Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme

Development and Demonstration of Systems Based Estuary Simulators (EstSim)

EstSim Conceptualisation Report

R&D Project Record FD2117/PR1



Environment Agency

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Development and Demonstration of Systems Based Estuary Simulators (EstSim)

Conceptualisation Report

Prepared by ABP Marine Environmental Research Ltd for the Estuaries Research Programme (ERP Phase 2) within the Defra and Environment Agency Joint Broad Scale Modelling Theme

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Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol BS32 4UD
Tel: 01454 624400 Fax: 01454 624409

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Contract Statement
This report describes work commissioned by Defra under Project FD2117 Development and Demonstration of Systems Based Estuary Simulators (EstSim). The Funders Nominated Project Officer was Nigel Pontee (Halcrow: Email: ponteeni@halcrow.com). The ABPmer Project Number was R/3434 and the Project Manager at ABPmer was Tim Wells (Email: twells@abpmer.co.uk).

Collaboration Statement
This report was prepared by the EstSim Consortium comprising: ABP Marine Environmental Research Ltd (lead), University of Plymouth (School of Engineering), University College London (Coastal & Estuarine Research Unit), HR Wallingford, WL | Delft Hydraulics and Discovery Software.

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R&D OUTPUTS: ESTSIM FD2117/PR1

EXECUTIVE OVERVIEW OF FD2117: DEVELOPMENT AND DEMONSTRATION OF SYSTEMS BASED ESTUARY SIMULATORS (EstSim)

Project Inception Report, July 2004

Purpose

The Broad Scale Modelling Theme of the Defra/EA Joint Thematic R&D Programme for Flood & Coastal Defence has funded three contracts under the Estuaries Research Programme, Phase 2 (FD2107, FD2116 and FD2117). FD2117 (EstSim) started in April 2004 and has the following headline aims:

- To extend the ability to simulate estuary response to change.
- Facilitate knowledge exchange through accessibility of simulation results.

The Project

The project is being undertaken by ABPmer, University College London, University of Plymouth, WL | Delft Hydraulics and Discovery Software. This report details the nine Scientific Objectives set-up to deliver the research requirements over the 3 year project duration (April 2004-April 2007).

The nine Scientific Objectives cover the following lines of research and dissemination:

1. **System Conceptualisation**: Boundary setting and focusing of research effort.
2. **Development of Management Questions**: Rationalisation of management questions that can be informed through application of systems approach.
3. **Development of Behavioural Statements**: Formal definition of estuarine system in terms of systems approach and behavioural statements.
4. **Mathematical Formalisation**: Development of behavioural statements into a logically consistent mathematical framework.
5. **Development of System Simulation**: Development of architecture for estuary simulation based on the mathematical formulation of the system definition.
6. **Manager System Interface**: Explore the use of decision support systems and visualisation techniques for proof of concept testing.
7. **Pilot Testing**: Performance evaluation of estuary simulator.
8. **Dissemination**: Increase awareness of function and utility of research.
9. **Peer Review**: Ensure research lines deliver against Scientific Objectives.

Contact Details

For more details please contact the FD2117 Project Manager Tim Wells (twells@abmer.co.uk) or the Funders' Nominated Project Officer Nigel Pontee (ponteeni@Halcrow.com).

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1. INTRODUCTION

1.1 Background

On 1st April 2004 ABP Marine Environmental Research Ltd (ABPmer) and its Project Partners were awarded research contract FD2117 (CSA 6064) within the Broad Scale Modelling Theme of the Defra/EA Joint Thematic R&D Programme for Flood & Coastal Defence.

The contract for FD2117 was awarded on the basis of a 'contract won in competition' after submission of a CSG7 (revised CSG7 submitted on 8th March 2004).

Entitled 'Development and Demonstration of Systems-Based Estuary Simulators' (hereafter EstSim), this research contract forms one of three contracts awarded under Phase 2 of the Estuary Research Programme (ERP). The two other contracts under the umbrella of ERP Phase 2 are (i) FD2107: Development of Estuary Morphological Models, and (ii) FD2116: Review and Formalisation of Geomorphological Concepts and Approaches.

The three phases of the Estuaries Research Programme seek to improve our understanding and prediction of estuarine morphological change over the medium to long-term, thereby facilitating strategic and sustainable decisions regarding flood and coastal defence.

The EMPHASYS Consortium undertook Phase 1 of this programme by evaluating existing morphological modelling approaches with the most promising of these approaches being developed within ERP Phase 2. It is anticipated that Phase 3 will seek to incorporate prior ERP research into an 'Integrated Estuary Management System'.

1.2 Project Aims

The overall aim of EstSim is to extend the ability to simulate estuarine response to change. This will be achieved through the delivery of research into the systems-based approach as an alternative yet complimentary methodology to those research lines being undertaken within the other ERP Phase 2 projects (morphological concepts, bottom-up, top-down and hybrid methods). EstSim will also explore the simulation process in order to facilitate knowledge exchange between the systems-based tools and estuary managers.

1.3 Role of Conceptualisation Report

The requirements and high-level approach for EstSim is outlined in the CSG7 Proposal and this forms the basic framework for the way forward with the project.

The Terms of Reference for the research requires an Inception process to confirm the way forwards and provides an opportunity to plan the approach in more detail prior to commencing research. The inclusion of a Conceptualisation Stage within EstSim recognises some inherent uncertainty in defining the research plan and the need for early discussion and agreement on the way forwards. The present report therefore

achieves the role of the inception process and extends this by including conceptualisation of the approach.

The following report does not duplicate the CSG7 proposal but draws upon key areas of it to both confirm and iterate the Project Objectives and Tasks and hence incorporates the requirements of Project Inception.

In order to achieve confirmation of the way forwards, a Conceptualisation Workshop was held between EstSim Project Partners on June 24th 2004. This report captures the findings from that Workshop and presents work plans for the initial stages of research.

Contact details for the Partners of EstSim are presented in Appendix A.

1.4 Conceptualisation Workshop (Kick-Off)

The aim of this stage was to focus future effort in the FD2117 project by defining the initial research boundaries.

At the Conceptualisation Workshop the team discussed in some detail the following topics:

- The role of the research and its benefits in relation to existing estuary science and current research initiatives.
- Working assumptions for development of approach.
- The status of estuary management questions.
- Relevant estuary system geomorphic elements, forcing factors and constraints.
- Relationships of EstSim to other ERP Phase 2 research projects.
- Initial research programme for EstSim until the end of 2004.

Key points from each of these discussions are presented in the following sections.

1.4.1 Role of Systems Approach

The systems-based approach can be considered as a qualitative method that seeks to express the ***behaviour*** of a system. The concept, as described by Capobianco et al., (1999) is to develop an understanding of the behaviour of a coastal system and map it onto a simple mathematical model, which exhibits the same behaviour although this needn't have any relationship to the underlying physical processes. Capobianco refers to the Bruun Rule (Bruun, 1962) as an example where the behaviour of a sandy shoreline is described by a geometric concept rather than a formulation of sediment transport. Townend (2003) also cites a number of examples including, estuary transgression (or rollover) and estuary development as a consequence of tidal asymmetry as examples of capturing systems behaviour.

Within the whole estuary context what is sought is an expression of the behaviour between morphological elements (e.g. cliff, beach, spit, mudflats, saltmarsh, tidal creek, etc.) and forcing functions so that key components the estuary system can be simulated and the likely response to change established. The interactions between system elements may be expressed in many ways including both qualitative and quantitative approaches.

The potential role of a systems based approach in complementing and strengthening the top down approaches being investigated as part of ERP was expressed in the ERP Phase 2 Research Plan (French *et al.* 2002).

Partners agreed that a clear statement on the benefits of the systems based approach would need to be developed in order to communicate its role and relevance. At the Conceptualisation Workshop initial thoughts on the role of the approach within FD2117 project, were discussed. Whilst its full benefits will emerge as a developing property, initial thoughts can be summarised as follows:

Likely role of systems-based approach;

- A new approach that extends selection of existing tools and methods of estuarine morphological research (Figure 1).
- Initially a qualitative approach, with quantification incorporated where possible, or as a basis for exploring the dynamic properties of the system in order to indicate changes in an estuary system over the medium term (50 years).
- Essentially a generic framework that can be applied in a bespoke manner to specific estuaries.
- Likely to have a role at the initial screening stage of a development to indicate the sensitive components of a system (and hence focus effort for detailed analysis).
- Ideally applied to inform management questions that are not well addressed by existing methods.
- Applied as a communication device to estuary managers and stakeholders (with Manager-System Interface applied to illustrate its potential application within the ERP Framework).

What a systems-based approach <u>is not</u>;

- An elaboration of existing morphological tools.
- Cellular or raster based approach (since this would become bottom-up dominated).

1.4.2 Initial working assumptions

Boundaries to the development of the systems approach were discussed and these can be considered as initial working assumptions in order to constrain and focus the way forwards. These included the following:

- Development of an approach to be driven by scientific understanding rather than need to answer specific management questions (Section 1.3.3). Management Questions that can be answered will emerge from the systems application.
- Essentially a qualitative and aspatial application (whilst not precluding quantitative elements where viable).
- Ideally no apriori assumptions on nature of relationships between systems (as opposed to target seeking approach of other top-down methods).
- Need to couple scales between layers of the system approach with a simplification from one to the next.
- Role of Pilot Testing to be defined and elaborated as development of systems approach emerges.

1.4.3 Changes to CSG7 proposal

The role of the research undertaken within FD2117 is quite clear in that its purpose is to inform answers to relevant coastal defence management questions. The Terms of Reference acknowledges that the research undertaken for FD2117 will be innovative and hence poses some risks to delivery of its objective. One way of minimising risk is to ensure that development of the systems based approach is not constrained by the need to answer specific management questions. This approach avoids the risk of pre-defining management questions that need to be addressed and then finding that the scientific principles being investigated and approaches available cannot actually address them. Whilst the need to inform answers to coastal defence management questions is still the purpose of the research, it is suggested that the actual range and complexity of management questions that can be addressed by this approach should not drive its development but rather will emerge from investigation of underlying science associated with estuarine morphology and development of the systems approach.

In accordance with the Terms of Reference it is still envisaged that the application of the systems based estuary simulator would be driven by particular management questions.

This approach means that the work on Behavioural Statements (Objective 3) will begin earlier than initially planned and consequently Management Questions (Objective 2) will occur later in the timetable. However, there will be high degree of interaction and iteration between development of the systems approach and management questions such that Objective 2 will start as soon as is appropriate. The Tasks for each of these objectives have also been refined.

As anticipated, the Conceptualisation Workshop has enabled refinement of the initial work plan. It was noted in the CSG7 Proposal that detailed planning of this research would need to take account of its emerging development and hence the need for iteration and flexibility. A work plan to initiate the Behavioural Statements Objective is detailed in Section 3.3 and will take the initial research focus up until the end of 2004 (project month 9/36). Further focusing of research effort at key points will be required and will in all instances be agreed with the Defra Project Officer to ensure.

At the current time it is not anticipated that there will be any change to the nature of the deliverables for each primary milestone. However, the timescale for these will vary according to the degree of re-focusing as the project continues.

In accordance with the findings from the Conceptualisation Workshop, delivery of Milestones 02/01 and 03/02 will vary from those in the Proposal and Project Contract (Table 1). Any alterations to the remaining milestones will be agreed with the Project Officer after re-focusing of tasks as the project continues.

An indicative Project Gantt chart showing the project timetable is given in Appendix B.

1.5 Research links with FD2107 and D2116

There are strong research links between all three ERP Phase 2 projects. In particular, the work on Mathematical Formalisation Objective in FD2117 is likely to benefit from the work on Geomorphological Assessment Tools (FD2116 WP2).

The linkages between all three ERP Phase 2 projects was discussed at a project summit meting on 14th June 2004. A number of joint meetings have been arranged in year 1 and further linkages will be defined in project years 2 and 3 as the research progresses.

It is understood that the joint effort will cover communication, dissemination and peer review of the project results.

Information exchange on project progress is to be facilitated through the dissemination of quarterly project progress reports (the first one of which is due end of September 2004).

Table 1. EstSim primary milestones

Primary Milestones				Variation
01/02	Y1 m4	m4	Agree Conceptualisation Report with Project Officer	None (completed July 2004)
02/01	Y1 m9	m9	Delivery of Report on Management Questions	To be defined
03/02	Y2 m7	m19	Delivery of Report on Behavioural Statements	Interim report m7 Final report m12
04/02	Y2 m12	m24	Completion of Mathematical Formalisation	To be defined
05/02	Y3 m6	m30	Completion of Estuary System simulation development	To be defined
06/01	Y3 m9	m33	Complete proof of concept testing for management system interface	To be defined
07/01	Y3 m10	m34	Completion of Pilot Testing	To be defined
08/01	Y3 m12	m36	Complete Dissemination	To be defined

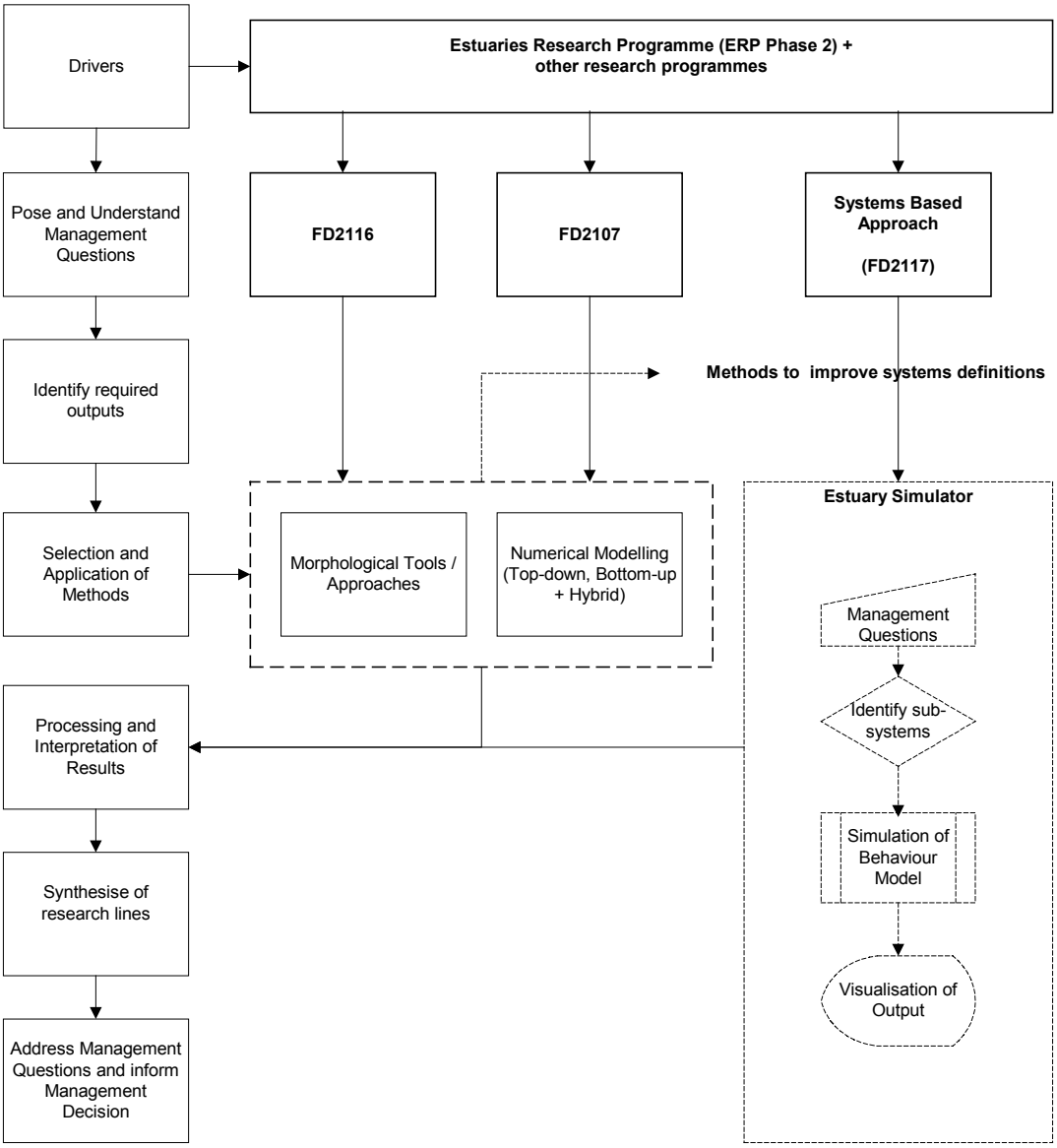

Figure 1. Integration of systems based approach

2. WORKING DEFINITIONS

For the purposes of this research project there is benefit in using definitions for key terminology. Initial working definitions for key systems based terminology are presented below and should compliment the standardization of terminology presented within FD2116. The definitions represent a collation of terminology and expressions referenced from various scientific papers (Capobianco *et al.* 1999, Cowell & Thom 1994, French *et al.* 2002 and Townend 2003).

2.1 Behavioural Models

A qualitative or quantitative representation of the interactions between physical processes (forcing factors) and geomorphological elements. A behavioural model seeks to capture the response of the system to changes in forcing or imposed constraints. The system response over different scales may be accompanied by alternative (simplified) models that represent the critical interactions to the relevant time frame.

A behavioural model may be set up through application of behavioural statements and systems diagrams with development into a full behavioural model occurring after the formalisation of the cause-effect relationships/rules (Figure 2)

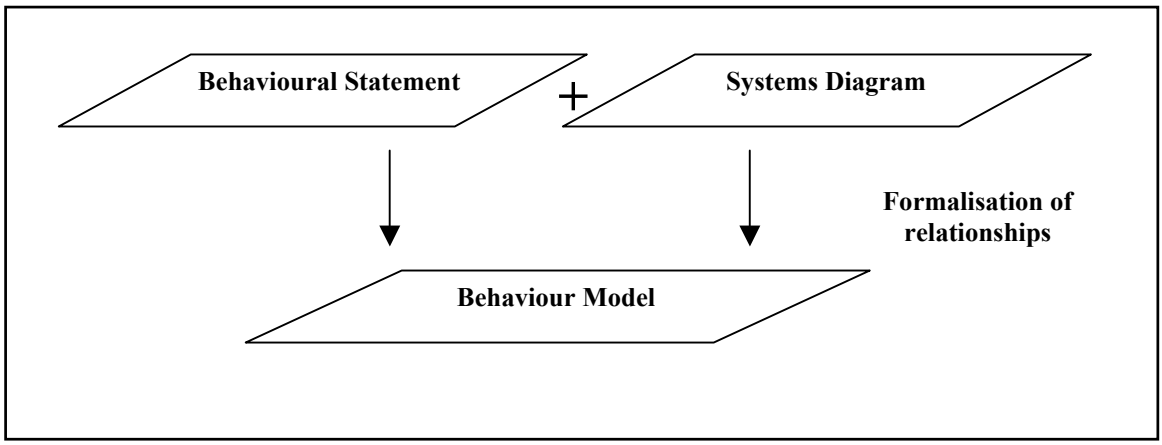

Figure 2. Elements of systems-based approach

2.2 Behavioural Statement

Textural description of the interactions and relationships within a system. The system components for an estuary may comprise different geomorphological elements (GE's) such as a saltmarsh and intertidal mudflat with the behavioural statement capturing a description of the range of forcing factors and their influence on the GE. A behavioural statement may capture the nature of relationships between system components and discuss the evolution of the system over time.

2.3 Systems Diagram/Model

A formal flow chart representation of the interactions between system components. Systems diagrams may capture the relationship between components (such as

directionality and relative importance/dominance) and may be integrated to capture critical elements over different time scales.

2.4 Behaviour Model

An extension of systems diagrams and behavioural statements that includes formalisation of the system interactions (behaviour). Formalisation may be in the form of existing models and morphological concepts or rules or through qualitative statements.

3. OBJECTIVES AND TASKS

Nine Scientific Objectives and associated Tasks are proposed in order to meet the overall aim of EstSim, which is to apply a systems-based approach to extend the ability to simulate estuarine response to change. The duration of each objective is shown in project month units with month 1 as April 2004.

3.1 System Conceptualisation (Objective 1)

Objective Leader - ABPmer (Months 1-4), inputs from all Partners

The first Objective (System Conceptualisation) has been completed through the acceptance of this report by the Defra Project Officer. The Conceptualisation Stage has allowed adaptation and focusing of initial research effort, particularly for Objectives 2 and 3 (Section 3.2 and 3.3).

Production of this report satisfies Project **Milestone 01/02** (Table 1).

3.2 Development of Management Questions (Objective 2)

Objective Leader - ABPmer (Months 20-29), inputs from all Partners

The role of Management Questions has been re-focused as noted in Section 1.4.3. Whilst it is still envisaged that relevant management questions will be the starting point for application of the systems based approach, development of the approach will be driven by the underlying science. This approach will minimise the risks associated with the research and maximise the utility of the deliverables. As it is now suggested that the range and complexity of questions that can be informed will emerge from the systems development, there is no need to pre-determine specific management questions that should be addressed. Therefore this Objective will now start later in the overall project timetable and will be phased to capture the emergent properties of the systems approach when these are better understood. This strategy will also allow greater focus to the consultation procedure. This Objective will start as soon the emergent properties of the systems based approach dictate.

The starting point for application of the systems approach will still be the choice of management question and the pathway to the estuary simulation is likely to come via a mapping of questions against the relevant building blocks (geomorphic units and processes). Thus, a role of the Manager System Interface (Objective 6) will be to identify and select the sub-systems that need to be represented as well as exploring how visualisation techniques can facilitate the process of interaction between the user and the operating system.

The Tasks presented in the CSG7 Proposal have been amended at an initial level here, but these may need to be re-focused again as development of the systems approach continues.

Task 2.1 Capture knowledge on predictive abilities of the systems based approach as defined throughout development phase.

Task 2.2 Map predictive end-points against initiating events / interventions to identify the range of management questions that could be informed, the degree to which they are addressed and the role those questions have in UK coastal planning and consents procedures.

Task 2.3 Develop Management Questions (from Task 2.2) into format that will be used to initiate simulation of the systems approach.

Task 2.4 Produce Technical Report on findings **(Milestone 02/01).**

3.3 Behavioural Statements (Objective 3)

Objective Leader - ABPmer (Months 4-12), inputs from all Partners as required

The objective of this research element is to develop a formal definition of an estuarine system(s).

This will require mapping out of the geomorphological sub-systems that are to be included as part of the estuary system (elements, processes and linkages), an exploration of systems diagrams and their ability to encapsulate different types of behavioural response, and development of behavioural statements.

The Conceptualisation Workshop has allowed re-focusing of the work plan for this Objective and is now composed of the following tasks:

Task 3.1 Cross-reference alternative estuary classification schemes against UK estuaries in order to identify (i) classification types for main UK estuaries, and (ii) the range of geomorphic elements present in these estuaries.

Task 3.2 For the estuarine geomorphic elements identified in Task 3.1, produce generic behavioural descriptions that include definitions of the links to driving physical processes and other elements.

Task 3.3 Review methods of presenting systems approach to identify suitable techniques and options for estuaries and specific geomorphological elements.

Task 3.4 Produce systems diagrams for geomorphic elements.

Task 3.5 Develop framework that links generic geomorphic elements, their behavioural description and their systems diagrams to the behaviour of specific estuaries over the short, medium and long term.

Task 3.6 Populate behaviour framework with two specific case estuaries (to be agreed).

Task 3.7 Document Protocol for developing estuary behavioural statements based on above tasks.

Task 3.8 Produce Interim Technical Report on findings and disseminate to Partners.

Task 3.9 Hold Translation Workshop where Partners can formulate and disseminate initial strategy regarding Mathematical Formulation and System Simulation.

Task 3.10 Iterate approach to systems development and produce final Technical Report **(Milestone 03/02).**

3.4 Mathematical Formalisation (Objective 4)

Objective Leader - Plymouth University (Months 7-24), inputs from all Partners as required

The objective of this research element is to develop the behavioural statements (Objective 3) into a logically consistent mathematical framework that preserves the geomorphological characteristics.

Formalisation of behavioural statements will require good knowledge of tools and techniques available for representing estuary processes and may need to develop simplified versions of existing numerical and expert modelling tools.

After delivery of the interim report on behavioural statements from Objective 3 (month 7) the Mathematical Formalisation Objective will begin with an initial view presented on translation of the Objective 3 outputs. This will facilitated by holding a Translation Workshop in project month 9.

Task 4.1 Prepare the mathematical framework for describing the connectivity and flows of the system. This will include an investigation of different approaches such as linked differential equations, linked Boolean logic systems and statistical correlation models.

Task 4.2 Review the proposed arrangement of objects and linkages within the system in relation to accepted means of describing the processes.

Task 4.3 Parameterise these processes into a form that is amenable to the mathematical framework and which also preserves the required geomorphological characteristics.

Task 4.4 Examine linear and non-linear stability issues and characteristics of the 'system' dynamics.

Task 4.5 Simplification/parameterisation of existing geomorphological concepts and approaches (particularly those considered under FD2116).

Task 4.6 Design, code and test the mathematical algorithms.

Task 4.7 Hold team workshop to disseminate findings

Task 4.8 Produce Technical Report on findings **(Milestone 04/02).**

3.5 Set-up of System Simulation and Validation (Objective 5)

Objective Leader - University College London (CERU) (Months 18-29), inputs from all Partners as required

The objective of this research element is to set-up the architecture and methodology for estuary simulation based on the system definition comprising the behavioural statements its mathematical formulation. The simulation phase thereby provides the system approach output to inform answers to the specific management questions.

This Objective will include sensitivity testing and validation of the estuary simulator.

Task 5.1 Critical review of simulation methods and tools (e.g. Stella, Modelmaker, Powersim, Matlab, Simulink and Extend) and choice of most appropriate simulation method to be applied.

Task 5.2 Translation of Systems output (Objective 3 and 4) into estuary simulator.

Task 5.3 Sensitivity testing and validation of simulator against development estuary properties.

Task 5.4 Hold team workshop to disseminate findings.

Task 5.5 Produce Technical reports on findings (code listings, user manuals etc.), and perform assessment of how well the resultant simulator addresses the management questions posed at the outset **(Milestone 05/02).**

Task 5.6 Demonstrate simulator in parallel with Objective 6 at Technical Stakeholder Group meeting.

3.6 Manager - System Interface (Objective 6)

Objective Leader - Discovery Software (Months 27-32), inputs from all partners as required

The objective of this research element is to explore the use of decision systems for identifying the most appropriate tools for given problems/management questions and explore visualisation techniques to aid information accessibility.

The Manager System Interface seeks to increase functionality and accessibility for estuarine managers and provides a direct link between the Management Questions and the model outputs.

Task 6.1 Review of decision support methods (e.g. those used in SimCoast and ERAD).

Task 6.2 Optimisation of decision support method for specific decision making requirements (in particular method/tool selection) and development of modular approach.

Task 6.3 Review visualisation options suitable for the presentation of management information. Select tools to apply in conjunction with the estuary simulator, and to undertake tests suitable for proof of concept.

Task 6.4 Produce technical report setting out the requirements of the Manager-System Interface, how well it can be delivered with the tools tested, and what further research and development is needed if this approach is to be implemented within the Environmental Management System (EMS) envisaged as part of ERP Phase 3 **(Milestone 06/01).**

Task 6.5 Demonstrate simulator in parallel with Objective 5 at Technical Stakeholder Group meeting.

3.7 Pilot Testing (Objective 7)

Objective Leader - Hydraulics Research (HR) Wallingford (Months 31-34), inputs from Delft

The objective of this research element is to pilot test the estuary simulator. This can be seen as an extension of the model validation stage in Objective 5 with a wider remit.

Task 7.1 Decision on options for pilot estuaries based on availability of data and knowledge on previously studied systems (i.e. ERP Phase 1 and HR/Delft experience) to be agreed with project officer.

Task 7.2 Perform range of simulations against pilot estuaries.

Task 7.3 Evaluate performance of simulators against present and emerging knowledge of estuary processes, including a critique of the simulators ability to help address the identified range of management issues (noting limitations, caveats, etc.).

Task 7.4 Hold team workshop to disseminate findings.

Task 7.5 Produce Technical Report on findings **(Milestone 07/01).**

3.8 Dissemination (Objective 8)

Objective Leader – ABPmer, inputs from all partners as required

Dissemination of project outputs and results will be undertaken via a range of methods and where possible these will be in liaison with FD2107 and FD2116 (Section 1.4). This synergy is being developed a result of discussions at the ERP Phase 2 summit meeting on 14th June 2004.

Task 8.1 Participate in a series of workshops/roadshows (in parallel with FD2107 and FD2116). An integrated approach for all three projects will maximise the delivery requirements of ERP Phase 2. The nature of these roadshows will be defined through Project Officers and Steering Groups (Defra nominated).

Task 8.2 Publicise the project and the Estuaries Research Programme through articles for the Defra/EA Flood and Coastal Defence Research Newsletter and other press releases as appropriate.

Task 8.3 Notification of research and presentation of results on joint project website to be hosted by the Proudman Oceanographic Laboratory (POL).

Task 8.4 Submission of at least two peer reviewed technical/application papers in scientific journals.

Task 8.5 Presentation of findings at national/international conferences.

Task 8.6 Application of methods within consultancy and research services.

3.9 Peer Review (Objective 9)

At the proposal stage it was envisaged that members of the Estuaries Advisory Group would be appointed to provide peer review prior to submission of deliverables to Defra. However, subsequent to the project summit meeting it is now envisaged that an external expert will be appointed to provide this capacity for all ERP Phase 2 projects (FD2107, FD2116 and FD2117).

4. PROJECT AND RISK MANAGEMENT

Specific project management issues and methods are presented in detail in the CSG7 proposal. However, it is worth highlighting the range of methods that will be employed to minimise project risks:

- Adaptively manage the Scientific Objectives at key stages within the project (as demonstrated with the Conceptualisation Stage).
- Facilitate involvement of all Project Partners in Scientific Objectives.
- Utilise expert peer review at key stages to ensure research is robust and meets client requirements.
- Hold regular project and joint ERP Phase 2 workshops to disseminate research and gain feedback.
- Monthly client progress reports highlighting research progress and early warning of potential risks.

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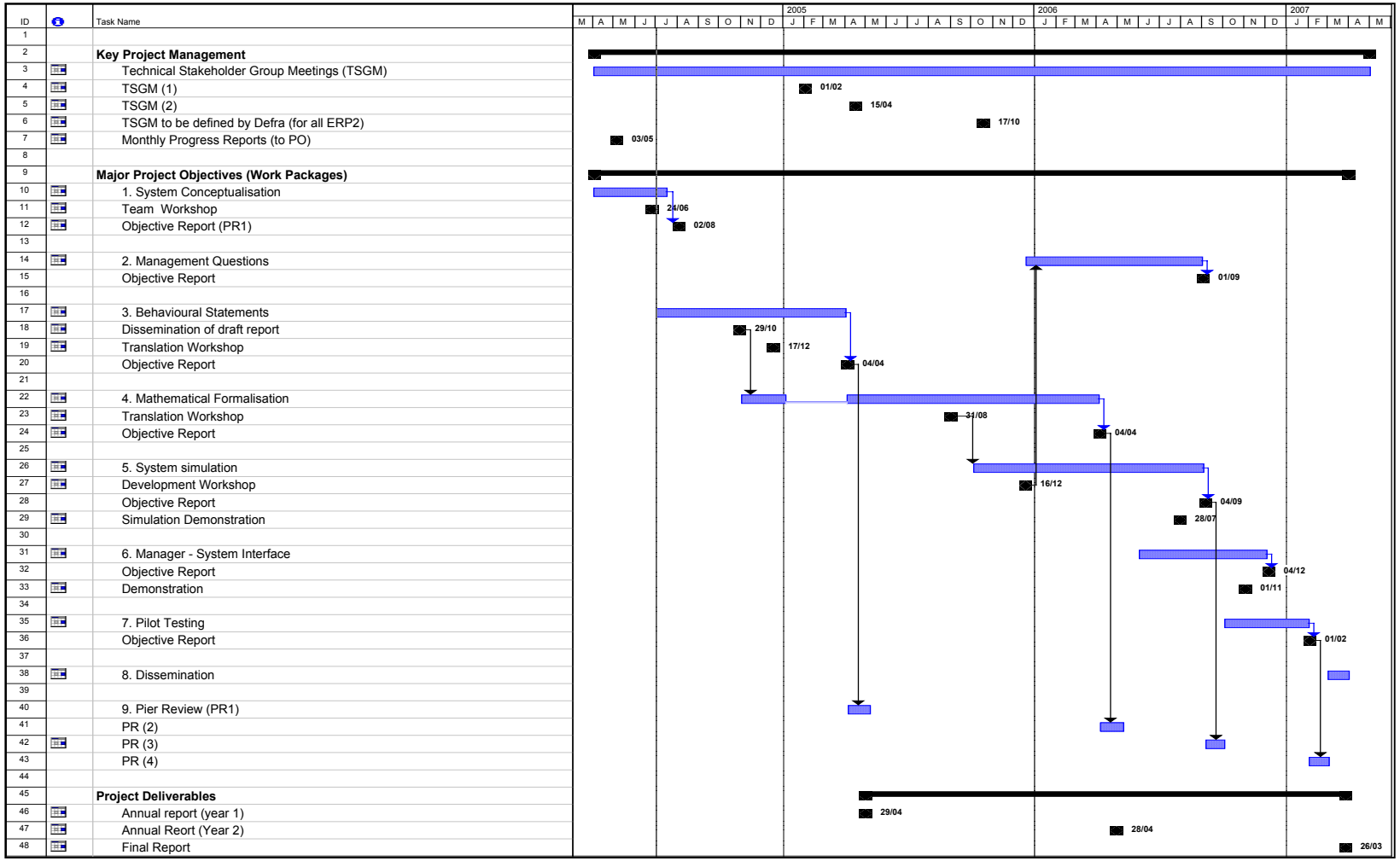
APPENDIX A. CONTACT DETAILS FOR ESTSIM PARTNERS

Name	Organisation	Address	Tel Nos.	Email
Jon French Helene Burningham	CERU UCL	Coastal & Estuarine Research Unit Department of Geography University College London London WC1N 1PF	+44 (0)20 76794280 +44 (0)20 76794277	j.french@ucl.ac.uk h.burningham@geog.ucl.ac.uk
Dominic Reeve	University of Plymouth	Plymouth University School of Engineering Reynolds Building University of Plymouth Drake Circus Plymouth PL4 8AA	+44 (0)17 52233672	dominic.reeve@plymouth.ac.uk
Mark van Koningsveld Zheng Bing Wang	WL | Delft Hydraulics	WL | Delft Hydraulics P.O. Box 177 2600 MH Delft The Netherlands	+00 31 15 2858585	Mark.vanKoningsveld@Wldelft.nl Zheng.Wang@Wldelft.nl
Mike Dearnaley Jez Spearman	HR Wallingford	HR Wallingford Ltd Howbery Park, Wallingford Oxfordshire OX10 8BA	+44 (0)1491 835381 +44 (0)1491 822462	m.dearnaley@hrwallingford.co.uk j.spearman@hrwallingford.co.uk
Kevin Morris	Discovery Software	Discovery Software 36 Elm Park Paignton Devon TQ3 3QQ	+44 (0)1803 663975	kpm@discoverysoftware.co.uk
Ian Townend Tim Wells Nick Cooper Ivan Haigh	ABPmer	ABP Marine Environmental Research Ltd Pathfinder House Maritime Way Southampton Hampshire SO14 3AE	+44 (0)23 80338100	itownend@abpmer.co.uk twells@abpmer.co.uk ncooper@abpmer.co.uk ihaigh@abpmer.co.uk
Possible Experts to include				
Marcel Stive	Delft University of Technology	Delft University of Technology Stevinweg 1 2600 GA Delft. The Netherlands		
David Prandle	Proudman Oceanographic Laboratory	Bidston Observatory Birkenhead CH43 7RA	+44 (0)151 6538633	dp@pol.ac.uk

APPENDIX B. PROJECT GANTT CHART



Ergon House
Horseferry Road
London SW1P 2AL

www.defra.gov.uk