PARTICLE TRACKING

Method Indicator		
Bottom-Up	Hybrid	Top-Down
YES		

Summary of key issues

Issue	**Description**
Description	This technique typically uses the output from hydrodynamic and/or advection-diffusion models to predict particle movements in a Lagrangian manner. The flow regime is seeded with particles having defined properties (size, density, settling velocity, etc) and tracked as they move with the flow. This is a useful means of visualising flow patterns, particularly eddies and recirculation cells but can also be used to examine the movement of material away from particular activities such as dredging, dumping, outfalls, etc. By examining the statistics of how particles are re-distributed in the model domain, it is also possible to extract some quantitative information.
Temporal Applicability	Typically applied to the short-term (single tide up to several months).
Spatial Applicability	Varying from a single point to estuary-wide including the open coast.
Links with Other Tools	Typically, particle models are run using the output from a hydrodynamic flow model. Links have also been established with bed updating methods to provide a form of hybrid bed updating model (Sandtrack)
Data Sources	• Particle Characteristics; • Boundary conditions; • Seaward and riverine suspended sediment concentrations; • Location of sediment inputs; • Calibration and verification data; • Suspended sediment concentration; • Historic bathymetric data.
Necessary Software Tools / Skills	A range of modelling skills can be required depending on the complexity of the hydrodynamics of the area being studied and the particles being simulated. Typically, expert knowledge of hydrodynamics and water quality is required.
Typical Analyses	Transport of particles, looking at the fate and concentration within the environment.
Limitations	Computation time increases linearly with the number of particles, this is often a limiting factor. Calibration data for the particle model is often limited with assumptions made for diffusion/dispersion coefficients.
Example Applications	Thames and Humber Estuaries.

Particle tracking uses the output from hydrodynamic and/or advection-diffusion models to predict particle movements in a Lagrangian manner. The flow regime is seeded with particles having defined properties (size, density, settling velocity, etc) and tracked as they move with the flow. This facilitates the visualisation of flow patterns, particularly eddies and recirculation cells but can also be used to examine the movement of material away from particular activities such as dredging, dumping, outfalls, etc. Quantitative information can be obtained by examining the statistics of how particles are re-distributed in the model domain.

The discharged or spilled material is considered as particles being advected with the surrounding water body and dispersed as a result of random processes including the dispersion caused by current, wind-induced turbulence and molecular diffusion. A corresponding mass is attached to each particle. This can change during the simulation. Additionally, the particles can deposit with a constant settling velocity and re-suspend.

Particle Tracking methods are crucial to simulating transport phenomena such as transport of pollutants in coastal waters. These methods are able to quite accurately predict the pollutant transport in cases of steep concentration gradients after the pollutant has just entered into the water whereas conventional methods such as finite difference and finite volume methods may have difficulties. Since the computation time in a particle model increases linearly with the number of particles, this often forms a limiting factor.

Prior to the start of the ERP Phase 2 project ‘Development of estuary morphological models’ (FD2107) (Huthnance *et al*., 2007) HR Wallingford had developed an existing model (SandTrack) for Lagrangian particle-tracking of sand-grains including bedload, suspended load, incipient motion and burial processes. The model operates by tracking “tagged” grains of sand, each representative of many billions of similar grains, as they move driven by the flow (predicted by a numerical model, e.g. TELEMAC), and runs over times of typically a few weeks to a few decades to give predictions of where the tagged grains are finally deposited. The model has been extended to associate a volume of sediment with each tagged grain, and deposit it on the bed in diffuse fashion as a sediment “lens” with defined maximum thickness and extent. The lenses combine to give the morphodynamic development of the estuary. By repeating this process at intervals of, for example, 1 year, with the hydrodynamics re-calculated at each step, this becomes a hybrid morphodynamic model: Morpho-SandTrack (Soulsby *et al*., 2007).

Particle tracking has the advantage over other hybrid models in that, in areas of deposition (e.g. tidal flats, saltmarshes) the source of the deposited sediment is known as well as its thickness. The tagged particles can carry a marker to indicate whether they are polluted with heavy metals, for example (although this feature was not implemented in FD2107; Huthnance *et al*., 2007). The characteristic dimensions of the lenses of transported sediment have been calibrated against the well-established Van Rijn (1993) sediment transport formula, by running Morpho-SandTrack for an idealised flume case with various steady current speeds and sediment grain sizes.

The newly developed and calibrated Morpho-SandTrack model was tested in the Thames Estuary, to predict the morphological changes over a 50-year interval, with a one-year update frequency for the bed and the flow. The results look plausible in some areas, although there are also some unresolved discrepancies, possibly due to the pre-existing Thames Estuary flow model having a rather coarse grid resolution within the narrower parts of the estuary. The present model does not include the effects of waves, although it would not be difficult to add these in future developments; they are already included in the original SandTrack model. Such wave effects might re-distribute the sediments in the outer parts of the estuary. The present model is a research-level version, which could usefully be run for comparison purposes alongside more conventional Eulerian morphodynamic models, to gain experience of its relative performance in terms of both speed and results (Soulsby *et al*., 2007).

Data requirements

In addition to the data requirements outlined for the hydrodynamic and advection/diffusion the following requirements are identified:

- **Model set-up:**
  - Characteristics of particle to be tracked;

- **Boundary conditions:**
  - Seaward and riverine suspended sediment concentrations;
  - Location of sediment inputs;

- **Calibration and verification data:**
  - Suspended sediment concentrations;
  - Historic bathymetric data.

For further information on particle tracking see: DHI (1991a, b; 1993); CERC (1993); van Stijn *et al.* (1987); Hai *et al.* (1998); WL|Delft Hydraulics (2001); and for more information on Morpho-SandTrack see Soulsby *et al*. (2007).

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