Institution:
Plymouth University

Unit of Assessment:
UoA15 General Engineering

Title of case study:

Research algorithms for coastal and estuarine evolution inform flood protection policies, and shoreline management plans.

1. Summary of the impact (indicative maximum 100 words)

This case study discusses research performed in Plymouth University that has had a significant impact on practice in estuarine flood risk management. Specifically, some of the research led to a long-term estuarine evolution predictor, and later informed Halcrow and the Exe Estuary Partnership on future evolution of the Exe Estuary under a number of scenarios.

2. Underpinning research (indicative maximum 500 words)

The research methodologies for the statistical approaches included in this case study were first developed by Prof. Dominic Reeve while in Nottingham (see Sect. 4, and paper: Reeve et al., Jour. Coast. Res., 2001), and further explored by the Plymouth team since Dominic Reeve joined Plymouth in 2004. The research carried out in Plymouth since 2004 involved: Prof. Dominic Reeve, Dr Harshinie Karunarathna, Dr Vanesa Magar, and Dr Jose Horrillo-Caraballo. This statistical research is on-going in Plymouth, as demonstrated by the papers in *PloS One* (Ref. 1 in Sect. 3).

Cooper and Hutchinson (2002) expressed the widespread acknowledgement that there is a need for more robust probabilistic methodologies to assess risks in coastal engineering design. This includes coastal protection; dredging works related to harbour maintenance; assessment of navigational channel evolution to inform port developments; and flooding and erosion assessments to inform future flood risk management, shoreline management, and coastal and estuarine policies. A large proportion of coastal areas depend upon the nearshore characteristics to protect them from flooding and erosion. For instance, it is recognised that sandbanks play a role similar to reefs in protecting the shoreline from eroding. Moreover, ‘soft engineering’ solutions currently are the preferred coastal management approach, as they help prevent coastal flooding and erosion. This move from a ‘hard’ to a ‘soft’ engineering approach in coastal management has increased the importance of understanding coastal processes, and how the seabed responds to prevailing tides, waves, and other possible forcing phenomena such as atmospheric oscillations.

The research was linked to a broader programme of research carried out within the ‘Flood Risk Management Research Consortium 2’ (FRMRC2) sponsored by the EPSRC, EA, and DEFRA, and within the DEFRA Project ‘Development and Demonstration of Systems Based Estuary Simulators’. In these projects, as well as subsequent and current research, several novel tools and algorithms were developed to analyse and forecast coastal and estuarine morphology. Morphological features analysed include navigational channels, sandbanks, and shorelines. The models developed in the project consisted of systems approaches, where coasts and estuaries are analysed in terms of morphological units such as sandbanks, spits, saltmarshes etc. In the FRMRC2 project and a consultancy project for International Port Holdings Ltd, the methods developed consisted of ‘top-down’ approaches - based on statistical techniques, nonlinear time series analyses, trend analyses, and linear forecasting methods. These ‘data-driven’ techniques make use of available surveys, and are

superior to other techniques for morphological investigations and morphological forecasts at yearly to decadal timescales. The examples in Sect. 3 (Refs. 1-3) show applications of novel approaches to different forms of beaches, with Ref. 4 introducing the Boolean method applied to long-term estuarine management. The methods provide a useful degree of forecast quality for coastal management.

3. References to the research (indicative maximum of six references)

1. **Magar, V**., M. Lefranc, R. B. Hoyle and D. E. Reeve (2012). Spectral quantification of nonlinear behaviour of the nearshore seabed and correlations with potential forcings at Duck, N.C., U.S.A. *PloS One* 7(6): e39196. doi:10.1371/journal.pone.0039196. *PloS One* is a peer-reviewed international journal dedicated to publishing high quality research. Impact factor (IF) = 3.73 in 2012.

2. Horrillo-Caraballo, J. M. and D. E. Reeve (2010). An investigation of the performance of a data-driven model on sand and shingle beaches. *Marine Geology*, 274 (1-4), 120-134. International peer-reviewed Journal of Marine Geology, Geochemistry and Geophysics, founded in 1964. Marine Geology publishes high-quality novel research, as well as reviews and discussions. It currently has a 5-year average impact factor of 2.96.

3. Reeve, D. E., J. M. Horrillo-Caraballo and **V. Magar** (2008). Statistical Analysis and Forecasts of Long-term Sandbank Evolution at Great Yarmouth, UK. *Est. Coast. Shelf Sci*. 79(3), 387-399. http://dx.doi.org/10.1016/j.ecss.2008.04.01 Estuarine, Coastal and Shelf Science is an international, peer-reviewed multidisciplinary journal devoted to the analysis of saline water phenomena. Its impact factor in 2012 was 2.324

4. Karunarathna, H and D. E. Reeve (2008) A Boolean Approach to Prediction of Long-term Evolution of Estuary Morphology. *Jour. Coast. Res.*, Vol. 24(2B), 51-61. 61. JCR is an international, peer-reviewed journal published by the Coastal Education & Research Foundation, Inc. [CERF] Research Papers and Technical Communications are peer reviewed by at least two referees. Its 5-year impact factor is 0.77.

5. Reeve, D. E., J. M. Horrillo-Caraballo and **V. Magar** (2007). Great Yarmouth Sandbanks Analysis: statistical analysis of past and future nearshore morphology. University of Plymouth Report, UK.

6. FRMRC2 Super Work Package 2 report. Available from [last accessed: 10/11/12]: http://web.sbe.hw.ac.uk/frmrc/downloads/Research%20Report/FRMRC2%20SWP2_WP2.2_Report.pdf

4. Details of the impact (indicative maximum 750 words)

The research underpinning the impact described in this case study was developed within various programmes in which relevant stakeholders, such as Halcrow, DEFRA, and/or the Environment Agency, were closely involved. Methods such as stakeholder and end-user meetings ensured full knowledge exchange to relevant parties. The methodologies developed resulted from the combination of different projects and underpinned different impacts, the development of the Est Sim Tool [Source 5.1], the application of the same methods to the Exe Estuary and the inputs to the National Coastal Erosion Risk Mapping (NCERM) tool are described in this case.

The Boolean method used in the systems description of estuaries, led to the estuarine simulator “EstSim” [5.1], and was developed under contract from Halcrow [5.2] during a ERP/DEFRA/EA project FD2117. EstSim was fully developed by Plymouth University and is detailed on the joint EA/DEFRA website http://www.estuary-guide.net/, it remains available

via Discovery Software Ltd's website. Unfortunately usage statistics were not specified as a requirement of the conversion of the tool to a web based application (conducted by specialist firm Discovery Software Ltd, not Plymouth) and thus, are not available. Whilst the tool is publicly available Halcrow remains the predominant user [5.2] and their Principal Coastal Scientist states that *"the Est Sim model was very innovative"*.

One of DEFRA's 2005 high level targets required local authorities to assess coastal erosion risks and reflect these in their development plans. However, at the time, no robust and consistent probabilistic approach to assessing coastal erosion risk existed. Therefore, in 2005, DEFRA and the EA commissioned (Research & Development project (FD2324)) Halcrow to develop such methods and in conjunction with Dominic Reeve's group at Plymouth the RACE (Risk Assessment of Coastal Erosion) project enabled knowledge built up in the Reeve group and new discovery to feed into a jointly developed methodology. This methodology was subsequently built into an online tool through the National Coastal Erosion Risk Mapping (NCERM) project [5.3]. Coastal mapping commenced in 2006 and in 2007 the prototype of a sophisticated online GIS tool was unveiled. By December 2008/early 2009 the first batch of National Coastal Erosion Risk Maps were published [5.4]. From then on, the online tool continued to be developed and the, by then, robust and stable current version (v4.6) of the tool went live on the NCERM website [5.5] on 14th July 2011. During the REF assessment period the coastal erosion maps were published, the final tool development has been completed and continues to provide coastal erosion risk mapping facilities to local authorities and similar bodies.

Coastal erosion is a major problem for the UK; DEFRA's National Assessment of Assets at Risk Study (Halcrow, 2001) suggested that £7.7Billion of capital value assets were at risk from coastal erosion. Subsequent broad-brush estimates suggest that this figure is closer to £21.5Billion (Halcrow, 2007). Halcrow's NCERM project final funding report to DEFRA/EA concluded: *"The National Coastal Erosion Risk Mapping project is a highly ambitious, national-scale undertaking which aims to combine the best science with the best local information. It represents the new collaborative approach between the Environment Agency and Local Authorities who together will provide the public with the best available information on the coast*". [5.6]

Halcrow's Principal Engineer [5.7] states: *"Plymouth made a fundamental contribution to the research in producing a statistical model to pull various datasets together in order that coastal erosion predictions for the next 100 years could be made. Sufficient records for coastal areas were not comprehensive, as you would expect (why keep records if erosion isn't an issue) but in many areas the model could be tested and validated, which it was. The Environment Agency took the research on to produce erosion maps. There are two versions – One in the 'In My Backyard' part of the EA website, which is for use by the public (and others, of course) which provides simplistic information and another more sophisticated site which can be interrogated for use by Local Authorities, the EA and one or two other stakeholders, like English Nature. This site is used to inform coastal protection spending, planning decisions and so on. It is run and maintained by Halcrow."*

In addition to the public facility all 108 maritime authorities around England and Wales have engaged with NCERM (the more sophisticated version of the erosion mapping technique). The majority have had hands-on experience of utilising the NCERM web-portal which is underpinned by the RACE methodologies developed jointly by Halcrow and Plymouth. For example Wyre BC's Head of Engineering Services [5.8] says *"NCERM is a useful planning tool, which now enables coastal erosion to be accounted for and thereby helps to justify investment and in debating spending priorities"*.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] EstSim: http://www.estuary-guide.net/

[5.2] Principal Coastal Scientist , Halcrow Group Limited, A CH2M HILL COMPANY, Burderop Park, Swindon, Wiltshire SN4 0QD, Tel +44 1793 816 328, Mob +44 7738 035109, www.halcrow.com

[5.3] http://www.halcrow.com/Our-projects/Project-details/National-coastal-erosion-risk-mapping-England-and-Wales/

[5.4] http://www.environment-agency.gov.uk/homeandleisure/134808.aspx

[5.5] https://race.halcrow.com/ncerm/home.aspx

[5.6] FCM09 NCERM FINAL Rogers.doc

[5.7] Principal Engineer, Halcrow Group Limited, A CH2M HILL COMPANY, Burderop Park, Swindon, Wiltshire SN4 0QD, Tel +44 1793 816309, www.halcrow.com

[5.8] Head of Engineering Services, Wyre Borough Council, Civic Centre, Breck Road, Poulton-le-Flyde, Lancashire, FY6 7PU.