MOTT MACDONALD

Environment Agency

# Medway Estuary and Swale Coastal Flood and Erosion Risk Strategy

## Technical Appendix C - Damage Assessment Report

May 2018

Environment Agency

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Environment Agency

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# Contents

# 1 Introduction

The Environment Agency has appointed Mott MacDonald (MM) to develop the Medway Estuary and Swale Coastal Flood and Erosion Strategy (hereafter known as MEASS), with the aim of providing a Flood and Coastal Risk Management (FCRM) Strategy for the Tidal Medway Estuary, the Swale Estuary, and the Isle of Sheppey. The aim of MEASS is to assess how to best manage the coastline to protect people, properties, designated habitats, and agricultural land from coastal flood and erosion risk. As with all flood and coastal risk management work, the wider impacts must be considered. This means that the best technical solutions for defences need to be found, while also considering the impacts and benefits for local communities, the environment, and the cost to the tax payer.

## 1.1 Why the Strategy is being developed

There are currently coastal flooding and erosion risks to the communities and landowners around the Medway Estuary and Swale. Aging flood defences, rising sea levels and climate change mean that coastal flood and erosion risk to people, properties, habitats, and agricultural land will significantly increase in the coming years. Over the next 100 years it is predicted that 17,226 properties will be at an increased risk of tidal flooding (up to a 0.1%AEP event) within the MEASS area.

Currently most of the Strategy frontage is defended, especially around the Isle of Sheppey to protect the important port at Sheerness, and along the tidal River Medway to protect the Medway Towns. A significant proportion of the defences in the area are nearing the end of their design lives and the risk of failure during a storm event is high. However, it is not sustainable in the long term to continue to maintain all of the defences in their current position. Therefore, MEASS will assess how this risk can be best managed, in line with government guidance, to deliver the most sustainable FCRM management approach.

The strategy area has large extents of both intertidal and freshwater habitats which are both nationally and internationally designated. Intertidal habitat is at risk as sea levels rise, ‘squeezing’ it against the existing defences. Freshwater habitat is at risk from the failure of the defences, resulting in the inundation of saltwater, as well as increased overtopping which could be associated with sea level rise. Also, MEASS is legally obliged to assess how the adverse impacts to these designated habitats can be mitigated by realigning defences or creating compensatory habitat in other locations.

## 1.2 Strategy Area

The Strategy area includes the Isle of Sheppey, the tidal extents of the Medway Estuary and the Swale estuary. The boundaries of the strategy area are:

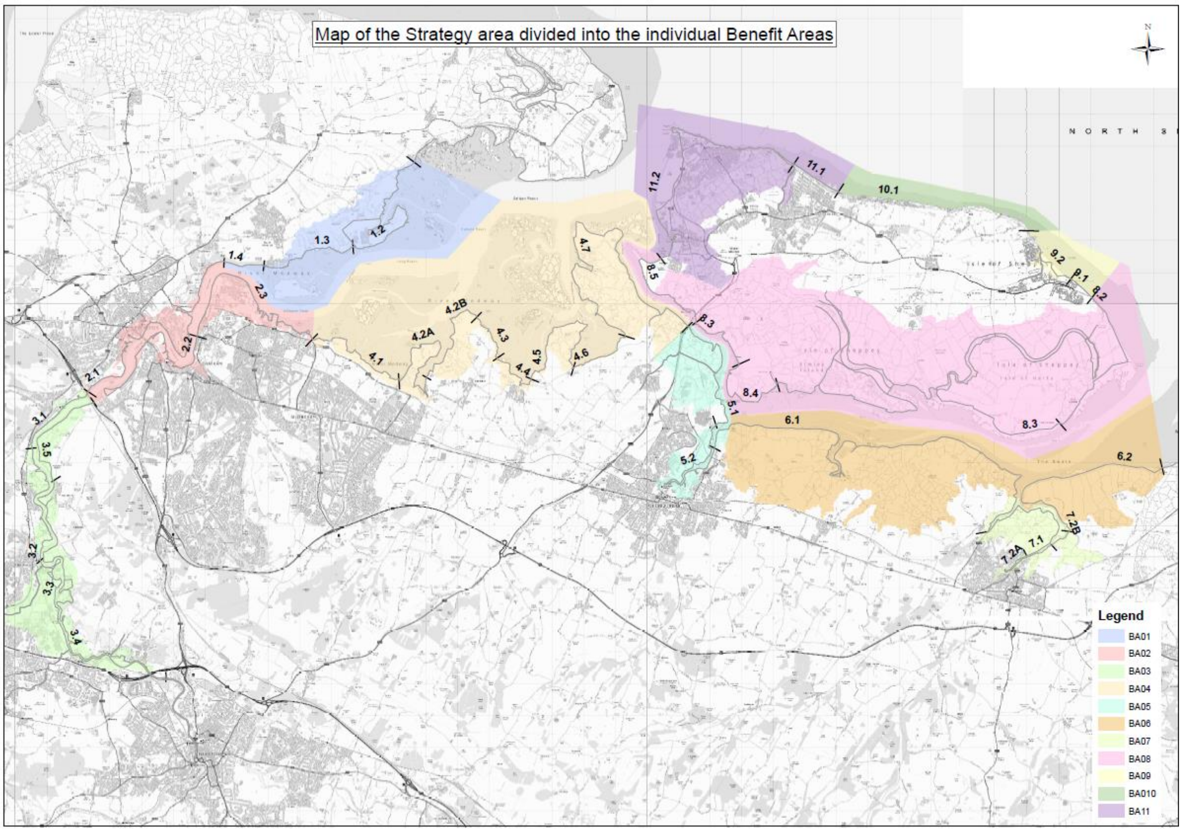
- Allington Sluice as the upstream tidal limit of the Medway;
- the village of Stoke on the Hoo Peninsula; and
- the Sportsman Public House on Cleve Marshes near Faversham.

MEASS encompasses the large urban areas of the Medway Towns including Rochester, Strood, Chatham and Gillingham; major industrial and commercial areas along the estuaries; and large swathes of rural farmland and extensive salt marsh and mudflats. Many of the rural areas are highly designated and protected for their heritage, landscape, and environmental value.

### 1.2.1 Benefit Areas

As the Strategy frontage is approximately 120km in length, and there are complex interactions between the different land uses, the MEASS area has been broken down into a series of Benefit Areas (BAs) based on the extent of discrete flood cells. These BAs have been broken down further into 35 sub-Benefit Areas based on the SMP Policy Units (Figure 1).

**Figure 1: The division of the frontage into 11 BAs and 35 sub BAs based on discrete flood cells (determined from modelling) and land use. Please note that BA1.1 is now included in the Thames Estuary 2100 Strategy. BA8.1 and 8.2 were merged to form BA8.2 to reflect the interconnectivity between these areas.**




Source: Mott MacDonald, 2017. Contains Ordnance Survey Data © Crown copyright and database right 2015

## 1.3 Aims of the strategy

MEASS will assess and consider a variety of economic, environmental, and technical approaches to manage the coastal flood and erosion risk, in order to balance the wide range of features and interests within the area.

The vision statement of MEASS is to "*work with the community to plan how we will sustainably reduce flood risk to 17,226 homes at risk in the Medway Estuary, Swale and Sheppey over the next 100 years (under a 0.1%AEP event), whilst also protecting and enhancing the local environment*."

Building on from this vision statement a series of primary and secondary objectives for MEASS have been developed (Table 1) to drive the delivery of an effective FCRM strategy which supports as many local plans and aspirations as possible.

**Table 1: MEASS Primary and Secondary Objectives**

| Primary Objectives | | Secondary Objectives | |
|---|---|---|---|
| 1) | Reduce flood and erosion risk to properties and infrastructure at significant or very significant risk in light of coastal change over the next 100 years. | 3) | Favour options that reduce the whole life costs of current defences. |
| 2) | Maintain the integrity of Natura 2000 sites (protected under the Habitats and Birds Directives) assuming the loss due to coastal squeeze of 113ha of saltmarsh habitat between years 0-20 and a further 140ha of saltmarsh habitat between years 20-50. | 4) | Favour options that support delivery of the Thames River Basin Management Plan. |
| | | 5) | Help enable local plan objectives to be realised where possible. |

## 1.4 Aims of this Report

This Report forms an appendix to MEASS and aims to explain the method followed to assess the damages for the Do Nothing scenario and each of the short listed options.

# 2 Economic Approach

The MEASS economic assessment is based on the latest Flood and Coastal Risk Management Appraisal Guidance [FCERM-AG], (EA, 2010), which provides guidance on the methodology to undertake effective economic appraisals. The guidance outlines how to consider economic benefits and losses that arise from particular options.

The economic assessment also uses the spreadsheet template provided by the Environment Agency (accessed 2015) which is the basis on which the Environment Agency will assess the viability of coastal defence schemes and grant funding. The economic assessment includes information from the HM Treasury Green Book (2011) and Multi-Coloured Manual (Middlesex University, 2010). It should be noted that the economic assessment was undertaken in line with current DEFRA and treasury guidance (FCERM-AG, 2010) and is appropriate as any future government funding for schemes will be assessed against these criteria.

This Report outlines the methods that have been undertaken to calculate the damages and benefits (damages avoided) associated with each of the short list options. This Report should be read in conjunction with Appendix D and G which describe the method to cost the short listed options and summarise the results of the economic assessment.

## 2.1 Discounting

The benefits of the options can be expressed in terms of their cash value in pounds sterling but also in terms of their Present Value (PV). The PV of the future pound is assumed to fall away through time. To include this in the economic assessment the discount factor provided in the HM Treasury Green Book (2011) is applied. The long-term discount rates are included in the assessment of the benefits to allow the uncertainty of the future to be included. This uncertainty is shown to cause a decline in discount rates over time. HM Treasury Green Book recommends that for economic assessments for longer than 30 years discounting of the costs needs to be applied. The following discount rates should be used:

- 3.5% (0 to 30 years);
- 3% (30 to 75 years); and
- 2.5% (75 to 100 years).

## 2.2 Assessment Scenarios

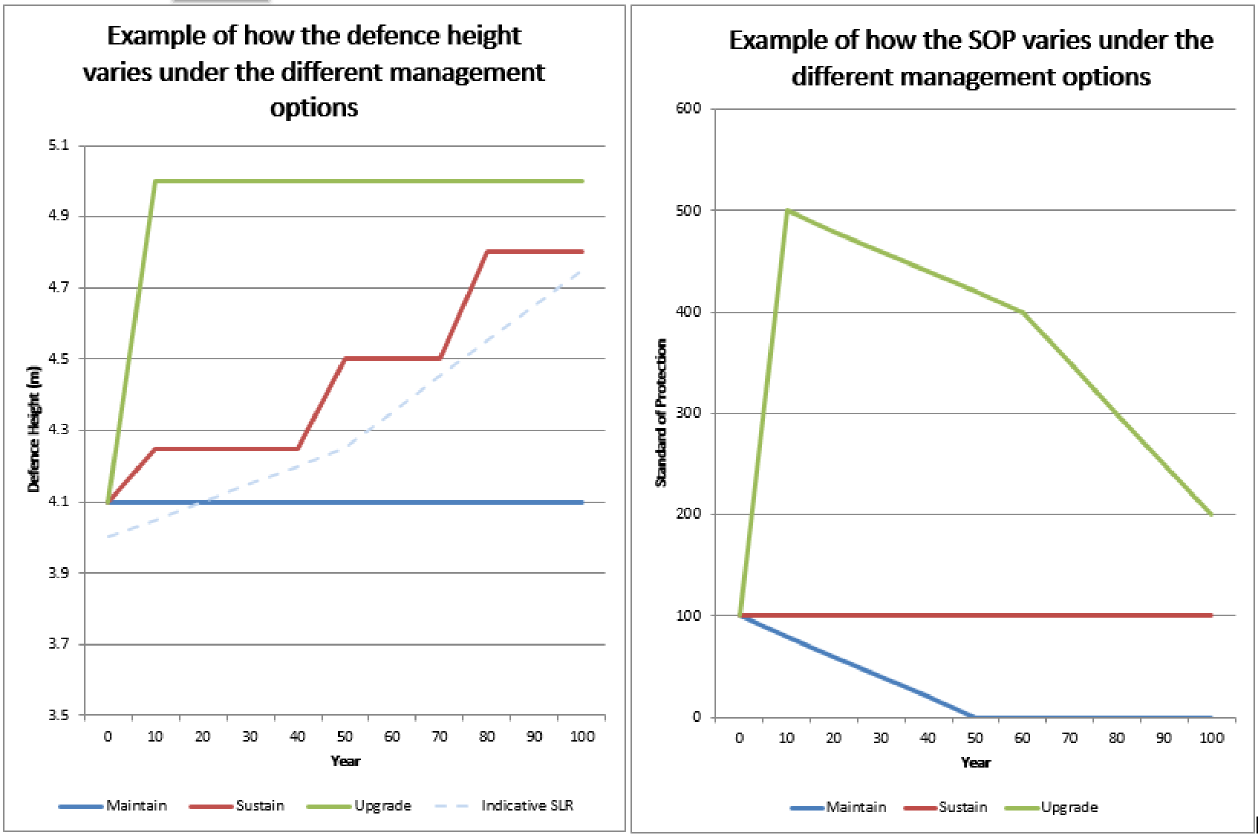
Five assessment scenarios were considered within this economic assessment. These are described in Table 2 and annotated in Figure 2.

**Table 2: Generic Options in Strategy**

| Option | Description |
|---|---|
| Do Nothing | The Do Nothing option is the baseline against which all other options to ‘Do Something’ are assessed. Adopting a Do Nothing approach would mean the cessation of all maintenance and capital works |
| Do Minimum/ Ongoing Maintenance (Patch and repair) | This option considers ongoing maintenance of the existing structures. Capital works are not considered within this option and therefore the condition of the structure will deteriorate over time. |
| Do Minimum/ Maintain (Capital) | This option considers ongoing maintenance of the existing structures until they reach the end of their residual lives. At this point the structure will be replaced with the exact same structure, therefore the crest level of the structure remains the same. Maintenance of the structure is then required throughout the appraisal period. Due to sea level rise, with this option the Standard of Protection (SOP) will reduce over time. |

| Option | Description |
|---|---|
| Sustain | This option considers immediate capital works to increase the SoP of the structure to a defined level by increasing the crest level of the structure. In year 50 further capital works are required to maintain this SOP with sea level rise. Maintenance of the structure is required throughout the appraisal period. |
| Upgrade | This option is similar to the sustain option, however all capital works occur immediately, i.e. the structure is increased to the largest SoP immediately. Dependent on the design life of the structure, future capital works may also be required. Maintenance of the structure is required throughout the appraisal period. |
| Managed Realignment with HTL maintain/ sustain/ upgrade of the residual defences | Maintain/Sustain/Upgrade defines the capital and maintenance works along the frontage as described above with the exception of the defences within the Managed Realignment (MR) site. For the MR site, capital works include a setback embankment providing the same SoP as the defences not within the MR site, and a breach. The setback embankment is maintained throughout the appraisal period. The existing defences within the MR site are no longer maintained. |

**Figure 2: Annotation of the HTL approaches used in the Strategy**




Source: Mott MacDonald

# 3 Assessment of Flooding and Coastal Retreat

## 3.1 Assessment of flooding

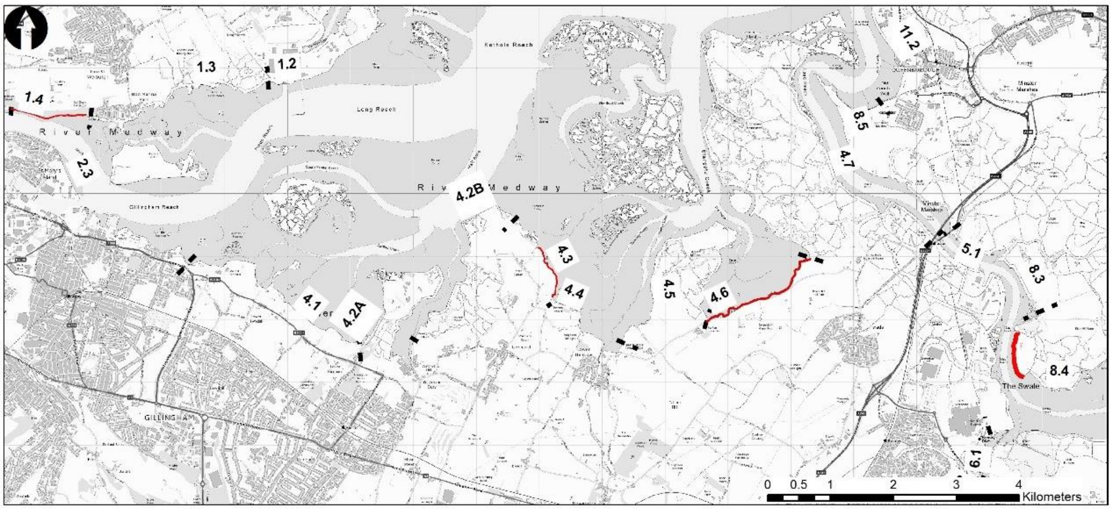
Numerical flood modelling was undertaken to predict flood extents within the Strategy area. Flood inundation models, built using MIKE 21 HD/MT software, were used to predict flood extents resulting from overflow of the coastal defences. The model has been run for 6 different return period extreme events (50%, 5%, 2%, 1%, 0.5% and 0.1% Annual Exceedance Probability (AEP)) within two epochs (present day and with 100 years sea level rise). The results of these runs are used to make up the scenarios for 'Do Nothing' and 'Do Something' options with climate change. The results of the modelling have been discussed within the Medway and Swale Strategy Modelling Report (Mott MacDonald, 2017), Technical Appendix I.

The flood extents and depths from the model were used to determine the flood risks to residential and commercial properties, and infrastructure. The results of this are explained further in Chapter 4.

## 3.2 Assessment of coastal retreat

Following a review of the Medway Estuary and Swale SMP (Halcrow Group, 2010) and the North Sheppey Erosion Study (Canterbury City Council, 2010) the areas at risk of erosion were determined. The areas at risk include a section of exposed cliffs north of the Isle of Sheppey (BA10.1 and BA9.2), as well as four smaller areas within the sheltered Medway and Swale estuaries (BA1.4, BA4.3, BA4.6 and BA8.4) (Figure 3).

**Figure 3: Sites at risk of erosion in the Medway and Swale Estuaries (in addition to the exposed cliffs on the north side of the Isle of Sheppey)**




Source: Mott MacDonald

To determine the risk of erosion over the next 100 years, the areas considered at risk of erosion have been assessed under a 'Do Nothing' scenario i.e. assuming that no maintenance takes place. This allows the potential change to the coastline from the current and future coastal processes to be understood, but also provides an economic baseline to compare the Do Something option against.

The robustness and accuracy of 'Do Nothing' scenarios are influenced by many factors, which include, but are not limited to;

- The availability of historical trend analysis (data assessment from different time periods to determine rates of change) for the specific frontages under consideration;
- The accuracy of condition survey results for existing structures;
- Knowledge of the geology behind the defences and how these may react to ongoing failure and erosion in the future;
- Records of the location and value of assets that would be impacted by erosion over time;
- Future events and conditions that are the forcing mechanisms for coastal erosion i.e. water levels, climate change, storm events, subaerial processes etc.

This assessment has assumed that in areas with coastal protection, the defences will fail at a time dependent upon their residual life. Once the defences have failed, erosion of the coast can occur unimpeded. The residual life for defences in areas around the Medway and Swale was used. The residual life of the defences in BA11 and BA09 is not available and therefore the worst case scenario of a 0 year residual life is assumed. Coastal erosion has been projected into the future based on recession scenarios of the coastline within a GIS system.

Specific rates for shoreline erosion have been identified using the Historical Trend Analysis Rule (HTAR). The HTAR is a model relating the rate of shoreline retreat to the rate of sea level rise (NRC, 1997; Leatherman, 1988; 1989 cited in Bray et al, 1992).

Future shoreline retreat rates have been estimated using the HTAR equation below:

$$\mathbf{R_2=(R_1/S_1).\ S_2}$$

Where:

$S_1$= historical sea-level rise rate (m/yr.)
$S_2$= future sea level rise rate (m/yr.)
$R_1$= historical retreat rate (m/yr.)
$R_2$= future retreat rate (m/yr.)

The HTAR is a commonly used approach for the assessment of shoreline retreat over defined periods. This approach however is relatively simplistic as the HTAR assumes that sea level rise is the dominant cause of coastal recession and other factors, such as the wave climate remain constant. In reality, it is likely that wave heights and potential wave energies will increase with climate change, which is a valid assumption to make during periods of rapid relative sea level rise (Bray et al., 1992). Therefore, the recession estimates could be under predicting the overall extent of change in the longer term.

### 3.2.1 HTAR Calculation Inputs

#### 3.2.1.1 Historic Sea Level Rise ($S_1$)

The rate of historic sea level rise ($S_1$) has been taken to be 2mm/yr. based on the regression of annual mean sea level measured at Sheerness from the Permanent Service for Mean Sea Level (PSMSL) (closest station). The data used in the regression analysis is from 1892-2006. This is the best available data set and corresponds to the time period over which the historic erosion rate is assessed. This rate is similar to Haigh et al's (2009) estimates from a regression analysis at Sheerness.

#### 3.2.1.2 Future Sea Level Rise ($S_2$)

Future sea level rise rates ($S_2$) are based on the UKCP09 data (95$^{th}$ percentile medium scenario) outputs as recommended in the Environment Agency guidance (EA, 2011). The annual sea level rise at Sheerness is used between 2015 and 2100. As UKCP09 data does not cover years beyond 2100, the last 15 years were extrapolated to predict values between 2101 and 2115. Projected sea level rise at Sheerness over the next 100 years is summarised in Table 3.

**Table 3: Projected sea level rise at Sheerness over the next 100 years (medium emission scenario 95%ile)**

| Year | Cumulative sea level rise (medium scenarios) (m) |
|---|---|
| Current Day i.e. 2018 | 0.00 |
| 2018-2033 | 0.09 |
| 2018-2068 | 0.33 |
| 2018-2093 | 0.53 |
| 2018-2118 | 0.75 |

Source: UKCP09 User Interface

#### 3.2.1.3 Historic Retreat Rate ($R_1$)

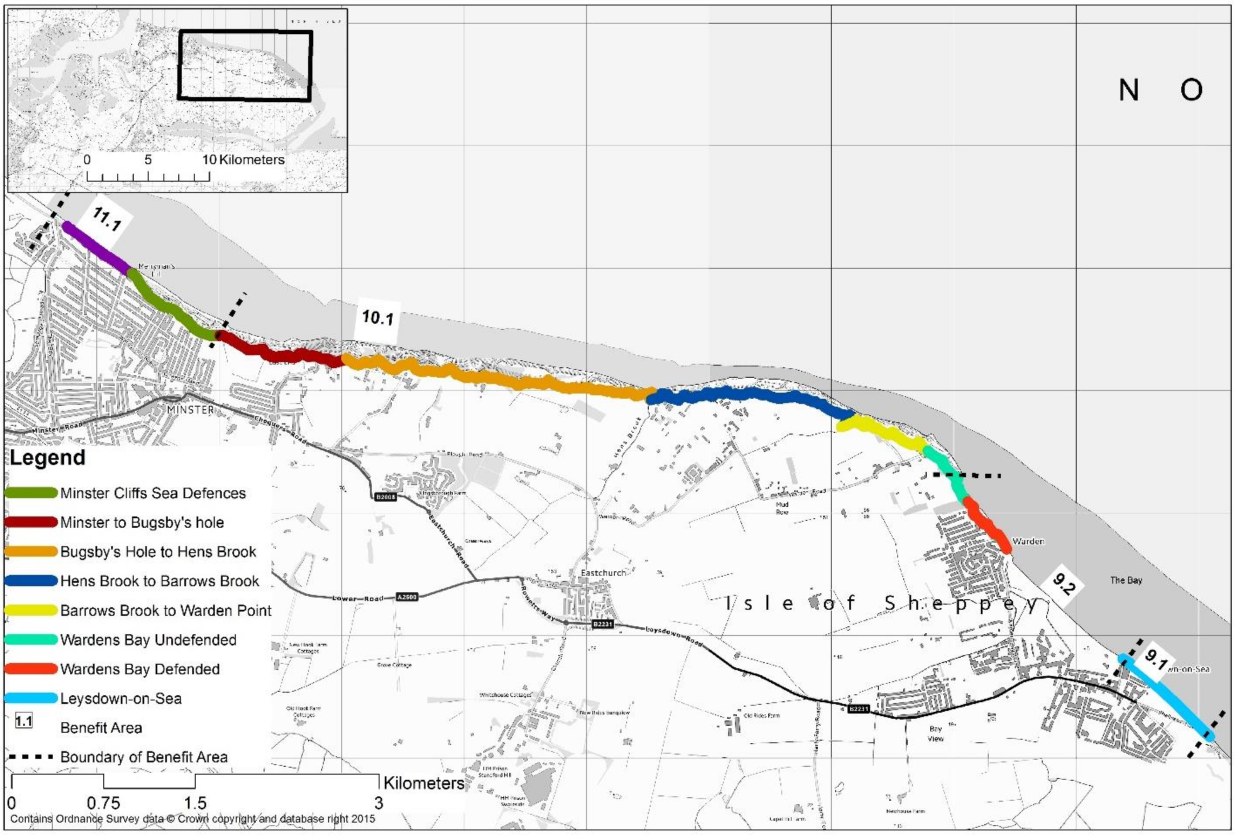
**North coast of the Isle of Sheppey (BA09-BA11)**

Historic retreat rates ($R_1$) which have been used to calculate the future retreat rates ($R_2$) for areas in BA09, BA10 and BA11 have been adopted from the North Sheppey Erosion Study (Canterbury City Council, 2010).

The areas in BA09 to BA11 have been divided into 7 sections based on varying historic erosion rates estimated by Canterbury City Council (2010). This division of the frontage into discrete erosion units, gives a more accurate estimate than assessing the frontage as a whole. Erosion rates are taken from the Canterbury City Council Report (2010), which are calculated from historic maps between 1869 and 2010. The Report noted that the years the erosion rates were determined differ as sections at the Leas and Minster Cliffs have been defended since the early 1980's (Canterbury City Council, 2010).

These sections are annotated in Figure 4: Cliff erosion sections extracted from the descriptions in the Canterbury City Council Report (2010) for BA09, BA10 & BA11. and the results from the Canterbury City Council report (2010) are presented in Table 4.

**Figure 4: Cliff erosion sections extracted from the descriptions in the Canterbury City Council Report (2010) for BA09, BA10 & BA11.**




Source: Mott MacDonald

**Table 4: Summary of the geology and historic cliff erosion rate for each section in BA09, BA10 and BA11.**

| BA | Location | Description | Minimum residual life of defences (years) | Historic cliff top erosion (m/yr.) | Years rates were determined |
|---|---|---|---|---|---|
| 11.1 | The Leas | Protected by sea wall, promenade, groynes, and cliff regrading. | No data on the residual life in this area. Assumed 0 as a worse case. | 0.11 | 1896-1981 (up until construction of sea wall) |
| 11.1 | Minster Cliffs Sea Defences | Protected by regraded and drained cliffs, as well as sea defences. | No data on the residual life in this area. Assumed 0 as a worse case. | 0.66 | 1896-1969 (data not available between 1969-1981) |
| 10.1 | Minster to Bugsby's Hole | No coastal defences. Sandy gravelly clay overlying sandy clay. | 0 – undefended section. | 0.59 | 1869-2010 |
| 10.1 | Bugsby's Hole to Hens Brook | No coastal defences. Brick earth capping London Clay. | 0 – undefended section. | 0.66 | 1869-2010 |

| BA | Location | Description | Minimum residual life of defences (years) | Historic cliff top erosion (m/yr.) | Years rates were determined |
|---|---|---|---|---|---|
| 10.1 | Hens Brook to Barrows Brook | No coastal defences. London Clay. | 0 – undefended section. | 0.77 | 1869-2010 |
| 10.1 | Barrows Brook to Warden Point | No coastal defences. Mostly London Clay. | 0 – undefended section. | 1.42 | 1869-2010 |
| 10.1 & 9.2 | Warden Bay Unprotected | No coastal defences. Entirely London Clay. | 0 – undefended section. | 0.83 | 1869-2010 |
| 9.2 | Warden Bay Protected | Protected by rock armour revetment. Residual life between 2 and 40 years in Benefit unit 9.2. | 40 year estimated for entire frontage protecting houses N.B. This Residual life refers only to the section of frontage at risk of erosion. | 0.83 | 1869-2010 |
| 9.1 | Leysdown-on-Sea | Protected by seawall and groynes. | No data on the residual life in this area. Assumed 0 as a worse case. | 0.83* | 1869-2010 |
| * The historic rate from Warden Bay used as no site specific data | | | | | |

Source: Canterbury City Council Engineering Services, 2010

### Medway and Swale Estuaries

Erosion in the estuaries has been considered separately to the north coast of the Isle of Sheppey as the inner estuary areas are more protected and the amount of wave action is significantly reduced. However, as the area is more sheltered, historically there has been more land reclamation for farming and therefore the majority of the frontage has been defended in some areas from as early as the 12$^{th}$ Century (Halcrow Group, 2010). Therefore, it is difficult to predict historic retreat from historic maps and photos, as the coastline has remained defended in all historic sources.

The Medway and Swale SMP (Halcrow Group, 2010) identifies several erosion areas in the Medway and Swale as either areas on highlands, narrow floodplains or outside of meanders (Halcrow Group, 2010). The Project Team have reviewed the SMP and noted that the key areas of erosion are at Cockham Wood (BA01), Ham Green (BA04), Bedlam Bottoms (BA04) and Elmley Hills (BA08). The Project Team used the National Library of Scotland (2015) interactive maps online resource, which had a collection of historic maps dating back to 1888 to determine the rates of historic retreat. The distances between the cliff line on historic maps and the most recent Ordnance Survey (OS) map were measured at approximately 20-50m intervals, and the average of this was taken to calculate retreat rates (Figure 5: Example of historic retreat analysis at Elmley Hills comparing 1888-1913 OS map with recent 2015 OS map). The SMP also noted that areas along the River Medway on the outside of the meanders are likely to be at risk of erosion. However, they have not been included in this assessment because they have been defended prior to 1888, so the behaviour of the meanders without defences is unknown. Furthermore, it is considered that the risk of flooding in these areas is greater than the erosion risk.

**Figure 5: Example of historic retreat analysis at Elmley Hills comparing 1888-1913 OS map with recent 2015 OS map**


Source: National Library of Scotland (2015)

**Table 5: Summary of the geology and historic cliff erosion rate for each section in BA01, BA04 and BA08.**

| BA | Location | Description | Minimum Residual Life of defences (years) | Historic cliff top erosion (m/yr.) | Years rates were determined |
|---|---|---|---|---|---|
| 1.4 | Cockham Wood | • No coastal defences in front of natural cliff.<br>• Natural shingle beach with clay geology. | 0 (AIMS has a residual life of 22 but this refers to the natural cliff therefore no structural measures in place. Small section of seawall to the west not included). | 0.07 | 1888-2015 |
| 4.3 | Ham Green | • Protected by embankment with rock revetments.<br>• Clay geology. | 9 | 0.07* | 1888-2015 |
| 4.6 | Bedlam Bottoms | • Natural coastal defences present to protect against coastal flooding.<br>• Alluvium geology. | 0 (AIMS has a residual life of 24 but this refers to the natural cliff therefore no structural measures in place). | 0.1 | 1869-2010 |

| BA | Location | Description | Minimum Residual Life of defences (years) | Historic cliff top erosion (m/yr.) | Years rates were determined |
|---|---|---|---|---|---|
| 8.4 | Elmley Hills | • Protected by earth embankments and embankments with rock revetment, old counter wall. • Clay geology. | 8 | 0.2 | 1888-1947 |
| *Cockham Wood historic erosion rate was used because the sections have the same geology. | | | | | |

Source: Geology from the Medway and Swale SMP (Halcrow Group, 2010). Assessment of historic rate of retreat calculated by Mott MacDonald using maps accessed online (National Library of Scotland, 2015)

## 3.3 Calculation outputs and conclusions

### 3.3.1 North coast of the Isle of Sheppey

Table 6 shows a summary of the cumulative shoreline retreat for North Sheppey Cliff under a 'Do Nothing' scenario. All areas apart from the Leas have a high annual erosion rate, with the fastest rate of erosion occurring between Barrows Brook and Warden Point; with a total of 496m of projected retreat over the next 100 years. A map of the projected shoreline retreat over the next 100 years is shown in Appendix A.

**Table 6: Summary of the cumulative shoreline retreat for the North Sheppey Cliff under a 'Do Nothing' scenario.**

| Year | Projected future cumulative retreat (m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Leysdown-on-Sea (BA8.2 & 9.1) | Warden Bay Defended (BA9.2) | Warden Bay Undefended (BA10.1 & 9.2) | Barrows Brook to Warden Point (BA 10.1) | Hen Brook to Barrows Brook (BA 10.1) | Bugsby Hole to Hen Brook (BA 10.1) | Minster to Bugsby Hole (BA10.1) | Minster Cliffs sea defence (BA 11.1) | The Leas (BA 11.1) |
| 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2065 | 125 | 28 | 125 | 214 | 116 | 100 | 89 | 100 | 17 |
| 2115 | 290 | 193 | 290 | 496 | 269 | 231 | 206 | 231 | 38 |

Source: Mott MacDonald, 2016

### 3.3.2 Medway and Swale Estuaries

Table 7 shows a summary of the future projected erosion rates ($R_2$) and cumulative projected shoreline retreat for areas in the Medway and Swale estuaries. The erosion rates are all relatively slow in comparison to the exposed cliffs on the Isle of Sheppey, with the largest retreat being the alluvium area at Bedlam Bottoms with 35m of projected retreat over the next 100 years. Maps of the shoreline retreat over the next 100 years also given in Appendix A. These maps take into account the residual life of the existing defences over the 100-year lifetime of the Strategy.

**Table 7: Summary of the cumulative shoreline retreat for the areas around the Medway and Swale Estuaries under a 'Do Nothing' scenario.**

| | Projected future cumulative retreat (m) | | | |
|---|---|---|---|---|
| Year | Cockham Wood (BA01) | Ham Green (BA04) | Bedlam Bottoms (BA04) | Elmley Hills (BA08) |
| 2015 | 0 | 0 | 0 | 0 |
| 2065 | 11 | 9 | 15 | 26 |
| 2115 | 24 | 23 | 35 | 66 |

Source: Mott MacDonald, 2016

# 4 Assessment of Damages and Benefits

Benefits are calculated as flood or erosion damages avoided. Following the Multi-Coloured Manual (MCM) guidance (Middlesex University, 2016) different approaches are used for valuing benefits at risk from flooding and erosion. Property flooding damages are valued as Annual Average Damages (AADs) and are calculated based on a combination of the damages from different return periods, whereas erosion damages are valued as properties lost due to erosion.

## 4.1 Flood Damages

### 4.1.1 Property Flood Damages

Annual Average Damages (AADs) have been calculated for the flooding of commercial and residential properties for 6 different return period events (50%, 5%, 2%, 1%, 0.5%, and 0.1% AEP) within 2 epochs (present day and with 100 years sea level rise) for each BA (i.e. BA1.1, 1.2, 1.3 and 1.4). The range of return periods assessed gives greater confidence in the calculations of the AAD curve and the overall economic assessment undertaken.

The Do Nothing scenario is calculated as an economic baseline to compare the Do Something options against. Under a Do Nothing scenario the AADs are calculated based on the defended scenario up until the year of the median residual life of the defences, after which the AADs are calculated based on the undefended scenario.

In order to determine the AADs the National Receptor Database (NRD) (Address Point database provided by the EA, (2014)) was used to calculate the number of properties within the flood extents output from the hydrodynamic model. The AADs have been calculated following the FCRM-AG (EA, 2010) and MCM (Penning-Rowsell *et al.* 2016) guidance. Data tables from the MCM (Penning-Rowsell *et al.* 2016) have been used to determine flood damage values. Key assumptions include:

- The AAD values for the properties have been capped at the value of the property (method for valuing the properties is described in further details in Section 4.1.1.2 and 4.1.1.3).
- Flood depths for each property have been calculated using the elevations taken from the DTM LIDAR data (*accessed* 2015).
- Doorstep levels have been assumed to be 0.2m for all properties.
- Properties at risk of less than a 1 in 3 year return period are "written off" at their capital value.
- The floor areas of the properties (not available in the NRD database) were assumed to have the area of the shape from the OS MasterMap in the same position of the property.

Damages have been calculated using guidance from the MCM (2016) and FCERM-AG (2010) over a 100 year period, with benefits discounted in accordance with the HM Treasury Green Book.

#### 4.1.1.1 Total number of properties at risk from flooding per BA

The number of properties considered at risk from flooding under the Do Nothing Scenario was calculated by comparing flood depths and extents developed in the hydrodynamic modelling, and address property data from the NRD.

Table 8 summarises the total properties considered to be at risk from flooding at present day sea levels under a Do Nothing Scenario across the whole Strategy area under the 6 return periods.

Table 9 summarises the total properties in the strategy considered to be at risk from flooding when sea level rise is taken into account under a Do Nothing Scenario based on100 years of sea level rise under the 6 return periods.

**Table 8: Number of residential and commercial properties at risk across the whole Strategy area, from flooding under a Do Nothing Scenario**

| Return Period | Residential Properties | Commercial Properties | Total |
|---|---|---|---|
| 1 in 2 year | 5,528 | 988 | 6,516 |
| 1 in 20 year | 6,319 | 1,247 | 7,566 |
| 1 in 50 year | 7,101 | 1,449 | 8,550 |
| 1 in 100 year | 7,849 | 1,858 | 9,707 |
| 1 in 200 year | 8,706 | 2,143 | 10,849 |
| 1 in 1000 year | 10,208 | 3,045 | 13,253 |

**Table 9: Number of residential and commercial properties at risk across the whole Strategy area, from flooding under a Do Nothing Scenario taking account of sea level rise.**

| Return Period | Residential Properties | Commercial Properties | Total |
|---|---|---|---|
| 1 in 2 year | 7,713 | 1,629 | 9,342 |
| 1 in 20 year | 9,582 | 2,503 | 12,085 |
| 1 in 50 year | 10,186 | 3,046 | 13,232 |
| 1 in 100 year | 11,058 | 3,380 | 14,438 |
| 1 in 200 year | 11,736 | 3,660 | 15,396 |
| 1 in 1000 year | 12,928 | 4,298 | 17,226 |

#### 4.1.1.2 Valuation of Residential Properties

The capital sum worth investing to reduce the risk of flooding to any residential property should be "capped" at its market value. Therefore, the present values of the residential properties were calculated and the AADs capped at these values. Values were taken from www.zoopla.co.uk, using the average property values for each postcode area (i.e. ME12) and each house type (Detached, Semi-detached, Terraced, or Flat). Zoopla is considered an accurate data source to use as it provides the most recent averages of property in each property area. Zoopla house prices were accessed on 27/11/15 and have been updated to a more current estimate using the Halifax house price index (www.halifax.co.uk/house-price-index); the UK's longest running monthly house price series. Residential property described as 'House Boats' were assumed to be water resistant and therefore not at risk of flooding and were removed from the assessment.

Following guidelines (Environment Agency, 2008), properties considered to be caravans or mobile homes were capped at a value estimated to relocate them (£5,000).

The NRD database was used to retrieve the postcode and house type of each property. Properties with no assigned house type in the NRD had to be assigned by evaluating OS MasterMap (2015) and/or Google Earth (Google Inc., 2015).

A MCM code is required to determine the AAD. The code takes into account the type and age of each property. The age of the house was estimated for each postcode by using the historic imagery available in Google Earth (Google Inc., 2015). Using the house type from the NRD and an estimated age, a MCM code was determined for each property.

#### 4.1.1.3 Valuation of Commercial Properties

As with the residential properties, the capital sum worth investing to reduce the risk of flooding to any commercial property should be “capped” at its market value. Valuation of these properties followed MCM guidance (2015). The Valuation Office Agency (VOA, http://www.2010.voa.gov.uk/rli/en/basic/find ) was used to obtain the rateable value of the property. Multiplying this value by ten gives an approximation of its market value.

Not all commercial properties were found in the VOA database. Therefore, the value of these properties was estimated using the average market value estimate per $m^2$ of the properties with the same MCM code, and multiplying this by the floor area of each property.

### 4.1.2 Agricultural Land Flood Damages

To calculate the damages from agricultural land an AAD has been calculated, similar to calculating the damages from properties. The damages for 6 different return period events (50%, 5%, 2%, 1%, 0.5%, and 0.1% AEP) were calculated for the 2 epochs (present day (2015) and future (2115)) for each BA (i.e. BA1.1, 1.2, 1.3 and 1.4) for both the Do Nothing options and the Do Something options.

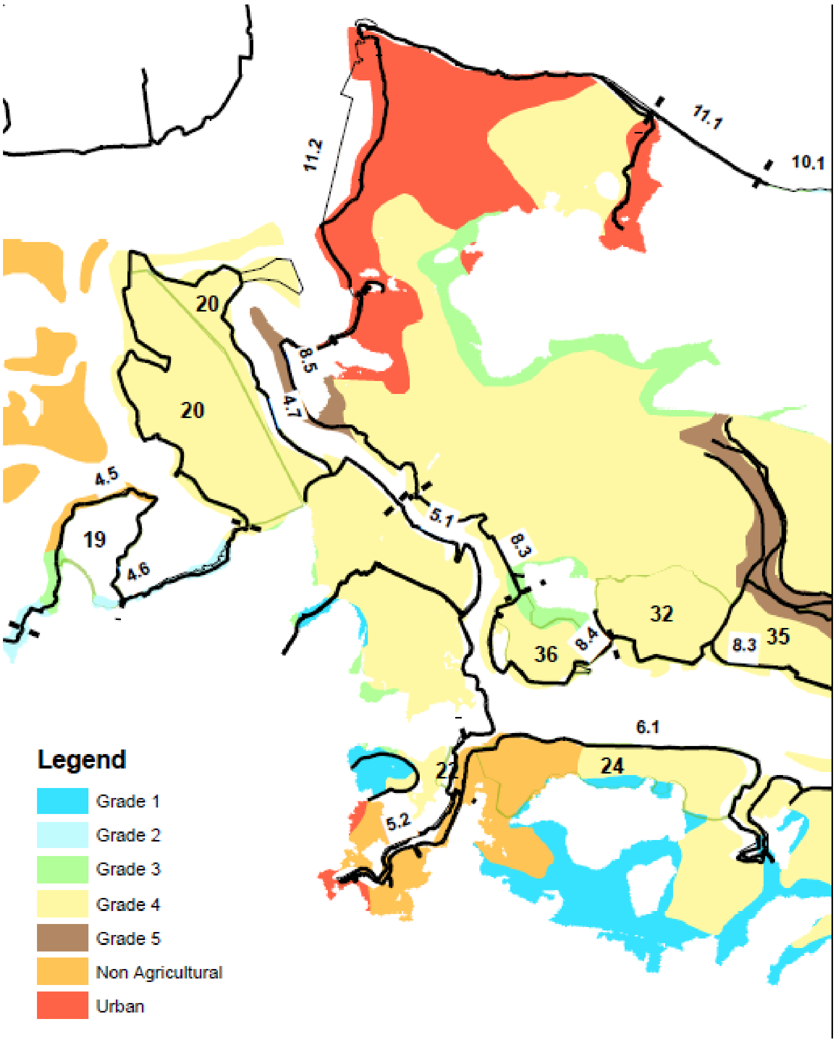
The AADs for the agricultural land were calculated using the method outlined in the MCM (Middlesex University, 2013). This included:

1) Defining the agricultural productivity and the impacts of flooding– identifying the total area of agricultural land liable to flooding and determining the grade of agricultural land at risk.
2) Calculating the monetary value of the impacts – estimating the costs associated with the flooding of the different agricultural grades.

#### 4.1.2.1 Classifying the agricultural land

Using GIS, the Agricultural Land Classification (ALC) dataset, which describes the potential of land for agricultural use, using five primary grades, was used to calculate the areas of land per classes were obtained for each of the return periods under the different scenarios.

**Figure 6: The classification of agricultural land based on the flood extent and the ALC dataset**




Source: ALC dataset clipped to the flood extent

The impact of flooding/cost of flooding was defined by type of agriculture land (grade). Each grade has a different economic value associated with it according to the MCM (Middlesex University, 2013). The costs were uplifted to present day using RPI values.

**Table 10: Land use and flood costs based on a single annual flood of more than one week's duration in England and Wales (Middlesex University, 2013). This assumes an equal monthly probability of flooding throughout the year allowing for fallow periods. Costs are based on loss of gross margins less savings in uncommitted costs. Grassland costs are based on replacement feed. Arable crops are based on value of market prices**

| Agricultural Land Classification (ALC) Grade | Land use assumptions | Flood costs (£/ha) (2005) | Flood cost (£/ha) (Q1 2016) |
|---|---|---|---|
| Grade 1 | 5% horticulture, 85% intensive arable, 10% extensive arable | £1,160.00 | £1,589.88 |
| Grade 2 | 5% horticulture, 60% intensive arable, 35% extensive arable | £770.00 | £1,055.35 |
| Grade 3 | 30% intensive agriculture, 70% extensive arable | £400.00 | £548.23 |
| Grade 4 | 100% intensive grass | £50.00 | £68.53 |
| Grade 5 | 100% extensive grass | £20.00 | £27.41 |

Source: Middlesex University, 2013

### 4.1.2.2 Calculating the AAD

To ensure that an accurate AAD was calculated it was also important to calculate the capital value of the land to ensure that the total of the AAD does not exceed the capital value of the land and will need to be capped, similar to capping a property. The value of the land was based on a Report by Savills for the cost of agricultural land in Great Britain for the different classifications (http://pdf.euro.savills.co.uk/uk/rural---other/uk-agricultural-land-2016.pdf). Table 11 presents the summary of the Report and the costs that were taken forwards in the assessment

**Table 11: Assumed price for the land based on Savills research**

| | | Assumption | approx. £/acre (2015) | approx. £/ha (2015) |
|---|---|---|---|---|
| Grade 1 | 5% horticulture, 85% intensive arable, 10% extensive arable | Assumed Prime Arable land | £9,500 | £23,475 |
| Grade 2 | 5% horticulture, 60% intensive arable, 35% extensive arable | Average between Prime Arable and Grade 3 | £8,750 | £21,622 |
| Grade 3 | 30% intensive agriculture, 70% extensive arable | Grade 3 | £8,000 | £19,769 |
| Grade 4 | 100% intensive grass | Assumed average grassland | £5,500 | £13,591 |
| Grade 5 | 100% extensive grass | Assumed poor grassland | £4,500 | £11,120 |

Source: Savills, 2016

Using the above information and the loss of agricultural land obtained using GIS, the AADs were calculated for each scenario.

### 4.1.2.3 Results

The ADD for each of the scenarios is included below in Table 12.

**Table 12: Summary of the agricultural AADs for each of the scenarios for the different BAs.**

| BA | Do Nothing | | Maintain | | Sustain | | Upgrade | |
|---|---|---|---|---|---|---|---|---|
| | Present | Future | Present | Future | Present | Future | Present | Future |
| 1.1 | £24,386 | £34,933 | £2,143 | £8,856 | £1,965 | £2,131 | £1,965 | £2,131 |
| 1.2 | £7,537 | £13,970 | £524 | £3,405 | £422 | £429 | £422 | £429 |
| 1.3 | £43,304 | £67,819 | £2,233 | £22,655 | £1,730 | £1,524 | £1,510 | £1,524 |
| 1.4 | £874 | £1,070 | £754 | £789 | £744 | £768 | £744 | £768 |
| 2.1 | £580 | £2,071 | £469 | £1,604 | £188 | £442 | £183 | £442 |
| 3.1 | £1,099 | £1,280 | £604 | £1,266 | £69 | £80 | £69 | £80 |
| 3.2 | £3,133 | £3,274 | £3,133 | £3,264 | £1,451 | £1,445 | £1,437 | £1,445 |
| 3.3 | £5,773 | £10,800 | £3,680 | £6,007 | £1,632 | £1,665 | £1,634 | £1,665 |
| 3.4 | £34,496 | £45,420 | £32,729 | £45,231 | £4,991 | £5,195 | £3,400 | £5,195 |
| 3.5 | £12,428 | £15,009 | £6,502 | £14,879 | £2,873 | £2,897 | £2,767 | £2,897 |
| 4.1 | £23,595 | £36,024 | £11,747 | £26,552 | £10,134 | £10,376 | £9,979 | £10,376 |
| 4.2A | £5,004 | £8,716 | £2,284 | £6,341 | £4,027 | £2,205 | £2,174 | £2,205 |
| 4.2B | £31,162 | £42,881 | £22,830 | £42,191 | £4,016 | £2,465 | £2,210 | £2,465 |
| 4.3 | £3,396 | £6,296 | £3,370 | £6,059 | £961 | £997 | £919 | £997 |
| 4.4 | £16,039 | £24,212 | £5,975 | £22,572 | £4,973 | £5,079 | £4,849 | £5,079 |
| 4.5 | £7,063 | £9,203 | £5,974 | £7,162 | £5,489 | £5,491 | £5,471 | £5,491 |
| 4.6 | £8,431 | £10,458 | £8,184 | £10,406 | £7,332 | £7,584 | £7,297 | £7,584 |
| 4.7 | £23,675 | £24,128 | £6,389 | £20,969 | £4,983 | £5,010 | £4,880 | £5,010 |
| 5.1 | £9,579 | £14,627 | £253 | £1,130 | £222 | £223 | £222 | £223 |
| 5.2 | £5,863 | £17,002 | £18 | £595 | £11 | £13 | £10 | £13 |
| 6.1 | £59,147 | £164,468 | £16,925 | £122,278 | £4,133 | £4,178 | £4,027 | £4,178 |
| 6.2 | £157,147 | £162,690 | £18,409 | £19,567 | £18,409 | £18,409 | £18,409 | £18,409 |
| 7.1 | £18,837 | £23,371 | £11,868 | £23,685 | £4,963 | £4,982 | £4,813 | £4,982 |
| 7.2A | £1,774 | £8,974 | £1,782 | £9,682 | £659 | £266 | £252 | £266 |
| 7.2B | £48,843 | £58,774 | £1,683 | £1,762 | £1,847 | £1,701 | £1,684 | £1,701 |
| 8.2 | £23,275 | £28,003 | £798 | £4,325 | £692 | £669 | £669 | £669 |
| 8.3 | £106,933 | £121,726 | £6,318 | £21,062 | £5,875 | £5,929 | £5,811 | £5,929 |
| 8.4 | £8,078 | £9,725 | £1,275 | £7,946 | £979 | £1,001 | £967 | £1,001 |
| 8.5 | £5,155 | £5,394 | £884 | £980 | £884 | £915 | £884 | £915 |
| 9.2 | £1,499 | £7,344 | £19 | £351 | £5 | £299 | £19 | £299 |
| 10.1 | £1,460 | £1,621 | £1,460 | £1,621 | £1,611 | £1,621 | £1,460 | £1,621 |
| 11.2 | £21,916 | £25,914 | £- | £193 | £- | £- | £- | £- |

### 4.1.3 Recreation Flood Damages

Similar to properties the Annual Average Damages (AAD) has been calculated for flooding of recreation sites in the Strategy for 6 flood events (50%, 5%, 2%, 1%, 0.5%, and 0.1% AEP) within 2 epochs (present day and with 100 years sea level rise).

Visitor numbers were taken from a number of sources; the source and corresponding amenity are detailed in Table 13. Based on MCM guidance (Middlesex University, 2013) it is assumed that the annual visitor numbers are based on a total of 220 days. This assumes that the majority of the visitors to a site are during weekends, bank holidays and school holidays. Therefore, the annual visitor numbers are divided by 220 to get the total number of visitors per day.

**Table 13: Recreational visitor numbers**

| Benefit Area | Attraction | Annual Visitor Numbers | Source | Year |
|---|---|---|---|---|
| 4.1 | Riverside Country Park | 400,000 | Email from Medway Council | 2015 |
| 4.2 | Motney Hill | 2,000 | RSPB | 2014 |
| 5.2 | Milton Creek Country Park | 200,000 | Estimated from Riverside Country Park as half the size and therefore estimated half the number of visitors | |
| 6.1 | Oare Nature Reserve | 2,000 | Estimated from Harty Marshes, Great Bells & Motney Hills | |
| 8.2 | Harty Marshes | 2,000 | RSPB | 2014 |
| 8.3 | Elmley Nature Reserve | 11,000 | RSPB | 2014 |
| 8.4 | Elmley Nature Reserve | 11,000 | RSPB | 2014 |
| 8.3 | Great Bells | 2,000 | RSPB | 2014 |
| 9.2 | Leysdown Beach | 5,972 | RNLI | 2015 |
| 11.2 | Sheerness Beach | 5,159 | RNLI | 2015 |

Table 14 shows the assumptions that determine the number of days a site will be impacted by flooding under each return period. Each visitor is assigned a value of £4.50. This is determined from the MCM and is based on the '£ loss' per visitor if the site cannot be accessed.

Using the above information, the AADs were calculated for each scenario were the amenities are at risk of flooding.

**Table 14: Assumed closure time for recreational sites for each return period**

| Return Period | Days of Flood | Clear Up time | Total time closed |
|---|---|---|---|
| 1 in 10 | 2 | 0 | 2 |
| 1 in 50 | 3 | 1 | 4 |
| 1 in 100 | 3 | 5 | 8 |
| 1 in 200 | 3 | 10 | 13 |
| 1 in 500 | 4 | 10 | 14 |
| 1 in 1000 | 5 | 10 | 15 |

Source: Mott MacDonald, 2016

### 4.1.4 Roads Flood Damages

The Annual Average Damages (AAD) have also been calculated for flooding of key infrastructure, including roads, in the Strategy for 6 flood events (50%, 5%, 2%, 1%, 0.5%, and 0.1% AEP) within 2 epochs (present day and with 100 years sea level rise). Based on the MCM guidance (Middlesex University, 2015) the Delayed-Hour Method was used to calculate the AAD associated with the roads at risk of flooding. The method follows the following steps:

- **Step 1:** Determine the flood risk to each road under each return period using GIS.
- **Step 2:** Assume the road suffers from delays, the duration of which is determined from the MCM data scenario detailed in Table 14 (Middlesex University, 2013).

**Table 15: Indicative delay duration at different return periods**

| Likelihood of flooding | Delay duration (Hours) |
|---|---|
| Up to and including 5 year return period (20% AEP) | 6 |
| Up to and including 10 year return period (10% AEP) | 6 |
| Up to and including 25 year return period (4% AEP) | 12 |
| Up to and including 50 year return period (2% AEP) | 24 |
| Up to and including 100 year return period (1% AEP) | 48 |
| Up to and including 200 year return period (0.5% AEP) | 96 |

Source: MCM (2013)

- **Step 3:** Annual Daily Flow (AADF) (accessed from http://www.dft.gov.uk/traffic-counts/cp.php?la=Kent#81495) is used for different vehicle categories and is converted to estimated hourly flows.
- **Step 4:** Costs per hour is determined from the MCM data of resource costs of travel as a function of speed detailed in Table 14. The speed of the road is determined by the speed limit for the road.

**Table 16: Total resource costs of travel as a function of speed (pence/km) (updated to 2015/16 prices)**

| | Total resource costs (pence per km) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Speed (km/hr) | 5 | 10 | 20 | 40 | 50 | 80 | 100 | 120 |
| Car average p/km | 262 | 133 | 70 | 39 | 33 | 222 | 20 | 18 |
| LGV average p/km | 307 | 160 | 85 | 48 | 41 | 31 | 29 | 27 |
| OGV1 p/km | 338 | 179 | 98 | 56 | 48 | 37 | - | - |
| OGV2 p/km | 432 | 234 | 132 | 80 | 69 | 55 | - | - |
| PSV p/km | 1942 | 995 | 521 | 282 | 234 | - | - | - |

Source: MCM (2015)

Using the above information, the AADs were calculated for each scenario were the road is at risk of flooding.

### 4.1.5 Rail Flood Damages

Rail flood damages have also been calculated by calculating the AADs. The MCM guidance for the loss due to disruptions of the rail network was used. The steps used to calculate the AADs are as follows:

- **Step 1:** Determine the flood risk to each rail line under each return period using GIS.
- **Step 2:** Determine the number of passenger and freight services over a normal weekday (accessed from network rail here http://www.networkrail.co.uk/aspx/3828.aspx). The number of services over a day was converted to estimated services per hour.
- **Step 3:** Following the MCM guidance it is assumed that a proportion of the services will be delayed and cancelled determined by Table 16.

**Table 17: Percentage delay/cancellation due to flooding (Posford Duvivier et al., 2002)**

| Rail Service | Delay % | Cancellation % |
|---|---|---|
| Passenger service | 40 | 60 |
| Freight service | 45 | 55 |

Source: MCM (2016)

- **Step 4:** Delayed and cancellation cost were determined from the MCM data detailed in Table 18. The medium values were used in this assessment.
- **Step 5:** The delay duration is determined from the MCM data scenario detailed in Table 14 (Middlesex University, 2013). This is the same data used for the road damages assessment.

**Table 18: Indicative compensation values of performance delays and cancelled services (data from Network Rail)**

| | Delay compensation value £s per minute per service* | | | Cancellation compensation value £s per service cancelled ** | | |
|---|---|---|---|---|---|---|
| | Low value (£) | Medium value (£) | High value (£) | Low value (£) | Medium value (£) | High value (£) |
| Passenger | 40 | 71 | 97 | 673 | 2034 | 2591 |
| Freight | - | 18 | - | - | 1900 | 0 |

*Including a delay multiplier of 3

**Including a cancellation multiplier of 3

These delay multipliers have been applied according to the Department of Transport (2009) which Burr (2008) argues is "used by the rail industry to recognise the unexpected delays are more costly to passengers".

Source: MCM 2016

Using the above information, the AADs were calculated for each scenario were the rail is at risk of flooding.

### 4.1.6 Health Impacts and Emergency Services

DEFRA guidance (2004) values the human health impact of flooding as £200 per household. Therefore, this value has been added to all the residential properties that have been affected by flooding. Additionally, the cost of emergency services being required to tackle flood events and assist in recovery process has been included within the economic appraisal. MCM guidance (Middlesex University, 2015) guidance incorporates a multiplier of 10.7% on the value of each residential property.

### 4.1.7 Others Flood Damages

Vehicle damages have been included within the economic appraisal based on the MCM guidance (Middlesex University, 2015) guidance. This guidance recommends a loss value of £3,600 per residential property. This is based on the cost of an average motor vehicle being £3,100 and the average number of vehicles per household of 1.15. The loss value is applied to properties with a flood depth of greater than 0.35 m as this is when vehicles are likely to be damaged and written off.

## 4.2 Erosion Damages

In addition to an assessment of assets at risk of flooding, an assessment of those at risk of erosion has also been undertaken. The methods used to calculate the value of the damages is outlined below.

#### 4.2.1 Property Erosion Damages

As for flood benefits the NRD database was used to determine what properties are at risk from erosion and a similar approach was used to value properties. Values for commercial and residential property were determined using the approach described in Sections 4.2.1 and 4.2.2, with the exception that under the 'Do Nothing' erosion scenario valuations have not been 'capped' but instead considered completely written off once the property is at risk of erosion. The values of entire Caravan Parks were not assessed as they are assumed to be valued with each individual caravan. Similar to the flooding assessment a value of £5,000 has been assigned to each caravan to account for the costs of relocating it.

The year of erosion of a property was calculated when the property or access to the property is 5m from the seaward extent of each 5 year erosion line. Following MCM guidelines (Middlesex University, 2015) the year of erosion of some properties were brought forward to account for the loss of the services e.g. electricity sub-station before the properties. It was assumed that these sub-stations serve the properties along the cliff top, and if they are lost the property is no longer connected to the utility network and deemed uninhabitable. A visual assumption was made on which properties are likely to be affected, based on their proximity to the sub-station.

The values and year of erosion for each property were entered into the FCERM-AG spreadsheet (EA, 2012). The discount rate was than applied to each property to determine the Present Value (PV) of the properties lost to erosion.

##### 4.2.1.1 Properties at risk of erosion

The properties at risk of erosion in all BAs under the 'Do Nothing' scenario are summarised in Table 19.

At Ham Green, Bedlam Bottoms and Elmley Hills there are no properties at risk from erosion. There is one valuable property at risk of erosion at Cockham Wood, which is the Medway Yacht Club, estimated to be lost in year 70.

**Table 19 Number of properties lost due to erosion under 'Do Nothing' over the next 100 years in BA01,09,10 & 11**

| Benefit Area | Property Type | Short term 0-20 years | Mid term 21-50 years | Long term 50-100 years | Total |
|---|---|---|---|---|---|
| 1.4 | Residential | 0 | 0 | 0 | 0 |
| | Commercial | 0 | 0 | 1 | 1 |
| | | | | **Total** | **1** |
| 9.1 | Residential | 54 | 129 | 178 | 361 |
| | Caravans | 0 | 5 | 5 | 10 |
| | Commercial | 3 | 8 | 38 | 49 |
| | | | | **Total** | **420** |
| 9.2 | Residential | 0 | 8 | 225 | 233 |
| | Caravans | 0 | 2 | 49 | 51 |
| | Commercial | 0 | 3 | 2 | 5 |
| | | | | **Total** | **289** |
| 10.1 | Residential | 14 | 54 | 62 | 129 |
| | Caravans | 8 | 62 | 115 | 185 |
| | Commercial | 1 | 0 | 3 | 4 |
| | | | | **Total** | **317** |

| Benefit Area | Property Type | Short term 0-20 years | Mid term 21-50 years | Long term 50-100 years | Total |
|---|---|---|---|---|---|
| 11.1 | Residential | 3 | 92 | 270 | 365 |
| | Commercial | 6 | 3 | 2 | 11 |
| | | | | **Total** | **376** |

Source: Mott MacDonald

### 4.2.2 Recreation Erosion Damages

Recreation erosion damages are included in BA 9.1 and 11.1. Recreation erosion damages are calculated with visitor numbers detailed in Table 13. The value per adult visit is taken as £7.23 from the MCM manual values for Herne Bay and Cliftonville beach and promenade erosion (MCM, 2015). Erosion damages are calculated as annual losses from the first year of erosion.

**Table 20: Visitor numbers used for erosion damages**

| Benefit Area | Attraction | Annual Visitor Numbers | Source | Year |
|---|---|---|---|---|
| 9.1 | Leysdown Beach | 5,972 | RNLI | 2015 |
| 11.1 | Minster Leas | 4,665 | RNLI | 2015 |

# 5 Summary of Do Nothing Damages

Table 21 below outlines the total damages under a Do Nothing scenario for each of the BAs. This provides the economic baseline against which the Do Something options are compared against, to determine if the options are viable.

**Table 21: Breakdown of Do Nothing Damages in each BA. Values are shown in £k.**

| BA | PV Damages (£k) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | Commercial | Vehicle and Health | Emergency Services | Written Off Property | Agricultural Land | Road and Railways | Recreation | Erosion (of which Recreation) | Total |
| **1.2** | 99 | 15,723 | 9 | 11 | 24,915 | 1989 | 212 | - | - | 41,167 |
| **1.3** | 201 | 2,007 | 17 | 22 | 1,500 | 797 | - | - | - | 4,543 |
| **1.4** | | | | - | 26 | - | | - | 37 | 63 |
| **2.1** | 5,241 | 20,945 | 465 | 561 | 12,259 | 24 | 1,262 | - | - | 40,757 |
| **2.2** | 2,241 | 3,676 | 189 | 240 | 4,961 | - | - | - | - | 11,307 |
| **2.3** | 21,347 | 10,652 | 2,373 | 2,284 | 26,515 | - | 25 | - | - | 63,195 |
| **3.1** | 8 | 459 | 0.3 | 1 | 277 | 26 | - | - | - | 772 |
| **3.2a** | 1,166 | 167 | 82 | 125 | 1,228 | 94 | 272 | - | - | 3,134 |
| **3.2b** | 1,166 | 167 | 82 | 125 | 1,228 | 94 | 272 | - | - | 3,134 |
| **3.3** | 5,019 | 91,532 | 509 | 537 | 115,852 | 164 | 1,516 | - | - | 215,128 |
| **3.4** | 4,662 | 5,037 | 405 | 512 | 10,791 | 1,057 | - | - | - | 22,464 |
| **3.4b** | 4,662 | 5,037 | 405 | 512 | 10,791 | 1,057 | - | - | - | 22,464 |
| **3.5** | 1 | 8 | 0.1 | 0.1 | 44 | 384 | - | - | - | 437 |
| **4.1** | 539 | 43 | 73 | 58 | 898 | 676 | 80 | 6,915 | - | 9,281 |
| **4.2a** | 10 | 351 | 0.7 | - | 1 | 77 | 146 | - | 35 | 622 |
| **4.2b** | 217 | 15 | 15 | 23 | 610 | 926 | - | - | - | 1,805 |
| **4.3** | 3 | 1,216 | 0.2 | 0.3 | 15,675 | 116 | - | - | - | 17,011 |
| **4.4** | 543 | 155 | 64 | 58 | 96 | 369 | - | - | - | 1,283 |
| **4.5** | - | 28 | - | - | 122 | 205 | - | - | - | 355 |
| **4.6** | - | - | - | - | - | 258 | - | - | - | 258 |
| **4.7** | 34 | 219 | 2 | 4 | 687 | 572 | - | - | - | 1,517 |

| BA | PV Damages (£k) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | Commercial | Vehicle and Health | Emergency Services | Written Off Property | Agricultural Land | Road and Railways | Recreation | Erosion (of which Recreation) | Total |
| **5.1** | 1,076 | 4,088.3 | 100 | 115 | 61,241 | 157 | 813 | - | - | 67,592 |
| **5.2** | 21,741 | 7,779.1 | 2,235 | 2,326 | 31,464 | 145 | 21 | 1,780 | - | 67,491 |
| **6.1** | 706 | 521.7 | 51 | 76 | 1,688 | 1,681 | 1,426 | 20 | - | 6,171 |
| **6.2** | 46 | 9.1 | 1 | 5 | 956 | 2,674 | - | - | - | 3,690 |
| **7.1** | 506 | 2,857.8 | 46 | 54 | 1,837 | 470 | - | - | - | 5,771 |
| **7.2a** | 5,274 | 1,138.6 | 597 | 564 | 3,895 | 91 | 1,007 | - | - | 12,567 |
| **7.2b** | 185 | 20.1 | 23 | 20 | 498 | 725 | - | - | - | 1,471 |
| **8.2a** | 7,671 | 266.5 | 1,057 | 971 | 2,489 | 43 | - | - | 6 | 12,503 |
| **8.2b** | 7,983 | 334.3 | 1,045 | 1,000 | 3,459 | 345 | - | 16 | - | 14,183 |
| **8.3a** | 0.4 | 11.0 | 0.1 | 0.05 | 2,816 | 2,474 | 1,390 | 138 | - | 6,830 |
| **8.4** | - | 0.1 | - | - | - | 146 | - | 10 | - | 156 |
| **8.5** | 242 | 75.6 | 31 | 6 | 1,281 | 84 | 782 | - | - | 2,522 |
| **9.1** | - | - | - | 0.0 | - | - | - | 1,287 | 11,167 (2,385) | 12,454 |
| **9.2** | 1,081 | 3,100.0 | 105 | 131 | 674 | 51 | - | 46 | 6,915 | 12,103 |
| **10.1** | - | - | - | - | - | - | - | - | 7,920 | 7,920 |
| **11.1** | - | - | - | - | - | - | - | 496 | 14,440 (509) | 14,937 |
| **11.2** | 26,283 | 6,133.4 | 2,136 | 2,812 | 576,202 | 352 | 905 | 89 | - | 614,914 |
| **Total** | 119,951 | 183,769.9 | 12,119 | 13,172 | 916,949 | 16,561 | 10,132 | 10,798 | 40,519 | 1,323,969 |

Source: Mott MacDonald

# 6 Summary of Benefits/ Damages Avoided

The benefits (damages avoided) for each of the short listed options were calculated based on the methods outlined in Chapter 4. These Do Something damages were subtracted from the Do Nothing damages to calculate the damages avoided (benefits). These benefits were then compared with the costs, outlined in Technical Appendix D, to undertake the economic assessment (Technical Appendix G).

The summary of the benefits for each of the short listed options are outlined in the AST's (Technical Appendix E).

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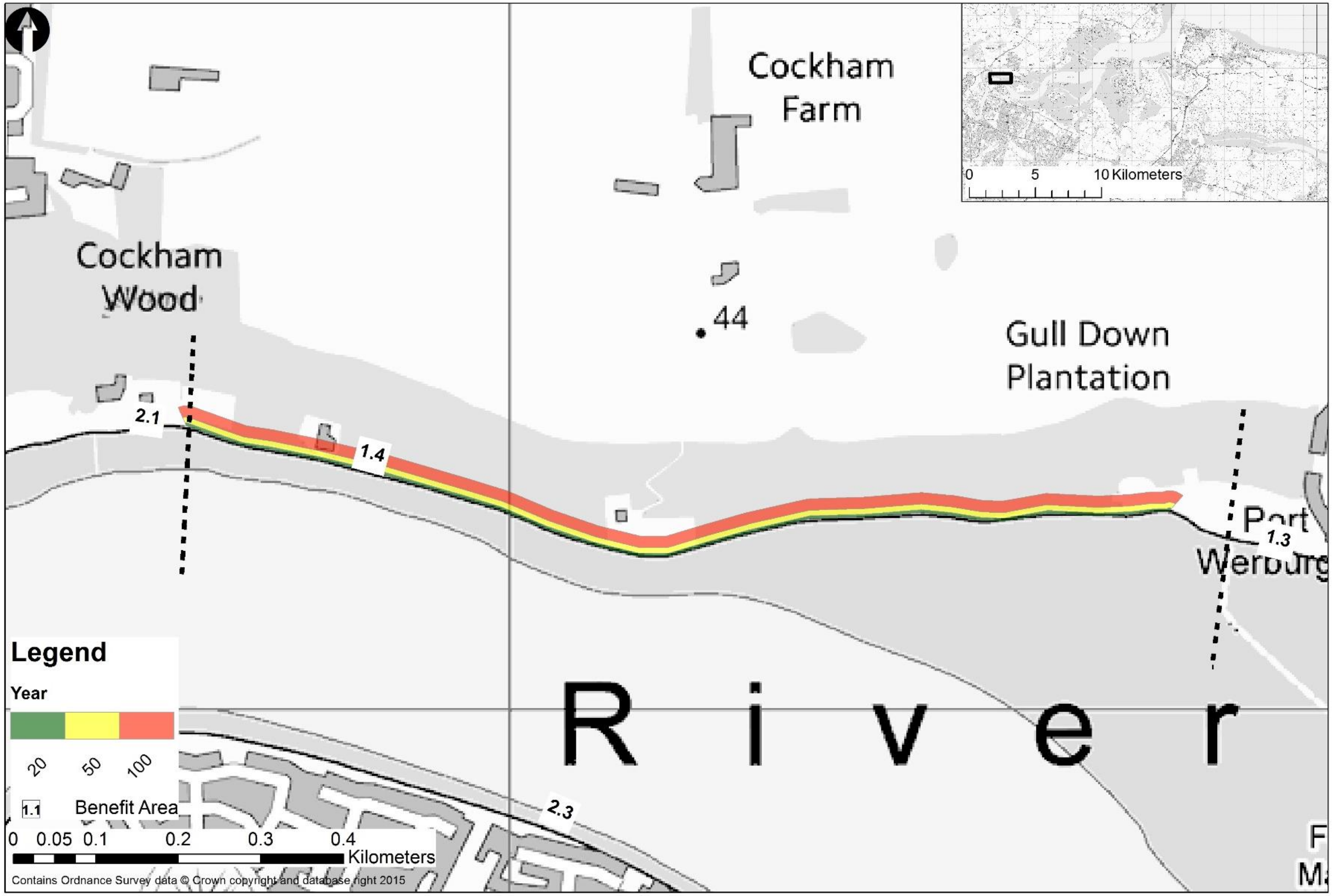
# Appendices

# A. Coastal Retreat Maps

**Figure 7: Coastal Retreat in BA1.2**

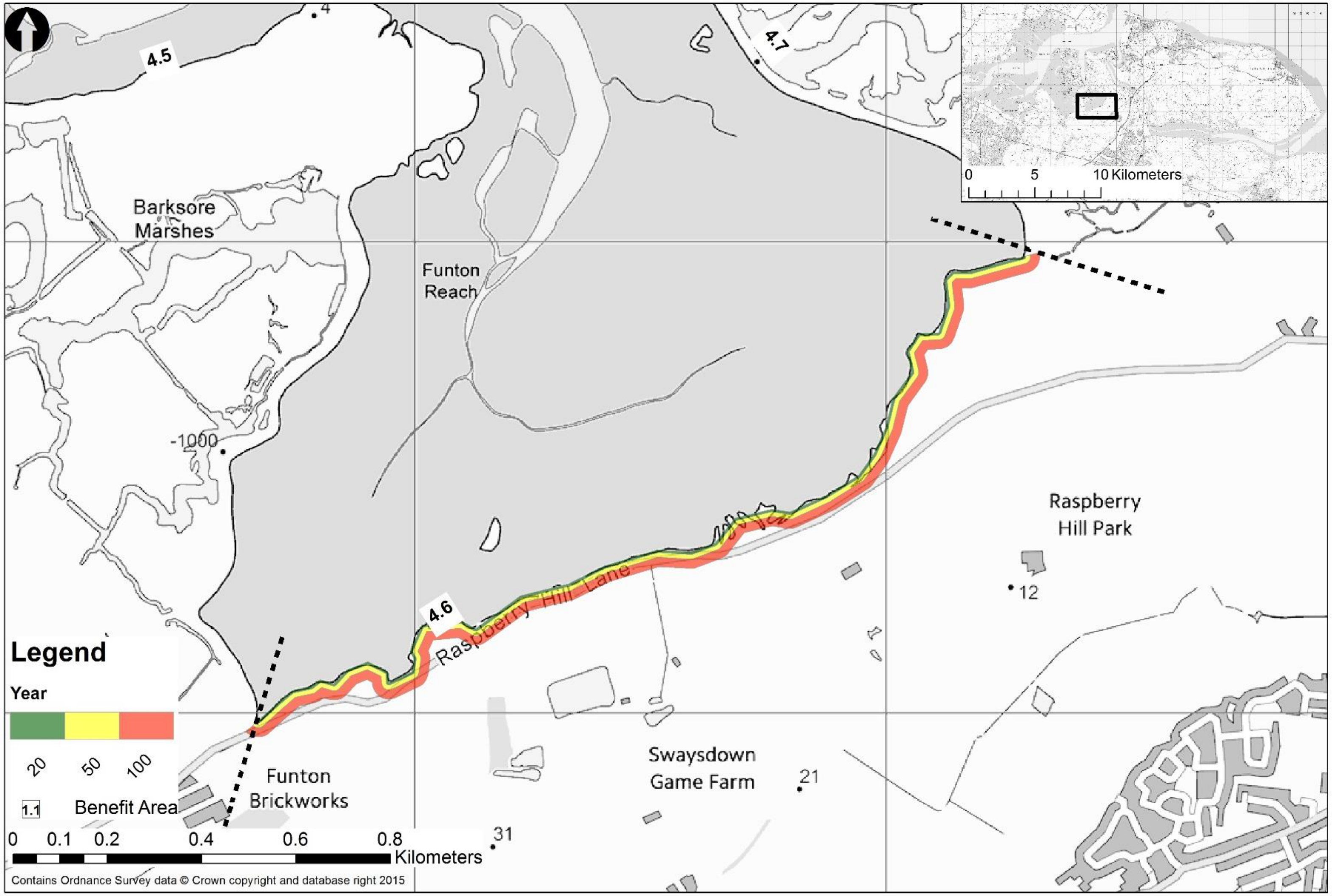



Source: Ordnance Survey data © Crown copyright database right 2015

**Figure 8: Coastal Retreat in BA4.3**


Source: Ordnance Survey data © Crown copyright database right 2015

**Figure 9: Coastal Retreat in BA4.6**




Source: Ordnance Survey data © Crown copyright database right 2015

**Figure 10: Coastal Retreat in BA8.4**

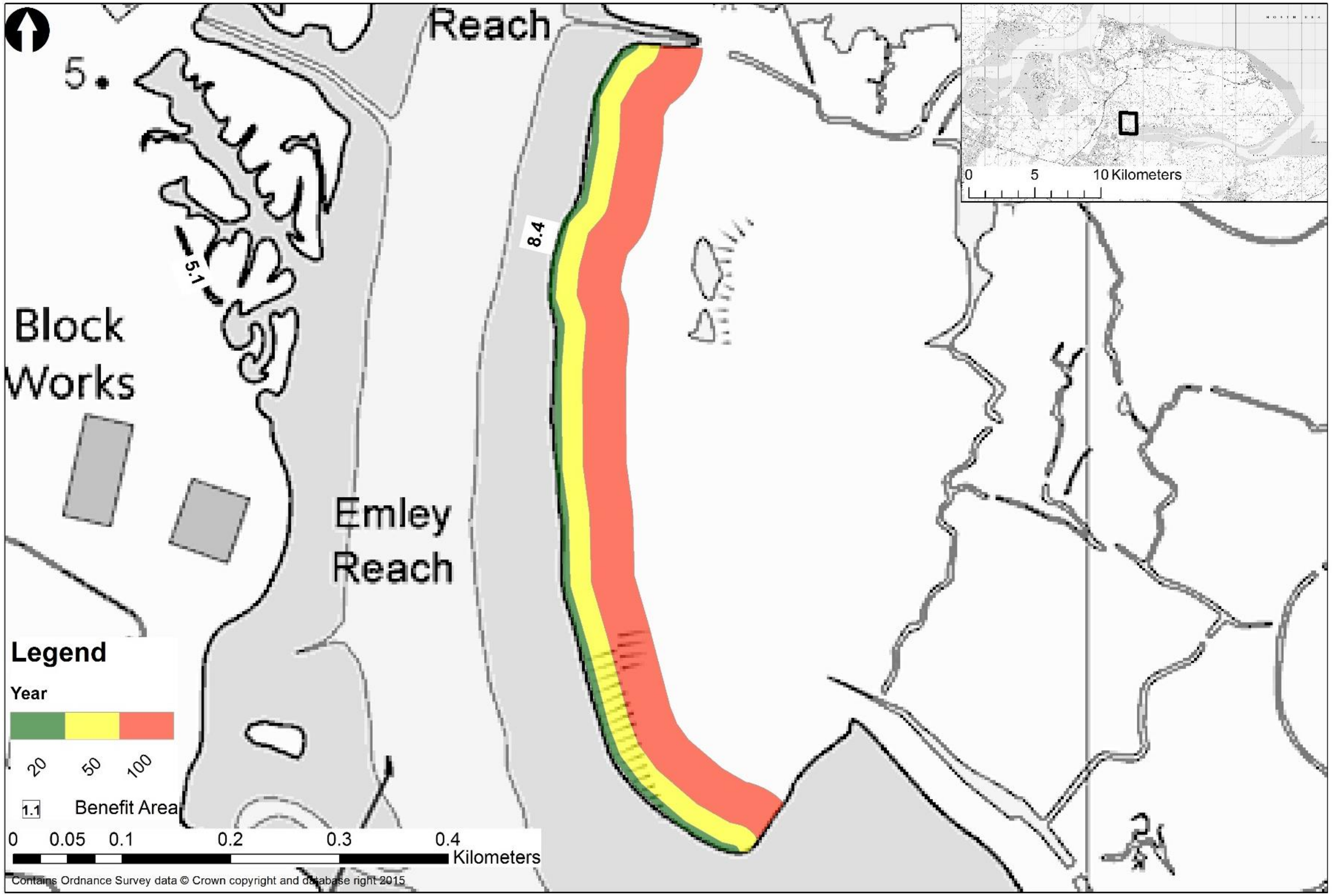



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**Figure 11: Coastal Retreat in BA9.1**

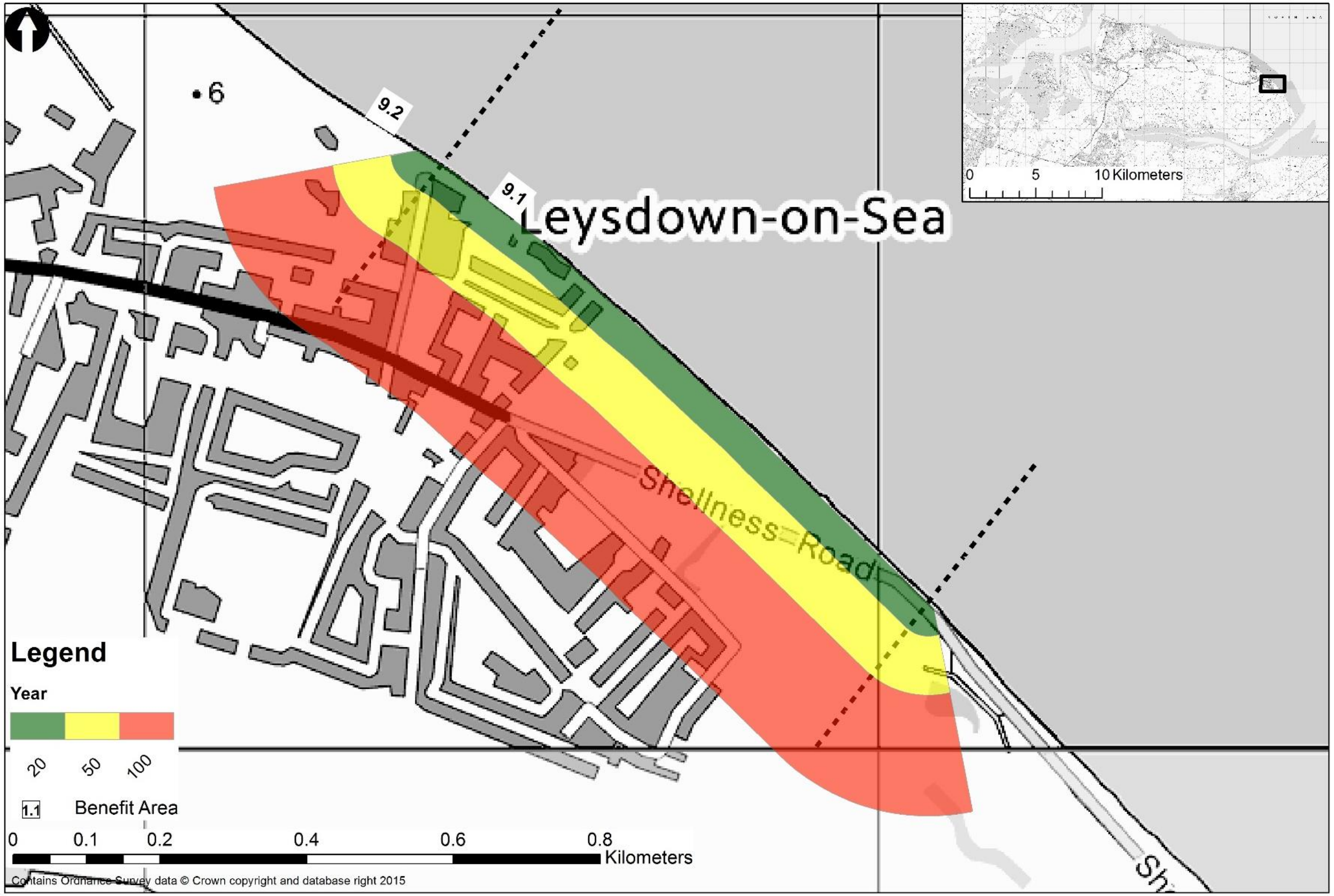


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**Figure 12: Coastal Retreat in BA9.2**

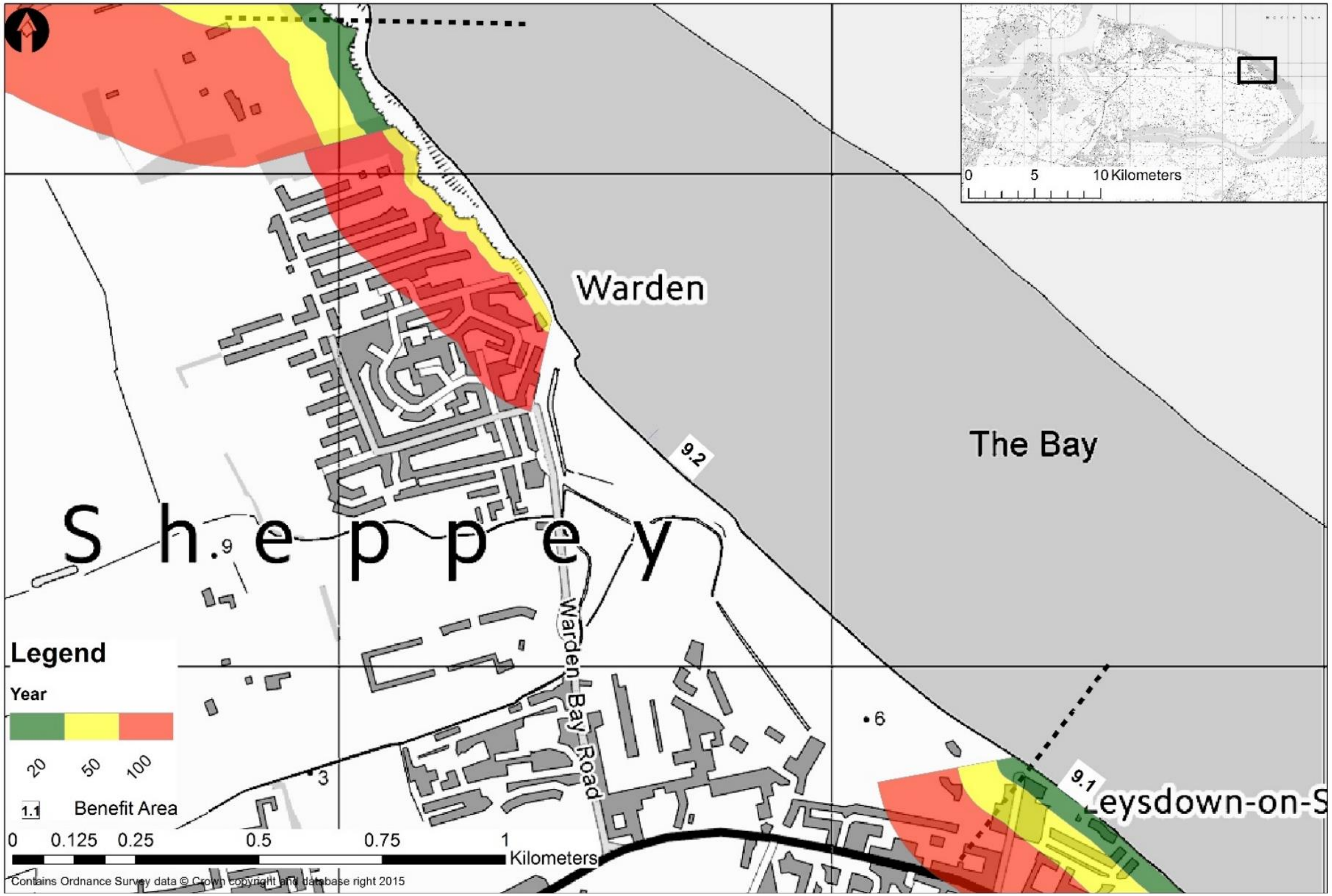


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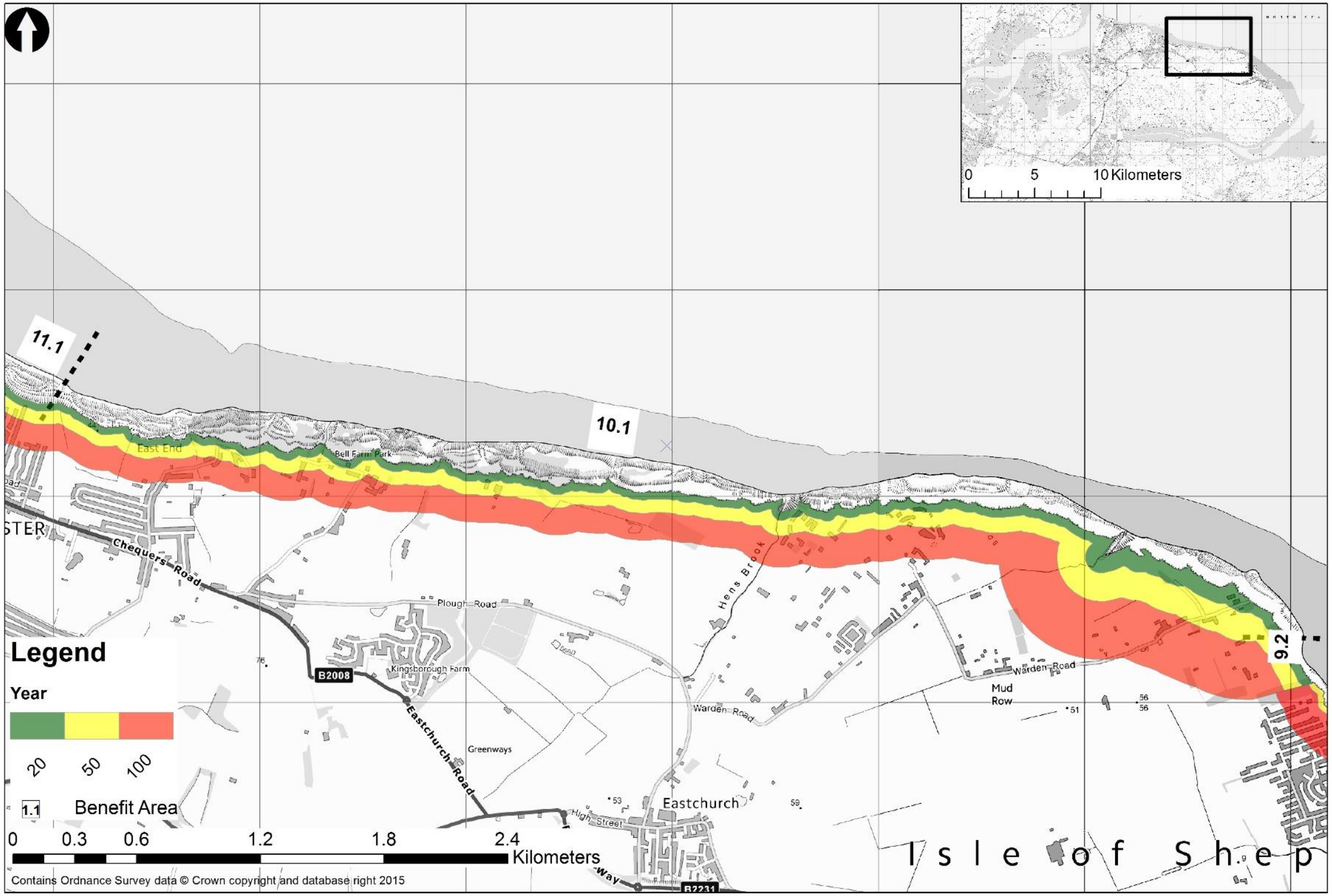
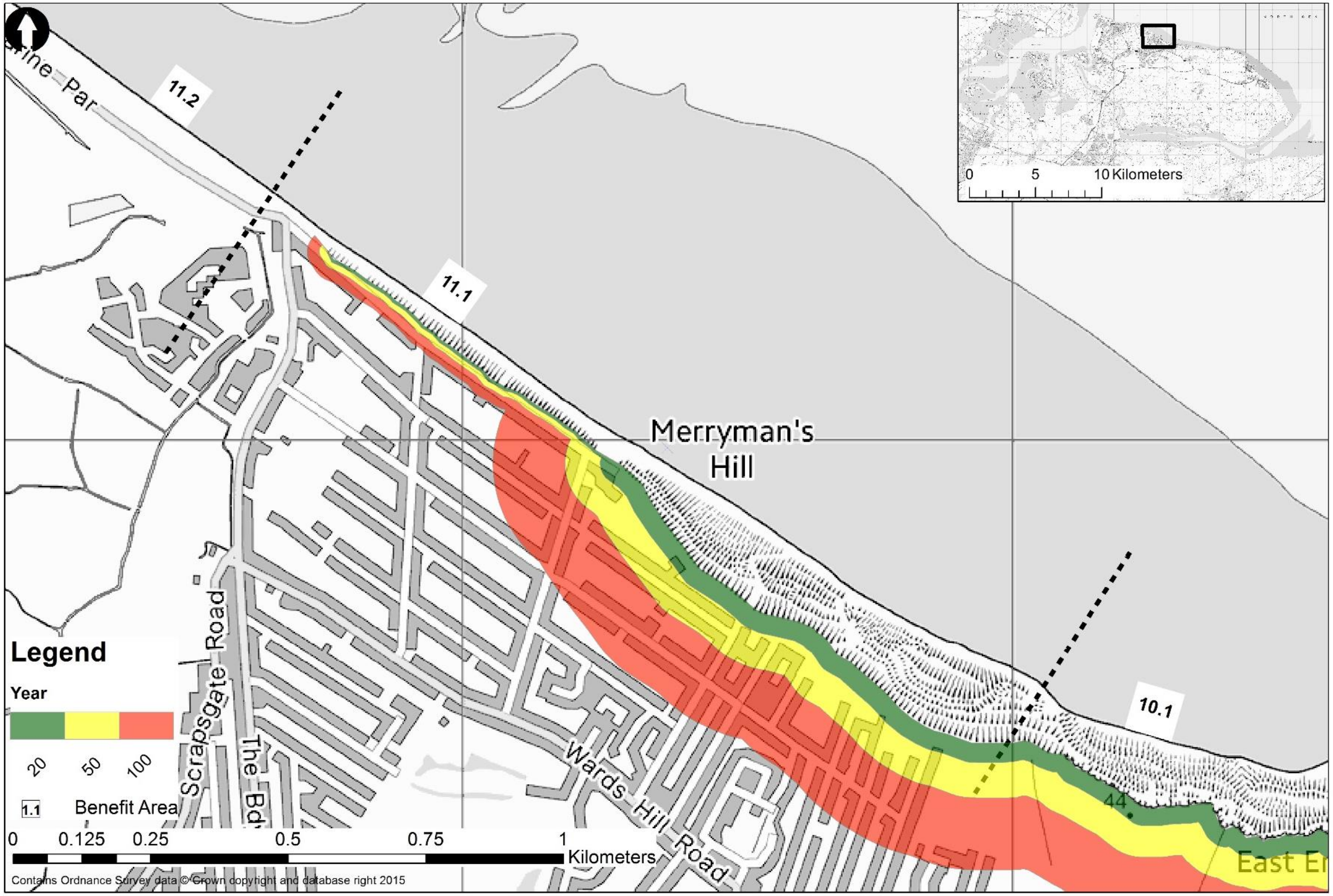
**Figure 13: Coastal Retreat in BA10.1**




Source: Ordnance Survey data © Crown copyright database right 2015

**Figure 14: Coastal Retreat in BA11.1**

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