Medway Flood Defence Strategy

High Level Appraisal of Potential Solutions to Manage Flood Risk in the Urban Medway

Final Report
February 2011

Prepared for

Revision Schedule

Medway Flood Defence Strategy – High Level Appraisal of Potential Solutions to Manage Flood Risk in the Urban Medway
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Executive Summary

Large scale physical regeneration is at the heart of the spatial strategies for both the Thames Gateway and for urban Medway. The successful redevelopment of the waterfront is required not only to improve the visual quality of the area and open up the river but also to meet development needs, including new housing and commercial development of a significant scale.

However the waterfront is vulnerable to flooding and, as such, a clear strategy is required to address this critical issue and provide a comprehensive response that can inform development and investment decisions and lead to coherent solutions that demonstrate a joined up approach.

For these reasons the Council commissioned this study with the active support of the Environment Agency.

This report is based on best available flood risk data and modelling information at the time of writing this report, which has been used to determine the standard of protection and condition of existing flood defence structures. The assessments have confirmed that a significant proportion of existing flood defences are below the required standard based on present day flood levels, which suggests that the study area has suffered from previous under investment in flood defence infrastructure.

The predicted impacts of climate change will exacerbate the existing situation and are likely to reduce the standard of protection further in the future, contributing to a requirement for additional investment to prevent a further reduction in the standard of protection into the future.

Potential 'high-level' flood defence options have been considered to provide the necessary level of flood defence. The generic options considered include use of 'hard' defences such as sheet piling and reinforced concrete walls in addition to 'soft' raised earth bunds.

The dockyard characteristics of the area and associated historic development policies which have been implemented have led to built development extending up to the flood defences in many areas. This typically prevents the use of 'soft' defences which require additional land take to provide the appropriate landscaped grading.

The provision of raised flood defence structures will create a barrier between the river environment and the surrounding area, however in order to provide flood protection intervention is required and the impacts of this must be understood.

The construction of a tidal barrage has not been considered as it is beyond the scope of this study which is focused on establishing flood defence options on a flood cell basis. The use of local planning policies which prevent development in close proximity to the river frontage and finished floor levels to be raised above floor levels are also not included within the scope of this study. However these management measures are likely to form the basis for redevelopment until such time as adequate flood defence provision is installed.

Economic analyses have been completed to estimate the likely damage costs attributed to flood events on a flood cell basis. These have been undertaken at an outline stage, and are based upon a number of assumptions; however the principal benefits and costs have been accounted for and the estimates are considered appropriate for broad strategy decision making.

The economic analyses have highlighted that the highest potential flood damages are located in the Gillingham Waterfront, St Mary's Island, Historic Dockyard, Medway City Estate and Strood areas. The Do

Nothing scenario flood damages for these three flood cells combined accounts for approximately 90% of the total damages calculated within the study area.

The costs of the required flood defence infrastructure are significant due to the extensive linear river frontage within the study area, which covers approximately 32.5km. The total estimated cost of providing the required standard of flood protection throughout the study area varies between approximately £190-280 million, which is clearly a very significant capital investment.

The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

Suggest phased implementation strategies have been produced on a flood cell basis in order to highlight areas where defence improvements should be prioritised for investment. The initial investment can be reduced by installing structures which will defend areas until 2060 which are then subsequently raised in the future.

Medway Council is considering whether a Supplementary Planning Document should be prepared, based, in part on the revised SFRA and this Flood Defence High Level Appraisal. This will involve decisions from the Council and other stakeholders regarding how flood risk management is approached along the Medway corridor.

1 Introduction

1.1 Background

1.1.1 A Strategic Flood Risk Assessment (SFRA) of the Medway Area was completed in 2006, under the now superseded Planning Policy Guidance (PPG) Note 25. The SFRA identified that the level of flood protection throughout the study area was generally inadequate and many of the defences were in poor condition.

1.1.2 The current Planning Policy Statement 25: Development and Flood Risk (PPS25) was subsequently released in December 2006 and has since been recently updated in December 2009. PPS25 included revised climate change predictions and more stringent requirements for flood risk management and does not permit development to proceed in areas which do not have the required standard of protection.

1.1.3 Since the 2006 SFRA was produced additional two-dimensional hydraulic modelling of the Medway has been completed. The modelling study only included flood risk information relating to overtopping of existing flood defences and did not consider defence breach scenarios. A number of flood event return periods were considered, including scenarios to represent present day conditions in addition to 50 years and 100 years of climate change. Linear interpolation has been applied to provide information relating to non-modelled events.

1.1.4 The Medway Estuary and Swale Shoreline Management Plan (SMP) was completed in 2010 which provides a large-scale assessment of the risks associated with coastal evolution and presents a policy framework to address these risks in a sustainable manner. The SMP concludes that the recommended policy throughout the study area is to 'hold the line' which means maintain the existing defence line.

1.1.5 Large scale physical regeneration is at the heart of the spatial strategies for both the Thames Gateway and for urban Medway, which includes the extensive urban waterfront and the adjoining town centres of Chatham and Strood.

1.1.6 The successful redevelopment of the waterfront is required not only to improve the visual quality of the area and open up the river but also to meet development needs, including new housing and commercial development of a significant scale.

1.1.7 However the waterfront is vulnerable to flooding and, as such, a clear strategy is required to address this critical issue and provide a comprehensive response that can inform development and investment decisions and lead to coherent solutions that demonstrate a joined up approach.

1.1.8 For these reasons the Council commissioned this study with the active support of the Environment Agency. The following extracts from the Pre-Publication Medway Draft Core Strategy illustrate the significance of the issue and the role that this report is intended to fulfil.

1.2 Pre-Publication Draft Core Strategy Extracts

Issues

1.2.1 Be aware that flood risk is a key environmental issue and therefore flood management issues need to be integrated into planning decisions. Whilst Medway has a significant proportion of previously developed land suitable for redevelopment within areas of lower flood risk, it is not appropriate to prevent all new developments in the areas of flood risk as it may be needed to avoid social and economic stagnation or blight.

Spatial Vision

1.2.2 Chatham will be transformed into a city centre for Medway that is also of regional significance. It will be a focus for shopping, leisure and cultural activity and a growing employment location, founded on its first class accessibility, city scale services and associated Higher and Further Education Centre of Excellence.

1.2.3 The urban waterfront (north bank: Temple Waterfront to Strood Waterfront; south bank: Rochester Riverside to Gillingham Waterfront) will have been similarly transformed, with mixed use developments of the highest quality linking the town centres and capitalising on the exceptional setting provided by the river Medway.

1.2.4 Rochester will continue to be recognised as a tourist destination, linked to the many attractions along the urban waterfront.

1.2.5 The River will be celebrated as the dominant and unifying geographical feature of the area through enhanced riverside walks and sensitive management of its commercial, leisure and environmental potential.

Strategic Objectives

1.2.6 To effectively realise Medway's role within the Thames Gateway and associated growth requirements primarily through effective physical regeneration, the reuse of previously developed land and the protection and enhancement of the area's many natural and heritage assets.

1.2.7 To develop Chatham as a city centre of regional significance with its role complemented by thriving and attractive traditional town centres in Strood, Rochester, Gillingham and Rainham together with a network of strong neighbourhood centres serving local communities.

1.2.8 To radically improve the quality of the townscape and public realm within the central urban area and along the urban waterfront.

1.2.9 To enhance the quality of life of local people through the promotion of healthier lifestyles and the provision of improved cultural, leisure and tourism facilities, including along the river Medway.

1.3 Summary

1.3.1 This overall study has been commissioned in order to firstly update the original SFRA in line with current policy and recent modelling information, and secondly to provide a further detailed study of the flood defence infrastructure which builds upon the recommendations of the SMP.

1.3.2 The deliverables of the overall study consist of an individual SFRA document, and this Flood Defence Strategy High Level Appraisal report, which should be read in conjunction with one another.

1.3.3 The key objectives of this report are as follows:

- Determine the flood cells and extents of flooding throughout the Medway area;
- Identify at a strategic level the current height and condition of flood defences to establish the general standard of protection within each flood cell;
- Undertake flood damage calculations in order to quantify the economic impact of flood events within each flood cell;
- Consider potential flood defence options and provide outline 'high-level' cost estimates;
- Summarise the benefits and costs of flood defence measures; and,
- Consider potential funding mechanisms and implementation strategies for the future.

1.3.4 In summary, this report sets out cost estimates to provide the required flood defence standard of protection and account for the predicted impacts of climate change. Medway Council is considering whether a SPD should be produced, which should be based in part, on this report and also other flood risk information to inform and support the SPD.

2 Flood Cells, Existing Defences and Flood Damages

2.1 Overview

2.1.1 This chapter provides an assessment of the existing risk of flooding throughout the study area, which has been split into a number of discrete flood cells in order to sub-divide the area.

2.1.2 The existing flood defences have been described and evaluated for each flood cell, following which the potential flood damages have been quantified.

2.1.3 The Environment Agency has confirmed that the 1 in 200 year (2110) flood event is the required standard of flood protection upon which this study is based. The Medway 2007 Modelling[1] outputs have been reviewed which confirm that the peak flood level throughout the study area for this scenario varies by approximately 0.07m.

2.1.4 The modelling report also states that the calibration exercise recorded differences in water levels of up to 0.08m for the climate change scenarios. As the variation in peak water levels over the study reach is less than 0.08m and is within the accuracy tolerance limits of the modelling, a constant flood level has been assumed throughout the study area. The highest flood level has been applied in line with the precautionary approach advocated within PPS25.

2.1.5 The Medway 2007 Modelling[2] study did not consider the impact of a breach in the flood defences, and simply considered overtopping scenarios. Where raised flood defences such as flood walls and embankments are present, consideration of failures and breaches is generally appropriate as detailed in PPS25. However where the defence is formed by raised ground, for example quay walls, breach scenarios are not necessarily appropriate as this would require failure of a significant volume of material which is highly unlikely.

2.1.6 As the majority of the study area does not contain raised defences the lack of breach information and the subsequent exclusion of these scenarios from this study is not considered to be a significant issue.

2.2 Flood Cells

2.2.1 The extent of an area at risk of flooding from a given flood event is essentially defined by the local topography. In simplistic terms, low lying areas adjacent to flood sources e.g. rivers, coasts and estuaries, typically have the highest risk of flooding, and the risk of flooding generally reduces as ground levels rise with distance from the flood source.

2.2.2 However this simplistic example does not account for localised areas of high ground and or the presence of built infrastructure which will affect the flow of water during times of flood. For example a local ridge line or a railway embankment may protect adjacent low lying areas from inundation during flood events.

2.2.3 The local topography throughout the study area has been used to divide the study area into a number of individual flood cells. This allows specific defence options, which are relevant to the flood cell under consideration, to be examined in an appropriate level of detail and cost estimates to be provided with a reasonable level of accuracy.

[1] Mott MacDonald (2007) *Lower Medway 2D Modelling & Flood Risk Mapping Phase 5',* Mott MacDonald: Cambridge.
[2] Mott MacDonald (2007) *Lower Medway 2D Modelling & Flood Risk Mapping Phase 5',* Mott MacDonald: Cambridge.

2.2.4 Nine flood cells have been delineated using the 1 in 200 year (2110) maximum flood extents from the Medway 2007 Modelling[3] as presented in Figure 1 of Appendix A. The model outputs were used to ensure that all relevant areas and land uses were included within subsequent cost-benefit analyses.

2.2.5 The flood extents produced by the modelling study have been compared with available topographic datasets. Any potential inconsistencies have been highlighted where necessary, however the model outputs are deemed to be the best available data.

2.2.6 A description of the flood cell extents is given in the following paragraphs.

Area 1 – Gillingham Waterfront, St Mary's Island and Historic Dockyard

2.2.7 This flood cell covers a large area of approximately 2.17km² incorporating the Historic Dockyard, Interface, St Marys Island, Gillingham Waterfront, Grange and Lower Tydall. The Historic Dockyard now forms an important tourist attraction as well as the recently developed Dickens World and outlet shopping within the Interface area.

2.2.8 St Marys Island is mainly a mixed residential development including a school, library and doctors surgery. The flood cell extends into Gillingham and incorporates "The Strand", which consists of a leisure park with outdoor swimming pool, miniature railway, 9-hole golf course and tennis courts.

Area 2 – Chatham Town Centre

2.2.9 The Chatham Town Centre flood cell covers an area of approximately 0.07 km² located on the southern bank of the River Medway. It includes the Medway Council Offices, shops and parkland. Higher ground located to the east constrains this flood cell to a relatively limited area along the river frontage.

Area 3 – Rochester Riverside

2.2.10 The Rochester Riverside flood cell is on the southern bank of the River Medway to the east of Rochester Town. The area of the flood cell is approximately 0.40km² that extends from Rochester to the end of Rochester High Street.

2.2.11 This flood cell includes a 32 hectare development site that has been granted planning permission for a mixed-used development which includes up to 2000 mixed-use houses, cafes/bars, restaurants, offices, a primary school, multi-storey car park and a hotel. The development includes upgraded flood defences and a new river wall.

2.2.12 During the site walkover it was noted that the ground levels across the development site had been raised, the upgraded flood defences and new river wall had been erected and a riverside footpath/cyclepath had been laid.

Area 4 – Rochester Town

2.2.13 The Rochester Town flood cell is located on the south side of the River Medway opposite Strood. The area of the flood cell is approximately 0.10km² and extends along the Esplanade in the south, to near the High Street in the north. It is limited by the topography that rises up into the historic town centre of Rochester.

[3] Mott MacDonald (2007) *Lower Medway 2D Modelling & Flood Risk Mapping Phase 5',* Mott MacDonald: Cambridge.

Area 5 – Lower Upnor

2.2.14 This flood cell extends from the landing stage in the Ministry of Defence land, to east of the Medway Yacht Club; covering approximately 0.06km². This flood cell is restricted to a narrow area extending along the river frontage as the land behind rises steeply to higher ground. Access and egress from Lower Upnor could potentially be a significant issue should flooding occur as there is only one access road.

Area 6 – Upper Upnor

2.2.15 This flood cell incorporates Gundolph Pool, Ministry of Defence land and a few residential dwellings. The flood cell covers an area of approximately 0.09km², and the land behind Upper Upnor rises steeply to restrict the flood cell to a relatively small area.

Area 7 – Medway City Estate

2.2.16 Medway City Estate is a development which mainly consists of offices and light industrial units constructed over the last 20 to 30 years. The estate is located on a peninsula and covers an area of approximately 1.1km^{2,} surrounded on three sides by the River Medway.

Area 8 – Strood & Strood Riverside

2.2.17 This flood cell incorporates the areas of Strood Centre, Strood Riverside and Medway City Estate, covering an area of approximately 1.55km². Strood Centre and Strood Riverside include some residential development and cleared/derelict brownfield land, however this area also includes local amenity shops along the High Street. There are some larger superstore shops such as Morrisons and Sports Direct, and towards the Temple Waterfront the flood cell includes some larger industrial warehouses.

Area 9 – Temple Waterfront

2.2.18 The Temple Waterfront flood cell is located on the north side of the River Medway upstream of Strood. The area of the flood cell is approximately 0.11km² and extends from Roman Way to the industrial estate behind Temple Marsh. Land to the west of the railway line is included within the flood cell, and it is understood this area floods via a culvert beneath the railway.

2.2.19 The 2007 Medway modelled flood extents show that this flood cell is independent from flooding of Temple Waterfront East. However the LiDAR data received as part of this study does not include any topographic features which would impede flood flows. The aerial photography was also reviewed and an impeding feature could not be identified.

2.3 Existing Defences

2.3.1 Medway Council has rights and responsibilities to manage the flood risk under Water Resource and Land Drainage Acts. It has further responsibilities due to its ownership of a significant number of sites and defences.

2.3.2 The Environment Agency has no ownership or maintenance responsibilities of any defences in this area, but as the Supervisory Authority, it has an overriding interest as the lead Flood Risk Management Authority. The Environment Agency will be leading on the production of a wider Flood Risk Management Strategy for the whole tidal Medway Basin (Allington Lock to Sheerness), which was highlighted as a priority action in the Medway Estuary SMP. It is

currently anticipated that the strategy will be progressed in 2012/13, however the precise start date is subject to funding availability. The flood defence strategy for urban Medway will help inform this.

2.3.3 An initial site walkover was undertaken which included visits to Chatham Town Centre; Gillingham Waterfront; Historic Dockyard; Rochester Riverside; St Marys Island; Strood Riverside; Strood Town Centre; and, Temple Waterfront. Following the initial site visit, an additional visit was undertaken to Lower and Upper Upnor and Medway City Estate.

Flood Defence Condition Grade

2.3.4 The NFCDD data includes information on the condition and crest level of the existing flood defences for the majority of the study area. However, unfortunately no NFCDD information was available from St Marys Island to Gillingham.

2.3.5 Where possible, information relating to the condition and crest level of the defences in this area has been inferred based on LiDAR data and site visits, however it should be noted that there are significant uncertainties associated with this part of the study area. It is recommended that additional verification is undertaken to confirm the defence information presented from St Marys Island to Gillingham, which is not included within the NFCDD information received.

2.3.6 The NFCDD includes a condition grade which is based on the guidance provided within the Environment Agency's Condition Assessment Manual[4]. The following condition classifications are assigned to each defence length:

- Very Good – Cosmetic defects that will have no effect on performance;
- Good – Minor defects that will not reduce the overall performance of the asset;
- Fair – Defects that could reduce the performance of the asset;
- Poor – Defects that would significantly reduce the performance of the asset. Further investigation need; and,
- Very Poor – Severe defects resulting in complete performance failure.

2.3.7 The condition grades contained within the NFCDD are presented as Figure 2A in Appendix A, which illustrates that the majority of the defences have been classified as 'Good' or 'Fair' condition. There is also a short defence length in Strood which is classified as 'Poor' condition. No defences have been classified as 'Very Good' or 'Very Poor'. A summary of condition grade by flood cell is shown overleaf in Table 2-1.

2.3.8 It should be noted that no condition information is available for a significant defence length stretching from St Marys Island to Gillingham, as indicated in Figure 2A (Appendix A). It was not considered appropriate to attempt to specify the condition of these defences due to a lack of suitable information sources and access problems during site visits. It was also considered that providing a condition grade based on unsuitable information could be mis-leading and would present a more significant risk than simply acknowledging that no relevant information is available for this area.

[4] Environment Agency (2006) *'Condition Assessment Manual Ref: 166_03_SD01',* Environment Agency: Bristol.

Table 2-1: NFCDD Defence Condition Grade

Flood Cell	Defence length by condition grade metres *(and as % of flood cell frontage)*					
	Very Good	Good	Fair	Poor	Very Poor	Not available
Gillingham, St Marys Island and Historic Dockyard	0 *(0%)*	2,670 *(21%)*	40 *(<1%)*	0 *(0%)*	0 *(0%)*	9,990 *(79%)*
Chatham Town Centre	0 *(0%)*	1,490 *(78%)*	420 *(22%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Rochester Riverside	0 *(0%)*	2,610 *(100%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Rochester Town	0 *(0%)*	1,230 *(83%)*	250 *(17%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Lower Upnor	0 *(0%)*	650 *(70%)*	280 *(30%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Upper Upnor	0 *(0%)*	300 *(44%)*	380 *(56%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Medway City Estate	0 *(0%)*	2,780 *(74%)*	1,000 *(26%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
Strood	0 *(0%)*	1,060 *(31%)*	1,970 *(58%)*	360 *(11%)*	0 *(0%)*	0 *(0%)*
Temple Waterfront	**0** *(0%)*	350 *(100%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*
TOTAL	**0** ***(0%)***	**13,140** ***(47%)***	**4,340** ***(16%)***	**360** ***(1%)***	**0** ***(0%)***	**9,990** ***(36%)***

Flood Defence Crest Levels

2.3.9 The NFCDD data provided as a GIS layer includes the following columns in relation to the crest height of the defence:

- "Actual Downstream Crest Level";
- "Actual Upstream Crest Level"; and,
- "Effective Crest Level".

2.3.10 For the majority of the defences, the 'Effective Crest Level' contained null values and therefore this was not used. The 'Actual Downstream Crest Level' and 'Actual Upstream Crest Level' values were typically the same, although as a conservative approach for this assessment an additional column was created using the minimum of these two values; "Minimum Actual Crest Level".

2.3.11 A full summary of the flood defence data is contained within Appendix B which lists the following information extracted from the NFCDD:

- NFCDD ID;
- Asset reference and maintainer;
- Asset comments and description;
- Asset location and grid reference;
- Asset length, design standard and condition; and,
- Actual crest levels (including upstream, downstream, and minimum values).

Identification of Sub-Standard Defence

2.3.12 The defences throughout the study area do not typically consist of raised walls and embankments, and raised ground areas forming quay wall structures are more common. When raised defences are present, the condition of the structure is often the key factor for determining whether defences are sub-standard, as this provides an indication of the likelihood of breach or failure. However when the 'defence' is formed by raised ground the crest level is the key driver for determining whether the defence is of an acceptable standard.

2.3.13 The crest level has therefore been used as the criteria to identify defences that are "sub-standard". The Environment Agency has confirmed that the 1 in 200 year event in 2110 flood level should be used as a conservative approach, using the 1D flood levels from the Medway Modelling.

2.3.14 The 1D in-channel flood levels from the 2006 Medway Model have been provided to inform the study, which include flood levels up to 2100. For the 2007 Medway model only the 2D water elevation grids, which includes climate change until 2110, have been made available.

2.3.15 The 2007 peak water level grids show that the modelled flood levels vary between the flood cells from 6.10mAOD in Hoo to 6.17mAOD in Temple Waterfront. The 2007 Medway modelling report[3] details the model calibration process and states that a difference in water levels of 0.08m was recorded between the modelled climate change scenarios and the January 1978 flood event at A2 Bridge in Rochester. Therefore given the likely margin of error in the model it was deemed that a 6.17mAOD is a reasonable flood level to use throughout the estuary.

2.3.16 Figure 2B in Appendix A presents the defences and their corresponding standard. Using the minimum actual crest level in the NFCDD the defences have been classified into 0.5m bands as follows. This information is also presented for each flood cell within Table 2-2.

- Dark Blue – Defence crest level between 5.67 and 6.17 mAOD;
- Light Blue – Defence crest level between 5.17 and 5.67 mAOD;
- Green – Defence crest level between 4.67 and 5.17 mAOD;
- Yellow – Defence crest level between 4.17 and 4.67 mAOD;
- Orange – Defence crest level between 3.67 and 4.17 mAOD;
- Red – Defence crest level less than 3.67 mAOD

2.3.17 As previously discussed, no NFCDD information was available from St Marys Island to Gillingham. The crest level for these defences was estimated based on LIDAR data and

information obtained during site visits. The estimated levels have been included in Figure 2B, Appendix B and are shown with a dashed/hatched line style to highlight that there is a greater uncertainty associated with this information.

2.3.18 It is recommended that the estimated crest levels from St Marys Island to Gillingham should not be relied upon without additional verification to confirm the levels specified are accurate.

2.3.19 A description of the defences has been compiled through a combination of the NFCDD, site walkover, anecdotal evidence and aerial photography which is contained in the following paragraphs. This should be read in conjunction with Figure 2B in Appendix A and Table 2-2.

Area 1 – Gillingham Waterfront, St Mary's Island and Historic Dockyard

2.3.20 The NFCDD describes the defences as a raised wall adjacent to the Historic Dockyard that is verified by the aerial photography. The Interface Area is described as having a masonry seawall with concrete blockwork capping / additional concrete wall on top. St Marys Island is described as having a backfilled seawall with a block revetment.

2.3.21 The NFCDD is not available east of St Marys Island due to the land being of private ownership. Therefore, a defence line was manually drawn using the 1:10,000 Ordnance Survey mapping, aerial photography and the LiDAR data. This line was firstly drawn continuously but as the types of defence vary it was split into sections based on points where it was identified that the defence type, and thus the crest level had changed. Where possible the defence condition was classified through a review of the aerial photography and observations made in the site walkover. The defence type consists of a mixture of sheet piling, concrete revetments with associated groynes.

2.3.22 Where available, the NFCDD classifies the defence condition as 'Good', with the exception of a very short length in the Chatham historic Dockyard area at King Stairs Wharf which is classified as 'Fair'.

Area 2 – Chatham Town Centre

2.3.23 The NFCDD describes the flood defence as a piled defence, which was verified during the site walkover and through reference to aerial photography. A concrete capping beam and safety railings on top of the piles were typically observed; the level of the adjacent river walkway was similar to the crest level of the capping beam.

2.3.24 The NFCDD classifies the defence condition as 'Good' throughout the majority of the flood cell, however some limited lengths between Ship Pier and Sun Pier are classified as 'Fair'.

Area 3 – Rochester Riverside

2.3.25 The NFCDD describes the defences along Acorn Wharf up to Gashouse Point as a piled wall. From Gashouse Point along Limehouse Wharf the defence is described as a piled defence backed up by a raised embankment. Corys Wharf and Stanley Wharf and described as a piled defence.

2.3.26 These defences have recently been upgraded, however the NFCDD classifies the condition as 'Good' throughout the flood cell. It is considered likely that the condition of these new defences should be revised to 'Very Good'. As part of the defence upgrades, land raising has also been undertaken to significantly reduce the residual risk in the unlikely event of a defence breach.

Area 4 – Rochester Town

2.3.27 The NFCDD describes the defences along the Esplanade (from far end of Applecross Close to Medway Rowing Club) as a concrete sea wall. The defences along the Esplanade (between Applecross Close and Tupman Close) are described as a seawall with concrete capping. The defences along the Esplanade (Hathaway Court to Tupman Close) are described as a concrete wall. The defence at the point near to Hathaway Court are described in the NFCDD as rock armour and concrete revetment with timber fenders. The defence along the Esplanade from the previous point along the salt marsh to Rochester Bridge is described as a concrete wall. Aerial photographs have been used to confirm and verify this information.

2.3.28 The defences throughout this area have typically been backfilled to create river walkways which have a similar ground level as the crest levels of the defences. However there are some areas where raised defence walls are present.

2.3.29 The NFCDD information classifies the defence condition as 'Good' throughout the majority of the flood cell, however some limited areas towards the southern extent of the flood cell, in the vicinity of Applecross Road are classified as 'Fair'.

Area 5 – Lower Upnor

2.3.30 The NFCDD describes the defence construction in this area as a concrete seawall. During the site walkover it was noted that the landward side of the defences had typically been backfilled to form a level consistent with the flood defence crest level. This was also observed during reviews of aerial photography.

2.3.31 The NFCDD information classifies the defence condition as 'Good' throughout the majority of the flood cell, however some areas in the vicinity of Medway Yacht Club are classified as 'Fair'.

Area 6 – Upper Upnor

2.3.32 The NFCDD describes the defence adjacent to Gundolph Pool as a rock revetment with concrete blockwork present adjacent to the Ministry of Defence landing stage. It was not possible to gain access to inspect these defences. To the north of the landing stage the NFCDD states a seawall is present. The ground behind the defences at this location rises steeply away from the river, with only a limited area being at risk of potential inundation.

2.3.33 The NFCDD information classifies the defence condition as either 'Fair' or 'Good' throughout the flood cell.

Area 7 – Medway City Estate

2.3.34 The NFCDD describes the defence around Medway City Estate as a mix of defences consisting of masonry wall, sheet pile wall or a rock armoured embankment. A continuous sheet pile or concrete wall was observed on the southern section during the site walkover, incorporating significant backfilling to form a level consistent with defence crest levels.

2.3.35 The NFCDD information classifies the defence condition as 'Good' throughout the majority of the flood cell. Some areas in the vicinity of Laser Quay, Chatham Ness and Clipper Close are classified as 'Fair'.

Area 8 –Strood & Strood Riverside

2.3.36 The NFCDD describes the defence adjacent to the Saw Mills in Strood as an earth embankment, further north adjacent to the scrap yard it is described as a rubble armoured embankment; this is verified in the aerial photography. The defence in the mouth of Jane's Creek is described as backfilled timber piling on the Strood Centre side of Jane's Creek, which becomes a concrete wall that was observed during the site walkover in the vicinity of the ambulance station. A backfilled sheet pile wall then continues from Jane's Creek under Rochester Bridge to Strood Pier. From Strood Pier to the public house the defences are a backfilled stone wall which becomes a backfilled masonry wall at the public house.

2.3.37 The NFCDD information classifies the defence condition as 'Fair' throughout the majority of the flood cell, with some areas from Strood Pier to the Civic Centre classified as 'Good'. In the vicinity of the Ambulance Station the defence condition is classified as 'Poor'.

Area 9 – Temple Waterfront

2.3.38 The NFCDD describes the existing defences as a concrete wall which has been verified in the site walkover. The LiDAR data shows that a significant proportion of the Temple Marsh area, located directly behind the defences has been raised.

2.3.39 The NFCDD information classifies the defence condition within this flood cell as 'Good'. Some adjacent areas are classified as 'Fair' condition, however these are located adjacent to higher ground which would prevent flooding of the land behind.

2.4 Potential Flood Damages

2.4.1 The residential and non-residential properties were delineated within the flood cell using Ordnance Survey mastermap data provided by Medway Council. The land use codes were classified based on observations during the site walkover and a review of the aerial photography; these were based on the codes with the multicoloured manual[5].

2.4.2 The damage prices were extracted from the multicoloured manual for residential properties (Appendix 4.1 (long duration)) and for the non-residential properties (Appendix 5.5). The 2005 prices in this index were adjusted using the House Prices Index available on the Land Registry website. For Kent the December 2005 index was recorded to be 273% and February 2010 (most recent available was recorded to be 278%, this is based on 1995 being 100%. Therefore the 2005 house prices were increased by 5%.

2.4.3 Excel spreadsheets were set up to calculate the 'Do Nothing' damage costs associated with the depth of flood for each of the properties (residential and non-residential) using the modelled results described later.

2.4.4 As this is a strategy study the residential properties were not further differentiated in terms of age and social class. For the non-residential properties the weighted mean values were taken for the shop/store, vehicle services, retail services, office and distribution logistics categories. For the non-residential properties the damage costs/m² were taken and then multiplied by the area derived from Ordnance Survey master map data using GIS.

[5] Flood Hazard Research Centre. (2005) *'The Benefits of Flood and Coastal Risk Management: A Handbook of Assessment Techniques',* Middlesex University: London.

2.4.5 The Medway 2007 modelled results were used to derive the flood depth at each of the delineated residential and non-residential properties. In order to create a more robust analysis it was agreed with the Environment Agency that additional return periods could be populated based on interpolations from available model runs. Further details are provided in Appendix C.

2.4.6 The flood damages were then calculated for these additional return periods as for the modelled return periods using the multi-coloured manual[5].

2.4.7 Using these damage costs the Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG[6]) Economic Appraisal spreadsheet was used to obtain the present value damages. As discussed in section 4.4 the flood damage calculations have not been completed for Rochester Riverside.

2.4.8 A summary of the potential flood damages for the Do Nothing scenario are presented in Table 2-2 in addition to a breakdown showing crest levels of the existing flood defences. A full breakdown of flood defence information extracted from the NFCDD is contained within Appendix B.

Table 2-2: Summary of Flood Defence Levels and Do Nothing Flood Damages

Flood Cell	Defence lengths in relation to 1 in 200 year 2110 flood level [6.17mAOD)] metres *(and as % of flood cell frontage)*						Total	Indicative 'Do Nothing' Damages (£ million)
	6.17-5.67mAOD [0-0.5m below]	5.67-5.17mAOD [0.5-1m below]	5.17-4.67mAOD [1-1.5m below]	4.67-4.17mAOD [1.5-2m below]	4.17-3.67mAOD [2-2.5m below]	<3.67mAOD [>2.5m below]		
Gillingham, St Mary's Island and Historic Dockyard*	1,190 *(9%)*	2,205 *(17%)*	540 *(4%)*	6,560 *(52%)*	2,210 *(17%)*	0 *(0%)*	12,705	28.62
Chatham Town Centre	0 *(0%)*	520 *(28%)*	860 *(46%)*	310 *(17%)*	180 *(10%)*	0 *(0%)*	1,870	4.58
Rochester Riverside	2570 *(100%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	0 *(0%)*	2,570	n/a
Rochester Town	450 (30%)	240 (16%)	0 (0%)	440 (30%)	350 (24%)	0 (0%)	1,480	1.19
Lower Upnor	240 *(26%)*	330 *(35%)*	270 *(29%)*	90 *(10%)*	0 *(0%)*	0 *(0%)*	930	1.57
Upper Upnor	30 *(4%)*	0 *(0%)*	230 *(33%)*	140 *(20%)*	210 *(30%)*	80 *(12%)*	690	0.96
Medway City Estate	560 *(15%)*	970 *(25%)*	895 *(23%)*	580 *(15%)*	660 *(17%)*	150 *(4%)*	3,815	20.40
Strood	0 *(0%)*	300 *(14%)*	120 *(6%)*	760 *(36%)*	920 *(44%)*	0 *(0%)*	2,100	23.21
Temple Waterfront	0 *(0%)*	0 *(0%)*	0 *(0%)*	350 *(0%)*	0 *(0%)*	0 *(0%)*	350	0.05

* NFCDD was not available for the majority of this area. The crest levels have been estimated based on LiDAR data and site visits, therefore significant uncertainties remain regarding the actual crest level, levels stated here should be taken as indicative only.

[6] Environment Agency (2010) *'Flood and Coastal Erosion Risk Management appraisal guidance',* Environment Agency: Bristol.

3 Flood Defence Strategy Options

3.1 Overview

3.1.1 Flood defence strategy options have been compiled for the entire study area. The specific areas are presented within Figures 3a to 12b, which provide schematic plans of potential defence options which have been formulated using the methodology contained below.

3.1.2 The Environment Agency has stated that the required standard of flood protection is based on the 1 in 200 year (2110) flood level of 6.17mAOD. Other options which provide a lower standard of protection have therefore not been considered.

3.2 Methodology

3.2.1 The potential flood defence strategy options have been prepared based on site walkovers and existing information. It should be noted that these are outline options only and are presented here in order to develop an appreciation of the approximate order of magnitude costs. The precise alignment of defences can be modified to however this is unlikely to have a significant impact on the costs and benefits.

3.2.2 Indicative sketches of typical defence types are shown within Figure 3-1 to Figure 3-3. These are generic options, which are not site specific and have been prepared in order to permit comparison of potential options only.

Figure 3-1: Generic Defence Type 1; Earth Bund

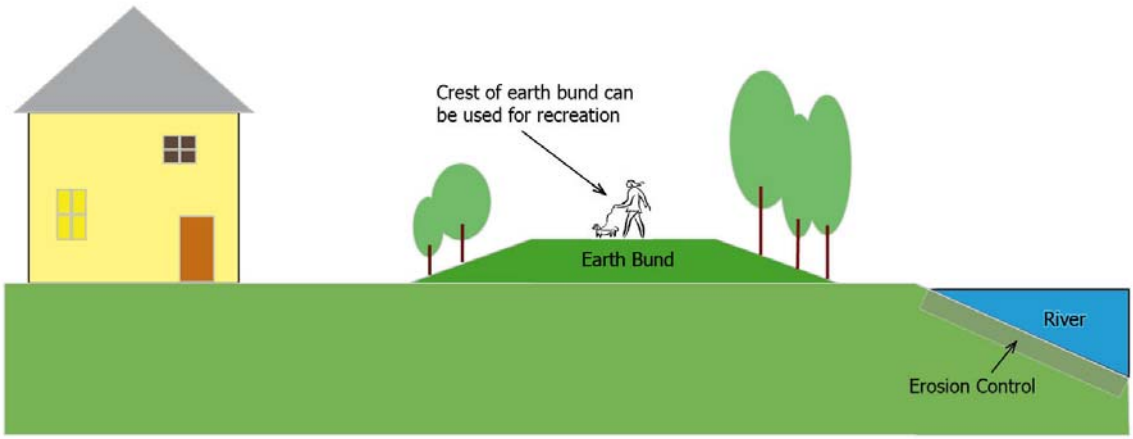


Figure 3-2: Generic Defence Type 2; Sheet Piling with Concrete Capping Beam

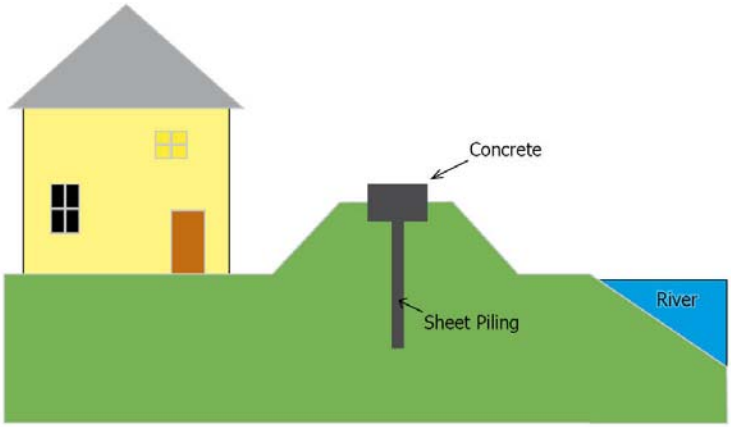
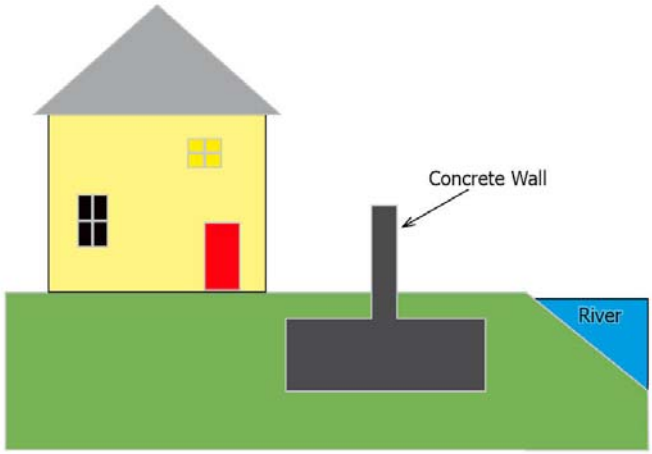


Figure 3-3: Generic Defence Type 3; Reinforced Concrete Wall



3.2.3 The costs of the indicative defence options have been prepared based on SPONs Civil Engineering and Highway Works Price Book (2007). This methodology is considered to be sufficient to develop 'rough order of magnitude' (ROM) costs at an options strategy stage, however further study will be required to provide greater cost certainty.

3.2.4 The estimated cost for sheet piling works were also compared with the actual costs for the construction of defences at Rochester Riverside, and modified to ensure the cost estimates appropriately reflected the actual construction costs in the study area.

3.2.5 The cost breakdown and materials diagrams are shown in Appendix D, which lists the assumptions made to calculate an approximate cost per metre of defence type. Due to the approximate nature of these calculations, the cost per metre of defence type has been rounded to the nearest thousand pounds.

3.2.6 It has been assumed that the reinforced concrete wall (generic option 3) can only be implemented when the defence crest is up to 0.5m below the required level. It has been assumed that the existing defence foundations will not be strong enough to support any

additional increase in crest level above this value. Flood defence options have also been extended to cover the entire river frontage and not just the flood cell.

3.2.7 As the existing flood defences are more than 0.5m below the required crest level throughout the vast majority (approximately 85%) of the study area, this assumption means that a phased programme of wall raising is unlikely to be a feasible approach, and complete replacement of defences throughout each flood cell is likely to be required.

3.2.8 For each flood cell the following potential flood defence options have been considered:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilience measures (refurbish existing properties to be flood proofed where possible together with demountable flood boards on windows and doors as necessary), estimated as 30% of the Do Nothing damages);
- Option C: New 'hard' sheet piled defence to the 1 in 200 year 2110 flood level of 6.17m AOD;
- Option D: New 'hard' sheet piled defence to the 1 in 1000 year 2110 flood level of 6.43m AOD;
- Option E: Combination of measures including use of 'soft' set-back flood defence bunds, 'hard' sheet piled defences, designating specific areas as 'water compatible' in combination with other measures in relation to the 1 in 200 year 2110 flood level of 6.17m AOD;
- Option F: Combination of measures including use of 'soft' set-back flood defence bunds, 'hard' sheet piled defences, designating specific areas as 'water compatible' in combination with other measures in relation to the 1 in 1000 year 2110 flood level of 6.43m AOD; and,
- Option G: Land raising throughout the flood cell to the 1 in 200 year 2110 flood level of 6.17m AOD in combination the measures included as Option E.

3.2.9 The flood resilience measures considered as Option B effectively involve retrofitting measures to existing properties. This will not reduce the risk of flooding, however it will reduce the consequences of flooding to existing properties through a reduced clean-up operation. However this option does not provide any benefit to new development within the flood cell.

3.2.10 'Hard' sheet piled defence has been considered for Options C and D as there is minimal land take involved and for much of the river front development is close to the waters edge, preventing the use of 'soft' setback defences which require greater areas of land take.

3.2.11 Options E and F have been considered to reflect the desire to minimise the use of hard defences where possible. 'Soft' defences have been included where there is likely to be space available, and flood gate structures have been included where possible to reduce the presence of 'hard' defences.

3.2.12 It should be noted that the use of flood gates is not a preferred option as manual intervention is typically required to operate the structure therefore this provides an additional 'failure' mechanism. The use of flood gates also relies upon railway embankments acting as 'de facto' defences in some areas. Whilst this is considered to be an appropriate assumption it should be noted that their maintenance and integrity cannot be guaranteed as fall under the responsibility of third parties.

3.2.13 Option G has been included to give an indication of the costs associated with land raising measures for each flood cell. It should be noted that this is only likely to be a feasible option when large scale regeneration of the entire flood cell is carried out, and the majority of existing development is demolished.

3.2.14 The required level of land raising is often up to several metres in some areas, therefore this would clearly have significant implications if existing buildings, services and associated infrastructure were required to be retained. It is considered unlikely that the compatibility issues associated with existing development and land raising could be overcome by modifications to existing infrastructure, therefore removal of the existing development and full replacement with new provision would be required. The costs for this new provision have not been accounted for.

3.2.15 Other options were initially considered. These include provision of flood storage, however the area of land that would be required for this is not available or practical. Channel improvements were also considered but due to the tidal nature of the river increasing conveyance would have a negligible impact on peak flood levels.

3.2.16 Defence options such as a tidal barrage, limiting development within 20m of the high water mark to facilitate future soft defences and only allowing development to go ahead with a finished floor level above 6.77m AOD are outside the scope of this study and/or considered to be risk management methods and not defence options.

3.2.17 The use of demountable flood defences has also not been considered, as they still require construction of supporting foundations the cost of which will be a similar order of magnitude to the sheet piled defence costs. The time required to erect long lengths of demountable defences is also a potential barrier to their successful deployment therefore they are only a realistic option when considering localised short lengths which is not appropriate for this strategy scale study. The Environment Agency has suggested the use of demountable defences on a site specific basis.

3.2.18 Although provision of a tidal barrage across the Medway is not within the scope of this study, the use of localised, smaller scale flood gates has been considered as a potential option. Further detailed investigations will be required to confirm whether these options are technically feasible, principally due to existing services and built infrastructure, and also to revise likely design and construction costs which are both highly dependent on local site conditions.

3.2.19 The defence options considered in this study have been developed to meet the Environment Agency's required 1 in 200 year 2110 flood level standard of protection. However a phased approach to defence construction should be considered, to enable initial provision to meet the 2060 flood level, but design such that straightforward raising to the 2110 flood level would be possible at some point in the future. This approach has already been adopted at both the Rochester Riverside and St. Mary's Island developments within the study area.

3.3 Benefit/Cost Analysis Methodology

3.3.1 In order to quantify the potential costs and benefits of provision of various flood defence options an economic assessment has been completed for each identified flood cell. The Environment Agency's Flood Risk and Coastal Erosion Risk Management appraisal guidance has been used in conjunction with guidance provided within the Flood Hazard Research Centre's Multi-Coloured Manual (MCM) and handbook.

3.3.2 However a full benefit/cost analysis has not been completed and corresponding ratios have not been presented within this report for the various options considered. This is because the benefits considered to not reflect the future development potential of the area, and due to the current economic uncertainties it is not considered to be appropriate to include benefit/cost ratios at this point in time.

3.3.3 It should be noted that the following assumptions have been made, in addition to the previously discussed flood defence options assumptions:

- The flood damages have been calculated based on the existing land use and scale of development located within the flood cell. If this is subject to change in the future then the associated benefits will also change, however it is against guidance to take this into account within the benefit/cost assessment;
- The flood damages associated with flood resilience option have been assumed to be 60% and 80% of the Do Nothing damages for residential and commercial property respectively. These percentages have been calculated by reviewing the various components which make up the depth-damage values within the Multi-Coloured Manual and estimating which damages could reasonably be avoided or reduced through flood resilience;
- The cost associated with flood resilience measures has been estimated as 30% of the 'Do Nothing' damages within the flood cell, this is based on the average reduction in flood damages assumed for this option for residential and commercial development;
- The cost associated with land raising has been estimated based on a rate of £40 per m^3 of fill material, and the required volume has been estimated from LiDAR data. The total cost for this option is therefore highly sensitive to the unit cost of material;
- The land raising costs also do not include for the associated infrastructure works which would be required to provide utility services such as gas, electricity, telecommunications, potable water, surface water drainage and sewerage. Implementation of this option is only likely to be feasible scenario if large scale regeneration of the flood cell is proposed, which will require demolition of existing development to permit land raising. No flood damages or benefits have therefore been estimated for this option as no existing property would be present to benefit from the works.
- The flood damages associated with events equal to and greater than a 1 in 1000 year event magnitude have been assumed to remain constant for all options, as no additional damages information is available for the options under consideration. This results in an over-estimation of the remaining damages for the defence options considered;
- An optimism bias adjustment of 60% has been assumed for costs, in line with Environment Agency guidance for strategy stage assessments;
- The estimated damages do not include any consideration of disruption to transport links. Environmental, social and deprivation impacts have also not been included within the assessments.
- All damages are based on hydraulic model outputs which although considered to provide an accurate representation of catchment wide flood depths it is possible they will not be sufficiently accurate on a localised property specific scale;
- The estimated capital costs do not include any provision for ongoing maintenance costs or allowances for professional fees, land acquisition, disposal of any contaminated spoil.

- The generic defence options have not been based upon any ground investigations which may determine that certain options are not technically feasible.

3.3.4 The benefit/cost analysis summary sheets for each flood cell are included within Appendix E.

3.4 Summary

3.4.1 The benefit/cost analyses completed for each flood cell are presented and discussed within chapter 4. A summary table showing the combined benefits and costs for all flood cells considered throughout the study area is shown as Table 3-1. It should be noted that this summary excludes any benefits and costs attributed from the Rochester Riverside development as discussed in section 4.4.

Table 3-1: Summary of Rough of Magnitude (ROM) Flood Damages, Benefits and Costs

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£80.68	n/a	n/a
B	Flood resilience measures	£63.60	£17.09	£38.73
C	New sheet piled hard defence to 1 in 200 year 2110 level	£8.47	£72.22	£269.98
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£6.32	£74.36	£288.71
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£25.47	£55.21	£150.64
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£24.45	£56.23	£156.77
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£524.78*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

3.4.2 The benefit/cost analysis suggests that the preferred option is implementing flood resilience measures throughout existing properties within the flood cell. However it should be noted that the costs and benefits of this option are based on assumptions because accurate quantification on a flood cell by flood cell basis is considered to be beyond the scope of this study.

3.4.3 It is possible that by following a phased approach to flood defence improvements, substantial costs could be deferred into the future. However this also has the effect of deferring the benefit provided by the works.

3.4.4 It should be noted that a number of factors have not been accounted for within the analyses, both in terms of benefits and the costs, as listed within section 3.3.

4 Site Specific Considerations

4.1 Overview

4.1.1 This chapter quantifies the estimated flood damages for the Do Nothing scenario for each flood cell and estimates of likely benefit provided by each defence option under consideration. Schematic plans illustrating the options considered are provided for each flood cell within Figures 3a – 12b in Appendix A.

4.1.2 As discussed in section 3.3, a full benefit/cost ratio analysis has not been completed because the benefits considered do not reflect the future development potential of the area, and due to the current economic uncertainties it is not considered appropriate to include benefit/cost ratios at this point in time.

4.1.3 The most appropriate solution to support wide scale regeneration is to consider defence improvements on a flood cell basis. This will ensure that large areas are unlocked for redevelopment, whilst reducing the additional costs associated with providing flood defence and safe access provision for individual sites. The implementation of a strategic solution throughout the flood cell reduces the risk of a fragmented defence network remaining as a future legacy, as is currently the case in some parts of the study are where a piecemeal approach has historically been applied.

4.1.4 Medway Renaissance has highlighted that certain flood cells and sites within the overall study area are higher development priorities. The Do Nothing flood damage curves have therefore also been provided for these areas for the present day, 2060 and 2110 timeframes. The damage curves show how the economic cost of flooding will change over time due to the predicted impacts of climate change.

4.1.5 It should be noted that the horizontal scales of the flood damage curves vary between the three timeframes considered for each flood cell. Due to the high damage costs of very low frequency occurrence events it is often difficult to determine changes in damage values from the graphs, however they are primarily provided here for illustrative purposes.

4.2 Area 1 – Gillingham Waterfront, St Mary's Island and Historic Dockyard

4.2.1 The existing defences in the vicinity of Gillingham Waterfront, St Mary's Island and the Historic Dockyard are typically between 1m and 2.5m below the required standard of protection. The area is heavily developed with residential, retail and industrial areas and has a number of key transport links including a major road (A289) and railway line (London to Faversham).

4.2.2 Due to the existing development infrastructure and characteristics of the built environment there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options. The historic dockyard will also pose as a constraint to the defence options available.

4.2.3 This flood cell covers a large area but due to the significant length of waterside dock frontage there is also a disproportionately high defence length required. As the dock areas could

provide a potential flood flow route, measures to defend the dock areas are required in order to protect the entire flood cell from 'backdoor flooding'.

4.2.4 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated at 30% of the Do Nothing damages;
- Option C: 4.3km of new sheet piled defence to the 1 in 200 year 2110 flood level;
- Option D: 4.3km of new sheet piled defence to the 1 in 1000 year 2110 flood level;
- Option E: 2.4km of new sheet piled defence[7], 2.3km of additional concrete capping or new concrete wall, new flood gate, earth bund to the 1 in 200 year 2110 flood level and existing defences retained along Gillingham Waterfront (area to be designated for water compatible uses);
- Option F: 2.4km of new sheet piled defence[7], 2.3km of additional concrete capping or new concrete wall, new flood gate, earth bund to the 1 in 1000 year 2110 flood level and existing defences retained along Gillingham Waterfront (area to be designated for water compatible uses).
- Option G: 2.6 x 10^6 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-1: Summary of Gillingham Waterfront, St. Mary's Island and Historic Dockyard 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£28.62	n/a	n/a
B	Flood resilience measures	£22.58	£6.04	£13.74
C	New sheet piled hard defence to 1 in 200 year 2110 level	£3.88	£24.74	£137.08
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£2.75	£25.87	£146.41
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£19.04	£9.58	£49.19
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£18.89	£9.73	£51.32
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£216.34*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

[7] Included to reflect limited land availability.

Figure 4-1: Gillingham et al; Do Nothing Flood Damage Curve (2010)

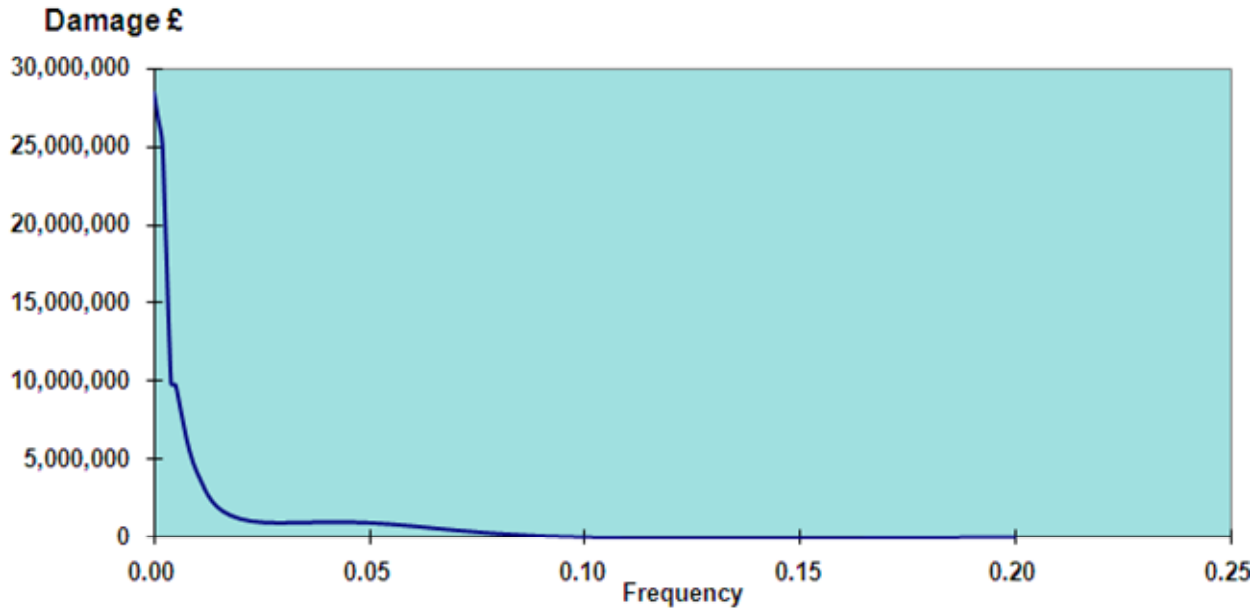


Figure 4-2: Gillingham et al; Do Nothing Flood Damage Curve (2060)

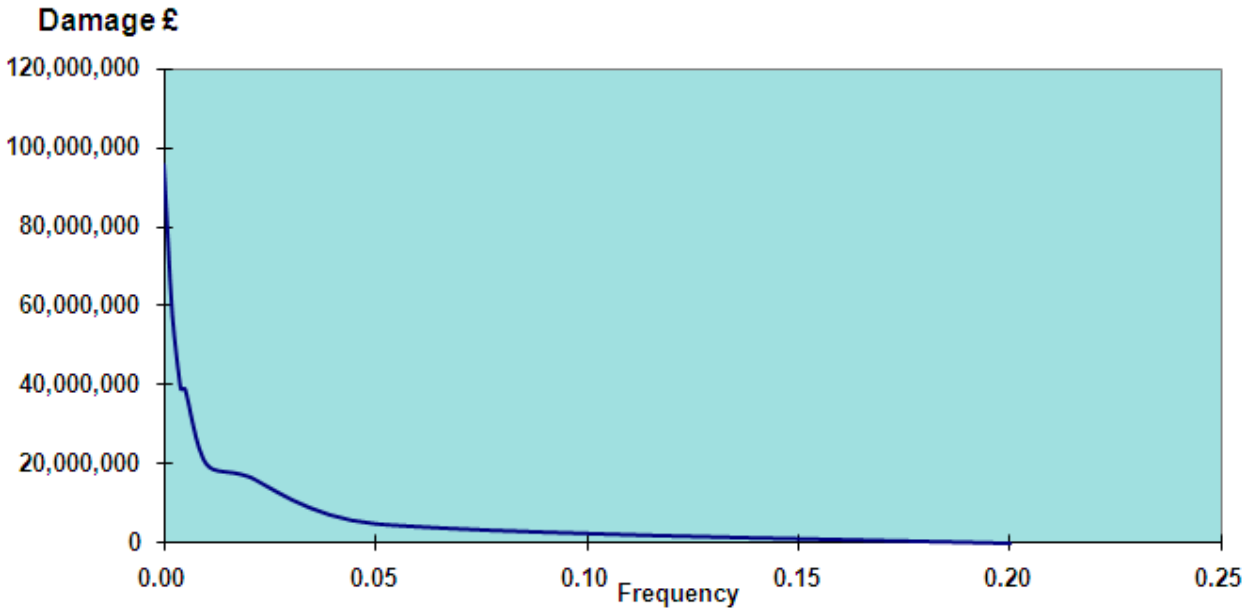
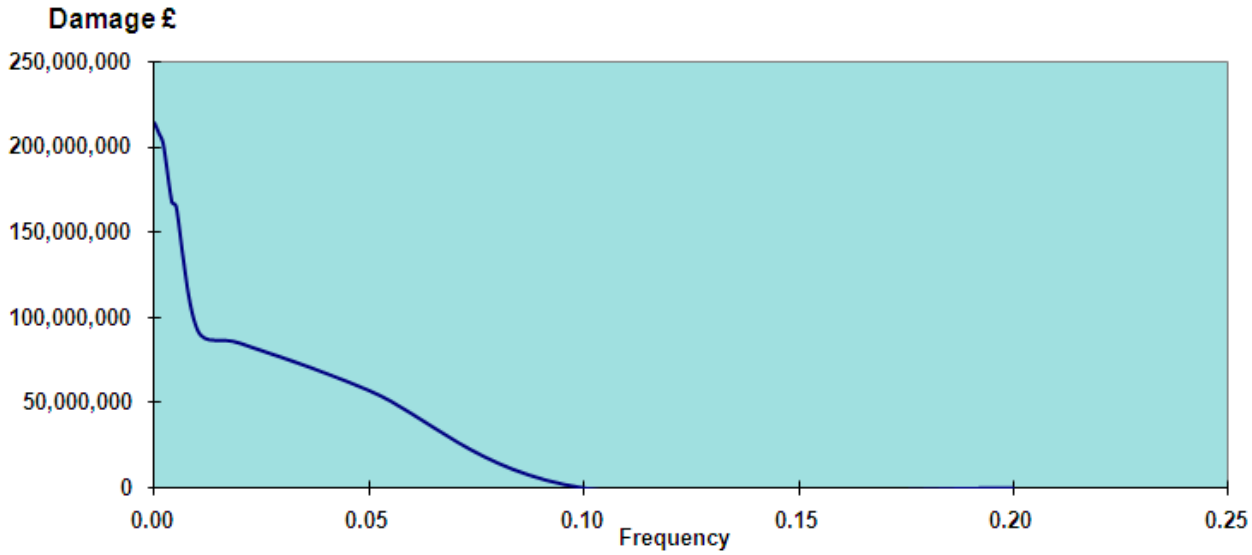


Figure 4-3: Gillingham et al; Do Nothing Flood Damage Curve (2110)



4.2.5 The Gillingham, St Mary's Island and Historic Chatham flood cell covers a very large area and therefore has the highest estimated flood damage cost for the Do Nothing scenario of £28.2 million.

4.2.6 It is understood that planning approval has recently been granted to raise the existing defences around the northern perimeter of the island to the 1 in 200 year 2110 level. However as this defence improvement has not yet been constructed, it has not been accounted for within this study.

4.2.7 The area contains extensive quay areas and therefore has a particularly long waterside frontage. All of these areas provide a potential flood flow path therefore in order to defend St. Mary's Island an extensive length of new walls/embankments would be required. This would also have the affect of creating visual barriers between the quay and the surrounding area which is undesirable.

4.2.8 The suggested option to prevent flooding via the dock is to install a flood gate at the lock entrance which significantly reduces the quay length which would require raising. There are two potential locations, the first is an outer gate at Bull Nose, and the second is an inner gate adjacent to Chatham Docks. Both options would require additional quay raising, with a longer length required with an inner gate.

4.2.9 An inner flood gate provides the opportunity to utilise the raised ground (located to the north-east of the quay areas) as part of the flood defence network, although it should be noted this would not provide protection to the industrial areas on the east of St Mary's Island to the north of Bull Nose

4.2.10 The flood cell also includes the Historic Dockyard, and the defence options in this area are likely to be significantly constrained by heritage requirements. It should be noted that the defences in this area, are generally higher than other locations in the flood cell.

4.2.11 The A289 Medway Tunnel also lies within this flood cell, which is an important asset and transport link which must be defended.

4.2.12 The defences along Gillingham Waterfront are the lowest within the flood cell, this area includes mainly lower risk industrial uses and the leisure park. The cost associated with defending the Gillingham frontage is significant, (£18-19 million) therefore a potential option could be designate this area as 'water compatible'. However the industrial uses have big floorspace and they therefore make up a large proportion of the total flood damages, as demonstrated by the significant flood damages remaining for Options E and F when this area is not actively defended.

4.2.13 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.3 Area 2 – Chatham

4.3.1 The existing defences in the vicinity of Chatham are typically between 1m and 1.5m below the required standard of protection. The area is developed with navy buildings, the Council Offices, and retail buildings.

4.3.2 Due to the existing development infrastructure and characteristics of the built environment there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options. However, an area of public open space is already located along the waterfront, and this could be landscaped to provide flood defence benefits.

4.3.3 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated at 30% of the Do Nothing damages;
- Option C: 1.8km of new sheet piled defence to the 1 in 200 year 2110 flood level;
- Option D: 1.8km of new sheet piled defence to the 1 in 1000 year 2110 flood level;
- Option E: 0.7km of new sheet piled defence[7] and 0.6km earth bund to the 1 in 200 year 2110 flood level, with 0.5km of the existing flood defence remaining;
- Option F: 0.7km of new sheet piled defence[7] and 0.6km earth bund to the 1 in 1000 year 2110 flood level, with 0.5km of the existing flood defence remaining.
- Option G: 1.1 x 10^5 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-2: Summary of Chatham 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£4.58	n/a	n/a
B	Flood resilience measures	£3.66	£0.92	£2.20
C	New sheet piled hard defence to 1 in 200 year 2110 level	£0.57	£4.01	£17.68
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£0.44	£4.14	£18.89
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£1.50	£3.08	£12.00
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£1.50	£3.08	£12.64
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£19.27*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

Figure 4-4: Chatham; Do Nothing Flood Damage Curve (2010)

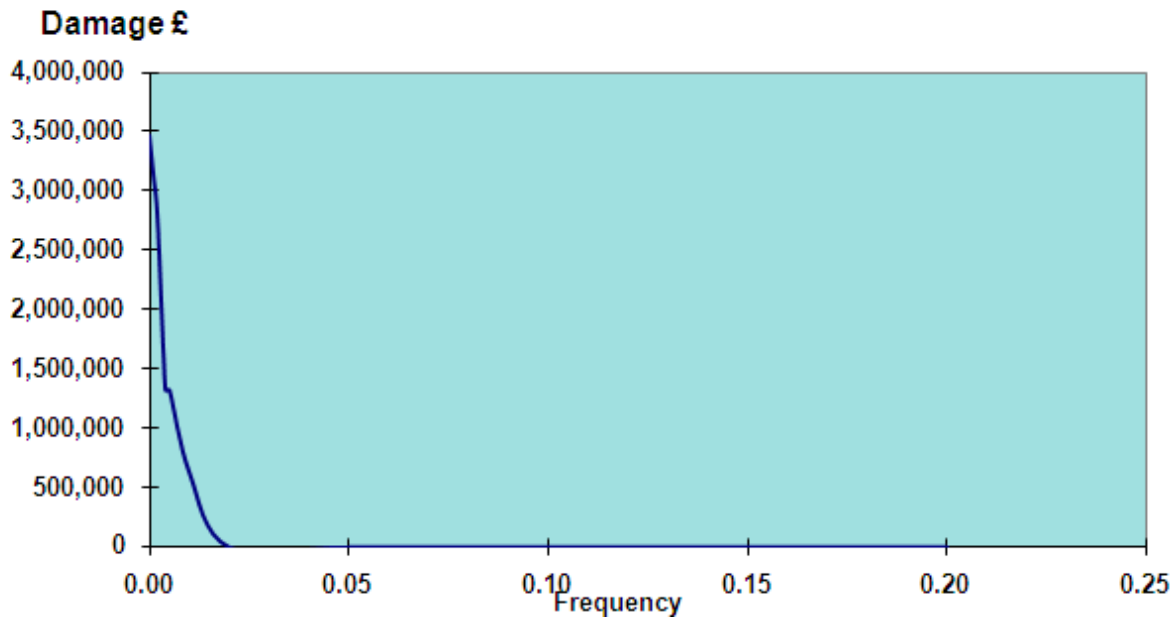


Figure 4-5: Chatham; Do Nothing Flood Damage Curve (2060)

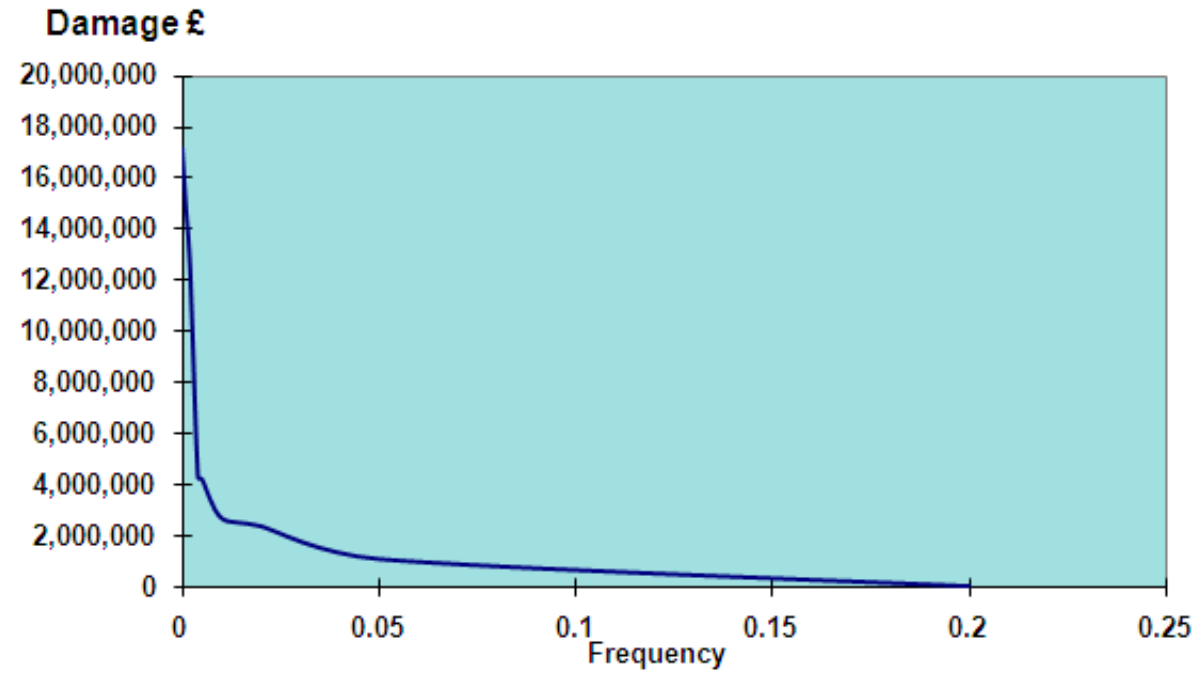
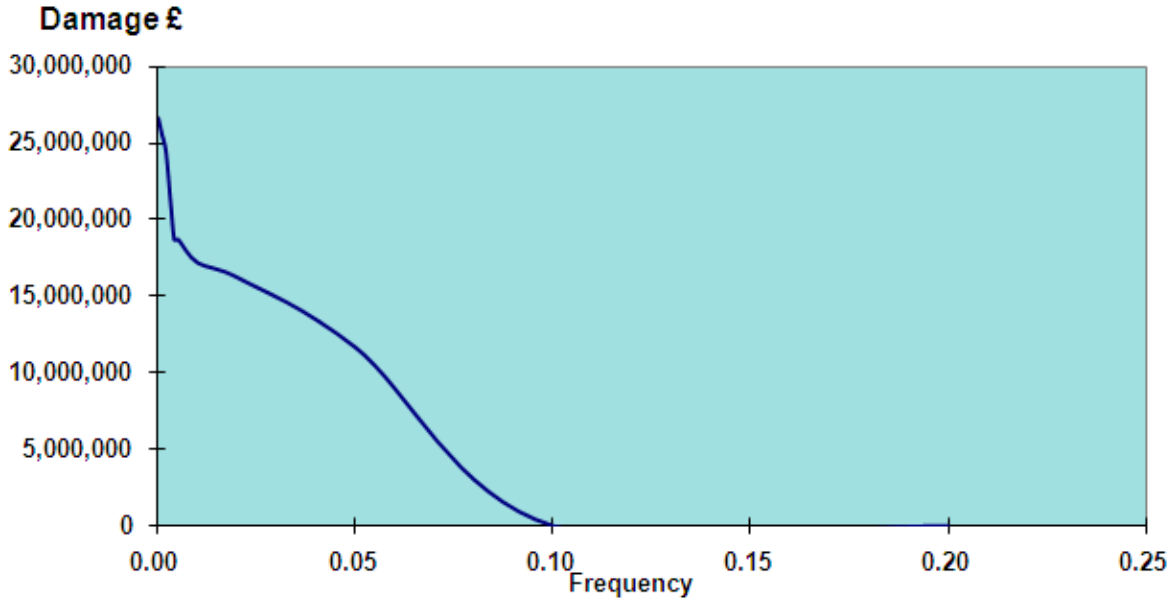


Figure 4-6: Chatham; Do Nothing Flood Damage Curve (2110)



4.3.4 The Chatham Town flood cell contains commercial properties, car parking and the council offices but covers a relatively small area as ground levels rise swiftly to the north-east and south-west. The LiDAR data indicates that the Pentagon Shopping Centre is located in a lower lying depression.

4.3.5 The modelling outputs upon which the flood damages calculations are based indicate that the Pentagon Shopping Centre is not flooded, therefore this area does not contribute to the estimated damages. As the shopping centre covers a large floor area if the modelling is incorrect in this respect, likely to be attributed to poor LiDAR data within this urban area then the damage calculations for this flood cell could be underestimated.

4.3.6 The options considered for this flood cell include utilising the open space amenity to construct an earth bund flood defence structure. This is one of the few locations within the study area where the increased land take that is required for soft defences is potentially available. The bund could also still be used to provide recreation facilities although as with all the raised defence options being considered the physical presence of the defence will provide a visual barrier between the river and the surrounding area.

4.3.7 Further north adjacent to Gunwharf the flood cell is very narrow as the topography rises steeply to the east. The council offices and southern part of Chatham Historic Dockyard located in this area contribute a significant proportion of the estimated damages in the flood cell. This is demonstrated by the relatively high remaining flood damages (£1.5 million) for Options E and F which consider the possibility of allowing the standard of protection to decrease in this part of the flood cell.

4.3.8 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.4 Area 3 – Rochester Riverside

4.4.1 Rochester Riverside has recently undergone extensive land raising and flood defence improvements, in order to facilitate development in the area. Sheet piling with concrete capping has been constructed along a 2.6km length from Chatham in the south to Rochester Bridge in the north. The total value of the works at Rochester Riverside was approximately £32 million, and the river wall piling works accounted for approximately £17 million of this.

4.4.2 The new defences are therefore sufficient to allow for protection to the 1 in 200 year 2060 flood level. The design of the flood defences in this area is such that there is potential to raise the defences in the future. Therefore only this option has been developed further.

- Option E: 2.5km of concrete capping, and 0.1km of raising the earth bund in the north, to the 1 in 200 year 2110 flood level;
- Option F: 2.4km of concrete capping, and 0.1km of raising the earth bund in the north, to the 1 in 1000 year 2110 flood level.

Table 4-3: Summary of Rochester Riverside 'rough order of magnitude' (ROM) defence option costs

Option		ROM Cost £mil
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£3.4
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£3.4

4.4.3 The existing defences have been configured to provide a 1 in 200 year standard of protection for the next 50 year time period. Additional investment in flood defence infrastructure is therefore not currently required.

4.4.4 However in order to provide the required standard of protection until 2110 an investment of approximately £3.4 million (present day value) will be required. As the area has not currently been developed a full benefit and cost assessment has not been completed. This is because the available hydraulic modelling and property information does not represent the anticipated level of development.

4.4.5 It is anticipated that the proposed level of development planned for this area should ensure a favourable significant benefit, which could be used to justify defence raising in the future. It is recommended that estimated peak water levels are monitored to ascertain whether current predictions of sea level rise due to current climate change provide an accurate representation of changes in water levels. The flood defence strategy for the flood cell should be reviewed based on future estimated water levels for the 1 in 200 year 2110 event, which will for the required standard of protection.

4.5 Area 4 – Rochester

4.5.1 The existing defences in the vicinity of Rochester are typically between 0.5m and 2m below the required standard of protection. The area is heavily developed with residential buildings.

4.5.2 Due to the existing built environment in the south of the flood cell there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options. However, an area of public open space is located along the waterfront in the north of the flood cell, and this could be landscaped to provide flood defence benefits.

4.5.3 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 1.5km of new sheet piled defence to the 1 in 200 year 2110 flood level;
- Option D: 1.5km of new sheet piled defence to the 1 in 1000 year 2110 flood level;
- Option E: 0.9km of new sheet piled defence[7], 0.2km earth bund, and 0.4km of additional concrete capping or new concrete wall, to the 1 in 200 year 2110 flood level;
- Option F: 0.9km of new sheet piled defence[7], 0.2km earth bund, and 0.4km of additional concrete capping or new concrete wall, to the 1 in 200 year 2110 flood level.

- Option G: 1.7 x 10^5 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-4: Summary of Rochester 'rough order of magnitude' ROM defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£1.19	n/a	n/a
B	Flood resilience measures	£0.73	£0.46	£0.57
C	New sheet piled hard defence to 1 in 200 year 2110 level	£0.05	£1.15	£15.19
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£0.04	£1.16	£16.09
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£0.05	£1.15	£2.95
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£0.04	£1.16	£2.96
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£14.04*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

4.5.4 The benefit/cost analysis suggests that the preferred option is implementing flood resilience measures throughout existing properties within the flood cell. However it should be noted that the costs and benefits of this option are based on assumptions. The costs associated with constructing sheet piling are significant when considered in comparison to the estimated benefit.

4.5.5 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.6 Area 5 – Lower Upnor

4.6.1 The existing defences in the vicinity of Lower Upnor are typically between 2m and 2.5m below the required standard of protection. The area is developed with residential buildings and recreational buildings.

4.6.2 The existing built environment means there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options.

4.6.3 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 1km of new sheet piled defence to the 1 in 200 year 2110 flood level;
- Option D: 1km of new sheet piled defence to the 1 in 1000 year 2110 flood level;
- Option E: 0.7km of new sheet piled defence[7] and a 0.04km earth bund to the 1 in 200 year 2110 flood level;
- Option F: 0.04km of new sheet piled defence[7] and a 0.07km earth bund, to the 1 in 1000 year 2110 flood level.
- Option G: 7.7 x 10^4 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-5: Summary of Lower Upnor 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£1.57	n/a	n/a
B	Flood resilience measures	£1.26	£0.31	£0.76
C	New sheet piled hard defence to 1 in 200 year 2110 level	£0.11	£1.47	£10.21
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£0.09	£1.49	£11.05
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£0.11	£1.47	£8.25
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£0.09	£1.49	£8.93
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£17.48*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

Figure 4-7: Lower Upnor; Do Nothing Flood Damage Curve (2010)

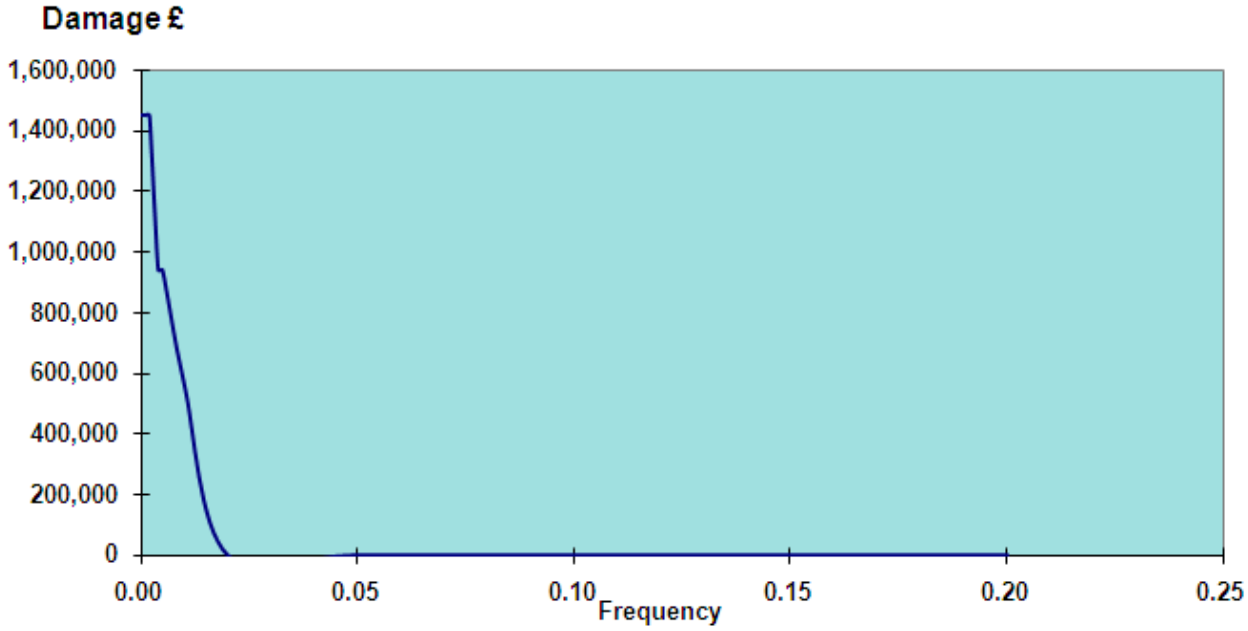


Figure 4-8: Lower Upnor; Do Nothing Flood Damage Curve (2060)

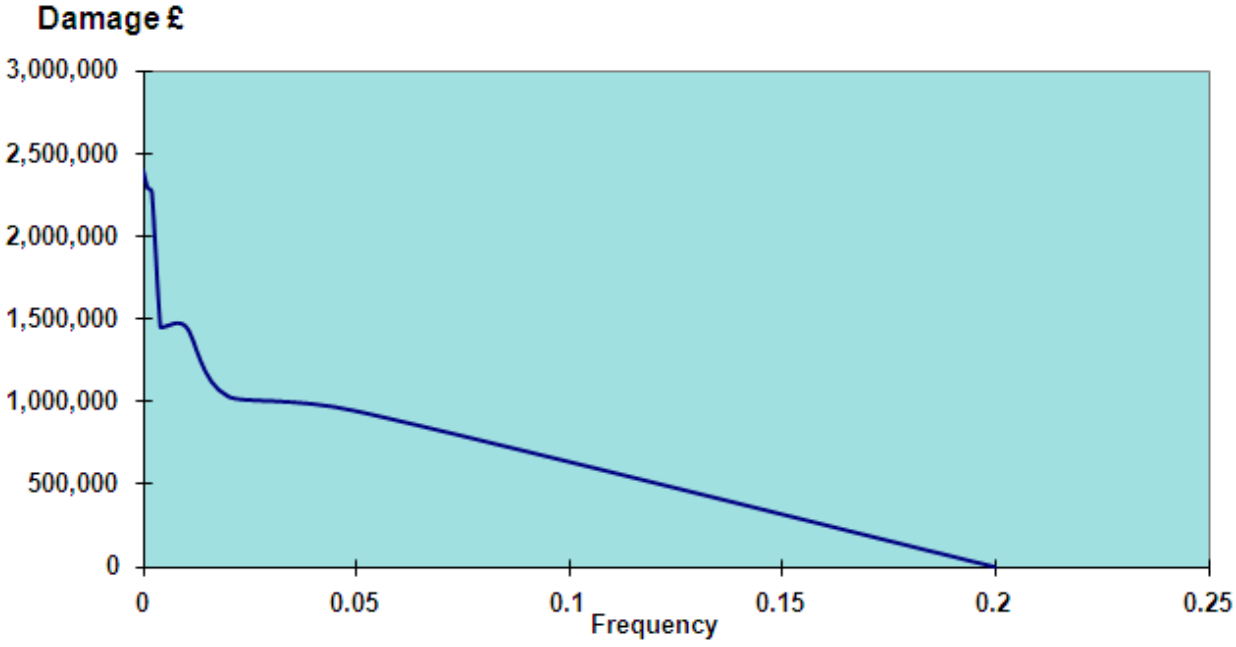
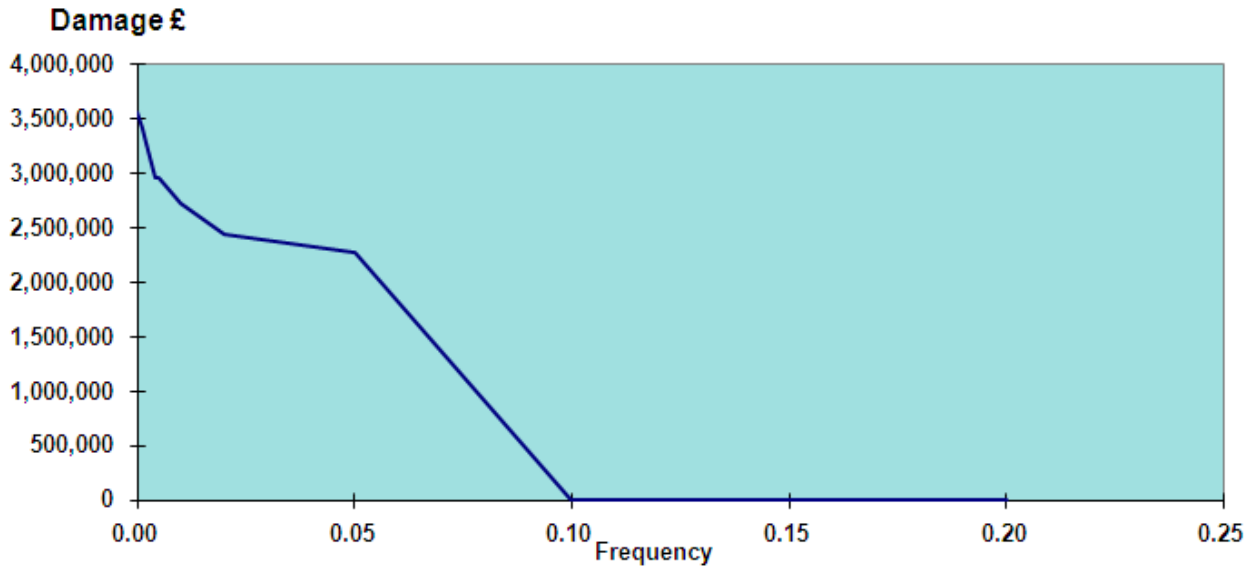


Figure 4-9: Lower Upnor; Do Nothing Flood Damage Curve (2110)



4.6.4 This small flood cell contains a several commercial riverside properties, a yacht club, an activity centre and some residential housing within the Lower Upnor community. Although the residential areas are shown within the flood cell the modelling outputs used to estimate the flood damages show that the majority of these properties are not subjected to flooding.

4.6.5 This could potentially be due to LiDAR data errors however as there are a relatively limited number of properties this would potentially not have a large impact on the estimated flood damages, unless the modelling should in reality be predicting very high flood depths which is unlikely.

4.6.6 As the level of development within the flood cell is limited the cost of implementing flood defence measures is greater than the estimated benefits. Options E and F consider a reduced length of sheet piling and allowing the standard of protection to decrease in the vicinity of the Yacht Club. However this still requires provision of flood defence infrastructure along a significant length of river frontage, with a corresponding significant cost.

4.7 Area 6 – Upper Upnor

4.7.1 The existing defences in the vicinity of Upper Upnor are typically between 2m and 2.5m below the required standard of protection. The area is developed with residential buildings and recreational buildings.

4.7.2 The existing built environment means there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options.

4.7.3 An earth bund around the tunnel entrance is required for Options E and F to prevent flooding into the Medway Tunnel.

4.7.4 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 0.7km of new sheet piled defence to the 1 in 200 year 2110 flood level;
- Option D: 0.7km of new sheet piled defence to the 1 in 1000 year 2110 flood level;
- Option E: 0.3km of earth bund to the 1 in 200 year 2110 flood level;
- Option F: 0.3km of earth bund to the 1 in 1000 year 2110 flood level.
- Option G: 1.1 x 10^5 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-6: Summary of Upper Upnor 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

Option		ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£0.96	n/a	n/a
B	Flood resilience measures	£0.77	£0.19	£0.46
C	New sheet piled hard defence to 1 in 200 year 2110 level	£0.04	£0.92	£8.75
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£0.03	£0.93	£9.41
E	Soft defences to protect A289 Tunnel to the 1 in 200 year 2110 level	£0.96	£0.00	£1.25
F	Soft defences to protect A289 Tunnel to the 1 in 1000 year 2110 level	£0.96	£0.00	£1.25
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£8.15*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

Figure 4-10: Upper Upnor; Do Nothing Flood Damage Curve (2010)

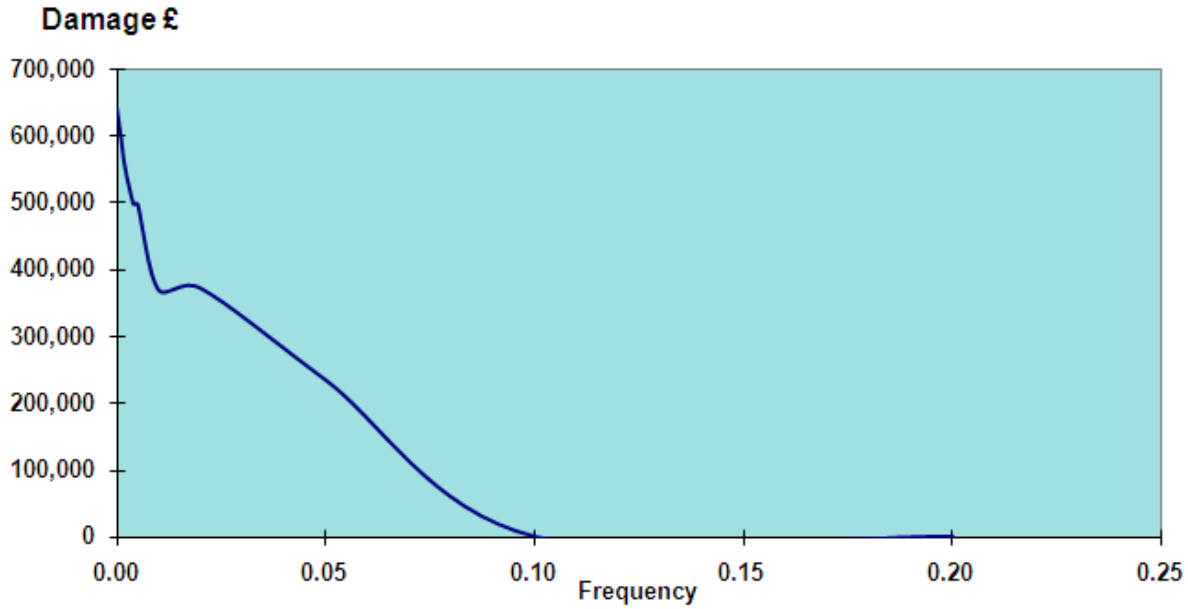


Figure 4-11: Upper Upnor; Do Nothing Flood Damage Curve (2060)

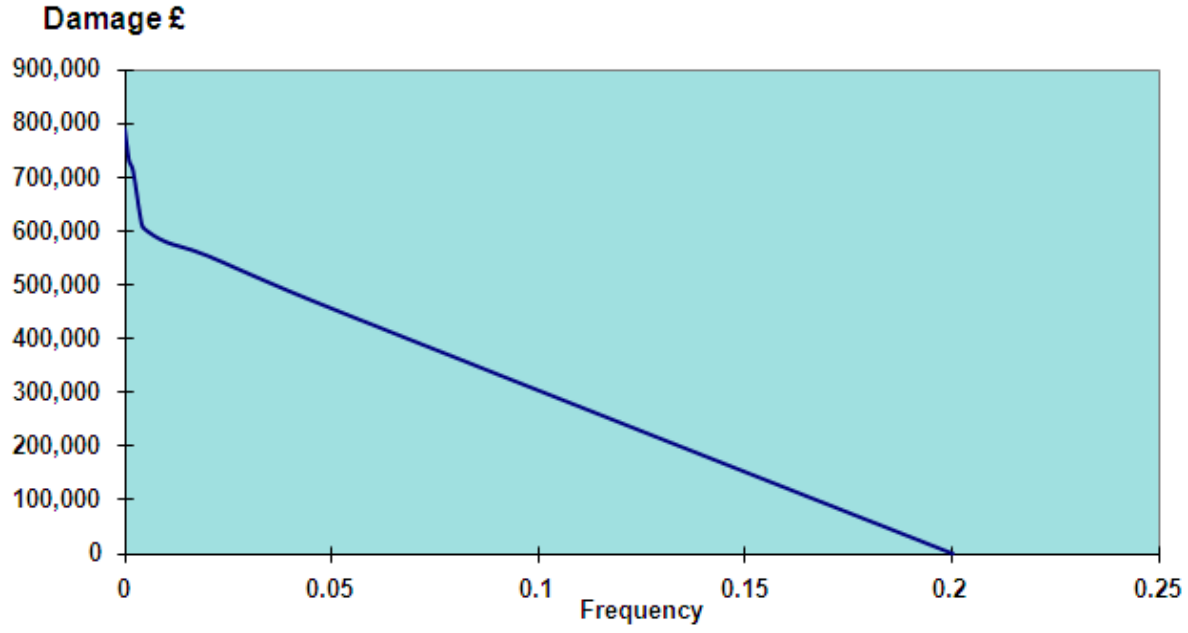
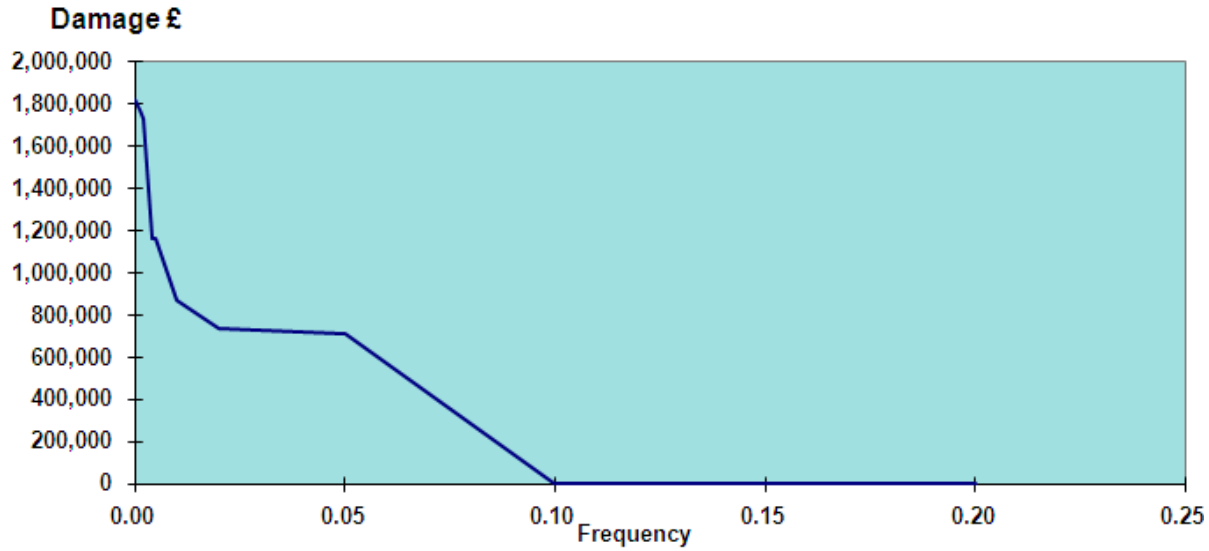


Figure 4-12: Upper Upnor; Do Nothing Flood Damage Curve (2110)



4.7.5 This small flood cell only includes a number of commercial buildings which are associated with the Ministry of Defence diver training school at Gundulph Pool. The benefits of providing flood defence in this area are therefore very limited.

4.7.6 The A289 road tunnel beneath the Medway is located adjacent to Gundulph Pool and this will require protection, firstly to defend an important asset and transport link and secondly to ensure it cannot provide a flood flow pathway to St Mary's Island and Chatham Historic Dockyard.

4.7.7 The LiDAR data indicates that the existing bunding around the entrance to the tunnel has a crest level of approximately 6.0mAOD, however as the data accuracy is +/-150mm, and significantly less than this in vegetated areas therefore the actual crest level requires confirmation.

4.7.8 It should also be noted that the modelling outputs which have been used to calculate estimated flood damages show that the tunnel entrance is inundated during extreme flood events, however this has not been included within the damage calculations as disruption to transport links have not been accounted for.

4.8 Area 7 – Medway City Estate

4.8.1 The existing defences in the vicinity of Medway City Estate are typically between 1m and 1.5m below the required standard of protection. The area is heavily developed with industrial buildings.

4.8.2 The existing built environment means there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options. However, the north-eastern section does potentially have some space available.

4.8.3 An earth bund is required in the north-west corner of Medway City Estate in order to separate this from the larger flood cell which also covers Strood. This will allow the area to be developed independently.

4.8.4 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 3.8km of new sheet piled defence and 1.3km of earth bund to the 1 in 200 year 2110 flood level;
- Option D: 3.8km of new sheet piled defence and 1.3km of earth bund to the 1 in 1000 year 2110 flood level;
- Option E: 2.6km of new sheet piled defence[7] and 1.3km of earth bund to the 1 in 1000 year 2110 flood level;
- Option F: 2.6km of new sheet piled defence[7] and 1.3km of earth bund to the 1 in 1000 year 2110 flood level;
- Option G: 1.2 x 10^6 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-7: Summary of Medway City Estate 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£20.40	n/a	n/a
B	Flood resilience measures	£16.32	£4.08	£9.79
C	New sheet piled hard defence to 1 in 200 year 2110 level	£2.19	£18.21	£43.66
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£1.65	£18.74	£46.54
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£2.19	£18.21	£33.25
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£1.65	£18.74	£35.58
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£112.32*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

4.8.5 The benefit/cost analysis suggests that the preferred option is achieved through a mixture of hard and soft defences. However as the flood cell consists of a peninsula there is an extensive river frontage which requires a significant length of flood defence to provide the required standard of protection. The investment required in flood defences is therefore a significant cost.

4.8.6 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.9 Area 8 – Strood

4.9.1 The existing defences in the vicinity of Strood are typically between 1.5m and 2m below the required standard of protection. The area is also heavily developed with retail, recreational and residential development, with a number of key transport links including major roads and railway lines.

4.9.2 Due to the existing development infrastructure and characteristics of the built environment there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options.

4.9.3 A number of earth bunds are required within this large flood cell in order to prevent flooding via adjacent flood cells. An earth bund is required in the north-east between Strood and Medway City Estate, and also in the south-west between Strood and Temple Waterfront.

4.9.4 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 3.7km of new sheet piled defence and 1.8km of new earth bunds to the 1 in 200 year 2110 flood level;
- Option D: 3.7km of new sheet piled defence and 1.8km of new earth bunds to the 1 in 1000 year 2110 flood level;
- Option E: 3.4km of new sheet piled defence[7] and 0.5km of earth bund to the 1 in 200 year 2110 flood level;
- Option F: 3.4km of new sheet piled defence[7] and 0.5km of earth bund to the 1 in 200 year 2110 flood level;
- Option G: 9.4 x 10^5 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-8: Summary of Strood 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£23.31	n/a	n/a
B	Flood resilience measures	£18.24	£5.07	£11.19
C	New sheet piled hard defence to 1 in 200 year 2110 level	£1.60	£21.71	£30.72
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£1.30	£22.01	£33.09
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£1.60	£21.71	£39.53
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£1.30	£22.01	£39.79
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£99.93*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

Figure 4-13: Strood; Do Nothing Flood Damage Curve (2010)

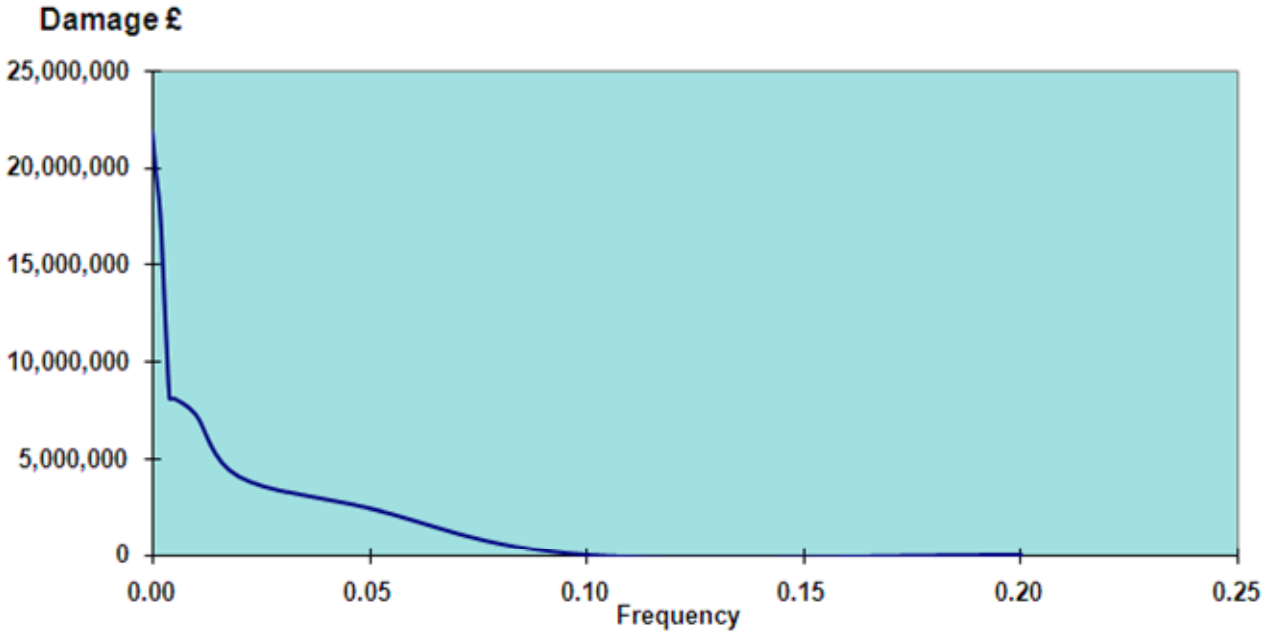


Figure 4-14: Strood; Do Nothing Flood Damage Curve (2060)

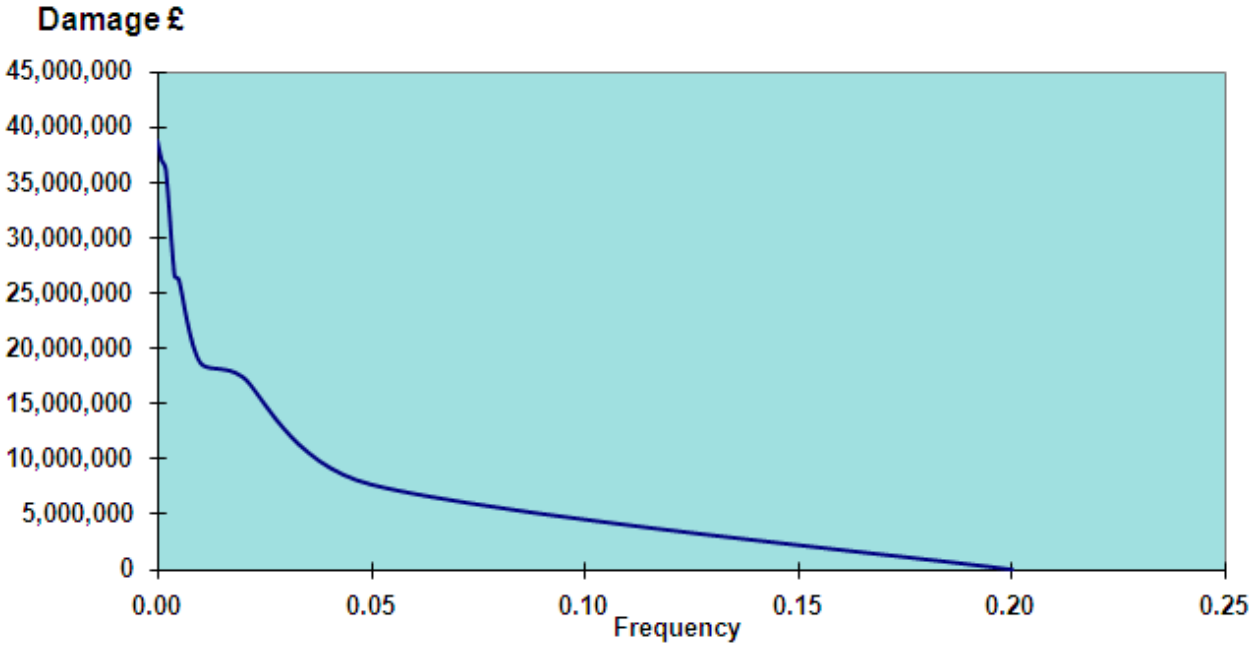
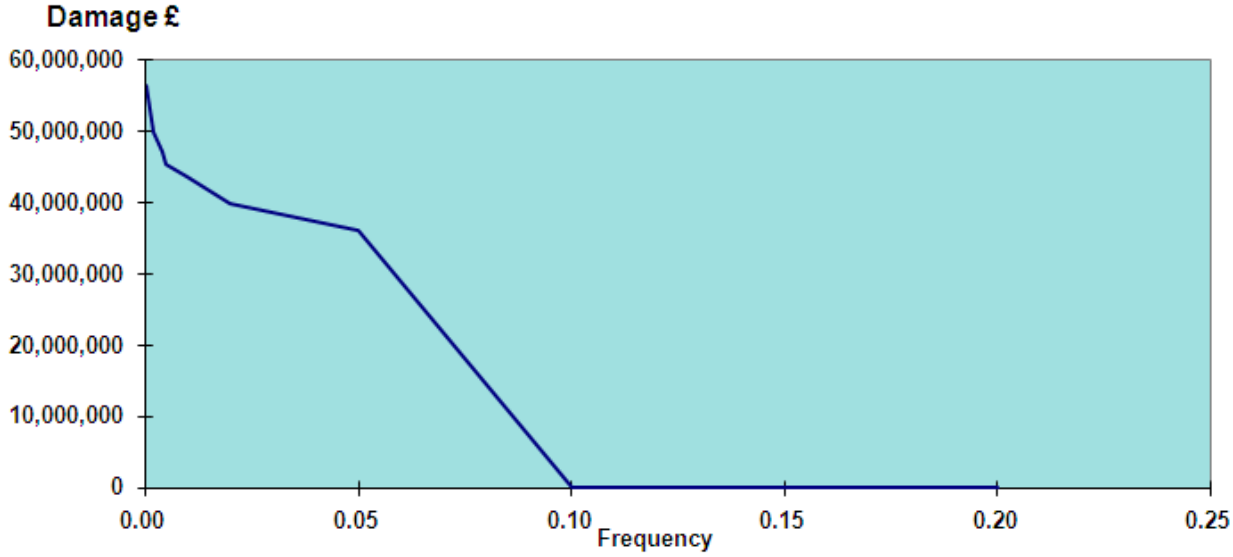


Figure 4-15: Strood; Do Nothing Flood Damage Curve (2110)



4.9.5 The Strood flood cell contains a significant proportion of existing development therefore the estimated benefits are the highest within the study area.

4.9.6 The ground level throughout Strood is typically very low, with the majority of the flood cell more than 2m below the required standard of protection. The existing flood defences also do not protect the area from the present day 1 in 200 year flood level. The low lying nature of the area and a lack of adequate flood defences significantly limit the available defence options and combine to make flood defence implementation extremely challenging.

4.9.7 Medway Renaissance has specified that several specific areas are considered within the Strood area, which includes Strood Riverside and Strood Civic Centre. These options are explored in greater detail below.

Strood Riverside

4.9.8 In order to separate the Strood and Medway City Estate flood cells, a soft defence earth bund is required close to Commissioners Road and Wingrove Road, (Figure 11a and 11b). Two flood gates are also required where Canal Road and Station Road pass through the railway embankment to prevent flooding of the Strood Riverside site from the west.

4.9.9 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 0.9km of new sheet piled defence, 0.1km of earth bund and 2 flood gates, to the 1 in 200 year 2110 flood level;
- Option D: 0.9km of new sheet piled defence, 0.1km of earth bund and 2 flood gates, to the 1 in 1000 year 2110 flood level;
- Option E: 0.6km of new sheet piled defence, 0.4km of earth bund and 2 flood gates, to the 1 in 200 year 2110 flood level;
- Option F: 0.6km of new sheet piled defence 0.4km of earth bund and 2 flood gates ,to the 1 in 200 year 2110 flood level;
- Option G: 3.7 x 10^5 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-9: Summary of Strood Riverside 'rough order of magnitude' (ROM) defence option costs

	Option	ROM Cost £mil
C	New sheet piled hard defence to 1 in 200 year 2110 level	£8.8
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£9.3
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£3.8
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£3.8
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	£27.8*

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material.

4.9.10 The option considered for the Strood Riverside site utilises the existing railway embankments to provide flood protection. It has been assumed that the embankments are impermeable and will prevent overland flood flows from reaching the site.

4.9.11 In order to prevent the roads beneath the embankments acting as flood pathways, flood gates will need to be installed. It is likely that the preferred option would be for a gate to be installed

beneath the road which can then be raised into position when required. This is preferable as space is not required at ground level to store the 'open' gate when it is not in use, which would be the vast majority of the time.

4.9.12 Existing pipe networks and services within the roads and footways may however mean that use of a gate installed beneath the road is not technically feasible, or the cost of the required diversions may prove to be exorbitant. The costs associated with the design, construction and installation of such flood gates are highly variable and more detailed investigations are required to confirm whether this is a practical option and improve confidence in the likely costs.

4.9.13 The use of flood gates could in theory protect the site from flooding and is a significantly cheaper option than undertaking extensive flood defence installations along the entire river Strood river frontage. However isolating the site in a flood event could cause emergency planning issues and would prevent access and egress from the site an additional access route from Canal Road to the north is also likely to be required.

Civic Centre, Strood

4.9.14 The Civic Centre, Strood has also been identified by Medway Renaissance. However, it is not possible to split the flood cell in order to allow phased development to occur. This is because the site is located on the riverside and could potentially be subjected to 'backdoor flooding' from all other parts of the flood cell due to the low ground levels which dominate the area.

4.9.15 The site's location therefore prevents implementation of appropriate potential solutions to protect the Civic Centre site. The only means of defending the site without addressing the poor standard of protection throughout the remainder of the flood cell would be to isolate the site by raising and/or localised defences around the perimeter. This is clearly not a preferred solution as this would ring fence the site

4.9.16 The potential for use of flood gates has been considered to reduce the length of flood defence infrastructure required as for the Strood Riverside site, but this would require a flood gate to be installed across the A2 which is a major route that consists of several lanes therefore this is not considered to be a feasible option for consideration.

4.9.17 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.10 Area 9 – Temple Waterfront

4.10.1 The existing defences in the vicinity of Strood are typically between 1.5m and 2.5m below the required standard of protection. The area is also heavily developed with a number of key transport links including major roads and railway lines.

4.10.2 Due to the existing development infrastructure and characteristics of the built environment there is limited space available for 'soft' defence measures such as provision of landscaped bunds, which require a significantly larger footprint than 'hard' defence options.

4.10.3 An earth bund is required to the south of Strood in order to separate this from the larger flood cell. This will allow the area to be developed independently.

4.10.4 The following flood defence options have been developed:

- Option A: Do Nothing (existing standard of protection will decrease over time);
- Option B: Flood resilient measures, estimated as 30% of the Do Nothing damages;
- Option C: 0.6km of new sheet piled defence and 0.1km of earth bund, to the 1 in 200 year 2110 flood level;
- Option D: 0.8km of new sheet piled defence and 0.1km of earth bund, to the 1 in 1000 year 2110 flood level;
- Option E: 0.2km of new sheet piled defence[7] and 0.6km of earth bund to the 1 in 200 year 2110 flood level;
- Option F: 0.2km of new sheet piled defence[7] and 0.6km of earth bund to the 1 in 200 year 2110 flood level;
- Option G: 8.2 x 10^4 m^3 volume of fill material to land raise to the 1 in 200 year 2110 flood level in addition to measures included as Option E.

Table 4-10: Summary of Temple Waterfront 'rough order of magnitude' (ROM) defence option costs in relation to potential damages

	Option	ROM Flood Damages £mil	ROM Benefit £mil	ROM Cost £mil
A	Do nothing	£0.05	n/a	n/a
B	Flood resilience measures	£0.04	£0.01	£0.02
C	New sheet piled hard defence to 1 in 200 year 2110 level	£0.04	£0.01	£6.69
D	New sheet piled hard defence to 1 in 1000 year 2110 level	£0.02	£0.03	£7.23
E	Combination of hard defence and soft defence bunds to 1 in 200 year 2110 level	£0.04	£0.01	£4.21
F	Combination of hard defence and soft defence bunds to 1 in 1000 year 2110 level	£0.02	£0.03	£4.31
G	Land raising to 1 in 200 year 2110 level in combination with measures included as Option E	n/a	n/a	£9.48

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

4.10.5 The benefit/cost analysis suggests that the benefit associated with providing flood defence infrastructure for this flood cell is minimal, however the costs are significant.

4.10.6 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical

regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

4.11 Summary

4.11.1 The estimated benefits and costs of providing flood defence infrastructure to meet the required standard of protection to manage the increasing flood risk due to climate change has been quantified. The potential funding mechanisms which are available and the flood defence priorities within the study area are examined in chapter 5.

4.11.2 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

5 Implementation Strategy

5.1 Overview

5.1.1 The flood defence cost estimates provided within chapter 3 confirm that the cost of providing the required standard of flood protection is significant. The benefit/cost analyses completed generally confirm that the estimated flood damages for existing development are significantly less than the estimated costs for provision of new flood defence infrastructure.

5.1.2 However flood defence provision will be required in order to protect existing development, and permit regeneration and redevelopment of riverside areas. The funding required to meet the costs of this could be generated from a number of potential funding sources. This chapter considers the available funding sources and highlights the short, medium and long term flood defence priorities for each flood cell.

5.1.3 A summary of the approximate costs for the various flood defence options considered within this study are shown in Table 5-1 below. Full details of the methodologies and assumptions which have been applied are contained within Chapter 3.

Table 5-1: Summary of 'rough order of magnitude' (ROM) defence option costs by flood cell

Area	Defence Option Costs £mil						
	A	B	C	D	E	F	G
	Do Nothing	Flood Resilience	Hard defence to 1 in 200yr 2110 level	Hard defence to 1 in 1000yr 2110 level	Hard/soft defences to 1 in 200yr 2110 level	Hard/soft defences to 1 in 1000yr 2110 level	Land raising to 1 in 200 year 2110 plus Option E
Area 1 – Gillingham Waterfront, St Mary's Island and Historic Dockyard	n/a	£13.74	£137.08	£146.41	£49.19	£51.32	£216.34*
Area 2 – Chatham	n/a	£2.20	£17.68	£18.89	£12.00	£12.64	£19.27*
Area 3 – Rochester Riverside	n/a	n/a	n/a	n/a	£3.40	£3.40	n/a
Area 4 – Rochester	n/a	£0.57	£15.19	£16.09	£2.95	£2.96	£14.04*
Area 5 – Lower Upnor	n/a	£0.76	£10.21	£11.05	£8.25	£8.93	£17.48*
Area 6 – Upper Upnor	n/a	£0.46	£8.75	£9.41	£1.25	£1.25	£8.15*
Area 7 - Medway City Estate	n/a	£9.79	£43.66	£46.54	£33.25	£35.58	£99.93*
Area 8 - Strood	n/a	£11.19	£30.72	£33.09	£39.53	£39.79	£27.28*
Area 9 – Temple Waterfront	n/a	£0.02	£6.69	£7.23	£4.21	£4.31	£9.48*
TOTAL £mil	**n/a**	**£38.73**	**£269.98**	**£288.71**	**£154.04**	**£160.17**	**£497.00***

*the estimated cost for land raising elements can be obtained by calculating the difference between costs for Options E and G. It should be noted that this cost is highly sensitive to the assumed cost per m^3 of fill material. It is not considered appropriate to include damages and benefits for this option as it is likely to require demolition of existing development and clearing of the flood cell to allow redevelopment.

5.2 Policy Drivers

5.2.1 Large scale physical regeneration is at the heart of the spatial strategies for both the Thames Gateway and for urban Medway, which includes the extensive urban waterfront and the adjoining town centres of Chatham and Strood.

5.2.2 The successful redevelopment of the waterfront is required not only to improve the visual quality of the area and open up the river but also to meet development needs, including new housing and commercial development of a significant scale.

5.2.3 However the waterfront is vulnerable to flooding and, as such, a clear strategy is required to address this critical issue and provide a comprehensive response that can inform development and investment decisions and lead to coherent solutions that demonstrate a joined up approach.

5.2.4 For these reasons the Council commissioned this study with the active support of the Environment Agency.

5.2.5 The following extracts from the Pre-Publication Medway Draft Core Strategy illustrate the significance of the issue and the role that this report is intended to fulfil.

5.3 Pre-Publication Draft Core Strategy Extracts

Issues

5.3.1 Be aware that flood risk is a key environmental issue and therefore flood management issues need to be integrated into planning decisions. Whilst Medway has a significant proportion of previously developed land suitable for redevelopment within areas of higher flood risk it is not appropriate to prevent all new developments in the areas of flood risk as it may be needed to avoid social and economic stagnation or blight.

Spatial Vision

5.3.2 Chatham will be transformed into a city centre for Medway that is also of regional significance. It will be a focus for shopping, leisure and cultural activity and a growing employment location, founded on its first class accessibility, city scale services and associated Higher and Further Education Centre of Excellence.

5.3.3 The urban waterfront (north bank: Temple Waterfront to Strood Waterfront; south bank: Rochester Riverside to Gillingham Waterfront) will have been similarly transformed, with mixed use developments of the highest quality linking the town centres and capitalising on the exceptional setting provided by the river Medway.

5.3.4 Rochester will continue to be recognised as a tourist destination, linked to the many attractions along the urban waterfront.

5.3.5 The River will be celebrated as the dominant and unifying geographical feature of the area through enhanced riverside walks and sensitive management of its commercial, leisure and environmental potential.

Strategic Objectives

5.3.6 To effectively realise Medway's role within the Thames Gateway and associated growth requirements primarily through effective physical regeneration, the reuse of previously developed land and the protection and enhancement of the area's many natural and heritage assets.

5.3.7 To develop Chatham as a city centre of regional significance with its role complemented by thriving and attractive traditional town centres in Strood, Rochester, Gillingham and Rainham together with a network of strong neighbourhood centres serving local communities.

5.3.8 To radically improve the quality of the townscape and public realm within the central urban area and along the urban waterfront.

5.3.9 To enhance the quality of life of local people through the promotion of healthier lifestyles and the provision of improved cultural, leisure and tourism facilities, including along the river Medway.

Policies

Policy CS1: Regenerating Medway

5.3.10 Priority will continue to be given to the established regeneration programme, namely:

- Major physical change in Chatham centre, including significant new retail floorspace between Best Street and the Brook and the expansion of the Pentagon Centre, mixed use developments at the Brook, the Station Gateway and Waterfront, major improvements to the Waterfront open space and, over the longer term, the development of a new cultural offer;
- On the west bank of the River Medway the creation of a dynamic new mixed use waterfront environment stretching from Medway Valley Park through Temple Waterfront, the former Civic Centre site and Strood Riverside. This will include the implementation of the Masterplan for Central Strood and associated access improvements and the creation of a river walk;
- On the east bank of the river, the creation of a new community at Rochester Riverside, the sensitive regeneration of the historic area between Star Hill and Sun Pier, the further development of the Chatham Historic Dockyard as a heritage destination and commercial quarter, development of the Interface Land and the completion of the residential communities at St. Mary's Island and Gillingham Waterfront;
- Sensitive change within Gillingham town centre to reinforce its role as an important 'District' centre and capitalise on the opportunities provided by the growing student population and new facilities at Medway Park and the Great Lines Heritage Park;
- By working with Network Rail and the train operating companies the creation of enhanced station environments and interchange facilities at Strood, Rochester, Chatham and Gillingham;
- The creation of a high quality public realm, including new public squares and spaces, new pedestrian routes connecting up the waterfront and town centres and major urban open spaces.

- The Council will continue to work in partnership with all relevant bodies and commercial interests in taking forward the programme and all developments will be expected to make a positive contribution to it.

5.3.11 A number of the key regeneration sites are located on the riverside and a strategic approach to their defence is appropriate. Accordingly the Council has commissioned a study of the existing defences and the potential defence works and strategies that should be applied to meet the required defence standard.

5.3.12 This approach will allow optimum solutions to be identified that balance the protection of sites with management of the natural environment but these are likely to require financial support.

Policy CS5: Development and Flood Risk

5.3.13 Proposals for development within flood zones 2 and 3 and on sites of over 1 hectare in zone 1 must be accompanied by a flood risk assessment. Permission will not be granted unless, following a flood risk assessment, it can be demonstrated that:

- It would not be at an unacceptable risk of flooding itself; and
- The development would not result in any increased risk of flooding elsewhere.

5.3.14 Exceptionally, sites within the Medway urban area which contribute to the regeneration of the area need to be redeveloped. In such cases and where the tests above cannot be met, development will only be permitted if:

- The development is designed to be compatible with potential flood conditions, and
- There are no alternative sites in a lower flood risk zone; and
- The development would make a significant contribution to the overall sustainable development objectives of the LDF, such that the wider sustainability benefits of the development outweigh the flood risk; and
- It can be demonstrated to the satisfaction of the Council and the Environment Agency that any residual flood risks are adequately mitigated to avoid an increased risk of flooding either on the site or elsewhere; and
- It is only for uses which are not defined as highly vulnerable by PPS25.

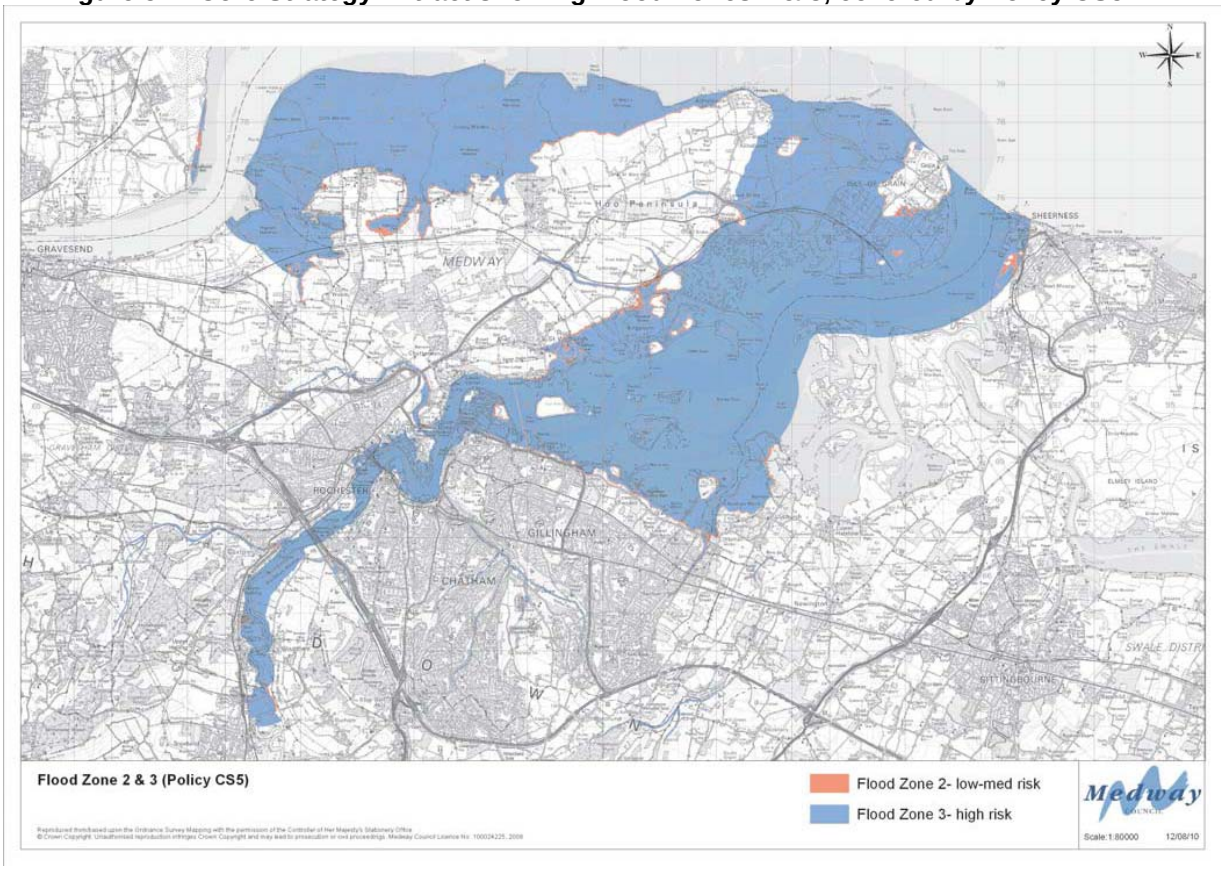
5.3.15 Development that would harm the effectiveness of existing flood defences or prejudice their maintenance or management will not be permitted.

5.3.16 Proposals in areas at risk from flooding must demonstrate that account has been taken of the resilience of buildings, infrastructure and other important local features.

5.3.17 Relevant flood defence works as identified in the Medway Strategic Urban Flood Defence Strategy should be incorporated, if applicable. All developments which have the potential to affect the ability of land to absorb rainwater will be required to incorporate and obtain approval for sustainable urban drainage systems (SUDS) in line with national standards, prior to construction.

5.3.18 All development within flood zones 2 and 3 (as shown in Figure 5-1 will require surface water run-off to be controlled as near to its source as possible.

Figure 5-1: Core Strategy Extract showing Flood Zones 2 & 3, covered by Policy CS5



New Development Funding

5.3.19 In order for new development within flood risk areas to be permitted it must be demonstrated that it will be safe from flooding throughout the development lifetime as required by PPS25: Development & Flood Risk. Only existing defences that are approved and fully funded can be used for this assessment as stated within the updated SFRA in paragraph 5.29).

5.4 Potential Sources of Funding

New Development Funding

5.4.1 In order for new development within flood risk areas to be permitted it must be demonstrated that it will be safe from flooding throughout the development lifetime as required by PPS25: Development & Flood Risk. Only existing defences that are approved and fully funded can be used for this assessment as stated within the updated SFRA in paragraph 5.29).

5.4.2 PPS25 aspires to locate all new development in areas at lowest risk of flooding, however it acknowledges that redevelopment is still required within flood risk areas to ensure that widespread areas are subjected to blight.

5.4.3 It is only correct that such new development should contribute to the cost of necessary flood defence infrastructure from which it benefits. A number of tariff schemes have been

implemented within the UK, which define standard levels of contribution related to the type and scale of development.

5.4.4 For example, based on the anticipated levels of development within each flood cell, appropriate contributions can be formulated for residential units, typically based on number of bedrooms for residential development, and net floorspace for commercial development.

5.4.5 Given the significant cost of providing flood defence infrastructure it is unlikely that new development alone should be expected to solely fund the cost of the required infrastructure, however the tariff contributions can be collected and as they accumulate over the time they will represent a proportion of the capital costs.

5.4.6 Tariff schemes such as this are more appropriate where existing defences provide the required standard of protection based on present day flood levels, but the impacts of climate change are predicted to necessitate new defences at some point in the future. This gives time for the tariff fund to accumulate during the interim period before the flood defence infrastructure is required.

5.4.7 The most efficient means for collecting the tariff is often considered to be through S106 legal agreements, as planning permission can be granted upon condition of completion of a satisfactory agreement which includes the appropriate flood defence contributions.

Existing Development Funding

5.4.8 This study has identified that there are many existing properties within the study area which are not currently afforded the required standard of protection by the existing flood defences, and the impacts of climate change are predicted to further reduce the standard of protection over time.

5.4.9 As these existing properties will benefit from investments in flood defence infrastructure, then again it seems correct that they should make a contribution to the (often significant) costs.

5.4.10 However the addition of a local flood defence tax, potentially incorporated within council taxes and/or business rates is likely to prove unpopular with existing residential and commercial occupants. It could also potentially cause deprivation and desertion of higher flood risk areas due to the increased charges. Although in flood risk terms, reducing the number of people within identified flood risk areas is the preferential flood risk management method, this could lead to blight of existing development areas therefore is not acceptable due to the potentially wide ranging associated social and economic issues.

5.4.11 This leads to the conclusion that a flood defence tax should be applied across the Medway administrative area, however this could be deemed to be unacceptable for many occupants who are living within low flood risk areas, a significant distance away from the river environment.

5.4.12 If it is deemed appropriate to raise a contribution towards flood defence infrastructure from existing development then it is again unlikely that this would generate the significant total funds which are required, however if contributions are accumulated over a period of time and potentially combined with funding from other sources they could potentially make a reasonable contribution.

Public Funding

5.4.13 There are a number of potential sources of public funds which are available for flood defence infrastructure, such as regional funding allocations, the Homes and Communities Agency and national infrastructure projects.

5.4.14 The current economic climate and recent change of Government means that the current arrangements are subject to review and it is currently uncertain how this will affect the existing processes and systems for obtaining such funding. The recent budget announcements are focussed around reducing budgets and public spending hence there is likely to be reduced funding available for the foreseeable future.

5.4.15 Regardless of the process for obtaining funding, any process is likely to involve comparison with other schemes in terms of benefit/cost ratios. The area within which schemes are compared depends upon the source of the funding. The Environment Agency undertakes capital schemes to protect existing properties from flooding, which are reviewed and allocated on a national basis based on a number of Outcome Measures.

5.4.16 The estimated benefits and costs presented within this study would result in significantly lower benefit/cost ratios than the Environment Agency minimum target values for funded schemes. A benefit/cost ratio of approximately 5:1 is typically required to secure funding, although it should be noted that each scheme is considered on its own merits and this indicative ratio does not represent a cut-off point for funding.

5.4.17 The Outcome Measures minimum national targets require considered projects to protect significant numbers of households (145,000 nationally within a comprehensive spending review period) and large areas of nationally important wildlife sites (24,000 hectares). It is therefore very unlikely that national funding would be allocated to the Medway area.

5.4.18 Some form of regional funding allocation therefore provides a more likely potential funding source for flood defence investment, the schemes considered for such funding will be geographically limited which increases the likelihood of investment within the Medway area. However it should be reiterated that the benefits and costs included within this study are unlikely to provide appropriate benefit/cost ratios and other schemes could easily demonstrate more favourable ratios which would secure any available funding.

5.4.19 The information contained within the study has only been completed at a strategic scale therefore further refinement of the costs and benefits may lead to more favourable ratios being produced. This would require further detailed investigation.

5.5 Flood Defence Phased Implementation Strategies

5.5.1 The overall objective is to provide the required 1 in 200 year (2110) standard of protection throughout the entire study area. However this requires significant funding which is not currently available and it is clearly not feasible to embark upon numerous construction projects concurrently.

5.5.2 The current standard of protection offered by the existing flood defences has therefore been reviewed and compared with the present day and estimated future peak flood levels on a flood cell basis, in order to highlight the short, medium and long term priorities for each flood cell within the study area.

5.5.3 The timeframes which have been considered are approximate, but have been based on the need to provide protection from the present day 1 in 200 year event within the near future, estimated as the following 25 year period and referred to as Phase 1.

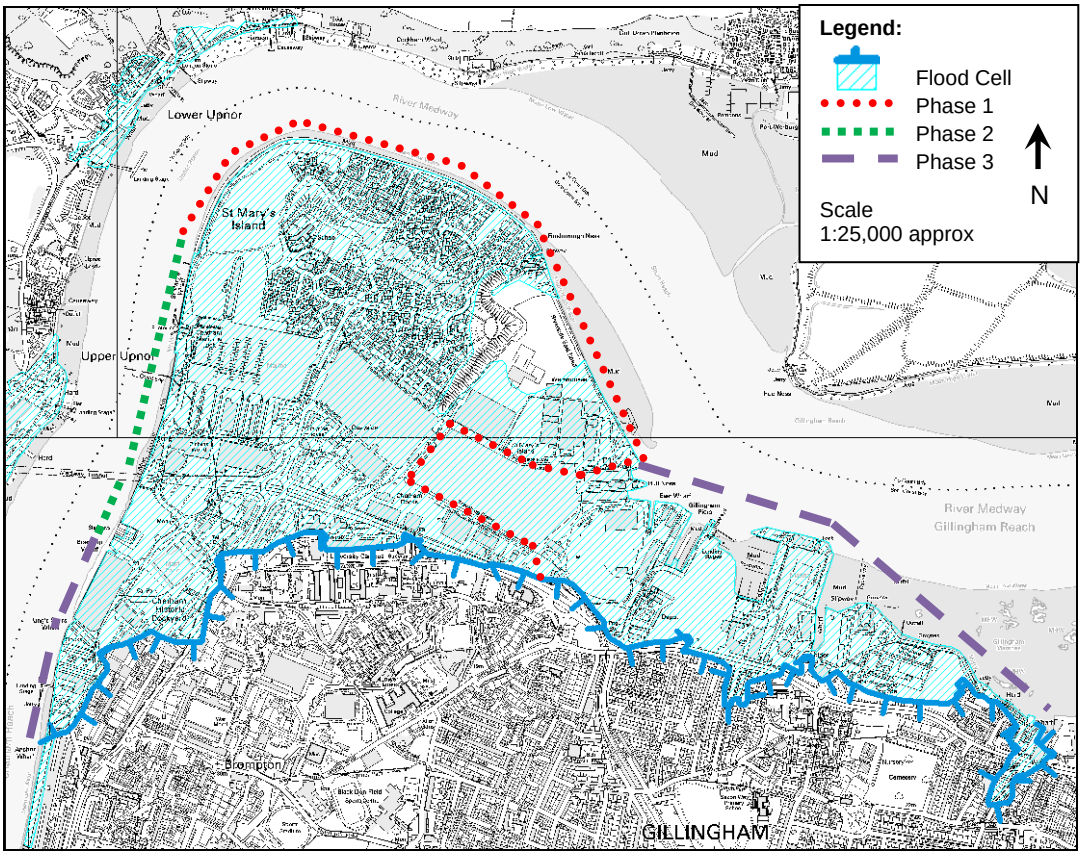
5.5.4 During the subsequent 25 year period, i.e. within 50 years time, flood protection from the 1 in 200 year 2060 flood level is required. This is referred to as Phase 2. Throughout the following 50 year period, i.e. within 100 years time, the required 1 in 200 year 2110 standard of protection must be achieved which is referred to as Phase 3.

5.5.5 The following sections set out the short, medium and long term priorities for each flood cell. It should be noted that some additional works may be required during Phases 2 and 3, to raise the crest level of defences which have initially been dealt with during Phase 1. This follows the example of the Rochester Riverside area, where defences are constructed to protect against the 1 in 2000 year 2060 event, however the structures have been designed to permit raising to the 1 in 200 year 2110 level at a later date.

5.5.6 This additional raising in the future has not been illustrated in the subsequent figures or explanatory text but should be considered as a generic requirement throughout the study area. Estimated flood levels should be monitored over time to determine the accuracy of current day climate change predictions and how these impact upon extreme flood levels.

5.5.7 It is recommended that a policy is developed which requires new defences to initially be constructed to the 1 in 200 year 2060 flood level, but the design and construction method includes provision for subsequent raising of defences to the 1 in 200 year 2110 flood level.

Figure 5-2: Area 1; Gillingham Waterfront, St Mary's Island and Historic Dockyard Phased Implementation Strategy



Short Term (next 25 years)

- The existing defences around the north of St Mary's Island have subsided during recent years, and planning approval has been granted for these defences to be raised to the 1 in 200 year 2110 level. Although the existing defences currently provide a high standard of protection when compared to other parts of the flood cell, these works have been included within the short term objectives as it is assumed the works will shortly be initiated.
- In order to prevent flooding of St Mary's Island from the south, the flood defences need to be improved along the dock areas located to the south of the main residential developments. Raising levels along the entire quayside is likely to be costly and technically complex, therefore limited defence raising in combination with a flood gate across the dock entrance is recommended.

Medium Term (25 – 50 years)

- The existing defences on the west of St Mary's Island are above the present day 1 in 200 year level, however they area approximately 0.3m below the 2060 200year level. In order to provide the required standard of protection a defence length of approximately 1000m.

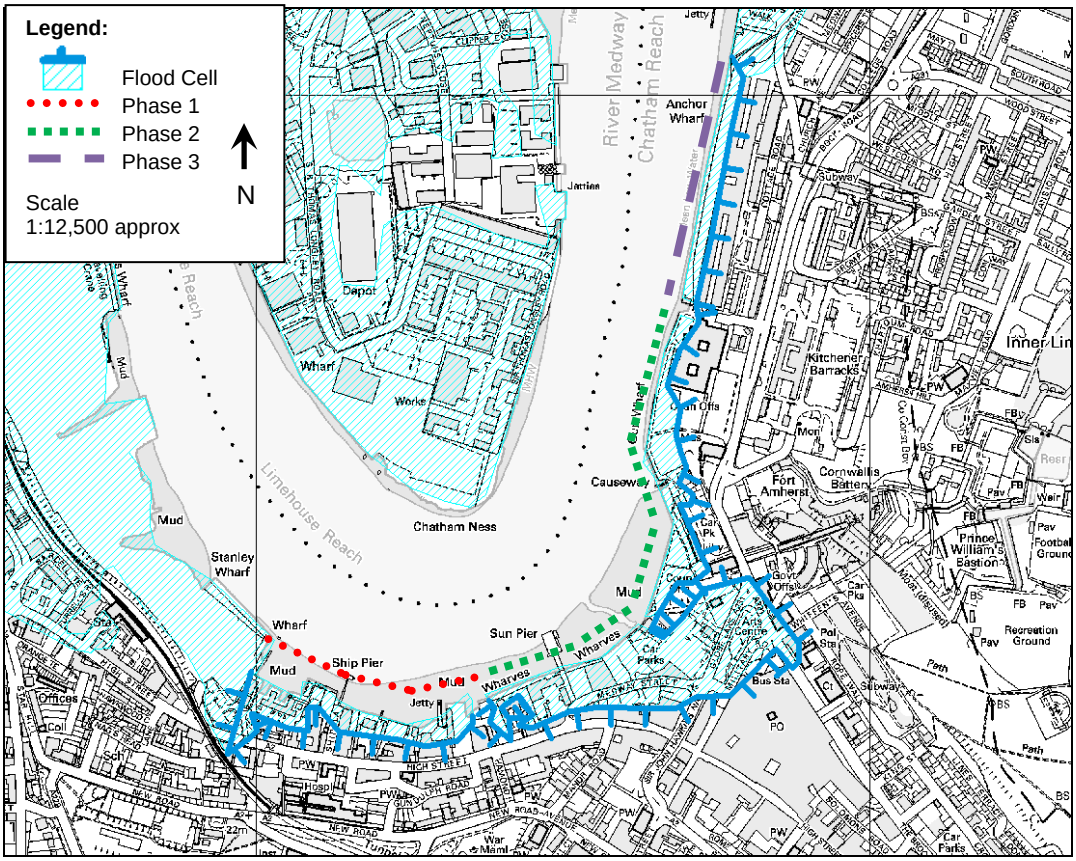
Long Term (50 – 100 years)

- The Gillingham Waterfront contains the lowest defences within the flood cell and the dominant land use is industrial. As this land use is typically designated as lower

vulnerability under PPS25 the upgrading of the defences in this area is unlikely to be prioritised in comparison with the residential development within this flood cell.

- The defences in the vicinity of the Historic Chatham Dockyard will provide the required 1 in 200 year standard of protection until the second half of this century; however proposed works will be required to raise crest levels in the longer term, which are likely to be influenced by heritage restrictions.

Figure 5-3: Area 2; Chatham Phased Implementation Strategy



Short Term (next 25 years)

- The defences in the vicinity of Ship Pier which connect into the Rochester Riverside works are approximately 1m below the present day 1 in 200 year flood level; these defences therefore should take priority in terms of flood defence works in this area.

Medium Term (25 – 50 years)

- The crest level of the flood defences which front the council offices and public open space amenity is approximately equivalent to the present day 1 in 200 year level, however these will require upgrading during the next 50 years to ensure the area is protected against the effects of climate change.

Long Term (50 – 100 years)

- The flood defences to the north of Gunwharf, towards the Historic Chatham Dockyard will provide the required 1 in 200 year standard of protection until the second half of this century; however proposed works will be required to raise crest levels in the longer term, which are likely to be influenced by heritage restrictions.

Area 3: Rochester Riverside

Short and Medium Term (next 50 years)

- The recently constructed defence scheme provides protection to the 1 in 200 year 2060 flood level therefore no significant capital works should be required during this period.

Long Term (50 – 100 years)

- The defences will need to be raised to account for the anticipated rise in tidal levels due to climate change in the future, and it is understood that the defences have been designed to account for this.

Area 4: Rochester

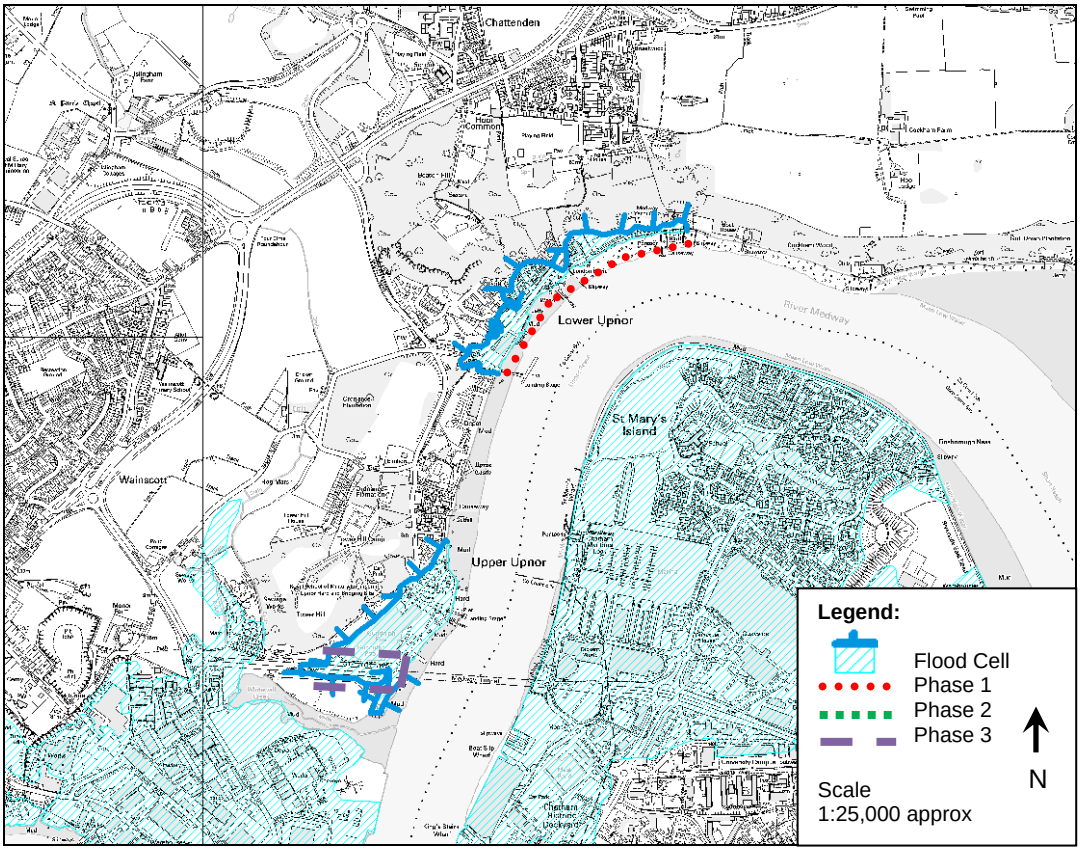
Short Term (next 25 years)

- The existing residential properties located on Hathaway Court adjacent to the riverside frontage will require flood protection. The current defences are up to 0.8m below the present day 1 in 200 year flood levels therefore investment will be required.

Medium and Long Term (25 – 100 years)

- The flood defences adjacent to the northern area of public open space amenity, which extend up to Rochester Pier are above the 1 in 200 year 2060 level, however they will require updating in the longer term in order to provide the required standard of protection.
- As the existing development within this narrow flood cell is very limited it is likely to be challenging to achieve favourable benefit/cost ratios.

Figure 5-4: Areas 5 and 6; The Upnors Phased Implementation Strategy



Short and Medium Term (50 years)

- The flood defences throughout Lower and Upper Upnor are generally very low, between 0.5m and 1.0m below the present day 1 in 200 year flood level.
- The level of existing development at risk of flooding within Upper Upnor is limited to the Ministry of Defence diver training facility therefore the benefits of protecting this entire area are unlikely to be sufficient to justify the costs.
- The existing development at risk of flooding in Lower Upnor will require flood defence measures to be implemented to protect the area from flooding.

Long Term (50 – 100 years)

- The entrance to the A289 tunnel beneath the road will require protection to ensure the tunnel is not flooded during extreme events. It is likely this could be achieved by raising the existing bund around the entrance. Protecting this asset is clearly important as it provides a key transport link and also forms a potential pathway for flood waters onto St Mary's Island.

Area 7: Medway City Estate

Short Term (next 25 years)

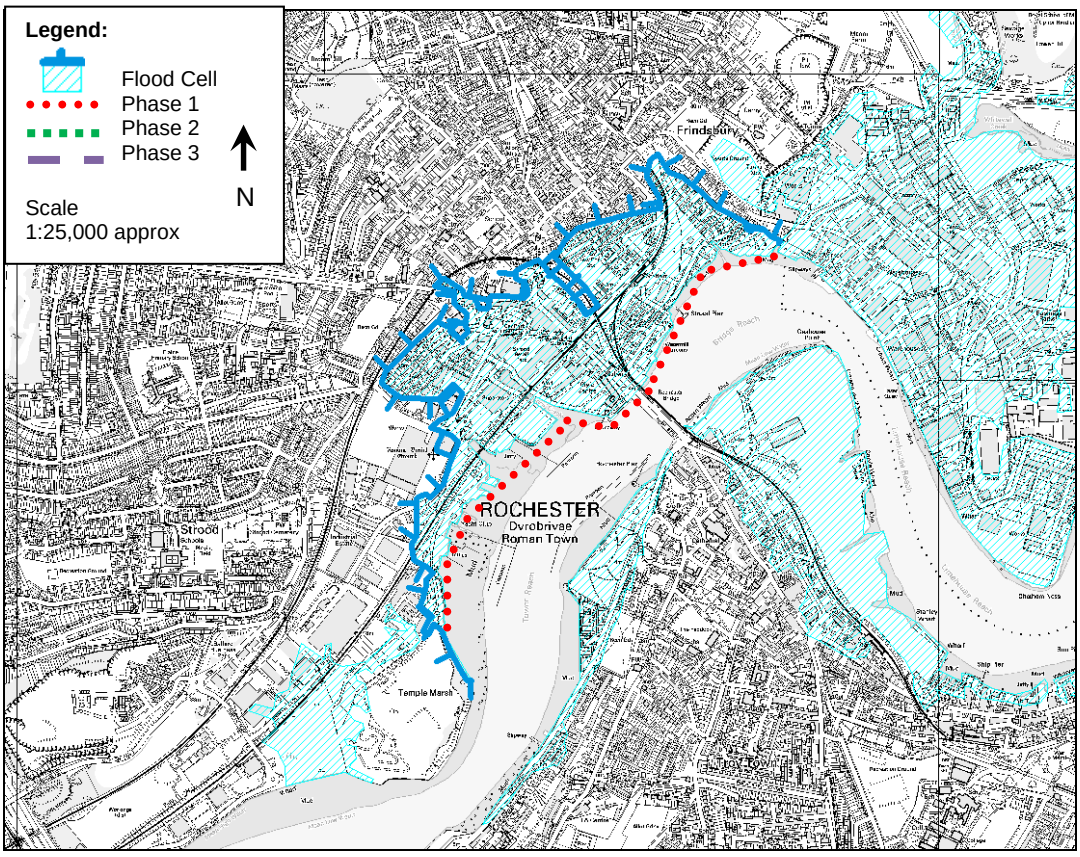
- The lowest flood defences around the Medway City Estate are located in the vicinity of Crown Wharf, on the north west of the peninsula where the defences are approximately 0.5m below the present day 1 in 200 year flood level.

- The defences are also below the present day 1 in 200 year level for a 200m length on the north east of the peninsula, opposite the Kings Stair wharf. These two areas should be prioritised for upgrade to improve the standard of protection.

Medium and Long Term (25 – 100 years)

- The flood defences around the remainder of the Medway City Estate perimeter are typically below the 1 in 200 year 2060 flood level and will therefore require upgrading in order to provide the required standard of protection.

Figure 5-5: Area 8; Strood Phased Implementation Strategy



Short Term (next 25 years)

- The flood defences along the Strood Riverside area are typically between 0.5m and 1.0m below the present day 1 in 200 year flood level, with the exception of a 100m length located to the north of Rochester Bridge.
- All of the defences along Strood Riverside require upgrading in order to provide the required standard of protection. The use of flood gates could be considered in order to allow redevelopment of specific sites without raising defences along the entire river frontage as discussed in chapter 4.

Medium and Long Term (25 – 100 years)

- If flood gates be installed to allow some site specific redevelopment then subsequent flood defence capital works will be required in order to allow redevelopment of the wider area.

Area 9: Temple Waterfront

Short Term (next 25 years)

- The Temple Waterfront consists of a significant proportion of higher raised ground, however the existing defences along the southern extent of Temple Marsh are approximately 1.0m below the present day 1 in 200 year flood level. The raising of the southern defences should therefore be given priority within this flood cell, which also has the effect of removing a potential flow route into the Strood Riverside flood cell.

Medium and Long Term (25 – 100 years)

- The flood defences to the north east of Temple Marsh are slightly below the present day 1 in 200 year flood level, however the raised ground located behind them prevents any significant inundation. Despite this, some flood defence raising in this area may be required in the future in order to provide the required 1 in 200 year level standard of protection.

5.6 Summary

5.6.1 Flood defence implementation phasing strategies have been suggested for each flood cell within the study area, primarily based on the level of the existing defences. This highlights that areas with the lowest current standard of protection should be addressed ahead of better defended areas. The priorities attributed to the flood cells themselves is likely to depend upon the regeneration aims of the council but the benefits and costs based on the existing development should also be taken into account.

5.6.2 There are a number of potential options available to secure funding to invest in the required flood defence infrastructure. However the current economic climate is very uncertain the recent Government budget cuts are likely to result is less funding being made available during immediate years.

5.6.3 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development of the waterfront in order to meet the significant housing and commercial development needs of the study area.

6 Conclusions

6.1 Issues

6.1.1 This report is based on available flood risk data and modelling information which has been used to determine the standard of protection and condition of existing flood defence structures.

6.1.2 The assessment which has been undertaken has confirmed that the majority of existing flood defences are below the required standard based on present day flood levels. This suggests that the study area has suffered from under investment in flood defence infrastructure in the past.

6.1.3 The predicted impacts of climate change will reduce the standard of protection further in the future as sea levels rise and storm surge predictions increase, which will require that additional investments are made in food defence infrastructure. This exacerbates the existing problem and the situation is likely to continue to deteriorate over time.

6.2 Options and Constraints

6.2.1 Potential 'high-level' flood defence options have been considered to provide the necessary level of flood defence. The generic options considered include use of 'hard' defences such as sheet piling and reinforced concrete walls in addition to 'soft' raised earth bunds.

6.2.2 The dockyard characteristics of the area and associated historic development policies which have been implemented have led to built development extending onto the river frontage and right up to the defences in many areas. This typically prevents the use of 'soft' defences which require additional land take to provide the appropriate landscaped grading.

6.2.3 The provision of raised flood defence structures will create a barrier between the river environment and the surrounding area, however in order to provide flood protection intervention is required and the impacts of this must be understood.

6.2.4 Flood defence options such construction of a tidal barrage has not been considered as it is beyond the scope of this study which is focused on establishing flood defence options on a flood cell basis. The use of local planning policies which prevent development in close proximity to the river frontage and finished floor levels to be raised above floor levels are also not included within the scope of this study. However these management measures are likely to form the basis for redevelopment until such time as adequate flood defence provision is installed.

6.3 Policy Drivers

6.3.1 Large scale physical regeneration is at the heart of the spatial strategies for both the Thames Gateway and for urban Medway, which includes the extensive urban waterfront and the adjoining town centres of Chatham and Strood.

6.3.2 The successful redevelopment of the waterfront is required not only to improve the visual quality of the area and open up the river but also to meet development needs, including new housing and commercial development of a significant scale.

6.3.3 However the waterfront is vulnerable to flooding and, as such, a clear strategy is required to address this critical issue and provide a comprehensive response that can inform development and investment decisions and lead to coherent solutions that demonstrate a joined up approach.

6.3.4 For these reasons the Council commissioned this study with the active support of the Environment Agency.

6.4 Recommendations

6.4.1 Economic analyses have been completed to estimate the likely damage costs attributed to flood events on a flood cell basis. These have been undertaken at an outline stage, and are based upon a series of assumptions which have been stated. However the principle benefits and costs have been accounted for and the estimates are considered appropriate for decision making on broad strategies.

6.4.2 The economic analyses have highlighted that the highest potential flood damages are located in the Gillingham Waterfront, St Mary's Island, Historic Dockyard, Medway City Estate and Strood areas. The Do Nothing scenario flood damages are estimated as over £70 million for these three flood cells which accounts for approximately 90% of the total damages calculated within the study area.

6.4.3 The costs of the required flood defence infrastructure are significant due to the extensive linear river frontage within the study area, which covers approximately 32.5km. The total estimated cost of providing the required standard of flood protection throughout the study area varies between approximately £190-280 million, which is clearly a very significant capital investment.

6.4.4 The outline economic analyses suggest that the benefits of the defences are not appropriate in comparison to the associated costs. By definition the level of existing development at risk of flooding is therefore not sufficient to economically justify the investment. In many areas improved defences will be required to allow regeneration and redevelopment to take place.

6.4.5 Suggest phased implementation strategies have been produced on a flood cell basis in order to highlight areas where defence improvements should be prioritised for investment.

6.4.6 To reduce the initial investment costs it is recommended that the Rochester Riverside approach should be followed whereby defences are installed to meet the 2060 standard of protection, but designed to allow subsequent raising to the 2110 standard.

6.5 Summary

6.5.1 The revised SFRA and this Flood Defence Strategy High Level Appraisal report should be used as a basis to produce the Supplementary Planning Document if required by Medway Council. This will involve decisions from the Council and other stakeholders regarding how flood risk management is approached along the Medway corridor.

6.5.2 The costs associated with provision of flood defence infrastructure are significant; therefore the key driver for any upgrading works is likely to be flood protection for new development as opposed to the benefits provided to existing development. The large scale physical regeneration which lies at the heart of the spatial strategies for both the Thames Gateway and for urban Medway is likely to form the key policy driver, which requires successful development

of the waterfront in order to meet the significant housing and commercial development needs of the study area.

Appendix A – Figures

Appendix B – Flood Defence Asset Records (NFCDD)

Appendix C – Flood Damage Calculation Methodology

The flood damage calculations are based on 2007 outputs from the Medway hydraulic model. This modelling was completed as an update to the 2006 SFRA Medway Model and was undertaken under the Environment Agency's Strategic Flood Risk Mapping Framework (SFRM).

The hydraulic model (from Allington to Gillingham) comprises of a one-dimensional (1D) model of the River Medway itself coupled with a two-dimensional (2D) model of the floodplain.

For the cost-benefit analysis the following defended design runs were used. All of these are tidal events, which also include a constant fluvial inflow of 100m³/sec:

- 5% (1 in 20 year) annual probability tidal event in 2007;
- 5% (1 in 20 year) annual probability tidal event in 2060;
- 5% (1 in 20 year) annual probability tidal event in 2110;
- 0.5% (1 in 200 year) annual probability tidal event in 2007;
- 0.5% (1 in 200 year) annual probability tidal event in 2060;
- 0.5% (1 in 200 year) annual probability tidal event in 2110;
- 0.1% (1 in 1000 year) annual probability tidal event in 2007;
- 0.1% (1 in 1000 year) annual probability tidal event in 2060; and,
- 0.1% (1 in 1000 year) annual probability tidal event in 2110.

To create a more robust cost-benefit analysis additional return periods are required and it was agreed with the Environment Agency that interpolation could be used instead of additional modelling due to budget limits.

A significant number of extreme sea levels for various return periods are contained in the JBA (2004) Extreme Sea Level Report[8] that were deemed possible to use for interpolation purposes. A comparison of the predicted flood levels is shown in Graph C-1, below and the interpolated levels are presented in Table C-1.

[8] JBA (2004) *'Extreme Sea Levels Kent, Sussex, Hampshire & the Isle of Wight Updated Summary Report'*, The Environment Agency: Worthing.

Graph C-1: Comparison of JBA Extreme Sea Levels and Modelling Flood Levels

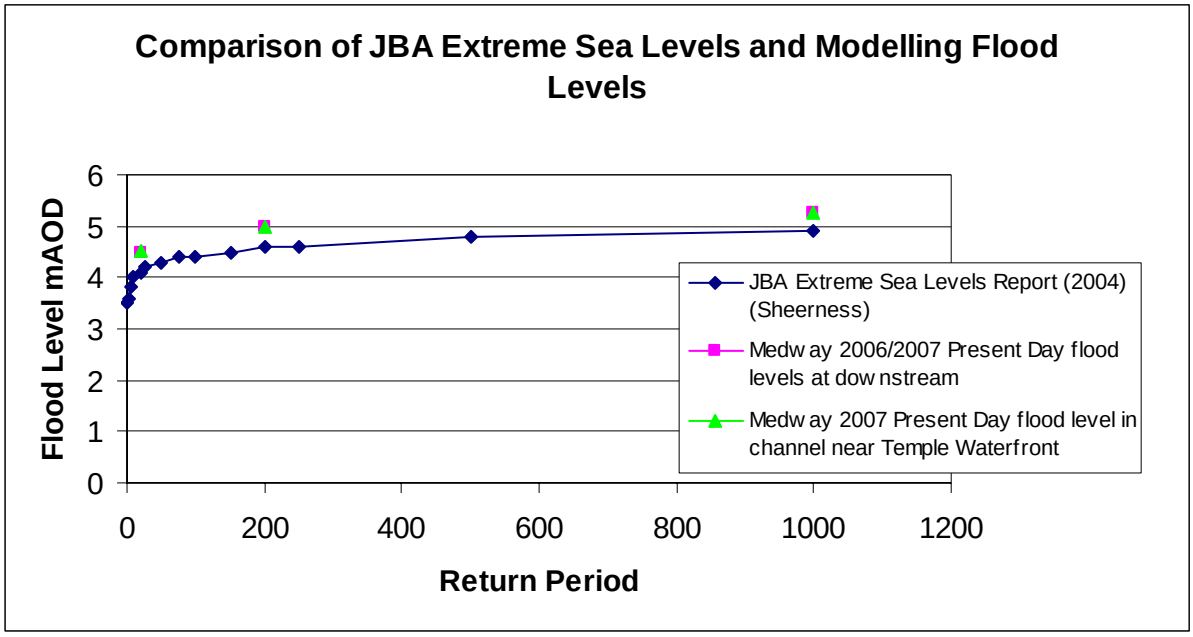


Table C-1: Interpolation of Flood Levels in mAOD *(interpolated values in italics)*

Source of Flood Levels	Return Period							
	10	20	50	100	200	250	500	1000
JBA Extreme Sea Levels Report (2004) (Sheerness)	**4.0**	**4.1**	**4.3**	**4.4**	**4.6**	**4.6**	**4.8**	**4.9**
Medway Model (2007) Present Day flood levels at downstream	***4.38***	**4.48**	***4.68***	***4.78***	**4.97**	***4.97***	***5.17***	**5.25**
Medway Model (2007) 2060 flood levels at downstream	***4.81***	**4.91**	***5.10***	***5.19***	**5.37**	***5.38***	***5.59***	**5.67**
Medway Model (2007) 2110 flood levels at downstream	***5.48***	**5.58**	***5.77***	***5.87***	**6.05**	***6.06***	***6.27***	**6.35**

The values for the 50, 100, 250 and 500 year return periods were interpolated based on the known modelled flood levels. All of the 2007 modelled results were reviewed to find the results that most closely matched the interpolated flood level. Where necessary a subtraction or addition was made to the flood depths.

Table C-2 presents which surrogate model results were used for each interpolated event and the required adjustment made to the flood depths.

Table C-2: Summary of potential damages and Lengths of Defence below 6.17maOD

Return Period (interpolate)	Interpolated Flood Level at downstream (see above) (mAOD)	Closest modelled run (2007 Medway Model)	Closest modelled run downstream flood level (mAOD)	Adjustment of flood depths required(m)
50 year present day	4.68	20 year_2007	4.48	+ 0.20
50 year 2060	5.1	1000 year_2007	5.25	-0.15
50 year 2110	5.77	1000 year 2060	5.67	+0.1
100 year present day	4.78	20 year _2060	4.91	- 0.11
100 year 2060	5.19	1000 year_2007	5.25	-0.06
100 year 2110	5.87	1000 year 2060	5.67	+0.2[9]
250 year present day	4.97	Same as 1 in 200 year present day		
250 year 2060	5.38	200 year 2060	5.37	+0.01
250 year 2110	6.06	200 year 2110	6.05	+0.01
500 year present day	5.17	200year_2060	5.37	-0.20
500 year 2060	5.59	20 year 2110	5.58	+0.01
500 year 2110	6.27	1000_2110	6.35	-0.08

[9] This return period was used to be consistent with the 50 year 2110

Appendix D – Flood Defence Options Costing

Appendix E – Benefit/Cost Analysis Summary Sheets