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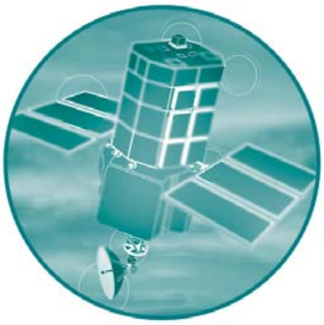

Guidance Notes for Assessing Morphological Change in Estuaries

R&D Technical Report FD2110/TR1

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GUIDANCE NOTES FOR ASSESSING MORPHOLOGICAL CHANGE IN ESTUARIES

R&D Technical Report FD2110/TR1

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ISBN: 0-85521-031-1

Dissemination Status
Internal: Released to regions
External: Released into Public Domain

Statement of use
This document provides best practice guidance to those with a management or decision-making role in estuaries, on the choice of approach for assessing dynamic and morphological change.

Keywords – Estuaries, Estuary Management, Morphology, Predictive Modelling, Uptake, Dissemination, Blackwater, Mersey.

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EXECUTIVE SUMMARY

The Estuaries Research Programme Phase 1 (carried out by the EMPHASYS consortium) evaluated a wide range of methods capable of predicting changes in the shape (morphology) of an estuary and parameters related to the morphology. Different classes of method were tested, in various estuaries around the UK, in terms of their ability to predict morphological responses to variables such as sea-level rise, changes in flows and tidal conditions, and engineering works.

It was recognised that the EMPHASYS consortium produced useful results that should be more widely used. These guidance notes are published as part of the Estuaries Research Programme Phase 1 Uptake Project, which is designed to carry out a programme of workshops and deliver several reports and other products to fulfil this uptake.

The primary objective of these notes is to introduce best practice guidance to those with a management or decision-making role in estuaries, on the choice of approach for assessing dynamic and morphological change. They provide an introduction to ways of formulating a programme of studies to address a particular estuary management issue, and how to interpret the resultant outputs. They go through the essential steps of the estuary management process including defining the issues in hand, data requirements, the choice of short- or long-term predictive methods and synthesis of available information.

These notes do not provide “solutions” or a comprehensive guide on how to manage an estuary, but rather they present a framework for making an evaluation of which approaches should be adopted that will result in better informed decision-making. The approaches that are introduced are those that should be scrutinised in the work of the specialist consultant so that confidence in the outcome of the study is maximised.

To aid the wider guidance objectives of the Uptake Project, the generic principles in these notes are illustrated throughout using examples or “demonstrations” in two estuaries: the Mersey and the Blackwater. These demonstrations have been designed to provide worked examples of good practice in undertaking estuary studies. The Blackwater Estuary demonstration utilises the predictive studies that led to a recently adopted managed realignment scheme at Abbotts Hall. The Mersey Estuary demonstration describes the approaches to evaluating the morphological impact of a hypothetical adjustment to the training walls in the outer estuary. The stages presented in the demonstrations are applicable to a large number of UK estuaries and provide valuable worked examples of how a proposed strategy or scheme can be approached.

These notes also provide details of other sources of information and guidance relating to the principles of estuary management, and these should be read to access a wealth of information and experiences.

CONTENTS

1. INTRODUCTION

These guidance notes have been written in parallel with the Estuaries Research Programme (ERP) Phase 1 Uptake Project workshops held in November 2002 at various locations around England and Wales. The Uptake Project has been undertaken by Posford Haskoning in consortium with HR Wallingford, Royal Holloway University of London, ABPmer and CIRIA within the Broad Scale Modelling Theme of the DEFRA/Environment Agency joint thematic R&D Programme for Flood and Coastal Defence. The background to the project and its overall objectives are introduced in Appendices A and B.

1.1 Purpose and Scope

The concern of estuary management is to have a basis for decision-making in order to design strategies, policies and plans. To do this, prediction of future changes is necessary. These guidance notes provide an introduction to ways of formulating a programme of studies to address a particular estuary management issue, and how to interpret the resultant outputs (Table 1.1). Importantly, they also highlight further more detailed sources of information and guidance relating to particular aspects of estuary studies.

Potential uses of these notes include:

- To scope consultants' work
- To provide a basis for evaluating proposals
- To know what sort of questions to ask of the consultant
- To form a basis for planning data collection exercises

The target audience for these notes is individuals or organisations that have to make decisions based on the outputs of this type of study. These organisations include the Environment Agency, DEFRA, English Nature, Local Authorities, RSPB, Port Authorities, Wildlife Trusts, Fisheries Committees and Dredging Organisations. The technical level of these notes therefore reflects the target audience.

1.2 Using these Notes

These notes are divided into five sections (including this one).

- Section 2 introduces the steps required to **define the issues** in hand.

- Section 3 introduces the approaches to assessing **data requirements** for estuary predictive studies and the issues and problems that relate to data quality and applicability.

- Section 4 introduces the approaches to assessing the choice of **short-term and/or long-term predictive methods**.

- Section 5 summarises how the data and methods are **synthesised** into a conceptual model and integrated with other aspects of estuary management.

Appendices A-C provide references and links to additional information sources, which deal more expansively with particular topics raised in these notes.

To aid the wider guidance objectives of these notes, the principles highlighted in Sections 2 to 5 are illustrated through the use of worked examples or "demonstrations" in two estuaries: the Mersey and the Blackwater. These demonstrations have been designed to provide a means of illustrating elements of good practice in approaching an estuary study, and are described in a series of boxes throughout the text. The Mersey and Blackwater Estuaries were chosen as demonstrations for several reasons:

- They provide strong contrast in terms of their associated problems and issues
- Both have a good range and quality of data
- Both estuaries were modelled and analysed at an earlier stage of ERP Phase 1

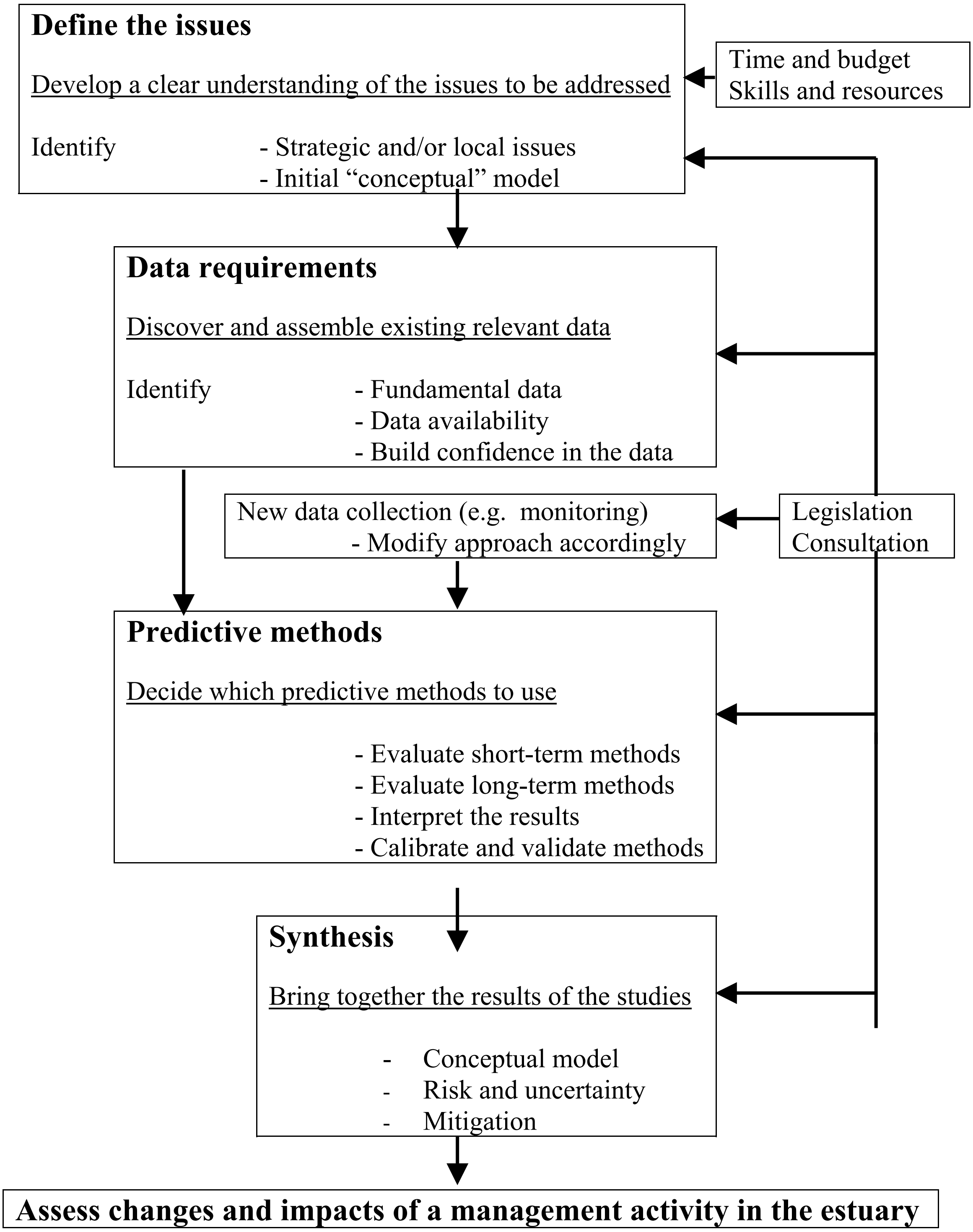
The Mersey Estuary demonstration describes the approaches required to identify the response of the inner and outer estuary to a hypothetical scenario of part removal of the training walls in Liverpool Bay. The construction of these training walls in the early part of the 20th century led to large-scale morphological change and their part removal might be considered to do the same.

The Blackwater Estuary demonstration summarises the elements of the managed realignment scheme at Abbotts Hall. This realignment is novel in that the area being inundated is relatively large compared to the tidal area of the creek. In order to provide information for the consents process a range of activities were undertaken to assess the extent and magnitude of the impact of the breaching on the adjacent physical regime.

Both the demonstration projects cover the following topics:

- scoping of the project
- a review of available data and collection of new data
- a description of the methods necessary to predict short- and long-term morphological change
- development of a "conceptual model" of the area

Table 1.1 Summary of approach to identify and predict morphological change in an estuary.



2. DEFINING THE ISSUES

At the outset of any project or planning initiative it is important to have a clear understanding of the issues to be addressed. Four important steps need to be taken before deciding which types of predictive method and data are required:

- The issues have to be placed into the context of legislation (Section 2.1)
- The temporal and spatial scales of the issues have to be determined (Section 2.2)
- The issues have to be discussed at consultation (Section 2.3)
- The issues have to be precisely defined within the framework of an initial "conceptual" model (Section 2.4)

A list of example issues, and key questions to ask when defining issues, are given in Sections 2.1 and 2.2 of A Guide to the Prediction of Morphological Change within Estuarine Systems (EMPHASYS Consortium 2000c) (see Appendix A). Definitions of issues related to the demonstration projects are described in Boxes 1 and 2.

2.1 Legislative Context

Legislation influences all stages of an estuary study and as such it should be considered throughout the assessment process (Table 1.1). Part of the reasoning behind evaluation of the ERP Phase 1 predictive methods was to enable statutory bodies to make management decisions to comply with UK legislation and EC Directives on flood defence, navigation, water quality and conservation. Further details on legislation as related to morphological change in estuaries are given in the Legislative Report (Posford Duvivier Environment 2000) (see Appendix A).

Present decision-making is generally steered by legislation related to ecology, water quality and human activities, and not on the basis of morphology directly. However, the requirements of legislation will dictate how the issue is defined and which predictive methods should be used. For example:

- The requirement of the Environmental Impact Assessment Regulations and the Habitats Directive is that the cumulative effects of any scheme on other interests are addressed.
- If the estuary is designated as a Special Protection Area, then development within or adjacent to it must not affect the integrity of the site, as defined by its designated status and conservation objectives.

These types of legislation mean that local issues need to be set within the broader context of whole estuary studies.

2.2 Strategic or Local Issues

The needs of the estuary users and other interested parties should be taken into consideration (through the consultation process, see Section 2.3) in the definition of the issues. Those needs may be at a whole estuary level (strategic) or at a more local level. Because of this, the study may need to utilise different methods and data to address the different levels of need, even though one influences the other. There is potential for small changes to have far-reaching effects, and as a consequence, when developing plans for estuary management, it is important to retain a clear estuary wide perspective, even when addressing seemingly local issues. This strategic approach will require a more in-depth assessment of baseline conditions across the range of process areas.

2.3 Consultation

There is a demand by the public to understand and be actively involved in the reasoning behind the decision-making process and the information on which the decisions are based. The estuary management process must therefore be flexible and responsive enough to meet the needs of the people upon which the decision will impact. For this to be achieved, consultation must take place at all stages of the process, from issue definition to synthesis (Table 1.1). Such an approach ensures that the views of the consultees can inform the overall process, and, more importantly, it allows for understanding and consensus to be developed. Three main areas for consultation are recognised (after Barham *et al.* 2001):

- Informing – making sure that everyone has the opportunity to understand what the issues are that need resolving and that all the relevant information is gathered to assist in determining options
- Involving – making sure that through better understanding of the issues, the information needed to inform the appraisal process and options for achieving solutions, more people can be properly involved in planning and delivering the work
- Influencing – making sure that through wider involvement, others will also help to promote and foster better understanding and acceptance

Continued liaison with consultees throughout the lifetime of a project and the subsequent design of a scheme will generate a scheme that should be acceptable to both the human and natural environment.

2.4 Initial Conceptual Model

Two generic types of issues can be defined:

- those that relate to development of a particular scheme
- those that relate to ongoing changes in the environment (such as sea- level rise) and how these might impact on wider interests in the estuary (such as flood defence, nature conservation etc).

Issue definition therefore requires not only knowledge of the issue itself, but also a basic understanding of the uses, functions and natural characteristics of the estuary to provide an appreciation of the likely potential modes of change. Even at the outset it is therefore helpful to start formulating this type of “conceptual” model (likely to be qualitative) using existing literature for well-studied estuaries or by comparison with similar estuaries for those that are less well studied. This model should identify the different process areas in the estuary, such as morphology, sediment dynamics, hydrodynamics, water quality, ecology and human activities, and how they interact.

Taking account of this conceptual model, the key potential effects can then be scoped. The next step is to consider the available data, the possibilities for collection of additional data within operative time and budget constraints, and the choice of appropriate methods, which can be used to predict the potential impacts and likely success of the scheme.

2.5 Indicative Costs

Each particular study is going to be unique in terms of its issues, data requirements and methods needed to resolve the issues. So, the indicative costs for any particular type of study will depend on the nature and scale of the project specification. The relative costs depend on many factors including the following:

- What is the level of study required? Is it a relatively cheap low level feasibility or scoping study, or a relatively expensive "full" study for capital works?
- What financial resources are available for the study? This will dictate the level of study that can reasonably be carried out
- What are the specific data and method requirements? Numerical methods are generally data hungry and computationally relatively expensive whereas the long-term methods are computationally relatively cheap
- Is the project likely to require new data collection, and if so, what type?

Box 1 Defining the Issues – Blackwater Demonstration Worked Example

As part of a number of initiatives in the field of sustainable flood defences, the Environment Agency is using a 40 ha site in Essex for a managed realignment scheme. The location of the realignment is at Abbotts Hall near the head of Salcott Creek, within the Blackwater Estuary (**Figure 2.1**) (HR Wallingford 2001; Posford Haskoning 2001). Four (of a proposed five) locations within the sea wall have been breached (early October 2002) so that the low-lying land behind is inundated with tidal waters. A major objective of the scheme is to create ecologically valuable habitats including saltmarsh, mudflat and saline lagoons. The fundamental issues to be considered were identified by considering the objectives of the scheme, the potential impacts and costs, and the prevailing legislative framework:

- What are the potential near-field and estuary-wide impacts of the scheme on processes, sediment mobility, morphology, habitat extent and distribution, associated fauna and flora, water quality and economic activities in the area (e.g. oyster fisheries and navigation)?
- Will the scheme result in scouring of the breaches and adjoining channels, possibly leading to increased sedimentation and water turbidity in Salcott Creek and elsewhere in the estuary, with potential implications for fisheries?
- Will the increase in tidal prism have any significant effect on hydrodynamic processes and the overall balance and distribution of erosion and sedimentation within the estuary?
- Who and what will be affected by these impacts?
- Are there options for mitigation and compensation?
- Is the scheme likely to be successful (i.e. achieve its stated objectives of creating sustainable saltmarsh, mudflat and saline lagoon habitat)?
- Is the scheme likely to be cost effective, taking into account construction and maintenance, any necessary compensation and mitigation, and the monetary and wider environmental value of the habitats created?
- Will the scheme accord with the necessary legislative requirements (e.g. Wildlife and Countryside Act, Habitats Directive, SPA, cSAC, Planning Regulations)?

Adopting the “Generic Approach” defined in the Guide to the Prediction of Morphological Change in Estuarine Systems (EMPHASYS Consortium 2000c), the first stage is to scope out the studies required to address these issues, within the framework of an initial conceptual model of the scheme within its estuarine context. The following questions may be asked to help build the initial conceptual model:

- What is the scale of the scheme in relation to the estuary as a whole?
- What are the underlying geological and geomorphological controls on the site and adjoining estuary (e.g. relief, bedrock framework, neotectonic movements, sediment supply and relative sea-level change)?
- What is the history of recent geomorphological, sedimentological and ecological change at the site and in the adjoining estuary?
- What are the dominant hydrodynamic and sedimentary processes in the estuary?
- What can be learned from earlier schemes in the Blackwater Estuary, and from other “natural” and experimental managed realignment sites in Essex?

Based on these questions, an initial conceptual model was developed which portrays the Abbotts Hall site as a relatively small, peripheral extension of an irregular, tide-dominated muddy estuary whose present morphology has been heavily influenced by sea wall construction and saltmarsh enclosure. In common with many estuaries in south-east England, the estuary currently experiences a slightly net erosional regime. Taking account of this conceptual model, the next step is to consider the available data, the possibilities for collection of additional data within operative time and budget constraints, and the choice of appropriate methods, which can be used to predict the potential impacts and likely success of the scheme.

Consultation with a diverse range of key organisations and individuals was an integral part of the Abbotts Hall study Posford Haskoning 2001). The consultation raised awareness about the scheme and highlighted consultees concerns. Consultees included Government departments, nature conservation bodies, local authority representatives, commercial organisations, local interest groups and representatives of other groups with an interest in the area. The consultation led to the redesign of one of the breaches in order to investigate the effects of a modification to the breach configuration.

Box 2 Defining the Issues – Mersey Demonstration Worked Example

Following consideration of a number of potential issues relating to the Mersey Estuary (**Figure 2.2**), a decision was made to examine the possible impacts of a **hypothetical** situation involving breaching, abandonment or removal of sections of the training walls in the mid part of the outer estuary. This issue was selected partly because the construction of the training walls has had an undeniably large impact on the morphology and hydrodynamics of the estuary, and partly because the pattern of morphological change indicated by recent bathymetric surveys suggests that the training walls are currently preventing natural adjustments of the major channels and banks, which would otherwise occur. Comparison of the 1988 and 2002 charts of the outer estuary (Pye *et al.* 2002) indicated major accumulation of sand adjacent to the training walls on the south side of Queen's Channel, with accompanying scour along the foot of the training wall on the north side adjacent to Taylor's Bank. These changes appear to reflect a natural tendency for the main channel to try to move northward, and to develop a tighter radius of curvature, which is inhibited by the training walls. As a hypothetical exercise, therefore, two scenarios have been selected for the purposes of demonstration. The first scenario involves an appraisal of the possible consequences of abandoning (or removing) part of the western training wall. The second scenario involves an appraisal of the possible consequences of removing part of the northern/eastern training wall.

Specific key issues which arise from the two hypothetical scenarios are as follows:

- What would be the effect on near-field and far-field hydrodynamic processes and sediment transport of abandoning or removing either section of training wall?
- In the case of the west training wall, would there be a tendency for deepening and re-opening of the former Rock Channel and/or other channels through Burbo Bank?
- What would be the effect of such changes on sediment circulation, foreshore levels and flood risk along the Wirral coastline?
- In the case of the northern/eastern training wall, would there be a tendency for deepening and possible re-opening of the former Formby Channel, and perhaps a northward movement and lowering of Taylor's Bank?
- What would be the effect on sediment circulation, wave exposure, foreshore levels and frontal dune erosion or accretion along the Sefton coastline of such changes?
- What are the likely implications for navigation (e.g. in terms of dredging requirements)?
- Would the rates and patterns of erosion and accretion in the inner estuary be affected?
- What would the specific impacts be on the nature conservation status of areas designated under national, European and wider international legislation (NNR, SPA, cSAC, Ramsar sites)?

As recommended in the Guide to the Prediction of Morphological Change in Estuarine Systems (EMPHASYS Consortium 2000c), a full scoping study would normally be undertaken to identify all of the issues associated with the two hypothetical scenarios, and to identify the types of study required to address them. A review of previous work has been used to construct an initial conceptual model of the estuary and the potential significance of the hypothetical changes in the training walls. The Mersey is one of the most studied estuaries in the UK with some of the best datasets (both empirical and modelled). Based on this information, a conceptual model was derived which views the estuary as a macrotidal, largely sandy estuary in which the present morphology of the outer estuary has been heavily influenced by the training walls and associated dredging activities. The adjoining shores are transitional from estuarine to fully open coast in character showing varying degrees of wave and tidal influence. While most of the Wirral coastline now has hard defences, much of the Sefton coastline consists of undefended sand beaches and dunes, which are of high conservation and recreational value. Studies of historical bathymetric changes in the outer estuary of the Mersey have demonstrated a strong correlation with changes in the erosion-accretion status of the beaches and frontal dunes, particularly on the Sefton side (Pye and Neal, 1994). Consequently, there is reason to believe that any future changes in the patterns of banks and channels in the outer Mersey Estuary might also have major knock-on effects on these systems.

Taking account of this conceptual model, the next step is to evaluate the available data and the choice of appropriate methods, which can be used to predict the potential impacts of the hypothetical scheme.

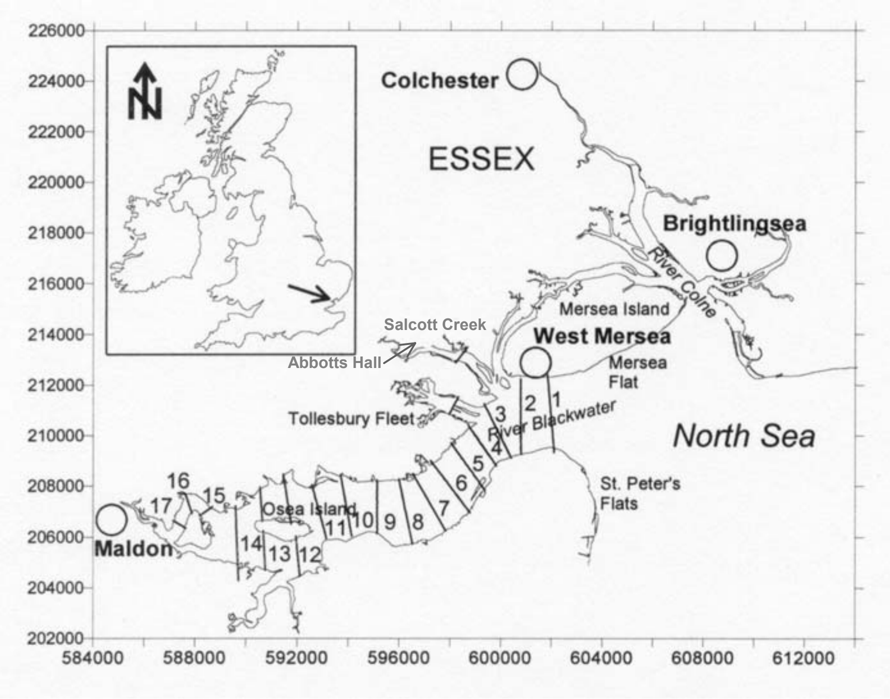


Figure 2.1 Location map of the Blackwater Estuary showing position of bathymetric survey profile lines (from Van der Wal and Pye 2000).

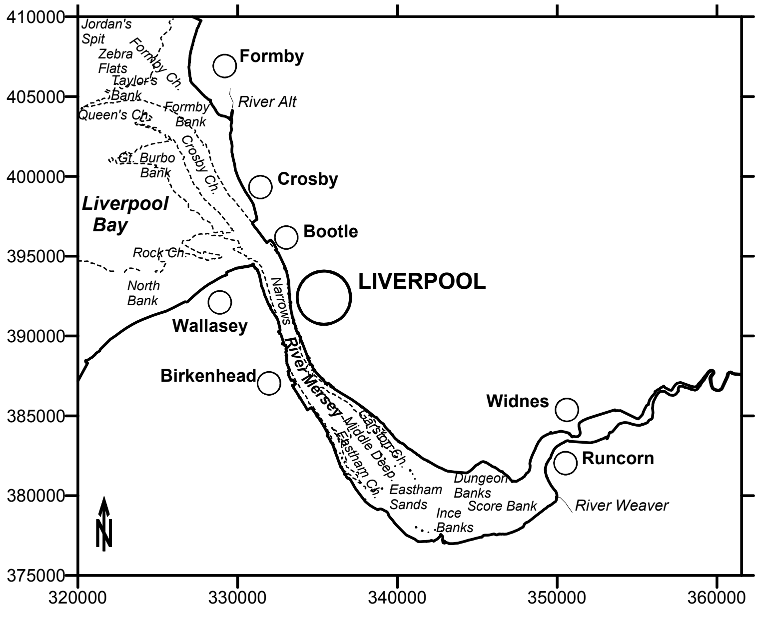


Figure 2.2 Location map of the Mersey Estuary and localities mentioned in the boxes (from Pye *et al.* 2002). Dashed line is Lowest Astronomical Tide at Liverpool.

3. DATA REQUIREMENTS

Once the issues are clearly defined the next stage in the estuary management process is to discover and assemble existing relevant data. This section introduces guidance on the approaches to assessing what types of data are required, and their limitations, to successfully implement predictive methods. The existing data will provide a basis for assessing the type and scope of any additional data (including monitoring), that may need to be collected for a study. The choice of data is critical to the success of a study. Data requirements related to the demonstration projects are described in Boxes 3 and 4.

This Uptake Project is producing a publicly available database on CD, which will contain key data from six estuaries: Blackwater, Mersey, Ribble, Humber, Southampton Water and Tamar. These data are considered an essential prerequisite to successful uptake of the methods evaluated within ERP Phase 1. Further details of the potential uses of the database CD (e.g. for individual estuaries, demonstrating data types and for information on where to go for similar data for other estuaries) and its accessibility are provided in Appendix B of these notes.

3.1 Fundamental Data

The data requirements for understanding and predicting the morphological behaviour of an estuary, that underpin planning and management, may be classified into two areas: material and process. The material data includes knowledge of the geology of the estuary, bathymetry, topography of the coastal plain, and the lithology and distribution of mobile and non-mobile sediments. The process data includes knowledge of the forcing such as waves, tide-generated currents, their strengths, directions and variability with time.

There are four fundamental datasets of any estuary system that have direct application to a wide range of issues:

- Bathymetry of the estuary bed
- Topography of the adjacent coastal plain
- Remote sensing data (see Section 3.1.1)
- Underlying geology and geomorphology

These four datasets (both time series and latest "snapshot") are a basic requirement in order to provide an initial insight into how the morphology of an estuary has evolved, and therefore predict how it may evolve in the future. However, there are several difficulties associated with compiling a coherent dataset, which mainly relate to the extent of data coverage. Generally, fewer data are available for intertidal areas than for subtidal areas and fewer data are available for smaller estuaries.

3.1.1 Remote Sensing

Remote sensing is a generic term describing the measurement of an attribute from a distance. It generally refers to measurement of a land attribute from the air or a sea bed attribute from the sea surface. There is a wide range of techniques available including satellite imagery and aerial photographs. Satellite imagery can provide a comparison of large areas over decadal time scales. Yearly vertical aerial photographic surveys can provide quantitative data on large-scale changes of the estuary coast, such as changes in channels and movement of the saltmarsh edge. Several questions have to be answered before remote-sensing data are collected:

- What are the dimensions of the area?
- What is the smallest unit to identify (strategic or local)?
- What type of product is required; is it a printed output in the form of maps and/or photographs or an electronic product to integrate with other data?
- Are the available funds sufficient?

3.2 Data Availability

Improved data coverage and quality facilitates better data interpretation of estuary conditions. However, often an incomplete understanding of the data requirements and the desired level of data quality leads to choices being made on availability alone. This may lead to collection of inappropriate data for the study. A more suitable approach is to compare the data required with the data available to identify the data gaps. These gaps can then be filled through further data collection (monitoring or a programme of field studies) appropriate to the needs of the study.

3.3 Confidence in the Data

An initial error assessment of the data needs to be undertaken to ensure the inaccuracies and uncertainties are highlighted before input into predictive methods. Full statements of the assumptions involved in testing, collecting and analysing data should be made, and carefully examined by the users of the results. Several factors need to be considered to ensure data quality and confidence in the data collation or collection process:

- Record the data source and method of collection
- Be aware of random and systematic errors in the data
- Assess the spatial coverage of the data

Once these factors have been evaluated, then an informed decision can be made as to how to increase the level of confidence in the data. This may involve collection of new data, which complements the existing data (this may include monitoring).

3.4 Monitoring

Collection of additional data to satisfy the requirements of a study may include monitoring. Monitoring comprises measurements taken on a regular basis in order to determine whether progression is being made towards an objective or goal. Monitoring must be tailored to develop the understanding and to supply the relevant data for input into the predictive methods. Monitoring should generally be used to help better decision-making but there is also a role for routine monitoring which may not be directly aimed at current decision-making but may be of value in the future (e.g. if a development proposal arises).

Before any monitoring campaign is implemented, the following key questions need to be addressed:

- What is going to be assessed?
- Which indicators should be measured?
- Where are the indicators to be measured?
- How will the indicators be measured?
- What is the required measurement frequency?
- What quality control standards are established for each indicator?
- Who will be responsible for providing the resources?
- Where is the data to be stored?

3.5 Information Sources

Further information on data requirements and best practice can be found in the following ERP Phase 1 reports and products (see Appendices A and B for more details and accessibility).

- Scientific Data Management by Project Consortia: Best Practice Guidelines (ERP Phase 1 Uptake Project 2002).

- Database CD and Report (ERP Phase 1 Uptake Project 2002).

- Section 3 of A Guide to the Prediction of Morphological Change within Estuarine Systems (EMPHASYS Consortium 2000c).

- Predictive Methods Report (Posford Duvivier 2000).

Box 3 Data Requirements – Blackwater Demonstration Worked Example

For the case of the Abbotts Hall managed realignment scheme existing data availability was poor, comprising the following:

- Bathymetry; limited in both extent and frequency of survey (**Figure 3.1**)
- LiDAR; good recent coverage for supratidal area around Abbotts Hall (**Figure 3.2**)
- Limited tidal level data but relatively far to data collection points (**Figure 3.3**)
- Virtually no current data but some freshwater input information
- Anecdotal bed sediment data
- Anecdotal suspended sediment data
- Nearby vertical saltmarsh sedimentation rates
- Sediment properties in active channels, saltmarshes, and on areas of land-claim

In order to utilise predictive methods for assessing the short-term impact of the scheme, and also to provide a framework for putting impacts into context, a programme of field studies and monitoring was initiated and data specifically collected for:

- Subtidal bathymetry
- Tidal levels at six locations along the main axis of the estuary
- Tidal currents at six locations
- Suspended sediment concentrations
- Waves at the entrance to the estuary
- Bed sediment

Recognising the need to build a long-term database, the Environment Agency commissioned a programme to collect this information routinely over the next five years.

The data from the initial surveys were used to further develop the conceptual model of the process regime of the estuary and to formulate questions and hypotheses for testing using short-term methods. Careful attention was paid at every stage to the limitations of data quality and the potential effect on method predictions. Critical questions included:

- Is the data coverage good (e.g. do the bathymetric surveys and LiDAR overlap or is there a gap)?
- How accurate is the data (e.g. an error in the LiDAR of 20 cm can make a large difference in the tidal volume)?
- What is known about the data collection processes (were conditions "typical" or adverse)?
- What datum(s) are the data referred to and can they be reliably condensed into one?
- What processing of the data is required so it can be used to calibrate the methods?

In view of the lack of historical time series data, long-term method selection was severely restricted for the Abbotts Hall study. However, the LiDAR data (**Figure 3.2**) were used in a separate sub-study to examine the pattern of flooding and drainage following creation of the five breaches. A digital elevation model was constructed and the pattern of immersion studied for each 5 cm increment of the tide above the level of each breach. The changes in tidal prism in the resulting flooded areas were calculated and used to predict likely current velocities through the breaches, with a view to predicting possible morphological changes. Longer-term morphological and sedimentological changes within the flooded areas, and adjoining areas of the estuary, were assessed by reference to existing historical data sets and sedimentological evidence from other marsh areas within the Blackwater Estuary and elsewhere in Essex.

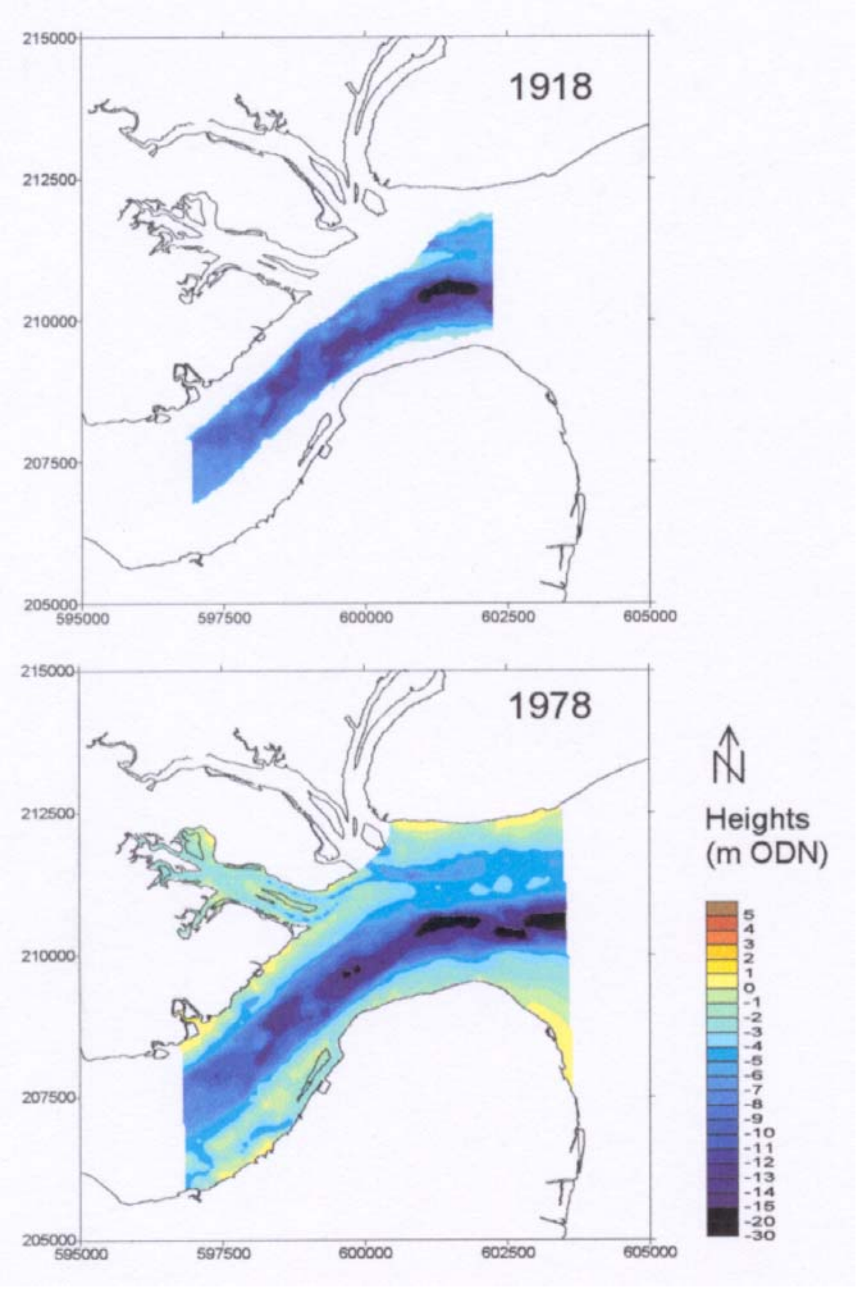


Figure 3.1 Bathymetry of the Blackwater Estuary in 1918 and 1978 from Admiralty Charts.

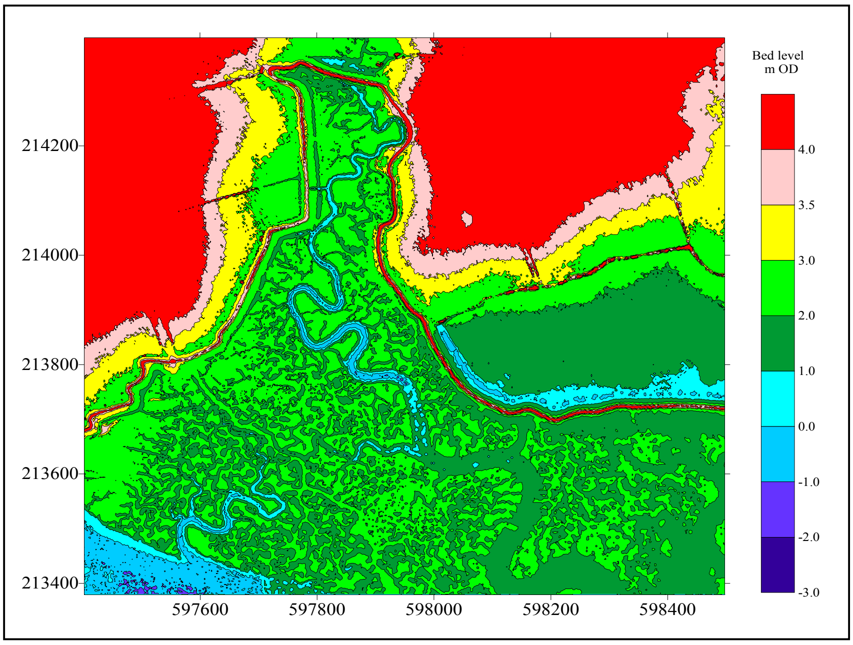


Figure 3.2 LiDAR data from near Abbotts Hall in the Blackwater Estuary. Data copyright of the Environment Agency.

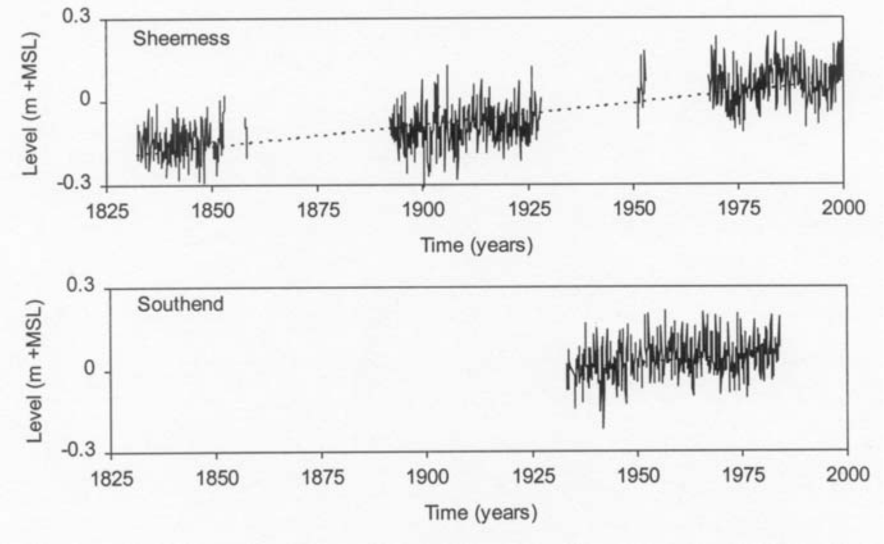


Figure 3.3 Changes in relative mean sea level at Sheerness and Southend (data from PSMSL 2000).

Box 4 Data Requirements – Mersey Demonstration Worked Example

For the case of the Mersey Estuary training wall removal, historical information relating to the construction of the original wall(s) and its (their) effect is obviously a crucial dataset. Being a large estuary with a long industrial and navigational heritage, data relating to some fields is extensive, including the following:

- Bathymetry; relatively well surveyed over subtidal areas; frequency and detail of cover best in main shipping channels and their immediate vicinity; coverage much poorer for outer estuary and intertidal areas (**Figure 3.4**)
- LiDAR; good recent coverage of intertidal zone and Sefton dunes (**Figure 3.5**)
- Ground survey profiles; good coverage and frequency, especially for Sefton coastline (**Figure 3.6**), including annual dune frontage erosion measurements since 1958
- Long-term tide gauge records for Liverpool
- Limited synoptic tide level data at various locations within the estuary
- Relatively good wind and offshore wave climate information; very limited inshore wave data
- Limited offshore sea bed sediment data; good beach sediment data coverage

Data requirements for short-term predictive hydrodynamic and sediment transport modelling include:

- Baseline bathymetry (**Figure 3.4**) and scheme definition
- Offshore wave information
- Tidal boundary conditions
- Sea bed sediment, bedform characterisation and particle size information
- Hydrodynamic calibration data (currents and levels)
- Processed historical bathymetric information (with which to verify sediment transport predictions)

Data requirements for long-term predictive methods are:

- Repeat bathymetric surveys to allow determination of spatial patterns of change and calculation of sediment volume change (**Figure 3.4**)
- Long time series of foreshore ground surveys and frontal dune erosion and accretion (supplemented in recent years by LiDAR data, **Figure 3.5**) from which profile and sediment volume information can be rapidly extracted
- Long time series of environmental forcing factors (tidal levels, winds and waves).
- Experimental and modelled information which relates process to form (e.g. subtidal and intertidal morphology to wave conditions at the shoreline)
- Information about surface sediment properties and the sedimentological record
- Information from other analogous locations where changes similar to those under hypothetical consideration have previously occurred (e.g. abandonment of training walls and dredging in the Ribble Estuary; breaching of training walls in the River Nith Estuary)

In relation to the long-term effects of possible training wall abandonment on the Sefton coastline, most of these requirements were met. However, availability of certain data types is more restricted in the case of the Wirral coastline, limiting the scope and precision of predictions, which can be made. The accuracy of the predictions made is heavily influenced by the inherent quality of the data available.

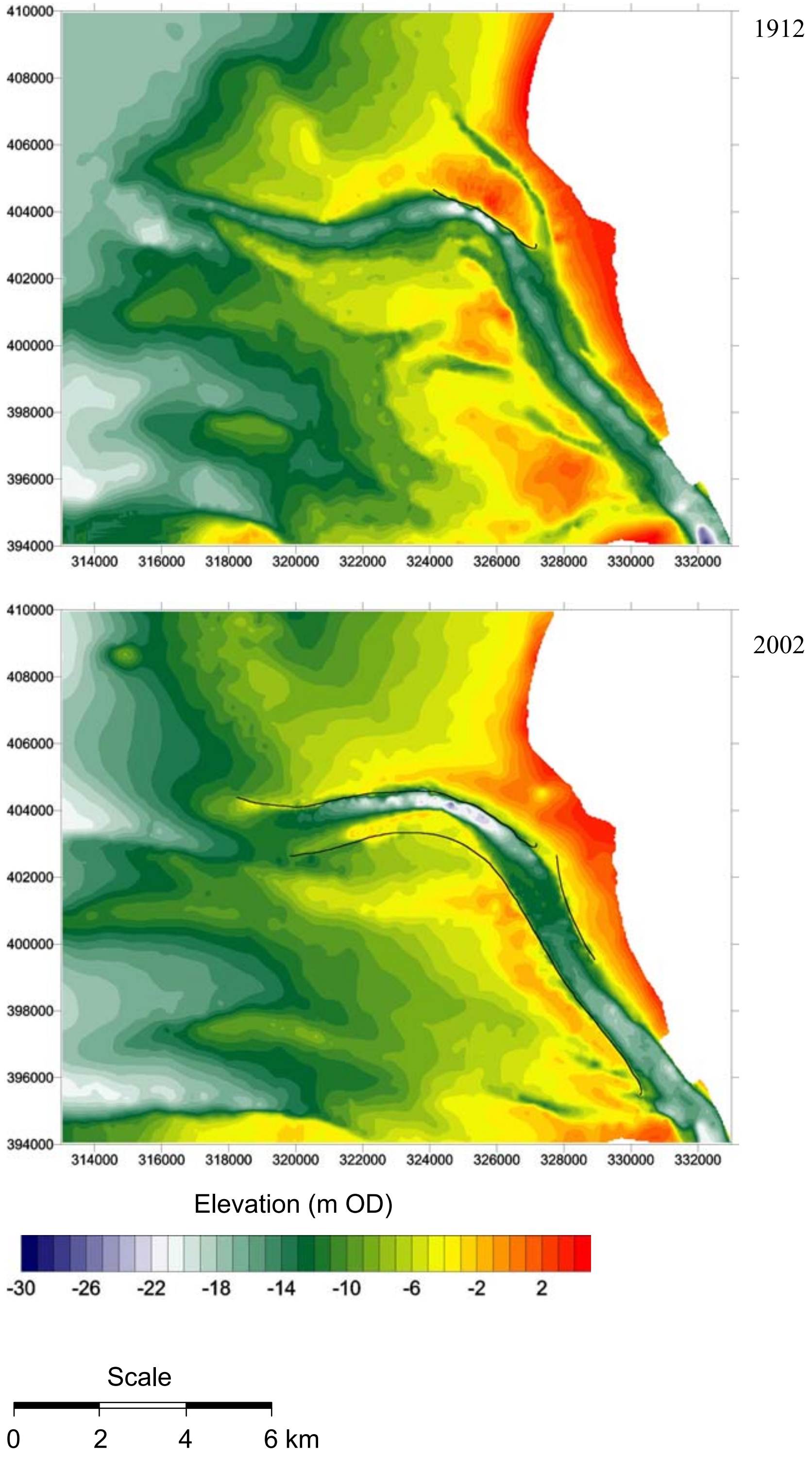


Figure 3.4 Bathymetry of the outer Mersey Estuary and Liverpool Bay in 1912 and 2002, digitised from Admiralty Charts (after Pye *et al*. 2002).

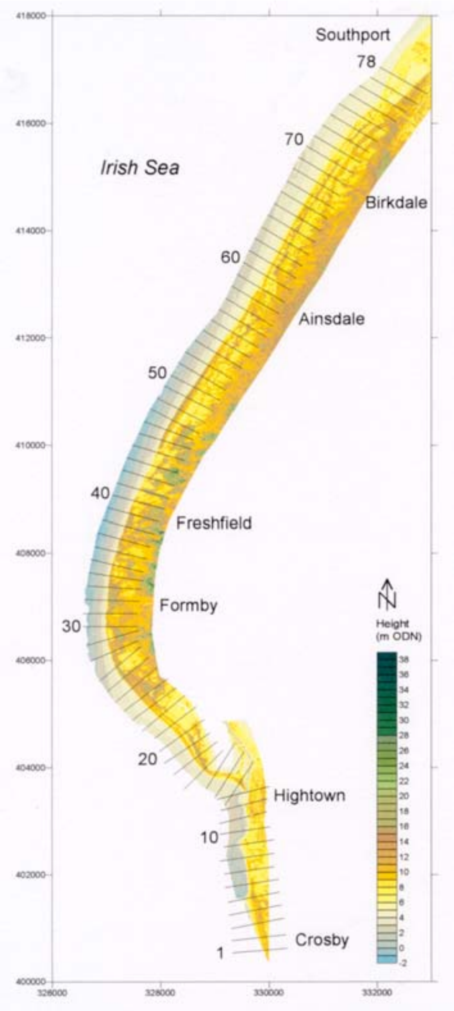


Figure 3.5 Digital elevation map of the Sefton coastline from LiDAR data, March 1999 (from Van der Wal *et al.* 2002).

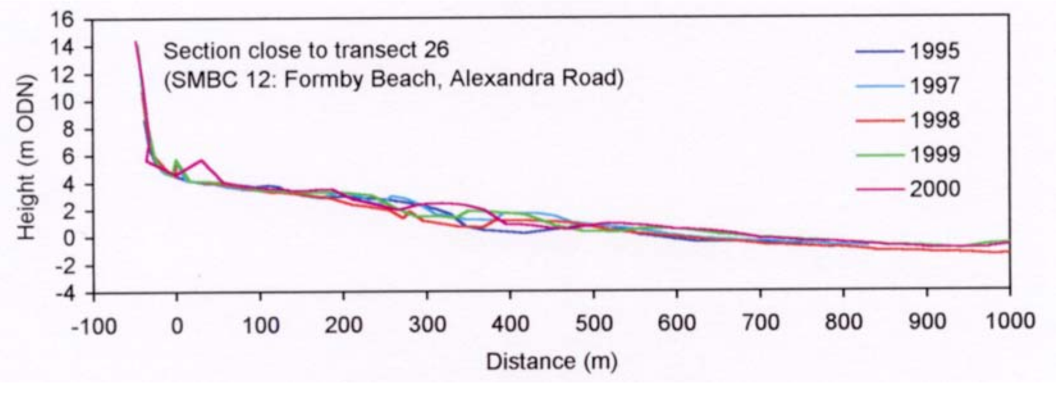


Figure 3.6 Beach profile changes along the Sefton coastline, based on ground survey data of Sefton Metropolitan Borough Council (after Van der Wal *et al.* 2001).

4. PREDICTIVE METHODS

Numerous predictive methods to understand and interpret estuary morphological change were documented and assessed by the EMPHASYS consortium during ERP Phase 1. Detailed guidance on selection is included in A Guide to the Prediction of Morphological Change within Estuarine Systems (EMPHASYS Consortium 2000c). They are categorised by considering how they deal with morphological changes in time, and how they deal with morphological changes in space. Most methods belong to one type in both the space and time categories. Short-term predictive methods (sometimes referred to as "Bottom-up" methods) represent detailed physical processes at local space scales over short timescales (Section 4.2). Long-term predictive methods (sometimes referred to as "Top-down" methods) are based on conceptual ideas and operate at larger space and longer timescales (Section 4.3). "Hybrid" methods combine the best features of "Bottom-up" and "Top-down" methods (Section 4.4).

The purpose of this section is not to describe the methods in detail but to focus on the approach to decide which methods are applicable and valid given the wide range of circumstances under which they may be applied. The interpretation of the resultant outputs is introduced, and how confidence in the results can be maximised. Each of the methods has it's strengths and weaknesses, and suitability to addressing the issues, but as every problem and every estuary is different it is impossible to make universally applicable predictions.

As an aid to the selection of the appropriate methods the Uptake Project has produced a prototype interactive software programme that guides the user through a series of steps from issue definition to the generic methods best suited to appraise the issue. Further details of the software and its accessibility are provided in Appendix B of these notes.

4.1 Deciding Which Predictive Methods to Use

At the outset of any study in which estuary predictive methods are envisaged, it is important to establish the type of morphological prediction required. To this end, it is first necessary to understand the capabilities of available methods that could be used in the study. The issue which needs addressing may require a number of different temporal and spatial scales of interest to be considered (see Section 2.2), which are dependent on the specific project and the specific location. The type of method used will also depend on the amount of data that is available or attainable for its development, the degree of accuracy or reliability that is warranted, and the resource constraints on the project (personnel, equipment and finance).

Any particular predictive method should not be used in a "black box" mode, whereby the internal workings of the method are not known. An understanding of the underlying scientific concepts (Section 2) and a clear idea of the type of data required (Section 3) for a particular application is essential. Several questions need to be asked before proceeding down the route of using a predictive method:

- Should predictive methods be used at all?
- Which type of method should be used?
- What mode of operation of the method should be used?

In the first instance, the issues at hand or the scale of the issues may not require the use of a predictive method. The type of information available from a non-predictive approach may be sufficient to answer the problem. Indeed, although predictive methods may be appropriate and would supply added value, the benefit may only be sufficiently marginal, not to justify the extra time or expense.

In the second instance, once the decision has been taken to use predictive methods, in order to most accurately predict changes within an estuary the temporal and spatial scales of interest need to be addressed. Typically, an issue that has large spatial scales (estuary-wide) also has long time scales. The choice of scales should be made in consultation with the appropriate consultees (Section 2.3). Time and space scales may be defined as in Table 4.1.

Table 4.1 Time and space scales.

Time	Space
Geological (10^6 years)	Underlying geology of the catchment area
Holocene (last 10 000 years)	Development of the main features of the estuary
Historical (centuries)	Large scale features such as channels or islands
Decadal (10-100 years)	Intertidal flats, saltmarshes, creeks etc
Annual/ seasonal	Sediment fluxes
Tidal Period (12.4 hours)	Ebb and flood channels, drainage channels etc
Wave Period (few seconds)	Bed features such as ripples

In the third instance, once the method has been chosen, there are likely to be a number of ways in which it can be used to produce results in different forms. Similarly, the input of data can take different forms. The way in which a method is used requires careful consideration of what type of information is needed. This should take account of both the nature of the application and what it is possible to achieve scientifically.

4.2 Short-Term (“Bottom-up”) Predictive Methods

Two types of method are generally applied to the understanding and prediction of processes over the short-term: physical methods and numerical methods.

4.2.1 Physical Methods

Physical methods aim to predict future conditions using a scaled reproduction of the situation in reality. These types of methods are frequently used to test engineering structures and help to reveal critical conditions for instability and factors influencing performance. Conditions can be controlled and experiments run under different simulated conditions.

Several pitfalls are associated with the use of physical methods. These relate to problems associated with scaling-down, where simplifications are often made, and with the difficulties of simulating and replicating the complex interaction and combination of processes. In addition, they are relatively expensive compared to numerical methods.

4.2.2 Numerical Methods

Numerical methods can overcome some of the difficulties of physical methods and, given the power of modern computers, are easy to run. There are two main types of numerical methods; hydrodynamic modelling and sediment transport modelling. Hydrodynamic modelling is the simulation of water movements including water levels, current speed and direction, and waves. Sediment transport modelling is the simulation of sediment movement due to hydrodynamic influences. Hydrodynamic models can be broken down further into 1D, 2D and 3D models, which are defined as follows:

- **1D -** One-dimensional models only simulate situations in one dimension and assume that the other dimensions do not vary. This is an inexpensive method of modelling in homogenous areas and can also be used to provide a quick and simple solution to determine whether additional modelling may be required.

- **2D -** Two-dimensional models can be horizontally 2D or vertically 2D along one profile. Horizontal 2D models assume that there is little or no variation through the profile. The most common type of 2D models are either depth-integrated or depth-averaged models. Vertical 2D models take one profile and consider variations with depth.

- **3D -** Three-dimensional models use the equations of motion in all three spatial dimensions to represent the behaviour of a system. These models are very complex and are usually used for looking at small areas only, due to excessive computer time demands. 3D coastal models are of most use when studying regions of complex behaviour, such as wave breaking.

Numerical models are based on formulations of the component processes reduced down, as far as possible, to the first principles of physics. This assumes that the physical principles are known and correct. Simplifications are often made and this may eliminate crucial or significant components.

Examples of the use of numerical models in the demonstration projects are described in Boxes 5 and 6.

4.2.3 Advantages and Disadvantages

The main advantages of short-term predictive methods are:

- They provide local, short-term predictions of morphological change
- They give additional information on changing current patterns and other physical processes
- They allow the effects of short-term events to be quantified
- They can quickly evaluate many different scenarios

The main disadvantages of short-term predictive methods are:

- They require a complete understanding of the physics of processes
- They are not suited to large-scale or long-term prediction

- They cannot predict major changes in flow or form
- They are computationally expensive

4.3 Long-Term (“Top-down”) Predictive Methods

Long-term predictive methods are highly varied, meaning different things to different people. The majority of methods are able to measure the long-term response of an estuary to natural changes in forcing, such as sea-level rise, and also account, to a varying degree, for changes in morphology following human interference such as engineering works or dredging. It is possible to use long-term methods to make hindcast predictions of estuary morphology, allowing comparison between the results from the methods and observed data. Long-term methods can take one of two approaches; expert analysis of data or consideration of regime type concepts. Several of the most commonly used methods are:

- Historical Trend Analysis
- Expert Geomorphological Assessment
- Rollover (using Regime Theory)

4.3.1 Historical Trend Analysis and Expert Geomorphological Assessment

The Historical Trend Analysis method essentially involves the interrogation of time series data to identify directional trends and rates of processes and morphological change, over varying time periods. The most common dataset is historic bathymetric charts. The Expert Geomorphological Assessment method incorporates output from Historical Trend Analysis, but also takes account information about current physical processes, geological constraints and sediment properties, and general relationships between processes and morphological responses.

As long as due regard is taken of data origins and accuracy, predictions based on extrapolation of trends can provide a reliable estimate of the most probable evolution of the estuary. However, a simple linear extrapolation into the future will not take into consideration the complex nature of natural estuary systems where future conditions may differ from the past. There are many reasons for this type of departure including climatic or human-induced change, or the presence of geological controls.

Examples of the use of Historical Trend Analysis and Expert Geomorphological Assessment in the demonstration projects are described in Boxes 5 and 6.

4.3.2 Regime Theory and the Rollover Method

Regime Theory uses an empirical relationship between estuary gross morphology and tidal prism, through simple power-law equations. Predictions of the effect of, for example, managed realignment of flood defences is made in terms of the resulting changes in estuary cross-section. The rollover method is based on Regime Theory and investigates the landward transgression of the estuary with sea-level rise. The change in shape, elevation or position of the estuary may be predicted, but caution must be exercised to account for man-made effects.

Crucial to the whole philosophy of prediction using Regime Theory is that the morphology will evolve to achieve an equilibrium between the forcing of the waves and currents moving sediment and the resulting form of the estuary created by that movement. At present there is no evidence that any estuary system is in long-term equilibrium. It is also difficult to quantify how close, or how far, an estuary is from an equilibrium morphology.

4.3.3 Advantages and Disadvantages

The main advantages of long-term predictive methods are:

- They provide an integrated approach making predictions for whole estuary over long periods
- They are computationally cheap, allowing various options and scenarios to be explored
- Whole estuary calibration takes account of other processes such as biological and sedimentological processes

The main disadvantages of long-term predictive methods are:

- They are not suited to predict local or short-term changes
- They generally omit detailed physics
- They cannot predict responses to extreme events

4.4 "Hybrid" Methods

"Hybrid" methods combine Regime Theory with detailed short-term methods based on physical principles and data. They provide a framework to interpolate between local, short-term and estuary-wide, long-term morphological change. They allow for long-term prediction and the inclusion of any feedback between process and form.

The main weaknesses of the hybrid methods are those inherent in Regime Theory (see Section 4.3.2). In addition, the results can only be evaluated qualitatively by comparison with what the expert thinks looks reasonable. To provide a quantitative evaluation, will require far more comprehensive datasets over longer times than are presently available.

4.5 Calibration, Validation and Interpretation of the Results

Decisions about how the results of a method should be interpreted need to be made at the start of the study, and should relate to a clear understanding of the type of information needed from the method. These decisions are reflected in the choice of method and its mode of use. It is important to understand what the assumptions in the method are, and the results should be interpreted in this context.

It is not necessary to understand the details of the different methods available, but rather to concentrate on considering how the confidence in the method can be maximised. This is achieved through calibration and validation, which consider the resolution and accuracy of the results. The aim of calibration and validation is to compare method predictions with data of sufficient quality and quantity, so that reliable conclusions can be made about the methods performance as a predictive tool. Although, the results of 1D, 2D and 3D methods offer increasing realism with the number of dimensions modelled, they also are increasingly difficult to calibrate and validate.

Several factors need to be considered to ensure confidence in the interpretation of the method outputs. These are:

- Do not assume either the method or data are accurate, both may contain a degree of uncertainty
- Use relevant data to calibrate and validate methods against observed patterns
- Ensure that the predicted changes are plausible
- Are the results consistent with those from other similarly classified estuaries?
- Are the results consistent with accepted geomorphological development?
- Evaluate the results using ranges of possibilities and probabilities of predictions as far as possible.

4.6 Information Sources

Further information on predictive methods can be found in the following ERP Phase 1 reports and products (see Appendices A and B for more details and accessibility).

- Experimental Interactive Software Decision Tree (ERP Phase 1 Uptake Project 2002).

- Modelling Estuary Morphology and Process Final Report (EMPHASYS Consortium 2000a).

- Section 4 and Appendix 3 of A Guide to the Prediction of Morphological Change within Estuarine Systems (EMPHASYS Consortium 2000c).

- Predictive Methods Report (Posford Duvivier 2000).

Box 5 Predictive Methods – Blackwater Demonstration Worked Example

The scoping study (see Box 1) is aimed at identifying the potential impacts as a means of building up an initial conceptual model of how the estuary will be affected by the proposed works. For the Abbotts Hall managed realignment scheme a number of short-term processes were identified as being potentially affected by the scheme and in this case, application of process-based methods can provide useful further development of the conceptual model (HR Wallingford 2001). It can also allow additional sensitivity testing to consider alternative schemes that may have a less adverse impact.

For these studies the short-term impact was interpreted by assessing the change to the hydrodynamic conditions at the site. It was anticipated that the scheme would give rise to increased discharge through the estuary (to fill the realignment areas), and hence this assessment focussed on determining the quantitative change in tidal currents, from which an appreciation of the impact on the morphology was made.

The approach adopted at Abbotts Hall was to apply a 2D hydrodynamic flow model (TELEMAC) to simulate the tidal processes over short timescales, for existing conditions and for the case following breaching. TELEMAC-2D was chosen for several reasons including:

- It allows detailed model resolution where required
- The availability of LiDAR data allows equally fine resolution of the creek networks through the saltmarsh for input into the model

Prior to simulating the proposed scheme an important stage of calibration and validation was undertaken, which in this case involved comparing tidal currents and tidal water levels to measurements throughout the estuary. An important aspect of this calibration stage was the requirement to demonstrate that the model was capable of predicting the tidal water levels over the upper half of the tide, when the realignment sites were filling and emptying. Calibration was performed on spring tides, in which the available model parameters were tuned to give a good representation of the tidal propagation. Validation was performed by comparing neap tidal currents and levels without any tuning of these parameters.

A direct comparison of before and after scenarios using the above method provided detailed information on the impact of the scheme. **Figure 4.1** shows a time-history plot of spring tidal currents for the two scenarios, at locations downstream of the proposed breaches. The increased tidal prism of the estuary following breaching has a small effect on tidal currents at these far-field locations. This information, together with further processing of method results led to an estimation of the potential erosion through the main channels at the entrance to the estuary. Other findings from the studies were that there would be significant changes to the tidal currents at each of the breaches, but that water levels and tidal range throughout the entire estuary would be little affected.

With respect to long-term evolution, the lack of multiple survey data of any type relating to the Abbotts Hall area, or indeed to much of the wider Blackwater Estuary, meant that Historical Trend Analysis and most of the other long-term methods could not be applied in their conventional form. Expert Geomorphological Assessment was therefore performed, using a combination of digital elevation modelling (DEM) and tidal inundation prediction, comparison with existing field datasets and predictions based on evaluation of historical change information provided by sedimentological and archival record both from within the Blackwater Estuary and from other Essex Estuaries.

The limited nature of the available bathymetric data (**Figure 3.1**) meant that it was not possible to calculate overall changes in sediment volume or areas for the estuary as a whole. However, it is evident that in recent decades the main channel in the outer estuary has experienced deepening while there has been little depth change in the inner estuary (**Figure 4.2**). There has been net saltmarsh loss since 1874 thoughout the estuary, but especially on the northern side of the main estuary.

The DEMs based on LiDAR data of the Abbotts Hall site indicate that the land levels behind the five breaches differ significantly. Previous studies of natural sea wall failures and "natural" setbacks in Essex (e.g. Burd *et al*. 1994; Crooks and Pye 2000) have demonstrated that some sites have successfully developed new saltmarsh while others have experienced progressive internal dissection and late stage mudflat creation. The critical determining factor has been shown to be relative elevation of the land surface relative to number of tidal floodings at the time of breaching. Based on this historical dataset, it can be predicted that present surfaces lying below 2.1 m OD at time of breaching are unlikely to develop saltmarsh and remain as mudflat. Surfaces between 2.1 and 2.35 m OD are likely to develop saltmarsh which is potentially unstable and may experience severe internal dissection in the medium term, while surfaces above 2.35 m are likely to develop saltmarsh which will remain stable in the medium to longer term. Using this model, predictive estimates have been made for the percentages of “stable”, “potentially unstable” and mudflat likely to be created within *c*. 5 years at each of the Abbotts Hall breaches. The spatial distribution of the three categories for the area behind breach A is shown in **Figure 4.3**.

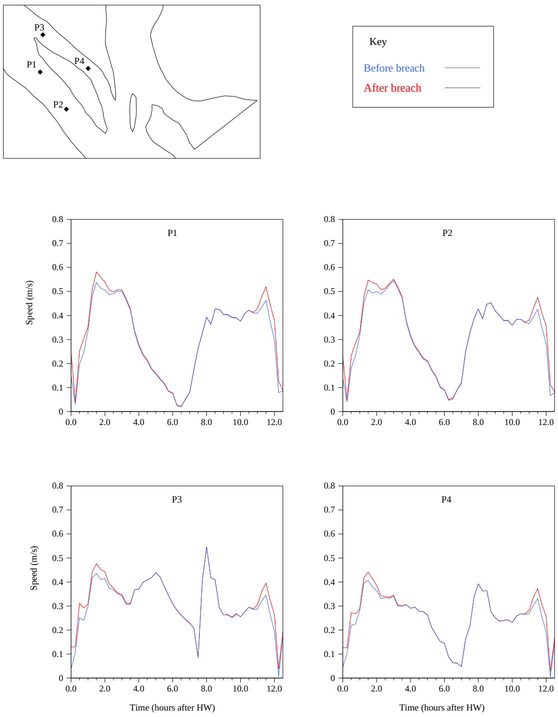


Figure 4.1 Time-history plots of spring tidal currents for existing conditions and following breaching at Abbotts Hall, in the Blackwater Estuary (from HR Wallingford 2001).

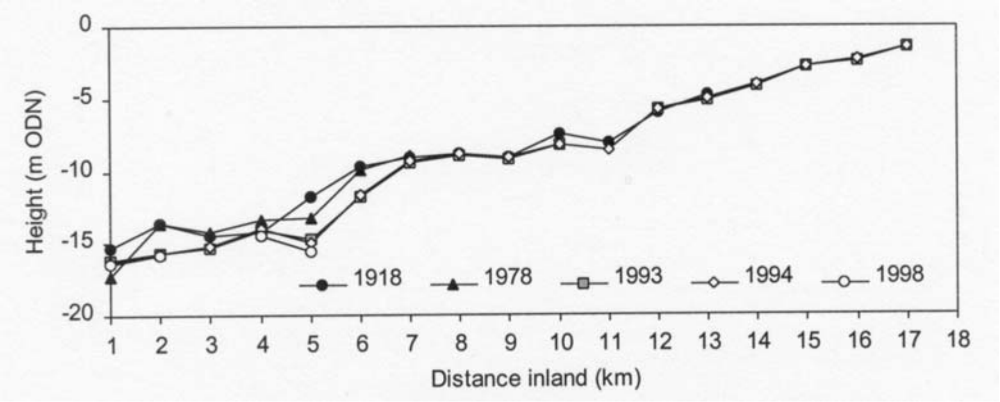


Figure 4.2 Changes in the thalweg of the Blackwater Estuary between 1918 and 1998, based on maximum depth recorded along the profile lines shown in Figure 2.1 (from Van der Wal and Pye 2000).

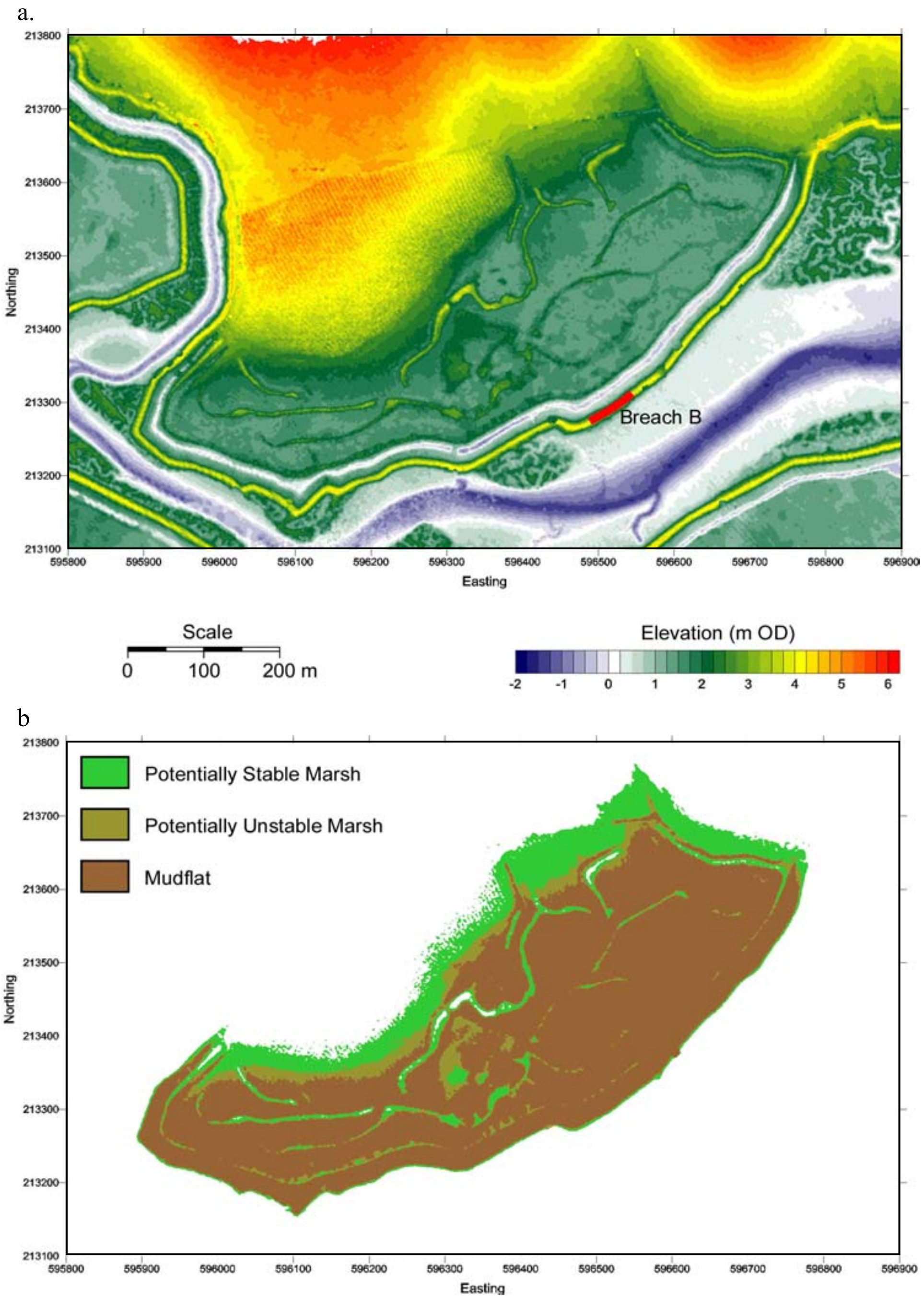


Figure 4.3 (a) Digital elevation model of part of Abbotts Hall managed realignment site generated from LiDAR data, and (b) areas of potentially stable saltmarsh (>3.35 mOD), potentially unstable saltmarsh (2.10 to 2.35 m OD) and mudflat (<2.10 m OD) habitats created at Breach B, predicted using data from historical sea wall failures in Essex (Burd *et al*. 1994). After Pye and Blott (2002).

Box 6 Predictive Methods – Mersey Demonstration Worked Example

Historical information collected as part of the data collation exercise (see Box 4) established that the entrance and lower reaches of the Mersey Estuary altered significantly (by design) following the construction of the original training walls. It is logical to assume that further changes to the training walls, when substantial, would also have an effect on the hydrodynamic and sediment transport processes, and that these effects would cover both short and long time-scales as well as small and large space-scales.

The impact on the tidal propagation and associated tidal currents was deduced by running numerical models for the existing conditions and following removal of part of the training wall. For this short-term worked example the scenario simulated comprised removing part of the training wall on the west side of the approach channel, close to the entrance to the Mersey Estuary where the flood channel had been prior to the original wall construction. Sea bed levels on the west side of the training wall were also reduced as a means of representing a hypothetical future scenario.

For these studies the short-term impact was interpreted by assessing the change to the hydrodynamic and sedimentological conditions at the site. Clearly, for a scheme as large as this, with large potential consequential impacts, there is a requirement to build a comprehensive conceptual model based on all available data, in order that the full effects on all relevant processes can be assessed. By relating the proposed scheme with the historical evolution of the estuary following construction of the original training walls, a basis for interpreting the potential impacts can be established.

It was anticipated that the scheme would significantly affect the tidal propagation into the estuary, and therefore alter current and sediment transport fields both locally and in the far-field. Extensive calibration of the model had been previously undertaken in which the tidal hydrodynamics were compared with data, and the sediment transport and associated rates of channel infill were compared with data arising from the maintenance dredging records.

Figure 4.4 shows the effect that the training wall removal has on the local tidal currents at peak flood tide. As expected, the discharge through the newly formed channel has the effect of reducing the influx through the main fairway. Sedimentation of the main channel should be anticipated as a consequence. In terms of far-field impact, **Figure 4.5** shows tidal levels for existing conditions and following removal of the training wall, indicating that the scheme has a significant impact within the estuary.

With respect to long-term predictions, the nature of the Mersey Estuary and the available datasets (see Box 4) mean that Historical Trend Analysis and Expert Geomorphological Assessment are the two most powerful long-term methods applicable to address the hypothetical issues of training wall removal.

GIS analysis of digitised chart data have shown there have been major changes in the morphology of the banks and channels in the outer estuary and Liverpool Bay in the last two hundred and fifty years (**Figure 4.6**). Prior to training wall construction and dredging, the outer estuary contained several flood and ebb channels separated by shifting banks. Following training wall construction, flow became concentrated in the main (Queen's and Crosby) channel, while the former Rock Channel and Formby Channels shoaled and essentially disappeared. There has been a trend for sedimentation within the main channel, with a requirement for maintenance dredging. The quantities dredged declined significantly after the late 1970s, and the result has been a significant increase in sediment volume within certain sections of Crosby and Queen's Channel (**Figure 4.7**). This is especially marked by an overspill of sand against the south training wall adjacent to the northern end of Burbo Bank.

Analysis of historical maps has shown major changes in the position of the adjoining coastlines since 1845. Between 1845 and 1906, Formby Point experienced progradation of up to 1 km, but since 1906 much of this dune coastline has been eroding. The change from accretion to erosion was due in large part to changes in the offshore bathymetry and wave focusing affected by training wall construction and dredge spoil dumping (Pye and Neal 1994).

Detailed analysis of LiDAR topographic data, beach profile data and measurements of dune accretion and erosion has demonstrated a close interrelationship between the width and height of the intertidal zone and the stability and morphology of the frontal dunes (van der Wal *et al*. 2001). The nature of the quantitative relationships derived allows prediction of the effect on the stability of the frontal dunes of a given change in intertidal zone width and height. In general, a reduction in width of the intertidal zone (e.g. due to channel shift) is likely to enhance wave energy and reduce the rate of frontal dune accretion (or enhance erosion, with resultant dune cliffing and higher frontal dune crests). A northeastward shift of the main navigation channel (due to training wall removal or abandonment) of 100 m would be predicted to change the position of the southern dune erosion limit slightly (perhaps by 200 m towards the south) but is unlikely to have much effect on erosion rates and limits from Formby Point northward.

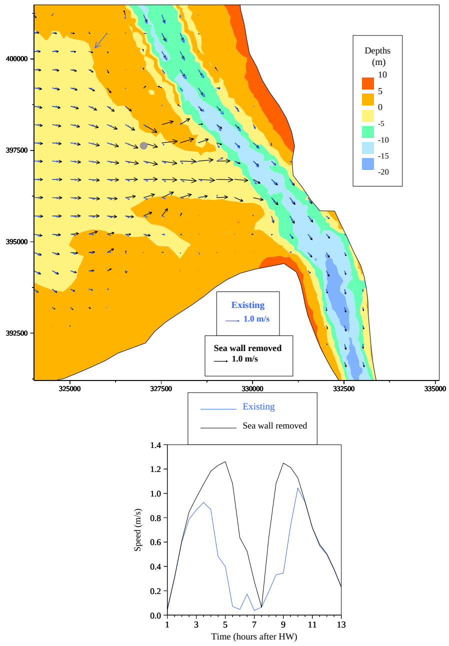


Figure 4.4 The effect on local tidal currents at peak flood of the removal of a section of the west training wall in the Mersey Estuary.

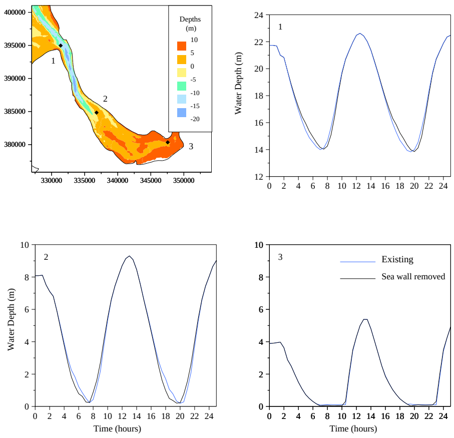


Figure 4.5 Tidal levels for existing conditions and after the removal of a section of the west training wall in the Mersey Estuary.

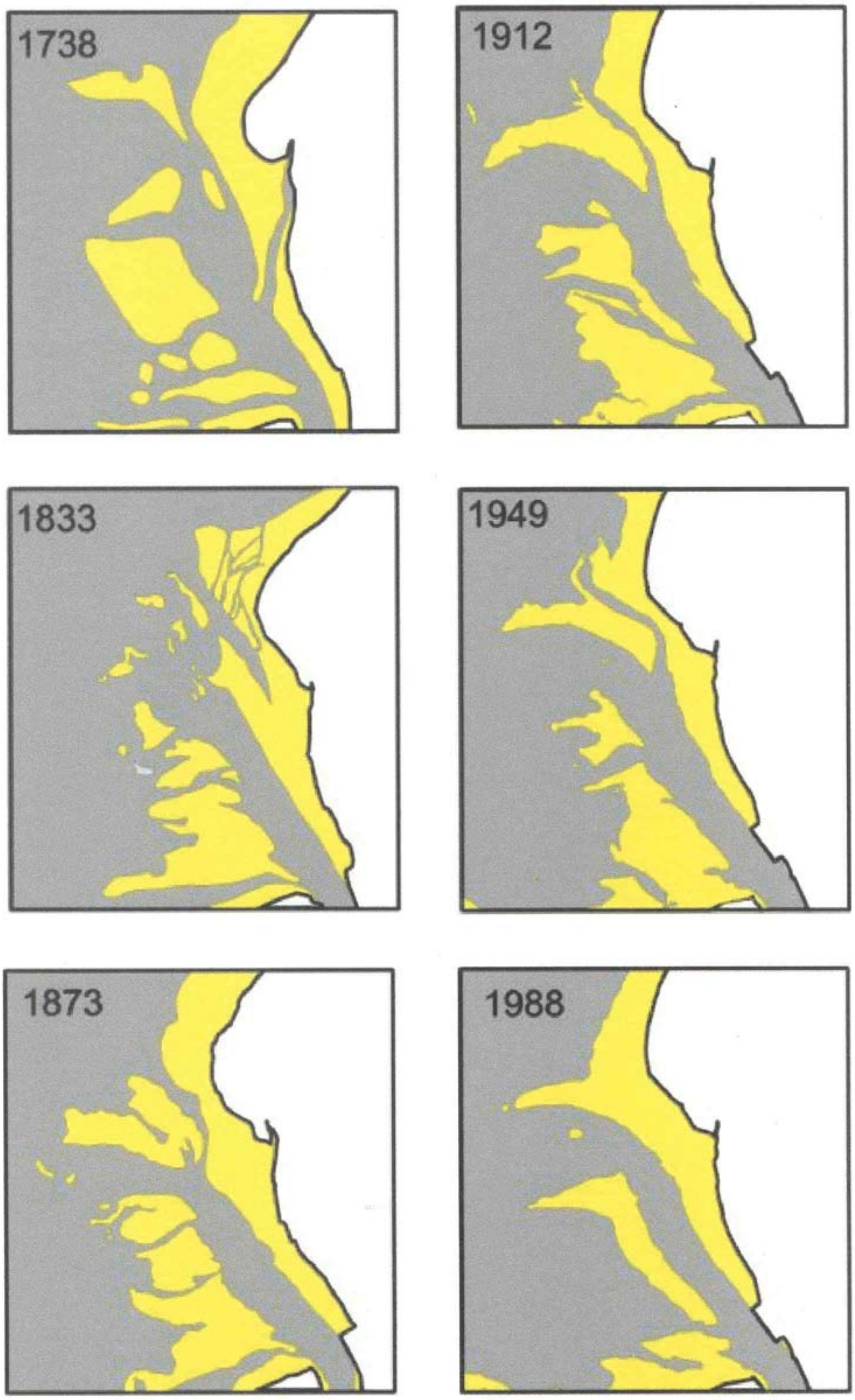


Figure 4.6 Position of sand banks and flats (areas above Liverpool Bay Datum, i.e. - 4.43 m OD) in the outer Mersey Estuary and Liverpool Bay (after Pye *et al*. 2002).

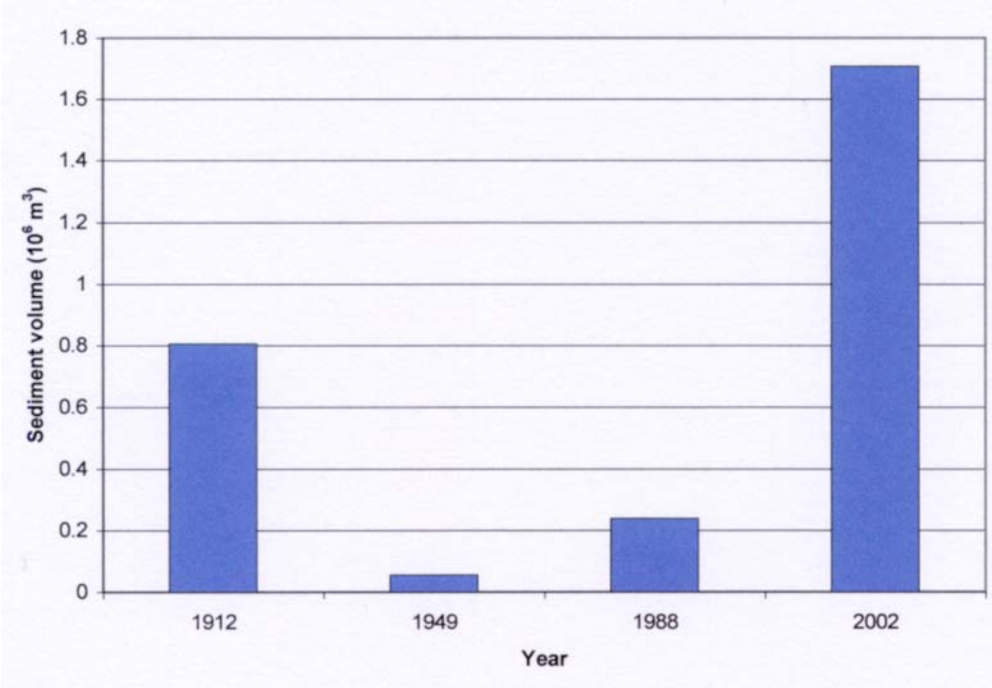


Figure 4.7 Changes in sediment volume above lowest astronomical tide in Crosby Channel and Queen's Channel, based on GIS analysis of charts such as those shown in Figure 3.4 (after Pye *et al*. 2002).

5. SYNTHESIS

Synthesis is the process of gathering together all the pertinent evidence from the existing (and new) data and the interpretation of the results of the predictive methods used. It allows decisions to be supported based on an understanding of the predicted behaviour and responses of the estuary to the issues (Section 2), and considers risks and uncertainties. The synthesis of information related to the demonstration projects in the Blackwater and Mersey Estuaries are described in Boxes 7 and 8.

The synthesis process has three main parts. The first relates to synthesising the scientific results by comparing the outputs from the short-term and long-term methods. This allows an assessment of their consistency and conflicts with respect to each other and their subsequent input into a conceptual model (Section 5.1). An outline of conceptual model development is provided in Section 5 of A Guide to the Prediction of Morphological Change within Estuarine Systems (EMPHASYS Consortium 2000c) (see Appendix A). The second relates to risk and uncertainty in the decision-making process (Section 5.2). This includes risk and uncertainty inherent in the methods themselves and the risk of unexpected future events, not catered for in the predictions. The third relates to examination and integration of the results with other aspects of estuary management including legislation, consultation and mitigation, and perhaps to modify the scheme in the light of these various aspects (Section 5.3). Summaries of the legislative context and consultation are provided in Sections 2.1 and 2.3, respectively.

5.1 Conceptual Model

The analysis of the available data (Section 3), application of the adopted methods and their interpretation (Section 4) provide a conceptual model of how the estuary's components function. The model should be tested against factual and interpreted data and refined as necessary before it can be used, together with additional studies, to define management objectives and options. To effectively manage all uses of an estuary, it may be necessary to present the conceptual model to a range of users (perhaps as part of the consultation process, Section 2.3). For this reason the basis for any conclusion needs to be logical and as transparent as possible.

The establishment of a conceptual model requires incorporation of information from a wide variety of sources including the method outputs. If the model is to be developed for a local issue, it may not need to contain as much detail as that for a larger strategic or whole-estuary study. The required level of understanding for the latter should combine the results from long-term methods with those from short-term methods that provide information on the important process parameters. The conceptual model can only provide answers on the time and space scales for which it was designed, and it is unlikely to be translatable to any other issue.

The approach to refine the conceptual model should utilise as much of the available data and knowledge of the estuary as possible. The main steps in evaluating the conceptual model (after Townend 2002) are three-fold. First, test the initial conceptual model (Section 2.4) against factual data to eliminate misrepresentations and identify areas of uncertainty, and then modify the model as necessary. At this stage the conceptual model is based on established behaviour (taken from the literature) and the factual information for the particular estuary. Second, test the conceptual model against interpreted outputs from the methods used (Section 4), noting assumptions and uncertainties. Where there are contradictions that cannot be reconciled, the results should be presented to highlight the uncertainty, or further studies undertaken to resolve the uncertainty. This stage provides further opportunity to update the model, but this should be carried out with a degree of caution, because the underlying assumptions in the methods may be the cause of discrepancies rather than some aspect of the conceptual model. Third, the conceptual model should be documented for ease of communication and the interpretation of changes and impacts clearly explained. The success of the conceptual model will depend on whether it has answered the questions that were posed when the issues were defined.

5.2 Risk and Uncertainty

With respect to predictive studies, risk has two aspects:

- A term used to convey the chance of an event happening, and its consequences
- Risk associated with the quality of the methods and data

In the first instance, the link between the likelihood and the consequences provides the key to risk assessment and risk-based decision-making. Consequences may include environmental, social or economic impacts. In the context of the estuary management process, although methods are able to predict long-term and short-term estuary morphological change, they will not be able to remove the risk of the unforeseen happening. For this reason, whilst all practical study should be undertaken, the scheme should be viewed within a risk-based framework to underpin the decision-making in policy, planning and implementation.

In the second instance, care has to taken to evaluate the risk and uncertainty of the methods not duplicating reality or the risk that the existing (or newly collected) data are not adequate. For some aspects of the conceptual model, there will only be limited information, whereas for other aspects, there may be many sources. In each case it will be necessary to assess the uncertainty, and to consider what further information would reduce the level of uncertainty.

Sections 4.2 and 4.3 highlight the potential risks of using short-term and long-term methods, respectively. To lower the risk and uncertainty associated with any method, calibration and validation exercises should be undertaken (see Section 4.5). To lower the risk of poor quality data being input into the method, an error assessment should be carried out (see Section 3.3).

Detailed information on risk and uncertainty can be found in the Risk and Uncertainty Review report (see Appendix C).

5.3 Mitigation

Where possible, potential adverse impacts of any scheme should be avoided through sensitive design. However, a number of potentially significant beneficial and adverse impacts will almost certainly be identified. Many of the adverse impacts can be avoided, reduced or minimised to acceptable levels through careful implementation of mitigation measures and good working practice. Mitigation measures may need to be implemented during both the construction and operational phases. In order to ensure the full implementation of any highlighted mitigation measures, detailed specifications should be included within in any contract documents for the scheme. Ideally this would be in the form of an Environmental Action Plan.

Mitigation may take the form of another scheme in the estuary. For example, the process of land-claim of saltmarsh may require mitigation by managed realignment to create new saltmarsh habitat elsewhere. Successful implementation of these new works will rely on a realistic conceptual model (Section 5.1), so the conceptual understanding can be applied to other parts of the estuary. The conceptual model is therefore important as it forms feedback in the study process; it can be used to evaluate steps for mitigation, but then it may be used to predict the consequences of the mitigation activities themselves.

Box 7 Synthesis – Blackwater Demonstration Worked Example

The use of factual information to establish and test the initial conceptual model of the Abbotts Hall site is described in Box 1. Following numerical hydrodynamic simulation and Expert Geomorphological Assessment of the breached conditions an improved conceptual model was constructed to assess the impact of the breaching on the existing regime, and thereby assess the potential effects on sediment transport and morphology within the Blackwater Estuary. The key components of the conceptual model for Abbotts Hall derived from the results and conclusions of the above methods include the following:

- Generally, the breaches will allow inundation of the areas behind the sea wall during the upper half of the tide only
- The pattern of flooding and subsequent sedimentation and ecological change is likely to be very different in each of the marsh re-creation areas associated with the five breaches; reflecting the nature of the pre-existing topography and land elevation
- In the case of most of the breaches there is likely to be some short-term erosion in and around the breaches, and in the adjoining natural channels due to increased current speeds, leading to slight elevation of local turbidities (Pye and Blott, 2002)
- In the longer term a complex creek system, with blind mud basins and areas of standing water, is likely to develop, especially in the lower re-flooded areas.
- Rates of vertical sedimentation will be dependent on ground elevation, but in most areas 70–100 cm of fresh mud can be expected to accumulate over the next century. Under most conditions saltmarsh plants are quite capable of keeping pace with such rates of vertical accretion.
- Some internal dissection of the new marsh areas can be expected but this is unlikely to result in large-scale mud basin creation through creek coalescence on a 50-100 year timescale
- The effects of this scheme on the Blackwater Estuary beyond Salcott Channel are likely to be minimal

The potential impacts associated with the construction and operational phases of the managed realignment scheme were highlighted in the context of the conceptual model (Posford Haskoning, 2001), and where potentially adverse impacts were identified, possible mitigation measures were examined. The significance of the impacts were evaluated through a process comprising consultation, field investigations, literature reviews and comparison to standards as appropriate. Potential adverse impacts and suggested mitigation measures during the operational phase include:

- Possible damage to intertidal and subtidal flora and fauna as a result of erosion due to increased current speeds; no mitigation possible as impact is unavoidable
- Potential smothering of benthic communities due to increases in suspended sediment; no mitigation possible as impact is unavoidable
- Potential erosion of existing saltmarsh due to increased current speeds; mitigation involves recommendation to monitor
- Potential loss of a freshwater pond due to tidal inundation leading to loss of great crested newt; mitigation involves construction of a bund seaward of the pond
- Smothering of oysters due to increases in suspended sediment; impact is negligible so no mitigation required
- Loss of terrestrial feeding and roosting areas for birds; no mitigation possible as impact is unavoidable

The risks associated with any predictions in the Blackwater Estuary include the danger of the data, field measurements and monitoring being recorded during unusual conditions. The risks of the unforeseen happening may include the future occurrence of storm events (e.g. a 1 in 100 year storm surge) or the risk that sea-level may be higher than predicted. There is clearly a need to identify and recognise these risks, which are intrinsic to the east coast, in relation to the Abbotts Hall scheme.

Box 8 Synthesis – Mersey Demonstration Worked Example

The use of factual information to establish and test the initial conceptual model of the outer Mersey Estuary is described in Box 2. Evaluation of sediment volume and morphological changes based on sequential bathymetric surveys (HTA), the nature of process-form relationships based on morphometric analysis and repeat beach and dune surveys (EGA), combined with hydrodynamic and sediment transport modelling, allows construction of an improved conceptual model.

Training wall construction and dredging have clearly had a profound effect on the regime of the Mersey Estuary, leading to net accretion of sediment in the outer estuary and Liverpool Bay on either side of the training walls, with associated infilling and drying of Formby Channel, Rock Channel and several other channels through Burbo Bank. Previous physical and theoretical modelling studies have indicated that this was due to a concentration of flow within the trained channel and enhanced flood-dominated sediment transport over the surrounding banks and channels. Wave modelling and studies of historical maps and charts have also indicated that training wall construction and dredge spoil dumping also had a significant impact on the erosion/accretion status of the adjoining coasts, especially the Sefton coastline. Consequently it is logical to hypothesise that further changes to the training walls might have a significant impact both on hydrodynamic and sediment transport processes and on morphology. This hypothesis is also supported by previous event sequences in the Ribble and Nith Estuaries following breaching of the training walls and abandonment of maintenance dredging.

By way of example, short-term hydrodynamic modelling has shown that removal of part of the west training wall and re-establishment of a secondary channel is likely to reduce the magnitude of tidal flow and velocities through the main channel, increasing the likelihood of sedimentation. Short-term modelling also suggests that there would be a significant impact on tidal levels throughout the estuary. It is likely that breaching or removal of the north / east training wall would have similar effect, but consideration of other analogue situations (e.g. Ribble, Nith) suggests that re-establishment of the former Formby and Rock Channels, is likely to be a slow process.

Of major concern would be the potential impact of resulting changes in outer estuary bathymetry on the accretion/erosion and flood risk status of the adjoining coastlines. The overall effect on net intertidal area and sediment volume can be estimated based on historical changes which occurred following training wall construction and the onset of dredging, although such estimates are reliant on a number of assumptions and the accuracy of the original data sources and processing methods. There has been a *c*. 30% reduction in intertidal sediment volume (i.e above LAT), and *c*. 10% reduction in intertidal area, in the outer Mersey Estuary since 1912, although little net change in the total sediment volume above the lower datum of survey (-30 m ODN).

A northward/eastward movement of the Queen's Channel and Crosby Channel, with associated change in position, area and possibly height of Taylor's Bank could have potentially serious consequences for the Sefton Coast cSAC and SPA. Wave energy, foreshore levels and dune erosion/accretion along the shore between Formby Point and Hightown are strongly dependent on the size and shape of Taylor's Bank. A consideration of the interactions between intertidal morphometric parameters and dune accretion/erosion trends, based on LiDAR data, repeat ground surveys and previous wave modelling results, suggests that a change in size of the bank without crestal lowering would result in a slight northward shift in the northern limit of dune erosion at Formby Point. A lowering of the crestal height, on the other hand, is likely to lead to reduced wave focusing and a probable reduction in the severity of frontal dune erosion along most of the coast, although the southern limit of erosion would probably move slightly to the south. Although there would be some loss of cSAC dune and intertidal SPA area, the losses would be unlikely to affect the overall integrity of the site.

The effects on changes in intertidal morphology on the Wirral coastline are more difficult to quantify due to a poorer database. However, a reduction in foreshore width and/or height due to possible channel re-establishment is unlikely to have a significant effect on the position of the shoreline erosion which is now almost entirely protected.

Predictions of the medium to long-term effects of any changes to the training walls are subject to a number of uncertainties, which pertain to such factors as future sea-level rise, changes in wind-wave climate and changes in dredging regime. The risks associated with these uncertainties, in addition to those arsing from deficiencies in existing data quality and understanding of process-form interactions, can be addressed using 'what-if?' modelling strategies for a range of alternative scenarios. In the event of any changes to the training walls taking place, a number of measures could be adopted to limit any potentially adverse consequences. These include: (a) monitoring to provide "early warning" of any potentially adverse impacts on SPA/cSAC area, (b) control of the rate of growth/movement of newly evolving channels and banks through further engineering works, and (c) mitigation of intertidal or dune habitat loss through beneficial use of dredgings and dune management strategies.

6. CONCLUSIONS

To address the needs of decision-makers to evaluate options for managing estuaries requires a well-developed theoretical framework. The ERP Phase 1 report “A Guide to the Prediction of Morphological Change within Estuarine Systems” (EMPHASYS Consortium 2000c) outlined such a framework for the application of methods currently available to predict estuary morphological behaviour. These guidance notes support the EMPHASYS consortium report by providing worked examples, from the Blackwater and Mersey Estuaries, of adopted approaches during the estuary management process.

The generic principles are described in these notes using four main components of the estuary management process; defining the issues, data requirements, predictive methods and synthesis.

Defining the Issues – A clear understanding of the issues to be resolved at the outset of a study provides the context within which morphological change should be predicted. Any initiative is likely to have specific goals, with constraints defined by the time and funds available. Key factors to take into consideration when defining the issues include their time and space scales, how they fit into present legislation and the needs of stakeholders.

Data Requirements - Predictive methods are only as good as the data that they are founded upon. Where data are greater in quality and quantity, so a more accurate prediction is likely to be made. Importance should be attached to confidence building in data quality. Gaps in the data requirements should be identified, and new data collected for input into the methods and for their calibration and validation.

Predictive Methods - It is evident that no one method can provide adequate prediction of morphological change in all estuaries in all cases. The problems of method application across space and time remain, and all methods have their strengths and weaknesses. It is therefore important to use a range of methods with which to generate confidence in the results. The methods adopted will depend on the prediction requirements (in terms of the issue), the quantity, type and quality of the data available and the time and budget. Evidence for calibration and validation of the methods must be presented.

Synthesis – Part of synthesis involves the development of a credible conceptual model of estuary functioning as a basis for making decisions. The conceptual model should be tested against factual information and the interpreted outputs from the methods, and modified accordingly. Other areas of synthesis include the use of risk and uncertainty principles to the data and the results of the methods, and the application of the conceptual model to assess and adopt mitigation measures.

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APPENDIX A

Outputs of ERP Phase 1 – DEFRA Project FD1401

In 1999 DEFRA, the Environment Agency and English Nature initiated Phase 1 of the Estuaries Research Programme. This project carried out by the EMPHASYS (Estuarine Morphology and Processes Holistic Assessment SYStem) consortium (a group of consulting engineers, research laboratories and university researchers) was successfully completed in 2000. The project described methods capable of predicting changes in the shape (morphology) of an estuary and parameters related to the morphology. The consortium also investigated how different methods could be used to evaluate different management strategies.

The EMPHASYS Consortium published three reports describing the results of the original ERP Phase 1 research. Two further research reports were also published.

1. EMPHASYS Consortium 2000a. Modelling Estuary Morphology and Process Final Report. Report TR111. HR Wallingford.

Description: This is the final report of ERP Phase 1 and comprises short papers devoted to each of the methods described during the research. The papers outline how the methods were tested and the results of those tests carried out on a number of representative estuaries for which the project established that there is good data coverage (Humber, Blackwater, Mersey, Ribble, Southampton Water and Tamar).

Source: A pdf version of this report can be downloaded from the HR Wallingford web site URL: http://www.hrwallingford.co.uk/projects/ERP/doclist.html.

2. EMPHASYS Consortium 2000b. Recommendations for Phase 2 of the Estuaries Research Programme Final Report. Report TR113. HR Wallingford.

Description: This report reviews recent and ongoing estuary research (December 2000) in the UK and overseas along with the requirements for future data collection, monitoring and research, in order to produce recommendations for ERP Phase 2. The report highlights recommendations for future data collections and sites, establishes a framework for the development of improved predictive methods and identifies basic research areas into new technologies and improved modelling techniques. A number of implementation possibilities are put forward, ranging from a larger number of individually undertaken research projects, to a single large consortium as was appropriate for ERP Phase 1. A Research Plan for ERP Phase 2 has subsequently been written (see Appendix C for details).

Source: A pdf version of this report can be downloaded from the HR Wallingford web ite URL: http://www.hrwallingford.co.uk/projects/ERP/doclist.html.

3. EMPHASYS Consortium 2000c. A Guide to Prediction of Morphological Change within Estuarine Systems Version 1B. Report TR114. HR Wallingford.

Description: This guide provides best practice guidance on what questions need to be asked, and the data and methods that can be applied to forecast the effects of development and protection schemes on estuary flood defence and navigation. Links are made between the understanding and prediction of changes in estuary morphology and the resulting changes in the ecology and water quality that are subject to legislative constraints, policy and directives. The guide highlights issues that the promoter or regulator should look for in work undertaken by specialists on their behalf such that confidence in the outcome of the studies is maximised. This is a key guide in the context of the Uptake Project and contains information relevant to many of the sections of these guidance notes.

Source: A pdf version of this report can be downloaded from the HR Wallingford web site URL: http://www.hrwallingford.co.uk/projects/ERP/doclist.html.

4. Posford Duvivier 2000. Predictive Methods Report

Description: This report provides a critique of the methods tested during ERP Phase 1 and the data required, to predict changes in estuary morphology, water/sediment quality, and ecology over short and long time scales. The report reflects the strengths and limitations of the methods evaluated by the EMPHASYS consortium, and their potential for future development. Selected methods were tested against their ability to meet user needs.

Source: A hard copy of this report is available from Posford Haskoning. Contact Alun Williams, Posford Haskoning, Rightwell House, Bretton, Peterborough, PE3 8DW.

5. Posford Duvivier Environment 2000. Legislative Report

Description: This report provides an overview of the legislation (as of March 2000) in the UK that potentially has implications with regard to morphological change within estuary systems. The report provides a synopsis of the relevant pieces of legislation and (in certain cases), their implementation, dealing with key activities and areas of interest.

Source: A hard copy of this report is available from Posford Haskoning. Contact Richard Cottle, Posford Haskoning, Rightwell House, Bretton, Peterborough, PE3 8DW.

APPENDIX B

Outputs of ERP Phase 1 Uptake Project – DEFRA Project FD2110

The success of ERP Phase 1 has enabled continuation into Phase 2. However, it was recognised that the outputs and developments achieved by the EMPHASYS consortium should be more widely disseminated to allow practitioners involved in the management of estuaries to realise the full benefit from the research. This is the objective of the Estuaries Research Programme Phase 1 Uptake Project.

The outputs from ERP Phase 1 highlighted the current state-of-the-art and how to make best use of existing tools in estuary management. The objective of the Uptake Project is to improve dissemination of the Phase 1 outputs to inform the decision-making process. These guidance notes form part of this dissemination. The original objectives of the Uptake Project were:

- To set up a take-up and training programme for ERP Phase 1, which utilises two demonstration projects as vehicles.
- To explore different approaches to some of the typical flood and coastal defence problems faced by estuary managers.
- To produce guidelines to explain what tools are currently available, their limitations and the sort of information needed to make use of them.
- To demonstrate the capabilities and potential future development of the ERP Phase 1 methods and approaches to all parties involved in estuary management.

In addition to these guidance notes the Uptake Project produced a number of other outputs relevant to estuary studies.

1. Experimental Interactive Decision Tree Software

Description: An experimental interactive software programme has been developed to invoke a rule base or decision tree. The software is designed to lead the user through a series of stages starting from an issue, through the topics affected by the issue to types of generic methods that could be used in the appraisal of the issue. The software is strictly a prototype intended to illustrate a thought process and not to be a comprehensive package to predictive method selection. The generic methods included in the software are drawn exclusively from ERP Phase 1.

Source: The software has been developed as a prototype for demonstration at the Uptake Project workshops, with a view to possible further development. The software is hosted on a web site URL: http://www.erp1software.net, from where it can be viewed and used. A short questionnaire allows feedback on the potential for its future development.

2. Database CD and Report

Description: An output of the Uptake Project is to update the original ERP Phase 1 database with any new data, and provide a public version on CD. The CD contains environmental data from six key estuaries; the Humber, Blackwater, Mersey, Ribble, Southampton Water and Tamar. The data are diverse, ranging from estuary gross properties to detailed time series of chemical and nutrient concentrations, bathymetry etc. The free STEM viewing software supplied with the CD enables the database to be quickly and simply queried and detailed metadata facilities provide access to key information about each dataset, such as creator and scale. A digital report on the CD provides a more detailed description of the datasets within the database and advises on how to get the most out of them when using the STEM viewer.

Source: The CD will be launched at a Data Best Practice Workshop (as part of the Uptake Project) scheduled to be held in December 2002. Details of the CD are available from ABPmer. Contact Claire Brown, ABPmer Ltd, Pathfinder House, Maritime Way, Southampton, SO14 3AE. Details of the proposed workshop are available from CIRIA. Contact Elizabeth Holliday, CIRIA, 1-2 Castle Lane, Westminster, London, SW1E 6DR.

3. Scientific Data Management by Project Consortia: Best Practice Guidelines

Description: This guide has been produced to assist individuals that are tasked as part of a project with collating scientific data. The aim is to ensure that those individuals both commissioning the project as well as those actually undertaking the work have a reference for what is involved. To accomplish this, this guide presents principles for data management for each lifecycle state. These principles give pointers for action as to what more detailed procedures should take account of. Examples are given from the experience of compiling the database as part of ERP Phase 1.

Source: The report is presently in draft form and will be completed by the end of November 2002. For details of progress contact Keiran Millard, HR Wallingford, Howbery Park, Wallingford, Oxon, OX10 8BA.

APPENDIX C

Other Published Guidance and Related Ongoing Research

It is important that the dissemination of information with respect to estuaries does not lose sight of other broader management methods and related ongoing research. In this respect, this appendix describes the products of some other relevant initiatives. Details of recent or proposed projects as part of the DEFRA/Environment Agency joint thematic R&D Programme for Flood and Coastal Defence can be found on the DEFRA web site URL: http://www.defra.gov.uk/environ/fcd/research/default.htm.

1. Estuaries Research Programme Phase 2 Research Plan

Description: The ERP Phase 2 Research Plan has produced a coherent, well justified and cost-effective programme of research, spanning the DEFRA/Environment Agency research themes, taking as its starting point the major recommendations of ERP Phase 1. The plan recognises the need to link with other DEFRA/Environment Agency R&D projects to be able to effectively deliver the tools for estuary management. The research plan contains an exploratory literature review to identify other potentially viable approaches to long-term estuary morphology modelling in addition to the approaches recommended by ERP Phase 1. It also identifies gaps in the ERP Phase 2 research recommendations as defined by the original EMPHASYS consortium.

Source: Details of the Research Plan can be obtained from Edward Evans, the Broad Scale Modelling Theme Leader Halcrow Group Ltd, Burderop Park, Swindon, Wiltshire, SN4 0QD.

2. EstProc – DEFRA Project FD1905

Description: There are two main aims to this ongoing project due to finish in 2004. First, to improve understanding and modelling of estuary hydrobiosedimentary processes, and second, to improve understanding and modelling of sediment erosion and deposition and the resulting changes in estuary morphology. The project will bring together, and be founded upon, existing data, and will lead to improved methods and confidence of prediction of short-term events and responses in estuary systems.

Source: For further information on this project contact the Fluvial, Estuarine and Coastal Processes Theme Leader, Mike Thorn or the Theme Manager, Jonathan Rogers both at Mouchel, West Hall, Parvis Road, West Byfleet, Surrey, KT14 6EZ.

3. Risk and Uncertainty Review – DEFRA Project FD2302

Description: This project is a comprehensive "defining review" including:

- The concepts and definitions of risk, performance and uncertainty
- The application of these principles in decision-making
- The move towards a more integrated risk-based framework for flood and erosion risk management
- Risk tools and techniques to facilitate risk assessment and decision-making

- Vision for future related R&D and identification of R&D needs

Source: A pdf version of this report can be downloaded from the joint DEFRA/Environment Agency web site URL: http://www.environment-agency.gov.uk/subjects/flood/351291/211195/316763/?lang=_e&region= (under Risk Theme).

4. Overview of Data Management Issues in Flood and Coastal Defence – DEFRA Project W5G-007

Description: The aims of this study were to investigate and document the systems in place to collect data and process information within the Environment Agency, other Governmental bodies and the public sector. The main areas covered by the study include:

- Data currently held
- Current format, usability and interoperability of data
- Data quality and documentation (Metadata)
- Data capture and storage methods

Source: A pdf version of this report can be downloaded from the joint DEFRA/Environment Agency web site URL: http://www.environment-agency.gov.uk/subjects/flood/351291/211195/316763/?lang=_e&region= under Risk Theme

5. Maximising the Use and Exchange of Coastal Data. A Guide to Best Practice

Description: This guide suggests policies and mechanisms that can be used to maximise the use and exchange of coastal data. It provides a guide to best practice aimed at improving the management of data by those who operate in the coastal zone. The first part is intended for the coastal manager or data user and introduces information and data provision requirements for coastal management. It provides a framework and set of best practice guidelines that can be adopted to maximise data exchange and re-use. The second part is aimed at the data collector or data manager. It details current practice and the factors that restrict better exchange and use of data, assesses technologies for wider data use and better exchange systems, and develops the principles of good data management by discussing what can be achieved now and in the future.

Source: This is CIRIA report C541 and is available using the CIRIA web site URL: http://www.ciria.org.uk/publications/bookshopentrance.htm.

6. Flood and Coastal Defence R&D Manager’s Route Map CD

Description: The process set out in the “Route Map” CD aims to help project managers achieve a successful outcome to their project, and effective implementation and adoption of the results. It follows a generic approach to project R&D planning, management and uptake. Managers with a good track record and experience of R&D projects may find the steps useful as a checklist. Managers with less experience should find the more detailed information useful in understanding how to approach a project to achieve successful uptake.

Source: The Route Map is available electronically as a zipfile from the joint DEFRA/Environment Agency web site URL: http://www.environment-agency.gov.uk/subjects/flood/351291/211195/316763/?lang=_e&region= (under Policy Theme).

7. A Guide to the Understanding and Management of Saltmarshes

Description: This guide provides a comprehensive review of saltmarshes and present information on existing knowledge and working practices for utilisation by flood defence managers, conservation officers and ecologists. The guide encourages the use of saltmarsh both for its sea defence functions, but also as a means of retaining and enhancing its conservation value. The guide also identifies areas in which future research will enhance knowledge of and value placed on saltmarshes as the first line of defence.

Source: This is Environment Agency R&D Note 324 and is available using the Environment Agency web site URL: http://www.eareports.com.

8. Beach Management Manual

Description: This manual provides best practice in beach management concentrating on the management of beaches for coastal defence. The manual sets out basic principles such as problem definition, design constraints and opportunities, likely option effectiveness, economic appraisal and environmental assessment. It also provides information on the design considerations and principles associated with the various management options, including beach nourishment, beach control structures and managed realignment.

Source: This is CIRIA report R153 and is available using the CIRIA web site URL: http://www.ciria.org.uk/publications/bookshopentrance.htm.