1. INTRODUCTION

In April 1994 HR Wallingford was commissioned by the Ministry of Agriculture Fisheries and Foods (MAFF, now the Department of the Environment, Food and Rural Affairs - DEFRA) to carry out numerical studies to estimate the impact of seawall breaching on the surrounding creek morphology at Tollesbury Creek (Figure 1). Further studies followed in November 1996, November 1997, November 1998, November 1999, December 2000 and November 2001, to survey the estuary and determine the morphological trends at the site. HR Wallingford carried out a further survey in November 2001. This report summarises the analysis of the bathymetric changes.

A full set of technical reports have been prepared and submitted for this project, as set out in the Reference section.

2. HYDROGRAPHIC SURVEY

Bathymetric surveys were carried out in Tollesbury Fleet in the late autumn of 1994, 1996 and every year subsequently to 2001. The area of the surveys is shown in Figure 1.

Line spacing for the survey was at 100m intervals in the widest part of the Fleet, and at 50m intervals in the narrower creek reaches; additional cross-check lines were run perpendicular to the survey lines. All lines surveyed were repeated each year. The survey vessel was positioned using the Trinity Lighthouse reference station at North Foreland (50° 34’ 32.29”N, 001° 17’ 52.16”W, height 94.9m) using a Trimble 4000DL receiver and Trimble Probeacon. Depths were measured using a Raytheon DE719C (210kHz) echo sounder with depth data logged at 10Hz. All data was logged to a NAVBOX, a PC-based navigational computer system which incorporates a helmsman display to facilitate precise positional control. Bed levels were reduced to ODN from visual observations to tide board gauges established at:

- Woodrolfe Creek (NG 597500E,211000N) and
- Tollesbury Creek (NG 596580E,211510N)

3. DATA ANALYSIS

Previous technical reports assessed annual changes, but this report will only present the total change from 1994 to 2001. The raw bathymetric data from the recent November 2001 survey were used in conjunction with the raw bathymetric data from the June 1994 survey taken prior to the breach, to derive information on the changes in bed level. The changes in bathymetry were computed in two ways.

- Survey data was sorted into pairs of points (one from each survey) less than 0.1m apart. This procedure gives changes in bathymetry at more or less exactly the same location and so removes uncertainty in bed level changes where the bathymetry is variable. Secondary analysis was also carried out which found pairs of points less than 1m apart. This was considered acceptable due to the fact that the echo sounder method of surveying averages the bed data over an area of the order of 1m radius, due to the expansion of the echo beam. The figures from this analysis could then be compared against the corresponding annual changes since June 1994. The results are presented to show both the spatial variation of changes and also to show the numerical distribution of changes.

- Further examination of trends within the Tollesbury Fleet was provided by comparing the cross-section profiles from various locations within the system, the data being derived from transects by the survey vessel over different years. Although the transects presented in this report differ slightly in their location, they are separated by no more than 12m upstream/downstream of each other and are considered to reflect an accurate representation of changes in these cross-sections over time. For presentation in this report the available data has been filtered.

4. RESULTS

4.1 Point-by-point analysis

The analysis for the June 1994 to December 2001 period again shows that there has been noticeable deepening since 1994 in areas of the main channels, particularly in Tollesbury Creek, Tollesbury Fleet and in Old Hall Creek (Figures 2 to 6). It is considered that deepening in Old Hall Creek is attributable to an increase in discharge through the upper end since breaching in order to fill the back of the estuary. This aspect was predicted by the numerical studies of the breaching process (Reference 7). Figure 6 highlights the shift in the distribution of bed level changes in Tollesbury Creek compared to other areas of the estuary, as it adjusts to a new regime. Note also that the distribution exhibits a greater frequency of points across the whole estuary with significant deepening compared to accretion. Tollesbury Fleet also appears to show significant deepening.

Table 1 shows the average changes in bed level throughout the estuary and in the different creeks. The mean changes for points separated by less than 0.1m broadly agree with those separated by less than 1m except where the data sets of the former are only represented by a relatively small number of points.
The results of this table (for points separated by up to 1m) are shown in graphical form in Figure 7 which shows the cumulative changes that have occurred within the estuary since June 1994. The figure shows clearly that the most significant influence on the mean bed level changes is that of natural year on year variation, probably due to variation in the annual wave climate. However, since the breach there has been overall deepening in Tollesbury Creek, in Tollesbury Fleet and Old Hall Creek that seems to have tailed off in recent years, suggesting an underlying effect caused by the breach itself.

Table 1 Mean changes in bed level (positive = increase in depth)

Time period		Mean bed level change (m)				
		Entire Estuary	Old Hall Creek	Tollesbury Creek	Tollesbury Fleet	Woodrolfe Creek
Jun 1994 to Nov 1996	0.1m separation of points	0.111	0.124	0.098*	0.131	0.045*
	1.0m separation of points	0.142	0.134	0.148	0.146	0.146
Nov 1996 to Nov 1997	0.1m separation of points	-0.034	-0.066	0.014	-0.061	0.051
	1.0m separation of points	-0.034	-0.081	-0.002	-0.012	-0.025
Nov 1997 to Nov 1998	0.1m separation of points	0.049	0.013	0.01	0.118	0.038
	1.0m separation of points	0.061	0.035	0.071	0.081	0.038
Nov 1998 to Nov 1999	0.1m separation of points	-0.106	-0.091	-0.117	-0.096	-0.163
	1.0m separation of points	-0.093	-0.079	-0.097	-0.104	-0.094
Nov 1999 to Dec 2000	0.1m separation of points	0.024	-0.002	0.059	0.028	0.025
	1.0m separation of points	0.030	0.033	0.049	0.022	0.014
Dec 2000 to Nov 2001	0.1m separation of points	0.002	-0.007	-0.001	0.01	-0.006
	1.0m separation of points	0.003	-0.01	0.023	0.004	-0.002
Jun 1994 to Nov 2001	0.1m separation of points	0.147	0.233	0.154	0.124	-0.056
	1.0m separation of points	0.136	0.131	0.270	0.119	0.038

* Calculated from a small data set and should be treated with caution

4.2 Analysis of cross-section profiles

Further analysis was undertaken by examining the changes to cross-section profiles taken from various parts of the estuary. The locations of the cross-sections examined are shown in Figure 8. The cross-sections themselves are presented in the Technical reports with only those for Tollesbury Creek shown here in Figures 9 and 10 It should be noted that the cross-section cannot be held to be representative of the whole estuary/creek but may serve to indicate trends for corroboration by other data.

Figures 9 and 10 show the changes to cross-section profiles in Tollesbury Creek. The figures show steady deepening over time of up to 0.4m (site A at the mouth) and up to 0.6m (site B further upstream) at the deepest point of the channel. Further upwards in the intertidal profile erosion is also shown of up to 0.2m. The period 2000-2001 does not show any significant further change at site A, but at site B the smaller channel to the south side has been shallowing since 1994 with the main channel increasing in size to compensate. This is to be expected as the flow in the main channel has greatly increased relative to pre-breach.

Changes to cross-section profiles in Old Hall Creek show that at the deepest point of the channel there was steady deepening over time over the period 1994-1999 followed by accretion in the period 1999-2000 raising the channel bed to levels similar to those in 1994. This suggests that steady accretion has occurred on some parts of the intertidal of up to 0.2m. The period 2000-2001 appears to be characterised by a small amount of further accretion.

Changes to cross-section profiles in Woodrolfe Creek show steady deepening over time of up to 0.4m at the deepest point of the channel. On the lower intertidal erosion of up to 0.2m has occurred, however above 0mOD the pattern is more mixed.

Changes to cross-section profiles in the North Channel of Tollesbury Fleet indicate little overall deepening over time in the LW channel but intertidal erosion of up to 0.4m on the Northern shallow bank of the channel, most of this deepening occurring between 1994 and 1997. Since this time there appear to be no significant changes to the section. Changes to cross-section profiles in the South Channel of Tollesbury Fleet show deepening over time of up to 0.2m on both the subtidal and intertidal, although over the 2000-2001 period there does not appear to have been any further deepening.

The analysis of cross-section profiles in general shows that parts of the estuary cross-section profile are displaying different types of bed level changes. In order to identify the differences in behaviour further bed level changes at different elevations were investigated.

4.3 Analysis of changes at different elevations

The data set for bed level changes between 1994-2001 was analysed for changes at different elevations in the subtidal/intertidal profile. The results are displayed in Figure 11. An important result of this analysis was that the number of "subtidal" points, with elevation below MLWS, was small compared to the number of intertidal points. This is because the creeks virtually dry out at LW, although subtidal changes are recorded for Tollesbury Fleet where the water depths are greater. The mean bed level changes discussed in Section 4.1 (and presented in Figure 7) are therefore biased towards intertidal changes.

Broadly speaking MLWS is at –2.5mOD and MHWS is at +3.0mOD. On intertidal areas there has been erosion around the lower intertidal, -2.5mOD to 0mOD, in the estuary as a whole and in each individual creek. The greatest changes in the estuary as a whole appear to have taken place around the –1.5mOD to -0.5mOD level, although in Tollesbury Fleet the greatest changes have taken place in deeper water, around the –2.5mOD to –2.0mOD level. It is likely that much of this effect is due to the breach as the depth of erosion at this level is strongest in Tollesbury Creek and Tollesbury Fleet, those parts of the estuary most experiencing changes in current speed as a result of the breach. The figure shows that the estuary as a whole has experienced deepening (on average) at all bed levels.

5. SUMMARY

In general, over the entire period June 1994 to November 2001 the whole estuary has deepened, particularly along Tollesbury Creek and in Tollesbury Fleet. This deepening has occurred in both subtidal and intertidal areas of the estuary. The subtidal and lower intertidal areas appear to be affected by the breach while the upper intertidal areas are affected by wave action. The most significant mechanism on the bed levels in the estuary as a whole appears to be the natural year on year variation in the wave climate. The estuary appears to have deepened as a whole over the period 1994-1996 and remained broadly stable since then. However, there is some suggestion that Old Hall Creek has not yet stabilised since examination of point measurements and cross-section profiles suggests it appears to be accreting and gradually returning to the depths that existed before the breach occurred in 1994. At other locations within the estuary there appears to be no significant further deepening in the LW channel and on intertidal areas.

6. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance of English Nature, the site owners, for their support.

7. REFERENCES

1. Tollesbury Creek Essex, MAFF – Set Back Trial Field Data Collection, HR Wallingford Report SR399, August 1994.

2. Tollesbury Creek Managed Set Back Experiment. Comparison of Model Results with Field Observations, HR Wallingford Report TR 35, October 1997.

3. Tollesbury Creek Managed Set Back Experiment. Analysis of bathymetric changes between 1996 and 1997, HR Wallingford Report TR 58, March 1998.

4. Tollesbury Creek Managed Set Back Experiment. Analysis of bathymetric changes between 1997 and 1998, HR Wallingford Report TR 76, March 1999.

5. Tollesbury Creek Managed Set Back Experiment. Analysis of bathymetric changes between 1998 and 1999, HR Wallingford Report TR 101, February 2000.

6. Tollesbury Creek Managed Set Back Experiment. Analysis of bathymetric changes between 1999 and 2000, HR Wallingford Report TR 120, February 2001.

7. MAFF Set Back Experiment, Tollesbury Creek, Report on model investigation of breaching scenarios, HR Wallingford Report SR 413, January 1995.

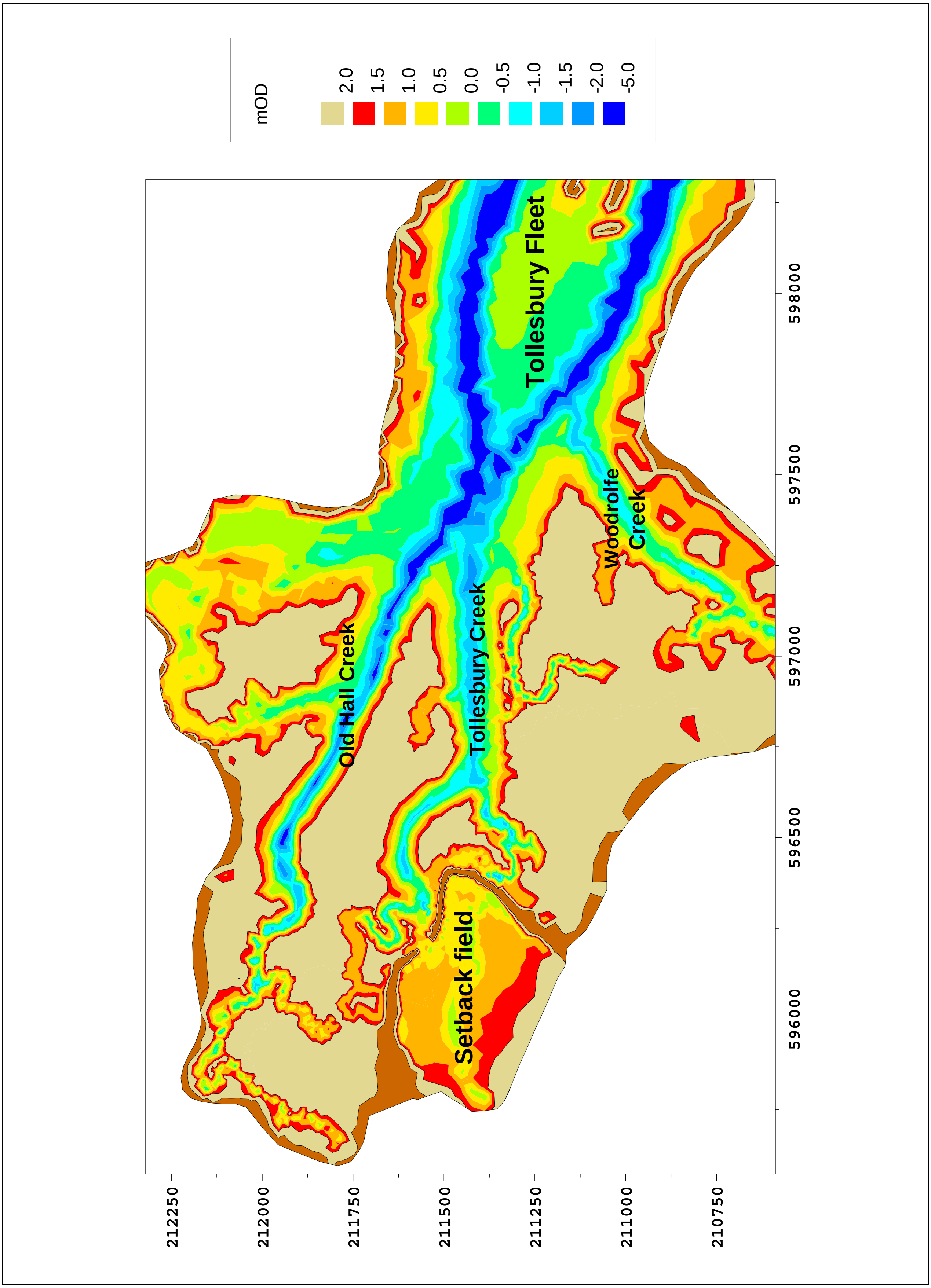

Figure 1 Location of Tollesbury Creek and breach

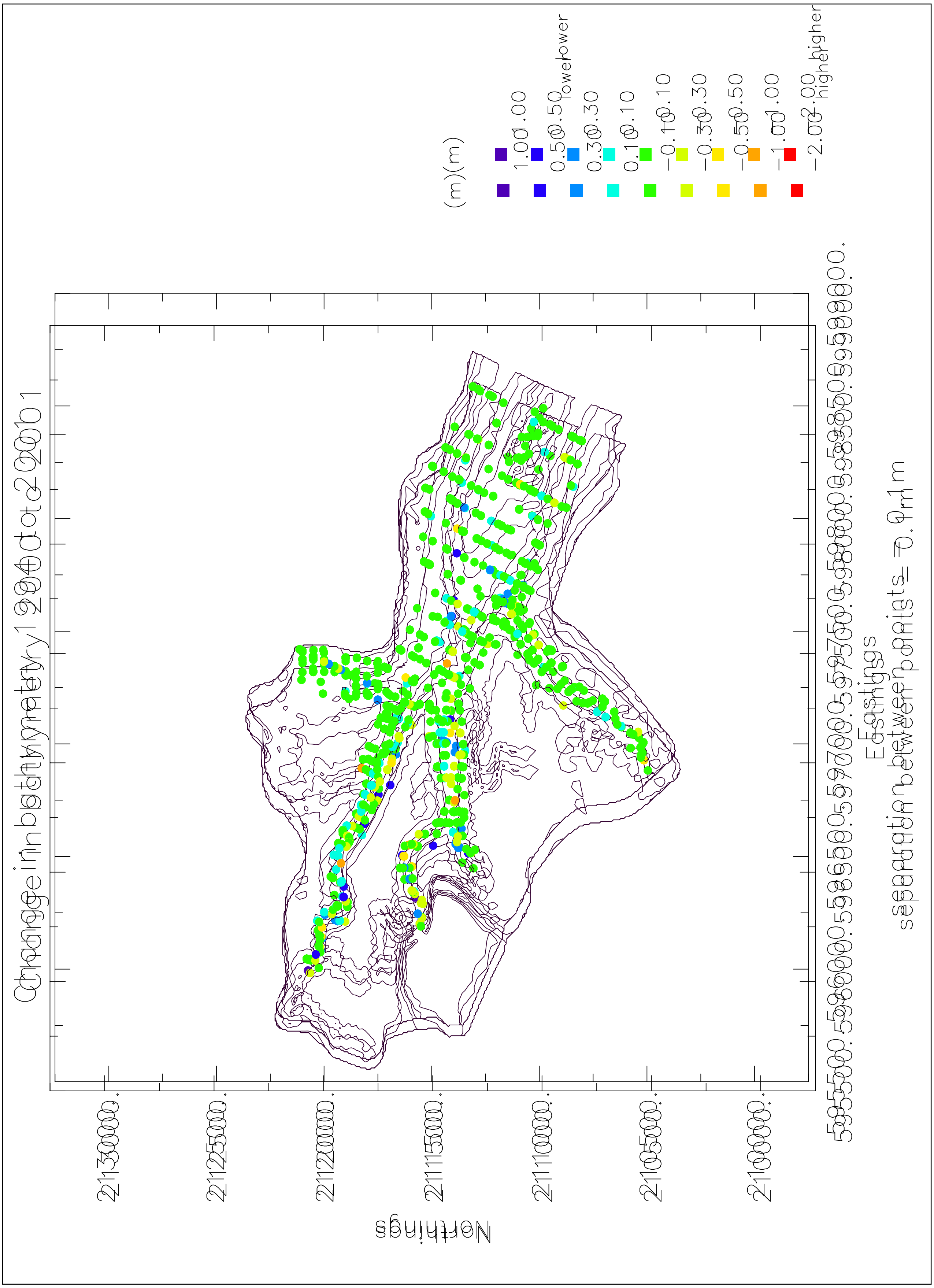

Figure 2 Changes in bathymetry June 1994 to November 2001 in the estuary, pairs of points separated by less than 0.1m

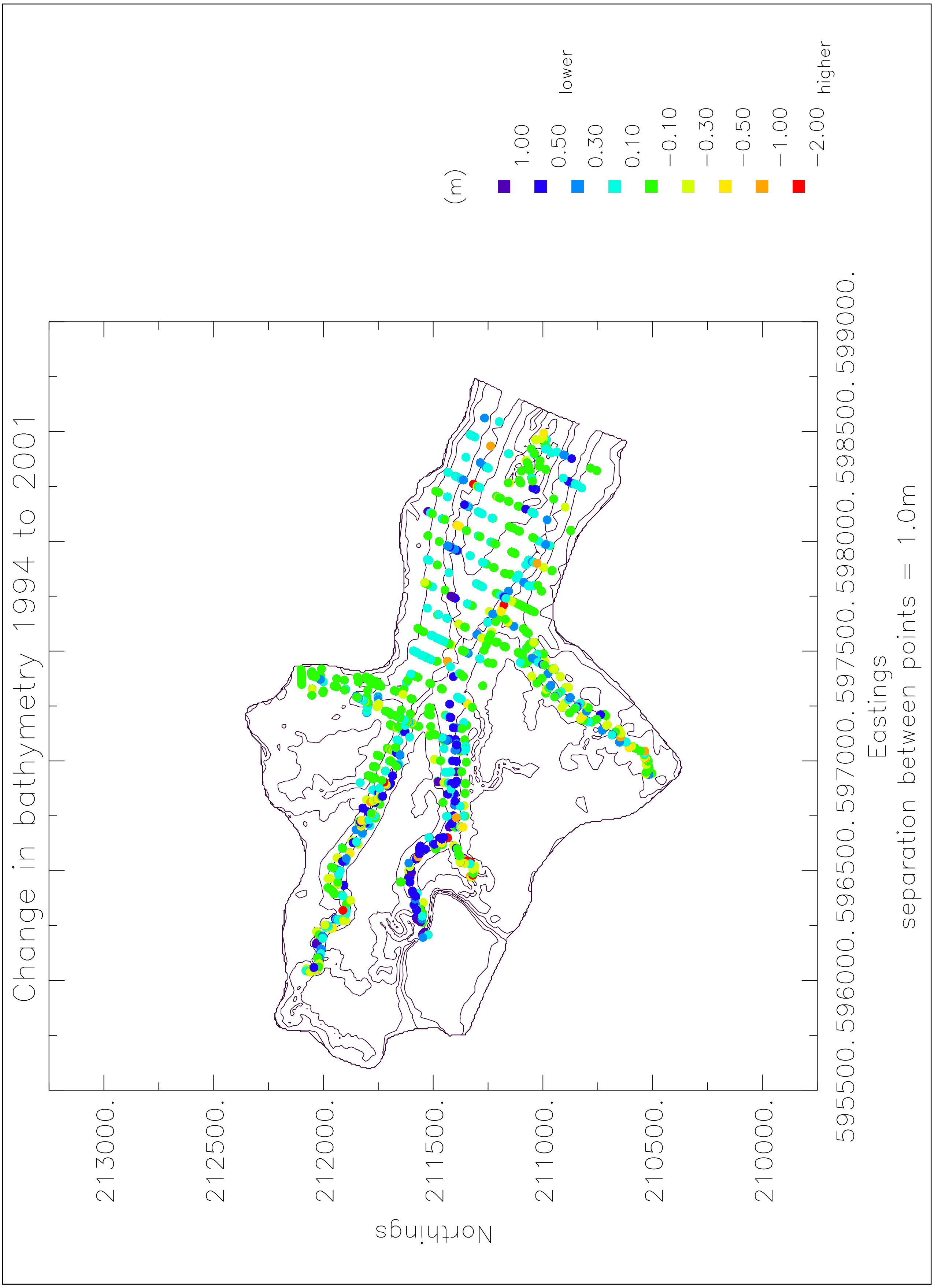

Figure 3 Changes in bathymetry June 1994 to November 2001 in the estuary, pairs of points separated by less than 1.0m

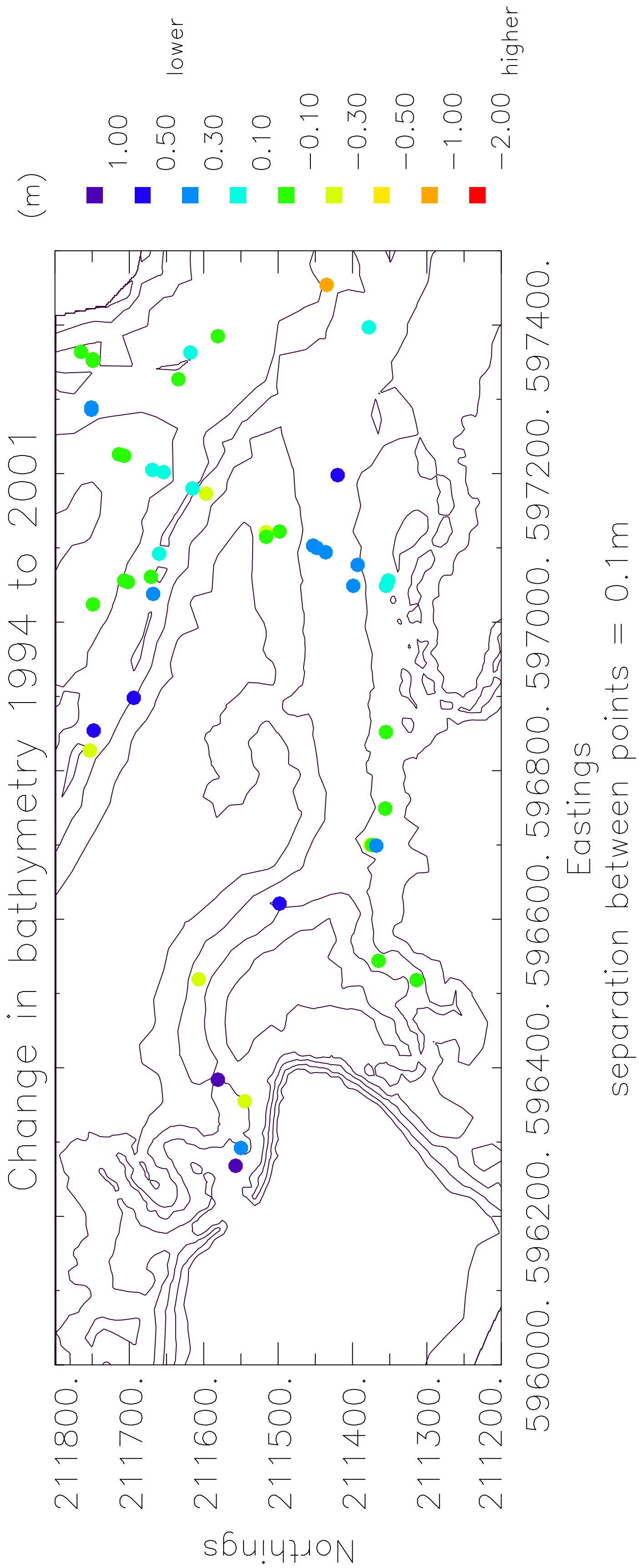

Figure 4 Changes in bathymetry June 1994 to November 2001 in Tollesbury Creek, pairs of points separated by less than 0.1m

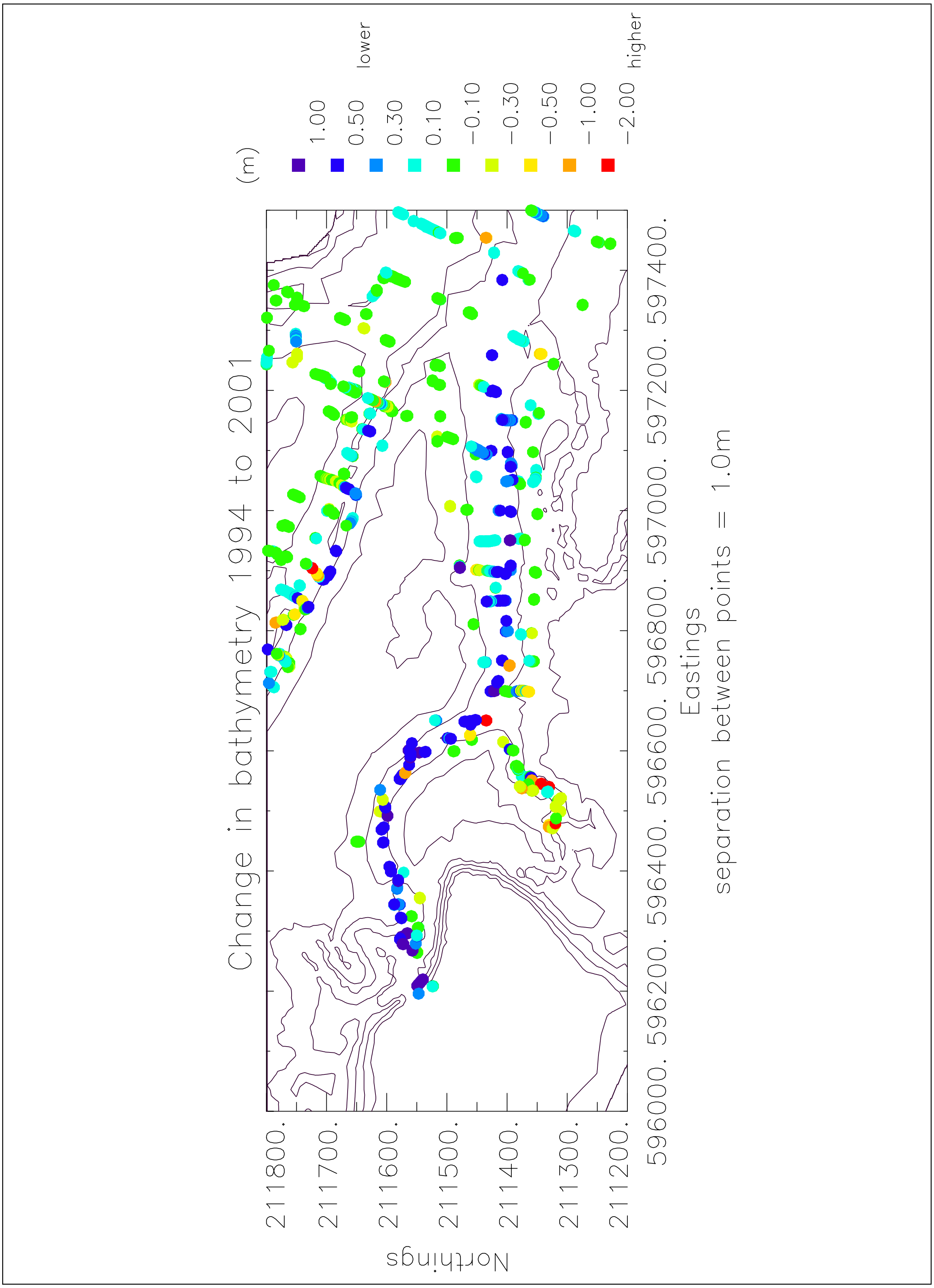

Figure 5 Changes in bathymetry June 1994 to November 2001 in Tollesbury Creek, pairs of points separated by less than 1.0m

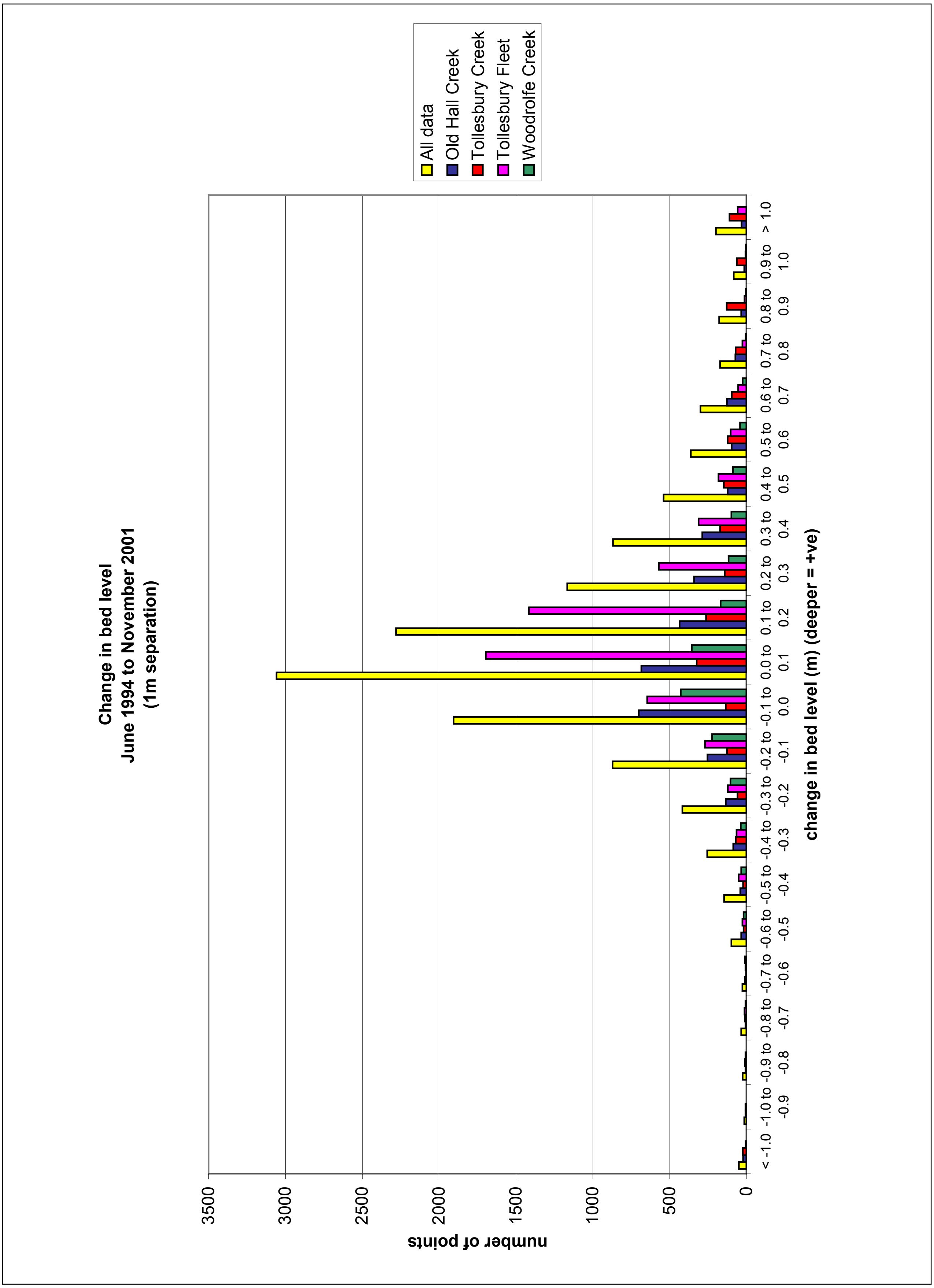

Figure 6 Summary of bathymetric changes June 1994 to November 2001

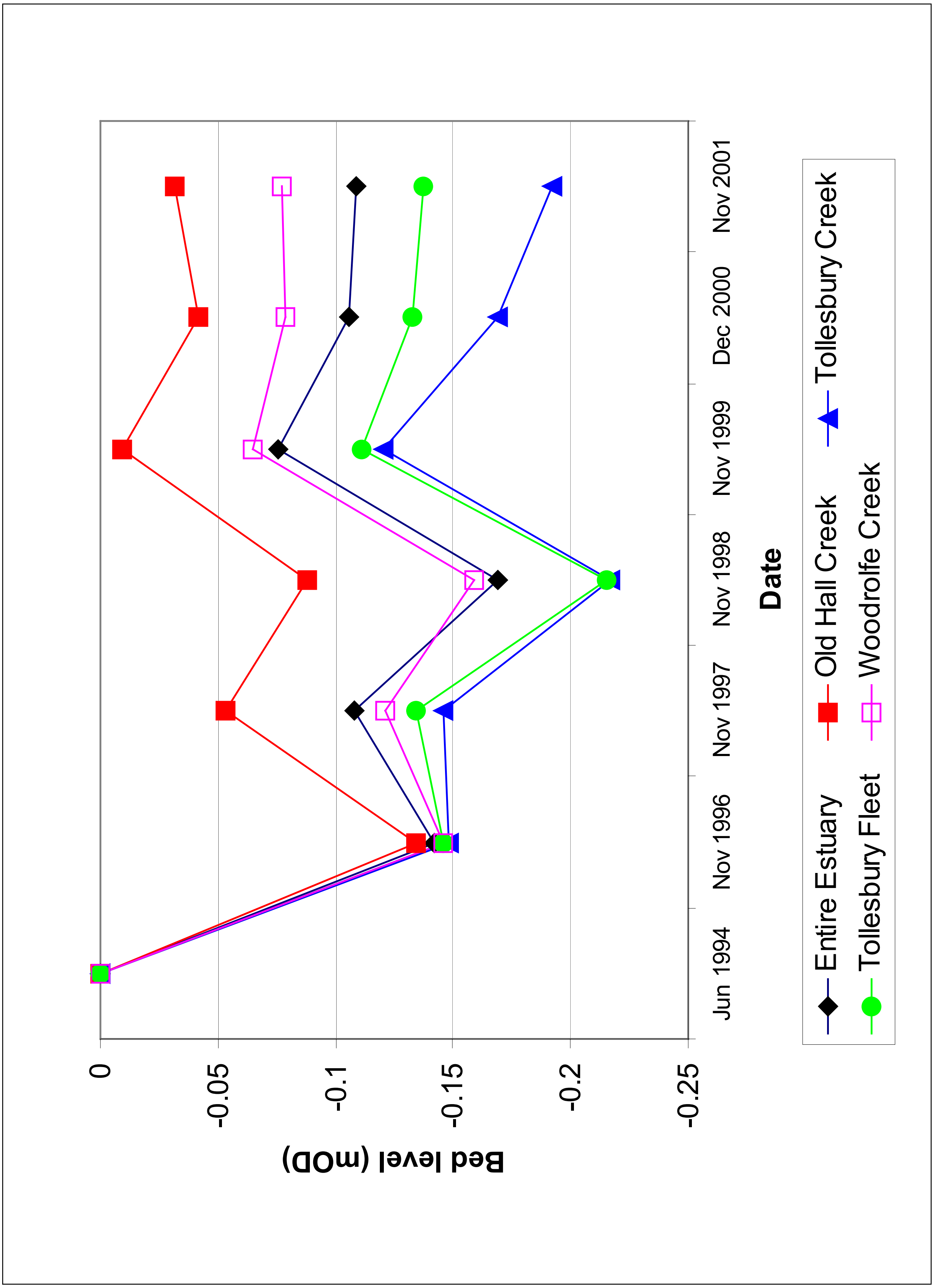

Figure 7 Mean cumulative changes in bed level throughout estuary

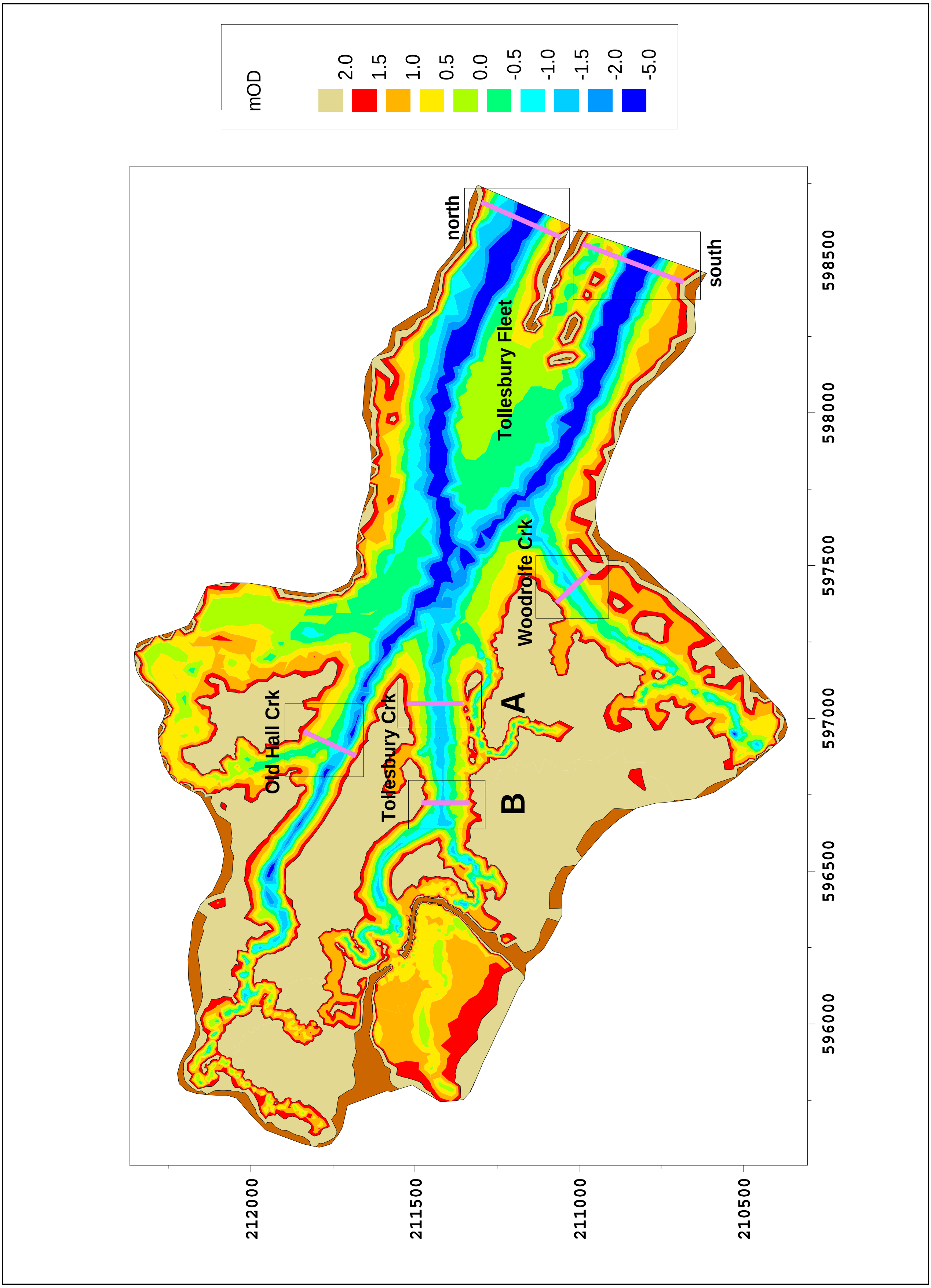

Figure 8 Locations of cross-section profile analysis

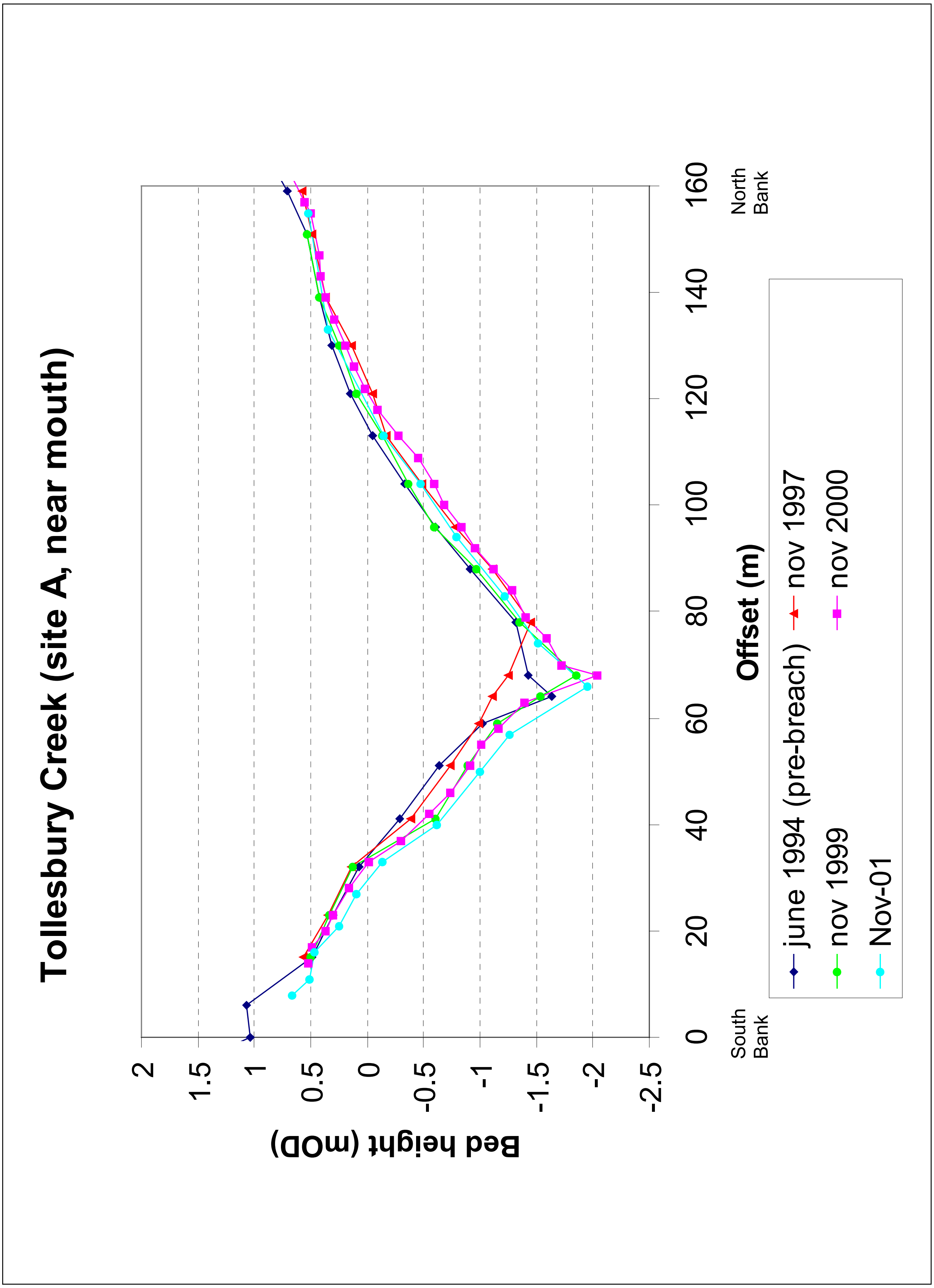

Figure 9 Changes in cross-section profile over the period June 1994 to November 2001 near mouth of Tollesbury Creek (site A)

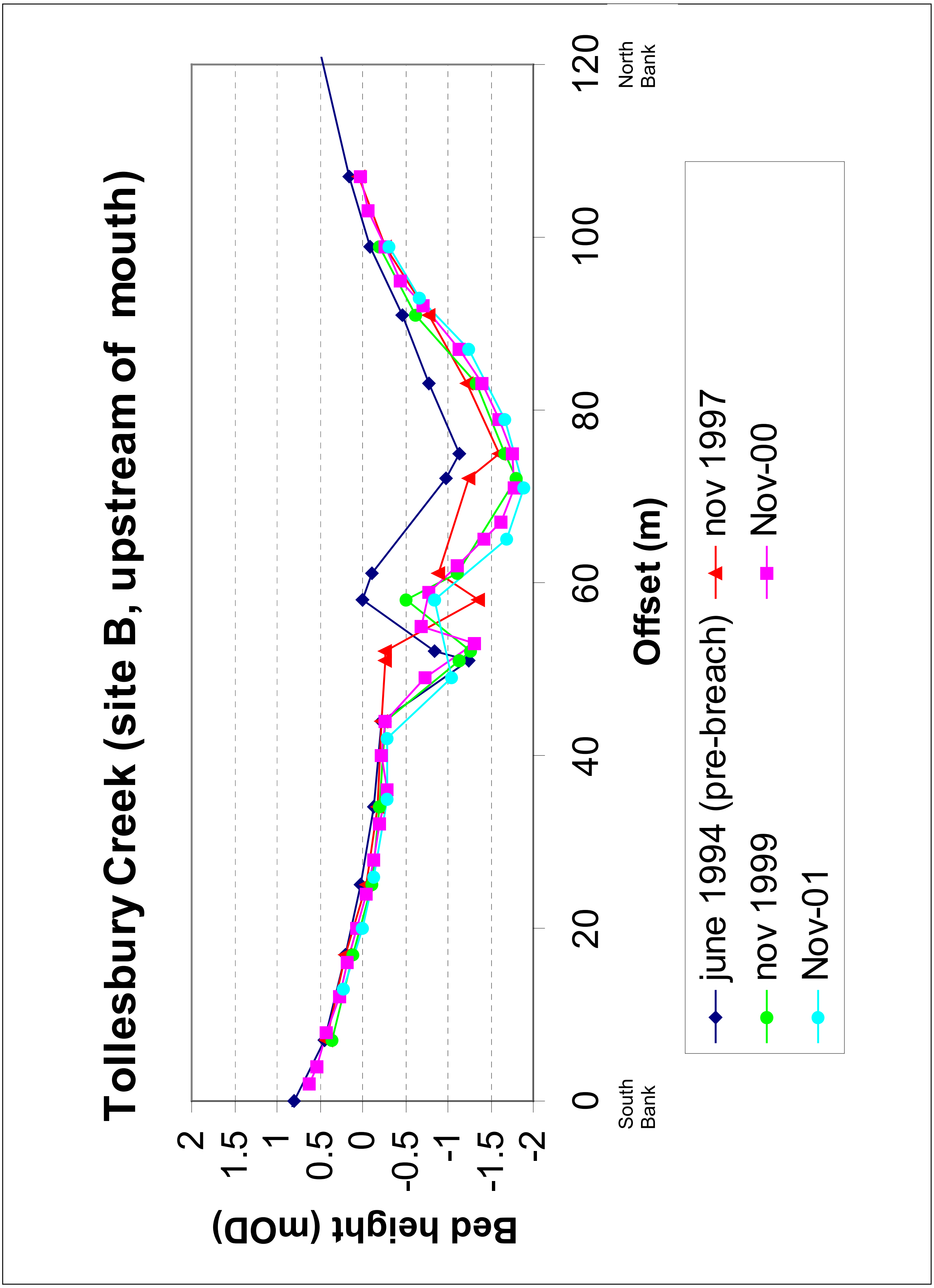

Figure 10 Changes in cross-section profile over the period June 1994 to November 2001 upstream of mouth of Tollesbury Creek (site B)

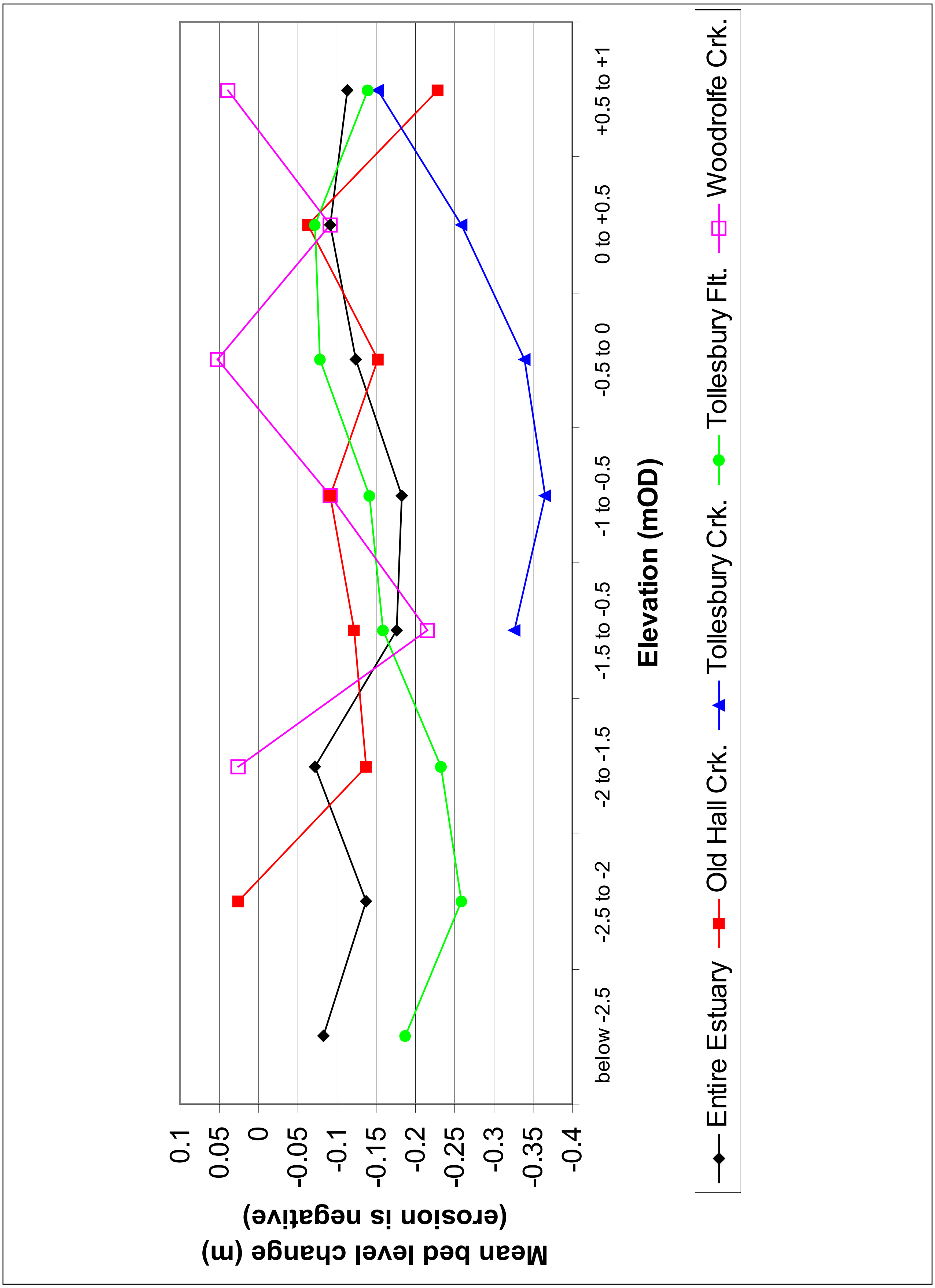

Figure 11 Changes in depth at different elevations over the period June 1994 to November 2001