MORPHOLOGICAL BED-UPDATING MODELS

Method Indicator		
Bottom-Up	Hybrid	Top-Down
YES		

Summary of key issues

Issue	Description
Description	Prediction of changes to bed levels based on sediment transport modelling. The bed elevations are updated at regular intervals to provide a feedback to the hydrodynamic and sediment transport models.
Temporal Applicability	Often applied to the medium-term (single tide up to several months) but can also be applied to consider the long-term.
Spatial Applicability	Varying from a single point to estuary-wide including the open coast.
Links with Other Tools	Hydrodynamic; sediment transport, and various top-down modelling tools.
Data Sources	Similar to those for the hydrodynamics and sediment transport modelling. • Model set up: - Land boundary (x,y format); - Bathymetric data; - Wind and atmospheric pressure; - Measurements of bed friction or roughness. • Boundary conditions: - Seaward tidal boundary conditions; - Freshwater discharge information; - Salinity boundary conditions; - Offshore wave climate. • Calibration data: - Water levels along the length of the estuary; - Flow speeds and directions (or vector format u, v); - Salinity measurements; - Wave measurements or statistics.
Necessary Software Tools / Skills	Hydrodynamic model (e.g. TELEMAC); top-down hybrid models such e.g. realignment model. A good understanding of long term estuary processes including hydrodynamics and sediment transport and long-term estuary response to environmental changes is required to interpret the predicted changes in bed elevations.
Typical Analyses	Sediment transport and hydrodynamic modelling. The hydrodynamic model predicts flows and water levels over the model domain. This information is then used to determine the sediment transport regime. The accretion or erosion estimates are then used to update the bed levels before the sequence recommences with calculations of water levels and current flows in the next time step of the model. Morphological models have to deal with a high degree of uncertainty regarding the processes which occur and the manner in which the system reacts to them as morphology is at the end of a chain of the following inter-related processes.

Limitations	Calibration and validation of the model predictions against historic bathymetric data is often a limitation. Sediment flux information for boundary conditions is often limited. Long computational time.
Example Applications	Tollesbury Creek, Humber Estuary

Morphological bed updating models are based on hydrodynamic and sediment transport models that consider feedback between the models. Generally the two components of the model are run in parallel with the results fed from one into the other at each time step. The hydrodynamic model predicts flows and water levels over the model domain. This information is then used to determine the sediment transport regime. The accretion or erosion estimates are then used to update the bed levels before the sequence recommences with calculations of water levels and current flows in the next time step of the model.

Morphological models have to deal with a high degree of uncertainty regarding the processes which occur and the manner in which the system reacts to them as morphology is at the end of a chain of the following inter-related processes (STOWA-RIZA, 1999).

Water levels → sediment transport → flow rates → morphology

The complexity and inaccuracy increase significantly with distance down this chain. A morphological bed-updating model requires the linking of the output morphology with the water level inputs, to recalculate both the intermediate steps and the bed morphology. Complexity and inaccuracy and therefore uncertainty in the modelling results will also increase with the number of iterations along this chain. The approach has been applied to the modelling of realignment or setback sites within estuaries.

Data requirements

The data requirements for Morphological Bed-Updating models are similar to those outlined for the hydrodynamic and sediment transport modelling.

The model methodology builds on the conceptual modelling approach to habitat development employed successfully by di Silvio (1989), di Silvio and Gambolati (1990) for lagoons. It is a Hybrid method, combining both bottom-up and top-down aspects to describe the essential inlet functioning, and also has built-in flexibility to incorporate the effects of waves and vegetation, and future developments.

Model structure

The model structure is based on a simple UNIX shell script which controls application of the model elements in Figure 1. The shell script allows flexibility, enabling the user to implement the software which they possess rather than proprietary software, and is simple to adapt to the Windows equivalent (e.g. Visual Basic). The run sequence is:

1. Set up initial bathymetry;

2. Work out time-averaged wave heights and periods at every point in model domain (using the wave model of Young and Verhagen, 1996);

3. Use TELEMAC-2D flow model to get flow conditions in set back field;

4. Post-process the flow results file and wave results:
   - To derive time-averaged spatial distribution of diffusion coefficients (Dronkers *et al*., 1982);
   - To derive the spatial distribution of time-averaged equilibrium concentrations C_E (an important morphological parameter);
   - Saving derived values in a form which can be used as input to SUBIEF-2D model;

5. Run "di Silvio-type" time-averaged sediment transport model SUBIEF-2D with net erosion *E* as originally given by Galappatti and Vreugdenhil (1985),

$$E = w\,(C_E - C) \qquad (1)$$

   - Where a negative value indicates deposition, *w* is the settling velocity, C_E is an equilibrium concentration and *C* is the actual concentration;
   - Using derived time-averaged diffusion coefficients and zero residual currents (i.e. diffusive process only);
   - Updating bathymetry during the model simulation;

6. Extrapolate predicted change in bathymetry from SUBIEF-2D model over a much longer time step and save to results file;

7. New bathymetry (5) is used as basis for another run of TELEMAC-2D – go to (2).

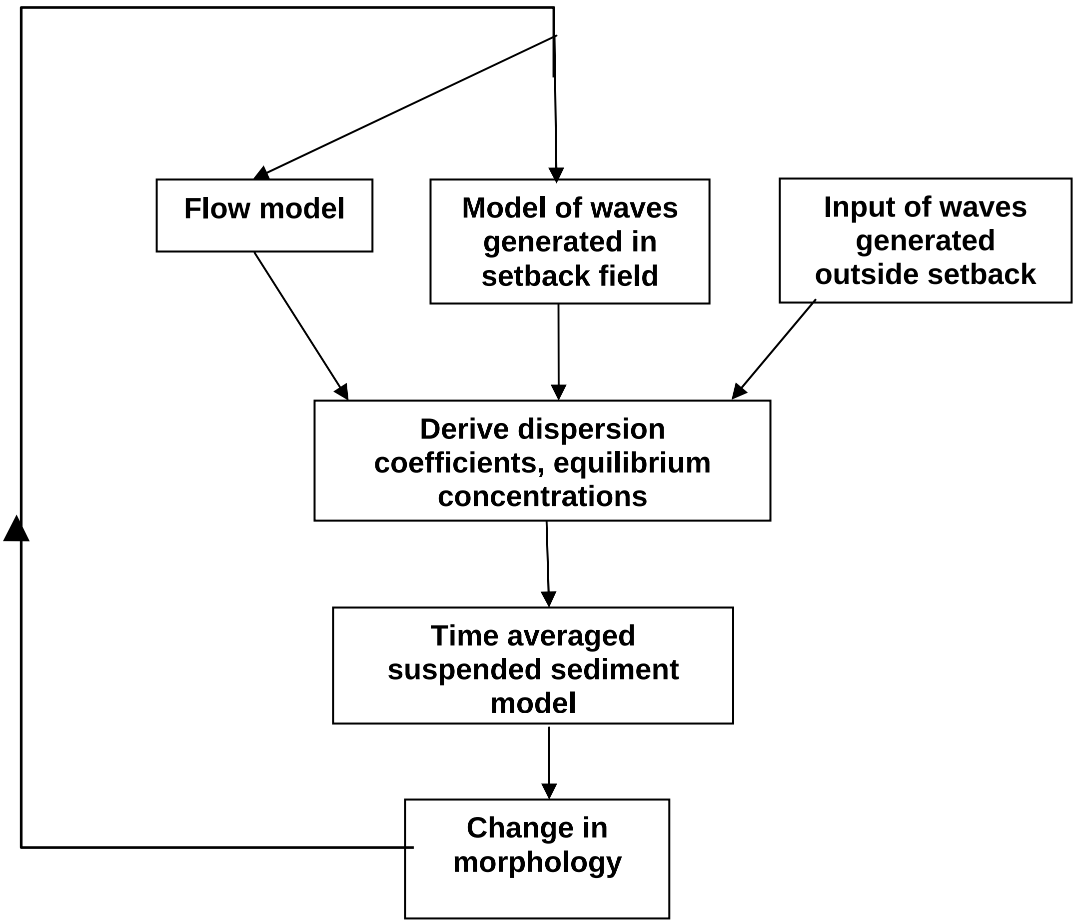

Figure 1. Basic structure of morphological Realignment model

Method for deriving the time-averaged diffusion

As there is no residual transport in the model setback fields, time-averaged sediment transport into the field is modelled as a diffusive process, controlled by the (spatially varying) diffusion coefficient. This coefficient is assumed to be proportional to the square of the time-averaged current speed within the setback field (based on Dronkers *et al.*, 1982). The absolute magnitude of the diffusion coefficients was calibrated along with the other model parameters.

Method for deriving the time-averaged equilibrium concentration C_E

A managed realignment site is "virgin"; any previous functioning (hydraulic, sedimentological, vegetative or biological) is an unrepresentative basis for evaluating equilibrium concentration empirically. In the absence of a general empirical law governing the evolution of muddy tidal inlets, a simple analytical method is used, based on process. C_E is given by equating the deposition occurring during slack water with the erosion during the rest of the tide:

$$\int_{\tau>\tau_e} M_e(\tau-\tau_e)\,dt = \int_{\tau<\tau_d} w_s C\left(1-\frac{\tau}{\tau_d}\right)dt = C_E \int_{\tau<\tau_d} w_s\left(1-\frac{\tau}{\tau_d}\right)dt \qquad (2)$$

Thus C_E depends on (spatially varying) current speed, wave action and the friction parameter (together determining bed shear stress), erosion and deposition thresholds, settling velocity and the erosion rate. There is inherent uncertainty in the values of the friction and sediment parameters; values can be estimated from literature but C_E will remain somewhat uncertain.

Processes not presently included in the model

The effect of biology on bed shear stress is not presently included; nor are erosion (via geotechnical processes) of the sea walls at the entrance to the set back site, or erosion of the initial bathymetry (re-erosion of deposited sediment *is* reproduced);

Commercial software used in the model

The morphological model uses the following commercial software:

a) The TELEMAC-2D flow model, designed by Laboratoire National d´Hydraulique et Environnement (LNHE), a finite element model which solves the shallow water equations;

b) The SUBIEF-2D suspended sediment model (mud transport module of TELEMAC, again designed by LNHE). For this study, the code was altered:
   - SUBIEF-2D reads the calculated dispersion coefficients and equilibrium concentrations;
   - the calculations of erosion and deposition were changed from the usual formulations (Krone 1962, Partheniades 1965) to that of Galappatti and Vreugdenhil (1985).

Case study: Tollesbury Creek (Blackwater)

Figure 2 shows predicted evolution of a managed realignment at Tollesbury Creek, compared with the observed evolution, using the morphological bed-updating approach. The modelling is detailed in Spearman (2007).

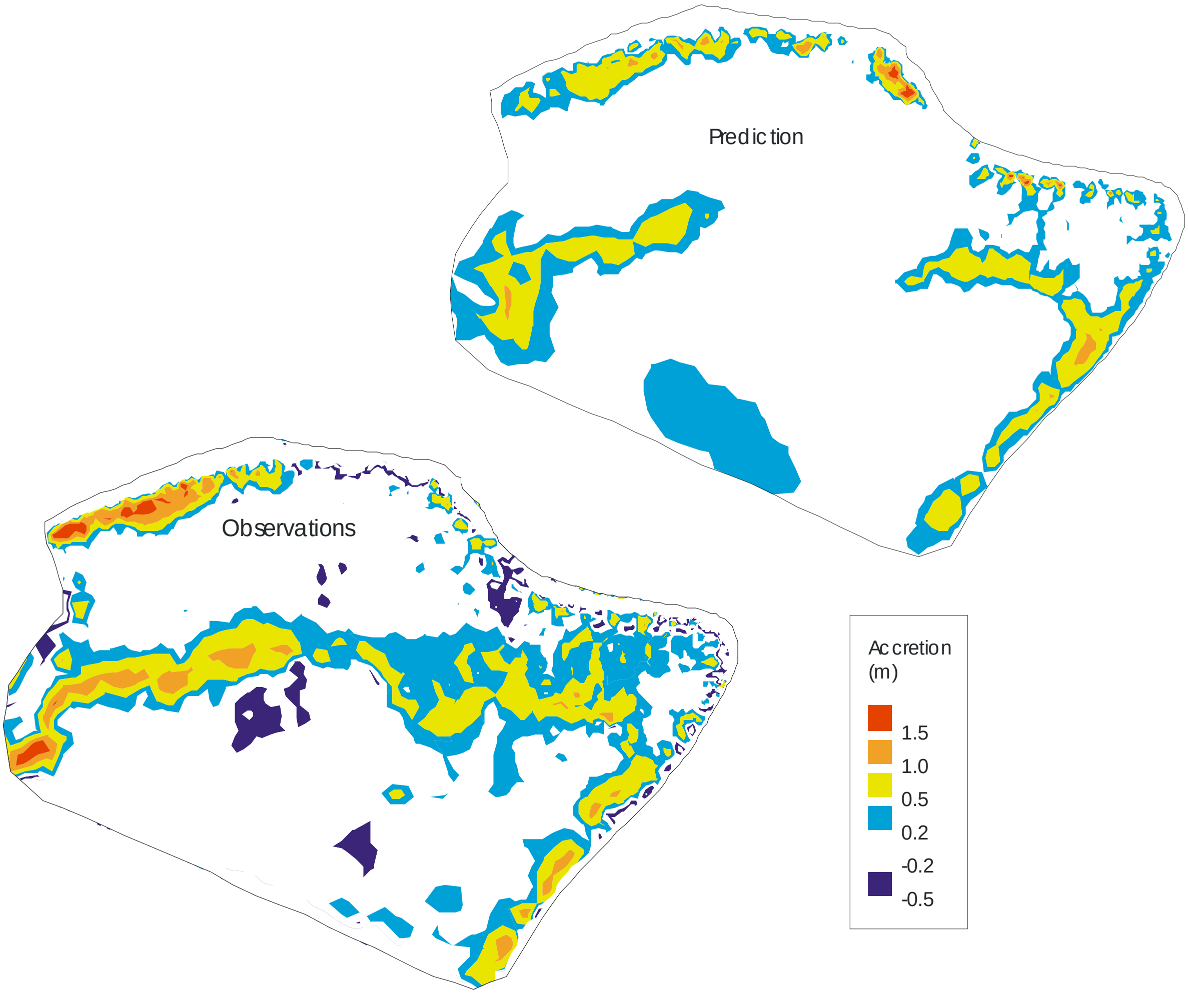

Figure 2. **Bed-level change in Tollesbury managed realignment site 1995-2002; comparison of observed and predicted (Spearman, 2007)**

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