Hydraulics Research
Wallingford

FURTHER STUDIES OF THE FIELD SETTLING VELOCITIES OF THAMES MUD

J R Stevenson B Sc and
T N Burt B Sc

Report No SR 10
March 1985

Registered Office: Hydraulics Research Limited,
Wallingford, Oxfordshire OX10 8BA.
Telephone: 0491 35381. Telex: 848552

CONTRACT

This report describes work carried out under contract No DGR/465/36, funded by the Department of Transport from April 1982 to March 1984 and thereafter by the Department of the Environment. Any opinions expressed in this report are not necessarily those of the funding Departments. The DoE (ESPU) nominated officer was Mr A J M Harrison. The work was carried out by Mr J R Stevenson under the direction of Mr T N Burt in the Tidal Engineering Department of Hydraulics Research, Wallingford, under the management of Mr M F C Thorn. It is published with the permission of the Department of the Environment.

ABSTRACT

This report describes work undertaken to meet an important need in the successful modelling of siltation processes and prediction of siltation rates. Most previous work on settling of solids from suspension has been laboratory based with little or no attempt to corroborate results in the field. Mr M W Owen developed an appropriate field instrument in 1969 and carried out a limited amount of field measurements, which indicated that settling velocities of cohesive sediments were about 10 times higher than previously measured in laboratory tests.

The recent work has comprised the collection of about 200 measurements in the Thames Estuary over 3 years. Sampling was carefully organised to cover the full range of suspended solids concentrations, salinities and tidal ranges normally experienced in the Thames, in order to assess the relative importance of each parameter. The results show that concentration of suspended solids is the only identifiable significant factor. The results were therefore used to derive a general empirical equation for the field settling velocity of Thames mud.

Finally, the results for the Thames were compared with those from other estuaries obtained in the context of specific project studies. This showed that while the general conclusions about settling behaviour can be applied in other estuaries some in-situ measurements are still necessary for accurate values of settling velocity.

This report is a sequel to HR Report No IT 251, August 1983, which described the results of the 1981 and 1982 surveys. It confirms the conclusions of the earlier report and adds further discussion on the effects of salinity and turbulence.

CONTENTS

FIGURES

1 INTRODUCTION

Hydraulics Research (HR) has undertaken a field study into the in-situ settling velocities of cohesive mud. Data was collected during 3 periods in October 1981, September 1982 and November 1983 from various locations in the Thames Estuary.

The instrument used in all three cases was the Owen Tube developed at HR in 1969 to investigate the cause of siltation around the new Woolwich Ferry terminals in the Thames[1]. A full description of the instrument and the way in which its samples are analysed can be found in Ref 2.

The 1982 survey was carried out mainly to fill some gaps in the data collected in 1981, thus providing a more comprehensive data bank. The 1983 survey provided supportive evidence for the conclusions drawn from the first two and at the same time investigated the effect of turbulence on particle settling velocity.

Ref 3 describes the analysis of the data collected from the 1981 and 1982 surveys which was carried out on the two sets of data combined.

The main conclusions relating to this data were:

- i) that the predominant influence on particle fall velocity is the concentration of suspended solids;
- ii) that there is no evidence that high concentrations of mud in the Thames statistically have a higher median particle size than lower concentration;
- iii) that it was in fact the concentration that was the important factor and not an implied particle size distribution;
- iv) that contrary to expectation there was no significant variation in settling velocities attributable to difference in

salinity. Some fairly small and inconclusive differences were observed at the lowest salinity (0-2.5 ppt).

It was also noted in Ref 3 that there were differences between the data collected in 1981 and 1982. The main difference being that the median settling velocity of the majority of the 1982 samples with concentration of less than about 500 ppm was greater than that of the 1981 samples of similar concentration.

This report compares the published 1981 and 1982 data with the new 1983 data and with the results from 4 previous similar (but smaller) sampling exercises in the Thames. Then, using the 1983 data as well as the data from previous Thames surveys, it checks the rather surprising conclusion of Ref 3 that salinity is not a significant factor in determining settling velocity.

The 1983 data is then used as the main basis to investigate whether there is a significant turbulence effect.

Finally, having satisfactorily generalised the Thames data a comparison is made of data from the Thames and seven other tidal locations where similar measurements have been made during recent years.

2 ANALYSIS OF ALL THAMES DATA

It was concluded in Ref 3 that the predominant influence on particle settling velocity was the concentration of the sample. Ref 3 also noted that this relationship varied between the data collected in the Thames during the 1981 and 1982 surveys. We now look at all the available Thames data to see whether there is generally agreement between data collected during separate sampling periods or whether the differences observed so far are typical. We then see if these differences can be easily explained by seasonal variations; the overall objective being to derive an equation or sets of equations which adequately describe the settling velocity of Thames mud. Figs 1 (a), (b) and (c) show all of the data from the 1981, 82 and 83 surveys in the form of graphs of median settling velocity (W_{50} mm/s) against concentration (C ppm). The lines in Fig 1 (d) drawn through the data are the best least squares fits of the form

$$W_{50} \propto C^{i}$$

where i is termed the settling index. For later reference the 1983 data is also plotted in Fig 1 (d) split into spring and neap tides.

It can be seen from this figure that it was the 1982 data that was exceptional, there being reasonable similarity between 1981 and 1983 data.

There is additional evidence available from the Thames. In-situ settling velocities were measured on 3 occasions in 1969 and once in 1971.

The following table summarises the seven sets of data now available:

SUMMARY OF THAMES SURVEYS

Date	Location	Concentration range ppm	Tidal range in	Salinity ppt	Temp °C	No of samples
Aug 69	Woolwich	300-2630	Spring	7	20	14
Sept 69	Woolwich	54-256	Neap	7	20	11
Sept 69	Tilbury	101-344	Spring	24	19	8
June 71	Woolwich	52-449	Spring	1	16	7
Oct 81	Various	97-4720	Spring	Various	11	65
Sept 82	Various	130-2941	Neap	Various	19	34
Nov 83	Various	159-4841	All	Mid-range	13	104

In all cases the sampling procedure and the laboratory analysis was the same as for the recent surveys, so direct comparisons of median settling velocities are valid.

Two of the 1969 tests were carried out at Woolwich specifically to investigate the effect on particle settling velocities of the new Woolwich Ferry Terminals. Samples were taken up and downriver of the new northern terminal during two periods of spring and neap range tides. The data is split into spring and neap tide samples but no distinction is made between the two positions. Full details of this work are reported in Refs 1 and 4.

The other data from 1969 was obtained during spring tides at Tilbury where 8 samples were taken. A further 7 samples were taken from Woolwich in 1971.

The best least squares lines for the three sets of Woolwich data are plotted with those for 1981, 1982 and 1983 in Fig 1 (d). There is no apparent correlation between settling velocity and concentration for the 1969 Tilbury data which is so out of character that it has been omitted from the figure and the argument. The range of concentration for which each line is valid is defined by the length of line.

This figure thus provides a means of comparing one data set with another and we can now explore possible seasonal influences. The 1971 data has slightly lower median settling velocities than the other data but its settling index is similar to the data from 1969 (Spring), 1981 and 1983. We thus have 4 data sets giving a similar result and 2 'rogue' data sets which give significantly different results to the others and to each other.

Can we attribute the differences of the 'rogue' sets to any obvious cause, ie a variation in factors which may affect the flocculation of in-situ suspended sediment? These are now examined in turn.

a) Turbulence. Although both sets of 'rogue' data were collected during periods of neap tides there is no obvious similarity between them and both are quite different from the neap tide data collected during the 1983 survey (Fig 1(d)). Therefore it seems unlikely that the differences are explained by a tidal range effect.

b) Temperature. Both 'rogue' sets of data were taken during warmer than average periods (water temperature around 20 °C) indicating a possible temperature effect (apart from the direct relationship between temperature and viscosity which is allowed for in the laboratory analysis of the Owen Tube data). It is difficult to conclusively disprove this possibility with the existing data, but as the 1971 Woolwich data was also obtained during a warm period (about 16-17 °C) it seems unlikely. In any case the effect of higher temperatures would evidently not be consistent because the two rogue sets of data are different.

c) Salinity. The salinity of the 1969 neap samples is recorded as 7 ppt and that for 1982 was mainly at the extremes of the range (<5 ppt and >20 ppt) so there is little similarity on this count.

d) Particle size. The laboratory analysis of Owen Tube samples does not automatically include particle size. However, this was done on all of the samples from the 1982 survey and on 18 of those from 1981 but the remainder of the samples were not analysed for size.

This limited evidence shows a difference between the data from 1981 and 1982. The average median deflocculated particle size (D_{50}) for 1981 is 0.0063 mm and for 1982, 0.0031 mm.

Although the absolute difference is small the relative difference is great. It has been shown[5] that fundamental particle size affects the degree of flocculation which takes place; smaller particles tend to flocculate to a greater extent. It is possible, therefore, that differences between the 1982 and the 1981 results are due to this effect. The implication is that the smaller particles, indigenous in 1982, flocculated more, resulting in higher average median settling velocities.

> There is no apparent reason why particle size should have varied, nor is there any way of telling whether it was particularly high or low during the neap tide survey of 1969.

Without being able to explain the reasons for the rogue sets of data and on the basis that 4 out of the 6 data sets show a consistent trend we argue that a best fit relationship using all the data from those 4 sets gives the best predictive equation that can be produced at the present time.

The best fit line for the 4 data sets, incorporating 190 plotted points is shown in Fig 2 and given by the equation:

$$W_{50} = 1.34 \times 10^{-4} C^{1.37}$$

where W is settling velocity (mm/s)
C is concentration (ppm $\equiv$ mg/l)

It needs to be stressed that the derived equation for W_{50} is only applicable within the range of concentrations measured, ie up to about 5000 ppm. At high concentrations hindered settling begins to take place. That is when there is a sufficient volumetric flux of sediment downwards to induce a significant volumetric flux of water upwards thus reducing the settling velocity.

It is interesting to compare the empirical value of 1.37 for the settling index with that obtained by Krone[6] from theoretical considerations. This leads to a prediction of the number of particles present in a floc after a finite time and hence a relative floc size and settling velocity. This predicts that settling velocity should be proportional to the concentration to the power 1.33.

Attention has been concentrated on median settling velocity so far. Analysis of the type described was also carried out for values of W_{30} and W_{70}. The results did not contradict any of the conclusions drawn. Nevertheless for siltation predictions it is useful to try to encompass all the data in one equation. This was done using the method below.

Fig 1 showed plots of W_{50} vs concentration. Similar graphs of W_{10}, W_{20} etc to W_{90} were produced using all the accepted data. The result was a series of displaced but parallel lines. Thus it was seen that $W_n \propto C^i$ where i, the settling index, is constant for all values of n. The vertical displacement is expressed in the equation by the effect of another variable A,

thus $W_n = Ac^i$

and A is a function of n.

The values of A for each value of n were obtained from the data and the result is shown in Fig 3. The general equation for the field settling velocity of Thames mud is thus:

$$W_n = C^{1.37} \times F(n)$$

where F(n) is $1.88 \times 10^{-4}\ n^{2.34}$,
W is mm/s, C is g/l, n is %

Having established the basic concentration effect we can now move on to see if the equation should be refined to take account of other parameters.

3 FURTHER DISCUSSION OF SALINITY EFFECT

We have seen in the previous section that the data from the 1983 survey taken as a whole fits in quite well with most of the other data from the Thames. Before analysing this data for possible tidal range effects it is worthwhile reviewing the conclusion of Ref 3 regarding the lack of a salinity influence on the settling velocities of Thames mud.

This conclusion was:

> there was no significant variation in settling velocity attributable to differences in salinity. Some fairly small and inconclusive differences were observed at the lowest salinities (0 - 2.5 ppt).

In theory salinity is expected to affect the strength of the cohesive bond between particles and in particular common salt aids the flocculation of negatively charged clay minerals. An increase in flocculation leads to increased settling velocity.

Owen's work on Avonmouth mud in the laboratory confirmed the flocculating effect of salinity[7]. These results are summarised in Fig 4 showing a very nearly linear affect of salinity varying between 0 and 28 ppt. Results from Krone[6] and Allersma et al[8] are also replotted in Fig 4. Krone found that for suspended solids concentrations up to 530 ppm the settling velocity of a cohesive sediment was independent of salinity above 5 ppt. Allersma's results show that, for example, at a salinity of 5 ppt the settling velocity increased to 30 times its freshwater value but at 25 ppt the settling velocity was only about twice its value at 5 ppt. Migniot[9] too observed that settling velocity was constant at salinities above 3 ppt for low suspended solids concentrations and above 10 ppt for high concentrations (an effect also evident in Krone's results).

This weight of evidence led to the expectation that salinity would play a significant part in determining the settling velocity of the Thames suspensions. The results, plotted in the same form as in Fig 4, are shown in Fig 5 using the 1981 survey data which covered the range of typical salinities and concentrations experienced in the Thames. Fig 5 shows that varying salinity has no observable effect on settling velocities measured 'in-situ' for any concentration in the range measured. To reinforce the conclusion, the data can be presented in another form.

The 1981 Thames data covered the full salinity range normally experienced in the Thames. Fig 6(a) represents this data in the form of median settling velocity against suspended solids concentrations treating each small salinity band separately. Although there is quite a spread of data for different salinities at low concentrations there is no consistent trend attributable to varying salinity.

The 1983 data did not cover such a comprehensive salinity range and only 3 of the bands in Fig 6(a) can be drawn. The result, shown in Fig 6(b) is inconclusive, again there being no consistent trend.

The evidence from the remaining usable Thames data lends strength to the argument that salinity is not a significant factor. The 1971 Woolwich data had very low salinity (0.7 ppt) and settling velocities slightly lower than most of the data, Fig 1(d), but not as low for example as the 5-10 ppt salinity band from 1983.

The most likely explanation for the difference between the laboratory and field effects of salinity on settling velocities is the fact that the laboratory work is based on reconstituted samples resuspended by mechanical agitation. Flocculation is a time dependant phenomena and the time taken for settling through laboratory columns is not sufficient to allow full re-flocculation to take place. This theory is supported by comparing evidence of absolute values of W_{50} obtained by Krone, Owen etc with those obtained from the field measurements. The latter are at least one order of magnitude higher. The implication is that in the Thames estuary, if not in all muddy estuaries, material is held in suspension long enough for a much greater degree of flocculation to occur not only at high salinities but also for the same degree of flocculation to occur at low salinities. In other words salinity does not affect the ultimate median floc size although it affects the speed with which the flocs reach that size.

4 TURBULENCE

Turbulence is by no means completely described by the parameter tidal range. However, there is a great deal more energy to be dissipated during spring tides than during neaps and so turbulence generally will be greater. Therefore, for this study an analysis of the tidal range effect is considered valid.

According to Owen[1] "The random movement of the water associated with turbulence brings silt particles into frequent collision with each other, and they flocculate, provided that the fluctuating internal shear generated by the turbulence is not greater than the bonding strength of the particles. It can thus be seen that the degree of turbulence can have widely differing effects".

This leads one to believe that turbulence could be a significant factor in its effect on particle settling velocity. Although this effect may not be simply a rise (or fall) in settling velocities with increasing turbulence; maximum settling velocity may be achieved at some intermediate value.

In the 1969 tests at Woolwich, Owen measured very different settling velocities for the samples taken during spring and neap tidal ranges. During the spring tide the settling velocity increased approximately linearly with suspended solids concentration. During the neap tide however the settling velocity was found to increase approximately with the square of suspended solids concentration[1,4] and the actual settling velocities were consistently higher during the neap tide measurements.

Although we concluded in Chapter 2 that the four sets of data from 1969 (spring tides) 1971, 1981 and 1983 can reasonably be treated as a whole the 1983 survey was deliberately planned to cover the full range of tides.

The 1983 data is therefore used alone to analyse the effect of turbulence as defined by tidal range. This data is shown in Fig 7 where W_{50} is plotted against tidal range for a number of concentration bands.

Despite the large scatter it is clear from this figure that no correlation exists for any concentration band. It is evident that the conclusions drawn from the 1969 data are contradicted by the 1983 data. This shows that for most concentrations the spring tide samples have higher settling velocities than the neap samples. And although the settling index is higher for the 1983 neap tide data than for any of the spring tide data the difference is not great and the conclusion is contradicted by the 1982 neap data which has the lowest settling index of all the Thames data.

It must be concluded on the above evidence that tidal range has no consistent effect on settling velocities. This is not to say that turbulence has no effect but rather that variations in tidal range do not induce relevant changes in turbulence. Relevant turbulence is likely to be that which is of a scale comparable with the size of the flocs.

5 COMPARISON WITH OTHER ESTUARIES

Having, with some reservations, reached an acceptable conclusion regarding the Thames data, and having produced a single line relating median settling velocity to suspended solids concentration it is now valid to compare this line and the Thames data generally with data from other estuaries.

A number of studies carried out by Hydraulics Research in recent years have included in situ measurements of settling velocity using the Owen tube. Results are available from Brisbane, Grangemouth, River Parrett, River Avon, River Severn, River Humber and River Scheldt. Further information concerning these data is given in the following table:

Location	Brisbane Australia	Grangemouth Scotland	Parrett England	Scheldt Belgium	Bristol Channel England	Avon England	Humber England	Thames England
Concentration range (ppm)	28-579	66-4049	420-10800	205-3285	123-1710	316-4439	90-1123	50-5000
Tidal range		Spring	Spring & Neap	Spring	All	Spring & Neap	Mean	All
Salinity (ppt)	30		10-26				29	0-30
Temp °C								13-20
No of samples	24	16	10	15	29	19	17	200+
D50 µm	4	20		20				4
% clay (by size)	40	28		22				32
% silt	42	66		58				67
% sand	18	6		20				1
% montmorillonite	30	0		20		<10		15
% kaolinite	15	17	< 10	10		<10		10
% illite/mica	5	17	30	10		30		25
% chlorite	0	17	35	0		30		20
% organics etc	0	10		5				13
% non clay minerals	50	39		55				17

It was noted in the first report on the recent Thames surveys[3] that the mineralogical composition of cohesive muds was a factor which may affect the settling velocity distribution.

It is generally assumed that there is little seasonal variation in the chemical make up of a particular estuarine mud. However, this is a factor which is known to vary considerably between estuaries and so becomes a significant part of the argument at this stage.

In a study of flocculation[7] Owen says "The cohesive forces exerted between two clay particles depend both on the mineralogy of the clay and on the electro-chemical nature of the suspending medium" and "with a negatively charged clay mineral, such as montmorillonite or illite, the additon of common salt, sodium chloride, causes flocculation to occur. Sea water has an even stronger flocculating effect, since it usually contains several salts of higher valency metals".

Particle size is also a factor which varies far more between estuaries than within an estuary and so becomes more important in this part of the study. Before making comparisons it is important to stress that the results for the Thames are based on over 200 samples taken over 15 years whereas other estuary data is the result of a single survey.

The results are summarised in Fig 8 together with the best-fit Thames data. There do not appear to be any consistent trends with this data. For example, Scheldt and Grangemouth muds have similar values of median particle size (D_{50} = 0.02 mm) as have Thames and Brisbane (D_{50} = 0.004 mm) but these similarities are not reflected in either the shape or position of the relevant lines in Fig 8.

If total clay mineral content is important in determining potential flocculation then Thames mud with a total clay mineral content of 70%, Parrett mud with at least 65% and Avon mud with at least 60% would be expected to show both the highest dependence on salinity and the highest settling velocities of all the muds. In fact the Thames results showed no dependence on salinity and only average settling velocities, and the Parrett and Avon samples are at the low end of the settling velocity distribution shown in the figure. The fact that Brisbane and Grangemouth muds with very similar clay minerals (about 50%) are closely related in Fig 8 and Scheldt mud, with 40%, falls a little below is rather slender evidence on which to draw any conclusion.

Perhaps the most interesting conclusions to be drawn from Fig 8 are that the slopes of the lines (the settling indices) are all contained within a band of 0.6 - 1.4, and that for a specified concentration, variations in W_{50} between estuaries can be up to an order of magnitude.

So, whilst the detailed findings of the Thames study are not directly applicable to sediment behaviour in other estuaries, the weight of evidence suggests that the broader conclusions relating to the Thames are generally valid elsewhere. In particular we would not expect to see significant salinity or tidal range effects on the in-situ settling velocities of other estuaries.

Further work is planned to study the physics of the settling of flocculated cohesive sediments using the new circular flume at HR. This will help to identify the parameters that influence settling in a more cost-effective way than repeating the large exercise carried out in the River Thames in another estuary.

6 SUMMARY AND CONCLUSIONS

In an attempt to gain a better understanding of the mechanisms affecting the settling characteristics of estuarine cohesive muds a three part field survey has been carried out in the River Thames.

Most previous work on settling velocities has been done in the laboratory. Very little has been done on in-situ settling velocities.
The results of the first two Thames surveys were reported in Ref 3. This report takes the evidence from the third survey and uses it to review the initial conclusions and to extend the study.

In addition to the 3 recent surveys, 3 other sets of data from similar, but smaller, field surveys in the Thames were studied and used for comparison.

Using the most reliable of all the Thames data a generalised relationship between in-situ median particle settling velocity and suspended solids concentration has been derived. This relationship was then used to compare the results of similar surveys conducted by HR in 7 other estuaries over recent years.

The conclusions drawn from this work are summarised below.

i) The median settling velocity (W_{50} mm/s) characterises the results sufficiently well to be used for studying correlations with relevant parameters.

ii) The Thames data conformed to the expected domination of the effect of concentration on W_{50}. The best fit line for the range of concentrations measured (up to about 5000 ppm) was:

$$W_{50} = 1.34 \times 10^{-4} C^{1.37}$$

iii) Data from two studies in the Thames did not comply with this general formula. It is thought that the smaller particles and lower concentrations sampled in 1982 resulted in higher settling velocities. There is not sufficient information to explain the difference in the 1969 (neap tide) survey.

iv) Using the accepted data a general empirical equation for settling velocities in the Thames was derived:-

$$Wn = C^{1.37} \times 1.88 \times 10^{-4} n^{2.34}$$

where W is settling velocity (mm/s)
and C is concentration (ppm ≡ mg/l)

v) The power of C (settling index) of 1.37 is close to the 4/3 predicted by Krone from theory.

vi) There is no evidence that high concentrations of mud in the Thames statistically have a higher median particle size than lower concentrations.

vii) Contrary to expectations salinity appeared to have no effect on settling velocities. It is surmised that this is because, in the field, flocs have time to develop to their optimum size whereas in the laboratory the effect of high salinity in speeding up flocculation is significant in the context of the settling time.

viii) Previous suggestions by Owen that variations in turbulence induced by variations in tidal range affected floc size and therefore settling velocities were not substantiated by the more intensive recent survey results.

ix) It is suggested that turbulence relevant to limiting floc size is likely to be of a scale comparable with the floc size - rather than the 'macro' turbulence generated by tidal flow.

x) The comparison of results from the Thames with those from other estuaries revealed no correlation of settling velocity with clay mineral content, particle size or organic content between estuaries. This does not rule out possibility that combinations of these or other parameters may have a significant effect.

xi) The settling indices for all estuaries sampled lie between 0.6 and 1.4 showing a universal pattern of behaviour. However, absolute values of settling velocity for a given concentration vary by an order of magnitude between estuaries.

xii) The general conclusions relating to the Thames study apply to other estuaries. However, the derived relationship between settling velocity and suspended solids concentration does vary between estuaries and some in-situ measurements are recommended if accurate values are required.

7 REFERENCES

1 HYDRAULICS RESEARCH STATION, Woolwich ferry terminals. Field study of the effect of turbulence on silt floc settling velocities. HR Report EX 467, October 1969.

2 OWEN M W, Determination of the settling velocities of cohesive muds. HR Report IT 161, October 1976.

3 BURT T N and STEVENSON J R, Field settling velocity of Thames mud. HR Report IT 251, August 1983.

4 OWEN M W, The effect of turbulence on the settling velocities of silt flocs, Proc Int Ass for Hydraulics Research 14th Conference, Paris 1971.

5 LAMBE T W, The structure of inorganic soil, Proc ASCE, Vol 79 Separate No 315, October 1953.

6 KRONE R B, Flume studies of the transport of sediment in estuarial shoaling processes: Final report. Hyd Eng Lab and Sanit Eng Res Lab, U of California, Berkeley, June 1962.

7 OWEN M W, A detailed study of the settling velocities of an estuary mud. HR Report INT 78, September 1970.

8 ALLERSMA E, HOEKSTRA A J and BIJKER E W Transport patterns in the Chao Phya estuary, Delft Hydraulics Laboratory, Publication No 47, March 1967.

9 MIGNIOT C, A study of the physical properties of various forms of very fine sediments and their behaviour under hydrodynamic actions, La Houille Blanche, No 7, 1968.

Figures

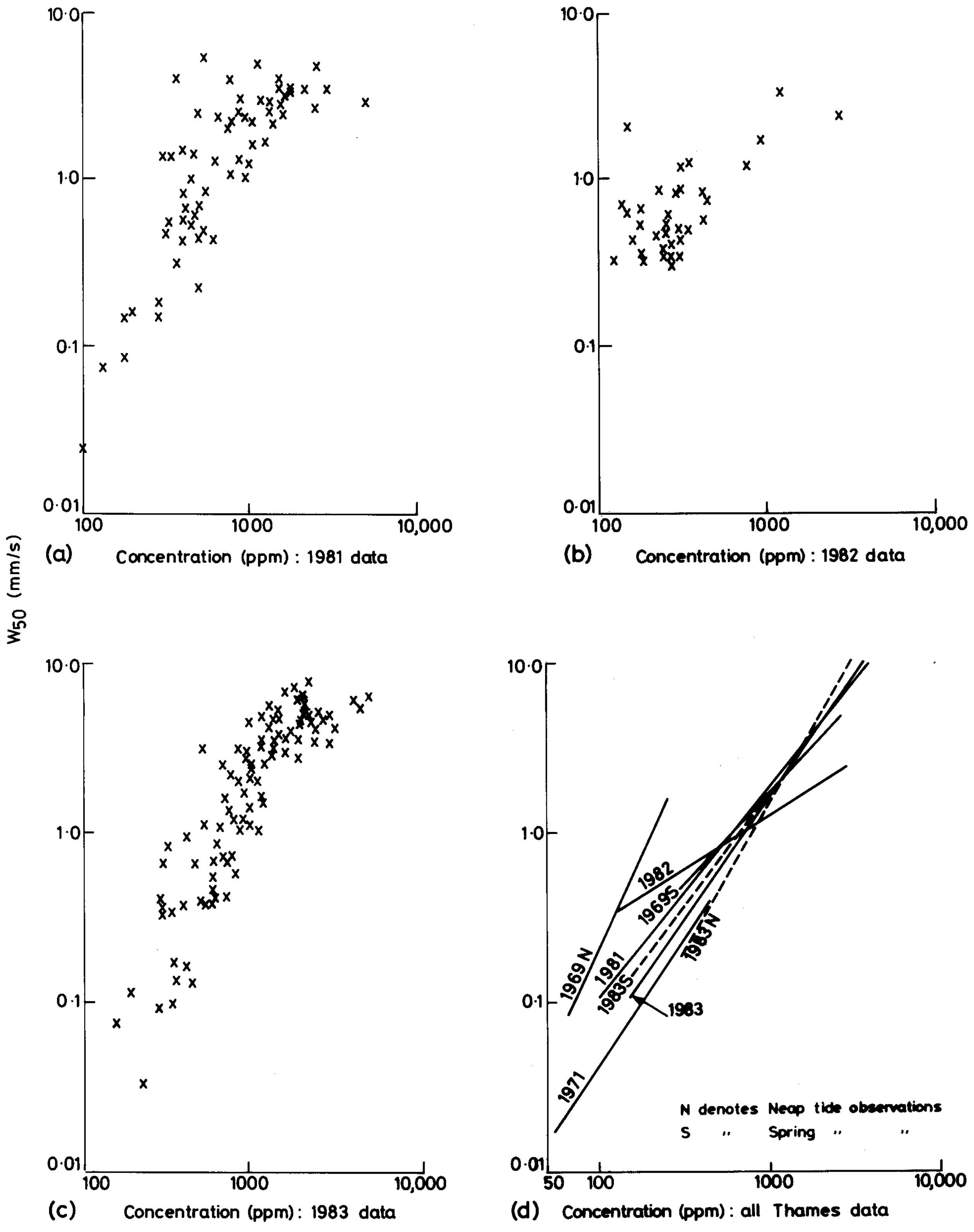

Fig 1 Comparison of median settling velocities : all Thames data sets

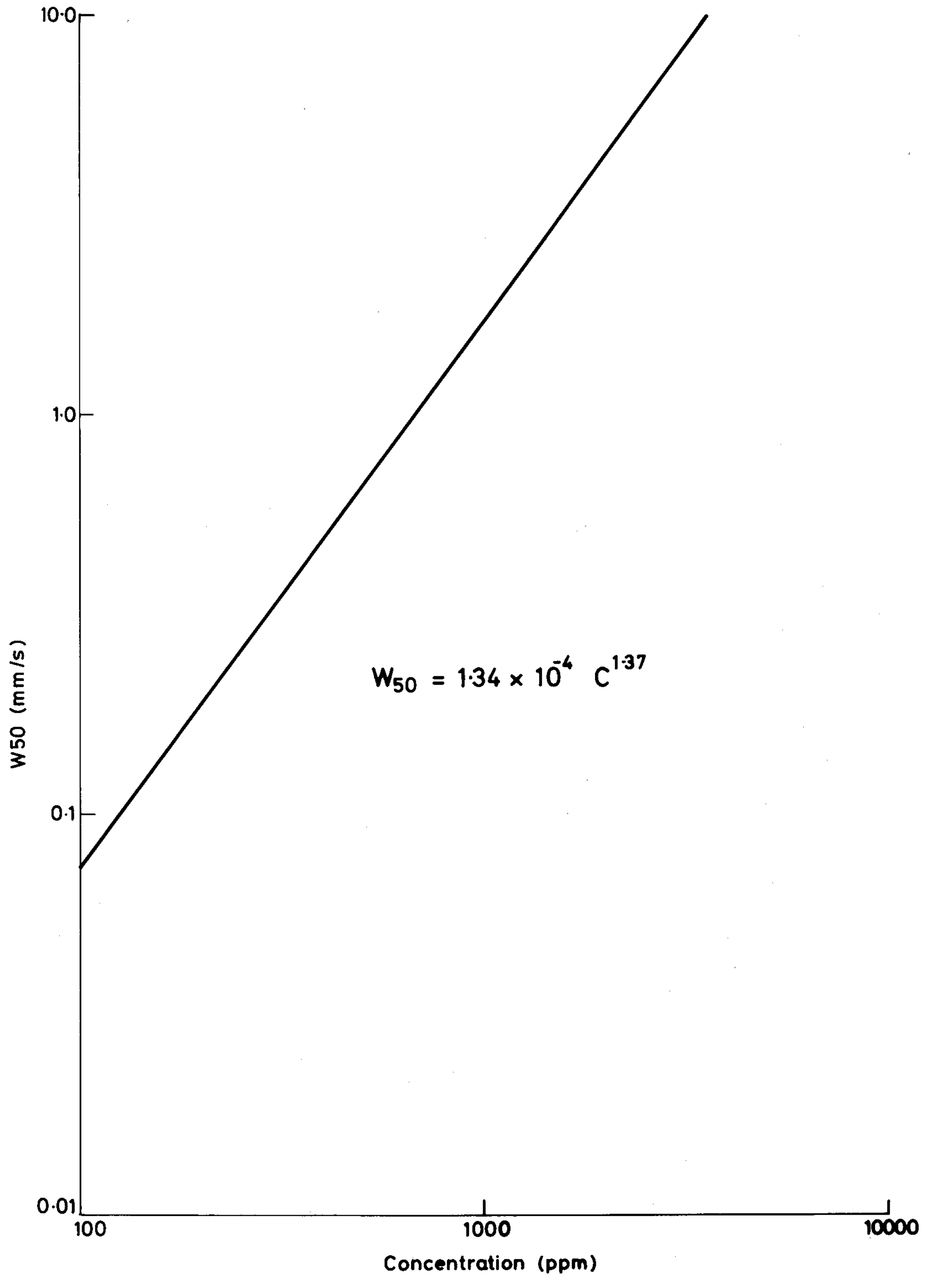

Fig 2 Concentration dependence of median fall velocity : best fit

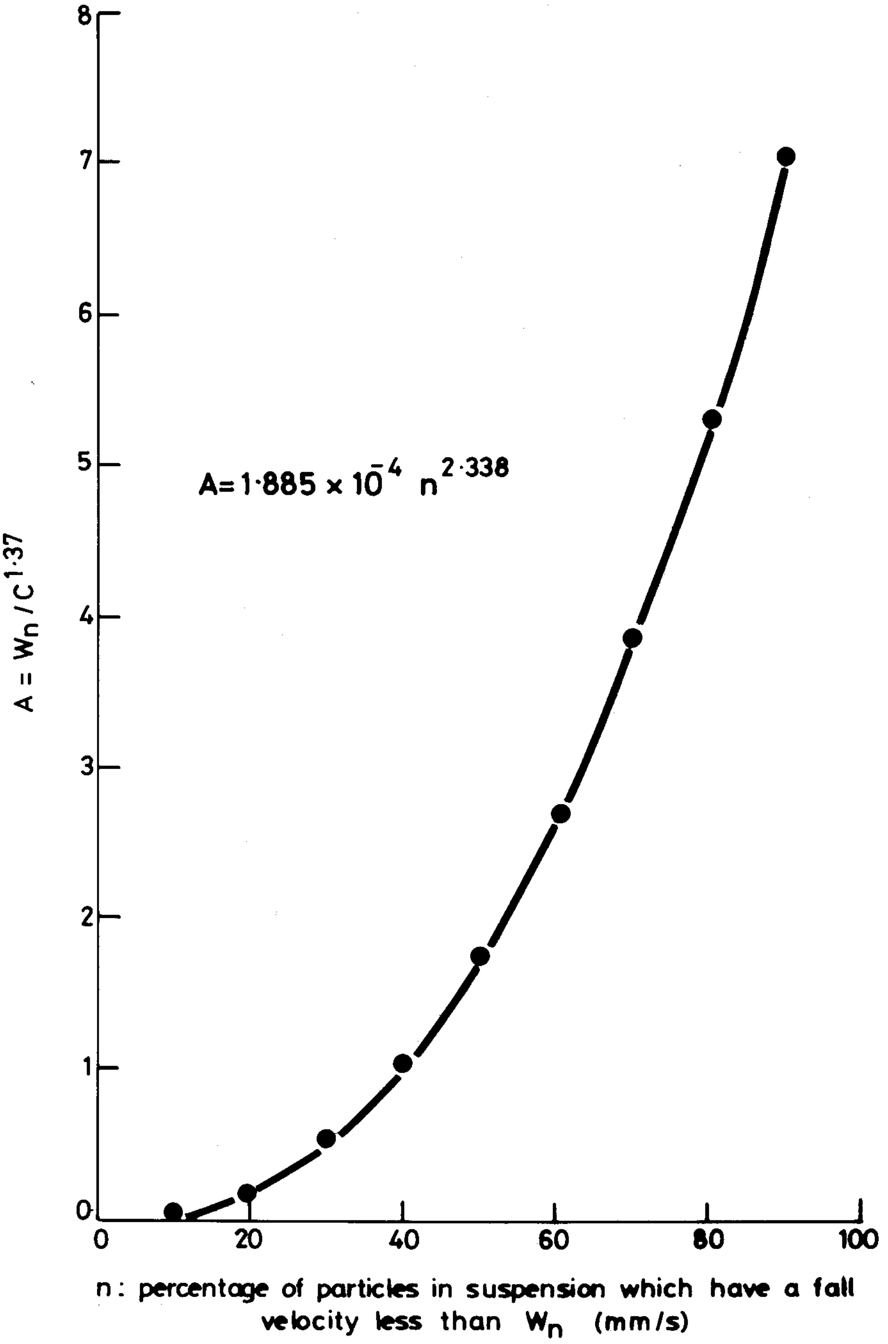

Fig 3 General equation for Thames data

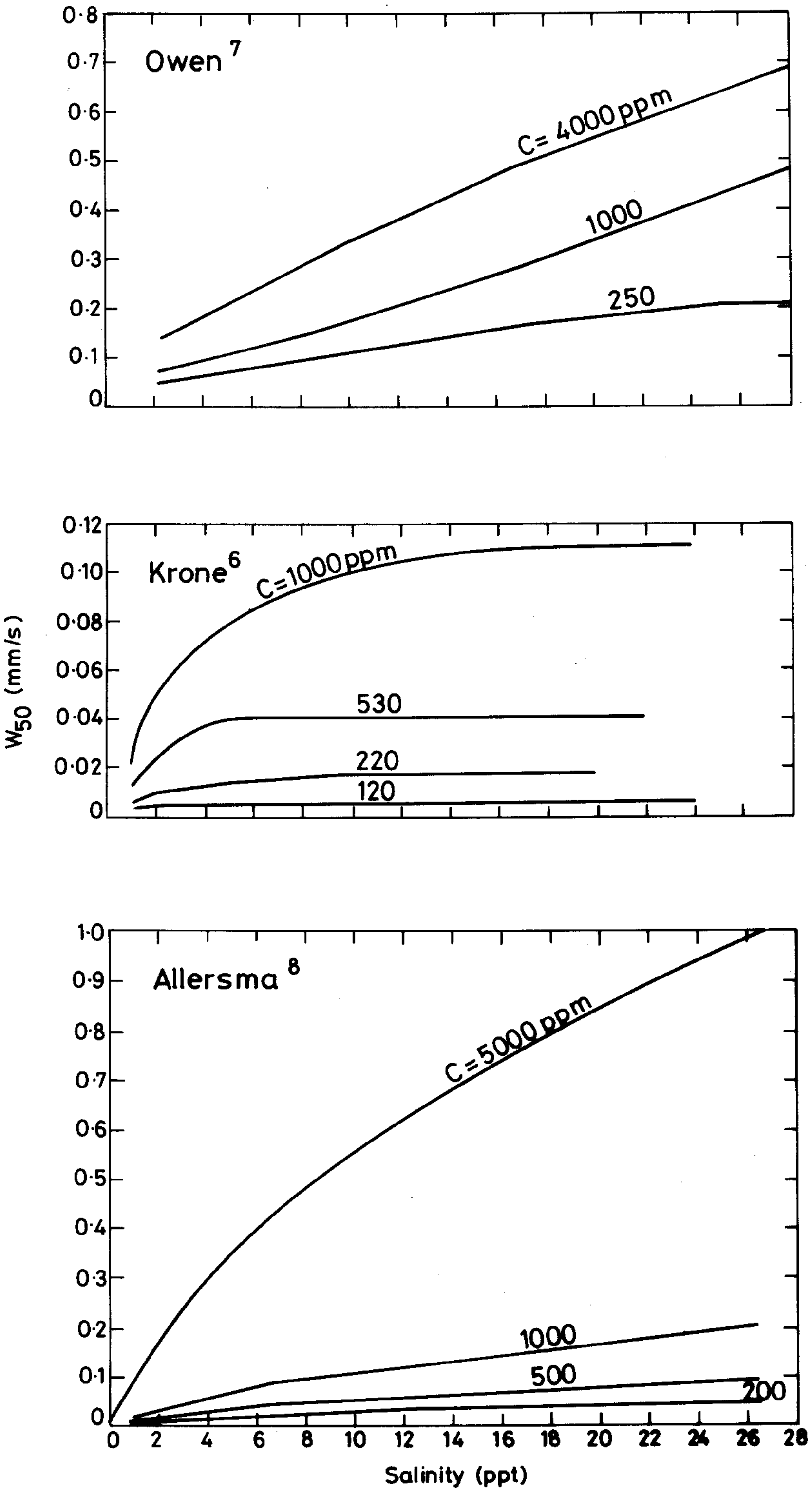

Fig 4 Effect of salinity on settling velocity: previous studies

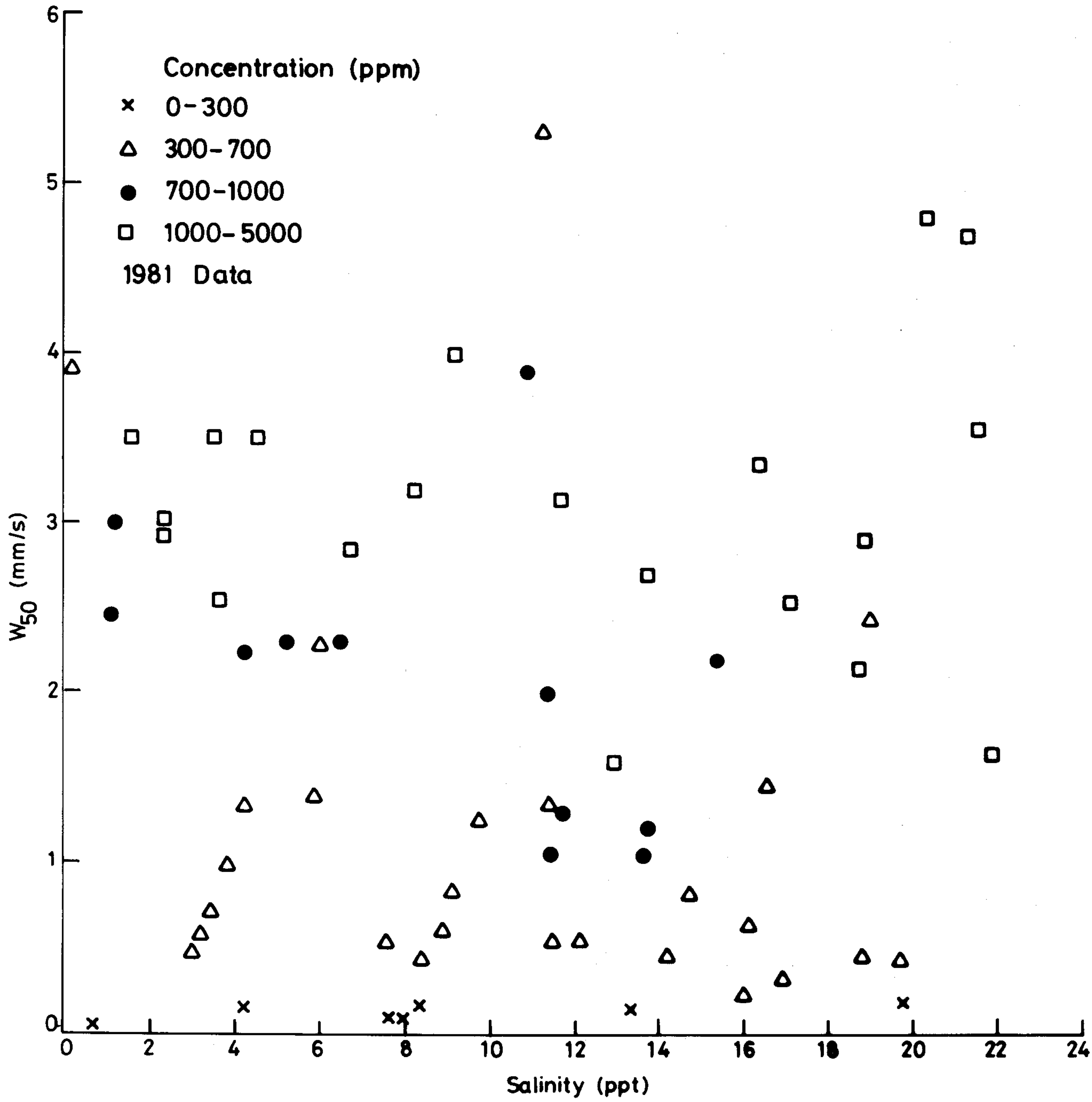

Fig 5 Effect of salinity on settling velocity: Thames field data (1)

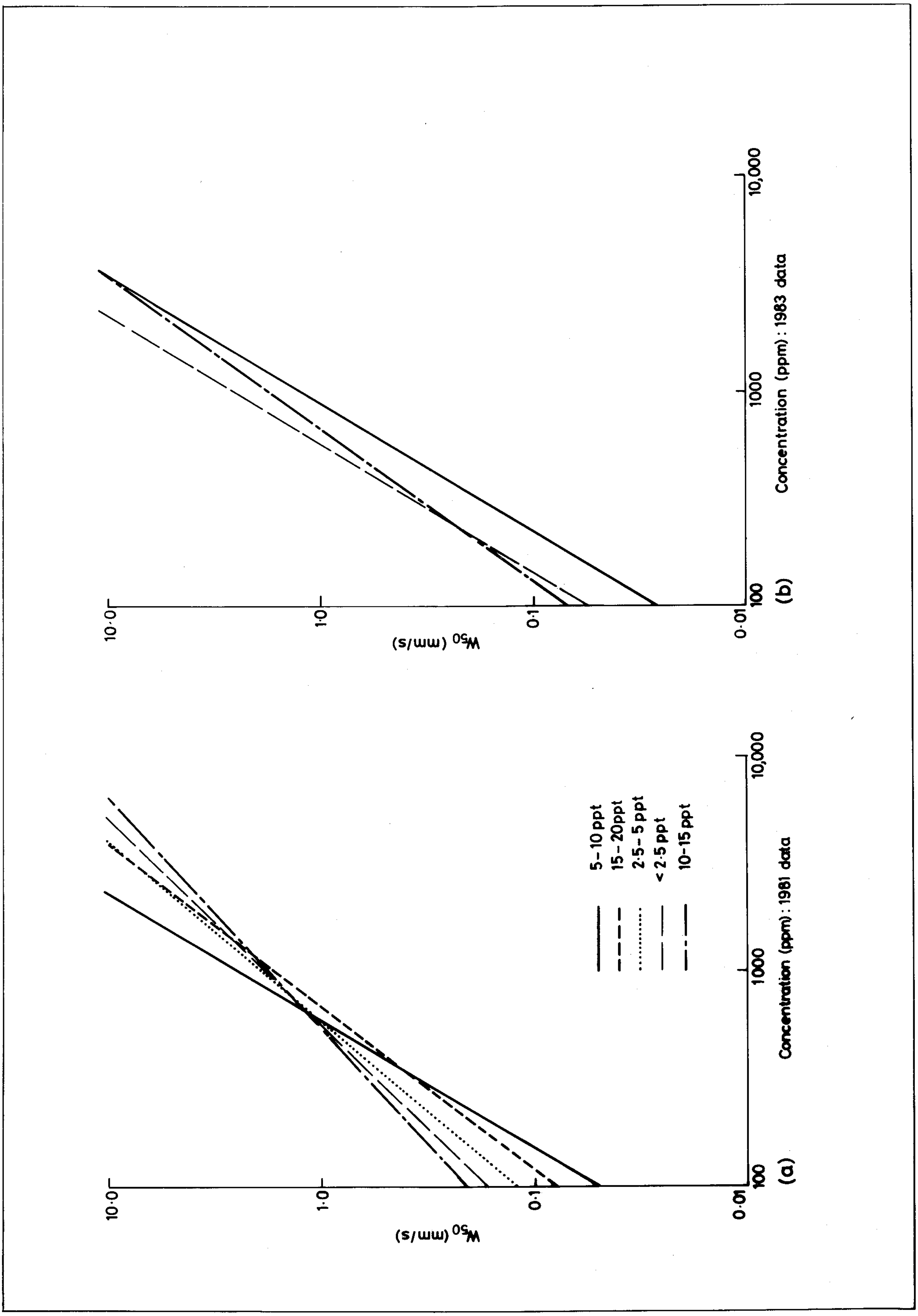

Fig 6 Effect of salinity on settling velocity : Thames field data (2)

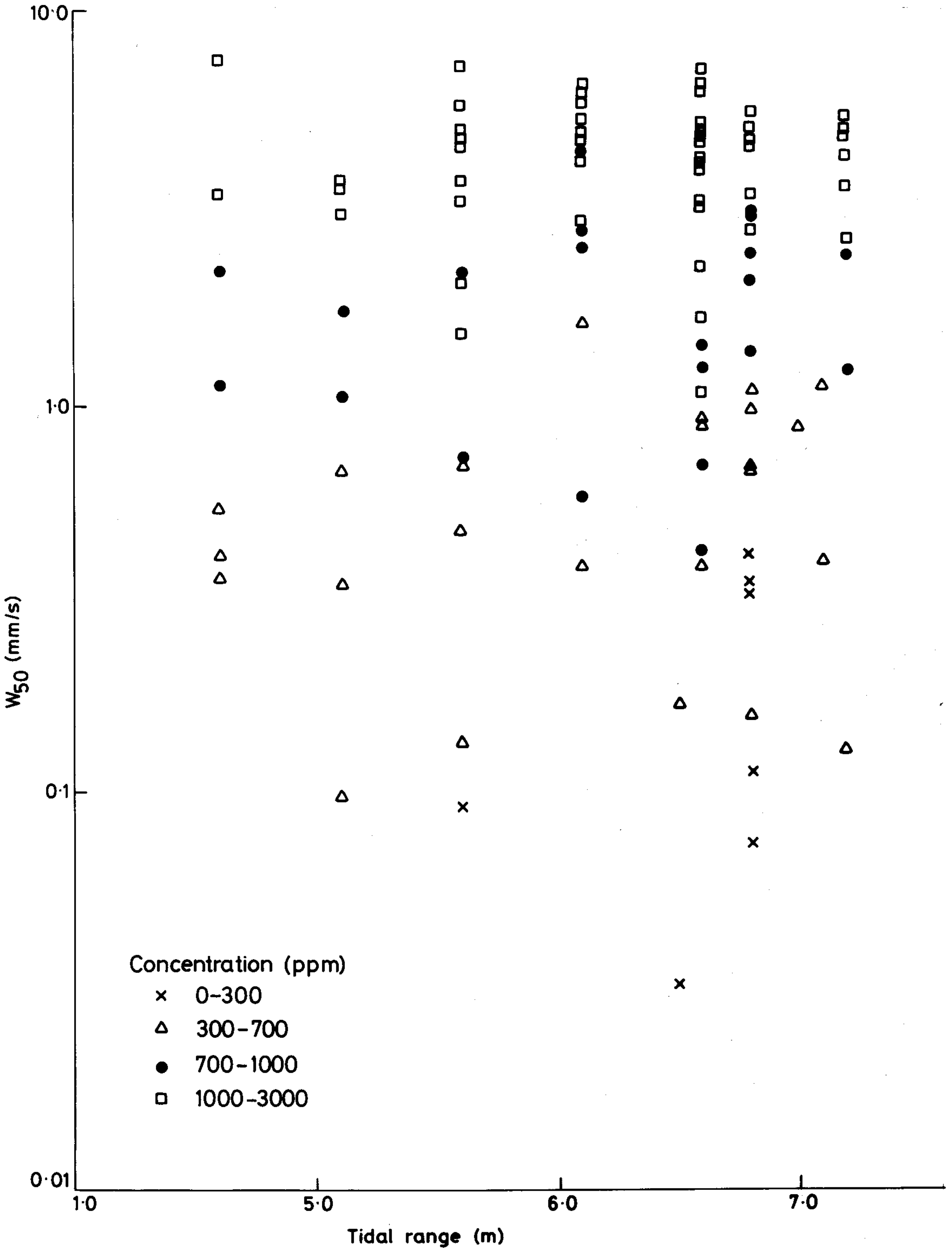

Fig 7 Effect of tidal range: all concentration ranges, 1983 data

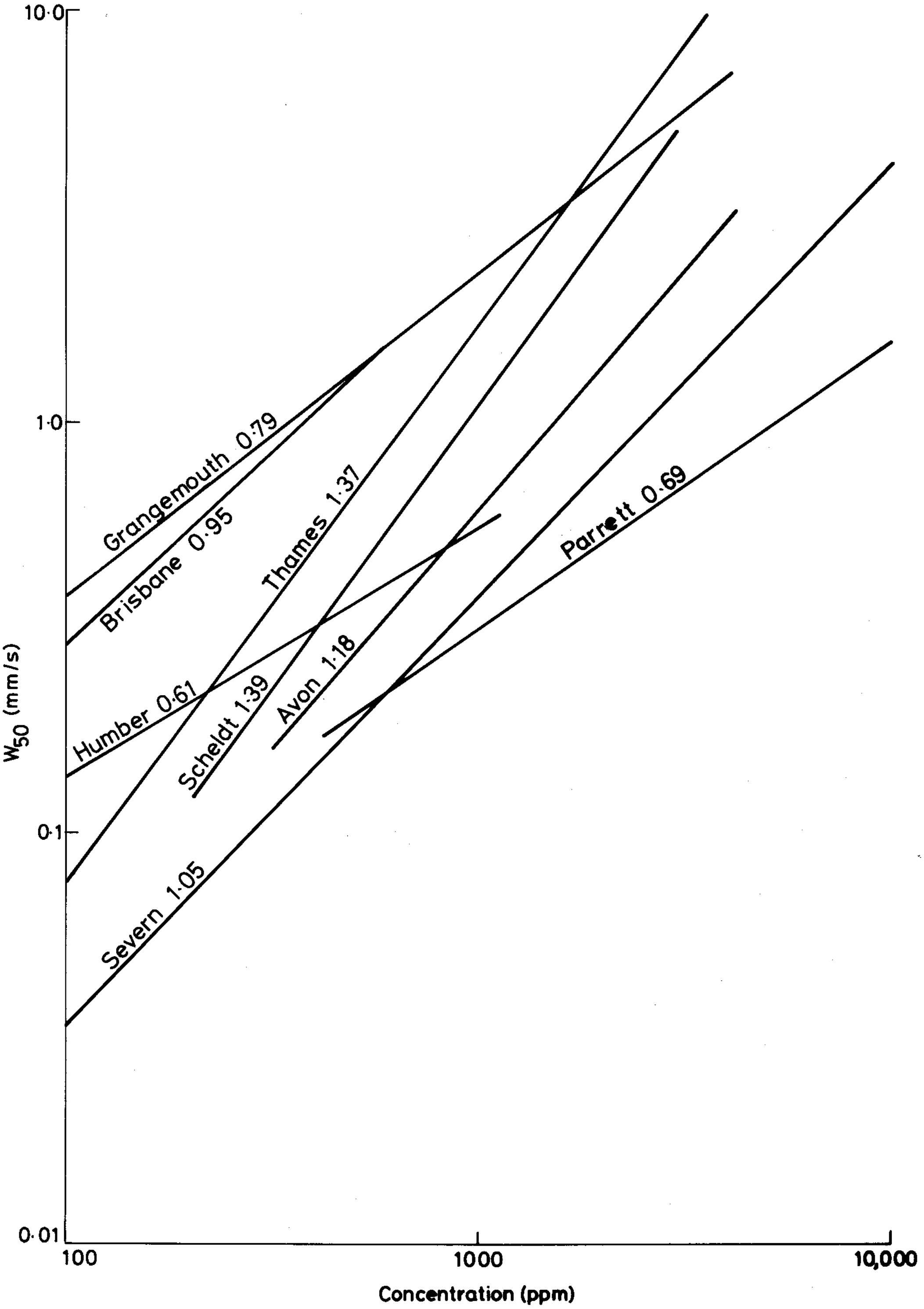

Fig 8 Comparison of data for 8 estuaries