# SEDIMENTOLOGICAL AND MORPHOLOGICAL DEVELOPMENT OF THE NEARSHORE AREA OF TEIGNMOUTH (UK)

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## 1. INTRODUCTION.

The nearshore area of Teignmouth (UK) was sedimentologically and morphologically investigated during the main COAST3D experiments in November 1999. Weather conditions included a stormy period characterised by a high-tidal and wave regime. As such, the results provide a better characterisation of the physical behaviour of an estuary-nearshore system in water depths ranging from 0 to -7 m ACD (Admiralty Chart Datum, Teignmouth Approaches).

Teignmouth is characterised by semi-diurnal tides of macrotidal range. The narrow estuary mouth gives rise to strong jet-like current flows that typically attain 2 m/s and gradually reduce in an offshore direction. The wave climate is mainly characterised by small, short period wind-driven waves. Fairly infrequent winds from the north to east are reponsible for generating storm waves and generally result in a dominant longshore drift to the south.

## 2. METHODOLOGY.

The survey platform, mv Sir Claude Inglis, allowed a detailed sampling of the surficial sediments and the deployment of a 410 kHz digital side-scan sonar. The surficial sediments were spatially collected along cross-shore transects up to 500 m offshore. The samples were analysed using a laser diffractometer and a series of sieves for the coarser fractions. The spatial extent of the small-scale morphology was investigated by means of rectified very-high resolution side-scan sonar mosaicing.

## 3. SEDIMENTOLOGICAL RESULTS.

Although the beach and nearshore bank system is composed of mixed sediments, the nearshore area off Teignmouth is characterised by fine, well-sorted sands (125-250 µm).
The estuary mouth itself is composed of very coarse sands up to the gravel size and its dynamics gives rise to three coarse-grained lobes, the position of which likely relates to shifts in the nearshore banks and channels. The observed grain-size distribution of these lobes results from selective transport processes arising from the reducing outflow velocities in a seaward direction. Hence, the area is characterised by deposition of coarse-grained bedload material, suspension fall-out and reworking of the fine-grained deposits. Outside the lobes no significant grain-size differentiation is observed. The sorting is moderate to poor in the lobes and moderately–well closer to the coast. The sorting is best in the offshore regions and areas shallower than -2 m ACD. Between -2 m and -5 m ACD, an admixture of fractions may be present. This is likely due to a coarser matrix that is sometimes enriched with finer grains. Bimodal sediments can occur where only a thin veneer of fine sands is deposited over coarse-grained ripple fields.

Using the sediment trend analysis procedure of Gao & Collins (1992), residual transport directions have been calculated on the basis of the areal distribution of the mean, sorting and skewness of the surficial sediments (Figure 1). As was expected from the general sedimentological findings, a significant transport pattern is seen from the lobes in an offshore direction. Still, this process is largely biased. To the north, the vectors clearly point to the southwest. However, southwest of the ebb tidal delta, the vectors point in an opposite way. Interestingly are the transport vectors at the offshore limit of the study area that point in an onshore direction and might be associated with an input of sediment from the offshore.

## 4. MORPHOLOGICAL RESULTS.

The acoustic facies on the side-scan sonar imagery can be interpreted in terms of sedimentological and morphological characteristics. Generally, the zones of higher reflectivity correspond with rippled areas where coarse-grained lag deposits predominate. The asymmetry of the NE-SW oriented ripples to megaripples is hard to distinguish. Although very restricted, eastward pointing lunate megaripples occur in the central lobe of the estuary mouth and are indicative of high current velocities. Around the rippled areas, zones of lighter reflectivity are present associated with finer sediments. Centrally, those areas are devoid of bedforms, whilst closer to the coast a more dynamic bedform pattern is observed (near East Pole Sand). To the north, the side-scan sonar imagery indicates the presence of cross-shore oriented megaripples. Most peculiar is the patchiness that dominates the nearshore area around the estuary mouth. Although, the acoustic facies resembles the presence of gravelly deposits, all of the samples consisted of fine well-sorted sands. Given the geological background of the area, the imagery might reflect an abrasion platform overlain with fine sandy sediments. Another or complementary explanation is the presence of fields of tube worms (presumably *Lanice conchilega*). This faunal assemblage is known to have a characteristic acoustic fingerprint as the colonies have a high capacity to trap suspended sediments forming an irregular bumpy surface.

## 5. SEDIMENT TRANSPORT PATHWAYS IN THE NEARSHORE AREA: DISCUSSION.

Generally, sediment transport pathways can be derived from the strike and asymmetry of bedforms and hence side-scan sonar imagery proves to be a valuable tool. However, in most shallow water environments the bedform patterns are generally more complex and no clear asymmetrical bedforms are observed. Still, the occurrence of bedforms itself is already a significant indication of sediment transport as it reflects an intense interaction of the seabed and the hydro-meteorological forces.

A superposition of the results of the sediment trend analysis vectors on the interpreted bedform map derived from side-scan sonar observations yields some interesting correlations (Figure 3). It is seen that the hatched zones, indicative of the occurrence of bedforms, correspond with a convergence of significant transport vectors derived from a sediment trend analysis. This could mean that in these areas, residual currents give rise to a sediment input and hence bedforms can be formed. This also implies that sediment availability is a major factor in bedform development.

To evaluate the sedimentological and morphological findings, they were compared with the results of the Coast3D modellers group. Generally, the models showed that the filling and the emptying of the estuary dominate the flow during spring tide. They showed a maximum flow velocity exceeding 2.5 m/s in the estuary throat ('jet-like outflow') whilst the offshore tidal flow speeds were less than 0.3 m/s. The flow models all produced a number of gyres or vortices during the emptying of the estuary. For spring tide conditions, the greatest calculated sediment transport rates were just outside the mouth of the estuary. For a single wave case, wave height, wave direction, wave-driven currents and sediment transport rates were modelled. The models all produced a clockwise gyre on the north side of the tip of 'Spratt Sand' and an anticlockwise gyre to the east of 'The Ness' as well as a number of other gyres towards the estuary mouth and along the coast. Interestingly, the pattern of the sediment transport vectors followed the pattern of the wave-induced current.

Compared to the field observations, the modelling results show some interesting similarities. The modelled jet-like outflow corresponds with the zone where coarse-grained ripples predominate and give rise to intense selective transport processes. From the sediment trend analysis, significant offshore directed transport vectors were calculated.
Although further research is needed, some correlation might exist between the larger modelled gyre structures associated with the strong outflow at the falling tide and the occurrence of bedforms in the nearshore. Especially, east of the estuary mouth, the occurrence of bedforms corresponds with a convergence of sediments as derived from the sediment trend analysis. Given more easterly directed significant transport vectors near 'Spratt Sand', the convergence might be associated with the modelled clockwise gyre structure.
It is thought that the southwestwards pointing transport vectors northeast of the study area reflect the normal littoral drift. Likely, they are also a reflection of an intensified sediment transport as the current is funneled through the flood channel close to the beach. This channel is the result of the flood tide eddy causing more southerly than northerly flow and giving rise to sandbars that are highly mobile (MILES et al. 1997).

The transport vectors at the offshore limit of the study area, southwest of the estuary mouth, are more difficult to understand as they show a highly significant sediment transport in an onshore direction. An explanation is however sought, taking into account the hydro-meteorological conditions preceeding the sampling campaign of November 4, 6-7$^{th}$.

In the pre-survey period, the high wind speeds were mainly generated from a south to northwestwards direction. From an offshore waverider buoy, it was shown that waves with a significant wave height exceeding 0.5 m had a mean incoming direction of 140 to 150°. Interestingly, this direction corresponds with the angle of the sediment transport vectors at the offshore limit of the study area. Towards the coast, this wave direction is known to induce a north to northeastwards longshore current direction (MILES et al. 2000). This might explain the direction of the transport vectors west of the estuary mouth.

## 6. CONCLUSIONS.

From the sedimentological and morphological evidence, it is clear that the Teignmouth site is very dynamic. Sediment mobility is high during fair-weather conditions owing to the strong jet-like current flows associated with the presence of the narrow estuary mouth. From digital side-scan sonar mosaicing, cross-shore and longshore oriented bedforms could be observed, with their characteristics largely dependent on the pre-survey hydro-meteo conditions. Although the nearshore system is dominated by the jet-outflow, leading to the formation of characteristic depositional lobes with poorly sorted sediment, littoral drift processes can also be important. Moreover, the influence of waves and associated longshore currents cannot be neglected as they form the link between different sedimentary environments. From combined side-scan sonar imagery and a sediment trend analysis, residual sediment transport directions were identified. This showed that fair-weather and storm-dominated processes are needed to explain the textural and morphological differentiation at this site. Further analysis will be required to identify the different time-scales involved in producing changes.

## 7. ACKNOWLEDGEMENTS.

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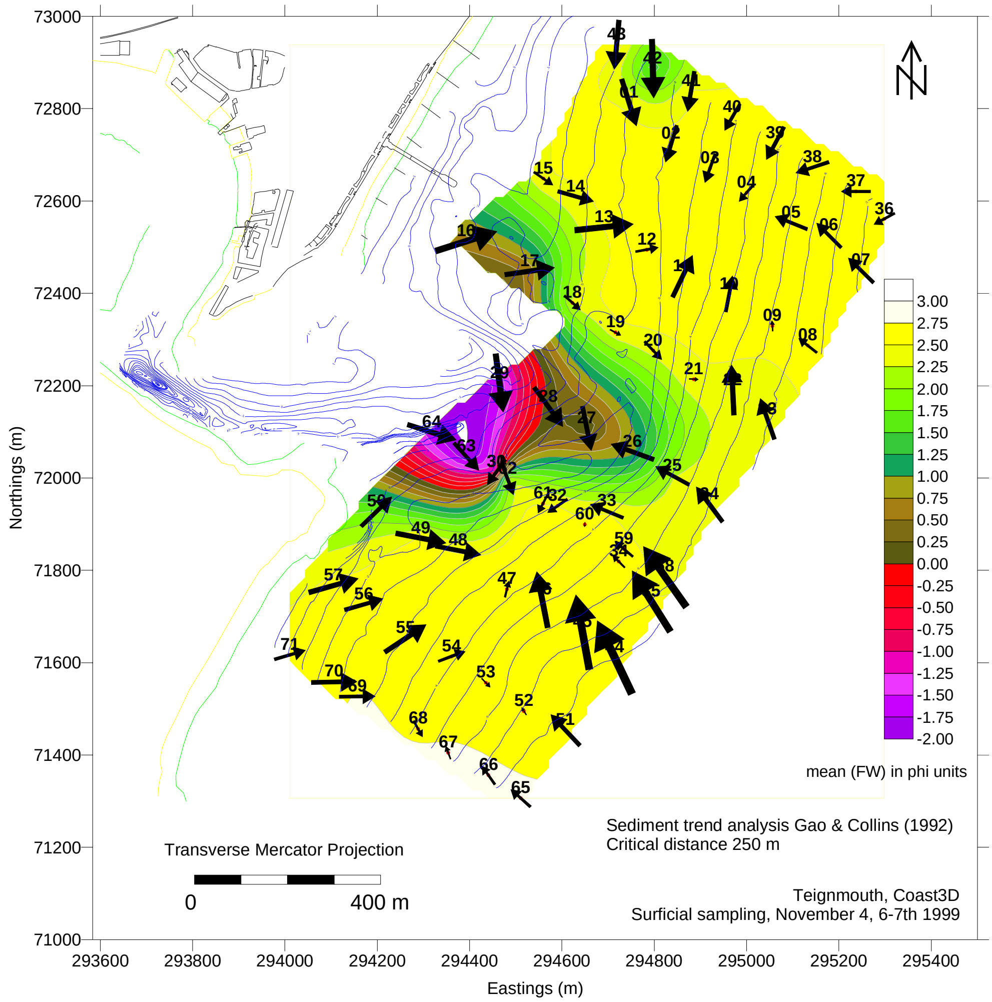


Figure 1: Sediment trend analysis using the GAO & COLLINS (1992) approach superimposed on a sedimentological map.

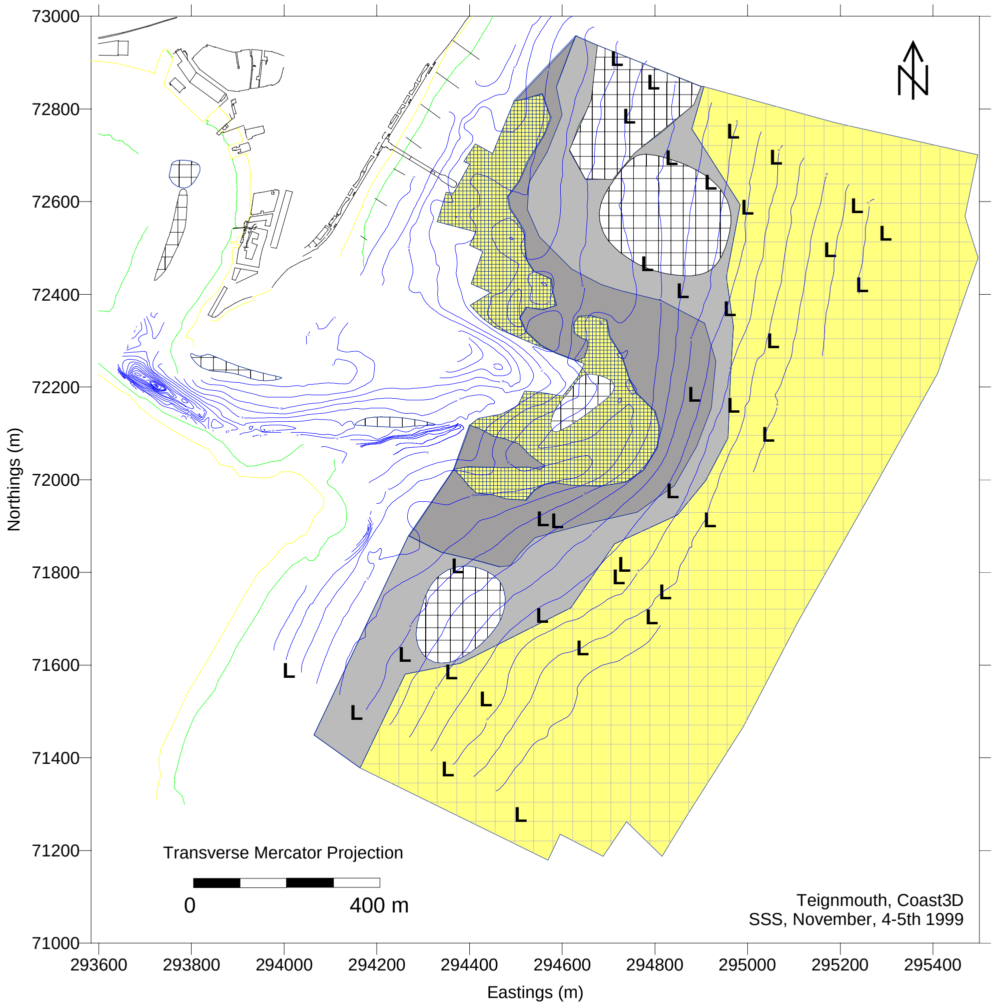


Figure 2: Areal distribution of the different acoustic facies in the estuary-nearshore area derived from side-scan sonar observations. The darkest hatched central part corresponds with the zones where coarse-grained ripples to megaripples are present. The surrounding grey zone is generally devoid of bedforms. However, in the lighter grey zone the hatched areas are representative of a higher dynamics witnessed by megaripples to sandwaves. The outer zone (lightest colour) corresponds with the area having a patchniness nature. “L” corresponds with the polychaet Lanice conchilega as found in the samples.