SUSPENDED SEDIMENT TRANSPORT IN THE TAMAR ESTUARY

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Abstract

The aim of this study was to develop and apply a sediment transport model to the lower Tamar estuary, to explain the suspended particulate matter variability observed within the tidal cycle, its transition in character from neat to spring tides, and to describe the distribution of bed sediment in the lower estuary.

Suspended sediment concentrations, obtained from the lower Tamar estuary using optical back scatter sensors, showed a depth-averaged concentration of 0.02 kg m\(^{-3}\) throughout most of the spring-neap cycle. On spring tides the concentration increased to 0.15-0.20 kg m\(^{-3}\) either side of low water, however, the concentration maxima did not correspond to the time of maximum tidal flow which suggests the importance of sediment advection.

The observations were simulated using two-dimensional depth-averaged models of tidal currents and suspended sediment concentrations. Harmonic constants generated by the tidal model were used to estimate the advective terms and the bed shear stress in the sediment transport model. The sediment model included size fractions which represented the low settling velocity wash load (2 µm), the cohesive (25 µm) and the non-cohesive (75 µm) suspended loads. During spring tides the bed sediment (25 µm and 75 µm fractions) was resuspended in the upper model region and advected down estuary on the ebb tide in agreement with the observed concentration maxima. The finer silty material (25 µm) was deposited in the shallower upper model region whereas the sand sized particles (75 µm) accumulated in the deeper parts of the estuary in agreement with published data.

At neap tides no sediment resuspension was simulated in the lower estuary, again in agreement with observations.

1. Observations

The Tamar estuary (Figure 1) is a drowned river valley in SW England, which has a mean tidal range of 3.5 m and an annual mean freshwater discharge of about 27 m\(^3\) s\(^{-1}\). The upper reaches of the estuary are narrow (50-100 m) and a turbidity maximum is present in summer (e.g. Uncles & Stephens, 1993), which migrates down estuary in winter due to increased river discharge. At the Narrows, the depth increases (15-20 m) and there are fewer intertidal areas.

2. Model Validation

A 2-D tidal model of the Tamar estuary was developed using the standard shallow water non-linear equations with a numerical scheme that was normal in time and space, and included an algorithm to enable drainage of shallow areas. Tidal analysis of a six month tide gauge record from Mill Bay (Figure 1) provided harmonic constants which were used to force the elevation across the open boundary at Plymouth Sound. Tidal velocities obtained from the harmonic constants generated by the model showed good agreement with drag data recorded in the estuary (Figure 2). Figure 2a shows a simulation fitted with a drag profile released during a flood spring tide on 31 July 1996. Good agreement was also achieved with a drag track from an ab side track on 9 September 1997 (Figure 2b). The harmonic constants were used to estimate the advective terms and the bed shear stresses in a 2-D sediment model of the Tamar.

3. Sediment Redistributions

Figure 3 shows the simulated depth-averaged SPM concentration with a 15 day step size from July 1997. As spring tides the model reproduced the background concentration and the ebb tide peak heights to within a factor of 2. The observed low water concentration maxima were simulated by the model in a manner that was consistent with the data but the flood tide peak was not reproduced because the critical erosion friction velocity in the model increased down estuary. Further simulations (Tattersall et al. 2002) which allowed recently deposited sediment to be resuspended more easily enabled the flood peak to be reproduced to within a factor of 5. The model results confirm that no bed sediment was resuspended or advected past the mooring at Saltash during spring tides. The instrument was sensitive to about 1 kg m\(^{-3}\) above which it became saturated. At low water spring tides the instrument was often close to the bed and the sensor read the range-pairs when this occurred are shaded grey in Figure 2.

4. Sediment Redistribution

The sediment model was used to simulate 8 spring-neap cycles (approximately 4 months) and Figure 4 shows the change in bed elevation and comparison at high water neaps after this time. Figure 4a the mean depositional areas are shown in green and blue and are generally the shallower regions at the sides of the estuary, towards the head of the rivers Tamar, Tavy and Lydher and in the Hamoaze. Areas of erosion are shown in red and orange and occurred in the central channel mouth of Saltash, in the Narrows and in Plymouth Sound. Admittedly charts show that the Hamoaze is continually denuded to maintain the measured depth of the sediment while the simulated erosion areas in the Narrows and in Plymouth Sound are rocky outcrops where the bed is clear of sediment.

Summary

Observations of suspended sediment at Saltash showed a background concentration of 0.02 kg m\(^{-3}\) throughout the springs-neap cycle. Superimposed was a two-peaked increase in concentration, the first peak corresponding to the late ebb and the second to the early flood tide. Simulations of the sediment regime in the Tamar using a 2-D sediment transport model confirmed that there was little or no sediment resuspension in the lower estuary at neap tides. At spring tides, the modelled sediment was advected down estuary on the ebb tide in agreement with the recorded increases in SPM concentration. The 0.15-0.20 kg m\(^{-3}\) observed peaks were reproduced to within a factor of 2-3 by the model. After 4 months (8 springs-neaps cycles) the simulation showed an accumulation of fine silty particles in the upper reaches of the estuary and an increase of sandy sediment in the deeper Hamoaze, in agreement with published data. The main area of erosion was to the north of the Saltash mooring, close to the confluence of the rivers Tavy and Tamar.

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References


