

FACT SHEET

MODELS AND MODELLING FOR DREDGING

WHAT IS MODELLING?

There are many definitions to choose from, a useful one is:

‘A model is a (simplified) representation of a system that accounts for its properties, their interaction and their reaction to external input.’

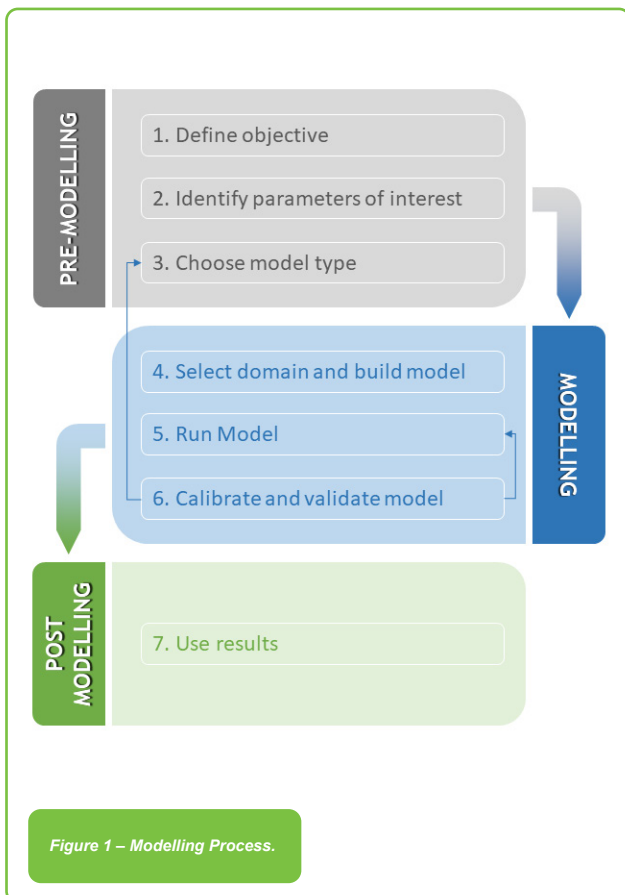
In other words, a model is a simulation tool, as such models can be used to provide information to inform the design, planning or management of a dredging project. It is important to remember that any model is a useful tool if, and only if, it is able to answer the required question sufficiently accurately and reliably within the required timeframe. A simple model can be applied quickly but may not be detailed enough to answer the question reliably. A more complex model may be sufficiently detailed but there may not be the available field data to provide sufficient

input information to run the model without considerable uncertainty in the results, or it may take too long to run all the necessary tests.

Typically, the modelling process can be summarised via the steps shown in Figure 1. This procedure may have to be repeated for different stages in the modelling process for instance calibration/validation of a flow model, followed by calibration/validation of a sediment transport model. However, each step in the process can be complex with multiple contributing factors, and a wrong choice at any step can lead to problems later in the project.

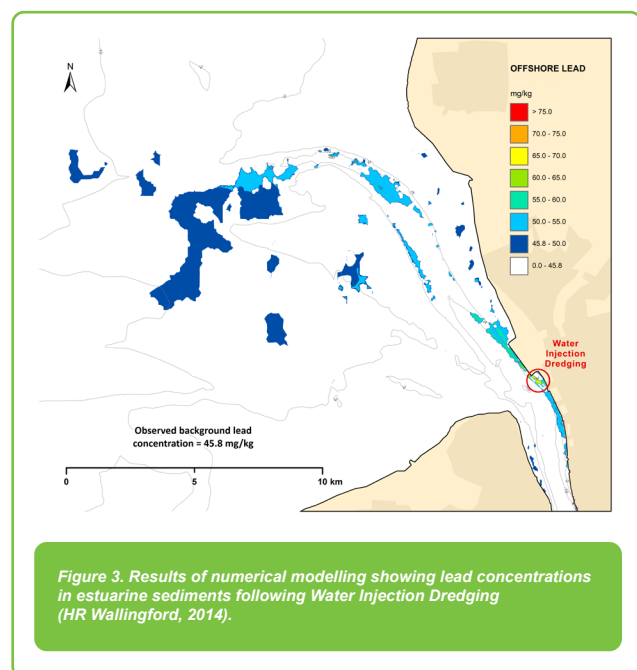
WHAT ARE THE DIFFERENT TYPES OF MODELLING?

Physical models – These models are generally used to reproduce physical processes in more complex marine environments, such as around structures, where numerical models are less reliable. Where dredging projects include the construction of coastal infrastructure physical models are likely to feature as they will be required for detailed design and testing of performance.



Numerical models – These models represent physical (or chemical or biological) processes by numerical algorithms solved by a computer. There is a hierarchy of such models ranging from the complex, which may only be practically used to represent physical processes for small periods of time and/or small spatial areas, to less complex models which can be used to represent longer

periods and larger spatial areas. Numerical models, particularly hydrodynamic and sediment transport models, are likely to be the workhorse used to support dredging projects during EIA and design. It is worth noting that numerical models often require field data collection for input conditions or for calibration/validation (increasingly this is expected or required by regulators).



Empirical models – Empirical models are based on observations rather than on mathematically describable relationships of the system modelled. Though the most simple type of model, they can be very reliable (since they are based on observations).

WHY IS IT NECESSARY TO UNDERTAKE MODELLING?

Modelling is typically used to provide information to help improve the understanding of the effects that a dredging project may have on the physical, chemical, biological environments or how bio-geophysical interactions take place. The types of information that models can provide can include:

Physical Effects

- Characterising the nature of waves and currents at the project site;
- Determination of the likely release rates and particle size distribution of sediment disturbed by dredging and released into the water column;
- Prediction of the near-field behaviour of sediment plumes released into the water column by dredging plant;
- Characterisation of far-field changes in Suspended Sediment Concentration (SSC) and far-field sediment deposition arising from dredging/disposal/reclamation plumes;
- Changes in light attenuation caused by dredging plumes;
- Determination of the longer-term effects of deepening, dredging and disposal on the local sediment regime (particularly estuarine systems);
- Modelling to understand and design the consolidation and dewatering of reclamations;
- Morphological change.

Chemical Effects

- Assessment of likelihood of changes in water quality (contaminants or nutrients) and associated impacts in the far-field as a result of the dredging disturbance.

Biological effects

- Determining whether sound generated by dredging (or other construction activities such as piling) is likely to cause disturbance to fish/marine mammals, and is sufficient to cause impact;
- Assessing the effects of improvements/reductions in light attenuation and water quality on sensitive species like phytoplankton, shellfish, coral or seagrass; and
- Predicting the creation of new habitats (sand mining pits, salt marsh, mangrove, seagrass, coral, etc.).

Bio-geophysical interactions

- In reality the physical, chemical and biological components of the ecosystem interact with each other and for some projects this interaction might be significant to the successful outcome of the project. This is often the case where living structures (e.g. vegetation, reefs and algae) are located at or near the project site, stabilising sediment, affecting fine sediment settling or attenuating waves.

WHAT IS ECOLOGICAL MODELLING

Ecological modelling is relatively uncommon at present but is growing in demand as ecological models become better supported by data. Ecological models are used for simulating and investigating the properties of ecological systems. Due to the sensitivity and importance of EIAs for large infrastructure projects, these projects typically require a quantitative assessment of the predicted effects of construction and operation on ecology and warrant dedicated modelling. A summary of the types of ecological models that are used is provided in Table 1.

Model type	What does it typically model the effects of?	Comment
Underwater sound	Seismic profiling, piling, dredging, vessels	Sound modelling is usually insufficient by itself and requires associated knowledge of behaviour thresholds of the species of concern.
Habitat models	The change in species abundance with variation in physical forcing (e.g. changes in light, water quality or smothering)	Requires data on the response of the species to the physical factors controlling species growth.
Fish	Underwater sound, effect of changes in flow on migration, intakes and turbines	Requires data on the response of the species to sound and other stimuli
Marine mammals	Underwater sound	Requires data on the response of the species to underwater sound
Birds	Effects of changes in habitat from development	Requires detailed surveys of food abundance throughout a study area
Larvae	New structures on ecosystem connectivity	
Jellyfish	Environmental conditions on jellyfish numbers in an area (with a view to predicting and preventing clogging intakes)	There are significant knowledge gaps regarding the onset of swarms
Trophic modelling	This type of model allows the development of an ecosystem to be represented over time. Biomass is represented in various trophic 'boxes', each including species with similar production, diet and predators. The model allows the biomass in each box and the flows between them to be quantified.	Empirical approach requiring considerable data on species throughout the food web
Dynamic energy budget modelling	A similar area of application and concepts to trophic modelling but this type of model is more detailed about the inputs and outputs of energy to/from a given species.	The approach is more abstract than trophic modelling. It is more difficult to calibrate but when calibrated is more generally applicable.

Table 1. Types of ecological modelling tools (after CEDA/IADC, 2018).

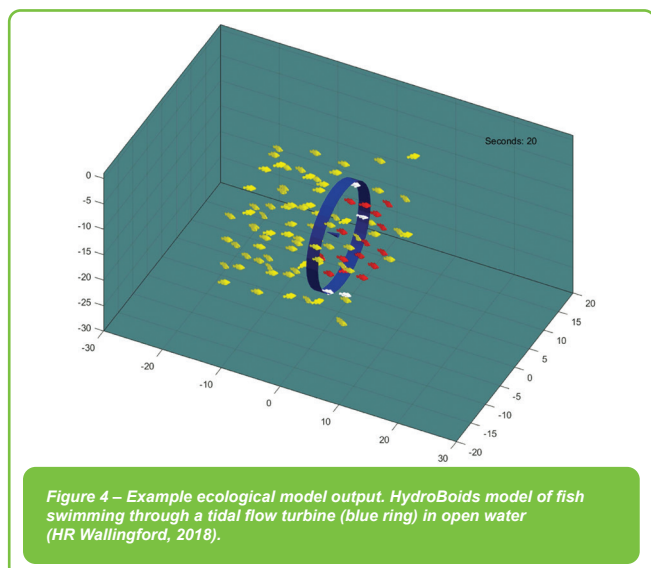


Figure 4 – Example ecological model output. HydroBoids model of fish swimming through a tidal flow turbine (blue ring) in open water (HR Wallingford, 2018).

WHEN SHOULD MODELLING BE UNDERTAKEN?

Modelling is often most helpful during the early stages of a project; during project initiation, planning and design. However, modelling can also be used during tender evaluation as a means of comparing the potential performance of different contractors' approaches to a project. Modelling may also be undertaken during operational conditions to forecast particular parameters.

A first step in the first stages of modelling is to develop a conceptual model of the hydrodynamic and sediment regime at the site – 'how the system works'. Depending on the project, this conceptual model might be extended to wider natural or social-economic considerations, if these are to be an important part of the project. This conceptual model will guide the emphasis of the studies (field data collection, modelling and subsequent monitoring) as to the most important processes and features of the site.

WHAT DATA IS NEEDED TO UNDERTAKE MODELLING?

It will usually be the case that some field data collection is necessary to obtain the information necessary to run and validate the models which will be used in the studies, and most importantly the flow, wave and sediment transport models. If the data is insufficient, the model results will be full of uncertainty and this may cause considerable problems for the entire project, in terms of design, schedule and cost.

Examples of data which may be required for establishing a model:

- Bathymetry data including surrounding land for the model area; and
- Locations of sources (e.g. sediment release, underwater sound, intake/outfall sources).

Examples of data which may be required for running a model:

- Boundary data in the form of water levels;
- Wind in the model area, for some more complex models; and
- Salinity and water temperature at the boundaries.

Examples of data which may be required for calibrating a model:

- Currents and sometimes wave measurements within the model area;
- Water level measurements; and
- Water quality measurements within the model, if sediment transport is of interest.

HOW TO COMMUNICATE MODELLING OUTPUTS

Models are often a convenient and practical way to communicate to regulators and other stakeholders the issues and opportunities associated with a particular infrastructure project and how these issues can be or have been addressed and opportunities realised through careful design and management. This is particularly true of models which provide a visual representation of the important processes. Physical modelling is often a very good medium for stakeholder communication, as are animations of numerical model outputs which show changing spatial distributions of properties (physical, chemical or biological) over time.

The presentation of results is the product which is delivered to regulators and other stakeholders (e.g. the general public) and however good the underlying modelling, if the presentation of results is poor, the whole project may be put at risk. Therefore:

- The presentation of results needs to inform;

The whole point of the presentation of results is that it needs to be able to convey the necessary information clearly.

- The presentation of results needs to address the items of interest to the regulator and other stakeholders;

In addition to providing information to inform the design of a scheme, the point of the modelling exercise is to identify the likelihood and nature of potential positive and negative effects which are of importance to the stakeholders. The questions of the stakeholders need to be answered.

- Results need to establish a clear narrative without contradictory statements from different reports;

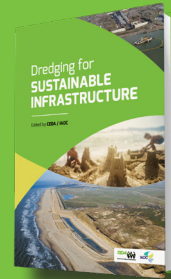
In a large study, there may be many different modelling reports, all dealing with different aspects of the project and potentially composed by different teams of consultants. It is important that these inputs from different teams are synthesised in such a manner as to present a consistent and non-contradictory description of the results.



Figure 5 – Communication of ideas about bathymetry to school students.

THIS FACT SHEET IS BASED ON THE BOOK *DREDGING FOR SUSTAINABLE INFRASTRUCTURE*

The book *Dredging for Sustainable Infrastructure* gives state-of-the-art guidance on how to design, implement and manage a water infrastructure project with a dredging component to project owners, regulators, consultants, designers and contractors.



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