Interreg MARITTIMO-IT FR-MARITIME
Fondo Europeo di Sviluppo Regionale
UNIONE EUROPEA
SEDRI PORT
10 04 2019
ITALIA, LIVORNO Fortezza Vecchia ITALIE, LIVORNO Vieille Forteresse
ITALY, LIVORNO Old Fortress
CEDA Central Dredging Association
AdSP MTS

WORKSHOP SULLA VALUTAZIONE DEGLI EFFETTI FISICI DOVUTI ALLA MOVIMENTAZIONE DEI SEDIMENTI IN AREE MARINO-COSTIERE: STRUMENTI E METODOLOGIE DI APPROCCIO
WORKSHOP SUR L'ÉVALUATION DES EFFETS PHYSIQUES CONSÉQUENTS À LA MANIPULATION DES SÉDIMENTS DANS LES ZONES MARINES CÔTIÈRES: INSTRUMENTS ET MÉTHODES D'APPROCHE
WORKSHOP ON THE ASSESSMENT OF PHYSICAL EFFECTS RELATED TO SEDIMENT HANDLING IN MARINE AND COASTAL AREAS: TOOLS AND SHARED APPROACHES

Dredging for Sustainable Infrastructure: Where Multidisciplinary Modelling Meets Robust, Practical Solutions

John Baugh, Jeremy Spearman, Mark Lee
HR Wallingford
Working with water

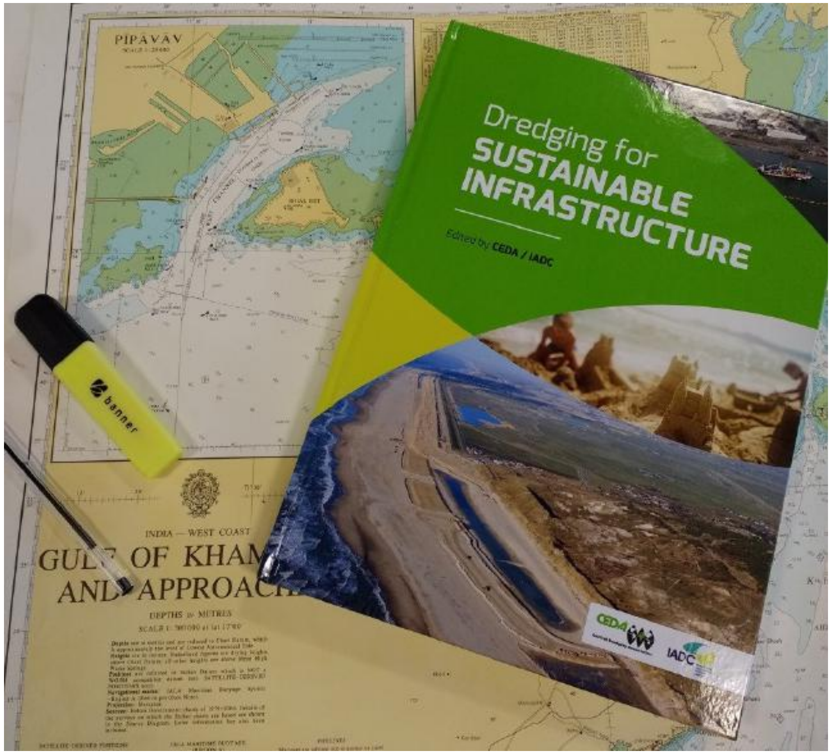
La cooperazione al cuore del Mediterraneo
La coopération au cœur de la Méditerranée

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA
ISPRA
Sistema Nazionale per la Protezione dell'Ambiente
ARPAL
Provincia di Livorno
Var Le Département
UNIVERSITÉ DE TOULON
Collectivité de Corse

Scope of talk

1. Introducing the 'Modelling and Tools' chapter of the CEDA book "Dredging for Sustainable Infrastructure"

2. Describe a UK case study to illustrate the approach described.

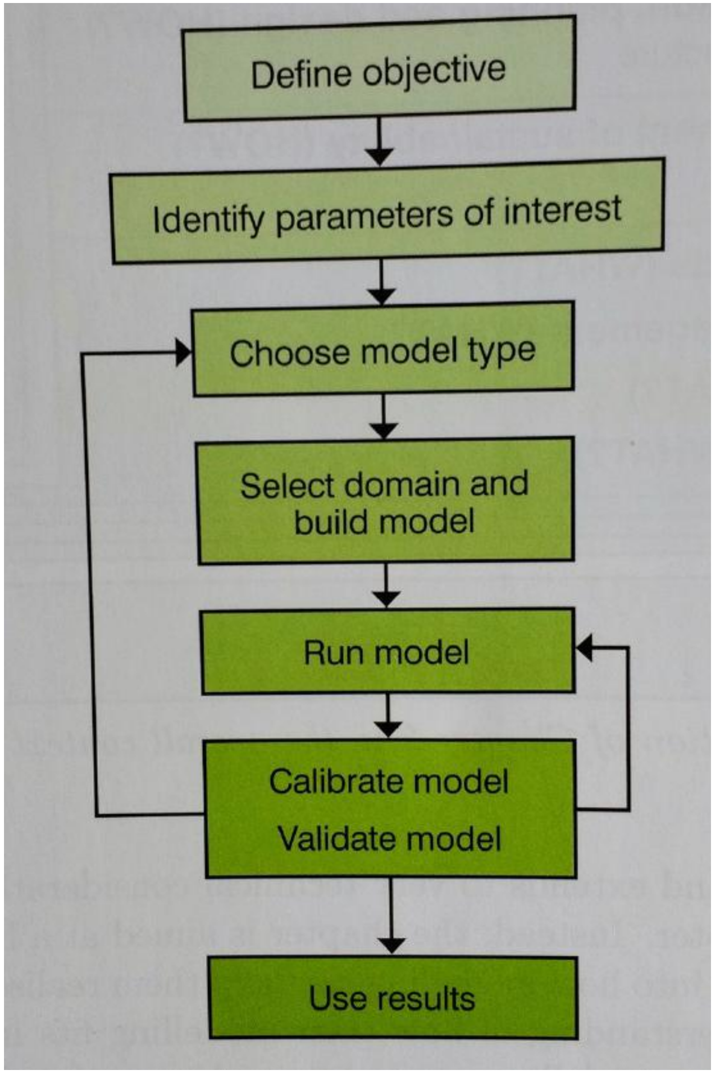


There are many definitions to choose from for a model. One useful one is …

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

Almost limitless subject so material is at a suitably high level, suitable for:

- *Project managers: better insight into how modelling can help them reach their goals,*
- *Modellers: greater understanding of how their modelling fits into the greater process of project realisation.*
- *Uses many case studies from practitioners world-wide*
- *Provides guidance towards sustainable infrastructure*



Typical modelling process

Subject to iterations/refinements

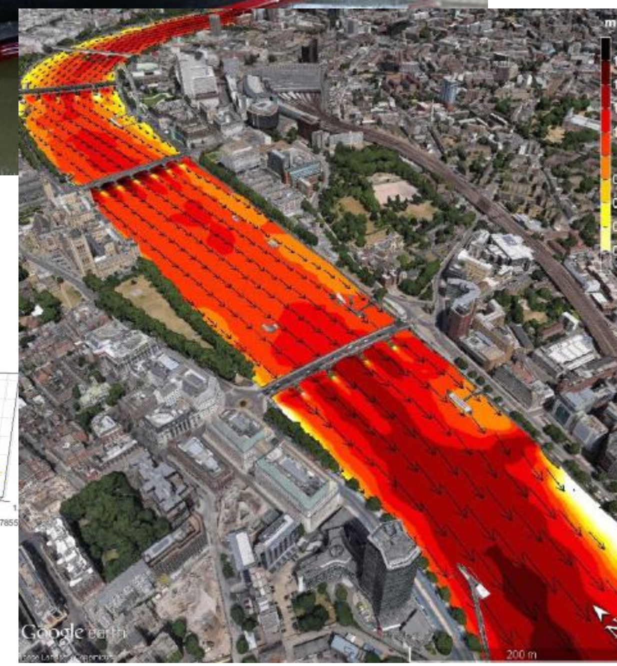
Possibly repeated at different stages of the project

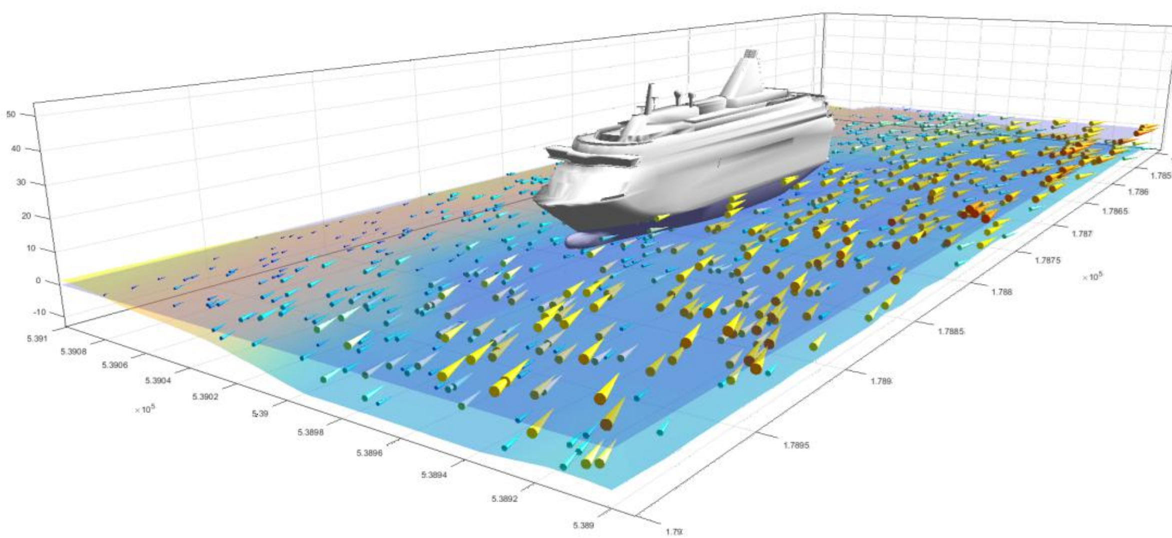
Projects increasingly need to bring positive benefits (Building with Nature concept). Or be adaptable to provide them.

Types of modelling

Choice guided by;

- Level of detail
- Geographical scale
- Key parameters
- Availability of data
- Time





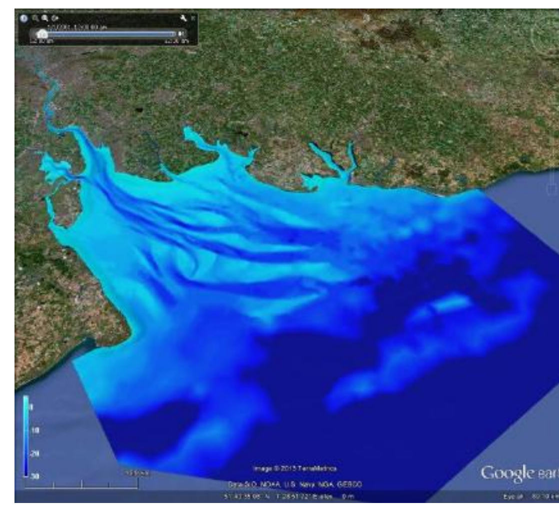
Types of modelling

Physical models

- Physical processes in complex environments e.g. close to structures, vessels, etc.
- Detailed design and testing of performance,
- Requires dedicated specialist laboratory facilities.

Numerical models

- Physical, chemical or biological processes can be expressed by equations, solvable by computers
- Ascending levels of complexity
- Require validation by field data



Empirical models

- Based on observations
- Reliable within range of conditions for which is was developed
- Example of ecological models of species response

Areas for modelling for infrastructure including dredging

Physical effects, for example;

- Waves, currents, overtopping, maximum water levels
- Suspended sediment concentration, patterns of bed change
- Morphological change, beach levels
- Dewatering of reclamations, design and testing of performance

Chemical effects, for example;

- Changes to water quality
- Changes to sediment quality

Biological effects

- Underwater noise
- Response to change in physical parameters
- Habitat recreation and recovery

Bio-geophysical interactions, for example

- Corals, salt marsh
- Benthos, algae

Example of bio-geophysical interaction

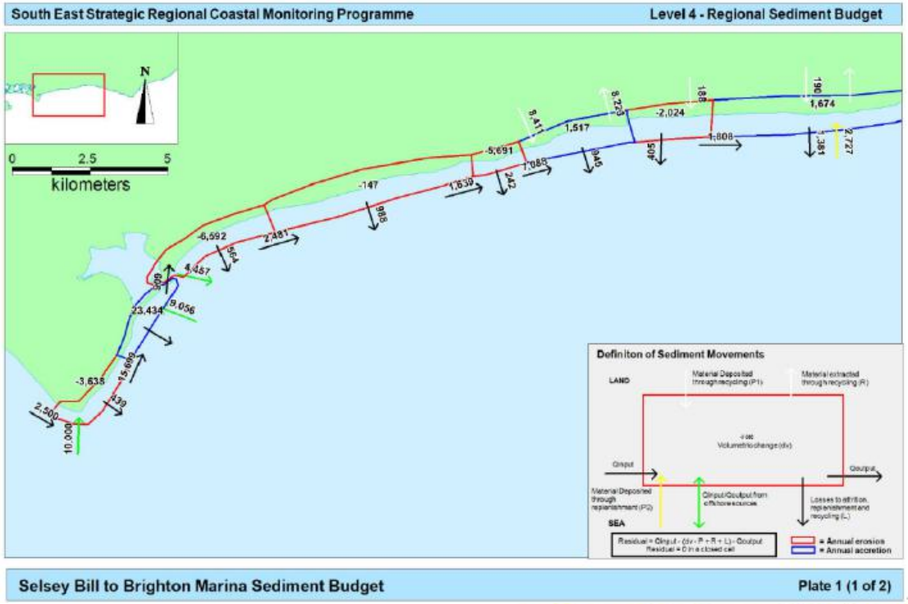
Flume with no mysids:- SPM = 0 mg/l

Flume with 500 mysids:- SPM = 160 mg/l

PML annular flume (J. Widdows)

Modelling for project initiation, planning and design

- desk assessment
- conceptual modelling,
- definition of data needs,
- selection of models, scales, calibration and validation targets
- pilot modelling
- are there opportunities for biodiversity net gain



Modelling for project detailed design, impact assessment

- Establish baseline conditions
- Assess sensitive receptors for impacts
- Data review and gap analysis
- Revisit calibration/validation
- Model the changes, assess impacts,
- Consider mitigation, compensation, monitoring,
- … again, are there opportunities for biodiversity net gain

Modelling for communication, education and presentation of results

Needs to:

- Inform
- Address the items of interest/concern
- Establish a clear narrative
- Clarify uncertainties

Modelling for tender preparation and tender evaluation

Tenderers may want to;

- Improve design for cost or programme
- Demonstrate further efficiency / reduced impact
- May offer further gains for biodiversity
- Tenderer's plant unlikely to be identical to that assessed.

Options include;

- Making models available
- Independent assessment
- Define agreed models for all tenderers

Modelling during construction

- Forecasting met ocean parameters – confirm downtime
- Short term forecasting impacts of tenderer's construction programme
- Model validation – reduction in uncertainties
- Adaptive management to further reduce impacts or increase benefits, respond to changes in conditions
- Usually includes monitoring
- Reporting to regulators and stakeholders – confidence building

Case study – broad scale modelling applied to sediment management in the context of channel deepening

Background

Many dredging projects have to confront the challenges of sustainable development

- competitive requirement for deeper channels, and
- the need to preserve nearby important coastal wetlands which function as *both* habitat and flood defence.

A good example of the competing pressures is found in the Stour/Orwell Estuary system

- internationally important for its wetland bird populations - designated Special Protection Areas, Ramsar
- location of the Port of Felixstowe (biggest UK container terminal)
- studies required to assess the impacts of deepening the Approach Channel from -12.5 mCD to -14.5 mCD (1998-2000) and management of impacts

Location

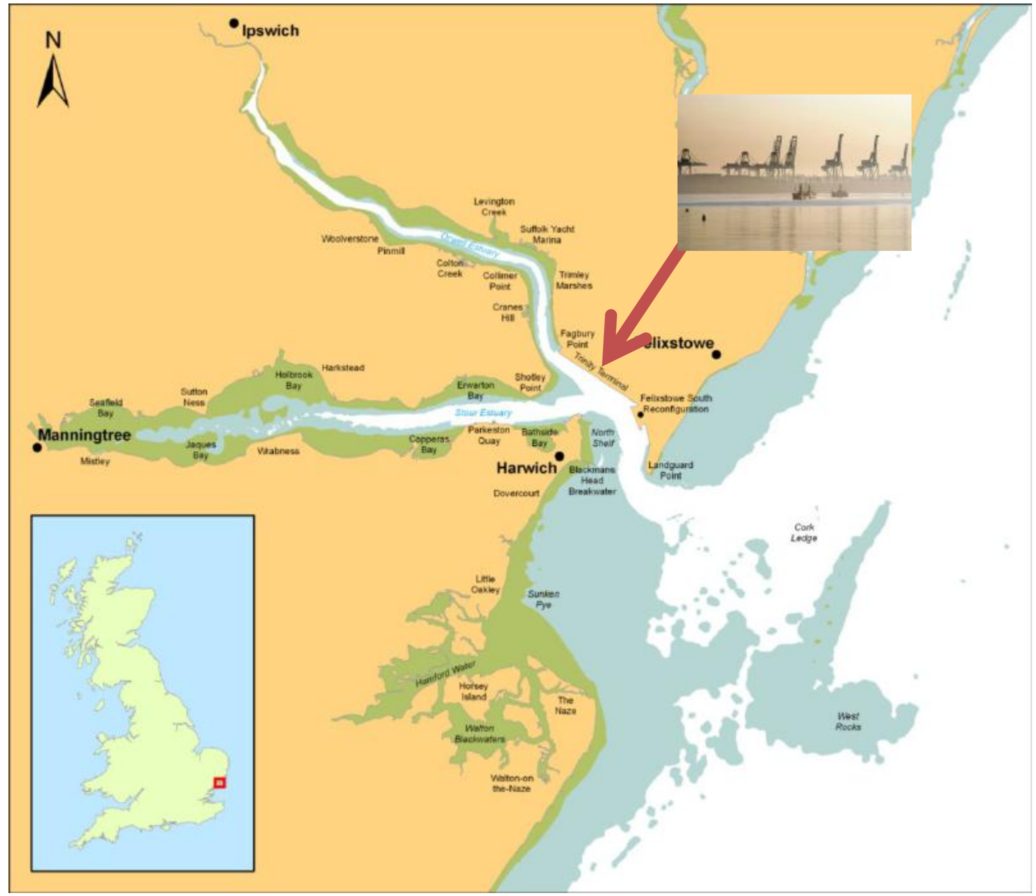
Meso-tidal: 3.6m mean spring tidal range

Very low river discharge

Waves inside the estuary system are small and locally generated (except in Harwich Harbour)

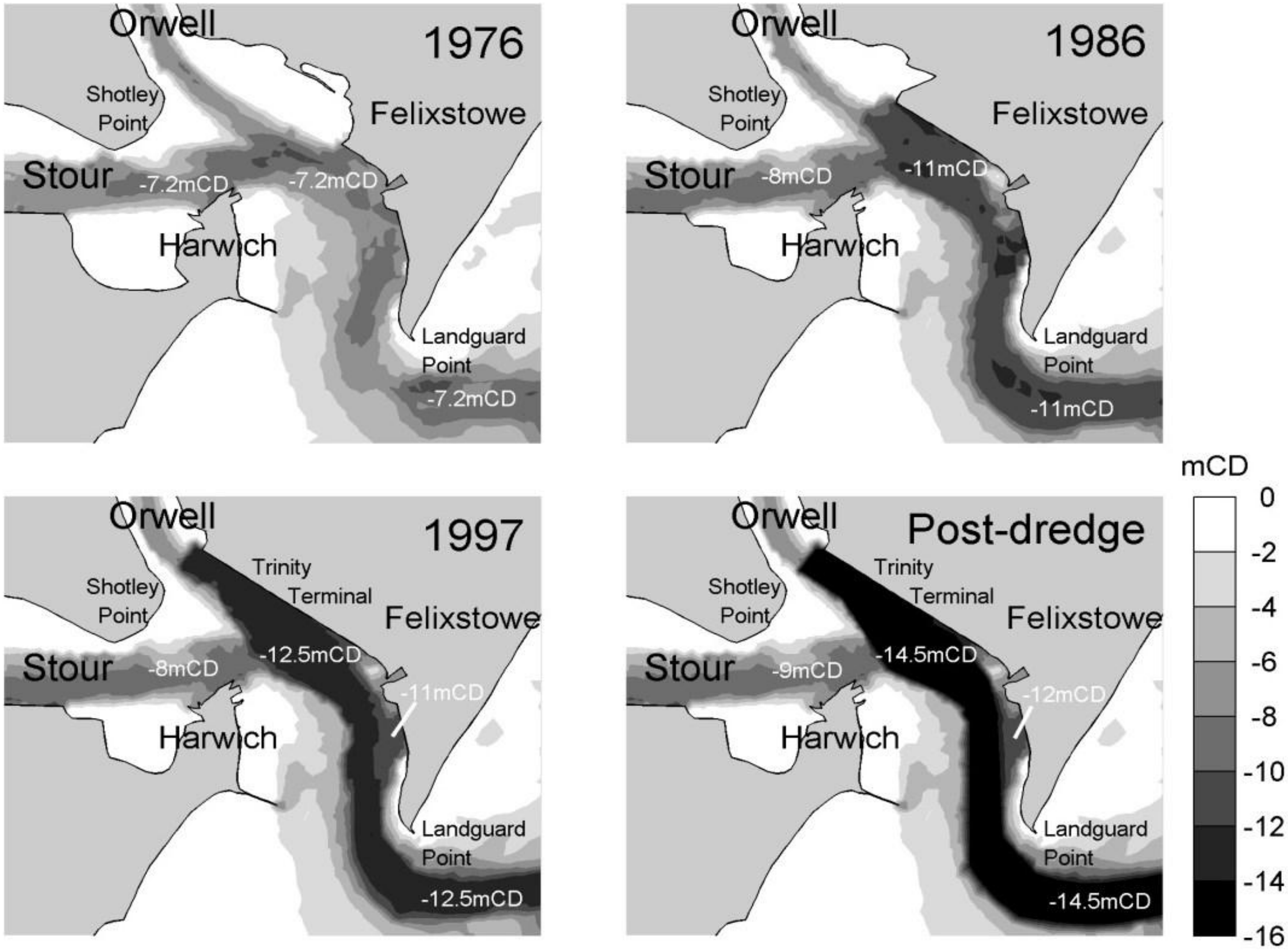
Annual average maintenance dredging (soft mud) of 2.3M m^3

Overall accretion within the system with almost all sediment coming from offshore sources.



Legacy of development

- 1906 Approach channel deepening from -5.0 mCD to -6.0 mCD
- 1930's Deepening of Orwell Channel to -4.5 mCD
- 1947-51 Deepening of Orwell Channel to -5.6 mCD
- 1968 Approach Channel deepening to –7.3 mCD
- 1981 Channel deepening to -8.9 mCD
- 1983 Walton Terminal
- 1985 Channel deepening to -11.0 mCD
- 1986 Trinity I Terminal
- 1987 Trinity II Terminal
- 1994 Harbour deepening to -12.5 mCD

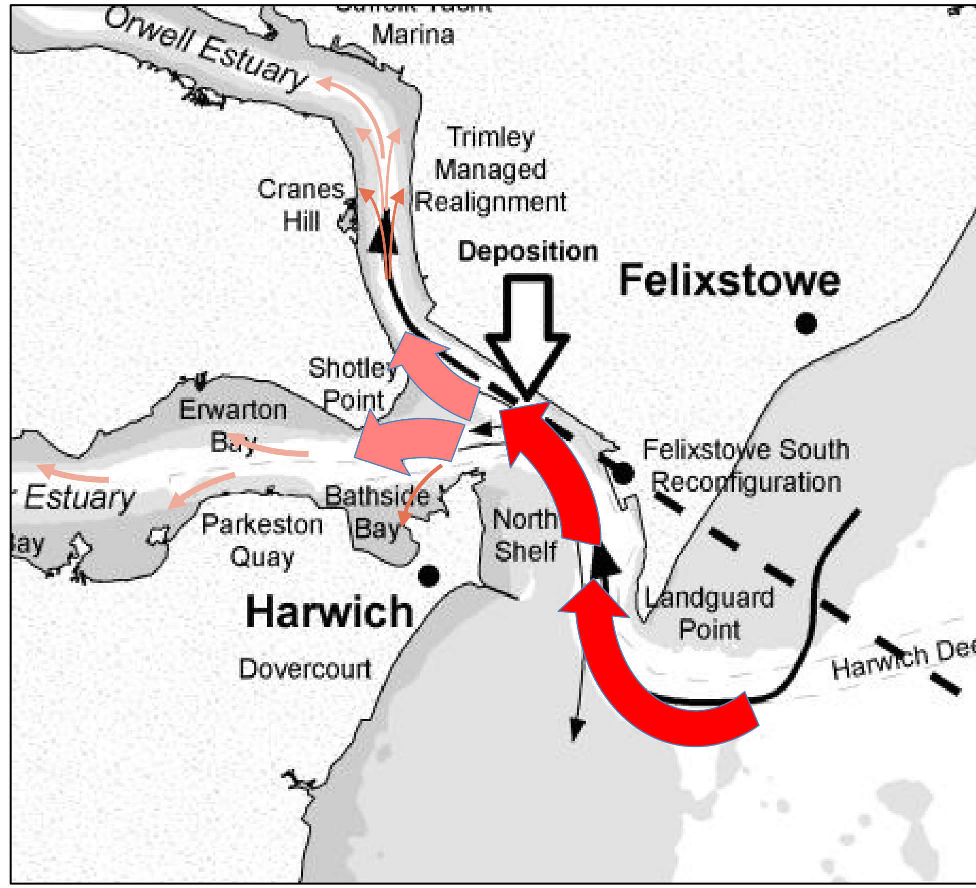

Orwell
1976
Shotley Point
Felixstowe
Stour
-7.2mCD
-7.2mCD
Harwich
Landguard Point
-7.2mCD
Orwell
1986
Shotley Point
Felixstowe
Stour
-8mCD
-11mCD
Harwich
Landguard Point
-11mCD
Orwell
1997
Trinity Terminal
Shotley Point
Felixstowe
Stour
-8mCD
-12.5mCD
-11mCD
Harwich
Landguard Point
-12.5mCD
Orwell
Post-dredge
Trinity Terminal
Shotley Point
Felixstowe
Stour
-9mCD
-14.5mCD
-12mCD
Harwich
Landguard Point
-14.5mCD
mCD
0
-2
-4
-6
-8
-10
-12
-14
-16

Period	Historical rate of loss of intertidal area (ha/year)*		
	Stour	Orwell	Estuary System
1965-1982	10-11	-6	4-5
1982-1994	14	-4	10
1994-1999	13	-4	9

* +ve loss, rounded to nearest ha/year

Potential effects of deepening:

- traps more sediment in harbour – from offshore or eroded from estuaries
- sediment deposited in harbour is dredged and placed offshore
- a risk is that harbour deepening acts to deplete estuaries of mud with consequences for intertidal areas

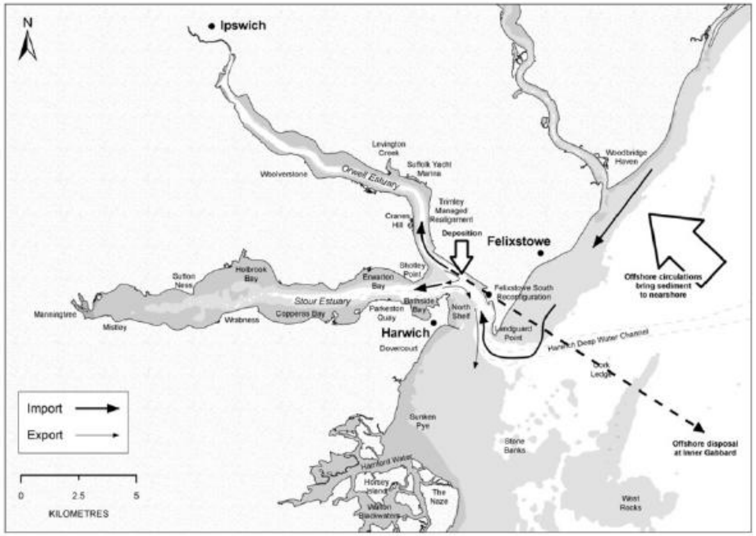


Predictive modelling for impact of deepening based on well-calibrated models developed over time using extensive dataset

- Flows
  - Extensive tidal records
  - ADCP transects
  - ADCP point measurements
  - Radar surface flows
  - Detailed bathymetry
- Waves
  - Long term measurements at various locations
- Sediment transport
  - ADCP backscatter calibrated to water samples
  - Long term OBS time series
  - Detailed dredging (TDS and bed level changes) and disposal records
  - Density profiling
  - Water samples
  - Grab samples/cores

Broad scale morphological model based on concept of two types of behaviour:

- deposition of imported sediment during calm periods
- erosion during wavy periods
- During erosion periods some eroded sediment returns to the estuaries and settles again, while the rest is lost to the Harbour area or offshore.



Broad scale morphological model

A simplified view of morphological changes can be expressed by

$$E = (1 - C)W - D$$

D **=** deposition on inter-tidal areas from import of material (predicted by calibrated mud transport model)

C **=** proportion of inter-tidal material resuspended by waves and re-depositing on inter-tidal areas (predicted by calibrated mud transport model)

E = net annual erosion of inter-tidal areas (calibrated from measured data)

W = mass of material eroded from inter-tidal areas in the estuary system by waves (calculated from equation and assumed broadly constant over time)

Calibration for several epochs

Model predictions of changes in morphology compared against measurements of loss of area and average vertical erosion

Also compared to maintenance dredging totals

Period	Net intertidal erosion (m^3/yr)				Vertical rate of erosion (mm/yr)			
	Stour		Orwell		Stour		Orwell	
	Predicted	Measured	Predicted	Measured	Predicted	Measured	Predicted	Measured
1976	190,00	Not known	-55,000	No data	10.3	~12	-8.5	No data
1986	250,000	240,000-280,000	-34,00	No data	13.6	13-16	-5.2	No data
1997	240,000	230,000-240,000	-32,000	-32,000	13.2	13-14	-4.9	-4 to -5

Model predictions shown to perform well.

Predicted increase in rate of loss of intertidal area

Prediction that rate of loss of intertidal area in the estuary system (at 0mCD) would increase from 10 ha/yr to 11.7 ha/yr if unmitigated

The deepening was given the go ahead following Public Inquiry and the capital works took place in 1998-2000

Conditions

- agreed mitigation plan for predicted effects
- programme of morphological and ecological monitoring

Objective of mitigation plan

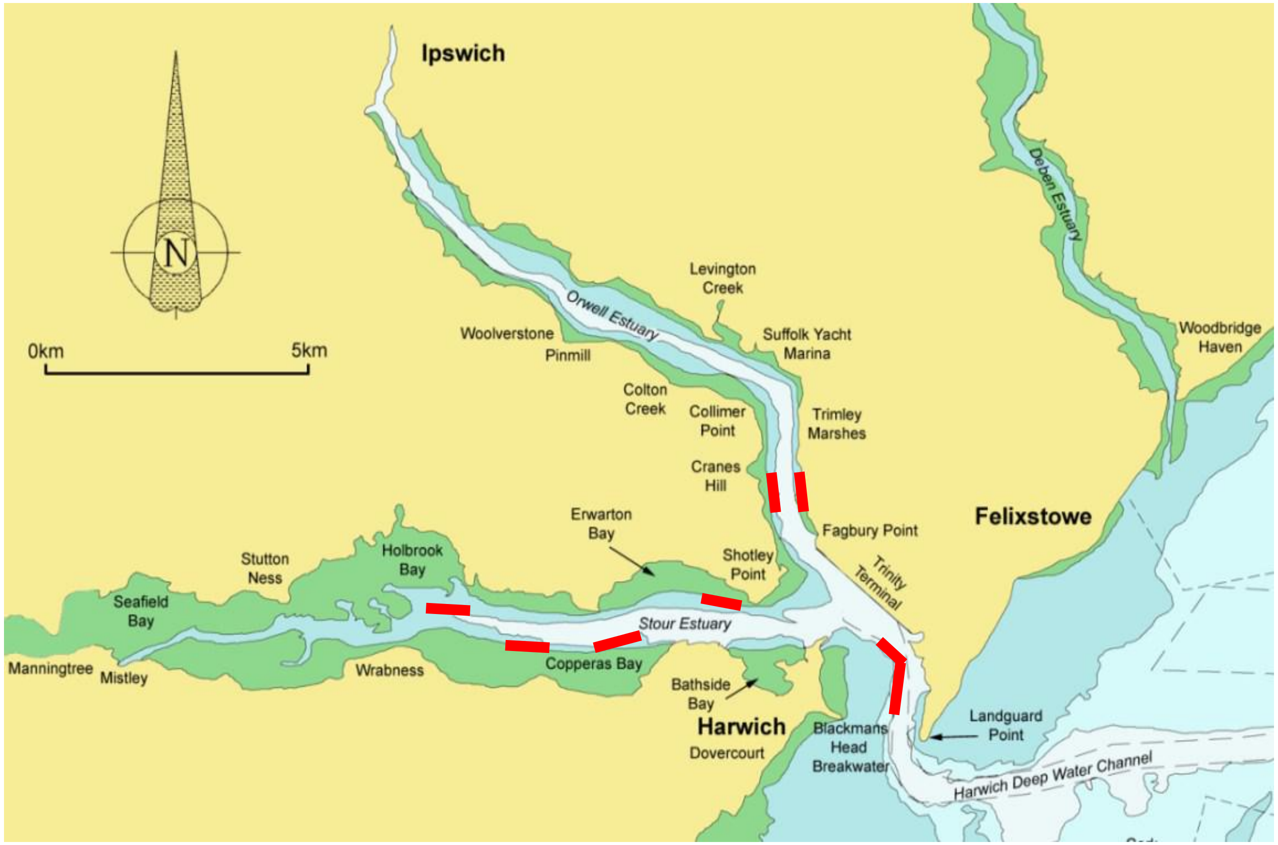
"… to avoid any impacts as a result of the dredge on the favourable conservation status of both [the Stour and Orwell] habitats "

- A small proportion of dredged material placed further upstream
- Larger placement in harbour
- Subtidal and water column recharge
- Not in itself economic, but cheaper than a compensation scheme

First large-scale mitigation of its type in the UK

Substantial monitoring programme:

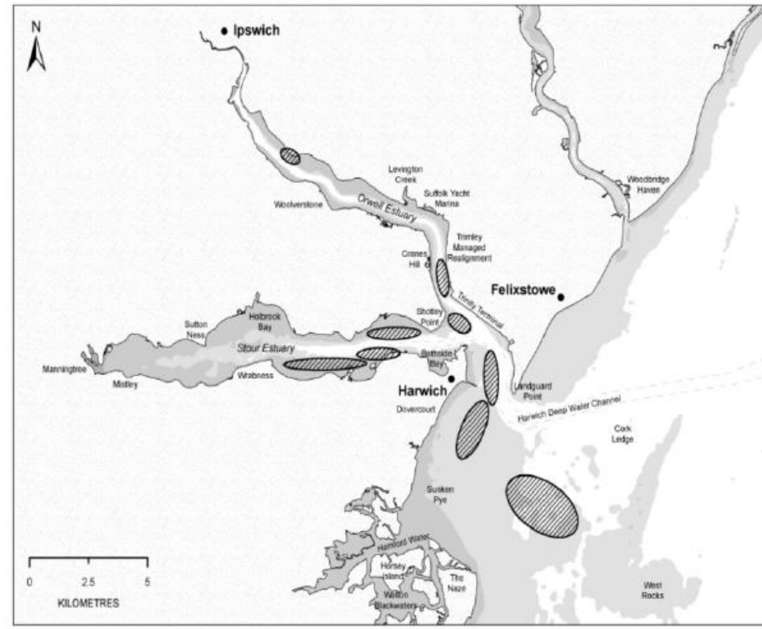
- Subtidal bathymetric surveys every 5 years over the whole estuary
- LiDAR measurements every 5 years over the whole of the intertidal areas in the estuary system
- Saltmarsh surveys of the estuary system using LiDAR and geo-rectified aerial photography every 5 years
- Annual bird counts of the whole estuary system
- Benthic ecology surveys every 5 years (targeted as appropriate)
- Monitoring of fish, shrimp, plankton, oyster and cockle populations



Original locations for sediment release as proposed

Activity	Details (annual placement)
Estuary placements	23,000 dry tonnes subtidal placement
	9,000 dry tonnes water column recharge
Harbour placements	200,000 m^3 subtidal placement

- User reports of silting up of areas of the estuary (and offshore) – confirmed by benthic sampling
- Discussion with dredger contractor highlighted that sediment was being placed onto bed instead of water column
- Further studies on the next port development project (Bathside Bay) produced better morphology data and sediment flux data.
- Further improved model calibration resulted in a <u>much lower </u>predicted impact.

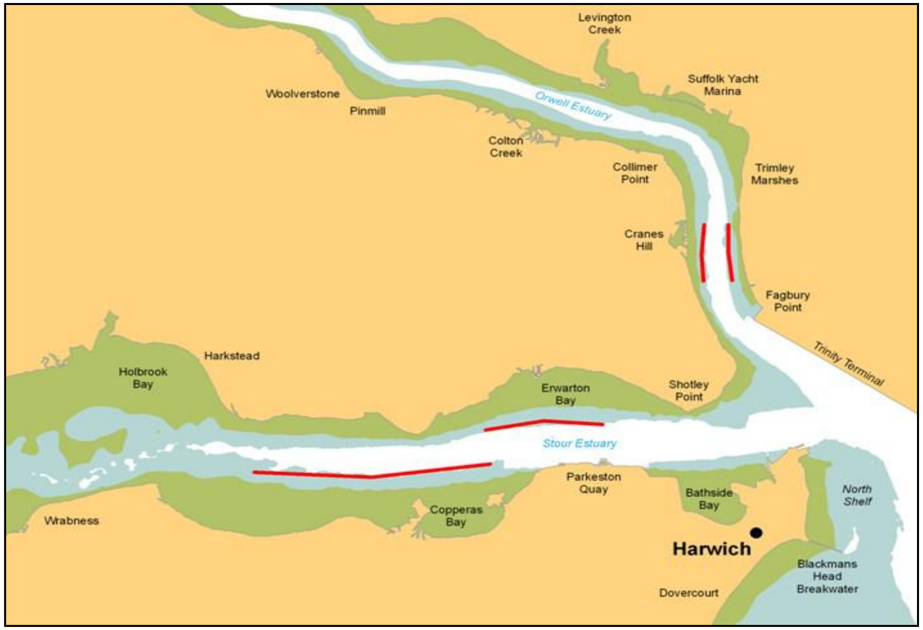


Silting areas reported

Conclusion: recharge was too much sediment and placed in the wrong way

The revised placement strategy (after 2008)

- 35,000 TDS/year placed in the Stour
- 15,000 TDS/year placed in the Orwell
- Water column recharge only
- No more placements near Holbrooke Bay
- No more placements within the Harbour
- Placement occurring more slowly whilst sailing over longer tracks to enhance mixing of the placement

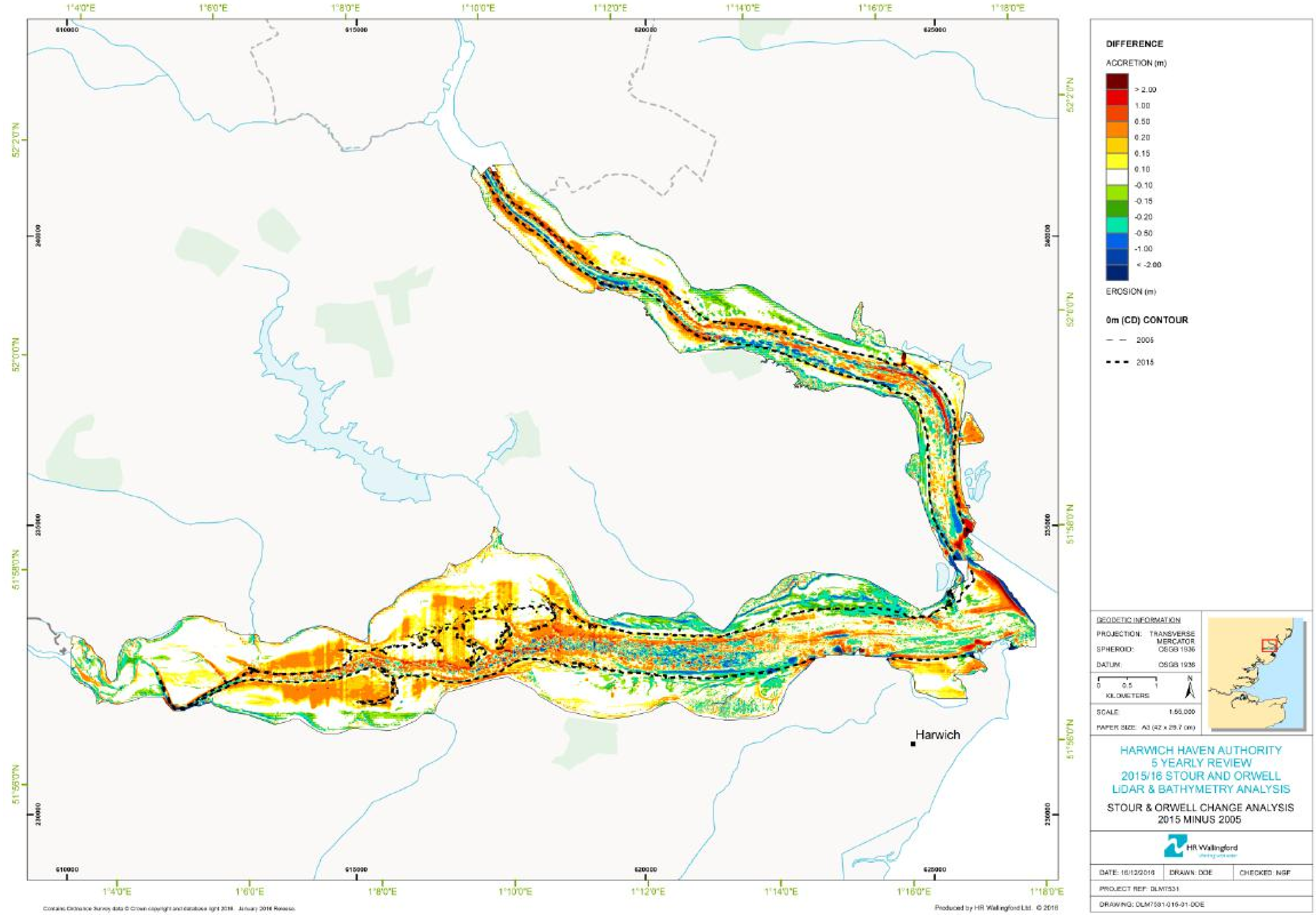


1994/9 to 2005/2010 Survey comparison

- Rate of loss of intertidal area in Stour and Orwell
- changed from -13.1 to +2.2 ha/yr in Stour, less effect in Orwell

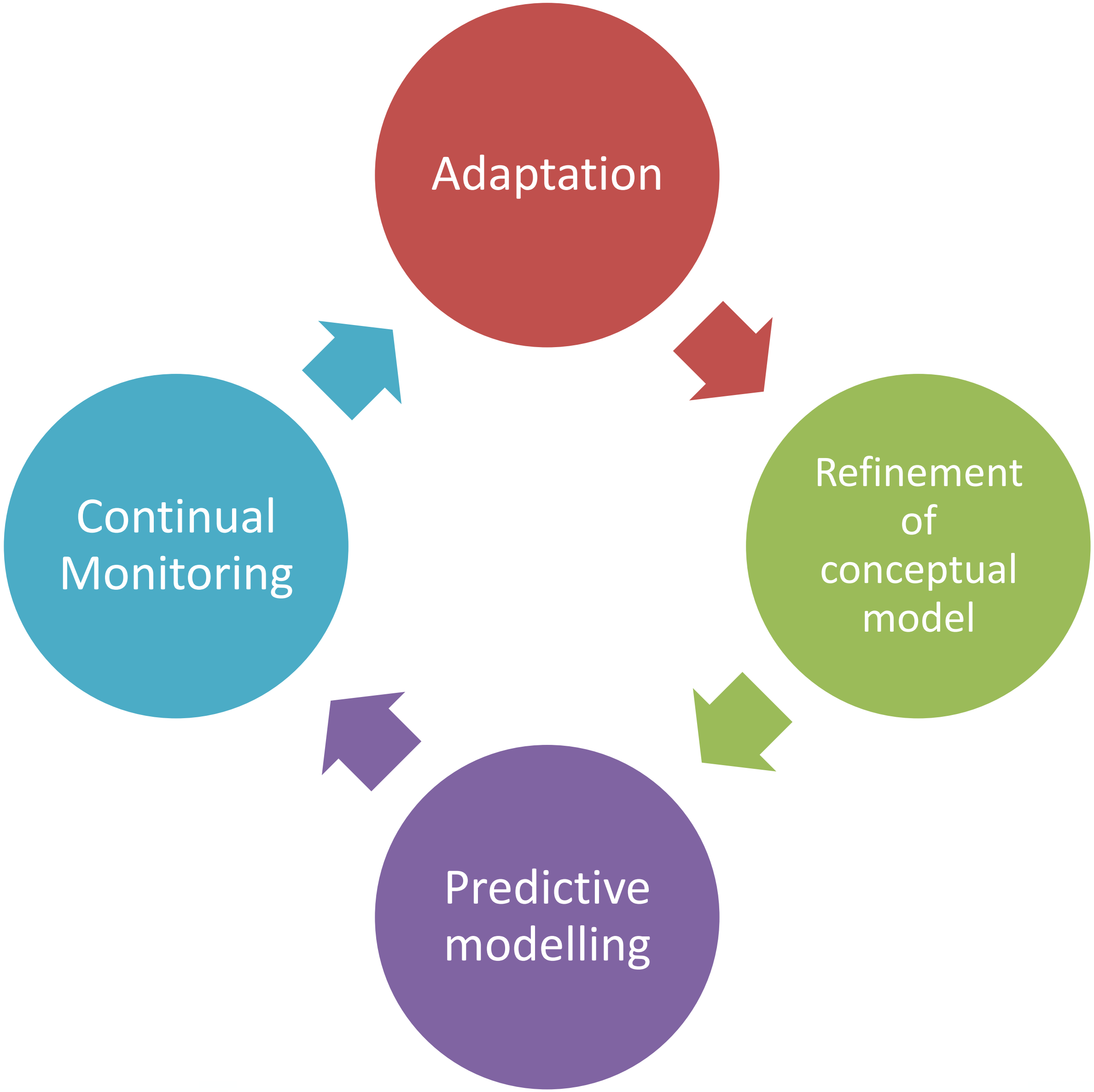
Year	Intertidal loss rate in the Stour (ha/year)	Intertidal loss rate in the Orwell (ha/year)
Pre dredge (1994-1999)	-13.1 (loss of area)	+3.8 (gain of area)
Post dredge (2005 -2010)	+2.2 (gain of area)	+2.8 (gain of area)
2010 - 2015	+2.8 (gain of area)	+2.4 (gain of area)

⇒ Mitigation not only mitigated for the dredge but also contributed to cessation of overall pattern of intertidal loss


DIFFERENCE
ACCRETION (m)
> 2.00
1.00
0.50
0.20
0.15
0.10
-0.10
-0.15
-0.20
-0.50
-1.00
< -2.00
EROSION (m)
0m (CD) CONTOUR
2005
2015
Harwich
GEODETIC INFORMATION
PROJECTION: TRANSVERSE MERCATOR
SPHEROID: OSGB 1936
DATUM: OSGB 1936
KILOMETERS
SCALE: 1:55,000
PAPER SIZE: A3 (42 x 29.7 cm)
HARWICH HAVEN AUTHORITY
5 YEARLY REVIEW
2015/16 STOUR AND ORWELL
LiDAR & BATHYMETRY ANALYSIS
STOUR & ORWELL CHANGE ANALYSIS
2015 MINUS 2005
HR Wallingford
DATE: 16/12/2016
DRAWN: DOE
CHECKED: NGF
PROJECT REF: DLM7531
DRAWING: DLM7531-016-01-DOE
Produced by HR Wallingford Ltd. © 2016

Impact of monitoring on updating conceptual model

- Estuary system is no longer losing intertidal area
- This change has come about because of
  - Sediment recycling
  - Full data coverage of intertidal using LiDAR
- As well as benefiting from recycling the Stour was probably always eroding less quickly than the previously partial data implied.
- The implications could be tested in the model
- Incorporation of the understanding into models (and re-calibrating) results in a reduced effect of future development


Adaptation
Refinement of conceptual model
Predictive modelling
Continual Monitoring

Conclusions for case study

- A relatively simple, broad scale methodology developed for predicting the effects of harbour development
- Methodology used to predict impacts of 1998/2000 deepening at Harwich and Felixstowe
- Mitigation developed to offset predicted effects of deepening
- Mitigation adjusted after initial period of monitoring/consultation
- Mitigation successful – additional benefit moving from net from intertidal erosion to intertidal accretion
- Model method accepted by regulators and available for subsequent schemes
- Framework set for sediment management
- Success story for port working with conservator, regulators and other stake-holders

Overall conclusions (1)

- Models and numerical tools can support most stages of infrastructure projects across a wide area of applications
- Models enable testing of innovative approaches to sustainable development and management
- Models can provide an important evidence base for decision makers and regulators

BUT

- The selection of models has to be considered carefully;
  - Which are the key processes to model – physical, chemical, biological (the what?)
  - What outcomes is the modelling working towards (the why?)
- Uncertainties have to be understood and preferably evaluated
- More data gives more confidence in outputs
- Monitoring will usually be required to cover uncertainties

Overall conclusions (2)

There are considerable benefits of thinking about modelling at the beginning of a project;

- plan the field studies
- think conceptually about the important processes to study (physical, chemical, biological)
- look for opportunities to develop infrastructure that enhances nature (win-win) and consider how to demonstrate this is possible.