Suffolk Marine Pioneer Deben

Wave protection provided by salt marshes

A GIS and remote sensing basic analysis approach

Orplands marshes, Essex (photo: J A Tempest)

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Summary

This report outlines a simple yet scientific GIS based method for the assessment of wave protection provided by salt marshes. The Deben Estuary in Suffolk provides a case study to demonstrate this method that could be 'rolled-out' to other areas

Underpinning science

Salt marshes can act as important buffer against damaging wave action[1]They do this because of two key attributes: (1) they effectively reduce the water depth because the marsh provides a 'platform' relative to the estuarine or sea bed. (2) the vegetation and other features of the marsh make for a rough surface which **slows the flow of water(?)**

The former acts to reduce wave height due to physically constraining the ability of the waves to form whilst the latter removes energy from the wave through added friction. Scientific testing has shown that the absolute minimum reduction in wave height as a result of these factors is 15% with a 40m wide marsh. This has the positive benefit of reducing the threat posed by storm events on the settlement, land or activities on the landward side of the marsh.

Precautionary principle

Factors such as marsh width, water depth, incoming wave heights, vegetation height and density affect the degree to which the presence of salt marsh reduces waves.

It is difficult to predict the precise likelihood of certain water depths or wave height conditions for future events. We also recognise that it is difficult (and expensive) to gather sufficient (or sufficiently accurate) information on vegetation height and density. This study thus works on the basis of the precautionary principle: It aims to provide a map for the Deben estuary that highlights the minimum relative wave reduction provided by the salt marsh for the most extreme wave conditions as well as those that occur more frequently. This allows any economic assessment of the coastal protection service of the marshes to be a conservative baseline, thus facilitating investment in marsh restoration where there is clear evidence for the marshes acting as significant additional flood and erosion risk mitigation elements.

Approach and Methods

Our approach is outlined in schematic format in Figure 1.

As the provision of a buffering function is, first and foremost, dependent on the generation of waves in the first place, this method starts with a simple computation and mapping of the likely maximum achievable wave height in front of any marsh within the estuary (wave exposure). Following such 'exposure mapping' the coastal protection provided by the presence salt marsh can be expressed as the degree to which waves are reduced by the presence of the marsh, i.e. the ratio between wave heights (H) arriving at the back of the marsh to wave heights that would be present at that same location if the marsh was not there:

$$Wave\ buffering\ (\%) = 100\ x\,\frac{H\ without\ marsh\ present - H\ with\ marsh\ present}{H\ without\ marsh\ present}$$

The 'wave height with marsh present' can further be separated into: 'wave height due to marsh platform alone' and 'wave height due to bed roughness on the platform'.

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[1] 1st ref.- pref in an accessible format?

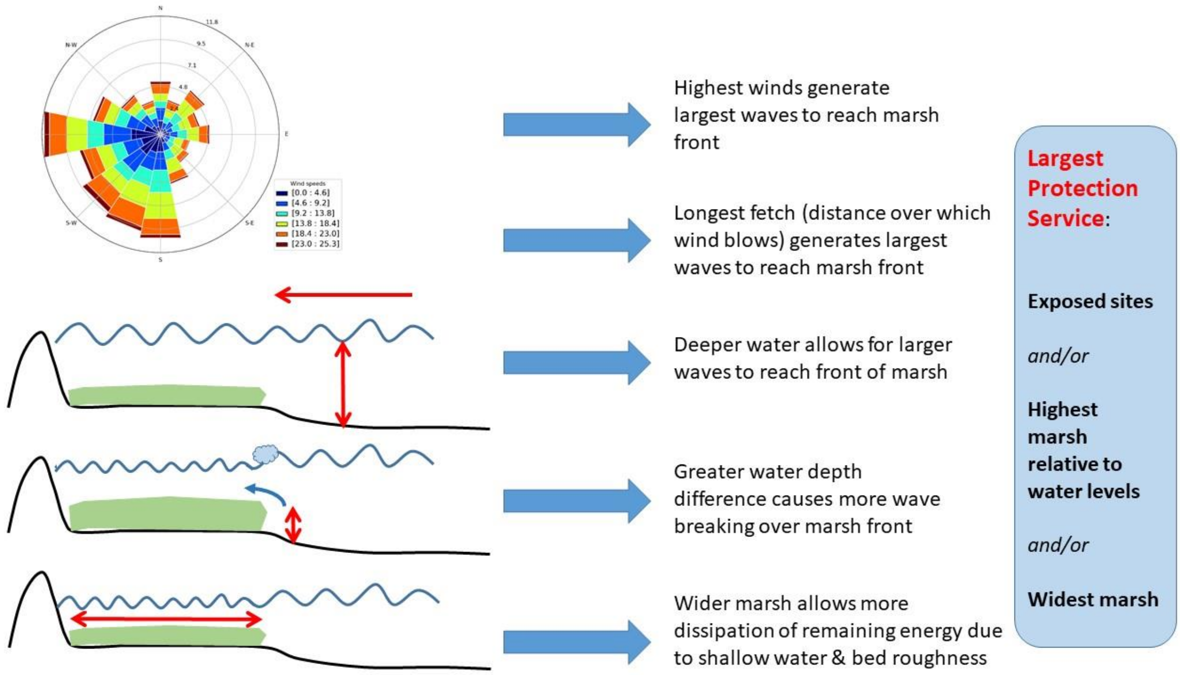


Figure 1: Schematic showing key factors determining coastal protection service provided by salt marsh fronting valuable structures

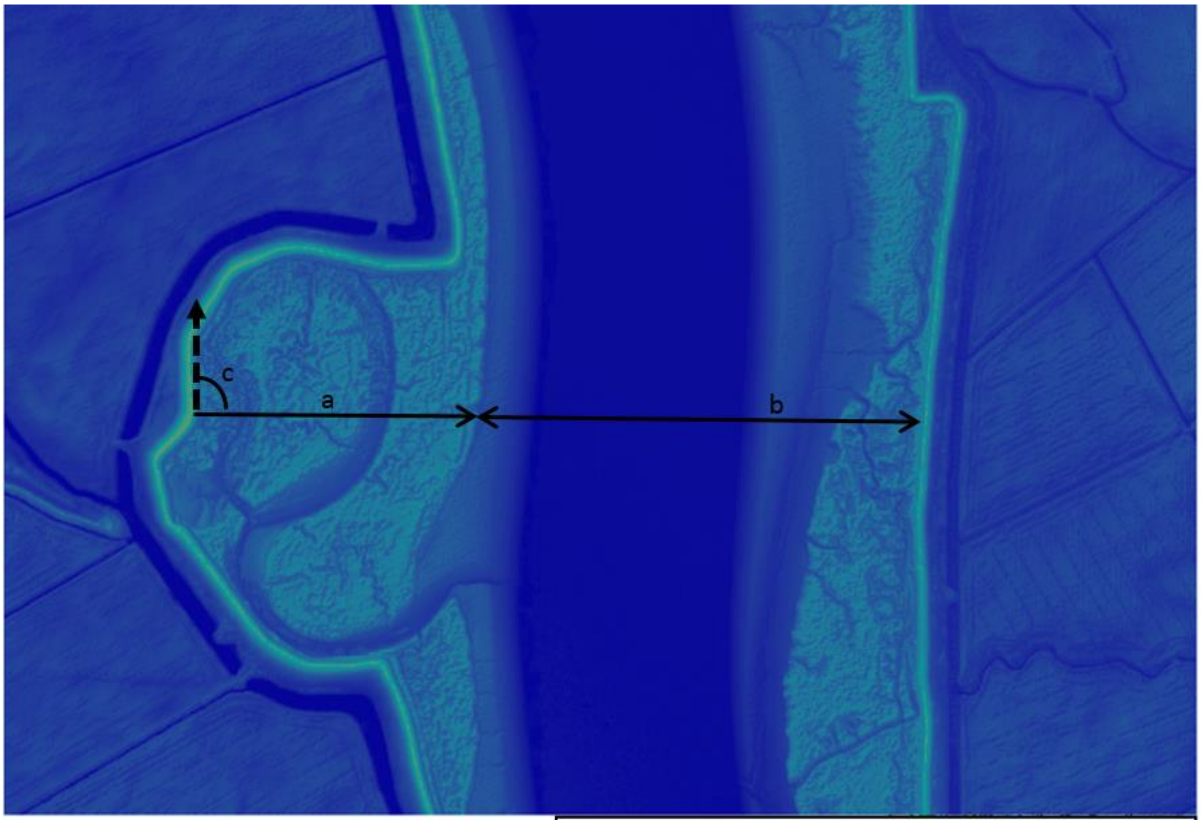
Exposure mapping

Given our precautionary principle approach, we start with the premise that the hydrodynamic conditions that are most likely to cause flooding or erosion are:

Water levels at their maximum: we assumed the maximum possible water levels, given historic records (Woodbridge tide gauge (Environment Agency)) and accounting for future sea level rise (although we do not account for within-estuary tidal modulation / modification);

Waves of maximum height: we used location-specific combinations of fetch distance (derived from OS maps), historic (10-year records) wind duration, direction, and speed to calculate the maximum wave height that is theoretically possible at the marsh margin, given observed wind conditions at the Meteorological Office station at Walton-on-the-Naze. For this purpose, a wind rose was generated to determine wind speed (average and maximum gust speeds) from a shore-normal direction at any given along-estuary position.

At each along-estuary position (XXm spacing), maximum water levels and average / extreme onshore wind conditions were thus used to compute maximum potential wave heights approaching the shore.



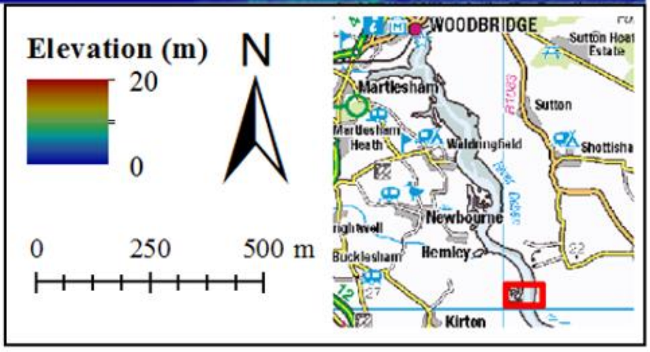


Figure 1: Visualisation of parameters collected through GIS and remote sensing analysis: a) salt marsh width; b) distance wind blows across water (fetch) and c) wind/ fetch direction relative to north.

Wave height buffering due to marsh platform alone

Assuming a given salt marsh experiences exposure to onshore winds, the degree to which it acts as a wave buffer depends first and foremost on its elevation and cross-shore width.

Marsh cross-shore width is estimated using …. .

Marsh platform height is estimated using …. .

For our estimates of wave heights landward of the marsh platform and in keeping with our precautionary principle, we estimate wave heights at the landward limit of the salt marsh as the maximum wave heights possible under the given wind conditions (average and maximum gust speeds) likely from an onshore direction at any given locality. These maximum potential wave heights are thus either:

- equivalent to those present on the tidal flat fronting the marsh (where the marsh platform does not reduce water levels to result in wave heights exceeding 0.78 x water depth) or

- they become reduced to the theoretical maximum of 0.78 x water depth (where the marsh platform reduces water depths such that wave heights exceed 0.78 x water depth).

For this part of the exercise, **the platform is assumed to be smooth** (i.e. no friction due to vegetation / topography) and no decay in wave heights other than the breaking limit is applied. Given our precautionary principle, this is our assumption for any marshes that are less than 40 m in width, the distance for which the most robust scientific evidence exists that vegetation cause significant additional buffering effects. In reality, some vegetation effects will be present for distances < 40 m, such that, in keeping with our precautionary principle, we can be confident that our estimates are an under- rather than over-estimate of the buffering function of the marsh.

Wave height buffering due to marsh platform with vegetation cover

The height, density and flexibility of the vegetation cover present affects the additional dissipation of wave energy achieved over the marsh platform (above and beyond the wave breaking due to the shallower water depth). In keeping with our precautionary principle, we will assume a vegetation cover composed predominantly of the flexible marsh species *Elymus* as simulated in a true-to-scale laboratory flume experiment in 2013[2]. For the same reason, we also assume that there are no creeks dissecting the marsh surface offering potential additional surface roughness and wave dissipation.

We use the 2013 flume experiment evidence for wave dissipation during 2 m above-marsh water depths. To comply with our precautionary principle, we apply a reduction of 15% (the minimum observed in that experiment) for any marsh of 40 m or more width to account for the effect of the vegetation canopy and micro-topographic surface roughness. In reality, dissipation is likely to be more, particularly where over-marsh distances far exceed 40 m.

Results

Outputs are available in the form of multiple GIS layers. This facilitates user interrogation of specific areas / locations and illustrates well the relative difference between wave heights at the sea defence line with and without fronting saltmarshes. Relative differences in ‘worst case’ wave heights at the landward limit of the marsh are presented for different marsh widths (no marsh, 10 m wide marshes throughout the estuary, and existing marsh widths).

GIS layers are delivered for five separate regions (colour coded separately in the map in Figure 3).

Key findings

Relative coastal protection provided by fringing estuarine salt marsh can be assessed relatively easily using the best available science and fundamental wave theory for water depth and wind condition associated with greatest flood and erosion risk exposure.

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[2] Möller, I., Kudella, M., Rupprecht, F., Spencer, T., Paul, M., van Wesenbeeck, B. K., et al. (2014). Wave attenuation over coastal salt marshes under storm surge conditions. *Nat. Geosci.* 7, 727–731. doi:10.1038/ngeo2251.

GIS mapping allows the results of such a relative analysis to be displayed at the regional (whole estuary) scale such that individual locations requiring more detailed attention can be identified.

Future outlook

Our approach is applicable to other estuarine sites, provided the key parameters required are available for such estuaries and basic maps of salt marsh and tidal flat elevation and extent are accessible.

The GIS approach lends itself to the use of Earth Observation data. With the increasing availability of such data, applications can be developed that use our approach alongside similar approaches for the quantification of other ecosystem services and display such information in multiple GIS layers.

As scientific knowledge on the specific parameters that drive the relative provision of ecosystem services grows, such applications can begin to incorporate an increasing amount of information and can be used as an attractive way to illustrate ecosystem service provision and trade-offs across the regional landscape.

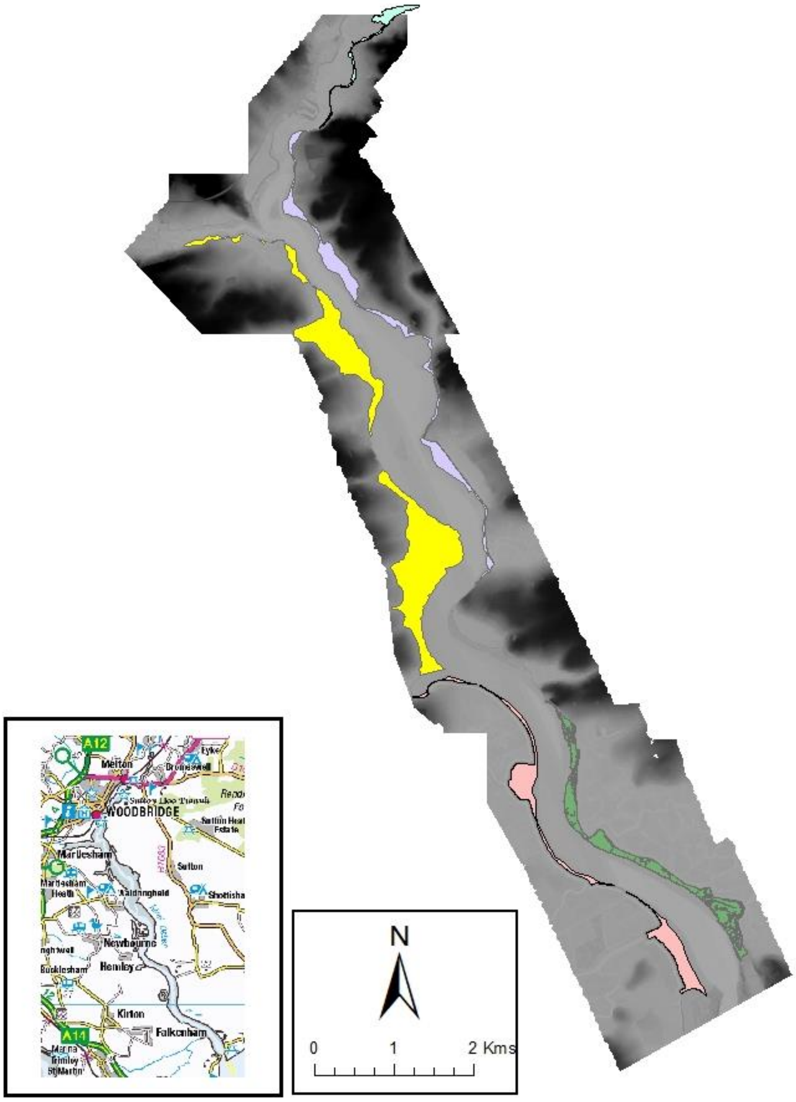
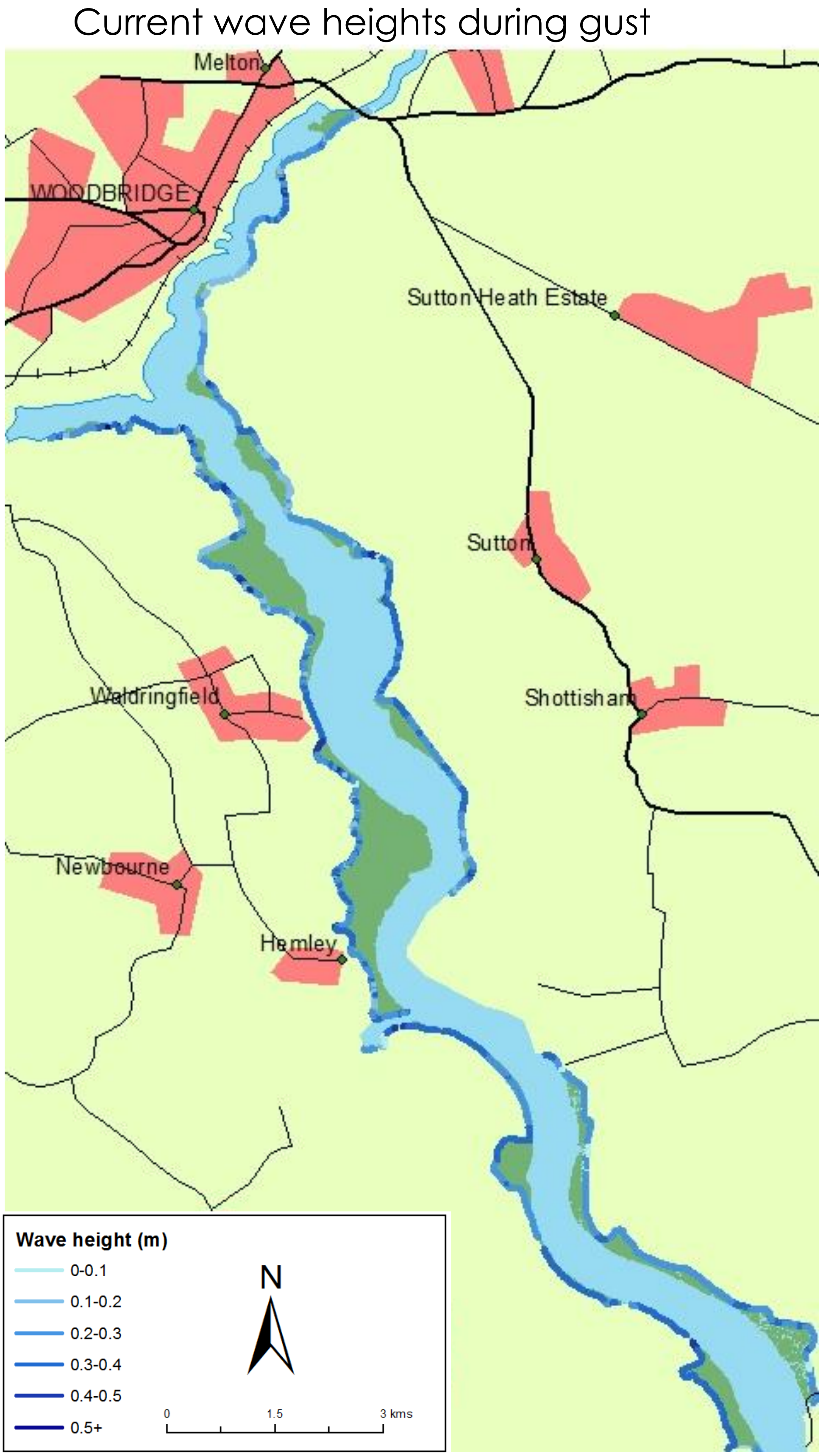
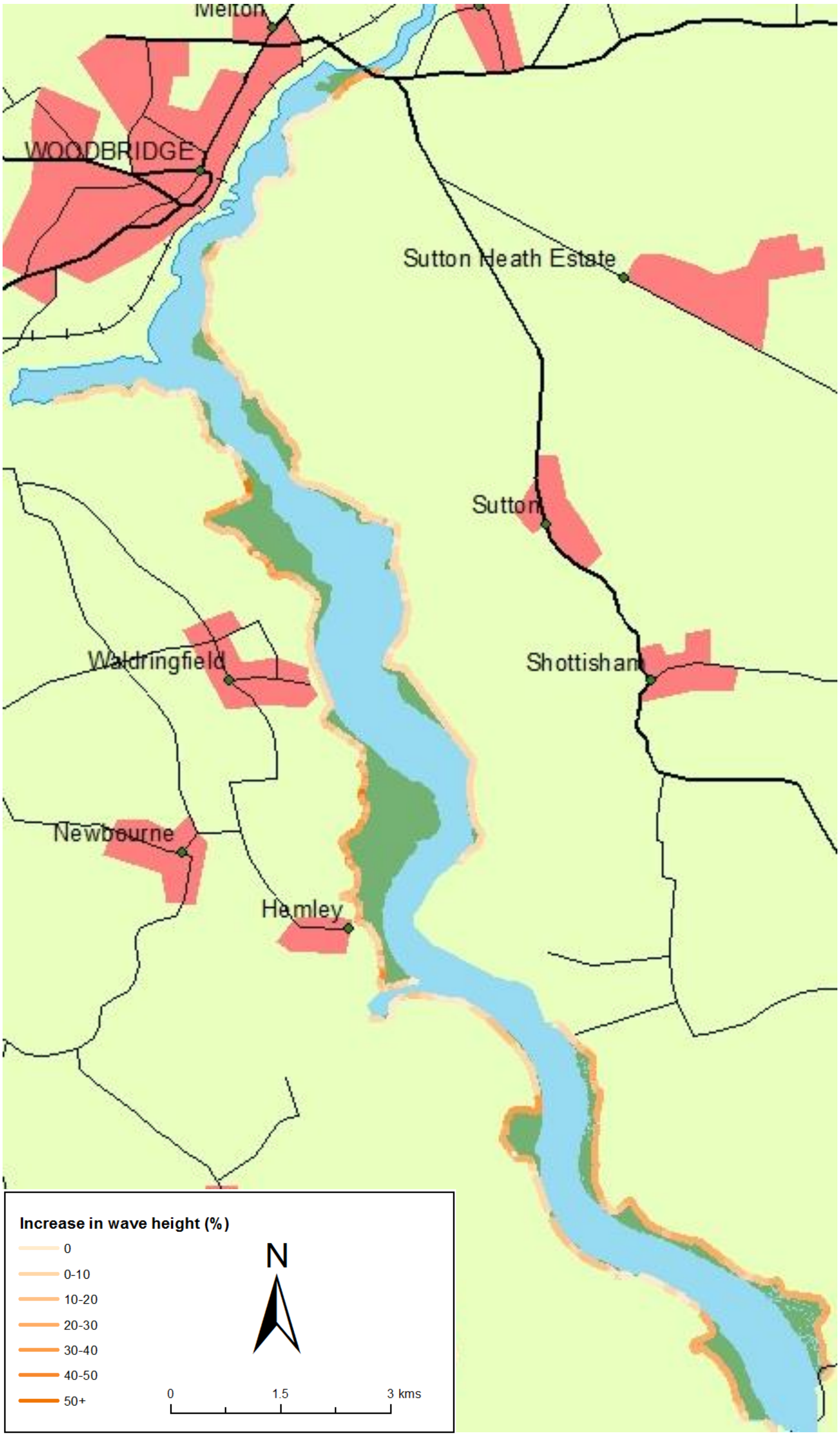


Figure 3: The five regions for which separate GIS layers are supplied showing the relative wave buffering function of salt marsh along the Deben estuary.



Wave height increase if saltmarsh width reduced to



Wave height increase if saltmarsh removed (%)