*HR Wallingford*

# Estuarine Sediments - Near Bed Processes

## Investigation of siltation mechanisms in Harwich Harbour

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## Contract

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## Abstract

A research programme has been undertaken by Hydraulics Research (HR) in conjunction with Harwich Harbour Authority (HHA), to study cohesive sediment behaviour at two points within Harwich Harbour. The project was jointly funded by Hydraulics Research, Harwich Haven Authority and the Department of the Environment.

The objective of the research is to increase understanding of near bed processes and their influence on cohesive sediment transport processes. The knowledge acquired will enable an improvement in accuracy and precision of predictive models of cohesive sediment movement.

The accuracy of the prediction of the movement of cohesive sediment is at present limited by the degree of understanding of the near bed hydrodynamics and the influence of the hydrodynamics on sediment transport processes.

The aims of the work described in this report were to study the cohesive sediment transport processes at two points within Harwich Harbour (Fig 1) and to calibrate and verify the siltation at a point (SAP) model. This involved the collection of field data over a spring and neap tide at the two points, long term monitoring of suspended sediment concentrations and wind speed and direction, application of previously obtained mud properties and recording the hours of operation of Jetsed dredging.

It was considered that the suspended sediment concentrations at any time was dependent on the state of the tide, the tidal range, the wave activity (as expressed by wind speed and direction), Jetsed dredging and seasonal effects. By analysing the long term suspended sediment concentration data in half tide periods, the independent effects of the forcing factors were to be assessed. However, the multiple combination of forcing factors and the shorter than anticipated period of measurement made the assessment difficult.

The two points were selected because point 1 was known to exhibit a relatively large rate of net deposition whereas point 2 showed little increase in bed depth over extended periods. It was considered by HHA (Ref 1) that sediment accreted at a rate of 1-2m per year in the vicinity of point 1. This material is considered to comprise deposited suspended sediment and material that slumps from the shallow region at the toe of the river bank. It is thought that this material drifts slowly towards the deeper parts of the harbour. Near point 2 no such slumping occurs and the processes of deposition and erosion of material seem to balance. It is estimated (Ref 1) that the accretion rate is less than 0.2m per year.

It is difficult to isolate the three forcing factors of tidal range, Jetsed dredging and wind speed that affect suspended sediment concentration and therefore erosion and deposition characteristics. It is thought that all three affect suspended sediment concentration.

Changes in suspended sediment concentration are shown to be similar over the Harbour area studied. Evidence shows that an increase in tidal range causes increases in suspended sediment concentration. An increase in the mean (half tide) wind speed above 30kts appears to cause an immediate increase in suspended sediment concentration. This high concentration reduces quickly as the wind speed abates. It appears that Jetsed dredging increases suspended

sediment concentration. Such increases are felt far from the dredging location. The magnitude of increases in suspended sediment concentration is dependant on the duration of jetsed dredging and the distance away from the operation. Results show increases in suspended concentration correlate well with increases in bed shear stress. This indicates the source of suspended material was close to the sites surveyed.

A successful analysis of the mechanisms concerning sediment settling and the associated in situ concentration profiles show that settling velocities calculated using an analysis of suspended sediment concentration profiles compared well with Owen tube measurements previously taken in the area.

SAP was calibrated by three methods at point 1 and for each method the model was successfully verified at point 2. Averaging the results predicted by SAP using methods 1 and 2, 500kgm$^{-2}$ per year was deposited at point 1 and 100kgm$^{-2}$ per year was deposited at point 2. This indicated increases of bed thickness of 1.2m and 0.1m respectively. The prediction from SAP compared well with the HHA estimated bed level changes, 1-2m at point 1 and less than 0.2m at point 2.

To acquire the most suitable suspended sediment concentration data to input into the SAP model, it is suggested that in the future the monitors be fixed to a stationary object at a height of 0.1m above the bed. This could be implemented using a jetty or wharf structure or where such constructions are not available a simple bed frame may be used. Both winter and summer measurements should be taken.

This study has increased the knowledge of the behaviour of cohesive sediments in estuarine and marine areas. Results have indicated that SAP can be calibrated successfully using field measurements. The calibration could be utilised to study deposition, erosion and consolidation at other points in an area where mud properties remain consistent with that used within the SAP input conditions.

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# 1. Introduction

## 1.1 Background

The ability to predict the movement of cohesive sediment within tidal waters has a significant economical and ecological importance in the development of new engineering works and the maintenance of existing installations. Schemes such as the reclamation of intertidal flats, the construction of new berths, or the enlargement and extension of dredged channels require a sound engineering appraisal of the likely changes in the patterns of sediment movement which will result after the scheme is built. Moreover, prediction of the movement of cohesive sediment is crucial in the understanding of the distribution of certain pollutants, in particular heavy metals which are adsorbed on to clay and silt particles.

The processes of transport, deposition, consolidation and erosion of cohesive sediment are controlled by a complex array of physical and chemical factors which are only partly understood. Any attempt to predict the movement of cohesive sediment must first investigate the nature of the hydrodynamics of the water and then relate the movement of water to the movement of cohesive sediment. As yet, it is not possible to predict the behaviour of a cohesive sediment from its physical and chemical properties alone and the principal thrust of research has been to determine in the laboratory or in the field, for a given set of flow conditions, the behaviour of a cohesive sediment.

## 1.2 Objective

The objective of the research is to increase understanding of near bed processes and their influence on cohesive sediment transport processes. The knowledge acquired will enable an improvement in accuracy and precision of predictive models of cohesive sediment movement.

The accuracy of the prediction of the movement of cohesive sediment is at present limited by the degree of understanding of the near bed hydrodynamics and the influence of the hydrodynamics on sediment transport processes.

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# 2. *Field Survey Measurements*

## 2.1 Long term sediment concentration

HR received two periods of long term data from HHA. The first from 27th October 89 to 13th March 90. The second from 2nd May 90 to 3rd June 90. Unfortunately data between the two periods were not available. The logged data during the two periods also had short breaks, which made the analysis of results more difficult.

During the study, suspended sediment concentration was measured using two silt meters. The first (monitor 1) was moved within the harbour area. Sites studied with the first monitor were as follows.

| | |
|---|---|
| 1) Lightship 2 | 626 148mE, 233 591mN<br>2/11/89-30/11/89 |
| 2) Lightship 10 | 624 461mE, 233 375mN<br>6/12/89- 5/2/90 |
| 3) Holbrook Beacon | 618 214mE, 233 622mN<br>14/2/90-13/3/90<br>2/5/90- 3/6/90 |

The second (monitor 2) was permanently attached to the Oil Jetty (627 872 mE, 233 282 mN). Unfortunately, the silt meters were mounted at different heights at each location.

| | |
|---|---|
| Oil Jetty | 5m above bed (fixed) |
| Lightship 2 | mid depth (variable) |
| Lightship 10 | 4m below surface (variable) |
| Holbrook Beacon | 1.5-2.0m above bed (fixed, mid depth at low water) |

The usual method of processing the suspended sediment concentration, is to split the data into half tide flood and ebb periods. To limit the effect of signal drift, the lowest 3 values of each half tide data set are averaged, this minimum or zero value is then subtracted from the mean value calculated for the corresponding flood or ebb tides. Using a similar system but using the average of the highest three values (after the drift effect has been removed) the maximum suspended sediment concentration over the half tide can be assessed.

The monitor at the Oil Jetty was prone to excessive drift. The drift was thought to be due to an adjacent discharge from a fermentation products effluent pipe creating a premature coating of the monitor. However, when the zero half tide value is subtracted from the half tide mean and maximum suspended sediment concentration, drift of the instrument is removed and realistic data can be presented.

Understandably, both monitors show that the zero value is increased considerably during periods of prolonged high suspended sediment concentration. Subsequently, when the zero reading is subtracted from the running mean an unreasonably low mean suspended sediment result is acquired. Thus, care should be taken when interpreting the data. The increased zero value shows a correlation with high tidal range/dredging/wind activity in the area.

## 2.2 Other long term data

Tidal range in the harbour was not measured. The data used within this report has been taken from Admiralty Tide Tables.

Wind speeds and directions were measured by HHA over the same periods that sediment concentration data were acquired. Both gust and mean wind speed measurements were available.

HHA provided Jetsed dredging records over the period of suspended sediment data collection. In summary a number of dredging campaigns took place between the following dates.

1) 8 Nov 89 to 22 Dec 89.
2) 13 Jan 90 to 15 Jan 90.
3) 31 March to 27 April 90.

The location and number of hours dredged are shown in Table 1.

HHA also provided shipping records at the Oil Jetty during the month of November 89. This is summarized in Table 2.

## 2.3 Short term measurements

Vertical profiles of velocity, salinity and turbidity were taken in Harwich Harbour during neap tides 26-27 July 1989, and during spring tides 18-19 September 1989. Locations used in this study were,

point 1; 626 216 mE 234 190 mN,
point 2; 627 121 mE 233 689 mN.

Two sets of instruments were used simultaneously. A lower bed frame unit contained a Partech current meter, a Partech turbidity meter and a Semat salinometer. The upper sets of instruments were used to profile from 1 m above the bed to the surface and consisted of a HR Severn current meter measuring speed and direction, a Partech turbidity meter and a Semat salinometer.

Simultaneous profiles were obtained from the two units at approximately half hourly intervals throughout the tidal cycle. Data collection was interrupted for short periods when the survey boat was swinging because of the changing wind or tide. Prior to both deployments the turbidity and current meters were calibrated, the turbidity meters being related to Formazin standard. Many in situ bottle samples were taken on the second deployment. This allowed the relationship between Formazin turbidity units and mg/l for the observation site to be obtained.

Despite pre-deployment calibrations for the first deployment on 26-27 July 1989, a sharp discontinuity in the turbidity between the two units was obtained, the upper unit reading higher than the lower one. This could have been caused by dirt fouling the optical window of one of the turbidity meters after calibration. To correct for this the suspended sediment concentrations for the upper unit were decreased by 50 FTU (285mgl$^{-1}$). While this creates profiles which are more consistent, some caution should be exercised in using the composite profiles obtained on these days.

## 2.4 Bed density profiles

Density profiles close to the two points under consideration have been supplied by HHA (Ref 1). However, the interpretation of the density profiles is made difficult due to the Jetsed operations beginning on November 8$^{th}$ 1989. The only data in the experimental area taken before the 8$^{th}$ November 1989 was taken on 1$^{st}$ December 1988.

# *3. Interpretation of Long Term Field Measurements*

## 3.1 Spacial variation

Figures 2-6 illustrate the way the relevant parameters vary with time. For example, figure 2a shows the variation of tidal range and wind speed with time. Figure 2b shows the variation of zero, mean and maximum suspended sediment concentration, for ebb and flood tides at monitor 1. Figure 2c shows the variation of zero, mean and maximum suspended sediment concentration, for ebb and flood tides at monitor 2.

It is shown in figures 2-6 that increases in background suspended sediment concentration basically follow similar spacial and temporal variations throughout the Harbour area. That is, an increase in suspended sediment seen at the Oil Jetty will also be seen at the Lightship instrument and visa versa. There are a few exceptions to this rule, usually due to the location of dredging activity. For example, during dredging on the flood tide at Trinity, increases in suspended sediment are only seen at the Lightship instrument. This is due to the fact that the Oil Jetty is seaward of the Trinity dredging area. On the ebb it seems that the suspended sediment has been deposited up river (at high water), and therefore, suspended sediment concentrations have reduced to values similar to pre-Jetsed data.

## 3.2 Tidal range

It has been found in other muddy tidal environments that the concentration of suspended sediment varies in proportion to the energy in the tide (for example, tidal range). This appears to be the case for the Harwich Harbour area also. Figures 2-6, clearly shows an increase in zero suspended sediment concentration during periods of high tidal range for both ebb and flood tides.

This increase in zero suspended sediment concentration is considered to be caused by any, or a combination of the following factors.

1) During periods of large tidal range both ebb and flood velocities will be increased. This suggests higher rates of erosion and therefore higher concentrations of suspended sediment in the water column.

2) The effect of surface waves will be more pronounced as water levels will be lower during periods of high tidal ranges. The effect of breaking waves on mud flats during the ebb tide, will erode considerable amounts of material in areas that would remain unaffected when covered by water during lower tidal range periods. High winds would also augment this effect.

## 3.3 Wind

It is interesting to note the linear relationship between gust and mean data. Graphs showing mean wind speed versus maximum gust speed for the months of December and March are shown as examples (Fig 7).

Periods of prolonged high wind speeds have a definite affect on suspended sediment concentration. For example, on January 25 1990 between 10.00 and 22.00hrs mean wind speeds measured were over 30kts. At times gust wind speeds reached 50kts. Figure 4 clearly shows a correspondingly large increase in suspended sediment concentration (approx 80 ppm) in both ebb and flood tides. These higher concentrations reduce quickly to lower values (approx 20ppm) in the following tide when wind speeds had reduced to values below 20kts.

The increase in suspended sediment during high wind speeds is short lived, and therefore, probably due to local wave stirring. That is, the choppy water surface eroding sediment in shallow mud flat areas.

## 3.4 Dredging

It is expected that the disturbed bed material caused by the Jetsed process will consolidate slowly and will initially have a low threshold to erosion. Therefore, this material will be easier to remove than the original bed material during conditions of high bed shear stress. This may be caused by high current velocities and/or wave activity.

## 3.5 Dredging, wind tidal range

During periods of dredging, high wind speeds, and high tidal ranges the suspended sediment concentration is increased well above that expected for any of the conditions experienced separately. It is unfortunate that during the period of study high or low values of the above parameters occurred generally at the same time. Thus, it is very difficult to isolate a single variable causing the change in suspended sediment concentration. Nevertheless, a description of the important points in Figures 2-6, and an attempt to distinguish the possible causes of each case of increased or decreased suspended sediment has been made.

With reference to the suspended sediment concentration data from monitor 1 which was relatively unaffected by signal drift, the following observations can be made. It appears that during neap tides (eg. 7 Nov, 22 Nov, 23 Dec, 20 Jan, 17 Feb, 6 Mar) the suspended sediment concentration remains low, between 20-40ppm. The suspended sediment content does not appear to be affected by winds of 10-20kts. During neap periods there appears to be correlation between peaks in wind speed (greater than 20kts) and suspended sediment concentration (eg 8, 9 and 24 Nov, 19 Feb, 9 March).

Similarly studying spring periods the following observations can be made. Between the 8-9 Nov and 16-17 Nov wind speeds are high (20-30kts). The zero remains unaffected but the mean shows a similar increase to the tidal range. Jetsed dredging is also taking place during this period. The dip in concentrations between the 11-16 Nov, seems to correlate with a decrease in wind activity.

During the spring period around 31 Dec, low winds are present (less than 10kts). There is no change in the zero, but a small rise in mean suspended sediment concentration occurs. This indicates that tidal range is important.

Wind speeds of 10-20kts are seen around the 13 Jan. There appears to be a small rise in the mean suspended sediment concentration due to the tidal range, but the two peaks are probably caused by the Jetsed dredging operations.

Wind speed is high and tidal range is large at the next spring tide (30 Jan). This causes a sustained rise in zero, mean and maximum suspended sediment concentration. It should be noted that after the wind speed decreases (26 Jan), the suspended sediment concentration continues to rise with the increase in tidal range. The 30kts peak in wind speed on the 25 Jan is clearly related to the peak in suspended sediment concentration on the same day.

On the 14 Feb wind speeds are high for that day which causes the peaks in zero, mean and maximum suspended sediment concentration. The change in tidal range between neap and spring tides is small, and therefore the zero suspended sediment concentration is relatively low.

In February monitor 1 was moved to a third location, Holbrook Beacon. On this occasion the monitor was positioned nearer to the bed than during previous deployments. This explains the higher peak in suspended sediment concentration on the 28 Feb when the wind speed is high (30-35kts), and the change in tidal range from neap to spring is large. Both these factors cause increases in zero, mean and maximum suspended sediment concentration.

The suspended sediment concentration derived from the second monitor at the Oil Jetty shows similar patterns to those described for monitor 1. In addition, data for the May-June period can be assessed. For both of the spring tides during this period, wind speeds are low (10-20kts), the change in tidal range between spring and neap tides are also low. This is portrayed by the very low levels in mean and maximum suspended sediment concentration during the spring tides. The maximum suspended sediment concentration appears to be very erratic during this period, increases in maximum suspended sediment concentration do not correspond with increases in wind speed.

It can be seen in figures 2 and 3, that during the Jetsed operations in November and December 89, particularly 11-13 and 16-19 November, flood suspended sediment concentrations at the Oil Jetty appear to be far larger than on the ebb. It is considered that this was caused by Jetsed operations carried out predominantly during flood periods. This would suggest sediment is being transported upstream, to deposit at high water. Little of the deposited material appears to be re-suspended during the ebb. The deposited material may be re-suspended by a storm event or period of high tidal range and be transported further upstream or downstream. It seems sensible to limit Jetsed operations to ebb tides only, to remove the sediment from the inner harbour area.

In conclusion, it is thought that periods of high tidal range increases suspended sediment concentration. High winds alone, also seem to raise suspended sediment concentration. During modest spring tides the wind effect seems to be enhanced (eg 26,27 and the 29 Feb). The large rises in zero, mean and maximum suspended sediment concentration on the 30 Jan and 27 Feb clearly show the effect of high tidal range augmented by high wind speed.

Lastly if we compare the springs of 14 Nov (Jetsed activity) and the 29 Feb (no Jetsed activity) it appears that Jetsed is increasing the length of the raised suspended sediment concentration during the former period. Wind is stronger on the 29 Feb but the periods of raised suspended sediment concentration are shorter with smaller magnitudes. Interpretation is difficult because dredging takes place during spring tide periods, and often during spells of high wind speed.

## 3.6 Ship movements

Figure 8 shows typical periods of suspended sediment concentrations at the Oil Jetty. The period 3-7 November covers a time span during which no dredging has taken place. The period 8-19 November covers a time span over which dredging has taken place. Also shown are the times of ship activity at the Oil Jetty. It can be seen that there is little change in suspended sediment concentration due to the churning of the bed by propeller action. Any slight increase in suspended sediment is quickly reduced as the water column is advected through the area. It can be expected that ship movements may cause greatest localised increases in suspended sediment concentration soon after dredging activities have occurred before the bed has had time to consolidate.

## 3.7 Bed profiles

Figure 9 shows typical bed profiles in the jetty area before the Jetsed operation took place. These profiles were taken south of the experimental positions. It has been assumed that they are typical of the area. Also plotted in figure 9 is an average profile (fitted by eye) which was used as input into the SAP model.

Profiles were taken south of points 1 and 2 before and after the Jetsed operation on the 7$^{th}$ and 23$^{rd}$ November 89, respectively. It was estimated from soundings that 1m of bed had been removed. Therefore, the post-Jetsed profile in figure 10 has been displaced by 1m to compare it with the pre-Jetsed profile. The continuity between the pre-Jetsed data and the post-Jetsed data substantiates the removal of 1m of bed. The post-dredge profile indicates that a small amount of material has been re-deposited. The lower bed layers seem to remain intact, but relatively closer to the bed surface.

The positions further away from the jetty (mid channel) appear to have steeper density gradients particularly close to the bed surface. This may be caused by larger current velocities sweeping the bed free of newly deposited low density material.

## 3.8 Analysis

It was hoped to quantify the correlation factor between the various independent variables, namely, tidal range, duration of Jetsed operations and wind speed with the dependent variable suspended sediment concentration. However, it was found that this was not possible for the following reasons.

1) Lack of data.
2) Signal drift of the monitors.
3) Complexity of the possible interaction between effects caused by the different forcing variables.

A linear increase in suspended sediment concentration with tidal range (neap to spring tides), followed by a linear decrease in suspended sediment concentration with tidal range (spring to neap tides) is often seen in the data. For example, figure 11 shows suspended sediment concentration versus tidal range for two consecutive periods, 21-30 Jan (neap-spring) and 31 Jan-5 Feb (spring- neap). The one erratic point during the neap-spring period is caused by the peak in wind speed on the 25 Jan. Figure 11 illustrates how quickly the suspended sediment concentration returns to value similar to the previous tide level on the next ebb tide.

Similar graphs during Jetsed operations show a much steeper gradient to the linear regression. It is difficult to say whether this is caused by the Jetsed operation or increased spring-neap tidal range, or a combination of both factors.

# *4. Interpretation of Short Term Measurements*

## 4.1 Velocity and concentration

### *4.1.1 Variation with time after high water*

Data at the two points 1 and 2 (Fig 1) have been analysed. Figures 12 and 13 compare the variation of water depth, depth mean velocity and near bed suspended sediment concentration at the associated location for Spring and Neap conditions.

Figures 12 and 13 show similar trends for both positions and conditions (except neap position 2). The velocity and also the suspended sediment concentration increase to a maximum (sharp peak) one hour after high water, followed by a decrease in both velocity and concentration towards a minimum at low water. One hour after low water, velocity and concentration increase to a maximum and remains fairly constant at this relatively high level for 3 hours. Both values then reduce towards high water.

At position 2 during the neap period there are only small changes in velocity and concentration over the 12.5 hour period measured. There are irregularities in both profiles. An extended increase in velocity towards the second high water is seen, this is similar to other plots in figures 12 and 13. It should also be noted that the velocity and concentration values are considerably lower than for other periods.

During data collection at point 1 (neap) a gap is present. This data has been estimated for use in the siltation at a point (SAP) model.

### *4.1.2 Velocity versus concentration*

The above data can be represented in another manner illustrating the relationship between concentration and velocity. Figure 14 shows an increase in average suspended sediment concentration with an increase in velocity, followed by a gradual decrease in concentration as the suspended material settles out during periods of lower velocities. This occurs for both flow directions, although on the ebb, velocities are greater and thus concentrations are larger.

It is interesting to note at point 2 (neap) the suspended sediment concentration does not increase substantially during the period of observation. An average of $0.15kgm^{-3}$ is fairly low compared to the peaks in concentration for the other periods of $0.6kgm^{-3}$.

Grabemann and Krause (Ref 3) showed that sediment erosion and deposition was dependent on the direction of the flows in the Wesser estuary. The effects of advection were clearly shown at the ends of the flood tide. Towards high water the advected particles settled with decreasing flood velocity within 1.5 hours. The particles continued to settle after reversal of the current during the ebb tide. Just when the critical current velocity (about $0.2ms^{-1}$; this value agrees well with results of HR [Ref 5]) was reached, re-suspension of particles and distribution into the water column took place.

Two to three hours after current reversal an effect of depletion of the particle source was observed: the water cleared despite persisting strong current velocities; there were no more particles available in the area. The particles were displaced downstream, and at the beginning of the flood tide there was only a small amount of material that could be re-suspended or eroded.

At Harwich Harbour the behaviour of the cohesive bed appears to be different to that in the Wesser estuary. It should be noted that the points at Harwich are close to the mouth of the estuary where sediment deposition would be the predominant factor. Points studied in the Wesser estuary were up to 20km upstream of the mouth of the estuary. Tidal currents at Harwich are also half that seen at the Wesser site. It can be seen in figures 12 and 13 that increases in suspended sediment concentration follow closely increases in velocity. This indicates that material is being re-suspended close to the points under consideration and the process of advection from further afield (such as at the Wesser estuary) is not predominant.

### *4.1.3 Near bed velocity profiles*

Typical near bed velocity profiles for position 2 are shown in figure 15. The plots illustrate good logarithmic near bed profiles. The length of the fitted line indicates the part of the profile used to calculate near bed shear stress. This illustrates that the shear stress calculated from the data should be accurate.

## 4.2 Calculation of shear stress

Shear stress has been calculated in a number of ways.

1) The velocity at a reference height of 1m was used to determine the shear stress using the smooth turbulent law.

2) The depth averaged velocity was calculated and used in the smooth turbulent law at 0.37 x depth of the water column. Results show that data derived using methods (1) and (2) gave very similar results.

3) The shear stress was calculated from the near bed velocity measurements using logarithmic profiles such as those shown in figure 15.

It was thought that the shear stress derived using method (3) was overestimated due to the bed frame sinking into the mud. A value of 0.04m was removed from the heights of the instruments to compensate for the sinking of the frame. This assumes that the bottom instrument is resting on the bed. The calculation in method (3) was repeated using the adjusted depths. These revised shear stresses from method (3) and results using methods (1) and (2) are plotted in figure 17.

Results using the corrected log profiles show a large reduction in the shear stress derived from the original profiles. Results in general are still higher than methods (1) and (2), but show similar patterns.

## 4.3 Settling velocity

A one-dimensional steady state analysis of the mechanisms concerning sediment settling and the associated suspended sediment concentration profiles has been completed at HR (Ref 5). The following is a brief review of the study.

At equilibrium, upwards diffusion balances downward settling;

$$WC = wsC(z) \quad (1)$$

$$ws = AC^n \quad (2)$$

where

C(z)is the time mean concentration at height z.
ws is the settling velocity.
A and n are constants derived from Owen tube tests.
WC is the upward flux which can be written in eddy diffusivity form:

$$WC = -\beta K(z)dC/dz \quad (3)$$

where
$\beta$ is a constant $\approx$ 1, and K is the eddy diffusivity.

Assuming a parabolic variation of K with depth,

$$K = kU_*z(1-z/h) \quad (4)$$

where
k is the von Karman's constant (0.4)
h is the water depth

Substituting and solving the above equations and using the boundary condition C=Ca at z=a we get;

$$C(z)/Ca = [1-S\ln\{a/z.(h-z)/h-a)\}]^{-1/n} \quad (5)$$

$$\text{where } S = Ca^nR = nACa^n/\beta kU_*. \quad (6)$$

The analysis was assessed using the Harwich data. Non-dimensional graphs are presented in figure 16. The profiles were taken at point 2. The lines plotted in figure 16 shows the values calculated using equation 1, symbols show measured data. The upper graph indicates the fit before adjustment of instrument levels, and the bottom graph after. It can be seen that the adjustment of the height level has made little difference to the calculated values. The calculated values compare well with the measured values above a depth of 0.6m, closer to the bed values of the concentration are significantly over estimated in equation 5. The analysis was used on profiles covering all neap/spring tide data. The value of n was taken to be 2 (eqn 2). This is consistent with the good profiles shown in Fig 16, and also in agreement with Owen tube measurements (Ref 3).

Instead of using a parabolic variation of K it is possible to use a linear method. This technique shows a good correlation of results above 0.6m with an over estimation below this height.

Figure 18 gives a comparison between Owen tube results (Ref 2) and the calculated in situ settling velocities for point 2 for neap and spring conditions. It should be noted that the gradients of the lower two plots have been forced as explained previously. Although this is the case it is encouraging to see that an average value passing through the scattered data sets in the lower two graphs coincides with the Owen tube results in the graph above. This suggests that the constant A derived from the Owen tube tests and the analysis above are in agreement.

# 5. SAP Model

## 5.1 Introduction

It is possible to measure near bed suspended sediment concentration and velocity, over a long term but in most cases cost and time limitations prevent such measurement. The method used in SAP is to measure spring and neap data, between which, values of near bed suspended sediment concentration and shear stress are interpolated. The calculated values of net sediment erosion or deposition for a spring-neap-spring period are then extrapolated over a number of such cycles. It is therefore important that the spring and neap data are representative.

From the present data set it can be seen that the suspended sediment concentration is dependent on the tidal range. This is taken into account in SAP by measuring the suspended sediment concentration during a spring and neap tide. Where the zero suspended sediment concentration remains high over a neap or spring period, it would be possible to add the zero suspended sediment concentration onto the mean measured data, or factor the mean suspended sediment concentration. This may be an important technique for use during increased zero suspended sediment concentration during period of high tidal range, wind activity and Jetsed dredging. The new set of data could be run through SAP again using the same velocity conditions. This would be similar to factoring the amount of material eroded or deposited after SAP had been run.

### *5.1.1 Comparison of long and short term data*

The data taken over a number of tides at the Oil Jetty possess similar suspended sediment profiles to those taken at points 1 and 2 using the bed frame earlier in the year. During a spring period two peaks in suspended sediment content are seen, which correlate with peaks in velocity during maximum ebb and flood flows. During the neap period it appears that the bed shear stress does not exceed the critical value for erosion on the ebb, therefore no material is taken into suspension. On the flood small amounts of material are eroded.

When the raw data has been averaged over the half tide period, the peaks at maximum flow are lost in the analysis. The results below show the calculated half tide average 5m above the bed taken during the bed frame campaign at points 1 and 2. The Oil jetty data is also presented as a comparison.

Point 1

| | EBB | FLOOD |
|---|---|---|
| spring | 360ppm | 460ppm |
| neap | 290ppm | 375ppm |

Point 2

| | | |
|---|---|---|
| spring | 410ppm | 360ppm |
| neap | 230ppm | 230ppm |

Oil Jetty

| | | |
|---|---|---|
| spring | 150ppm | 150ppm |
| neap | 50 ppm | 50 ppm |

As expected the suspended sediment concentration during spring periods is higher than that during neap. However the lower suspended sediment concentration values at the Oil Jetty are hard to explain. A reliable relationship between Formazin turbidity units and suspended sediment concentration for the monitor at the Oil Jetty and Lightships were not obtained and this could be a reason for the low suspended sediment concentration content at these positions.

### *5.1.2 Seasonal variations*

Higher sediment load can be expected in the winter during periods of high runoff. In addition, increased coastal swell is likely to cause increased bed shear stress and therefore higher suspended sediment concentrations. Using the long term data it is evident that the summer neap suspended sediment concentration is very similar to that in winter. However, larger peaks during the winter spring periods are noticeable during periods of high tidal range, wind activity and Jetsed dredging.

The changes in suspended sediment concentration occur very soon after the onset of the forcing factor, and therefore, the sources of suspended sediment are considered to be local in origin. Consequently, wind, Jetsed or tidal range must affect changes in bed level within the harbour area, that is, erosion during periods of high suspended sediment concentration. This type of behaviour cannot be modelled effectively by SAP unless both the near bed shear stress (cause) and suspended sediment profiles (effect) are measured during such periods.

If short term data had been measured during the spring period 13 November 89, then a more realistic set of high suspended sediment concentrations and probably higher near bed shear stresses would have been encountered. As we do not have such data the best estimate of mass and depth of material deposited is a slow continuous build up of material throughout the year given by the short term data of the summer months. This estimate is probably reasonable as disturbed sediment eroded in the winter would deposit quickly remaining in the harbour area.

To run the siltation at a point (SAP) model it is necessary to input values for near bed suspended sediment concentrations (spring and neap tides), bed shear stresses (spring and neap) and the density profile of the bed in the area. Mud properties (erosion, consolidation and settling velocity) have been investigated previously by HR (Ref 2). For a review of the SAP model see appendix 6.

## 5.2 Calibration of SAP

Firstly, SAP was run for point 1 using the original parameters described in section 4.1. The model was run for a year, that is, 26 spring-neap-spring tides. No account was taken of enhanced suspended sediment concentration during winter months. This run showed that velocities and therefore near bed shear stresses (derived using the smooth turbulent law) appeared very low. Consequently, large amounts of material were deposited (up to 2m per tide) and very small amounts were eroded. It appeared necessary to change the input parameters somewhat to reduce the depth of material deposited on the bed to no more than 2m per year at point 1.

It was thought necessary to increase substantially the rate of consolidation. Consolidation shown by the numerical model was low compared with that of consolidation of similar muds in a laboratory column. Therefore, a revised relationship based on re-analysed laboratory tests was used to enhance consolidation.

Shear stress data calculated from log profiles using velocity data in the water column and those calculated using the smooth turbulent law show large variations in values especially at velocity peaks. Although in general log profile results are higher than those using the smooth turbulent law, the peaks of both log and law profiles coincide (see Fig 17). A shear stress value comparable to the log profiles may be more appropriate than the low shear stress values used previously. In order to increase the shear stress to the log profile values, the smooth turbulent values were multiplied by two.

After the initial trail run three methods were used to calibrate the SAP model at point 1. Calibration methods and SAP input values are summarised in Table 4. Methods 1 and 2 were used to reduce the thickness of the deposited material. Method 3 also includes seasonal variation effects.

The value of the critical shear stress of deposition ($\tau_d$) was 0.05Nm$^{-2}$ in method 1. This relatively low value of $\tau_d$ decreased the amount of deposition without increasing the rate of erosion. Bed shear stresses used were calculated from the smooth turbulent law.

A higher value of the critical shear stress for deposition was taken as 0.09Nm$^{-2}$ in method 2. Greater bed shear stress values (twice that given by the smooth turbulent law) increased the likely hood of erosion and reduced the amounts of deposition. The higher critical stress for deposition allowed deposition at greater bed shear stresses.

Table 5 shows the parameters used for method 2 at point 1. Towards the bottom of table 5 is an example of the water depth, velocity, suspended sediment concentration and bed shear stress data input into the SAP model.

Method 3 is an attempt to incorporate seasonal variations, Jetsed operation, high tidal range, and wind activity into the model by factoring suspended sediment concentration. To simulate the seasonal variations, it was assumed that the year could be split up into two equal periods. These were summer and winter, each possessing 13 spring-neap-spring tides. Assuming there is a calibration problem and the measured short term suspended sediment concentration is too large, it is possible to factor the suspended sediment concentration down to a value corresponding to that at the Oil Jetty. In all the following cases the neap suspended sediment concentrations have been reduced by a factor of 2 to give suspended sediment concentration readings comparable with the long term data. Three sets of augmented winter, spring suspended sediment concentration data have been assessed.

1) Short term data reduced by a factor of 2.
2) Equal to the measured short term data.
3) Short term data increased by a factor of 1.5.

The SAP model is very sensitive to the suspended sediment concentration. If the measured values are doubled deposition far exceeds that seen in situ at point 1 and 2.

## 5.3 Verification of SAP

Using the same mud properties at point 2 that were used at point 1, SAP was re-run using the spring-and-neap suspended sediment concentration and bed shear stress values at point 2. For the three methods described results at point 2 were comparable with those expected, namely a net deposition of between 0.0 and 0.2m per year.

## 5.4 Results

Figures 19 to 22 show the changes in mass and bed thickness for points 1 and 2 (methods 1 and 2) during a spring-neap-spring cycle of 26 tides. Note the initial settlement of the bed before acquiring its equilibrium position. This bed consolidation is caused by the low density of the input bed profile close to the bed surface. The initial settlement is less than 0.2m and can be ignored as it occurs only in the first spring-neap-spring cycle as the bed profile adjusts to its equilibrium position.

Within engineering bounds the two methods gave similar rates of deposition. Approximately 500kgm$^{-2}$ is deposited at point 1 with a corresponding increase in bed depth of 1.2m. Although the increase in bed depth at point 2 is small (0.0-0.2m), 160kgm$^{-2}$ of material is deposited, this is consolidated to a greater density than at point 1.

Figure 23 illustrates the amounts of material eroded and deposited over a spring-neap-spring cycle (second method). The lack of erosion at position 1 is due to the low shear stresses which remain below the critical shear stress of erosion (0.43Nm$^{-2}$). It is shown that the average amount of deposition per tide at point 1 is approximately 0.6kgm$^{-2}$, this is far higher than at point 2 where the average is less than 0.25kgm$^{-2}$ per tide.

When erosion is taken into account at point 2 relatively small amounts of material remain to consolidate on the bed. The values of erosion and deposition are largest on the spring tides where velocities and concentrations are highest. During the spring tides there is slightly greater erosion than deposition. For the above reason the bed thickness in figure 22 decreases until the bed reaches its equilibrium position. The bed then remains at a constant level for a number of cycles as erosion and deposition cancel each other out. As the bed surface density and therefore the strength of the bed increase due to consolidation, erosion is reduced, deposition dominates and the bed thickness begins to increase. The cause of the dip at cycles 16 and 17 (Figs 20 and 22 respectively) were caused by the model's schematic interpretation of the bed. Similar dips are seen in figures 19, 20 and 21, but they are less noticeable because greater amount of material are being deposited.

Fig 24 shows a sample plot using output data from SAP for position 2 (spring tide). The plot illustrates values of eroded and deposited material over a single spring tide. Erosion only occurs as the ebb and flood shear stress reach a maximum. Deposition peaks once during the ebb, at a point which has high suspended sediment concentration and low shear stress. The periods of zero deposition or erosion are caused when the bed shear stress is between the critical values for deposition ($\tau_d$=0.09Nm$^{-2}$) and erosion ($\tau_e$=0.43Nm$^{-2}$).

After SAP was run for a period of a year the final bed density profiles were found to be consistent with in situ profiles from the area. There was little change in the bed profile for point 1 because the deposited material takes the place of the material that was consolidated. At point 2 the picture was slightly different, a slightly denser upper profile was present. This was caused by continuous consolidation, and constant deposition which kept the bed at a similar level over the time period.

Comparing methods 1 and 2, method 2 seems to be more realistic, allowing both deposition and erosion. In method 1 the critical shear stress for deposition has been set quite low, this gives greater weighting to the second method.

As a sensitivity test, instead of using the near bed (0.05m) suspended sediment concentrations, suspended sediment concentrations at 1m were used, all other parameters remaining constant. The amount of deposition was reduced by about half. This result indicated how critical the near bed suspended sediment concentration was. That is, taking a point 1m above the bed was certainly not satisfactory as the suspended sediment concentration reduces considerably from the bed upwards. It was possible that the suspended sediment concentrations at 1m could be factored up.

Results for method 3 are also summarised in Table 4. Little deposition occurs in the summer months (methods 3b and 3e for points 1 and 2 respectively). By factoring the suspended sediment concentration correctly, it was possible to reproduce depositions of similar magnitudes to that seen in situ at both points during the winter period only (methods 3c and 3f for points 1 and 2 respectively). Thus, using method 3 it is shown that over a period of 1 year 360kgm$^{-1}$ (1.0m) and 135kgm$^{-1}$ (0.2m) was deposited from the water column at points 1 and 2 respectively.

In addition to the material settling from the water column at point 1, material also slumps from the shallow region at the toe of the river bank. This material drifts slowly towards the deeper parts of the harbour. Unfortunately, little is known about the proportion of slumping material to settling material. HHA suggested that in total 1-2m of material is accreted at point 1 per year. The SAP model give results (deposition from water column only) that show an increase in bed thickness towards a value at the bottom of this range. It is unlikely that the additional slumping material will increase the total material accreted to a value exceeding 2m. Near point 2 no such slumping occurs, therefore, the results given in table 4 do not need to be enhanced.

# 6. Conclusions

1. It is difficult to isolate the three forcing factors of tidal range, Jetsed dredging and wind speed in their affect on suspended sediment concentrations.

2. Changes in long term suspended sediment concentration are shown to be similar at the two monitors under investigation.

3. An increase in tidal range causes increases in suspendedsediment concentration.

4. An increase in the mean (half tide) wind speed above 30kts appears to cause an immediate increase in suspended sediment concentration. This high concentration reduces quickly as the wind speed abates.

5. It appears that Jetsed dredging increases suspended sediment concentration. The magnitude of increases in suspended sediment concentration is dependent on the duration of Jetsed dredging, and the distance away from the operation.

6. It was shown that settling velocities calculated using an analysis of suspended sediment concentration profiles compared well with Owen tube measurements taken in the area previously.

7. The siltation at a point (SAP) model was calibrated by a number of methods at point 1 and for each method the model was successfully verified at point 2.

8. Averaging the results predicted by SAP using methods 1 and 2, 500kgm$^{-2}$ per year was deposited at point 1 and 100kgm$^{-2}$ per year was deposited at point 2. This indicated increases of bed thickness of 1.2m and 0.1m respectively per annum.

9. Method 3 shows that it is possible to estimate the effects of seasonal variation by factoring the suspended sediment concentration.

10. Seasonal variations could be assessed with a greater degree of accuracy if representative short term data was available.

11. It is interesting to note that there are numerous calibrations that appear to give similar end results, all of which are valid in their own respects.

## 7. Recommendations

It is fortunate that during this study both long term and short term measurement have been taken. Unfortunately, the two sets of data have been measured during different seasonal conditions. Long term measurements were taken during the winter months, November 89 - May 90. Short term measurements were taken during the summer months July and September 89. An additional problem encountered during the comparison of long and short term data is the difference in the vertical position and location of the suspended sediment monitors.

To acquire the most suitable suspended sediment concentration data to input into the SAP model, it is suggested that the monitors be fixed to a stationary object at a height of 0.1m above the bed. This could be implemented using a jetty or wharf structure or where such constructions are not available a simple bed frame may be used. Both winter and summer measurements should be taken.

## 8. References


1. Webster. I., 16/7/1990. Private communication. Harwich Haven Authority.

2. Water injection dredging of mud; Field monitoring in Harwich Harbour - Phase I. Report EX 2159 Hydraulics Research, Wallingford, England.

3. Harwich Harbour mud properties, Report EX 1835 Hydraulics Research, Wallingford, England.

4. Grabemann. I and Krause. G., 1989. Transport processes of suspended matter derived from time series in a tidal estuary. Journal of Geophysical Research, Vol.94, C10, 14,373-14,379.

5. Soulsby, R, private communication. Hydraulics Research, Wallingford, England.

6. Erosion characteristics of estuarine muds, Rep. IT 265, Hydraulics Research, Wallingford, England.

# Tables

***Table 1. Jetsed dredging activity in the Harwich Harbour area***

| Position | Date | Hours |
|---|---|---|
| Parkstone Quay | 8/11/89 | 4 |
| Trinity | 9/11/89 | 11 |
| Trinity | 10/11/89 | 14 |
| Navy Yard | 10/11/89 | 1.5 |
| Trinity | 11/11/89 | 15 |
| Felixstowe Dock ent. | 11/11/89 | 2 |
| Trinity | 12/11/89 | 3 |
| Landguard | 12/11/89 | 4.5 |
| Oil jetty | 14/11/89 | 5 |
| Parkstone Quay | 14/11/89 | 1.5 |
| Landguard | 15/11/89 | 10 |
| Trinity | 16/11/89 | 6 |
| Landgaurd | 17/11/89 | 12 |
| Trinity | 18/11/89 | 9 |
| Shotley Marsh | 19/11/89 | 1.5 |
| Mistley | 19/11/89 | 9 |
| Mistley | 22/11/89 | 6 |
| Mistley | 23/11/89 | 6 |
| Landguard | 30/11/89 | 8.5 |
| Landguard | 4/12/89 | 4 |
| Trinity | 7/12/89 | 4 |
| Landguard | 12/12/89 | 4 |
| Landguard | 15/12/89 | 9 |
| Mistley | 16/12/89 | 7 |
| Trinity | 20/12/89 | 3 |
| Landguard | 20/12/89 | 6 |
| Trinity | 21/12/89 | 2 |
| Landguard | 22/12/89 | 4 |
| Felixstowe | 13/1/90-15/1/90 | |
| Felixstowe | 31/3/90-12/4/90 | |
| Felixstowe | 20/4/90-22/4/90 | |
| Felixstowe | 27/4/90 | |
| Felixstowe | 21/6/90-26/6/90 | |
| Felixstowe | 2/7/90-3/7/90 | |
| Felixstowe | 14/9/90-20/9/90 | |

## *Table 2. Shipping activity at the Oil Jetty (November 89)*

| Vessel | Date | On (GMT) | Draft (m) | Off (GMT) | Draft (m) |
|---|---|---|---|---|---|
| Nicholas M | 3 | 0833 | 4.8 | 1920 | 3.7 |
| Nicholas M | 6 | 0738 | 5.5 | 2038 | 3.2 |
| Authenticity | 9 | 0130 | 5.3 | 1628 | 3.8 |
| Magic Sky | 10 | 1948 | 6.6 | 14/1315 | 6.0 |
| Stolt Birchwood | 17 | 0926 | 4.6 | 1438 | 4.0 |
| Black Rock | 18 | 1357 | 4.9 | 2214 | 3.8 |
| Flottbeck | 18 | 2307 | 6.5 | 19/0745 | 6.0 |
| Benskov Junior | 23 | 1345 | 4.5 | 224/1008 | 3.8 |
| Authenticity | 25 | 0214 | 5.2 | 1533 | 4.0 |

## *Table 3. Bed density profile used in SAP*

| | Depth from surface (m) | Layer thickness (m) | Dry Density (Kgm$^{-3}$) |
|---|---|---|---|
| Layer 1 | 0 | 0.2 | 160 |
| Layer 2 | 0.2 | 0.2 | 248 |
| Layer 3 | 0.4 | 0.2 | 288 |
| Layer 4 | 0.6 | 0.2 | 328 |
| Layer 5 | 0.8 | 0.2 | 368 |
| Layer 6 | 1 | 0.2 | 408 |
| Layer 7 | 1.2 | 0.2 | 448 |
| Layer 8 | 1.4 | 0.2 | 488 |

## *Table 4. SAP results*

| Method | $\tau_d$ ($Nm^{-2}$) | $\tau_e$ ($Nm^{-2}$) | Calibration values for SAP Input: No Cycles | Bed shear stress | SSC | Calibration results at point 1: Mass deposited ($kgm^{-2}$/year) | Thickness (m) | Verification at point 2: Mass deposited ($kgm^{-2}$/year) | Thickness (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.05 | 0.43 | 26 | Values calculated using the smooth turbulent law | Spring and neap data measured during STD | 550 | 1.5 | 160 | 0.25 |
| 2 | 0.09 | 0.43 | 26 | 2x values calculated using the smooth turbulent law | Spring and neap data measured during STD | 450 | 1.2 | 80 | 0.15 |
| | | | | | | Mass deposited ($kgm^{-2}$/6 months) | Thickness (m) | Mass deposited ($kgm^{-2}$/6 months) | Thickness (m) |
| 3a | 0.09 | 0.43 | 13 | 2x values calculated using the smooth turbulent law | Neap ssc reduced by a factor of 2 | 127 | 0.25 | 2 | 0.0 |
| 3b | 0.09 | 0.43 | 13 | 2x values calculated using the smooth turbulent law | Both neap and spring ssc reduced by a factor of 2 | 28 | 0.05 | 0 | 0.0 |
| 3c | 0.09 | 0.43 | 13 | 2x values calculated using the smooth turbulent law | Neap ssc reduced by a factor of 2, spring ssc increased by a factor of 1.5 | 359 | 1.0 | 135 | 0.2 |

ssc = suspended sediment concentration
STD = short term deployment

## *Table 5. Input conditions for SAP model (point 1)*

| | |
|---|---|
| 720 | Length of tidal cycle (minutes) |
| 30 | Time step (minutes) |

**Settling velocity = WSCON1*concentration$^{WSCON2}$**

| | |
|---|---|
| 0.00200 | WSCON1 |
| 2.0 | WSCON2 |
| 125.0 | Density of new deposits (kgm$^{-3}$) |
| 0.09 | Crit. shear stress for deposition (Nm$^{-2}$) |

**Shear stress for erosion = DCON1*density$^{DCON2}$**

| | |
|---|---|
| 0.0005 | DCON1 |
| 1.4 | DCON2 |
| 0.00070 | Erosion constant (kgN$^{-1}$s$^{-2}$) |
| 0.43 | Crit. shear strèss for erosion (Nm$^{-2}$) |

**Permeability = PERM1CONST + PERM2CONST*density**

| | |
|---|---|
| -3.500 | PERM1CONST |
| -0.010 | PERM2CONST |

**Effective stress = ES1CONST + ES2CONST x density + E3CONST x density$^2$**

| | |
|---|---|
| -15.0 | ES1CONST |
| -0.150 | ES2CONST |
| 0.00110 | ES3CONST |

Input for Spring and neap tides:

| Time (mins) | Tidesp (m CD) | Tidenp (m CD) | Cbedsp (kgm$^{-3}$) | Cbedn (kgm$^{-3}$) | ShearS (Nm$^{-2}$) | ShearN (Nm$^{-2}$) |
|---|---|---|---|---|---|---|
| 0.0 | 14.0 | 14.0 | 0.204 | 0.375 | 0.036 | 0.072 |
| 30.0 | 13.7 | 14.0 | 0.134 | 0.286 | 0.151 | 0.072 |
| 60.0 | 14.5 | 13.5 | 0.415 | 0.725 | 0.520 | 0.188 |
| 90.0 | 14.0 | 13.7 | 0.855 | 0.725 | 0.352 | 0.175 |
| 120.0 | 14.0 | 13.3 | 0.317 | 0.286 | 0.056 | 0.056 |
| 150.0 | 12.3 | 12.8 | 0.317 | 0.286 | 0.056 | 0.080 |
| 180.0 | 12.0 | 12.3 | 0.261 | 0.375 | 0.089 | 0.020 |
| 210.0 | 12.0 | 12.0 | 0.289 | 0.114 | 0.049 | 0.002 |
| 240.0 | 11.5 | 11.8 | 0.289 | 0.114 | 0.002 | 0.002 |
| 270.0 | 10.7 | 11.6 | 0.261 | 0.114 | 0.012 | 0.003 |
| 300.0 | 10.5 | 11.4 | 0.429 | 0.114 | 0.020 | 0.009 |
| 330.0 | 10.8 | 11.2 | 0.204 | 0.286 | 0.009 | 0.012 |
| 360.0 | 9.9 | 11.0 | 0.148 | 0.286 | 0.006 | 0.016 |
| 390.0 | 11.5 | 11.3 | 0.486 | 0.286 | 0.108 | 0.036 |
| 420.0 | 11.2 | 11.6 | 0.826 | 0.199 | 0.129 | 0.025 |
| 450.0 | 12.1 | 11.5 | 0.554 | 0.286 | 0.080 | 0.056 |
| 480 | 12.4 | 12.2 | 0.289 | 0.375 | 0.089 | 0.064 |
| 510 | 12.6 | 12 | 0.571 | 0.199 | 0.175 | 0.049 |
| 540 | 12.8 | 12 | 0.401 | 0.199 | 0.118 | 0.14 |
| 570 | 13.1 | 13 | 0.514 | 0.286 | 0.201 | 0.163 |
| 600 | 13.5 | 13.5 | 0.969 | 0.286 | 0.108 | 0.369 |
| 630 | 13.7 | 13.2 | 0.401 | 0.464 | 0.072 | 0.129 |
| 660 | 14 | 13.5 | 0.289 | 1.08 | 0.025 | 0.201 |
| 690 | 14 | 13.7 | 0.232 | 0.553 | 0.036 | 0.14 |
| 720 | 14 | 14 | 0.204 | 0.375 | 0.036 | 0.072 |

## Figures

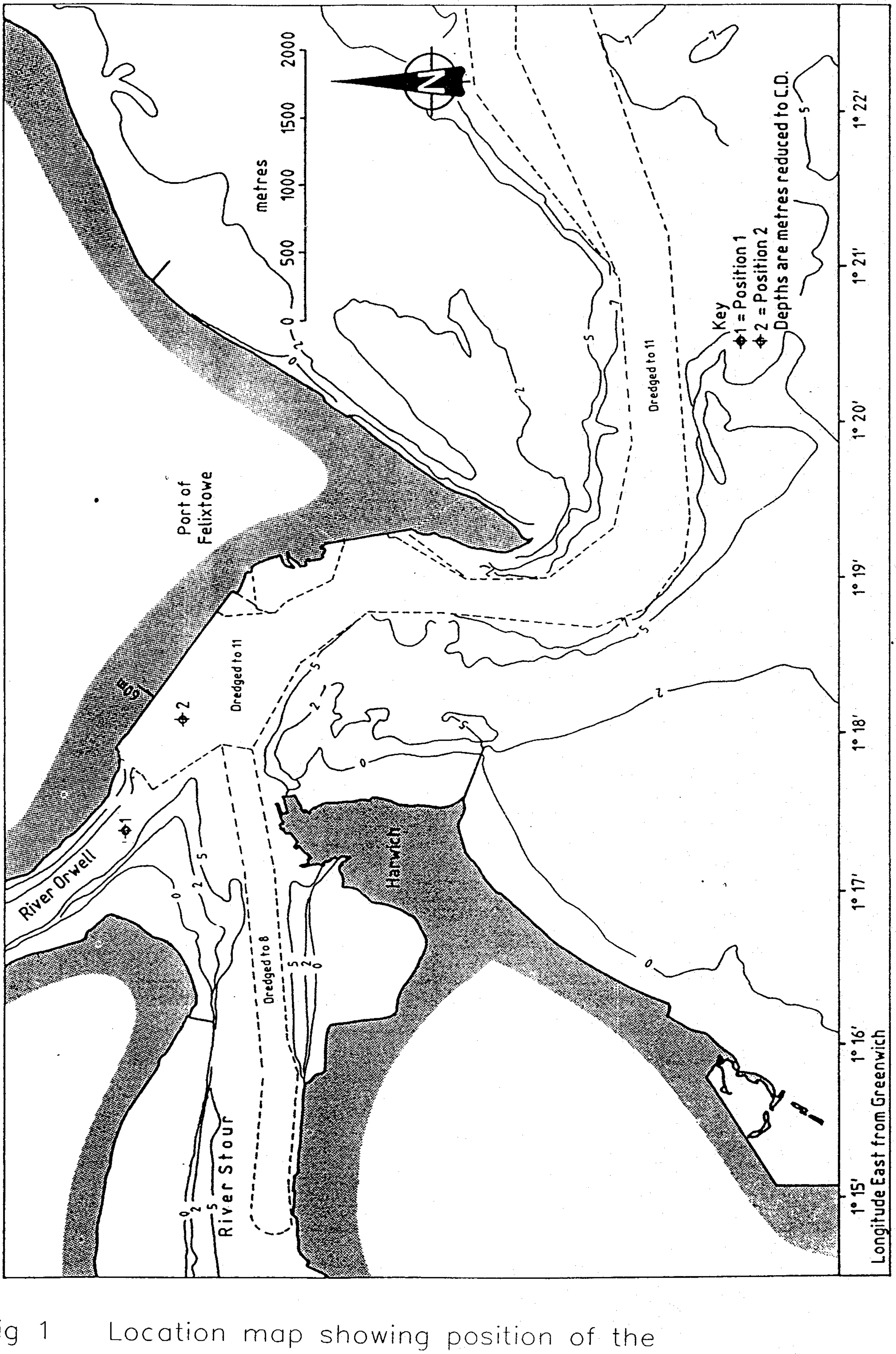



Fig 1 Location map showing position of the experimental points

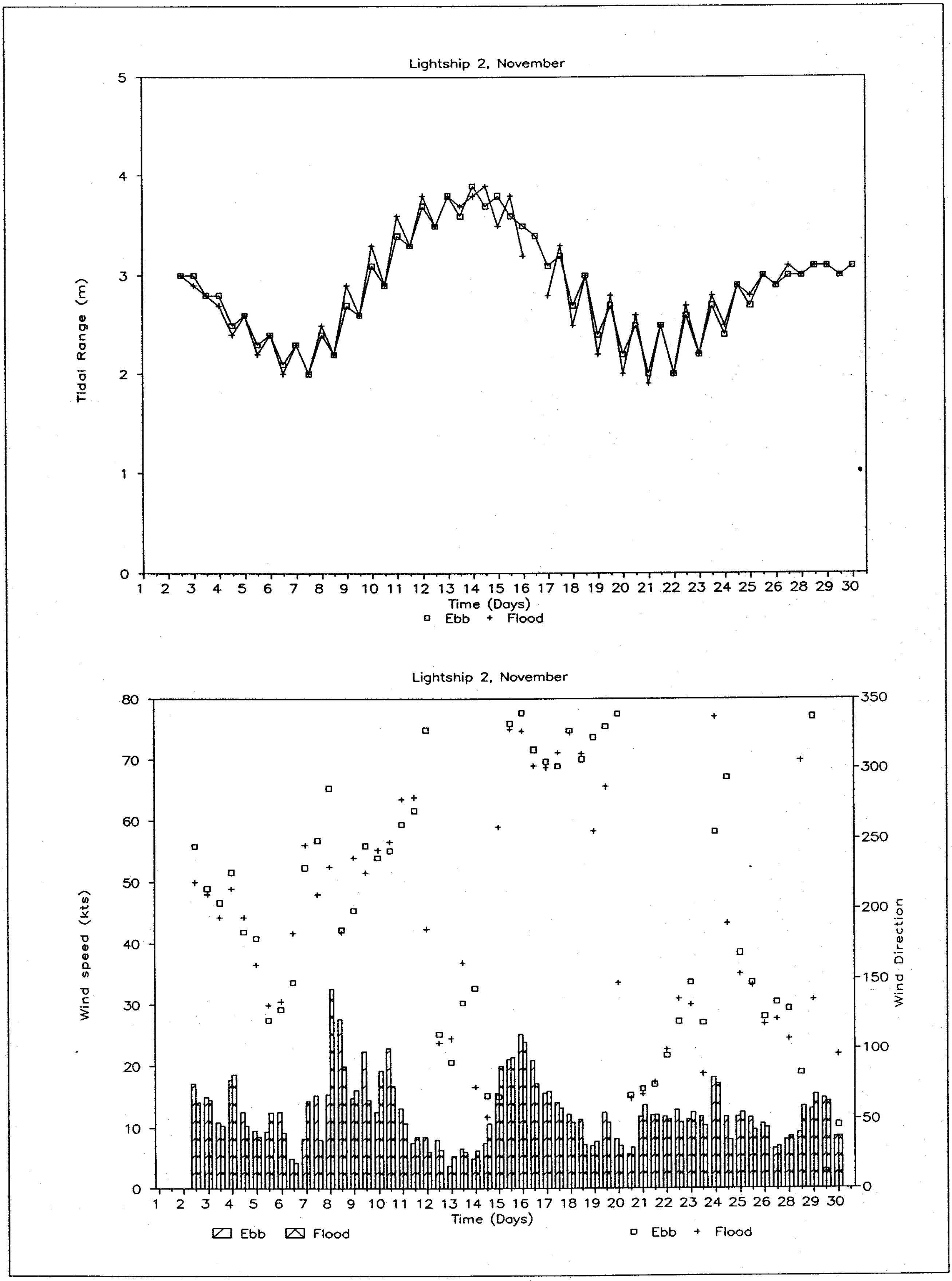



Fig 2a Tidal range and wind speed/direction, November 1989.

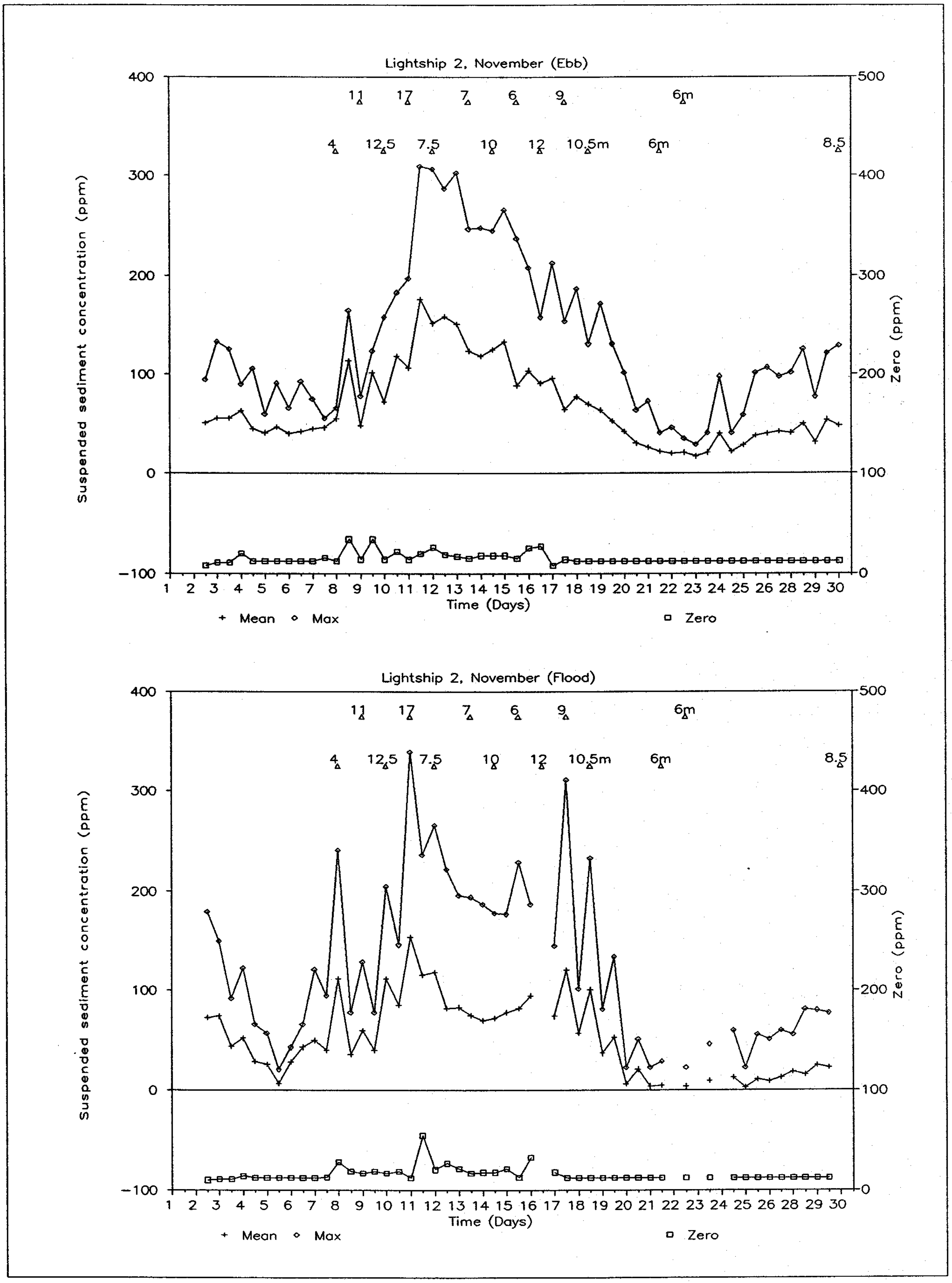



Fig 2b Suspended sediment concentration, lightship 2, November 1989

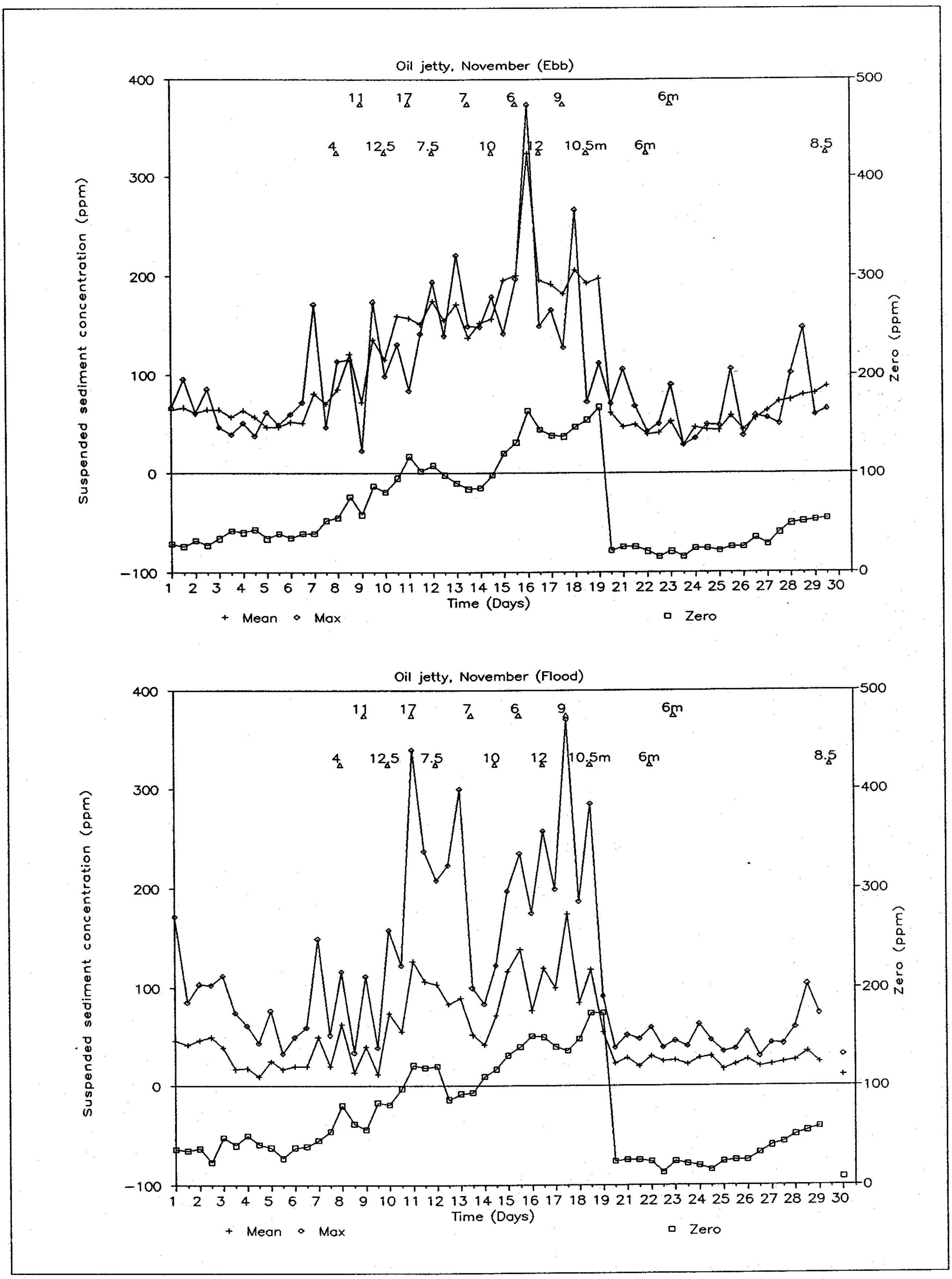
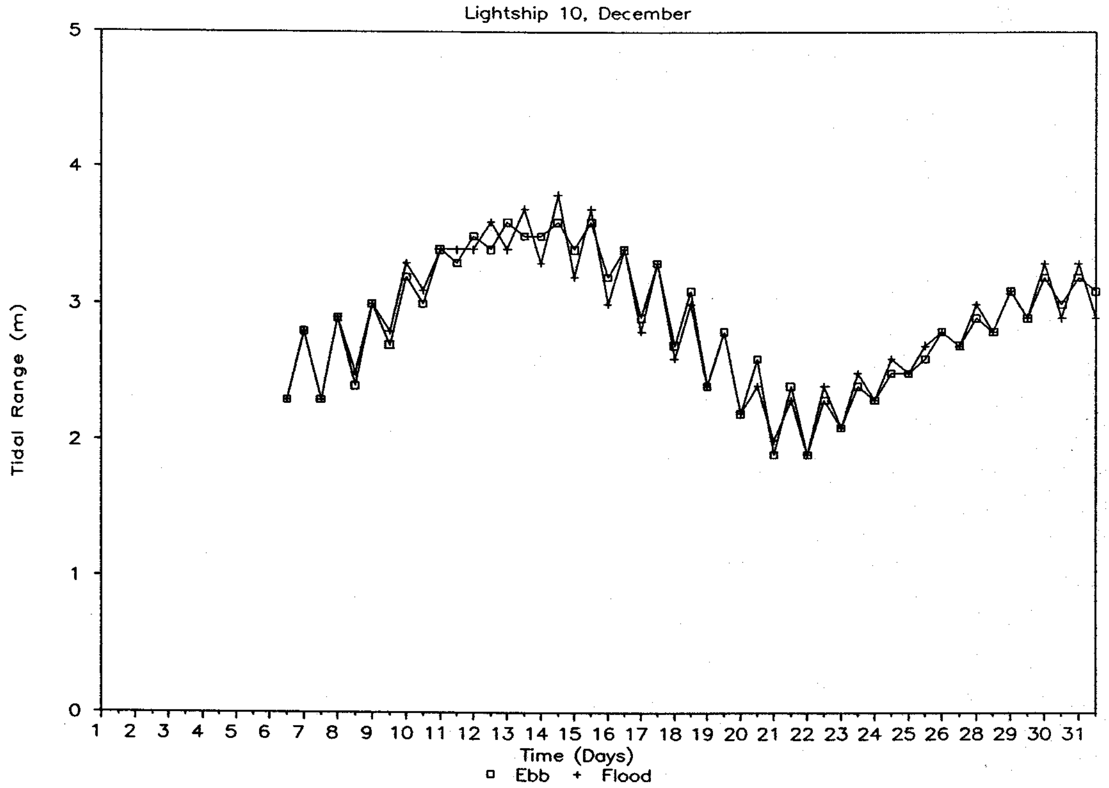



Fig 2c Suspended sediment concentration, oil jetty, November 1989.



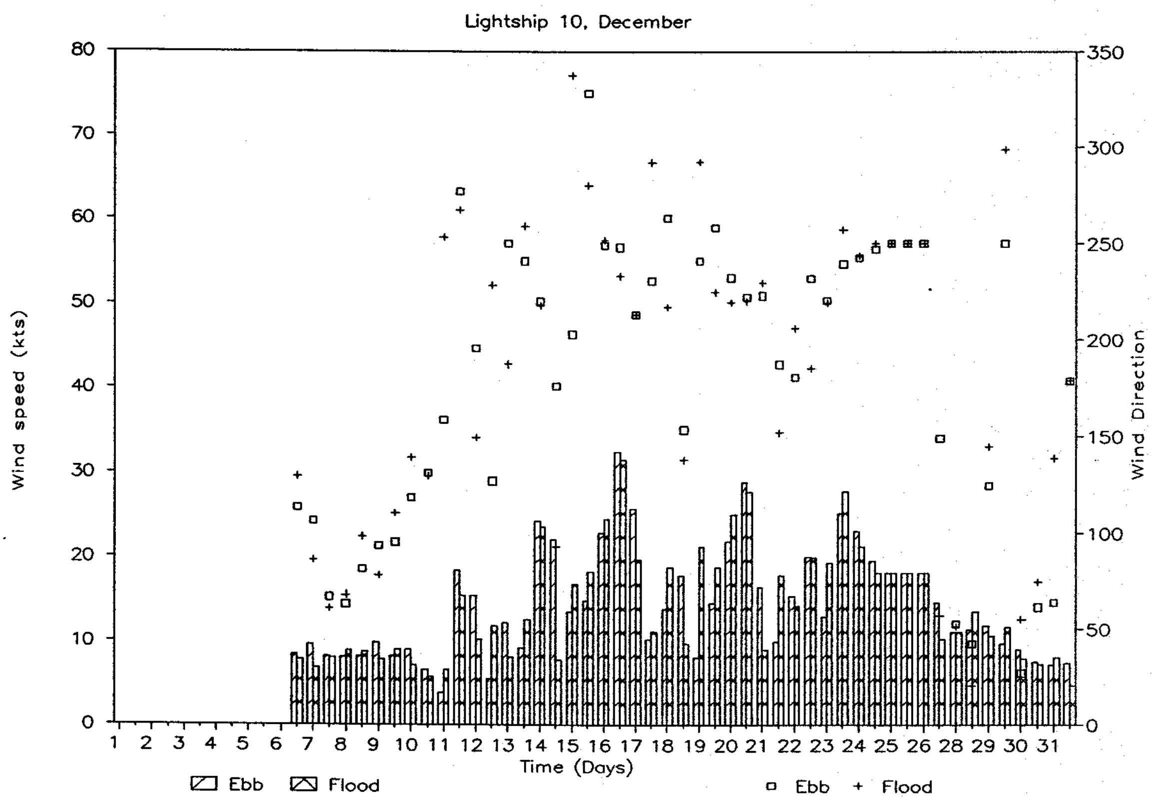




Fig 3a Tidal range and wind speed/direction, December 1989.

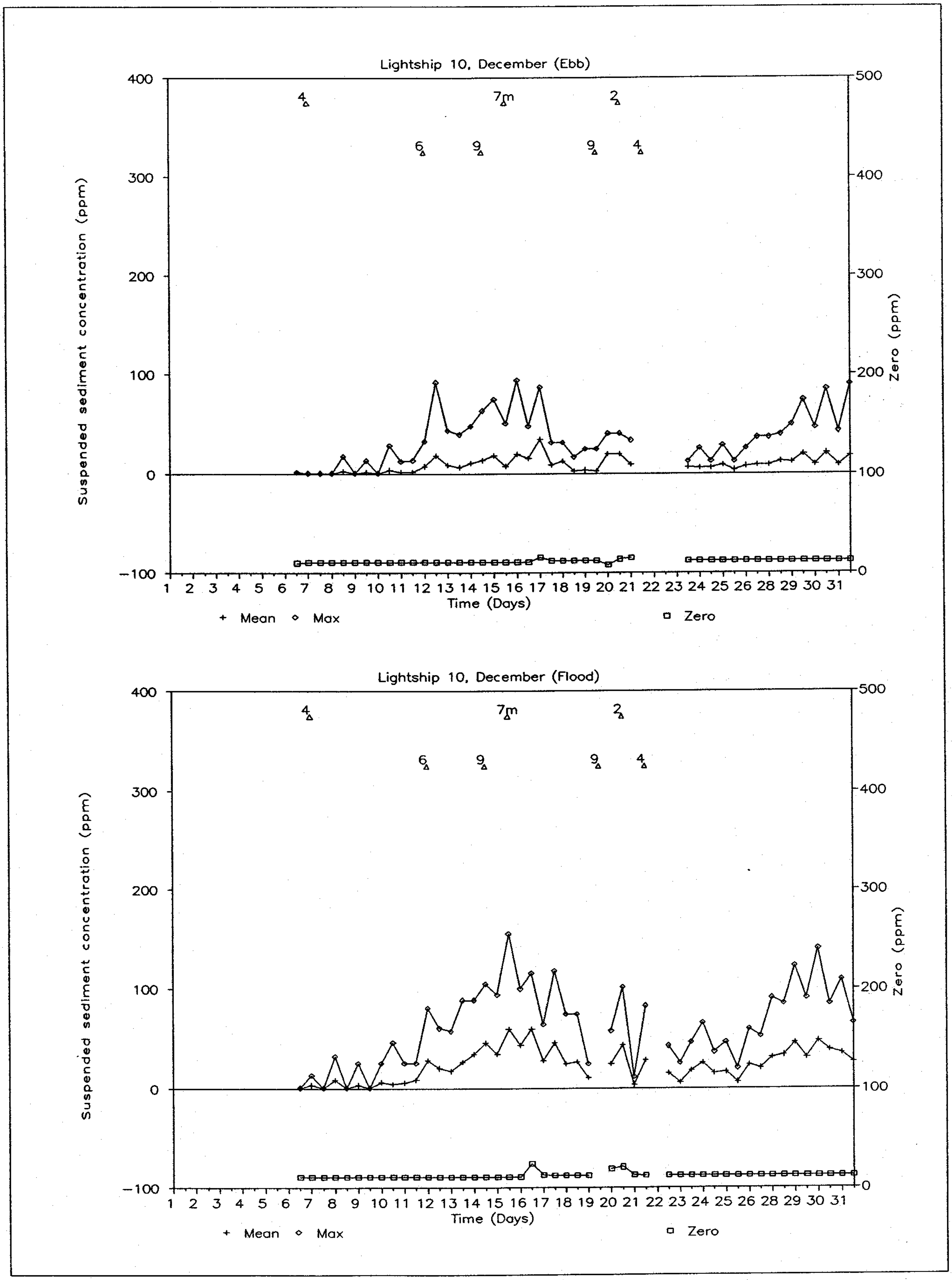



Fig 3b Suspended sediment concentration, Lightship 10, December 1989

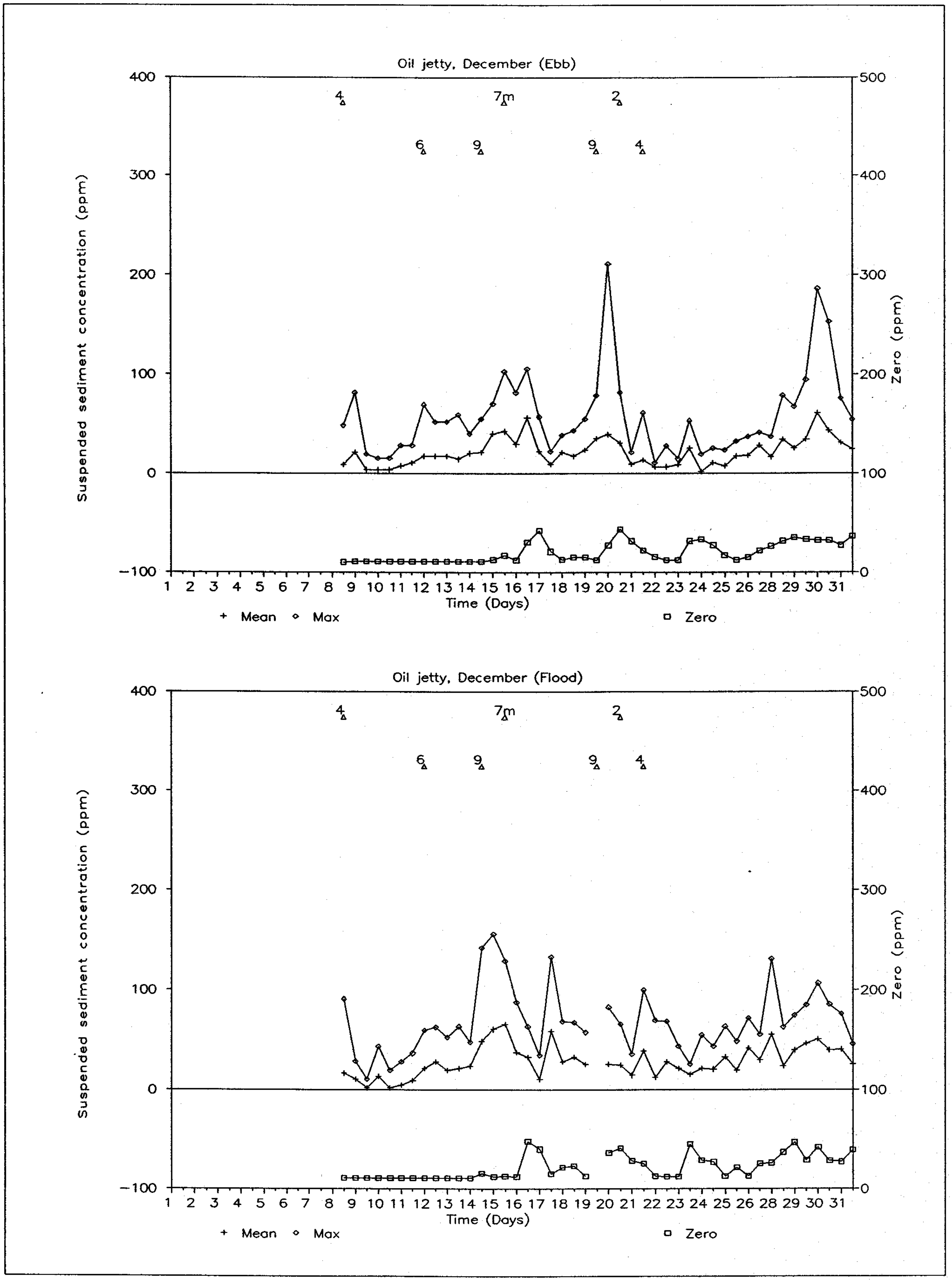
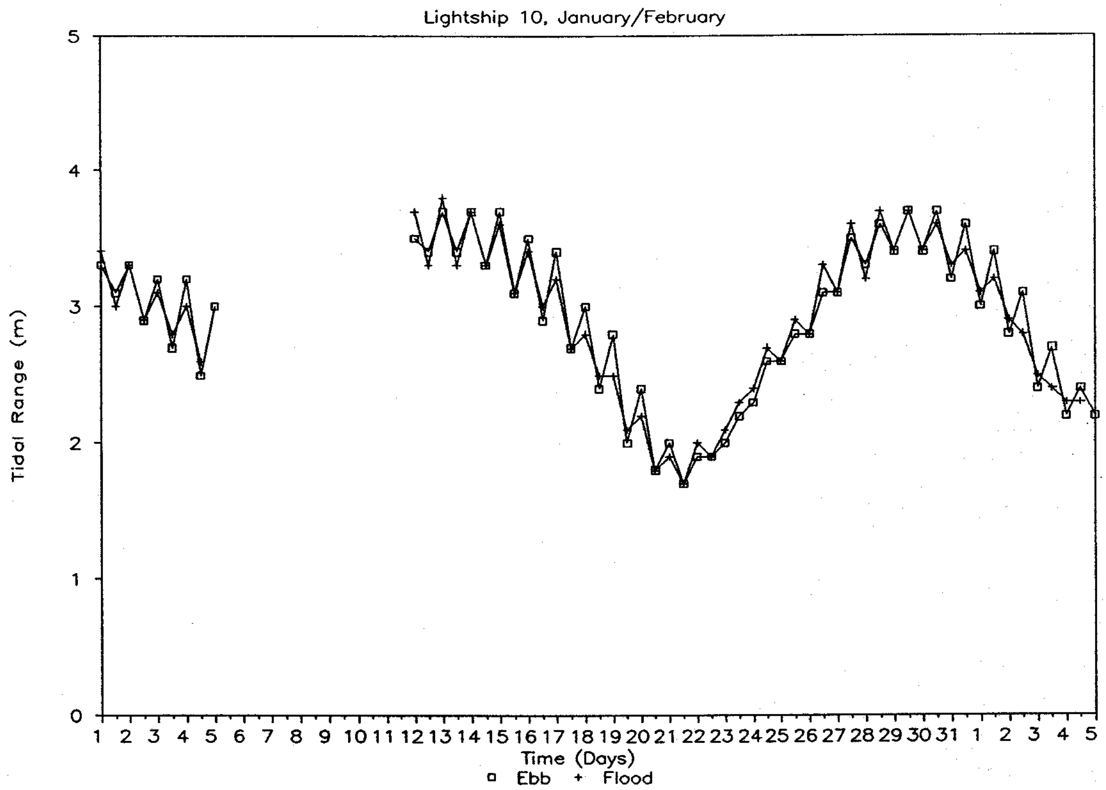



Fig 3c Suspended sediment concentration, Oil jetty, December 1989.



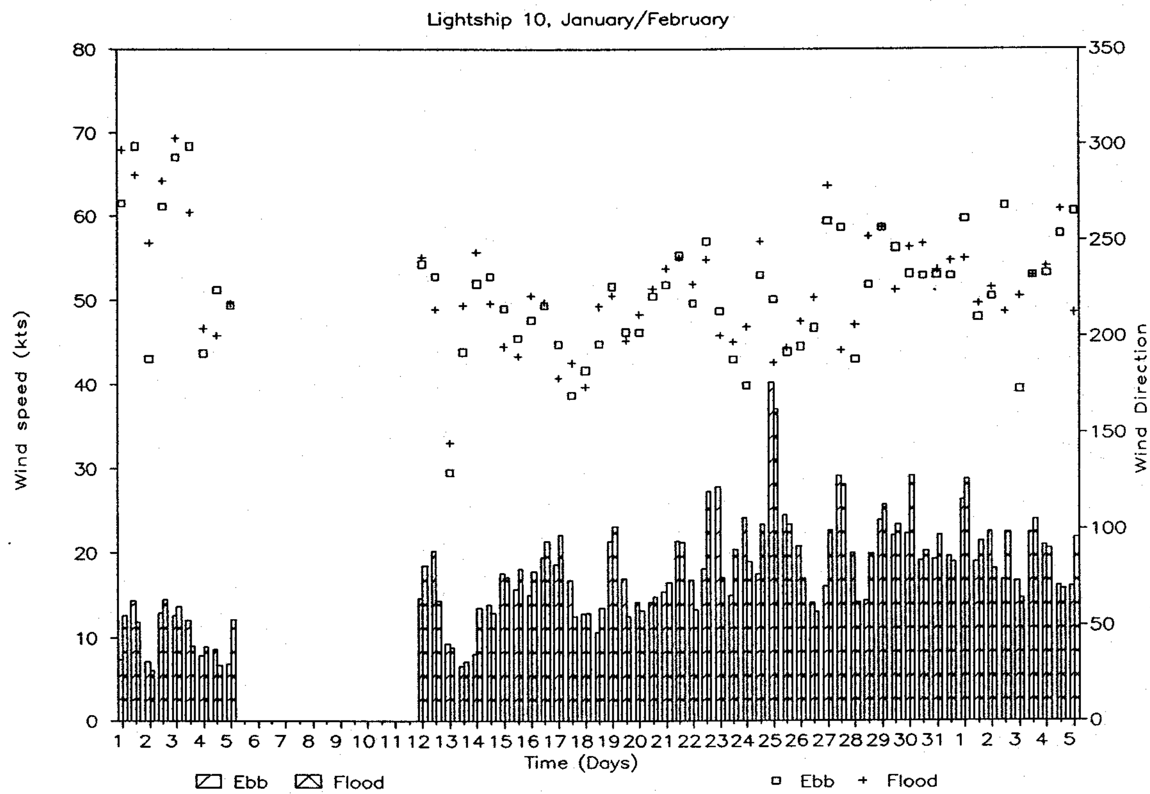




Fig 4a Tidal range and wind speed/direction, January/February 1990.

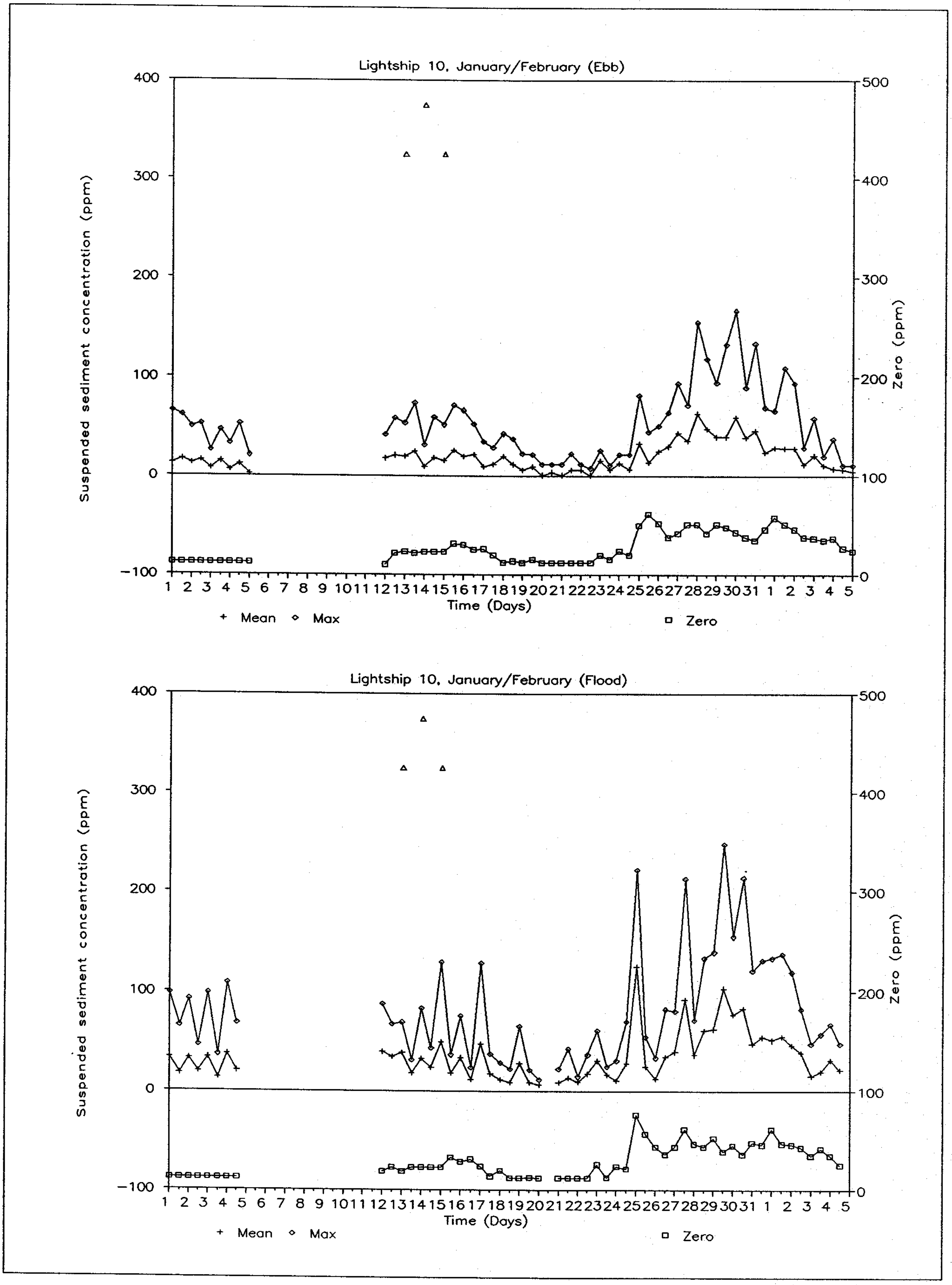
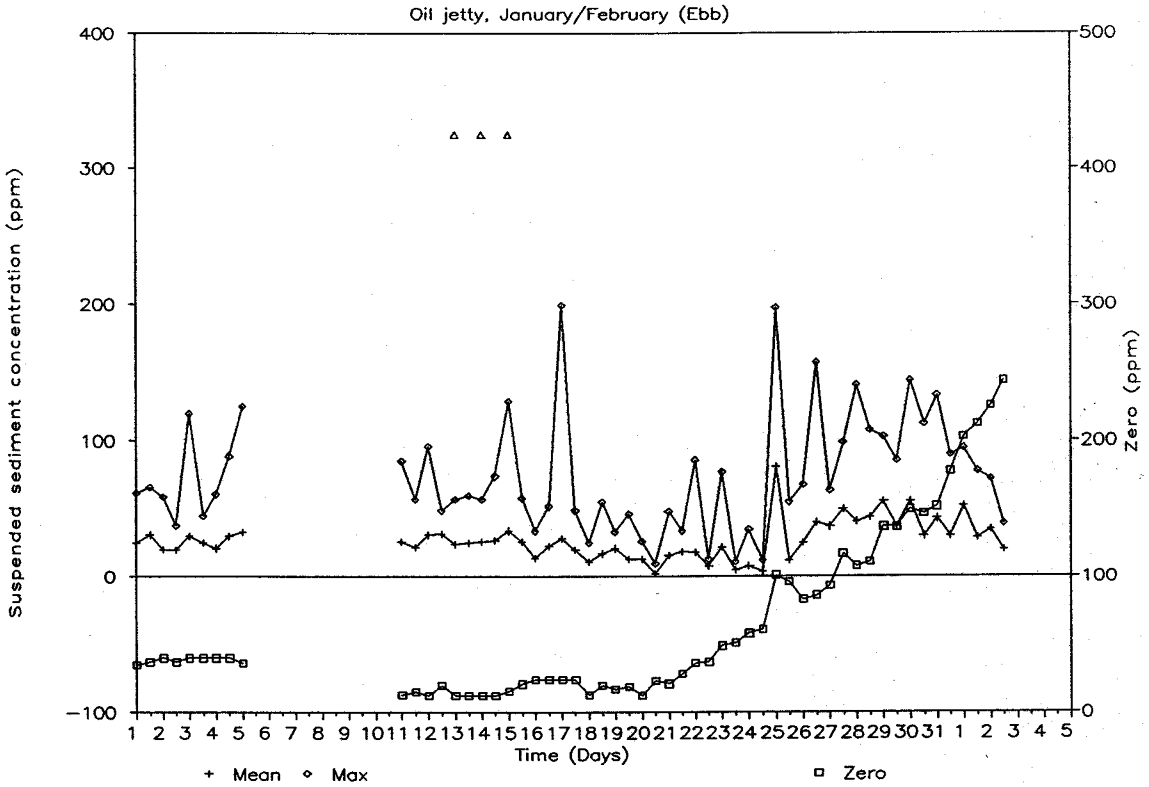



Fig 4b Suspended sediment concentration, Lightship 10, January/February 1990.



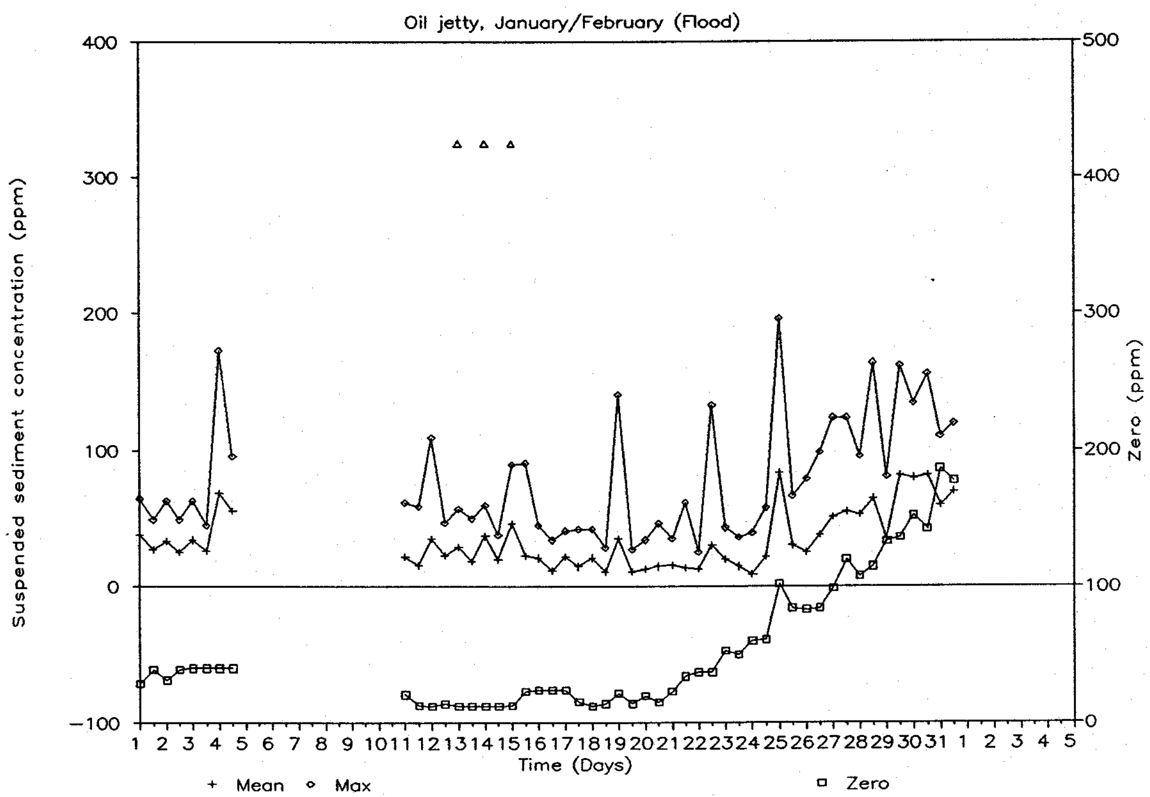




Fig 4c Suspended sediment concentration,
Oil jetty, January/February 1990.

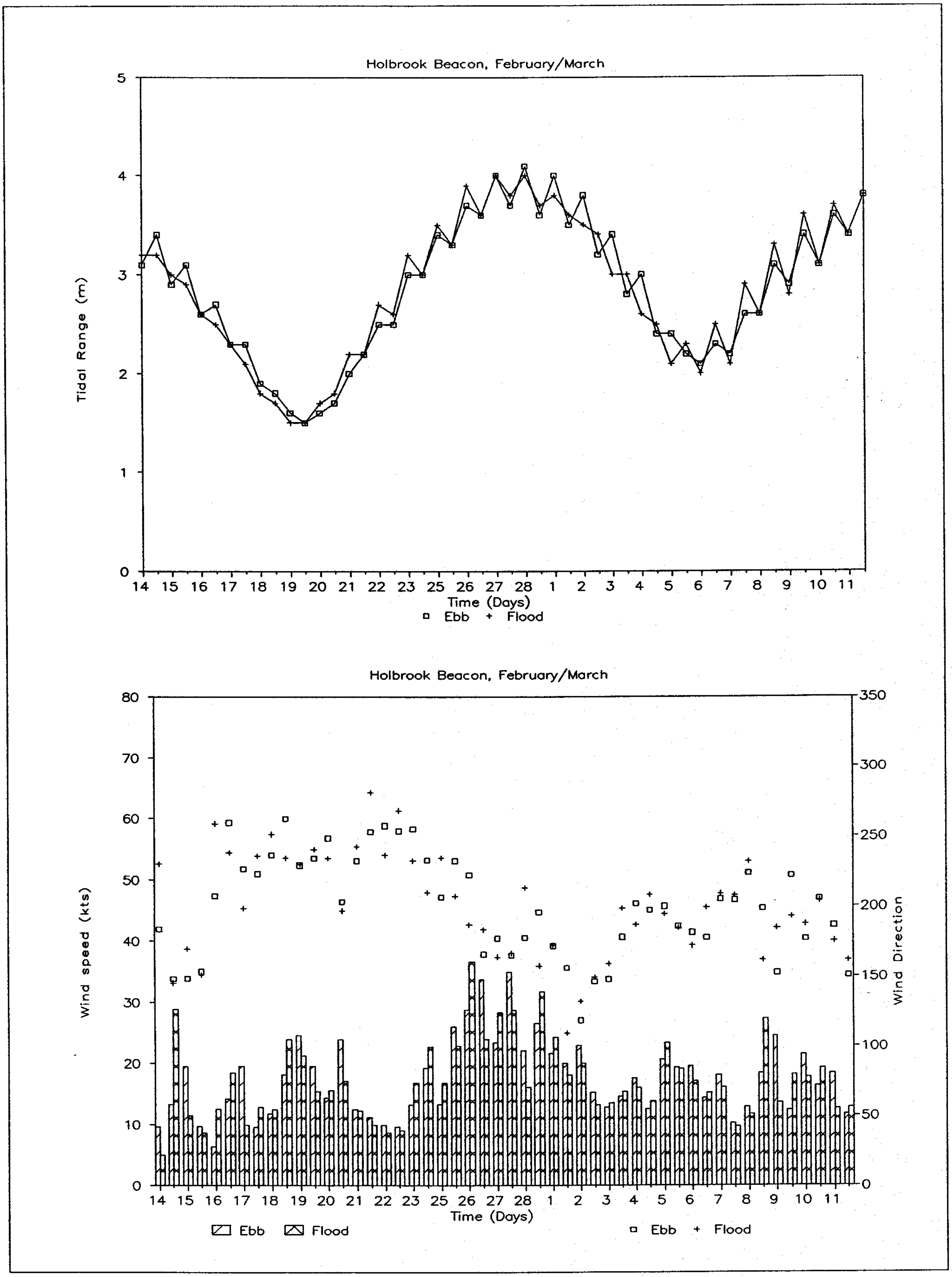



Fig 5a Tidal range and wind speed/direction, February/March 1990.

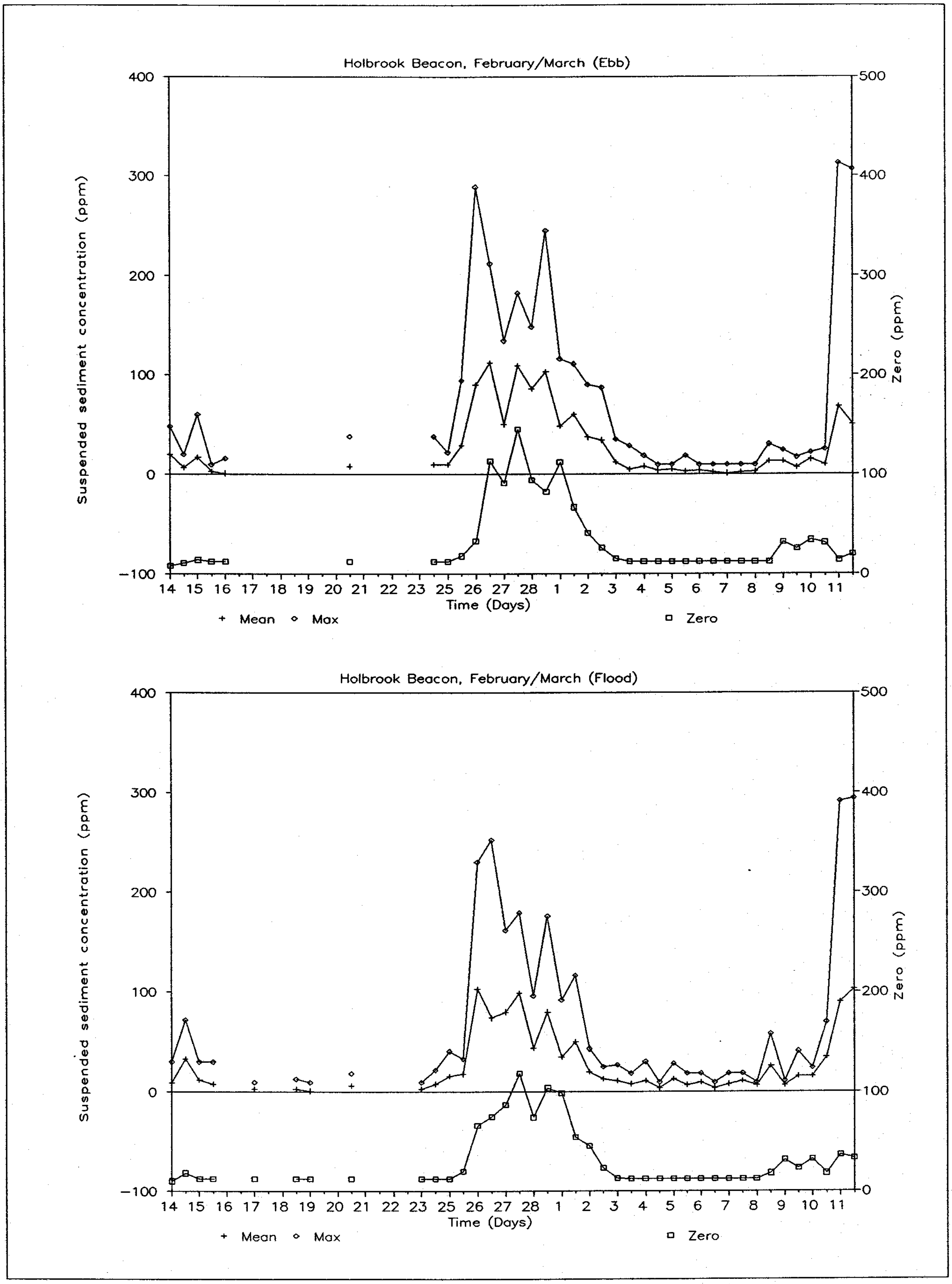



Fig 5b Suspended sediment concentration, Holbrook Beacon, February/March 1990.

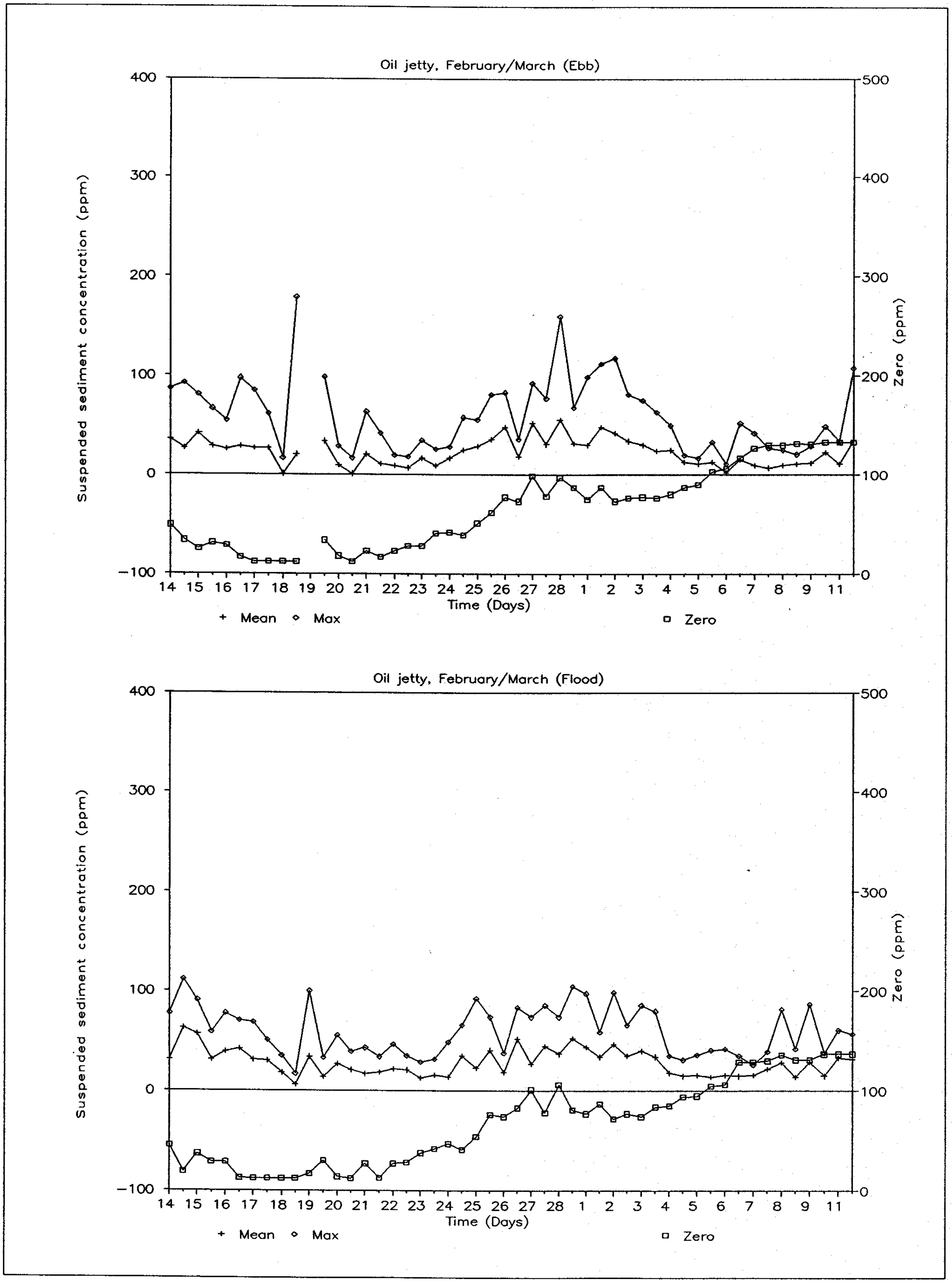



Fig 5c Suspended sediment concentration, Oil jetty, February/March 1990.

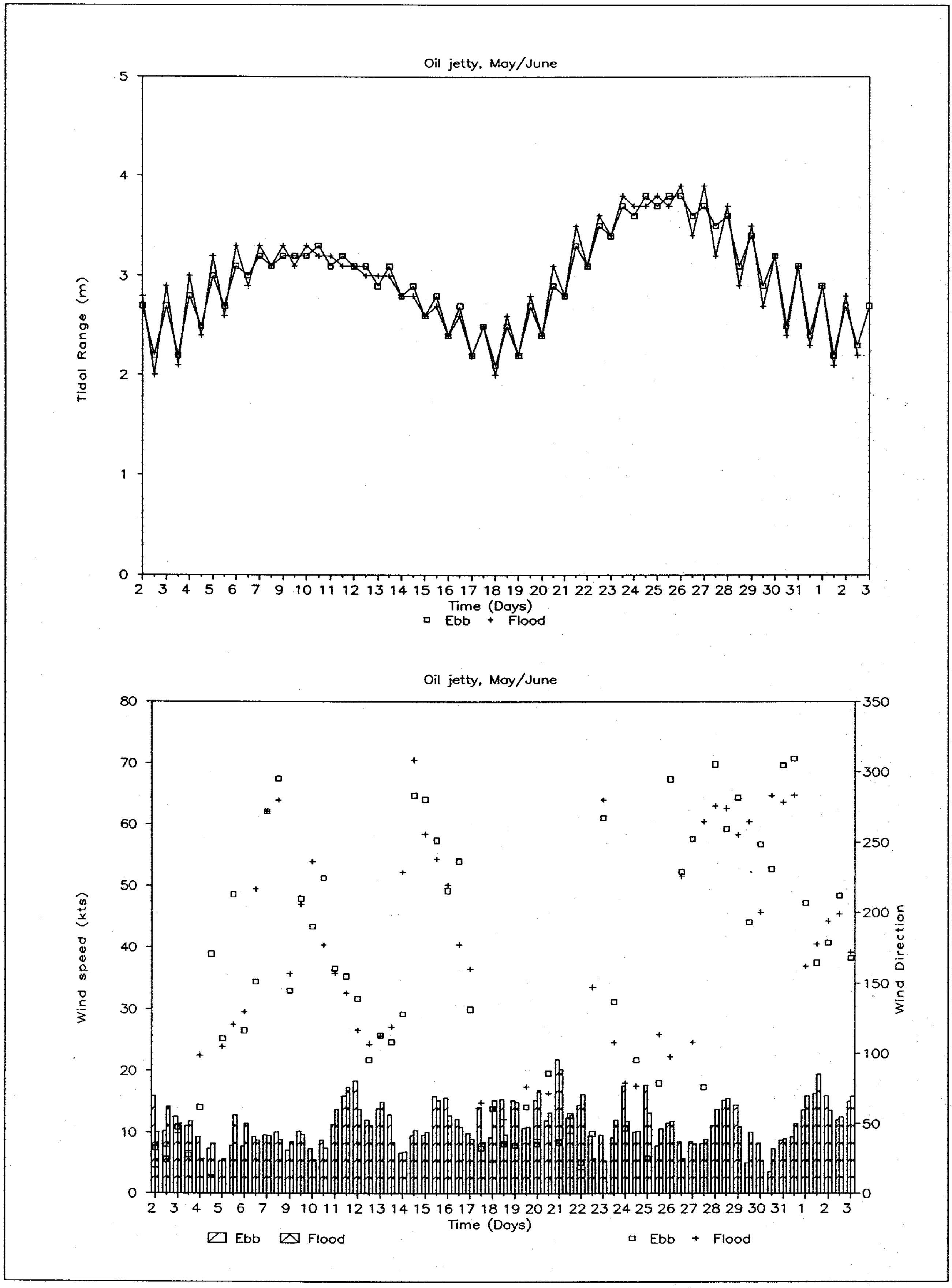



Fig 6a Tidal range and wind speed/direction, May/June 1990.

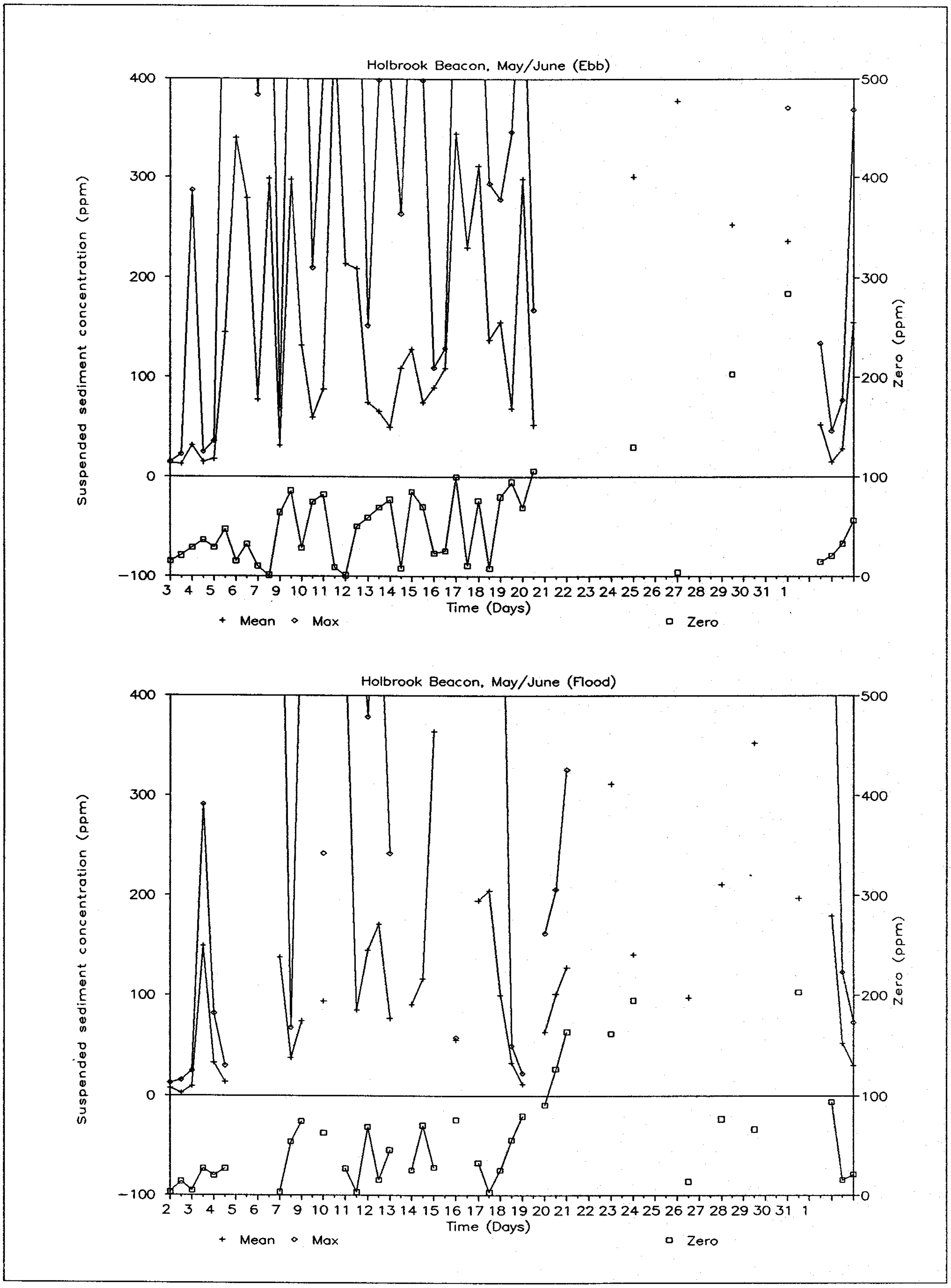



Fig 6b Suspended sediment concentration, Holbrook Beacon, May/June 1990.

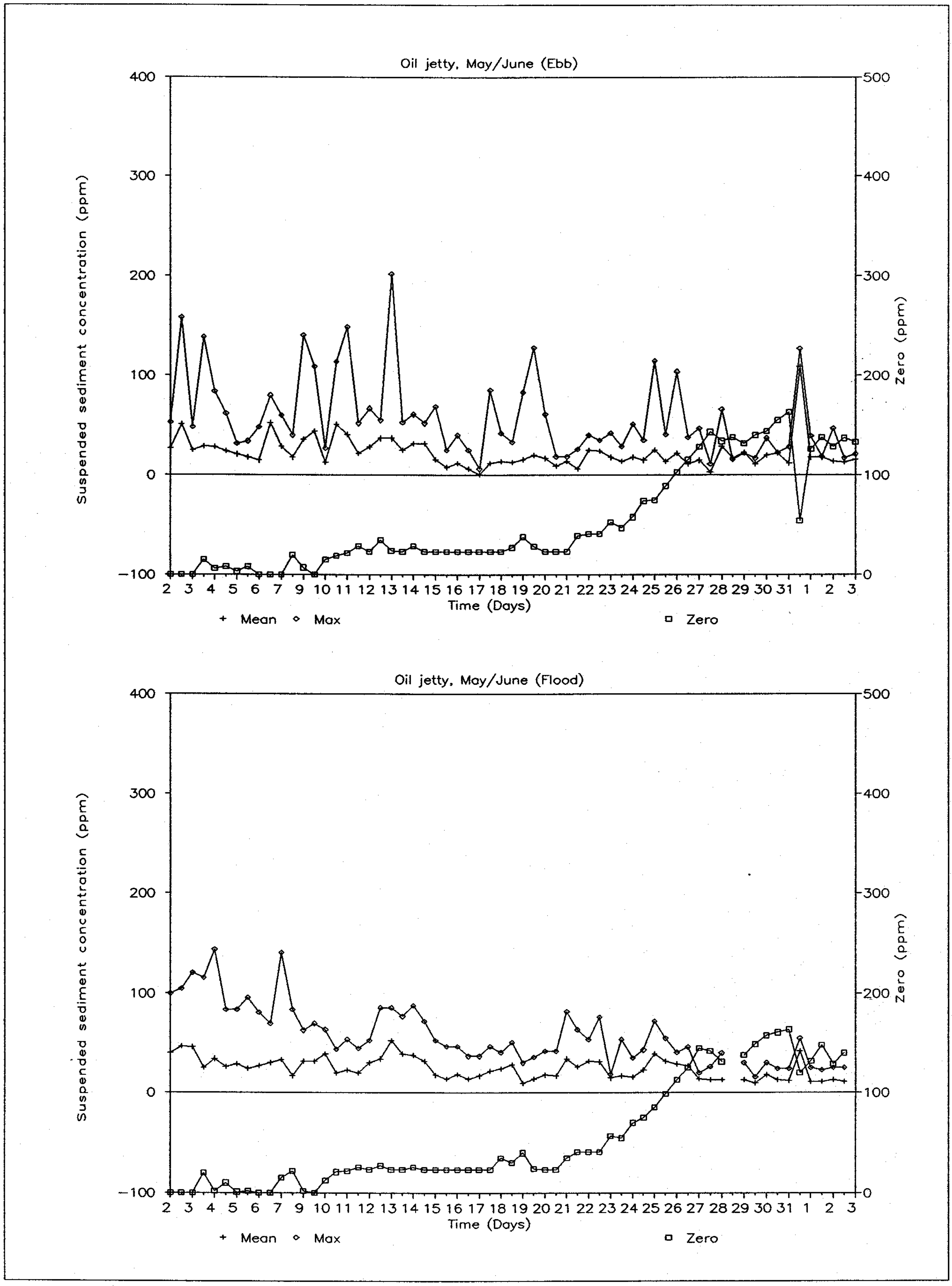



Fig 6c Suspended sediment conentration, Oil jetty, May/June 1990.

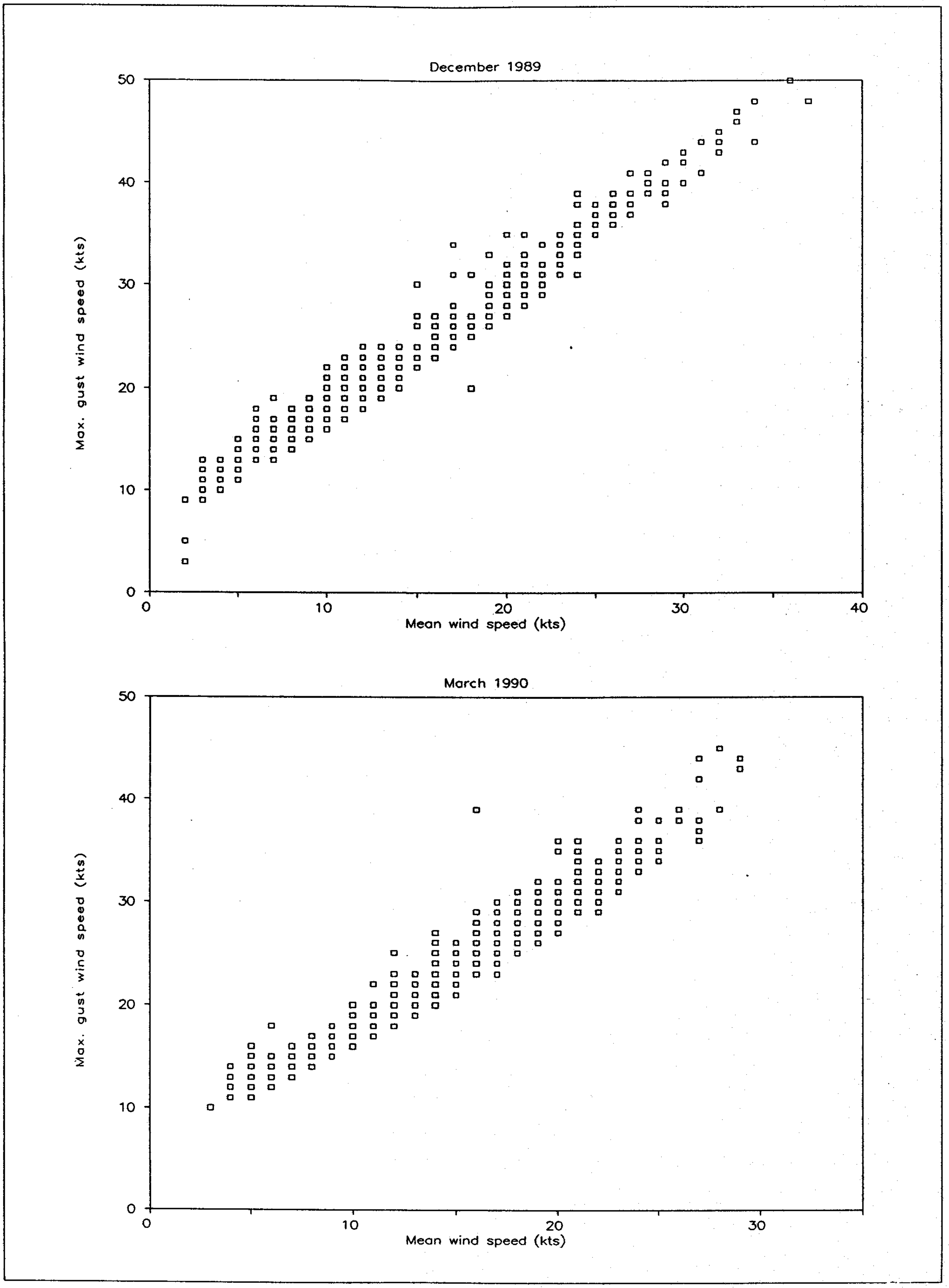



Fig 7 Mean wind speed versus max. gust speed.

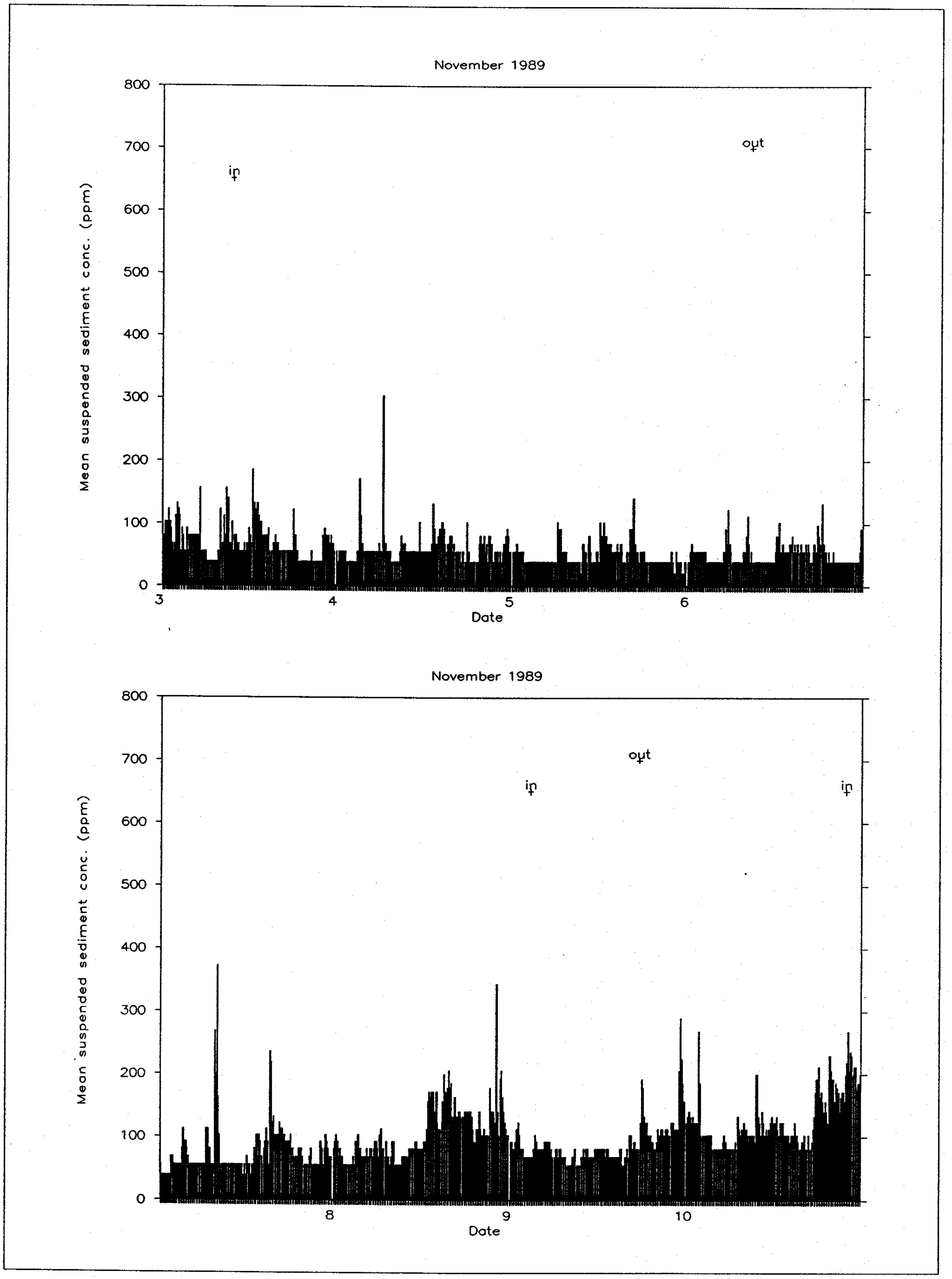



Fig 8a Ship movement and suspended sediment concentration, November 1989.

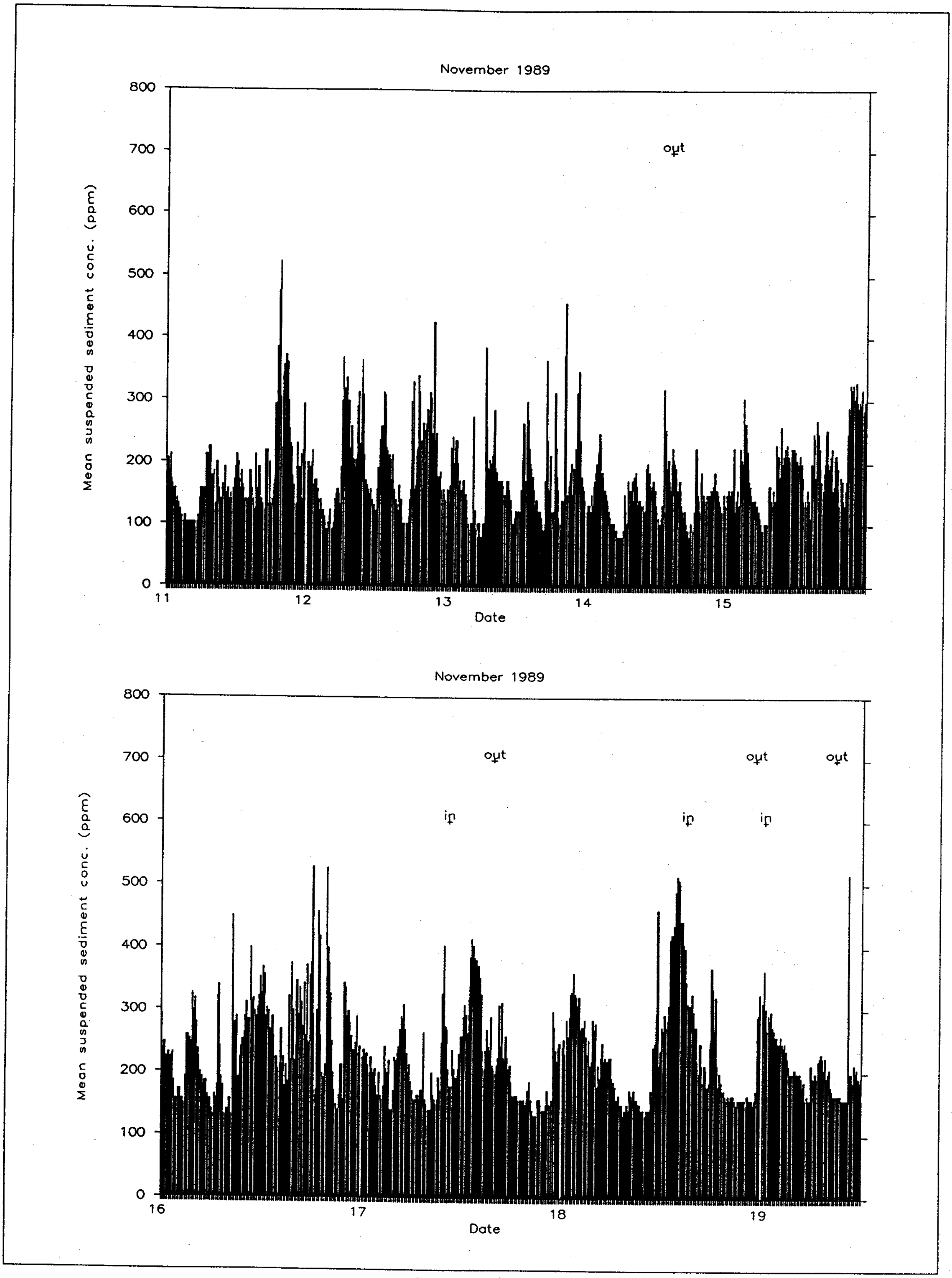



Fig 8b Ship movement and suspended sediment concentration, November 1989.

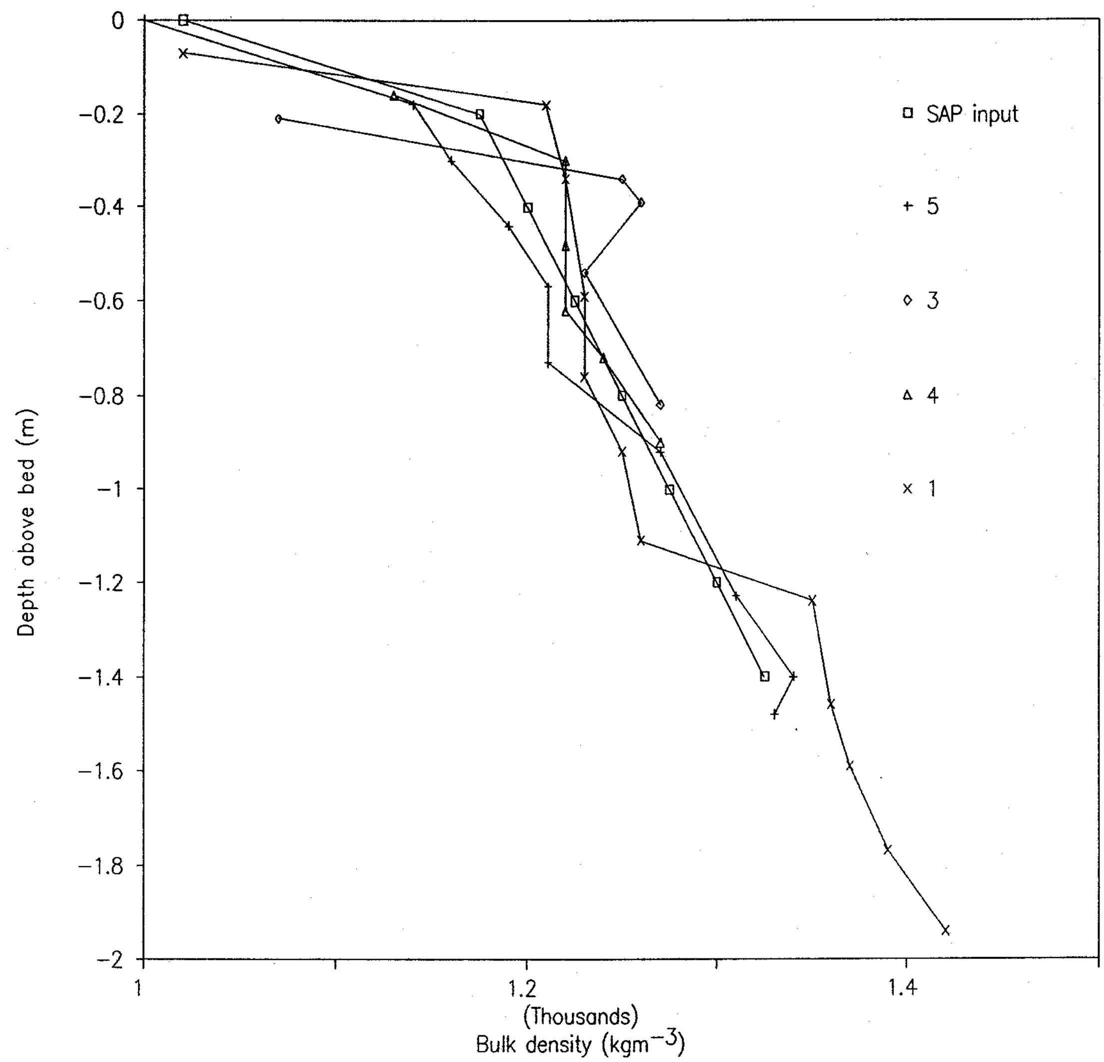



Fig 9 Examples of insitu bed density profiles taken before any Jetsed operations.

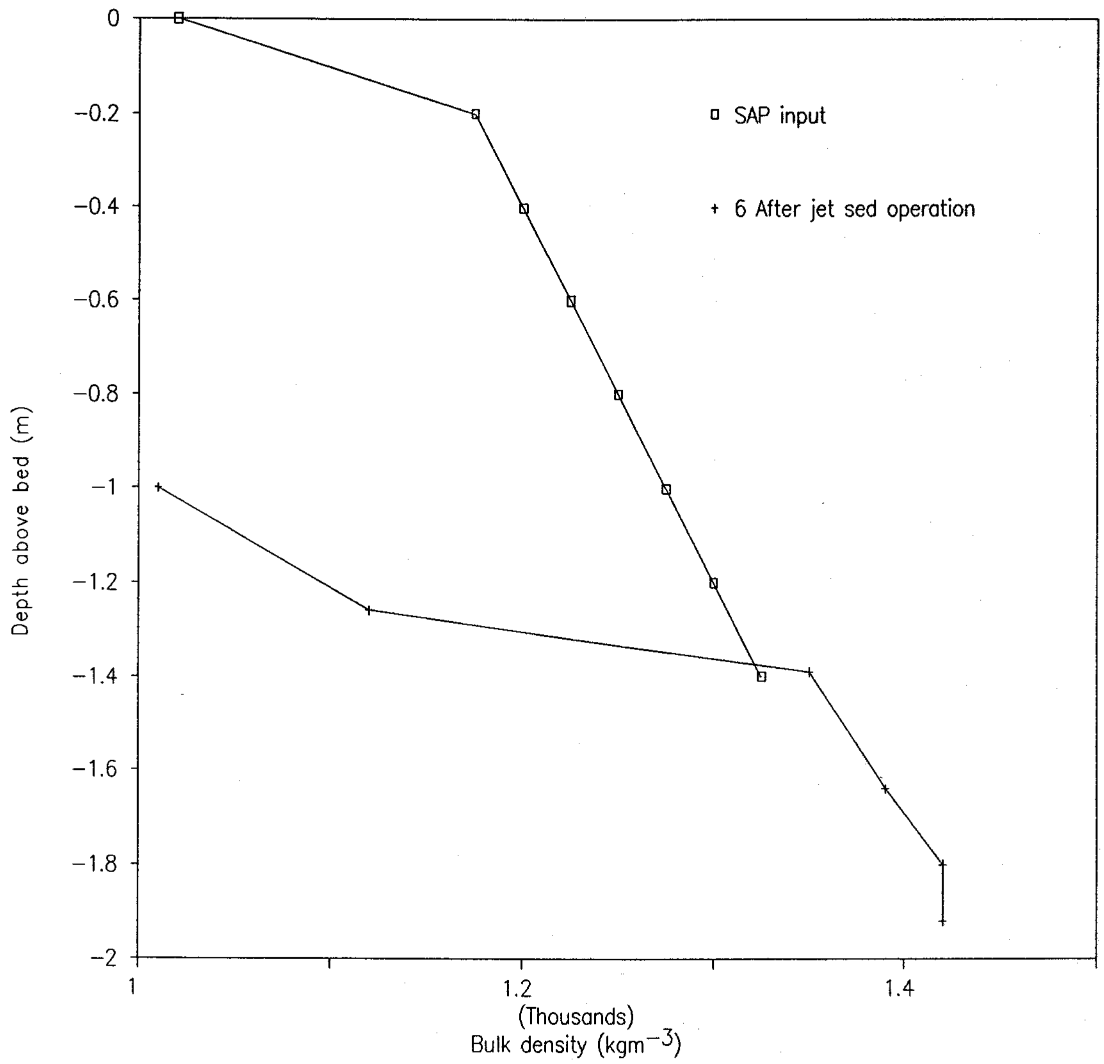



Fig 10 Typical bed profile after the Jetsed operation compared with SAP input data.

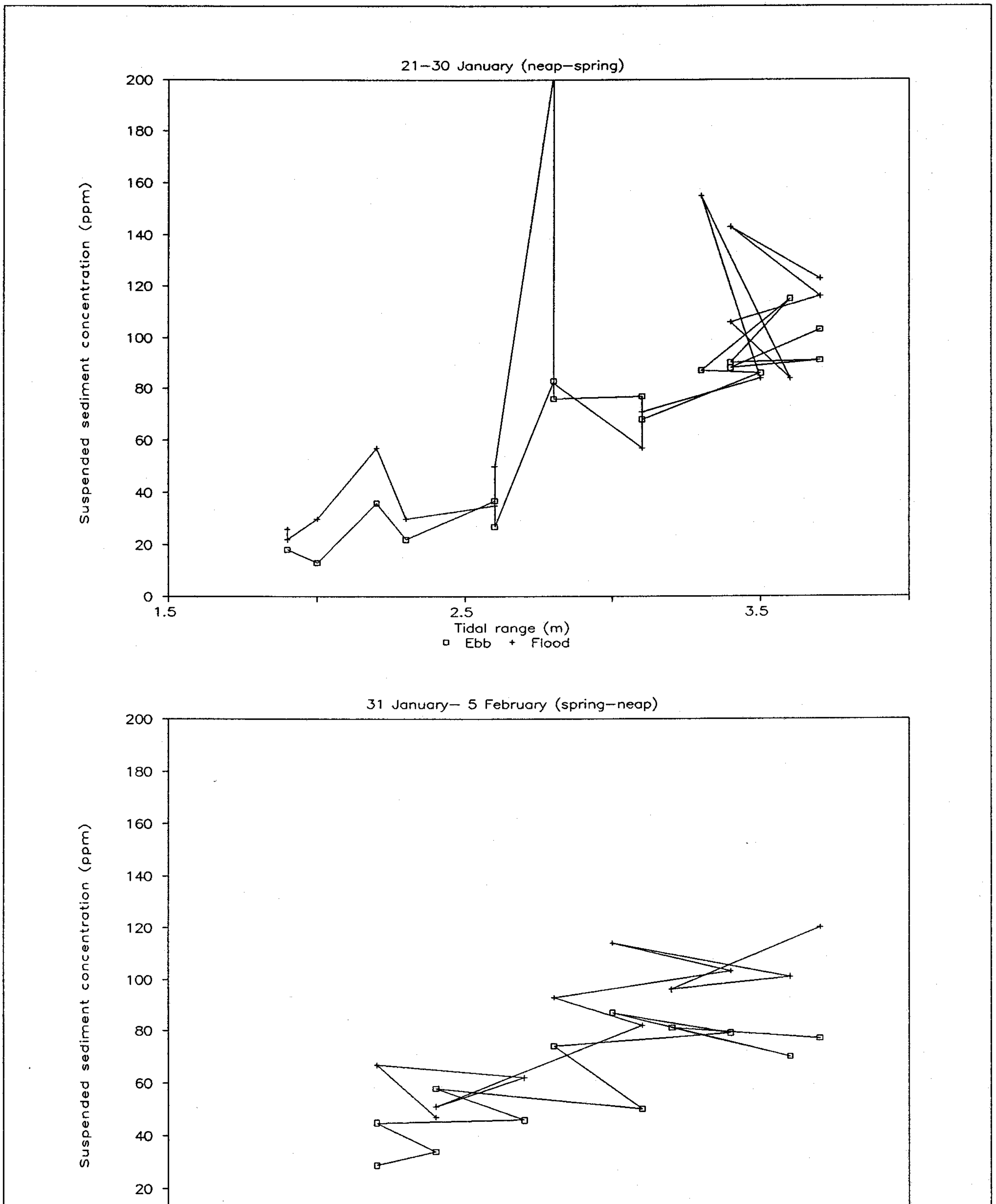



Fig 11 Suspended sediment concentration versus tidal range, Lightship 10.

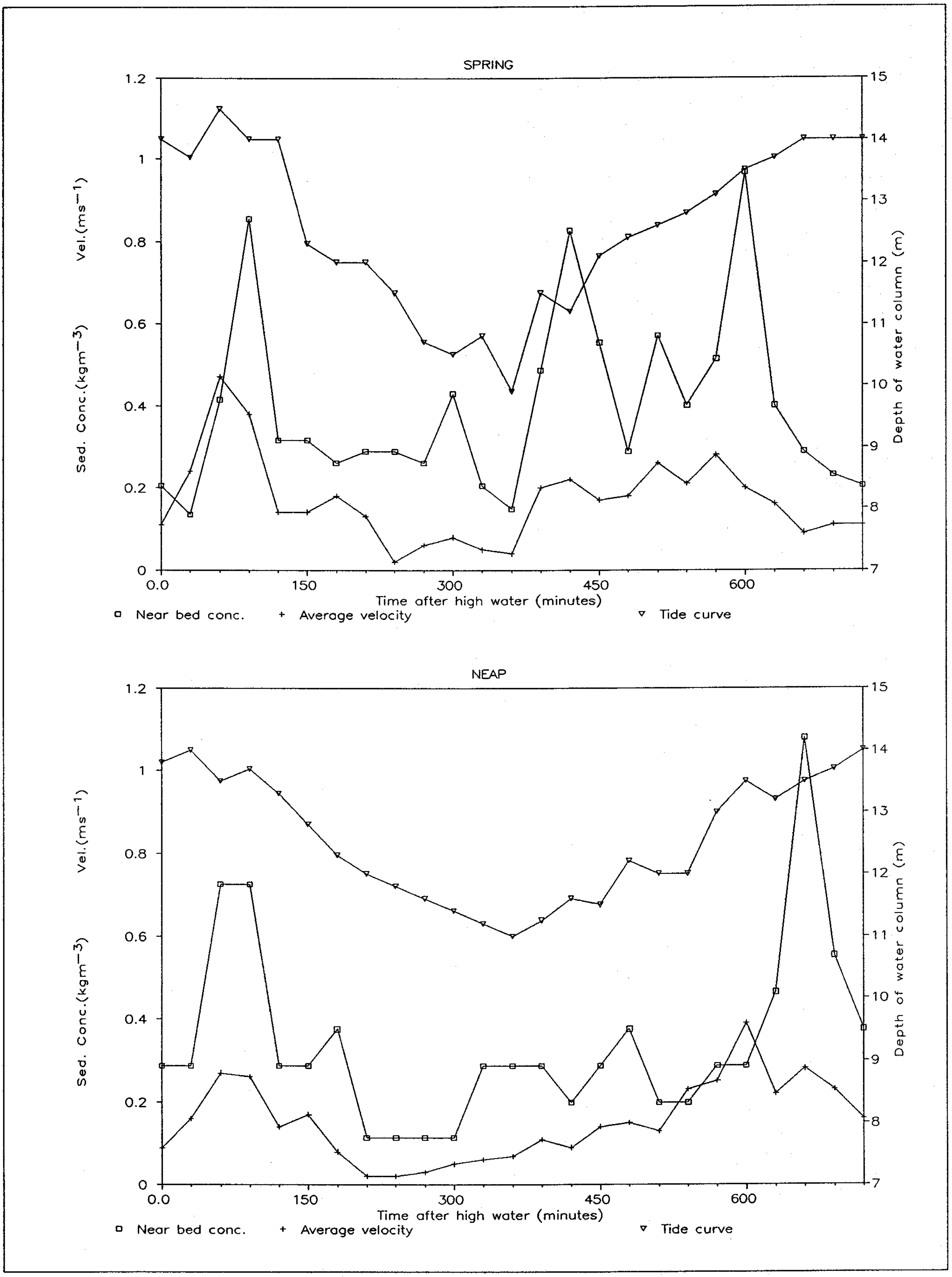



Fig 12 Spring and neap conditions at point 1.

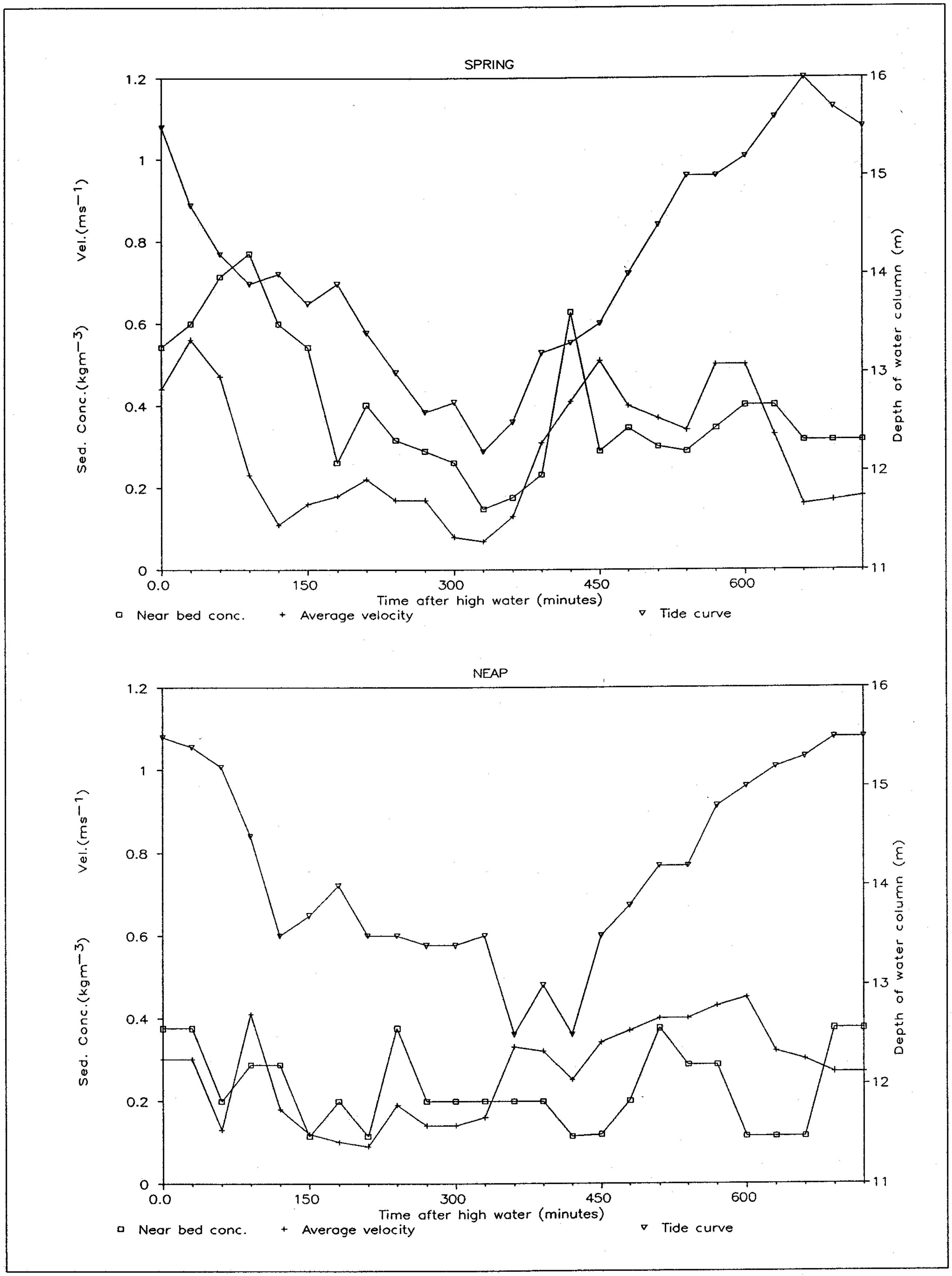



Fig 13 Spring and neap conditions at point 2.

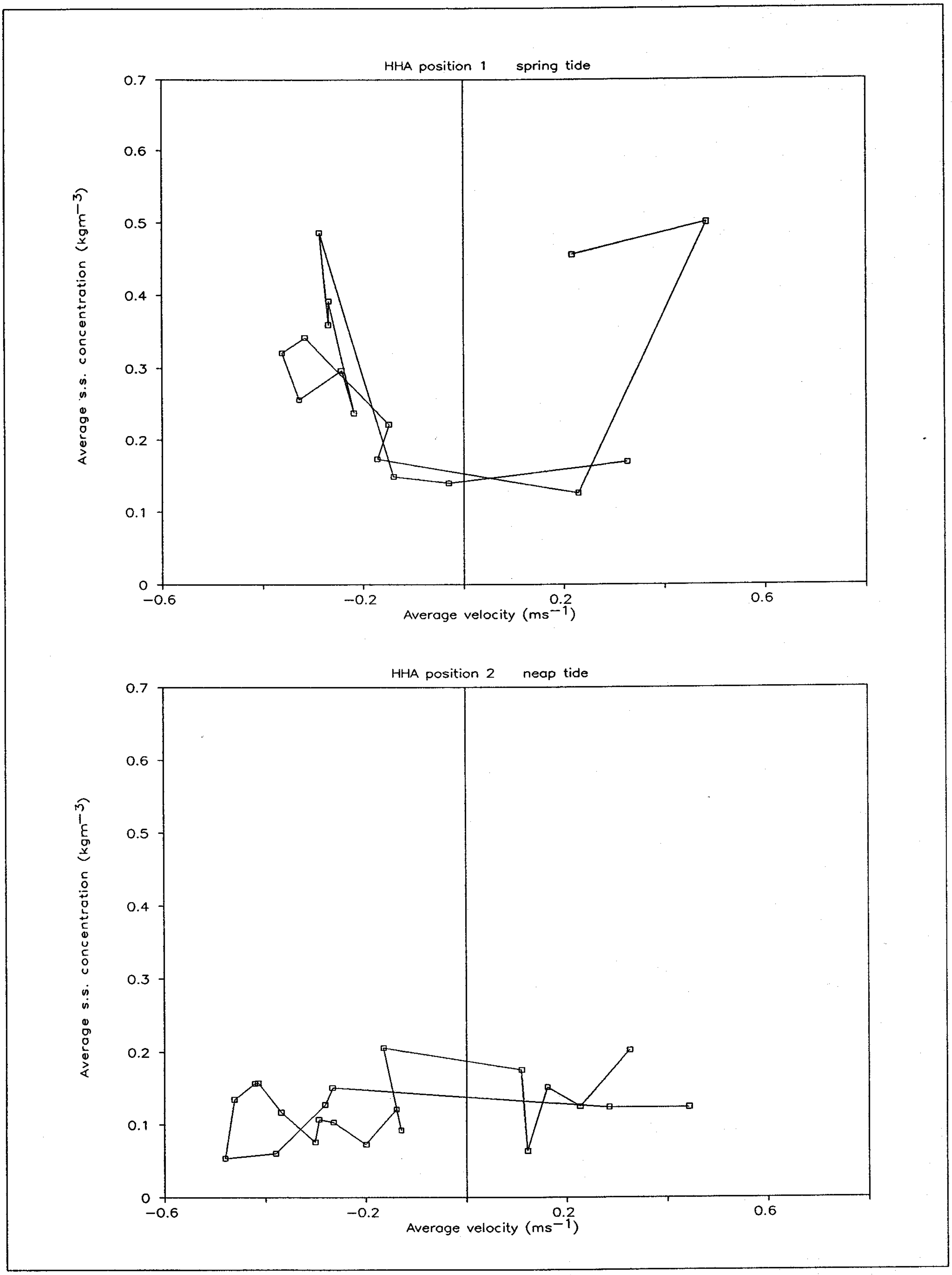



Fig 14a Ebb and flood velocities vs concentration.

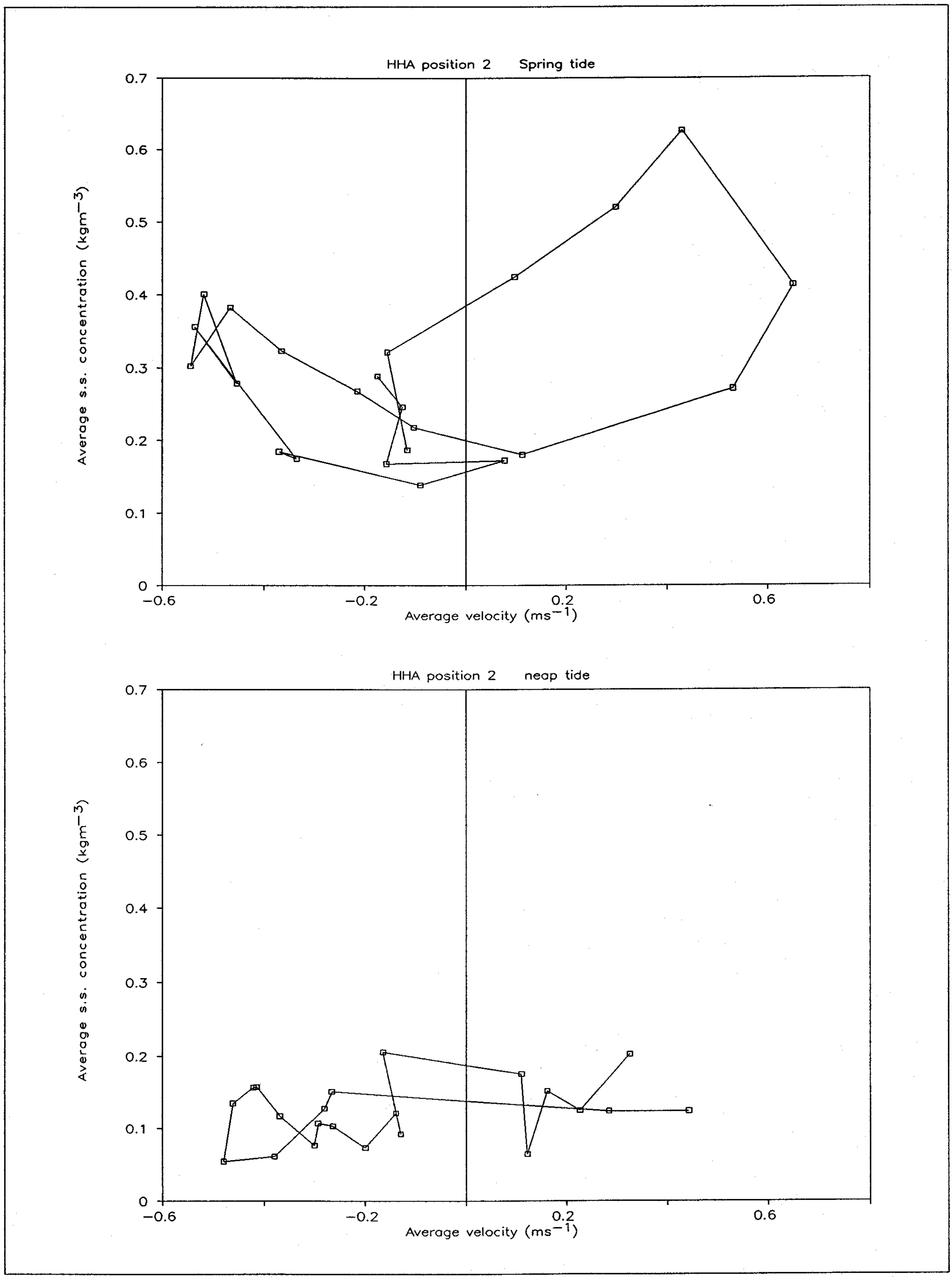



Fig 14b Ebb and flood velocities vs concentration.

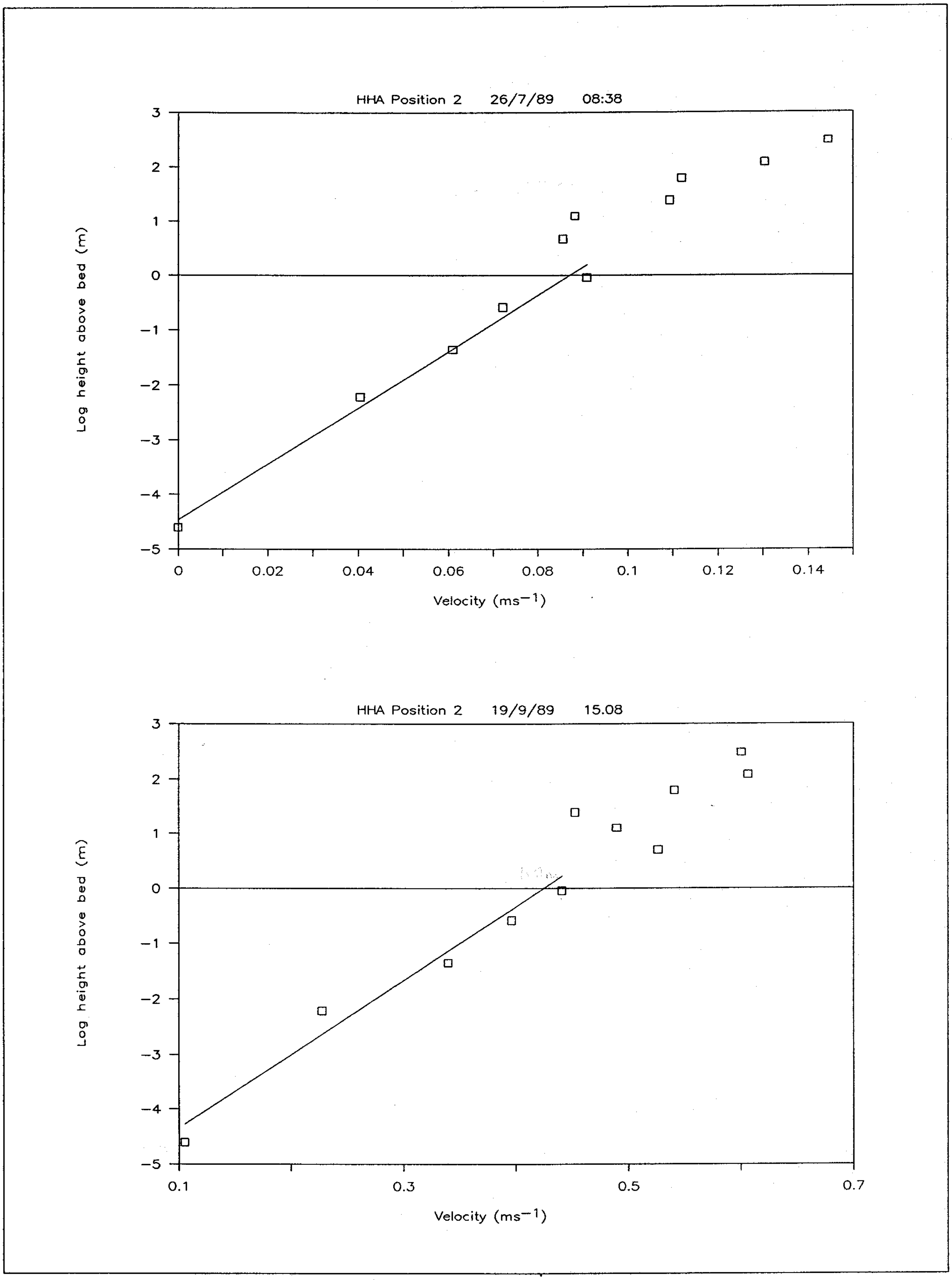



Fig 15 Examples of typical near bed velocity profiles at position 2.

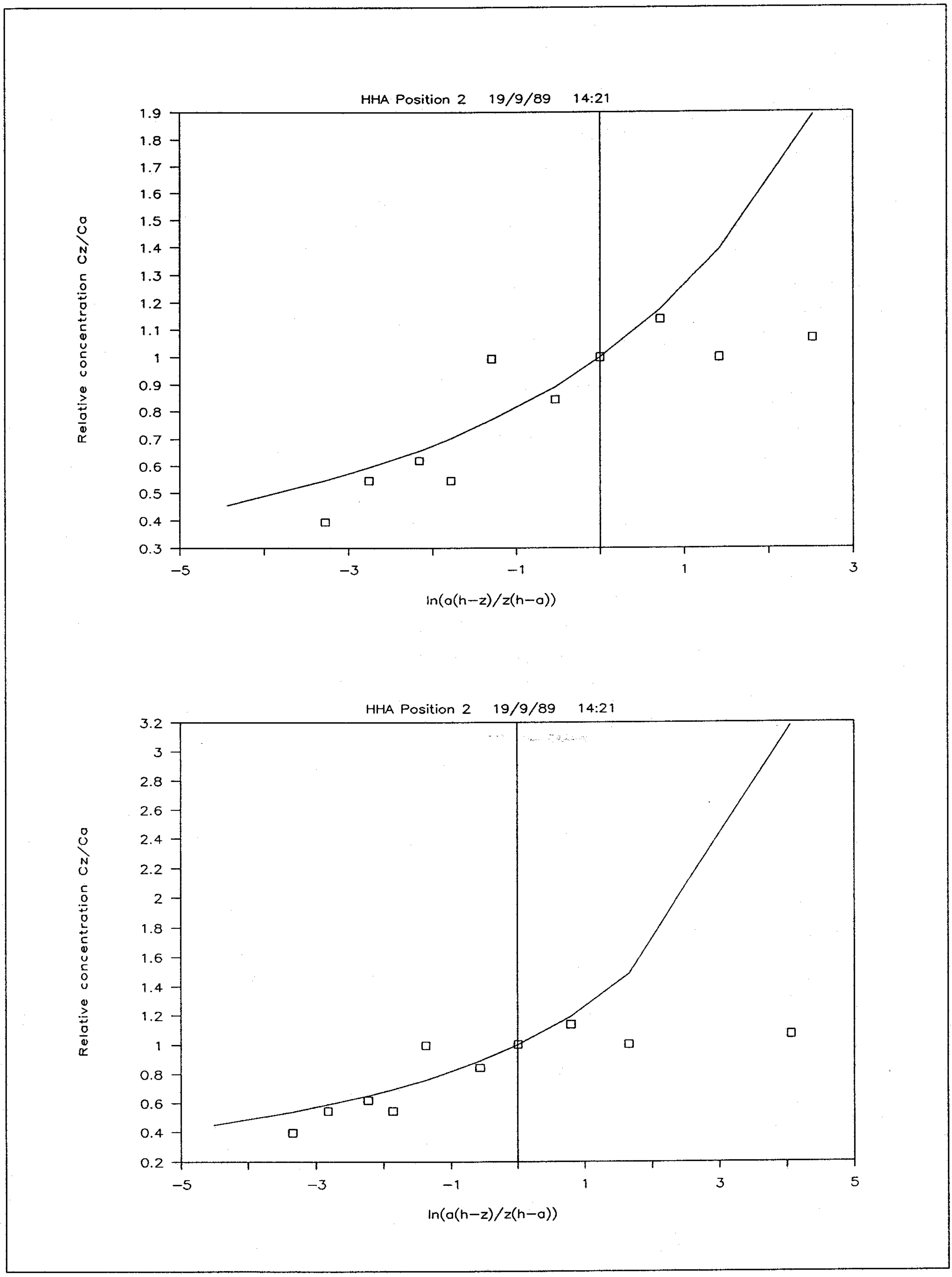



Fig 16a Non dimensional concentration profiles.

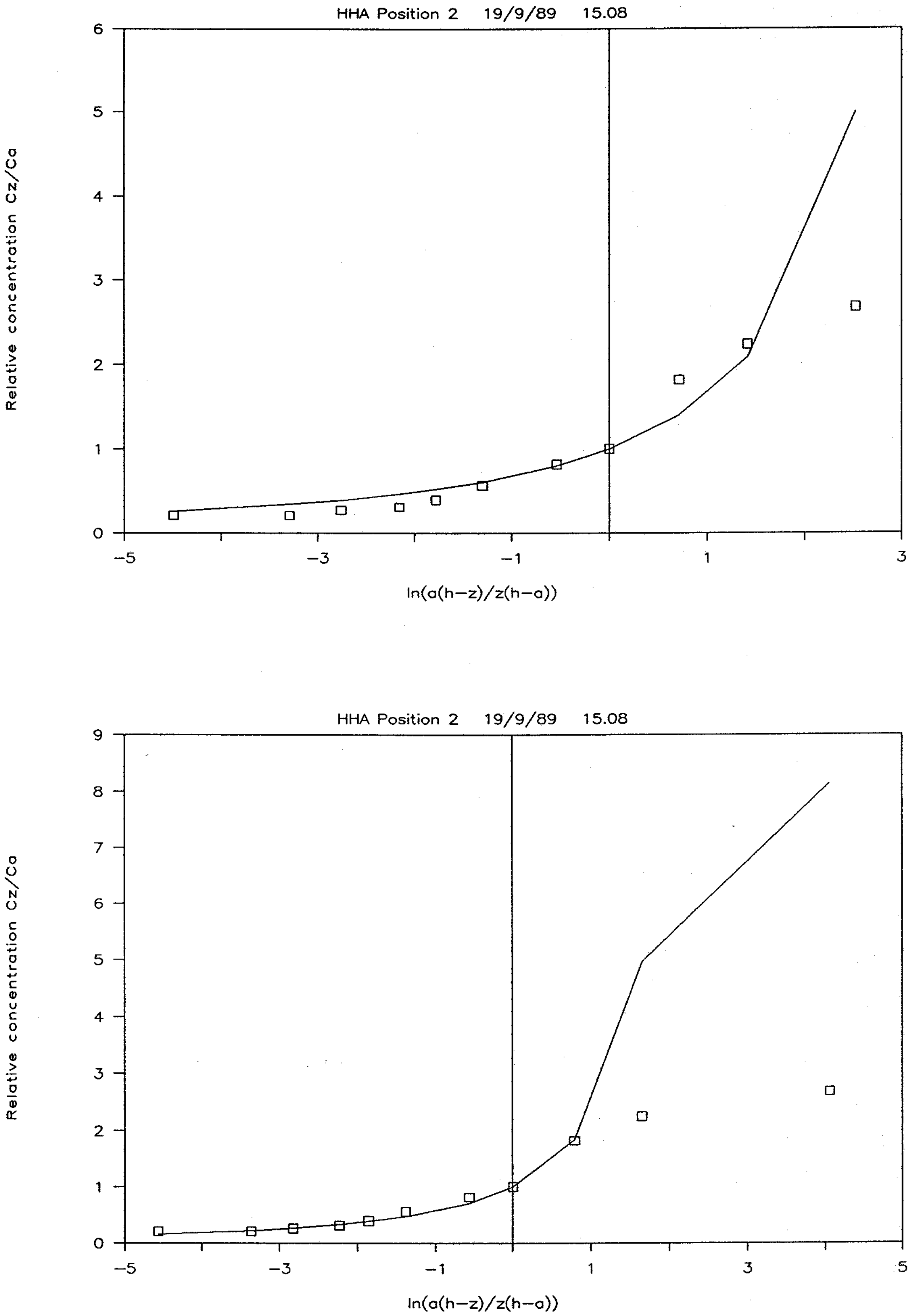



Fig 16b Non dimensional concentration profiles.

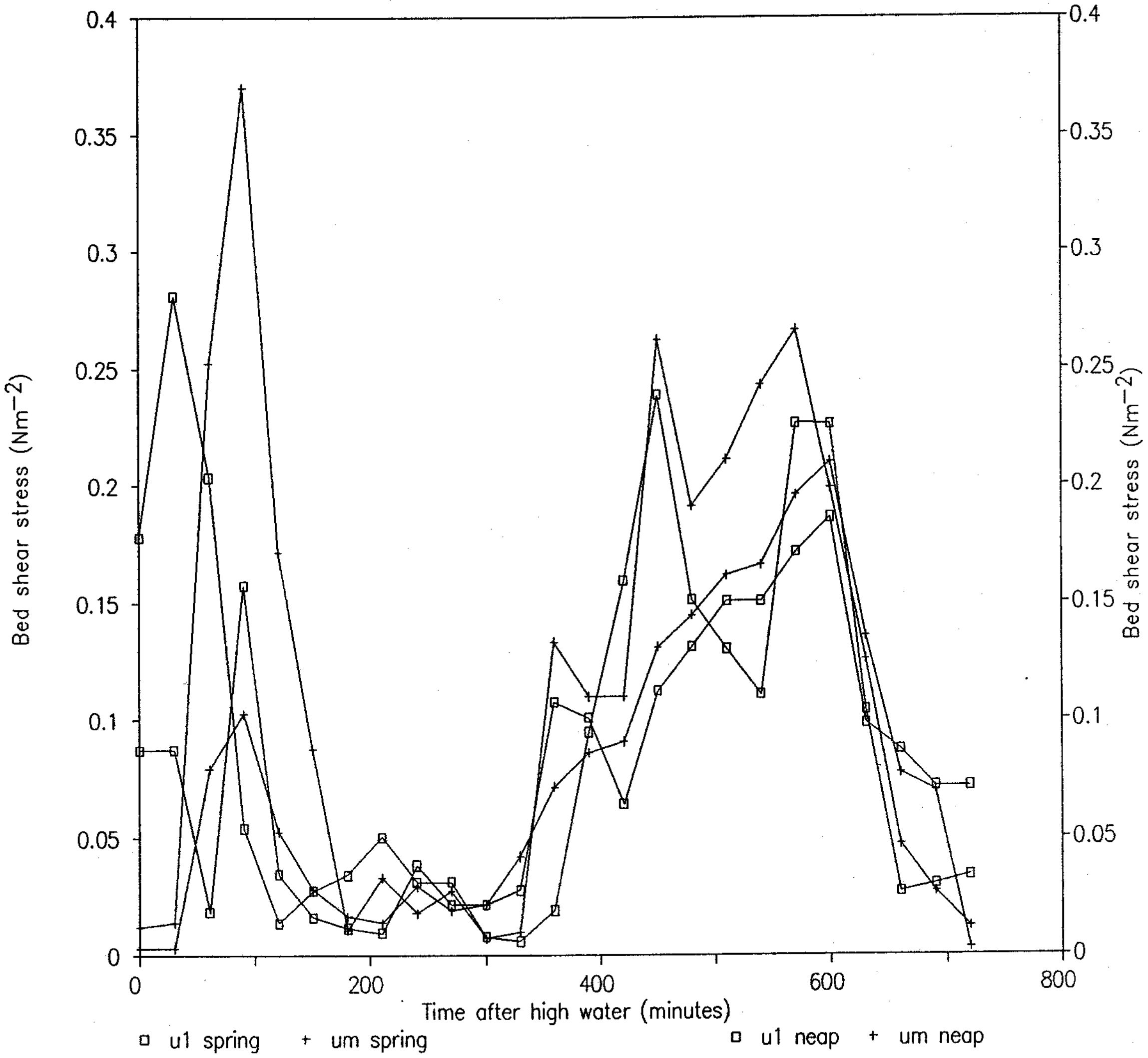



Fig 17 Shear stress values calculated using three different methods (point 2).

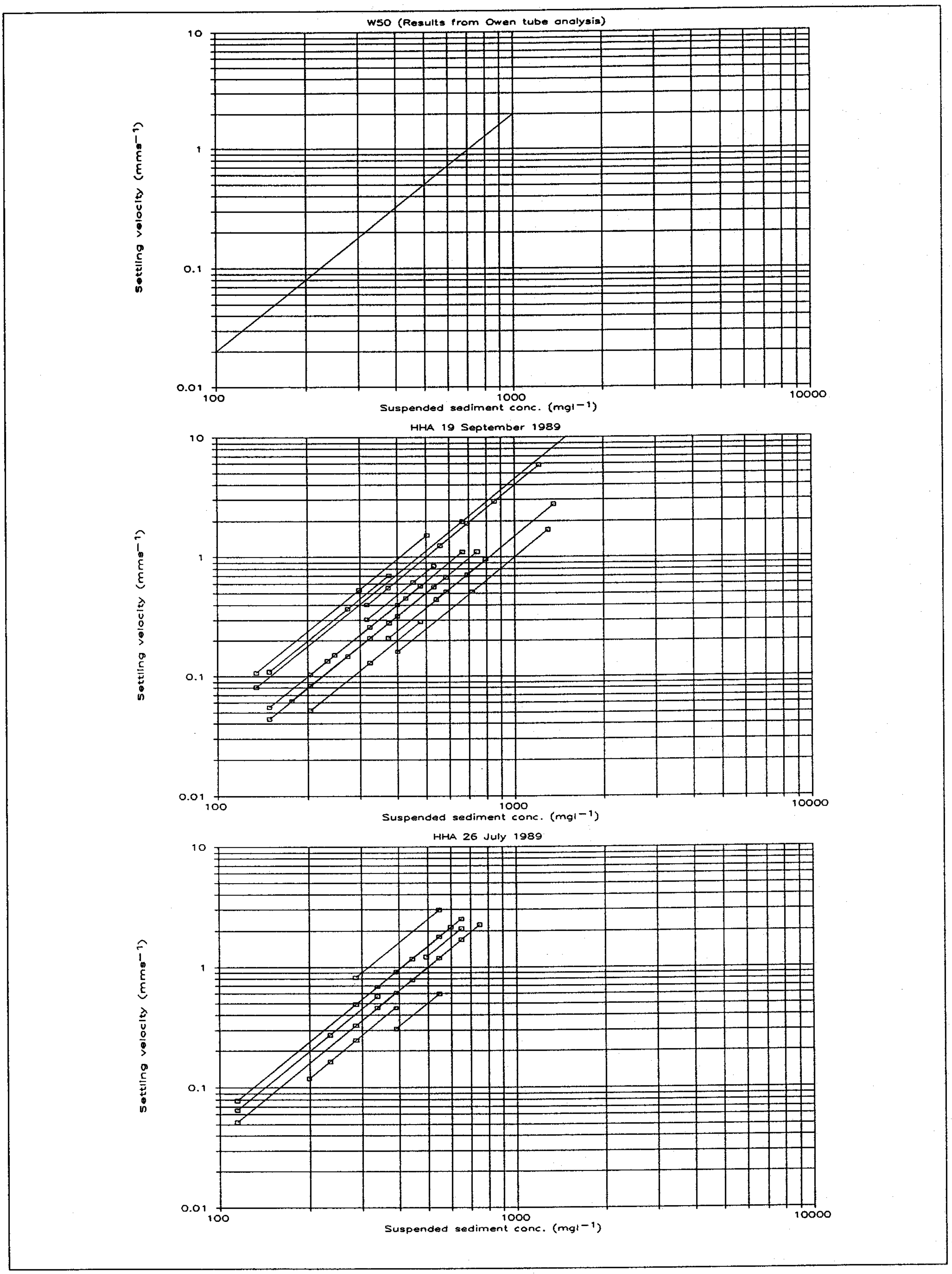



Fig 18 Settling velocities; Owen tube analysis and values calculated from conc. profiles.

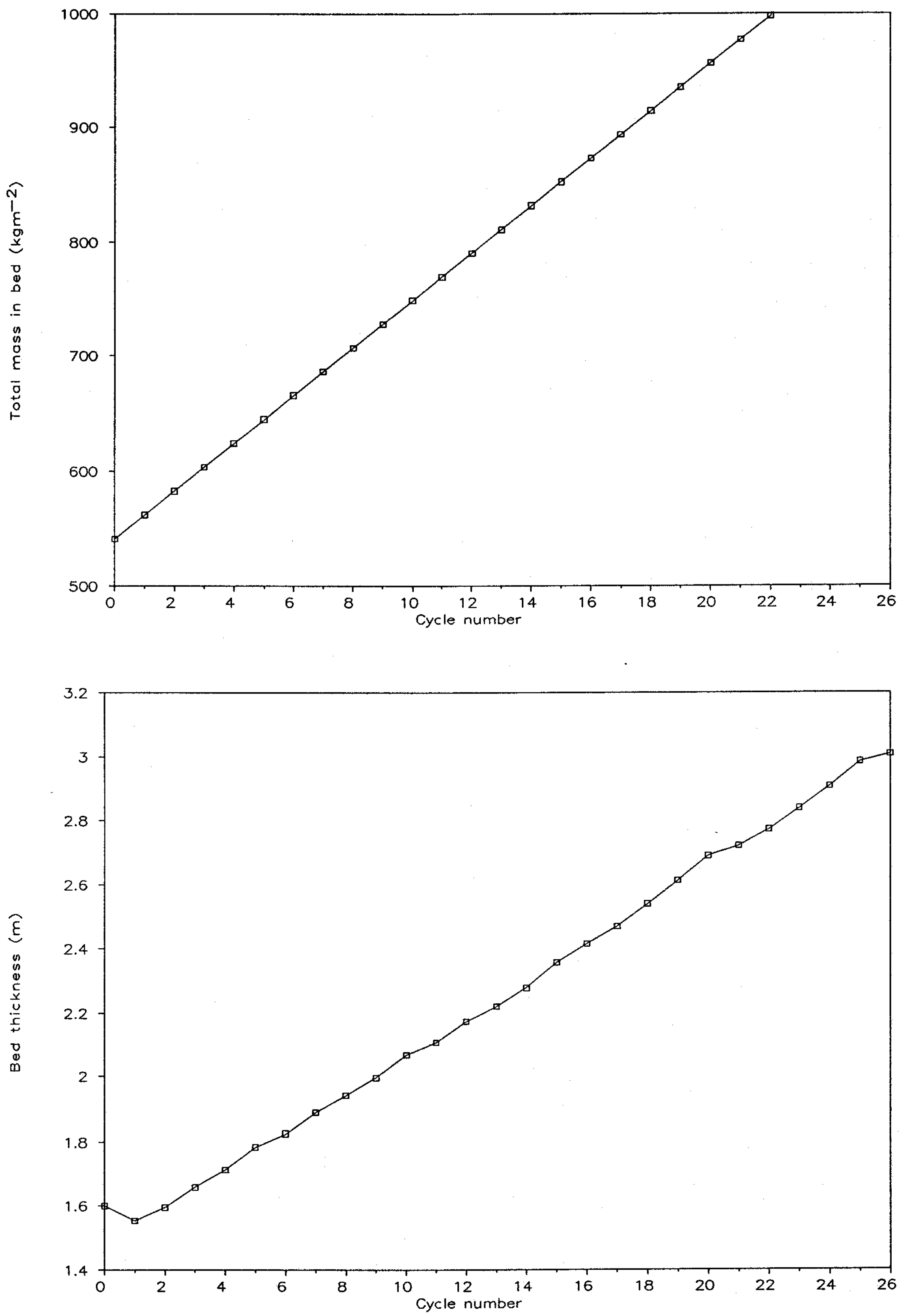



Fig 19 Change in mass and bed depth at point 1 (method 1).

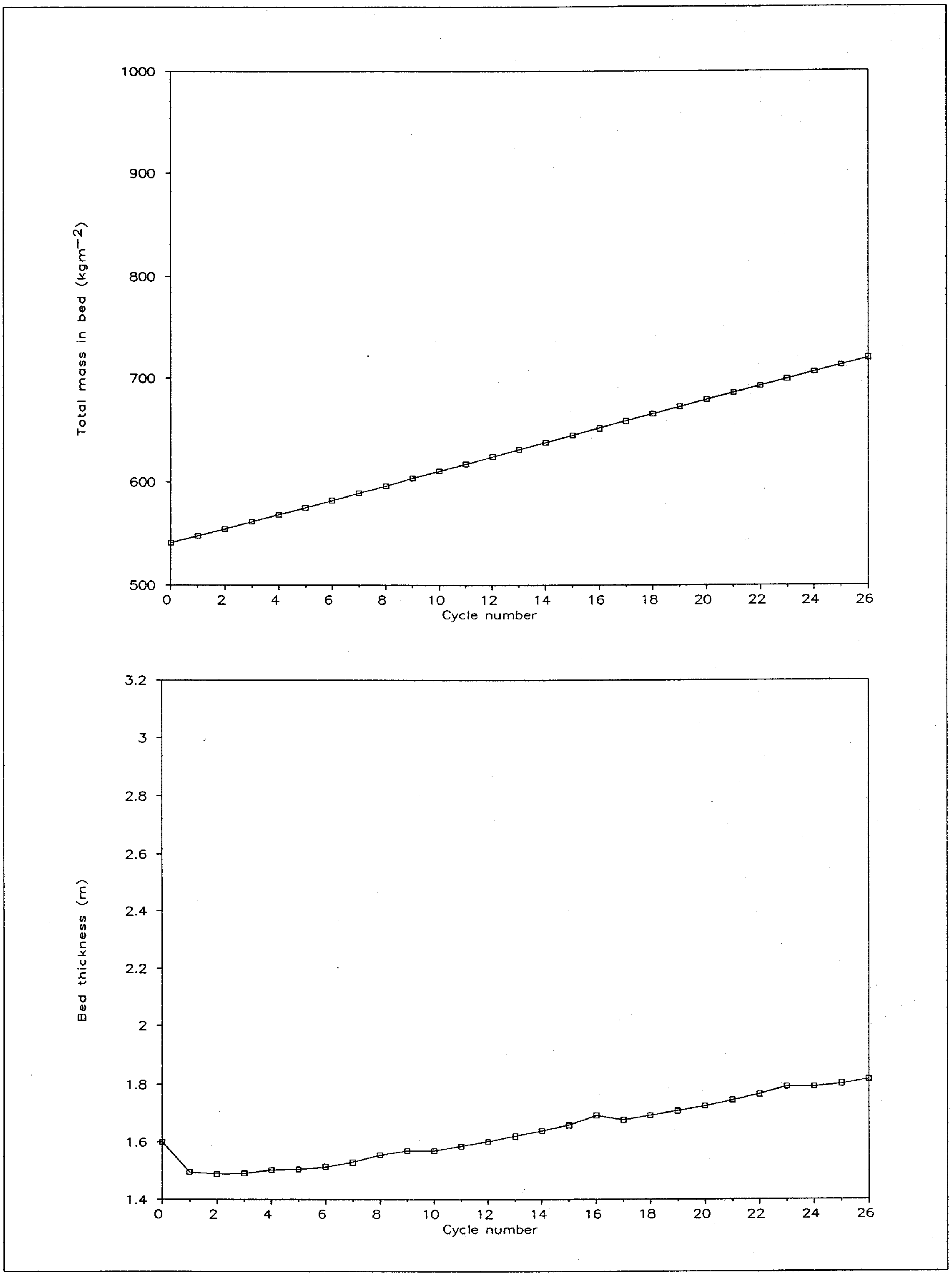



Fig 20 Change in mass and bed depth at point 2 (method 1).

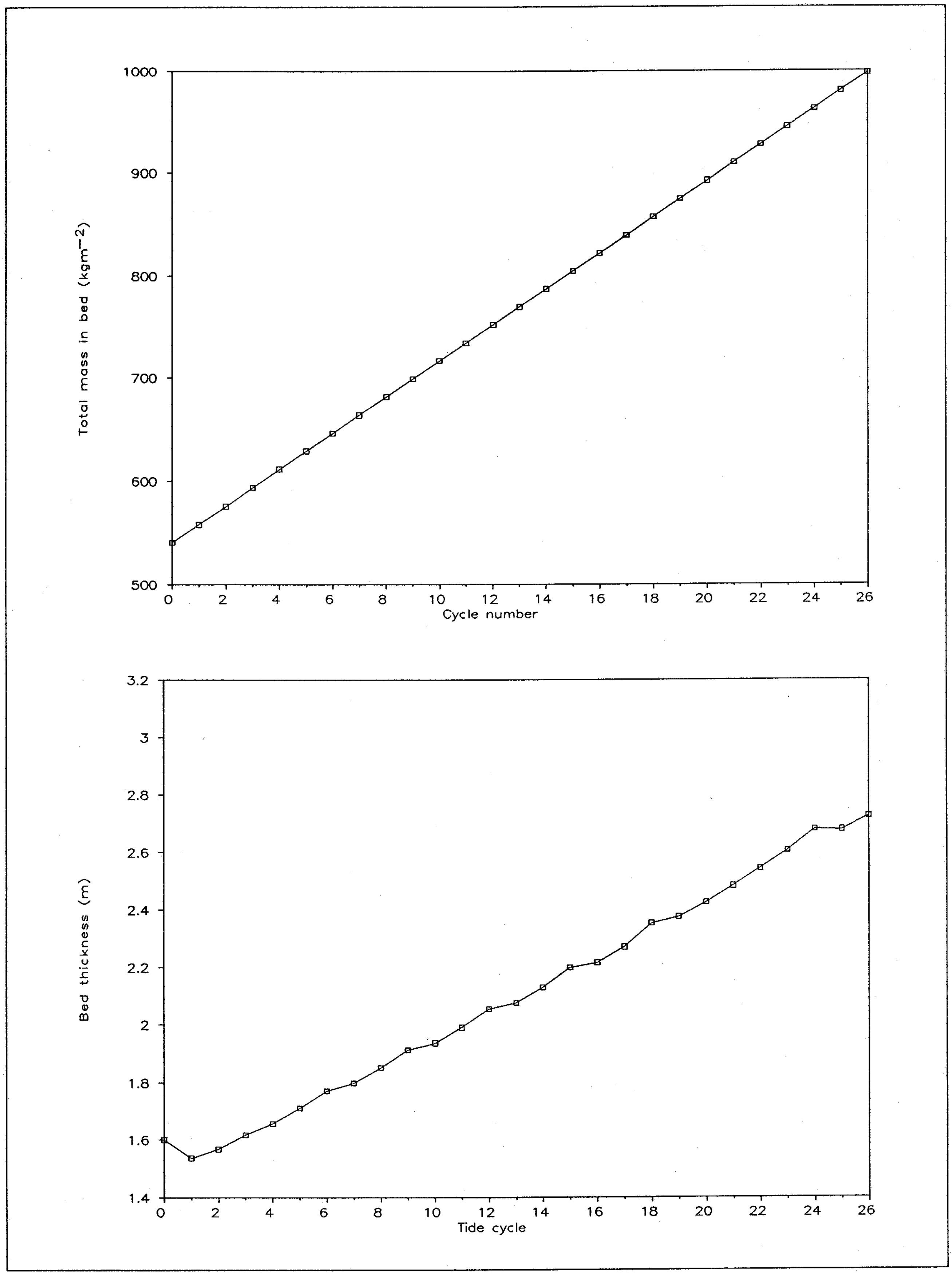



Fig 21 Change in mass and bed depth at point 1 (method 2).

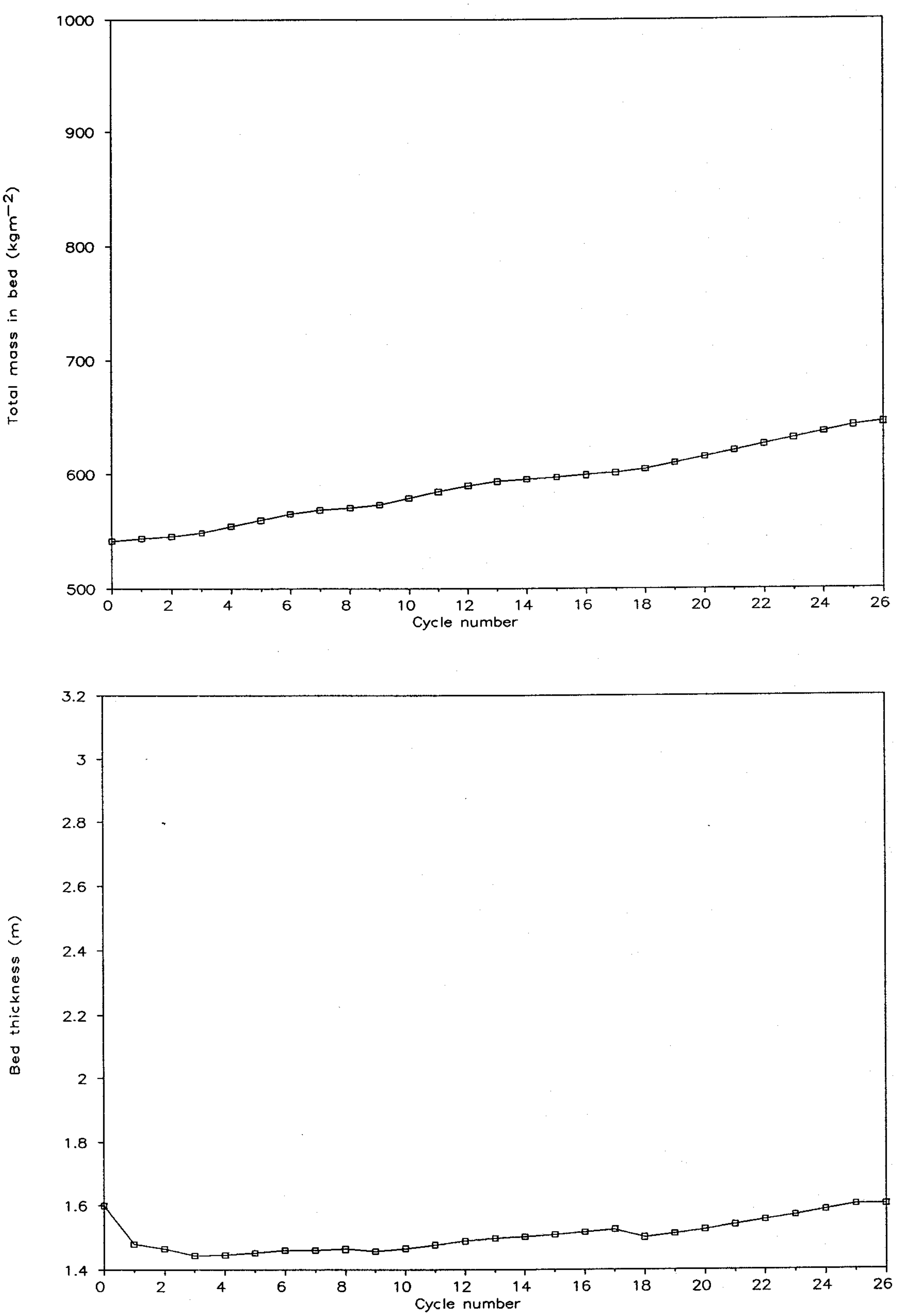



Fig 22 Change in mass and bed depth at point 2 (method 2).

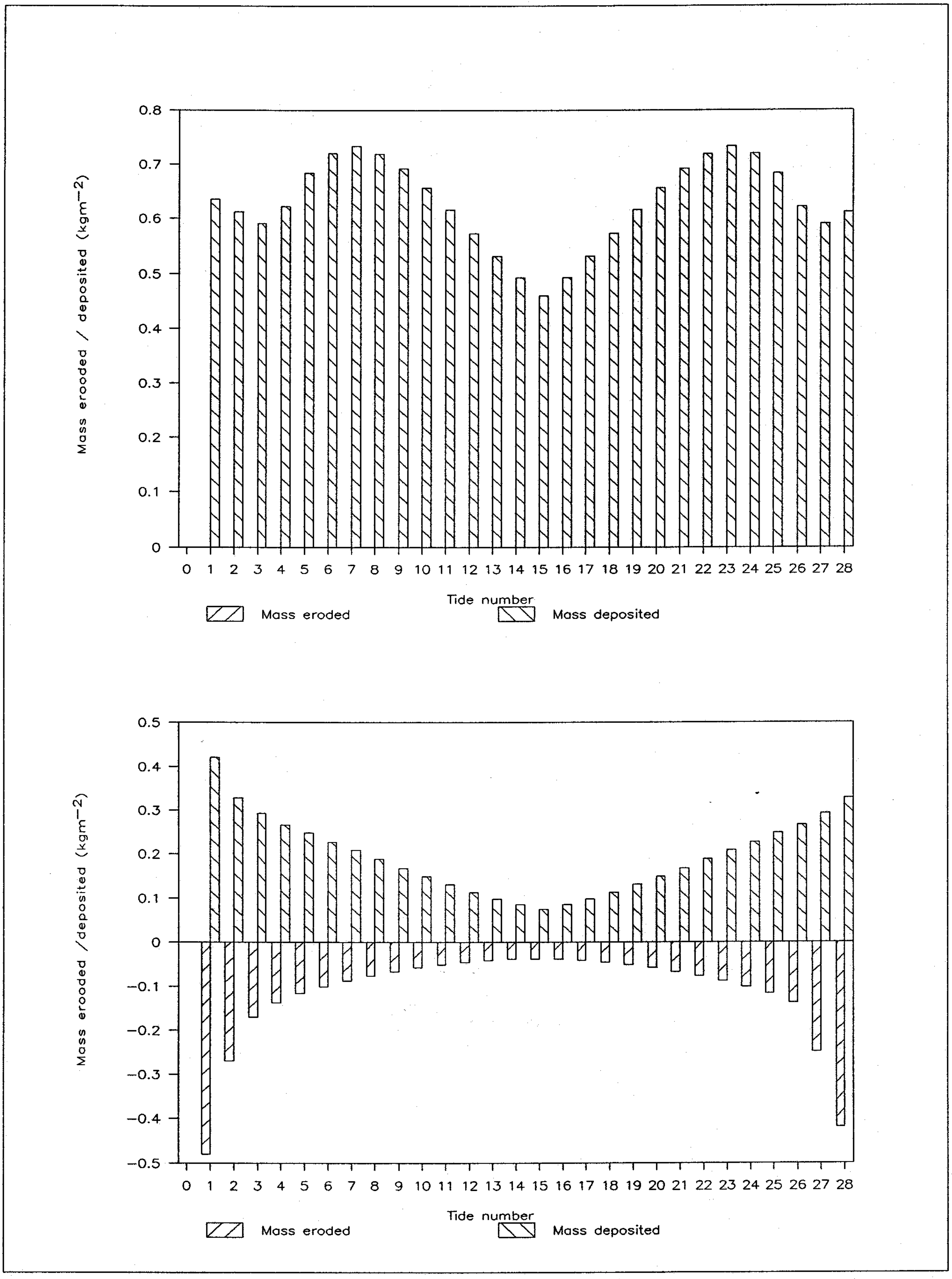



Fig 23 Mass eroded and deposited at points 1 and 2 over a single spring—neap—spring period.

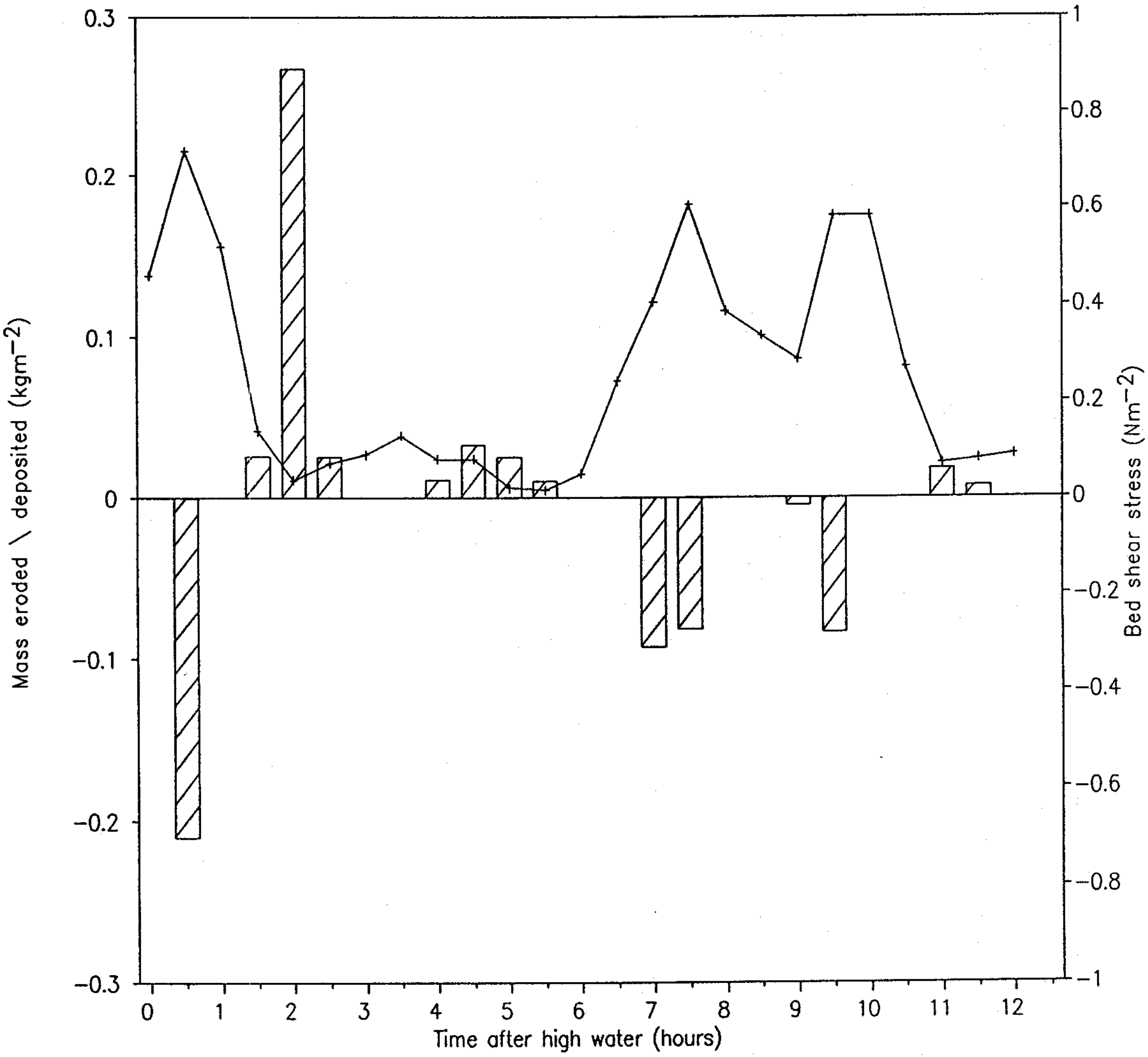



Fig 24 Mass eroded and deposited at point 2 over a single spring tide.

# Appendices

## *Appendix 1 Suspended sediment data obtained from monitor 1 (ebb)*

Data obtained from lightship 2

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1434 | 2 11 89 | 3.0 | 339 | 8 | 95 | 43 |
| 245 | 3 11 89 | 3.0 | 345 | 11 | 133 | 45 |
| 1508 | 3 11 89 | 2.8 | 337 | 11 | 126 | 45 |
| 319 | 4 11 89 | 2.8 | 346 | 20 | 90 | 43 |
| 1547 | 4 11 89 | 2.5 | 335 | 12 | 106 | 33 |
| 357 | 5 11 89 | 2.6 | 352 | 12 | 60 | 29 |
| 1632 | 5 11 89 | 2.3 | 338 | 12 | 91 | 35 |
| 445 | 6 11 89 | 2.4 | 360 | 12 | 66 | 28 |
| 1728 | 6 11 89 | 2.1 | 346 | 12 | 93 | 30 |
| 544 | 7 11 89 | 2.3 | 378 | 12 | 75 | 33 |
| 1839 | 7 11 89 | 2.0 | 358 | 16 | 56 | 30 |
| 657 | 8 11 89 | 2.4 | 391 | 12 | 66 | 43 |
| 1957 | 8 11 89 | 2.2 | 360 | 34 | 165 | 80 |
| 813 | 9 11 89 | 2.7 | 387 | 14 | 78 | 34 |
| 2112 | 9 11 89 | 2.6 | 352 | 34 | 124 | 68 |
| 923 | 10 11 89 | 3.1 | 379 | 14 | 158 | 58 |
| 2218 | 10 11 89 | 2.9 | 342 | 22 | 183 | 97 |
| 1028 | 11 11 89 | 3.4 | 367 | 14 | 197 | 93 |
| 2316 | 11 11 89 | 3.3 | 336 | 20 | 310 | 156 |
| 1126 | 12 11 89 | 3.7 | 358 | 26 | 307 | 126 |
| 6 | 13 11 89 | 3.5 | 334 | 19 | 287 | 140 |
| 1219 | 13 11 89 | 3.8 | 353 | 17 | 303 | 134 |
| 53 | 14 11 89 | 3.6 | 334 | 15 | 247 | 109 |
| 1307 | 14 11 89 | 3.9 | 349 | 18 | 248 | 101 |
| 136 | 15 11 89 | 3.7 | 338 | 18 | 245 | 107 |
| 1353 | 15 11 89 | 3.8 | 348 | 18 | 266 | 115 |
| 219 | 16 11 89 | 3.6 | 343 | 15 | 237 | 74 |
| 1440 | 16 11 89 | 3.5 | 344 | 25 | 208 | 79 |
| 301 | 17 11 89 | 3.4 | 348 | 27 | 158 | 64 |
| 1526 | 17 11 89 | 3.1 | 343 | 8 | 213 | 88 |
| 344 | 18 11 89 | 3.2 | 356 | 14 | 154 | 51 |
| 1614 | 18 11 89 | 2.7 | 343 | 12 | 187 | 65 |
| 429 | 19 11 89 | 3.0 | 365 | 12 | 131 | 58 |
| 1707 | 19 11 89 | 2.4 | 341 | 12 | 172 | 52 |
| 520 | 20 11 89 | 2.7 | 374 | 12 | 131 | 41 |
| 1806 | 20 11 89 | 2.2 | 341 | 12 | 102 | 30 |
| 619 | 21 11 89 | 2.5 | 381 | 12 | 64 | 18 |
| 1914 | 21 11 89 | 2.0 | 340 | 12 | 73 | 14 |
| 728 | 22 11 89 | 2.5 | 384 | 12 | 41 | 10 |
| 2023 | 22 11 89 | 2.0 | 344 | 12 | 46 | 8 |
| 838 | 23 11 89 | 2.6 | 379 | 12 | 35 | 9 |
| 2127 | 23 11 89 | 2.2 | 346 | 12 | 29 | 5 |
| 940 | 24 11 89 | 2.7 | 370 | 12 | 41 | 9 |
| 2219 | 24 11 89 | 2.4 | 345 | 12 | 98 | 28 |
| 1032 | 25 11 89 | 2.9 | 360 | 12 | 41 | 10 |
| 2303 | 25 11 89 | 2.7 | 345 | 12 | 59 | 16 |
| 1117 | 26 11 89 | 3.0 | 353 | 12 | 102 | 26 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2341 | 26 11 89 | 2.9 | 345 | 12 | 107 | 28 |
| 1157 | 27 11 89 | 3.0 | 345 | 12 | 98 | 30 |
| 18 | 28 11 89 | 3.0 | 341 | 12 | 102 | 29 |
| 1234 | 28 11 89 | 3.1 | 341 | 12 | 126 | 38 |
| 50 | 29 11 89 | 3.1 | 343 | 12 | 77 | 19 |
| 1310 | 29 11 89 | 3.0 | 337 | 12 | 122 | 42 |
| 124 | 30 11 89 | 3.1 | 344 | 12 | 129 | 36 |

Data obtained from lightship 10

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1816 | 6 12 89 | 2.3 | 345 | 10 | 2 | 2 |
| 629 | 7 12 89 | 2.8 | 380 | 11 | 1 | 1 |
| 1924 | 7 12 89 | 2.3 | 350 | 11 | 1 | 1 |
| 736 | 8 12 89 | 2.9 | 384 | 11 | 1 | 1 |
| 2034 | 8 12 89 | 2.4 | 350 | 11 | 18 | 3 |
| 847 | 9 12 89 | 3.0 | 381 | 11 | 1 | 1 |
| 2143 | 9 12 89 | 2.7 | 346 | 11 | 14 | 2 |
| 956 | 10 12 89 | 3.2 | 372 | 11 | 1 | 1 |
| 2248 | 10 12 89 | 3.0 | 340 | 11 | 29 | 4 |
| 1103 | 11 12 89 | 3.4 | 361 | 11 | 13 | 2 |
| 2344 | 11 12 89 | 3.3 | 340 | 11 | 14 | 2 |
| 1202 | 12 12 89 | 3.5 | 353 | 11 | 33 | 8 |
| 34 | 13 12 89 | 3.4 | 344 | 11 | 92 | 19 |
| 1254 | 13 12 89 | 3.6 | 349 | 11 | 44 | 9 |
| 121 | 14 12 89 | 3.5 | 346 | 11 | 40 | 7 |
| 1343 | 14 12 89 | 3.5 | 344 | 11 | 48 | 11 |
| 204 | 15 12 89 | 3.6 | 351 | 11 | 64 | 14 |
| 1430 | 15 12 89 | 3.4 | 340 | 11 | 75 | 19 |
| 247 | 16 12 89 | 3.6 | 354 | 11 | 51 | 8 |
| 1513 | 16 12 89 | 3.2 | 339 | 11 | 94 | 20 |
| 329 | 17 12 89 | 3.4 | 357 | 11 | 48 | 16 |
| 1558 | 17 12 89 | 2.9 | 336 | 16 | 87 | 35 |
| 410 | 18 12 89 | 3.3 | 361 | 12 | 32 | 9 |
| 1643 | 18 12 89 | 2.7 | 334 | 12 | 32 | 13 |
| 452 | 19 12 89 | 3.1 | 365 | 12 | 17 | 3 |
| 1730 | 19 12 89 | 2.4 | 333 | 12 | 25 | 4 |
| 537 | 20 12 89 | 2.8 | 370 | 12 | 25 | 3 |
| 1819 | 20 12 89 | 2.2 | 335 | 8 | 41 | 20 |
| 629 | 21 12 89 | 2.6 | 374 | 14 | 41 | 20 |
| 1917 | 21 12 89 | 1.9 | 339 | 15 | 34 | 10 |
| 729 | 22 12 89 | 2.4 | 377 | | | |
| 2020 | 22 12 89 | 1.9 | 346 | | | |
| 838 | 23 12 89 | 2.3 | 371 | | | |
| 2123 | 23 12 89 | 2.1 | 350 | | | |
| 946 | 24 12 89 | 2.4 | 361 | 12 | 13 | 7 |
| 2219 | 24 12 89 | 2.3 | 353 | 12 | 26 | 6 |
| 1043 | 25 12 89 | 2.5 | 353 | 12 | 13 | 6 |
| 2307 | 25 12 89 | 2.5 | 353 | 12 | 29 | 9 |
| 1131 | 26 12 89 | 2.6 | 348 | 12 | 13 | 4 |
| 2351 | 26 12 89 | 2.8 | 351 | 12 | 26 | 8 |
| 1215 | 27 12 89 | 2.7 | 342 | 12 | 37 | 9 |
| 30 | 28 12 89 | 2.9 | 350 | 12 | 37 | 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1254 | 28 12 89 | 2.8 | 338 | 12 | 40 | 13 |
| 108 | 29 12 89 | 3.1 | 350 | 12 | 50 | 12 |
| 1334 | 29 12 89 | 2.9 | 334 | 12 | 74 | 20 |
| 146 | 30 12 89 | 3.2 | 350 | 12 | 47 | 10 |
| 1413 | 30 12 89 | 3.0 | 332 | 12 | 85 | 21 |
| 224 | 31 12 89 | 3.2 | 352 | 12 | 43 | 9 |
| 1452 | 31 12 89 | 3.1 | 332 | 12 | 90 | 18 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 302 | 1 1 90 | 3.3 | 355 | 12 | 66 | 13 |
| 1532 | 1 1 90 | 3.1 | 333 | 12 | 62 | 17 |
| 340 | 2 1 90 | 3.3 | 359 | 12 | 50 | 13 |
| 1615 | 2 1 90 | 2.9 | 332 | 12 | 53 | 16 |
| 422 | 3 1 90 | 3.2 | 362 | 12 | 26 | 8 |
| 1700 | 3 1 90 | 2.7 | 334 | 12 | 47 | 15 |
| 507 | 4 1 90 | 3.2 | 365 | 12 | 33 | 6 |
| 1752 | 4 1 90 | 2.5 | 335 | 12 | 53 | 12 |
| 601 | 5 1 90 | 3.0 | 370 | 12 | 21 | 2 |
| 110 | 12 1 90 | 3.5 | 351 | 10 | 42 | 18 |
| 1335 | 12 1 90 | 3.4 | 340 | 22 | 59 | 21 |
| 153 | 13 1 90 | 3.7 | 352 | 23 | 54 | 20 |
| 1417 | 13 1 90 | 3.4 | 336 | 22 | 74 | 25 |
| 233 | 14 1 90 | 3.7 | 353 | 23 | 32 | 10 |
| 1458 | 14 1 90 | 3.3 | 333 | 23 | 60 | 19 |
| 309 | 15 1 90 | 3.7 | 356 | 23 | 52 | 16 |
| 1536 | 15 1 90 | 3.1 | 333 | 31 | 72 | 26 |
| 346 | 16 1 90 | 3.5 | 357 | 30 | 67 | 20 |
| 1612 | 16 1 90 | 2.9 | 332 | 25 | 53 | 22 |
| 421 | 17 1 90 | 3.4 | 358 | 26 | 35 | 10 |
| 1649 | 17 1 90 | 2.7 | 330 | 20 | 29 | 12 |
| 456 | 18 1 90 | 3.0 | 361 | 12 | 43 | 20 |
| 1727 | 18 1 90 | 2.4 | 333 | 14 | 38 | 12 |
| 535 | 19 1 90 | 2.8 | 366 | 12 | 23 | 6 |
| 1809 | 19 1 90 | 2.0 | 342 | 16 | 22 | 10 |
| 623 | 20 1 90 | 2.4 | 373 | 12 | 12 | 1 |
| 1903 | 20 1 90 | 1.8 | 354 | 12 | 12 | 4 |
| 728 | 21 1 90 | 2.0 | 377 | 12 | 12 | 1 |
| 2013 | 21 1 90 | 1.7 | 363 | 12 | 23 | 6 |
| 852 | 22 1 90 | 1.9 | 367 | 12 | 12 | 6 |
| 2129 | 22 1 90 | 1.9 | 365 | 12 | 8 | 1 |
| 1011 | 23 1 90 | 2.0 | 356 | 20 | 26 | 16 |
| 2235 | 23 1 90 | 2.2 | 363 | 16 | 11 | 6 |
| 1110 | 24 1 90 | 2.3 | 349 | 24 | 22 | 13 |
| 2328 | 24 1 90 | 2.6 | 359 | 20 | 22 | 7 |
| 1158 | 25 1 90 | 2.6 | 343 | 50 | 82 | 33 |
| 13 | 26 1 90 | 2.8 | 355 | 62 | 45 | 14 |
| 1240 | 26 1 90 | 2.8 | 339 | 52 | 51 | 25 |
| 54 | 27 1 90 | 3.1 | 353 | 38 | 65 | 30 |
| 1321 | 27 1 90 | 3.1 | 335 | 42 | 94 | 44 |
| 135 | 28 1 90 | 3.5 | 350 | 51 | 72 | 36 |
| 1400 | 28 1 90 | 3.3 | 332 | 51 | 155 | 64 |
| 213 | 29 1 90 | 3.6 | 351 | 42 | 119 | 48 |
| 1440 | 29 1 90 | 3.4 | 330 | 51 | 95 | 40 |
| 251 | 30 1 90 | 3.7 | 351 | 48 | 133 | 40 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1519 | 30 1 90 | 3.4 | 329 | 43 | 167 | 60 |
| 327 | 31 1 90 | 3.7 | 353 | 38 | 90 | 39 |
| 1558 | 31 1 90 | 3.2 | 329 | 35 | 134 | 46 |
| 405 | 1 2 90 | 3.6 | 356 | 46 | 70 | 24 |
| 1641 | 1 2 90 | 3.0 | 329 | 58 | 67 | 29 |
| 448 | 2 2 90 | 3.4 | 357 | 51 | 110 | 28 |
| 1727 | 2 2 90 | 2.8 | 330 | 46 | 94 | 28 |
| 537 | 3 2 90 | 3.1 | 363 | 38 | 29 | 12 |
| 1822 | 3 2 90 | 2.4 | 337 | 37 | 59 | 21 |
| 639 | 4 2 90 | 2.7 | 372 | 35 | 20 | 11 |
| 1931 | 4 2 90 | 2.2 | 353 | 37 | 38 | 8 |
| 757 | 5 2 90 | 2.4 | 383 | 27 | 11 | 7 |
| 2051 | 5 2 90 | 2.2 | 363 | 24 | 11 | 5 |

Data obtained from Holbrook Beacon

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1539 | 14 2 90 | 3.1 | 333 | 8 | 48 | 20 |
| 347 | 15 2 90 | 3.4 | 355 | 11 | 20 | 7 |
| 1610 | 15 2 90 | 2.9 | 333 | 14 | 60 | 17 |
| 418 | 16 2 90 | 3.1 | 354 | 12 | 10 | 3 |
| 1641 | 16 2 90 | 2.6 | 333 | 12 | 16 | 1 |
| 452 | 17 2 90 | 2.7 | 356 | | | |
| 1716 | 17 2 90 | 2.3 | 337 | | | |
| 533 | 18 2 90 | 2.3 | 361 | | | |
| 1759 | 18 2 90 | 1.9 | 349 | | | |
| 626 | 19 2 90 | 1.8 | 376 | | | |
| 1900 | 19 2 90 | 1.6 | 377 | | | |
| 749 | 20 2 90 | 1.5 | 381 | | | |
| 2028 | 20 2 90 | 1.6 | 386 | | | |
| 936 | 21 2 90 | 1.7 | 360 | 12 | 38 | 8 |
| 2158 | 21 2 90 | 2.0 | 372 | | | |
| 1045 | 22 2 90 | 2.2 | 350 | | | |
| 2302 | 22 2 90 | 2.5 | 361 | | | |
| 1135 | 23 2 90 | 2.5 | 344 | | | |
| 2351 | 23 2 90 | 3.0 | 354 | | | |
| 1219 | 24 2 90 | 3.0 | 339 | 12 | 38 | 10 |
| 33 | 25 2 90 | 3.4 | 353 | 12 | 22 | 10 |
| 1301 | 25 2 90 | 3.3 | 335 | 18 | 94 | 29 |
| 114 | 26 2 90 | 3.7 | 350 | 33 | 289 | 90 |
| 1341 | 26 2 90 | 3.6 | 331 | 113 | 212 | 112 |
| 153 | 27 2 90 | 4.0 | 349 | 91 | 134 | 50 |
| 1420 | 27 2 90 | 3.7 | 329 | 145 | 182 | 109 |
| 231 | 28 2 90 | 4.1 | 349 | 94 | 148 | 86 |
| 1459 | 28 2 90 | 3.6 | 328 | 82 | 245 | 103 |
| 308 | 1 3 90 | 4.0 | 350 | 112 | 116 | 48 |
| 1539 | 1 3 90 | 3.5 | 329 | 67 | 111 | 60 |
| 347 | 2 3 90 | 3.8 | 352 | 41 | 90 | 37 |
| 1619 | 2 3 90 | 3.2 | 331 | 26 | 87 | 34 |
| 429 | 3 3 90 | 3.4 | 353 | 15 | 35 | 12 |
| 1703 | 3 3 90 | 2.8 | 336 | 12 | 28 | 5 |
| 520 | 4 3 90 | 3.0 | 356 | 12 | 19 | 8 |
| 1757 | 4 3 90 | 2.4 | 345 | 12 | 10 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 623 | 5 3 90 | 2.4 | 369 | 12 | 10 | 5 |
| 1905 | 5 3 90 | 2.2 | 367 | 12 | 19 | 3 |
| 750 | 6 3 90 | 2.1 | 377 | 12 | 10 | 4 |
| 2034 | 6 3 90 | 2.3 | 378 | 12 | 10 | 2 |
| 930 | 7 3 90 | 2.2 | 367 | 12 | 10 | 1 |
| 2203 | 7 3 90 | 2.6 | 371 | 12 | 10 | 2 |
| 1043 | 8 3 90 | 2.6 | 356 | 12 | 10 | 3 |
| 2306 | 8 3 90 | 3.1 | 364 | 12 | 30 | 13 |
| 1137 | 9 3 90 | 2.9 | 347 | 32 | 24 | 13 |
| 2354 | 9 3 90 | 3.4 | 358 | 25 | 17 | 7 |
| 1222 | 10 3 90 | 3.1 | 339 | 34 | 22 | 15 |
| 36 | 11 3 90 | 3.6 | 353 | 31 | 25 | 10 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1300 | 11 3 90 | 3.4 | 334 | 14 | 313 | 68 |
| 112 | 12 3 90 | 3.8 | 351 | 20 | 307 | 50 |
| 1823 | 2 5 90 | 2.7 | 381 | 10 | 6 | 6 |
| 719 | 3 5 90 | 2.2 | 349 | 11 | 19 | 15 |
| 1938 | 3 5 90 | 2.7 | 385 | 15 | 15 | 14 |
| 837 | 4 5 90 | 2.2 | 350 | 21 | 23 | 13 |
| 2055 | 4 5 90 | 2.8 | 378 | 29 | 287 | 32 |
| 944 | 5 5 90 | 2.5 | 349 | 36 | 25 | 15 |
| 2200 | 5 5 90 | 3.0 | 368 | 29 | 36 | 18 |
| 1038 | 6 5 90 | 2.7 | 344 | 47 | 621 | 145 |
| 2252 | 6 5 90 | 3.1 | 360 | 15 | 653 | 340 |
| 1123 | 7 5 90 | 3.0 | 341 | 32 | 636 | 279 |
| 2335 | 7 5 90 | 3.2 | 353 | 10 | 384 | 78 |
| 1201 | 8 5 90 | 3.1 | 340 | 1 | 667 | 299 |
| 13 | 9 5 90 | 3.2 | 349 | 64 | 69 | 32 |
| 1234 | 9 5 90 | 3.2 | 342 | 86 | 582 | 298 |
| 49 | 10 5 90 | 3.2 | 344 | 28 | 640 | 132 |
| 1307 | 10 5 90 | 3.3 | 343 | 75 | 210 | 60 |
| 122 | 11 5 90 | 3.1 | 342 | 82 | 420 | 88 |
| 1336 | 11 5 90 | 3.2 | 345 | 9 | 588 | 446 |
| 155 | 12 5 90 | 3.1 | 339 | 1 | 667 | 214 |
| 1406 | 12 5 90 | 3.1 | 347 | 50 | 618 | 209 |
| 227 | 13 5 90 | 2.9 | 339 | 59 | 152 | 75 |
| 1435 | 13 5 90 | 3.1 | 351 | 69 | 399 | 66 |
| 301 | 14 5 90 | 2.8 | 337 | 77 | 406 | 50 |
| 1508 | 14 5 90 | 2.9 | 353 | 8 | 264 | 109 |
| 337 | 15 5 90 | 2.6 | 338 | 85 | 515 | 128 |
| 1544 | 15 5 90 | 2.8 | 358 | 70 | 399 | 75 |
| 419 | 16 5 90 | 2.4 | 339 | 23 | 110 | 90 |
| 1628 | 16 5 90 | 2.7 | 364 | 25 | 129 | 109 |
| 509 | 17 5 90 | 2.2 | 344 | 100 | 568 | 345 |
| 1720 | 17 5 90 | 2.5 | 375 | 11 | 411 | 230 |
| 609 | 18 5 90 | 2.1 | 355 | 76 | 560 | 312 |
| 1823 | 18 5 90 | 2.5 | 388 | 8 | 294 | 137 |
| 719 | 19 5 90 | 2.2 | 362 | 80 | 278 | 155 |
| 1935 | 19 5 90 | 2.7 | 388 | 95 | 347 | 69 |
| 833 | 20 5 90 | 2.4 | 357 | 69 | 540 | 299 |
| 2045 | 20 5 90 | 2.9 | 381 | 106 | 168 | 52 |
| 942 | 21 5 90 | 2.8 | 347 | | | |
| 2153 | 21 5 90 | 3.3 | 371 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1042 | 22 5 90 | 3.1 | 342 | | | |
| 2255 | 22 5 90 | 3.5 | 362 | | | |
| 1137 | 23 5 90 | 3.4 | 339 | | | |
| 2352 | 23 5 90 | 3.7 | 355 | | | |
| 1227 | 24 5 90 | 3.6 | 339 | | | |
| 44 | 25 5 90 | 3.8 | 350 | | | |
| 1314 | 25 5 90 | 3.7 | 342 | 130 | 538 | 301 |
| 134 | 26 5 90 | 3.8 | 347 | | | |
| 1359 | 26 5 90 | 3.8 | 344 | | | |
| 221 | 27 5 90 | 3.6 | 345 | | | |
| 1444 | 27 5 90 | 3.7 | 349 | 4 | 664 | 378 |
| 308 | 28 5 90 | 3.5 | 344 | | | |
| 1527 | 28 5 90 | 3.6 | 356 | | | |
| 357 | 29 5 90 | 3.1 | 342 | | | |

| **Time BST** | **Date** | **Range (m)** | **Period (mins)** | **Zero (ppm)** | **Max (ppm)** | **Mean (ppm)** |
|---|---|---|---|---|---|---|
| 1612 | 29 5 90 | 3.4 | 363 | | | |
| 448 | 30 5 90 | 2.9 | 341 | 203 | 465 | 253 |
| 1702 | 30 5 90 | 3.2 | 368 | | | |
| 542 | 31 5 90 | 2.5 | 341 | | | |
| 1755 | 31 5 90 | 3.1 | 376 | | | |
| 643 | 1 6 90 | 2.4 | 340 | | | |
| 1856 | 1 6 90 | 2.9 | 379 | 284 | 371 | 236 |
| 748 | 2 6 90 | 2.2 | 343 | | | |

## *Appendix 2 Suspended sediment data obtained from monitor 1 (flood)*

Data obtained from lightship 2

| Time BST | Date | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 2013 | 2 11 89 | 3.0 | 392 | 10 | 179 | 73 |
| 830 | 3 11 89 | 2.9 | 398 | 11 | 150 | 74 |
| 2045 | 3 11 89 | 2.8 | 394 | 11 | 92 | 44 |
| 905 | 4 11 89 | 2.7 | 402 | 14 | 123 | 52 |
| 2122 | 4 11 89 | 2.4 | 395 | 12 | 66 | 29 |
| 949 | 5 11 89 | 2.6 | 403 | 12 | 57 | 26 |
| 2210 | 5 11 89 | 2.2 | 395 | 12 | 21 | 7 |
| 1045 | 6 11 89 | 2.4 | 403 | 12 | 43 | 28 |
| 2314 | 6 11 89 | 2.0 | 390 | 12 | 66 | 43 |
| 1202 | 7 11 89 | 2.3 | 397 | 12 | 122 | 50 |
| 37 | 8 11 89 | 2.0 | 380 | 13 | 95 | 40 |
| 1328 | 8 11 89 | 2.5 | 389 | 28 | 241 | 112 |
| 157 | 9 11 89 | 2.2 | 376 | 19 | 78 | 36 |
| 1440 | 9 11 89 | 2.9 | 392 | 17 | 129 | 60 |
| 304 | 10 11 89 | 2.6 | 379 | 19 | 78 | 40 |
| 1542 | 10 11 89 | 3.3 | 396 | 17 | 205 | 112 |
| 400 | 11 11 89 | 2.9 | 388 | 19 | 146 | 85 |
| 1635 | 11 11 89 | 3.6 | 401 | 12 | 339 | 154 |
| 452 | 12 11 89 | 3.3 | 394 | 55 | 236 | 116 |
| 1724 | 12 11 89 | 3.8 | 402 | 21 | 266 | 119 |
| 540 | 13 11 89 | 3.5 | 399 | 27 | 222 | 82 |
| 1812 | 13 11 89 | 3.8 | 401 | 22 | 196 | 83 |
| 627 | 14 11 89 | 3.7 | 400 | 17 | 194 | 75 |
| 1856 | 14 11 89 | 3.8 | 400 | 18 | 187 | 70 |
| 714 | 15 11 89 | 3.9 | 399 | 18 | 178 | 72 |
| 1941 | 15 11 89 | 3.5 | 398 | 22 | 177 | 78 |
| 802 | 16 11 89 | 3.8 | 398 | 13 | 229 | 82 |
| 2024 | 16 11 89 | 3.2 | 397 | 33 | 187 | 95 |
| 2109 | 17 11 89 | 2.8 | 395 | 18 | 145 | 74 |
| 940 | 18 11 89 | 3.3 | 394 | 12 | 311 | 121 |
| 2157 | 18 11 89 | 2.5 | 392 | 12 | 102 | 57 |
| 1034 | 19 11 89 | 3.0 | 393 | 12 | 233 | 101 |
| 2248 | 19 11 89 | 2.2 | 392 | 12 | 81 | 37 |
| 1134 | 20 11 89 | 2.8 | 392 | 12 | 134 | 53 |
| 2347 | 20 11 89 | 2.0 | 392 | 12 | 23 | 6 |
| 1240 | 21 11 89 | 2.6 | 394 | 12 | 51 | 21 |
| 54 | 22 11 89 | 1.9 | 394 | 12 | 23 | 4 |
| 1352 | 22 11 89 | 2.5 | 391 | 12 | 29 | 5 |
| 207 | 23 11 89 | 2.0 | 391 | | | |
| 1457 | 23 11 89 | 2.7 | 390 | 12 | 23 | 4 |
| 313 | 24 11 89 | 2.2 | 387 | | | |
| 1550 | 24 11 89 | 2.8 | 389 | 12 | 46 | 10 |
| 404 | 25 11 89 | 2.5 | 388 | | | |
| 1632 | 25 11 89 | 2.9 | 391 | 12 | 60 | 13 |
| 448 | 26 11 89 | 2.8 | 389 | 12 | 23 | 3 |
| 1710 | 26 11 89 | 3.0 | 391 | 12 | 56 | 11 |
| 526 | 27 11 89 | 2.9 | 391 | 12 | 51 | 9 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1742 | 27 11 89 | 3.1 | 396 | 12 | 60 | 13 |
| 559 | 28 11 89 | 3.0 | 395 | 12 | 56 | 19 |
| 1815 | 28 11 89 | 3.1 | 395 | 12 | 81 | 16 |
| 633 | 29 11 89 | 3.1 | 397 | 12 | 80 | 25 |
| 1847 | 29 11 89 | 3.0 | 397 | 12 | 77 | 23 |

Data obtained from lightship 10

| Time BST | Date | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 1138 | 6 12 89 | 2.8 | 398 | 8 | 32 | 13 |
| 1 | 7 12 89 | 2.3 | 388 | 11 | 1 | 1 |
| 1249 | 7 12 89 | 2.8 | 395 | 11 | 14 | 4 |
| 114 | 8 12 89 | 2.3 | 382 | 11 | 1 | 1 |
| 1400 | 8 12 89 | 2.9 | 394 | 11 | 33 | 9 |
| 224 | 9 12 89 | 2.5 | 383 | 11 | 1 | 1 |
| 1508 | 9 12 89 | 3.0 | 395 | 11 | 26 | 4 |
| 329 | 10 12 89 | 2.8 | 387 | 11 | 1 | 1 |
| 1608 | 10 12 89 | 3.3 | 400 | 11 | 26 | 7 |
| 428 | 11 12 89 | 3.1 | 395 | 11 | 47 | 5 |
| 1704 | 11 12 89 | 3.4 | 400 | 11 | 26 | 6 |
| 524 | 12 12 89 | 3.4 | 398 | 11 | 26 | 9 |
| 1755 | 12 12 89 | 3.4 | 399 | 11 | 81 | 29 |
| 618 | 13 12 89 | 3.6 | 396 | 11 | 61 | 21 |
| 1843 | 13 12 89 | 3.4 | 398 | 11 | 58 | 18 |
| 707 | 14 12 89 | 3.7 | 396 | 11 | 89 | 27 |
| 1927 | 14 12 89 | 3.3 | 397 | 11 | 89 | 35 |
| 755 | 15 12 89 | 3.8 | 395 | 11 | 105 | 46 |
| 2010 | 15 12 89 | 3.2 | 397 | 11 | 94 | 35 |
| 841 | 16 12 89 | 3.7 | 392 | 11 | 155 | 60 |
| 2052 | 16 12 89 | 3.0 | 397 | 11 | 100 | 44 |
| 926 | 17 12 89 | 3.4 | 392 | 24 | 116 | 60 |
| 2134 | 17 12 89 | 2.8 | 396 | 13 | 65 | 28 |
| 1011 | 18 12 89 | 3.3 | 392 | 12 | 118 | 46 |
| 2217 | 18 12 89 | 2.6 | 395 | 12 | 75 | 25 |
| 1057 | 19 12 89 | 3.0 | 393 | 12 | 75 | 27 |
| 2303 | 19 12 89 | 2.4 | 394 | 12 | 25 | 11 |
| 2354 | 20 12 89 | 2.2 | 395 | 19 | 58 | 25 |
| 1243 | 21 12 89 | 2.4 | 394 | 21 | 102 | 44 |
| 56 | 22 12 89 | 2.0 | 393 | 13 | 12 | 4 |
| 1346 | 22 12 89 | 2.3 | 394 | 12 | 83 | 29 |
| 206 | 23 12 89 | 1.9 | 392 | | | |
| 1449 | 23 12 89 | 2.4 | 394 | 12 | 43 | 16 |
| 313 | 24 12 89 | 2.1 | 393 | 12 | 26 | 6 |
| 1547 | 24 12 89 | 2.5 | 392 | 12 | 47 | 19 |
| 412 | 25 12 89 | 2.3 | 391 | 12 | 66 | 26 |
| 1636 | 25 12 89 | 2.6 | 391 | 12 | 37 | 16 |
| 500 | 26 12 89 | 2.5 | 391 | 12 | 47 | 17 |
| 1719 | 26 12 89 | 2.7 | 392 | 12 | 21 | 7 |
| 542 | 27 12 89 | 2.8 | 393 | 12 | 60 | 24 |
| 1757 | 27 12 89 | 2.7 | 393 | 12 | 53 | 21 |
| 620 | 28 12 89 | 3.0 | 394 | 12 | 91 | 32 |
| 1832 | 28 12 89 | 2.8 | 396 | 12 | 85 | 34 |
| 658 | 29 12 89 | 3.1 | 396 | 12 | 123 | 46 |
| 1908 | 29 12 89 | 2.9 | 398 | 12 | 91 | 32 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 736 | 30 12 89 | 3.3 | 397 | 12 | 140 | 48 |
| 1945 | 30 12 89 | 2.9 | 399 | 12 | 85 | 39 |
| 816 | 31 12 89 | 3.3 | 396 | 12 | 109 | 36 |
| 2024 | 31 12 89 | 2.9 | 398 | 12 | 66 | 27 |
| 857 | 1 1 90 | 3.4 | 395 | 12 | 99 | 34 |
| 2105 | 1 1 90 | 3.0 | 395 | 12 | 66 | 18 |
| 939 | 2 1 90 | 3.3 | 396 | 12 | 93 | 33 |
| 2147 | 2 1 90 | 2.9 | 395 | 12 | 47 | 20 |
| 1024 | 3 1 90 | 3.1 | 396 | 12 | 99 | 34 |
| 2234 | 3 1 90 | 2.8 | 393 | 12 | 37 | 14 |
| 1112 | 4 1 90 | 3.0 | 400 | 12 | 109 | 38 |
| 2327 | 4 1 90 | 2.6 | 394 | 12 | 69 | 21 |
| 701 | 12 1 90 | 3.7 | 394 | 19 | 88 | 40 |
| 1915 | 12 1 90 | 3.3 | 398 | 23 | 68 | 35 |
| 745 | 13 1 90 | 3.8 | 392 | 19 | 70 | 39 |
| 1953 | 13 1 90 | 3.3 | 400 | 23 | 32 | 19 |
| 826 | 14 1 90 | 3.7 | 392 | 23 | 84 | 33 |
| 2031 | 14 1 90 | 3.3 | 398 | 23 | 44 | 24 |
| 905 | 15 1 90 | 3.6 | 391 | 23 | 130 | 50 |
| 2109 | 15 1 90 | 3.1 | 397 | 33 | 37 | 19 |
| 943 | 16 1 90 | 3.4 | 389 | 29 | 76 | 34 |
| 2144 | 16 1 90 | 3.0 | 397 | 31 | 24 | 12 |
| 1019 | 17 1 90 | 3.2 | 390 | 24 | 129 | 48 |
| 2219 | 17 1 90 | 2.7 | 397 | 14 | 38 | 18 |
| 1057 | 18 1 90 | 2.8 | 390 | 20 | 29 | 12 |
| 2300 | 18 1 90 | 2.5 | 395 | 12 | 23 | 9 |
| 1141 | 19 1 90 | 2.5 | 388 | 12 | 66 | 28 |
| 2351 | 19 1 90 | 2.1 | 392 | 13 | 22 | 9 |
| 1236 | 20 1 90 | 2.2 | 387 | 12 | 12 | 7 |
| 57 | 21 1 90 | 1.8 | 391 | | | |
| 1345 | 21 1 90 | 1.9 | 388 | 12 | 23 | 9 |
| 216 | 22 1 90 | 1.7 | 396 | 12 | 43 | 14 |
| 1459 | 22 1 90 | 2.0 | 390 | 12 | 15 | 10 |
| 334 | 23 1 90 | 1.9 | 397 | 12 | 37 | 18 |
| 1607 | 23 1 90 | 2.1 | 388 | 26 | 62 | 31 |
| 438 | 24 1 90 | 2.3 | 392 | 13 | 25 | 17 |
| 1659 | 24 1 90 | 2.4 | 389 | 24 | 31 | 11 |
| 527 | 25 1 90 | 2.7 | 391 | 22 | 71 | 28 |
| 1741 | 25 1 90 | 2.6 | 392 | 76 | 222 | 126 |
| 608 | 26 1 90 | 2.9 | 392 | 57 | 55 | 25 |
| 1819 | 26 1 90 | 2.8 | 395 | 44 | 34 | 13 |
| 647 | 27 1 90 | 3.3 | 394 | 36 | 83 | 35 |
| 1856 | 27 1 90 | 3.1 | 399 | 44 | 81 | 40 |
| 725 | 28 1 90 | 3.6 | 395 | 62 | 213 | 93 |
| 1932 | 28 1 90 | 3.2 | 401 | 47 | 72 | 37 |
| 804 | 29 1 90 | 3.7 | 396 | 44 | 134 | 62 |
| 2010 | 29 1 90 | 3.4 | 401 | 53 | 140 | 63 |
| 842 | 30 1 90 | 3.7 | 397 | 39 | 248 | 104 |
| 2048 | 30 1 90 | 3.4 | 399 | 45 | 155 | 78 |
| 920 | 31 1 90 | 3.6 | 398 | 36 | 214 | 84 |
| 2127 | 31 1 90 | 3.3 | 398 | 48 | 122 | 48 |
| 1001 | 1 2 90 | 3.4 | 400 | 46 | 132 | 55 |
| 2210 | 1 2 90 | 3.1 | 398 | 62 | 134 | 52 |
| 1045 | 2 2 90 | 3.2 | 402 | 47 | 138 | 56 |
| 2257 | 2 2 90 | 2.9 | 400 | 46 | 120 | 47 |
| 1140 | 3 2 90 | 2.8 | 402 | 43 | 83 | 39 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2359 | 3 2 90 | 2.5 | 400 | 35 | 48 | 16 |
| 1251 | 4 2 90 | 2.4 | 400 | 42 | 58 | 20 |
| 124 | 5 2 90 | 2.3 | 393 | 35 | 68 | 32 |
| 1420 | 5 2 90 | 2.3 | 391 | 25 | 48 | 22 |

Data obtained from Holbrook Beacon

| Time BST | Date | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 2112 | 14 2 90 | 3.2 | 395 | 10 | 30 | 9 |
| 942 | 15 2 90 | 3.2 | 388 | 18 | 72 | 33 |
| 2143 | 15 2 90 | 3.0 | 395 | 12 | 30 | 12 |
| 1012 | 16 2 90 | 2.9 | 389 | 12 | 30 | 8 |
| 2214 | 16 2 90 | 2.6 | 398 | | | |
| 1048 | 17 2 90 | 2.5 | 388 | | | |
| 2253 | 17 2 90 | 2.3 | 400 | 12 | 10 | 3 |
| 1134 | 18 2 90 | 2.1 | 385 | | | |
| 2348 | 18 2 90 | 1.8 | 398 | | | |
| 1242 | 19 2 90 | 1.7 | 378 | 12 | 13 | 3 |
| 117 | 20 2 90 | 1.5 | 392 | 12 | 10 | 1 |
| 1410 | 20 2 90 | 1.5 | 378 | | | |
| 254 | 21 2 90 | 1.7 | 402 | | | |
| 1536 | 21 2 90 | 1.8 | 382 | 12 | 19 | 6 |
| 410 | 22 2 90 | 2.2 | 395 | | | |
| 1635 | 22 2 90 | 2.2 | 387 | | | |
| 503 | 23 2 90 | 2.7 | 392 | | | |
| 1719 | 23 2 90 | 2.6 | 392 | | | |
| 545 | 24 2 90 | 3.2 | 394 | 12 | 10 | 3 |
| 1758 | 24 2 90 | 3.0 | 395 | 12 | 22 | 8 |
| 626 | 25 2 90 | 3.5 | 395 | 12 | 41 | 16 |
| 1836 | 25 2 90 | 3.3 | 398 | 20 | 33 | 18 |
| 704 | 26 2 90 | 3.9 | 397 | 66 | 230 | 103 |
| 1912 | 26 2 90 | 3.6 | 401 | 75 | 252 | 74 |
| 742 | 27 2 90 | 4.0 | 398 | 87 | 162 | 80 |
| 1949 | 27 2 90 | 3.8 | 402 | 119 | 179 | 99 |
| 820 | 28 2 90 | 4.0 | 399 | 74 | 96 | 44 |
| 2027 | 28 2 90 | 3.7 | 401 | 104 | 176 | 80 |
| 858 | 1 3 90 | 3.8 | 401 | 99 | 92 | 35 |
| 2108 | 1 3 90 | 3.6 | 399 | 54 | 117 | 50 |
| 939 | 2 3 90 | 3.5 | 400 | 45 | 43 | 20 |
| 2150 | 2 3 90 | 3.4 | 399 | 23 | 25 | 13 |
| 1022 | 3 3 90 | 3.0 | 401 | 13 | 27 | 11 |
| 2239 | 3 3 90 | 3.0 | 401 | 12 | 19 | 8 |
| 1116 | 4 3 90 | 2.6 | 401 | 12 | 30 | 11 |
| 2342 | 4 3 90 | 2.5 | 401 | 12 | 10 | 4 |
| 1232 | 5 3 90 | 2.1 | 393 | 12 | 28 | 13 |
| 112 | 6 3 90 | 2.3 | 398 | 12 | 19 | 7 |
| 1407 | 6 3 90 | 2.0 | 387 | 12 | 19 | 10 |
| 252 | 7 3 90 | 2.5 | 398 | 12 | 10 | 4 |
| 1537 | 7 3 90 | 2.1 | 386 | 12 | 19 | 8 |
| 414 | 8 3 90 | 2.9 | 389 | 12 | 19 | 11 |
| 1639 | 8 3 90 | 2.6 | 387 | 12 | 10 | 7 |
| 510 | 9 3 90 | 3.3 | 387 | 18 | 58 | 26 |
| 1724 | 9 3 90 | 2.8 | 390 | 31 | 11 | 7 |
| 552 | 10 3 90 | 3.6 | 390 | 23 | 41 | 16 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1801 | 10 3 90 | 3.1 | 395 | 32 | 24 | 16 |
| 629 | 11 3 90 | 3.7 | 391 | 18 | 70 | 35 |
| 1834 | 11 3 90 | 3.4 | 398 | 36 | 291 | 90 |
| 703 | 12 3 90 | 3.8 | 392 | 33 | 294 | 103 |

| Time BST | Date | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 44 | 3 5 90 | 2.8 | 395 | 3 | 13 | 8 |
| 1308 | 3 5 90 | 2.0 | 390 | 14 | 16 | 3 |
| 203 | 4 5 90 | 2.9 | 394 | 5 | 25 | 10 |
| 1427 | 4 5 90 | 2.1 | 388 | 27 | 291 | 149 |
| 313 | 5 5 90 | 3.0 | 391 | 20 | 82 | 33 |
| 1533 | 5 5 90 | 2.4 | 387 | 27 | 30 | 14 |
| 408 | 6 5 90 | 3.2 | 390 | | | |
| 1622 | 6 5 90 | 2.6 | 390 | | | |
| 452 | 7 5 90 | 3.3 | 391 | | | |
| 1704 | 7 5 90 | 2.9 | 391 | | | |
| 528 | 8 5 90 | 3.3 | 393 | 3 | 665 | 138 |
| 1741 | 8 5 90 | 3.1 | 392 | 54 | 68 | 38 |
| 602 | 9 5 90 | 3.3 | 392 | 75 | 503 | 74 |
| 1816 | 9 5 90 | 3.1 | 393 | | | |
| 633 | 10 5 90 | 3.3 | 394 | 63 | 242 | 94 |
| 1850 | 10 5 90 | 3.2 | 392 | | | |
| 704 | 11 5 90 | 3.2 | 392 | 27 | 625 | 442 |
| 1921 | 11 5 90 | 3.1 | 394 | 3 | 665 | 85 |
| 734 | 12 5 90 | 3.1 | 392 | 69 | 379 | 145 |
| 1953 | 12 5 90 | 3.0 | 394 | 16 | 541 | 171 |
| 806 | 13 5 90 | 3.0 | 389 | 46 | 242 | 77 |
| 2026 | 13 5 90 | 3.0 | 395 | | | |
| 838 | 14 5 90 | 2.8 | 390 | 25 | 643 | 91 |
| 2101 | 14 5 90 | 2.8 | 396 | 71 | 525 | 117 |
| 915 | 15 5 90 | 2.6 | 389 | 28 | 640 | 365 |
| 2142 | 15 5 90 | 2.7 | 397 | | | |
| 958 | 16 5 90 | 2.4 | 390 | 76 | 58 | 56 |
| 2232 | 16 5 90 | 2.6 | 397 | | | |
| 1053 | 17 5 90 | 2.2 | 387 | 33 | 635 | 195 |
| 2335 | 17 5 90 | 2.5 | 394 | 3 | 607 | 205 |
| 1204 | 18 5 90 | 2.0 | 379 | 25 | 643 | 100 |
| 51 | 19 5 90 | 2.6 | 388 | 56 | 50 | 33 |
| 1321 | 19 5 90 | 2.2 | 374 | 80 | 23 | 12 |
| 203 | 20 5 90 | 2.8 | 390 | | | |
| 1430 | 20 5 90 | 2.4 | 375 | 91 | 162 | 64 |
| 306 | 21 5 90 | 3.1 | 396 | 127 | 206 | 102 |
| 1529 | 21 5 90 | 2.8 | 384 | 164 | 326 | 128 |
| 404 | 22 5 90 | 3.5 | 398 | | | |
| 1624 | 22 5 90 | 3.1 | 391 | | | |
| 457 | 23 5 90 | 3.6 | 400 | | | |
| 1716 | 23 5 90 | 3.4 | 396 | 162 | 506 | 312 |
| 547 | 24 5 90 | 3.8 | 400 | | | |
| 1806 | 24 5 90 | 3.7 | 398 | 195 | 473 | 141 |
| 634 | 25 5 90 | 3.7 | 400 | | | |
| 1856 | 25 5 90 | 3.8 | 398 | | | |
| 721 | 26 5 90 | 3.7 | 398 | | | |
| 1943 | 26 5 90 | 3.9 | 398 | | | |
| 806 | 27 5 90 | 3.4 | 398 | 14 | 654 | 98 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2033 | 27 5 90 | 3.9 | 395 | | | |
| 852 | 28 5 90 | 3.2 | 395 | | | |
| 2123 | 28 5 90 | 3.7 | 394 | 77 | 591 | 211 |
| 939 | 29 5 90 | 2.9 | 393 | | | |
| 2215 | 29 5 90 | 3.5 | 393 | | | |
| 1029 | 30 5 90 | 2.7 | 393 | 67 | 588 | 353 |
| 2310 | 30 5 90 | 3.2 | 392 | | | |

| **Time BST** | **Date** | **Range (mins)** | **Period (ppm)** | **Zero (ppm)** | **Max (ppm)** | **Mean** |
|---|---|---|---|---|---|---|
| 1123 | 31 5 90 | 2.4 | 392 | | | |
| 11 | 1 6 90 | 3.1 | 392 | | | |
| 1223 | 1 6 90 | 2.3 | 393 | 203 | 465 | 197 |
| 115 | 2 6 90 | 2.9 | 393 | | | |
| 1331 | 2 6 90 | 2.1 | 391 | | | |

## *Appendix 3 Suspended sediment data obtained from monitor 2 (ebb)*

Data obtained from oil jetty

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1331 | 31 10 89 | 3.3 | 341 | 14 | 187 | 65 |
| 146 | 1 11 89 | 3.2 | 341 | 29 | 67 | 36 |
| 1402 | 1 11 89 | 3.2 | 340 | 26 | 96 | 41 |
| 216 | 2 11 89 | 3.2 | 341 | 32 | 61 | 29 |
| 1434 | 2 11 89 | 3.0 | 339 | 27 | 86 | 38 |
| 245 | 3 11 89 | 3.0 | 345 | 34 | 47 | 31 |
| 1508 | 3 11 89 | 2.8 | 337 | 42 | 39 | 15 |
| 319 | 4 11 89 | 2.8 | 346 | 40 | 51 | 24 |
| 1547 | 4 11 89 | 2.5 | 335 | 43 | 38 | 14 |
| 357 | 5 11 89 | 2.6 | 352 | 34 | 62 | 13 |
| 1632 | 5 11 89 | 2.3 | 338 | 39 | 49 | 8 |
| 445 | 6 11 89 | 2.4 | 360 | 35 | 60 | 17 |
| 1728 | 6 11 89 | 2.1 | 346 | 39 | 72 | 12 |
| 544 | 7 11 89 | 2.3 | 378 | 39 | 172 | 42 |
| 1839 | 7 11 89 | 2.0 | 358 | 52 | 47 | 19 |
| 657 | 8 11 89 | 2.4 | 391 | 55 | 114 | 30 |
| 1957 | 8 11 89 | 2.2 | 360 | 76 | 116 | 46 |
| 813 | 9 11 89 | 2.7 | 387 | 58 | 23 | 14 |
| 2112 | 9 11 89 | 2.6 | 352 | 87 | 174 | 49 |
| 923 | 10 11 89 | 3.1 | 379 | 81 | 99 | 35 |
| 2218 | 10 11 89 | 2.9 | 342 | 95 | 131 | 65 |
| 1028 | 11 11 89 | 3.4 | 367 | 117 | 84 | 41 |
| 2316 | 11 11 89 | 3.3 | 336 | 102 | 142 | 50 |
| 1126 | 12 11 89 | 3.7 | 358 | 108 | 194 | 67 |
| 6 | 13 11 89 | 3.5 | 334 | 98 | 140 | 58 |
| 1219 | 13 11 89 | 3.8 | 353 | 90 | 221 | 82 |
| 53 | 14 11 89 | 3.6 | 334 | 84 | 150 | 54 |
| 1307 | 14 11 89 | 3.9 | 349 | 85 | 149 | 68 |
| 136 | 15 11 89 | 3.7 | 338 | 98 | 179 | 59 |
| 1353 | 15 11 89 | 3.8 | 348 | 120 | 142 | 76 |
| 219 | 16 11 89 | 3.6 | 343 | 131 | 197 | 70 |
| 1440 | 16 11 89 | 3.5 | 344 | 163 | 374 | 161 |
| 301 | 17 11 89 | 3.4 | 348 | 144 | 150 | 52 |
| 1526 | 17 11 89 | 3.1 | 343 | 138 | 166 | 54 |
| 344 | 18 11 89 | 3.2 | 356 | 137 | 128 | 45 |
| 1614 | 18 11 89 | 2.7 | 343 | 147 | 267 | 59 |
| 429 | 19 11 89 | 3.0 | 365 | 154 | 73 | 39 |
| 1707 | 19 11 89 | 2.4 | 341 | 167 | 112 | 31 |
| 1806 | 20 11 89 | 2.2 | 341 | 22 | 71 | 39 |
| 619 | 21 11 89 | 2.5 | 381 | 25 | 106 | 22 |
| 1914 | 21 11 89 | 2.0 | 340 | 25 | 68 | 24 |
| 728 | 22 11 89 | 2.5 | 384 | 21 | 42 | 18 |
| 2023 | 22 11 89 | 2.0 | 344 | 16 | 50 | 25 |
| 838 | 23 11 89 | 2.6 | 379 | 21 | 90 | 31 |
| 2127 | 23 11 89 | 2.2 | 346 | 16 | 28 | 12 |
| 940 | 24 11 89 | 2.7 | 370 | 24 | 35 | 22 |
| 2219 | 24 11 89 | 2.4 | 345 | 24 | 49 | 20 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1032 | 25 11 89 | 2.9 | 360 | 22 | 48 | 21 |
| 2303 | 25 11 89 | 2.7 | 345 | 25 | 106 | 33 |
| 1117 | 26 11 89 | 3.0 | 353 | 25 | 38 | 19 |
| 2341 | 26 11 89 | 2.9 | 345 | 35 | 58 | 20 |
| 1157 | 27 11 89 | 3.0 | 345 | 28 | 56 | 35 |
| 18 | 28 11 89 | 3.0 | 341 | 40 | 50 | 33 |
| 1234 | 28 11 89 | 3.1 | 341 | 49 | 102 | 25 |
| 50 | 29 11 89 | 3.1 | 343 | 51 | 148 | 28 |
| 1310 | 29 11 89 | 3.0 | 337 | 53 | 59 | 28 |
| 124 | 30 11 89 | 3.1 | 344 | 54 | 65 | 34 |

| Time BST | Date (m) | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 2034 | 8 12 89 | 2.4 | 350 | 10 | 49 | 9 |
| 847 | 9 12 89 | 3.0 | 381 | 11 | 82 | 22 |
| 2143 | 9 12 89 | 2.7 | 346 | 11 | 20 | 4 |
| 956 | 10 12 89 | 3.2 | 372 | 11 | 16 | 4 |
| 2248 | 10 12 89 | 3.0 | 340 | 11 | 16 | 4 |
| 1103 | 11 12 89 | 3.4 | 361 | 11 | 29 | 8 |
| 2344 | 11 12 89 | 3.3 | 340 | 11 | 29 | 11 |
| 1202 | 12 12 89 | 3.5 | 353 | 11 | 70 | 18 |
| 34 | 13 12 89 | 3.4 | 344 | 11 | 53 | 18 |
| 1254 | 13 12 89 | 3.6 | 349 | 11 | 53 | 18 |
| 121 | 14 12 89 | 3.5 | 346 | 11 | 60 | 15 |
| 1343 | 14 12 89 | 3.5 | 344 | 11 | 41 | 21 |
| 204 | 15 12 89 | 3.6 | 351 | 11 | 56 | 22 |
| 1430 | 15 12 89 | 3.4 | 340 | 13 | 71 | 41 |
| 247 | 16 12 89 | 3.6 | 354 | 17 | 103 | 43 |
| 1513 | 16 12 89 | 3.2 | 339 | 12 | 82 | 30 |
| 329 | 17 12 89 | 3.4 | 357 | 30 | 106 | 57 |
| 1558 | 17 12 89 | 2.9 | 336 | 42 | 58 | 23 |
| 410 | 18 12 89 | 3.3 | 361 | 21 | 23 | 10 |
| 1643 | 18 12 89 | 2.7 | 334 | 13 | 39 | 22 |
| 452 | 19 12 89 | 3.1 | 365 | 15 | 44 | 18 |
| 1730 | 19 12 89 | 2.4 | 333 | 15 | 56 | 24 |
| 537 | 20 12 89 | 2.8 | 370 | 12 | 79 | 36 |
| 1819 | 20 12 89 | 2.2 | 335 | 27 | 211 | 40 |
| 629 | 21 12 89 | 2.6 | 374 | 43 | 82 | 31 |
| 1917 | 21 12 89 | 1.9 | 339 | 31 | 22 | 10 |
| 729 | 22 12 89 | 2.4 | 377 | 22 | 62 | 14 |
| 2020 | 22 12 89 | 1.9 | 346 | 16 | 11 | 7 |
| 838 | 23 12 89 | 2.3 | 371 | 12 | 28 | 7 |
| 2123 | 23 12 89 | 2.1 | 350 | 12 | 15 | 9 |
| 946 | 24 12 89 | 2.4 | 361 | 31 | 54 | 26 |
| 2219 | 24 12 89 | 2.3 | 353 | 33 | 20 | 2 |
| 1043 | 25 12 89 | 2.5 | 353 | 27 | 26 | 11 |
| 2307 | 25 12 89 | 2.5 | 353 | 17 | 24 | 8 |
| 1131 | 26 12 89 | 2.6 | 348 | 12 | 33 | 18 |
| 2351 | 26 12 89 | 2.8 | 351 | 15 | 38 | 19 |
| 1215 | 27 12 89 | 2.7 | 342 | 22 | 42 | 29 |
| 30 | 28 12 89 | 2.9 | 350 | 26 | 38 | 17 |
| 1254 | 28 12 89 | 2.8 | 338 | 31 | 79 | 35 |
| 108 | 29 12 89 | 3.1 | 350 | 35 | 68 | 26 |
| 1334 | 29 12 89 | 2.9 | 334 | 33 | 95 | 35 |
| 146 | 30 12 89 | 3.2 | 350 | 32 | 186 | 62 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1413 | 30 12 89 | 3.0 | 332 | 32 | 153 | 44 |
| 224 | 31 12 89 | 3.2 | 352 | 27 | 76 | 32 |
| 1452 | 31 12 89 | 3.1 | 332 | 36 | 55 | 25 |
| 302 | 1 1 90 | 3.3 | 355 | 35 | 62 | 25 |
| 1532 | 1 1 90 | 3.1 | 333 | 37 | 66 | 31 |
| 340 | 2 1 90 | 3.3 | 359 | 40 | 59 | 20 |
| 1615 | 2 1 90 | 2.9 | 332 | 37 | 38 | 20 |
| 422 | 3 1 90 | 3.2 | 362 | 40 | 120 | 30 |
| 1700 | 3 1 90 | 2.7 | 334 | 40 | 45 | 25 |
| 507 | 4 1 90 | 3.2 | 365 | 40 | 61 | 21 |
| 1752 | 4 1 90 | 2.5 | 335 | 40 | 89 | 30 |
| 601 | 5 1 90 | 3.0 | 370 | 36 | 125 | 33 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 23 | 11 1 90 | 3.3 | 352 | 13 | 85 | 26 |
| 1249 | 11 1 90 | 3.3 | 344 | 15 | 57 | 22 |
| 110 | 12 1 90 | 3.5 | 351 | 12 | 96 | 31 |
| 1335 | 12 1 90 | 3.4 | 340 | 20 | 49 | 32 |
| 153 | 13 1 90 | 3.7 | 352 | 12 | 57 | 24 |
| 1417 | 13 1 90 | 3.4 | 336 | 12 | 60 | 25 |
| 233 | 14 1 90 | 3.7 | 353 | 12 | 57 | 26 |
| 1458 | 14 1 90 | 3.3 | 333 | 12 | 74 | 27 |
| 309 | 15 1 90 | 3.7 | 356 | 16 | 129 | 34 |
| 1536 | 15 1 90 | 3.1 | 333 | 21 | 58 | 26 |
| 346 | 16 1 90 | 3.5 | 357 | 24 | 34 | 14 |
| 1612 | 16 1 90 | 2.9 | 332 | 24 | 52 | 23 |
| 421 | 17 1 90 | 3.4 | 358 | 24 | 199 | 28 |
| 1649 | 17 1 90 | 2.7 | 330 | 24 | 49 | 20 |
| 456 | 18 1 90 | 3.0 | 361 | 13 | 25 | 11 |
| 1727 | 18 1 90 | 2.4 | 333 | 20 | 55 | 17 |
| 535 | 19 1 90 | 2.8 | 366 | 17 | 33 | 21 |
| 1809 | 19 1 90 | 2.0 | 342 | 19 | 46 | 13 |
| 623 | 20 1 90 | 2.4 | 373 | 12 | 26 | 13 |
| 1903 | 20 1 90 | 1.8 | 354 | 23 | 10 | 2 |
| 728 | 21 1 90 | 2.0 | 377 | 21 | 48 | 16 |
| 2013 | 21 1 90 | 1.7 | 363 | 28 | 34 | 19 |
| 852 | 22 1 90 | 1.9 | 367 | 36 | 86 | 18 |
| 2129 | 22 1 90 | 1.9 | 365 | 37 | 13 | 8 |
| 1011 | 23 1 90 | 2.0 | 356 | 49 | 77 | 22 |
| 2235 | 23 1 90 | 2.2 | 363 | 51 | 11 | 5 |
| 1110 | 24 1 90 | 2.3 | 349 | 58 | 35 | 8 |
| 2328 | 24 1 90 | 2.6 | 359 | 61 | 12 | 4 |
| 1158 | 25 1 90 | 2.6 | 343 | 101 | 197 | 81 |
| 13 | 26 1 90 | 2.8 | 355 | 96 | 55 | 12 |
| 1240 | 26 1 90 | 2.8 | 339 | 83 | 68 | 25 |
| 54 | 27 1 90 | 3.1 | 353 | 86 | 157 | 40 |
| 1321 | 27 1 90 | 3.1 | 335 | 93 | 64 | 37 |
| 135 | 28 1 90 | 3.5 | 350 | 117 | 99 | 50 |
| 1400 | 28 1 90 | 3.3 | 332 | 108 | 141 | 41 |
| 213 | 29 1 90 | 3.6 | 351 | 111 | 108 | 44 |
| 1440 | 29 1 90 | 3.4 | 330 | 137 | 103 | 56 |
| 251 | 30 1 90 | 3.7 | 351 | 137 | 86 | 37 |
| 1519 | 30 1 90 | 3.4 | 329 | 150 | 144 | 56 |
| 327 | 31 1 90 | 3.7 | 353 | 147 | 113 | 30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1558 | 31 1 90 | 3.2 | 329 | 152 | 133 | 43 |
| 405 | 1 2 90 | 3.6 | 356 | 178 | 90 | 30 |
| 1641 | 1 2 90 | 3.0 | 329 | 203 | 95 | 52 |
| 448 | 2 2 90 | 3.4 | 357 | 213 | 78 | 29 |
| 1727 | 2 2 90 | 2.8 | 330 | 226 | 72 | 35 |
| 537 | 3 2 90 | 3.1 | 363 | 244 | 39 | 20 |
| 1822 | 3 2 90 | 2.4 | 337 | | | |
| 639 | 4 2 90 | 2.7 | 372 | | | |
| 1931 | 4 2 90 | 2.2 | 353 | | | |
| 757 | 5 2 90 | 2.4 | 383 | | | |
| 2051 | 5 2 90 | 2.2 | 363 | | | |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 316 | 14 2 90 | 3.7 | 353 | 49 | 87 | 36 |
| 1539 | 14 2 90 | 3.1 | 333 | 34 | 93 | 27 |
| 347 | 15 2 90 | 3.4 | 355 | 25 | 81 | 42 |
| 1610 | 15 2 90 | 2.9 | 333 | 31 | 67 | 29 |
| 418 | 16 2 90 | 3.1 | 354 | 29 | 55 | 26 |
| 1641 | 16 2 90 | 2.6 | 333 | 17 | 98 | 29 |
| 452 | 17 2 90 | 2.7 | 356 | 12 | 85 | 27 |
| 1716 | 17 2 90 | 2.3 | 337 | 12 | 62 | 27 |
| 533 | 18 2 90 | 2.3 | 361 | 12 | 17 | 1 |
| 1759 | 18 2 90 | 1.9 | 349 | 12 | 179 | 21 |
| 626 | 19 2 90 | 1.8 | 376 | | | |
| 1900 | 19 2 90 | 1.6 | 377 | 34 | 99 | 34 |
| 749 | 20 2 90 | 1.5 | 381 | 18 | 29 | 10 |
| 2028 | 20 2 90 | 1.6 | 386 | 12 | 17 | 1 |
| 936 | 21 2 90 | 1.7 | 360 | 23 | 64 | 21 |
| 2158 | 21 2 90 | 2.0 | 372 | 17 | 42 | 11 |
| 1045 | 22 2 90 | 2.2 | 350 | 23 | 20 | 9 |
| 2302 | 22 2 90 | 2.5 | 361 | 28 | 19 | 7 |
| 1135 | 23 2 90 | 2.5 | 344 | 28 | 35 | 17 |
| 2351 | 23 2 90 | 3.0 | 354 | 41 | 26 | 9 |
| 1219 | 24 2 90 | 3.0 | 339 | 42 | 28 | 17 |
| 33 | 25 2 90 | 3.4 | 353 | 39 | 58 | 25 |
| 1301 | 25 2 90 | 3.3 | 335 | 51 | 56 | 29 |
| 114 | 26 2 90 | 3.7 | 350 | 62 | 81 | 36 |
| 1341 | 26 2 90 | 3.6 | 331 | 77 | 83 | 48 |
| 153 | 27 2 90 | 4.0 | 349 | 73 | 36 | 19 |
| 1420 | 27 2 90 | 3.7 | 329 | 99 | 93 | 52 |
| 231 | 28 2 90 | 4.1 | 349 | 78 | 77 | 31 |
| 1459 | 28 2 90 | 3.6 | 328 | 97 | 160 | 56 |
| 308 | 1 3 90 | 4.0 | 350 | 87 | 68 | 32 |
| 1539 | 1 3 90 | 3.5 | 329 | 75 | 99 | 30 |
| 347 | 2 3 90 | 3.8 | 352 | 87 | 112 | 48 |
| 1619 | 2 3 90 | 3.2 | 331 | 73 | 118 | 42 |
| 429 | 3 3 90 | 3.4 | 353 | 76 | 81 | 34 |
| 1703 | 3 3 90 | 2.8 | 336 | 77 | 75 | 30 |
| 520 | 4 3 90 | 3.0 | 356 | 76 | 63 | 24 |
| 1757 | 4 3 90 | 2.4 | 345 | 80 | 50 | 25 |
| 623 | 5 3 90 | 2.4 | 369 | 87 | 20 | 13 |
| 1905 | 5 3 90 | 2.2 | 367 | 90 | 17 | 11 |
| 750 | 6 3 90 | 2.1 | 377 | 103 | 33 | 13 |
| 2034 | 6 3 90 | 2.3 | 378 | 106 | 11 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 930 | 7 3 90 | 2.2 | 367 | 117 | 52 | 16 |
| 2203 | 7 3 90 | 2.6 | 371 | 127 | 42 | 10 |
| 1043 | 8 3 90 | 2.6 | 356 | 130 | 27 | 7 |
| 2306 | 8 3 90 | 3.1 | 364 | 130 | 25 | 10 |
| 1137 | 9 3 90 | 2.9 | 347 | 132 | 21 | 11 |
| 2354 | 9 3 90 | 3.4 | 358 | 131 | 29 | 12 |
| 1222 | 10 3 90 | 3.1 | 339 | 133 | 49 | 23 |
| 36 | 11 3 90 | 3.6 | 353 | 133 | 34 | 11 |
| 1300 | 11 3 90 | 3.4 | 334 | 133 | 108 | 35 |
| 112 | 12 3 90 | 3.8 | 351 | 143 | 47 | 22 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1823 | 2 5 90 | 2.7 | 381 | 0 | 53 | 27 |
| 719 | 3 5 90 | 2.2 | 349 | 0 | 159 | 51 |
| 1938 | 3 5 90 | 2.7 | 385 | 0 | 48 | 25 |
| 837 | 4 5 90 | 2.2 | 350 | 15 | 139 | 29 |
| 2055 | 4 5 90 | 2.8 | 378 | 6 | 84 | 28 |
| 944 | 5 5 90 | 2.5 | 349 | 8 | 62 | 24 |
| 2200 | 5 5 90 | 3.0 | 368 | 3 | 32 | 21 |
| 1038 | 6 5 90 | 2.7 | 344 | 8 | 34 | 18 |
| 2252 | 6 5 90 | 3.1 | 360 | 0 | 48 | 15 |
| 1123 | 7 5 90 | 3.0 | 341 | 0 | 80 | 52 |
| 2335 | 7 5 90 | 3.2 | 353 | 0 | 60 | 29 |
| 1201 | 8 5 90 | 3.1 | 340 | 20 | 40 | 18 |
| 13 | 9 5 90 | 3.2 | 349 | 7 | 141 | 36 |
| 1234 | 9 5 90 | 3.2 | 342 | 0 | 109 | 44 |
| 49 | 10 5 90 | 3.2 | 344 | 15 | 27 | 13 |
| 1307 | 10 5 90 | 3.3 | 343 | 19 | 114 | 51 |
| 122 | 11 5 90 | 3.1 | 342 | 22 | 149 | 41 |
| 1336 | 11 5 90 | 3.2 | 345 | 29 | 52 | 22 |
| 155 | 12 5 90 | 3.1 | 339 | 23 | 67 | 28 |
| 1406 | 12 5 90 | 3.1 | 347 | 35 | 55 | 37 |
| 227 | 13 5 90 | 2.9 | 339 | 24 | 202 | 37 |
| 1435 | 13 5 90 | 3.1 | 351 | 23 | 53 | 25 |
| 301 | 14 5 90 | 2.8 | 337 | 29 | 61 | 32 |
| 1508 | 14 5 90 | 2.9 | 353 | 23 | 52 | 32 |
| 337 | 15 5 90 | 2.6 | 338 | 23 | 69 | 16 |
| 1544 | 15 5 90 | 2.8 | 358 | 23 | 25 | 8 |
| 419 | 16 5 90 | 2.4 | 339 | 23 | 40 | 12 |
| 1628 | 16 5 90 | 2.7 | 364 | 23 | 25 | 6 |
| 509 | 17 5 90 | 2.2 | 344 | 23 | 6 | 1 |
| 1720 | 17 5 90 | 2.5 | 375 | 23 | 85 | 12 |
| 609 | 18 5 90 | 2.1 | 355 | 23 | 42 | 14 |
| 1823 | 18 5 90 | 2.5 | 388 | 27 | 33 | 13 |
| 719 | 19 5 90 | 2.2 | 362 | 38 | 83 | 16 |
| 1935 | 19 5 90 | 2.7 | 388 | 28 | 128 | 20 |
| 833 | 20 5 90 | 2.4 | 357 | 23 | 61 | 17 |
| 2045 | 20 5 90 | 2.9 | 381 | 23 | 19 | 9 |
| 942 | 21 5 90 | 2.8 | 347 | 23 | 19 | 14 |
| 2153 | 21 5 90 | 3.3 | 371 | 39 | 26 | 6 |
| 1042 | 22 5 90 | 3.1 | 342 | 41 | 40 | 25 |
| 2255 | 22 5 90 | 3.5 | 362 | 41 | 35 | 24 |
| 1137 | 23 5 90 | 3.4 | 339 | 53 | 42 | 18 |
| 2352 | 23 5 90 | 3.7 | 355 | 47 | 29 | 14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1227 | 24 5 90 | 3.6 | 339 | 58 | 51 | 18 |
| 44 | 25 5 90 | 3.8 | 350 | 74 | 35 | 15 |
| 1314 | 25 5 90 | 3.7 | 342 | 75 | 115 | 25 |
| 134 | 26 5 90 | 3.8 | 347 | 89 | 41 | 14 |
| 1359 | 26 5 90 | 3.8 | 344 | 103 | 104 | 22 |
| 221 | 27 5 90 | 3.6 | 345 | 116 | 38 | 11 |
| 1444 | 27 5 90 | 3.7 | 349 | 128 | 47 | 15 |
| 308 | 28 5 90 | 3.5 | 344 | 143 | 11 | 3 |
| 1527 | 28 5 90 | 3.6 | 356 | 134 | 66 | 29 |
| 357 | 29 5 90 | 3.1 | 342 | 138 | 16 | 17 |
| 1612 | 29 5 90 | 3.4 | 363 | 132 | 22 | 23 |
| 448 | 30 5 90 | 2.9 | 341 | 140 | 17 | 11 |
| 1702 | 30 5 90 | 3.2 | 368 | 144 | 37 | 20 |

| **Time BST** | **Date** | **Range (m)** | **Period (mins)** | **Zero (ppm)** | **Max (ppm)** | **Mean (ppm)** |
|---|---|---|---|---|---|---|
| 542 | 31 5 90 | 2.5 | 341 | 155 | 23 | 22 |
| 1755 | 31 5 90 | 3.1 | 376 | 163 | 28 | 12 |
| 643 | 1 6 90 | 2.4 | 340 | 54 | 127 | 109 |
| 1856 | 1 6 90 | 2.9 | 379 | 126 | 39 | 18 |
| 748 | 2 6 90 | 2.2 | 343 | 138 | 19 | 18 |
| 2002 | 2 6 90 | 2.7 | 381 | 128 | 47 | 14 |
| 854 | 3 6 90 | 2.3 | 347 | 137 | 17 | 13 |
| 2109 | 3 6 90 | 2.7 | 374 | 133 | 21 | 16 |

# *Appendix 4 Suspended sediment data obtained from monitor 2 (flood)*

Data obtained from oil jetty

| Time BST | Date (m) | Range (mins) | Period (ppm) | Zero (ppm) | Max (ppm) | Mean |
|---|---|---|---|---|---|---|
| 1912 | 31 10 89 | 3.3 | 394 | 25 | 110 | 58 |
| 727 | 1 11 89 | 3.2 | 395 | 36 | 172 | 46 |
| 1942 | 1 11 89 | 3.2 | 394 | 35 | 86 | 42 |
| 757 | 2 11 89 | 3.1 | 397 | 37 | 104 | 47 |
| 2013 | 2 11 89 | 3.0 | 392 | 23 | 103 | 50 |
| 830 | 3 11 89 | 2.9 | 398 | 48 | 113 | 39 |
| 2045 | 3 11 89 | 2.8 | 394 | 40 | 75 | 17 |
| 905 | 4 11 89 | 2.7 | 402 | 50 | 62 | 18 |
| 2122 | 4 11 89 | 2.4 | 395 | 41 | 44 | 10 |
| 949 | 5 11 89 | 2.6 | 403 | 38 | 77 | 25 |
| 2210 | 5 11 89 | 2.2 | 395 | 27 | 33 | 17 |
| 1045 | 6 11 89 | 2.4 | 403 | 38 | 50 | 20 |
| 2314 | 6 11 89 | 2.0 | 390 | 39 | 60 | 20 |
| 1202 | 7 11 89 | 2.3 | 397 | 45 | 150 | 50 |
| 37 | 8 11 89 | 2.0 | 380 | 54 | 52 | 20 |
| 1328 | 8 11 89 | 2.5 | 389 | 80 | 117 | 63 |
| 157 | 9 11 89 | 2.2 | 376 | 62 | 34 | 14 |
| 1440 | 9 11 89 | 2.9 | 392 | 56 | 112 | 40 |
| 304 | 10 11 89 | 2.6 | 379 | 83 | 39 | 12 |
| 1542 | 10 11 89 | 3.3 | 396 | 81 | 158 | 74 |
| 400 | 11 11 89 | 2.9 | 388 | 97 | 123 | 56 |
| 1635 | 11 11 89 | 3.6 | 401 | 121 | 340 | 127 |
| 452 | 12 11 89 | 3.3 | 394 | 119 | 237 | 107 |
| 1724 | 12 11 89 | 3.8 | 402 | 120 | 208 | 104 |
| 540 | 13 11 89 | 3.5 | 399 | 86 | 223 | 84 |
| 1812 | 13 11 89 | 3.8 | 401 | 92 | 300 | 90 |
| 627 | 14 11 89 | 3.7 | 400 | 93 | 100 | 52 |
| 1856 | 14 11 89 | 3.8 | 400 | 110 | 84 | 42 |
| 714 | 15 11 89 | 3.9 | 399 | 117 | 123 | 72 |
| 1941 | 15 11 89 | 3.5 | 398 | 131 | 197 | 117 |
| 802 | 16 11 89 | 3.8 | 398 | 140 | 235 | 139 |
| 2024 | 16 11 89 | 3.2 | 397 | 151 | 175 | 77 |
| 849 | 17 11 89 | 3.5 | 397 | 150 | 257 | 120 |
| 2109 | 17 11 89 | 2.8 | 395 | 140 | 199 | 100 |
| 940 | 18 11 89 | 3.3 | 394 | 136 | 371 | 174 |
| 2157 | 18 11 89 | 2.5 | 392 | 148 | 187 | 85 |
| 1034 | 19 11 89 | 3.0 | 393 | 175 | 285 | 119 |
| 2248 | 19 11 89 | 2.2 | 392 | 175 | 92 | 55 |
| 2347 | 20 11 89 | 2.0 | 392 | 24 | 39 | 23 |
| 1240 | 21 11 89 | 2.6 | 394 | 25 | 52 | 28 |
| 54 | 22 11 89 | 1.9 | 394 | 25 | 48 | 20 |
| 1352 | 22 11 89 | 2.5 | 391 | 24 | 60 | 30 |
| 207 | 23 11 89 | 2.0 | 391 | 13 | 39 | 25 |
| 1457 | 23 11 89 | 2.7 | 390 | 24 | 46 | 26 |
| 313 | 24 11 89 | 2.2 | 387 | 22 | 41 | 22 |
| 1550 | 24 11 89 | 2.8 | 389 | 20 | 63 | 28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 404 | 25 11 89 | 2.5 | 388 | 16 | 47 | 30 |
| 1632 | 25 11 89 | 2.9 | 391 | 24 | 35 | 17 |
| 448 | 26 11 89 | 2.8 | 389 | 25 | 38 | 22 |
| 1710 | 26 11 89 | 3.0 | 391 | 25 | 55 | 27 |
| 526 | 27 11 89 | 2.9 | 391 | 33 | 30 | 20 |
| 1742 | 27 11 89 | 3.1 | 396 | 40 | 44 | 22 |
| 559 | 28 11 89 | 3.0 | 395 | 44 | 43 | 24 |
| 1815 | 28 11 89 | 3.1 | 395 | 51 | 60 | 26 |
| 633 | 29 11 89 | 3.1 | 397 | 55 | 104 | 35 |
| 1847 | 29 11 89 | 3.0 | 397 | 59 | 74 | 24 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1400 | 8 12 89 | 2.9 | 394 | 8 | 32 | 11 |
| 224 | 9 12 89 | 2.5 | 383 | 11 | 91 | 17 |
| 1508 | 9 12 89 | 3.0 | 395 | 11 | 29 | 11 |
| 329 | 10 12 89 | 2.8 | 387 | 11 | 11 | 2 |
| 1608 | 10 12 89 | 3.3 | 400 | 11 | 44 | 14 |
| 428 | 11 12 89 | 3.1 | 395 | 11 | 20 | 2 |
| 1704 | 11 12 89 | 3.4 | 400 | 11 | 28 | 5 |
| 524 | 12 12 89 | 3.4 | 398 | 11 | 37 | 10 |
| 1755 | 12 12 89 | 3.4 | 399 | 11 | 60 | 22 |
| 618 | 13 12 89 | 3.6 | 396 | 11 | 63 | 28 |
| 1843 | 13 12 89 | 3.4 | 398 | 11 | 53 | 20 |
| 707 | 14 12 89 | 3.7 | 396 | 11 | 64 | 22 |
| 1927 | 14 12 89 | 3.3 | 397 | 11 | 48 | 24 |
| 755 | 15 12 89 | 3.8 | 395 | 16 | 142 | 49 |
| 2010 | 15 12 89 | 3.2 | 397 | 12 | 156 | 61 |
| 841 | 16 12 89 | 3.7 | 392 | 13 | 129 | 66 |
| 2052 | 16 12 89 | 3.0 | 397 | 12 | 88 | 38 |
| 926 | 17 12 89 | 3.4 | 392 | 48 | 64 | 33 |
| 2134 | 17 12 89 | 2.8 | 396 | 40 | 35 | 11 |
| 1011 | 18 12 89 | 3.3 | 392 | 15 | 133 | 59 |
| 2217 | 18 12 89 | 2.6 | 395 | 22 | 69 | 28 |
| 1057 | 19 12 89 | 3.0 | 393 | 23 | 68 | 33 |
| 2303 | 19 12 89 | 2.4 | 394 | 13 | 58 | 26 |
| 2354 | 20 12 89 | 2.2 | 395 | 36 | 83 | 26 |
| 1243 | 21 12 89 | 2.4 | 394 | 41 | 66 | 25 |
| 56 | 22 12 89 | 2.0 | 393 | 28 | 36 | 15 |
| 1346 | 22 12 89 | 2.3 | 394 | 25 | 100 | 39 |
| 206 | 23 12 89 | 1.9 | 392 | 13 | 70 | 13 |
| 1449 | 23 12 89 | 2.4 | 394 | 12 | 69 | 28 |
| 313 | 24 12 89 | 2.1 | 393 | 12 | 44 | 22 |
| 1547 | 24 12 89 | 2.5 | 392 | 45 | 26 | 16 |
| 412 | 25 12 89 | 2.3 | 391 | 29 | 55 | 22 |
| 1636 | 25 12 89 | 2.6 | 391 | 27 | 44 | 21 |
| 500 | 26 12 89 | 2.5 | 391 | 13 | 64 | 33 |
| 1719 | 26 12 89 | 2.7 | 392 | 22 | 49 | 20 |
| 542 | 27 12 89 | 2.8 | 393 | 13 | 72 | 42 |
| 1757 | 27 12 89 | 2.7 | 393 | 25 | 56 | 30 |
| 620 | 28 12 89 | 3.0 | 394 | 26 | 131 | 56 |
| 1832 | 28 12 89 | 2.8 | 396 | 37 | 63 | 24 |
| 658 | 29 12 89 | 3.1 | 396 | 47 | 75 | 40 |
| 1908 | 29 12 89 | 2.9 | 398 | 29 | 85 | 47 |
| 736 | 30 12 89 | 3.3 | 397 | 42 | 107 | 51 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1945 | 30 12 89 | 2.9 | 399 | 28 | 86 | 40 |
| 816 | 31 12 89 | 3.3 | 396 | 27 | 76 | 41 |
| 2024 | 31 12 89 | 2.9 | 398 | 39 | 46 | 26 |
| 857 | 1 1 90 | 3.4 | 395 | 29 | 65 | 38 |
| 2105 | 1 1 90 | 3.0 | 395 | 39 | 49 | 27 |
| 939 | 2 1 90 | 3.3 | 396 | 31 | 63 | 33 |
| 2147 | 2 1 90 | 2.9 | 395 | 39 | 49 | 25 |
| 1024 | 3 1 90 | 3.1 | 396 | 40 | 63 | 34 |
| 2234 | 3 1 90 | 2.8 | 393 | 40 | 45 | 26 |
| 1112 | 4 1 90 | 3.0 | 400 | 40 | 173 | 69 |
| 2327 | 4 1 90 | 2.6 | 394 | 40 | 96 | 56 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1748 | 10 1 90 | 3.0 | 395 | 16 | 79 | 28 |
| 615 | 11 1 90 | 3.5 | 394 | 21 | 62 | 22 |
| 1833 | 11 1 90 | 3.2 | 397 | 13 | 59 | 16 |
| 701 | 12 1 90 | 3.7 | 394 | 12 | 110 | 35 |
| 1915 | 12 1 90 | 3.3 | 398 | 14 | 47 | 23 |
| 745 | 13 1 90 | 3.8 | 392 | 12 | 57 | 29 |
| 1953 | 13 1 90 | 3.3 | 400 | 12 | 50 | 19 |
| 826 | 14 1 90 | 3.7 | 392 | 12 | 60 | 37 |
| 2031 | 14 1 90 | 3.3 | 398 | 12 | 38 | 20 |
| 905 | 15 1 90 | 3.6 | 391 | 13 | 90 | 46 |
| 2109 | 15 1 90 | 3.1 | 397 | 23 | 91 | 23 |
| 943 | 16 1 90 | 3.4 | 389 | 24 | 45 | 21 |
| 2144 | 16 1 90 | 3.0 | 397 | 24 | 34 | 12 |
| 1019 | 17 1 90 | 3.2 | 390 | 24 | 41 | 22 |
| 2219 | 17 1 90 | 2.7 | 397 | 16 | 42 | 15 |
| 1057 | 18 1 90 | 2.8 | 390 | 12 | 42 | 21 |
| 2300 | 18 1 90 | 2.5 | 395 | 14 | 28 | 11 |
| 1141 | 19 1 90 | 2.5 | 388 | 22 | 141 | 35 |
| 2351 | 19 1 90 | 2.1 | 392 | 14 | 27 | 11 |
| 1236 | 20 1 90 | 2.2 | 387 | 20 | 34 | 13 |
| 57 | 21 1 90 | 1.8 | 391 | 15 | 46 | 15 |
| 1345 | 21 1 90 | 1.9 | 388 | 23 | 35 | 16 |
| 216 | 22 1 90 | 1.7 | 396 | 34 | 62 | 14 |
| 1459 | 22 1 90 | 2.0 | 390 | 37 | 25 | 13 |
| 334 | 23 1 90 | 1.9 | 397 | 37 | 133 | 30 |
| 1607 | 23 1 90 | 2.1 | 388 | 53 | 43 | 20 |
| 438 | 24 1 90 | 2.3 | 392 | 50 | 36 | 15 |
| 1659 | 24 1 90 | 2.4 | 389 | 60 | 39 | 9 |
| 527 | 25 1 90 | 2.7 | 391 | 61 | 58 | 22 |
| 1741 | 25 1 90 | 2.6 | 392 | 102 | 196 | 84 |
| 608 | 26 1 90 | 2.9 | 392 | 84 | 67 | 30 |
| 1819 | 26 1 90 | 2.8 | 395 | 83 | 79 | 25 |
| 647 | 27 1 90 | 3.3 | 394 | 84 | 99 | 38 |
| 1856 | 27 1 90 | 3.1 | 399 | 99 | 124 | 51 |
| 725 | 28 1 90 | 3.6 | 395 | 120 | 124 | 55 |
| 1932 | 28 1 90 | 3.2 | 401 | 108 | 96 | 53 |
| 804 | 29 1 90 | 3.7 | 396 | 115 | 164 | 65 |
| 2010 | 29 1 90 | 3.4 | 401 | 133 | 81 | 35 |
| 842 | 30 1 90 | 3.7 | 397 | 136 | 162 | 82 |
| 2048 | 30 1 90 | 3.4 | 399 | 152 | 135 | 80 |
| 920 | 31 1 90 | 3.6 | 398 | 142 | 156 | 82 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2127 | 31 1 90 | 3.3 | 398 | 187 | 111 | 60 |
| 1001 | 1 2 90 | 3.4 | 400 | 178 | 120 | 70 |
| 2210 | 1 2 90 | 3.1 | 398 | | | |
| 1045 | 2 2 90 | 3.2 | 402 | | | |
| 2257 | 2 2 90 | 2.9 | 400 | | | |
| 1140 | 3 2 90 | 2.8 | 402 | | | |
| 2359 | 3 2 90 | 2.5 | 400 | | | |
| 1251 | 4 2 90 | 2.4 | 400 | | | |
| 124 | 5 2 90 | 2.3 | 393 | | | |
| 1420 | 5 2 90 | 2.3 | 391 | | | |
| 254 | 6 2 90 | 2.3 | 396 | | | |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 2040 | 13 2 90 | 3.4 | 396 | 37 | 116 | 56 |
| 909 | 14 2 90 | 3.5 | 390 | 45 | 78 | 31 |
| 2112 | 14 2 90 | 3.2 | 395 | 19 | 112 | 63 |
| 942 | 15 2 90 | 3.2 | 388 | 37 | 91 | 57 |
| 2143 | 15 2 90 | 3.0 | 395 | 29 | 59 | 31 |
| 1012 | 16 2 90 | 2.9 | 389 | 29 | 78 | 39 |
| 2214 | 16 2 90 | 2.6 | 398 | 13 | 71 | 42 |
| 1048 | 17 2 90 | 2.5 | 388 | 12 | 69 | 31 |
| 2253 | 17 2 90 | 2.3 | 400 | 12 | 51 | 30 |
| 1134 | 18 2 90 | 2.1 | 385 | 12 | 35 | 18 |
| 2348 | 18 2 90 | 1.8 | 398 | 12 | 17 | 6 |
| 1242 | 19 2 90 | 1.7 | 378 | 17 | 100 | 34 |
| 117 | 20 2 90 | 1.5 | 392 | 30 | 33 | 14 |
| 1410 | 20 2 90 | 1.5 | 378 | 14 | 56 | 27 |
| 254 | 21 2 90 | 1.7 | 402 | 12 | 39 | 21 |
| 1536 | 21 2 90 | 1.8 | 382 | 27 | 43 | 17 |
| 410 | 22 2 90 | 2.2 | 395 | 13 | 34 | 19 |
| 1635 | 22 2 90 | 2.2 | 387 | 27 | 47 | 22 |
| 503 | 23 2 90 | 2.7 | 392 | 28 | 35 | 21 |
| 1719 | 23 2 90 | 2.6 | 392 | 38 | 29 | 13 |
| 545 | 24 2 90 | 3.2 | 394 | 42 | 32 | 16 |
| 1758 | 24 2 90 | 3.0 | 395 | 47 | 49 | 14 |
| 626 | 25 2 90 | 3.5 | 395 | 41 | 66 | 35 |
| 1836 | 25 2 90 | 3.3 | 398 | 54 | 93 | 23 |
| 704 | 26 2 90 | 3.9 | 397 | 76 | 74 | 41 |
| 1912 | 26 2 90 | 3.6 | 401 | 74 | 38 | 19 |
| 742 | 27 2 90 | 4.0 | 398 | 83 | 84 | 52 |
| 1949 | 27 2 90 | 3.8 | 402 | 101 | 74 | 27 |
| 820 | 28 2 90 | 4.0 | 399 | 78 | 86 | 45 |
| 2027 | 28 2 90 | 3.7 | 401 | 106 | 74 | 37 |
| 858 | 1 3 90 | 3.8 | 401 | 81 | 105 | 53 |
| 2108 | 1 3 90 | 3.6 | 399 | 77 | 98 | 44 |
| 939 | 2 3 90 | 3.5 | 400 | 87 | 59 | 34 |
| 2150 | 2 3 90 | 3.4 | 399 | 72 | 99 | 47 |
| 1022 | 3 3 90 | 3.0 | 401 | 77 | 66 | 35 |
| 2239 | 3 3 90 | 3.0 | 401 | 74 | 86 | 40 |
| 1116 | 4 3 90 | 2.6 | 401 | 84 | 80 | 34 |
| 2342 | 4 3 90 | 2.5 | 401 | 85 | 35 | 18 |
| 1232 | 5 3 90 | 2.1 | 393 | 94 | 31 | 15 |
| 112 | 6 3 90 | 2.3 | 398 | 95 | 36 | 16 |
| 1407 | 6 3 90 | 2.0 | 387 | 105 | 41 | 14 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 252 | 7 3 90 | 2.5 | 398 | 106 | 42 | 16 |
| 1537 | 7 3 90 | 2.1 | 386 | 129 | 35 | 15 |
| 414 | 8 3 90 | 2.9 | 389 | 129 | 26 | 16 |
| 1639 | 8 3 90 | 2.6 | 387 | 130 | 39 | 22 |
| 510 | 9 3 90 | 3.3 | 387 | 136 | 82 | 28 |
| 1724 | 9 3 90 | 2.8 | 390 | 131 | 42 | 14 |
| 552 | 10 3 90 | 3.6 | 390 | 131 | 87 | 29 |
| 1801 | 10 3 90 | 3.1 | 395 | 137 | 38 | 15 |
| 629 | 11 3 90 | 3.7 | 391 | 137 | 61 | 33 |
| 1834 | 11 3 90 | 3.4 | 398 | 137 | 57 | 32 |
| 703 | 12 3 90 | 3.8 | 392 | 149 | 55 | 34 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 44 | 3 5 90 | 2.8 | 395 | 0 | 100 | 40 |
| 1308 | 3 5 90 | 2.0 | 390 | 0 | 105 | 47 |
| 203 | 4 5 90 | 2.9 | 394 | 0 | 121 | 46 |
| 1427 | 4 5 90 | 2.1 | 388 | 20 | 116 | 25 |
| 313 | 5 5 90 | 3.0 | 391 | 2 | 144 | 34 |
| 1533 | 5 5 90 | 2.4 | 387 | 10 | 84 | 26 |
| 408 | 6 5 90 | 3.2 | 390 | 1 | 84 | 29 |
| 1622 | 6 5 90 | 2.6 | 390 | 2 | 96 | 24 |
| 452 | 7 5 90 | 3.3 | 391 | 0 | 81 | 27 |
| 1704 | 7 5 90 | 2.9 | 391 | 0 | 70 | 30 |
| 528 | 8 5 90 | 3.3 | 393 | 15 | 141 | 33 |
| 1741 | 8 5 90 | 3.1 | 392 | 22 | 84 | 17 |
| 602 | 9 5 90 | 3.3 | 392 | 2 | 63 | 32 |
| 1816 | 9 5 90 | 3.1 | 393 | 0 | 70 | 32 |
| 633 | 10 5 90 | 3.3 | 394 | 12 | 64 | 39 |
| 1850 | 10 5 90 | 3.2 | 392 | 21 | 44 | 20 |
| 704 | 11 5 90 | 3.2 | 392 | 22 | 54 | 23 |
| 1921 | 11 5 90 | 3.1 | 394 | 25 | 45 | 20 |
| 734 | 12 5 90 | 3.1 | 392 | 23 | 53 | 30 |
| 1953 | 12 5 90 | 3.0 | 394 | 27 | 86 | 34 |
| 806 | 13 5 90 | 3.0 | 389 | 23 | 86 | 53 |
| 2026 | 13 5 90 | 3.0 | 395 | 23 | 77 | 39 |
| 838 | 14 5 90 | 2.8 | 390 | 25 | 88 | 38 |
| 2101 | 14 5 90 | 2.8 | 396 | 23 | 72 | 32 |
| 915 | 15 5 90 | 2.6 | 389 | 23 | 53 | 18 |
| 2142 | 15 5 90 | 2.7 | 397 | 23 | 47 | 14 |
| 958 | 16 5 90 | 2.4 | 390 | 23 | 47 | 19 |
| 2232 | 16 5 90 | 2.6 | 397 | 23 | 37 | 14 |
| 1053 | 17 5 90 | 2.2 | 387 | 23 | 37 | 17 |
| 2335 | 17 5 90 | 2.5 | 394 | 23 | 47 | 22 |
| 1204 | 18 5 90 | 2.0 | 379 | 35 | 41 | 24 |
| 51 | 19 5 90 | 2.6 | 388 | 30 | 51 | 28 |
| 1321 | 19 5 90 | 2.2 | 374 | 40 | 30 | 10 |
| 203 | 20 5 90 | 2.8 | 390 | 24 | 36 | 14 |
| 1430 | 20 5 90 | 2.4 | 375 | 23 | 42 | 18 |
| 306 | 21 5 90 | 3.1 | 396 | 23 | 42 | 17 |
| 1529 | 21 5 90 | 2.8 | 384 | 35 | 82 | 34 |
| 404 | 22 5 90 | 3.5 | 398 | 41 | 64 | 26 |
| 1624 | 22 5 90 | 3.1 | 391 | 41 | 54 | 32 |
| 457 | 23 5 90 | 3.6 | 400 | 41 | 76 | 31 |
| 1716 | 23 5 90 | 3.4 | 396 | 57 | 19 | 15 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 547 | 24 5 90 | 3.8 | 400 | 55 | 54 | 17 |
| 1806 | 24 5 90 | 3.7 | 398 | 70 | 35 | 16 |
| 634 | 25 5 90 | 3.7 | 400 | 75 | 43 | 23 |
| 1856 | 25 5 90 | 3.8 | 398 | 85 | 72 | 39 |
| 721 | 26 5 90 | 3.7 | 398 | 99 | 55 | 32 |
| 1943 | 26 5 90 | 3.9 | 398 | 113 | 41 | 29 |
| 806 | 27 5 90 | 3.4 | 398 | 125 | 46 | 27 |
| 2033 | 27 5 90 | 3.9 | 395 | 145 | 20 | 14 |
| 852 | 28 5 90 | 3.2 | 395 | 142 | 26 | 13 |
| 2123 | 28 5 90 | 3.7 | 394 | 131 | 40 | 13 |
| 939 | 29 5 90 | 2.9 | 393 | | | |
| 2215 | 29 5 90 | 3.5 | 393 | 138 | 30 | 13 |
| 1029 | 30 5 90 | 2.7 | 393 | 149 | 16 | 10 |
| 2310 | 30 5 90 | 3.2 | 392 | 158 | 30 | 18 |

| Time BST | Date | Range (m) | Period (mins) | Zero (ppm) | Max (ppm) | Mean (ppm) |
|---|---|---|---|---|---|---|
| 1123 | 31 5 90 | 2.4 | 392 | 161 | 24 | 13 |
| 11 | 1 6 90 | 3.1 | 392 | 164 | 24 | 12 |
| 1223 | 1 6 90 | 2.3 | 393 | 120 | 55 | 42 |
| 115 | 2 6 90 | 2.9 | 393 | 132 | 25 | 11 |
| 1331 | 2 6 90 | 2.1 | 391 | 148 | 23 | 11 |
| 223 | 3 6 90 | 2.8 | 391 | 129 | 25 | 13 |
| 1441 | 3 6 90 | 2.2 | 388 | 140 | 25 | 11 |

## Appendix 5 Half tide wind speed and direction (ebb and flood)

| | | Ebb | | | Flood | | |
|---|---|---|---|---|---|---|---|
| Time BST | Date | Mean (kts) | Dirn | Gust (kts) | Mean (kts) | Dirn | Gust (kts) |
| 1331 | 31 10 89 | 19 | 181 | 25 | 11 | 192 | 19 |
| 146 | 1 11 89 | 9 | 197 | 16 | 7 | 216 | 15 |
| 1402 | 1 11 89 | 8 | 248 | 16 | 10 | 245 | 18 |
| 216 | 2 11 89 | 14 | 244 | 22 | 21 | 257 | 30 |
| 1434 | 2 11 89 | 17 | 244 | 28 | 14 | 219 | 22 |
| 245 | 3 11 89 | 15 | 214 | 23 | 14 | 211 | 23 |
| 1508 | 3 11 89 | 11 | 204 | 19 | 10 | 194 | 18 |
| 319 | 4 11 89 | 18 | 226 | 26 | 19 | 214 | 28 |
| 1547 | 4 11 89 | 13 | 184 | 23 | 10 | 194 | 17 |
| 357 | 5 11 89 | 10 | 179 | 17 | 9 | 160 | 16 |
| 1632 | 5 11 89 | 9 | 120 | 17 | 12 | 131 | 20 |
| 445 | 6 11 89 | 13 | 128 | 20 | 9 | 134 | 16 |
| 1728 | 6 11 89 | 5 | 147 | 12 | 4 | 183 | 11 |
| 544 | 7 11 89 | 8 | 229 | 16 | 14 | 245 | 22 |
| 1839 | 7 11 89 | 15 | 248 | 23 | 8 | 210 | 16 |
| 657 | 8 11 89 | 15 | 286 | 25 | 33 | 230 | 48 |
| 1957 | 8 11 89 | 28 | 185 | 40 | 20 | 183 | 29 |
| 813 | 9 11 89 | 15 | 199 | 23 | 16 | 236 | 25 |
| 2112 | 9 11 89 | 22 | 245 | 32 | 14 | 226 | 22 |
| 923 | 10 11 89 | 13 | 236 | 21 | 19 | 242 | 28 |
| 2218 | 10 11 89 | 23 | 241 | 32 | 17 | 248 | 25 |
| 1028 | 11 11 89 | 13 | 260 | 21 | 11 | 278 | 19 |
| 2316 | 11 11 89 | 8 | 270 | 16 | 9 | 280 | 17 |
| 1126 | 12 11 89 | 8 | 327 | 16 | 6 | 186 | 13 |
| 6 | 13 11 89 | 8 | 110 | 15 | 6 | 104 | 14 |
| 1219 | 13 11 89 | 4 | 90 | 11 | 5 | 107 | 13 |
| 53 | 14 11 89 | 7 | 133 | 14 | 6 | 162 | 14 |
| 1307 | 14 11 89 | 5 | 143 | 13 | 6 | 73 | 15 |
| 136 | 15 11 89 | 8 | 66 | 16 | 11 | 51 | 20 |
| 1353 | 15 11 89 | 16 | 66 | 24 | 20 | 258 | 28 |
| 219 | 16 11 89 | 21 | 332 | 28 | 21 | 328 | 29 |
| 1440 | 16 11 89 | 25 | 340 | 33 | 24 | 327 | 32 |
| 301 | 17 11 89 | 21 | 316 | 29 | 18 | 304 | 26 |
| 1526 | 17 11 89 | 16 | 305 | 23 | 16 | 300 | 24 |
| 344 | 18 11 89 | 14 | 301 | 22 | 13 | 311 | 20 |
| 1614 | 18 11 89 | 12 | 327 | 20 | 11 | 325 | 18 |
| 429 | 19 11 89 | 11 | 306 | 18 | 7 | 310 | 15 |
| 1707 | 19 11 89 | 7 | 322 | 14 | 10 | 285 | 17 |
| 1806 | 20 11 89 | 8 | 339 | 16 | 7 | 147 | 14 |
| 619 | 21 11 89 | 6 | 66 | 13 | 7 | 64 | 15 |
| 1914 | 21 11 89 | 12 | 71 | 22 | 14 | 67 | 26 |
| 728 | 22 11 89 | 12 | 74 | 23 | 12 | 76 | 24 |
| 2023 | 22 11 89 | 12 | 95 | 20 | 11 | 99 | 19 |
| 838 | 23 11 89 | 13 | 119 | 21 | 11 | 135 | 18 |
| 2127 | 23 11 89 | 11 | 147 | 18 | 12 | 131 | 19 |
| 940 | 24 11 89 | 12 | 118 | 19 | 10 | 82 | 19 |
| 2219 | 24 11 89 | 18 | 255 | 27 | 17 | 337 | 25 |
| 1032 | 25 11 89 | 12 | 293 | 20 | 8 | 190 | 16 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2303 | 25 11 89 | 12 | 169 | 19 | 13 | 153 | 20 |
| 1117 | 26 11 89 | 12 | 147 | 19 | 10 | 145 | 16 |
| 2341 | 26 11 89 | 11 | 123 | 18 | 10 | 117 | 17 |

| Time BST | Date | Mean (kts) | Dirn | Gust (kts) | Mean (kts) | Dirn | Gust (kts) |
|---|---|---|---|---|---|---|---|
| 1157 | 27 11 89 | 7 | 133 | 14 | 7 | 121 | 14 |
| 18 | 28 11 89 | 8 | 128 | 15 | 9 | 106 | 16 |
| 1234 | 28 11 89 | 9 | 83 | 17 | 14 | 305 | 21 |
| 50 | 29 11 89 | 13 | 337 | 20 | 15 | 135 | 23 |
| 1310 | 29 11 89 | 15 | 12 | 22 | 14 | 14 | 22 |
| 124 | 30 11 89 | 8 | 52 | 17 | 8 | 96 | 16 |
| | | | | | 9 | 68 | 18 |
| 2034 | 8 12 89 | 8 | 81 | 16 | 9 | 98 | 17 |
| 847 | 9 12 89 | 10 | 93 | 18 | 8 | 78 | 16 |
| 2143 | 9 12 89 | 8 | 95 | 15 | 9 | 110 | 16 |
| 956 | 10 12 89 | 9 | 118 | 16 | 7 | 139 | 15 |
| 2248 | 10 12 89 | 7 | 131 | 14 | 6 | 129 | 14 |
| 1103 | 11 12 89 | 4 | 158 | 11 | 7 | 253 | 13 |
| 2344 | 11 12 89 | 18 | 277 | 27 | 15 | 267 | 24 |
| 1202 | 12 12 89 | 15 | 196 | 24 | 10 | 149 | 18 |
| 34 | 13 12 89 | 6 | 127 | 13 | 12 | 228 | 20 |
| 1254 | 13 12 89 | 12 | 250 | 21 | 8 | 187 | 16 |
| 121 | 14 12 89 | 9 | 241 | 17 | 13 | 259 | 22 |
| 1343 | 14 12 89 | 24 | 220 | 36 | 24 | 218 | 34 |
| 204 | 15 12 89 | 22 | 176 | 34 | 8 | 93 | 16 |
| 1430 | 15 12 89 | 13 | 203 | 21 | 17 | 337 | 25 |
| 247 | 16 12 89 | 15 | 328 | 23 | 18 | 280 | 27 |
| 1513 | 16 12 89 | 23 | 249 | 34 | 25 | 252 | 34 |
| 329 | 17 12 89 | 32 | 248 | 43 | 31 | 233 | 44 |
| 1558 | 17 12 89 | 26 | 213 | 37 | 20 | 213 | 29 |
| 410 | 18 12 89 | 10 | 231 | 19 | 11 | 292 | 19 |
| 1643 | 18 12 89 | 14 | 263 | 21 | 19 | 217 | 29 |
| 452 | 19 12 89 | 18 | 153 | 27 | 10 | 138 | 17 |
| 1730 | 19 12 89 | 8 | 241 | 16 | 21 | 292 | 31 |
| 537 | 20 12 89 | 14 | 258 | 23 | 19 | 225 | 28 |
| 1819 | 20 12 89 | 22 | 232 | 34 | 25 | 220 | 37 |
| 629 | 21 12 89 | 29 | 222 | 41 | 28 | 220 | 39 |
| 1917 | 21 12 89 | 16 | 223 | 25 | 9 | 230 | 17 |
| 729 | 22 12 89 | 10 | 187 | 18 | 18 | 152 | 27 |
| 2020 | 22 12 89 | 15 | 181 | 23 | 14 | 206 | 22 |
| 838 | 23 12 89 | 20 | 232 | 30 | 20 | 185 | 33 |
| 2123 | 23 12 89 | 13 | 220 | 22 | 19 | 219 | 29 |
| 946 | 24 12 89 | 25 | 240 | 36 | 28 | 257 | 39 |
| 2219 | 24 12 89 | 23 | 243 | 34 | 21 | 243 | 30 |
| 1043 | 25 12 89 | 19 | 247 | 26 | 18 | 250 | 20 |
| 2307 | 25 12 89 | 18 | 250 | 20 | 18 | 250 | 20 |
| 1131 | 26 12 89 | 18 | 250 | 20 | 18 | 250 | 20 |
| 2351 | 26 12 89 | 18 | 250 | 20 | 18 | 250 | 20 |
| 1215 | 27 12 89 | 15 | 149 | 21 | 10 | 57 | 20 |
| 30 | 28 12 89 | 11 | 52 | 22 | 11 | 51 | 21 |
| 1254 | 28 12 89 | 11 | 42 | 21 | 14 | 21 | 22 |
| 108 | 29 12 89 | 12 | 124 | 21 | 11 | 144 | 19 |
| 1334 | 29 12 89 | 10 | 250 | 18 | 12 | 299 | 19 |
| 146 | 30 12 89 | 9 | 27 | 18 | 8 | 55 | 17 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1413 | 30 12 89 | 8 | 61 | 15 | 7 | 74 | 16 |
| 224 | 31 12 89 | 7 | 63 | 15 | 8 | 139 | 16 |
| 1452 | 31 12 89 | 7 | 178 | 15 | 5 | 179 | 12 |
| 302 | 1 1 90 | 7 | 269 | 15 | 13 | 297 | 20 |
| 1532 | 1 1 90 | 14 | 299 | 22 | 12 | 284 | 19 |

| Time BST | Date | Mean (kts) | Dirn | Gust (kts) | Mean (kts) | Dirn | Gust (kts) |
|---|---|---|---|---|---|---|---|
| 340 | 2 1 90 | 7 | 189 | 15 | 6 | 249 | 14 |
| 1615 | 2 1 90 | 13 | 268 | 20 | 14 | 281 | 22 |
| 422 | 3 1 90 | 13 | 293 | 20 | 14 | 303 | 21 |
| 1700 | 3 1 90 | 12 | 299 | 20 | 9 | 265 | 17 |
| 507 | 4 1 90 | 8 | 192 | 16 | 9 | 204 | 16 |
| 1752 | 4 1 90 | 9 | 224 | 16 | 7 | 201 | 14 |
| 601 | 5 1 90 | 5 | 206 | 13 | | | |
| | | | | | 17 | 226 | 25 |
| 23 | 11 1 90 | 15 | 228 | 22 | 15 | 223 | 22 |
| 1249 | 11 1 90 | 15 | 221 | 23 | 15 | 238 | 23 |
| 110 | 12 1 90 | 15 | 238 | 23 | 18 | 241 | 27 |
| 1335 | 12 1 90 | 20 | 231 | 30 | 14 | 214 | 22 |
| 153 | 13 1 90 | 9 | 129 | 17 | 9 | 144 | 16 |
| 1417 | 13 1 90 | 7 | 192 | 14 | 7 | 216 | 15 |
| 233 | 14 1 90 | 8 | 228 | 15 | 13 | 244 | 21 |
| 1458 | 14 1 90 | 14 | 231 | 21 | 13 | 217 | 20 |
| 309 | 15 1 90 | 18 | 215 | 25 | 17 | 195 | 26 |
| 1536 | 15 1 90 | 16 | 199 | 23 | 18 | 190 | 27 |
| 346 | 16 1 90 | 15 | 209 | 25 | 18 | 221 | 26 |
| 1612 | 16 1 90 | 19 | 216 | 29 | 21 | 218 | 31 |
| 421 | 17 1 90 | 19 | 196 | 28 | 22 | 179 | 34 |
| 1649 | 17 1 90 | 17 | 170 | 27 | 12 | 186 | 20 |
| 456 | 18 1 90 | 13 | 182 | 20 | 13 | 174 | 21 |
| 1727 | 18 1 90 | 11 | 196 | 18 | 13 | 216 | 21 |
| 535 | 19 1 90 | 21 | 226 | 30 | 23 | 221 | 32 |
| 1809 | 19 1 90 | 17 | 202 | 25 | 13 | 198 | 20 |
| 623 | 20 1 90 | 14 | 202 | 21 | 13 | 211 | 21 |
| 1903 | 20 1 90 | 14 | 221 | 21 | 15 | 225 | 22 |
| 728 | 21 1 90 | 15 | 227 | 23 | 17 | 236 | 24 |
| 2013 | 21 1 90 | 21 | 242 | 30 | 21 | 241 | 30 |
| 852 | 22 1 90 | 17 | 217 | 25 | 13 | 227 | 21 |
| 2129 | 22 1 90 | 18 | 250 | 27 | 27 | 240 | 39 |
| 1011 | 23 1 90 | 28 | 213 | 40 | 17 | 201 | 25 |
| 2235 | 23 1 90 | 15 | 188 | 24 | 20 | 197 | 32 |
| 1110 | 24 1 90 | 24 | 174 | 35 | 19 | 205 | 28 |
| 2328 | 24 1 90 | 17 | 232 | 26 | 23 | 249 | 34 |
| 1158 | 25 1 90 | 40 | 219 | 60 | 37 | 187 | 53 |
| 13 | 26 1 90 | 25 | 192 | 34 | 23 | 194 | 33 |
| 1240 | 26 1 90 | 21 | 195 | 31 | 17 | 208 | 26 |
| 54 | 27 1 90 | 14 | 205 | 23 | 13 | 220 | 21 |
| 1321 | 27 1 90 | 16 | 260 | 24 | 23 | 279 | 33 |
| 135 | 28 1 90 | 29 | 257 | 42 | 28 | 193 | 41 |
| 1400 | 28 1 90 | 20 | 188 | 33 | 14 | 206 | 23 |
| 213 | 29 1 90 | 14 | 227 | 22 | 20 | 252 | 29 |
| 1440 | 29 1 90 | 24 | 257 | 35 | 26 | 257 | 37 |
| 251 | 30 1 90 | 22 | 246 | 33 | 23 | 224 | 35 |
| 1519 | 30 1 90 | 22 | 233 | 34 | 29 | 247 | 42 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 327 | 31 1 90 | 19 | 232 | 30 | 20 | 248 | 30 |
| 1558 | 31 1 90 | 19 | 232 | 30 | 22 | 235 | 32 |
| 405 | 1 2 90 | 20 | 232 | 28 | 19 | 240 | 29 |
| 1641 | 1 2 90 | 26 | 261 | 38 | 29 | 241 | 43 |
| 448 | 2 2 90 | 19 | 210 | 29 | 21 | 217 | 32 |
| 1727 | 2 2 90 | 23 | 221 | 35 | 18 | 226 | 26 |
| 537 | 3 2 90 | 17 | 268 | 26 | 22 | 213 | 34 |
| 1822 | 3 2 90 | 17 | 173 | 26 | 15 | 221 | 22 |

| Time BST | Date | Mean (kts) | Dirn | Gust (kts) | Mean (kts) | Dirn | Gust (kts) |
|---|---|---|---|---|---|---|---|
| 639 | 4 2 90 | 22 | 232 | 31 | 24 | 232 | 34 |
| 1931 | 4 2 90 | 21 | 233 | 30 | 20 | 237 | 29 |
| 757 | 5 2 90 | 16 | 254 | 24 | 16 | 266 | 24 |
| 2051 | 5 2 90 | 15 | 262 | 23 | 22 | 217 | 32 |
| | | | | | 26 | 174 | 40 |
| 316 | 14 2 90 | 26 | 164 | 40 | 16 | 170 | 26 |
| 1539 | 14 2 90 | 10 | 184 | 17 | 5 | 230 | 13 |
| 347 | 15 2 90 | 13 | 148 | 23 | 29 | 145 | 43 |
| 1610 | 15 2 90 | 19 | 148 | 30 | 11 | 170 | 19 |
| 418 | 16 2 90 | 10 | 153 | 17 | 9 | 151 | 16 |
| 1641 | 16 2 90 | 6 | 207 | 14 | 12 | 259 | 20 |
| 452 | 17 2 90 | 14 | 259 | 21 | 18 | 239 | 26 |
| 1716 | 17 2 90 | 20 | 227 | 28 | 10 | 199 | 18 |
| 533 | 18 2 90 | 9 | 223 | 17 | 13 | 236 | 20 |
| 1759 | 18 2 90 | 12 | 237 | 19 | 12 | 251 | 20 |
| 626 | 19 2 90 | 18 | 262 | 27 | 24 | 234 | 35 |
| 1900 | 19 2 90 | 25 | 229 | 35 | 21 | 230 | 30 |
| 749 | 20 2 90 | 20 | 234 | 28 | 15 | 240 | 25 |
| 2028 | 20 2 90 | 14 | 248 | 22 | 16 | 234 | 23 |
| 936 | 21 2 90 | 24 | 203 | 37 | 17 | 197 | 27 |
| 2158 | 21 2 90 | 12 | 233 | 20 | 12 | 243 | 20 |
| 1045 | 22 2 90 | 11 | 253 | 19 | 10 | 281 | 18 |
| 2302 | 22 2 90 | 10 | 257 | 17 | 9 | 236 | 16 |
| 1135 | 23 2 90 | 10 | 253 | 17 | 9 | 268 | 17 |
| 2351 | 23 2 90 | 13 | 255 | 21 | 17 | 232 | 24 |
| 1219 | 24 2 90 | 19 | 233 | 28 | 23 | 210 | 33 |
| 33 | 25 2 90 | 13 | 207 | 21 | 17 | 235 | 25 |
| 1301 | 25 2 90 | 26 | 233 | 37 | 23 | 207 | 34 |
| 114 | 26 2 90 | 29 | 222 | 40 | 37 | 187 | 57 |
| 1341 | 26 2 90 | 34 | 166 | 57 | 24 | 183 | 37 |
| 153 | 27 2 90 | 23 | 177 | 37 | 28 | 164 | 43 |
| 1420 | 27 2 90 | 35 | 165 | 52 | 29 | 166 | 43 |
| 231 | 28 2 90 | 22 | 178 | 32 | 16 | 213 | 25 |
| 1459 | 28 2 90 | 27 | 196 | 42 | 32 | 157 | 48 |
| 308 | 1 3 90 | 22 | 172 | 32 | 24 | 172 | 36 |
| 1539 | 1 3 90 | 20 | 156 | 32 | 18 | 109 | 28 |
| 347 | 2 3 90 | 23 | 118 | 33 | 20 | 132 | 29 |
| 1619 | 2 3 90 | 15 | 146 | 25 | 13 | 149 | 21 |
| 429 | 3 3 90 | 13 | 148 | 20 | 14 | 159 | 22 |
| 1703 | 3 3 90 | 15 | 178 | 25 | 15 | 198 | 24 |
| 520 | 4 3 90 | 18 | 202 | 26 | 16 | 187 | 24 |
| 1757 | 4 3 90 | 12 | 197 | 19 | 14 | 208 | 21 |
| 623 | 5 3 90 | 21 | 200 | 29 | 23 | 195 | 34 |
| 1905 | 5 3 90 | 19 | 186 | 29 | 19 | 184 | 29 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 750 | 6 3 90 | 20 | 181 | 30 | 17 | 172 | 28 |
| 2034 | 6 3 90 | 14 | 178 | 23 | 15 | 199 | 23 |
| 930 | 7 3 90 | 18 | 205 | 27 | 16 | 209 | 24 |
| 2203 | 7 3 90 | 10 | 204 | 17 | 10 | 208 | 17 |
| 1043 | 8 3 90 | 13 | 224 | 20 | 12 | 232 | 19 |
| 2306 | 8 3 90 | 18 | 198 | 27 | 27 | 161 | 43 |
| 1137 | 9 3 90 | 24 | 152 | 36 | 14 | 185 | 22 |
| 2354 | 9 3 90 | 12 | 222 | 19 | 18 | 193 | 28 |
| 1222 | 10 3 90 | 21 | 177 | 33 | 18 | 187 | 28 |
| 36 | 11 3 90 | 16 | 206 | 25 | 19 | 204 | 28 |
| 1300 | 11 3 90 | 18 | 186 | 27 | 13 | 175 | 21 |
| 112 | 12 3 90 | 12 | 150 | 19 | 13 | 161 | 21 |

| Time BST | Date | Mean (kts) | Dirn | Gust (kts) | Mean (kts) | Dirn | Gust (kts) |
|---|---|---|---|---|---|---|---|
| 1823 | 2 5 90 | 16 | 33 | 24 | 10 | 18 | 19 |
| 719 | 3 5 90 | 10 | 24 | 17 | 14 | 33 | 21 |
| 1938 | 3 5 90 | 13 | 47 | 20 | 11 | 43 | 18 |
| 837 | 4 5 90 | 11 | 27 | 18 | 12 | 30 | 19 |
| 2055 | 4 5 90 | 9 | 61 | 17 | 6 | 98 | 13 |
| 944 | 5 5 90 | 7 | 170 | 15 | 8 | 13 | 15 |
| 2200 | 5 5 90 | 5 | 110 | 13 | 6 | 104 | 13 |
| 1038 | 6 5 90 | 8 | 213 | 15 | 13 | 120 | 19 |
| 2252 | 6 5 90 | 8 | 116 | 15 | 11 | 129 | 20 |
| 1123 | 7 5 90 | 9 | 151 | 18 | 9 | 217 | 17 |
| 2335 | 7 5 90 | 10 | 271 | 17 | 10 | 272 | 17 |
| 1201 | 8 5 90 | 10 | 295 | 17 | 9 | 280 | 16 |
| 13 | 9 5 90 | 7 | 144 | 15 | 8 | 156 | 16 |
| 1234 | 9 5 90 | 10 | 210 | 18 | 10 | 206 | 18 |
| 49 | 10 5 90 | 7 | 190 | 14 | 6 | 236 | 13 |
| 1307 | 10 5 90 | 9 | 225 | 16 | 7 | 177 | 16 |
| 122 | 11 5 90 | 11 | 160 | 19 | 14 | 157 | 22 |
| 1336 | 11 5 90 | 16 | 154 | 25 | 17 | 143 | 25 |
| 155 | 12 5 90 | 18 | 139 | 26 | 14 | 116 | 22 |
| 1406 | 12 5 90 | 12 | 95 | 21 | 11 | 106 | 19 |
| 227 | 13 5 90 | 14 | 112 | 21 | 15 | 112 | 23 |
| 1435 | 13 5 90 | 13 | 108 | 21 | 8 | 118 | 16 |
| 301 | 14 5 90 | 7 | 128 | 14 | 7 | 229 | 14 |
| 1508 | 14 5 90 | 9 | 283 | 16 | 10 | 308 | 17 |
| 337 | 15 5 90 | 10 | 280 | 17 | 10 | 256 | 17 |
| 1544 | 15 5 90 | 16 | 251 | 24 | 15 | 238 | 23 |
| 419 | 16 5 90 | 16 | 216 | 24 | 13 | 220 | 21 |
| 1628 | 16 5 90 | 12 | 236 | 20 | 11 | 177 | 18 |
| 509 | 17 5 90 | 10 | 131 | 17 | 9 | 160 | 17 |
| 1720 | 17 5 90 | 14 | 32 | 22 | 8 | 65 | 16 |
| 609 | 18 5 90 | 9 | 60 | 17 | 15 | 22 | 23 |
| 1823 | 18 5 90 | 15 | 36 | 23 | 10 | 53 | 19 |
| 719 | 19 5 90 | 15 | 35 | 23 | 15 | 23 | 22 |
| 1935 | 19 5 90 | 11 | 62 | 19 | 11 | 76 | 19 |
| 833 | 20 5 90 | 15 | 35 | 23 | 17 | 39 | 25 |
| 2045 | 20 5 90 | 12 | 86 | 21 | 13 | 72 | 22 |
| 942 | 21 5 90 | 22 | 36 | 30 | 20 | 39 | 28 |
| 2153 | 21 5 90 | 12 | 56 | 22 | 13 | 43 | 22 |
| 1042 | 22 5 90 | 14 | 22 | 21 | 16 | 17 | 23 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2255 | 22 5 90 | 9 | 43 | 17 | 6 | 147 | 13 |
| 1137 | 23 5 90 | 10 | 267 | 17 | 5 | 280 | 13 |
| 2352 | 23 5 90 | 9 | 136 | 17 | 12 | 107 | 21 |
| 1227 | 24 5 90 | 18 | 46 | 26 | 12 | 79 | 20 |
| 44 | 25 5 90 | 10 | 95 | 17 | 10 | 77 | 19 |
| 1314 | 25 5 90 | 18 | 25 | 26 | 13 | 48 | 21 |
| 134 | 26 5 90 | 8 | 79 | 15 | 11 | 113 | 18 |
| 1359 | 26 5 90 | 12 | 295 | 19 | 12 | 97 | 19 |
| 221 | 27 5 90 | 8 | 229 | 16 | 6 | 226 | 13 |
| 1444 | 27 5 90 | 8 | 252 | 16 | 8 | 108 | 16 |
| **Time BST** | **Date** | **Mean (kts)** | **Dirn** | **Gust (kts)** | **Mean (kts)** | **Dirn** | **Gust (kts)** |
| 308 | 28 5 90 | 8 | 76 | 16 | 9 | 265 | 16 |
| 1527 | 28 5 90 | 11 | 305 | 18 | 14 | 276 | 21 |
| 357 | 29 5 90 | 15 | 260 | 22 | 16 | 274 | 22 |
| 1612 | 29 5 90 | 14 | 282 | 21 | 11 | 255 | 18 |
| 448 | 30 5 90 | 5 | 193 | 12 | 10 | 265 | 17 |
| 1702 | 30 5 90 | 8 | 248 | 15 | 5 | 200 | 13 |
| 542 | 31 5 90 | 4 | 231 | 11 | 7 | 283 | 15 |
| 1755 | 31 5 90 | 9 | 305 | 16 | 9 | 278 | 16 |
| 643 | 1 6 90 | 9 | 310 | 17 | 11 | 284 | 19 |
| 1856 | 1 6 90 | 14 | 207 | 23 | 16 | 162 | 25 |
| 748 | 2 6 90 | 16 | 164 | 26 | 19 | 178 | 29 |
| 2002 | 2 6 90 | 16 | 178 | 25 | 14 | 194 | 21 |
| 854 | 3 6 90 | 12 | 212 | 19 | 13 | 199 | 21 |
| 2109 | 3 6 90 | 15 | 167 | 23 | 16 | 171 | 24 |

# Appendix 6

## Siltation at a Point Model (SAP)

The siltation at a point model (SAP) is a zero-dimensional mathematical model which predicts the changes at a point on a cohesive sediment bed, over a period of many tides. The processes of erosion, deposition and consolidation are modelled. The model requires field and experimentally determined cohesive sediment parameters as well as knowledge of the bed shear stresses, which may be derived from either field measurement, a physical model or a numerical model.

The cohesive sediment bed in the SAP model is represented by ten discrete layers which are each assumed to be homogeneous, with a certain density and thickness. Sediment is subtracted or added to the uppermost layer, according to the processes of erosion and deposition respectively. In addition, the layers are consolidated under their self-weight and the excess pore pressures within the bed are dissipated. At each time step the density and the thickness of each layer is calculated.

The erosion of a cohesive sediment bed may be assumed to occur when the applied bed shear stress $\tau$, exceeds the erosion strength $\tau_e$. The rate of erosion of sediment from the bed dm/dt, may be expressed as

$$dm/dt = m_e (\tau - \tau_e) \qquad \tau > \tau_e \qquad (1)$$

The erosion shear strength, $\tau_e$, and the erosion constant, $m_e$, may be found experimentally. The erosion shear strength $\tau_e$, increases with dry density and may be related to the dry density $\rho_d$, in the form

$$\tau_e = A \rho_d^B \qquad (2)$$

where A and B are experimentally determined constants for a particular cohesive sediment.

The deposition of suspended cohesive sediment to the bed is assumed only to occur when the applied shear stress $\tau$, is less than a critical shear stress $\tau_d$. The rate of deposition may be expressed as the multiple of the near-bed concentration of suspended sediment c, the median floc settling velocity $w_{50}$ and a probability function, such that

$$dm/dt = c\, w_{50} (\tau_d - \tau) / \tau_d \quad , \tau < \tau_d \qquad (3)$$

This gives a zero rate of deposition when $\tau = \tau_d$ and a maximum for a particular concentration of suspended sediment when $\tau = 0$. The median floc settling velocity must be determined in the field and can usually be expressed as a function of the suspended sediment concentration, where

$$w_{50} = D\, c^E \qquad (4)$$

where D and E are constants for a particular field location.

The consolidation of the cohesive sediment bed is modelled on the basis of three principal assumptions. The first is the assumption that the bed can be represented as discrete layers each having a particular density and thickness.

The second is that there exists an engineering relationship between the effective stress $\sigma_v'$ and the dry density $\rho_d$ of the cohesive sediment of the form

$$\sigma_v' = F + G\rho_d + H\rho_d^2 \qquad (5)$$

where F, G and H are constants. In addition, it is necessary to know the dry density $\rho_{d0}$, of the sediment immediately on deposition to the bed. This by definition is the density at which the effective stress is zero. The third assumption is that there also exists an engineering relationship between the permeability of the cohesive sediment k, and its dry density $\rho_d$, of the form

$$\log(k) = J + K\rho_d \qquad (6)$$

where J and K are constants. Laboratory experiments can be conducted in columns on deposited beds to determine the relationships given in equations 5 and 6.

Because the model is zero-dimensional the process of advection is not represented. As the model is applied to small areas it is feasible to assume that the suspended sediment concentration field may be taken to be the same at all points within the study area, although the bed shear stresses at different points may well be different. The time varying near-bed suspended sediment concentrations need to be determined for the application area, for typical spring and neap tides. This requires field measurements to be taken at least during one spring tide and one neap tide, and ideally over a period of some months.

The SAP model requires the bed shear stresses at the application point to be specified during a spring tide and a neap tide. This data may be obtained from field measurement of the near-bed velocities, or from either a numerical or physical model of the study area. Such models provide data at a number of points which enables the SAP model to be run at each of these points.