Barnstaple Flood Defence Improvements - Non Technical Summary

Final Report

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Revision History

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Draft Report v1.0 March 2015		**John Galt, Devon County Council Sally Nelson North Devon DC Andrew Austen North Devon DC Simon Dart Environment Agency**
Draft Final Report v2.0 June 2015	**Inclusion of Flood Cells E and F**	**John Galt, Devon County Council Sally Nelson North Devon DC Andrew Austen North Devon DC Simon Dart Environment Agency**
Final Report v1.0	**Updated with respect to comments from the project team on the Draft Final version**	**John Galt, Devon County Council Sally Nelson North Devon DC Andrew Austen North Devon DC Simon Dart Environment Agency**

Contract

This report describes work commissioned by Devon County Council by a letter dated 8th September 2014. Devon County Council's representative for the contract was John Galt. Phil Emonson, Chris Smith, Rachel Drabble, Oliver Francis and Angus Pettit of JBA Consulting carried out this work.

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Purpose

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Acknowledgements

JBA would like to acknowledge assistance John Galt (Devon County Council), Simon Dart (Environment Agency), Sally Nelson and Andrew Austen (North Devon District Council) for their support and timely supply of data during the commission.

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JBA is aiming to reduce its per capita carbon emissions.

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Abbreviations

AEP .... Annual Exceedance Probability
AONB .... Area of Outstanding Natural Beauty
CDA .... Critical Drainage Area
JBA .... JBA Consulting Ltd
LLFA .... Lead Local Flood Authority
PLP .... Property Level Protection
SHLAA .... Strategic Housing Land Availability Assessment
SSSI .... Site of Special Scientific Interest
SuDS .... Sustainable Drainage Systems

Definitions

Critical infrastructure is classified as the following

- Education establishments
- Electricity
- Emergency services
- Gas
- Health establishments
- Military
- Oil
- Socially vulnerable
- Telecommunications
- Transport infrastructure
- TV, radio and other associated media
- Water infrastructure

1 Introduction

1.1 Project background

Current and future flood risks in Barnstaple are cause for concern for Devon County and North Devon District Councils. Resultantly, JBA Consulting was commissioned by Devon County Council to investigate potential solutions to address future flood risk in Barnstaple.

Barnstaple is identified as the sub-regional centre and forms the economic, administrative and commercial centre of Northern Devon. The publication of the draft North Devon and Torridge Local Plan (2014) proposes approximately 4,000 new homes and 26 hectares of additional employment land, both within Barnstaple and in the immediate surrounding areas, between 2011 and 2031. It has been recognised from work by the Environment Agency and in the spatial strategy for Barnstaple within the emerging joint Local Plan (Policy BAR) that a long term flood defence improvement strategy is required to help facilitate this growth.

The production of a flood defence improvement strategy for the next 60 to 100 years for Barnstaple will enable future redevelopment of housing and employment sites, many of which are brownfield sites that cannot gain planning approvals due to current and projected flood risks. The production of this strategy will promote economic development and raise employment opportunities, helping to promote infrastructure investment (especially in areas such as Pottington), unlocking land potential and raising land values. Reducing future flood risks will help to revitalise and regenerate the northern part of the town.

This study explores a variety of conceptual flood alleviation options and identifies preferred option(s) for different parts of the town. The study will assess future flooding by addressing the lifetime of development, which is 60 years for commercial uses and 100 years for residential uses. Each of the preferred options will be modelled to assess the impacts on levels of future flood risk. An outline appraisal of the technical feasibility of each option will be undertaken, together with an assessment of cost, environmental impact, and priority.

1.2 Study area

Barnstaple is situated on the tidal stretch of the River Taw, with substantial parts of the town at risk of flooding from the rivers Taw and Yeo, Coney Gut and Bradiford Water and their associated tributaries.

The study area has been split into six separate flood cells as shown on Figure 1-1. These cells are not directly connected hydraulically, which enables options, costs and phasing for each flood cell to be assessed independently. The main study area extends from Bradiford Water in the north, past the Longbridge in the centre of Barnstaple and includes the River Yeo, a major tributary of the Taw which flows through Pilton, and to the south to Newport and Rock Park.

The extent and location of the flood cells was defined by North Devon District Council, Devon County Council and the Environment Agency prior to the study. The decisions were based around the source of the flood risk, the perceived level of risk now and in the future (based on best available data), and future development opportunities as identified in the North Devon and Torridge Local Plan (2014) and the 2010 Strategic Housing Land Availability Assessment (SHLAA).

In addition to the level of flood risk, the Taw-Torridge estuary is a Site of Special Scientific Interest (SSSI), due to major importance for overwintering and migratory populations of wading birds. Furthermore the Taw-Torridge estuary is designated as part the buffer zone of a UNESCO Biosphere Reserve, and on route to the sea flows past the North Devon Coast Area of Outstanding Natural Beauty (AONB) and Heritage Coast, demonstrating the significance of the area as a scientifically and historically important conservation site.

Flood cell F has been excluded from the analysis of costs and benefits as defences here are imminently being improved as part of the Anchorwood Bank development. These will extend along the entire frontage of flood cell F.

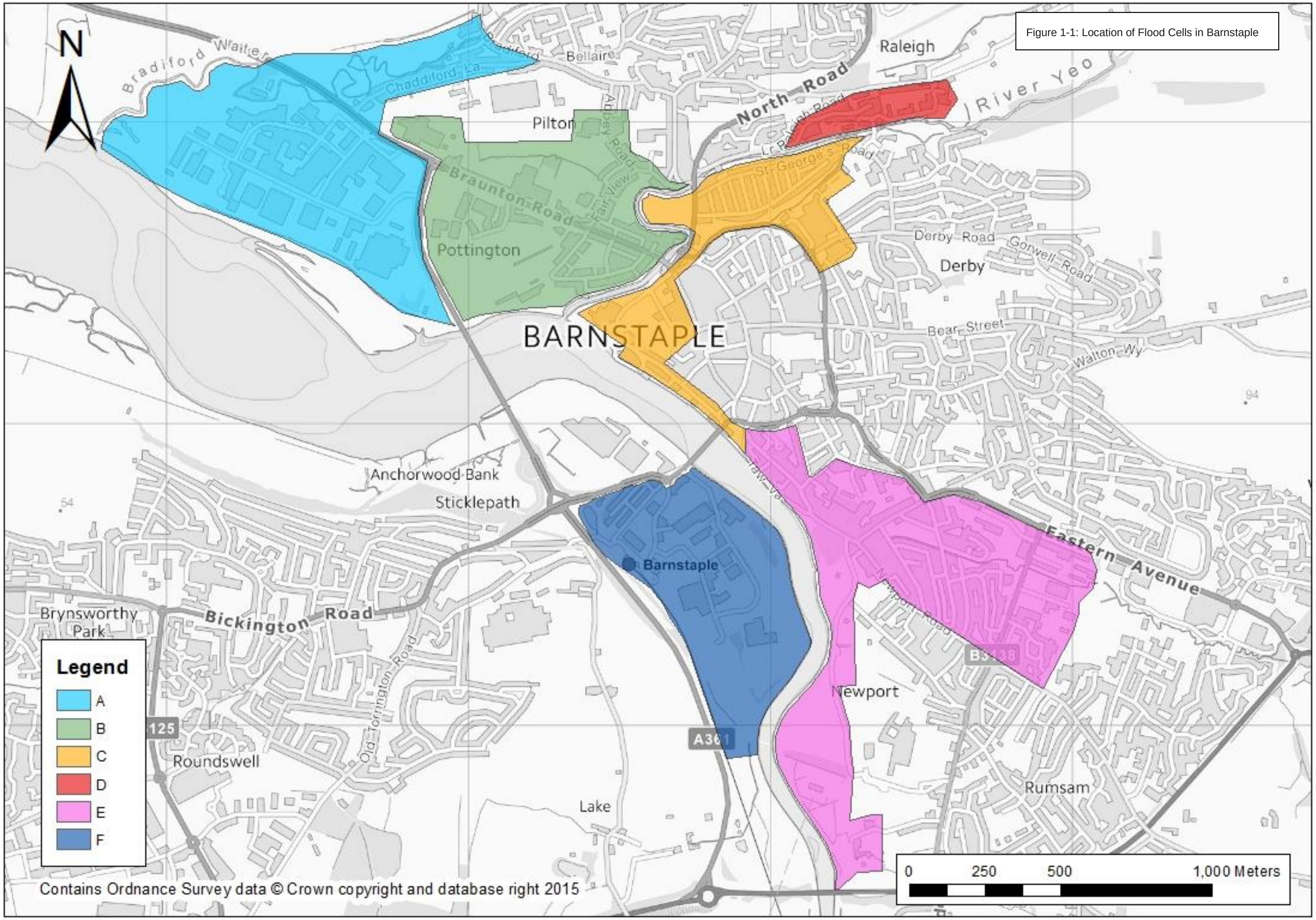
Figure 1-1: Location of Flood Cells in Barnstaple
N
Legend
A
B
C
D
E
F
BARNSTAPLE
Pilton
Pottington
Raleigh
Derby
Anchorwood Bank
Sticklepath
Barnstaple
Newport
Rumsam
Roundswell
Lake
Brynsworthy Park
North Road
Braunton Road
River Yeo
Derby Road
Bear Street
Eastern Avenue
Bickington Road
0 250 500 1,000 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015

2 Current and future flood risks

2.1 An overview of risk

Flood risk has two components: the chance (probability) of a particular flood and the impact (or consequence) that the flood would have if it happened. The probability of a flood relates to the likelihood of a flood of that size occurring within a one year period, it is expressed as a percentage. For example, a 1% annual probability flood has a 1% chance of occurring in any one year, and a 0.5% annual probability flood has a 0.5% chance of occurring in any one year. People are often familiar with the concept of return period, which is the period in years over which a flood of a particular size is statistically likely to reoccur. This is only a statistical probability, and of course floods of similar size can occur in any year. It is therefore more appropriate to express the likely of floods as a percentage, as shown below.

Table 2-1 Conversion between return period and AEP

Return period (yrs)	2	5	10	20	30	50	75	100	200	1000
AEP (%)	50	20	10	5	3.33	2	1.33	1	0.5	0.1

There are two main sources of flooding in Barnstaple; tidal flooding from the Taw estuary, and fluvial flooding from the many rivers and watercourses. These include the River Yeo, Bradiford Water and Coney Gut. Two additional watercourses, the Venn Stream and the Fremington Stream are also sources of fluvial flooding, but lie beyond the study area. Tidal flooding can occur when existing tidal defences along the banks of the Taw estuary are overtopped during more extreme tidal flood events. Also, the River Yeo and Bradiford Water are susceptible to tidal flooding as tidal flood water extends back along them. High tide levels in these watercourses can also cause flooding from river water becoming locked and unable to flow freely into the estuary.

River flooding occurs when the capacity of the river channels is exceeded and flow in to the floodplain is experienced. Areas most susceptible to river flooding on the River Yeo are immediately downstream of the A39 Bridge adjacent to Pilton Park, and upstream of the A39 road bridge in the area adjacent to Raleigh Road. There is also a risk of river flooding along the Bradiford Water corridor and near to the Pottington Business Park.

There are both surface water and foul sewage flood risks in Barnstaple. Surface water flooding is caused when the drainage systems are exceeded or rainwater cannot infiltrate due to saturated conditions. This can cause overland flow, creating problems especially in urban areas where impermeable surfaces exist. Foul flooding is caused during high rainfall conditions when foul drainage systems become overwhelmed and can cause sewerage to back-up. Neither surface water nor foul flooding issues were considered in this study.

2.2 What is at risk, and where?

Flood risk in flood cells in Barnstaple has been modelled for the current 2015 conditions and two horizons in the future; 2075 and 2115 (as these represent the 60 and 100 year lifespans of commercial and residential properties respectively). The risks have been modelled for both tidal and fluvial flooding. Where necessary the 2045 horizon has been considered but not modelled.

Currently in Barnstaple there are a range of flood embankments and walls which protect to a variety of standards from both fluvial and tidal floods. These are mostly along the Taw estuary, along the lower reaches of the River Yeo and round Pilton Park. Flood defences in Barnstaple are generally of a high standard of protection and protect the town from all but extreme tidal and fluvial flooding (Figure 2-1 shows existing standard of tidal defences based on Environment Agency data).

Climate change and associated increased sea levels and river flows will reduce the effectiveness of these defences over time. By 2115 the tidal defences in Barnstaple (at existing levels) could be overtopped every year in places causing frequent and extensive flooding (Figure 2-2). Hydraulic modelling using an updated version of an Environment Agency model has been undertaken to ascertain the risks to the town in 2015, 2075 and 2115 and gain an understanding of the changes over that time.

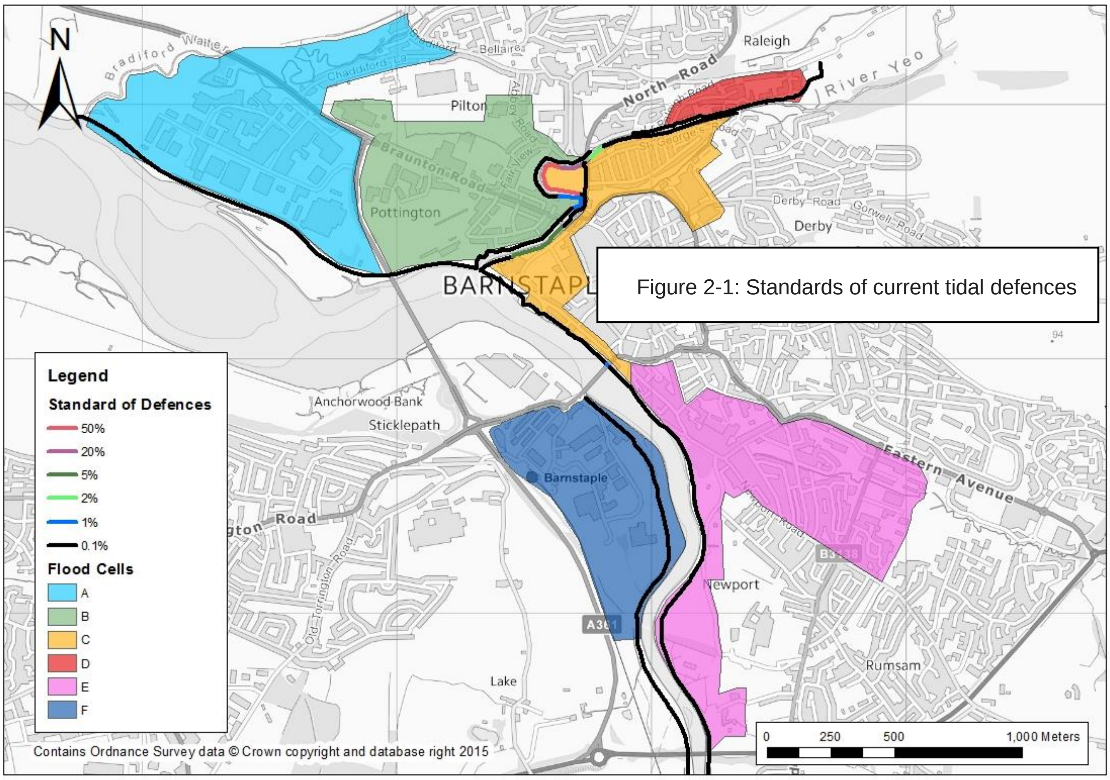

Figure 2-1: Standards of current tidal defences

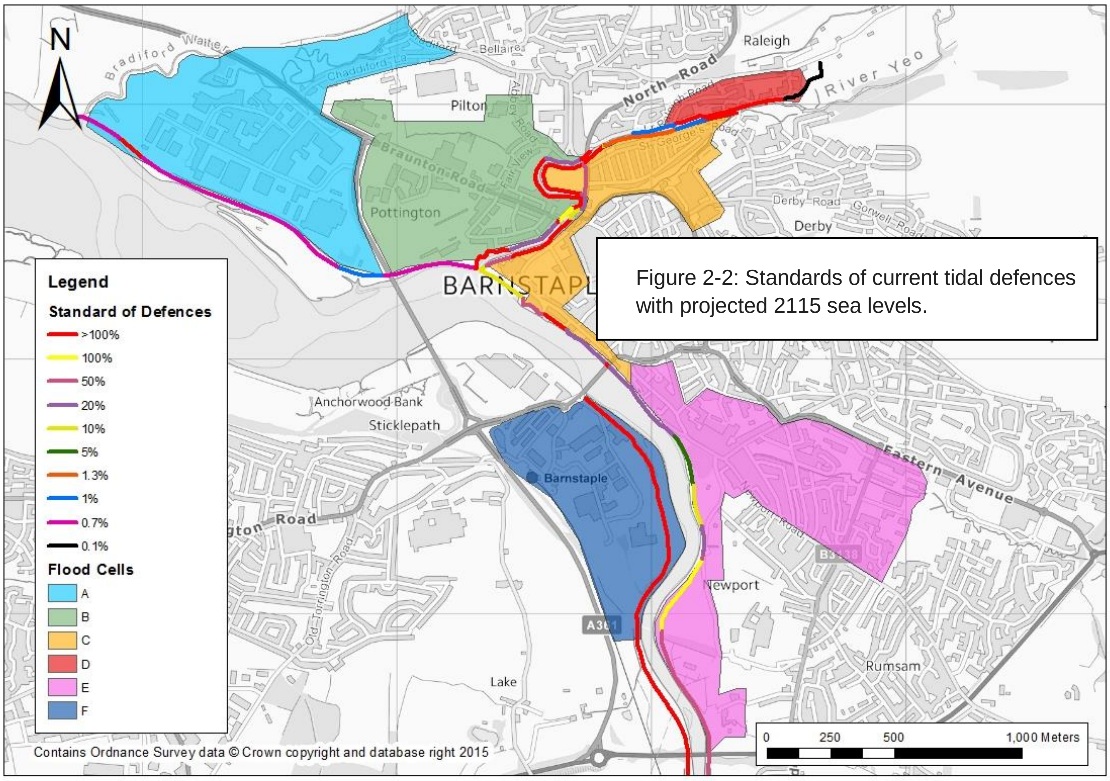

Figure 2-2: Standards of current tidal defences with projected 2115 sea levels.

These figures are derived using Environment Agency defence level data from the AIMS database. There may be some discrepancies between this and the model results which uses different bank level data.

2.2.1 Areas at risk

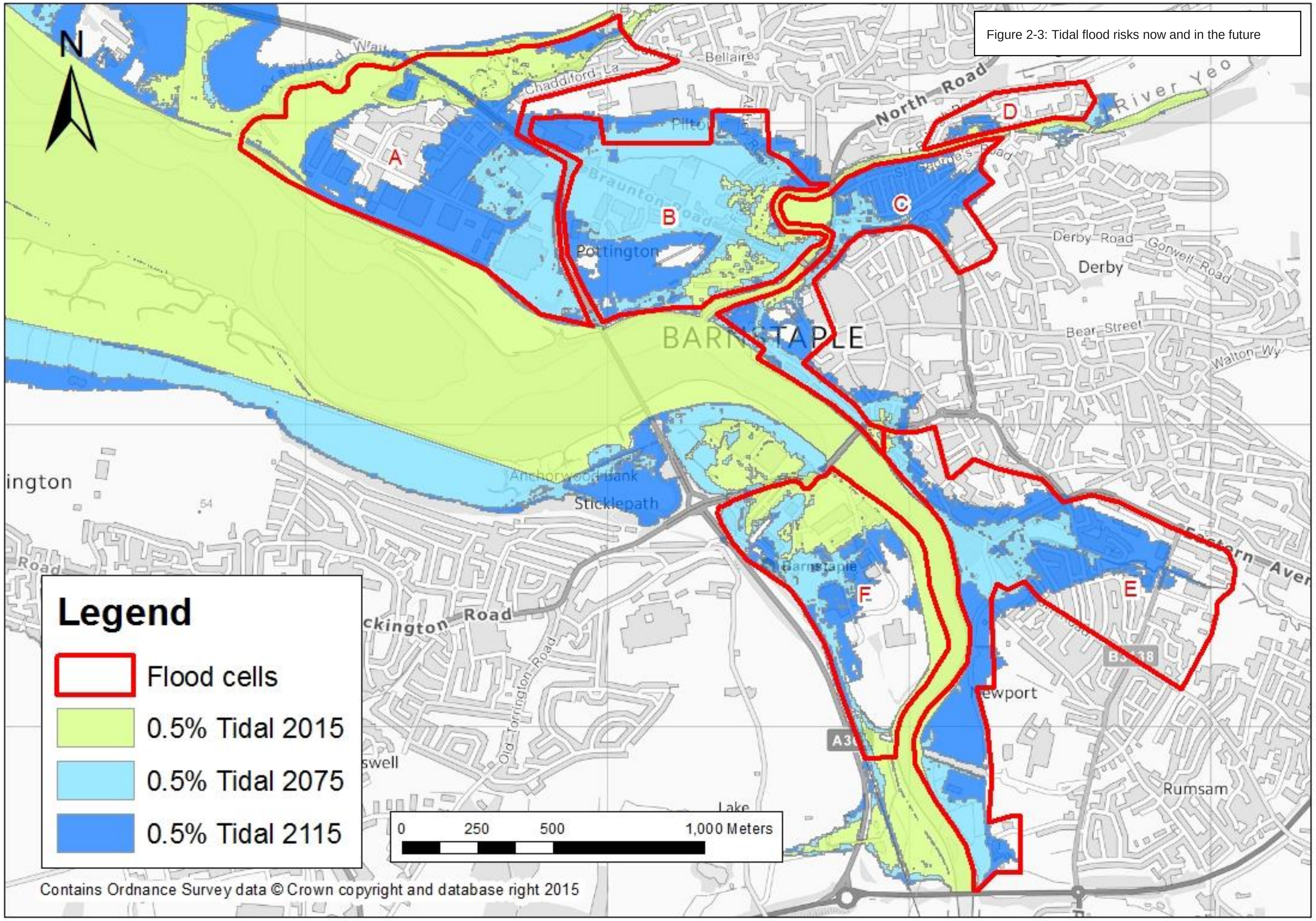

Figure 2-3: Tidal flood risks now and in the future

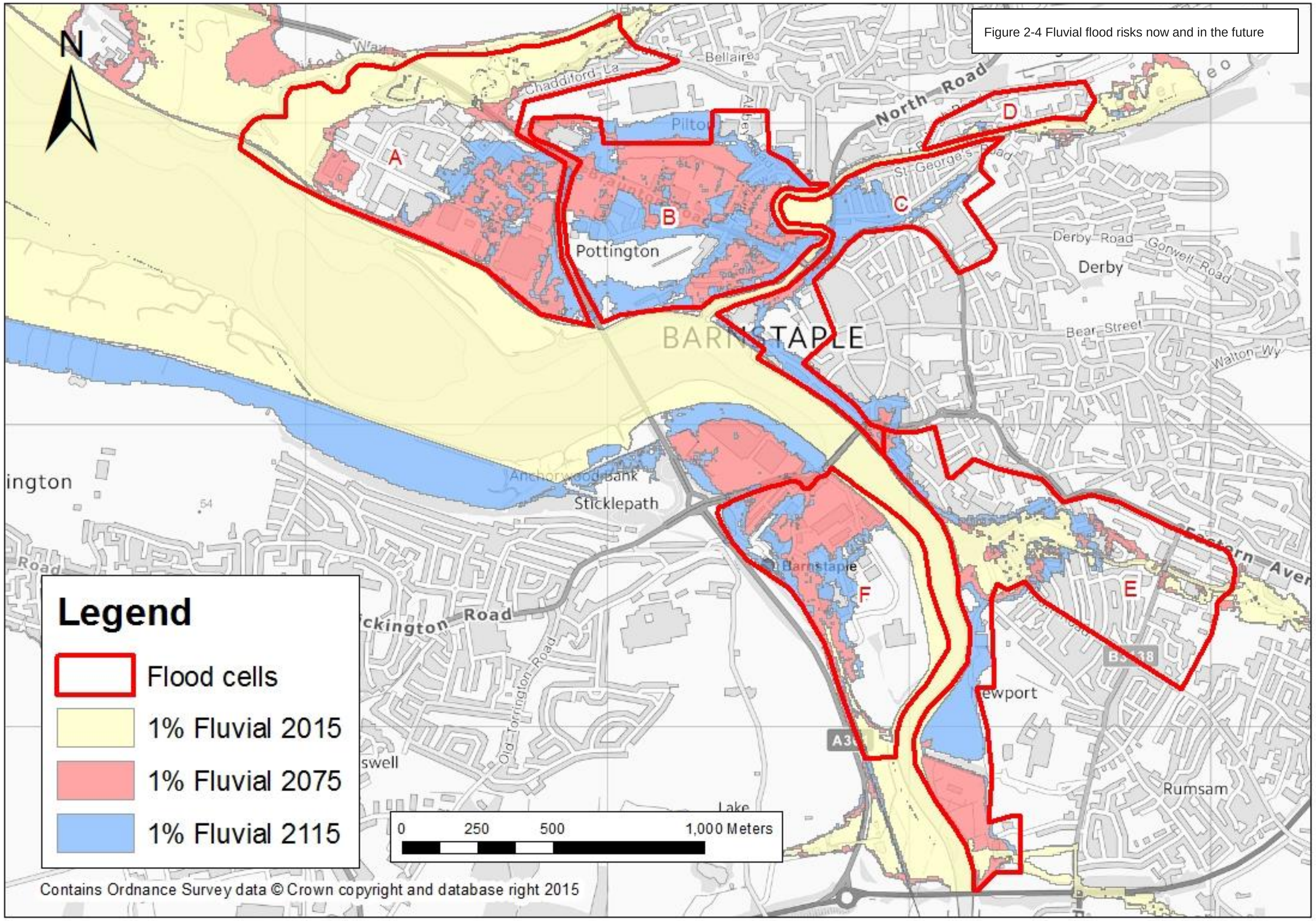
Figure 2-4 Fluvial flood risks now and in the future
N
Legend
Flood cells
1% Fluvial 2015
1% Fluvial 2075
1% Fluvial 2115
0
250
500
1,000 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015
A
B
C
D
E
F
BARNSTAPLE
Pottington
Sticklepath
Derby
Rumsam
North Road
Derby Road
Bear Street
Chaddiford La
Bellaire

2.2.2 What is at risk?

Table 2-2 Properties at risk from tidal flooding now and in the future

	2015 Tidal 0.5% AEP			2075 Tidal 0.5% AEP			2115 Tidal 0.5% AEP		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	0	5	0	0	40	2	12	122	9
Cell B	74	55	0	442	165	8	506	198	11
Cell C	0	3	2	87	61	4	444	101	8
Cell D	0	0	0	0	0	0	27	0	0
Cell E	1	2	0	115	44	0	617	113	4
Cell F	Excluded from analysis								

Table 2-3 Properties at risk from fluvial river flooding now and in the future

	2015 Fluvial 1% AEP			2075 Fluvial 1% AEP			2115 Fluvial 1% AEP		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	24	23	1	37	76	5	34	89	8
Cell B	0	0	0	108	79	4	460	180	9
Cell C	0	1	1	0	3	2	150	70	5
Cell D	0	0	0	0	0	0	2	0	0
Cell E	96	31	1	171	42	1	214	47	1
Cell F	Excluded from analysis								

Table 2-2 gives the number of properties predicted to be at risk from a 0.5% AEP tidal flooding event in 2015, 2075 and 2115. These are divided into residential, commercial and critical infrastructure. Table 2-3 gives the same information for the 1% AEP fluvial flooding. Flood cell F has been excluded as defences are imminently being improved.

Fluvial flood risk is currently highest in flood cells A and E. In flood cell A this is due to overtopping of the Bradiford Water, in the area from Meadow Road to the estuary. This is in part due to river water not being able to discharge into the estuary at high tide. In flood cell E this is due to flooding from Coney Gut.

Tidal flood risks are currently highest in flood cell B. In flood cell B tidal flooding along the River Yeo causes overtopping of existing defences near Rolle Quay and near Pilton Park.

By 2075 fluvial flooding increases quite significantly in flood cells A, B, and E. However, overall there are much greater increases associated with tidal flooding. By 2115 tidal and fluvial risks in all flood cells increase from 2075 to 2115.

It is very clear from these modelled results that flooding is predicted to increase substantially in Barnstaple as a result of climate change driven sea level rise and fluvial flow increases.

2.3 Economic Damages

Economic damages have been calculated for these properties at risk. Given the strategic nature and timescales of the analysis the results should only be considered indicative. They will however give an indication of the economic damages associated with flooding now and in the future and can be compared to likely costs of constructing improved flood defences. Initial estimates of flood damages suggest current damages are modest, as would be expected given the generally high standard defences in place. These increase very significantly to 2075 and dramatically further in 2115 given the hundreds of residential and commercial properties then at risk from frequent flooding.

Table 2-4 Present Value Damages associated with tidal flooding

Present Value Damages (PvD)	2015 (£k)	2075 (£K)	2115 (£k)
Cell A	58	2,727	35,449
Cell B	1,195	68,638	101,112
Cell C	42	2,439	39,522
Cell D	0	0	247
Cell E	40	6,442	81,161
Cell F	Excluded from analysis		
Total	**1,335**	**80,246**	**257,491**

To give that some context, in 2115 the £257M PvD figure would be equivalent to an average annual damage of approximately £9M from tidal flooding (i.e. very significant tidal flooding occurring every year).

Table 2-5 Present Value Damages associated with fluvial flooding

Present Value Damages (PvD)	2015 (£k)	2075 (£K)	2115 (£k)
Cell A	4,590	8,864	26,663
Cell B	3,795	29,389	94,430
Cell C	28	3,355	29,108
Cell D	0	184	635
Cell E	3,387	11,386	15,457
Cell F	Excluded from analysis		
Total	**11,800**	**53,178**	**166,293**

In the 2015 scenario the fluvial flooding is more economically important than tidal flooding but by 2075 tidal flooding has become dominant and is more so by 2115. The two cannot be separated out entirely as fluvial future scenarios also include sea level rise which causes much of the increase in flooding. The two sources are flooding many of the same properties by overtopping the same defences so must be considered together in most areas. There are some areas where fluvial flooding can be separated such as on the upper parts of Coney Gut in flood cell E and Bradiford Water in flood cell A.

Calculation of economic damages is very uncertain, particularly when looking into the future. A lot of detailed work can be done to refine these figures and that should be done at future stages of option development. The figures presented here should only be considered indicative. The impact of the flooding of critical infrastructure is also something that should be considered in more detail.

Damages for flood cell F in 2015, 2075 and 2115 have been excluded as improved defences are being constructed imminently as part of the Anchorwood Bank development.

3 Discounted options

Options for reducing flood risk in Barnstaple in future have been considered. The following options were discussed amongst the project team, and considered not suitable to take further to the options testing stage.

3.1 Do nothing

In a heavily populated area such as Barnstaple doing nothing in the face of increasing flood risk due to climate change is not an option. A failure to invest in the existing defence assets would result in a significant deterioration in their condition increasing the risk of a breach during a large event. Many areas of Barnstaple are at levels significantly below the defence heights and a breach of the defences would be catastrophic and would have the potential to result in loss of life as well as significant damage to property and infrastructure.

3.2 Do minimum – maintain existing practices

With the predicted increase in sea levels over the next hundred years just maintaining the current standard of flood protection is not an option. A failure to improve the defences would result in a significant increase in both the frequency of flooding, the resultant damages from a flood event, as well as increasing the risk of experiencing loss of life.

Do minimum may however be appropriate to continue until such time as a structural defence option becomes viable.

3.3 Demountable defences

These include flood gates, drop in defences, temporary flood walls and other temporary defences (e.g. water filled tubes). These are not feasible options due to the requirements for a permanent flood solution for Barnstaple.

3.4 River restoration

A restoration project would be limited in terms of quantifiable benefits to flood risk mitigation and would only affect the fluvial flooding element of the flood cells in the study area.

3.5 Tidal barrier

This is not a feasible option due to the proximity to the Site of Special Scientific Interest (SSSI) in the Taw estuary and the fact that the only feasible location would be beneath the A361 crossing which would not protect flood cell A. It would be an extremely high cost option and could only be considered if no other options existed for the other flood cells. A tidal barrier would also present issues in regard to navigation rights which would have to be addressed if it were to be considered.

3.6 Source control measures

These include upland catchment land management and retrofitting of Sustainable Drainage Systems (SuDS) in the urban areas. The flood risk management benefits are very difficult to quantify and they do nothing to alleviate tidal flood risk. Source control measures are being considered by the EA and local planning authority on a case by case basis with respect to planning applications. The Coney Gut is a Critical Drainage Area (CDA) area and a higher standard is applied to SUDS. From April 2015, the LLFA have responsibility for surface water drainage within the CDA.

3.7 Increasing channel capacity

Dredging or channel widening are unsuitable due to the tidal nature of flood risk; increasing channel capacity will do nothing to reduce flood water levels due to the volume of tidal water. Widening of the channel in an urban environment presents difficulties regarding relocation of property, therefore this option would be overly costly when compared to its lack of benefit. Dredging is not a permanent solution and will require regular works to maintain the channel at its dredged capacity, as well as the issues regarding disposal of dredged material. In addition the environmental impacts of dredging or channel widening of the SSSI would need to be fully understood and it is unlikely that would prove acceptable.

3.8 Removal / adaptation of restrictive hydraulic structure at a strategic level

Due to the prevalent tidal flood risk, removal of channel restricting hydraulic structure is not appropriate to reduce flood risk across the study area as a whole but if the modelling demonstrates that a specific structure or group of structures in a locality is having an adverse effect then the benefit of their removal could be considered on an individual basis.

3.9 Estuary management

Changes to the estuary would be difficult considering the presence of the SSSI and are unlikely to have any measureable benefit in regard to flood risk but some of the other defence options may require compensatory habitat and it may be possible to identify locations within the estuary to provide this

4 Flood Risk Management Options

Two options to alleviate future flooding have been developed, costed and modelled. These options cover Flood Cells A to F and are largely the same with the only difference being the route of the River Yeo around Pilton Park. The detail of these are given below.

The proposed options are outline ideas at this stage and more work would be required to develop them into detailed proposals.

4.1 Option 1

Option 1 assumes works at the following locations and assets.

Flood Cell A

- Raising of A361 and cycle track north towards Pilton Community College
- Embankment / land raising around edge of Bradiford Nature Reserve
- Property level protection (PLP) for properties at risk in Meadow Road area
- Replace the existing tidal defences over time to meet required standards

Flood Cell B

- Raising of A361 and cycle track north towards Pilton Community College
- Raised wall along Rolle Quay
- Increased parapet (or gates) along Rolle Street Bridge
- Piling around existing course of Yeo through Pilton Park
- Replace the existing tidal defences over time to meet required standards

Flood Cell C

- Raise wall opposite Raleigh Road
- Flood relief culverts beneath A39 bridge
- Wall raising along Castle Quay
- Raised existing tidal defence

Flood Cell D

- Replace the existing defences over time to meet required standards

Flood Cell E

- Replace the existing tidal defences over time to meet required standards
- Flood walls along Coney Gut

Flood Cell F

- Flood defences are being upgraded imminently as part of the Anchorwood Bank development

4.2 Option 2

Option 2 assumes the same works as Option 1 other than the following amendments.

Flood Cell B/C

- Re-routing of Yeo along A39 Pilton Causeway instead of piling around the existing course of the Yeo through Pilton Park

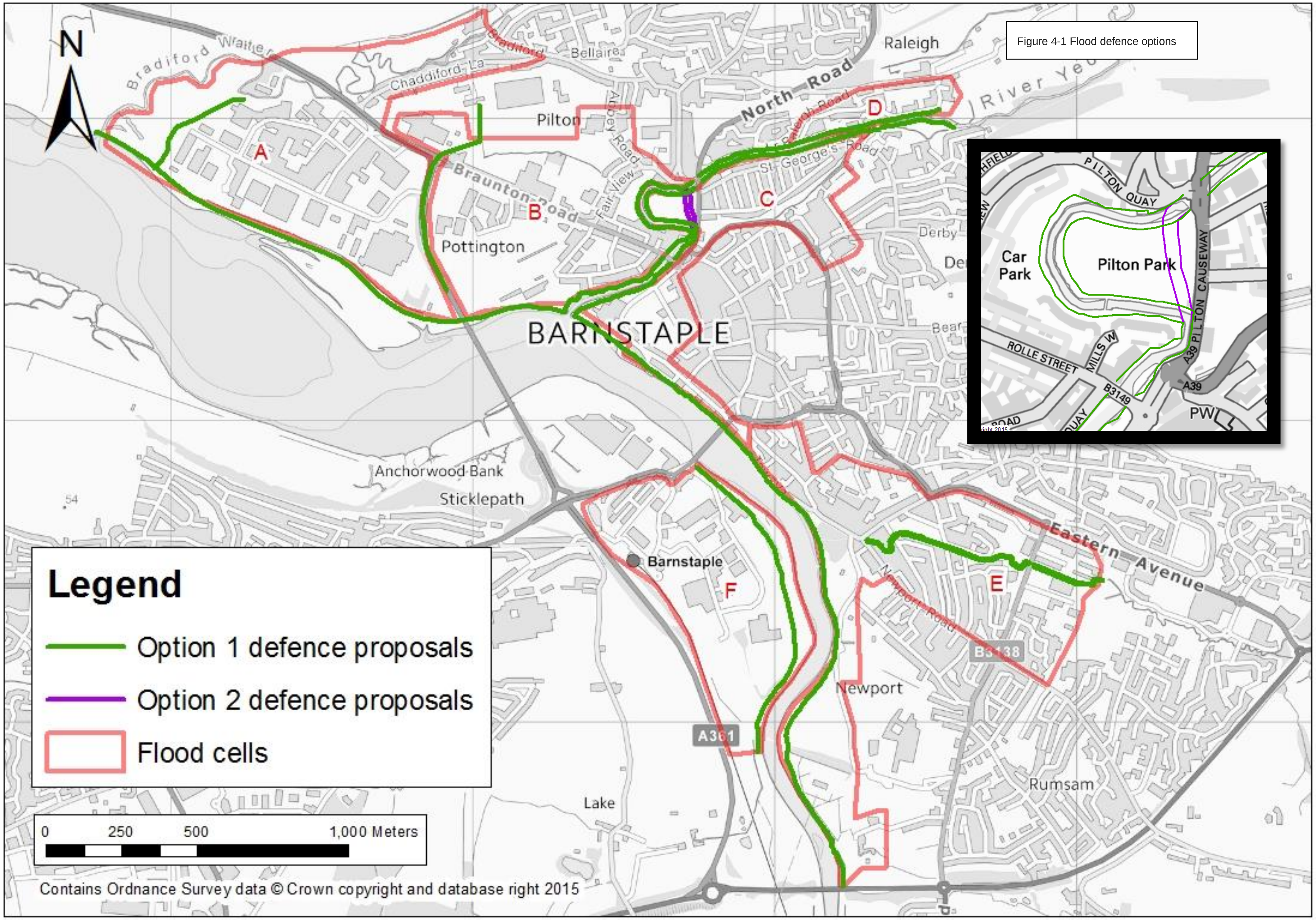
Figure 4-1 Flood defence options
Legend
Option 1 defence proposals
Option 2 defence proposals
Flood cells
0
250
500
1,000 Meters
Contains Ordnance Survey data © Crown copyright and database right 2015
BARNSTAPLE
Pottington
Pilton
Raleigh
Anchorwood Bank
Sticklepath
Barnstaple
Newport
Rumsam
Lake
North Road
Braunton Road
St George's Road
Eastern Avenue
River Yeo
Bradiford Water
Chaddiford La
Abbey Road
Fair View
Newport Road
A361
B3138
A
B
C
D
E
F
Car Park
Pilton Park
PILTON QUAY
ROLLE STREET
PILTON CAUSEWAY
A39
B3149

5 Effectiveness of options

The effectiveness of the flood defence options has been considered by modelling the options and calculating the numbers of properties at risk and the economic benefits that may be achieved. The property count tables below are directly comparable to Table 2-2 and 2-3 and show the reduction in numbers of properties at risk. In both options current risk will remain the same, as it has been assumed that the improvements for flood defences will occur in the future.

5.1 Option 1

Table 5-1 Properties at risk from tidal flooding now and in the future with option 1

	2015 Tidal 0.5% AEP No intervention			2075 Tidal 0.5% AEP With Option 1			2115 Tidal 0.5% AEP With Option 1		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	0	5	0	0	5	0	6	24	0
Cell B	74	55	0	0	0	0	0	4	0
Cell C	0	3	2	0	1	1	0	1	1
Cell D	0	0	0	0	0	0	0	0	0
Cell E	1	2	0	0	0	0	0	0	0
Cell F	Excluded from analysis								

Table 5-2 Properties at risk from fluvial flooding now and in the future with option 1

	2015 Fluvial 1% AEP No intervention			2075 Fluvial 1% AEP With Option 1			2115 Fluvial 1% AEP With Option 1		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	24	23	1	30	12	0	30	12	0
Cell B	0	0	0	0	0	0	0	0	0
Cell C	0	1	1	0	1	1	0	1	1
Cell D	0	0	0	0	0	0	0	0	0
Cell E	96	31	1	1	0	0	1	0	0
Cell F	Excluded from analysis								

Table 5-3 Economic benefits in relation to tidal flooding for Option 1 (£k)

	2045 Indicative	2075	2115
Cell A		£2,669	£34,262
Cell B	£28,000	£68,638	£101,090
Cell C		£2,411	£39,494
Cell D		£0	£247
Cell E		£6,442	£81,161
Cell F	Excluded from analysis		

Table 5-4 Economic benefits in relation to fluvial flooding for Option 1 (£k)

	2045 Indicative	2075	2115
Cell A		£1,700	£17,026
Cell B	£14,000	£27,210	£92,062
Cell C		£3,327	£29,080
Cell D		£184	£635
Cell E		£11,186	£15,257
Cell F	Excluded from analysis		

5.2 Option 2

Table 5-5 Properties at risk from tidal flooding now and in the future with option 2

	2015 Tidal 0.5% AEP No intervention			2075 Tidal 0.5% AEP With Option 2			2115 Tidal 0.5% AEP With Option 2		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	0	5	0	0	5	0	6	23	0
Cell B	74	55	0	0	0	0	0	4	0
Cell C	0	3	2	0	2	1	0	2	1
Cell D	0	0	0	0	0	0	0	0	0
Cell E	1	2	0	0	0	0	0	0	0
Cell F	Excluded from analysis								

Table 5-6 Properties at risk from fluvial flooding now and in the future with option 2

	2015 Fluvial 1% AEP No intervention			2075 Fluvial 1% AEP With Option 2			2115 Fluvial 1% AEP With Option 2		
	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure	Residential	Commercial	Critical Infrastructure
Cell A	24	23	1	30	12	0	31	12	0
Cell B	0	0	0	0	0	0	0	0	0
Cell C	0	1	1	0	2	1	0	2	1
Cell D	0	0	0	0	0	0	0	0	0
Cell E	96	31	1	1	0	0	1	0	0
Cell F	Excluded from analysis								

Table 5-7 Economic benefits in relation to tidal flooding for Option 2 (£k)

	2045 Indicative	2075	2115
Cell A		£2,669	£34,262
Cell B	£28,000	£68,638	£101,090
Cell C		£2,391	£39,474
Cell D		£0	£247
Cell E		£6,442	£81,161
Cell F	Excluded from analysis		

Table 5-8 Economic benefits in relation to fluvial flooding for Option 2 (£k)

	2045 Indicative	2075	2115
Cell A		£1,700	£17,026
Cell B	£14,000	£27,216	£92,070
Cell C		£3,308	£29,060
Cell D		£184	£635
Cell E		£11,186	£15,257
Cell F	Excluded from analysis		

Compared to the flood risks shown in Section 2 which assume that the same level of existing defences remain in the future, with option 1 both tidal and fluvial flood risks are dramatically reduced. This is especially noticeable in flood cells B and E where both fluvial and tidal flood risks are reduced significantly.

For option 2 an almost identical level of future flood risk as option 1 is achieved in future for both fluvial and tidal sources. Benefits increase greatly over time as properties are defended from flooding.

6 Costs

6.1 Capital cost estimates

Costs for protecting Barnstaple from tidal flooding are provided in the table below. An upper and lower cost range have been provided due to the level of uncertainty associated with the required works. The following assumptions have been used:

- Cash costs have been assumed (i.e. no discounting of costs have been assumed at this stage).
- Costs assume that existing defences have an asset life that will last through to 2115 and beyond.
- Operation and maintenance costs are calculated separately.
- No allowance for current asset condition grades or asset deterioration is assumed.
- An additional 20% is included for items such as site supervision, design, contractor risks etc.).
- No allowance for land purchase or compensation is included.
- An optimism bias of 60% is assumed as there is a known tendency for project appraisals to be overly optimistic.
- Costs for flood cell F have been excluded as they have already been secured as part of the Anchorwood Bank development.

Table 6-1 Capital costs of options 1 and 2

Capital cost (£k)	Option 1 - capital cost		Option 2 - capital cost	
	Low cost	High cost	Low cost	High cost
Cell A	2,508	4,671	2,508	4,671
Cell B	5,087	18,898	1,586	5,824
Cell C	1,109	2,135	1,291	3,143
Cell D	600	1,114	600	1,114
Cell E	4,419	8,154	4,419	8,154
Cell F	Excluded from analysis			
Total	13,723	34,972	10,404	22,906

Table 6-2 Costs of options 1 and 2 including capital costs, preliminaries and optimism bias

Costs including capital cost, 20% preliminaries and 60% optimism bias (£k)	Option 1 - costs		Option 2 - costs	
	Low cost	High cost	Low cost	High cost
Cell A	4,815	8,968	4,815	8,968
Cell B	9,767	36,284	3,045	11,182
Cell C	2,129	4,099	2,479	6,035
Cell D	1,152	2,139	1,152	2,139
Cell E	8,484	15,656	8,484	15,656
Cell F	Excluded from analysis			
Total	26,348	67,146	19,975	43,979

The costs in the table show Option 2 (diverting the River Yeo) could be substantially cheaper than Option 1 given the shorter route of the watercourse along which defences would be required.

Clearly cost is only one factor in determining which would be the preferred option and they are very similar in their effectiveness. At a high level the costs of the options are many times less than the potential benefits and are therefore likely to be economically viable (depending on funding criteria at the time investment is required). However cost benefit ratios are not overwhelming and will need consideration in more detail in future to try to maximise these values.

Timing of the investment is an important factor and is largely dependent on sea level rise. The current projections used to 2075 and 2115 suggest the most dramatic increase in risk from 2075 to 2115 as the Barnstaple defences (existing levels) overtop much more frequently. This should be monitored and the outcomes of this study kept updated over coming decades as the time for investment gets nearer. Timing of actions is considered in more detail in the following section.

6.2 Maintenance costs

The cost of maintaining the new defences in the future have been estimated and are presented in the table below. Maintenance costs are provided per year. No allowance for discounting of future maintenance costs has been undertaken at this stage.

Table 6-3 Maintenance costs for options 1 and 2

Costs (£k)	Option 1 Maintenance cost		Option 2 Maintenance cost	
	Low cost	High cost	Low cost	High cost
Cell A	3.3	40.4	3.3	40.4
Cell B	0.3	2.5	0.2	2.1
Cell C	1.1	7.7	1.2	8.1
Cell D	0.1	0.4	0.1	0.4
Cell E	2.3	25.7	2.3	25.7
Cell F	Excluded from analysis			
Total	7.1	76.6	7.1	76.6

7 Proposed outcomes

7.1 Outcomes for each flood cell

Each flood cell has been considered bringing together the various factors around the defences including costs, benefits and standard of protection. From this a series of proposed actions has been generated and these are described in the tables below divided into three time horizons, short term (2015-2045), medium term (2045-2075) and long term (2075-2115).

The costs and benefits of the proposed flood defences show that the benefits are generally far greater than the costs. However, for a scheme to progress fully funded the ratio costs and benefits must be high (around 15:1 but this is dependent on many additional Outcome Measures) and the ratios produced here will not always meet that criteria. It will need to be considered on a flood cell by flood cell basis (and even broken down within that in some cells) looking at the costs and benefits in more detail as the proposed schemes become closer to being required.

The partnership funding options will also need to be considered as this will likely be needed where benefits are not high enough or to bring a scheme forward earlier than might otherwise be possible. At this stage it is difficult to suggest what partner funding options there may be in the future but it could include developer contributions and EU funds both of which the EA have successfully used in other parts of the country. By the time these defences are required the rules are likely to have changed, however, having a strategy in place to consider developer contributions towards future defences in the interim would be a valuable outcome of this process.

The uncertainty of the analysis and outcomes increases into the future particularly as many of the future actions are dependent on the rate of sea level rise over the next 100 years.

7.2 Flood Cell A

Timescale	Actions	Comment
2015 to 2045	Do Minimum, except consider PLP to residential properties in Meadow Road area.	Benefits are low overall, however there are residential benefits that could be realised locally.
2045 to 2075	Do Minimum, except consider PLP to residential properties in Meadow Road area if not already done so.	Benefits are low overall, however there are residential benefits that could be realised locally.
2075 to 2115	Implement remaining proposed defences.	Options become financially viable now that existing defence levels are more vulnerable to overtopping.

7.3 Flood Cell B

Timescale	Action	Comment
2015 to 2045	Do Minimum More detailed consideration of improvement works to defences on River Yeo should be undertaken.	2015 benefits are not high enough for full scheme however some defences along the River Yeo are already modelled as overtopping during a 0.5% AEP event leaving flood cell B vulnerable. By 2045 there may be enough benefits to undertake at least part of the scheme.
2045 to 2075	Defence works on the River Yeo will be required.	Benefits expected to far exceed likely costs by 2075.
2075 to 2115	Implement remaining proposed defences.	If not carried out already.

7.4 Flood Cell C

Timescale	Action	Comment
2015 to 2045	Do Minimum. River Yeo works should be considered alongside those in Flood Cell B, i.e. undertake works on both sides of the Yeo.	Benefits in flood cell C unlikely to be high enough to proceed with scheme, unless part can be joined with flood cell B.
2045 to 2075	Do Minimum. River Yeo works should be considered alongside those in Flood Cell B, i.e. undertake works on both sides of the Yeo.	Benefits in flood cell C unlikely to be high enough to proceed with scheme, unless part can be joined with flood cell B.
2075 to 2115	Implement proposed defences on Taw frontage and River Yeo, if not carried out already.	Works on flood cell C only become economically viable after 2075.

7.5 Flood Cell D

Timescale	Action	Comment
2015 to 2045	Do Minimum.	No justification for defence improvements.
2045 to 2075	Do Minimum.	No justification for defence improvements.
2075 to 2115	Do Minimum.	Benefits in flood cell D unlikely to be high enough for scheme.

7.6 Flood Cell E

Timescale	Action	Comment
2015 to 2045	Do Minimum.	No justification for defence improvements.
2045 to 2075	Do Minimum.	Benefits in flood cell E unlikely to be high enough to for scheme.
2075 to 2115	Improve Taw defences. Consider viability of improved Coney Gut defences.	Benefits of tidal flooding far exceed likely costs of tidal defences. Fluvial benefits unlikely to be high enough to proceed with scheme but additional information may be available by this time.

7.7 Flood Cell F

Timescale	Action	Comment
2015 to 2045	Defences are being updated imminently.	Anchorwood development is driving these defence improvements.
2045 to 2075	Maintain improved defences.	May be a need to review the defences are still meeting the sea levels being observed.
2075 to 2115	Maintain improved defences.	May be a need to review the defences are still meeting the sea levels being observed.

8 Summary and Conclusions

8.1 Summary

Current and future flood risks in Barnstaple are cause for concern for Devon County and North Devon District Councils. The production of a flood defence improvement strategy for the next 60 to 100 years will enable future redevelopment of housing and employment sites, promoting economic development and raise employment opportunities. It will also help to revitalise and regenerate the northern part of the town.

The current and future (2075 and 2115) flood risks from both fluvial and tidal sources were modelled. From these results the numbers of properties at risk was extracted for a range of flood events and the resultant economic damages were calculated within each flood cell. Results were determined for 2015, 2075 and 2115 through modelling and an indication of 2045 results through interpolation of the 2015 ad 2075 results.

A suite of options were considered for each flood cell, and these were modelled to assess how future levels of flood risk could be managed. These included the raising of existing embankments and flood walls, raising of the A361 and cycle track north towards Pilton Community College, and the option of either piling around the existing course of the Yeo through Pilton Park (option 1), or re-routing it along the A39 Pilton Causeway (option 2).

With the proposed flood defences in place in the future, the fluvial and tidal flood risks will substantially reduce compared to the situation in the future without them (Do Minimum). The level of flood risk achieved by both options is essentially the same. In flood cell B, where there is likely to be the greatest risk in future, flood risks to commercial and residential properties will reduce to near zero.

The cost of each option has been estimated. From this work we have estimated that total costs for all of the proposed flood defence improvements are £67 m (high cost) for Option 1, and £44m (high cost) for Option 2. These options are likely to be economically viable as they are far less than the potential benefits of the schemes, however they will need refining and it could be some parts of the options are not viable. Timing of the investment is hard to determine at this time and is largely dependent on the rate of increasing sea levels due to climate change. The recommendations in the previous section give the likely time horizon of investment based on current projections.

Flood damages and benefits, particularly for the future scenarios, can only be considered indicative as there are many significant uncertainties in these calculations so far in the future. The rate of sea level rise for example is a large influence on the flood risks being predicted and then the damage calculations are also very uncertain.

8.2 Conclusions

It is clear from the analysis that flood risk in Barnstaple is predicted to increase substantially over the next 100 years both from tidal sources, as a result of sea level increases, and from fluvial sources, as a result of expected peak flow increases and increased duration of tide locking of outfalls. In future Barnstaple will need more and larger flood defences and many more properties will be relying on flood defence infrastructure. This in itself can bring challenges as residual risk of defence failure or overtopping will exist and may require additional emergency planning.

The rate of sea level rise at Barnstaple and the timing of investment should be monitored and the outcomes of this study kept updated over coming decades. More pressing maintenance needs on individual defences will perhaps be of most immediate concern in Barnstaple to retain existing effective defences.

This study should in part give a framework to help unlock future development potential in Barnstaple. It should also facilitate the consideration of how external funding sources can be used to help fund future flood defences.

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