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Waterbouwkundig Laboratorium
Borgerhout
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SEDIMENT TRANSPORT MEASUREMENTS ON THE RIVER SCHELDT AT TEMSE

13.05.1991

I. INTRODUCTION

On may 13th 1991 a six-hours sediment transport measuring-campaign took place on the river Scheldt. During the flood period of a spring tide the water level, the velocity profile, the suspended load and the bed load, the salinity and the turbidity were continuously recorded in two verticals, from a bridge crossing the river Scheldt at Temse.

The whole campaign was a large scale cooperation between five Belgian universities and two hydraulic laboratories. This resulted not only in an extensive set of field data and a better idea about the use of different measuring-instruments, but also in understanding the behaviour of the measured hydraulic parameters during an important tidal wave.

II. MOTIVE

A sediment transport measuring-campaign was organized in the framework of an interuniversity F.K.F.O.-research project . Since January 1990 five Belgian universities (Catholic University of Leuven, Catholic University of Louvain-la-Neuve, University of Liège, University of Gent and Free University of Brussels) are working together on a 4 year study about the "Erosion, sedimentation and resuspension of partly cohesive, partly non-cohesive material, in particular due to unsteady flow". To gain more knowledge about these processes experimental work in laboratory set-ups (Gent, Leuven, Liège) is combined with field measurements (in the sewers of Brussels and Louvain-la-Neuve) and a literature review.

The subject of the research has been split up, for practical reasons, in 2 parts:

- erosion, sedimentation and resuspension of partly cohesive, partly non cohesive material in uniform flow, and
- sediment transport in unsteady flow.

For the unsteady flow part it was difficult to find field data to compare with the results of laboratory experiments carried out in Leuven. So the group decided to organize a field measuring-campaign. Besides the five universities also the Hydraulic Laboratory of Borgerhout, the Laboratory for Hydraulic Research of Chatelet and the students of the Inter University Program for Hydrology took part in the measurements.

The aim of the campaign was double :

- Collect field data of sediment transport in unsteady flow conditions. These field data can give a first idea about the evolution of sediment transport during a tidal wave. And this campaign will also allow a comparison between field data and results of analogous lab experiments.
- Try out and get acquainted to different instruments and techniques for measuring sediment transport in the field.

III. DESCRIPTION OF THE MEASURING-CAMPAIGN

1. *General information.*

Since the subject of the measuring-campaign was to measure sediment transport in unsteady flow, it was decided to work on the tidal part of the river Scheldt during a tidal wave. To be able to collect as much usefull data as possible, measurements were made on may 13th, spring tide, during the flood period. Thus higher discharge-, higher velocity- and higher water level differences could be measured and greater sediment load variations could be expected.

The predicted tides for that day at the choosen site were :

low tide	at 11:33h	-0.25 m (TAW)
high tide	at 16:24h	5.86 m (TAW)
low tide	at 23:54h	-0.24 m (TAW)

In figure 1 it can be seen that, in order to start measuring at the beginning of the flood (slack water on the ebb), the campaign was started at 12:00h. The end (slack water on the flood) was planned to be around 17:30h.

Figure 1 also gives some information about the discharges, velocities and water levels to be expected during a spring tide on the river Scheldt near Temse.

Between 12:00 h and 17:30h continuously measurements were made in two verticals. In each point there were two students per measuring-instrument to collect and record the data. They were guided by technicians and scientific personnel of the universities and laboratories that participated.

2. *Site description.*

As location for this campaign a bridge crossing the river Scheldt at Temse was chosen (figure 2). Temse is approximately 98.5 km upstream from the mouth of the river Scheldt and about 25 km upstream from Antwerp. At Temse, the river has a width of about 300 m and the tidal levels are more or less the same as in Antwerp, with a delay of one hour.

The bridge is a combined railroad - road traffic bridge and has a steel superstructure. Next to the railroad, at the downstream side of the bridge, is a footpath (width 1 m) that is hardly ever used (figure 3). This pavement could be closed for a whole day without causing problems and it would make an undisturbed working area. The bridgerails at both sides of the path were handy to fix the instruments firmly.

The bridge has six spans, the total length is 375 m. The second span, starting from the left bank, is a movable part, used mainly for ocean going navigation, and can not be used for measurements. Other ships use also spans 3 and 4; but in consultation with the Dienst van de Zeeschelde, all navigation could be sent through spans 2 and 3 during our measurements.

On a preliminary visit of the site it was noticed that most of the sediment passed through spans 2,3 and 4, although also in the side parts of the river suspended sediment could be seen.

In the following table the mean bottom levels under the bridge are given for each span :

Span no.	1	2	3	4	5	6
Bottom (m TAW)	-4.5	-8	-6	-5.5	-1.5	+0.5

Taking into account depth, visual sediment transport and the disturbing of navigation, span 4 was chosen for the measurements. In figure 4 the position of the two measuring points (A and B) is given.

The distance between the road surface and the bottom of the river was everywhere less than 20 m. Since the winch cables, to which the used instruments were connected, were all longer than 20 m, this was not a problem.

Measurements were made at the downstream side of the bridge so that during flood the influence of the bridge piers was avoided.

3. Measurements

The following measurements were taken :

water level	reading from a staff gauge
velocity profile	OTT-current meter
salinity, temperature	probe
suspended sediment concentration	pump sampler
turbidity	Partech
bed load	BTMA

In each point two winches were installed : one for a pump sampler and one for the current meter, the Partech turbidity meter and the temperature/salinity probe. In point A there was also a special winch for the BTMA. Generators provided the necessary electrical energy.

IV. FIELD OBSERVATIONS & RESULTS

1. Water level measurements

Water level measurements were recorded in the following three ways :

- a) From the staff gauge attached to the bridge pier; observations were done at every 3 minutes.
- b) By OTT current meter during measurements taken at each vertical.
- c) By BTMA during each sampling.

From measurements b en c only these values were used which were recorded when the winch cables were not inclined.

Fig. 5 shows the average value of the water depth obtained from the three sources and plotted with respect to time. After 16:30 h maximum water level rises to 5.5 m from the water level recorded at 12:00 h. Converted to the TAW-reference system, the maximum water level is 5.75 m TAW which corresponds very well with the predicted tidal level. The level at 12:00 h was + 0.4 m TAW.

2. Velocity measurements

An OTT current meter was used to measure the velocity at different levels of a vertical during the passing of the flood. Using the winch the OTT-current meter was brought to a certain depth. The number of revolutions per time step of the propeller, which is proportional to the flow velocity at that depth, is then recorded. For each velocity profile these measurements were taken at 0.4 m and 1.0 m. from the bottom and at 0.2D, 0.4D, 0.6D and 0.8D and 0.3 m from the surface; D being the total depth at the beginning of the measurement of that profile. In this way continuously profiles were measured. Fig. 6(a) to Fig. 6(p) show the velocity profile at different times. It has been observed that the velocity profile at 15:29 h, 15:47 h and 16:02 h shows some irregular pattern. This may be because of the highly turbulent situation of the flow when the velocity approaches its peak value. During the recession of the flood i.e. beyond the time 16:12 h the pattern of the velocity profile gets better. Fig. 7(a) to Fig. 7(g) shows the temporal variation of velocities at seven levels of the vertical.

Possible sources of error :

Following are the possible sources of error :

- a) Instrumental error = 5 %.
- b) Inaccurate determination of the measuring depth due to the horizontal movement of the instrument due to current.
- c) Due to time lag between the first and last reading in a vertical.

3. *Suspended materials*

Suspended sediment concentration profiles were measured continuously by taking 1 liter samples at predefined depths (i.e. the same depths as in the velocity profiles) using a pump sampler. The samples were collected in bottles on which sample number, location, time and depth were noted for later analysis. In the laboratory the sediment concentration of each sample was determined by filtration. Before being filtered through the filter having pore size 5 μm the sample was shaken through the ultrasonic mixer for 5 minutes. One typical sample analysis sheet used to calculate the concentration in mg/l is shown in Appendix 1.

Fig. 8(a) to Fig. 8(l) shows the suspended sediment concentration profile during flood.

Because of short sampling periods, results may not be accurate but errors cannot be reduced by collecting samples for longer periods because of the non-steady hydraulic conditions.

Fig. 8(m) shows the temporal variation of suspended load and a comparison with the velocity variation. Both measurements were taken at 1 m above the bed.

4. *Turbidity*

Two Partech turbidity sensors from the Antwerpse Zeediensten were used to monitor turbidity. The Partech has three spans which were in this case calibrated as : span 1 : 0 to 500 ppm; span 2 : 0 to 1000 ppm; span 3 : 0 to 2000 ppm. In each point the Partech was also connected to the same cable as the OTT. When measuring simultaneously with the OTT, a reading between 0 and 100 was recorded together with the span number. Although turbidity was not measured at the same time and location as the suspended sediments, one still can get similarities in vertical distribution pattern and magnitude among the two measured parameters. Fig 9(a) to Fig. 9(o) shows the different measured turbidity profiles.

5. *Bed material transport*

In point A the bed load was measured using a Bed load Transport Meter Arnhem (BTMA). The instrument was let down unto the bottom by a special winch and left there for 10 minutes. During that time water laden with sediments flows through the funnel, that only traps the sediment coarser than 0.13 mm and finer than 50 mm. Afterwards the instrument is taken out of the water and emptied in a collection tank. From that tank the sediment is flushed into a sample box. In total 16 samples were collected. In the laboratory the total amount of sediment and the sieve analysis of each sample are determined. Fig. 10 shows the bed load transport variation with respect to time.

The maximum transport rate in kg/s/m was reached at 15:55 h which is at the same time as the velocity reached its maximum. Bed material was collected 3 h and 52 minutes before and 1 h 36 minutes after the time of maximum transport rate. Total transport during the rising limb (i.e. from 12:00 h to 15:55 h) was 28,9 kg/m and during the falling limb (i.e. from 15:55 h to 17:30 h) was 12,7 kg/m (Fig. 10).

6. Salinity & Temperature

Along with the velocity measurements salinity and temperature were also measured at the same time and location. Measured temperature varied between 13.2 to 13.8°C during the flood. It has been observed that salinity does not change along the vertical which gives the evidence of the well mixed salinity. Because of this character of the flow the average value of salinity for each vertical was plotted against time which may be seen in Fig. 11.

7. Friction velocity

From the collected data a friction velocity (u_*) can be determined using the following methods :

1. The general expression for the logarithmic velocity distribution is :

$$\frac{u}{u_*} = \frac{1}{K} \ln y + C$$

with u = velocity

K = Von Karman constant

y = depth

C = constant depending on boundary conditions

u_* = friction velocity

By applying this logarithmic law to the measured velocity profiles, u_* can be determined.

- 2.a. In uniform flow conditions u_* can be calculated from the channel slope using $u_* = \sqrt{gRS}$, where R = the hydraulic radius, g = acceleration of gravity and S is the bed slope.

- b. The friction velocity in unsteady flow conditions can be deduced from the St. Venant equation, given by W. Graf as

$$u_*^2 = R \left[g \left(\frac{1}{c} \frac{\partial y}{\partial t} + S_0 \right) - \frac{\partial u}{\partial t} \left(1 - \frac{u}{c} \right) \right]$$

with c = wave celerity = $u + \sqrt{gy}$

S_0 = bottom slope

For the river Scheldt at Temse the exact hydraulic radius is not known. For using methods 2a and 2b the local depth in the measuring position was taken as R-value.

The results of these calculations can be seen in Fig. 12 together with the water level hydrograph. Method 1 and method 2b give the same sort of result-maximum u_* -values occur before maximum water level - but give different u_* - and time lag-values. This is mainly due to the choice of the local depth as R-value. Changing this R-value by 1 m or more gives a significant difference, as is explained in Fig. 13.

8. Overview of different parameters

Fig. 14

Kabir, M. Eng.

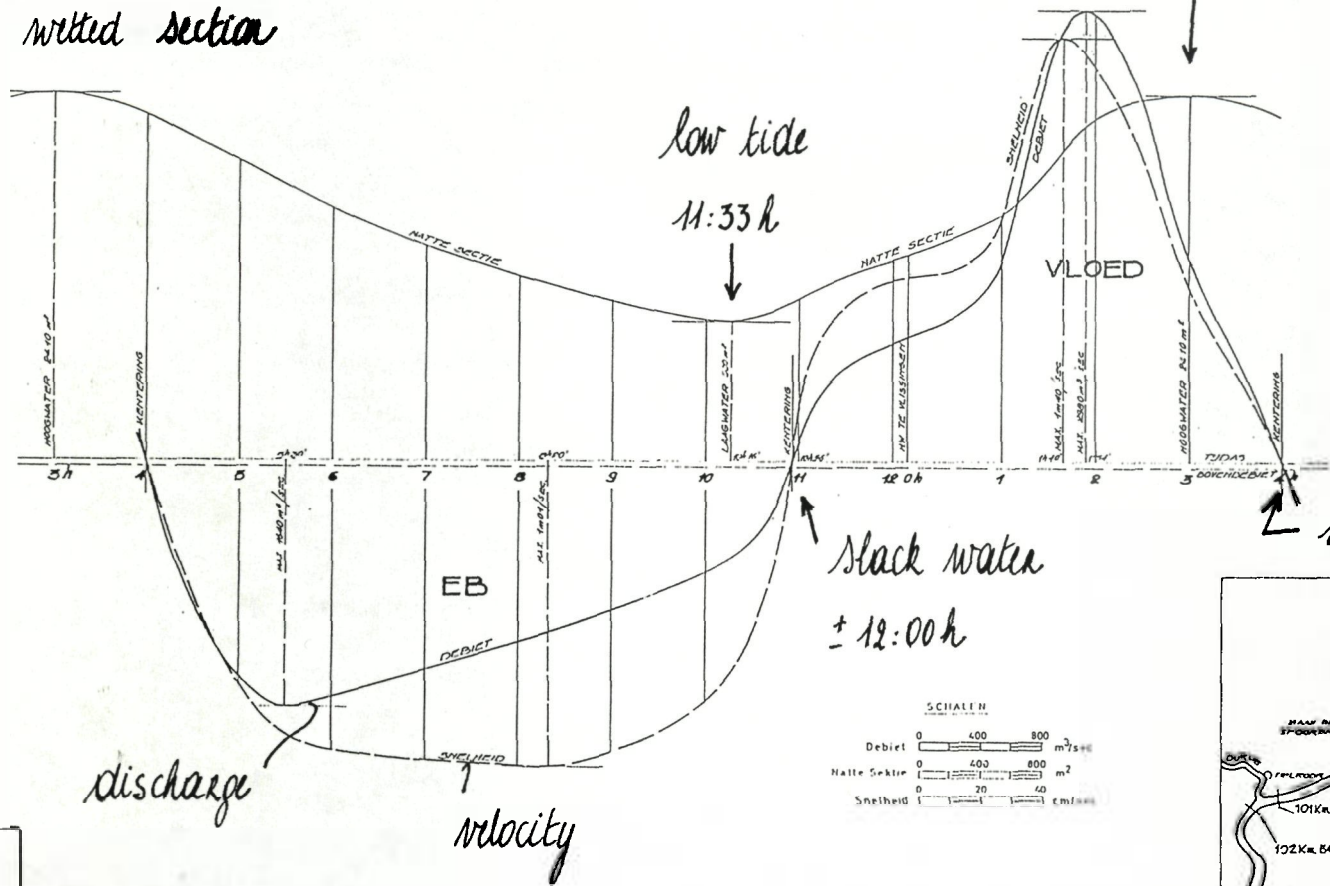
Ir. H. Torfs

TJRESSE SCHELDEREN
1941-1950

5 SCHELDE SPRINGTJ 5 IV. 1950
13 97Km 560 OPW MONDING SCHELDE

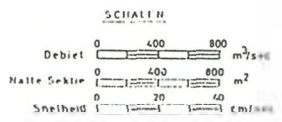
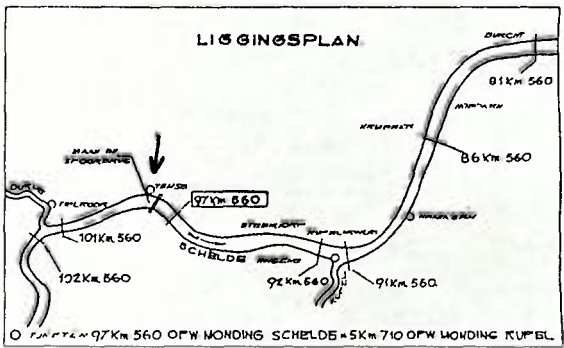
HOOE WATER 5m79 OM 5:00	TJVERSCHIL 5m40
LAAG WATER 0m31 OM 10:15	
Duur: 3:30min DALING	3:30 1:15

wetted section



	VLOED	EB
KENTERING	4:00	10:30
Duur	5:14	6:58
GEN DEBIET	1300 m ³ /SEC	1080 m ³ /SEC
MAX DEBIET	2300 m ³ /SEC OM 1:51	1400 m ³ /SEC OM 5:30
GEN Snelheid	0m71/SEC	0m88/SEC
MAX Snelheid	1m40/SEC OM 1:40	1m01/SEC OM 8:20
TJVOLUME	65.707.380 m ³	67.571.780 m ³
DOVENDEBIET PER SEC		38 m ³
DOVENDEBIET PER BETUUF		166.400 m ³
KAPACITEIT		50.034.810 m ³
TOTAAL VLOEDDEBIET		080
TOTAAL DOVENDEBIET		065

Slack water ± 17:00h



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Springtide

Fig. 1

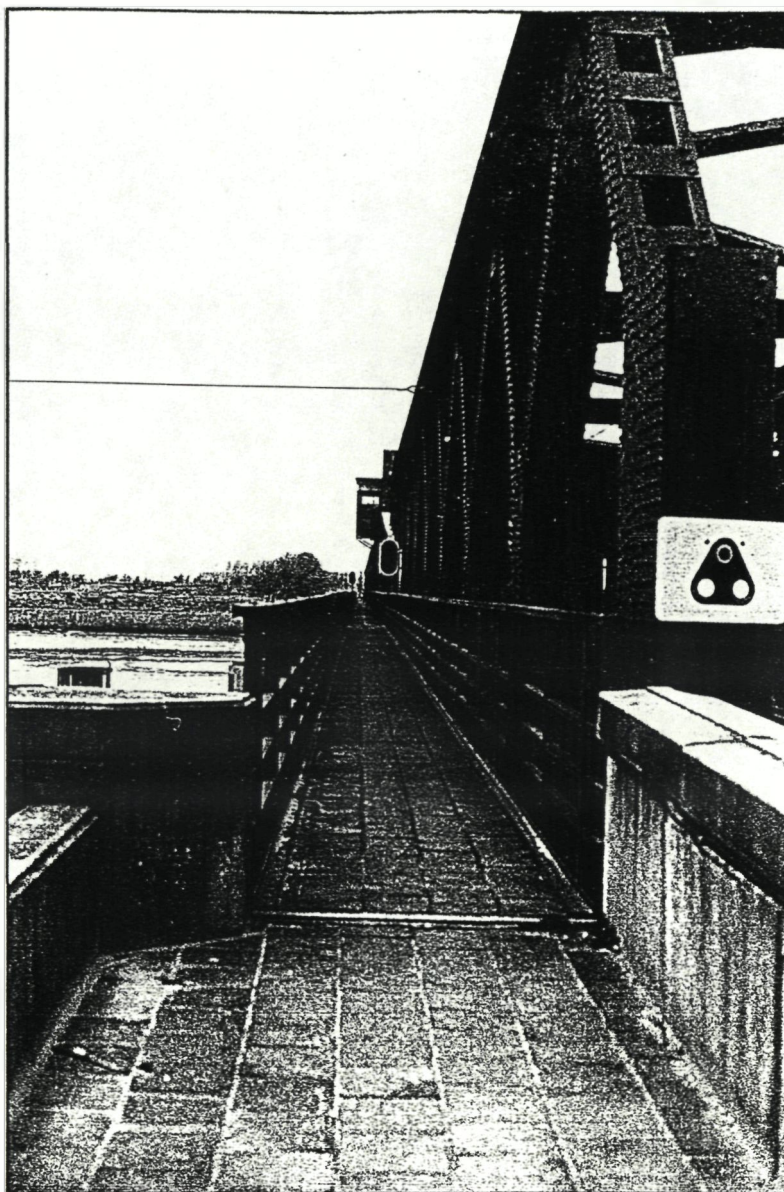


Fig. 3.

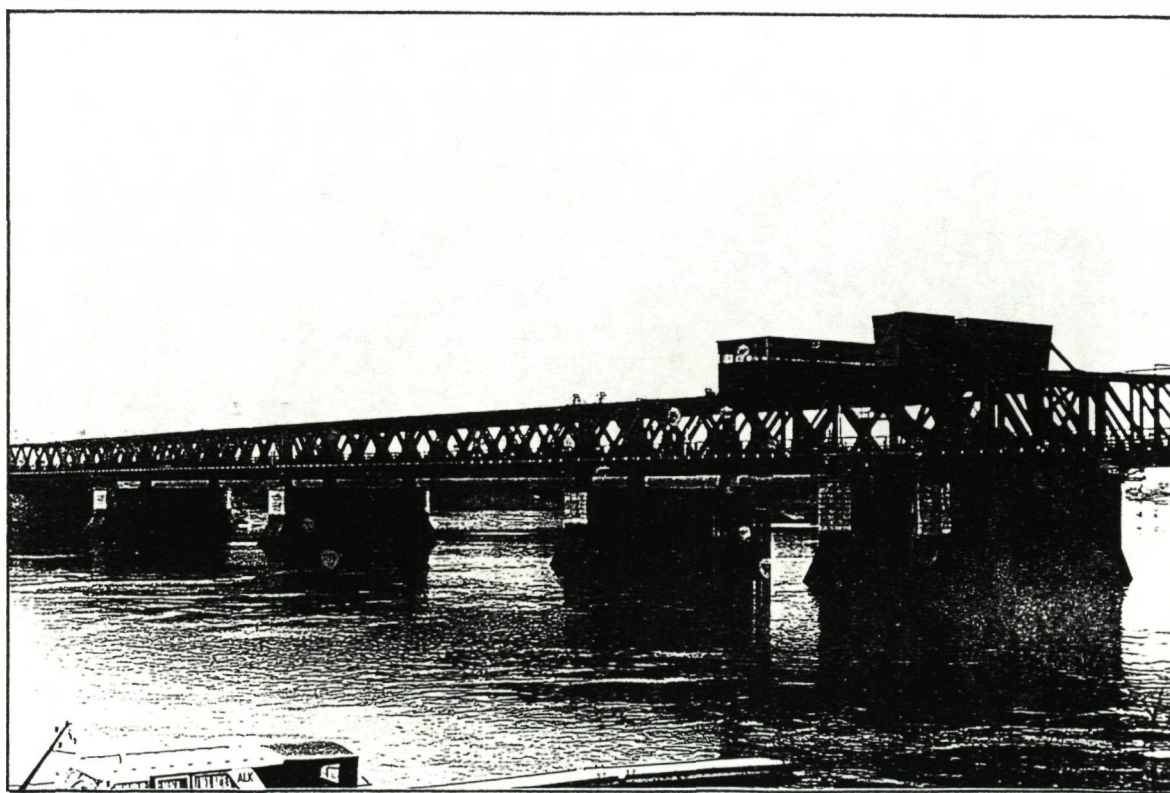


Fig. 2.

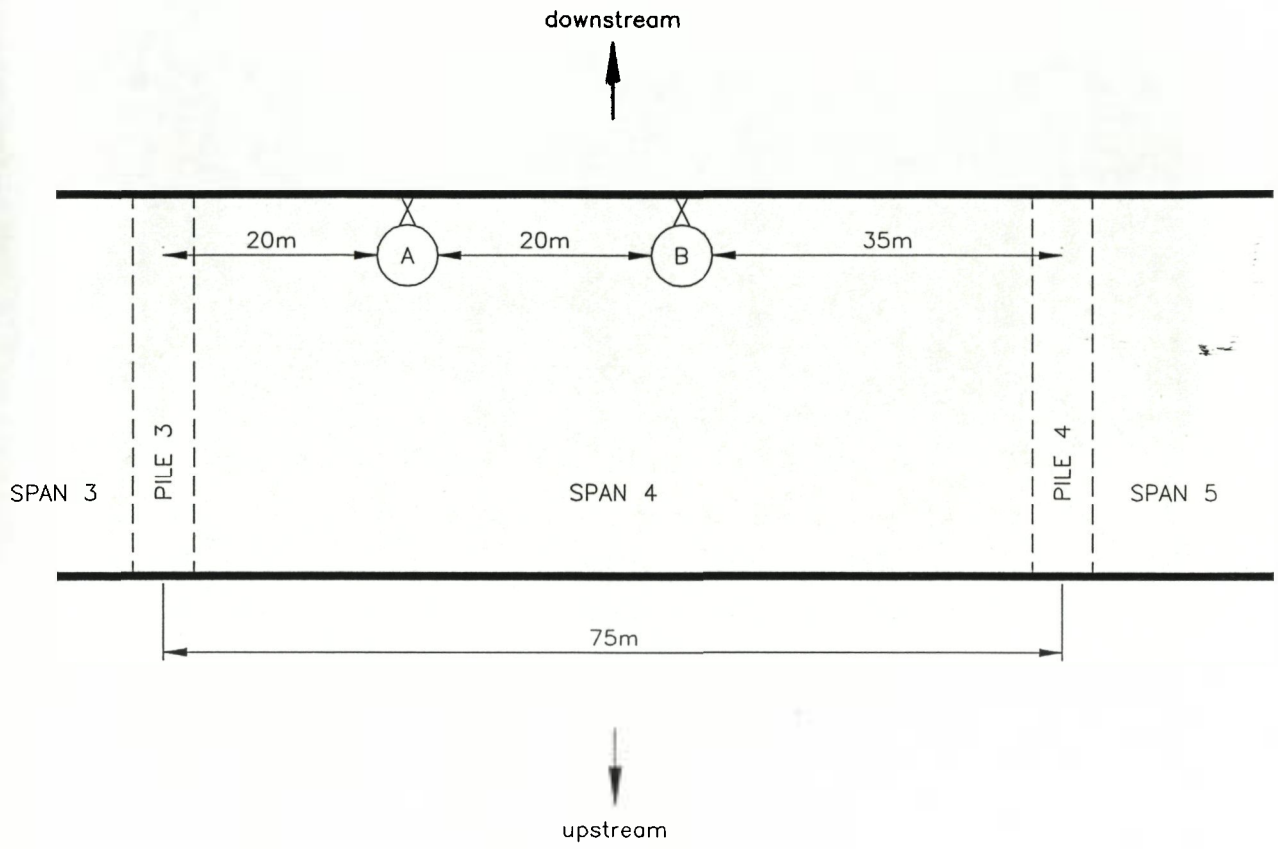


Fig. 4 : Measuring positions

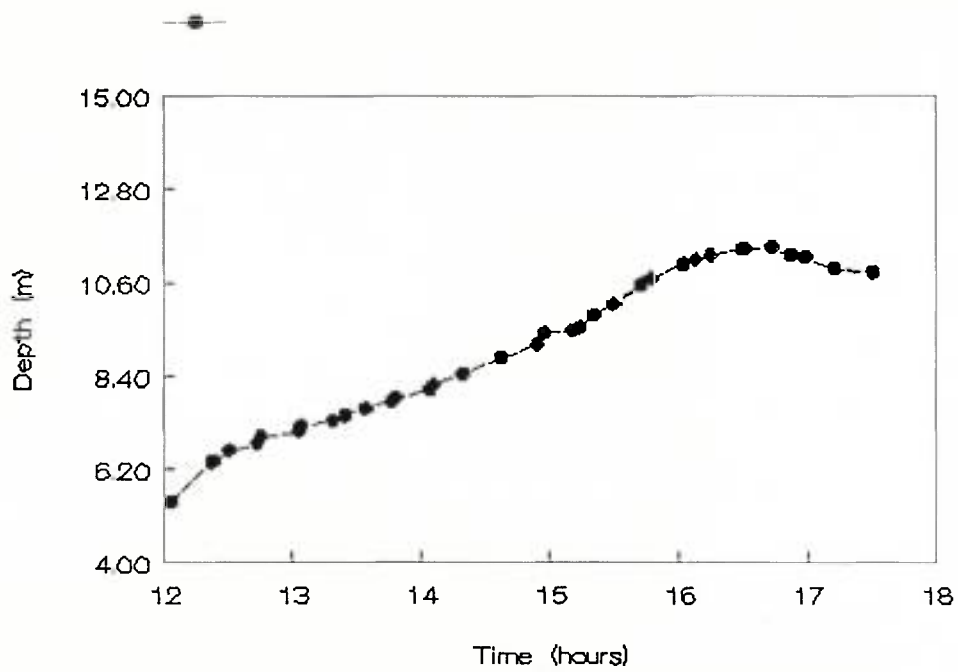
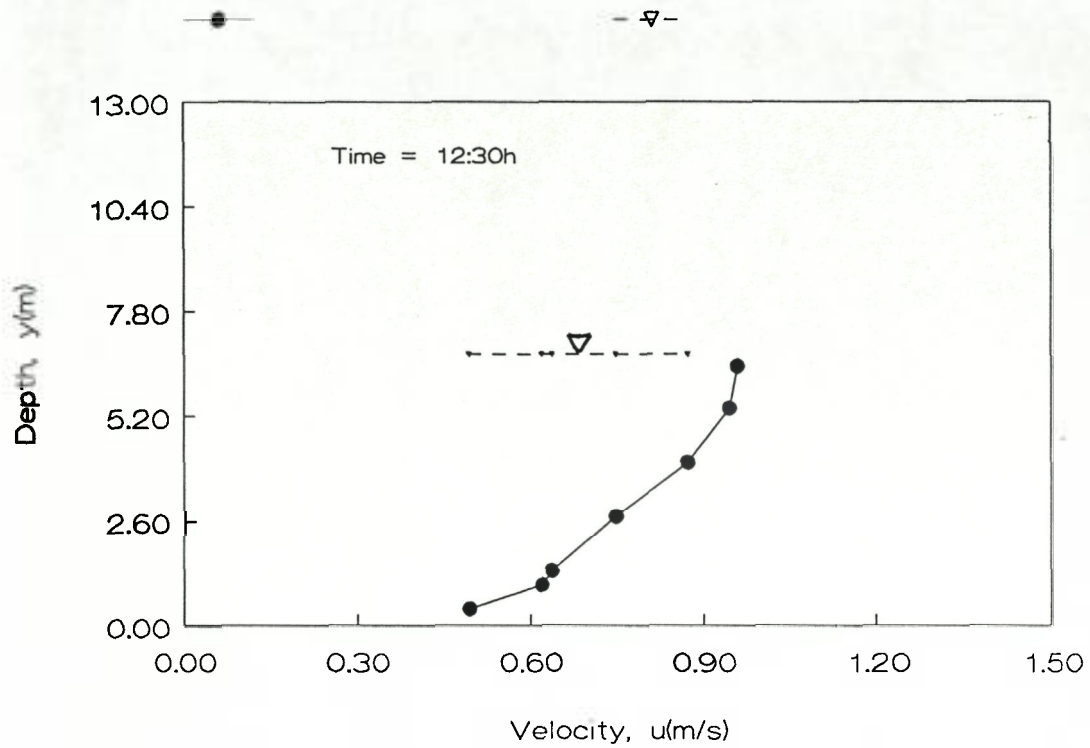
FIG.5. WATER DEPTH HYDROGRAPH

FIG.6a. VELOCITY DISTRIBUTION

LOCATION A

**FIG.6b. VELOCITY DISTRIBUTION**

LOCATION A

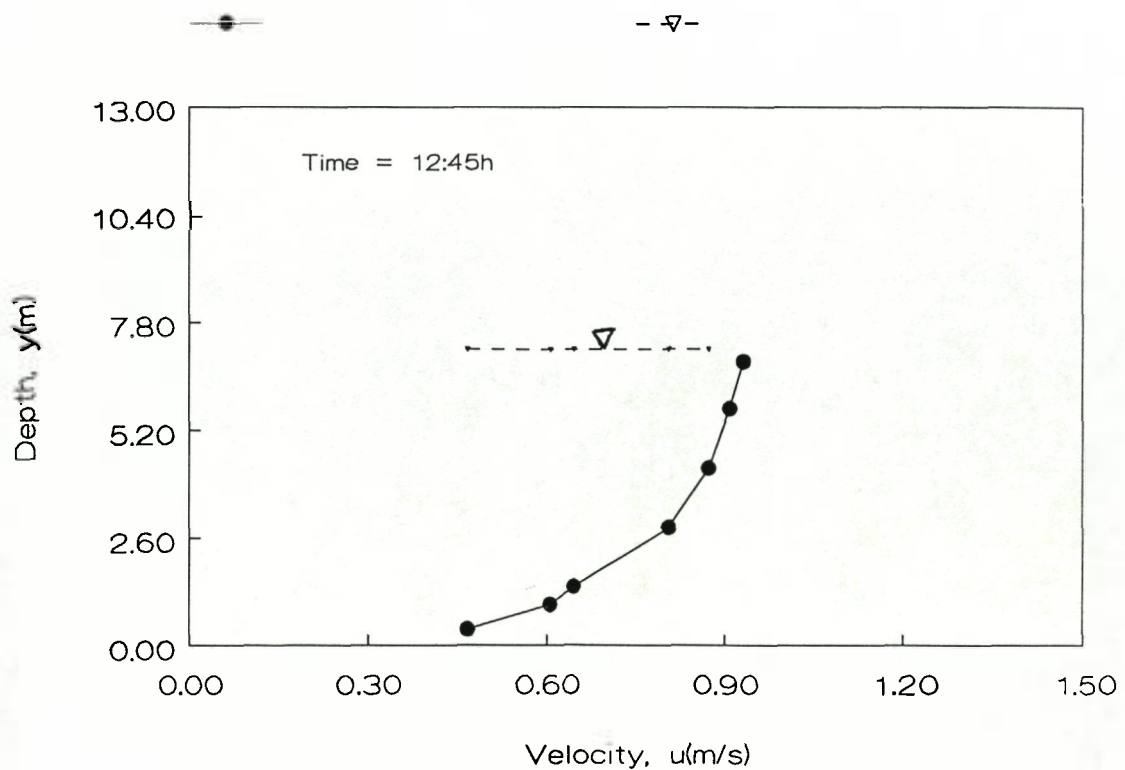


FIG.6c. VELOCITY DISTRIBUTION
LOCATION A

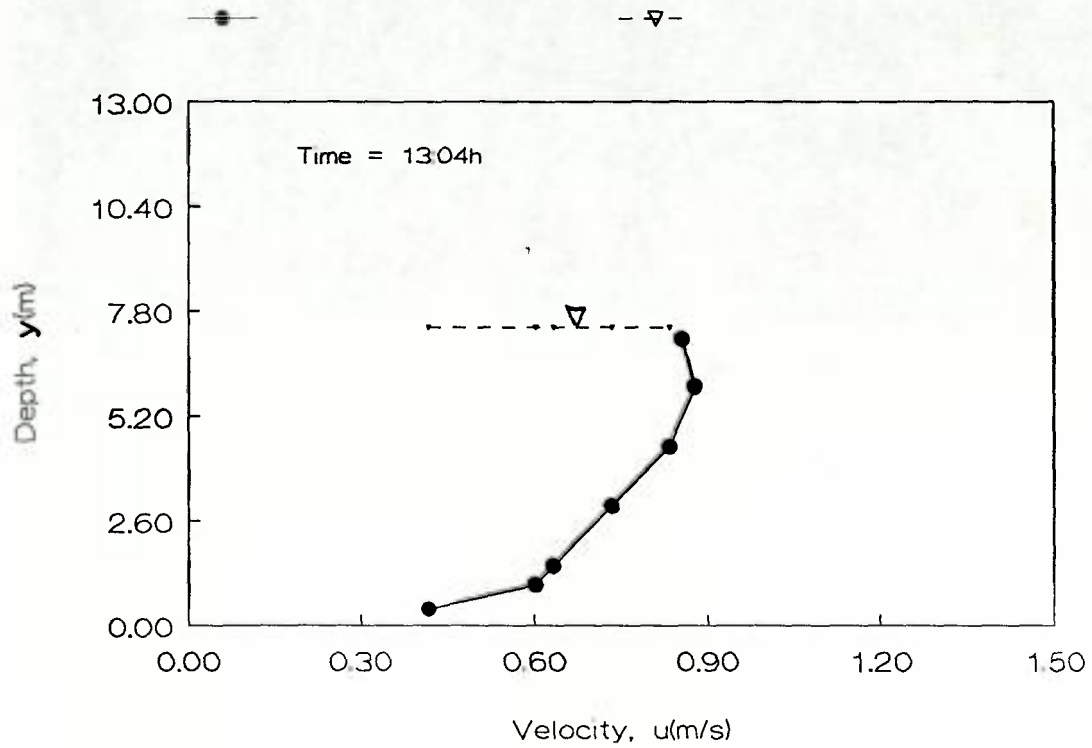


FIG.6d. VELOCITY DISTRIBUTION
LOCATION A

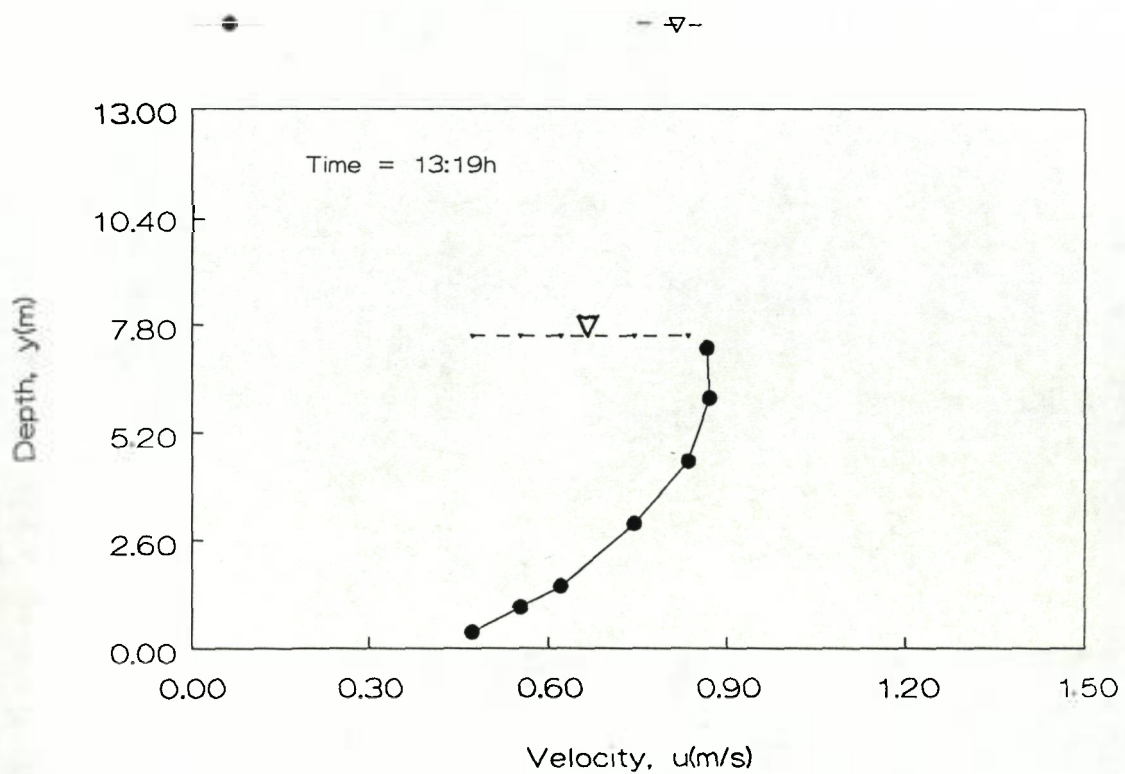
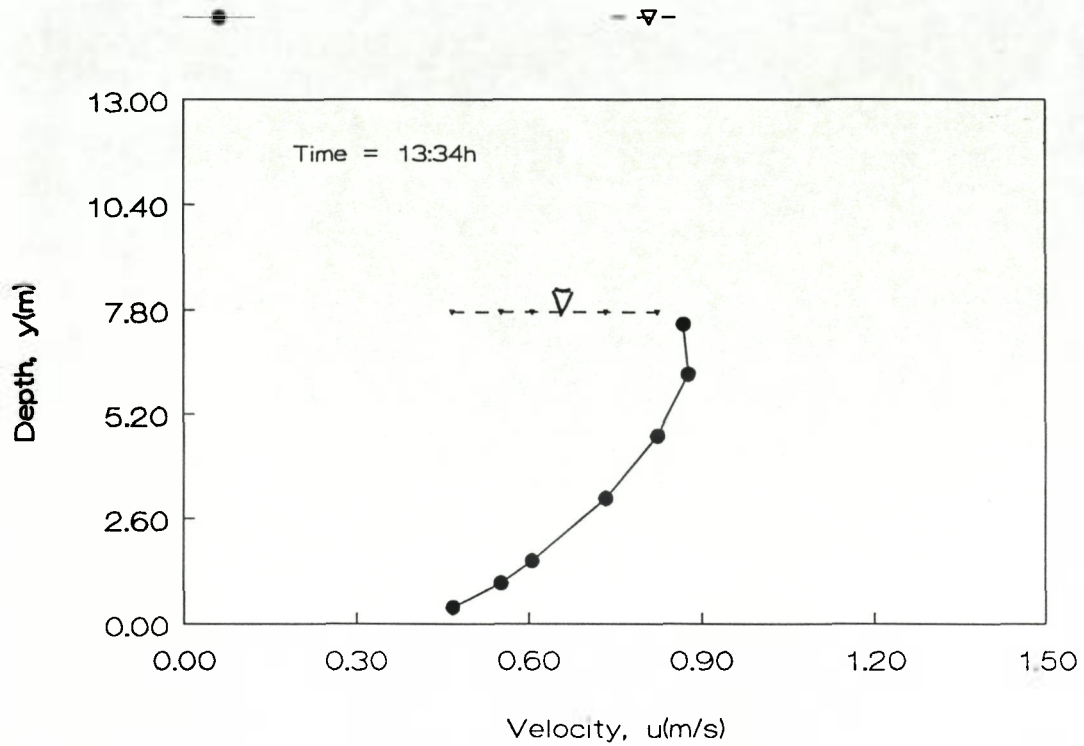


FIG.6e. VELOCITY DISTRIBUTION

LOCATION A

**FIG.6f. VELOCITY DISTRIBUTION**

LOCATION A

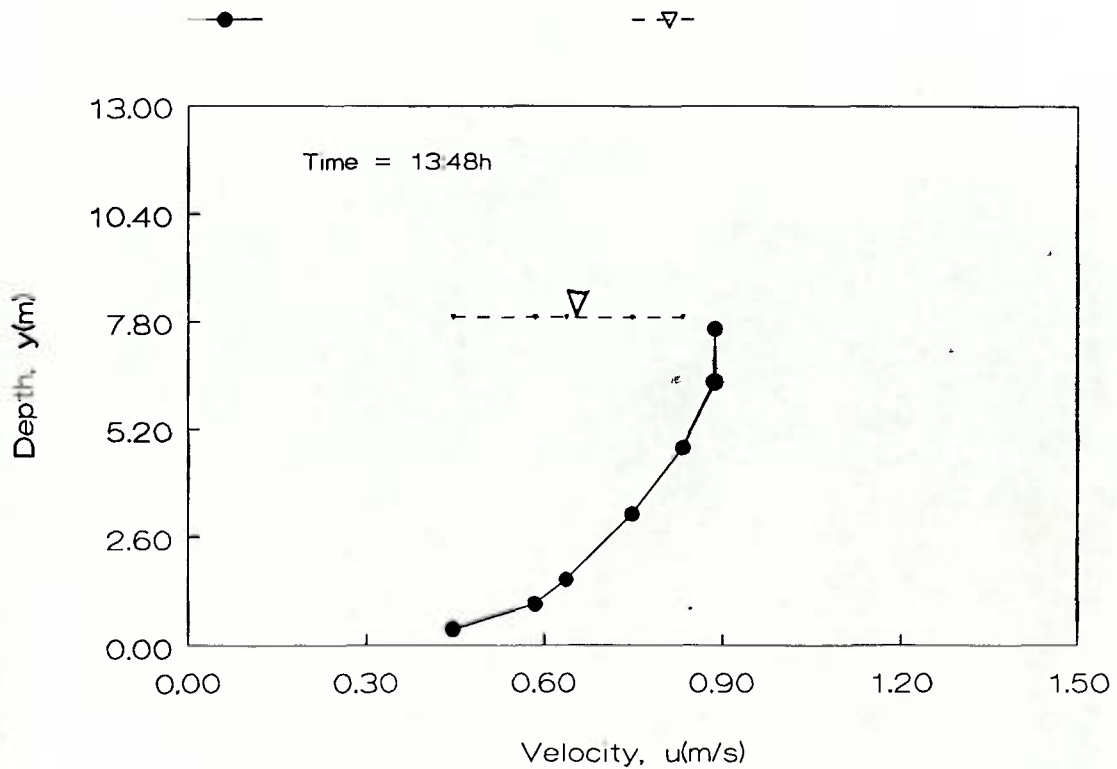


FIG.6g. VELOCITY DISTRIBUTION

LOCATION A

- ▽ -

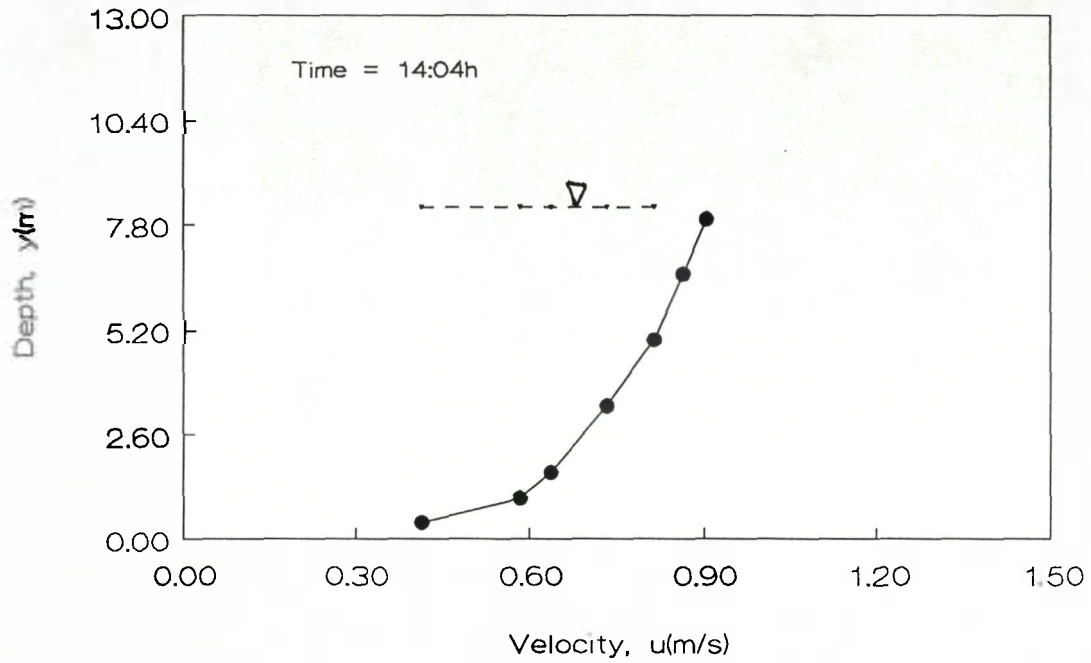


FIG.6h. VELOCITY DISTRIBUTION

LOCATION A

- ▽ -

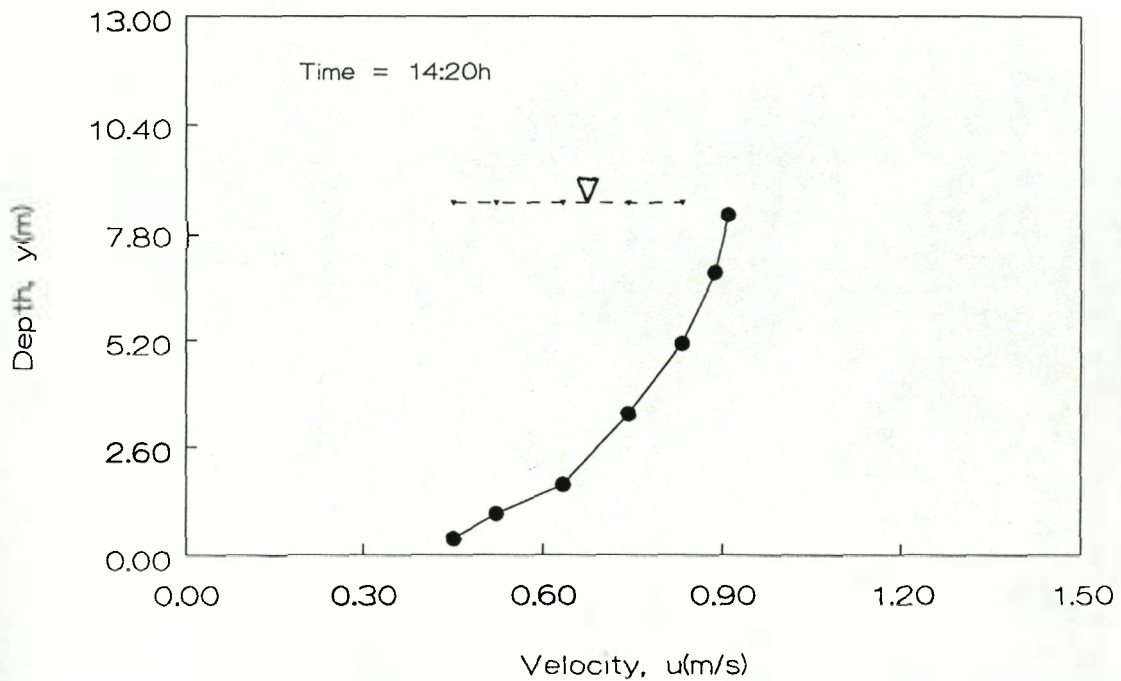


FIG.6i. VELOCITY DISTRIBUTION

LOCATION A

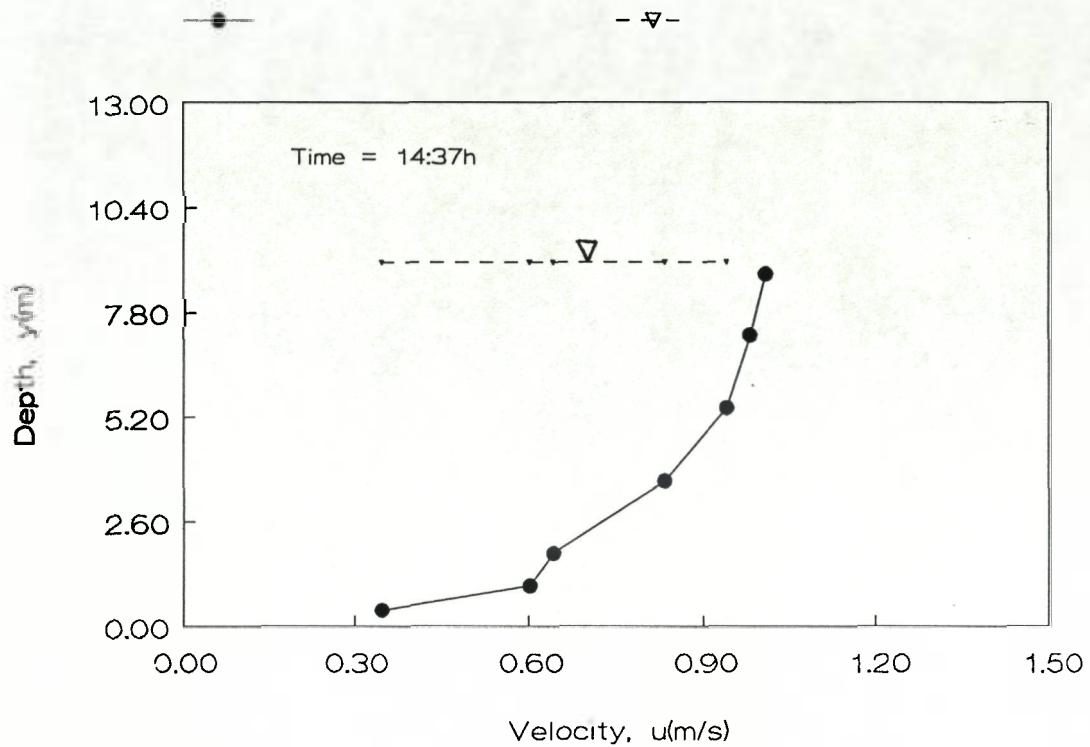


FIG.6j. VELOCITY DISTRIBUTION

LOCATION A

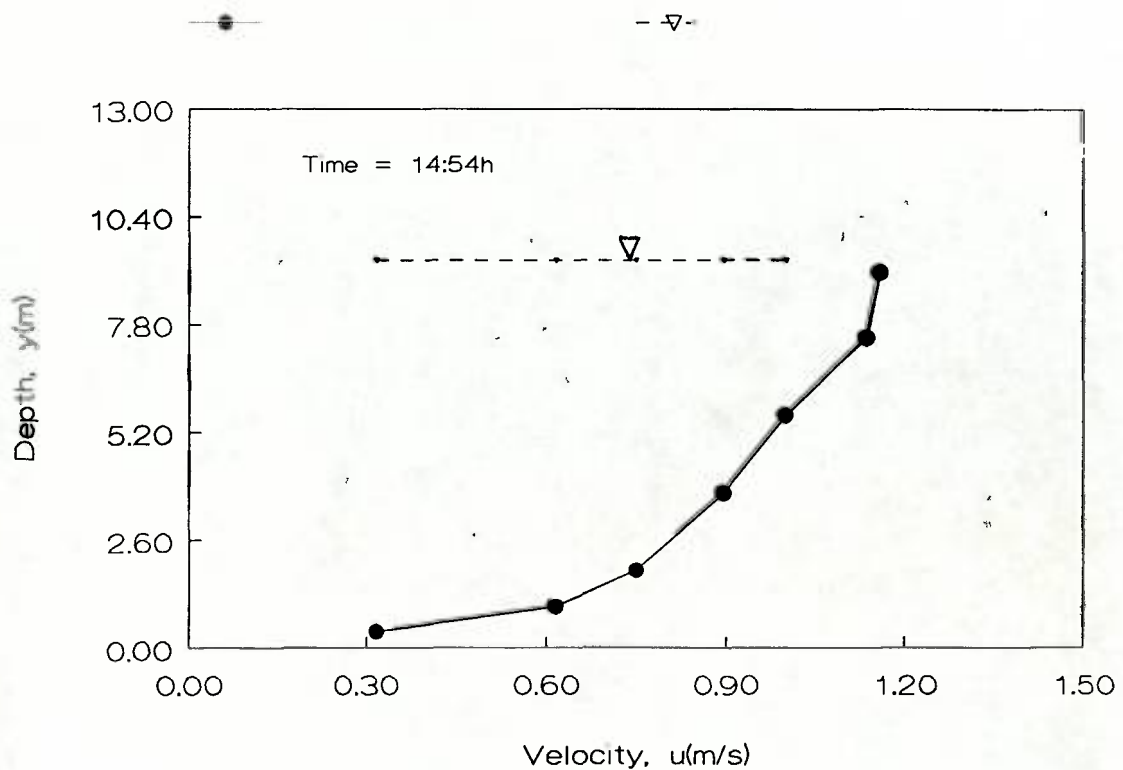


FIG.6k. VELOCITY DISTRIBUTION
LOCATION A

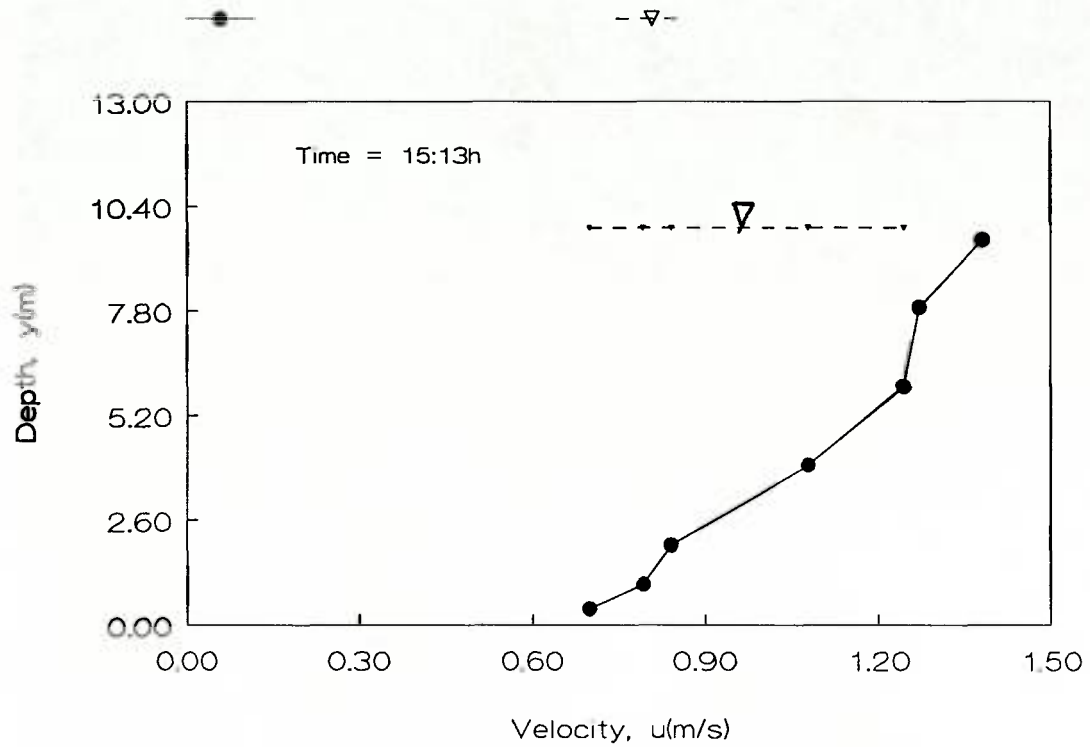


FIG.6l. VELOCITY DISTRIBUTION
LOCATION A

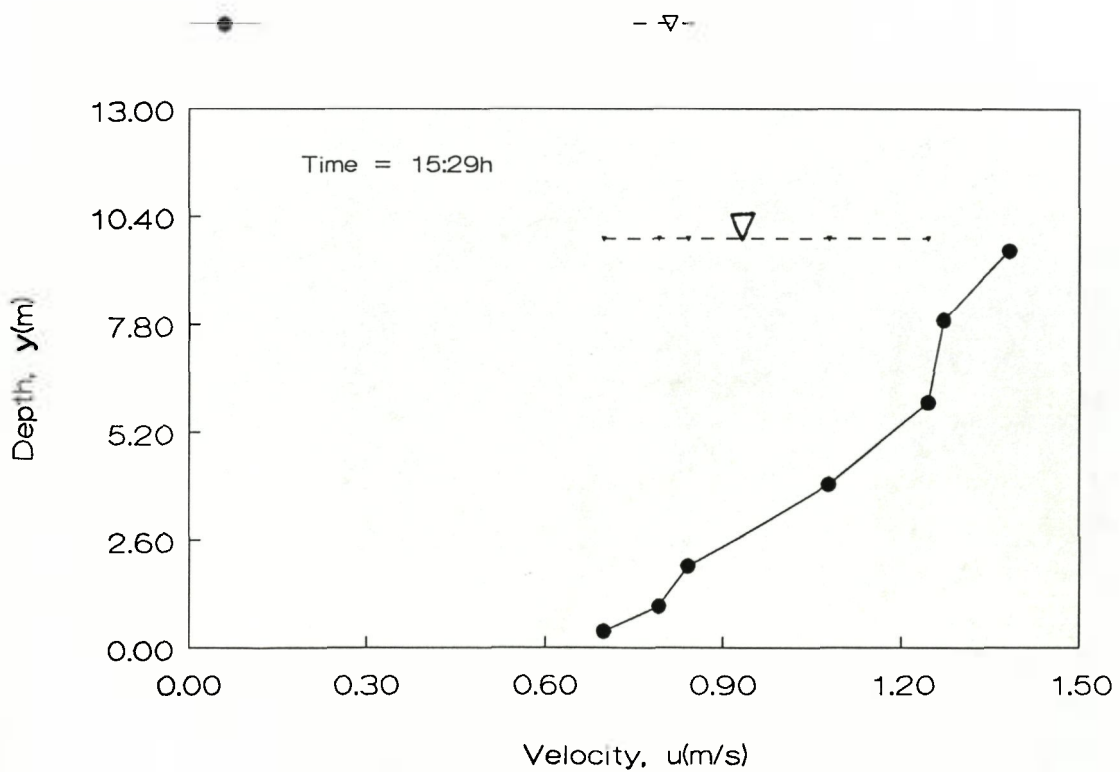


FIG.6m. VELOCITY DISTRIBUTION
LOCATION A

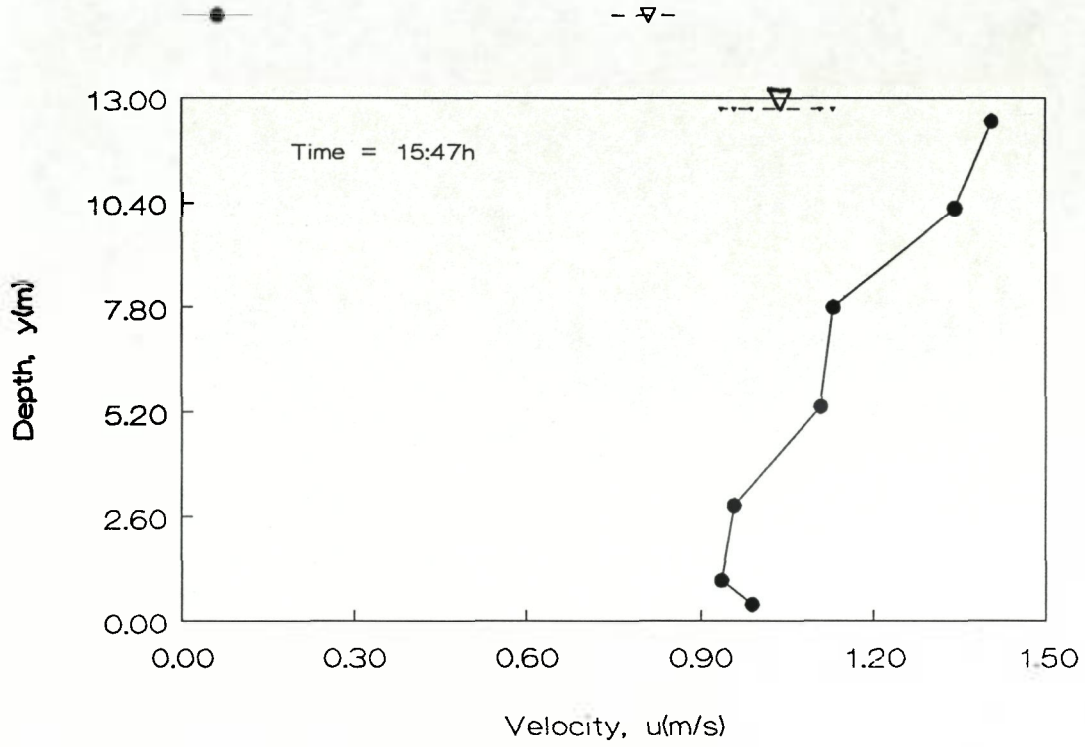


FIG.6n. VELOCITY DISTRIBUTION
LOCATION A

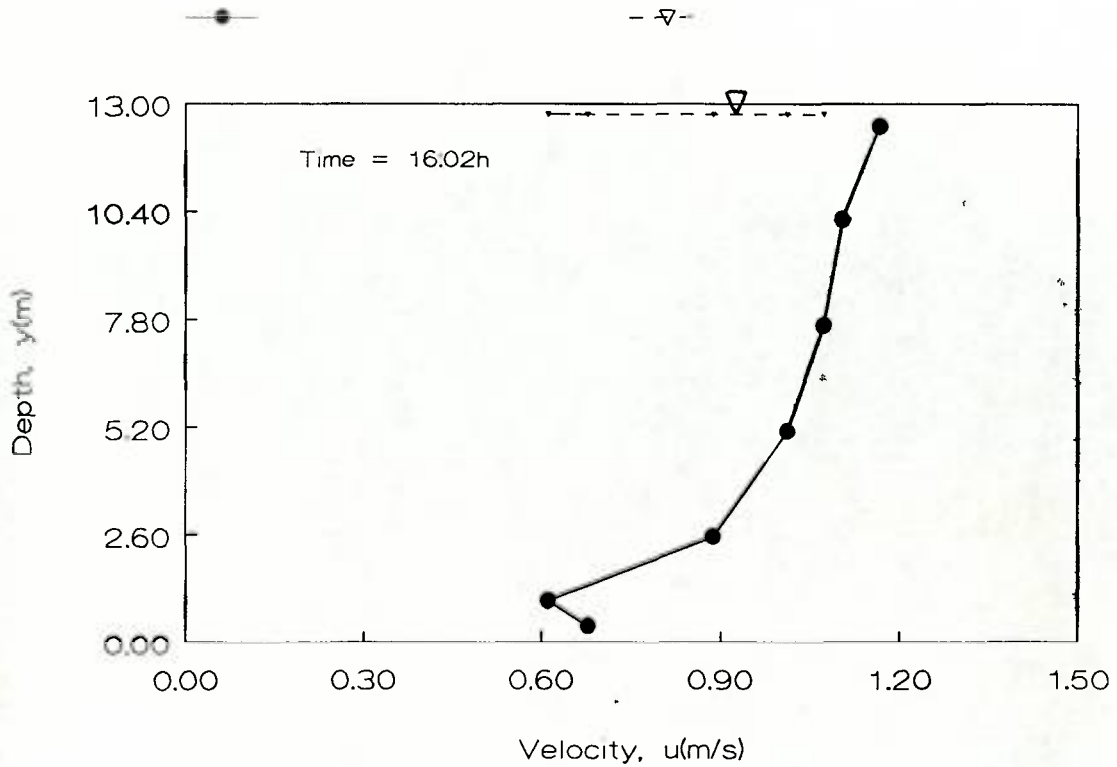


FIG. 6o. VELOCITY DISTRIBUTION
LOCATION A

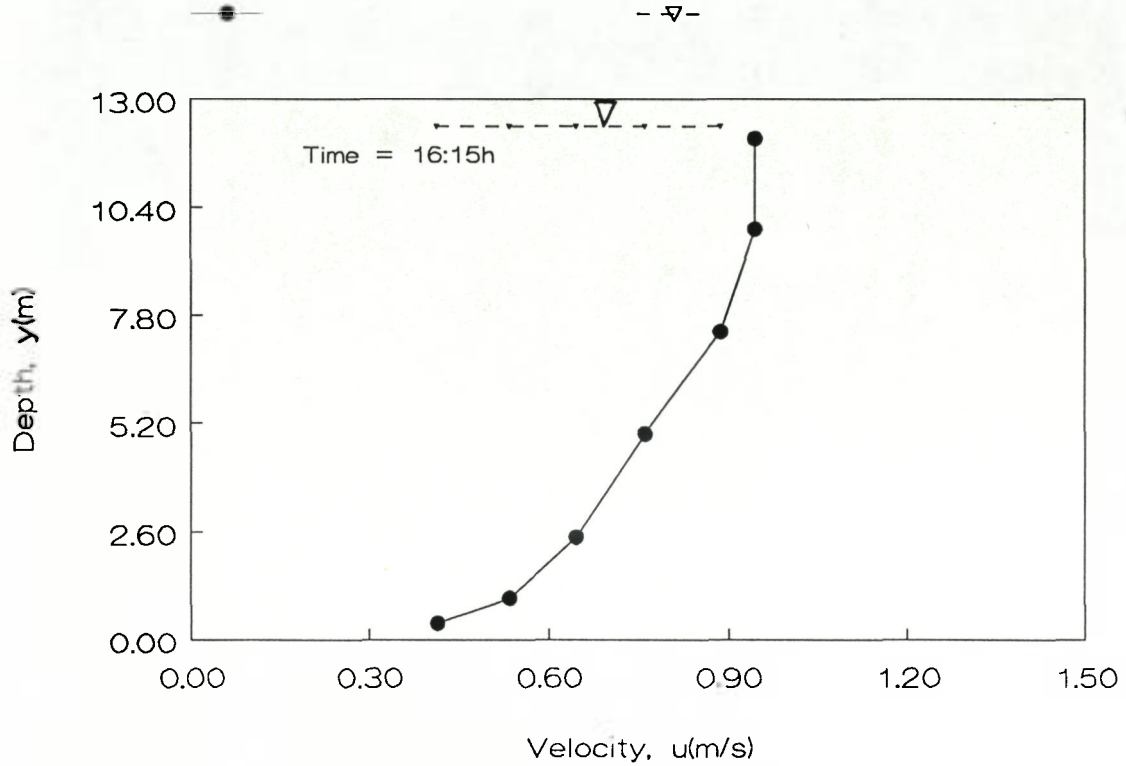


FIG.6p. VELOCITY DISTRIBUTION
LOCATION A

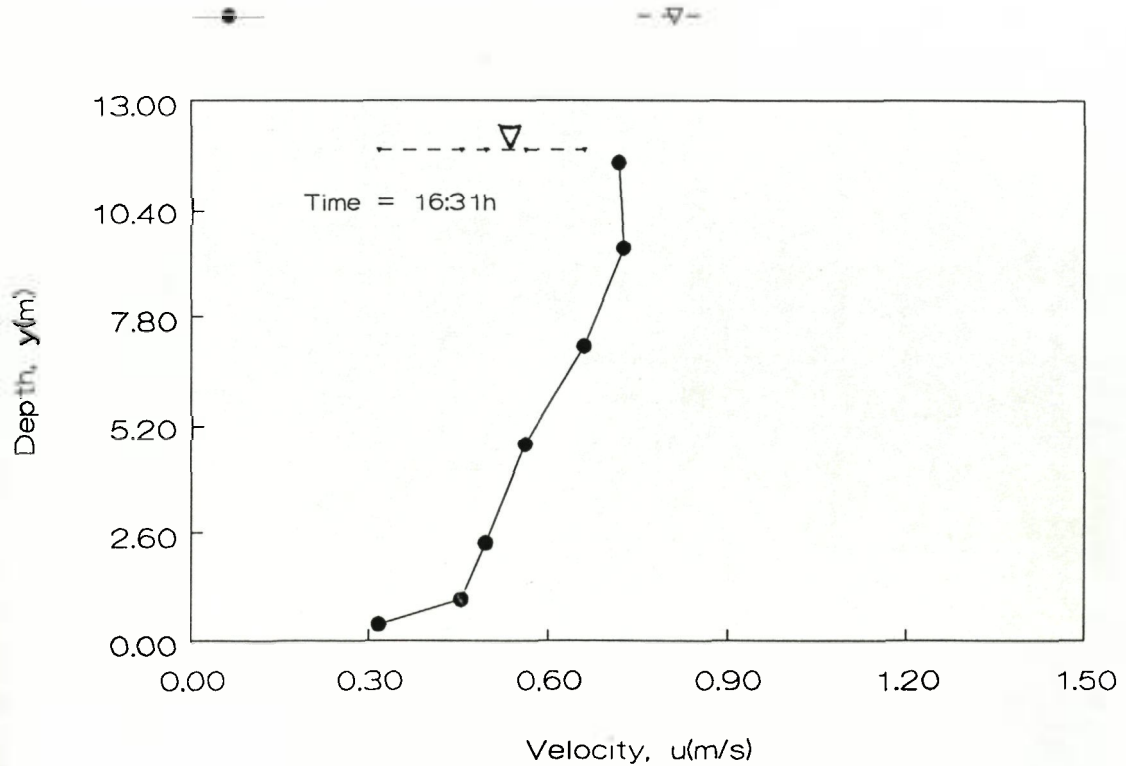
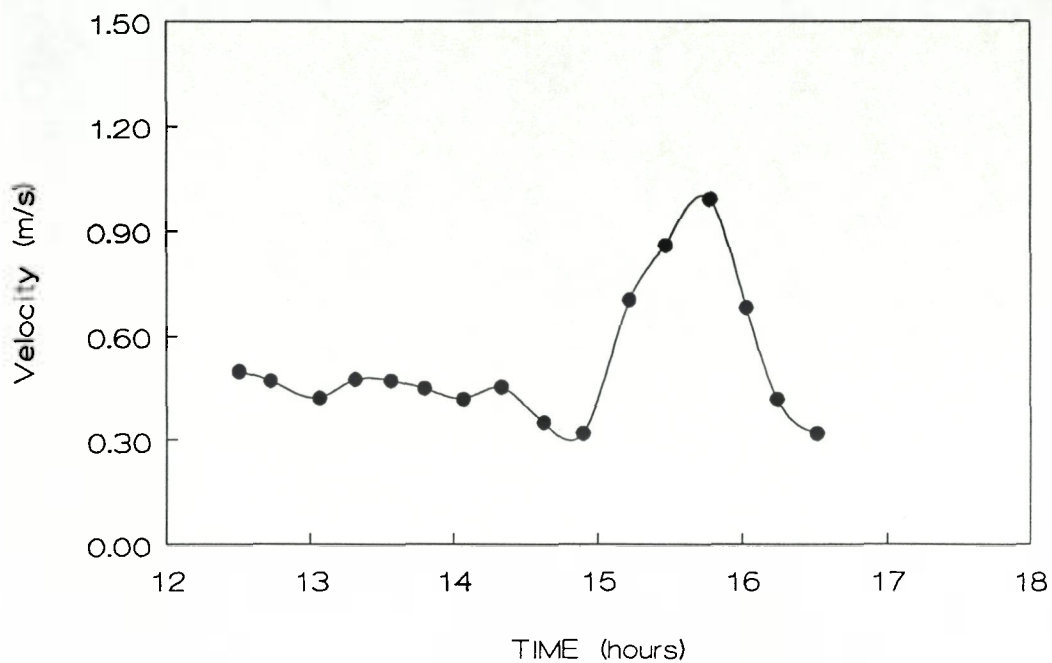


FIG.7a. VELOCITY DISTRIBUTION

LOCATION A (40cm Above Bed)

**FIG.7b. VELOCITY DISTRIBUTION**

LOCATION A (1m From Bed)

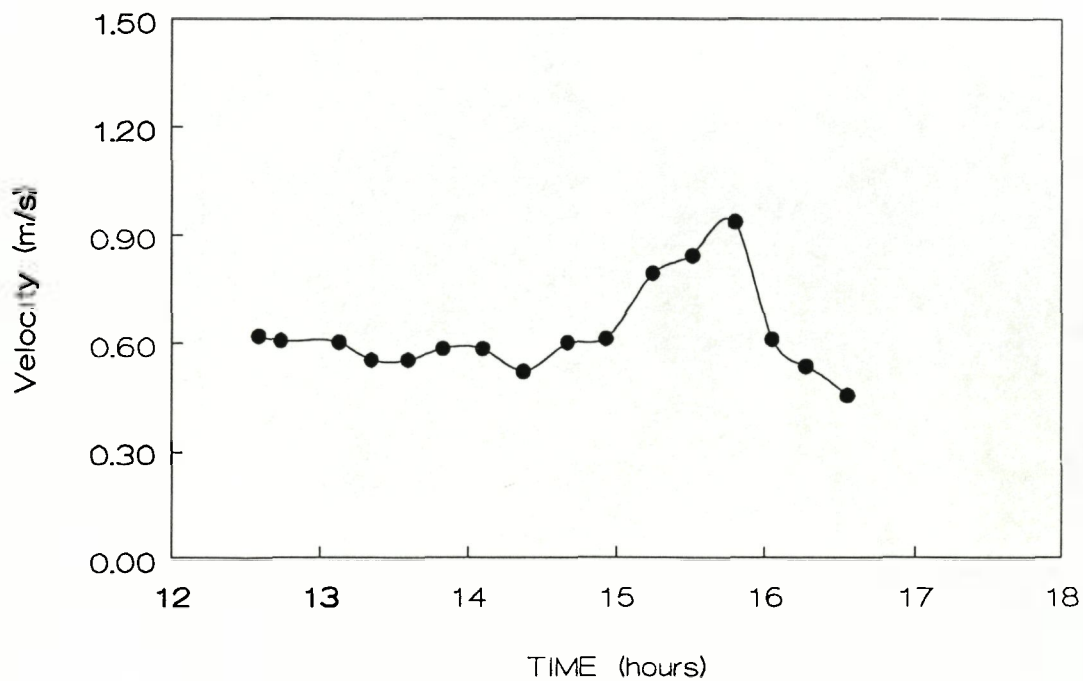
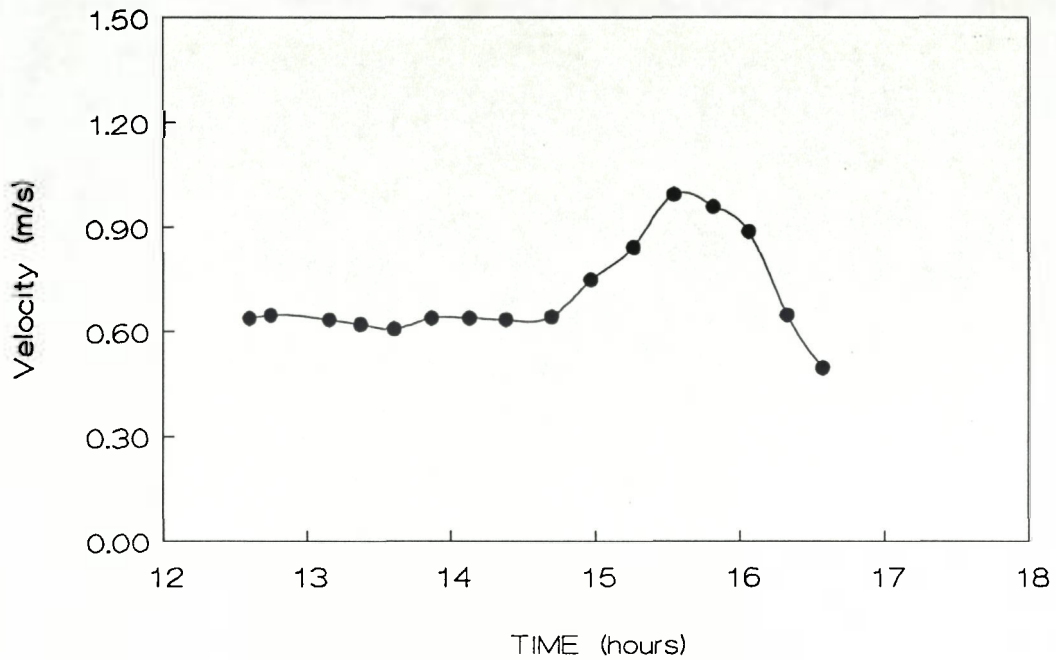


FIG.7c. VELOCITY DISTRIBUTION

LOCATION A (0.2D Above Bed)

**FIG.7d. VELOCITY DISTRIBUTION**

LOCATION A (0.4D Above Bed)

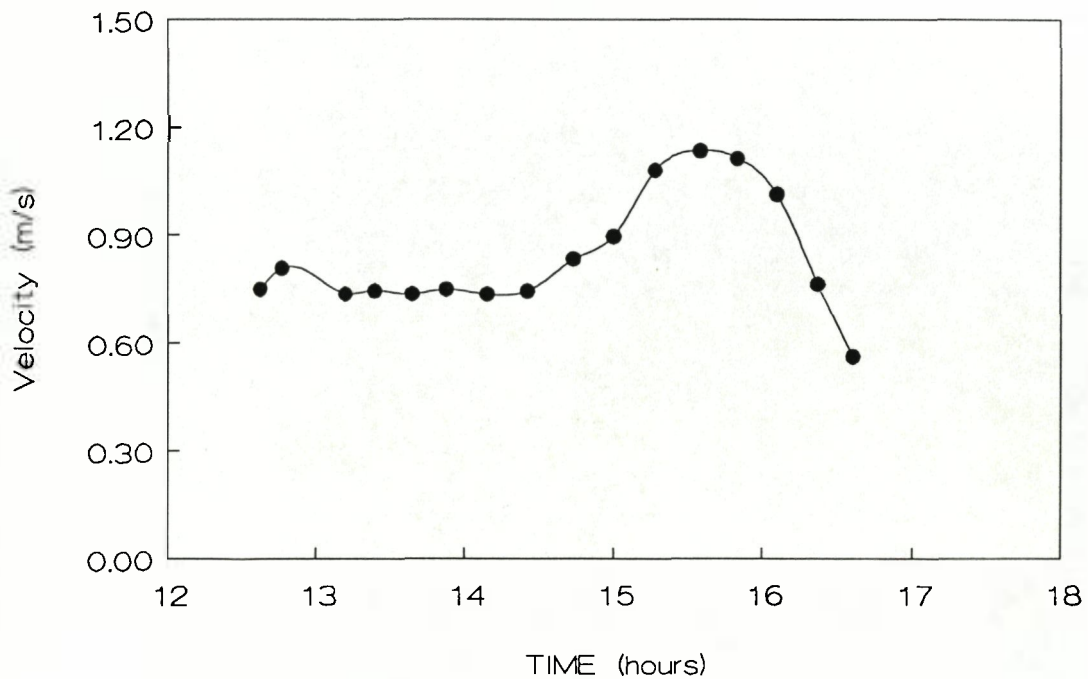
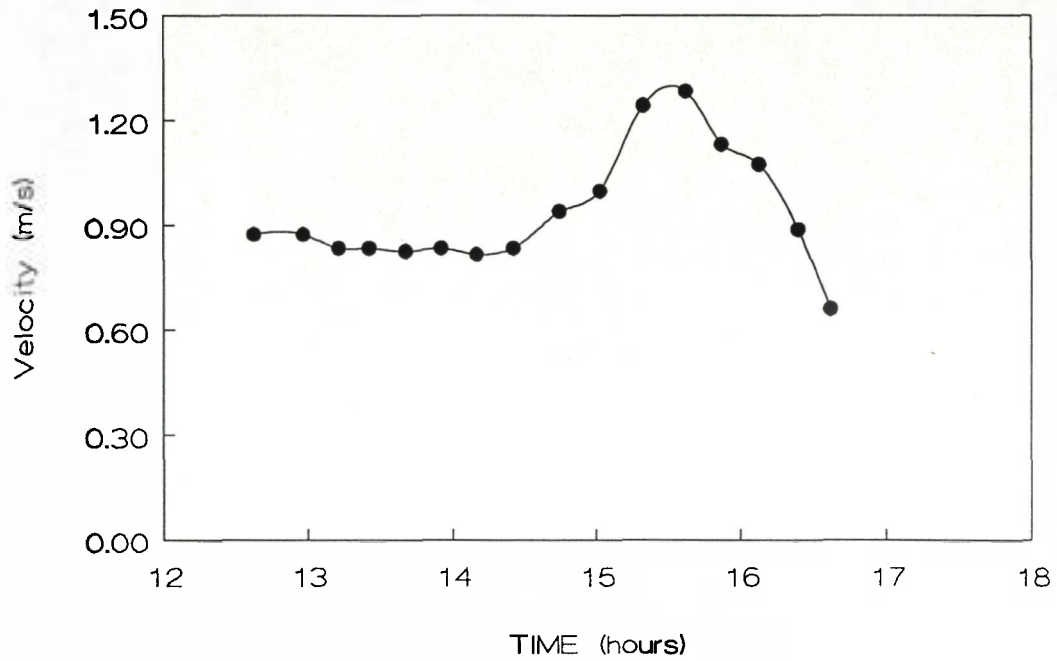


FIG.7e. VELOCITY DISTRIBUTION

LOCATION A (0.6D Above Bed)

**FIG.7f. VELOCITY DISTRIBUTION**

LOCATION A (0.8D Above Bed)

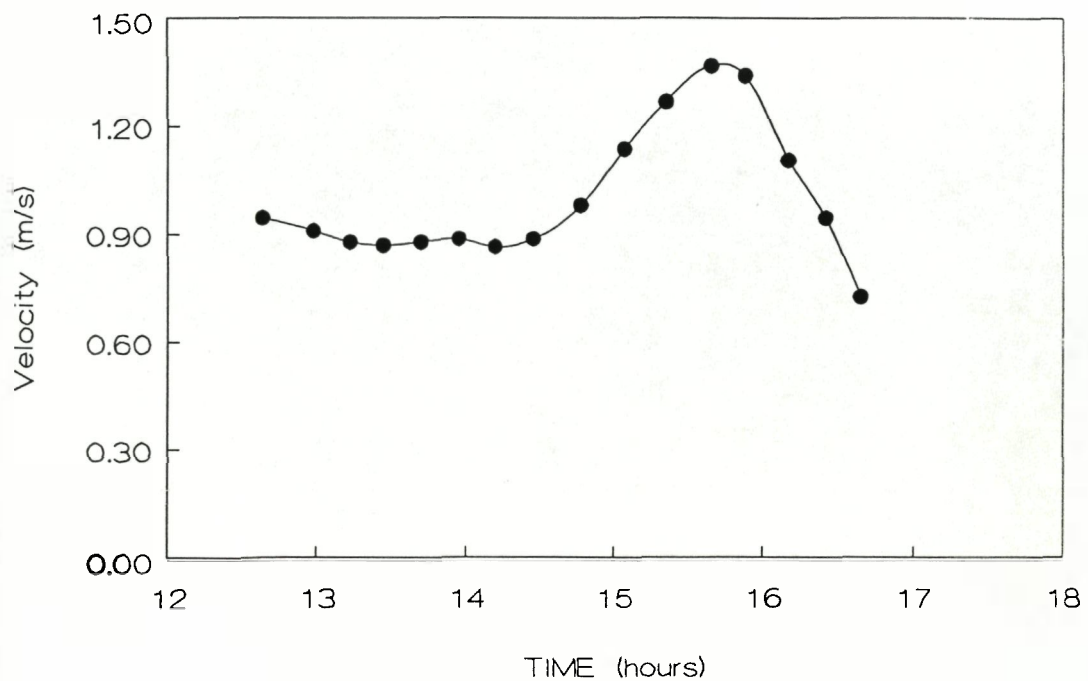


FIG.7g. VELOCITY DISTRIBUTION
LOCATION A (30cm below surface)

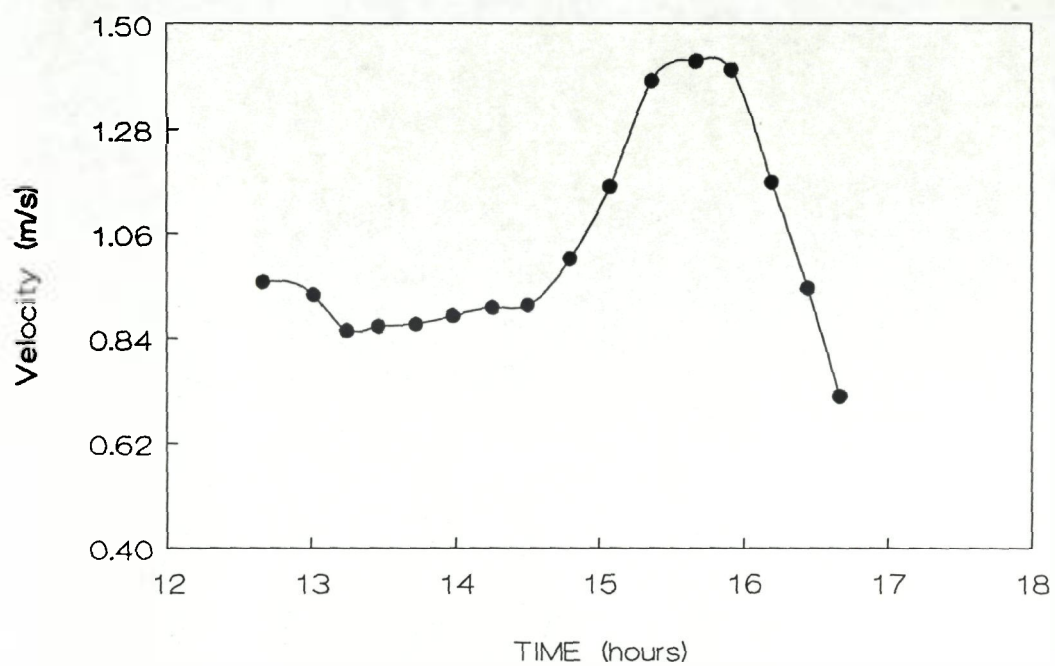


FIG.8a. SEDIMENT CONCENTRATION
LOCATION A

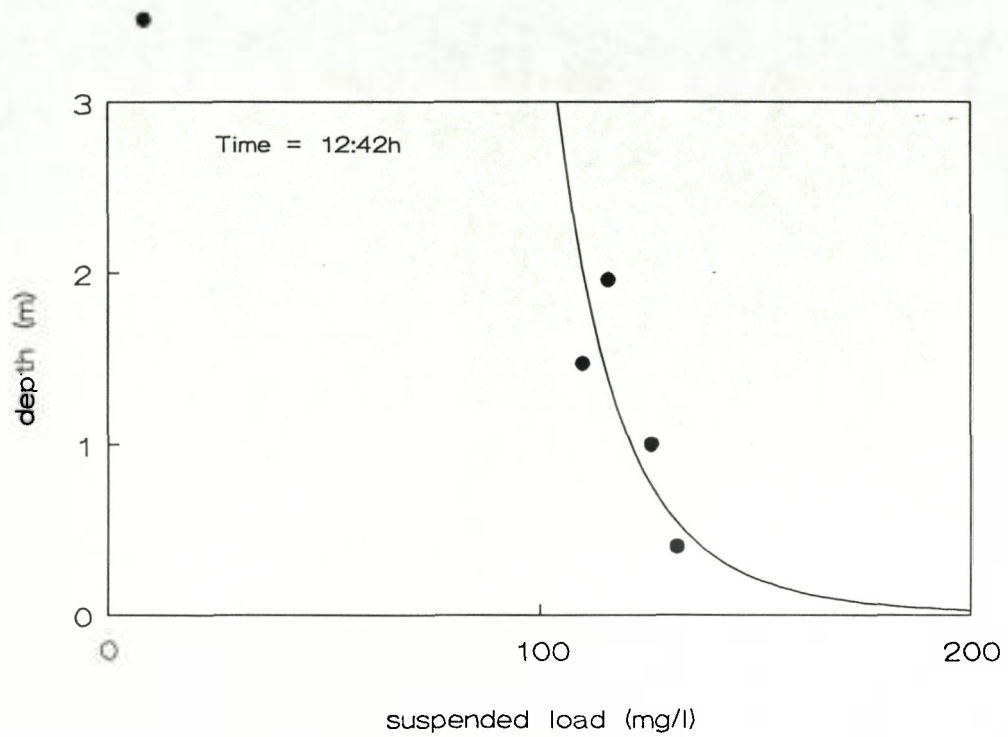


FIG.8b. SEDIMENT CONCENTRATION
LOCATION A

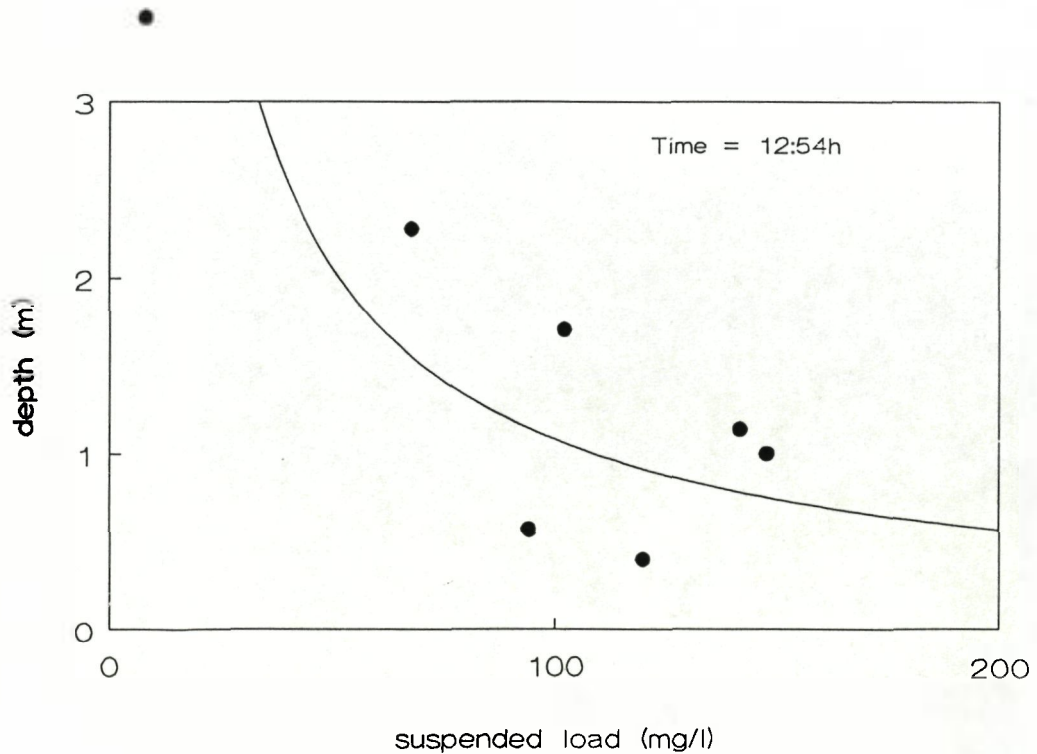


FIG.8c. SEDIMENT CONCENTRATION
LOCATION A

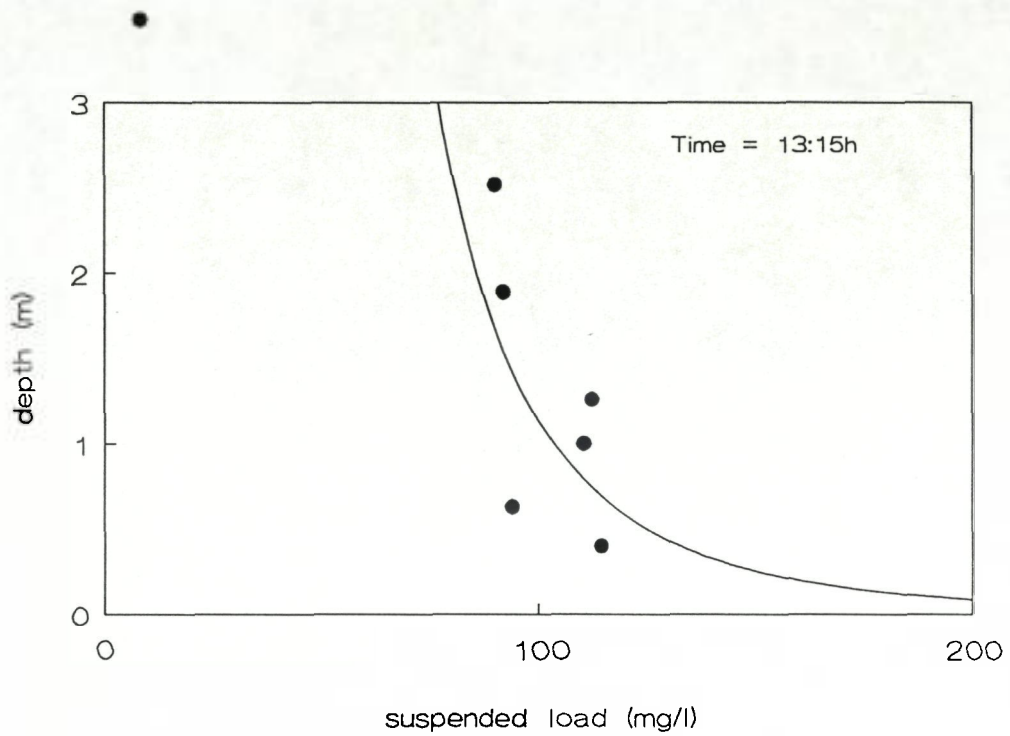


FIG.8d. SEDIMENT CONCENTRATION
LOCATION A

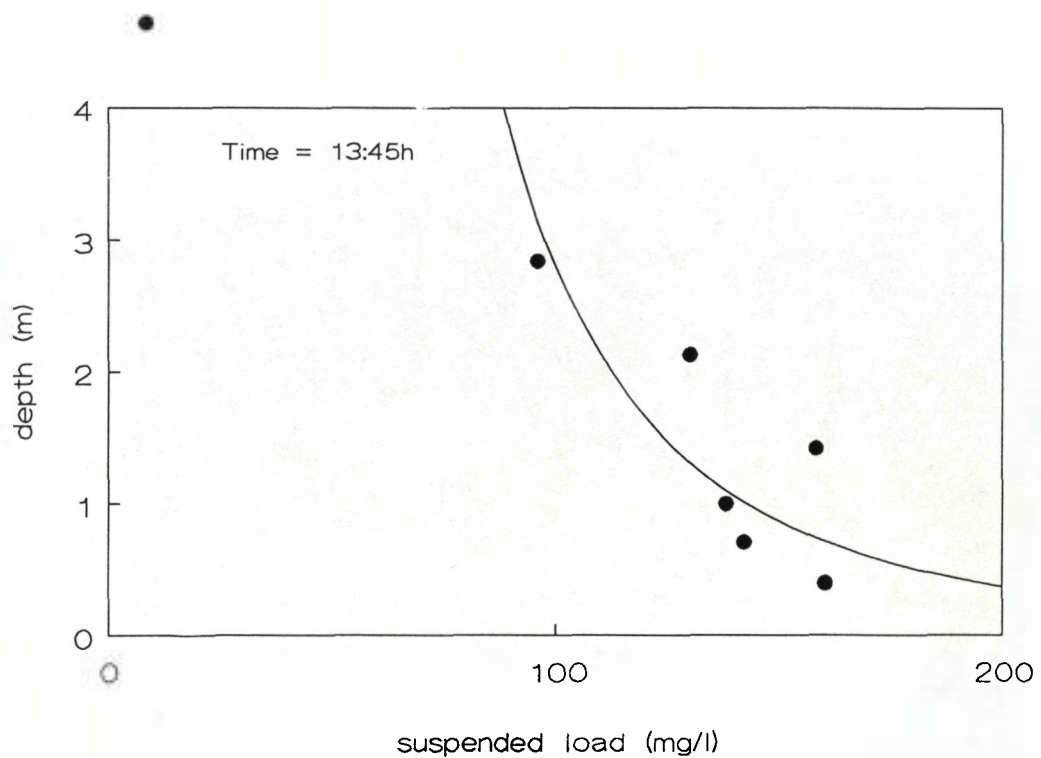


FIG.8e. SEDIMENT CONCENTRATION
LOCATION A

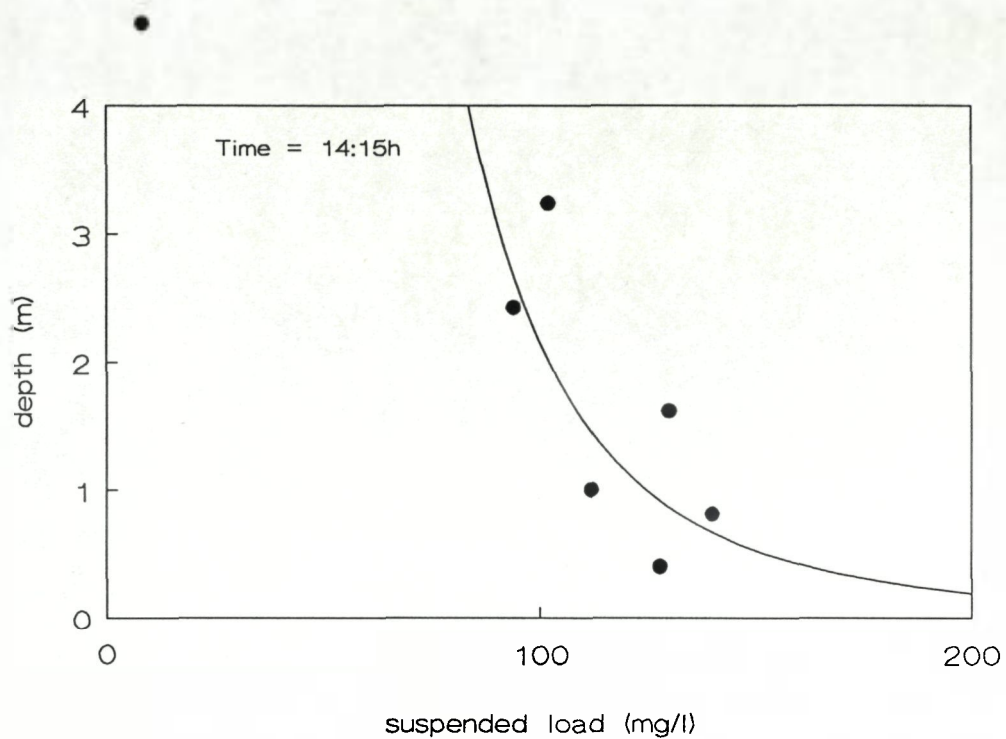


FIG.8f. SEDIMENT CONCENTRATION
LOCATION A

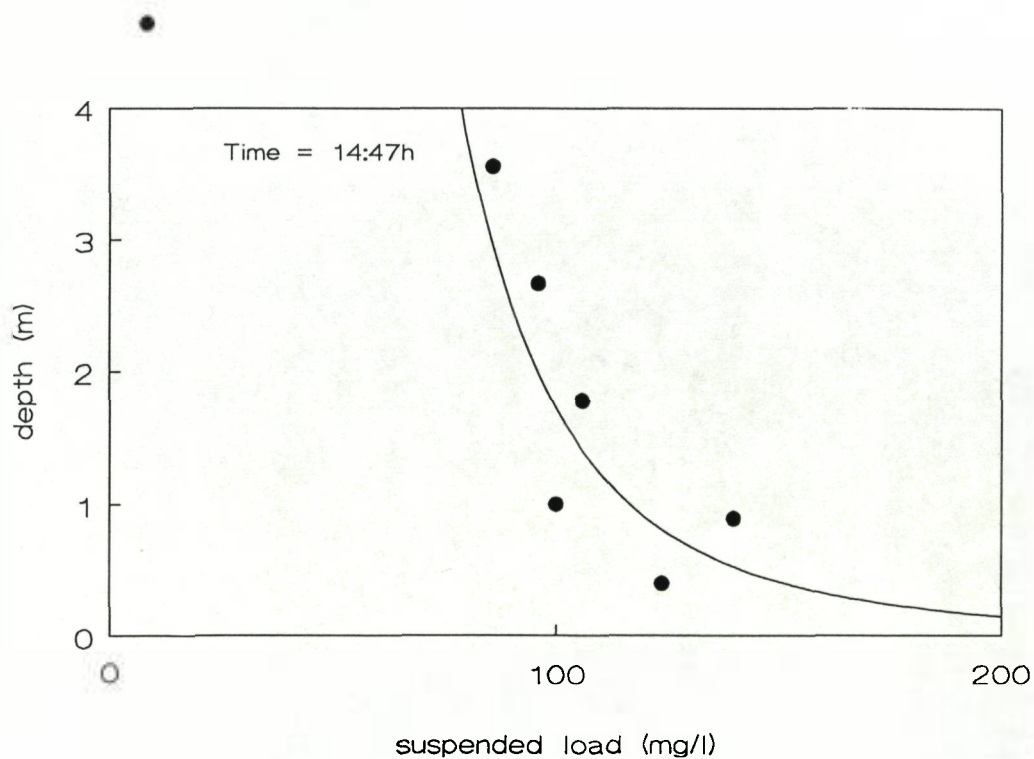


FIG.8g. SEDIMENT CONCENTRATION
LOCATION A

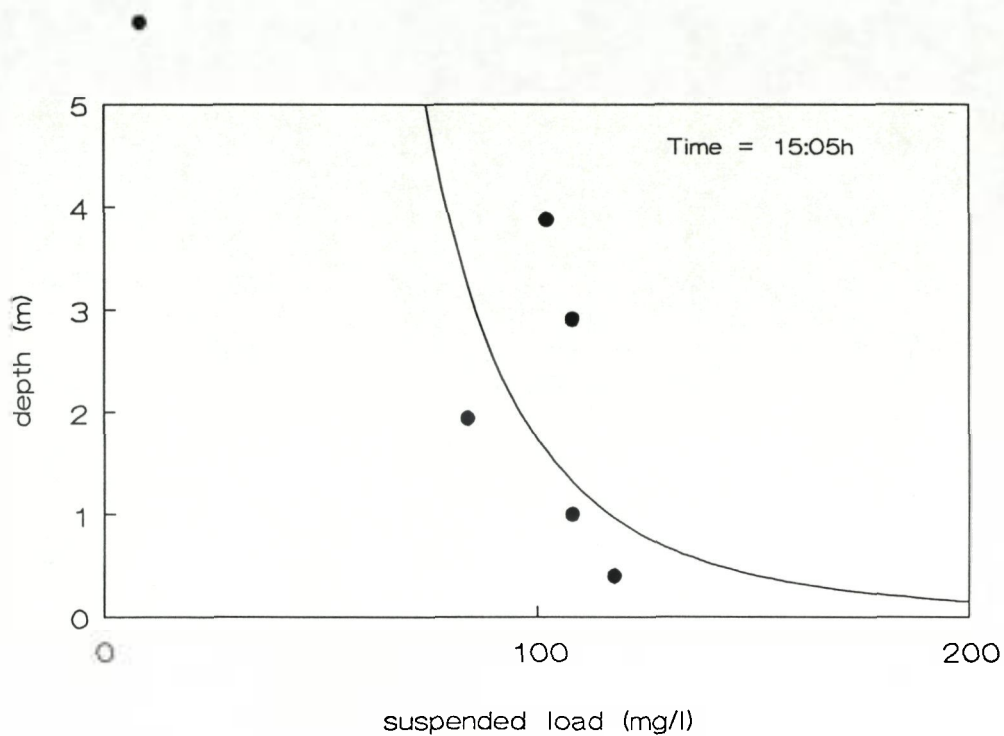


FIG.8h. SEDIMENT CONCENTRATION
LOCATION A

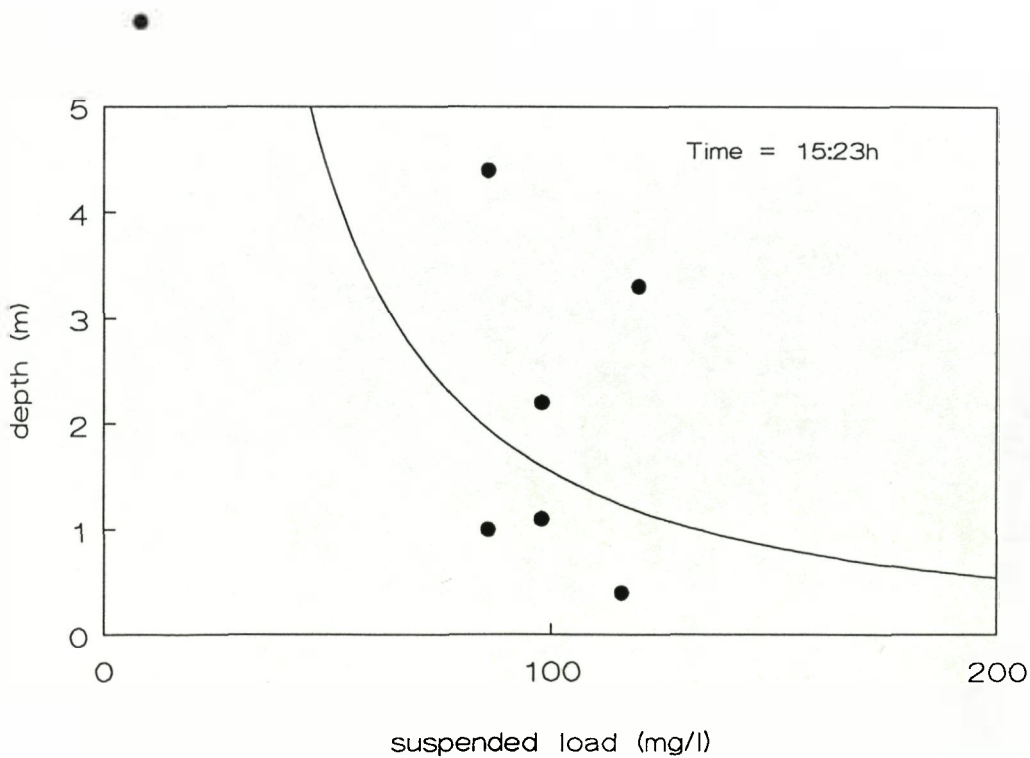


FIG.8i. SEDIMENT CONCENTRATION
LOCATION A

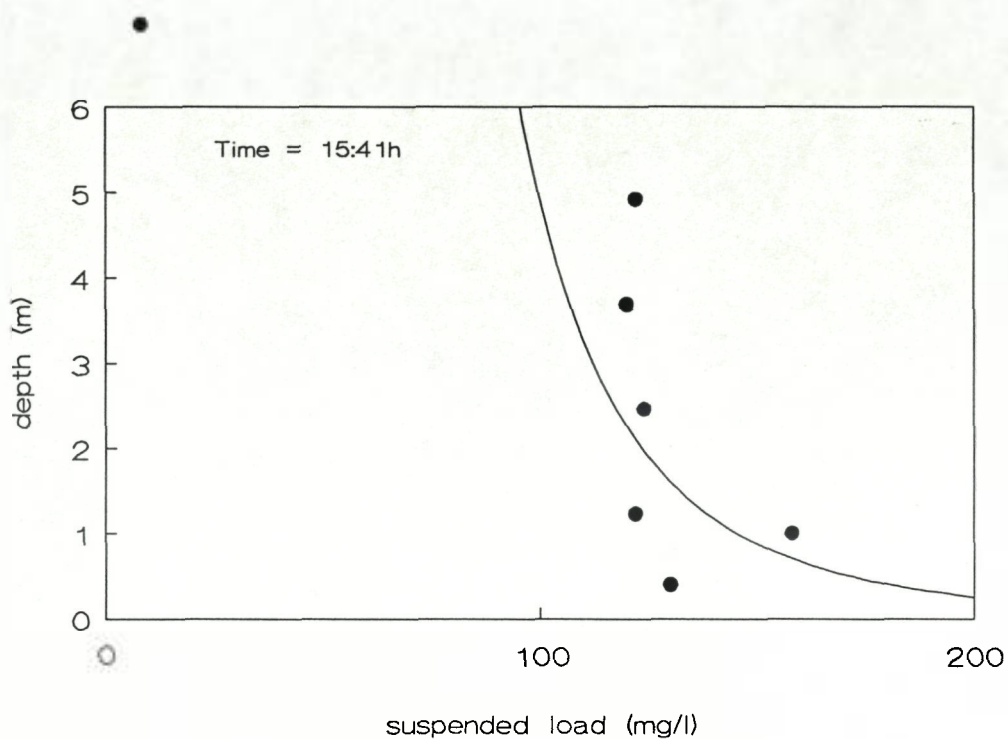


FIG.8j. SEDIMENT CONCENTRATION
LOCATION A

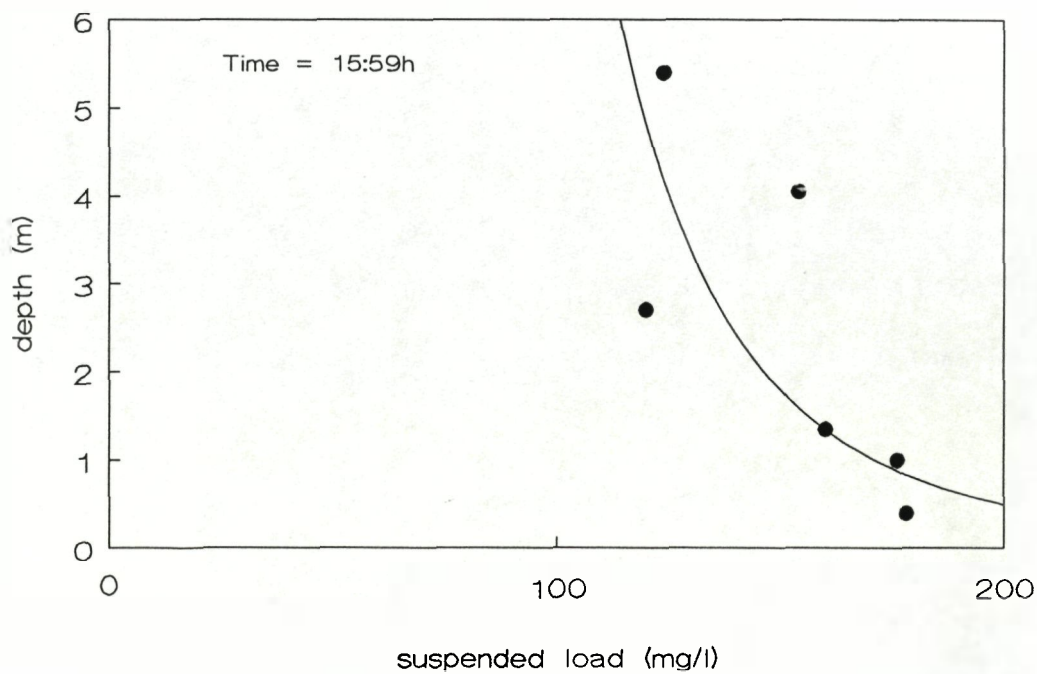


FIG.8k. SEDIMENT CONCENTRATION
LOCATION A

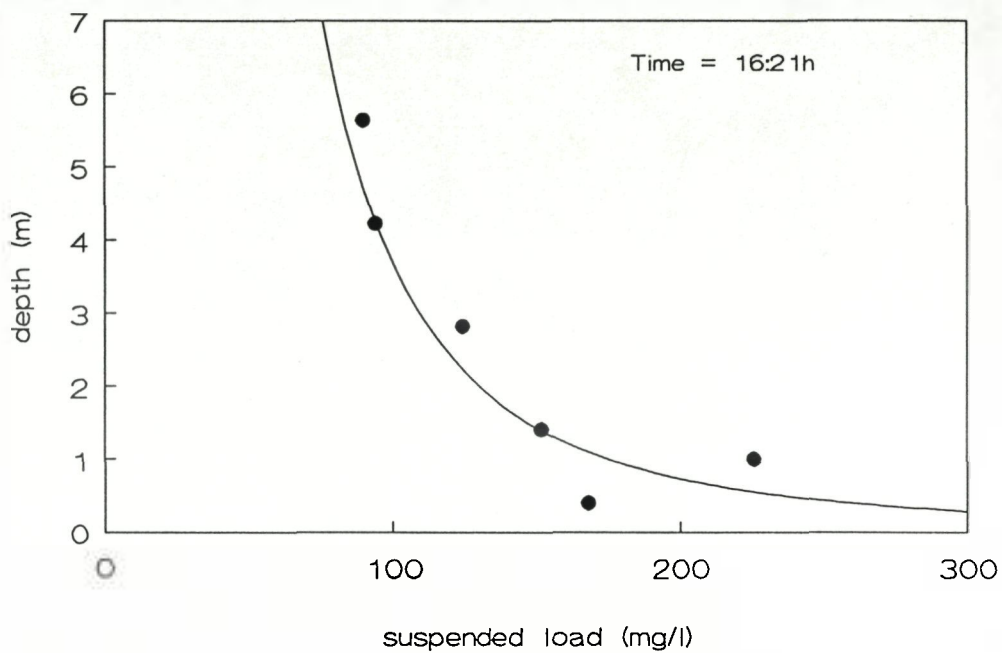


FIG.8l. SEDIMENT CONCENTRATION
LOCATION A

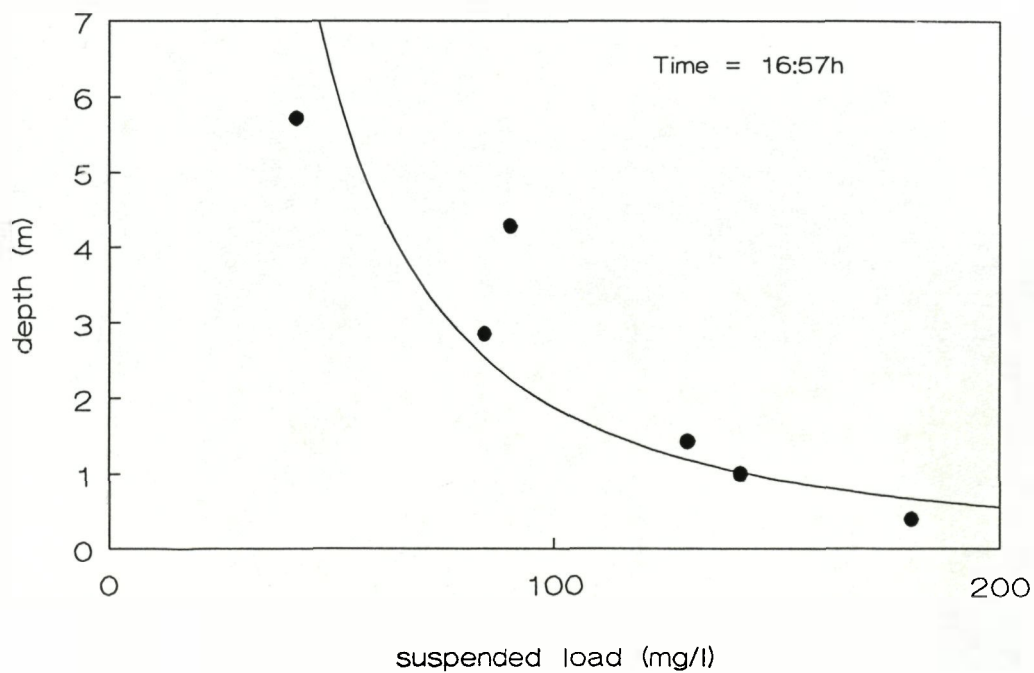


FIG.8m. TEMPORAL VARIATION OF SUSPENDED LOAD AND VELOCITY (1m above bed)

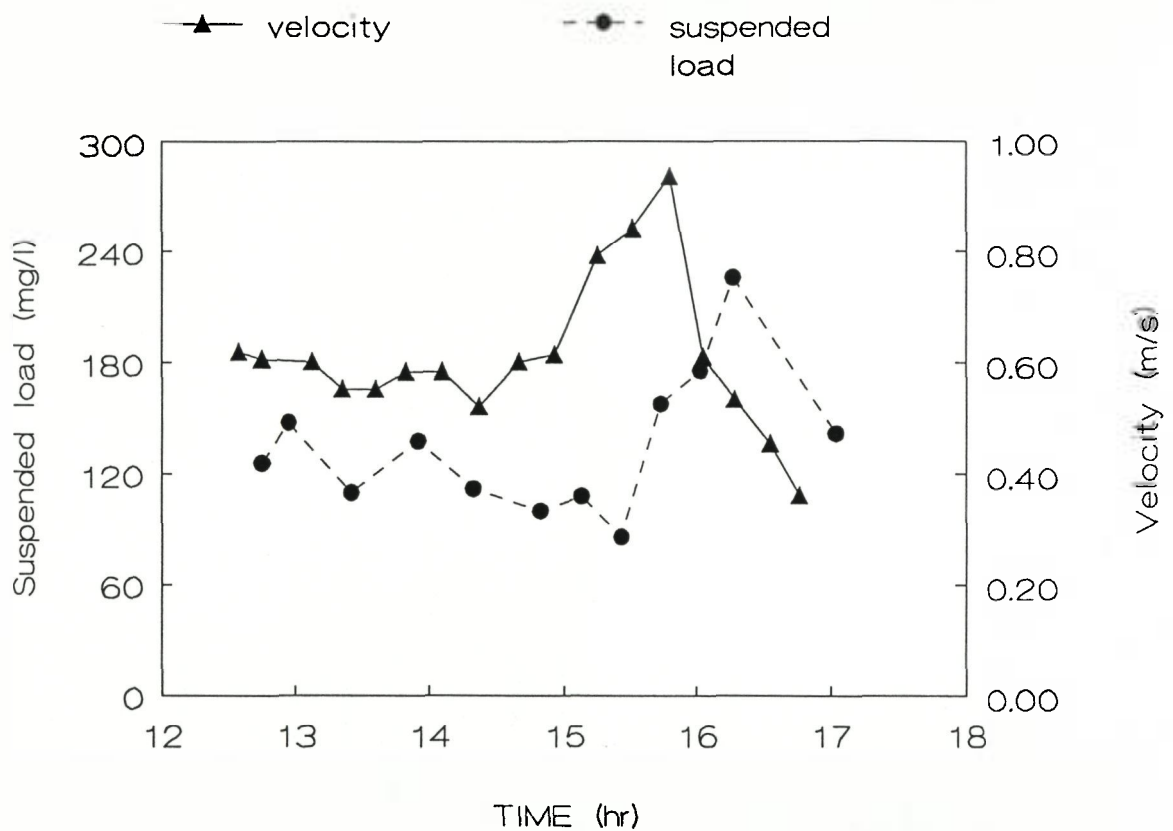


FIG.9a. TURBIDITY DISTRIBUTION
LOCATION A

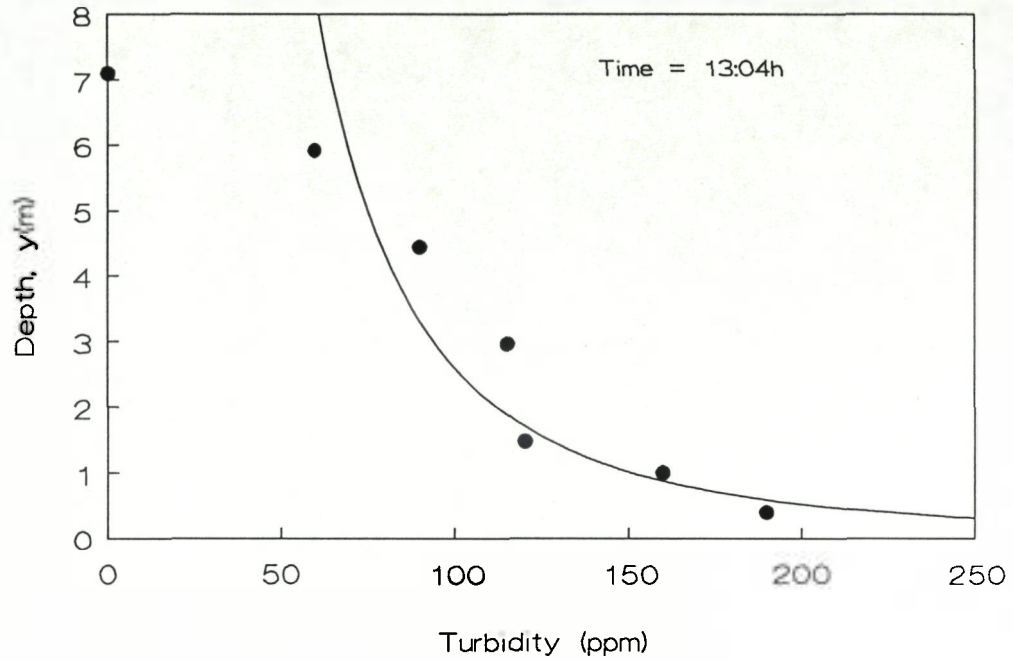


FIG.9b. TURBIDITY DISTRIBUTION
LOCATION A

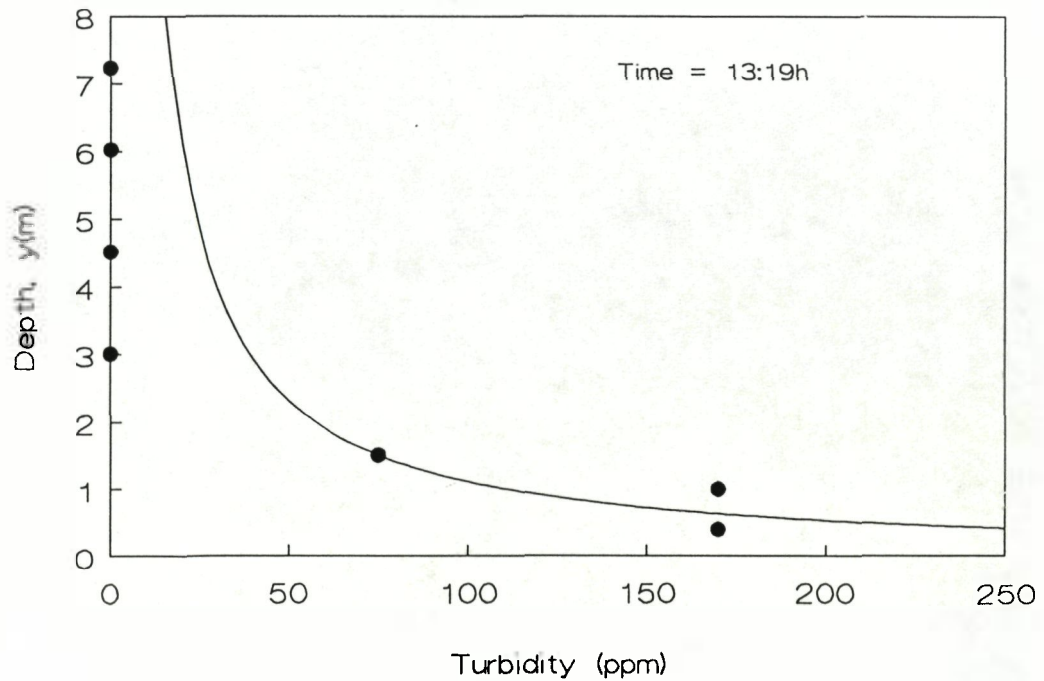


FIG.9c. TURBIDITY DISTRIBUTION
LOCATION A

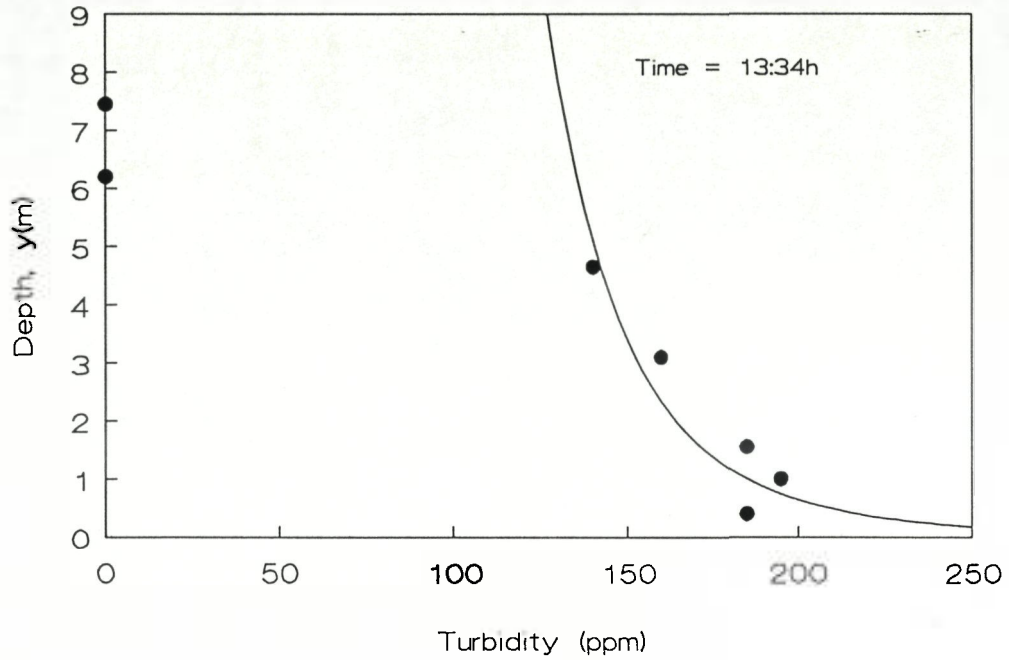


FIG.9d. TURBIDITY DISTRIBUTION
LOCATION A

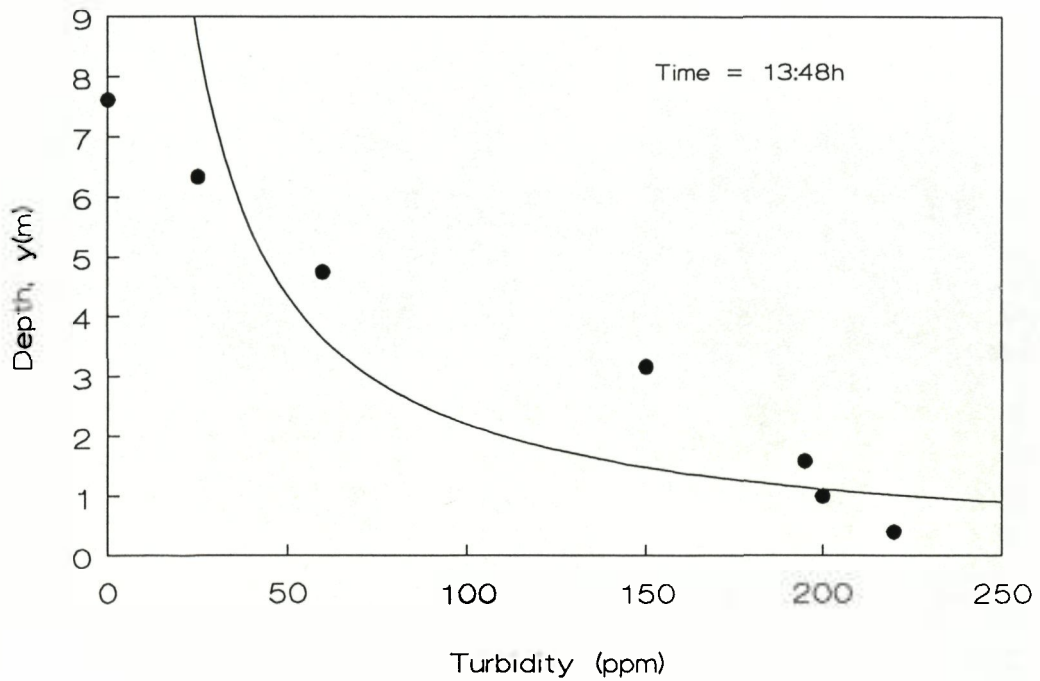


FIG.9e. TURBIDITY DISTRIBUTION
LOCATION A

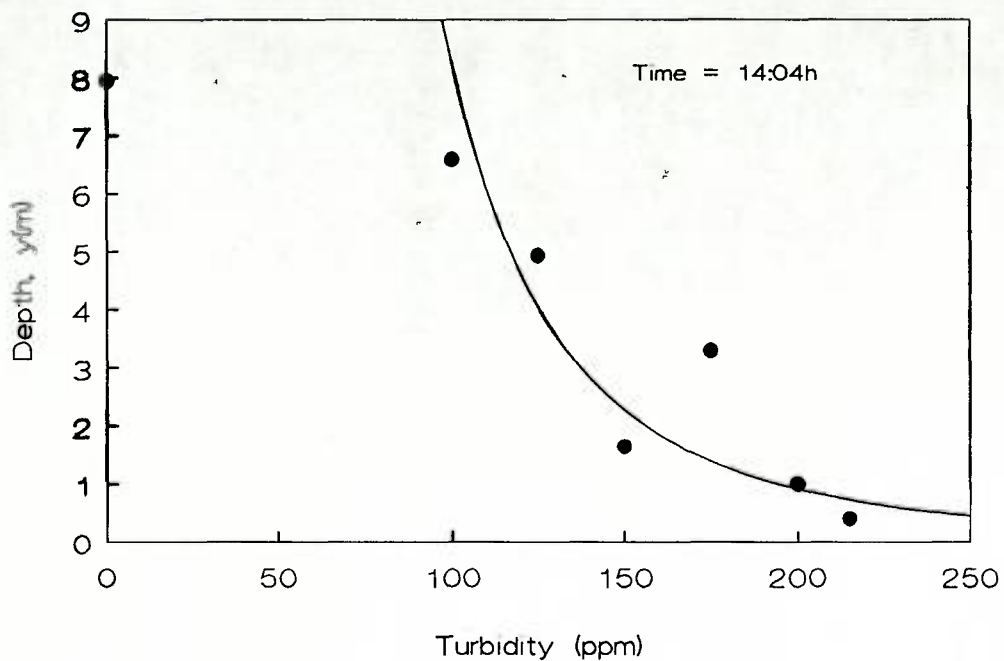


FIG.9f. TURBIDITY DISTRIBUTION
LOCATION A

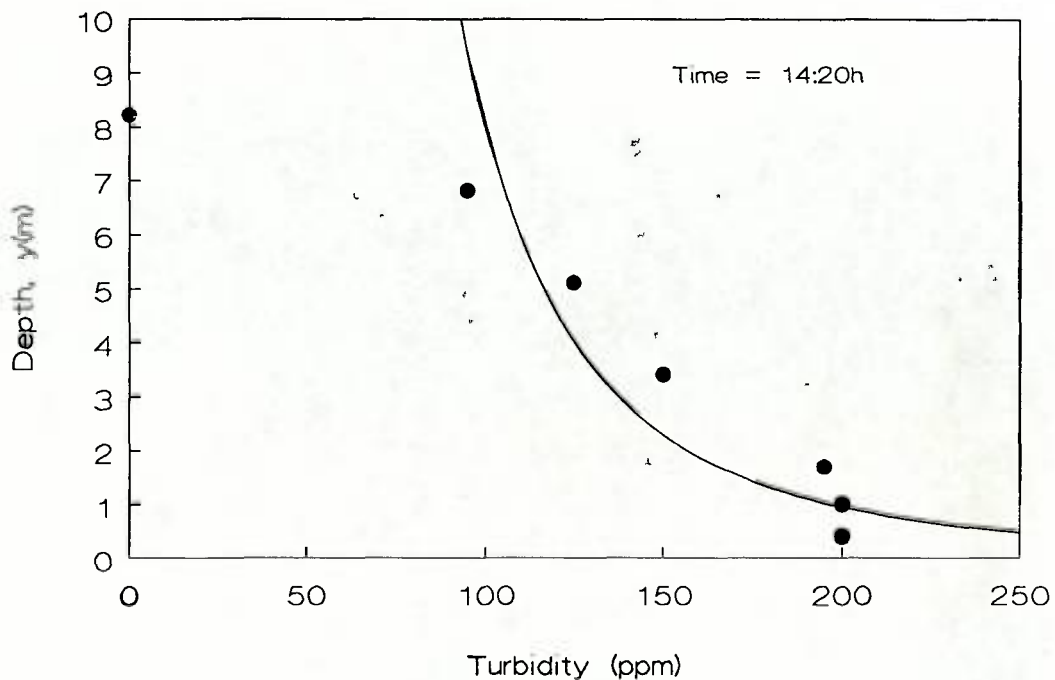


FIG.9g. TURBIDITY DISTRIBUTION
LOCATION A

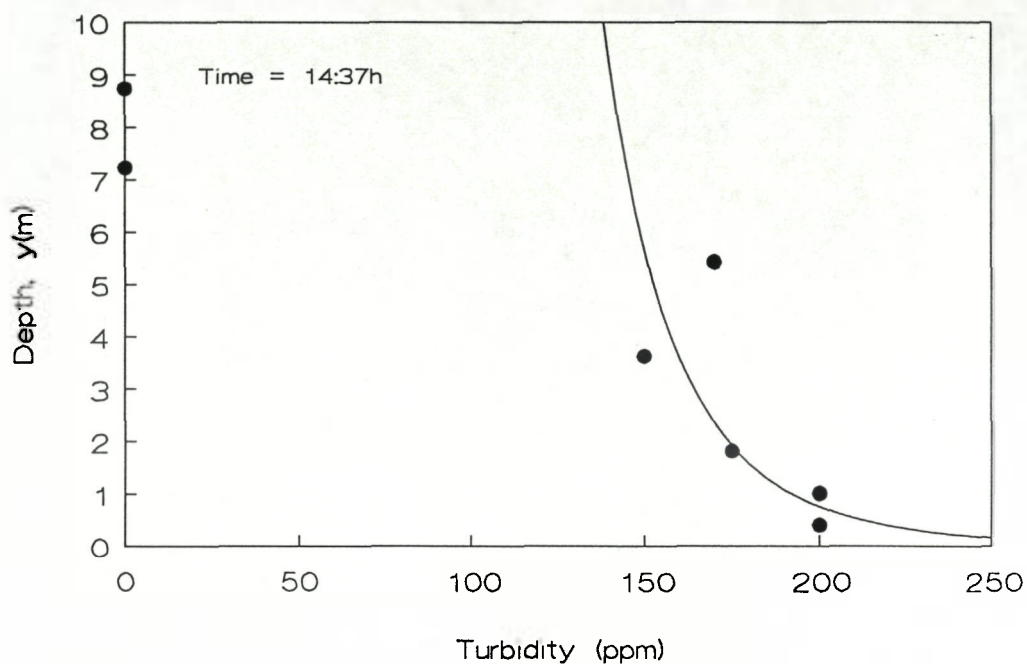


FIG.9h. TURBIDITY DISTRIBUTION
LOCATION A

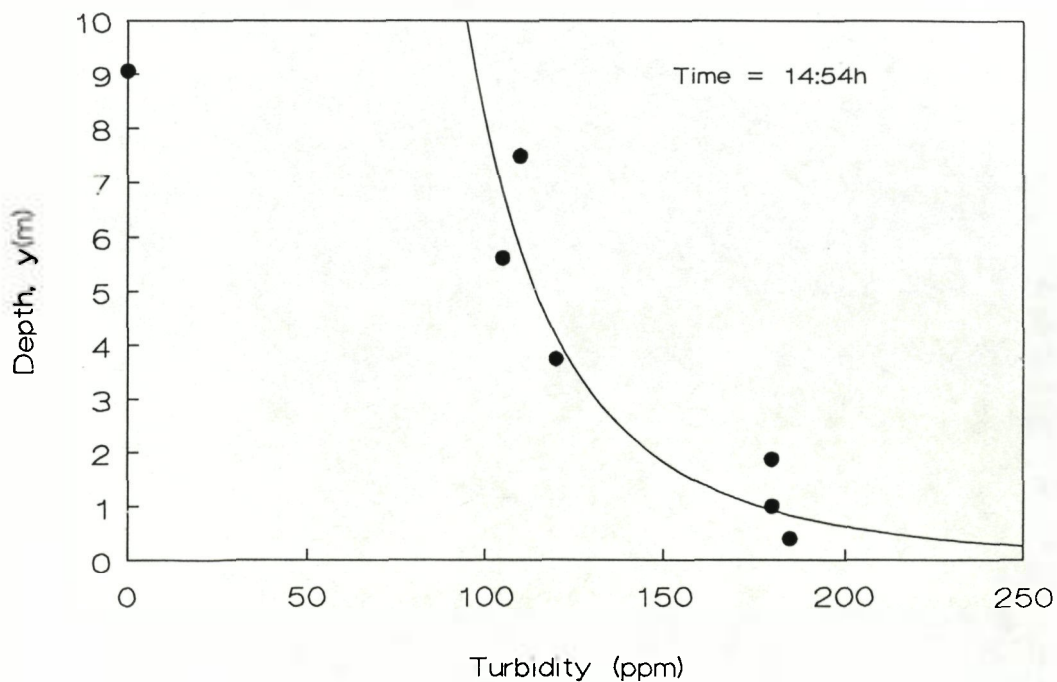


FIG.9i. TURBIDITY DISTRIBUTION
LOCATION A

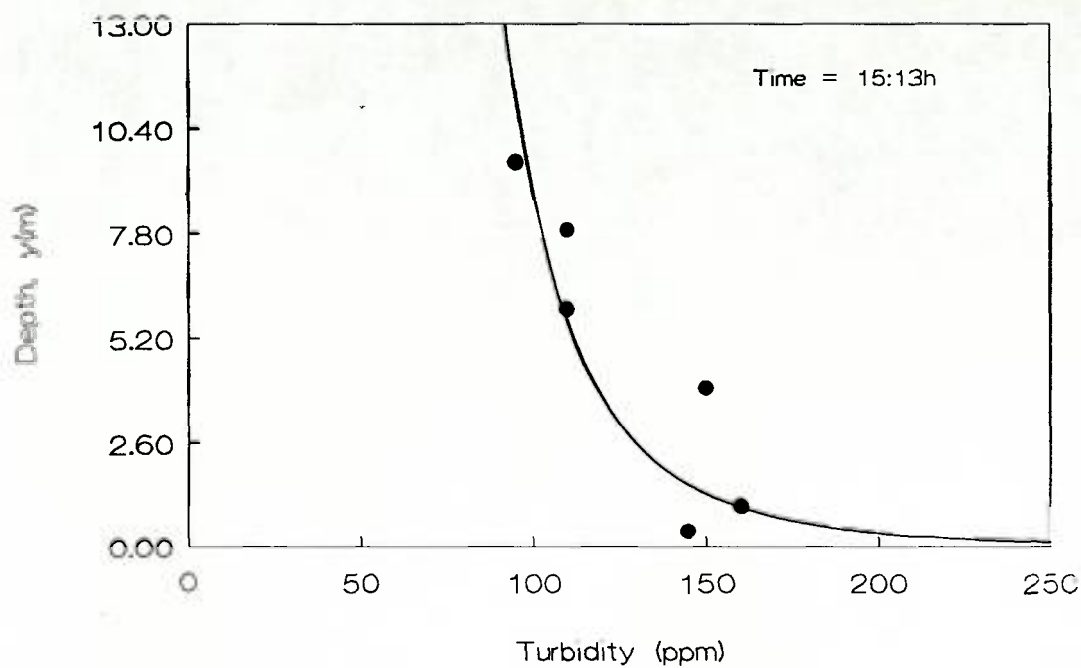


FIG.9j. TURBIDITY DISTRIBUTION
LOCATION A

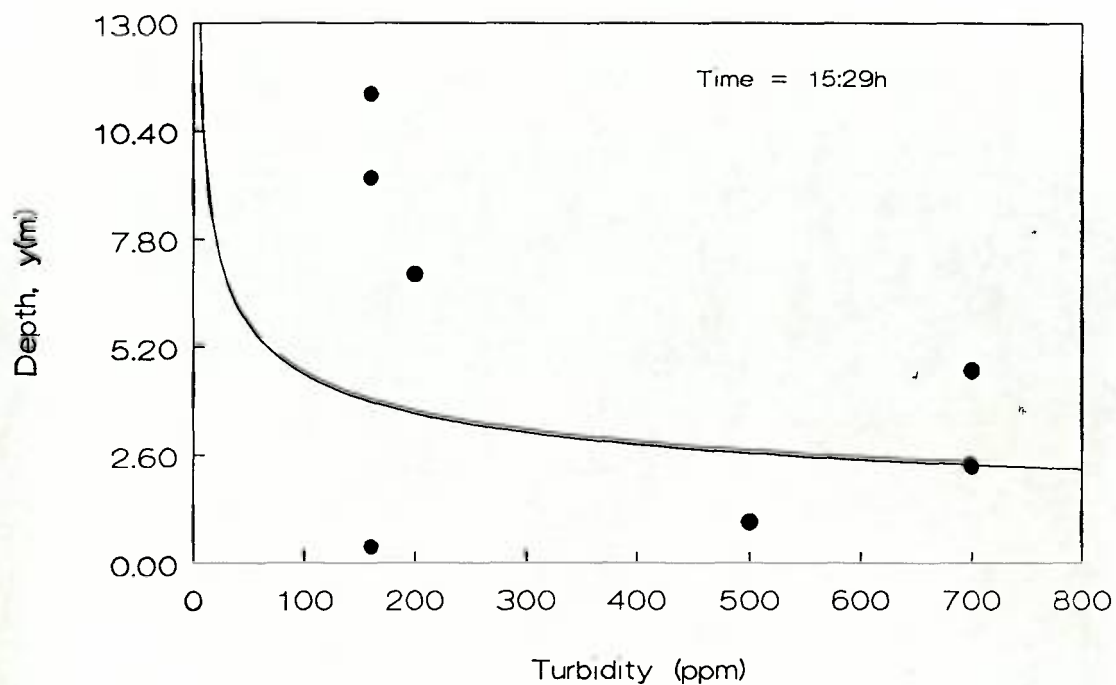


FIG.9k. TURBIDITY DISTRIBUTION
LOCATION A

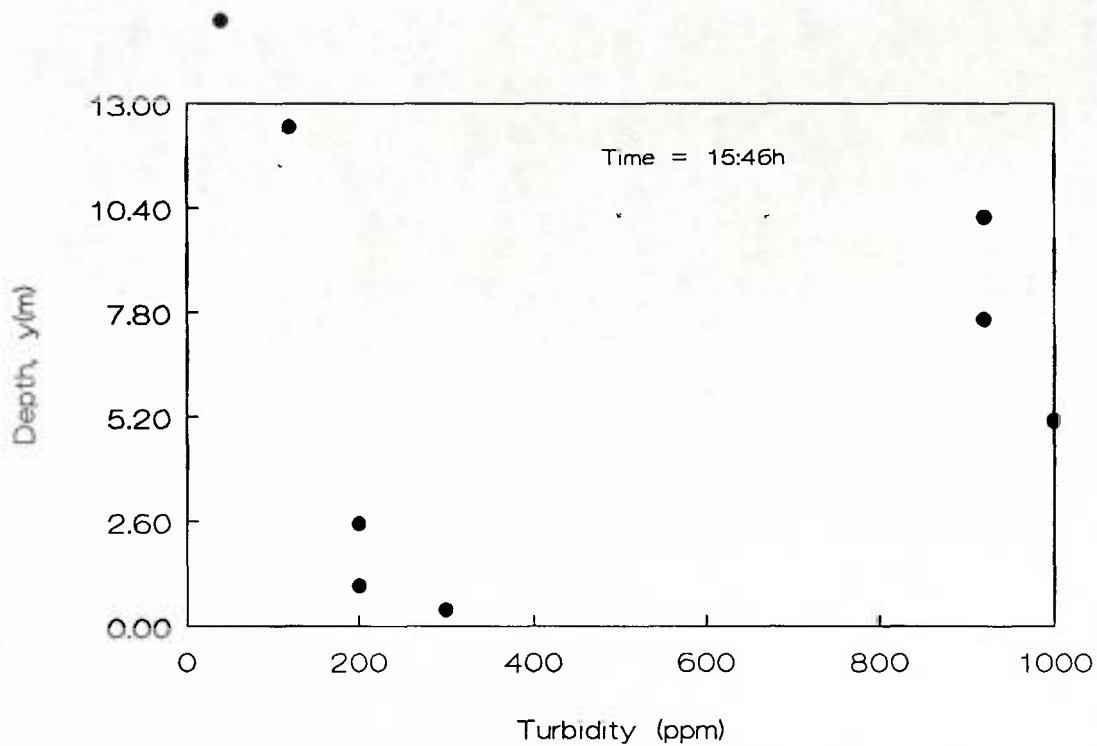


FIG.9l. TURBIDITY DISTRIBUTION
LOCATION A

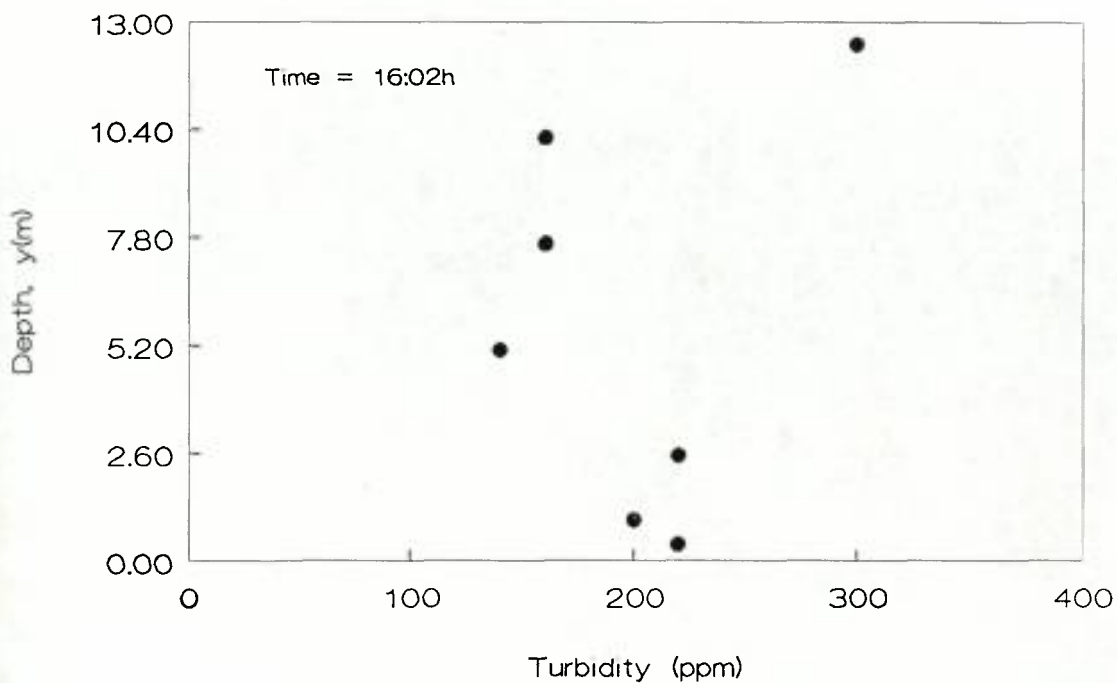


FIG.9m. TURBIDITY DISTRIBUTION
LOCATION A

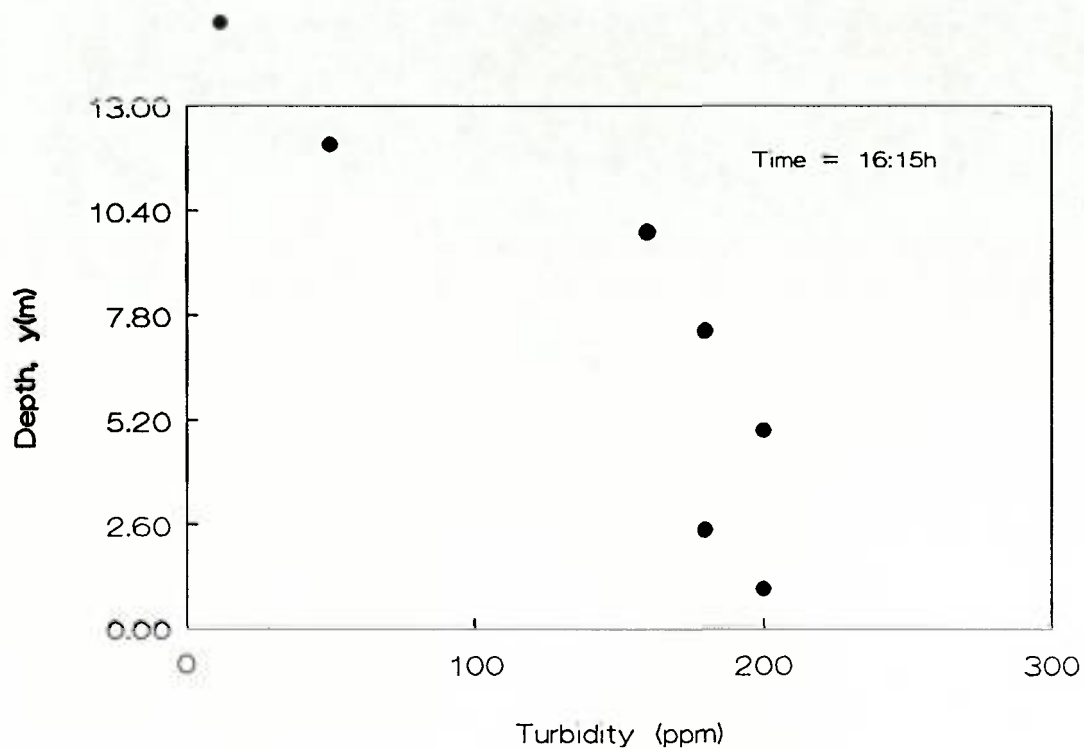


FIG.9n. TURBIDITY DISTRIBUTION
LOCATION A

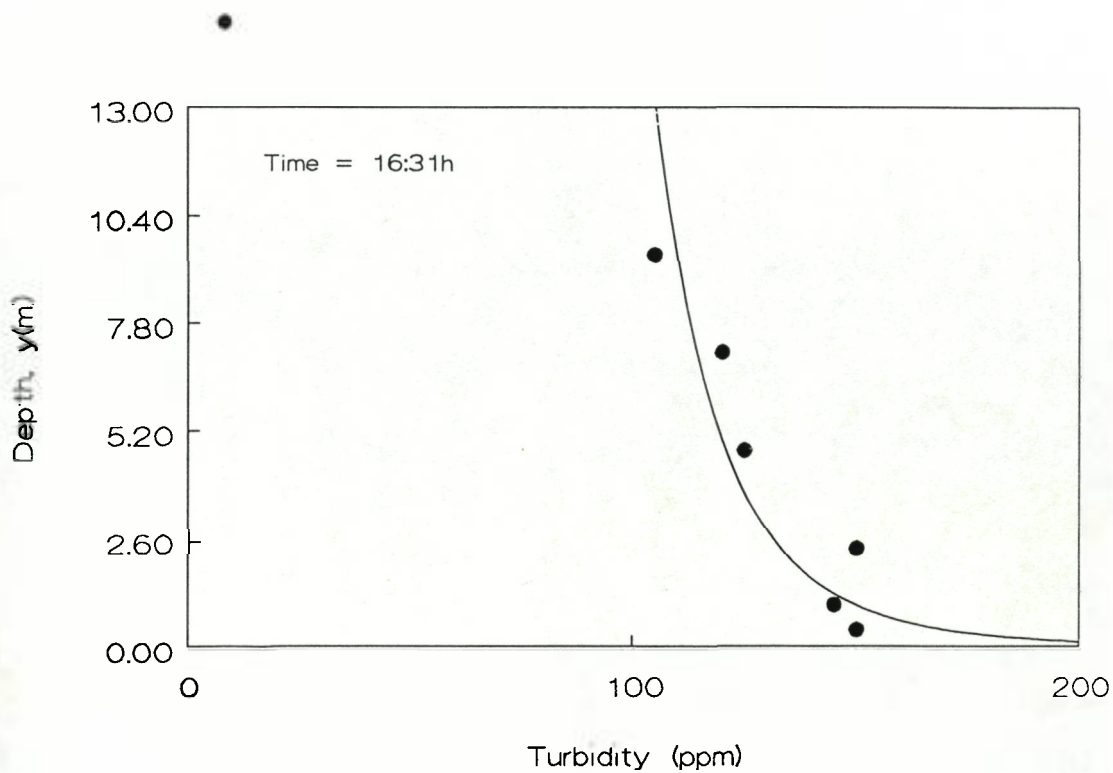


FIG.9o. TURBIDITY DISTRIBUTION
LOCATION A

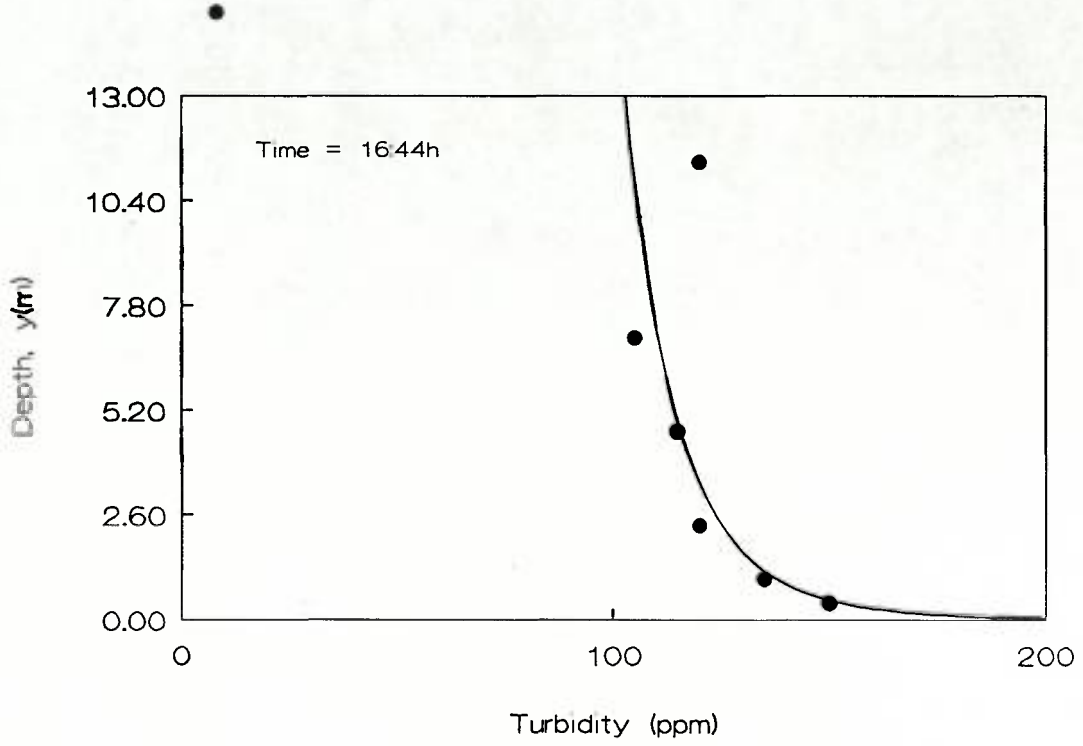


FIG.10. BED LOAD TRANSPORT
(BTMA RESULTS)

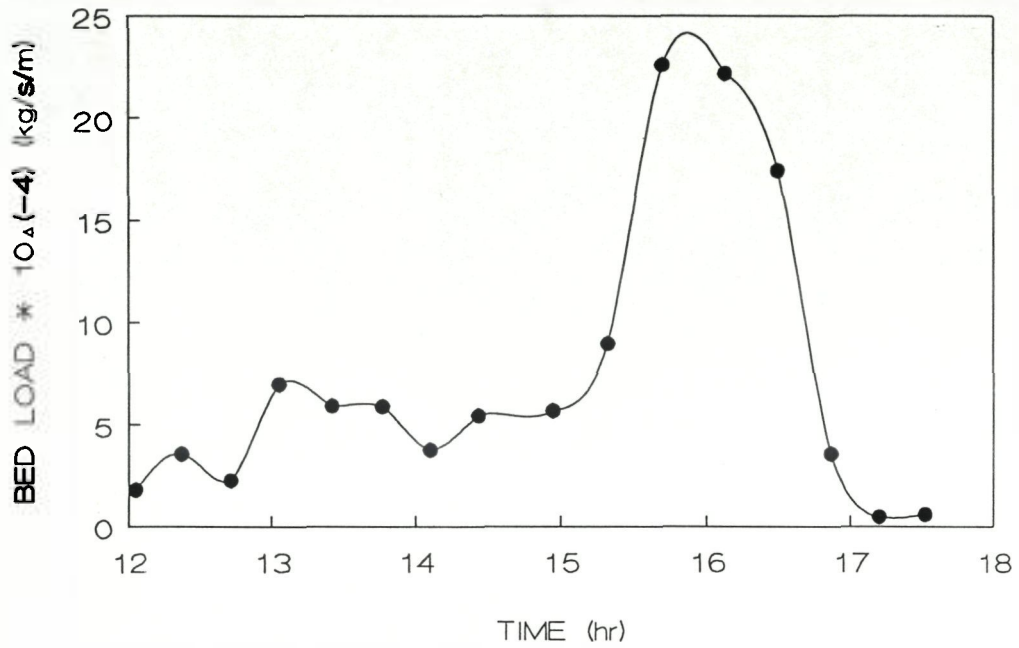


FIG.11. SALINITY
LOCATION A

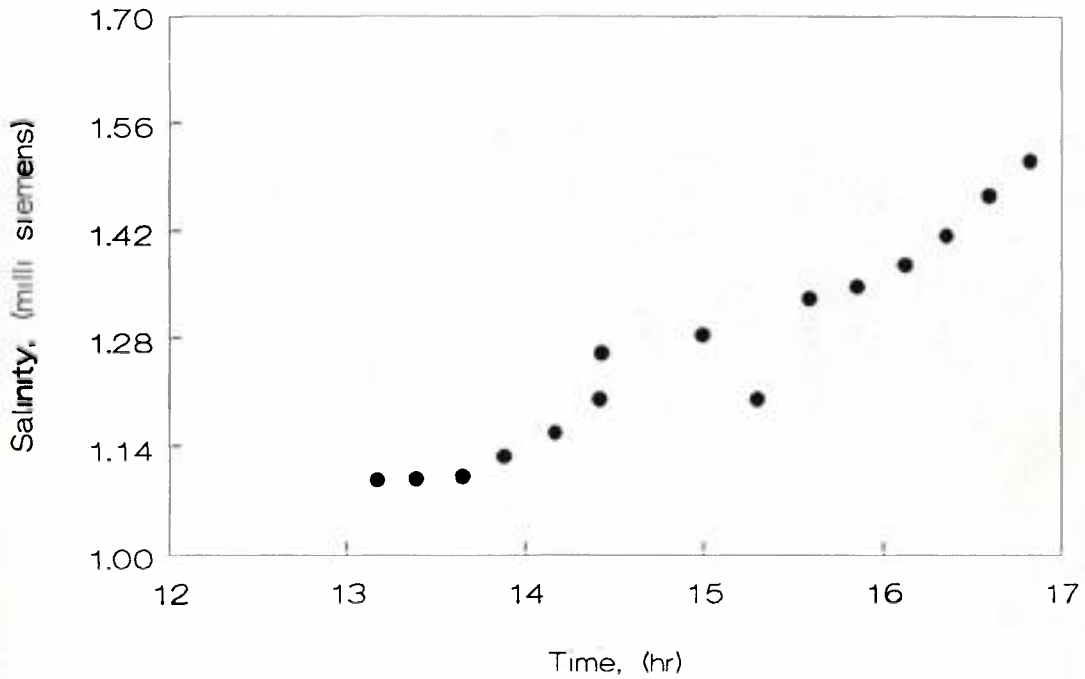


FIG.12. TEMPORAL VARIATION OF FRICTION VELOCITY (u^*) & DEPTH

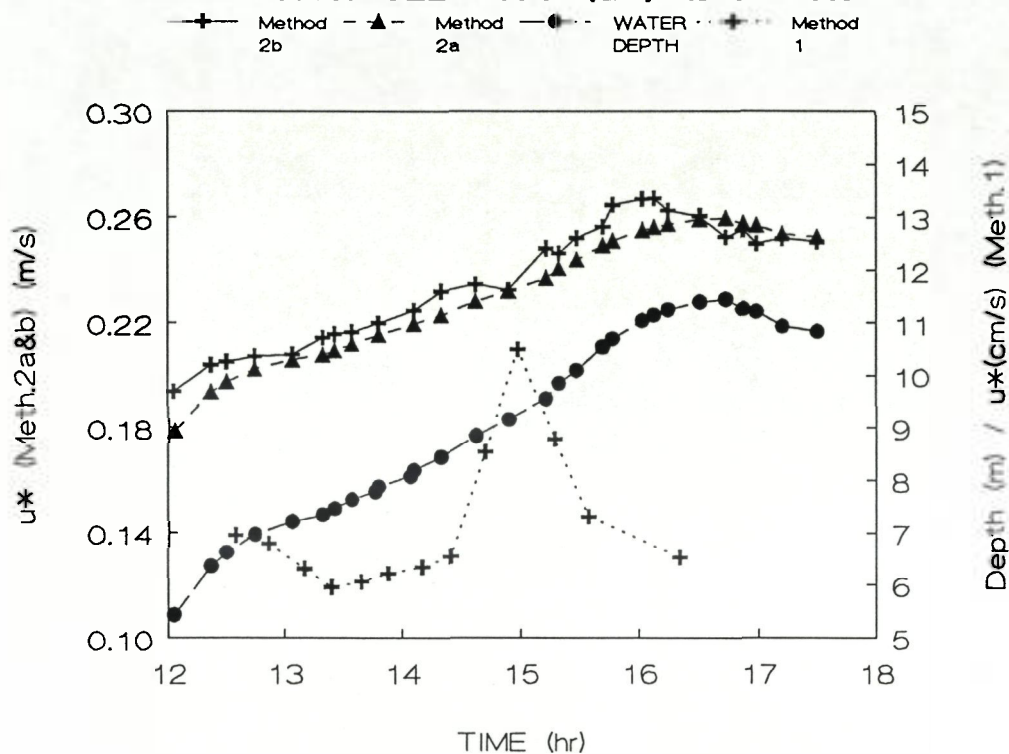


FIG.13. VARIATION OF FRICTION VELOCITY (u^*) WITH DEPTH (METH.2b)

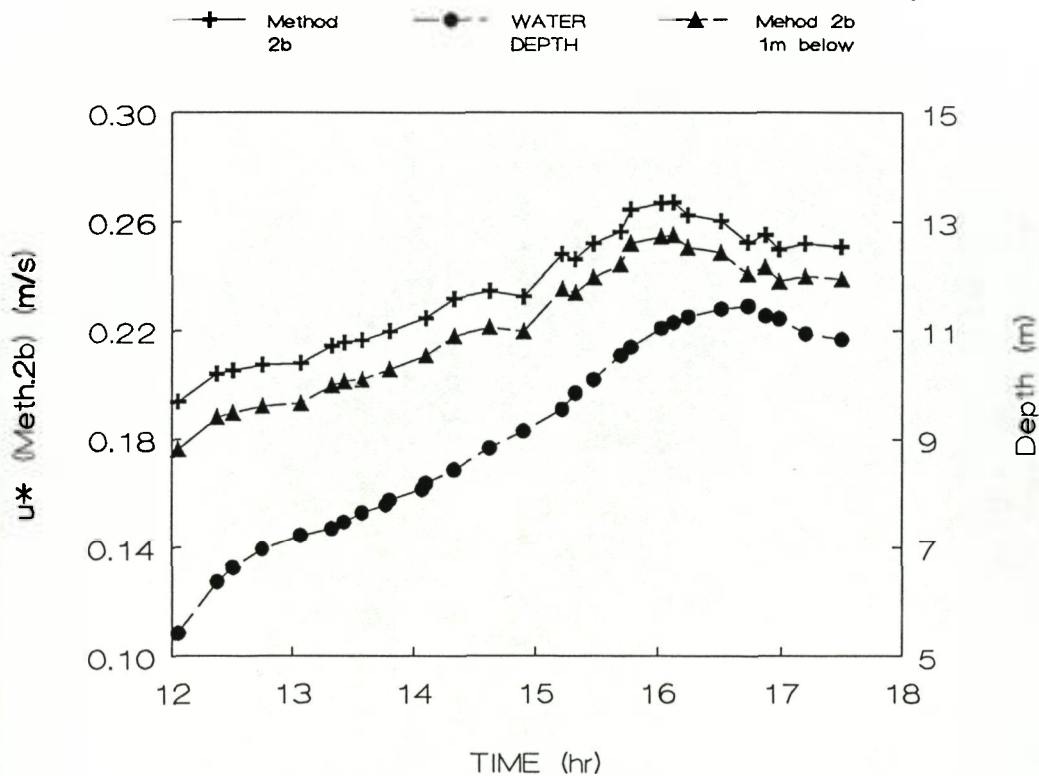
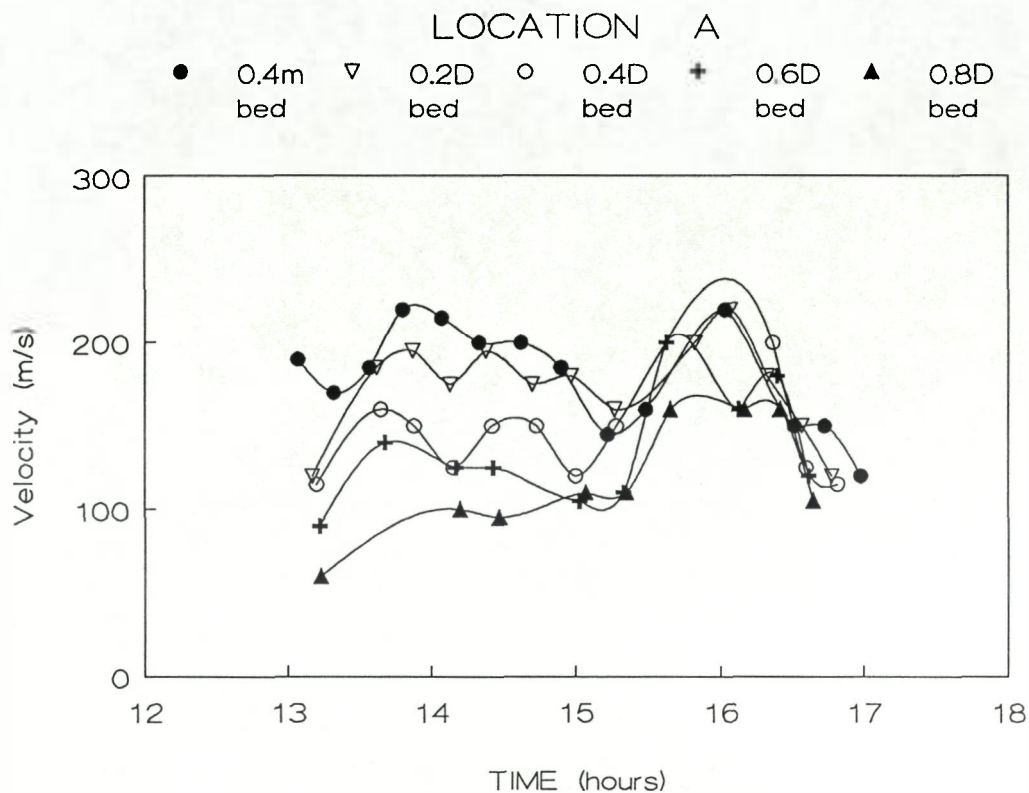
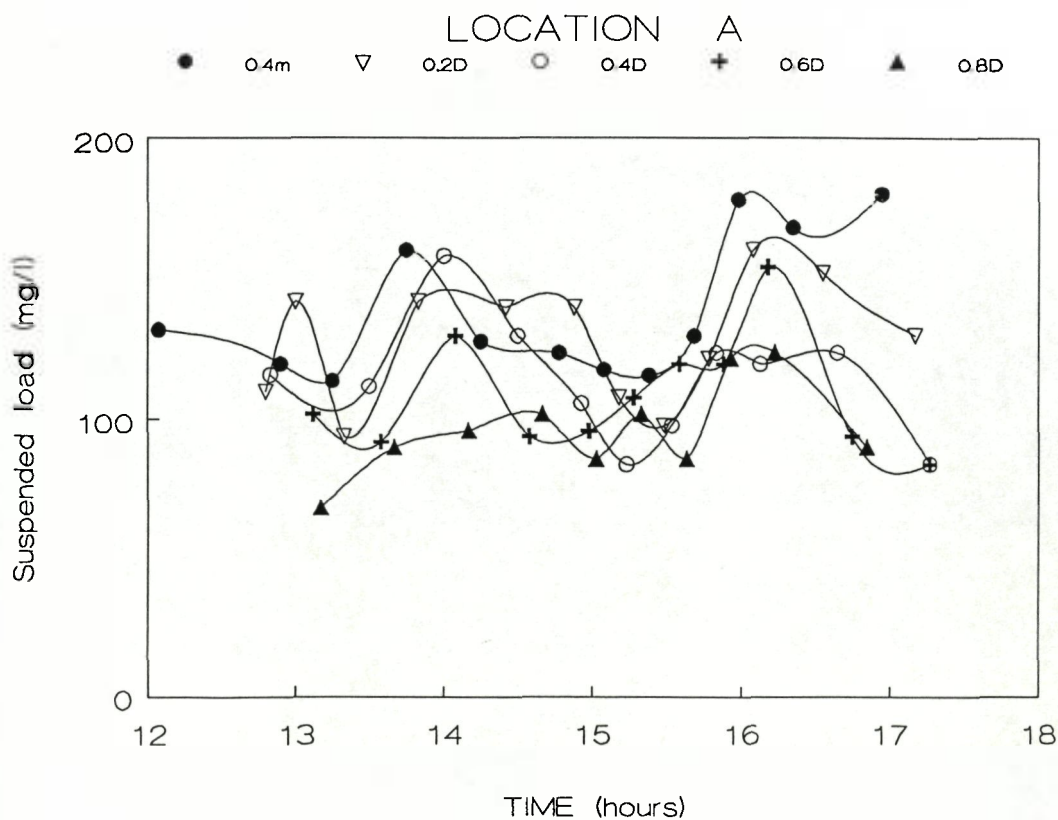


FIG. 14a. TURBIDITY DISTRIBUTION**FIG. 14b. SUSPENDED SEDIMENT**

**FIG.14c. WATER DEPTH AND
SEDIMENT HYDROGRAPH**

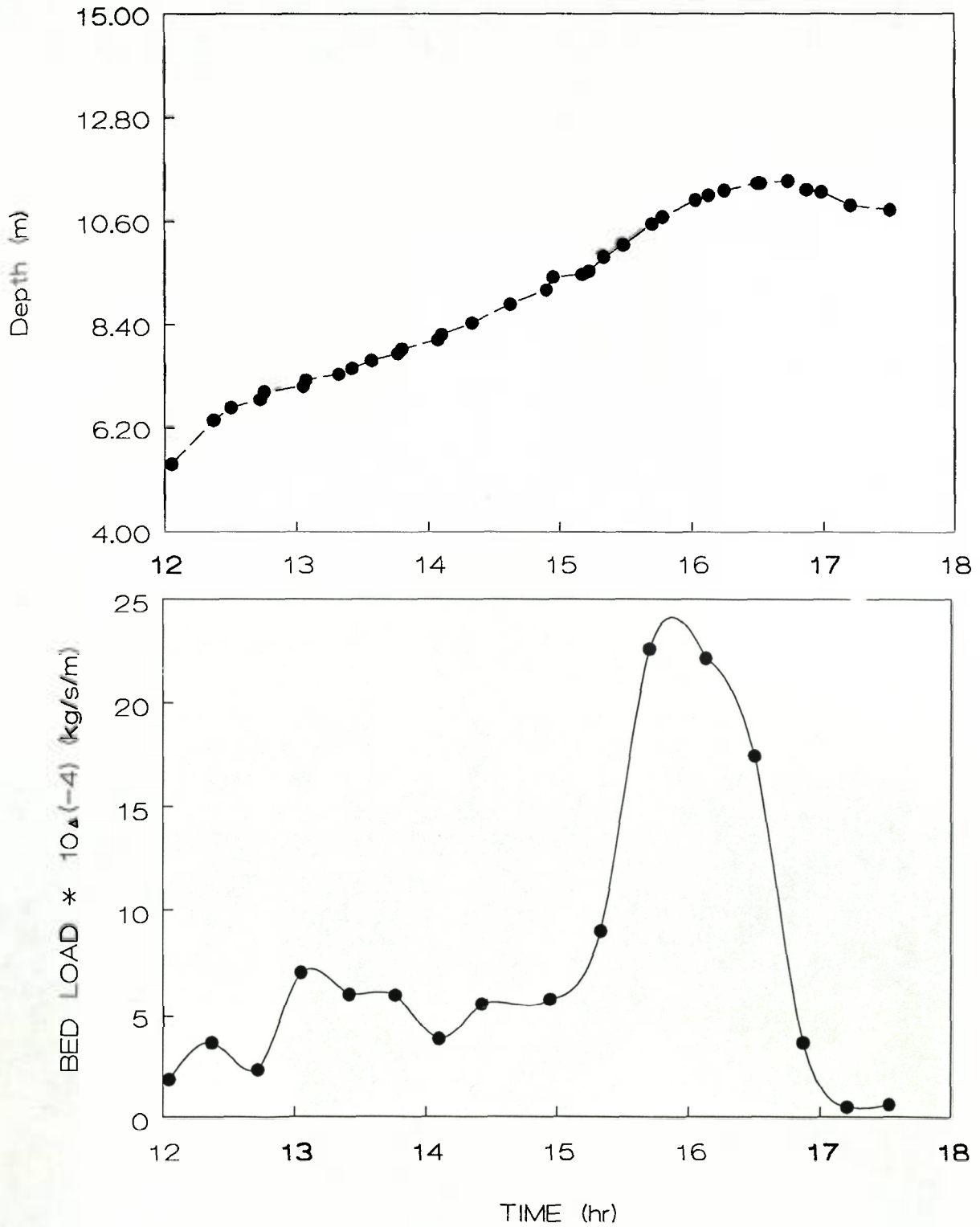
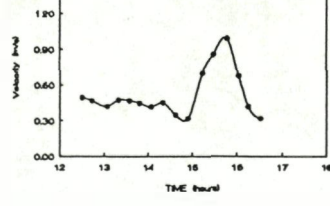
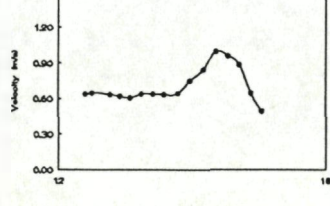
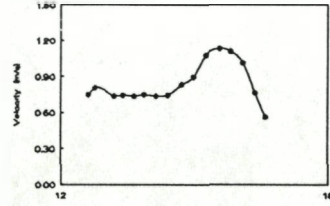
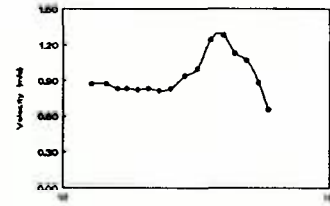
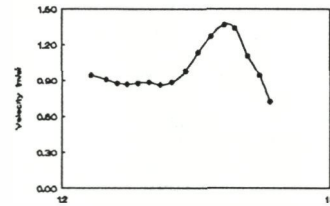
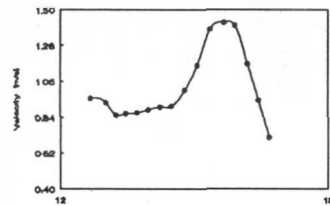


FIG.14d VELOCITY AT DIFFERENT LEVELS



TIME hour

Operator Kabir

 Datum 18.06.91

 MONSTERNAME TEMSE

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NAAM OF NUMMER MONSTER	Nr. FILTER	GEWICHT FILTER (g)	GEWICHT F + S (g)	GEWICHT SLIB (g)	GEBRUIKT VOLUME (ml)	TROEBEL- HEID (mg/l)
	129	0.0600	0.0688	0.0088	50	176
	130	0.0589	0.0669	0.0080	50	160
	131	0.0580	0.0640	0.0060	50	120
	132	0.0581	0.0658	0.0077	50	154
	133	0.0580	0.0643	0.0062	50	124
	134	0.0639	0.0723	0.0084	50	168
	135	0.0639	0.0670	0.0031	50	61
	136	0.0640	0.0753	0.0113	50	226
	137	0.0639	0.0715	0.0076	50	152
	138	0.0628	0.0690	0.0062	50	124
	139	0.0625	0.0672	0.0047	50	94
	140	0.0621	0.0666	0.0045	50	90
	141	0.0619	0.0709	0.0090	50	180
	142	0.0620	0.0691	0.0071	50	142
	143	0.0625	0.0690	0.0065	50	130
	144	0.0620	0.0662	0.0042	50	84
	145	0.0614	0.0659	0.0045	50	90
	146	0.0619	0.0640	0.0021	50	42
	147	0.0616	0.0671	0.0055	50	110
	148	0.0611	0.0670	0.0059	50	118
	149	0.0610	0.0645	0.0035	50	70
	150	0.0588	0.0662	0.0074	50	148
	151	0.0601	0.0669	0.0068	50	136
	152	0.0610	0.0659	0.0049	50	98
	153	0.0587	0.0632	0.0045	50	90
	154	0.0592	0.0634	0.0042	50	84
	155	0.0590	0.0656	0.0066	50	132
	156	0.0588	0.0623	0.0035	50	70
	157	0.0580	0.0638	0.0058	50	116
	158	0.0571	0.0650	0.0079	50	158
	159	0.0650	0.0738	0.0088	50	176
	160	0.0643	0.0730	0.0087	50	174