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RECENT ADVANCES IN SEDIMENT TRANSPORT PREDICTION
with particular reference to the Solent/Isle of Wight coastline

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1 INTRODUCTION

Sediment transport plays an important role in a wide diversity of practical problems. Furthermore, its prediction embraces many disciplines, with the most appropriate prediction method depending on the type of answers required. Two main classes of approach are in common use, which can be broadly classified as geological and physics-based.

2 GEOLOGICAL METHODS

For problems in which the main interest lies in describing the past and present sedimentary environment, the most appropriate approach is geological. The great strength of this approach is that it is based on what has actually happened to the sediments over a period of tens or hundreds of years. Techniques include observation of: presence and orientation of spits; groyne build-up; type and asymmetry of bedforms; direction of fining of sediments; mineralogy of known sediment sources; historical information on erosion/accretion; and many others. They can be supplemented by analysis of grab samples and sea-bed cores, and by biological indicators. An example of a biological indicator is the presence of weed growth in areas of low sediment mobility, such as the gravel beds to the west of the Isle of Wight. A good illustration of the application and interpretation of geological techniques is shown in Figure 1 (taken from Ref [1]), representing the sediment transport paths in the Solent/Isle of Wight area.

The arrows give a reliable indication of the directions of net sediment transport, but give no information about the rates of transport.

3 PHYSICS-BASED METHODS

Although the geological approach is the most powerful, and usually the cheapest, method of obtaining a qualitative description of past and present sediment transport, it is much less satisfactory for providing quantitative answers, or for predicting the sedimentary consequences of coastal engineering works. For this physical and mathematical techniques are most well situated. These do, however, suffer from the disadvantages of being indirect techniques in as much as their primary ability is the prediction of water movements, which are subsequently used to predict sediment transport rates. Areas of net erosion and accretion are then calculated as the long-term means of derivatives of the transport rates. Since the answer is often based on small differences between large numbers there is possible scope for error. To boost confidence in the model's predicted response to proposed engineering works one can compare model predictions of present day sediment transport paths with independent predictions made using the geological approach. Such comparisons have yielded encouraging results [Ref 2].

For the majority of problems, particularly around the British coast, both currents and waves are important agents for sediment transport. A current is capable of transporting sediment on its own, but waves can enhance the transport rate by a factor of several hundred. In essence the waves stir up the sediment which is then transported by the current. The currents may be tidal, wind-induced, or wave-induced (as in longshore currents).

Significant advances have recently been made in the modelling of sediment transport by waves and currents (W+C). Over the past five to ten years a number of

W+C numerical models have been devised in the UK and abroad to make predictions for coastal areas. Most of them, however, have concentrated on refining the hydrodynamic predictions of the distributions of currents and waves, while still using at the final step sediment transport formulae of doubtful validity. A recent comparison [Ref 3] of some of these formulae with field and lab data showed that none was capable of predicting transport rates to within a factor of 10x for more than 50% of the data. Our own MAFF-funded research has therefore been largely directed towards deriving an improved formula. We are also tackling a second problem, which strongly influences the hydrodynamics as well as being intermediate in the transport formulation, namely the prediction of the mean and peak bed shear stresses. Existing analytical methods of obtaining bed shear stresses yield answers which are complicated to apply as they are usually iterative, and frequently also require higher mathematical functions to be calculated. Through a combination of field measurements [Ref 4], numerical methods [Ref 5, 6], and analytical interpretation [Ref 7] we are developing simple algebraic predictors for the bed shear stresses, which are nevertheless likely to be as accurate as the more complex methods. Similar methods are being used to devise the improved W+C sediment transport formula [Ref 7].

At the same time we are directing effort towards improving the operational side of the prediction capability. A simple method has been devised [Ref 8] to calculate the wave orbital velocity at the sea bed for natural random seas, thereby bypassing a previously laborious computation step. The orbital velocity is required as the input to W+C boundary layer calculations. A full two-dimensional W+C numerical model can only be run economically for a limited number of tidal and wave conditions, from which the long-term mean sediment transport pattern over several years must be deduced. Clearly the resulting answers depend strongly on the inputs chosen, and a more rational method of selecting these has been devised [Ref 9]. To test the methods being developed, and compare them with existing alternatives, a one-dimensional numerical W+C model has been developed, simulating a slice taken perpendicular to a long straight coastline on which both tides and waves act [Ref 10]. All the modes of interaction between wave and current are included in the model. Being 1D the model can be run inexpensively for large numbers of inputs (eg hourly wave and current conditions over several years) making it additionally a powerful tool for practical problems.

Turning to the example of the Solent/Isle of Wight coastline, the 1D model could feasibly be applied to selected, relatively straight, stretches of coastline, such as that between Sandown and Ventnor. The input data required by the model are: tidal height information from the Admiralty Tide Tables supplemented by any available current measurements, wave data either from measurements or by hindcasting from wind data, beach profiles, and sediment grain-size information. Such a model could be constructed and run sequentially through one year's worth of hourly wave and current inputs (8760 values) for a cost of £4-6K per site. However, to simulate mathematically the sediment transport paths over an area similar to that in Fig 1 would require a full 2D W+C numerical model. Inputs would be similar to those used for the 1D model, but only a rather limited number (perhaps 30) of wave and current conditions could be modelled within a budget of £60-80K which is a typical cost for the construction and use of a 2D model.

In October 1986 we took measurements at a site on the gravel area south west of Freshwater. These were intentionally made on a generally immobile area of bed in order to optimise their value in aiding understanding of the hydrodynamics of the W+C boundary layer. They do not therefore yield any direct information on sediment transport, though they would help to validate the wave and current predictions of a 2D numerical model.

4 SUMMARY

Geological methods provide the best approach to determining the present sediment transport paths. However, if quantitative answers are required, or most particularly if predictions of the sedimentary consequences of proposed engineering works are required, the physical/mathematical approach is much more powerful. To produce a quantitative map of the sediment transport paths in the whole Solent/Isle of Wight area would require the construction of a 2D numerical model costing £60-80K. Selected stretches of relatively straight coastline could be modelled in detail by a fully interactive 1D numerical W+C model for a cost of £4-6K per site. Recent advances in the understanding and application of the physical processes involved are improving the accuracy of numerical models of sediment transport due to combined waves and currents. Present research will enhance the prediction capability significantly further, aiding the design of offshore structures and coast protection measures.

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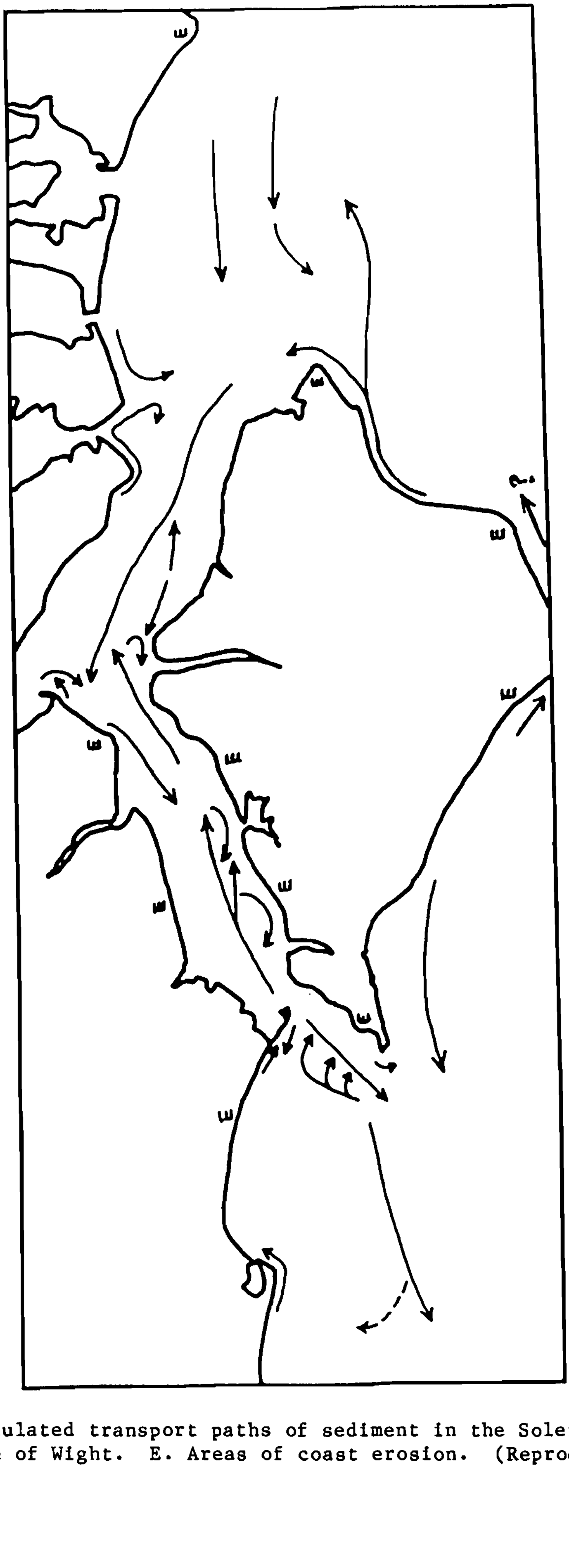

Fig 1: Postulated transport paths of sediment in the Solent and around the Isle of Wight. E. Areas of coast erosion. (Reproduced from Ref. 1)