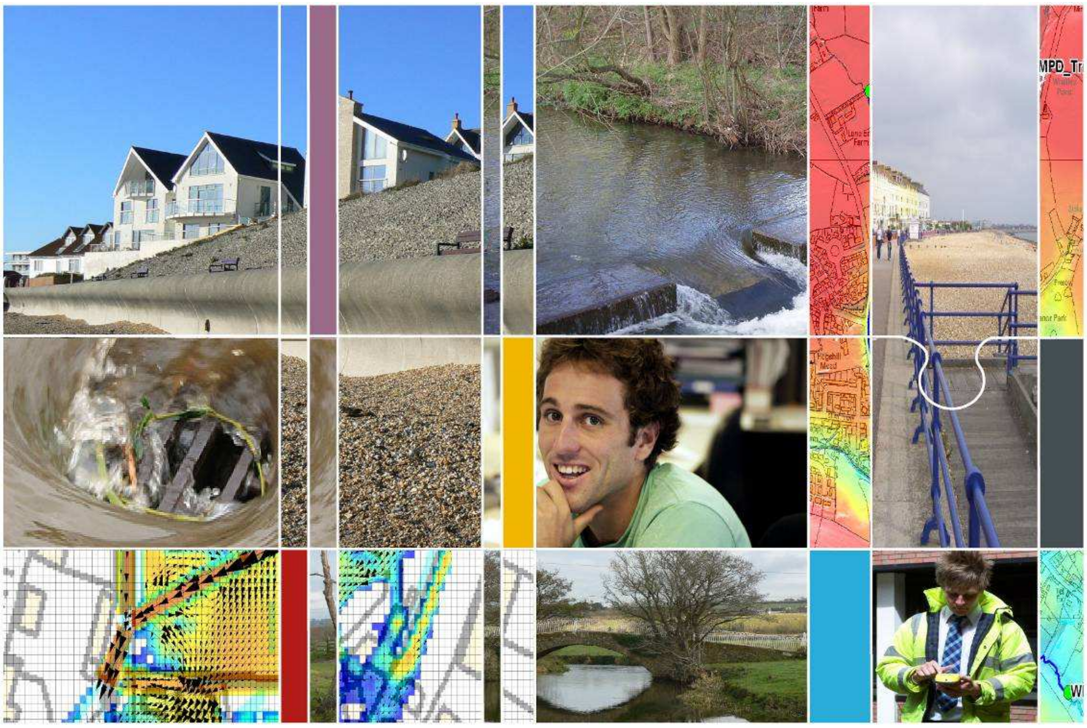
East Sussex County Council



Cuckmere Estuary Option Impact Study
Options Analysis Report
Final

May 2011

CAPITA SYMONDS

Document overview

Capita Symonds was commissioned by East Sussex County Council to undertake a modelling and technical study of the Cuckmere Estuary. This report summaries the findings and results of the modelling.

Document history

Version	Status	Issue date	Prepared by	Reviewed by	Approved by
V3	Draft	30/03/2011	Bryony Smith	Scott Ferguson	Scott Ferguson
V4	Final	30/03/2011	Bryony Smith	Scott Ferguson	Scott Ferguson
V5	Final	20/05/2011	Bryony Smith	Scott Ferguson	Scott Ferguson

Notice

This document has been produced by Capita Symonds for East Sussex County Council on behalf of a wider audience of the Cuckmere Estuary Partnership in relation to the 'Pathfinder Project.

Any liability arising out of use by a third party of this document for purposes not wholly connected with the above shall be the responsibility of that party who shall indemnify Capita Symonds Ltd against all claims, costs, damages and losses arising out of such use.

Capita Symonds Ltd
Capita Symonds House
Wood Street
East Grinstead
West Sussex
RH19 1UU
Telephone: 01342 333 566
Fax: 01342 315 927
Project contact: Scott.Ferguson@capita.co.uk

Contents

Appendices

1. Introduction

1.1 Background

Following the completion of the Flood Risk Management (FRM) strategy for the Cuckmere Estuary, the Environment Agency is now implementing the strategy's preferred option, which is the withdrawal of maintenance to the existing flood defences along the tidal River Cuckmere south of Exceat Bridge (referred to as the Cuckmere Estuary) from April 2011. After this the estuary would be affected by natural processes only.

Defra has provided a Pathfinder grant to assist in exploring different ways of planning for, and managing, this change. The Pathfinder Project, led by East Sussex County Council (ESCC) working together with the local community, is considering a number of alternatives for the management of the Cuckmere Estuary. The project has developed a list of management options which it wishes to consider further. The Project is interested in understanding how each of these options might affect the estuary, in the near future and in the longer term.

This option impact study needs to quantify the changes to the estuary by means of a detailed hydraulic study of the estuary under the different options with a geomorphological and ecological assessment, reviewing where this has already been done in previous work. As part of the study the changes to the estuary also need to be visualised effectively so that stakeholders can interpret the predicted short, medium and long-term consequences of each option.

1.2 Options considered

The list of 7 options to be considered are:

1. Option A: Partial breach managed realignment
2. Option B: Full breach managed realignment
3. Option C: Engineered reactivation of meanders and meandering creeks
4. Option D: Maintain the existing defences at their current level
5. Option E: Raising the existing defences to keep pace with climate change
6. Option F: Raising the existing defences by 300mm
7. Do nothing

The "do nothing" option is included as the baseline for comparison for all the other options. This is based on the current situation of the Environment Agency withdrawing maintenance of defences from April 2011 but continuing to clear the river mouth for either 15 years or until the river system becomes self regulating.

The purpose of this study is to provide an assessment of the likely changes to the estuary morphology, and the subsequent changes to flooding, vegetation, habitats and assets in the estuary, as well as a cost comparison of construction and maintenance of each option.

This document presents the findings of the modelling work carried out to help assess the likely impact of a range of future management options of the River Cuckmere estuary. The results from the modelling take the form of a series of map which show the extent and depth of inundation within the estuary for a range of tide and river conditions for each of the possible management options. They also show how the estuary will change in the short term (i.e. immediately after the option has been implemented, in 50 years time and in 100 years time (approximately). Additional outputs from the modelling tell us where the areas of highest water velocities will occur at different stages of the tide, allowing us to determine where erosion or deposition is likely to take place in the future. We can use this information to build a picture of how the land surface will change, and when combined with the water levels we know from the models, we can determine what vegetation and what kind of habitat are likely to form. A separate set of maps show the different vegetation and land cover that we believe is likely to develop over the same period, for the same management options. Although these maps are based on the output from the model, we have also involved a geomorphologist and an ecologist in helping to ensure the results are sensible and realistic. The information associated with the output from the study is tabulated in the tables below in section 3.

2. Non-technical Summary

2.1 Approach

It is widely accepted that it is the behaviour of the water within the estuary that will dictate the future landscape. Whilst it is important to recognise that some significant changes in the estuary may occur during a single storm event, and embankments and floodplains can be shaped by a sudden breach occurring, the key to predicting how the estuary might look and the habitats it may support in the future, is to understand the day-to-day rising and falling of the tides and the normal flow of the river. It is the changes in flow paths, changes in water depth and duration of inundation, and changes in water velocities and volumes over many decades that will determine where new channels will form, where mud flats may be deposited and settle, and where and how quickly saltmarsh may begin to grow.

Our approach has been to focus the modelling and reporting largely on the 'normal' flow and water level conditions in the estuary by modelling a 24 hour period in time, covering two full tidal cycles. We have assumed a steady flow in the river which reflects a typical day at any time throughout the year. The main factor we have modelled which has the greatest influence on the estuary is the rise and fall of the tides. As tidal range normally changes on an approximately monthly cycle, we have selected a typical neap tide (smallest tidal range resulting in a relatively low high tide), and a typical spring tide (largest tidal range resulting in a relatively high high tide). We have run the model for both of these tidal conditions for all the different management options, for the current and future conditions, taking into account both climate change (including sea level rise) and changes in the ground surface in the estuary. We can now show what the estuary is likely to look like at any time on a 'typical' day in the future for any of the proposed management options.

We have also investigated the impact any changes in the estuary might have on possible flooding in the area, both in the estuary itself, and upstream around Alfriston. In order to do this, we have also run a series of flood events through the model and again, mapped the extent and depth of inundation. Because flooding may occur as a result of either tidal flooding or fluvial (river) flooding, or a combination of both, we have looked at a range of combined high river flows and extreme tides. The severity of these flood events is expected to increase in the future through increased storminess due to climate change, as well as sea level rise due to a combination of polar ice-caps melting and lowering land levels resulting from geological changes.

The changes to the land form and levels within the estuary have been made to the underlying digital terrain model (DTM) which forms the basis of the hydraulic model. The changes made for each time horizon are based on the modelling from the previous time horizon, looking at velocities and depth for the neap and spring tides, but also making use of professional judgment from a geomorphologist and an ecologist to help determine how the land is most likely to change.

The seven options that have been agreed by the community to be considered are:

1. Baseline: Do nothing
2. Option A: Partial breach managed realignment
3. Option B: Full breach managed realignment
4. Option C: Engineered reactivation of meanders and meandering creeks
5. Option D: Maintain the existing defences at their current level
6. Option E: Raising the existing defences to keep pace with climate change
7. Option F: Raising the existing defences by 300mm

The modelling work to determine water levels and flows for this study has been carried out using a sophisticated 2-D hydrodynamic modelling software called Tuflow which can replicate the physical processes within the estuary reasonably accurately. There are however some limitations to this approach and the following assumptions and uncertainties have been taken into account as part of the modelling process:

- Future estimates of climate change – these are taken from standard growth curves for increase in sea level rise, increased storminess, and increased flood frequency, issued by Defra, and represent the best available information at the present time. However; there is no way of really knowing how future changes to the climate will affect the frequency and severity of storms. The further into the future we look, the greater the uncertainty there is.
- Estimating future changes on morphology as a result of the different options is not an exact science. Changes in the flows in, around and out of the estuary will change the morphology of the estuary, whilst changes in the morphology will change the flow patterns themselves. Assessing the changes involves an iterative process looping through the cycle of looking at how the river flows change and how that will affect the morphology, and how that in turn will affect the changes in flow. Again, this can be reasonably well predicted for a short period indo the future, particularly for the defended options, where change in the morphology is minimal. For options where wide scale inundation will become frequent, it is less easy to predict exactly where the tidal creeks and mud flats will form. Although the uncertainty in this process makes it difficult to accurately predict the detail in the long term, because we can relatively accurately predict the water levels, flow routes and duration of inundation, we can be reasonably confident in our prediction of the broad outcome of each option.
- Fundamental to the future of the Cuckmere Estuary is the continued existence of the beach across the mouth of the river. A separate investigation has been carried out to assess the likely changes and need to maintain the beach in its current form and location. The report from this study has identified some uncertainty, due in part to the lack of data and information available from previous studies. The report, together with the CVs of the panel members is attached in Appendix E.

2.2 Results

A full list of modelling scenarios we carried out is presented in Appendix A. However as the same scenarios were modelled for each of the seven options, and at each time horizon i.e. current (following the option implementation), 50 years and 100 years, they can be summarised as follows:

- Mean spring tide cycle with an average daily flow in the river (approx 1.5 cubic metres per second)
- Spring tide cycle with an average daily flow in the river (approx 1.6 cubic metres per second current and 1.9 cubic metres per second for the future)
- A very severe fluvial (river) flood event (i.e. 1% Annual Exceedance Probability (AEP) event) combined with a normal spring tide)
- A very severe tidal flood event resulting from a storm surge (i.e. 1% AEP) combined with an average daily flow in the river
- A severe combined flood event (i.e. approx 1% AEP - relatively common river flood event (i.e. 10% AEP event) combined with a severe tidal flood event (2% AEP) – resulting in a severe combined flood event

In presenting the impact of possible flooding, we have merged the results from the three flood events (ie. from either fluvial or tidal events or combined) into one map. This provides an indicative flood map which, although not representative of a single flood event, allows direct comparison of how the options would affect flooding from a range of sources.

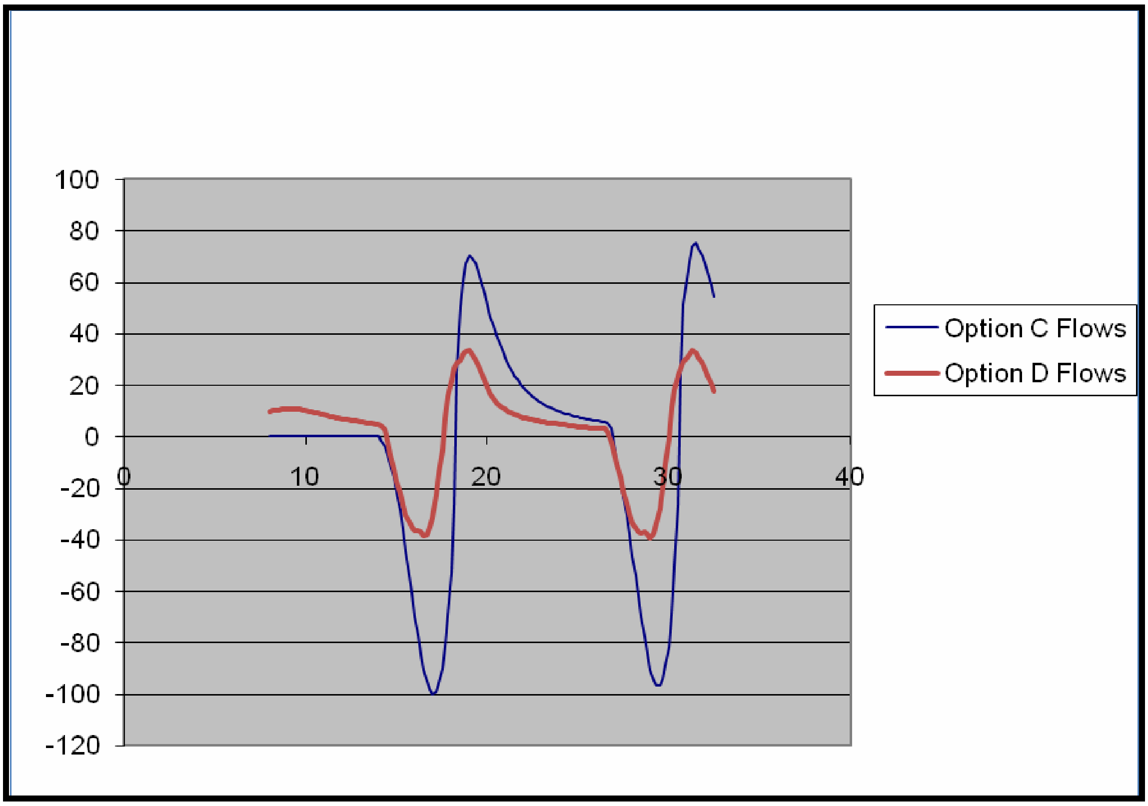
The results of the modelling work are presented as:

- A series of maps showing flood depth and extent for neap tides, spring tides and extreme flood events (Appendix C)
- A series of maps showing resulting land cover as potential habitat (based solely on water/land levels, not taking into account the varying time needed to develop different habitat types (Appendix D)
- A series of still images showing the landscape from predefined locations
- A series of animations with a 'fly through' showing the rise and fall of the tides
- Set of tables providing interpretation of the modelling work outcomes and supporting information (Section 3)

The key findings from the modelling work are as follows:

- The main impact on typical flow conditions in the river channel is due to the greater volume of water entering and leaving the estuary during each tidal cycle. This will increase with time regardless of the management option as a result of sea level rise and to a lesser extent, climate change. However the options which allow more of the existing flood plain to become part of a naturally functioning inter-tidal zone will increase the volume of water within the estuary still further. This increase in velocity is significant, and will be a significant factor in keeping the mouth of the estuary free from the build-up of shingle. An example of the flow in and out of the estuary at the river mouth is shown in Figure 2.1 below. The flow values are for a spring tide in 2060 for Option C and Option D for comparison, with negative flows being the flows into the estuary as the tide comes in.

Figure 2.1 – Spring tide flows at the river mouth for Options C and D



- The A259 road level across the valley is approximately 3.75m to 4.0m AOD. The current 1% AEP (i.e. 100 year tidal flood event) tide level in the estuary next to the road is approximately 4.0m AOD, and would therefore overtop the road in a few locations by at most around 25cm. This is a very extreme and unlikely event, and if it did occur, would result in water levels greater than the current road level for a period of less than 1 hour. The equivalent flood event in the future, taking sea level rise and climate change into account, will result in a water level of approximately 4.6m AOD, which would inundate the road in places up to a depth of 85cm. The period of inundation would also increase from less than 1 hour, to approximately 2.5 hours. It should be noted however, under current normal spring high tides, the water does not reach the road embankment under any of the scenarios. In the future undefended options, the high tide water level will reach the base of the road embankment, however it is expected that saltmarsh will develop under these conditions the water depths will be shallow. The energy from any wave action will be absorbed by the shallow water and saltmarsh vegetation, and waves will have a minimal impact.

- The modelling has shown how the options have different impacts on assets within the estuary. In addition to showing what is affected by flood events under different management options, we can also identify those assets that will not be directly impacted by flooding, such as the Coastguard cottages and Foxhole farm. The assets in the lower estuary identified through the modelling as being at risk from flood events are:
    1. Footpath on west river bank (providing access to the west beach)
    2. Footpath on east river bank (providing access to the east beach)
    3. Footpath along the west side of the valley (the Vanguard Way, providing access to the west beach)
    4. Footpath/track along the east side of the valley (concrete track, providing access to Foxhole farm from the A259 and access to the east beach)
    5. Canoe centre club house
    6. Canoe centre car park
    7. A259 road
    8. Exceat Bridge (A259 road bridge)
    9. Heritage assets (discussed in a separate report by East Sussex County Council)

Table 2.1 – Long term impact on assets

Option	Impact on assets
Baseline (Do nothing)	• Footpaths along both banks of the river will eventually disappear as the embankments are eroded. • Vanguard way will initially only be affected during a severe flood, and only in parts by relatively shallow water. By 2060, spring tides will regularly inundate low lying parts of the path. • The southern end of the footpath/track along the east of the valley will become unusable as the low lying areas behind the beach become more frequently inundated. • Foxhole farm will remain above the extreme flood event however access from the estuary along the concrete footpath/track will be flooded. • The canoe clubhouse and car park will be inundated by an extreme flood event, but will be unaffected by normal spring tides. • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). • The A259 bridge will remain largely unaffected
Option A	• The footpath along the west bank of the river will be unusable as breaches are created through the embankment. The footpath on the east bank will remain unaffected. • Vanguard way will initially only be affected during a severe flood, and only in parts by relatively shallow water. By 2060, spring tides will regularly inundate low lying parts of the path. • The southern end of the footpath/track along the east of the valley will be raised in places to maintain access to the South Downs Way. • Foxhole farm will remain above the extreme flood event however

	access from the concrete track will be flooded under an extreme flood event. • The canoe clubhouse and car park will only be inundated by the extreme flood event, but will be unaffected by normal spring tides. • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). • The A259 bridge will remain largely unaffected.
Option B	• The footpaths along both sides of the river will be unusable as breaches are created through the embankment. • Vanguard way will initially only be affected during a severe flood, and only in parts by relatively shallow water. By 2060, spring tides will regularly inundate low lying parts of the path. • The southern end of the footpath/track along the east of the valley will be raised in places to maintain access to the South Downs Way. • Foxhole farm will remain above the extreme flood event however access from the concrete track will be flooded. • The canoe club house and car park will only be inundated by the extreme flood event, but will be unaffected by normal spring tides (protected by additional embankment as part of option B). • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). • The A259 bridge will remain largely unaffected
Option C	• The footpaths along both sides of the river will be unusable as the embankments are removed. • Vanguard way will initially only be affected during a severe flood, and only in parts by relatively shallow water. By 2060, spring tides will regularly inundate low lying parts of the path. The track will be raised slightly and re-routed in places as part of the option. • The southern end of the footpath/track along the east of the valley will be raised in places to maintain access to the South Downs Way. • Foxhole farm will remain above the extreme flood event however access from the concrete track will be flooded under an extreme flood event. • By 2060, the canoe clubhouse and car park will be occasionally inundated by high spring tides to a shallow depth. Inundation by the extreme flood event will also occur, becoming more frequent in 50 to 100 years time. • The A259 will not suffer from flooding due to the raising of the causeway to 5.7mAOD. • The tight engineered bend just downstream of the bridge is likely to result in significant turbulence and potential scour in the area, this is likely to affect the A259 bridge, and possibly the road embankment close to the bridge.
Option D	• The footpaths along both sides of the river will remain usable, at least for short term. Once overtopping becomes more common, the condition will deteriorate and they will become too hazardous for public use. • Vanguard way will initially only be affected during a severe flood,

	and only in parts by relatively shallow water. By 2060, more frequent flooding will occur, but still relatively shallow flooding is likely. • Occasional flooding of the footpath/track along the east of the valley may occur during extreme flood events, becoming slightly more frequent by 2060. • Foxhole farm will remain above the extreme flood event however access from the concrete track will be flooded under an extreme flood event. • The canoe clubhouse and car park will only be inundated by the extreme flood event, but will be unaffected by normal spring tides. • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). • The A259 bridge will remain largely unaffected
Option E	• The footpaths along both sides of the river will remain usable throughout the period until beyond 2100. • Vanguard way will be largely protected from even a severe flood. • The footpath/track along the east of the valley will be largely protected from flooding beyond 2060. • Foxhole farm will remain above the extreme flood event however access from the concrete track will be flooded under an extreme flood event. • The canoe clubhouse and car park will be largely protected from even an extreme flood event. • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). Flood water will reach the road from upstream of the A259. • The A259 bridge will remain largely unaffected
Option F	• The footpaths along both sides of the river will remain usable until well after 2060. However, once overtopping becomes more common in the very long term, the condition will deteriorate and they will become too hazardous for public use. • Vanguard way will initially be largely protected from even a severe flood. Beyond 2060, more frequent flooding will occur, but will be relatively shallow and short lived. • The footpath/track along the east of the valley will be largely protected from flooding. Flooding may become slightly more frequent beyond this, but with relatively shallow water and the flooding will be short lived. • Foxhole farm will remain above the extreme flood event. • The canoe club house and car park will be largely protected up to 2060 from even an extreme flood event. Beyond that, flooding may become more frequent. • The A259 will suffer minor flooding during an extreme (1% AEP) flood event (approx 0.2 – 0.4m). Inundation will become slightly more frequent in the future, with greater depth during an extreme event (Approx 0.3 – 0.5m). Flood water will reach the road from upstream of the A259. • The A259 Bridge will remain largely unaffected

- Previous studies have stated that there will be no significant impact on flood risk upstream (north) of the A259 crossing as a result of changes to the way the estuary is managed. This study confirms this, and although it must be recognised that flood risk will inevitably increase as a result of climate change, the management activities in the estuary have little affect on flooding upstream. By simply comparing the peak flood levels shown in Table 2.2 below, we can clearly see that even over a range of different flood mechanisms, the flooding levels at Alfriston are almost identical for every option. It is also clear from these values, that different flood mechanisms affect different parts of the estuary in different ways. The largest change over time occurs at the river mouth resulting from sea level rise. This effect diminishes further upstream away from the influence of the sea. The impact of increased river flow due to climate change also has only a relatively small impact on flood levels in the river upstream of the A259. This is largely because the embankments are overtopped during a severe flood event, and any additional flow can spill out onto the already inundated floodplain. The effect of the increased overtopping on the extent of floodplain inundation however is minimal as the floodplain storage volume in this area is large, and the extent is constrained by the valley sides. It should be noted that these values do not include any blockage at the mouth of the river, which has been shown in previous studies to make flooding upstream more likely.

Table 2.2 – Predicted flood levels at Alfriston, Exceat Bridge and the estuary mouth

Options	Storm (combined 2%AEP Tide and 10% AEP flow)			1% AEP tide			1% AEP flow		
	Current (Following implementation of the option)	Medium Term (2060)	Long Term (2100)	Current (Following implementation of the option)	Medium Term (2050)	Long Term (2100)	Current (Following implementation of the option)	Medium Term (2060)	Long Term (2100)
Alfriston									
Baseline	4.2	4.3	4.3	3.8	3.8	3.8	4.3	4.4	4.4
Option A	4.2	4.3	4.3	3.8	3.8	3.9	4.3	4.4	4.4
Option B	4.2	4.3	4.3	3.7	3.8	3.9	4.3	4.4	4.4
Option C	4.2	4.3	4.3	3.7	3.8	3.8	4.3	4.4	4.4
Option D	4.2	4.3	4.3	3.8	3.9	3.9	4.3	4.4	4.4
Option E	4.2	4.3	4.3	3.8	3.8	3.9	4.3	4.4	4.4
Option F	4.2	4.3	4.3	3.8	3.9	3.9	4.3	4.4	4.4

Exceat Bridge									
Baseline	4.0	4.1	4.1	4.1	4.1	4.2	3.2	3.3	3.4
Option A	4.1	4.3	4.3	4.1	4.1	4.2	3.1	3.6	3.8
Option B	3.9	4.1	4.1	3.9	4.3	4.3	3.0	3.3	3.5
Option C	3.9	4.0	4.2	3.9	4.1	4.1	3.0	3.3	3.4
Option D	4.0	4.1	4.2	4.1	4.3	4.3	3.2	3.4	3.6
Option E	4.2	4.4	4.5	4.3	4.5	4.7	3.2	3.4	3.6
Option F	4.2	4.4	4.5	4.3	4.5	4.6	3.2	3.4	3.6
River Mouth									
Baseline	4.3	4.5	4.7	4.4	4.8	5.0	3.1	3.3	3.5
Option A	4.3	4.5	4.6	4.4	4.8	5.0	3.1	3.3	3.5
Option B	4.3	4.5	4.7	4.4	4.7	5.0	3.1	3.2	3.5
Option C	4.3	4.5	4.7	4.4	4.8	5.0	3.1	3.3	3.5
Option D	4.3	4.5	4.6	4.4	4.8	5.0	3.1	3.3	3.5
Option E	4.3	4.5	4.6	4.4	4.8	5.0	3.1	3.3	3.5
Option F	4.3	4.6	4.7	4.4	4.8	5.0	3.1	3.3	3.5

- The main impact the choice of management option will have on habitat is the effect it has on the extent, depth and duration of inundation. A simple rule of thumb for the formation of saltmarsh is that it will form in a zone above the neap high tide, and below the spring high tide. This is assuming all the other conditions are conducive, where water is sufficiently sheltered and containing sufficient sediment load to keep pace with climate change, and the water quality and sediment structure and composition are favourable. Through a series of sea water samples taken at the river mouth, we have established that the quantity of sediment in the water entering the estuary is approximately 0.1%, which equates to approximately 0.4mm of potential deposition from an average depth of 0.5m sea water. This gives a potential sedimentation rate of approximately 300mm per year. It should be noted that this is ‘potential’ deposition, and depends on all the suspended material settling out of the water column. In practice, this would not occur and would rely on perfectly still water. It does however support the assumption that an average deposition of 6mm/year is entirely plausible. This is the value quoted in other studies as typical for similar locations along the south coast of England (see Appendix B for more detail). There are three main habitat types created as a result of all the management options selected: saltmarsh; mudflat; and grassland (which may vary in the degree of wetland or grazing marsh it may contain), however the relative amount of each will vary significantly with time, depending on the option chosen. Table 2.3 below shows the estimate of varying percentage habitat for each option and for all three time horizons (based on the outputs from the hydraulic modelling giving water and land levels).

Table 2.3 – Predicted potential percentage habitat for each option

Time horizon	Habitat	Baseline	Option A	Option B	Option C	Option D	Option E	Option F
2010 to 2030	Mudflat	4	20	25	28	4	4	4
	Saltmarsh	6	22	28	24	7	7	7
	Grass	90	58	47	48	90	90	90
2031 to 2060	Mudflat	6	16	19	24	4	4	4
	Saltmarsh	10	39	43	44	8	8	7
	Grass	84	45	38	32	87	88	89
2061 to 2110	Mudflat	5	15	23	29	15	5	5
	Saltmarsh	8	41	57	55	15	10	8
	Grass	86	44	20	16	69	85	86

- The impact on landscape of each of the seven options is largely dependant on the eventual extent of regular inundation from high tide. Where defence embankments are retained, the land benefiting from the defence will remain largely unchanged. Assuming a similar land use continues, i.e. grazing, the landscape in the protected areas is likely to remain very similar to today. Where embankments are eventually lost (either in the short term or long term), the landscape will change dramatically. The current grazing fields on either side of the river will be submerged at high tide (particularly on the western side of the river), and will become a large inter-tidal zone with extensive areas of exposed mudflat and saltmarsh at low tide and will be almost entirely covered in water at high tide. As the high tide will only last for a short period twice a day, the typical appearance will be a constantly changing combination of some exposed mudflat and some extent of open water. In order to help communicate the likely changes to the estuary to a wider none-technical audience, we have developed a range of animations and simple visualisations to allow stakeholders to understand and interpret the information provided.

- An assessment of the changes likely to occur to the beach has been carried out as a separate study, attached as Appendix E. This study has included a review of all the readily available data and information relating to the Cuckmere Haven and relevant studies of the south coast. The coastal study was carried out by a group of independent coastal geomorphology specialists who agreed on a number of key aspects of the coast and interaction with the Cuckmere estuary:

1. The cliffs on either side of the beach (termed a pocket beach) are essential to the stability and continued existence of the beach in its present condition and location. The rate of erosion of these chalk cliffs is approximately 0.2 to 0.5m per year. This rate of loss is not expected to significantly threaten the beach over the next 100 years.

2. It is thought unlikely that there will be any overall net loss of beach material over the next 100 years. Erosion of the cliffs provides a small local supply from embedded flint, and this is likely to be sufficient to balance any loss through storm action.

3. There is likely to be a net gain on the east beach and a net loss to the west beach over time, unless artificial circulation is maintained. It was felt that this process was inevitable, and would cause minimal impact to the flood risk and the local habitat.

4. The main aspect of management option choice that will impact on the beach is whether the flows in and out of the river mouth increases or not. Figure 1 of this report shows how much the flows will vary depending on whether additional areas of the estuary are inundated or not. Where additional areas are allowed to flood during normal high tides, the increased velocity through the river mouth will ensure the mouth is naturally scoured, and will most likely widen and will remain clear of shingle. This is important to avoid any increase in flood risk upstream around Alfriston (as shown through previous studies). If the river embankments are maintained in their current form, it is probable that continued dredging of the river mouth will be required.

5. Whilst the river mouth may become more mobile, it was not possible to say where it would end up, although it was possible that it would simply reach equilibrium somewhere roughly in the middle.

6. It was thought that in the absence of training walls, the river mouth would widen and either side of the beach would pivot slightly, maintaining the current position at the cliff base, but moving landward slightly at the river mouth.

2.3 Summary of findings

The result of the hydraulic modelling has been used to determine the likely morphology, habitat and landscape in the estuary over time, under the different options. A summary of the key outcomes for each option is provided in Table 2.4 below.

Table 2.4 – Summary of key outcomes for each option

Option	Key outcomes
Baseline (Do nothing)	Under the 'do nothing' option, the current embankments will fail in an unpredictable way, initially allowing inundation to occur during a flood event, but will quickly allow regular inundation of the floodplain on a regular basis under high tides. This is particularly true for the low lying western bank, which is currently below the neap tide level. Water will initially be trapped behind the defences, potentially forming large areas of standing water to the west of the river. These lagoons and ponds will be relatively short lived, as the defence embankments continue to erode and drainage onto and off the floodplain becomes unhindered, and the floodplain starts to become part of an active intertidal zone with the associated development of saltmarsh and mudflat. The timing and progression of this change is very difficult to predict, and will depend on where and when the initial embankment failures occur. In the long term however, the system is likely to revert back to a relatively natural intertidal habitat with extensive areas of saltmarsh and mudflat. The current meanders are likely to be lost, as they eventually fill up in parts, whilst probably becoming integrated into the network of tidal creeks. The location of the cut and main river channel is likely to remain largely the same, although it will widen and may become more mobile as time goes by. The eventual increase in tidal prism (volume of water flowing into the estuary at high tide) is likely to keep the river mouth clear of shingle.
Option A	Under option A, i.e. partial breach managed realignment, the areas where breaches have been made will behave in a more predictable way, with breaches designed to allow relatively free flow of sea water across the floodplain, with sufficient constraint on drainage to encourage sediment deposition and the development of tidal creeks, mudflats and eventually saltmarsh. Where the defences are retained, it has been assumed that they will be maintained into the future, and raised accordingly to keep pace with climate change. The areas protected by defences to the east of the river will remain largely as they are today. The increase in tidal prism (volume of water flowing into the estuary at high tide) caused by the larger area of inundation is likely to help keep the river mouth clear of shingle.
Option B	Under option B, i.e. full breach managed realignment, the transition from a fully defended floodplain to an integrated intertidal zone will take place in a relatively predictable manner, although there is no way to fully control the pattern of tidal creeks, mudflats and saltmarsh that will form. The increase in tidal prism (volume of water flowing into the estuary at high tide) caused by the larger area of inundation is likely to help keep the river mouth clear of shingle.
Option C	Under option C, i.e. engineered reactivation of meanders & meandering creeks, the gradual inundation across large areas of existing floodplain will commence immediately. The engineered development and opening of historic creeks across the floodplain will very rapidly convert the grassland into a fully dynamic intertidal zone across large parts of the of the valley floor and encourage growth of saltmarsh and mudflats. Removal of all embankments, filling in of the cut and opening up the meanders will ensure a naturally functioning system develops quickly. The meanders will almost certainly move as the meandering process is reinstated, and the tight bend in the river just downstream of Exceat Bridge will need considerable engineering works and ongoing maintenance to ensure it remains in that location. It is considered likely that sufficient sedimentation will take place over time at a rate which keeps pace with sea level rise, and salt mash will develop widely. Access along the centre of the valley will be lost, and the only access will be along the

	existing footpaths around the edge of the valley floor. These are currently sufficiently high to allow access in all but the highest flood tides, and would be raised in the future as part of this option.
Option D	Under option D, i.e. maintain the existing defences, the impact of sea level rise will result in more frequent overtopping by sea water. This will not be sufficiently frequent to allow an intertidal habitat to form, but may create lagoons and ponds of saline and brackish water where drainage is poor. This will result in the loss of the existing grazing grassland in some areas, replaced by more wetland habitats. The existing paths and access routes will remain, although public footpaths running along embankments may be surrounded on either side by water and could be overtopped by high tides.
Option E	Under option E, i.e. maintaining and raising the existing defences to keep pace with climate change (by at least 600mm). This maintains the estuary in its current form, and assuming the same land use continues into the future, the landscape will remain largely unchanged. It is probable that dredging of the river mouth will be required throughout the period to prevent excessive build up of shingle which would increase flood risk upstream at Alfriston.
Option F	Under option F, i.e. maintaining and raising the existing defences by 300mm – keeping pace with climate change up till 2060, the valley downstream of Exceat Bridge will remain largely unchanged, probably well beyond 2060. Beyond that time, it is likely that the estuary will begin to behave in a similar manner to the 'do nothing' option, although by that time, the river levels will be significantly higher relative to the floodplain, which will have remained largely unchanged – resulting in much deeper inundation when it does happen, and a significantly reduced likelihood of developing natural intertidal habitats, particularly to the west of the river where ground levels are lower. It is likely that these areas will remain inundated with water trapped behind the raised defences for a considerable period, resulting in extensive saline lagoons and ponds, with a reduced rate of mud flat development and saltmarsh growth. It is probable that dredging of the river mouth will be required until at least 2060, at which time, the more frequent inundation of the floodplain will increase the tidal prism within the estuary and the river mouth may start to become self clearing.

2.4 Conclusions

Although it is impossible to say exactly how the valley below Exceat Bridge will change as a result of these options, much of the prediction relating to the general features is reasonably certain. Where regular inundation occurs, it is likely that saltmarsh or mudflats will form. Where the river becomes part of an integrated intertidal habitat, the landscape is likely not only to change from grassland to saltmarsh, but will become an ever changing landscape varying constantly throughout the day as the tides rise and fall, from a wide expanse of open water during peak tides, to a wide expanse of mud, saltmarsh and tidal creeks at the lowest tide. Where defences are maintained and raised in the future, the landscape is likely to remain largely unchanged.

None of the management options proposed are predicted to increase flooding upstream of the Exceat Bridge, although the frequency and severity of flooding is predicted to increase with time as a result of climate change, regardless of the option selected. For options where there will be an increase in the extent of inundation and the river mouth is kept clear as a result, the flood risk upstream at Alfriston will actually be reduced. The impact of flooding within the estuary itself is small, as the existing assets will be impacted only occasionally by a severe flood event. These should be sufficiently resilient to suffer minimal damage.

The future outcome within the estuary is largely dependant on the continued existence of the beach, which currently protects the estuary from wave action, allowing mudflats and saltmarsh to form. If the beach is lost from its current position, the existing valley floor will erode and the intertidal zone will move back up the estuary. However, a study carried out by a panel of coastal geomorphological experts has concluded that although the cliffs will move landward through erosion., the rate of erosion is relatively slow and is unlikely to recede more than 50m over the next hundred years. The beach itself is inherently mobile, however; it is described as a ‘pocket’ beach, which means it is trapped between two headlands or outcrops – i.e. the cliffs either side, and although there is little new material being added, there is thought to be very little being lost to the system. With no further intervention, the majority of the material of the west beach is likely to migrate eastwards to the east beach, and what is left would pivot round to face a more south westerly direction. The east beach would act in a similar way, pivoting on the eastern end and moving landward no more than a few hundred metres. The beach would lengthen as it moves inland, and would consequently lower in height. This would result in an increased possibility of overtopping during a storm, which would have little impact for the realignment options A, B and C, but would be potentially more serious for options D, E and F, where the areas behind the beach are normally protected from flooding.