NATURAL DESIGN AND MANAGEMENT OF AN ESTUARY MOUTH SYSTEM

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INTRODUCTION

Estuaries often are the focus of both man-made infrastructure and valuable flora and fauna. Sand spits are common at the mouth of estuaries, and are one of the key features that influence hydrodynamics and geomorphology in estuaries. The Environment Agency has delivered a long term coastal management scheme, which has recently been designed and built, to manage the Dawlish Warren sand spit at the mouth of the Exe Estuary, in south Devon, UK. This scheme is designed to

- Protect 3,000 properties and critical national infrastructure from flooding.
- Restore 2km of internationally designated (SAC) dune and associated ecology continue protection to the SPA bird assemblages in the Exe Estuary.
- Provide a flexible way forward through this century for the sand spit to be managed in a sustainable and balanced manner.

The Exe Estuary is macrotidal with a range of 4m, and main tributary inflows of the order of 20-400m^3/s. Dawlish Warren sand spit covers three quarters of the estuary mouth width, sheltering the estuary from the coastal wave and tide climate. Consequently, the in-estuary extreme wave heights are limited to less than 1.1m, with storm surges of up to 1-2m. The estuary exhibits high tidal velocities through its mouth, with flood/ebb tidal deltas and offshore banks present. The sand spit has breached around 13 times over the last two centuries, prompting reactive construction of concrete, rock armour and gabion revetments over the 19th and 20th centuries.

SCHEME CONCEPT

The scheme concept was developed through the UK hierarchy of strategic coastal management, consisting of shoreline management plans, strategies and schemes. The Exe Estuary Flood and Coastal Erosion Risk Management Strategy (EEFCERMS; Environment Agency, 2014) was the key study that determined the optimal economic and environmental approach for managing the estuary mouth. The justification of the scheme is based on the estuary-wide storm sheltering function that the sand spit provides, with baseline analyses indicating an increasing risk of breach (due to continued erosion and sea level rise) and partial loss of sheltering function if the sand spit management was not changed. The management of the sand spit therefore also influences the wider management of flood defences throughout the Exe Estuary (see Figure 1).

The EEFCERMS analyses identified that the optimal scheme approach (see Canning, 2015) consists of continuation of the storm sheltering function provided by the sand spit through to the 2040s, removal of the gabions to support reactivation of the dunes by 2030, and up-engineering of in-estuary flood defences in the 2040s once the storm sheltering function is lost. To enable these objectives, beach recharge and/or recycling (preferentially dredging from the local ebb delta) was proposed.

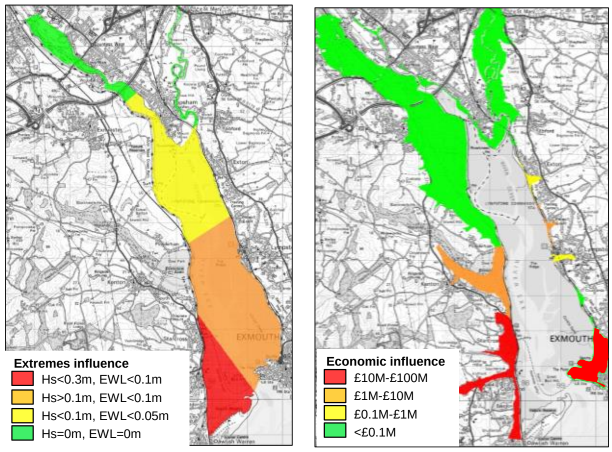

Figure 1. Influence of partial loss of sheltering function on wave-tide extremes and economic damages.

DESIGN OF ESTUARY MOUTH SYSTEM

The scheme is shown in overview in Figure 2.

Figure 2. Overview of scheme design.

The scheme consists of:

- A localized flood wall and proximal revetment extension. This provided the transition from a concrete revetment to natural dunes, and protects the local village from flooding if the dune ridge breaches. The revetment design relies on provision of higher managed beach levels.
- Gabion removal and dune reactivation. Removal of the gabions would allow the dune ridge to respond naturally to storm and calm conditions. Analysis of the existing beach conditions identified that there was very limited dry beach width, with coarse sand, that would discourage Aeolian transport. Additionally, application of empirical methods (Vellinga, Van Rijn, EurOtop) indicated that the existing dune ridge would breach during storms due to the low-lying beach. Both these findings identified that beach recharge would be required to increase beach levels, and provide a wider, drier, fine-medium sand beach.

- Hard neck asset. As the neck section of the sand spit is 10-20m wide, it is at risk of breach in 4%AEP events and greater. Application of the above empirical methods was used to determine the required beach recharge, and the design of a buried geotube. The geotube is required environmentally to only be exposed in extreme storm conditions, and be removable in the 2040s.
- Beach recharge and groyne system. The previous analyses determined the need for a wider, drier, fine-medium sand beach. To design the groyne system and assess the required beach recharge volume, near-field 2D wave, tide, and sediment transport modelling was undertaken, and interpreted within the wider conceptual model.
- Dredging of the local ebb delta. Dredging from the local ebb delta required a rigorous suite of field surveys and near/far-field 2D wave, tide, sediment transport and plume modelling; to inform the design and enable licensing. Field surveys consisted of CPTs and vibrocores; wave, tide, turbidity, dye and drogue deployments; infauna and bird sampling and monitoring. The field surveys enabled confirmation of sand particle size distribution, depth and volumes, and areas of no/minimal ecological interest. The hydrodynamic deployments were used to calibrate the near/far-field 2D numerical modelling. This was used to find the optimal dredge location, extent and depth that would avoid on-shore wave-tide impacts; and dredge method that would result in minimal plume dispersion.

Photographs of the dune and beach system before and after the scheme construction are shown in Figures 3 and 4.

Figure 3. Dunes and beach before scheme (gabions on lower dune face).

Figure 4. Dunes and beach after scheme.

CONCLUSIONS

The scheme development provides a useful example of the competing interests and challenges of managing a sand spit and estuary mouth system, particularly in relation to climate change. Making changes to the coast to enable more sustainable management can be difficult to justify (Canning, 2016), or are dependent on a particularly pressing combination of drivers. However, it is possible to justify strategically, and design in detail, schemes that integrate and manage natural and man-made infrastructure. In this case the optimal approach is to change existing management towards a significantly more natural system.

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