999
	Shinmoji	X (m)	95880	
		Y (m)	52	
Carrier frequency (MHz)		Master station	2920	2977
		Aoyama	2963	3010
		Shinmoji	2953	3020
Elevation of slave station (m)		Aoyama	237	224
		Shinmoji	10	5

Note : The origin of X, Y coodinate : 33° 00′ 00″N, 131° 00′ 00″E

Fig. Ⅱ−1 Location of the AUDISTER





Specification

Size	Weight	Diameter of card
96×190 mm	450g	60 mm

Fig. II－2 HAND BEARING COMPASS

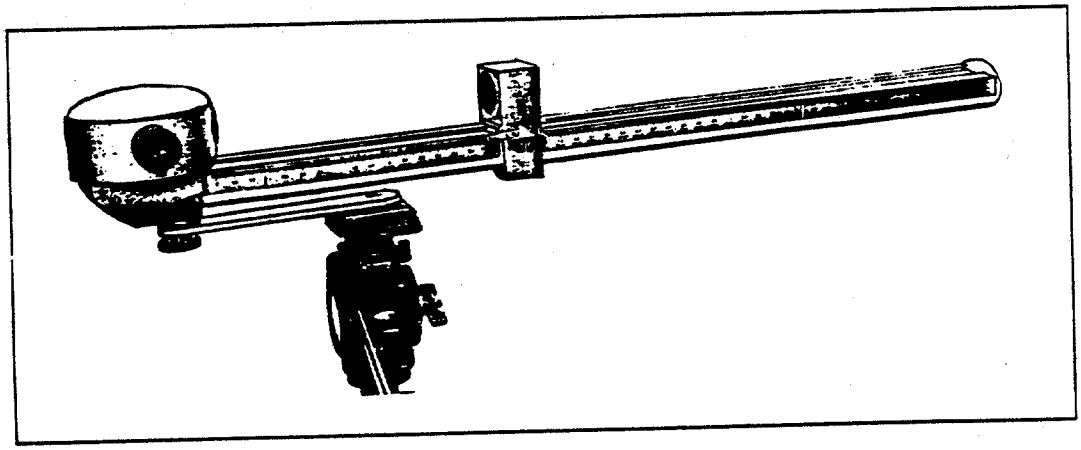


Fig. II－3 PORTABLE DISTANCE METER

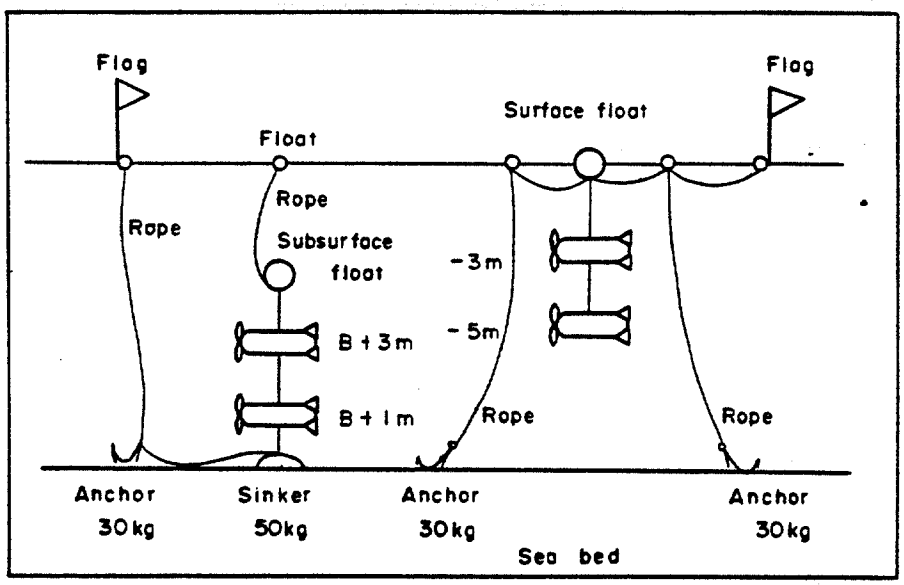
Specification

Range	Measurment accuracy	Weight	Full length
8~100m	Dist. × ± 1/100	1100g	590mm
100~500m	Dist. × ± 3/100		

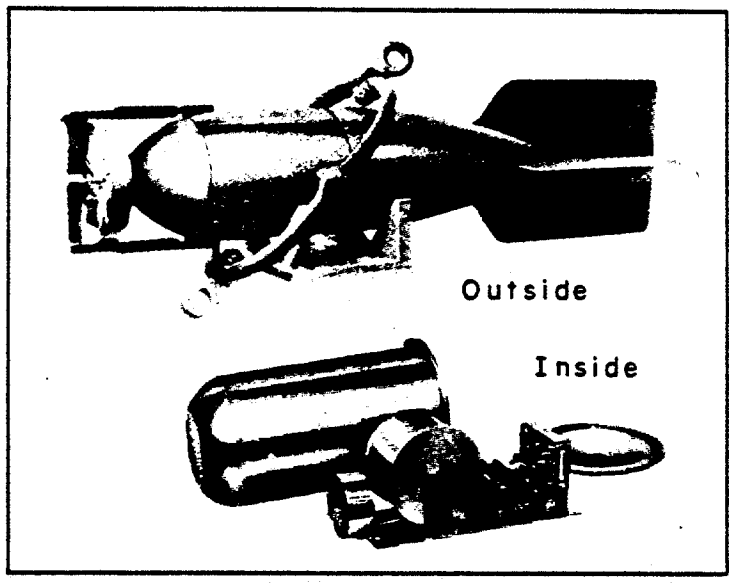
II - 2. Current measurements

Currents were measured at four depths every 10 minutes. Two current meters were suspended from a surface buoy to keep them at constant depths of 3 and 5 m below the sea surface. A bottom mooring method was applied for the remaining two current meters to keep them at constant levels above the bottom (1 m and 3 m off the bottom). The mooring methods are shown in Fig. II-4.

The current meter used was an ONO (impeller) type which has been developed by the Japan Hydrographic Office. A detailed explanation is given in the Appendices - 24.



Mooring system of current meter



Ono type current meter

Specification

Type	Range	Depth	Duration	Full length	Underwater weight
OC-1	0.02~1.5m/s	50m(max)	30or7days	990 mm	16.2 kg

Fig. II-4 Current meter and mooring system used in this study

II - 3. Bottom sediment sampling and analyses

Bottom sediments were sampled from six points along the center line of the dredging site (Fig. II-5 and Table II-2). The sampling was conduted by the main boat (No. 2 boat) and the positions were determined by the radio wave distance meter. Samples were taken with a grab sampler developed by the Port and Harbour Research Institute, Ministry of Transport (Fig. II-6).

The sediment samples were analysed for three parameters, particle size distribution, water content and specific gravity. Methods of analyses are the same as the American Standard Testing of Material. The corresponding procedures are shown in the Appendices - 30,31,32.

Table. II-2 X•Y coordinate and Latitude•Longitude of the positions where bottom sediment samples were taken.

	X (m)	Y (m)	Latitude (N)	Longitude (E)
1	100801	10348	33° 54′ 32.2″	131° 06′ 42.9″
2	100715	10574	33° 54′ 29.4″	131° 06′ 51.6″
3	100587	10739	33° 54′ 25.3″	131° 06′ 58.1″
4	100464	11004	33° 54′ 21.3″	131° 07′ 08.4″
5	100298	11175	33° 54′ 15.9″	131° 07′ 15.0″
6	100137	11386	33° 54′ 10.7″	131° 07′ 23.2″
a	100778	10268	33° 54′ 31.5″	131° 06′ 39.7″
b	100983	10411	33° 54′ 38.1″	131° 06′ 45.3″
c	100237	11476	33° 54′ 13.9″	131° 07′ 26.7″
d	100032	11332	33° 54′ 07.2″	131° 07′ 21.1″

Note: The origin of X,Y coodinate: 33° 00′ 00″ N, 131° 00′ 00″ E

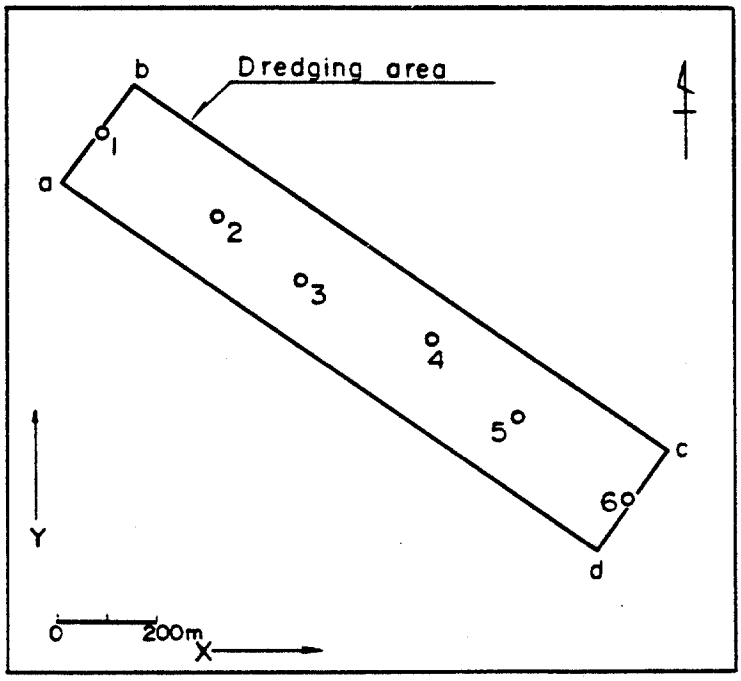


Fig. II-5 Locations of bottom sediment samples

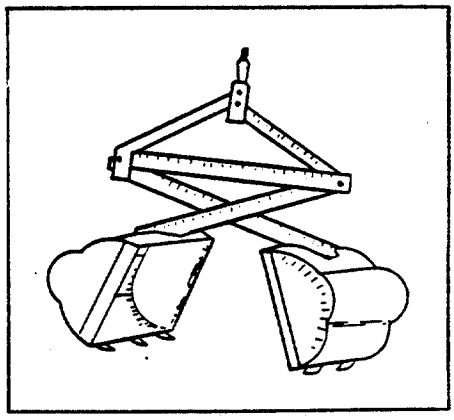


Fig. II-6 bottom sediment sampler

II - 4. Water sampling for determining SS concentration and particle size distribution

Water samples were taken on board the Kaihomaru and the survey boats Nos.1, 2 and 3, from the central part of the turbidity plume.

All samples were preprocessed at the Tanoura base port by filtering through a 1 μm glass filter.

1) On board the Kaihomaru

Samples were taken two points : at the hopper weir and the drag head. Overflow water (slurry) from the weir was sampled with a bucket three times for each case (Fig. II-7). Turbid water raised by the drag head was pumped up continuously from just behind the head and sampled five times for each case. The pumping rate was 2.1 ℓ/sec, and the water travel time in the hose was computed to be 26 seconds. The sampling methods and the dimensions of the drag head are shown in Figs. II-8 and II-9.

2) On board the boats

Water samples were taken from six depth levels (1, 3, 5, 7, 10 and 12 meters) with a water pump (pumping rate, 1.5 ℓ/sec). Some of the samples were saved for measuring SS concentration and particle size distribution. Fig. II-10 shows the sampling method schematically.

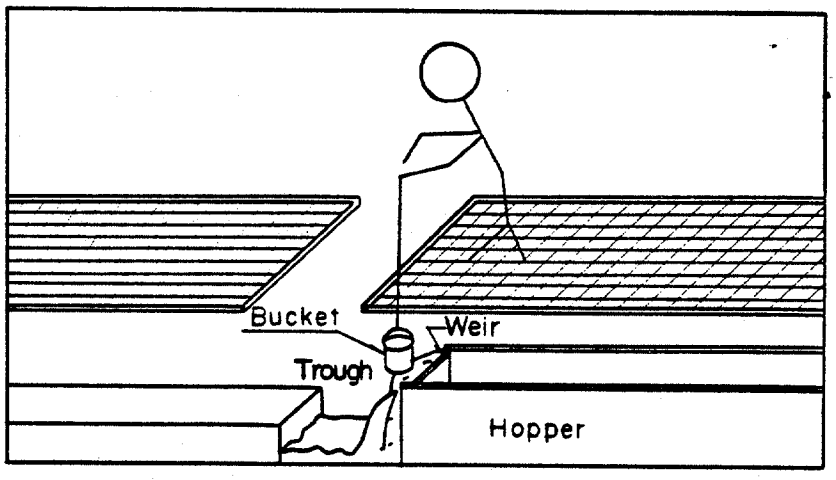


Fig. II-7 Overflow water sampling

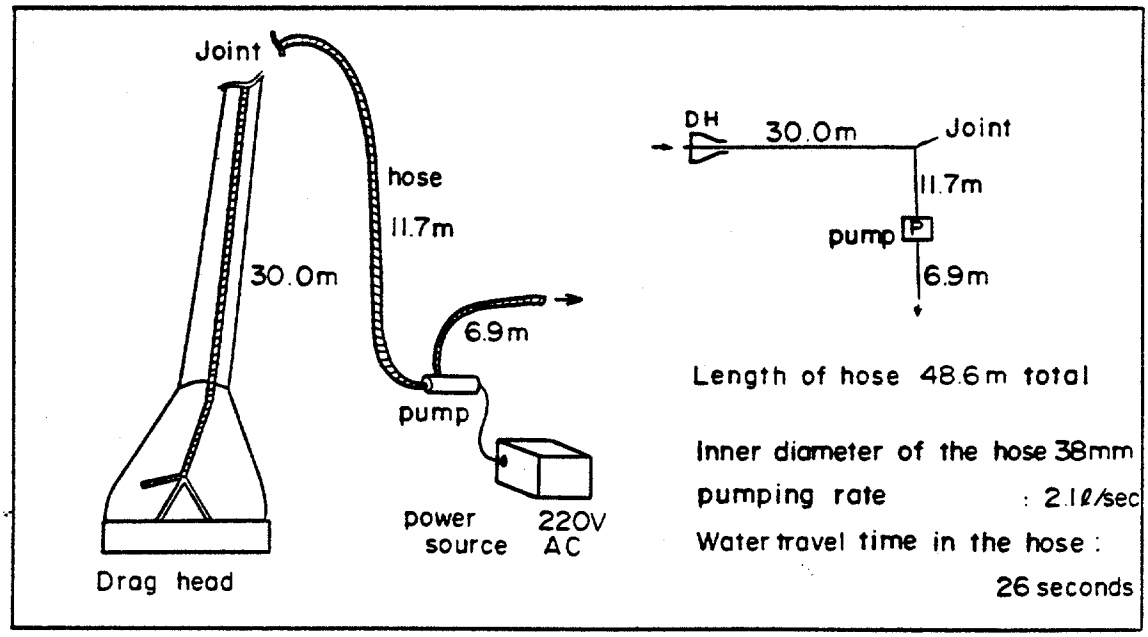


Fig. II-8 Arrangement of pump sampling on D.H.

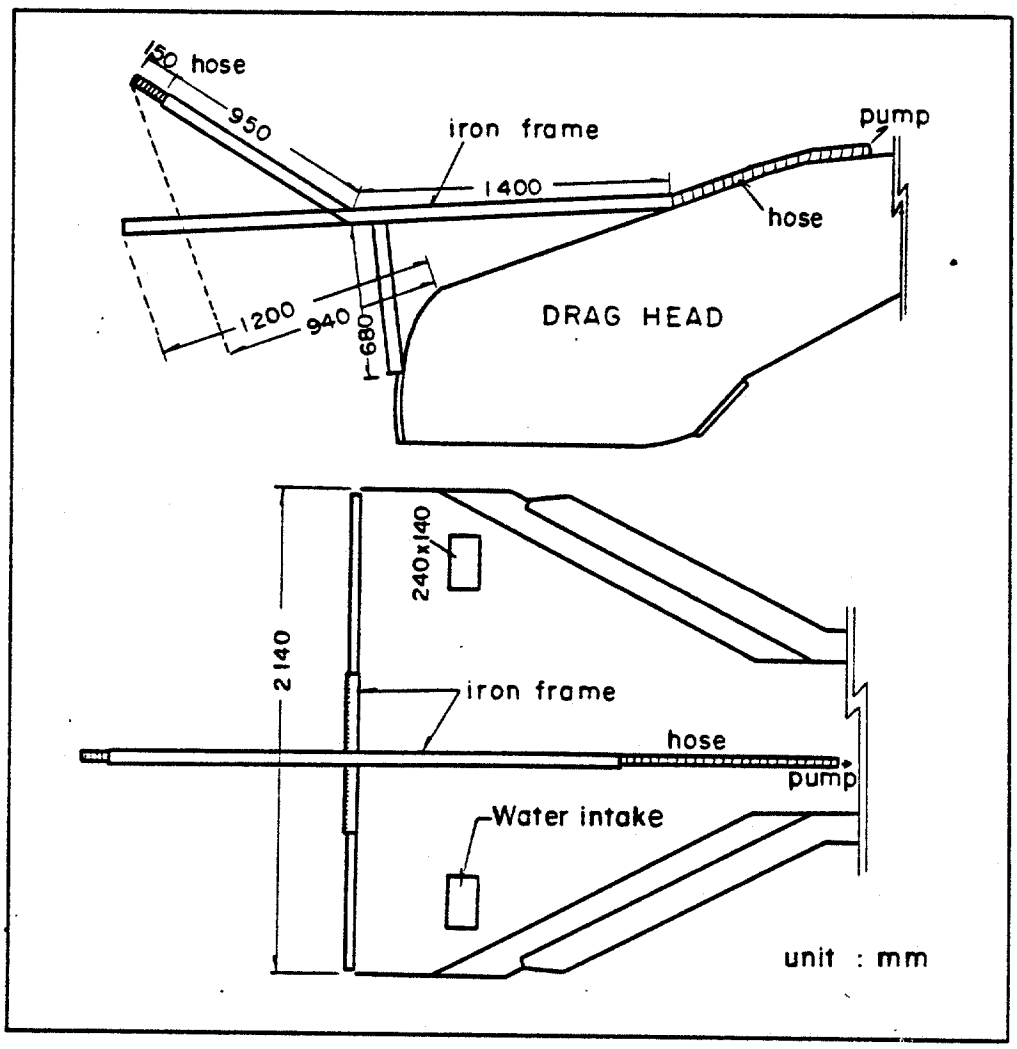


Fig. II-9 Drag head dimension and sampling hose arrangement

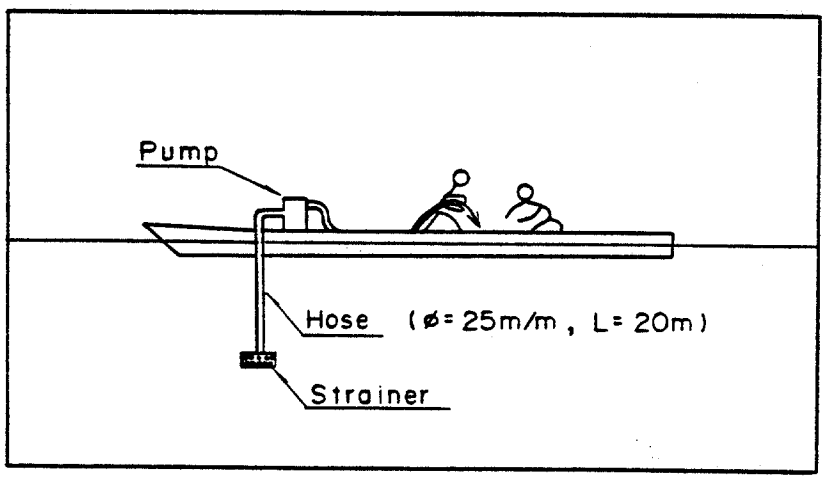


Fig. II-10 Water sampling with a pump

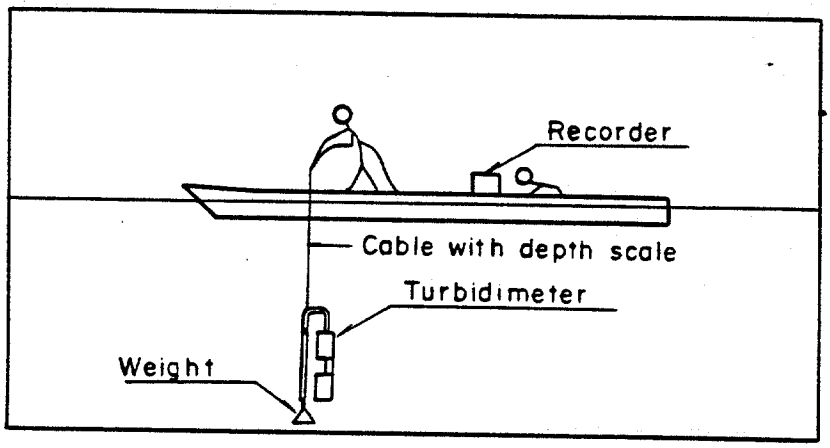


Fig. II-11 Vertical turbidity profile observation

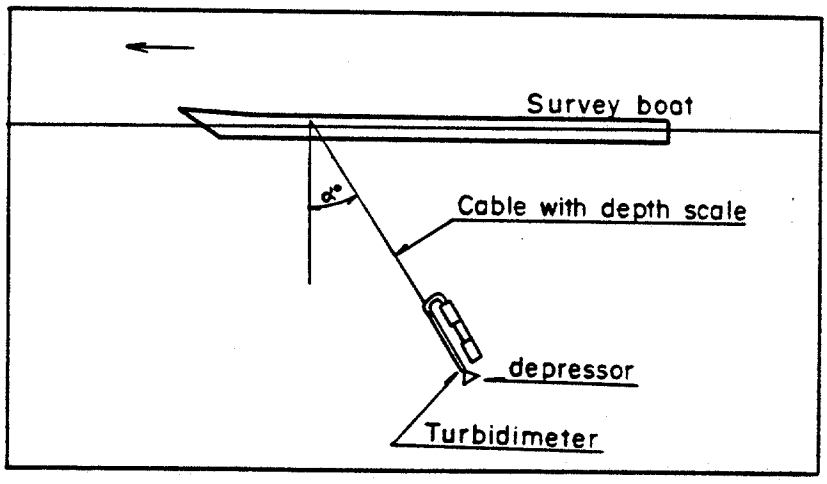
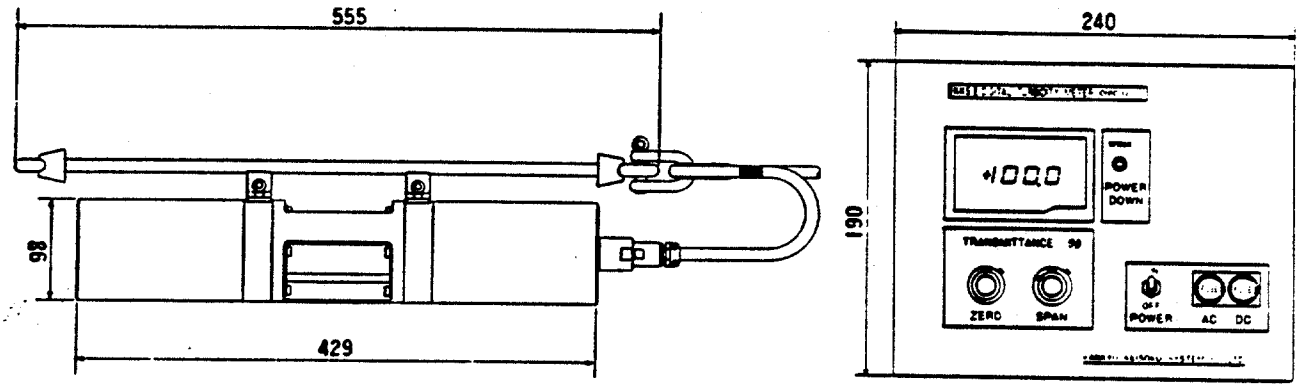


Fig. II-12 Cross-plume turbidity profile observation with a towed turbidimeter



SPECIFICATIONS

SENSOR

Measuring method	Single beam transmittance light
Measuring range	Trans. : 0 - 100 % SS : refer to the calibration curve
Accuracy	Trans. : ± 0.2 % (at transmittance) SS : refer to the calibration curve
Resolution	± 0.1 % (at transmittance)
Optical system	Cylindrically limited system
Light path length	100 mm (light path length can be changed to 50 mm by inserting attachment)
Beam diameter	2 mmØ
Light source	LED, λ = 670 nm, $\Delta\lambda$ = 30 nm
Detector	Silicon photocell
Lens	3 groups 4 pieces
Window	Quartz glass, n = 1.456
Temperature control method for light source	Comparison of referance light and direct light
Connector	Stainless steel, water tight type (max. durable depth : 100 m)
Cable	5-core combined cable with steel wire, 10 mmØ, 0.12 kg/m, cutting load:150 kg
Housing	Anti-corrosion aluminum, maximum durable depth : 60 m
Weight	3.5 kg (in air), 2.5 kg (in water)
Size	429 mm^L x 86 mmØ

INDICATION AND POWER SOURCE UNIT

Display	LED, digital indication (0 - 100 %)
Analog output	DC 0 - 1 V
Housing	Stainless steel, SUS 304
Construction	Water resistant type
Power source	NM-460 type DC 12V battery pack (able to 13 hours continuous use), AC 100V, DC 12V outside battery
Weight	7 kg
Size	429 mm^L x 190 mm^D x 160 mm^H

OPTION

Attachment	For light path length of 50 mm (anti-corrosion alminum)
Experimental cell	For light path length of 50 mm and 100 mm (anti-corrosion alminum)

Fig. II – 13 DIGITAL UNDERWATER TRANSMISSOMETER

II - 6. Data collected on board the Kaihomaru

Information related to the Kaihomaru's dredging activities (dredging course, time of dredging start and finish, pumping rate of slurry, weather and sea state, etc.) were collected.

III Results

All of the original data and additional information are given in a separate data report (Appendices) . Here, results are summarized in the forms of figures and tables. Source data used for constructing them are designated by the Appendix numbers so as to be able to refer the original data in case of need.

III-1. Time - events table

III-2. Weather

III-3. Plume center tracking (location of the boats) for all cases.
Appendices Nos. 1, 2, 3, 27

III-4. Plume center tracking and progressive vector diagrams based on current observations
Appendices Nos. 2, 3, 7, 23, 24

III-5. Progressive vector diagrams from four depths
Appendices Nos. 7, 23, 24

III-6. Time variation of SS of waters sampled at the drag head and the hopper weir
Appendices Nos. 10, 28

Continued on page 52

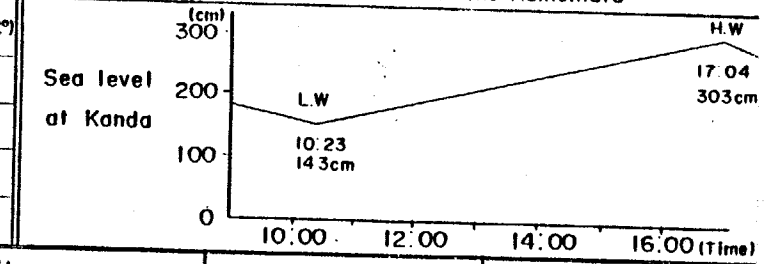
Table Ⅲ－1－1

Time Table

Date	July 23 1984	
Experiment	10:15－12:45	13:45－15:58
Case	Ⅰ, No overflow	
Current drogue	Depth 10.3m	Depth 10.4 m
Current obs	10:10 － 16:00	

Time	Wind force Direc.	Wind force F	Wave Direc.	Wave eye obs	Weather	Temp(C°)
10	E	4	E	slight	cloudy	26.5
12	E	4	E	slight	cloudy	27.5
14	E	3	E	smooth	cloudy	28.5
16	E	3	E	smooth	cloudy.	30.0

Weather data were collected on the Kaihomaru



morning

Time	Kaihomaru Dredging min	work	Sampling from Draghead min	No.	Sampling from overflow water min	No.	Pump sampling #1 min	No.	#2 min	No.	#3 min	No.	Turbidimeter #2 min	No.	#4 min	No.	#5 min	No.
10:15									15	B.G			No B.G data					
30	29	Dredging start	34	1 △														
	40	Dredging finish	39	2 △														
	48	Dredging start																
	49	Overflow																
					54	1												
11:00					59	2 △												
	04	Dredging finish			04	3												
:30							25	1	25	1 △	25	1	25	1	25	1－1	25	1－1
															32	2	28	2
							35	2	35	2	35	2	35	2	34	3	35	2－1
															36	2－1	39	2
															38	2		
							45	3	45	3 △	45	3	45	3	45	3－1	45	3－1
															50	2	48	2
12:00							55	4	55	4	55	4	55	4	55	4－1	55	4－1
															58	2	57	2
													05	5	05	5－1	06	5－1
															10	2	09	2
							20	6	20	6	20	6	20	6	20	6－1	20	6－1
30															24	2	24	2
							40	7	40	7	40	7	40	7	40	7－1	43	7－1
															45	2	46	2

afternoon

Time	Kaihomaru Dredging min	work	Sampling from Draghead min	No.	Sampling from overflow water min	No.	Pump sampling #1 min	No.	#2 min	No.	#3 min	No.	Turbidimeter #2 min	No.	#4 min	No.	#5 min	No.
									45	B.G								
													52	B.G				
14:00																		
	10	Dredging start																
	17	Dredging finish	13	1														
			16	2 △														
			17	3														
	23	Dredging start			23	1	20	1	20	1 △	20	1	20	1	22	1－1	20	1－1
		ATOS open	29	4	28	2 △									25	2	25	2
30																	26	3
							30	2	30	2	30	2	30	2	30	2－1	30	2－1
	36	Dredging finish	34	5 △	33	3											33	2
															35	2	35	3
							40	3	40	3 △	40	3	40	3	40	3－1	40	3－1
																	43	2
															45	2	45	3
																	47	4
							50	4	50	4	50	4	50	4	50	4－1	51	4－1
15:00															55	2	55	2
																	57	3
													00	5	00	5－1	01	5－1
															03	2	04	2
															07	3	08	3
							10	6	10	6	10	6	10	6	10	6－1	11	6－1
															13	2	13	2
															17	3		
																	20	3
30													30	7	30	7－1	31	7－1
															33	2	34	2
																	37	3
							50	8	50	8	50	8	50	8	50	8－1	52	8－1
16:00															55	2	55	2
															58	3	57	3

note. B.G. : background sampling

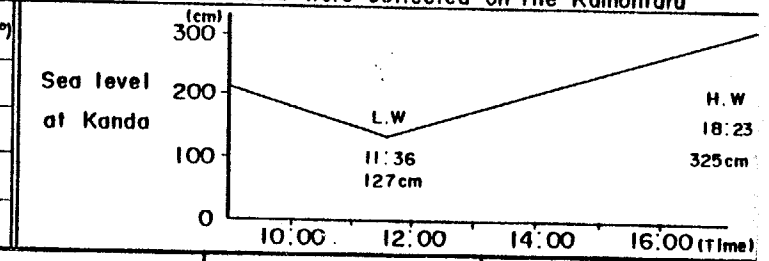
△ : Sampling for Coulter counter

Table Ⅲ－1－2 Time Table

Date	July 24 1984	
Experiment	10:30－12:28	14:15－16:16
Case	Ⅱ, over flow with ATOS	Ⅲ, over flow without ATOS
Current drogue	Depth 5.0m	Depth 2.0 m
Current obs	10:00－16:20	

Time	Wind force Direc.	Wind force F	Wave Direc.	Wave eye obs	Weather	Temp(C°)
10	SE	1	SE	calm	fine	27.0
12	SE	2	SE	calm	cloudy	30.0
14	E	3	E	smooth	cloudy	29.0
16	E	3	E	smooth	cloudy	32.0

Weather data were collected on the Kalhomaru



Time	Kalhomaru Dredging min	Dredging work	Sampling from Draghead min	Sampling from Draghead No.	Sampling from overflow water min	Sampling from overflow water No.	Pump sampling #1 min	#1 No.	#2 min	#2 No.	#3 min	#3 No.	Turbidimeter #2 min	#2 No.	#4 min	#4 No.	#5 min	#5 No.
10:15																		
30	31	Dredging start							30	B.G			30	BG				
			34	1														
			37	2 △														
			40	3														
	43	Dredging finish																
	49	Dredging start & Overflow	53	4	54	1												
			57	5 △														
11:00			01	6	59	2 △	00	1	00	1 △	00	1	00	1	00	1－1	00	1－1
	04	Dredging finish			04	3									04	2	02	2
															08	3	05	3
							10	2	09	2	09	2	09	2	10	2－1	11	2－1
															15	2	13	2
																	16	3
							20	3	20	3 △	20	3	20	3	20	3－1	18	4
															24	2	21	3－1
																	24	2
30															29	3	26	3
																2 m		8 m
															34	Towing	33	Towing
															37		38	
							40	5	40	5	40	5	40	5	40	5－1	41	5－1
															45	2	45	2
																	47	3
													50	6	50	6－1	52	6－1
															55	2	54	2
																	56	3
12:00													00	7	00	7－1	01	7－1
															03	2	04	2
																	06	3
							20	8	20	8	20	8	20	8	20	8－1	21	8－1
															24	2	25	2
30															28	3	27	3

morning

Time	Kalhomaru Dredging min	Dredging work	Sampling from Draghead min	Sampling from Draghead No.	Sampling from overflow water min	Sampling from overflow water No.	Pump sampling #1 min	#1 No.	#2 min	#2 No.	#3 min	#3 No.	Turbidimeter #2 min	#2 No.	#4 min	#4 No.	#5 min	#5 No.
14:00																		
	18	Dredging start							15	B.G			15	B.G				
			21	1														
			24	2 △														
			27	3														
30	28	Dredging finish																
	34	Dredging start																
	35	Overflow	38	4														
			42	5 △	40	1												
			44	6	42	2 △												
	45	Dredging finish			44	3	45	1	45	1 △	45	1	45	1	45	1－1	45	1－1
															50	2	49	2
																	52	3
							55	2	55	2	55	2	55	2	55	2－1	56	2－1
15:00															00	2	59	2
																	02	3
							05	3	05	3 △	05	3	05	3	05	3－1	07	3－1
															10	2	09	2
															14	3	12	3
																2 m	13	8m
													17	4	20	Towing	18	Towing
															24			
							25	5	25	5	25	5	25	5	25	5－1	27	5－1
30																	30	2
															33	2	32	3
															40	3		
													45	6	45	6－1	47	6－1
															50	2	49	3
																	51	2
16:00															58	3		
							05	7	05	7	05	7	05	7	05	7－1	07	7－1
															11	2	09	2
															16	3		

afternoon

note. B.G. : background sampling

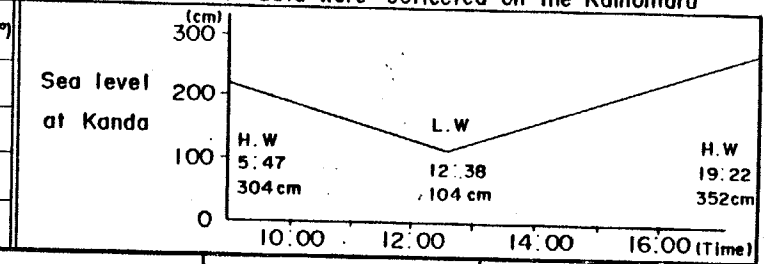
△ : Sampling for Coulter counter

Table Ⅲ－1－3 Time Table

Date	July 25 1984	
Experiment	10:10－12:20	13:50－15:57
Case	Ⅲ, Over flow without ATOS	Ⅱ, Over flow with ATOS
Current drogue	Depth 1.0m	Depth 6.0m
Current obs	10:00 － 15:50	

Time	Wind force Direc.	Wind force F	Wave Direc.	Wave eye obs	Weather	Temp(C°)
10	NE	1	NE	calm	cloudy	27.0
12	－	0	－.	calm	cloudy	30.0
14	ENE	2	ENE	smooth	cloudy	31.0
16	NE	2	NE	calm	cloudy	29.0

Weather data were collected on the Kaihomaru



Kaihomaru

Time	Dredging work	Dredging min	Sampling from Draghead min	Sampling from Draghead No.	Sampling from overflow water min	Sampling from overflow water No.
10:00						
	Dredging start	23	26	1		
			29	2 △		
30			32	3		
	Dredging finish	35	35	4		
	Dreging start & overflow	41	45	5	46	1
			49	6 △	51	2 △
			53	7		
11:00	Dredging finish	57	57	8	56	3
30						
12:00						
30						

Pump sampling

morning

Time	#1 min	#1 No.	#2 min	#2 No.	#3 min	#3 No.
10:00			10	B.G△		
30						
11:00	49	1	49	1 △	49	1
	59	2	59	2 △	59	2
	09	3	09	3 △	09	3
30	29	5	29	5	29	5
12:00	09	7	09	7△	09	7
30						

Turbidimeter

Time	#2 min	#2 No.	#4 min	#4 No.	#5 min	#5 No.
10:00	10	B.G				
30						
11:00	49	1	49	6m 1	49	1－1
			53		51	2
			54	1m 2		
			58			
	59	2	59	6m 3	00	2－1
			04		02	2
			05	1m 4	05	3
	09	3	09		06	4
					10	3－1
			12	6m 5	12	2
					13	3
	19	4	18		14	4
					20	4－1
			21	1m 6	22	2
			26		24	3
					26	4
30	29	5	27	6m 7	30	5－1
			32		32	2
			33	1m 8	33	3
			37		38	4
			40	6m 9		
			45			
	49	6	45	1m 10	50	6－1
			51		52	2
			54	6m 11	54	3
			59		57	4
12:00			59	1m 12		
			05			
	09	7	08	6m 13	10	7－1
					12	2
			14		14	3
			14	1m 14	15	4
			20			
30						

Depth of towing

Kaihomaru

Time	Dredging work	Dredging min	Sampling from Draghead min	Sampling from Draghead No.	Sampling from overflow water min	Sampling from overflow water No.
14:00	Dredging start	57				
			00	1		
	Dredging finish	06	03	2 △		
			06	3		
	Dredging start Overflow	12 13				
			16	4		
			18	5 △	18	1
			21	6		
			24	7	23	2 △
					26	3
	Dredging finish	26				
30						
15:00						
30						
16:00						

Pump sampling

afternoon

Time	#1 min	#1 No.	#2 min	#2 No.	#3 min	#3 No.
14:00			50	B.G△		
30	21	1	21	1 △	21	1
	31	2	31	2△	31	2
	41	3	41	3 △	41	3
15:00	01	5	01	5△	01	5
30	41	7	41	7	41	7
16:00						

Turbidimeter

Time	#2 min	#2 No.	#4 min	#4 No.	#5 min	#5 No.
14:00	50	B.G				
30	21	1	21	6m 1	21	1－1
			26		23	2
	31	2	27	1m 2	33	2－1
			33		34	2
			36	1m 3	36	3
	41	3	41		38	4
			44	6m 4	41	3－1
					43	2
					45	3
	51	4			47	4
			53		52	4－1
			54	1m 5	53	2
					55	3
	01	5	00		57	4
			03	6m 6	01	5－1
					02	2
					04	3
			12		06	4
			15	1m 7		
	21	6			23	6－1
			25		24	2
			25	6m 8	27	3
					29	4
			37			
	41	7	44		41	7－1
					43	2
				1m 9	45	3
					47	4
			57			

note. B.G. : background sampling

△ : Sampling for Coulter counter

Table. Ⅲ－2 Result of meteorological observations.

(on the Kaihomaru)

Date	Time	Wind Direct	Wind Force	Wave Direct	Wave Eye obs.	Weather	Temp Air (℃).	V (Km)	Atom Press (mmb)
	2	---	---	---	---	---	---	---	---
	4	E	3	E	SMOOTH	CLOUDY	25.0	7	1003
	6	---	---	---	---	---	---	---	---
	8	E	3	E	SMOOTH	CLOUDY	26.0	7	1004
July	10	E	4	E	SLIGHT	CLOUDY	26.5	7	1004
23	12	E	4	E	SLIGHT	CLOUDY	27.5	7	1003
1984	14	E	3	E	SMOOTH	CLOUDY	28.5	7	1002
	16	E	3	E	SMOOTH	CLOUDY	30.0	7	1001
	18	E	3	E	SMOOTH	CLOUDY	29.0	6	1001
	20	SSW	3	SSW	SMOOTH	CLOUDY	26.5	7	1002.
	22	NE	1	NE	CALM	CLOUDY	25.0	7	1003
	24	W	2	W	CALM	CLOUDY	24.5	7	1003.
	2	W	1	W	CALM	CLOUDY	26.0	7	1003.
	4	W	1	W	CALM	CLOUDY	26.0	7	1002.
	6	S	2	S	CALM	CLOUDY	26.0	7	1003.
	8	---	0	---	CALM	CLOUDY	26.0	6	1003.
July	10	SE	1	SE	CALM	FINE	27.0	6	1003.
24	12	SE	2	SE	CALM	CLOUDY	30.0	7	1003.
1984	14	E	3	E	SMOOTH	CLOUDY	29.0	7	1002.
	16	E	3	E	SMOOTH	CLOUDY	32.0	7	1002.
	18	E	3	E	SMOOTH	CLOUDY	28.5	7	1003.
	20	E	2	E	CALM	CLOUDY	26.0	7	1003.
	22	E	3	E	SMOOTH	CLOUDY	26.5	7	1004.
	24	E	3	E	SMOOTH	CLOUDY	26.0	7	1004.
	2	E	3	E	SMOOTH	CLOUDY	27.5	7	1003.
	4	E	3	E	SMOOTH	CLOUDY	26.0	7	1003.
	6	E	3	E	SMOOTH	CLOUDY	26.0	7	1003.
	8	E	2	E	CALM	CLOUDY	27.0	6	1004.
July	10	NE	1	NE	CALM	CLOUDY	27.0	6	1005.
25	12	---	0	---	CALM	CLOUDY	30.0	6	1005.
1984	14	ENE	2	ENE	SMOOTH	CLOUDY	31.0	6	1004.
	16	NE	2	NE	CALM	CLOUDY	29.0	6	1004.
	18	NW	2	NW	CALM	CLOUDY	29.0	6	1004.
	20	NW	2	NW	CALM	CLOUDY	27.5	6	1005.
	22	NW	2	NW	CALM	CLOUDY	27.0	7	1005.
	24	WNW	3	WNW	SMOOTH	CLOUDY	26.5	7	1005.

Note: ---No observation or not determinable, V.Visibility.(Km)

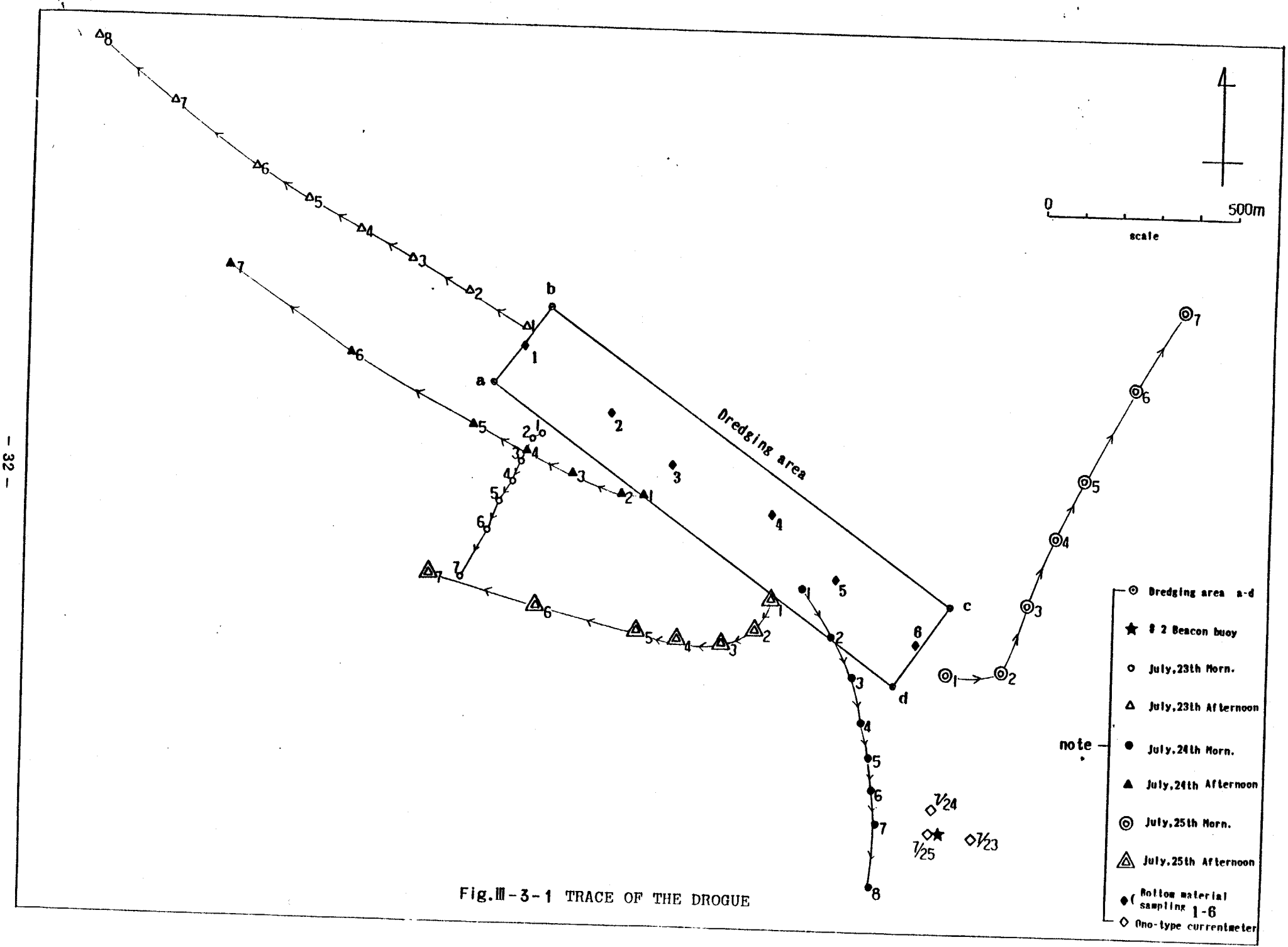


Fig.Ⅲ-3-1 TRACE OF THE DROGUE

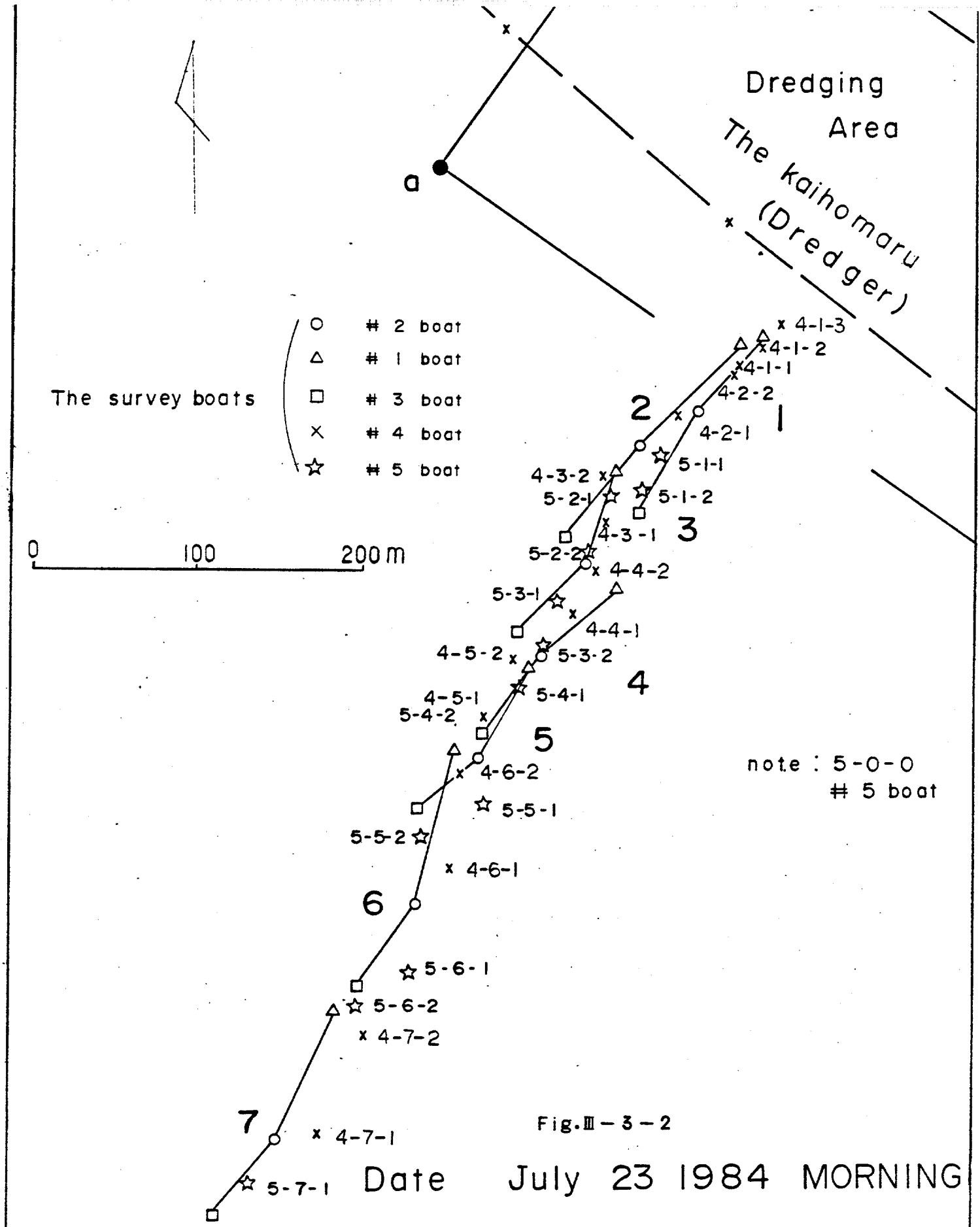


Fig.Ⅲ－3－2

Date July 23 1984 MORNING

Case Ⅰ, No over flow

Location of the survey boats.

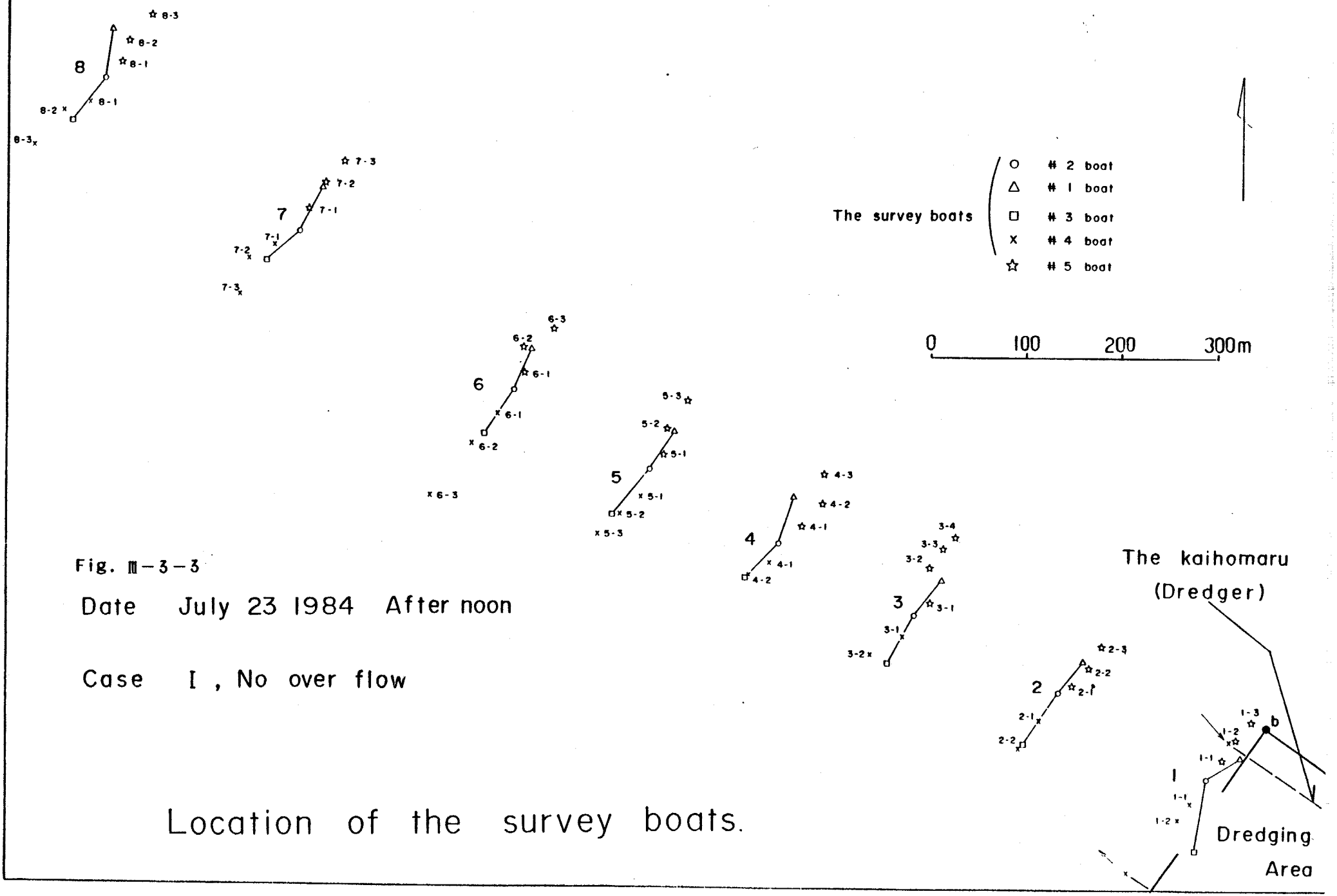


Fig. Ⅲ−3−3

Date July 23 1984 After noon

Case Ⅰ, No over flow

Location of the survey boats.

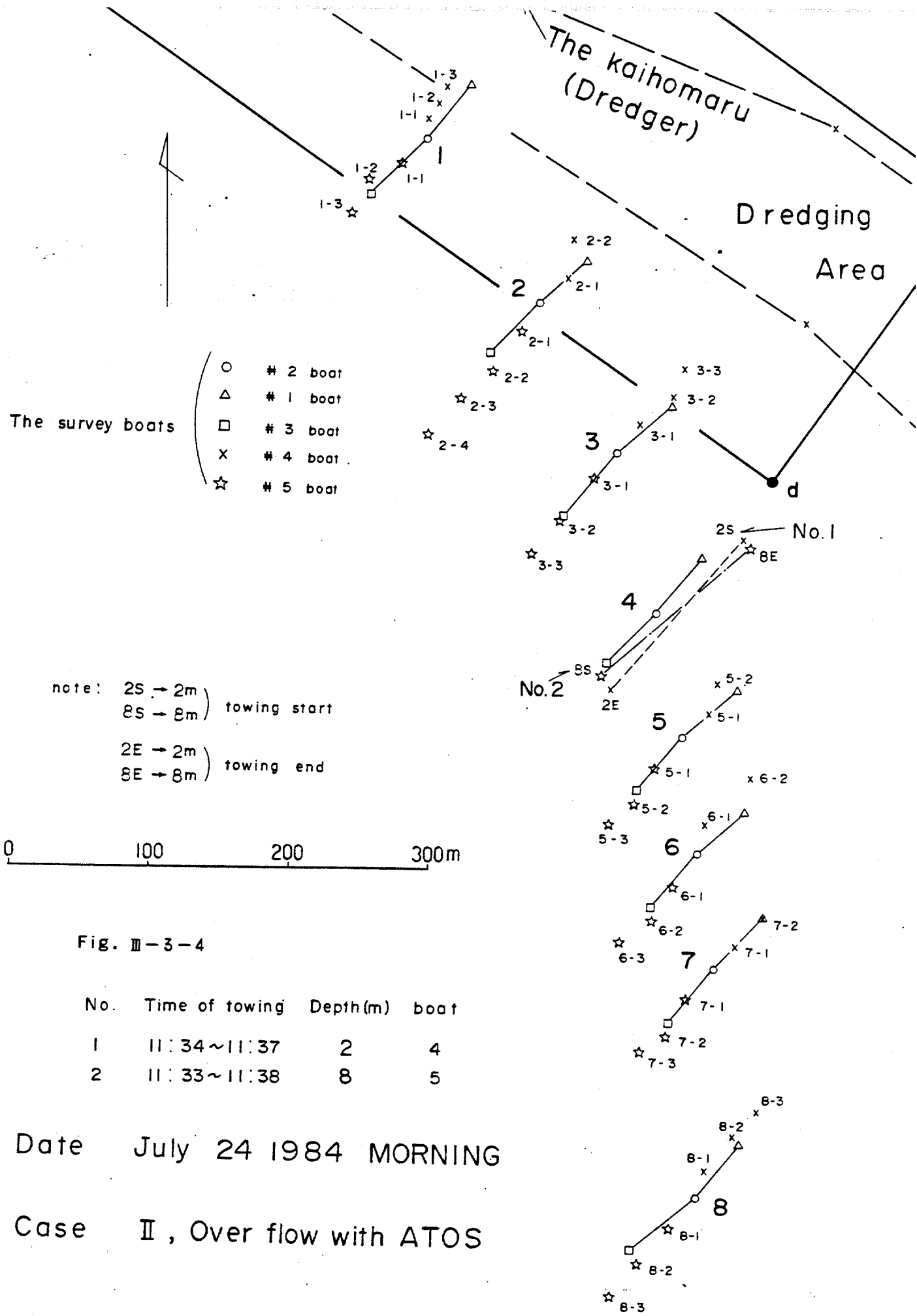


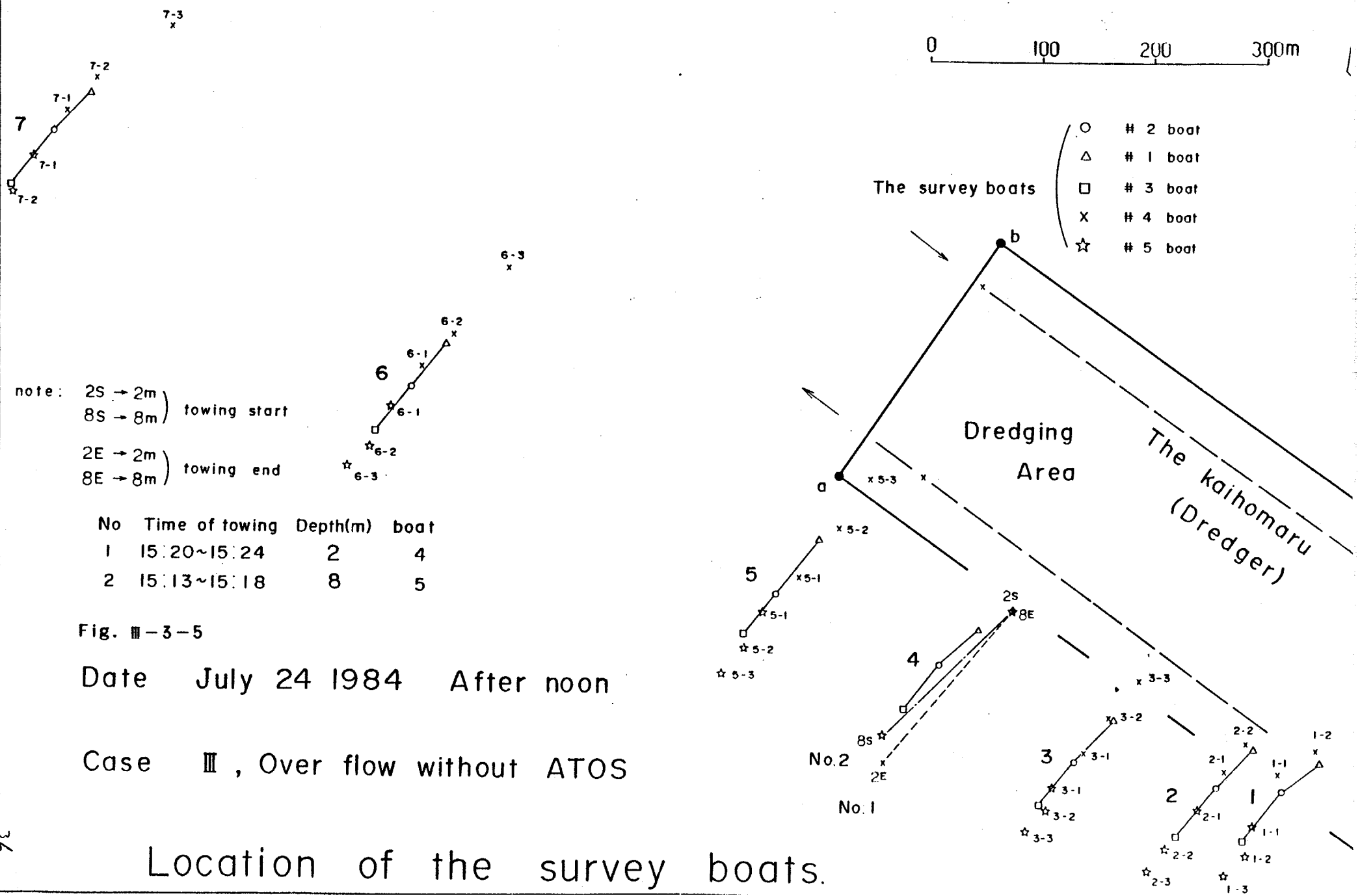
Fig. Ⅲ−3−4

No.	Time of towing	Depth(m)	boat
1	11:34~11:37	2	4
2	11:33~11:38	8	5

Date July 24 1984 MORNING

Case Ⅱ, Over flow with ATOS

Location of the survey boats.



note: 2S → 2m, 8S → 8m) towing start

2E → 2m, 8E → 8m) towing end

No	Time of towing	Depth(m)	boat
1	15:20~15:24	2	4
2	15:13~15:18	8	5

Fig. Ⅲ−3−5

Date July 24 1984 After noon

Case Ⅲ, Over flow without ATOS

Location of the survey boats.

The survey boats

- ○ # 2 boat
- △ # 1 boat
- □ # 3 boat
- × # 4 boat
- ☆ # 5 boat

Towing turbidimeter

No.	Time of towing	Depth(m)	boat
1	10:49~10:53	6	4
2	10:54~10:58	1	4
3	10:59~11:04	6	4
4	11:05~11:09	1	4
5	11:12~11:18	6	4
6	11:21~11:26	1	4
7	11:27~11:32	6	4
8	11:33~11:37	1	4
9	11:40~11:45	6	4
10	11:45~11:51	1	4
11	11:54~11:59	6	4
12	11:59~12:05	1	4
13	12:08~12:14	6	4
14	12:14~12:20	1	4

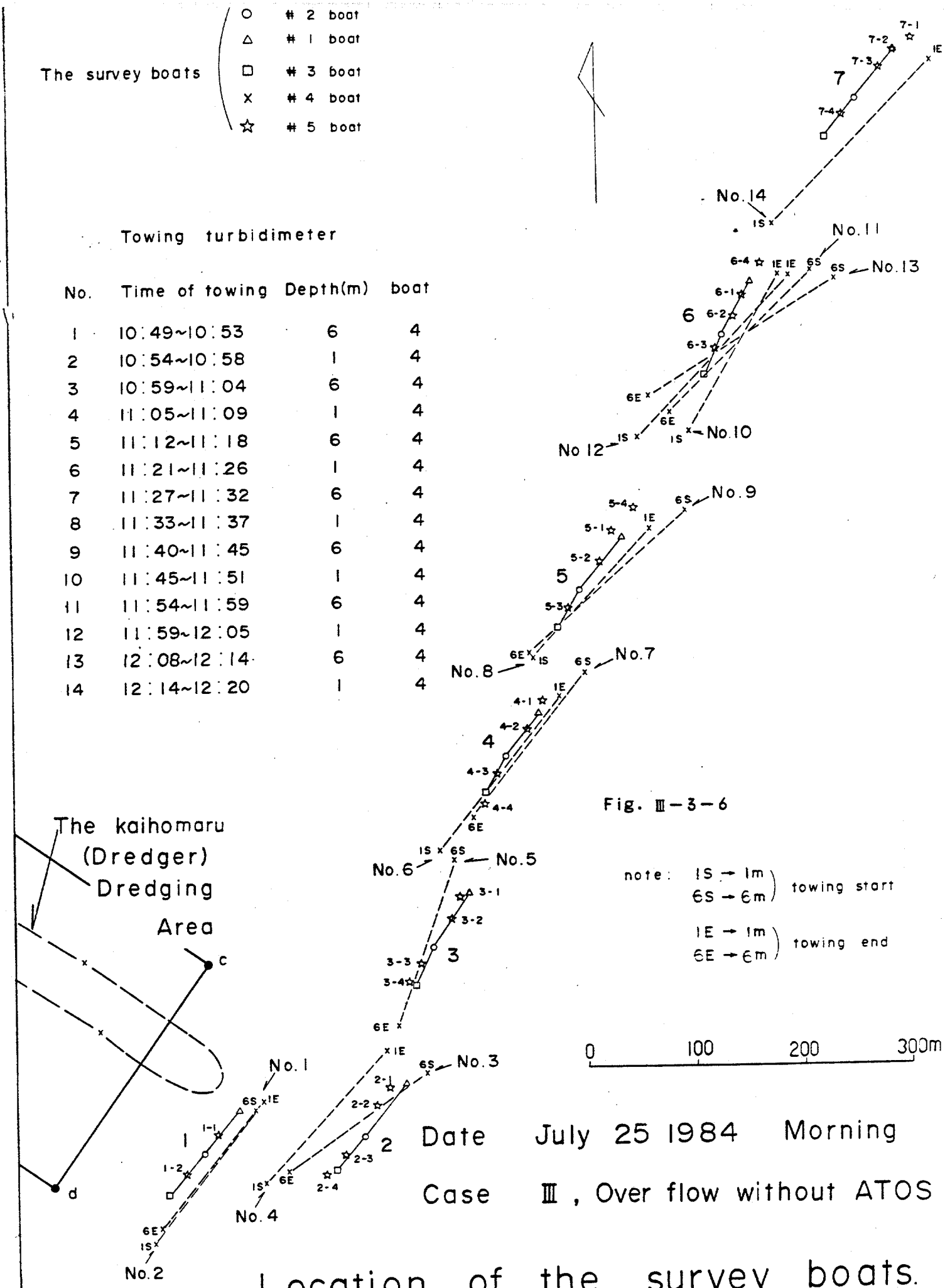


Fig. Ⅲ-3-6

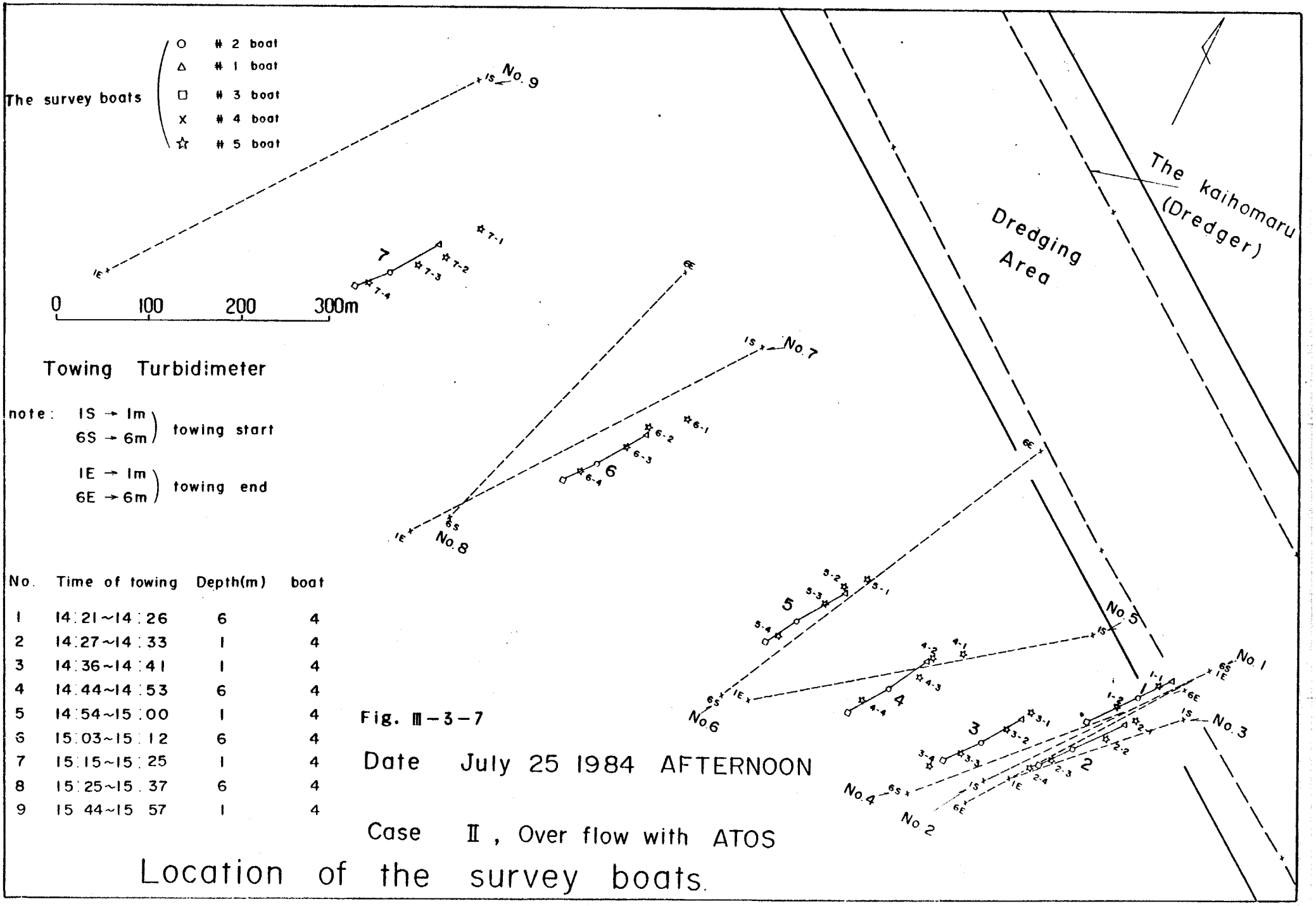
note: 1S → 1m, 6S → 6m) towing start

1E → 1m, 6E → 6m) towing end

Date July 25 1984 Morning

Case Ⅲ, Over flow without ATOS

Location of the survey boats.



No.	Time of towing	Depth(m)	boat
1	14:21~14:26	6	4
2	14:27~14:33	1	4
3	14:36~14:41	1	4
4	14:44~14:53	6	4
5	14:54~15:00	1	4
6	15:03~15:12	6	4
7	15:15~15:25	1	4
8	15:25~15:37	6	4
9	15:44~15:57	1	4

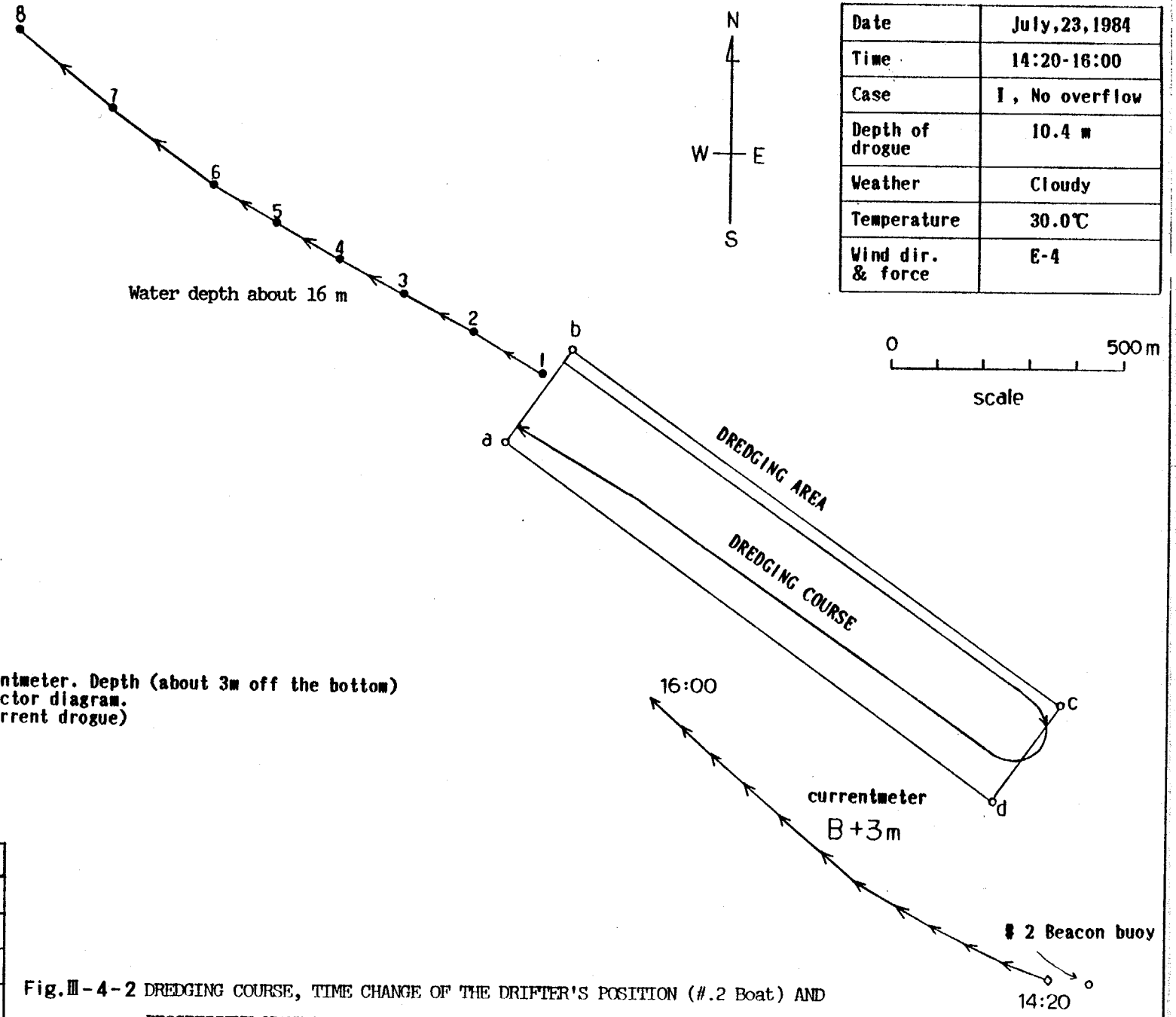
Fig. Ⅲ-3-7

Date July 25 1984 AFTERNOON

Case Ⅱ, Over flow with ATOS

Location of the survey boats.

Date	July,23,1984
Time	14:20-16:00
Case	I , No overflow
Depth of drogue	10.4 m
Weather	Cloudy
Temperature	30.0℃
Wind dir. & force	E-4



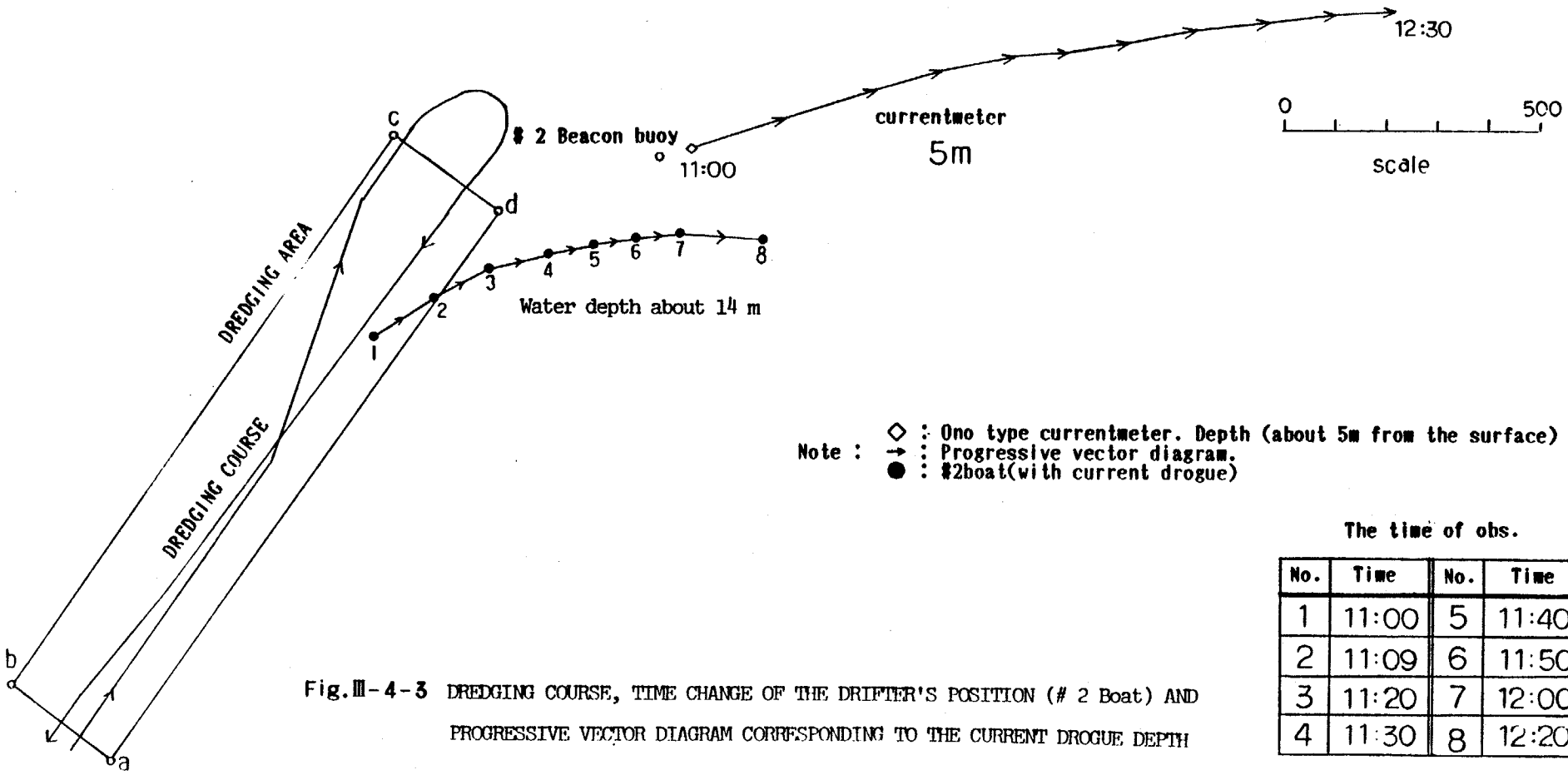
Note : ◇ : Ono type currentmeter. Depth (about 3m off the bottom)
→ : Progressive vector diagram.
● : #2boat(with current drogue)

The time of obs.

No.	Time	No.	Time
1	14:20	5	15:00
2	14:30	6	15:10
3	14:40	7	15:30
4	14:50	8	15:50

Fig.Ⅲ-4-2 DREDGING COURSE, TIME CHANGE OF THE DRIFTER'S POSITION (#.2 Boat) AND PROGRESSIVE VECTOR DIAGRAM CORRESPONDING TO THE CURRENT DROGUE DEPTH

Date	July,24,1984
Time	11:00-12:30
Case	II , Overflow with ATOS
Depth of drogue	5.0 m
Weather	Cloudy
Temperature	30.0℃
Wind dir. & force	E-4

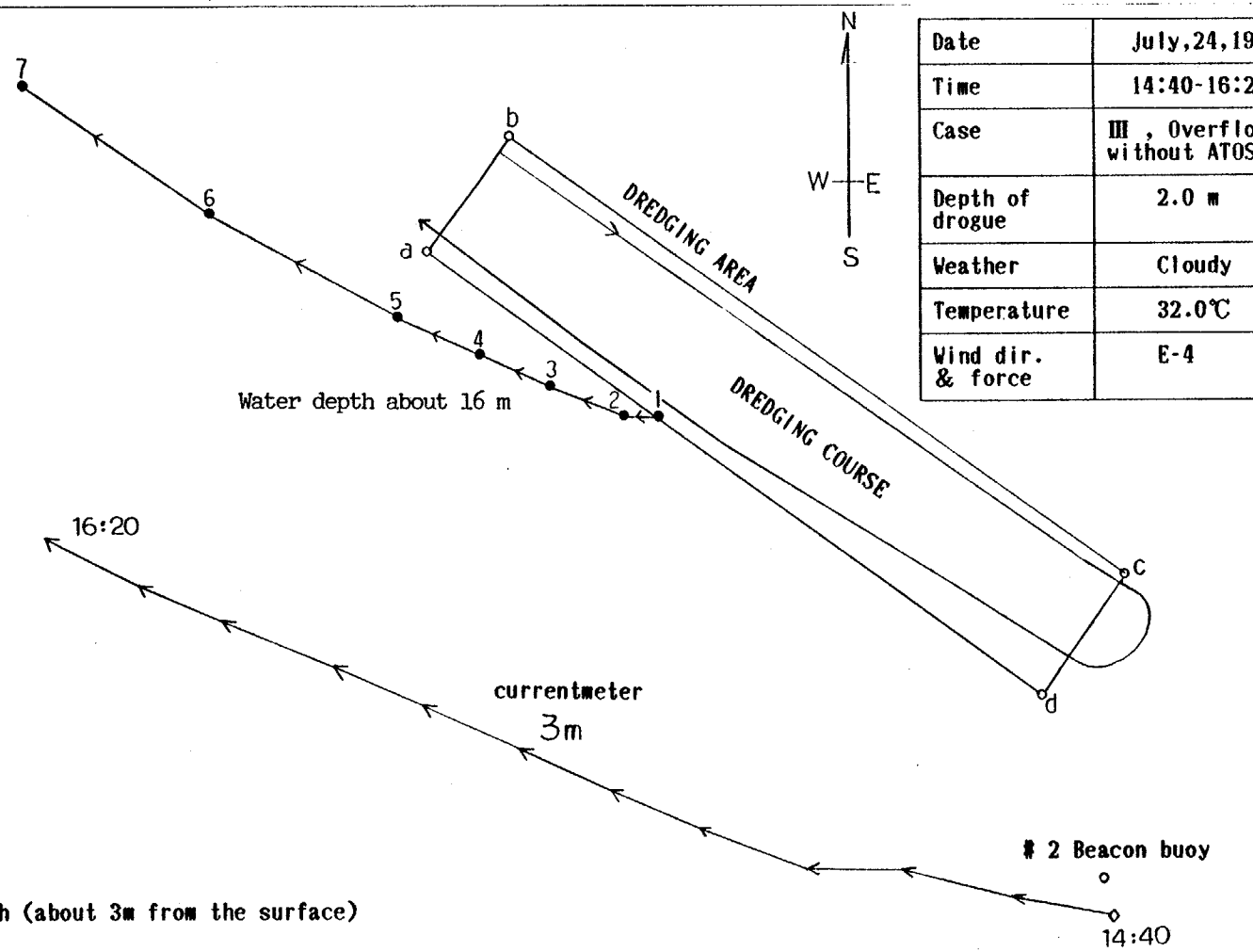


Note : ◇ : Ono type currentmeter. Depth (about 5m from the surface)
→ : Progressive vector diagram.
● : #2boat(with current drogue)

The time of obs.

No.	Time	No.	Time
1	11:00	5	11:40
2	11:09	6	11:50
3	11:20	7	12:00
4	11:30	8	12:20

Fig.Ⅲ-4-3 DREDGING COURSE, TIME CHANGE OF THE DRIFTER'S POSITION (# 2 Boat) AND PROGRESSIVE VECTOR DIAGRAM CORRESPONDING TO THE CURRENT DROGUE DEPTH



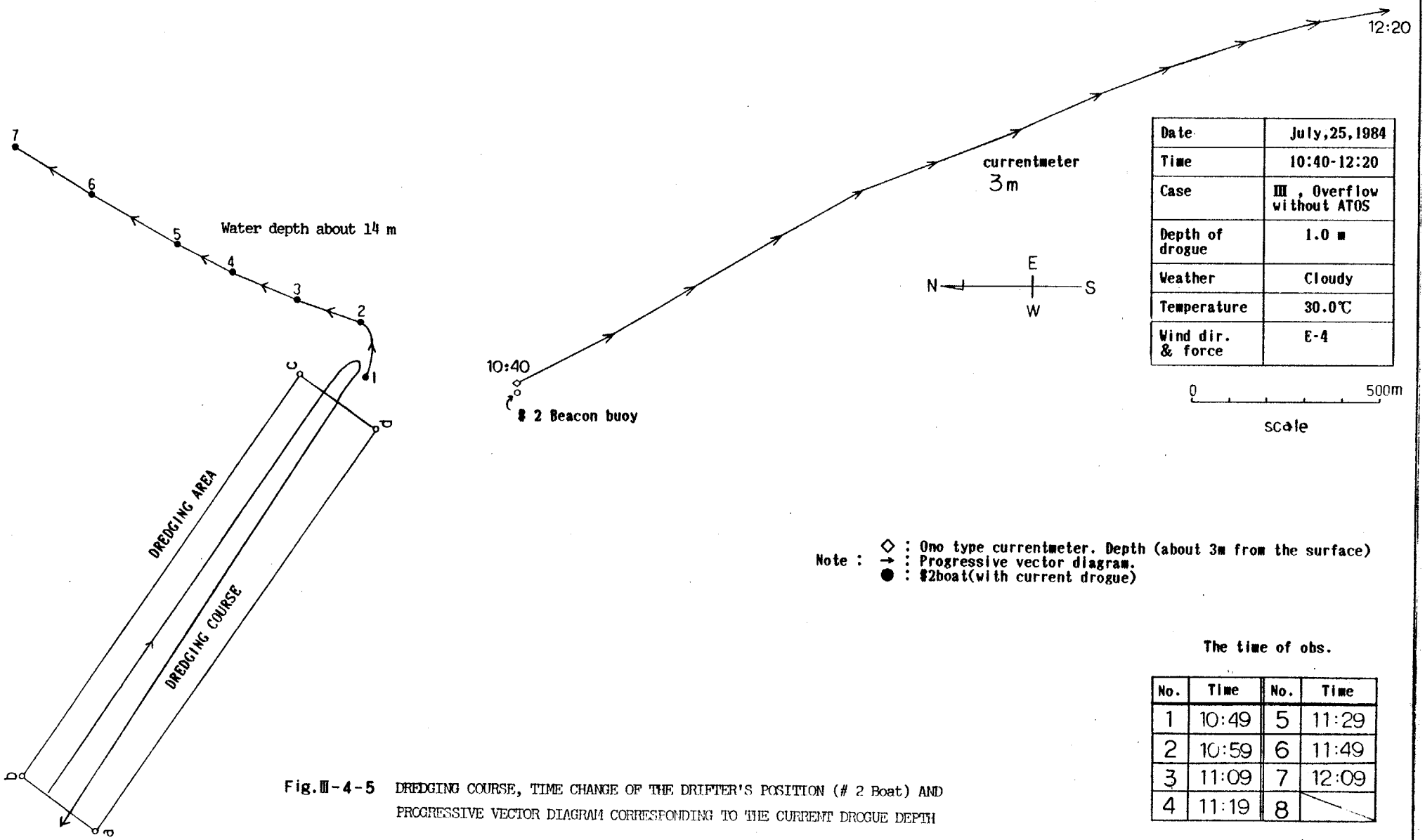
Date	July,24,1984
Time	14:40-16:20
Case	Ⅲ , Overflow without ATOS
Depth of drogue	2.0 m
Weather	Cloudy
Temperature	32.0℃
Wind dir. & force	E-4

Note : ◇ : Ono type currentmeter. Depth (about 3m from the surface)
→ : Progressive vector diagram.
● : #2boat(with current drogue)

The time of obs.

No.	Time	No.	Time
1	14:45	5	15:25
2	14:55	6	15:45
3	15:05	7	16:05
4	15:17	8	

Fig.Ⅲ-4-4 DREDGING COURSE, TIME CHANGE OF THE DRIFTER'S POSITION (# 2 Boat) AND PROGRESSIVE VECTOR DIAGRAM CORRESPONDING TO THE CURRENT DROGUE DEPTH

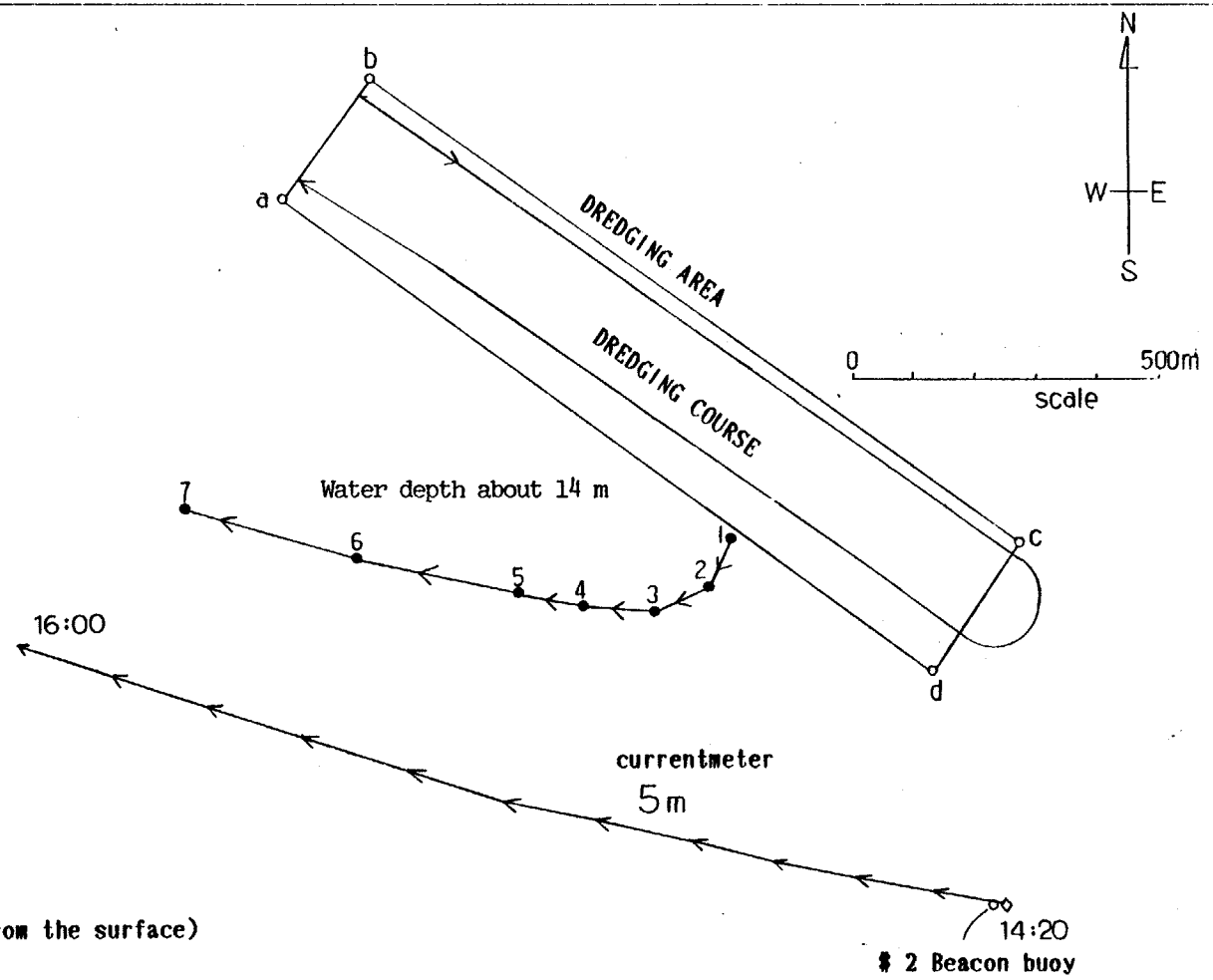


Date	July,25,1984
Time	10:40-12:20
Case	Ⅲ , Overflow without ATOS
Depth of drogue	1.0 m
Weather	Cloudy
Temperature	30.0℃
Wind dir. & force	E-4

The time of obs.

No.	Time	No.	Time
1	10:49	5	11:29
2	10:59	6	11:49
3	11:09	7	12:09
4	11:19	8	

Fig.Ⅲ-4-5 DREDGING COURSE, TIME CHANGE OF THE DRIFTER'S POSITION (# 2 Boat) AND PROGRESSIVE VECTOR DIAGRAM CORRESPONDING TO THE CURRENT DROGUE DEPTH



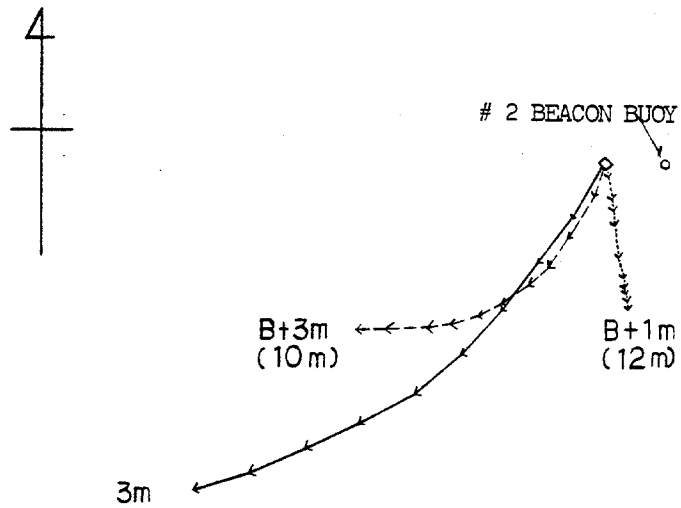
Note : ◇ : Ono type currentmeter. Depth (about 5m from the surface)
→ : Progressive vector diagram.
● : #2boat(with current drogue)

The time of obs.

No.	Time	No.	Time
1	14:21	5	15:01
2	14:31	6	15:21
3	14:41	7	15:41
4	14:51	8	

Date	July,25,1984
Time	14:20-16:00
Case	II , Overflow with ATOS
Depth of drogue	6.0 m
Weather	Cloudy
Temperature	29.0℃
Wind dir. & force	E-4

Fig. III-4-6 DREDGING COURSE, TIME CHANGE OF THE DRIFTER'S POSITION (# 2 Boat) AND PROGRESSIVE VECTOR DIAGRAM CORRESPONDING TO THE CURRENT DROGUE DEPTH

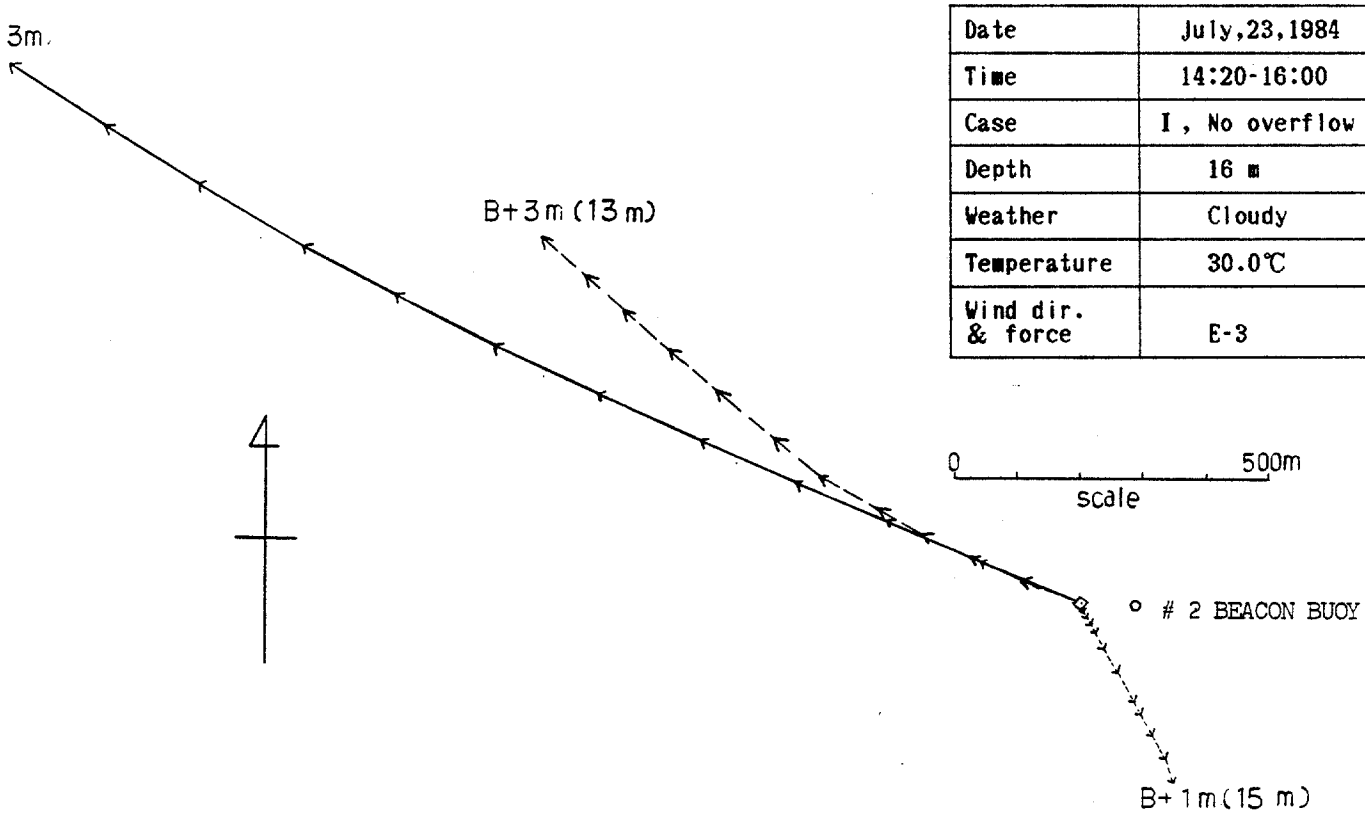


Date	July,23,1984
Time	11:20-12:50
Case	I , No overflow
Depth	13 m
Weather	Cloudy
Temperature	27.5℃
Wind dir. & force	E-4

0 500m
scale

※ 5m: No data available

Fig.Ⅲ-5-1 PROGRESSIVE VECTOR DIAGRAM

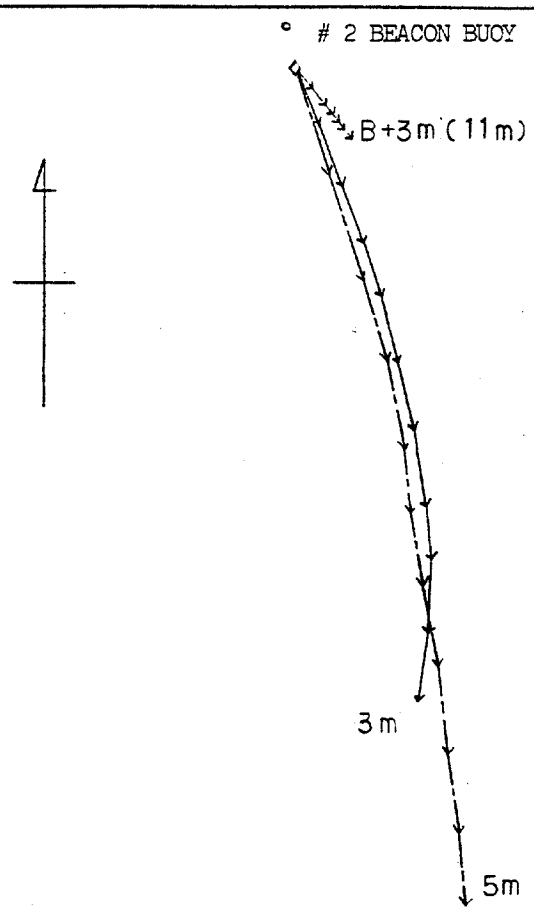


Date	July,23,1984
Time	14:20-16:00
Case	I , No overflow
Depth	16 m
Weather	Cloudy
Temperature	30.0℃
Wind dir. & force	E-3

0 500m
scale

※ 5m: No data available

Fig.Ⅲ-5-2 PROGRESSIVE VECTOR DIAGRAM

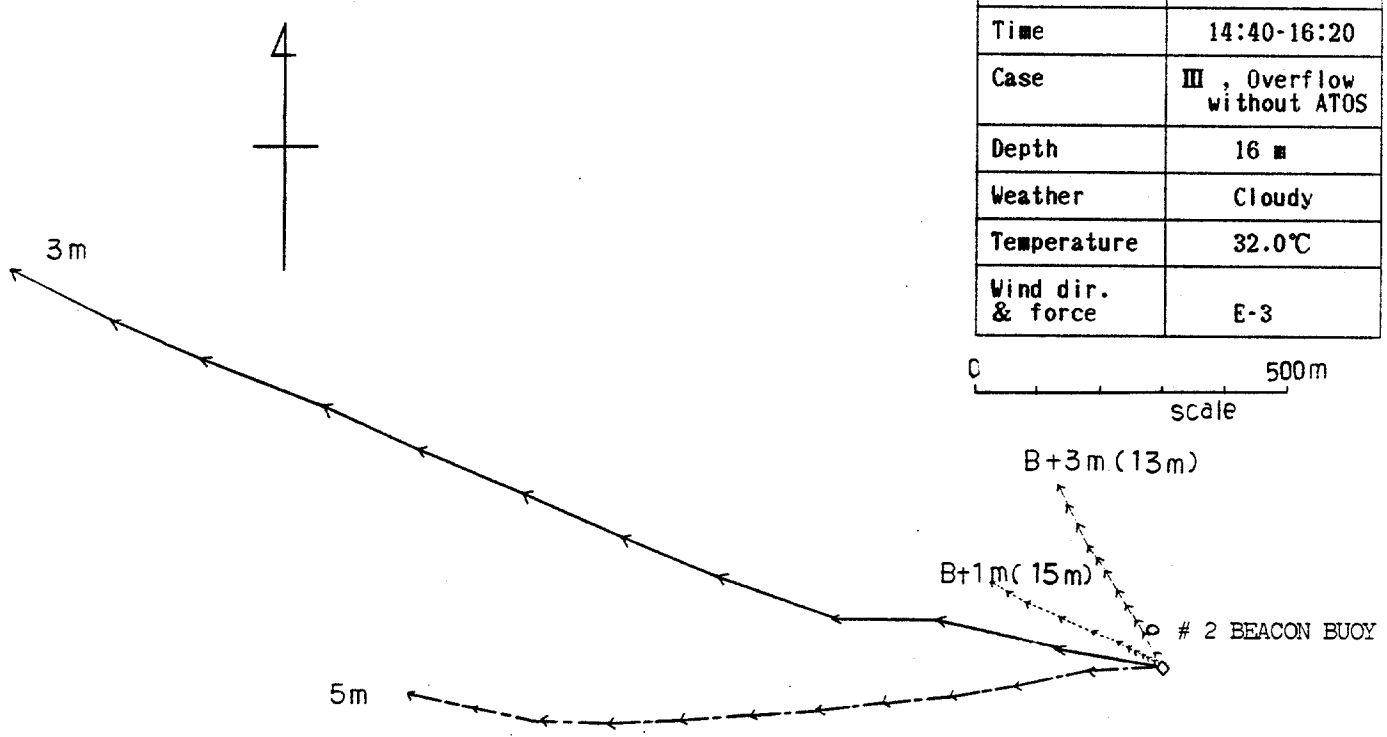


Date	July,24,1984
Time	11:00-12:30
Case	II , Overflow with ATOS
Depth	14 m
Weather	Cloudy
Temperature	30.0℃
Wind dir. & force	SE-2

0 500m
scale

B+1m: Below threshold value.

Fig.III-5-3 PROGRESSIVE VECTOR DIAGRAM



Date	July,24,1984
Time	14:40-16:20
Case	III , Overflow without ATOS
Depth	16 m
Weather	Cloudy
Temperature	32.0℃
Wind dir. & force	E-3

0 500m
scale

Fig.III-5-4 PROGRESSIVE VECTOR DIAGRAM

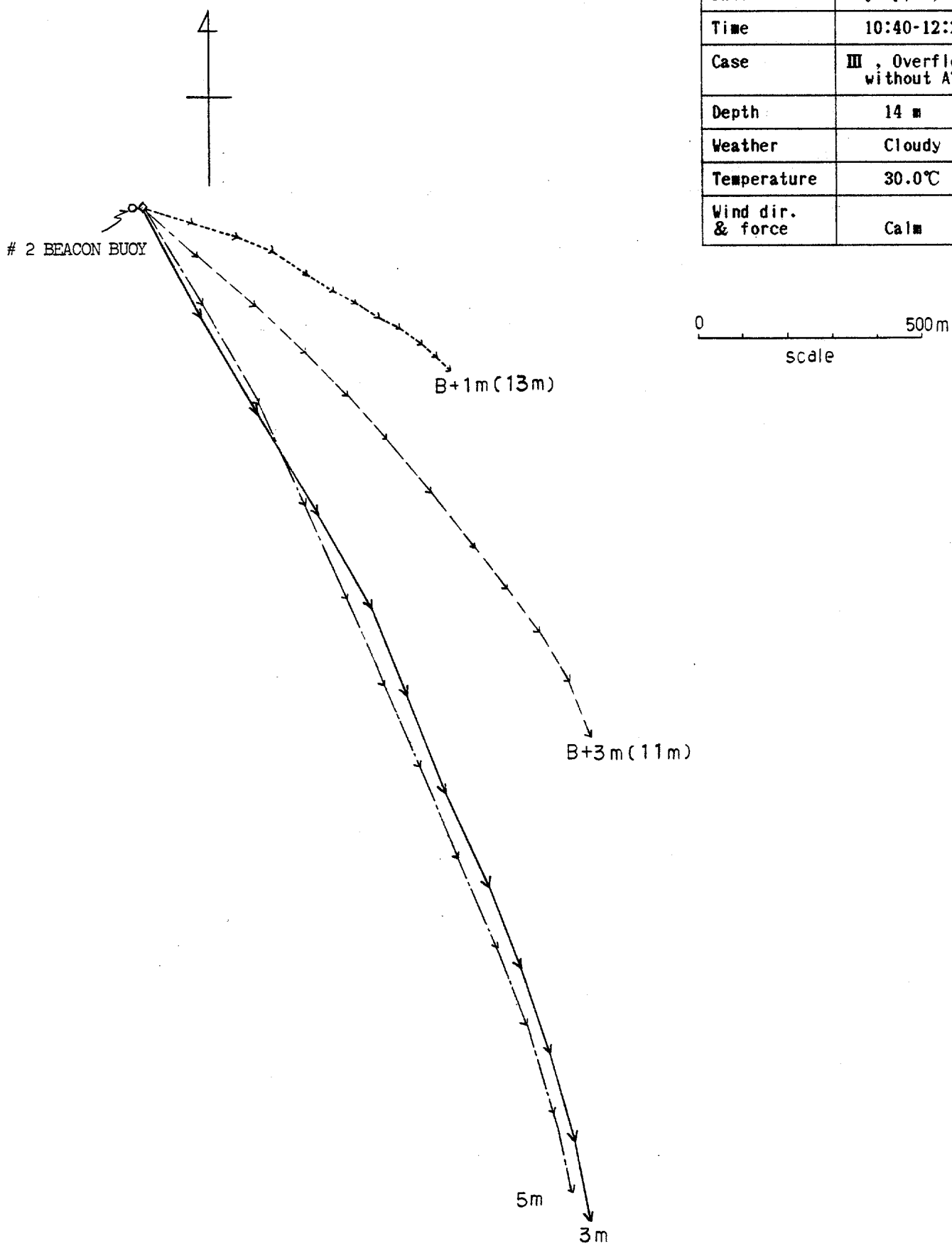


Fig.III-5-5 PROGRESSIVE VECTOR DIAGRAM

Date	July,25,1984
Time	14:20-16:00
Case	II , Overflow with ATOS
Depth	14 m
Weather	Cloudy
Temperature	29.0℃
Wind dir. & force	NE-2

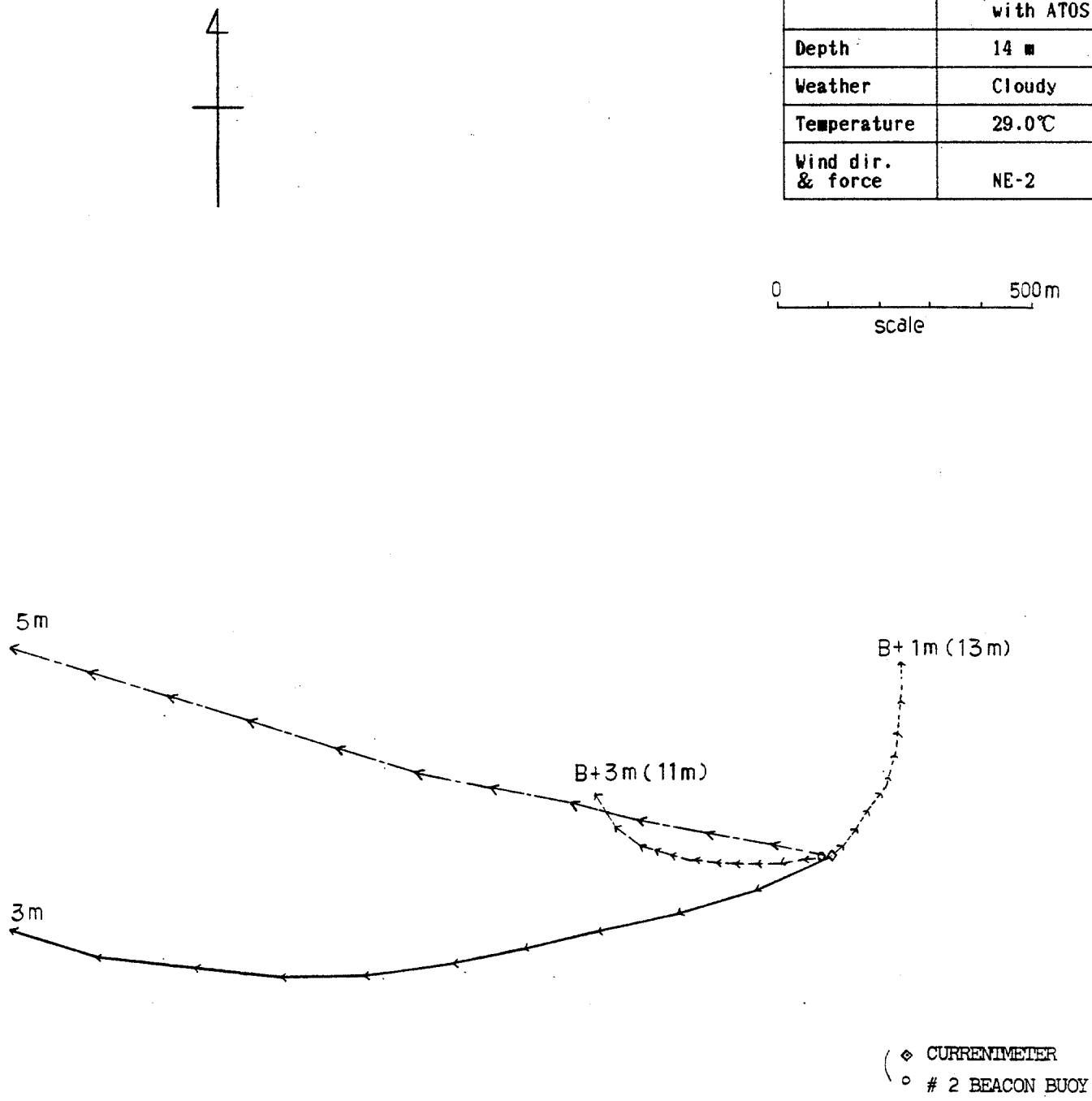


Fig.Ⅲ-5-6 PROGRESSIVE VECTOR DIAGRAM

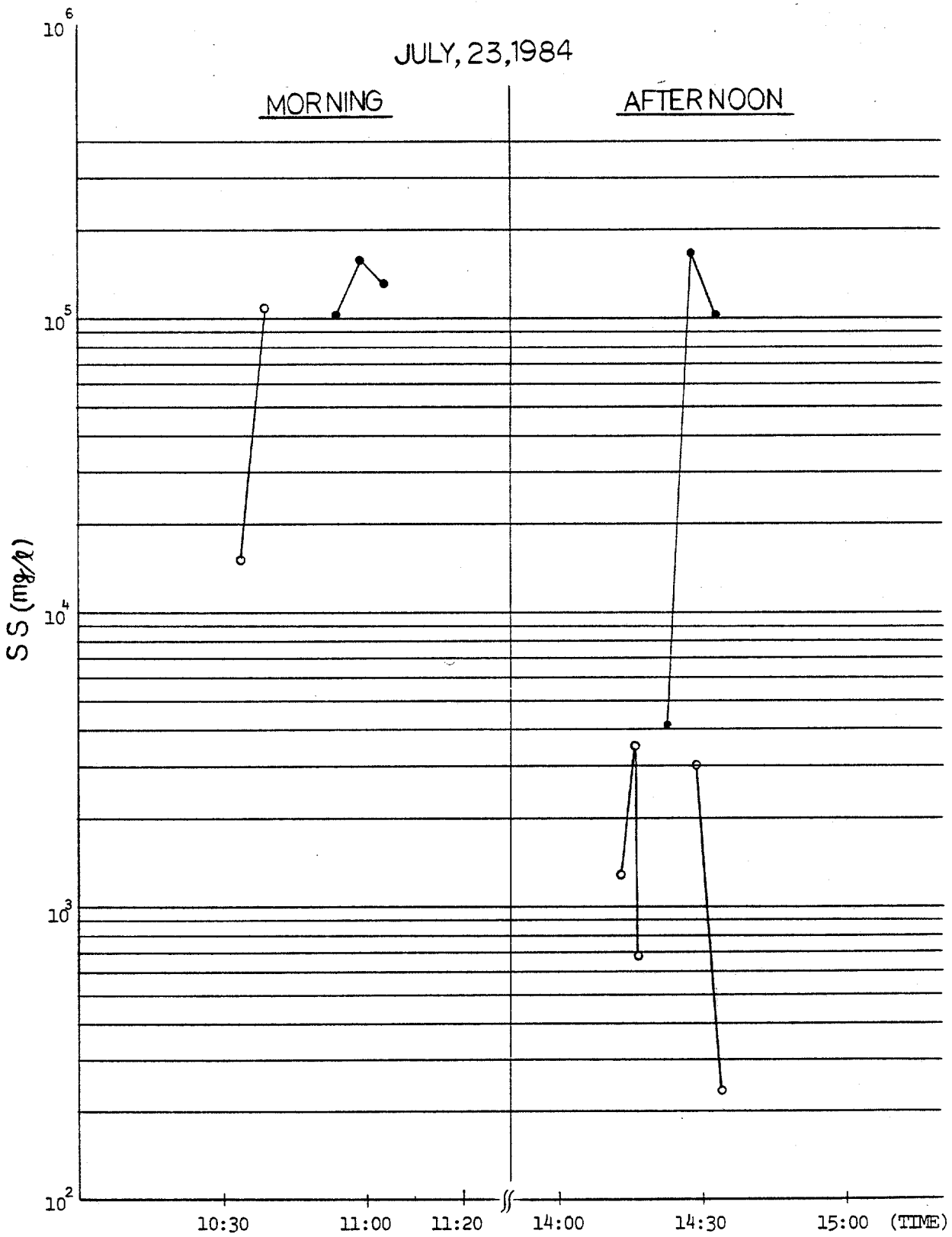


Fig. III-6-1 SS VALUES SAMPLED AT DRAG HEAD AND HOPPER WEIR

○ DRAG HEAD
● OVERFLOW

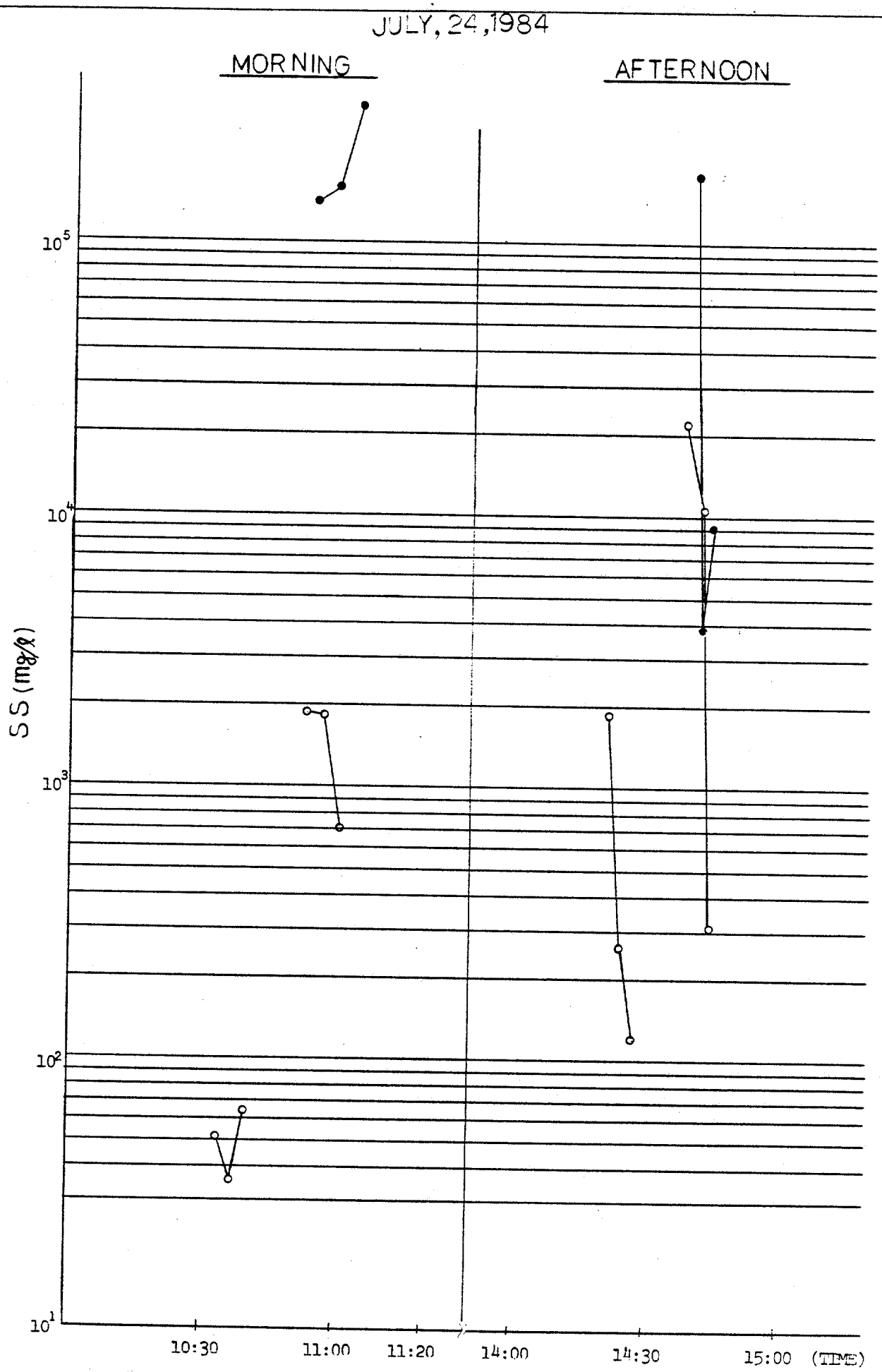


Fig.Ⅲ-6-2 SS VALUES SAMPLED AT DRAG HEAD AND HOPPER WEIR

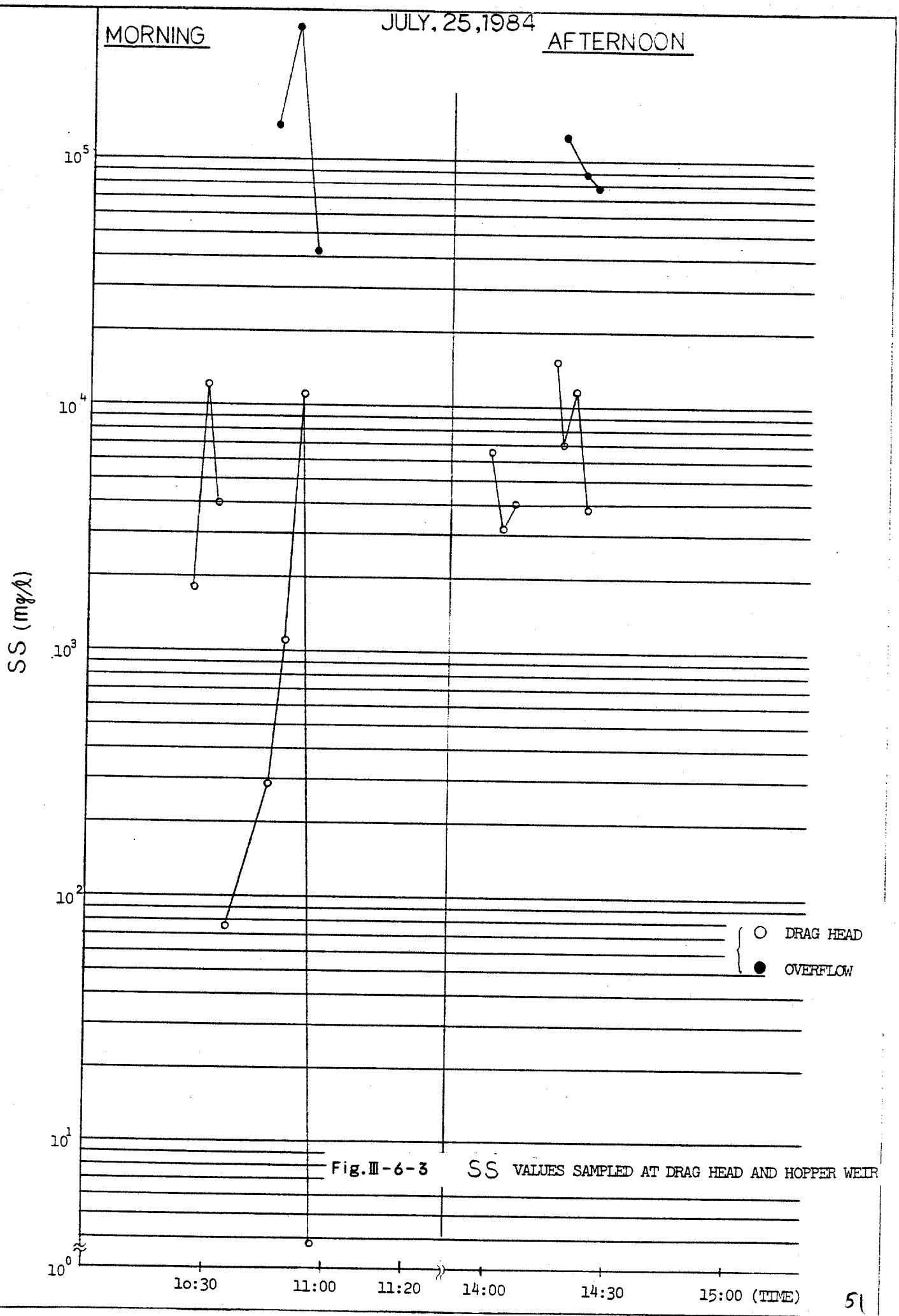


Fig.Ⅲ-6-3 SS VALUES SAMPLED AT DRAG HEAD AND HOPPER WEIR

III-7. Time variation of particle numbers contained in the waters sampled at the drag head and the hopper weir
Appendices Nos. 8, 29

III-8. Mutual relation of SS values determined by water sample and turbidimeter in the field
Appendices Nos. 5, 10, 11, 25, 28

III-9. Mutual relation of SS values determined by water sample prepared in laboratory and turbidimeter
Appendices Nos. 4, 5, 25, 28

III-10. Time change of vertical SS distribution at the center of the plume (SS values delived from turbidimeter observation on the No. 2 boat)
Appendices Nos. 2, 3, 4, 5, 11, 25

III-11. Time change of vertical SS distribution at the center of the plume (SS values determined from water sample analysis)
Appendices Nos. 2, 3, 10, 28

Continued on page 62

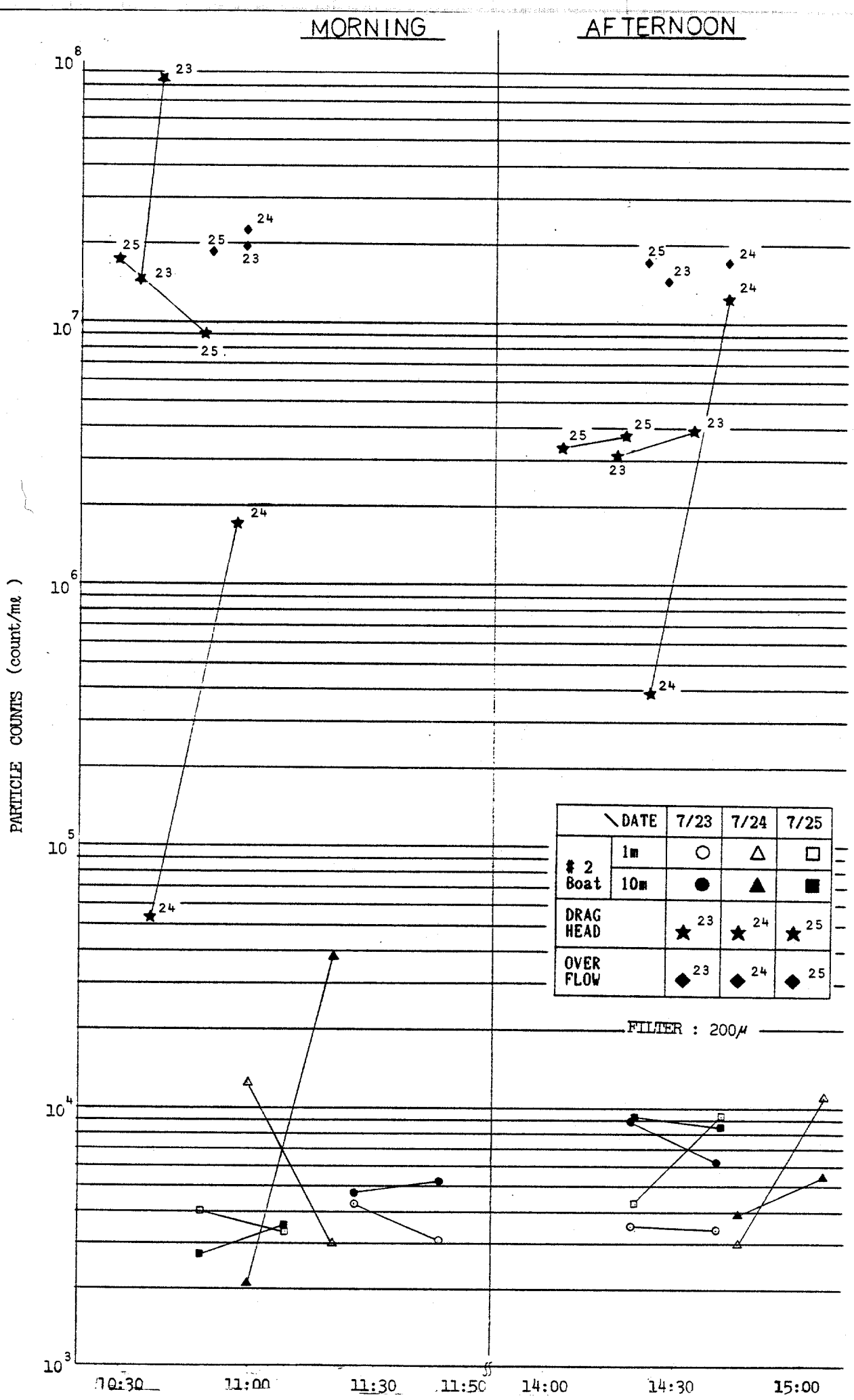
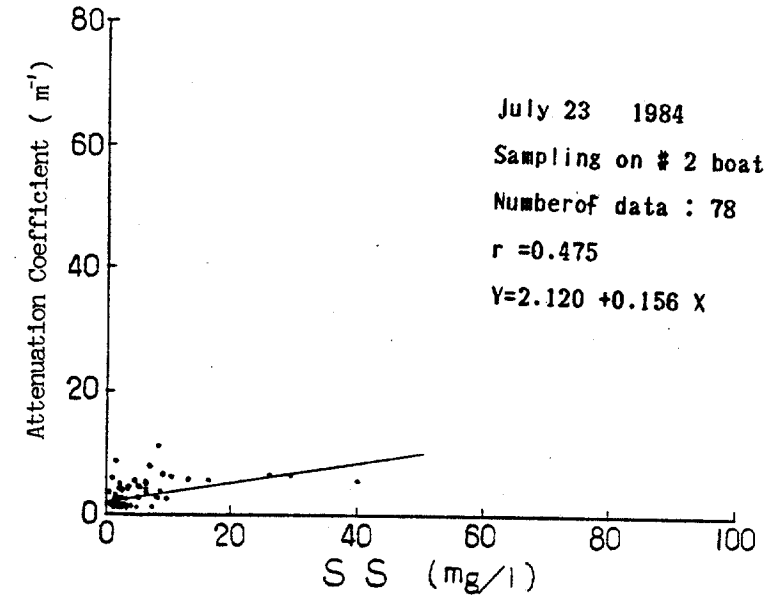
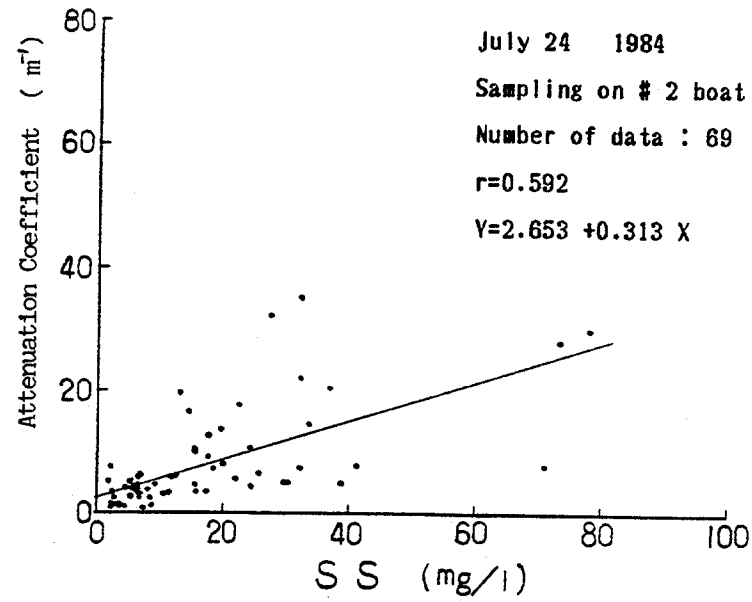


Fig.Ⅲ-7 PARTICLE COUNTS ANALYSED WITH COULTER COUNTER





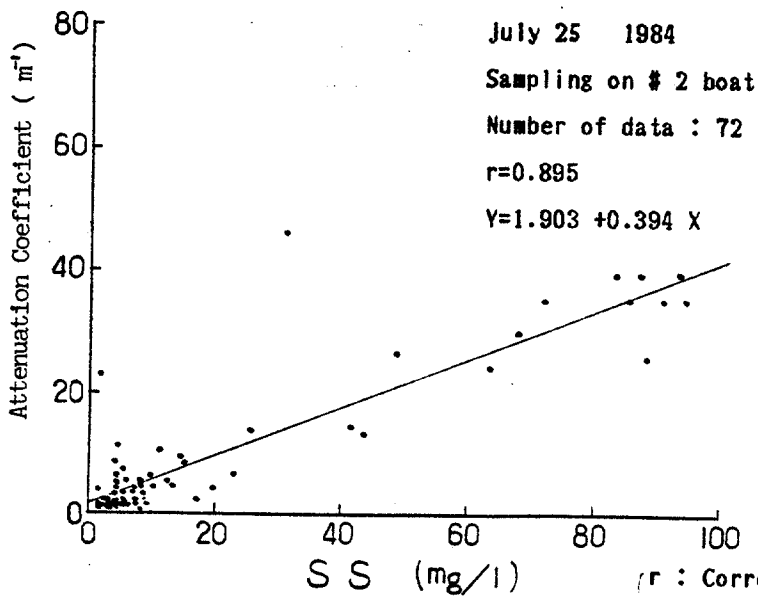
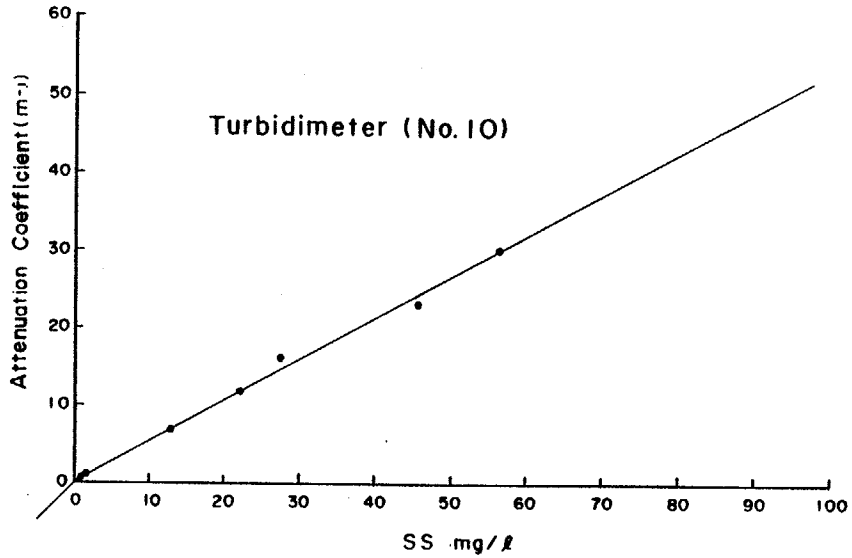
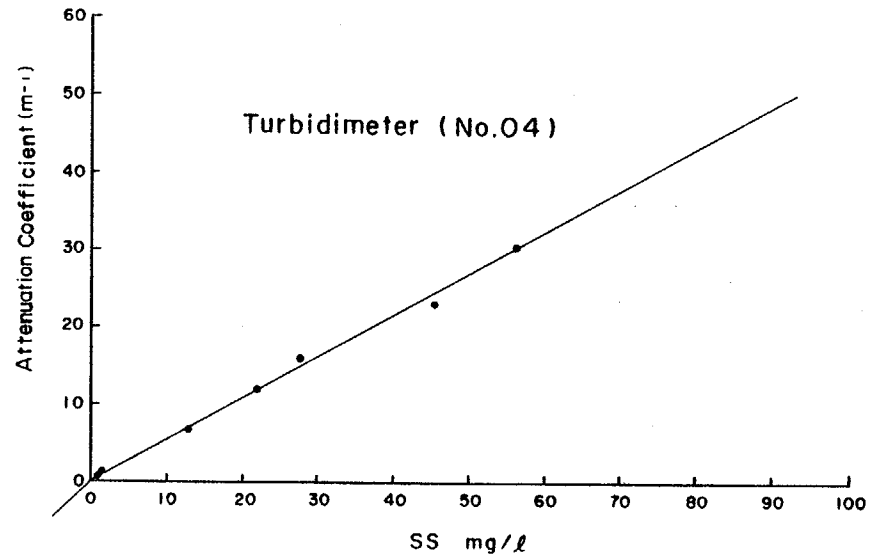
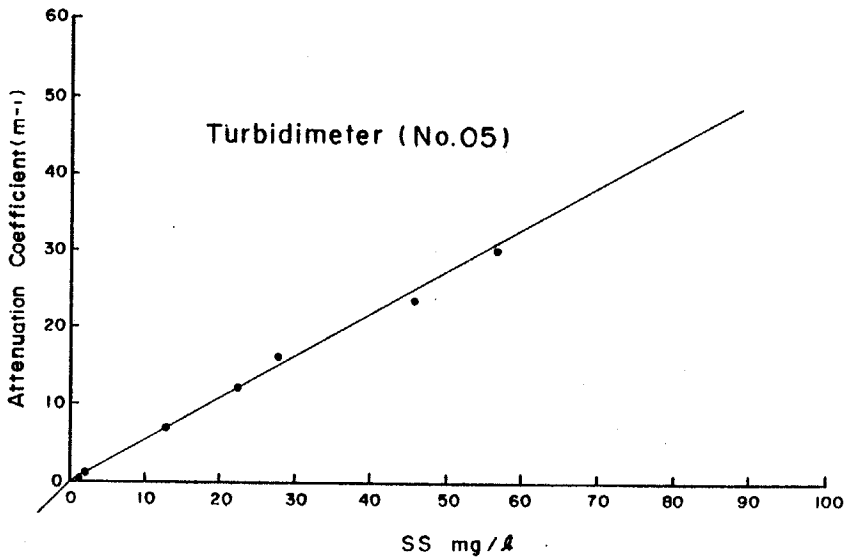


Fig.Ⅲ-8 Regressin analysis of SS values determined from water sample and turbidimeter.

note. r : Correlation coefficient
X : SS (mg/ℓ)
Y : Attenuation coefficient







turbidimeter	boat	number of data	regression coefficient	correlation coefficient
10	5	7	y=0.243 +0.526 x	0.997
4	4	7	y=0.179 +0.529 x	0.997
5	2	7	y=0.078 +0.527 x	0.997

$$y = Bx + A$$

Attenuation Coefficient — SS

$$\text{Attenuatin Coefficient} = 10 \times \text{Ln}\,\frac{100}{T}$$

T : Transmittance(%)

Fig. Ⅲ – 9 Regression analysis between Attenuation coefficient and SS determined at Lab.
Mud sampled at dredge area is used to make the turbid water served for this analysis

Date : July 23 1984 Case : I , No overflow.
Depth of drogue : 10.3m

DEPTH (m)	B.G	1	2	3	4	5	6	7
(No.)		1	2	3	4	5	6	7
(min)		25	35	45	55	05	20	40
(Hour)	10:15	11:30			12:00		12:30	13:00
0								
0.5		2.0	1.8	2.0	1.8	2.0	1.8	2.0
1	*2.4	2.5	1.8	2.0	1.8	1.8	1.8	2.0
2		2.3	1.8	2.0	1.8	2.0	1.8	1.8
3	*1.3	2.3	2.0	2.0	1.8	2.3	1.8	2.7
4		2.7	2.0	3.4	1.8	2.3	1.8	3.2
5	*7.3	3.6	2.0	4.6	3.6	2.5	1.8	3.8
6		10.8	6.6	7.7	3.8	4.1	2.3	4.1
7	*2.2	24.0	9.5	8.3	8.9	4.6	4.6	9.2
8		24.7	10.8	10.2	11.5	11.5	6.1	9.5
9		27.7	13.0	16.7	14.6	8.3	10.5	7.4
10	*2.1	11.9	20.3	14.6	11.9	7.7	7.7	6.3
11		12.2	13.0	11.2	8.3	9.2	10.8	7.4
12	*1.8	10.5	11.5	9.8	10.5	10.5	11.2	7.7 7.7
13								
14								
15								
16								
17								

Bottom

Date : July 23 1984 Case : I , No overflow.
Depth of drogue : 10.4m

DEPTH (m)	B.G	1	2	3	4	5	6	7	8
(No.)		1	2	3	4	5	6	7	8
(min)		20	30	40	50	00	10	30	50
(Hour)	13:52	14:20	14:30			15:00		15:30	16:00
0									
0.5	2.5	2.7	8.0	3.4	3.2	3.2	3.2	2.9	2.9
1	2.5	2.7	6.1	3.2	3.2	3.2	3.2	2.9	2.9
2	2.5	2.7	8.3	3.4	2.9	3.2	2.9	2.9	2.9
3	2.5	2.7	5.6	2.9	2.9	3.2	3.2	2.7	2.9
4	3.2	2.7	5.0	2.9	2.7	2.9	2.9	2.5	2.5
5	1.6	2.5	4.8	2.9	2.7	2.5	2.5	2.0	1.8
6	1.6	2.5	4.8	2.7	2.5	2.3	2.5	2.0	1.6
7	1.6	2.5	4.8	2.7	2.0	2.0	1.8	7.4	10.8
8	2.0	2.5	4.6	2.7	2.0	2.0	1.6	5.3	5.3
9	4.8	1.8	4.3	2.3	2.0	2.0	1.8	3.8	4.6
10	6.1	2.3	4.3	2.5	3.8	2.7	4.6	5.3	4.8
11	5.6	2.7	4.6	6.1	3.6	5.3	6.3	5.8	5.3
12	15.4	4.8	9.5	7.4	7.4	4.8	6.9	6.3	7.2
13		7.2	17.2	16.3	14.2	6.6	14.6	6.3	8.3
14			15.8	16.3 8.0	15.4	15.8	17.2	13.8	10.2
15			17.2		13.4 8.3	16.3	8.9	8.6	9.2
16						9.8	11.5	9.2	9.2
17									

Bottom

※ Determined at laboratory. Fig.Ⅲ－10－1 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (TURBIDIMETER) unit : mg/ℓ

Date : July 24 1984 Case : II, Overflow with ATOS.
Depth of drogue : 5.0m

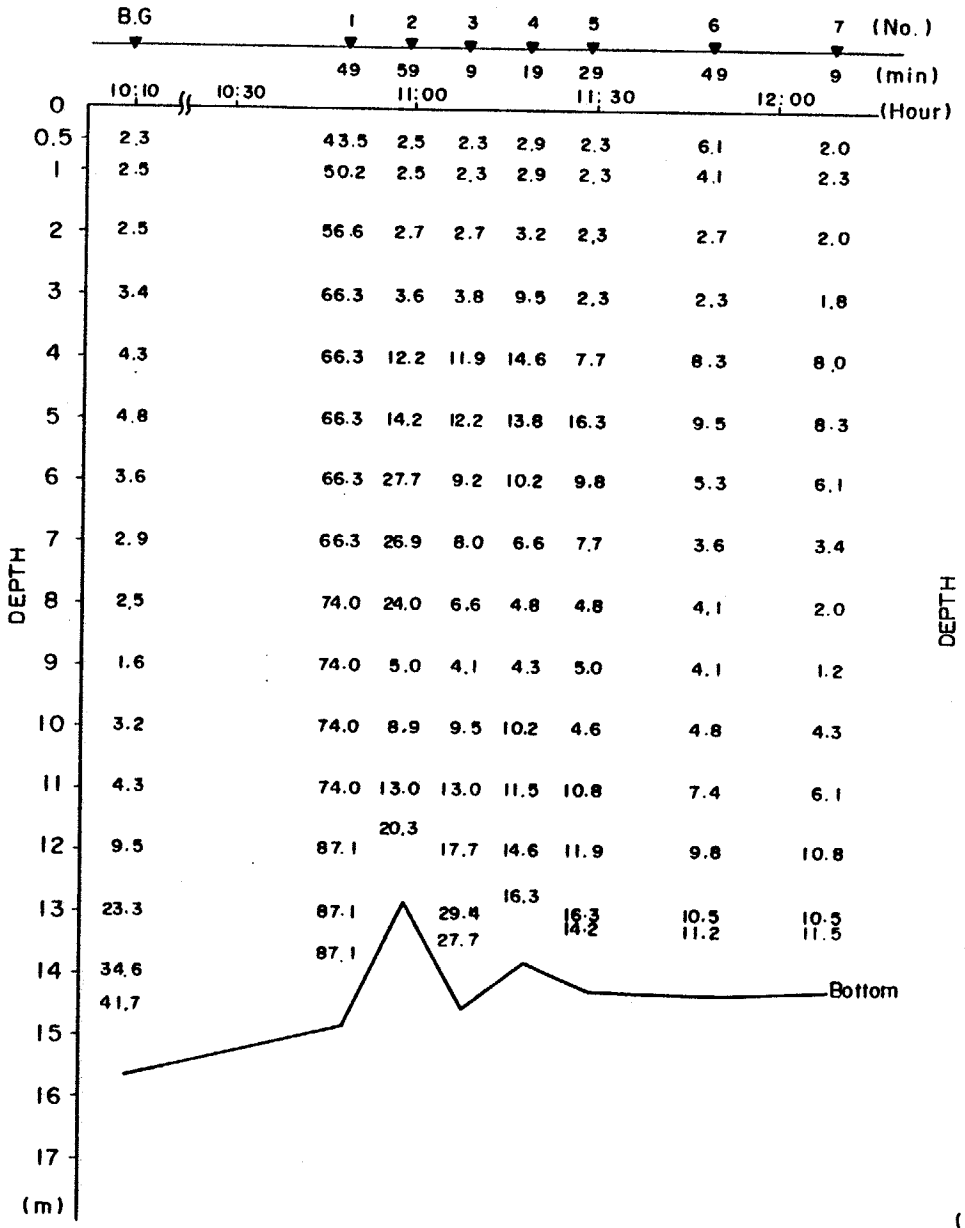
DEPTH (m)	B.G	1	2	3	5	6	7	8
(No.)		1	2	3	5	6	7	8
(min)		00	9	20	40	50	00	20
(Hour)	10:30	11:00			11:30		12:00	12:30
0								
0.5	5.0	19.2	3.6	2.7	2.7	2.7	2.7	2.7
1	4.6	13.8	7.2	4.6	2.7	2.7	2.9	2.7
2	2.7	26.1	7.7	8.9	6.1	5.6	2.9	2.7
3	3.2	33.4	19.7	14.6	6.1	2.9	3.2	2.3
4	2.5	38.5	22.0	6.6	4.1	3.6	8.3	1.8
5	1.8	38.5	26.1	7.2	6.6	9.5	7.7	3.2
6	1.8	87.1	22.7	15.4	5.0	10.8	3.2	6.9
7	1.8	>100.	41.7	31.3	8.9	15.4	1.8	8.9
8	1.8	>100.	56.6	33.4	3.6	2.7	1.8	5.6
9	2.5	>100.	47.7	35.8	23.3	4.1	3.2	7.7
10	4.6	>100.	14.6	15.4	18.2	11.9	8.3	7.2
11	5.3	26.1	11.5	11.9	9.2	11.9	9.5	7.4
12	13.0	>100. >100.	14.6	9.5	9.5	18.2		7.4
13			22.7 22.0	10.8	8.6	19.2		Bottom
14				15.4 22.7	7.7			
15								
16								
17								

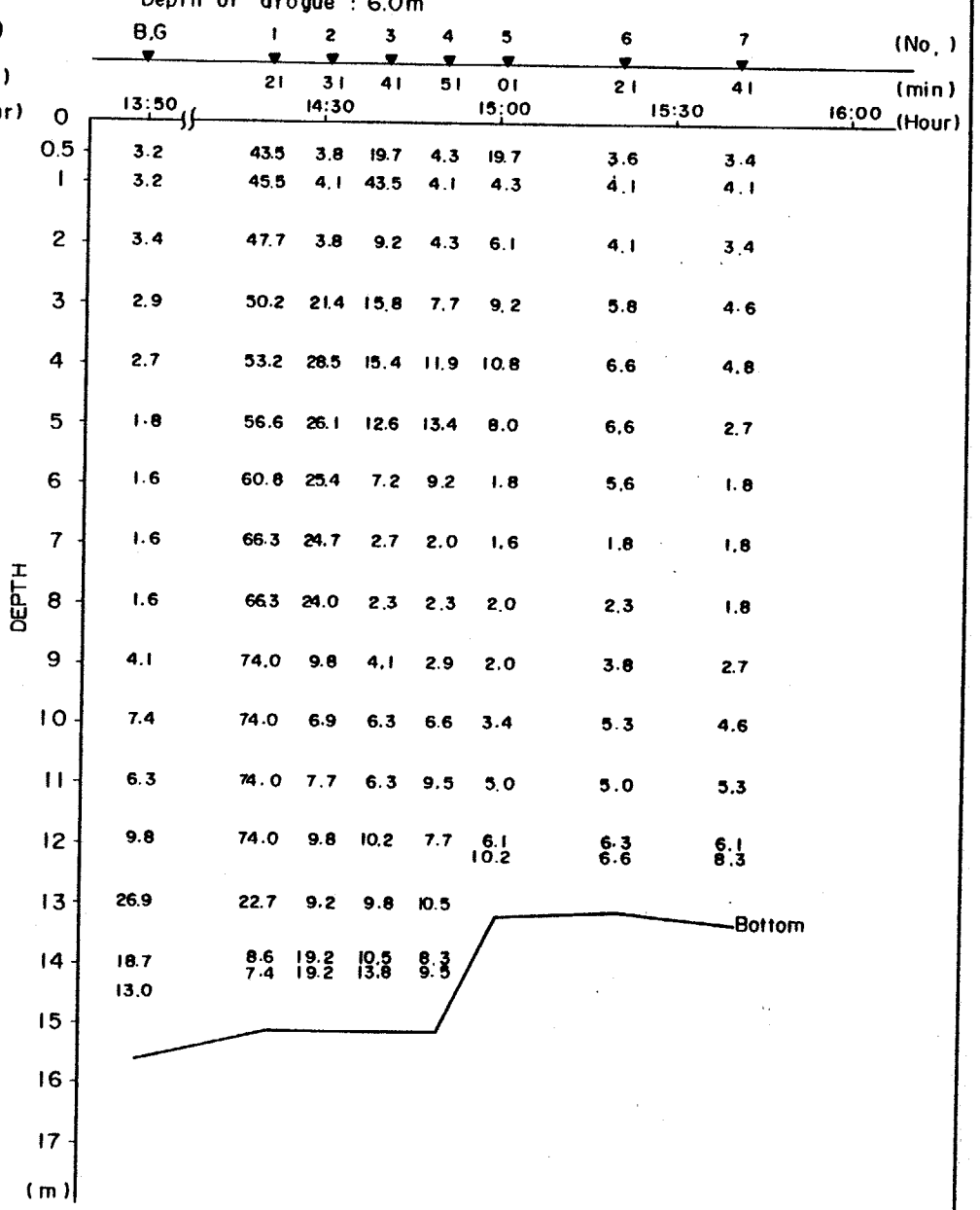
Date : July 24 1984 Case : III, Overflow witthout ATOS
Depth of drogue : 2.0m

DEPTH (m)	B.G	1	2	3	4	5	6	7
(No.)		1	2	3	4	5	6	7
(min)		45	55	5	17	25	45	5
(Hour)	14:15	14:30	15:00			15:30		16:00
0								
0.5	2.9	53.2	15.4	10.2	15.4	8.6	4.1	2.7
1	2.9	53.2	14.6	10.8	15.4	11.5	4.1	2.7
2	2.9	53.2	21.4	16.3	17.2	11.5	3.8	2.7
3	2.7	56.6	24.0	20.3	21.4	11.2	2.7	2.7
4	2.3	60.8	26.9	21.4	19.2	11.5	2.3	2.7
5	2.5	60.8	27.7	20.9	13.0	8.9	2.3	2.7
6	2.0	66.3	26.9	19.7	3.6	2.3	1.8	3.8
7	1.8	66.3	9.8	8.3	4.1	1.6	3.6	5.0
8	2.7	53.2	3.2	4.1	3.2	1.6	4.1	6.9
9	3.6	43.5	6.6	4.3	3.8	8.6	5.6	6.6
10	6.3	37.1	7.7	5.8	5.0	7.7	6.1	6.6
11	7.2	12.2	9.2	8.3	6.6	5.8	5.8	6.6
12	7.7	12.2	9.5	11.2	7.7	5.8	6.6	6.6
13	8.9	87.1	12.2	11.9	8.9	10.5	13.0	11.5
14		87.1	25.4	26.9	11.2 10.8	11.9	13.0	13.0
15			>100.	34.6		28.5	26.1 31.3	40.0
16								47.7 40.0
17								

Bottom

Fig. III — 10—2 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (TURBIDIMETER) unit : mg/ℓ





Date : July 25 1984 Case : III, Overflow without ATOS.
Depth of drogue : 1.0m

DEPTH (m)	B.G	1	2	3	4	5	6	7 (No.)
		49	59	9	19	29	49	9 (min)
	10:10	10:30	11:00			11:30	12:00	(Hour)
0.5	2.3	43.5	2.5	2.3	2.9	2.3	6.1	2.0
1	2.5	50.2	2.5	2.3	2.9	2.3	4.1	2.3
2	2.5	56.6	2.7	2.7	3.2	2.3	2.7	2.0
3	3.4	66.3	3.6	3.8	9.5	2.3	2.3	1.8
4	4.3	66.3	12.2	11.9	14.6	7.7	8.3	8.0
5	4.8	66.3	14.2	12.2	13.8	16.3	9.5	8.3
6	3.6	66.3	27.7	9.2	10.2	9.8	5.3	6.1
7	2.9	66.3	26.9	8.0	6.6	7.7	3.6	3.4
8	2.5	74.0	24.0	6.6	4.8	4.8	4.1	2.0
9	1.6	74.0	5.0	4.1	4.3	5.0	4.1	1.2
10	3.2	74.0	8.9	9.5	10.2	4.6	4.8	4.3
11	4.3	74.0	13.0	13.0	11.5	10.8	7.4	6.1
12	9.5	87.1	20.3	17.7	14.6	11.9	9.8	10.8
13	23.3	87.1		29.4	16.3	16.3	10.5	10.5
14	34.6	87.1		27.7		14.2	11.2	11.5
15	41.7							
16								
17								

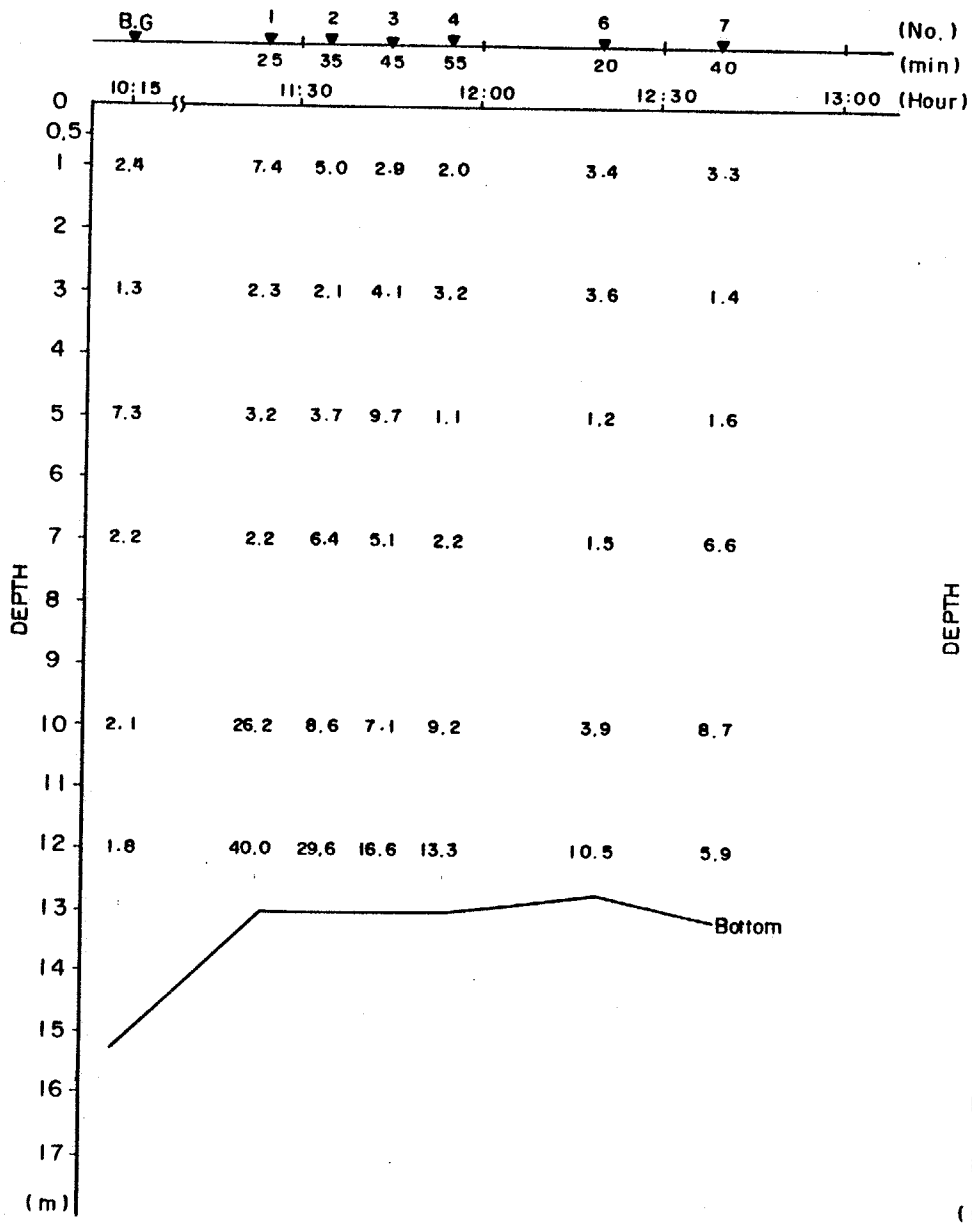
Bottom

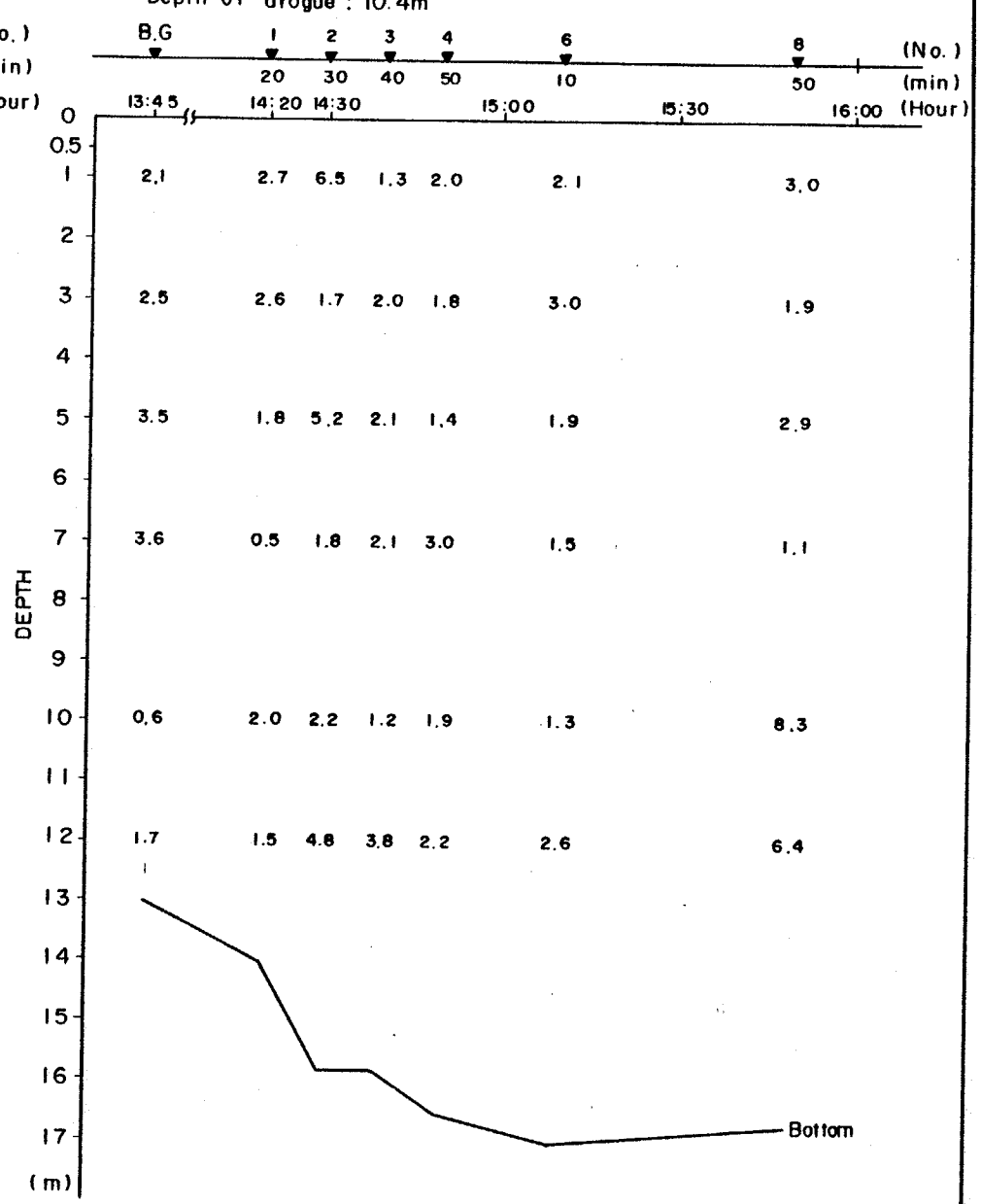
Date : July 25 1984 Case : II, Overflow with ATOS
Depth of drogue : 6.0m

DEPTH (m)	B.G	1	2	3	4	5	6	7 (No.)
		21	31	41	51	01	21	41 (min)
	13:50	14:30			15:00		15:30	16:00 (Hour)
0.5	3.2	43.5	3.8	19.7	4.3	19.7	3.6	3.4
1	3.2	45.5	4.1	43.5	4.1	4.3	4.1	4.1
2	3.4	47.7	3.8	9.2	4.3	6.1	4.1	3.4
3	2.9	50.2	21.4	15.8	7.7	9.2	5.8	4.6
4	2.7	53.2	28.5	15.4	11.9	10.8	6.6	4.8
5	1.8	56.6	26.1	12.6	13.4	8.0	6.6	2.7
6	1.6	60.8	25.4	7.2	9.2	1.8	5.6	1.8
7	1.6	66.3	24.7	2.7	2.0	1.6	1.8	1.8
8	1.6	66.3	24.0	2.3	2.3	2.0	2.3	1.8
9	4.1	74.0	9.8	4.1	2.9	2.0	3.8	2.7
10	7.4	74.0	6.9	6.3	6.6	3.4	5.3	4.6
11	6.3	74.0	7.7	6.3	9.5	5.0	5.0	5.3
12	9.8	74.0	9.8	10.2	7.7	6.1	6.3	6.1
13	26.9	22.7	9.2	9.8	10.5	10.2	6.6	8.3
14	18.7	8.6	19.2	10.5	8.3			
15	13.0	7.4	19.2	13.8	9.5			
16								
17								

Bottom

Fig. III – 10–3 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (TURBIDIMETER) unit : mg/ℓ





unit : mg/ℓ

Fig. Ⅲ — 11—1 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (Determined by water samples)

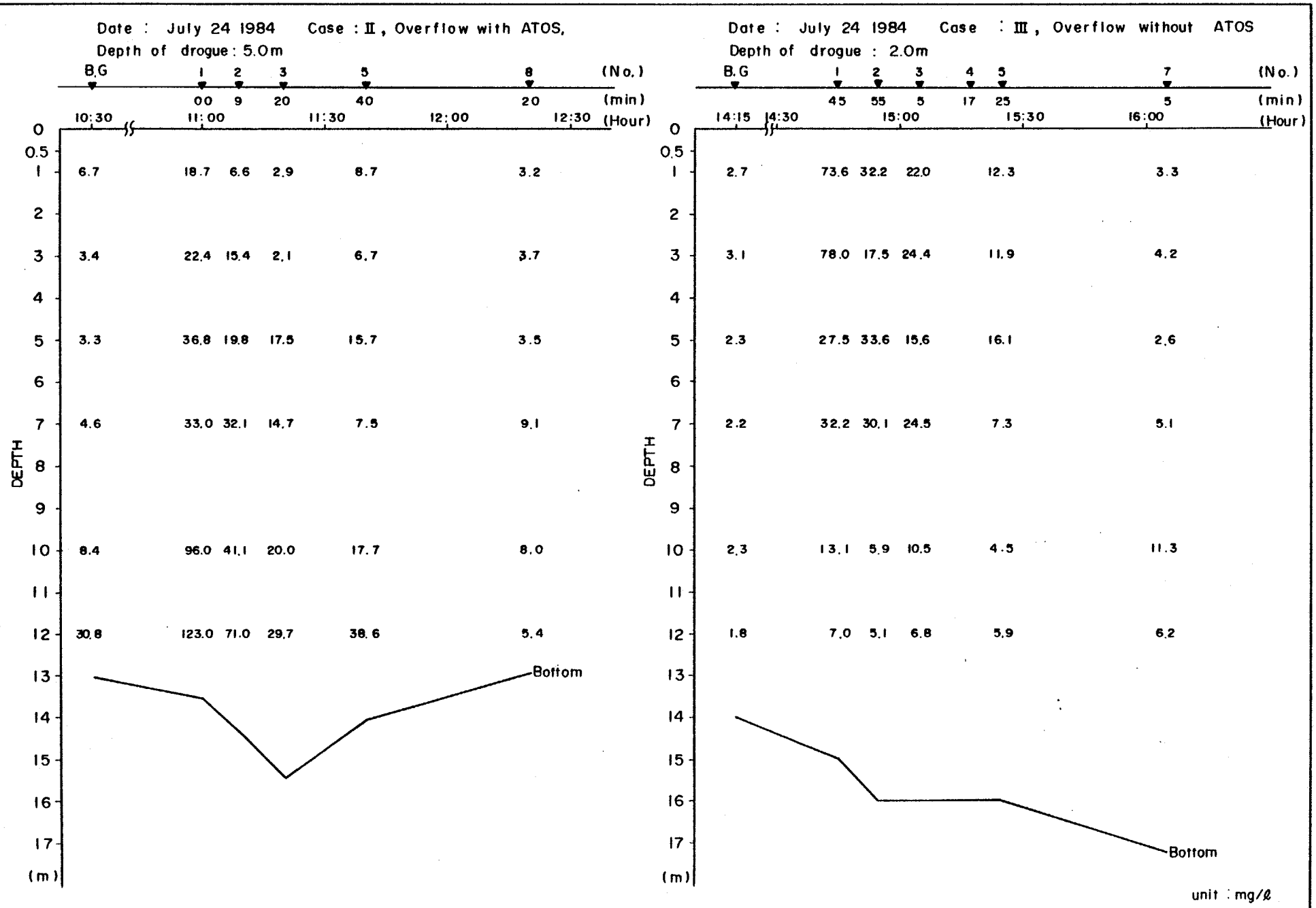


Fig. III − 11−2 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (Determind by water samples)

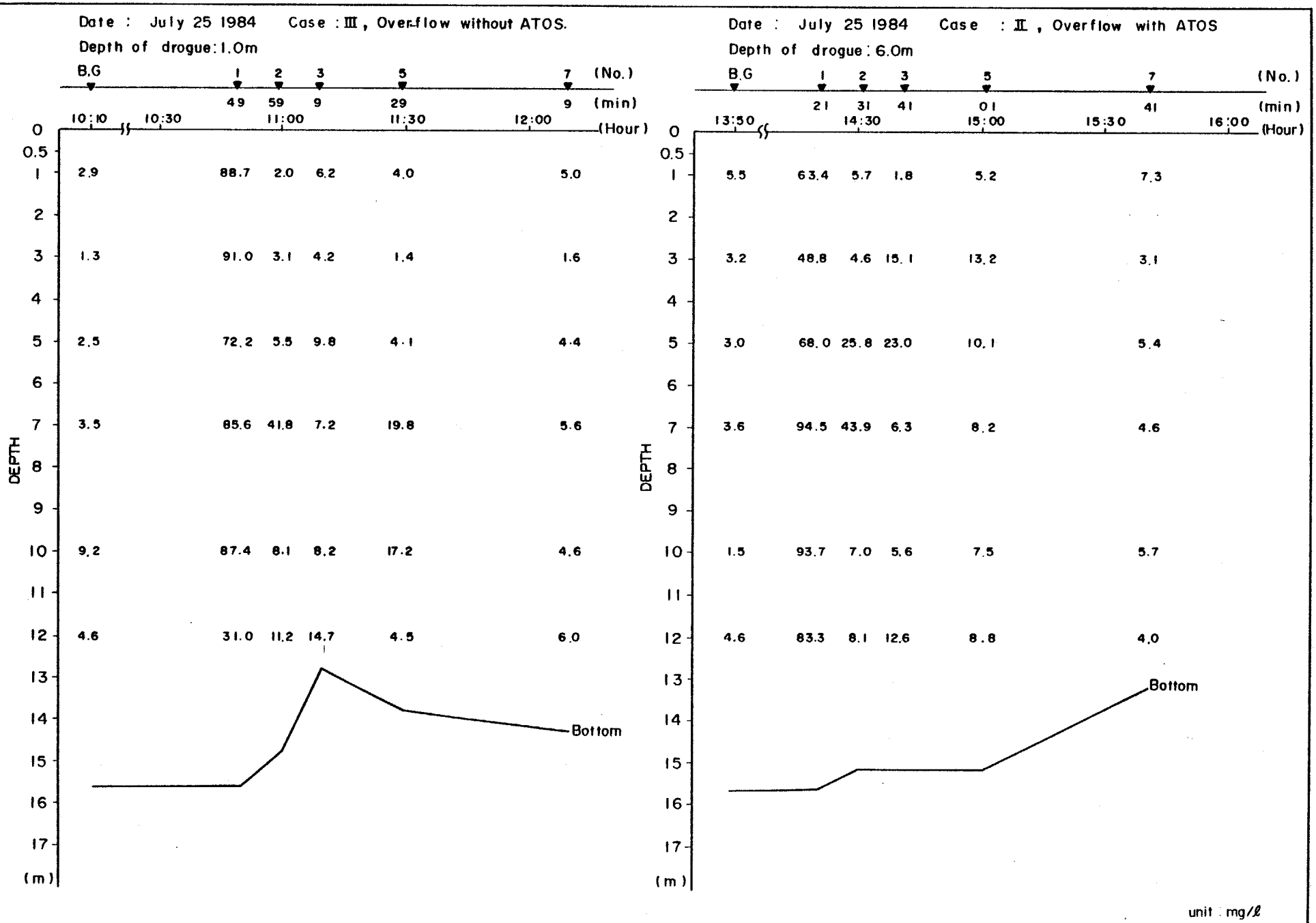


Fig. III – 11–3 TIME CHANGE OF VERTICAL SS DISTRIBUTION AT THE CENTER OF THE PLUME. (Determined by water samples)

III-12. SS distribution in vertical cross-plume section. SS values from Nos.1 and 3 boats are based on water samples (under lined values), others by turbidimeter. Some stations have two SS values determined by the two methods. In such cases, the SS values from water samples are shown.
Appendices Nos 1, 2, 4, 5, 10, 11, 25, 28

III-13. Cross plume SS distributions at some depths measured with a towed turbidimeter.
Appendices Nos. 4, 5, 12, 25

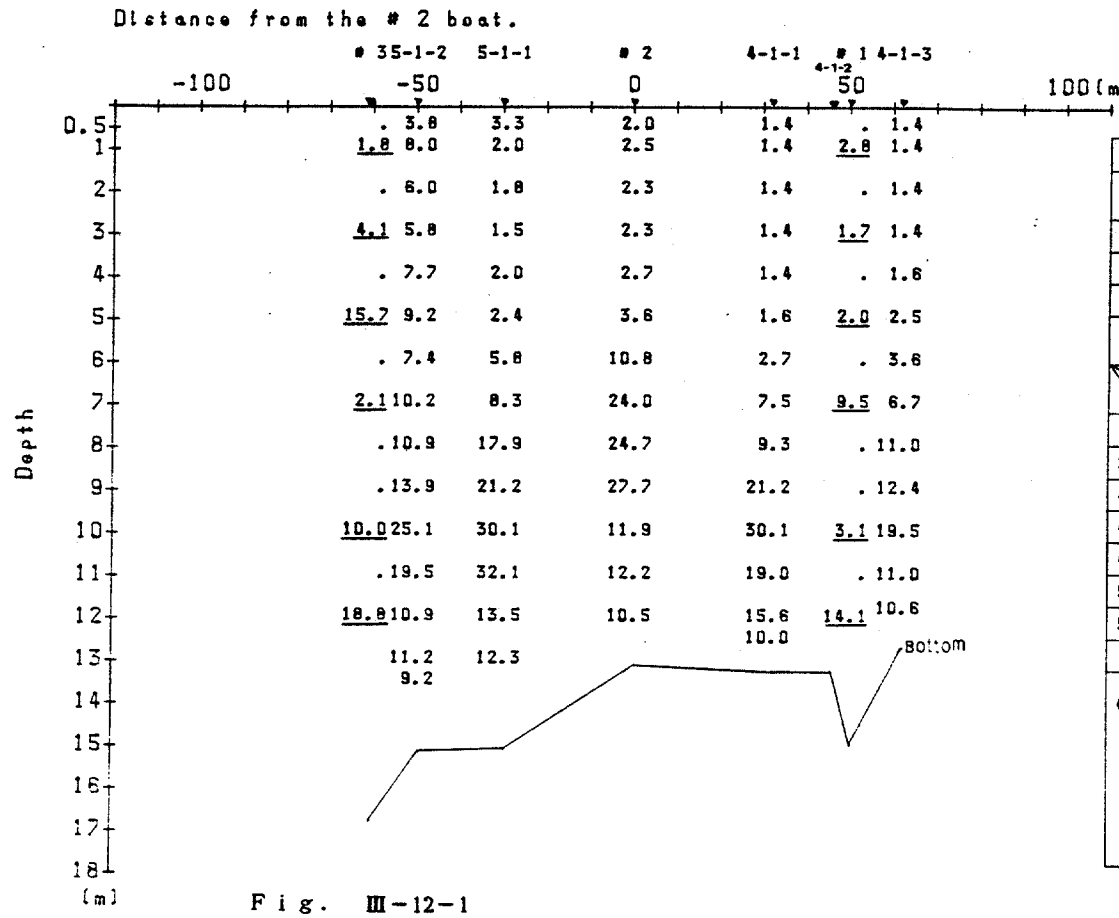
III-14. Time change of vertical distribution of particle numbers in the water at the center of the plume (only two cases measured on July 25, 1984)
Appendices Nos. 2, 3, 8, 29

III-15. Particle size analysis with a Coulter Counter Size (in micro m) - Particle counts diagrams arranged in time and depth
Appendices Nos. 8, 29

III-16. Particle size analysis with a Coulter Counter Size (in micro m) - Volume (percent) diagrams arranged in time and depth
Appendices Nos. 8, 29

III-17. The Kaihomaru dredging course

III-18. The Kaihomaru pumping rate



Date	July.23.1984
Time of # 2 boat	11:25
Serial No.	1
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Sta.	Observation time of each boat
1	1	11:25
3	1	11:25
4	1-1	11:25
4	1-2	11:32
4	1-3	11:34
5	1-1	11:25
5	1-2	11:28

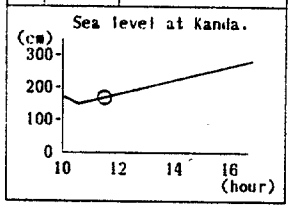
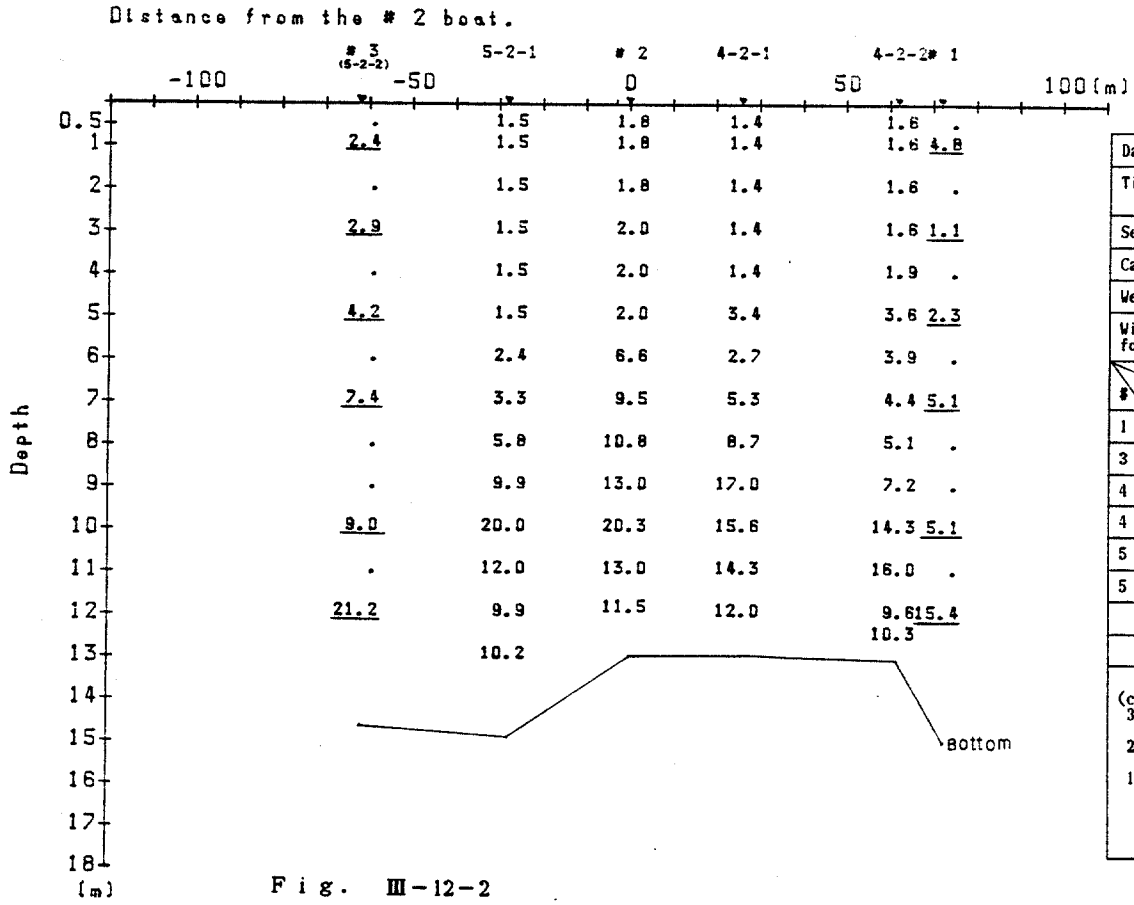


Fig. Ⅲ-12-1



Date	July.23.1984
Time of # 2 boat	11:35
Serial No.	2
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Sta.	Observation time of each boat
1	2	11:35
3	2	11:35
4	2-1	11:36
4	2-2	11:38
5	2-1	11:35
5	2-2	11:39

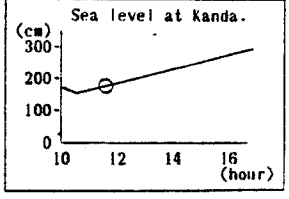
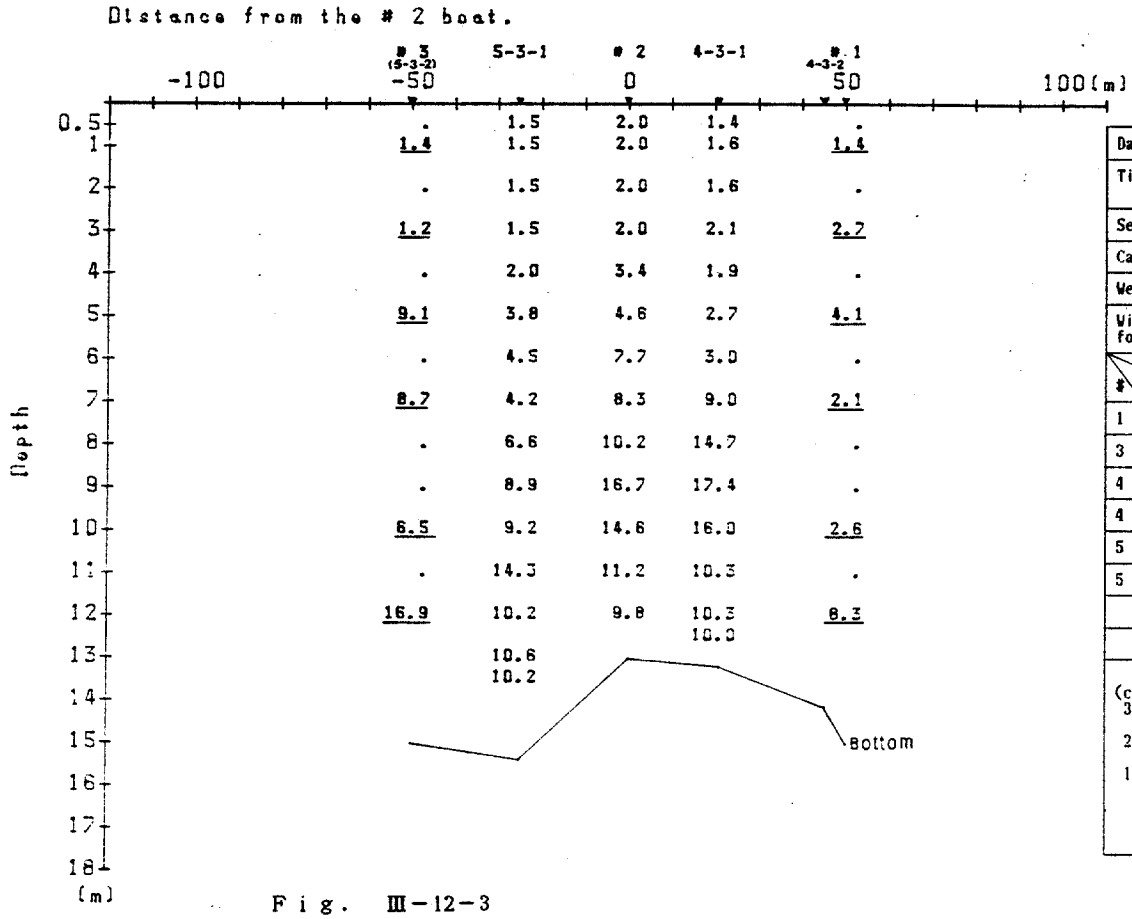


Fig. Ⅲ-12-2



Date	July,23,1984
Time of # 2 boat	11:45
Serial No.	3
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Item / Sta.	Observation time of each boat
1	3	11:45
3	3	11:45
4	3-1	11:45
4	3-2	11:50
5	3-1	11:45
5	3-2	11:48

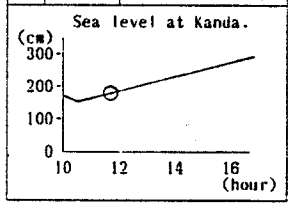
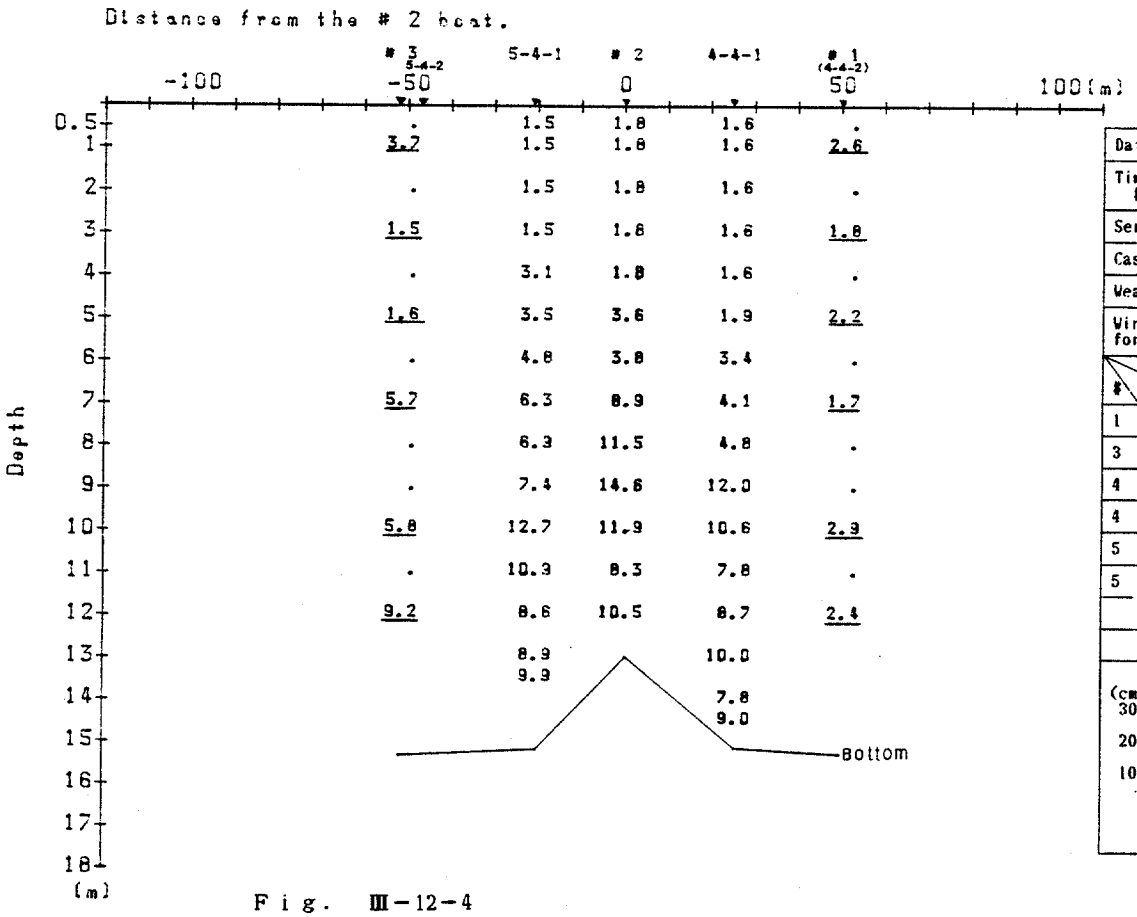


Fig. Ⅲ-12-3



Date	July,23,1984
Time of # 2 boat	11:55
Serial No.	4
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Item / Sta.	Observation time of each boat
1	4	11:55
3	4	11:55
4	4-1	11:55
4	4-2	11:58
5	4-1	11:55
5	4-2	11:57

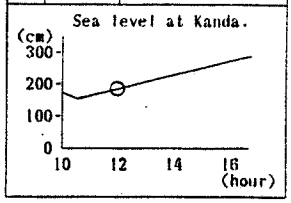
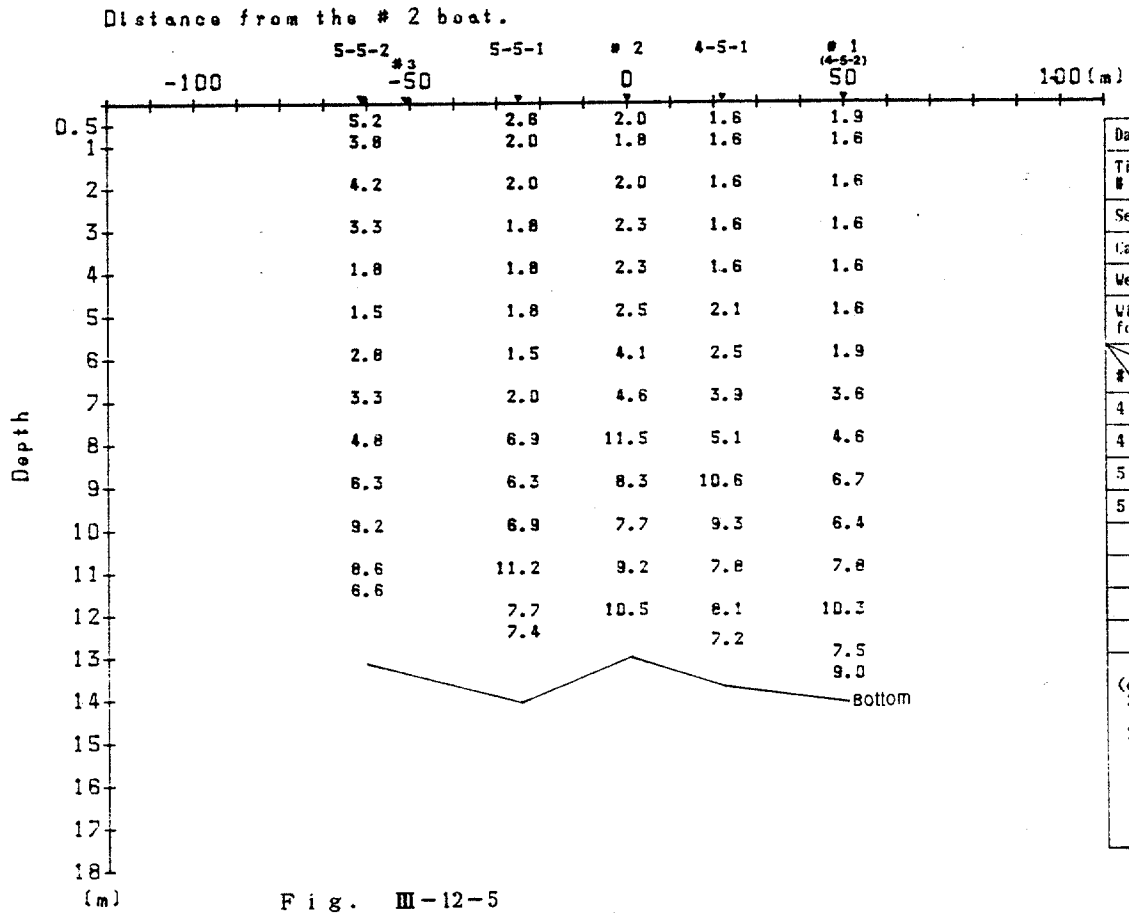


Fig. Ⅲ-12-4



Date	July,23.1984
Time of # 2 boat	12:05
Serial No.	5
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Item / Sta.	Observation time of each boat
4	5-1	12:05
4	5-2	12:10
5	5-1	12:06
5	5-2	12:09

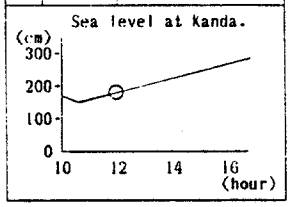
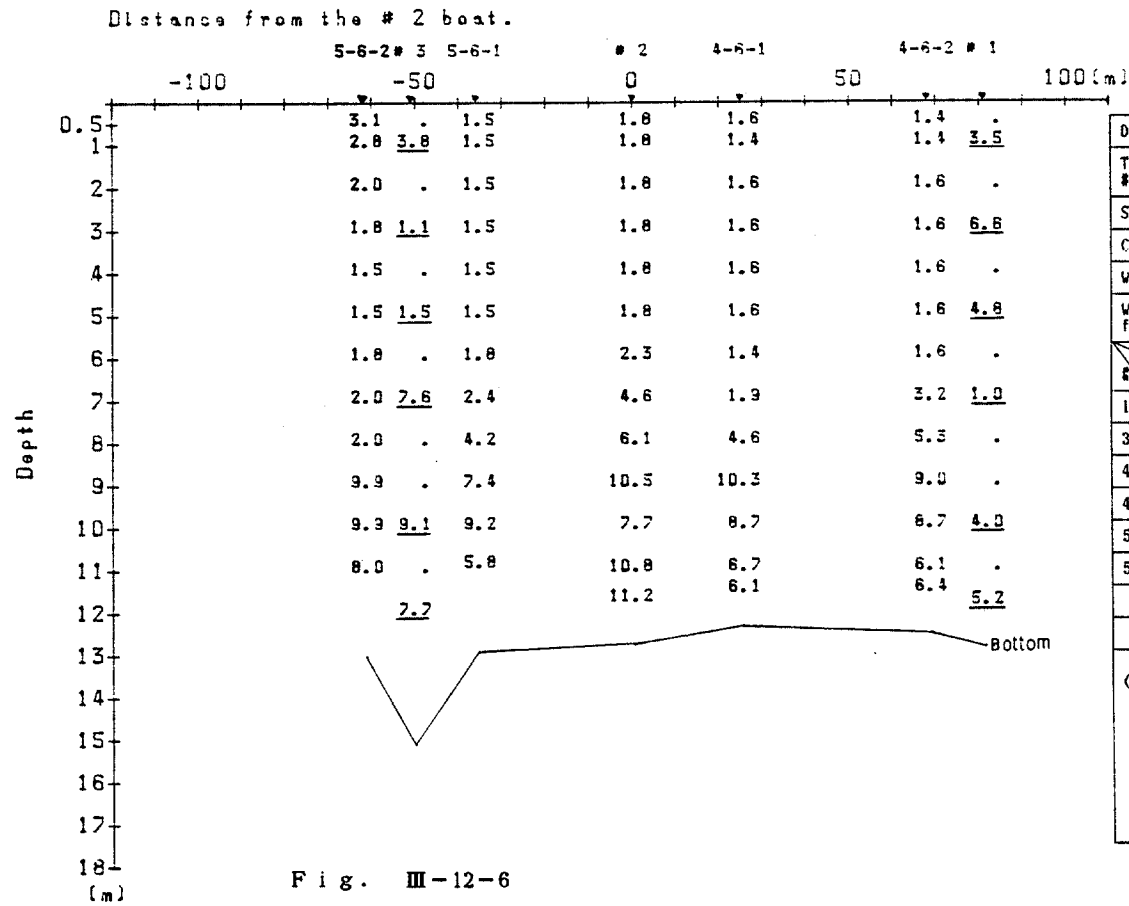


Fig. III-12-5



Date	July,23.1984
Time of # 2 boat	12:20
Serial No.	6
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Item / Sta.	Observation time of each boat
1	6	12:20
3	6	12:20
4	6-1	12:20
4	6-2	12:24
5	6-1	12:20
5	6-2	12:24

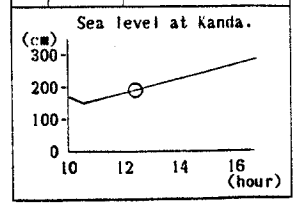
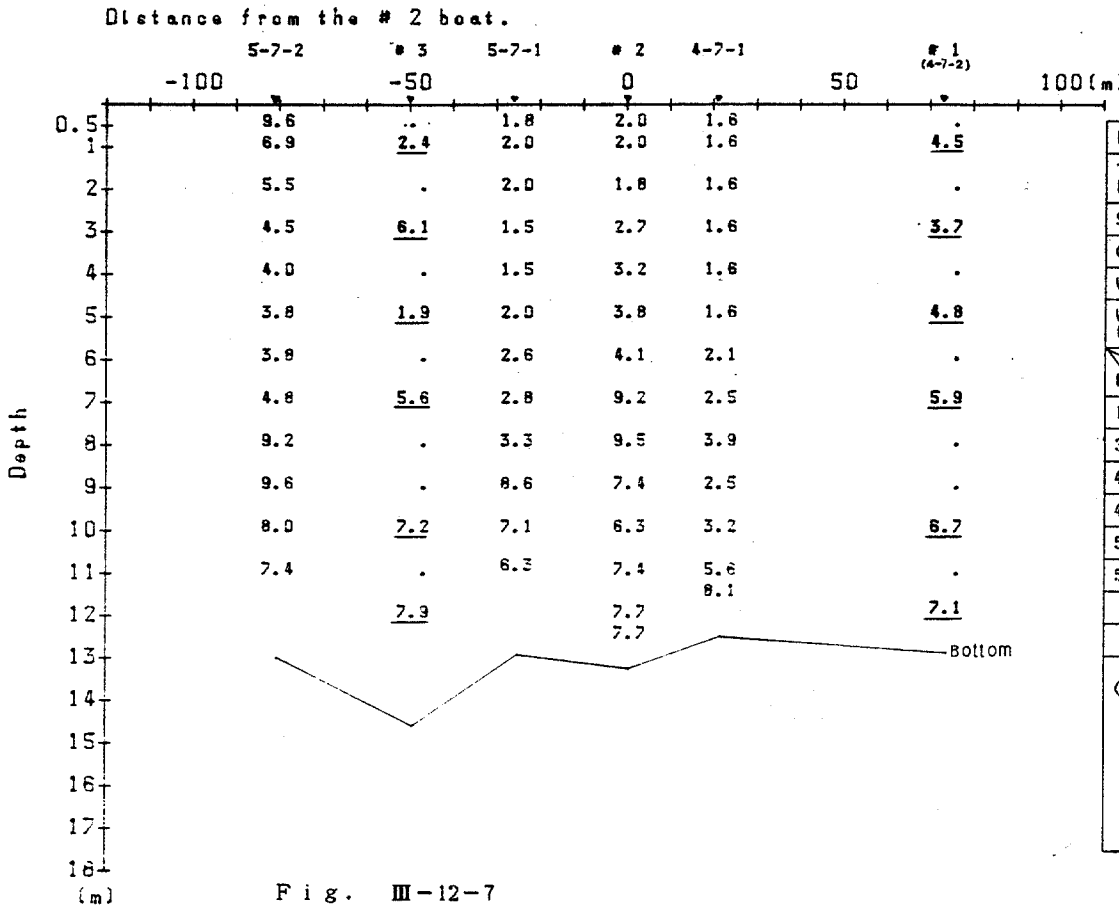


Fig. III-12-6



Date	July.23.1984
Time of # 2 boat	12:40
Serial No.	7
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--4

#	Sta.	Observation time of each boat
1	7	12:40
3	7	12:40
4	7-1	12:40
4	7-2	12:45
5	7-1	12:43
5	7-2	12:45

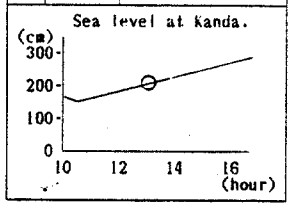
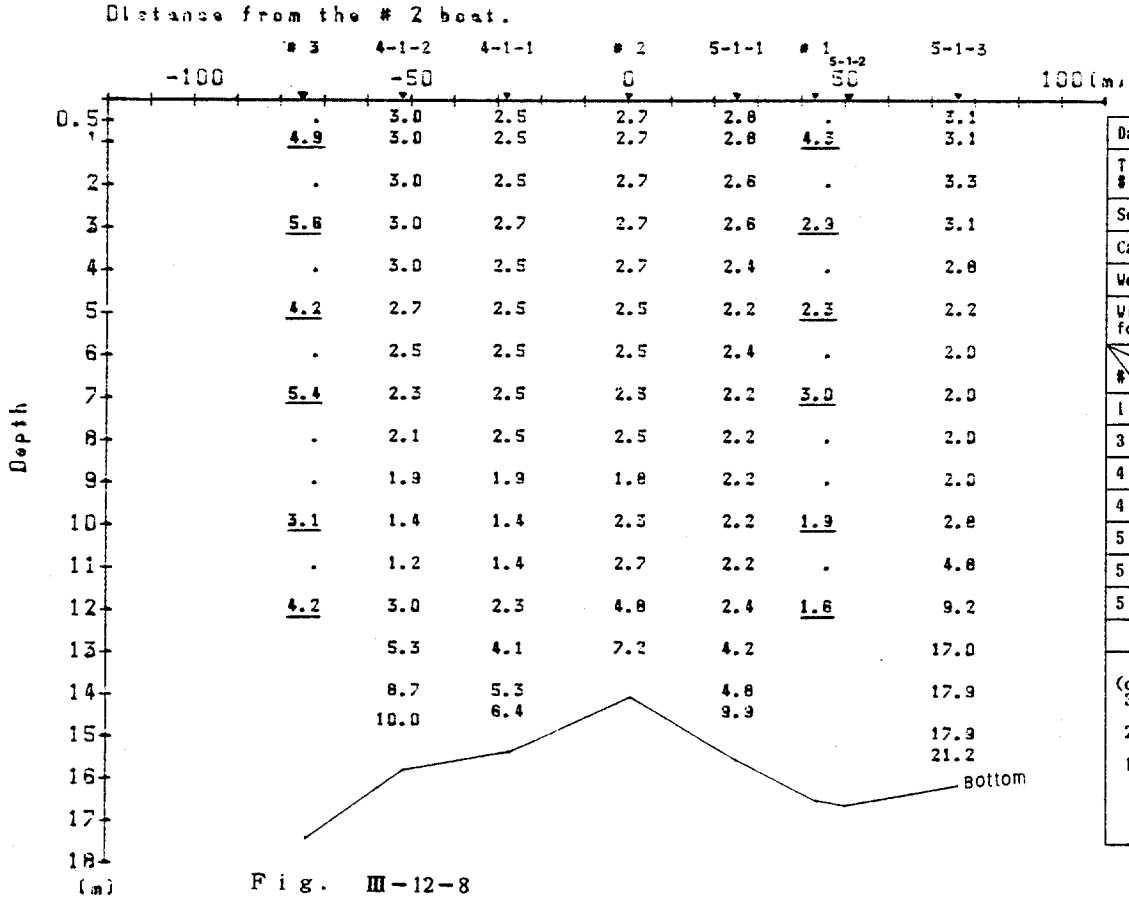


Fig. Ⅲ-12-7



Date	July.23.1984
Time of # 2 boat	14:20
Serial No.	1
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	1	14:20
3	1	14:20
4	1-1	14:22
4	1-2	14:25
5	1-1	14:20
5	1-2	14:25
5	1-3	14:26

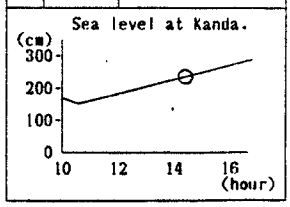
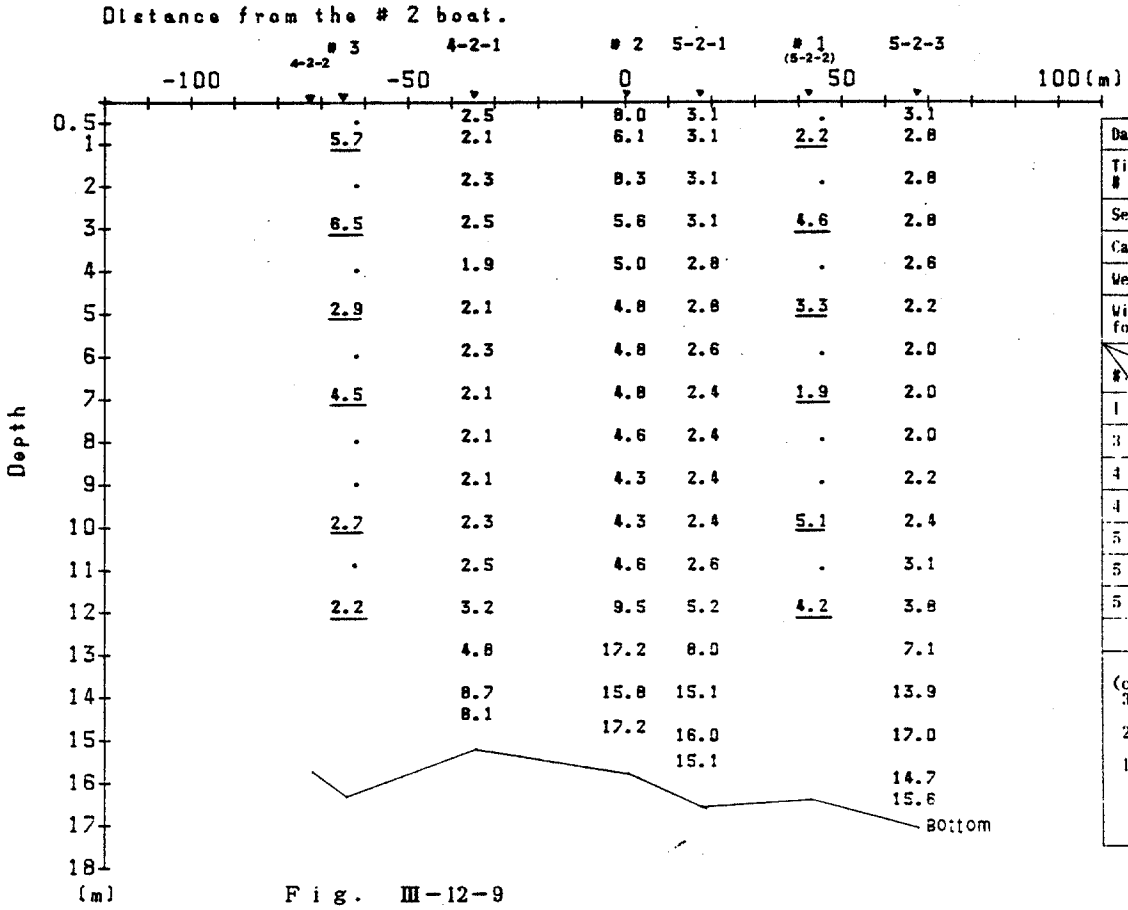


Fig. Ⅲ-12-8



Date	July.23.1984
Time of # 2 boat	14:30
Serial No.	2
Case	I .No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	2	14:30
3	2	14:30
4	2-1	14:30
4	2-2	14:35
5	2-1	14:30
5	2-2	14:33
5	2-3	14:35

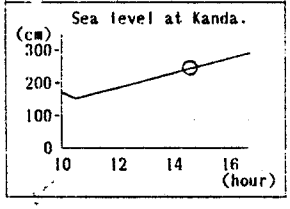
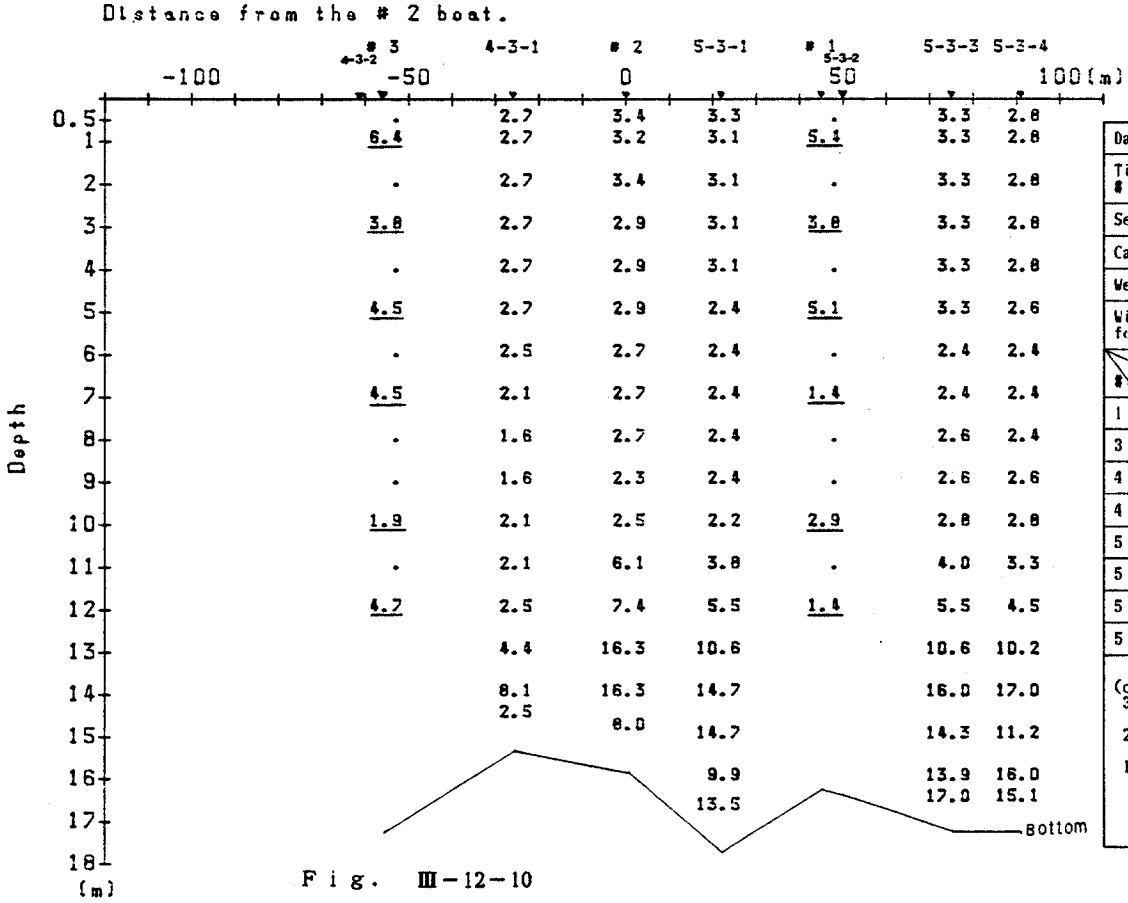


Fig. III-12-9



Date	July.23.1984
Time of # 2 boat	14:40
Serial No.	3
Case	I .No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	3	14:40
3	3	14:40
4	3-1	14:40
4	3-2	14:45
5	3-1	14:40
5	3-2	14:43
5	3-3	14:45
5	3-4	14:47

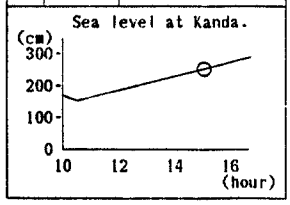
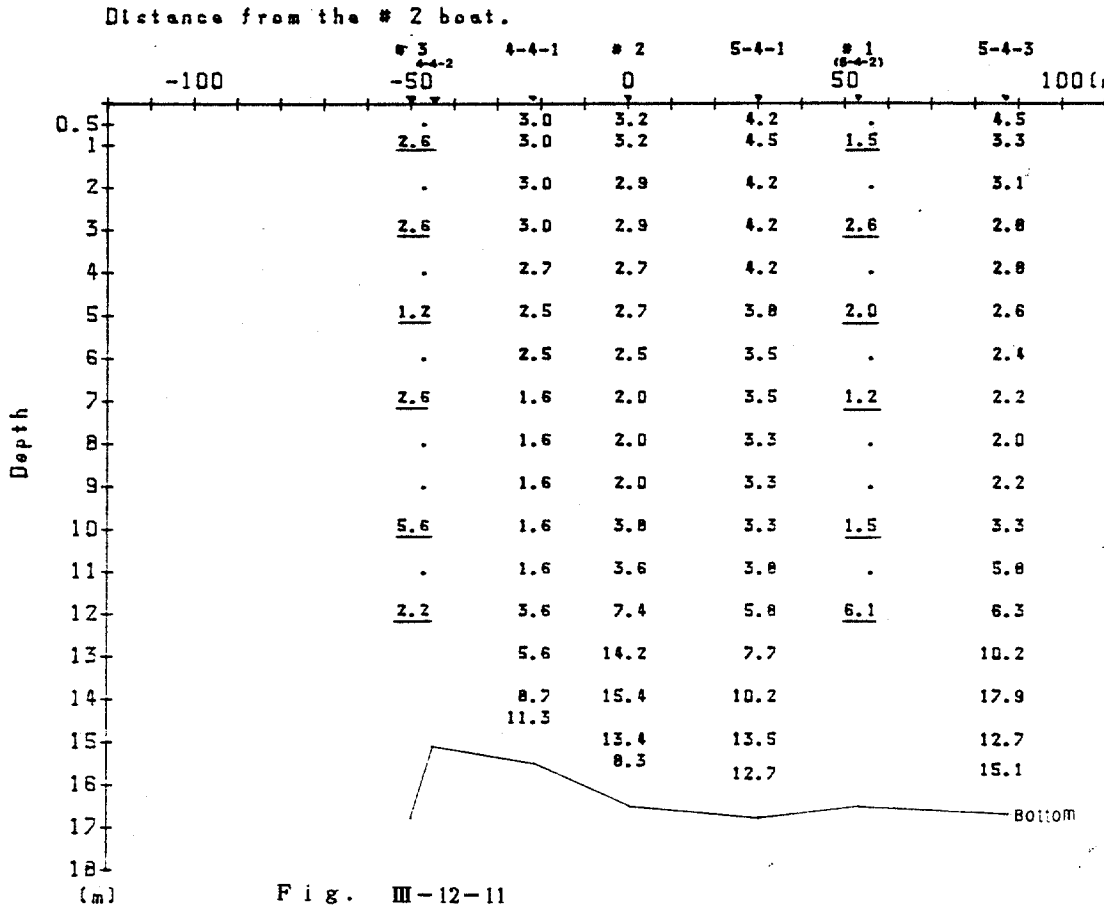


Fig. III-12-10



Date	July.23.1984
Time of # 2 boat	14:50
Serial No.	4
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	4	14:50
3	4	14:50
4	4-1	14:50
4	4-2	14:55
5	4-1	14:51
5	4-2	14:55
5	4-3	14:57

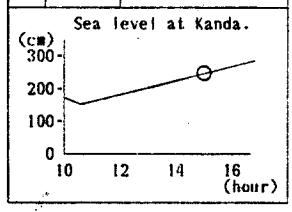
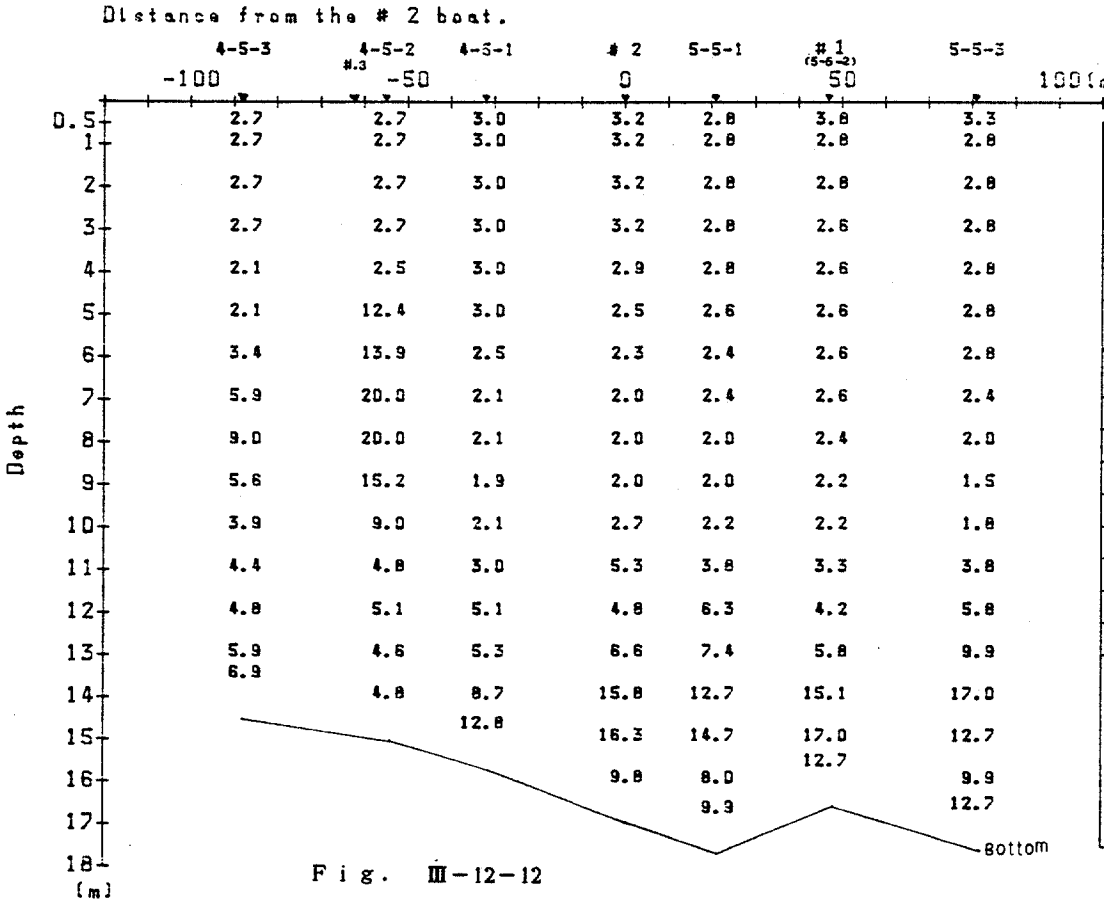


Fig. III-12-11



Date	July.23.1984
Time of # 2 boat	15:00
Serial No.	5
Case	I ,No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
4	5-1	15:00
4	5-2	15:03
4	5-3	15:07
5	5-1	15:01
5	5-2	15:04
5	5-3	15:08

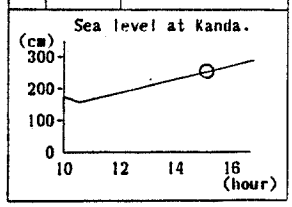
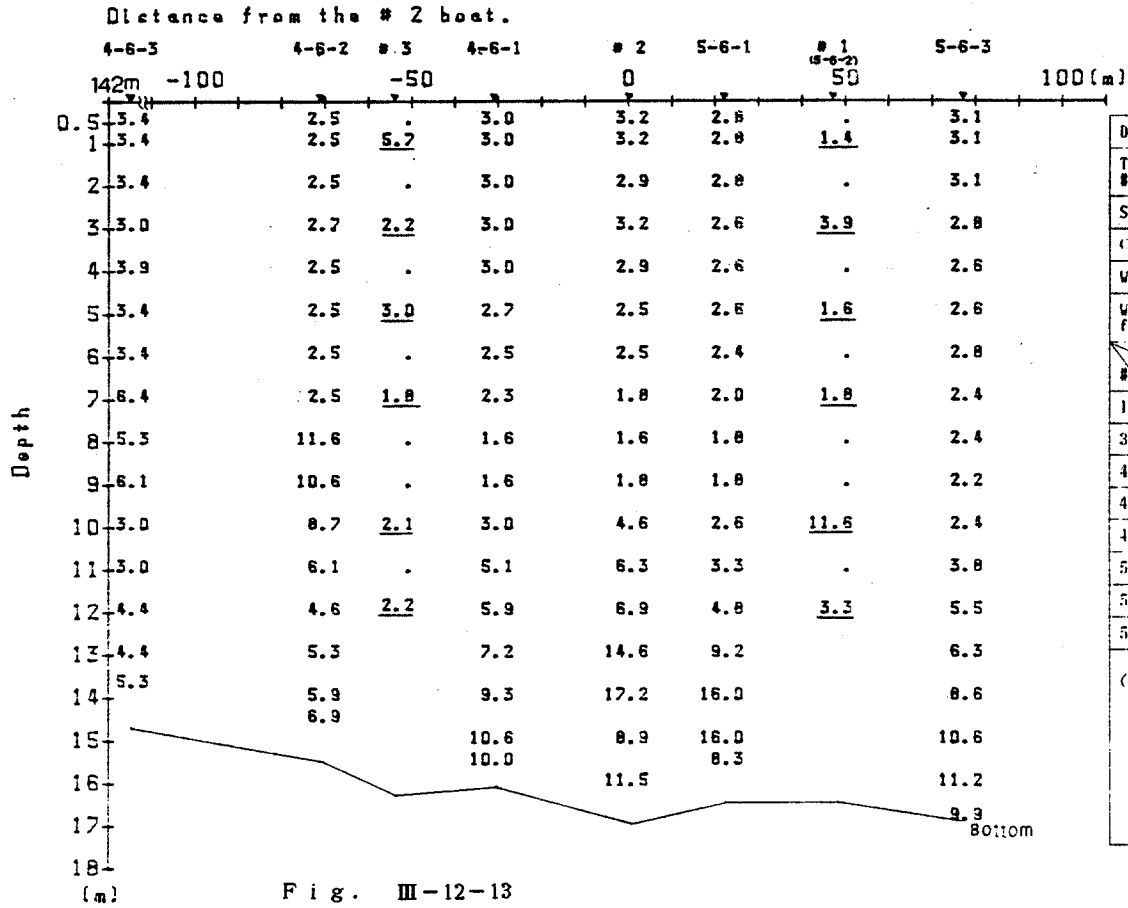


Fig. III-12-12



Date	July.23.1984
Time of # 2 boat	15:10
Serial No.	6
Case	I .No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Item / Sta.	Observation time of each boat
1	6	15:10
3	6	15:10
4	6-1	14:10
4	6-2	15:13
4	6-3	15:17
5	6-1	15:11
5	6-2	15:13
5	6-3	15:20

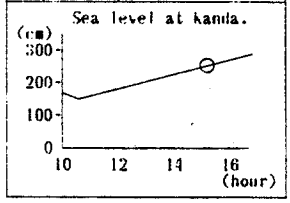
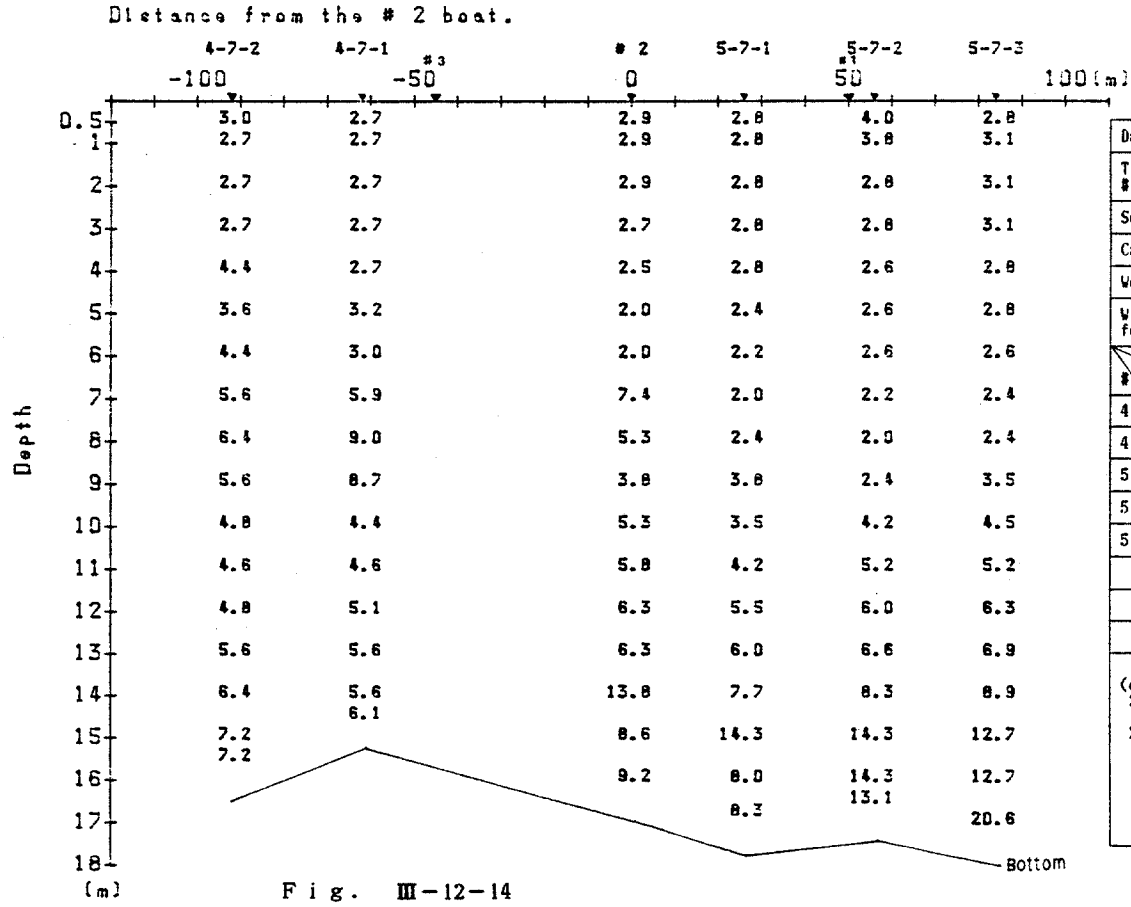


Fig. III-12-13



Date	July.23.1984
Time of # 2 boat	15:30
Serial No.	7
Case	I .No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Item / Sta.	Observation time of each boat
4	7-1	15:30
4	7-2	15:33
5	7-1	15:31
5	7-2	15:34
5	7-3	15:37

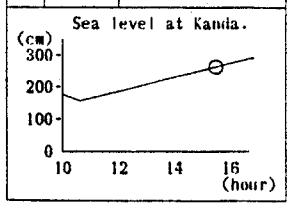
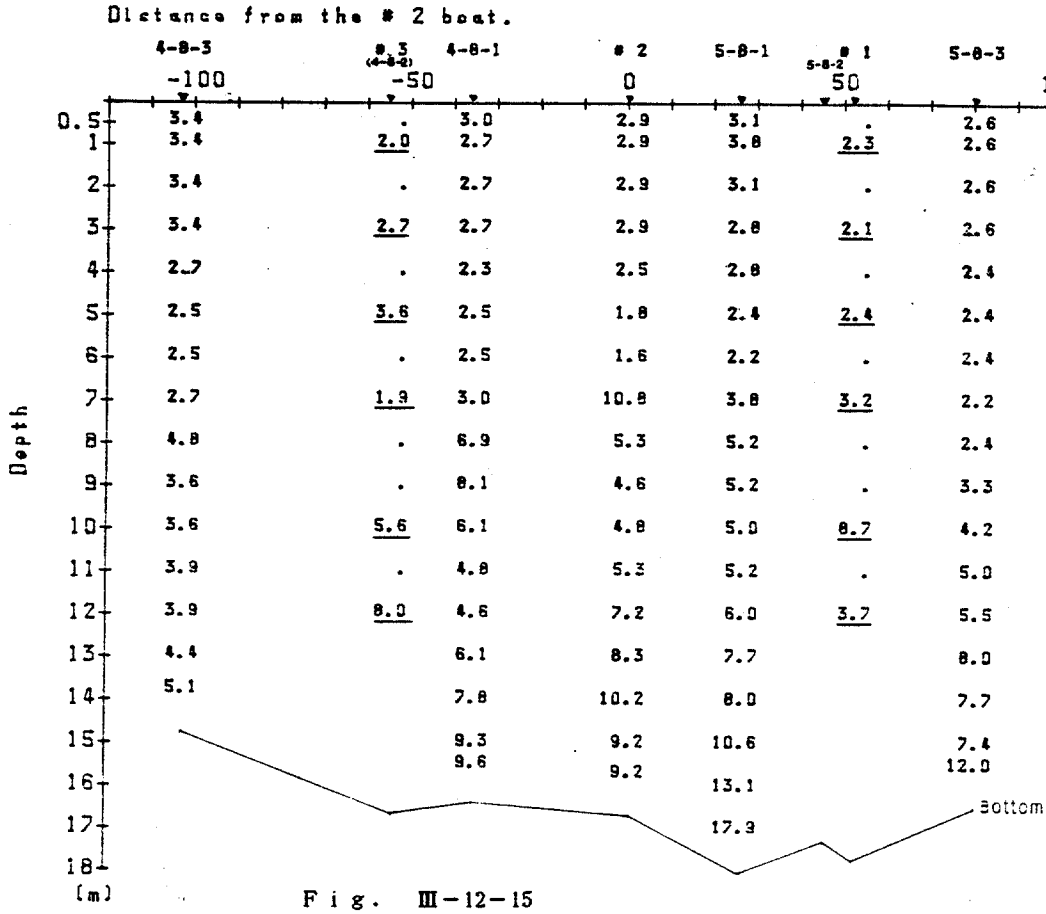


Fig. III-12-14



Date	July.23,1984
Time of # 2 boat	15:50
Serial No.	8
Case	I .No overflow
Weather	Cloudy
Wind force(F)	E--3

#	Item / Sta.	Observation time of each boat
1	8	15:50
3	8	15:50
4	8-1	15:50
4	8-2	15:55
4	8-3	15:58
5	8-1	15:52
5	8-2	15:55
5	8-3	15:57

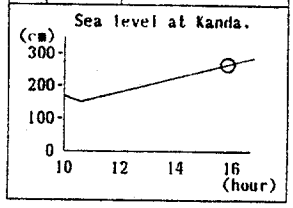
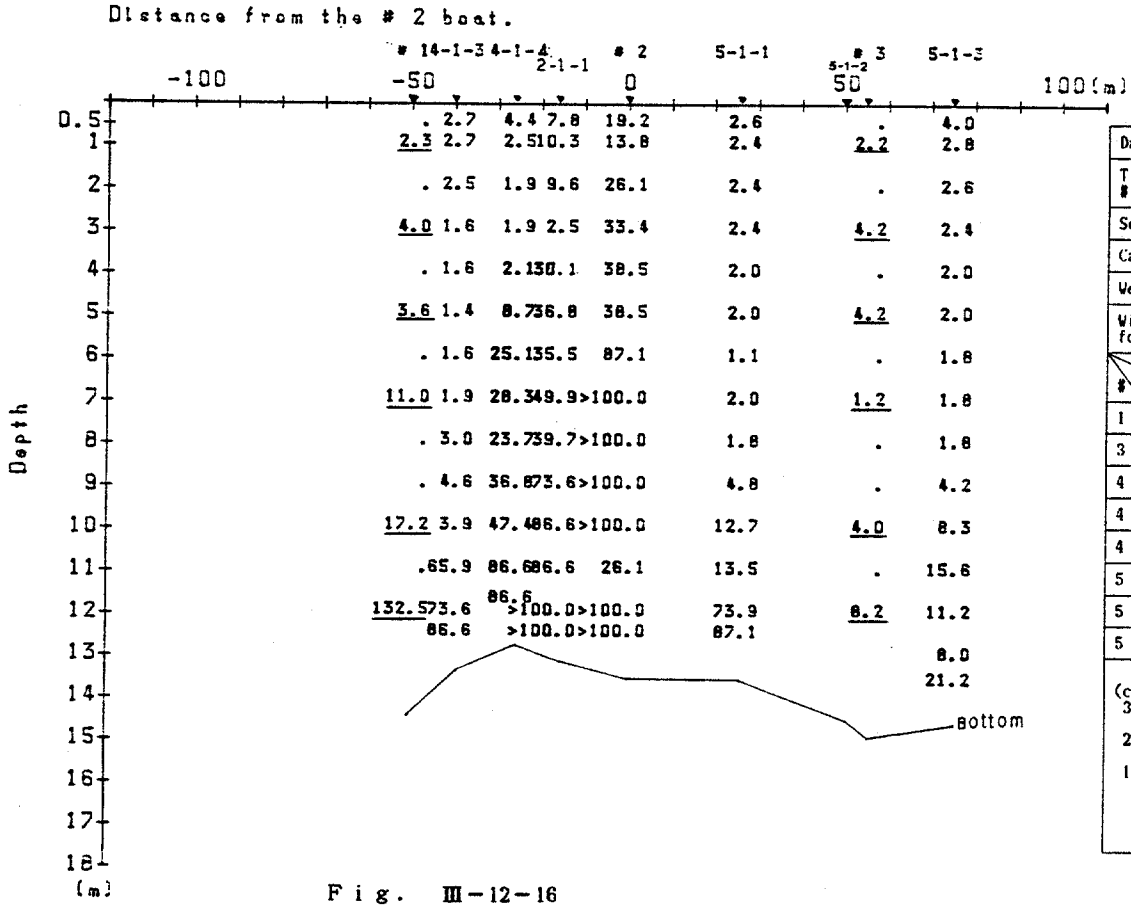


Fig. III-12-15



Date	July.24,1984
Time of # 2 boat	11:00
Serial No.	1
Case	II .with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Item / Sta.	Observation time of each boat
1	1	11:00
3	1	11:00
4	1-1	11:00
4	1-2	11:04
4	1-3	11:08
5	1-1	11:00
5	1-2	11:02
5	1-3	11:05

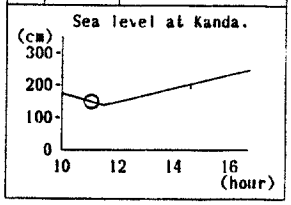
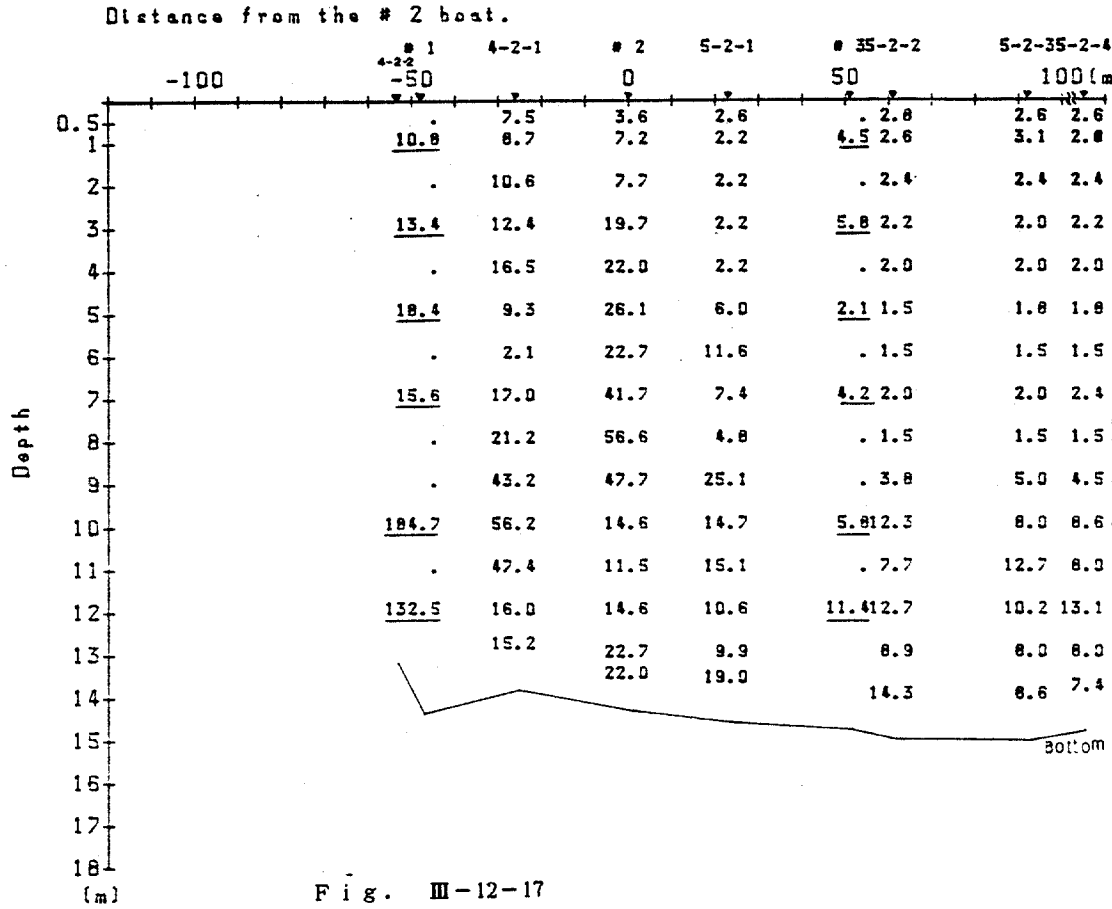


Fig. III-12-16



Date	July.24,1984
Time of # 2 boat	11:09
Serial No.	2
Case	II, with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Sta.	Observation time of each boat
1	2	11:10
3	2	11:09
4	2-1	11:10
4	2-2	11:15
5	2-1	11:11
5	2-2	11:13
5	2-3	11:16
5	2-4	11:18

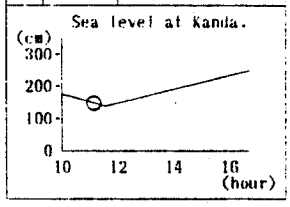
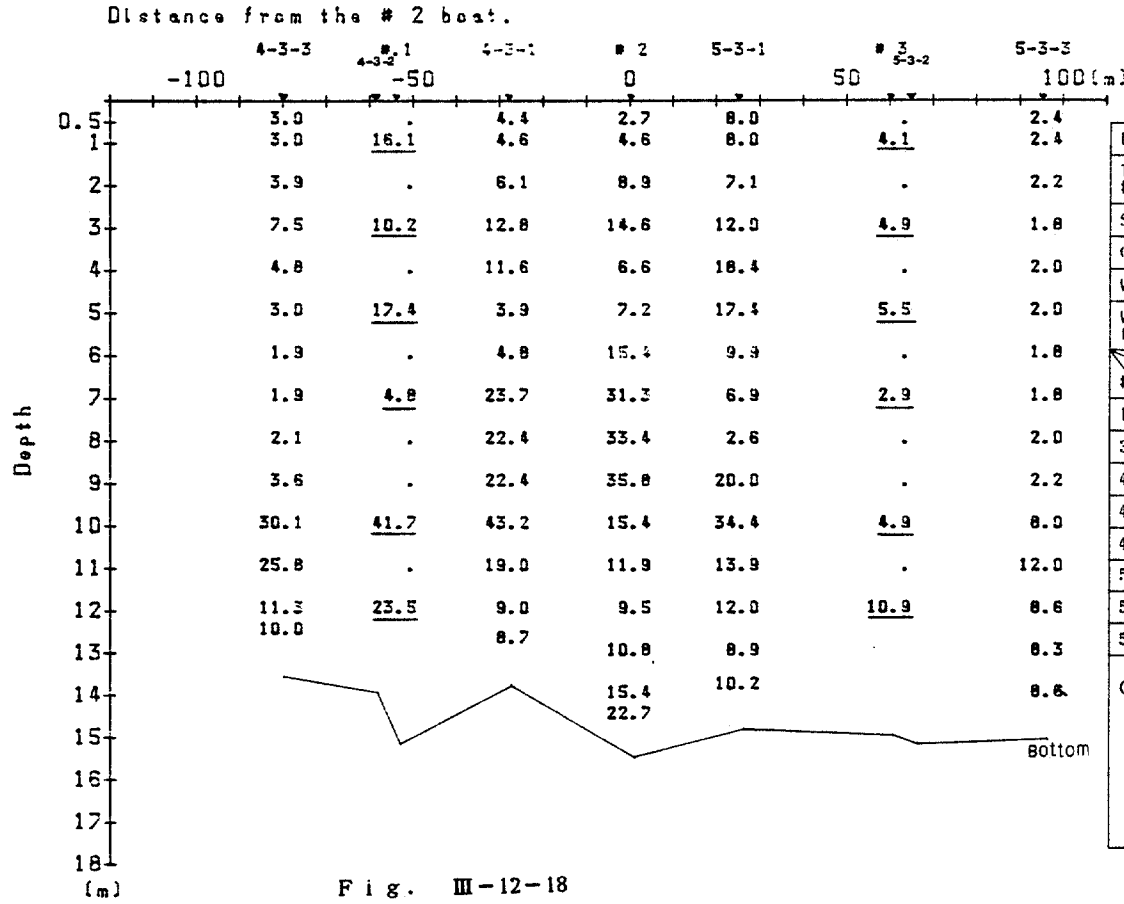


Fig. III-12-17



Date	July.24,1984
Time of # 2 boat	11:20
Serial No.	3
Case	II, with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Sta.	Observation time of each boat
1	3	11:20
3	3	11:20
4	3-1	11:20
4	3-2	11:24
4	3-3	11:29
5	3-1	11:21
5	3-2	11:24
5	3-3	11:26

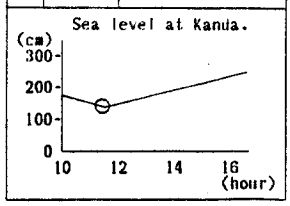
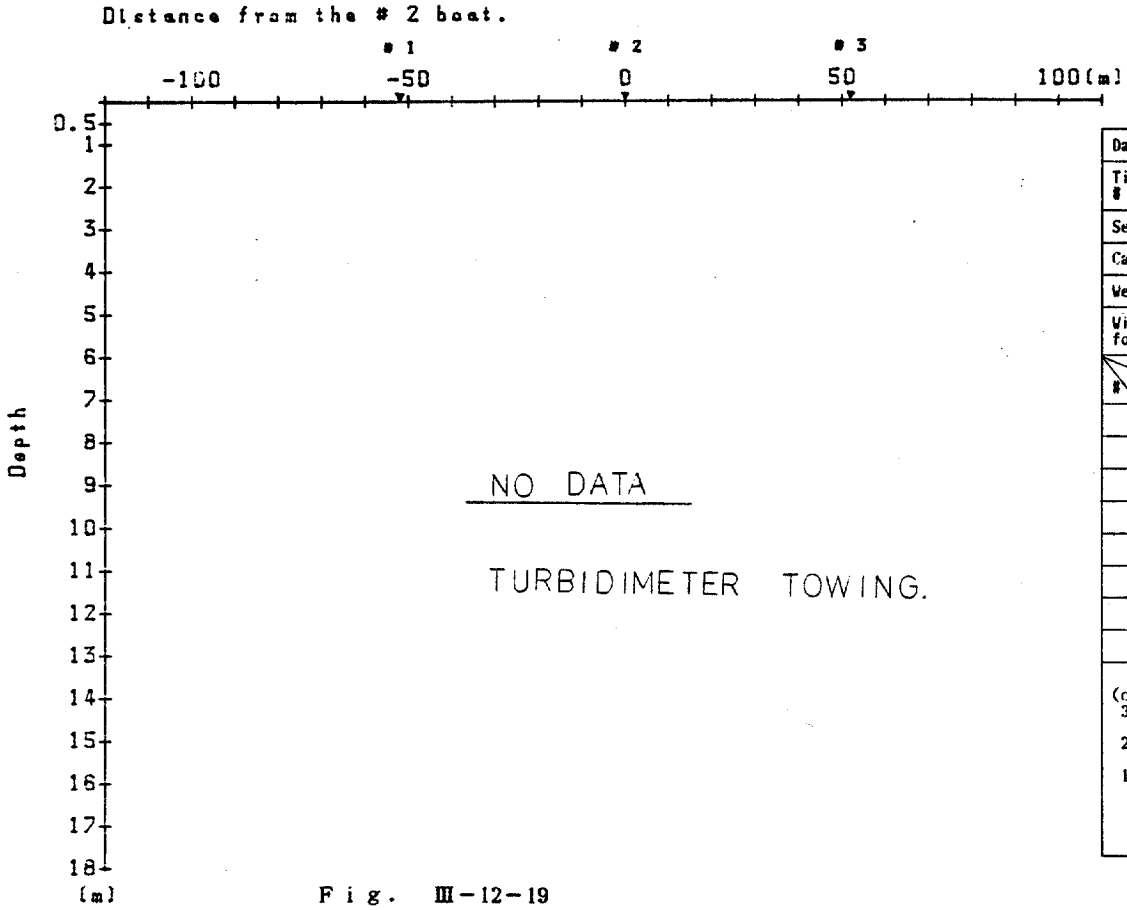


Fig. III-12-18



Date	July.24.1984
Time of # 2 boat	11:30
Serial No.	4
Case	II, with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Sta.	Observation time of each boat

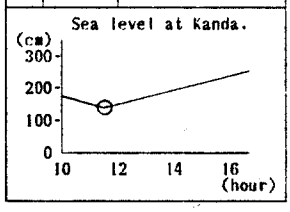
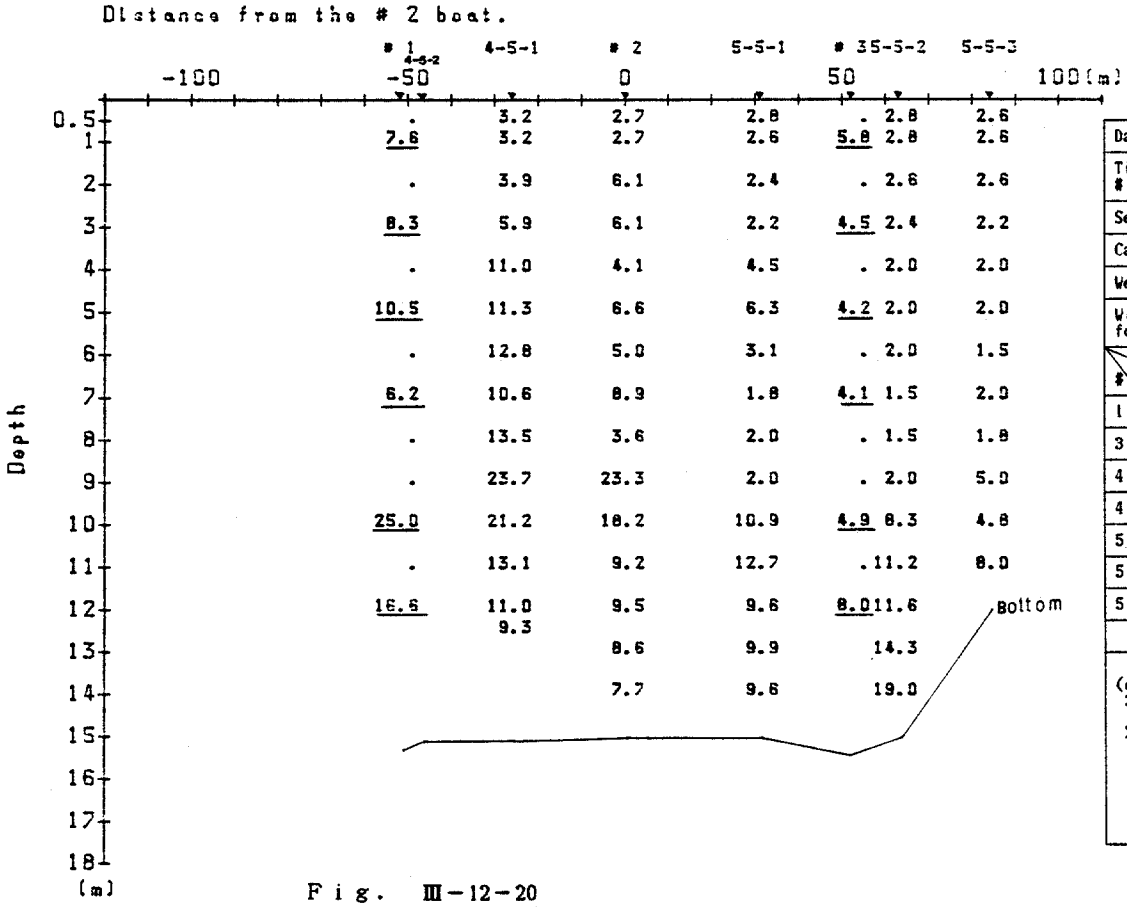


Fig. III-12-19



Date	July.24.1984
Time of # 2 boat	11:40
Serial No.	5
Case	II, with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Sta.	Observation time of each boat
1	5	11:40
3	5	11:40
4	5-1	11:40
4	5-2	11:45
5	5-1	11:41
5	5-2	11:45
5	5-3	11:47

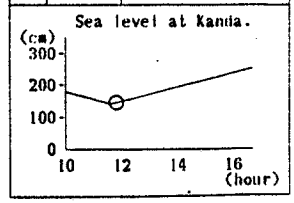
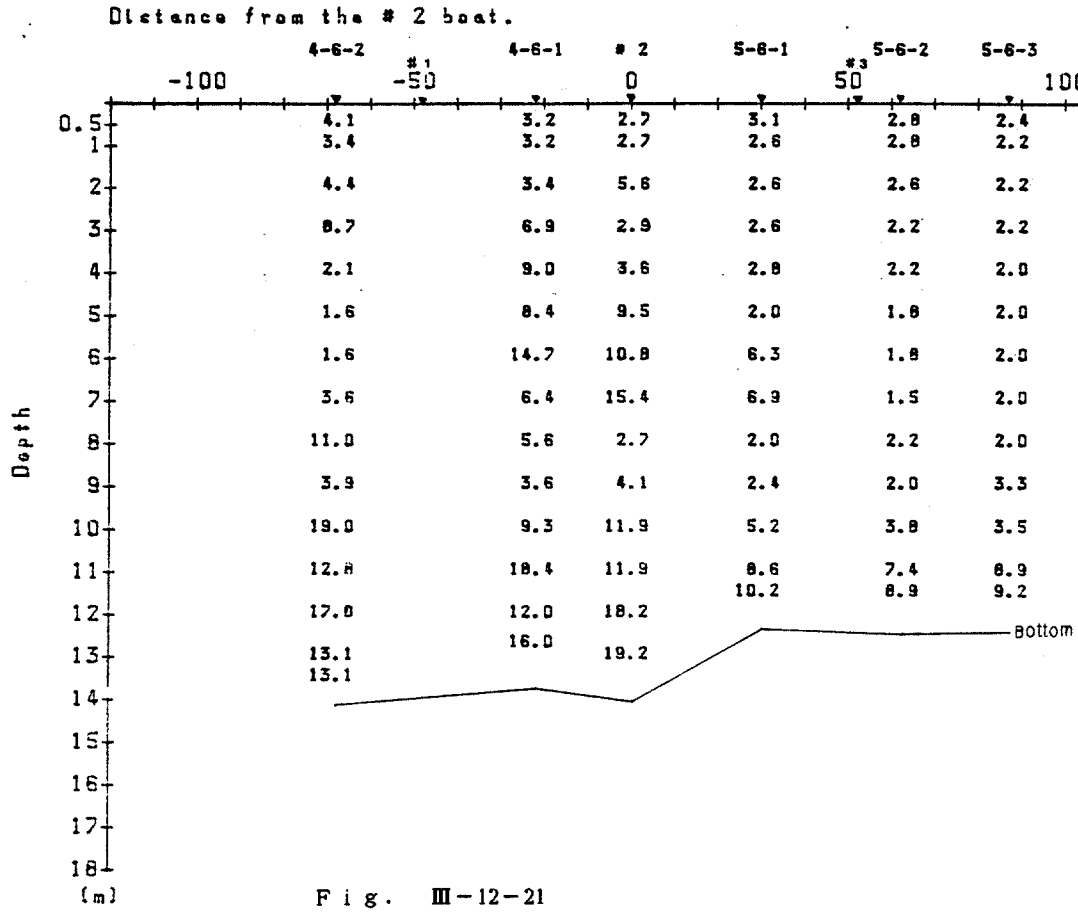


Fig. III-12-20



Date	July.24.1984
Time of # 2 boat	11:50
Serial No.	6
Case	II. with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Item / Sta.	Observation time of each boat
1	6-1	11:50
4	6-2	11:55
5	6-1	11:52
5	6-2	11:54
5	6-3	11:56

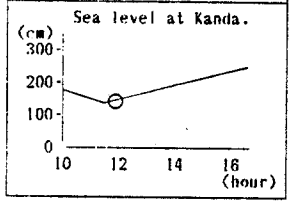
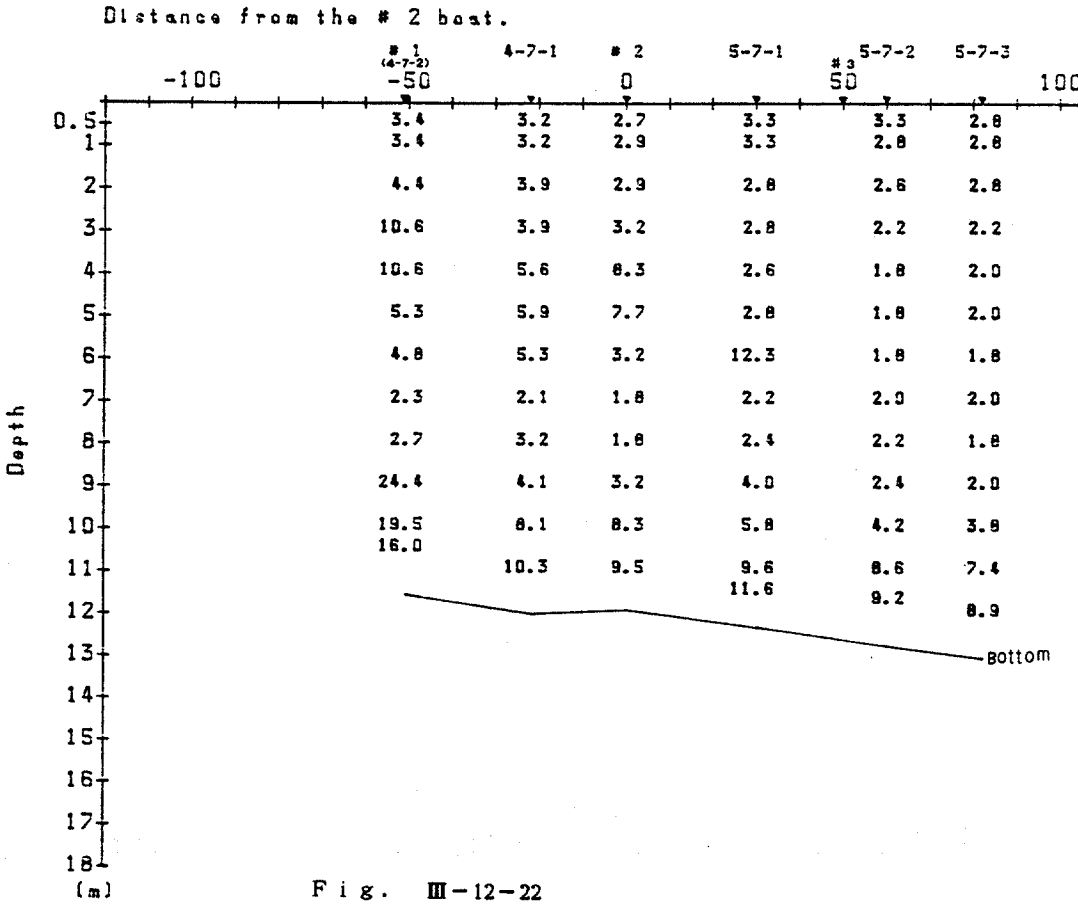


Fig. III-12-21



Date	July.24.1984
Time of # 2 boat	12:00
Serial No.	7
Case	II. with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Item / Sta.	Observation time of each boat
4	7-1	12:00
4	7-2	12:03
5	7-1	12:01
5	7-2	12:04
5	7-3	12:06

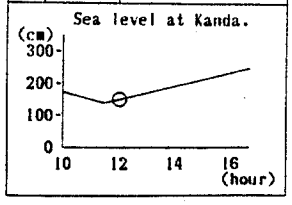
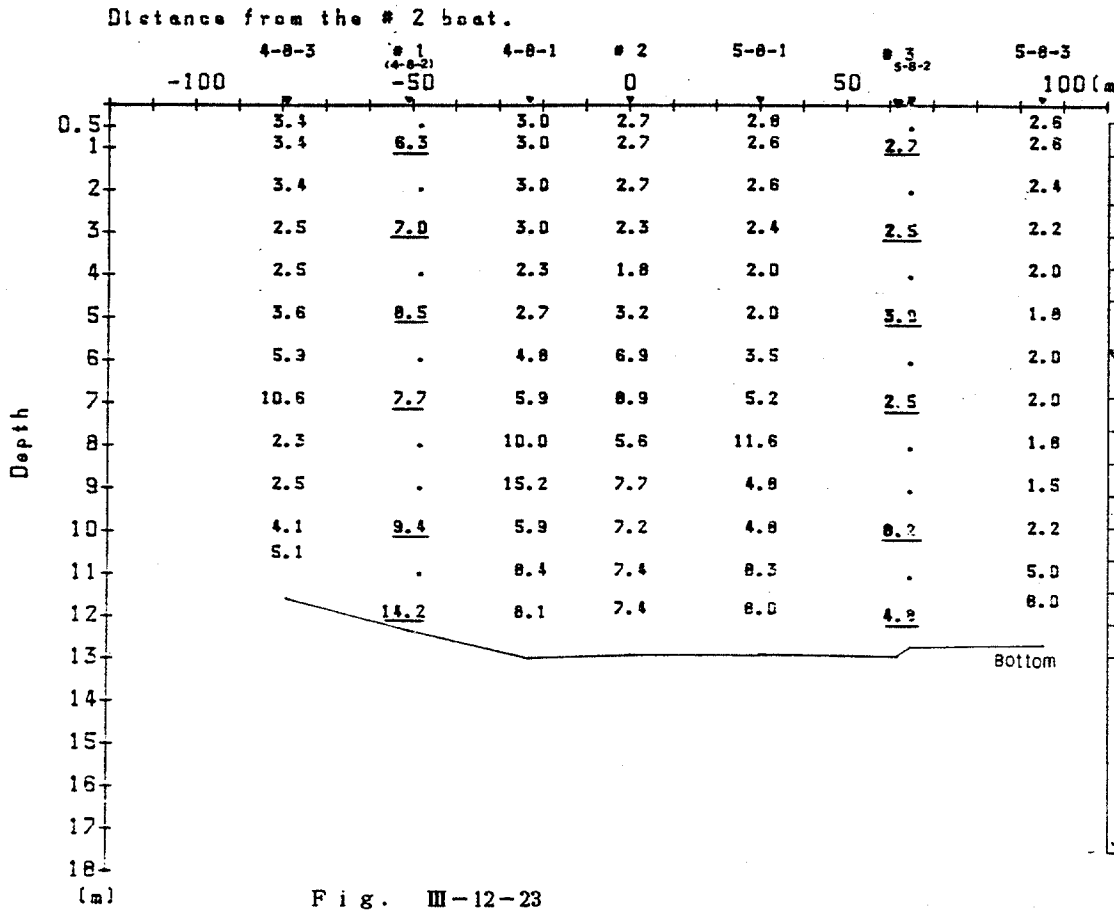


Fig. III-12-22



Date	July.24.1984
Time of # 2 boat	12:20
Serial No.	8
Case	II. with ATOS
Weather	Cloudy
Wind force(F)	SE--2

#	Sta.	Observation time of each boat
1	8	12:20
3	8	12:20
4	8-1	12:20
4	8-2	12:24
4	8-3	12:28
5	8-1	12:21
5	8-2	12:25
5	8-3	12:27

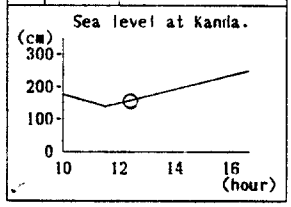
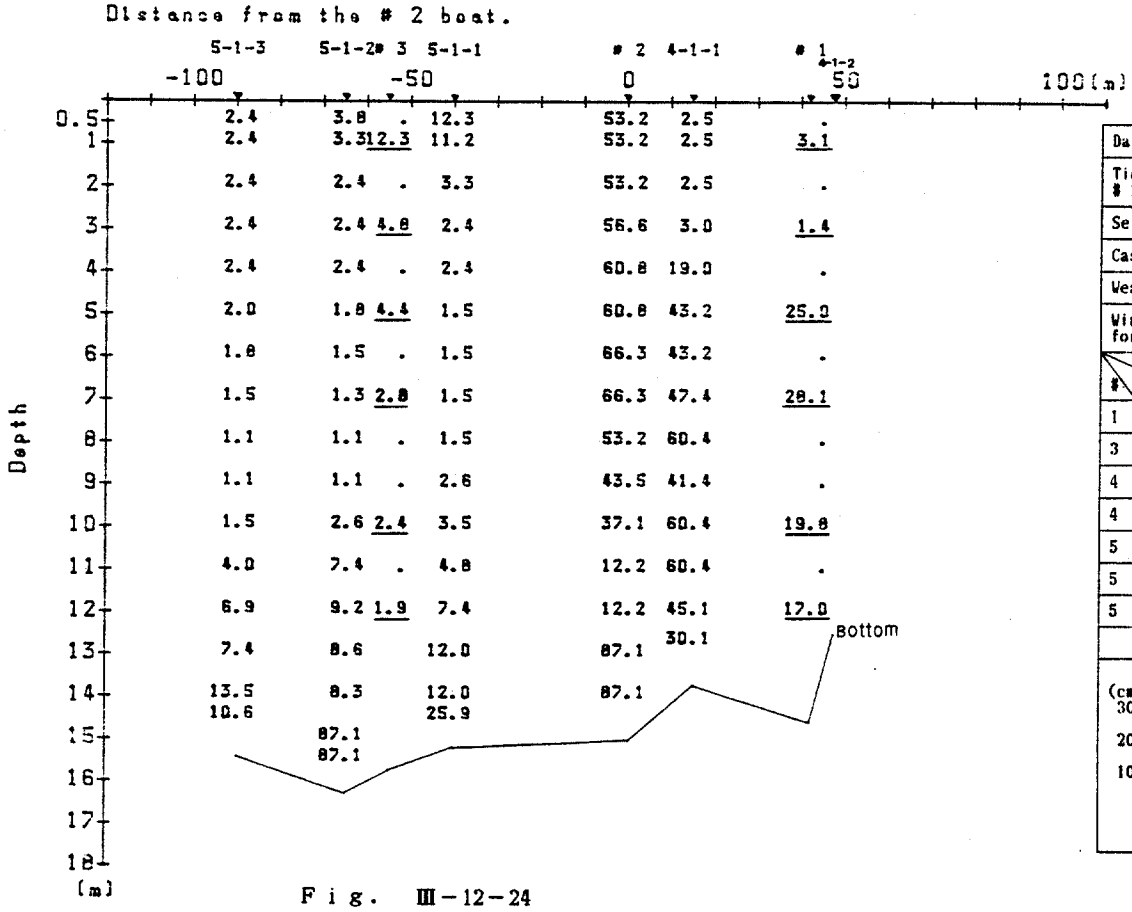


Fig. III-12-23



Date	July.24.1984
Time of # 2 boat	14:45
Serial No.	1
Case	III.without ATOS
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	1	14:45
3	1	14:45
4	1-1	14:45
4	1-2	14:50
5	1-1	14:45
5	1-2	14:49
5	1-3	14:52

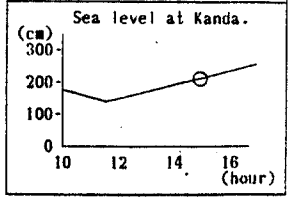
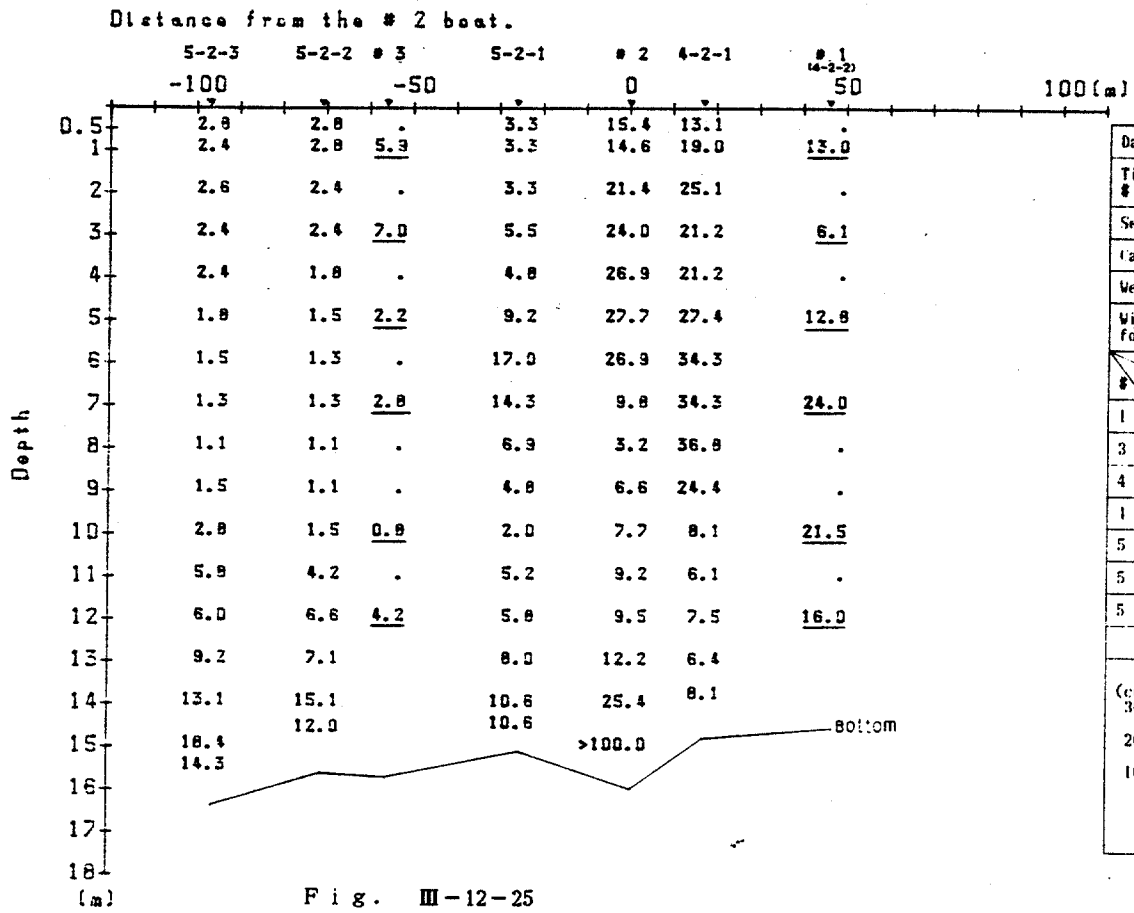


Fig. III-12-24



Date	July,24,1984
Time of # 2 boat	14:55
Serial No.	2
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	E--3

#	Sta. \ Item	Observation time of each boat
1	2	14:55
3	2	14:55
4	2-1	14:55
1	2-2	15:00
5	2-1	14:56
5	2-2	14:59
5	2-3	15:02

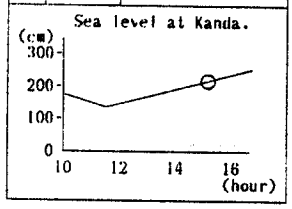
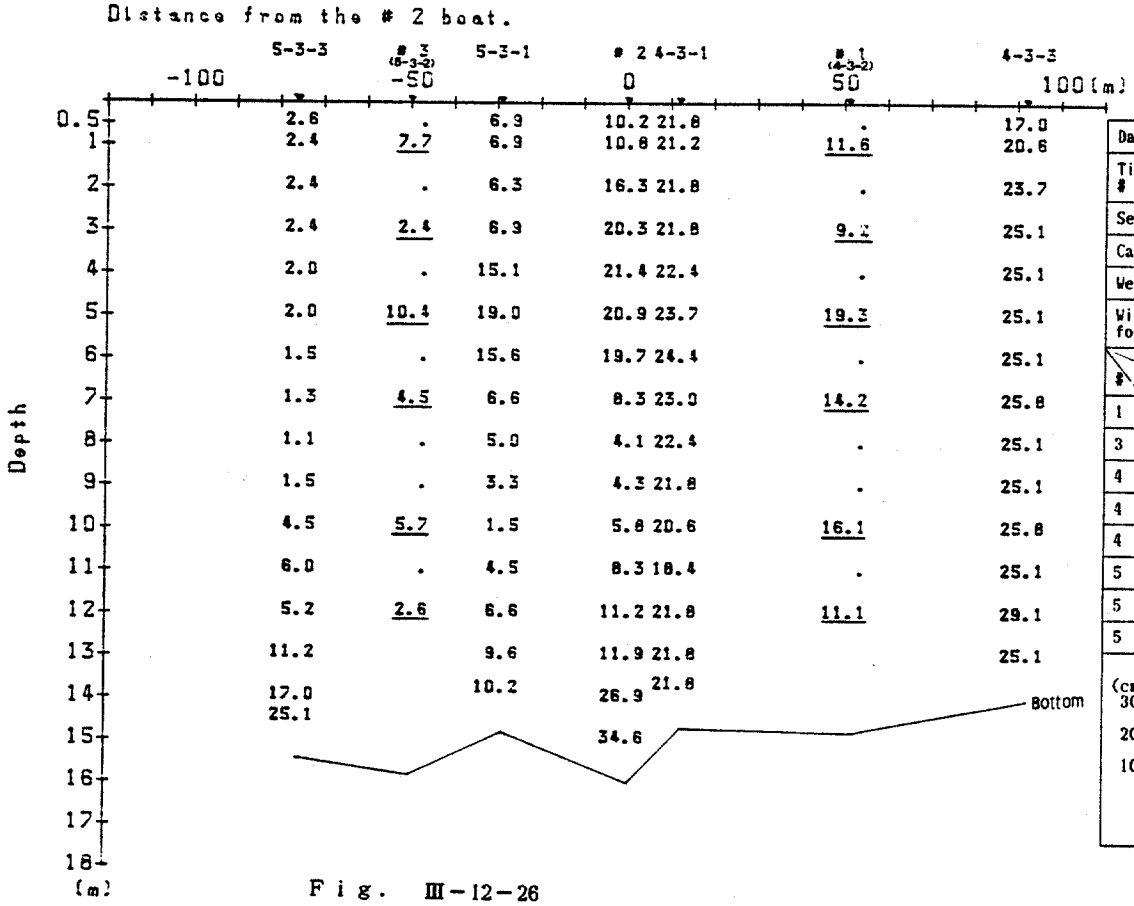


Fig. Ⅲ-12-25



Date	July,24,1984
Time of # 2 boat	15:05
Serial No.	3
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	E--3

#	Sta. \ Item	Observation time of each boat
1	3	15:05
3	3	15:05
4	3-1	15:05
4	3-2	15:10
4	3-3	15:14
5	3-1	15:07
5	3-2	15:09
5	3-3	15:12

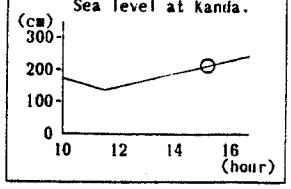
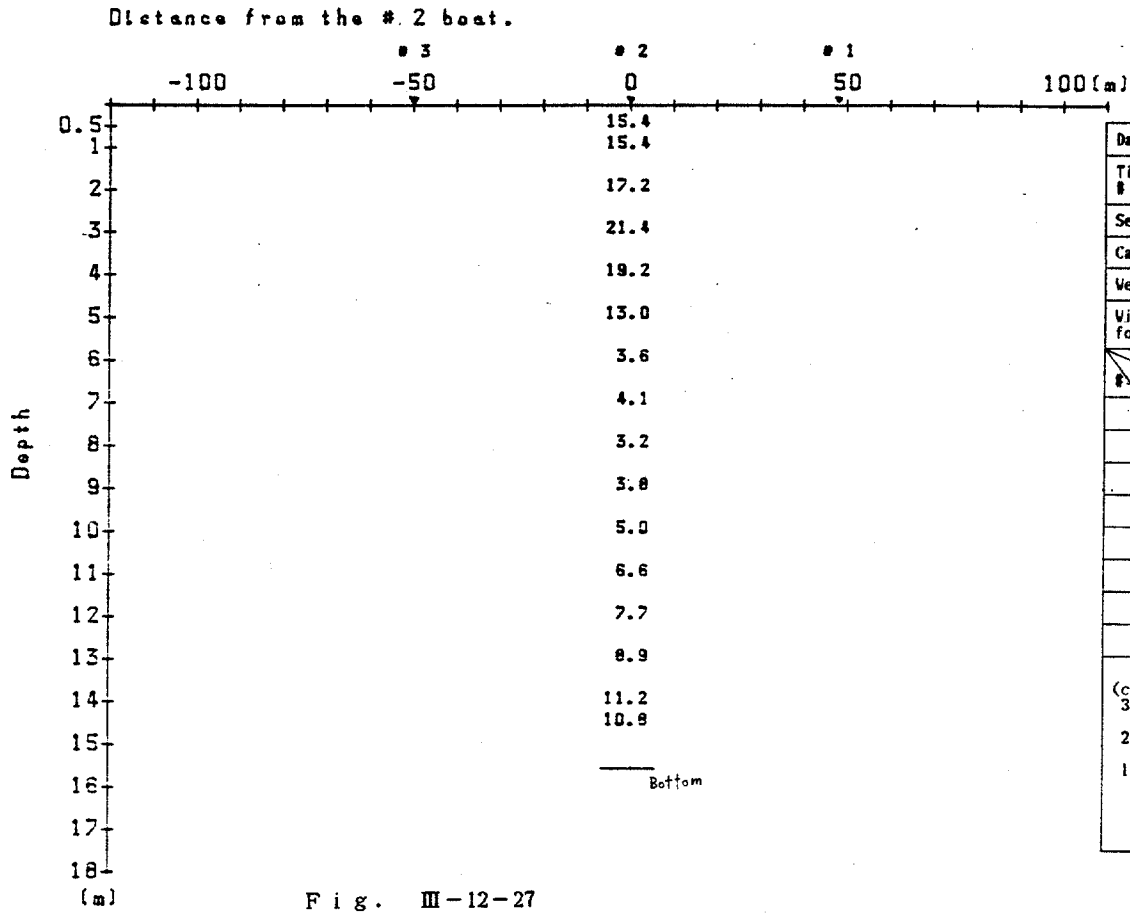


Fig. Ⅲ-12-26



Date	July,24,1984
Time of # 2 boat	15:17
Serial No.	4
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat

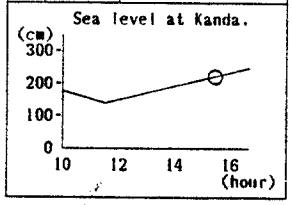
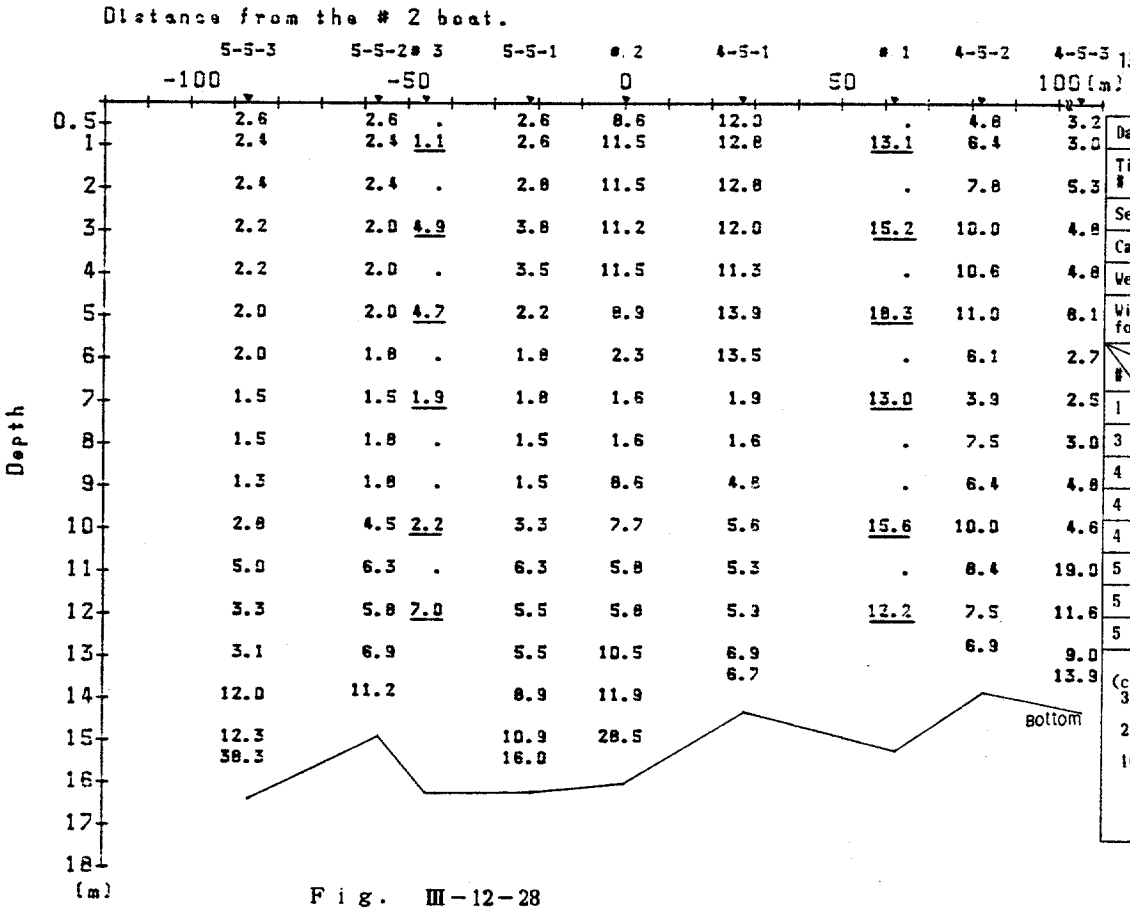


Fig. Ⅲ-12-27



Date	July,24,1984
Time of # 2 boat	15:25
Serial No.	5
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	E--3

#	Sta.	Observation time of each boat
1	5	15:25
3	5	15:25
4	5-1	15:25
4	5-2	15:33
4	5-3	15:40
5	5-1	15:27
5	5-2	15:30
5	5-3	15:32

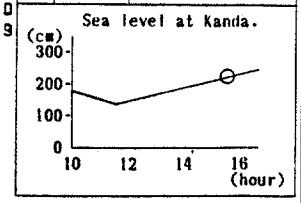


Fig. Ⅲ-12-28

76

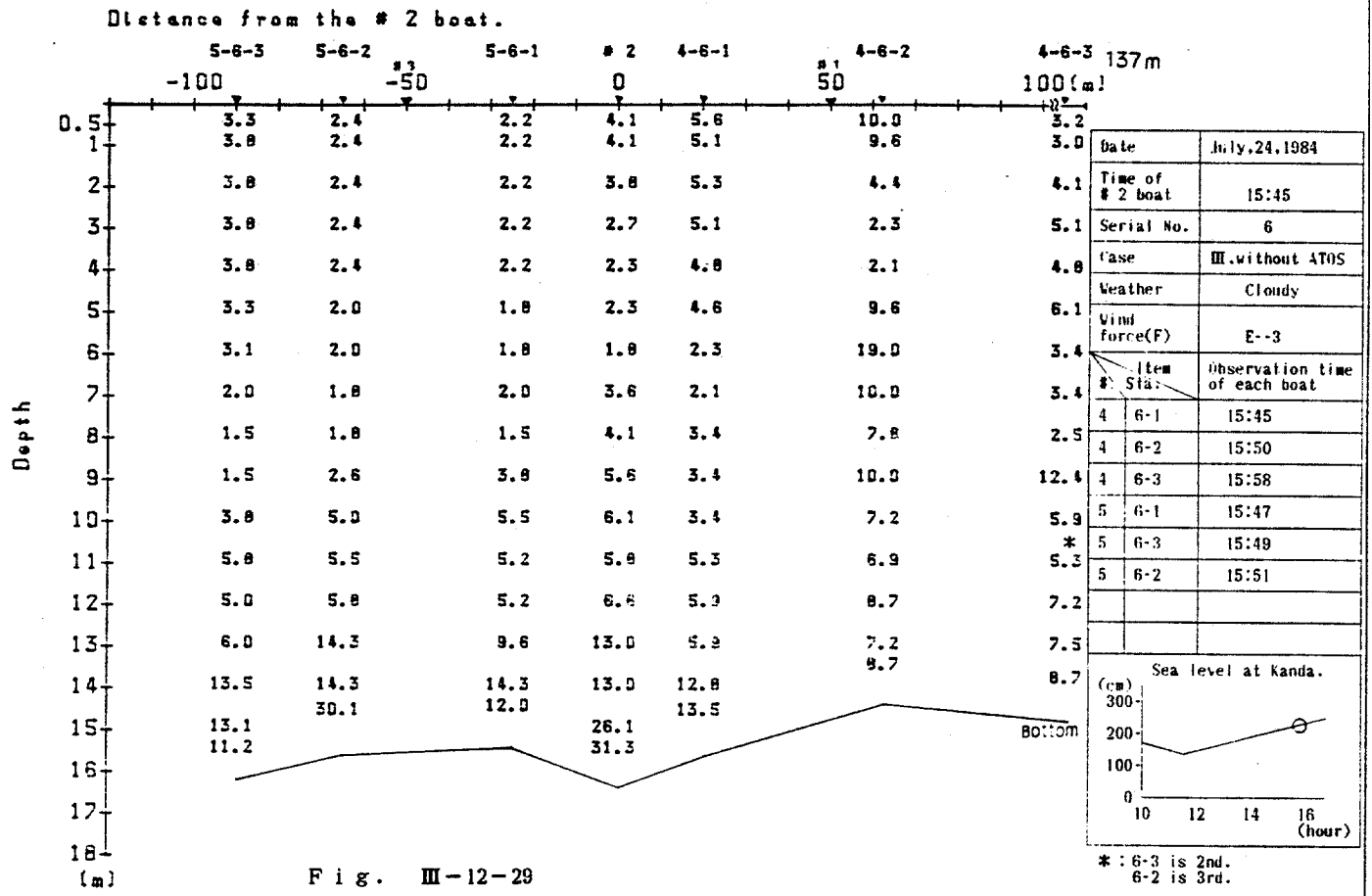


Fig. Ⅲ-12-29

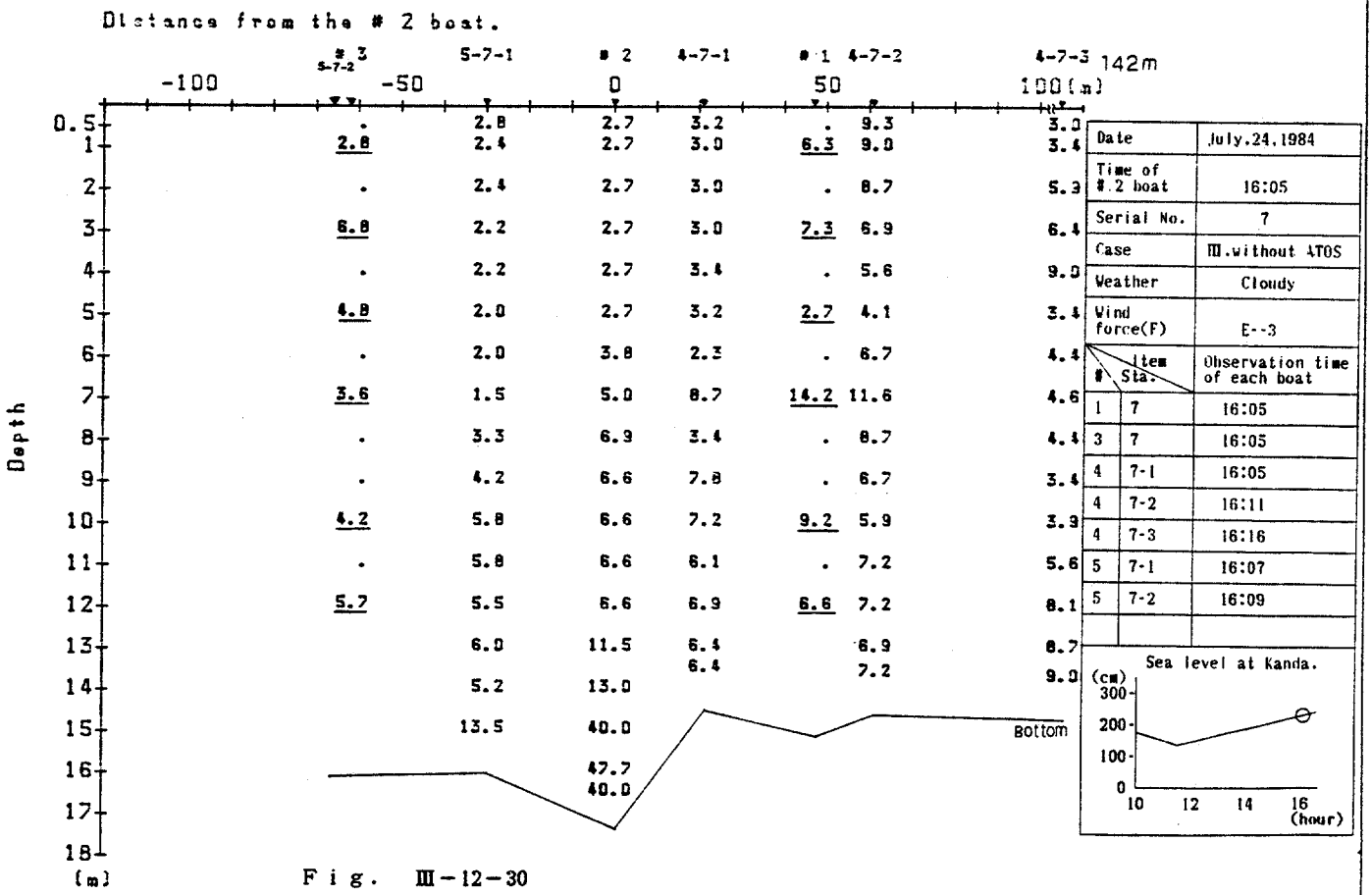
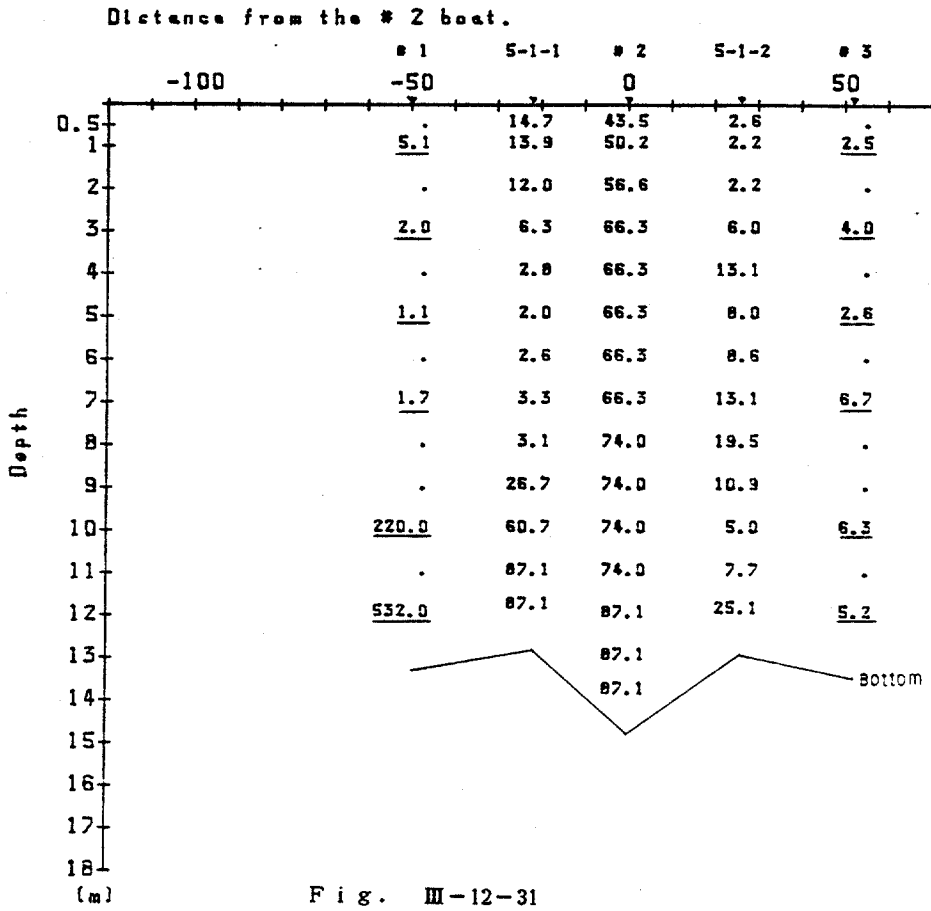


Fig. Ⅲ-12-30



Date	July,25,1984
Time of # 2 boat	10:49
Serial No.	1
Case	III,without ATOS
Weather	Cloudy
Wind force(F)	NE--1

#	Sta. \ Item	Observation time of each boat
1	1	10:49
3	1	10:49
5	1-1	10:49
5	1-2	10:51

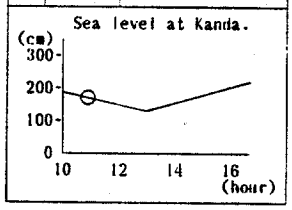
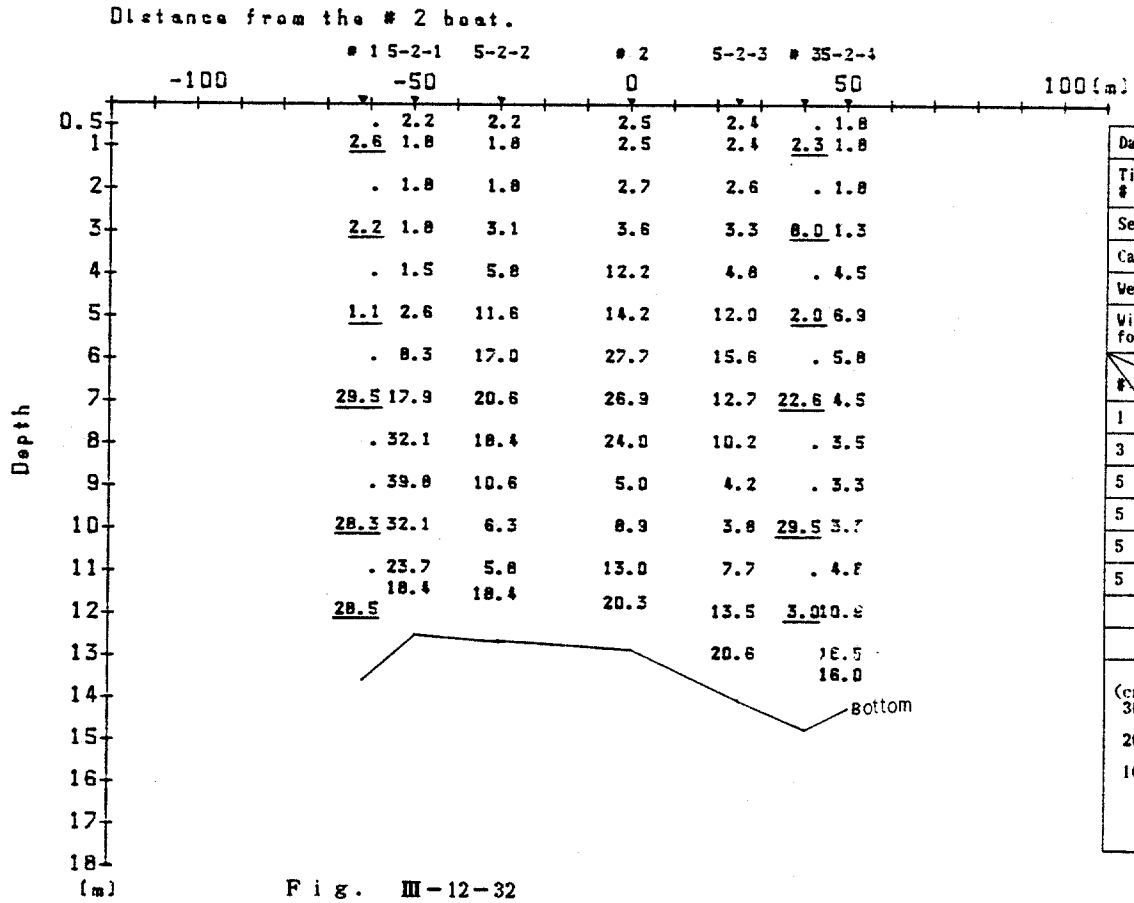


Fig. III-12-31



Date	July,25,1984
Time of # 2 boat	10:59
Serial No.	2
Case	III,without ATOS
Weather	Cloudy
Wind force(F)	NE--1

#	Sta. \ Item	Observation time of each boat
1	2	10:59
3	2	10:59
5	2-1	11:00
5	2-2	11:02
5	2-3	11:05
5	2-4	11:06

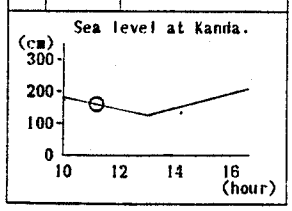
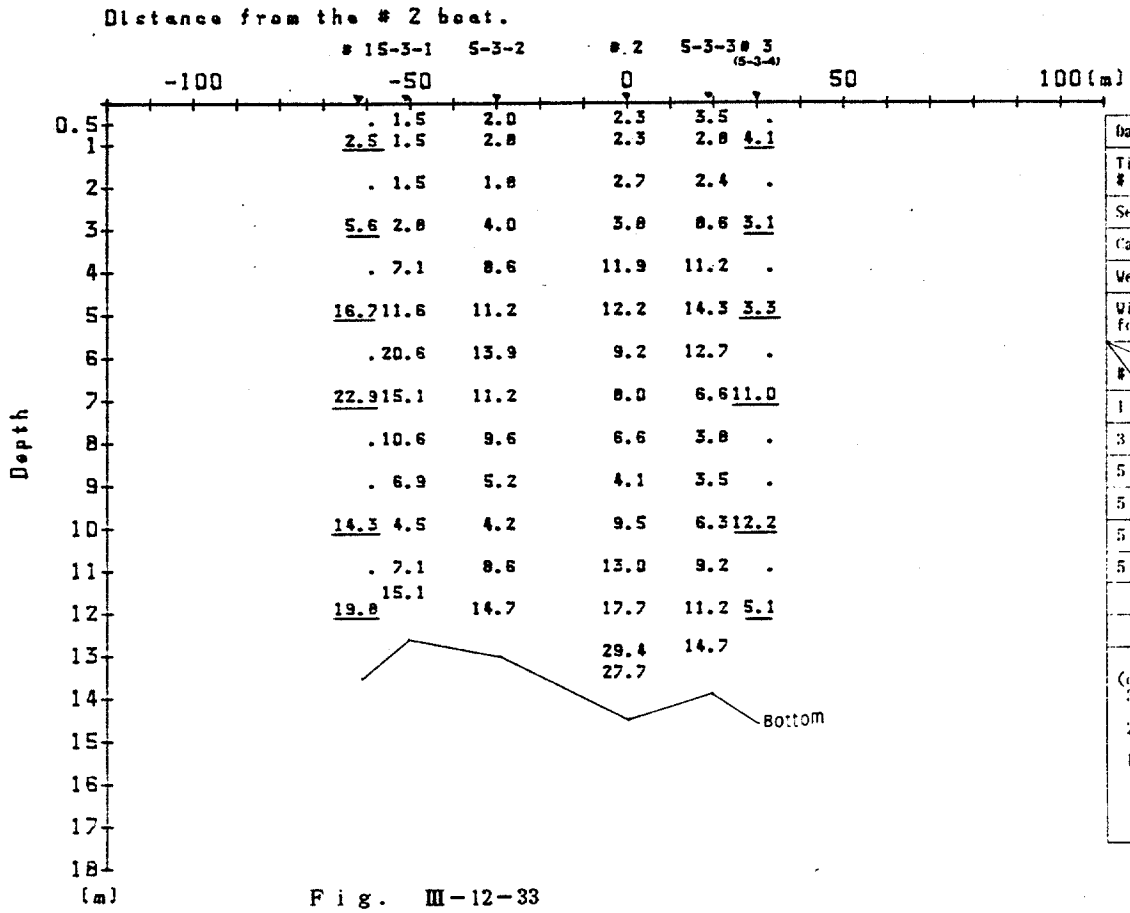


Fig. III-12-32



Date	July.25.1984
Time of # 2 boat	11:09
Serial No.	3
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	Calm

#	Item / Sta.	Observation time of each boat
1	3	11:09
3	3	11:09
5	3-1	11:10
5	3-2	11:12
5	3-3	11:13
5	3-4	11:14

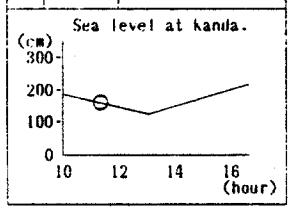
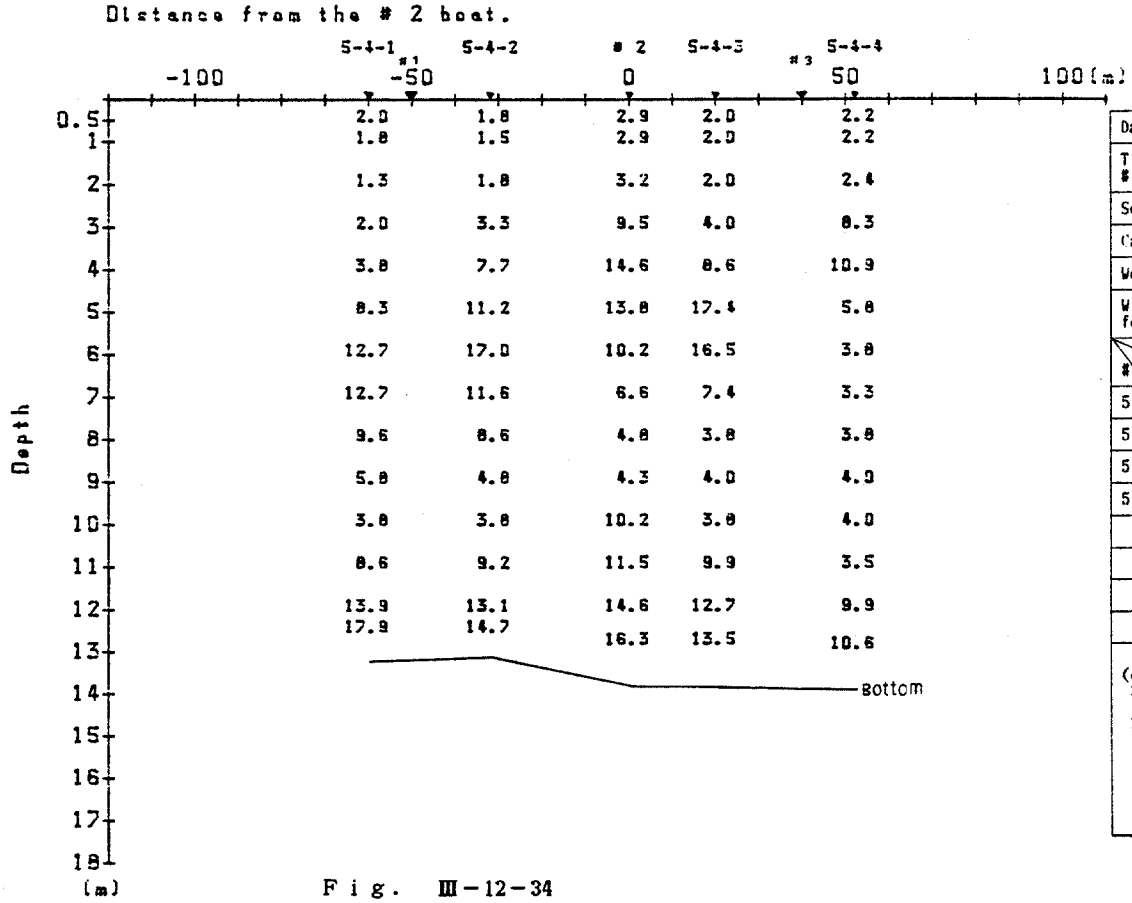


Fig. Ⅲ-12-33



Date	July,25,1984
Time of # 2 boat	11:19
Serial No.	4
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	Calm

#	Item / Sta.	Observation time of each boat
5	4-1	11:20
5	4-2	11:22
5	4-3	11:24
5	4-4	11:26

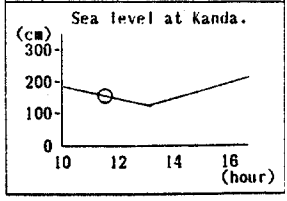
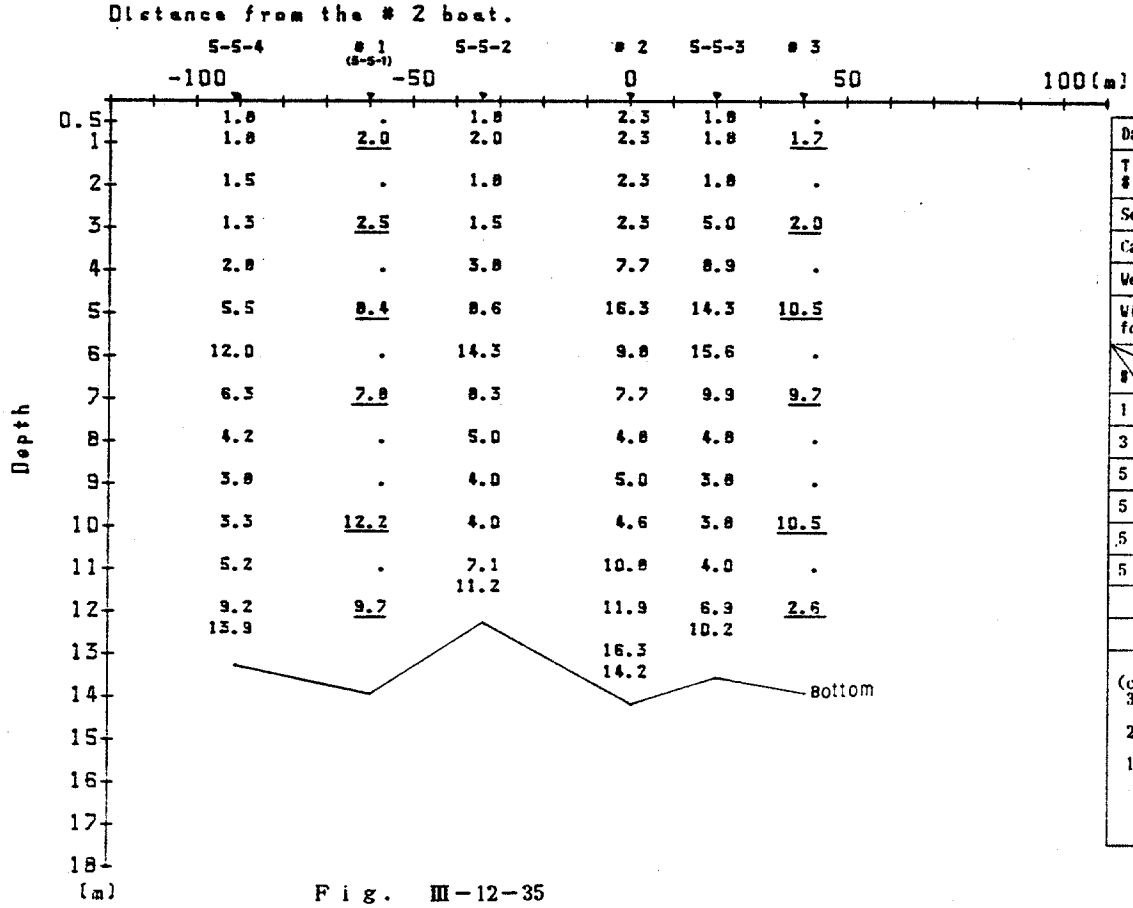


Fig. Ⅲ-12-34



Date	July.25,1984
Time of # 2 boat	11:29
Serial No.	5
Case	III,without ATOS
Weather	Cloudy
Wind force(F)	Calm

#	Sta.	Observation time of each boat
1	5	11:29
3	5	11:29
5	5-1	11:30
5	5-2	11:32
5	5-3	11:33
5	5-4	11:38

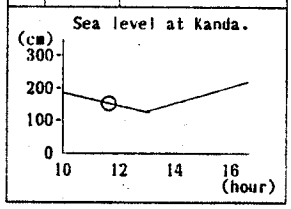
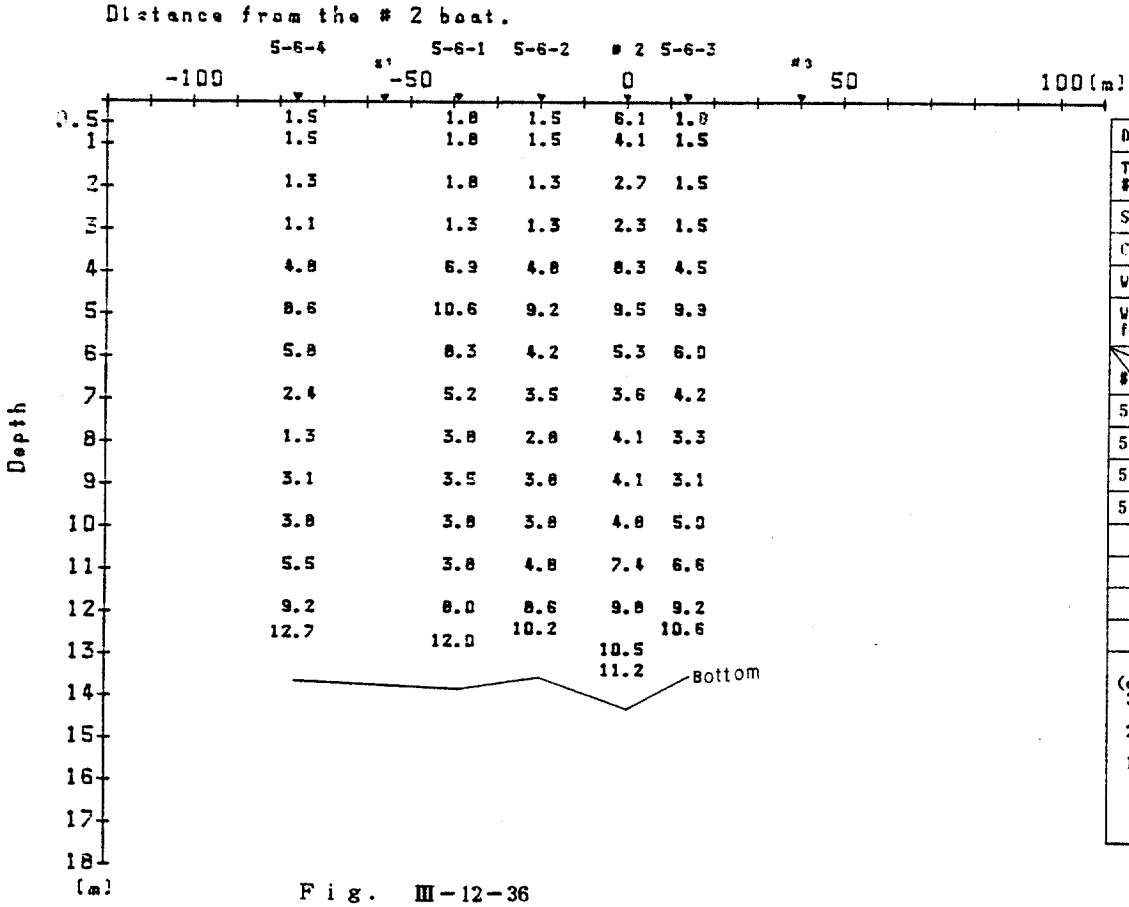


Fig. III-12-35



Date	July.25,1984
Time of # 2 boat	11:49
Serial No.	6
Case	III,without ATOS
Weather	Cloudy
Wind force(F)	Calm

#	Sta.	Observation time of each boat
5	6-1	11:50
5	6-2	11:52
5	6-3	11:54
5	6-4	11:57

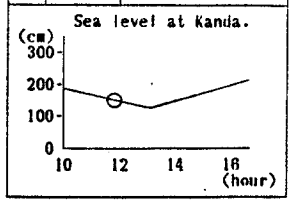
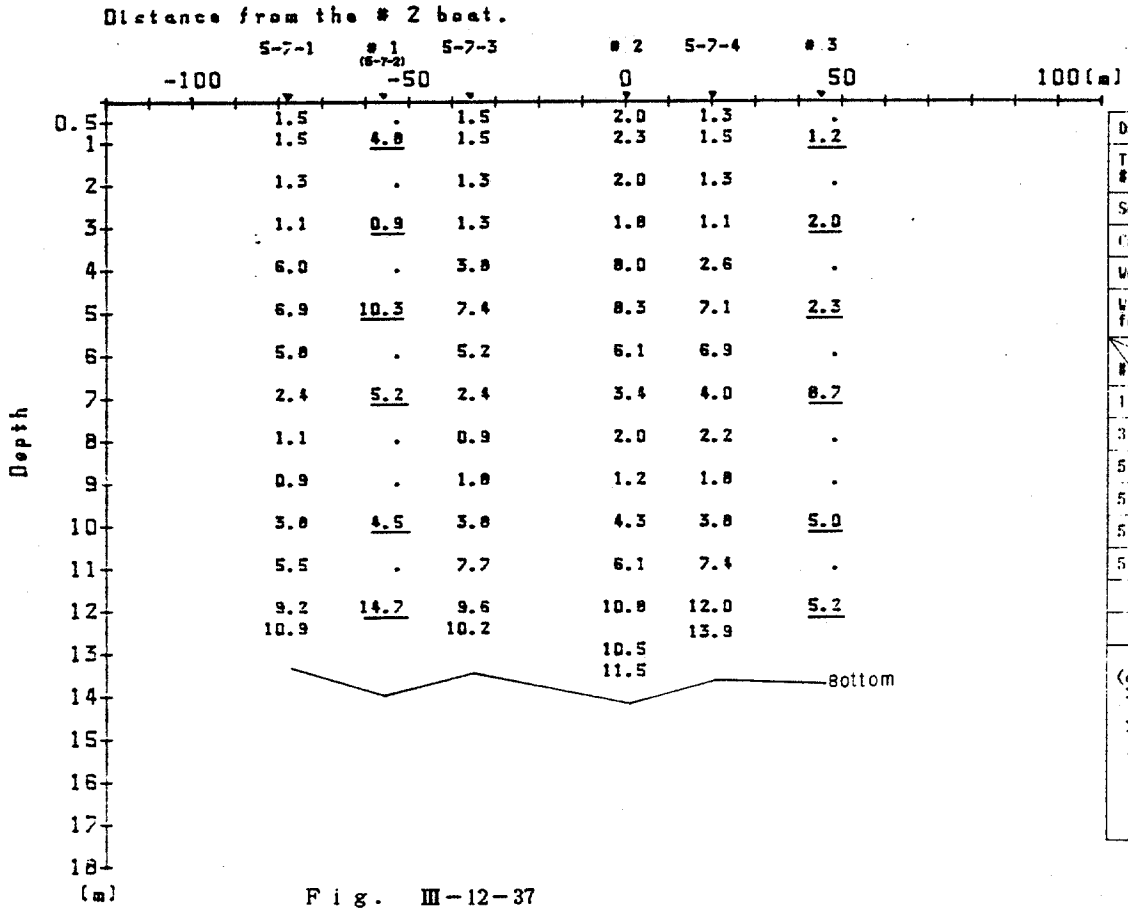


Fig. III-12-36



Date	July.25.1984
Time of # 2 boat	12:09
Serial No.	7
Case	Ⅲ.without ATOS
Weather	Cloudy
Wind force(F)	Calm

#	Sta. \ Item	Observation time of each boat
1	7	12:09
3	7	12:09
5	7-1	12:10
5	7-2	12:12
5	7-3	12:14
5	7-4	12:15

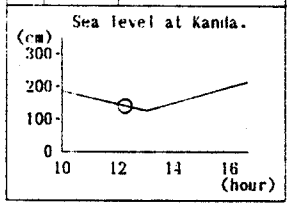
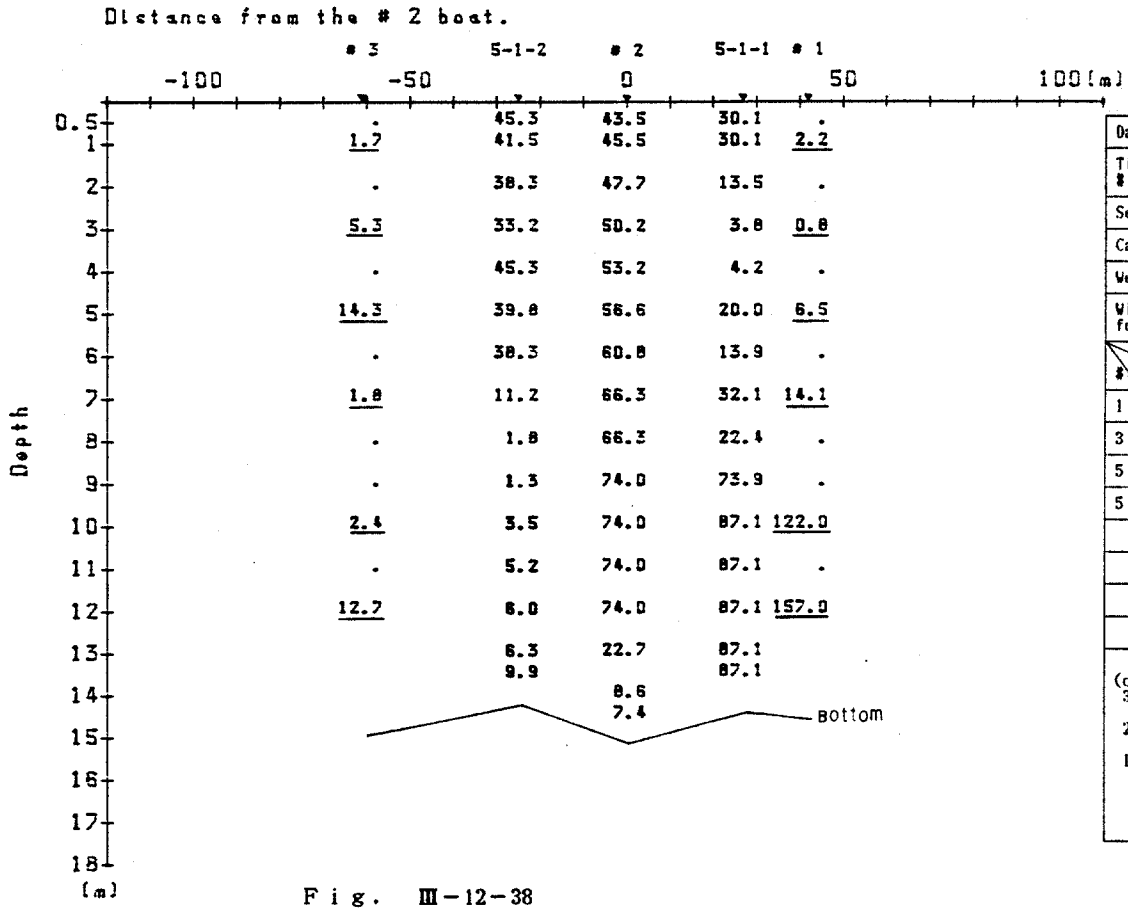


Fig. Ⅲ-12-37



Date	July.25.1984
Time of # 2 boat	14:21
Serial No.	1
Case	Ⅱ.with ATOS
Weather	Cloudy
Wind force(F)	ENE--2

#	Sta. \ Item	Observation time of each boat
1	1	14:21
3	1	14:21
5	1-1	14:21
5	1-2	14:23

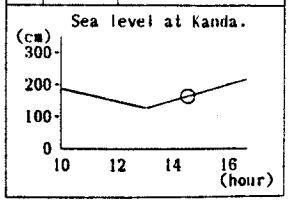
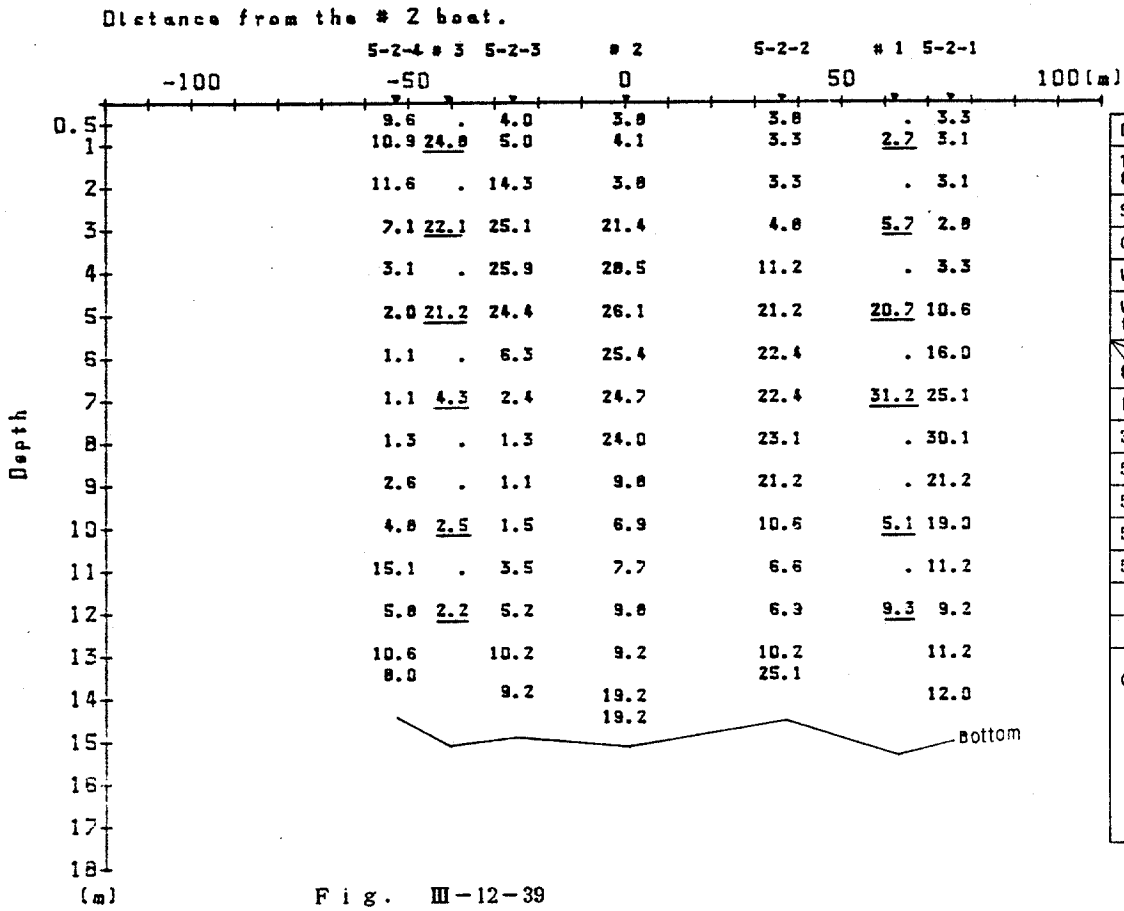


Fig. Ⅲ-12-38



Date	July,25,1984
Time of # 2 boat	14:31
Serial No.	2
Case	II,with ATOS
Weather	Cloudy
Wind force(F)	ENE--2

#	Sta.	Observation time of each boat
1	2	14:31
3	2	14:31
5	2-1	14:33
5	2-2	14:34
5	2-3	14:36
5	2-4	14:38

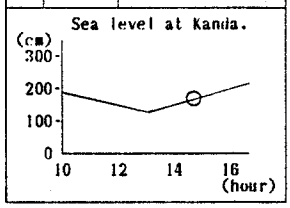
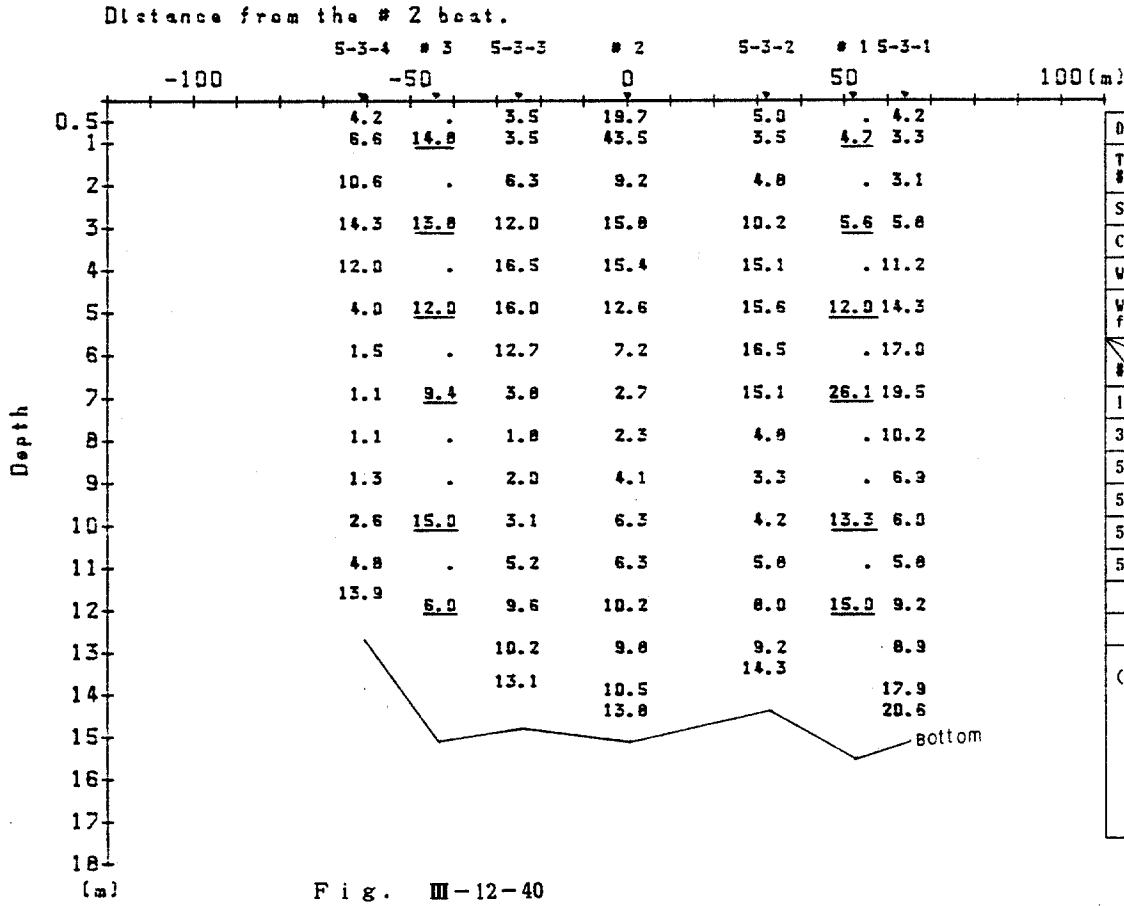


Fig. III-12-39



Date	July,25,1984
Time of # 2 boat	14:41
Serial No.	3
Case	II,with ATOS
Weather	Cloudy
Wind force(F)	ENE--2

#	Sta.	Observation time of each boat
1	3	14:41
3	3	14:41
5	3-1	14:41
5	3-2	14:43
5	3-3	14:45
5	3-4	14:47

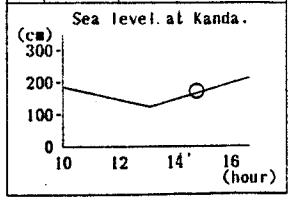
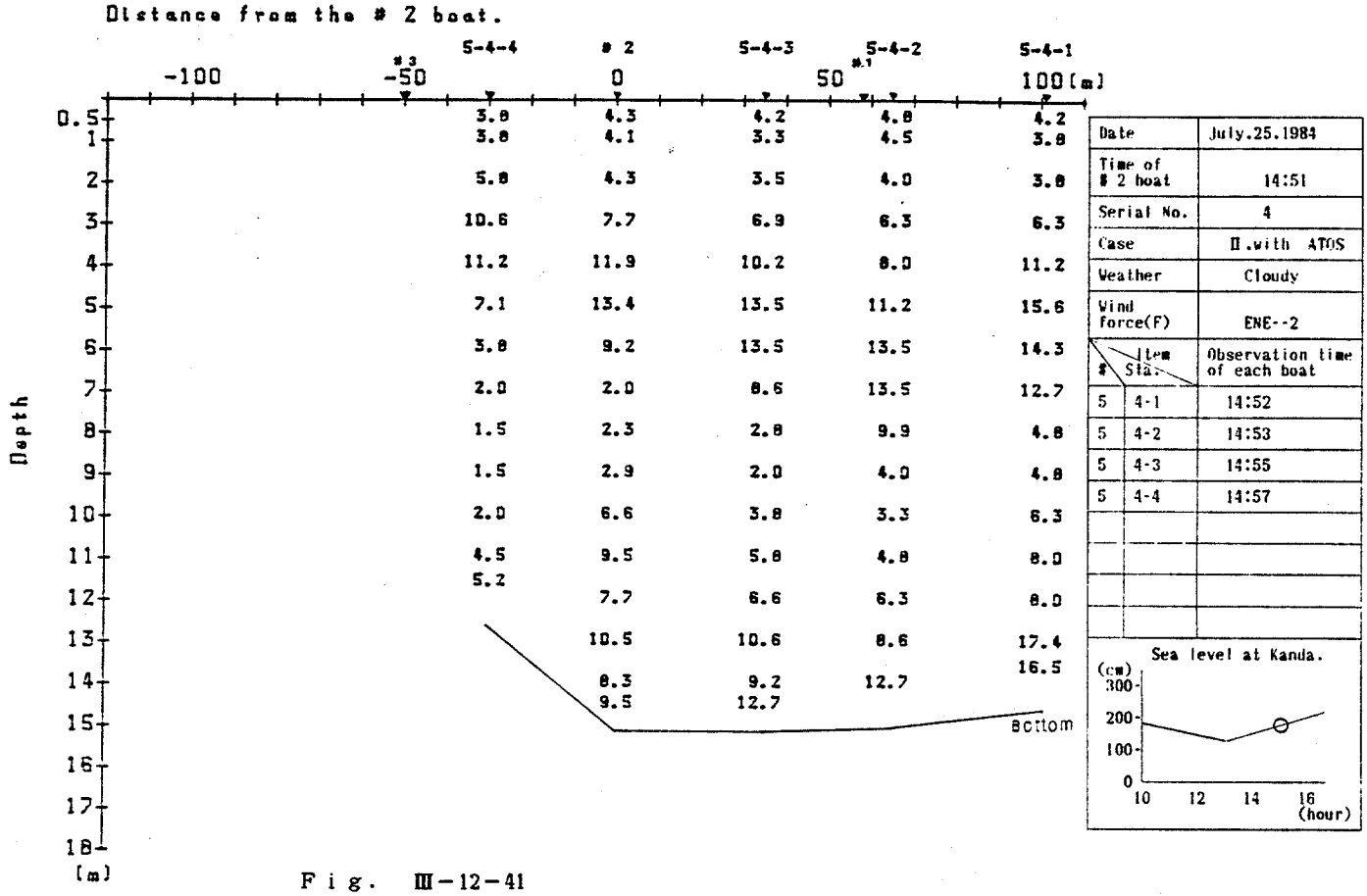


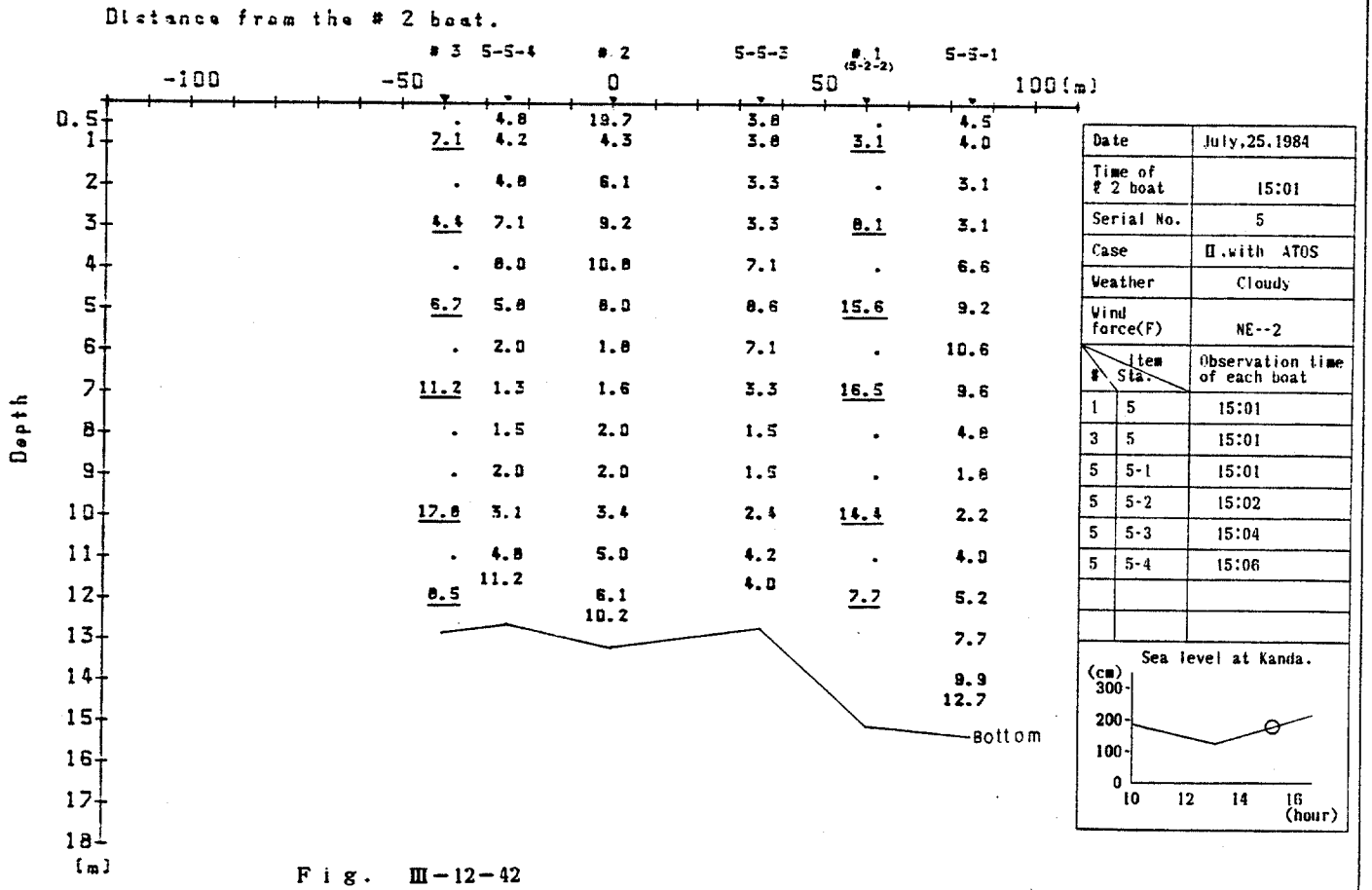
Fig. III-12-40



Date	July.25.1984
Time of # 2 boat	14:51
Serial No.	4
Case	II.with ATOS
Weather	Cloudy
Wind force(F)	ENE--2

#	Sta.	Observation time of each boat
5	4-1	14:52
5	4-2	14:53
5	4-3	14:55
5	4-4	14:57

Fig. III-12-41



Date	July.25.1984
Time of # 2 boat	15:01
Serial No.	5
Case	II.with ATOS
Weather	Cloudy
Wind force(F)	NE--2

#	Sta.	Observation time of each boat
1	5	15:01
3	5	15:01
5	5-1	15:01
5	5-2	15:02
5	5-3	15:04
5	5-4	15:06

Fig. III-12-42

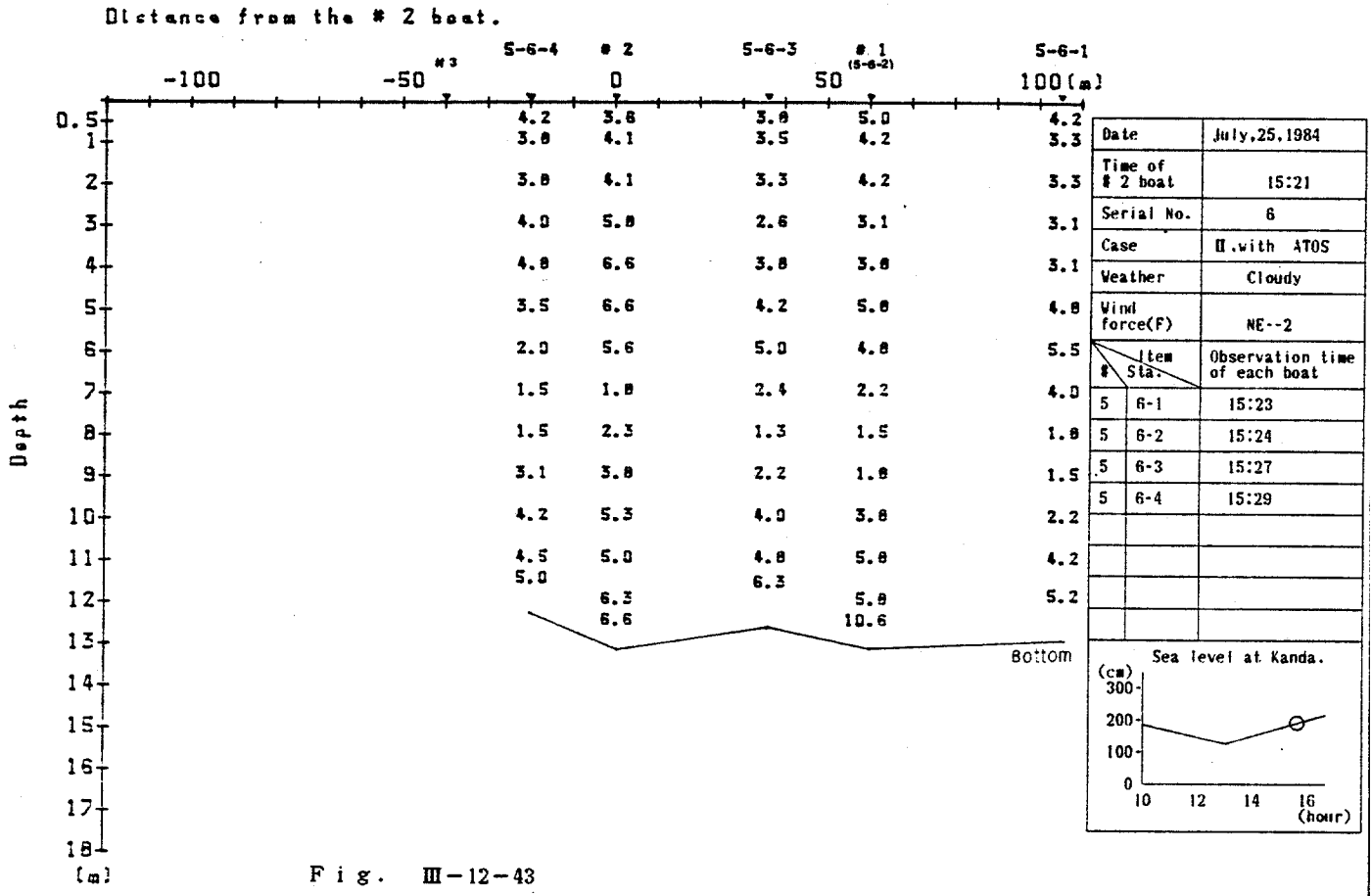


Fig. III-12-43

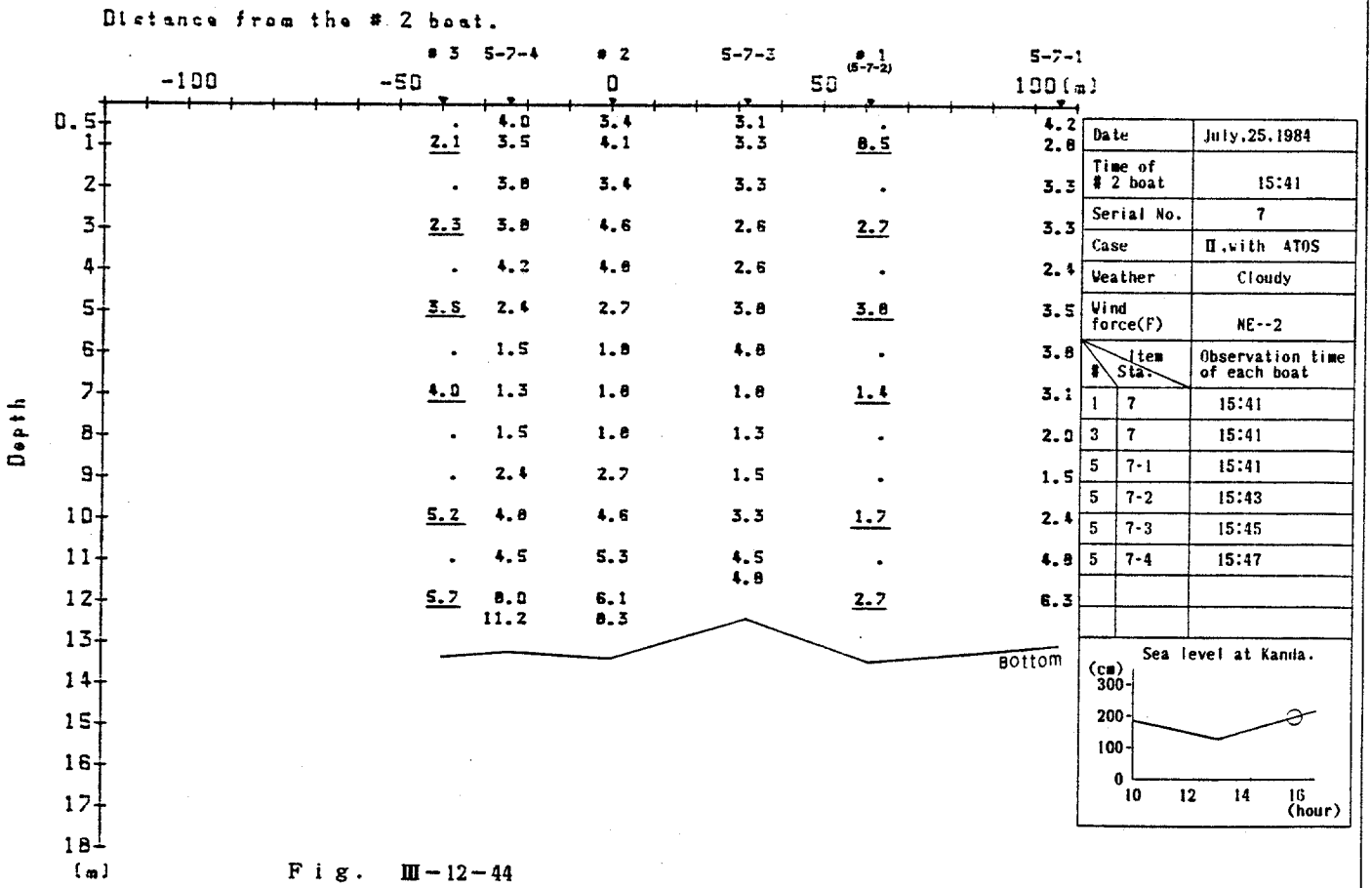


Fig. III-12-44

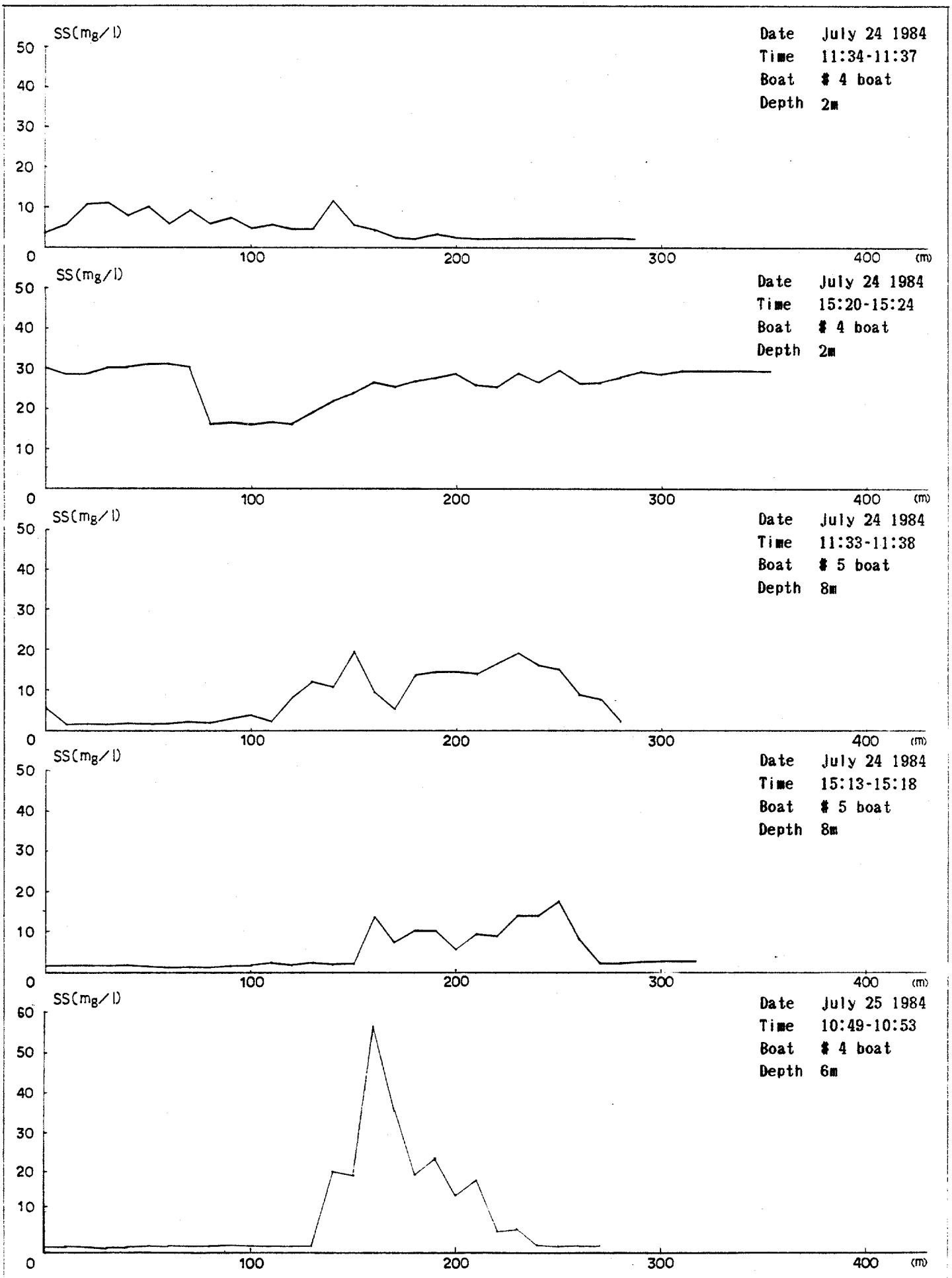


Fig.Ⅲ − 13−1 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED (measured with a towed turbidimeter)

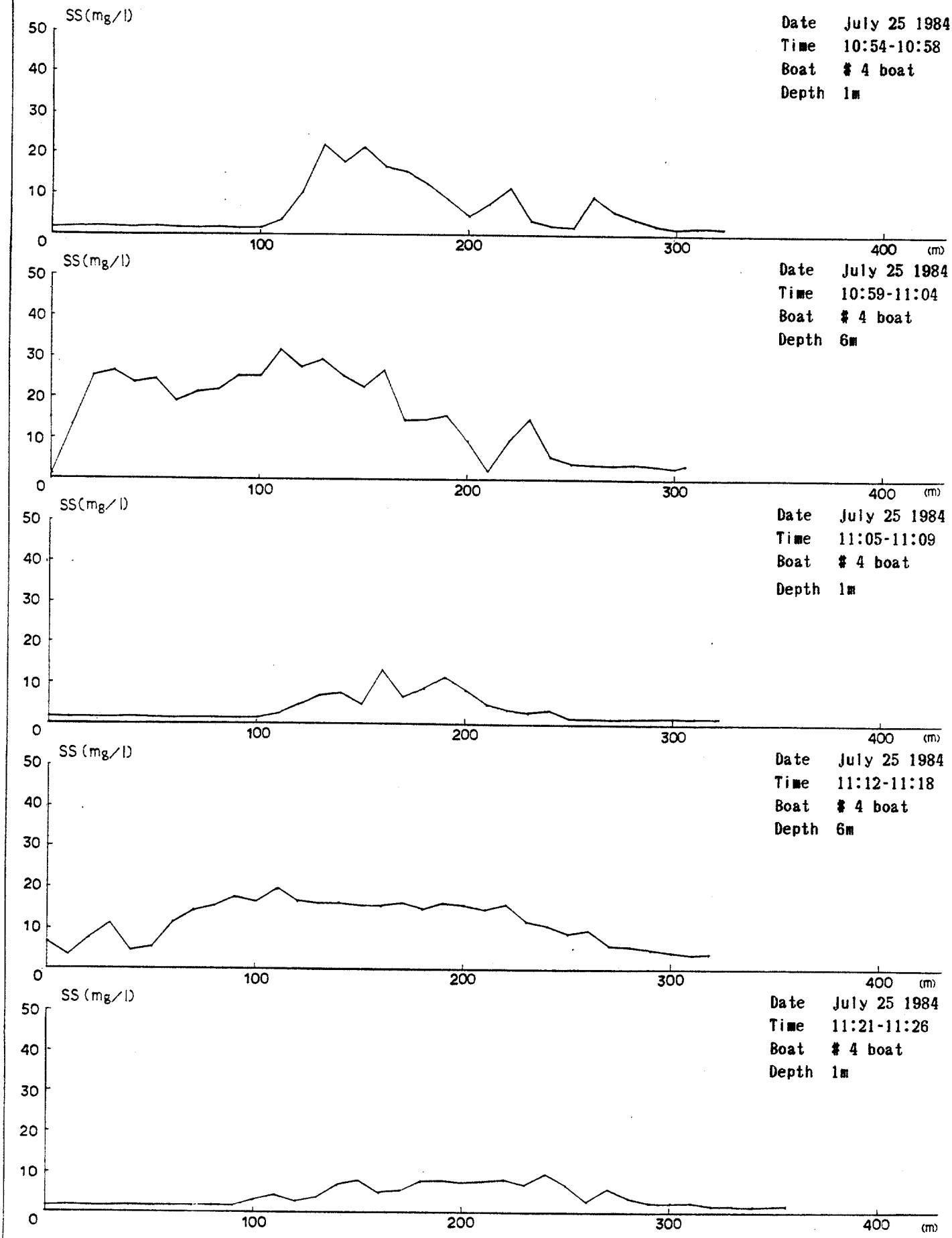


Fig. III − 13−2 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

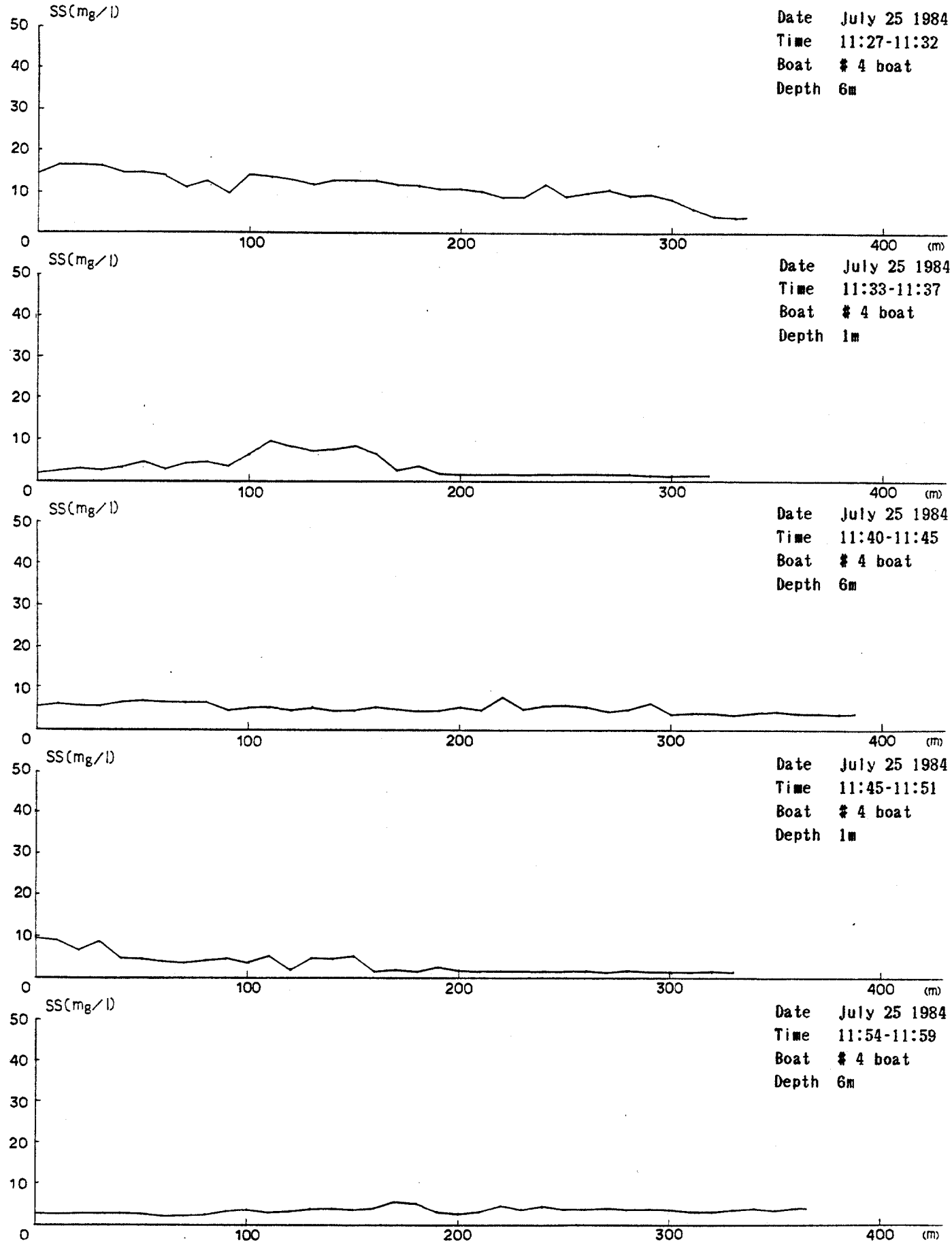


Fig. Ⅲ − 13−3 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

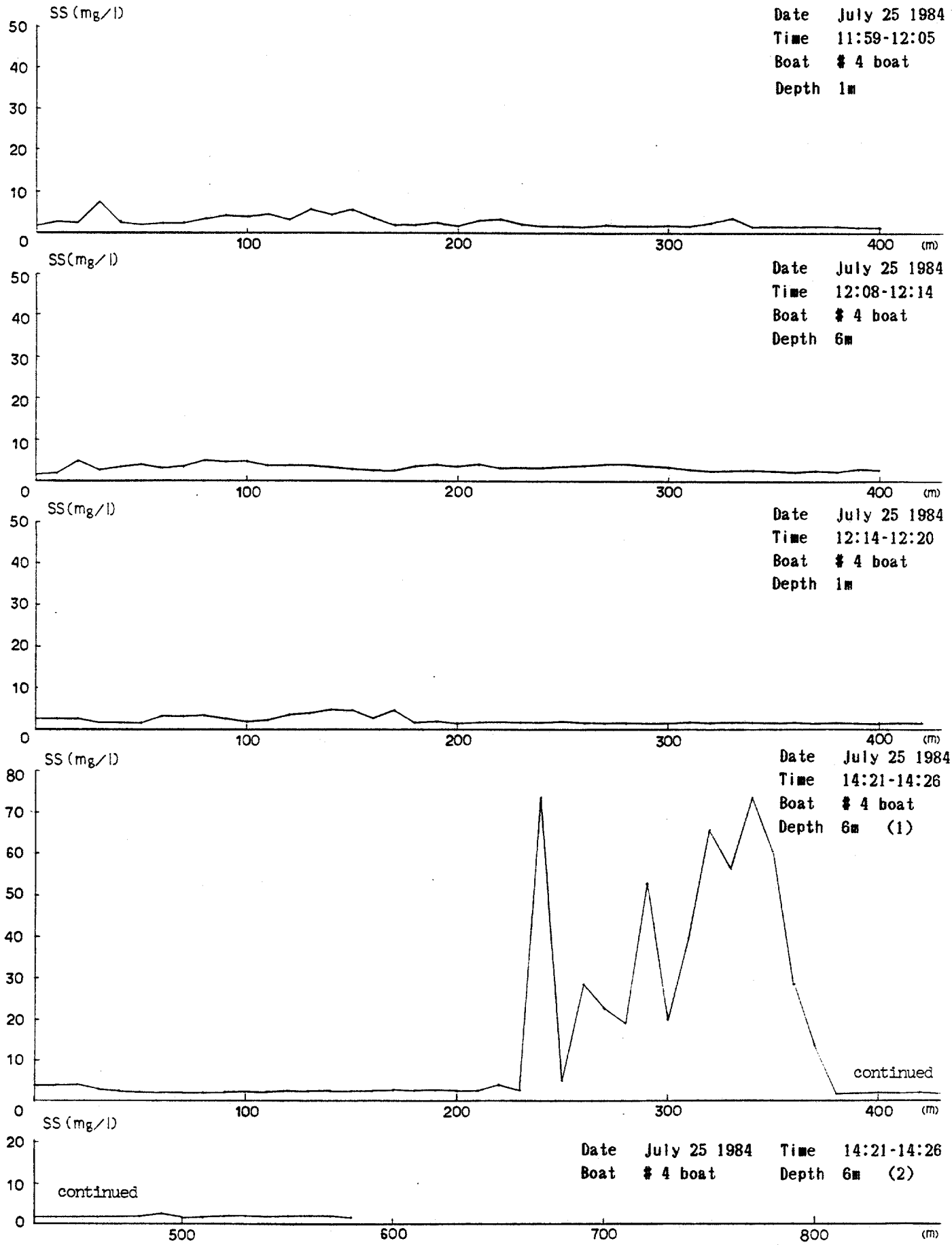


Fig. III − 13−4 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

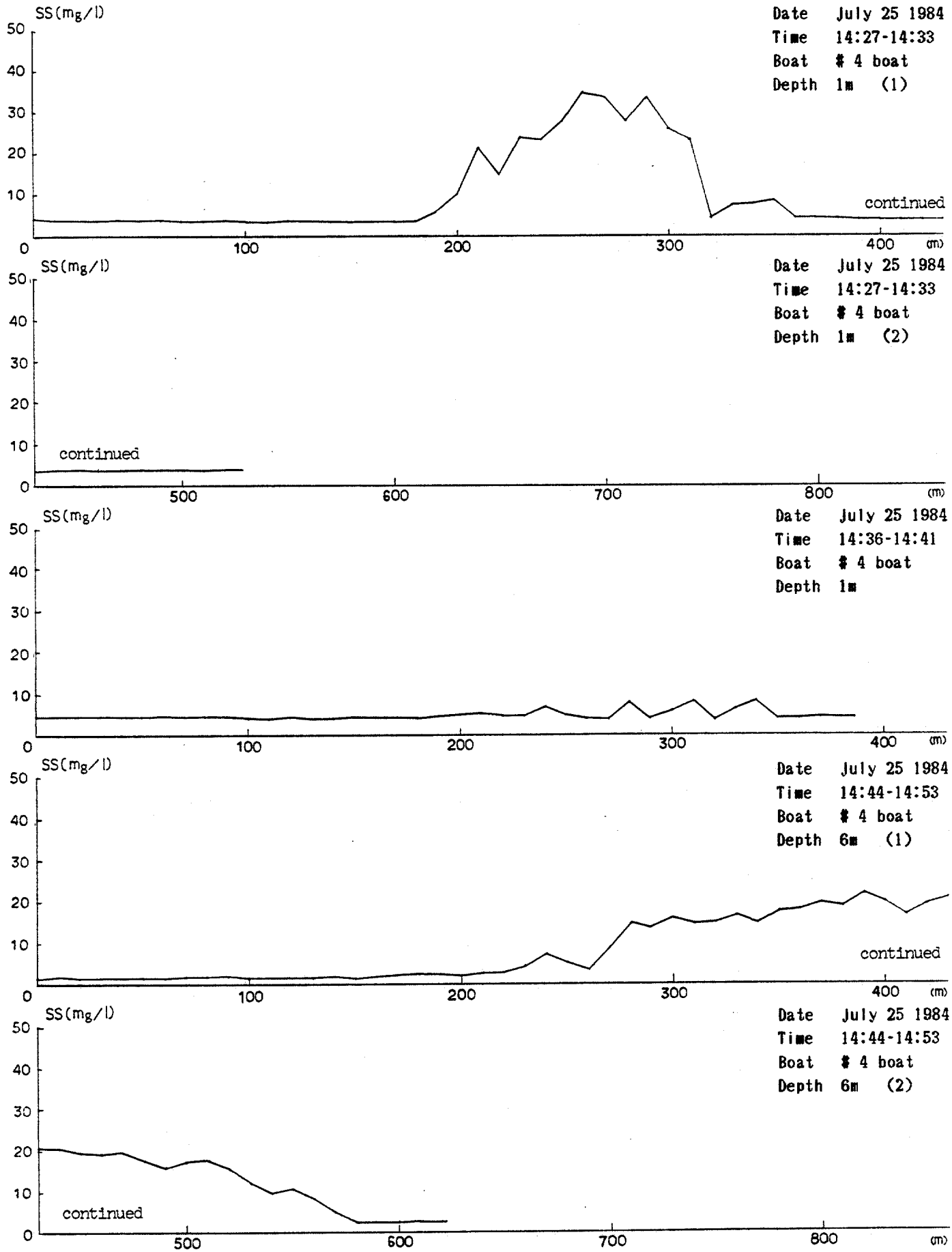


Fig. Ⅲ − 13−5 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

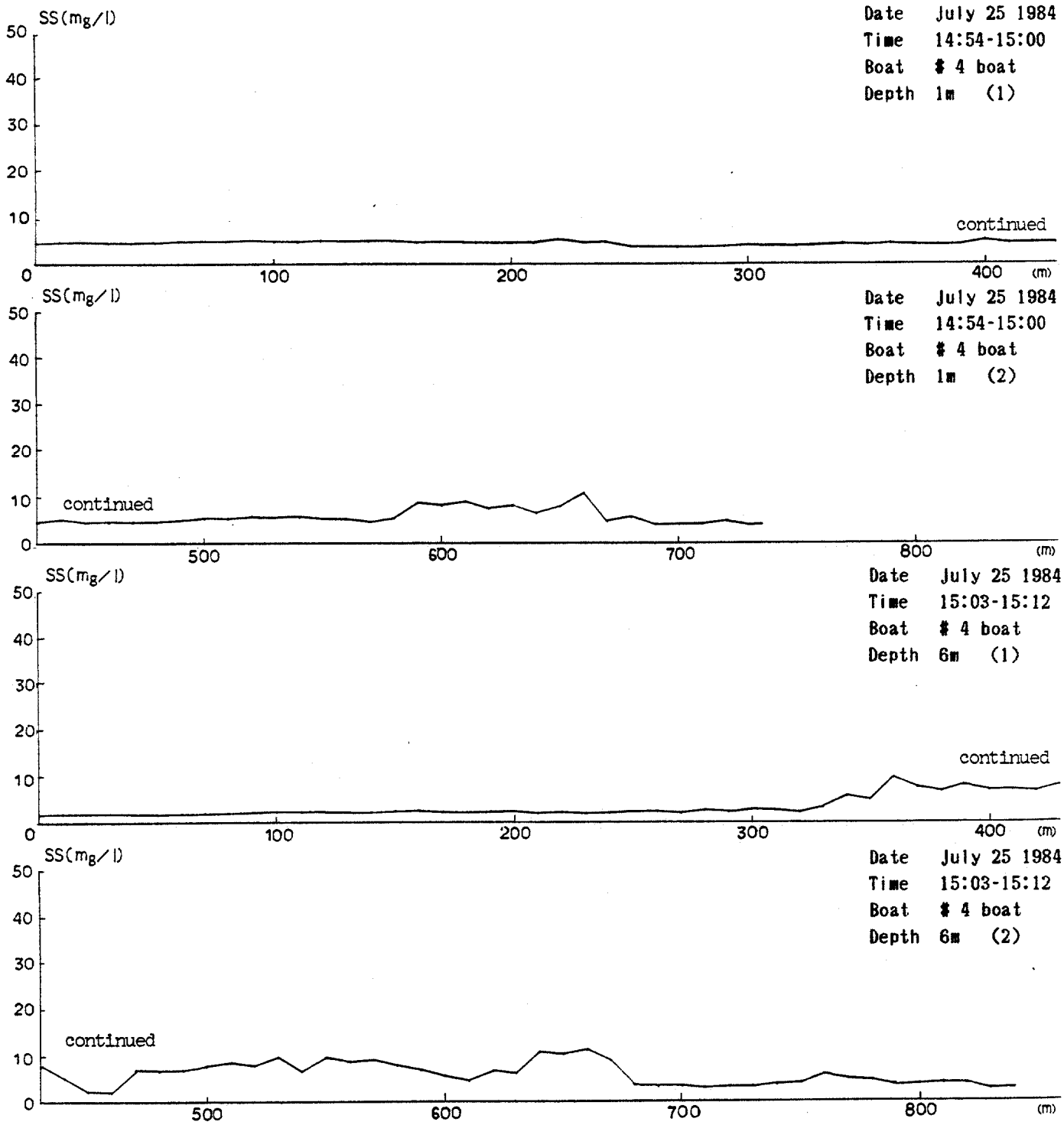


Fig. Ⅲ − 13−6 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

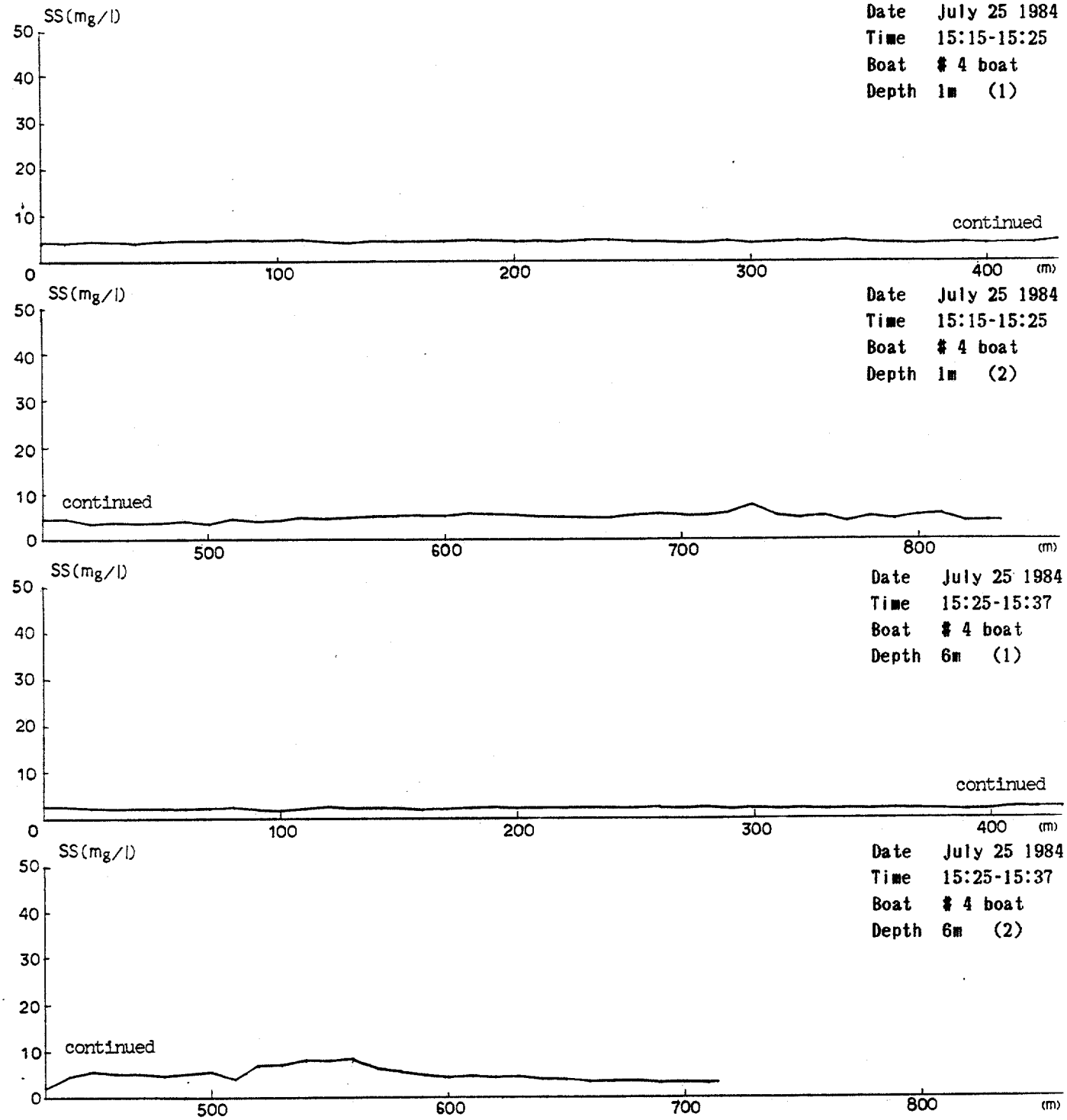


Fig. Ⅲ − 13−7 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)

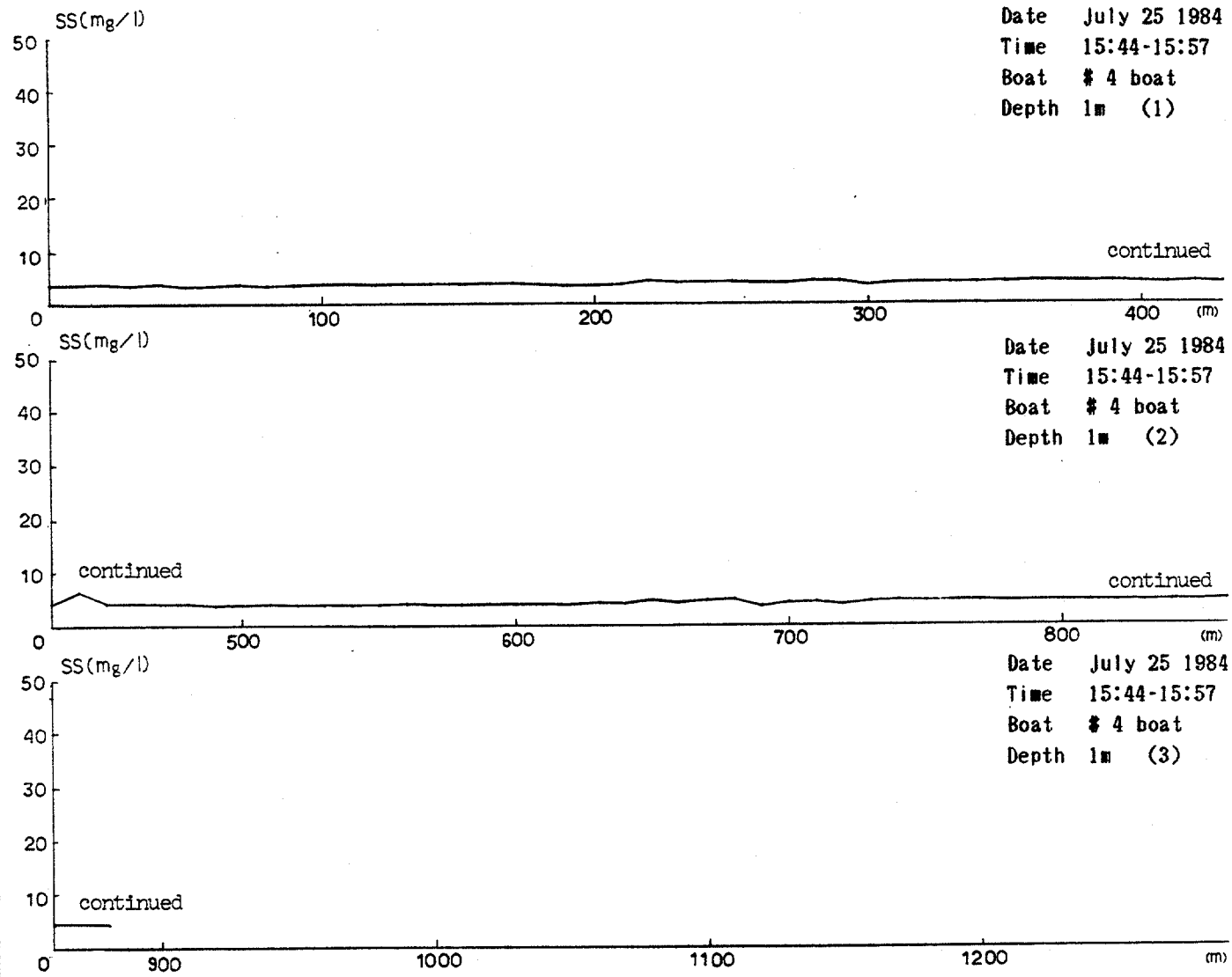
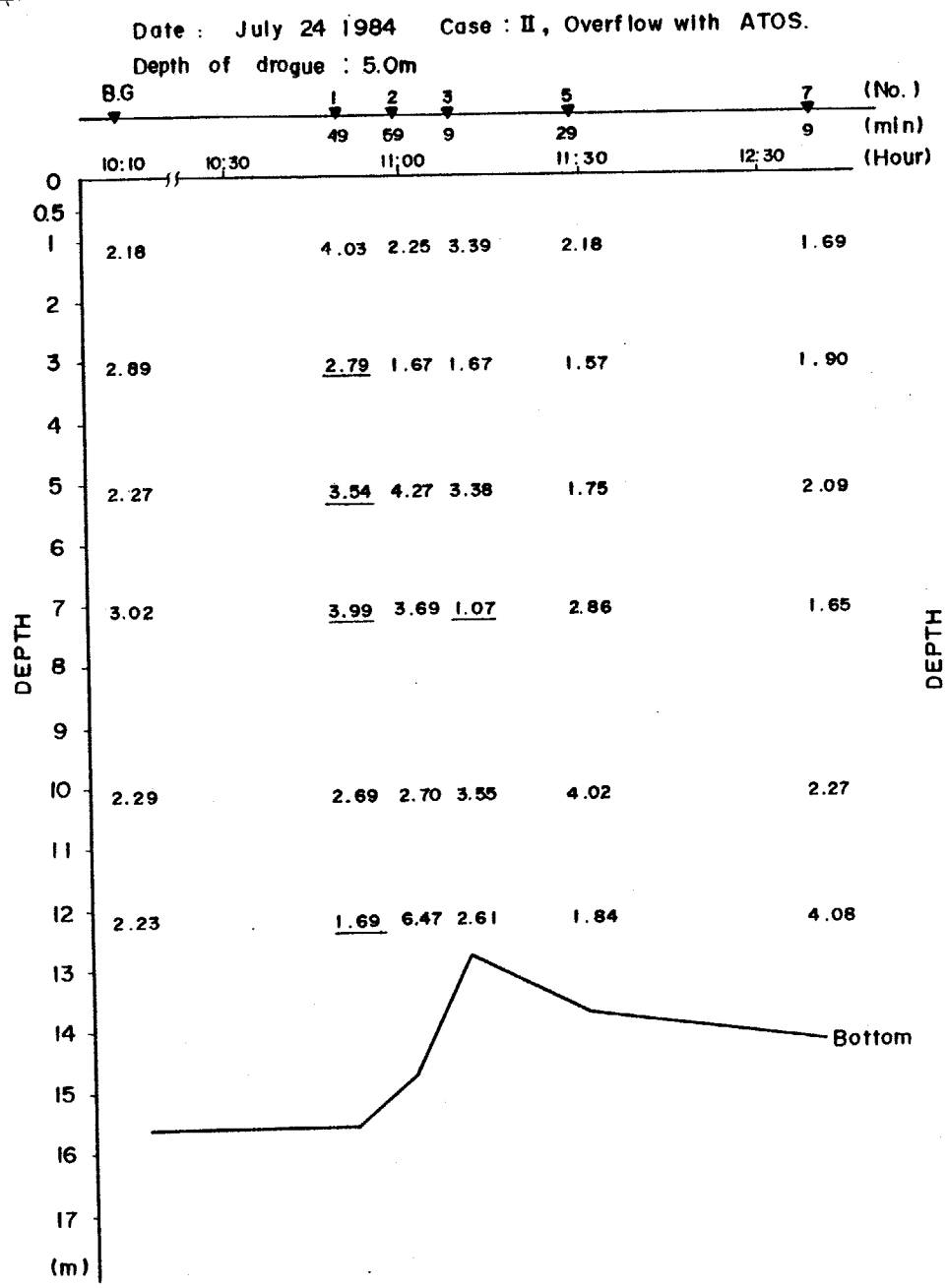


Fig. Ⅲ − 13−8 CROSS-PLUME SS DISTRIBUTION AT DEPTHS INDICATED
(measured with a towed turbidimeter)



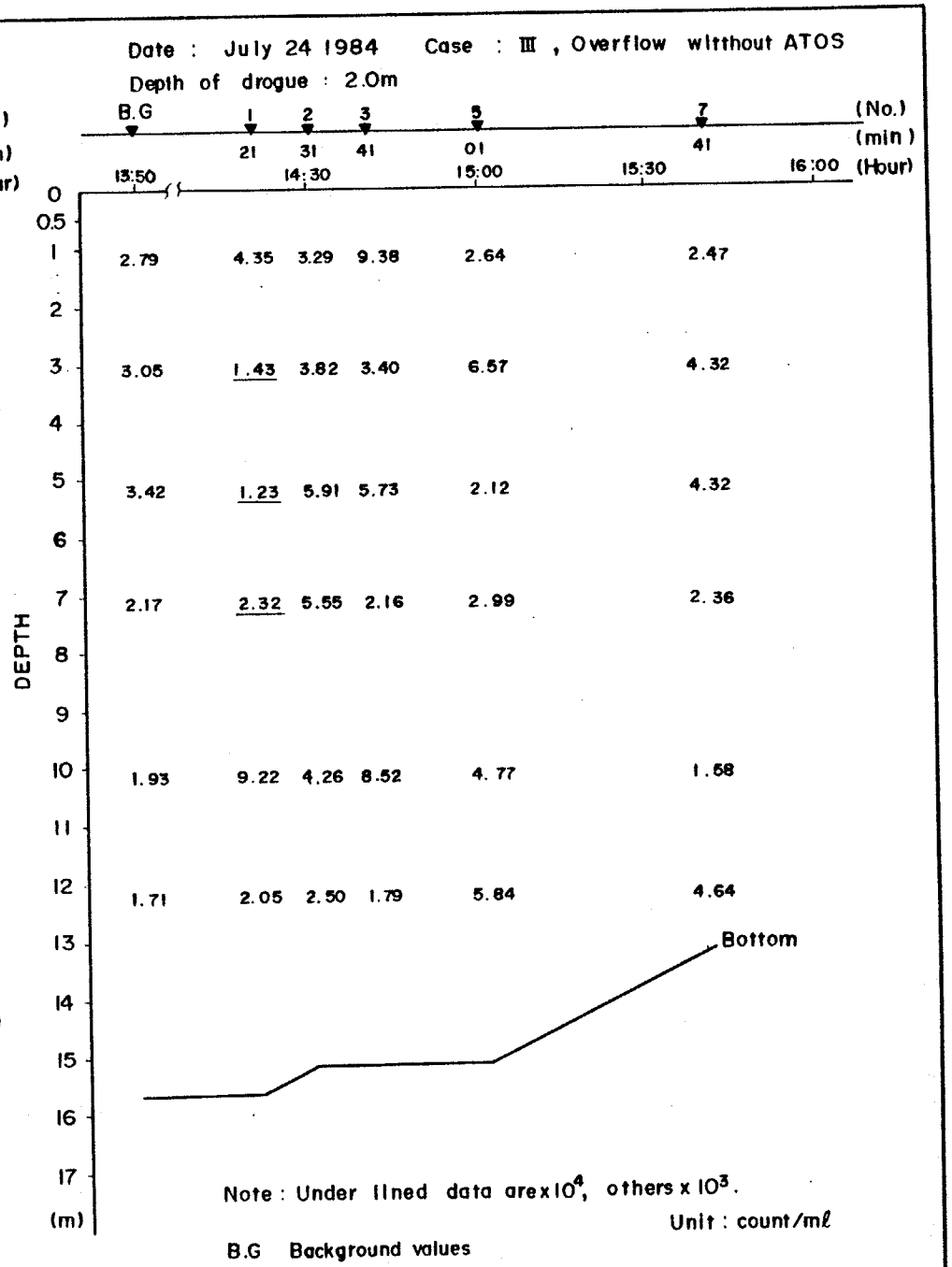


Fig. III — 14 TIME CHANGE OF VERTICAL PARTICLE DISTRIBUTION AT THE CENTER OF THE PLUME

Date : July 25 1984 Morning Case : Ⅲ, Overflow without ATOS Depth of current drogue : 1.0m

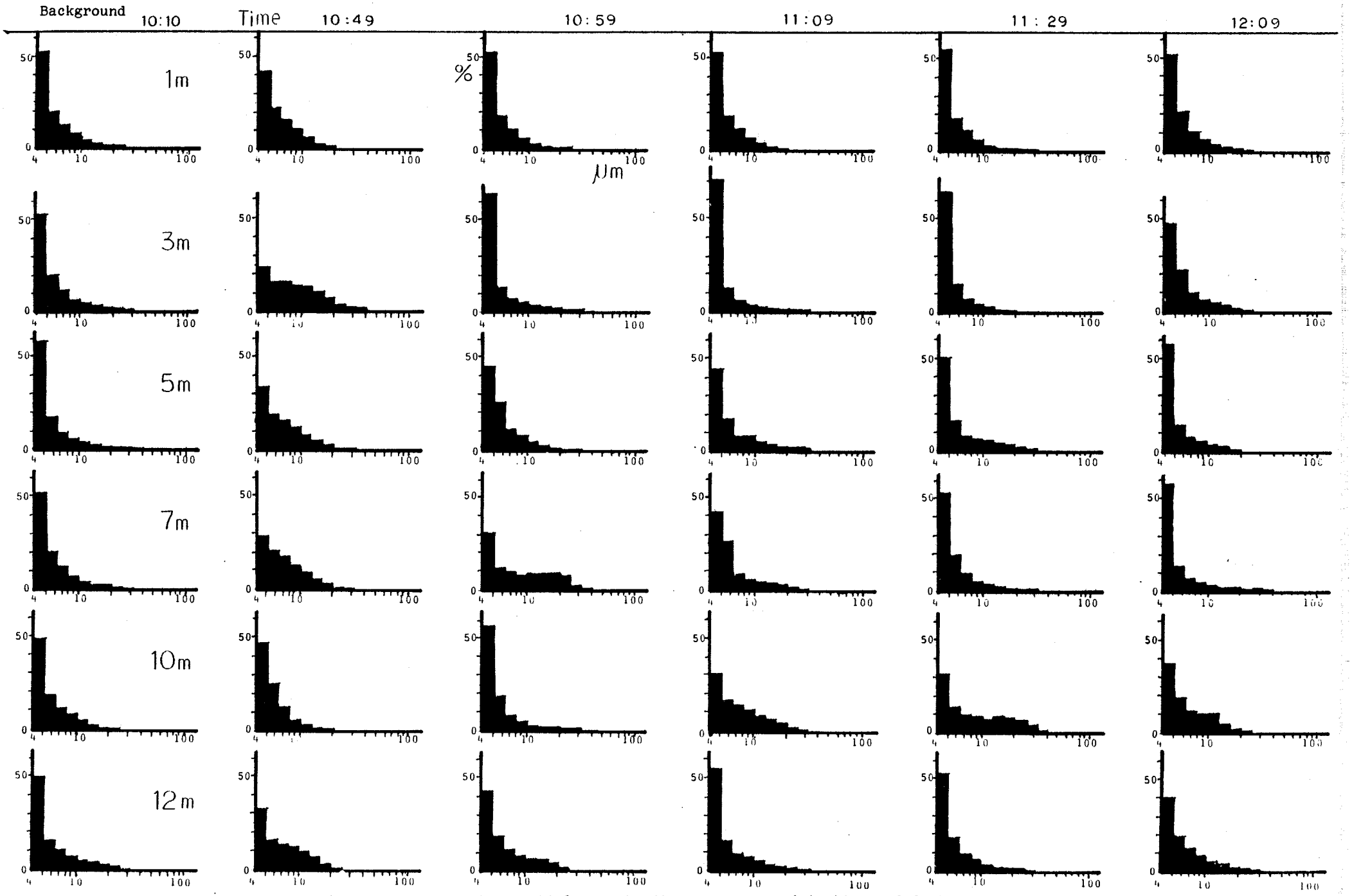


Fig. III.15.1 Size Particle counts diagrams averaged in time and depth

Date : July 25 1984 Afternoon Case : II , Overflow with ATOS Depth of current drogue : 6.0 m

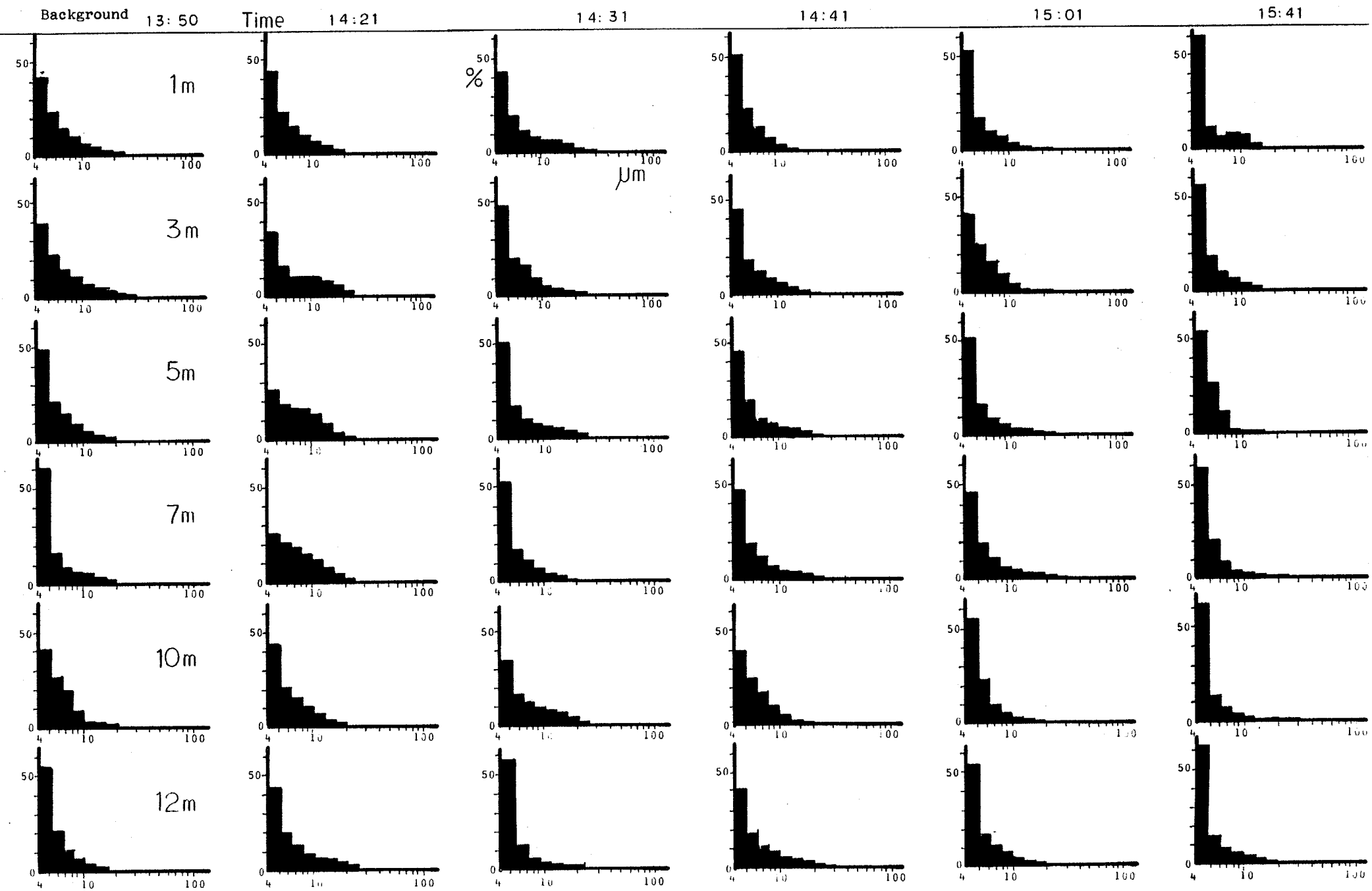


Fig. III-15-2 Size-Particle counts diagrams arranged in time and depth

Date : July 25 1984 Morning Case : Ⅲ, Overflow without ATOS Depth of current drogue : 1.0m

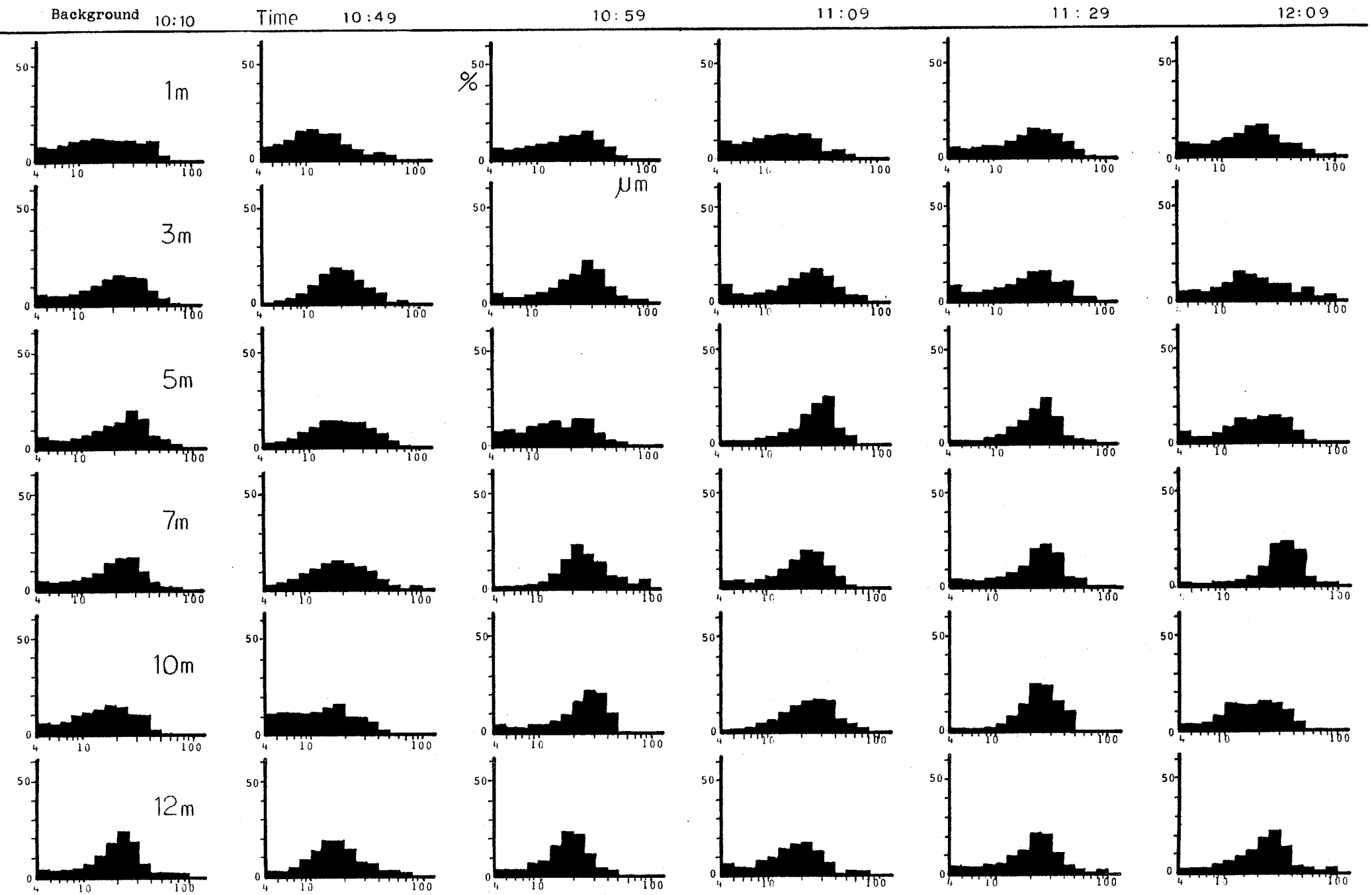


Fig. III-16-1 Size-Volume diagrams arranged in time and depth

Date : July 25 1984 Afternoon Case : II , Overflow with ATOS Depth of current drogue : 6.0m

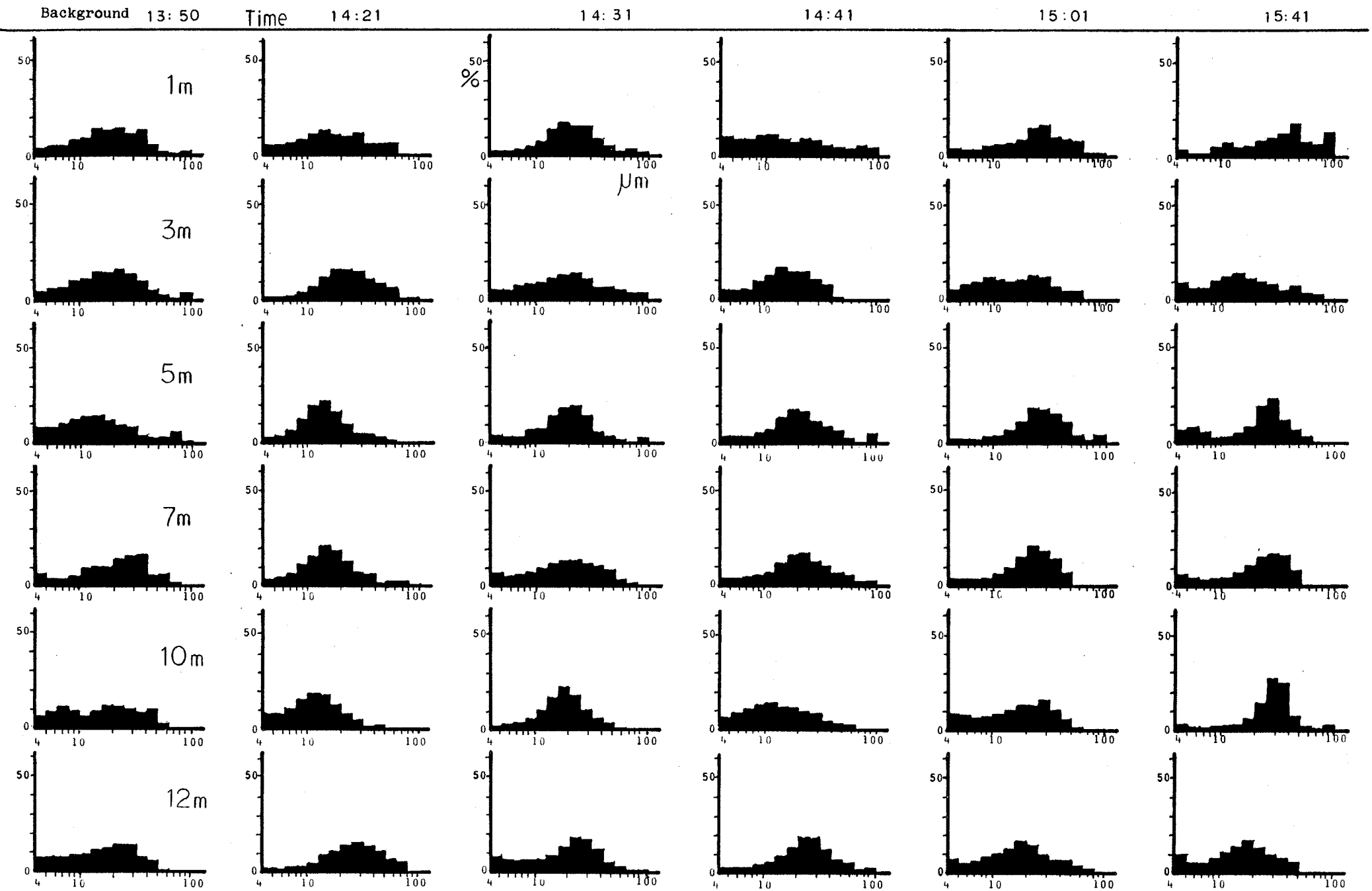
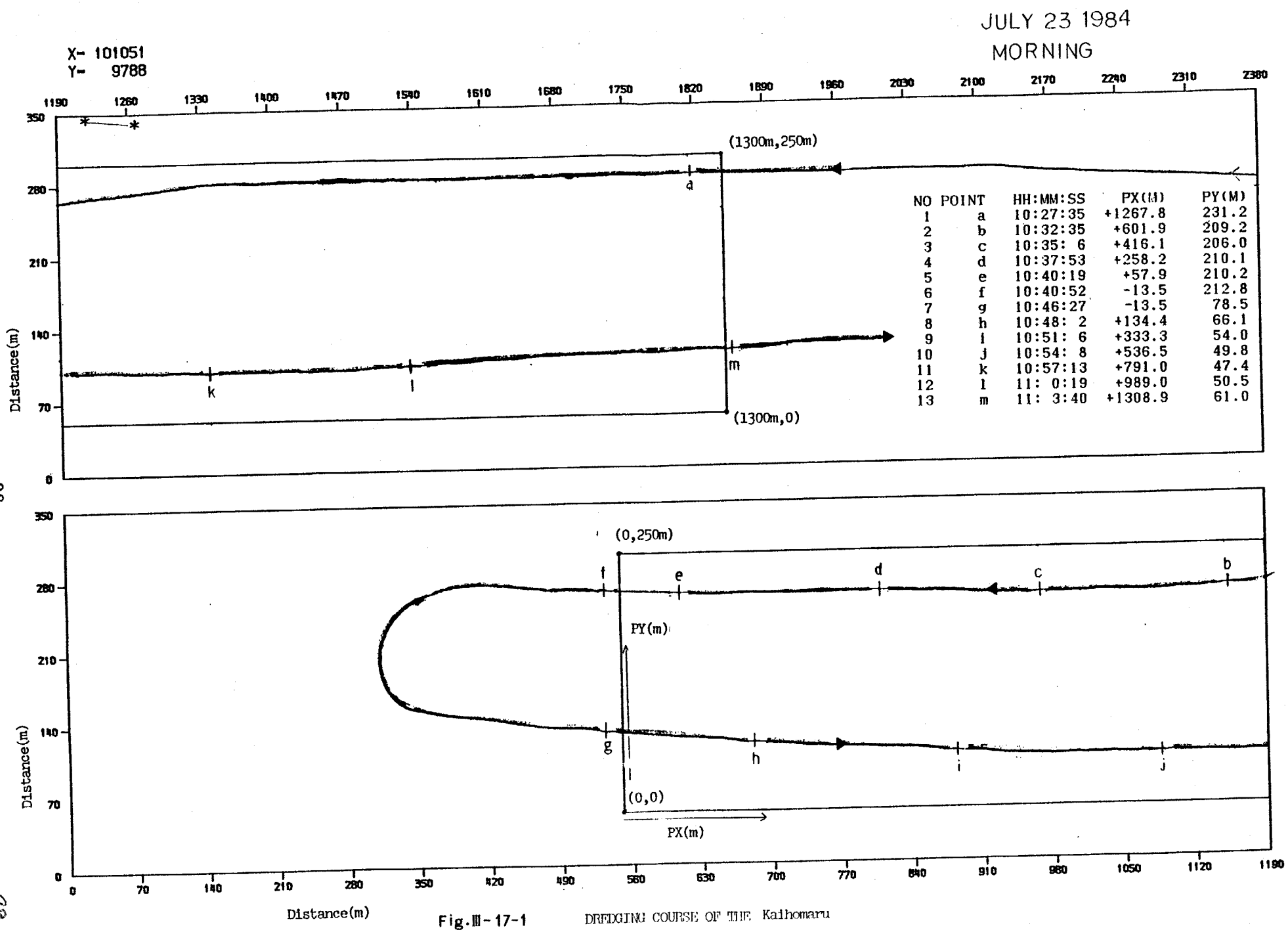
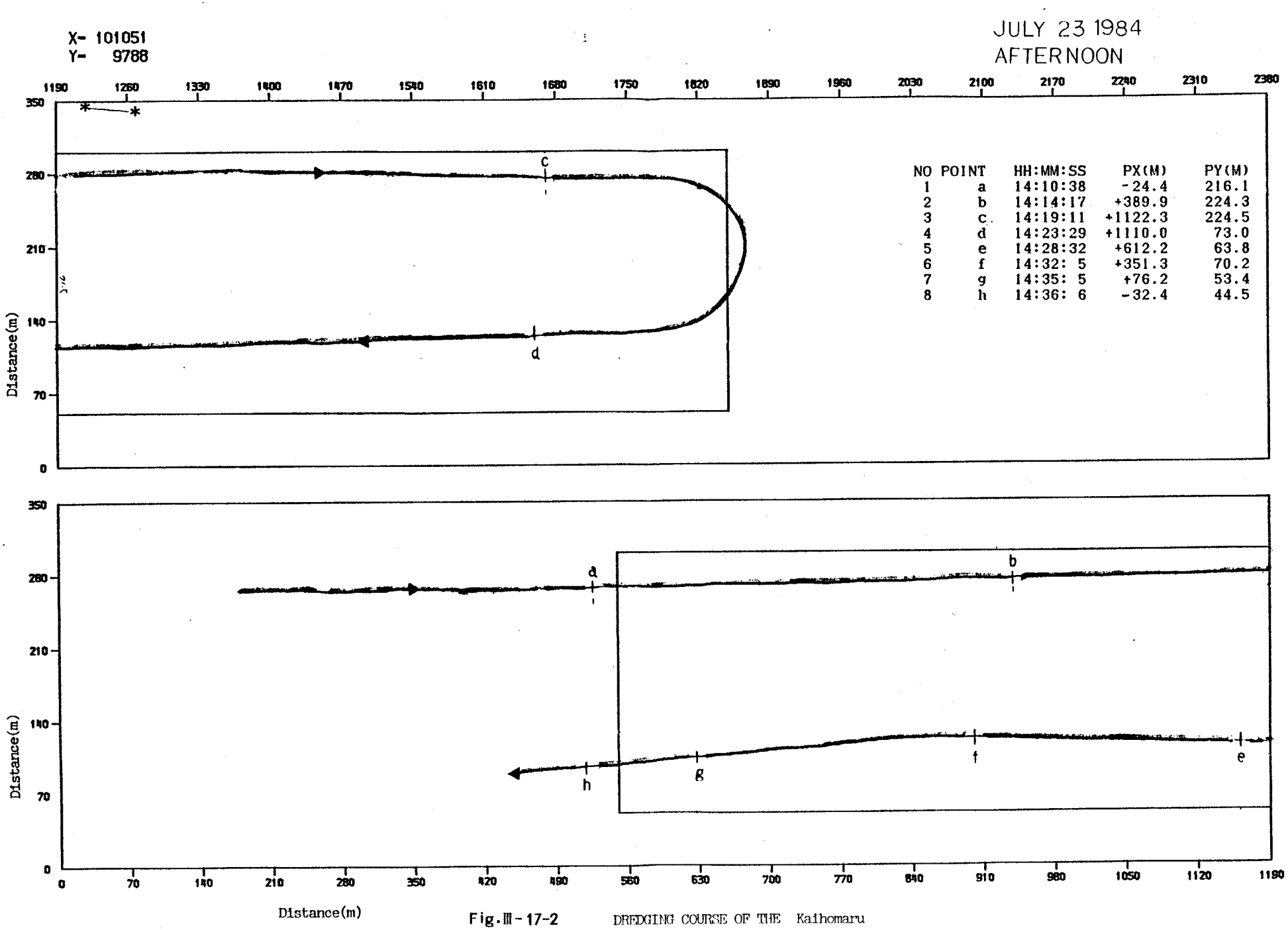


Fig. III-16-2 Size-Volume diagrams arranged in time and depth



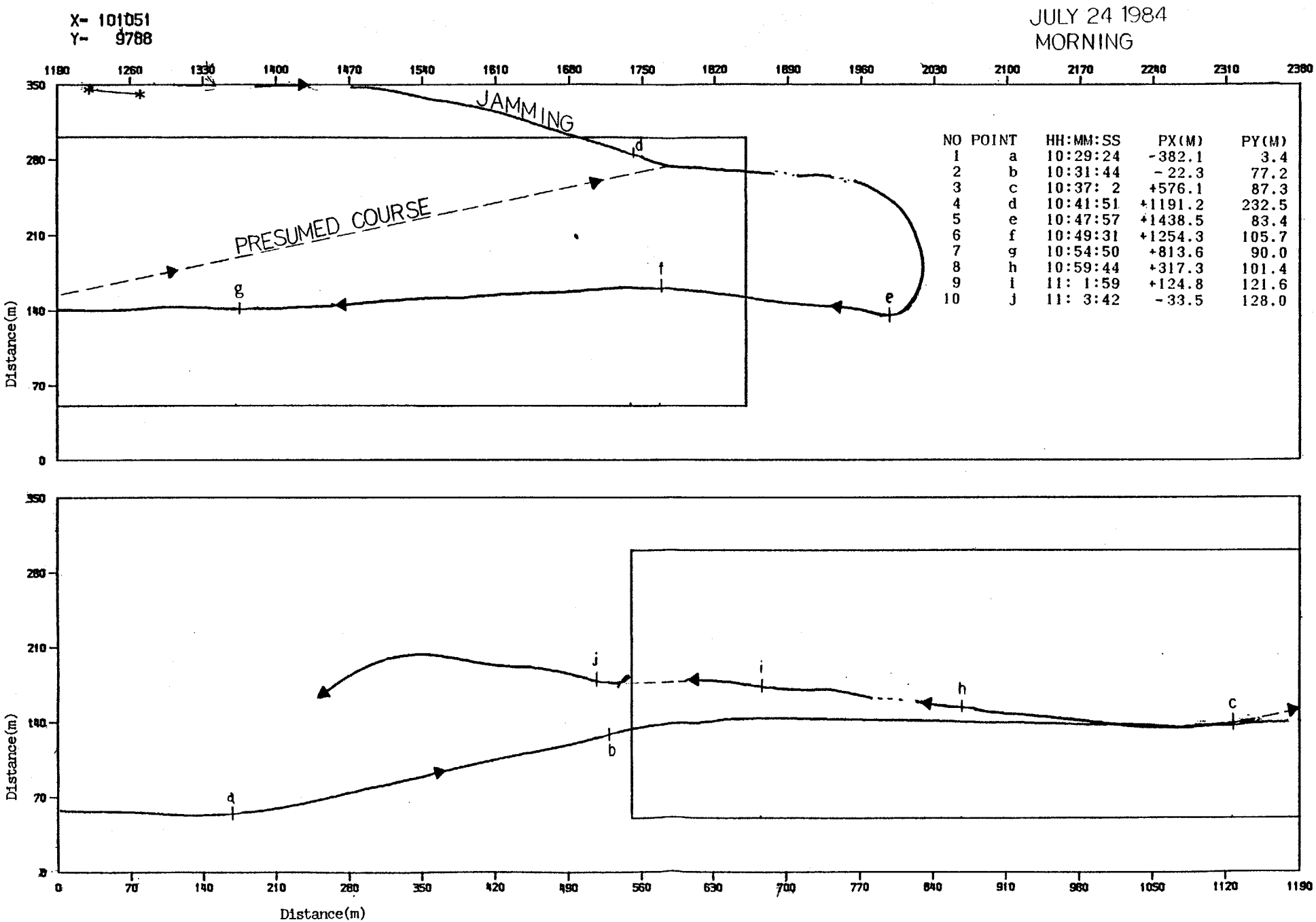
NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	10:27:35	+1267.8	231.2
2	b	10:32:35	+601.9	209.2
3	c	10:35: 6	+416.1	206.0
4	d	10:37:53	+258.2	210.1
5	e	10:40:19	+57.9	210.2
6	f	10:40:52	-13.5	212.8
7	g	10:46:27	-13.5	78.5
8	h	10:48: 2	+134.4	66.1
9	i	10:51: 6	+333.3	54.0
10	j	10:54: 8	+536.5	49.8
11	k	10:57:13	+791.0	47.4
12	l	11: 0:19	+989.0	50.5
13	m	11: 3:40	+1308.9	61.0

Fig.Ⅲ-17-1 DREDGING COURSE OF THE Kaihomaru



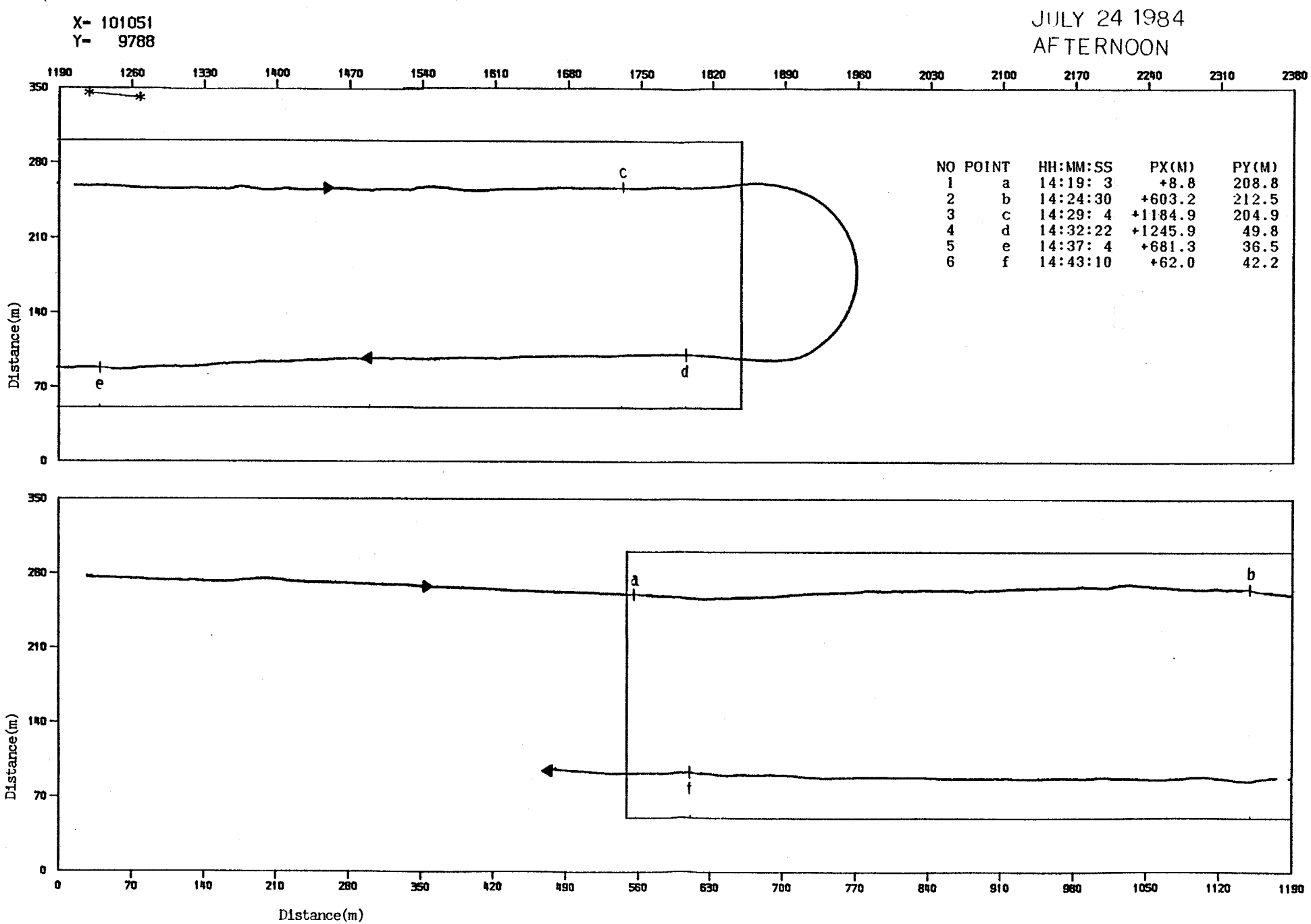
NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	14:10:38	-24.4	216.1
2	b	14:14:17	+389.9	224.3
3	c	14:19:11	+1122.3	224.5
4	d	14:23:29	+1110.0	73.0
5	e	14:28:32	+612.2	63.8
6	f	14:32: 5	+351.3	70.2
7	g	14:35: 5	+76.2	53.4
8	h	14:36: 6	-32.4	44.5

Fig.Ⅲ-17-2 DREDGING COURSE OF THE Kaihomaru



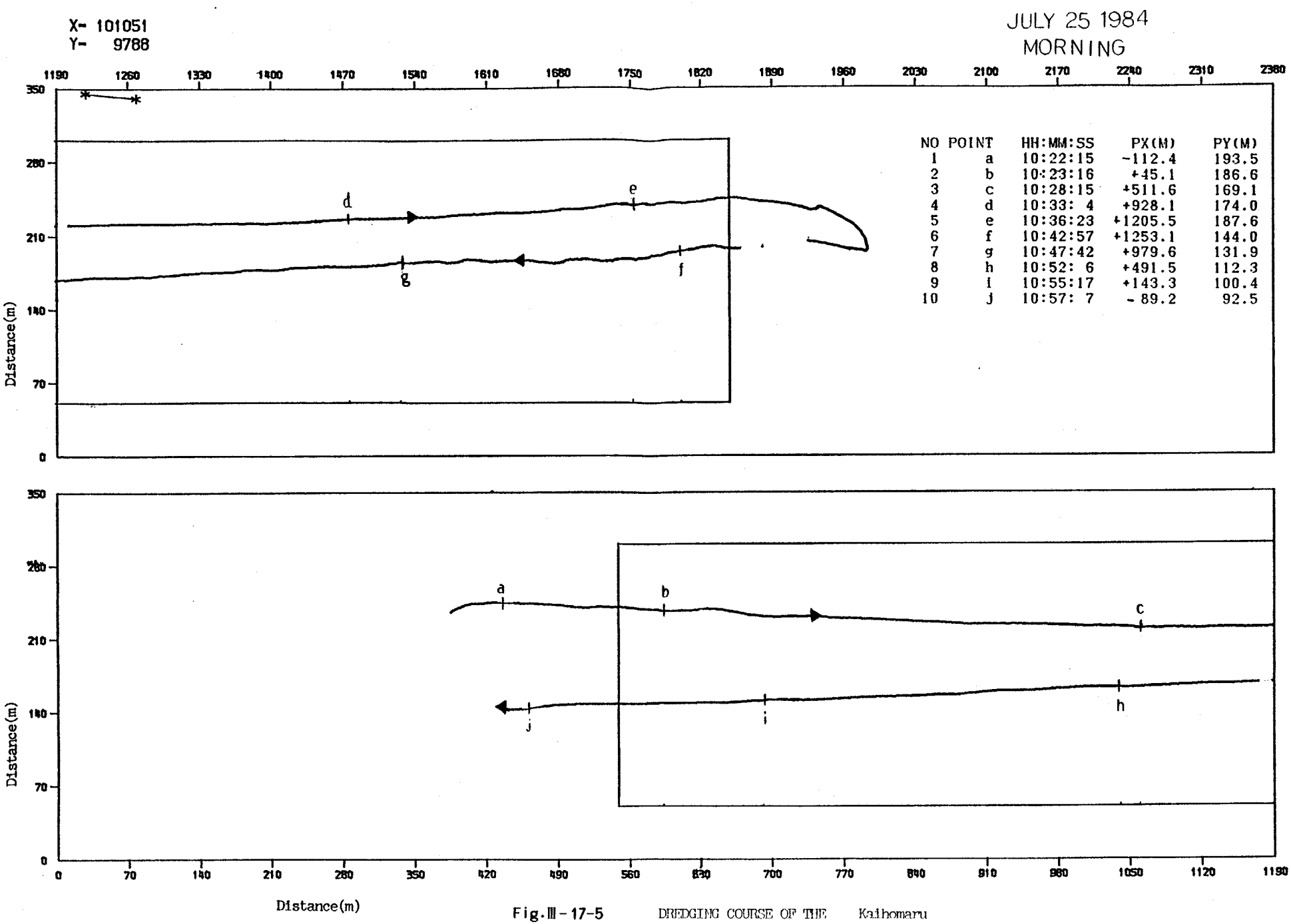
NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	10:29:24	-382.1	3.4
2	b	10:31:44	-22.3	77.2
3	c	10:37: 2	+576.1	87.3
4	d	10:41:51	+1191.2	232.5
5	e	10:47:57	+1438.5	83.4
6	f	10:49:31	+1254.3	105.7
7	g	10:54:50	+813.6	90.0
8	h	10:59:44	+317.3	101.4
9	i	11: 1:59	+124.8	121.6
10	j	11: 3:42	-33.5	128.0

Fig.Ⅲ-17-3 DREDGING COURSE OF Kaihomaru



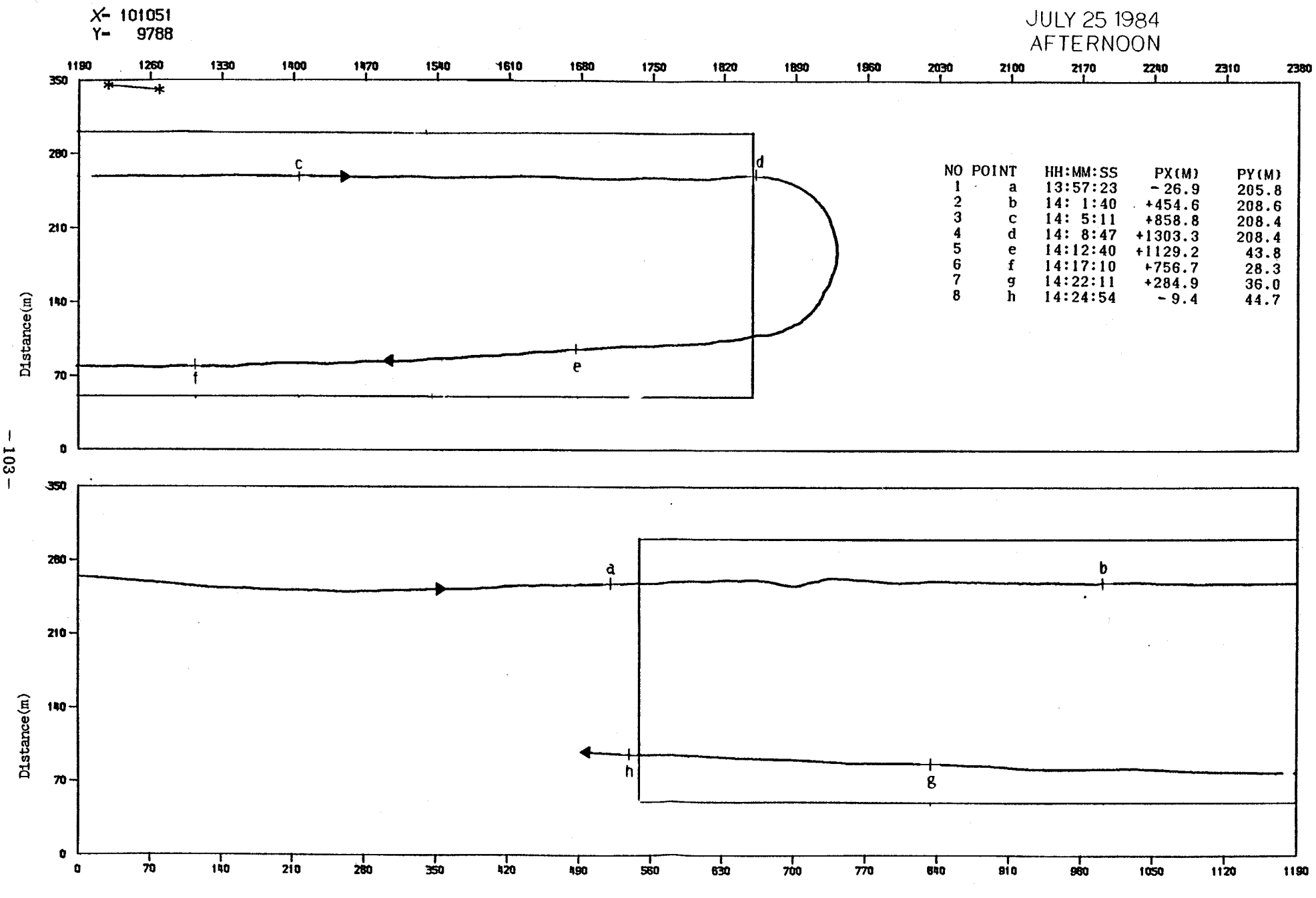
NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	14:19: 3	+8.8	208.8
2	b	14:24:30	+603.2	212.5
3	c	14:29: 4	+1184.9	204.9
4	d	14:32:22	+1245.9	49.8
5	e	14:37: 4	+681.3	36.5
6	f	14:43:10	+62.0	42.2

Fig.Ⅲ-17-4 DREDGING COURSE OF THE Kaihomaru



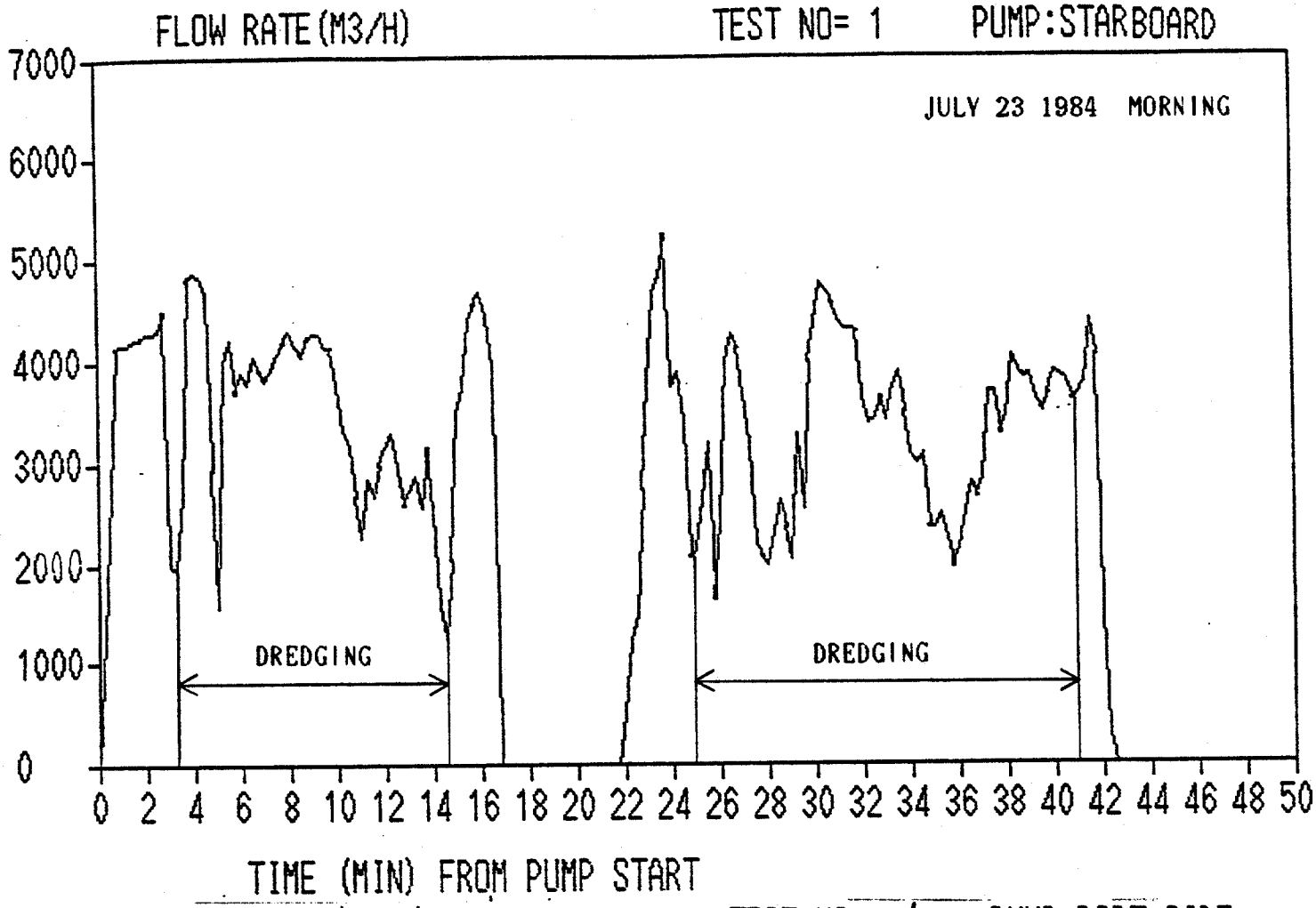
NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	10:22:15	-112.4	193.5
2	b	10:23:16	+45.1	186.6
3	c	10:28:15	+511.6	169.1
4	d	10:33: 4	+928.1	174.0
5	e	10:36:23	+1205.5	187.6
6	f	10:42:57	+1253.1	144.0
7	g	10:47:42	+979.6	131.9
8	h	10:52: 6	+491.5	112.3
9	i	10:55:17	+143.3	100.4
10	j	10:57: 7	- 89.2	92.5

Fig.Ⅲ-17-5 DREDGING COURSE OF THE Kaihomaru



NO	POINT	HH:MM:SS	PX(M)	PY(M)
1	a	13:57:23	-26.9	205.8
2	b	14: 1:40	+454.6	208.6
3	c	14: 5:11	+858.8	208.4
4	d	14: 8:47	+1303.3	208.4
5	e	14:12:40	+1129.2	43.8
6	f	14:17:10	+756.7	28.3
7	g	14:22:11	+284.9	36.0
8	h	14:24:54	-9.4	44.7

Fig.Ⅲ-17-6 DREDGING COURSE OF THE Kaihomaru



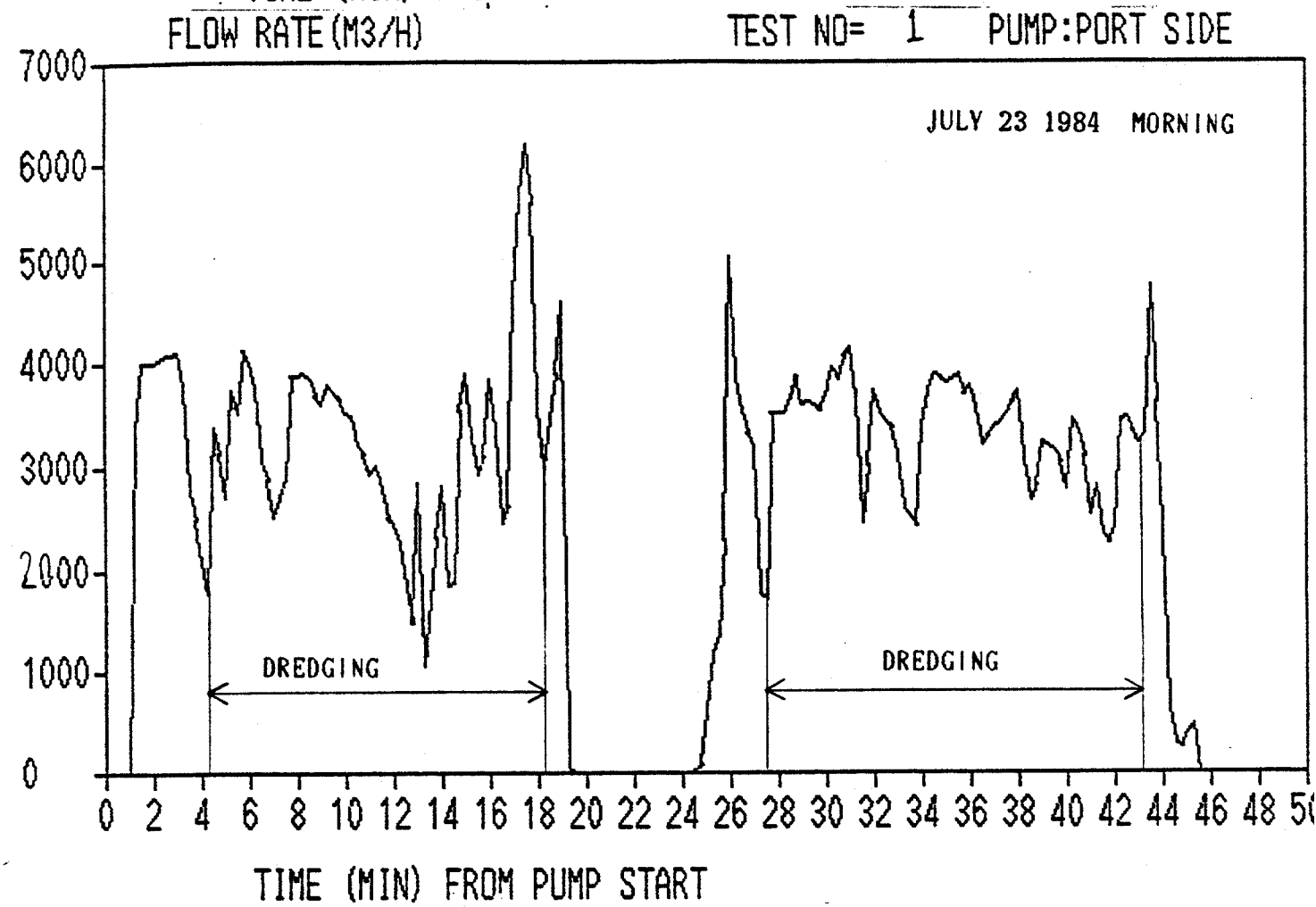
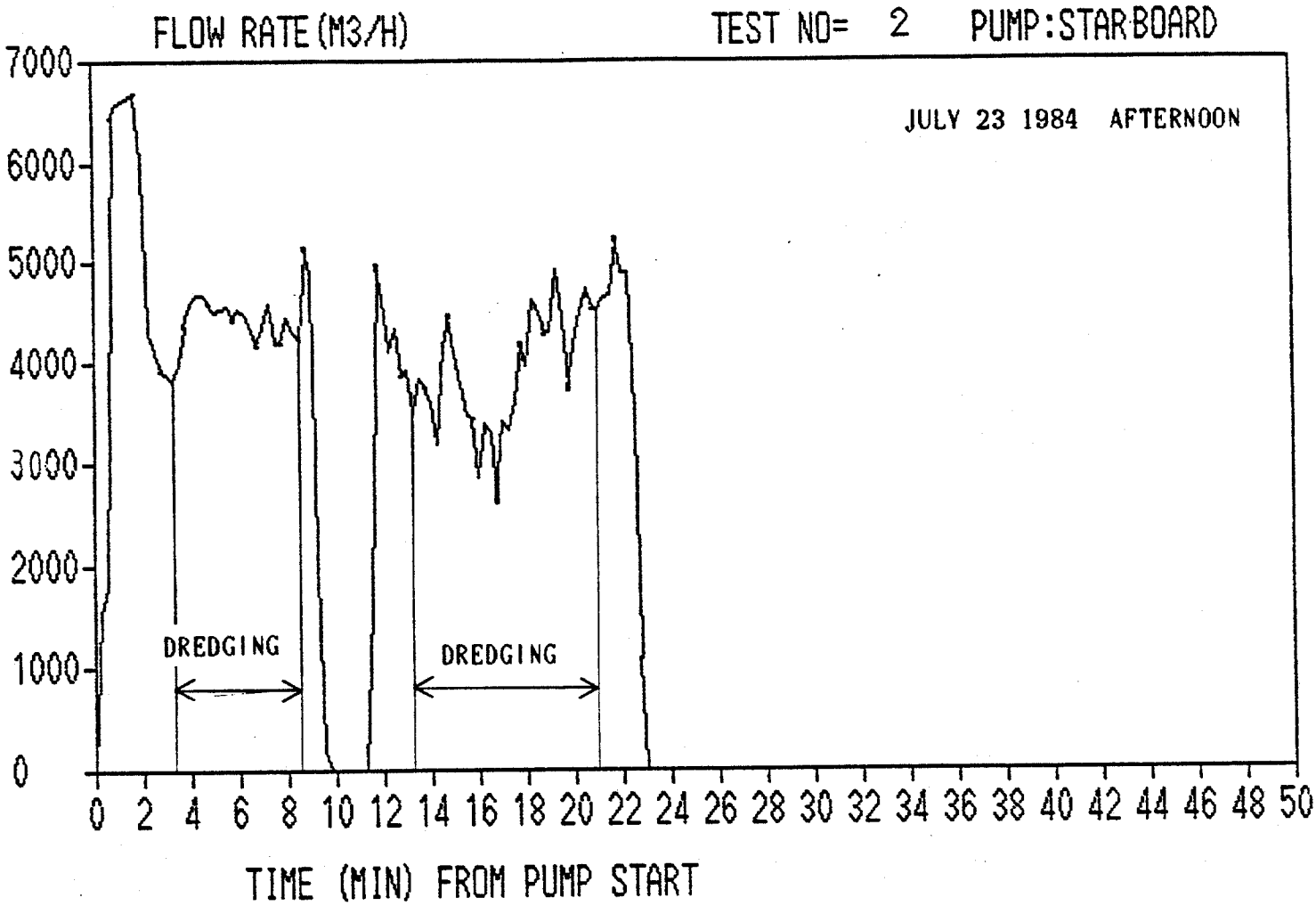


Fig. Ⅲ-18-1 FLOW RATE OF THE PUMP OF BOTH SIDES.



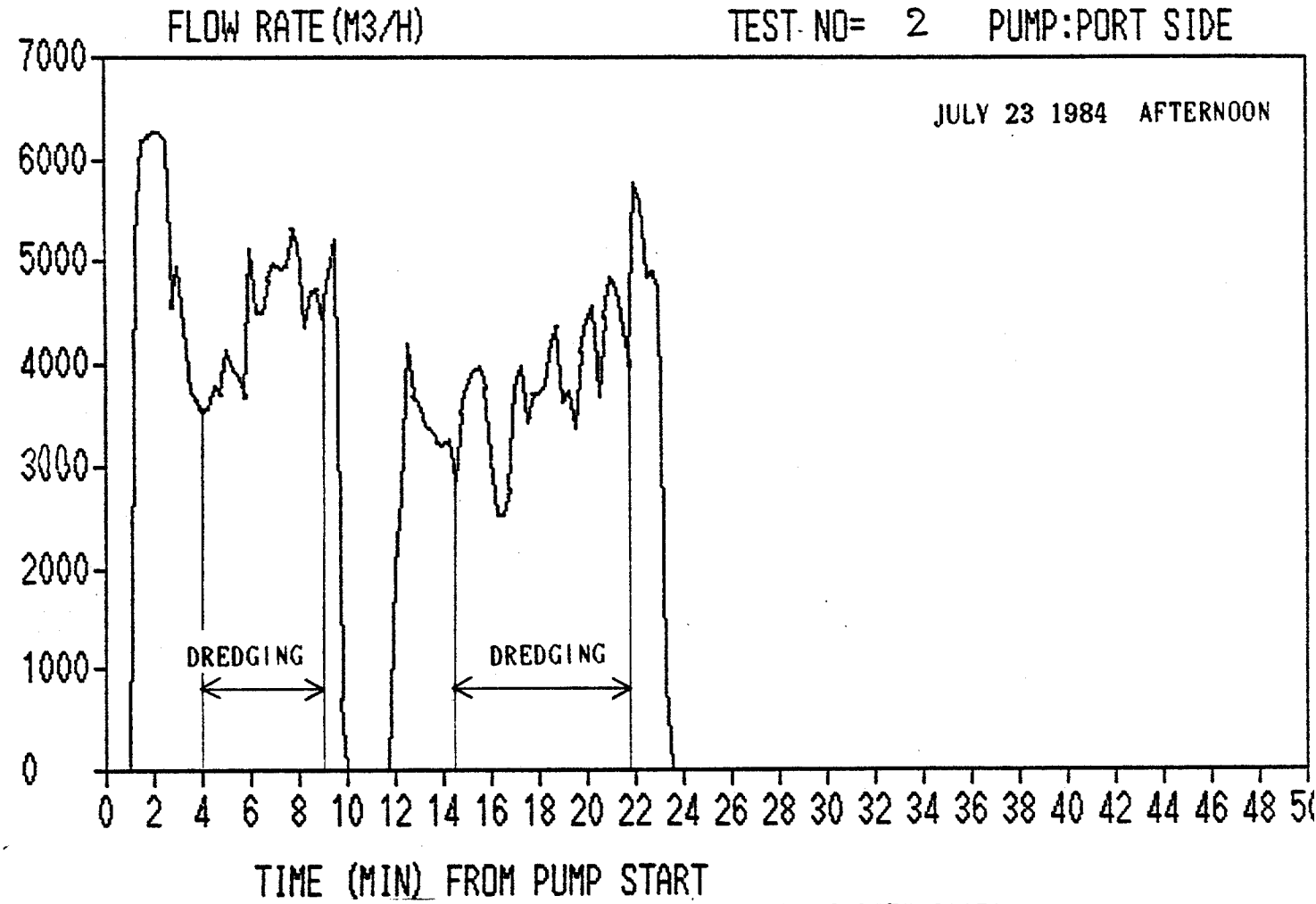
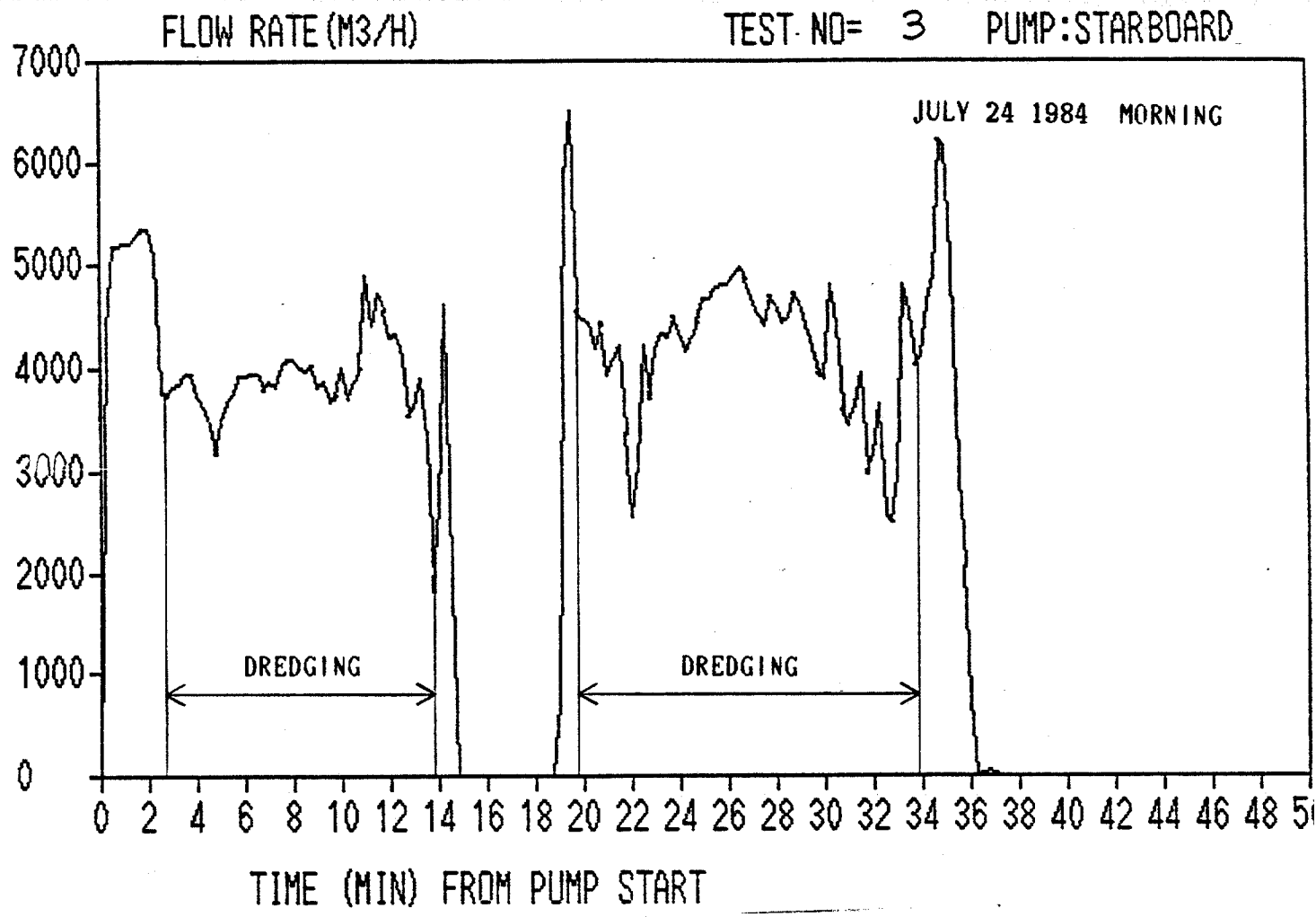


Fig. Ⅲ-18-2 FLOW RATE OF THE PUMP OF BOTH SIDES.



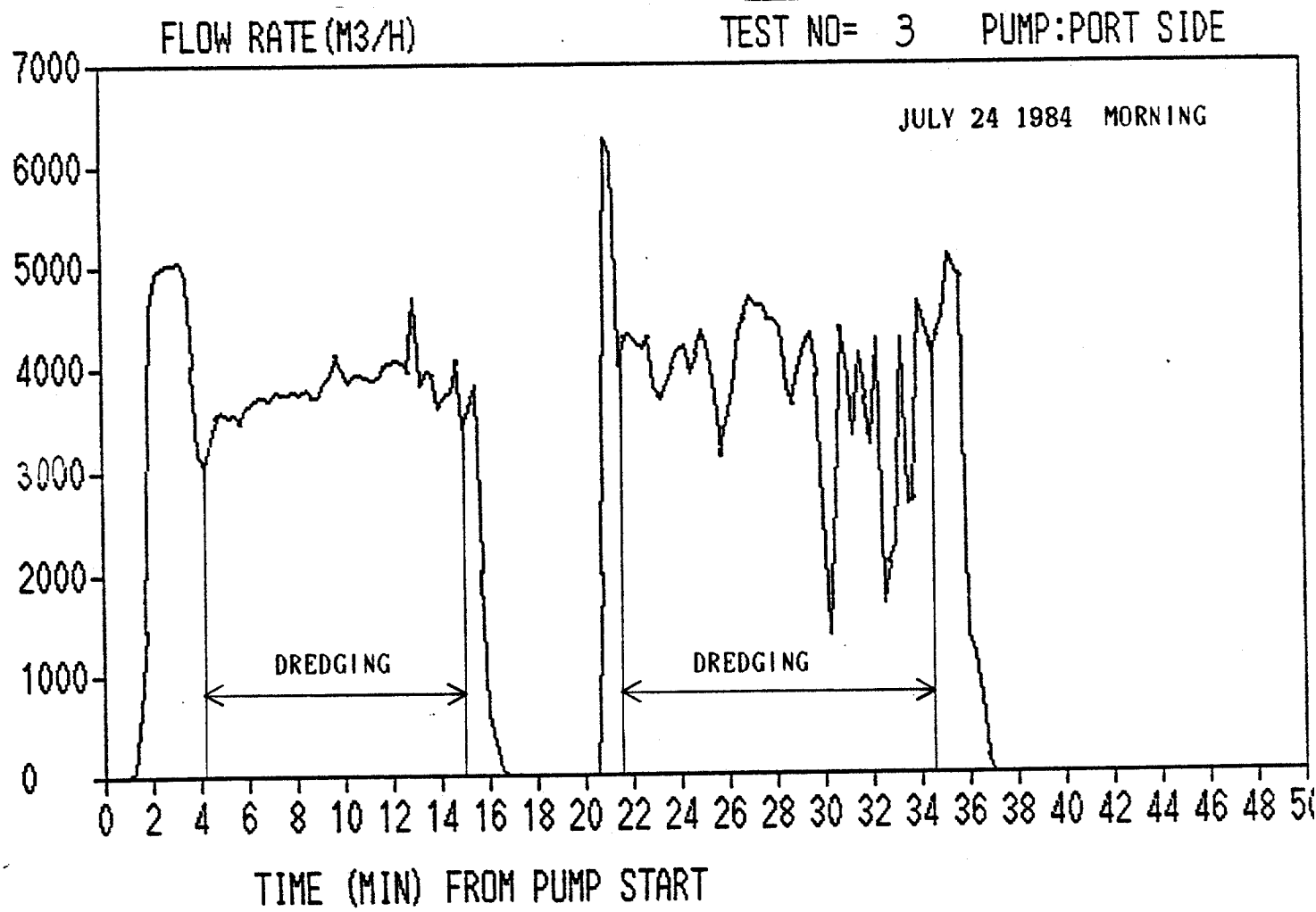
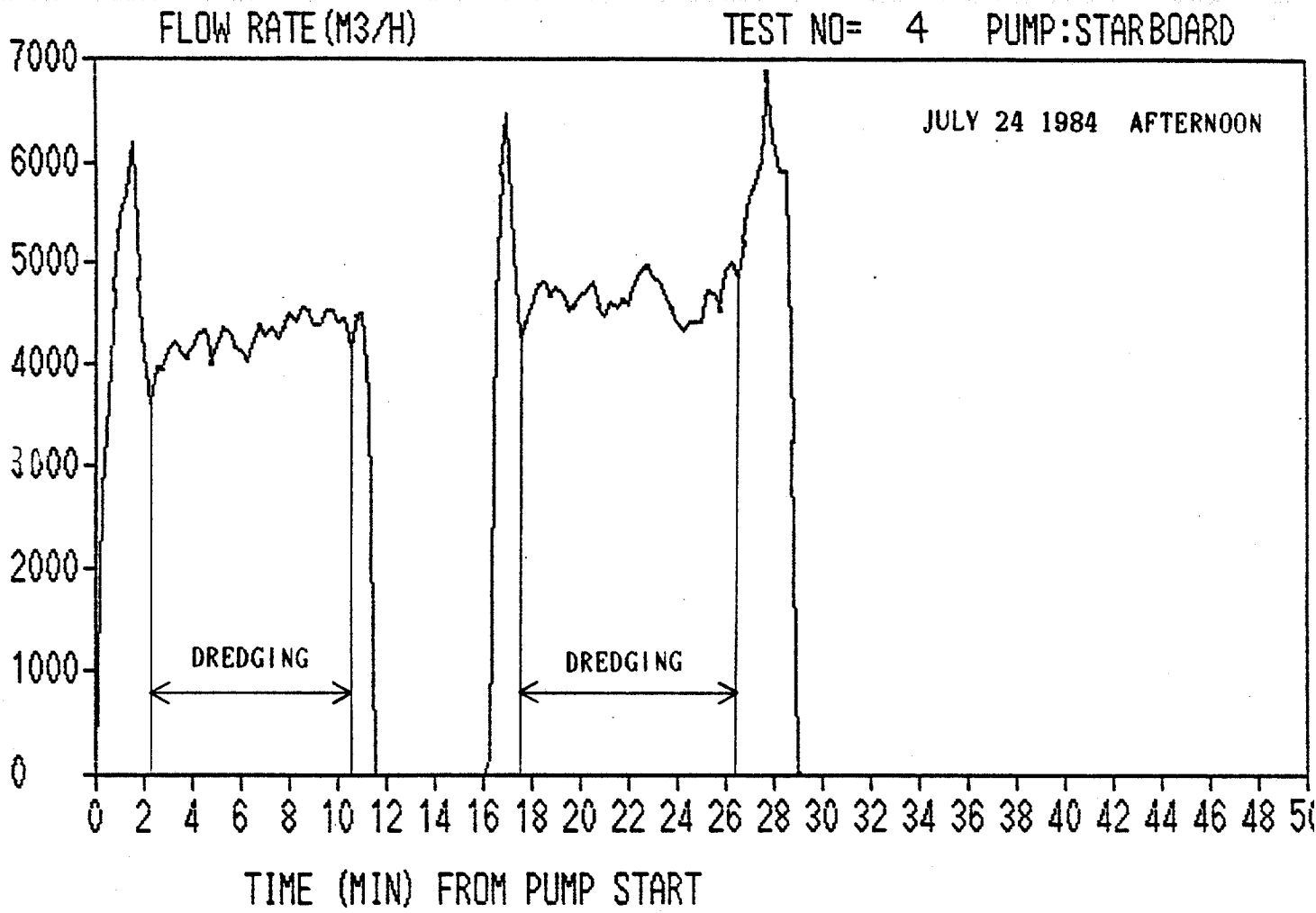


Fig. Ⅲ-18-3 FLOW RATE OF THE PUMP OF BOTH SIDES.



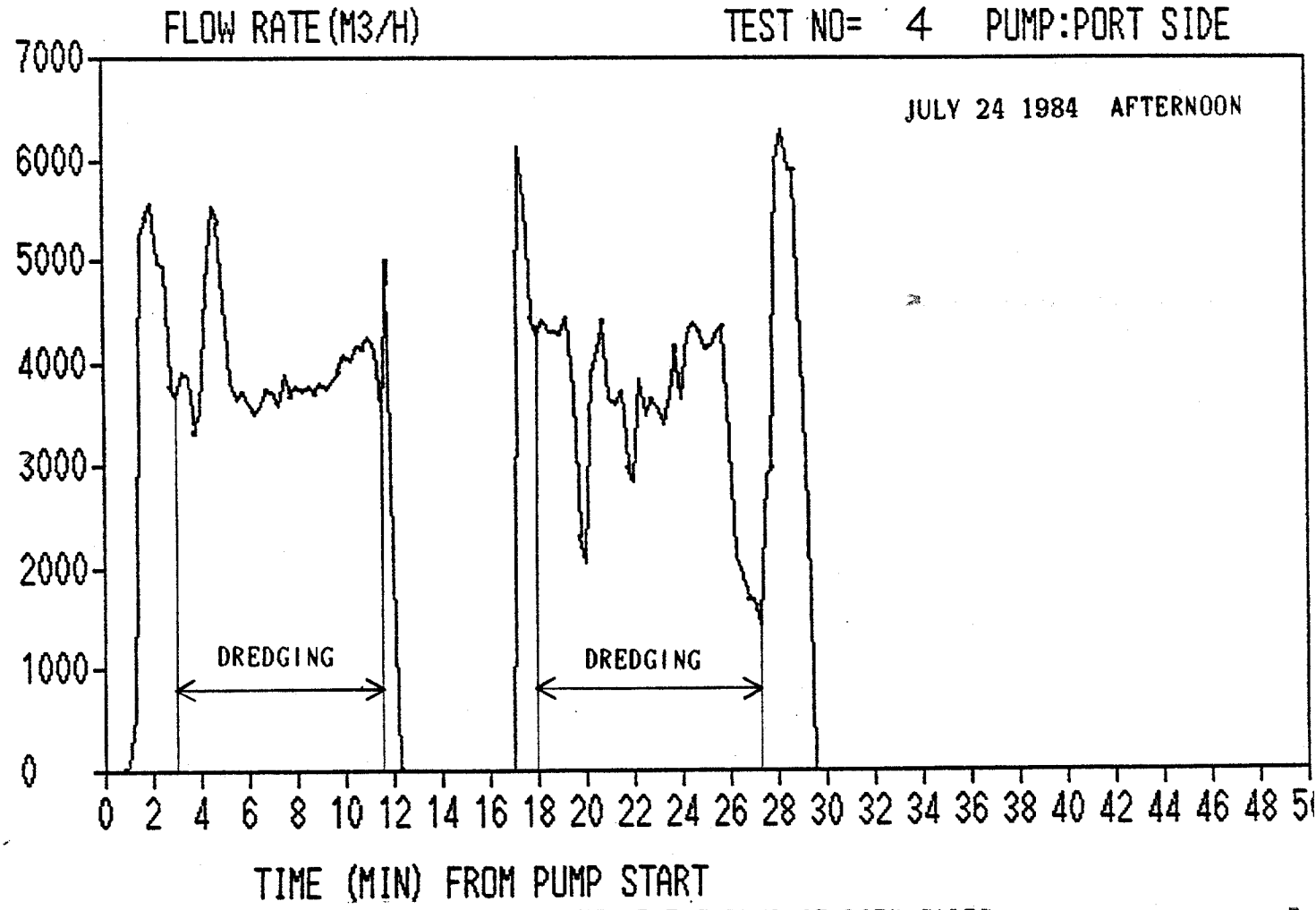
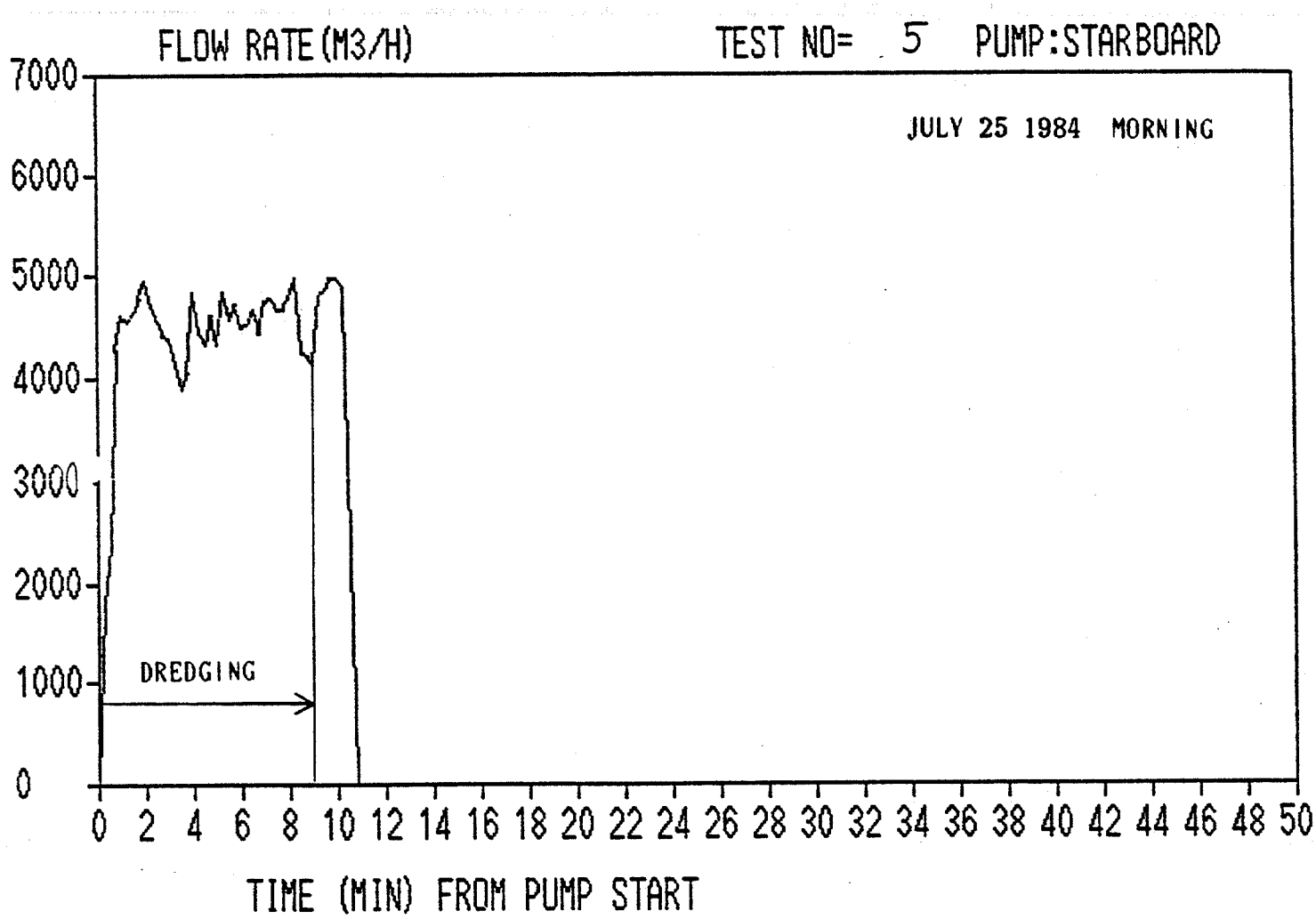


Fig. Ⅲ-18-4 FLOW RATE OF THE PUMP OF BOTH SIDES.



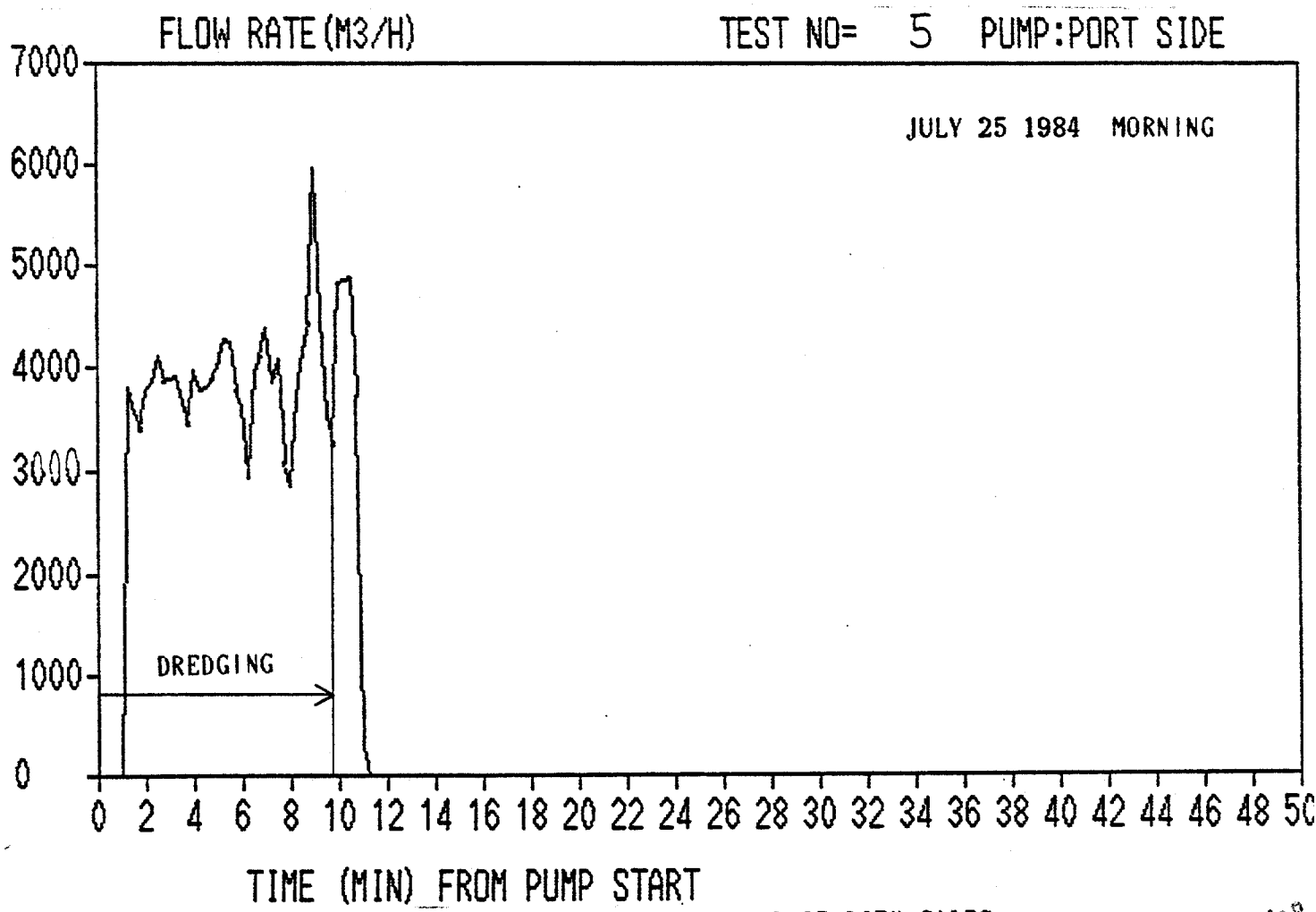
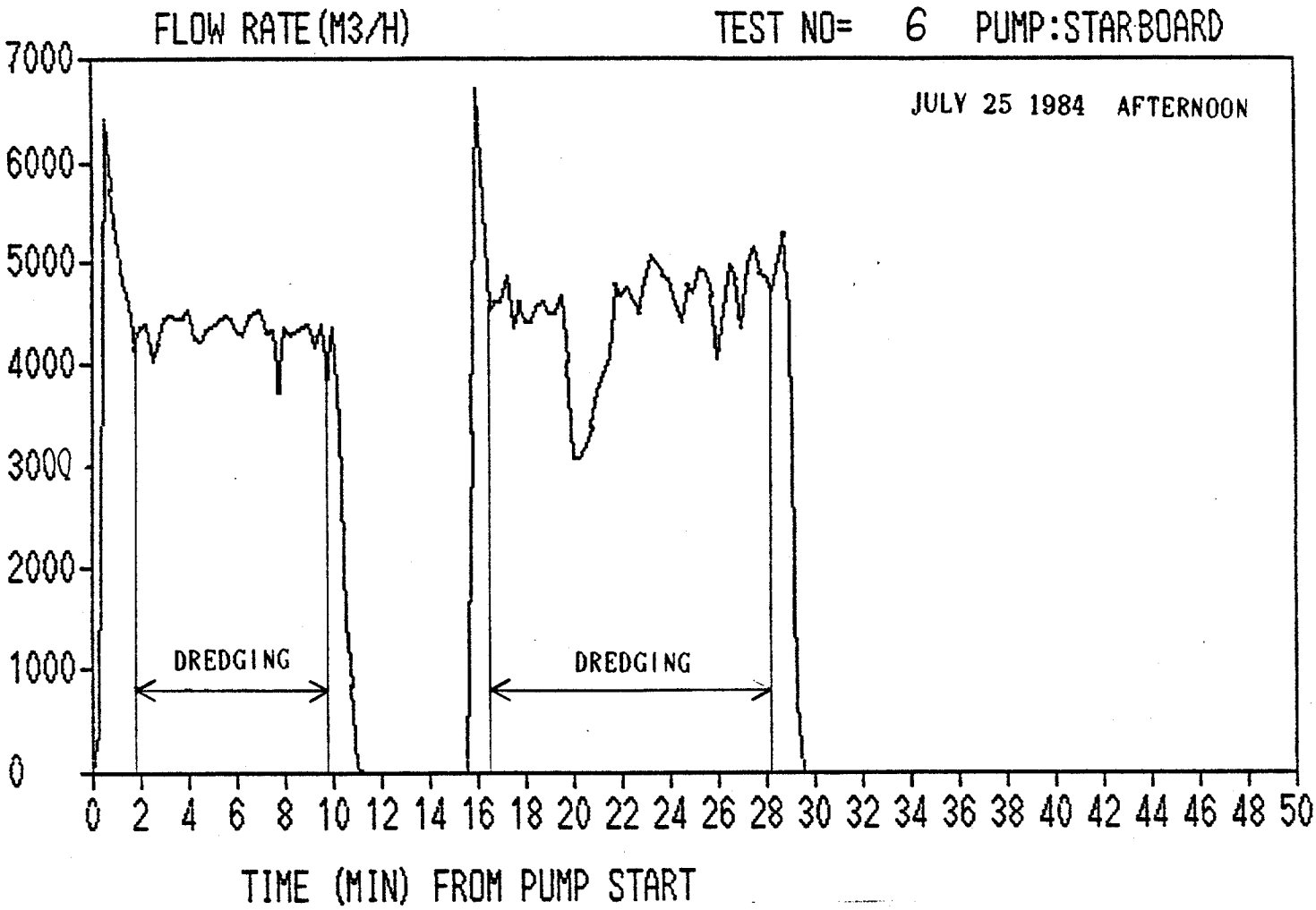


Fig. Ⅲ-18-5 FLOW RATE OF THE PUMP OF BOTH SIDES.



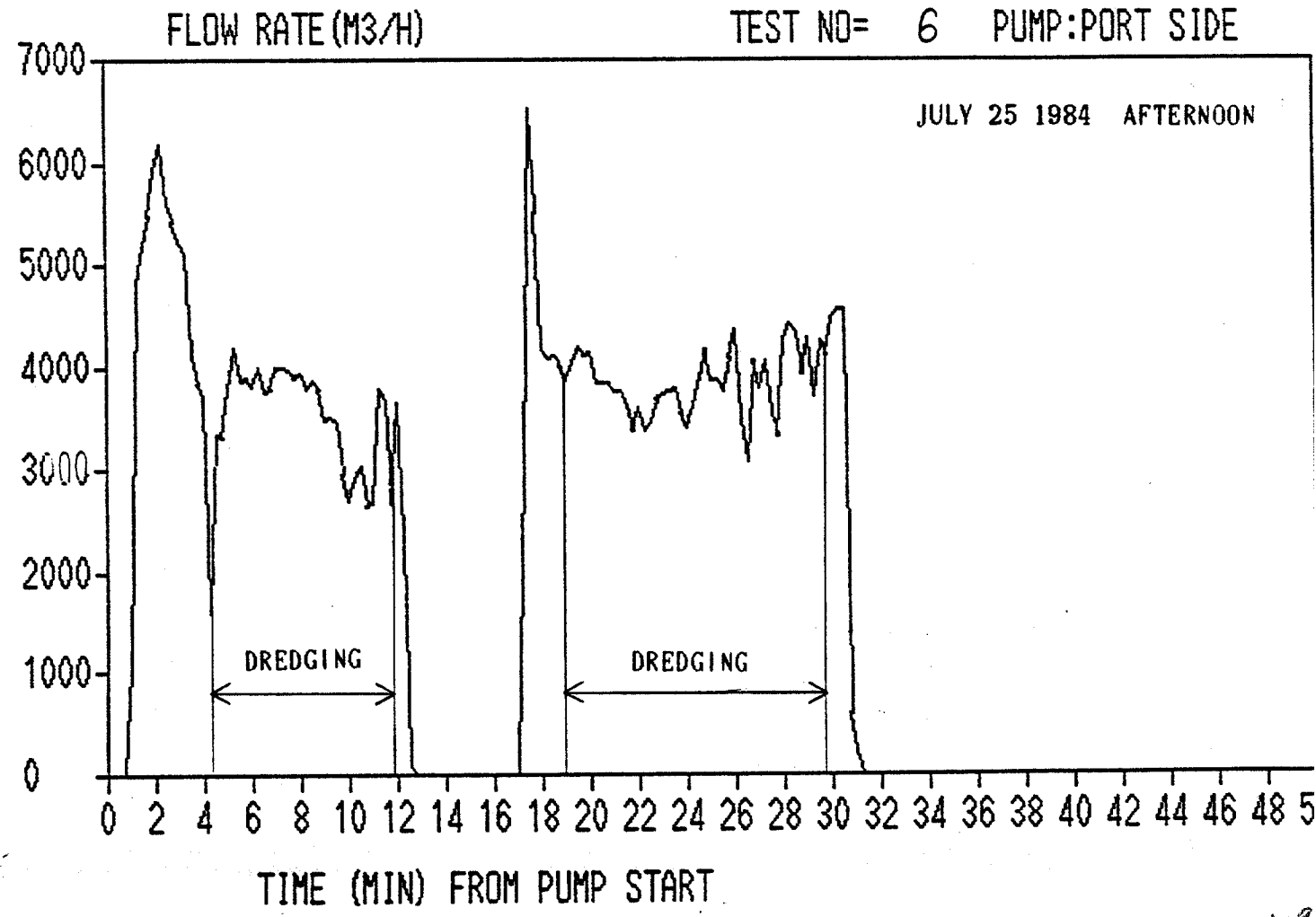


Fig. Ⅲ-18-6 FLOW RATE OF THE PUMP OF BOTH SIDES.