

***RIVER AVON TIDAL FLOOD RISK
MANAGEMENT STRATEGY***

Preferred Option Report

April 2017

Prepared for Bristol City Council

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TABLE OF CONTENTS

0.	EXECUTIVE SUMMARY	9
0.1	Background.....	9
0.2	Flood Risk – Now and Future	9
0.3	Short List Options	9
0.4	Studies Undertaken	11
0.5	Appraisal and Comparison of Options	12
0.5.1	Key facts	12
0.5.2	Non-discounted (cash) costs	13
0.5.3	Standard of Protection	14
0.5.4	Environment.....	15
0.5.5	Development.....	16
0.5.6	Economic Appraisal	16
0.5.7	Comparison of Options	17
0.5.8	Wider Opportunities – Second Avon Crossing, Tidal Power Generation and Synergies	18
0.5.9	Uncertainty.....	18
0.6	Funding.....	18
0.7	Preferred Option	22
0.8	Next steps.....	23
1.	PROJECT BACKGROUND	24
1.1	Strategy objectives	24
1.2	Previous studies	24
1.3	Structure of this report	28
2.	FLOOD RISK	29
2.1	Overview of tidal flood risk in Bristol	29
2.2	Extreme water levels adopted by the Strategy.....	29
2.3	What is at risk in Do Nothing?.....	30
2.4	What is at risk in Do Minimum?	37
3.	OPTION APPRAISAL OVERVIEW	40
3.1	Purpose of this report	40
3.2	Option objectives	40
3.3	Strategy time epochs	40
3.4	Appraisal to date.....	40
3.5	Assumptions	42
4.	OVERVIEW OF MEASURES	43
4.1	Do Minimum.....	43
4.2	Property Level Protection / temporary defences	43
4.2.1	Overview.....	43
4.2.2	Design Assumptions	44
4.2.3	Costing.....	44
4.3	Low Defences	44
4.3.1	Overview.....	44
4.3.2	Alignments and Design Assumptions	45
4.3.3	Numerical Modelling	45
4.3.4	Costing.....	46
4.4	High Defences	46
4.4.1	Overview.....	46
4.4.2	Alignments and Design Assumptions	46
4.4.3	Numerical Modelling	47
4.4.4	Costing.....	47
4.5	Tidal flood barrier.....	48
4.5.1	Overview.....	48
4.5.2	Design Assumptions	48
4.5.3	Numerical Modelling	49
4.5.4	Costing.....	49

5.	STRATEGIC OPTION A (PLP – LOW DEFENCES – HIGH DEFENCES)	51
5.1	Description.....	51
5.1.1	Epoch 1 (PLP / temporary defences).....	51
5.1.2	Epoch 2 (Low Defences).....	55
5.1.3	Epoch 3 (High Defences).....	60
5.1.4	All Epochs (Do Minimum and Maintenance).....	66
5.2	Economic Costs and Benefits.....	67
5.2.1	Non-discounted (cash) costs.....	67
5.2.2	Present value costs.....	71
5.2.3	Economic benefits.....	72
5.3	Development.....	74
5.4	Environmental impacts.....	75
5.4.1	Epoch 1 (PLP).....	75
5.4.2	Epoch 2 (Low Defences).....	76
5.4.3	Epoch 3 (High Defences).....	78
5.4.4	Summary.....	80
5.5	Risks.....	80
5.5.1	Ground conditions.....	80
5.5.2	Services accommodation.....	80
5.5.3	Transport links issues.....	80
5.5.4	Lack of confidence in long-term.....	80
5.5.5	Visual and landscape impact of permanent defences.....	81
5.5.6	Impact on fluvial flood risk.....	81
5.5.7	Operation and disruption – temporary and demountable defences.....	81
5.5.8	Private property and landowner support.....	82
5.5.9	Commitment to maintenance.....	82
5.5.10	Commitment to flood forecasting and warning systems.....	82
5.6	Wider opportunities.....	82
5.6.1	Adaptive approach to flood risk management.....	82
5.6.2	Facilitate development and redevelopment opportunities.....	83
5.6.3	Environmental enhancement.....	83
5.7	Next steps.....	84
6.	STRATEGIC OPTION B (PLP – HIGH DEFENCES – HIGH DEFENCES)	86
6.1	Description.....	86
6.1.1	Epoch 1 (PLP / temporary defences).....	86
6.1.2	Epoch 2 (High Defences).....	87
6.1.3	All epochs (Do Minimum and Maintenance).....	88
6.2	Economic Costs and Benefits.....	90
6.2.1	Non-discounted (cash) costs.....	90
6.2.2	Present value costs.....	93
6.2.3	Economic benefits.....	95
6.3	Development.....	97
6.4	Environmental impacts.....	98
6.4.1	Epoch 1 (PLP).....	98
6.4.2	Epoch 2 and Epoch 3 (High Defences).....	98
6.4.3	Summary.....	101
6.5	Risks.....	102
6.5.1	Ground conditions.....	102
6.5.2	Services accommodation.....	102
6.5.3	Transport links issues.....	102
6.5.4	Lack of confidence in long-term.....	102
6.5.5	Visual and landscape impact of permanent defences.....	103
6.5.6	Impact on fluvial flood risk.....	103
6.5.7	Operation and disruption – temporary and demountable defences.....	103
6.5.8	Private property and landowner support.....	104
6.5.9	Commitment to maintenance.....	104
6.5.10	Commitment to flood forecasting and warning systems.....	104
6.5.11	Precautionary approach to flood risk management.....	104
6.6	Wider opportunities.....	104

6.6.1	Facilitate development and redevelopment opportunities	104
6.6.2	Environmental enhancement	105
6.7	Next steps	105
7.	STRATEGIC OPTION C (PLP – TIDAL BARRIER – TIDAL BARRIER).....	106
7.1	Description	106
7.1.1	Epoch 1 (PLP / temporary defences)	106
7.1.2	Epoch 2 (Tidal barrier)	107
7.1.3	All epochs (Do Minimum and Maintenance)	109
7.2	Economic Costs and Benefits	110
7.2.1	Non-discounted (cash) costs	110
7.2.2	Present value costs	112
7.2.3	Economic benefits	114
7.3	Development.....	116
7.4	Environmental impacts	117
7.4.1	Epoch 1 (PLP)	117
7.4.2	Epoch 2 and Epoch 3 (Tidal Barrier).....	117
7.4.3	Summary	119
7.5	Risks	120
7.5.1	Ground conditions	120
7.5.2	Hydraulic performance.....	120
7.5.3	Geomorphology and siltation	120
7.5.4	Environment.....	120
7.5.5	Land acquisition.....	120
7.5.6	Planning Consent and other Consenting Issues	120
7.5.7	Water Quality, Outfalls and Watercourses	120
7.5.8	Precautionary approach to flood risk management.....	120
7.5.9	Costs	120
7.5.10	Lead Time.....	120
7.6	Wider opportunities	120
7.6.1	High standard of flood protection	120
7.6.2	Development opportunities	121
7.6.3	Tidal energy production opportunities	121
7.6.4	Tourism benefits	121
7.6.5	Separate schemes at Pill and Shirehampton	121
7.6.6	Fluvial flood mitigation by storage.....	121
7.7	Next steps.....	121
8.	STRATEGIC OPTION D (LOW DEFENCES – LOW DEFENCES – HIGH DEFENCES).....	123
8.1	Description	123
8.1.1	Epoch 1 (Low Defences).....	123
8.1.2	Epoch 3 (High Defences).....	125
8.1.3	All Epochs (Do Minimum and Maintenance)	127
8.2	Economic Costs and Benefits	129
8.2.1	Non-discounted (cash) costs	129
8.2.2	Present value costs	133
8.2.3	Economic benefits	134
8.3	Development.....	136
8.4	Environmental impacts	137
8.4.1	Epoch 1 and Epoch 2 (Low Defences)	137
8.4.2	Epoch 3 (High Defences).....	139
8.4.3	Summary	141
8.5	Risks	142
8.6	Wider opportunities	142
8.6.1	Adaptive approach to flood risk management.....	142
8.6.2	Facilitate development and redevelopment opportunities	142
8.6.3	Environmental enhancement	142
8.7	Next steps.....	142
9.	STRATEGIC OPTION E (LOW DEFENCES – TIDAL BARRIER – TIDAL BARRIER)	144
9.1	Description.....	144

9.1.1	Epoch 1 (Low Defences).....	144
9.1.2	Epoch 2 (Tidal barrier)	145
9.1.3	All epochs (Do Minimum and Maintenance)	146
9.2	Economic Costs and Benefits	147
9.2.1	Non-discounted (cash) costs	147
9.2.2	Present value costs	150
9.2.3	Economic benefits	151
9.3	Development.....	153
9.4	Environmental impacts	154
9.4.1	Epoch 1 (Low Defences).....	154
9.4.2	Epoch 2 and 3 (Tidal Barrier).....	156
9.4.3	Summary	158
9.5	Risks.....	159
9.6	Wider opportunities	159
9.7	Next steps.....	159
10.	STRATEGIC OPTION F (HIGH DEFENCES – HIGH DEFENCES – HIGH DEFENCES).....	160
10.1	Description.....	160
10.1.1	Epoch 1 (High Defences).....	160
10.1.2	All epochs (Do Minimum and Maintenance)	161
10.2	Economic Costs and Benefits	163
10.2.1	Non-discounted (cash) costs	163
10.2.2	Present value costs	165
10.2.3	Economic benefits	167
10.3	Development.....	169
10.4	Environmental impacts	170
10.4.1	Epoch 1, 2 and 3 (High Defences).....	170
10.4.2	Summary	172
10.5	Risks.....	173
10.5.1	Ground conditions.....	173
10.5.2	Services accommodation.....	173
10.5.3	Transport links issues	173
10.5.4	Visual and landscape impact of permanent defences.....	173
10.5.5	Impact on fluvial flood risk.....	174
10.5.6	Private property and landowner support	174
10.5.7	Commitment to maintenance	174
10.5.8	Precautionary approach to flood risk management.....	174
10.6	Wider opportunities	174
10.6.1	Facilitate development and redevelopment opportunities	174
10.6.2	Environmental enhancement	175
10.7	Next steps.....	175
11.	STRATEGIC OPTION G (DO MINIMUM – DO MINIMUM – HIGH DEFENCES).....	176
11.1	Description.....	176
11.1.1	Epoch 3 (High Defences).....	176
11.1.2	All epochs (Do Minimum and Maintenance)	177
11.2	Economic Costs and Benefits	179
11.2.1	Non-discounted (cash) costs	179
11.2.2	Present value costs	181
11.2.3	Economic benefits	183
11.3	Development.....	185
11.4	Environmental impacts	186
11.4.2	Summary	188
11.5	Risks.....	189
11.6	Wider opportunities	189
11.7	Next steps.....	189
12.	APPRAISAL OF SHORT LIST OPTIONS.....	190
12.1	Decision making process.....	190
12.1.1	Stage 1 – whole life costs and benefits.....	190
12.1.2	Stage 2 – organise options	190
12.1.3	Stage 3 – consider Strategy objectives.....	190

12.1.4	Stage 4 – accounting for contributions and funding	190
12.1.5	Stage 5 – testing uncertainty	190
12.2	Appraisal.....	191
12.2.1	Economic analysis (whole life costs and benefits and ordering options).....	191
12.2.2	Objectives - Overview	194
12.2.3	Objectives - Environment.....	194
12.2.4	Objectives - Growth	194
12.2.5	Wider Opportunities – Second Avon Crossing, Tidal Power Generation and Synergies	195
12.2.6	Conclusion	196
12.3	Contributions and Funding.....	196
12.3.1	Partnership Funding	196
12.3.2	Gross Value Added Benefits (GVA).....	200
12.3.3	Contributions.....	203
12.3.4	Potential synergies	204
12.4	Uncertainty.....	204
13.	PREFERRED STRATEGIC OPTION	206
14.	NEXT STEPS	207
1.	APPENDIX 1: COSTING METHODOLOGY	208
1.1	Approach to option costing	208
1.1.1	Approach	208
1.1.2	Optimism bias	208
1.1.3	Discounting	208
1.2	Do minimum.....	208
1.2.1	Floating harbour operation and maintenance and temporary defence deployment	209
1.2.2	Maintenance of existing flood defence structures	209
1.3	Property level protection / temporary defences.....	210
1.3.1	PLP / temporary defences capital works.....	210
1.3.2	PLP / temporary defences maintenance	211
1.4	Raised defences (low and high defences)	211
1.4.1	Sheet piled wall.....	211
1.4.2	Crest raising.....	212
1.4.3	Embankments	213
1.4.4	Demountables / flood gates	214
1.4.5	Tidal lock / stop gates upgrades	214
1.4.6	Raised defence maintenance	215
1.5	Tidal Barrier	215
1.5.1	Capital works	215
1.5.2	Maintenance and operation	215
2.	APPENDIX 2: RAISED DEFENCE ALIGNMENTS	217
3.	APPENDIX 3: PARTNERSHIP FUNDING CALCULATIONS... ..	226
4.	APPENDIX 4: PROPERTIES AT RISK.....	236

0. EXECUTIVE SUMMARY

0.1 Background

This project will deliver a Tidal Flood Risk Management Strategy (TFRMS) (the 'Strategy') for the area of Bristol at risk of flooding from the River Avon, including the city centre (between Cumberland Basin and Netham) Shirehampton and Pill. Downstream and upstream impacts will be considered, including Avonmouth and Portbury.

The flood risk in the study area is dominated by tidal events and this is the focus of the study. The development of the Strategy will be underpinned by an appraisal of management options of 'strategy alternatives' to address present and future tidal flood risk. The Strategy will recommend the preferred programme of adaptive measures identifying when measures are needed and how they will be funded.

This report follows on from the Short Listing report which identified for further assessment 7 Strategic Options, each comprised of a number of measures spanning over 100 years in 3 time epochs.

0.2 Flood Risk – Now and Future

Flood risk, and the assessment of potential Options, has been undertaken in a series of 3 'Epochs' each representing a period time. Epoch 1 represents the period to 2030, Epoch 2 2030-2065 and Epoch 3 2065-2115.

Flood risk has been assessed using a numerical model, using parameters for projected Sea Level Rise in accordance with current Defra guidance.

The modelling work has shown that Bristol currently faces a significant risk of tidal flooding and that this risk will increase substantially over the next 100 years.

To generate a flood risk baseline, modelling studies have been completed for two baseline scenarios – 'Do Nothing' and 'Do Minimum'. Do Nothing represents a hypothetical scenario where there would be no operation of maintenance of existing defences and no construction of new defences. Flood gates (Pill and Shirehampton), and crucially, the Harbour's flood stop gates are assumed not to be operated therefore default to fail-open positions. This is a worst case scenario. Do Minimum represents the situation where there are no new defences or raising of defences, but operation and maintenance continues (i.e. the flood gates and harbour gates are closed during periods of increased flood risk).

In Epoch 1, a 1 in 200 year event (also known as an event with a 0.5% probability of exceedance in a given year) under a Do Nothing scenario would result in the flooding of around 2700 properties. Under the more realistic Do Minimum scenario which reflects current practices, the number of properties at risk would be around 1000.

By Epoch 3 the potential consequences of a tidal event are extremely severe, and the difference between the Do Nothing and Do Minimum scenarios becomes more marginal, as rising sea levels negate the presence of many existing control structures. In a 1 in 200 year (0.5%) event, some 4300 properties would be flooded in the Do Nothing scenario, and large areas would have flood depths of more than 1m. In the Do Minimum scenario some 3700 properties would be affected in the same event.

In a Do Nothing scenario it is estimated that the present value of flood damages would exceed £1.6 billion over the 100 year period until 2115.

These figures exclude any properties built after 2011, or any which are planned to be built in the affected areas. Flood risk currently constrains scale and form of development in many areas of the city.

0.3 Short List Options

This report describes the process by which the short-listed 7 Strategic Options have been narrowed down to a single Preferred Option.

The 7 short-listed Strategic Options are shown in **Table 1** below, with a brief description. To provide a baseline for the economic assessment of Options and to comply with the Environment Agency's FCERM-AG investment rules, two further Options have been included – Do Nothing and Do Minimum. It is assumed that each implementation measure (i.e. PLP, raised defences, or a tidal barrier) are implemented from the start of each epoch.

Table 1 Overview of the short list of Strategic Options

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
	Do Nothing	No maintenance, no new defences	No maintenance, no new defences	No maintenance, no new defences
	Do Minimum	Do Minimum approach, existing defences maintained but no new defences	Do Minimum approach, existing defences maintained but no new defences	Do Minimum approach, existing defences maintained but no new defences
A	PLP* – Low Defences – High Defences	Property level measures and temporary barriers used to mitigate flood risk	Linear flood walls built to protect Bristol to a 1 in 200 year standard in 2030.	Additional linear flood walls built to protect Bristol to a 1 in 200 year standard until 2115, with existing walls being raised or replaced as necessary
B	PLP – High Defences – High Defences	Property level measures and temporary barriers used to mitigate flood risk	Linear flood walls built to protect Bristol to a 1 in 200 year standard to 2115.	Walls maintained, standard falls over time to 1 in 200 in 2115
C	PLP –Tidal Barrier – Tidal Barrier	Property level measures and temporary barriers used to mitigate flood risk	'Narrow' tidal flood barrier built to protect Bristol to a 1 in 200 year standard or higher, for the next 100 years	Barrier maintained, standard falls over time to 1 in 200 or higher
D	Low Defences – Low Defences – High Defences	Linear flood walls built to protect Bristol to a 1 in 200 year standard or higher for 2030.	Walls maintained, standard falls over time.	Additional linear flood walls built to protect Bristol to a 1 in 200 year standard or higher until 2115, with existing walls being raised or replaced as necessary
E	Low Defences – Tidal Barrier– Tidal Barrier	Linear flood walls built to protect Bristol to a 1 in 200 year standard or higher for 2030.	'Narrow' tidal flood barrier built to protect Bristol to a 1 in 200 year standard or higher, for the next 100 years	Barrier maintained, standard falls over time to 1 in 200 or higher
F	High Defences- High - High	Linear flood walls built to protect Bristol to a 1 in 200 year standard or higher for 2115.	Walls maintained	Walls maintained, standard falls over time to 1 in 200 in 2115
G	Do Min – Do Min – High Defences	Do Minimum approach, existing defences maintained but no new defences	Do Minimum approach, existing defences maintained but no new defences	Linear flood walls built to protect Bristol to a 1 in 200 year standard or higher until 2115

*PLP refers to property level protection and temporary flood defences. Property level protection is a generic term for permanent flood defences fitted to individual properties, such as property barriers, non-return valves and airbrick vent covers. Temporary or demountable defences are removable defences or require operation/deployment during flood events and typically protect a number of properties at once.

0.4

Studies Undertaken

The following technical studies have been completed to support the selection of the Preferred Option:

- Numerical modelling of flood risk for the Do Nothing and Do Minimum Options. The CAFRA Workstream 3 model has been modified to represent the Do Nothing (walk-away) scenario and a series of model runs completed to represent different tidal events over the three epochs. The model was then modified to represent the Do Minimum (continue with existing defences) scenario and run for a range of tidal events over the three epochs.
- Assessment of Do Nothing and Do Minimum flood damages. Flood extents have been mapped, and damages have been calculated using the methods mandated by the Environment Agency's procedures for flood and coastal risk management studies.
- Outline design of the flood defence measures comprising each Strategic Option, to a level proportionate to a Strategic study, with indicative alignments/locations of walls and a plan/section for a tidal barrier.
- Costing of each Strategic Option to arrive at total Capital and Maintenance costs for each Option over a 100 year period, as well as the total Present Value Cost using discounting techniques set by HM Treasury.
- Modelling of each Strategic Option to determine flood risks, and assessment of flood damages. The CAFRA Workstream 3 and 4 models have been modified and used as most appropriate. The numerical modelling work has confirmed that the options focussed on construction of low/high walls and the options focussed on a tidal barrier would all effectively protect Bristol from tidal flooding. This has included assessing the impact of a barrier in its open position on river levels during high fluvial flows, the impact of a closed barrier on upstream water levels during a fluvial event, and the impact of wall options on water levels during high fluvial flows. In all cases the results showed that either the option was satisfactory, or produced only minor negative impacts which could be readily resolved.
- Strategic Environmental Assessment of all the Strategic Options
- Economic Appraisal of all Options - benefits of each Option (i.e. damages avoided) in comparison to the Do Nothing Option have been determined. Benefit-cost ratios for each option, and incremental benefit-cost ratios for each step in investment from a lower-cost Option to a higher-cost Option, have been identified
- Initial Partnership Funding calculations have been made, identifying the potential for Grant in Aid and also the potential funding shortfalls for each option.
- Identification of wider benefits, risks, and opportunities related to each Option, particularly with regard to sustaining future development in the city.

0.5

Appraisal and Comparison of Options

The following tables provide a comparison of the Strategic options.

0.5.1

Key facts

Table 2 Strategic option key facts

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
A	PLP – Low Defences – High Defences	Protection to around 250 residential properties	5.3 km of defences with average height of 1.0m, flood gates at either end of Floating Harbour	Additional 1.9 km of defences plus raising of existing defences by average 0.6m
B	PLP – High Defences – High Defences	Protection to around 250 residential properties	7.2 km of defences with average height of 1.5m, flood gates at either end of Floating Harbour	Maintenance
C	PLP –Tidal Barrier – Tidal Barrier	Protection to around 250 residential properties	Tidal Barrier at Nibley – Ham Green	Maintenance
D	Low Defences – Low Defences – High Defences	5.3 km of defences with average height of 1m, flood gates at either end of Floating Harbour	Maintenance only	Additional 1.9 km of defences plus raising of existing defences by average 0.6m
E	Low Defences – Tidal Barrier– Tidal Barrier	5.3 km of defences with average height of 1m, flood gates at either end of Floating Harbour	Tidal Barrier at Nibley – Ham Green	Maintenance
F	High Defences- High - High	7.2 km of defences with average height of 1.5m, flood gates at either end of Floating Harbour	Maintenance	Maintenance
G	Do Min – Do Min – High Defences	Maintenance	Maintenance	7.2 km of defences with average height of 1.5m, flood gates at either end of Floating Harbour

0.5.2

Non-discounted (cash) costs**Table 3 Non-discounted (cash) costs of the Strategic Options**

Option	Option Title	Epoch 1 (2015-2030) Cost (£m)	Epoch 2 (2030-2065) Cost (£m)	Epoch 3 (2065-2115) Cost (£m)	Total
A	PLP – Low Defences – High Defences	11.3	161.7	123.2	296.2
B	PLP – High Defences – High Defences	11.3	208.1	88.3	307.7
C	PLP –Tidal Barrier – Tidal Barrier	11.3	788.5	159.7	959.5
D	Low Defences – Low Defences – High Defences	135.8	45.3	123.2	304.2
E	Low Defences – Tidal Barrier– Tidal Barrier	135.8	788.5	159.7	1083.9
F	High Defences- High - High	174.6	58.5	88.3	321.5
G	Do Min – Do Min – High Defences	8.9	29.2	237.9	276.0

0.5.3

Standard of Protection**Table 4 Strategic option standards of protection**

Option	Option Title	2015	2030	2065	2115
A	PLP – Low Defences – High Defences	Existing with damage mitigation	Initially 1 in 200, falling over time. Includes Pill and Shirehampton	>1 in 200 Includes Pill and Shirehampton	1 in 200 Includes Pill and Shirehampton
B	PLP – High Defences – High Defences	Existing with damage mitigation	>1 in 200 Includes Pill and Shirehampton	>1 in 200 Includes Pill and Shirehampton	1 in 200 Includes Pill and Shirehampton
C	PLP –Tidal Barrier – Tidal Barrier	Existing with damage mitigation	>1 in 1000 Excludes Pill and Shirehampton	>1 in 1000 Excludes Pill and Shirehampton	1 in 1000 Excludes Pill and Shirehampton
D	Low Defences – Low Defences – High Defences	>1 in 200 Includes Pill and Shirehampton	Initially 1 in 200, falling over time. Includes Pill and Shirehampton	>1 in 200 Includes Pill and Shirehampton	1 in 200 Includes Pill and Shirehampton
E	Low Defences – Tidal Barrier– Tidal Barrier	>1 in 200 Includes Pill and Shirehampton	>1 in 1000 Excludes Pill and Shirehampton 1 in 200 Pill and Shirehampton	>1 in 1000 Excludes Pill and Shirehampton <1 in 200 Pill and Shirehampton	1 in 1000 Excludes Pill and Shirehampton <1 in 200 Pill and Shirehampton
F	High Defences- High - High	>1 in 200 Includes Pill and Shirehampton	>1 in 200 Includes Pill and Shirehampton	>1 in 200 Includes Pill and Shirehampton	1in 200 Includes Pill and Shirehampton
G	Do Min – Do Min – High Defences	Existing	Less than existing	>1 in 200 Includes Pill and Shirehampton	1 in 200 Includes Pill and Shirehampton

Table 5 Key findings in regard to each strategic option

Option	Option Title	Epoch 1 (2015-2030)	Epoch 2 (2030-2065)	Epoch 3 (2065-2115)
A	PLP – Low Defences – High Defences	Minor, temporary impacts related to disruption to residents and businesses.	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.
B	PLP – High Defences – High Defences	Minor, temporary impacts related to disruption to residents and businesses.	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.	Visual, landscape impacts
C	PLP –Tidal Barrier – Tidal Barrier	Minor, temporary impacts related to disruption to residents and businesses.	Significant construction impacts in terms of noise, traffic disruption, restrictions on navigation. Potential for significant ecological, and geomorphological impacts on designated sites adjacent to works.	Visual, landscape impacts Possible ongoing ecological and geomorphological impacts
D	Low Defences – Low Defences – High Defences	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.	Visual, landscape impacts	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.
E	Low Defences – Tidal Barrier– Tidal Barrier	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.	Significant construction impacts in terms of noise, traffic disruption, restrictions on navigation. Potential for significant ecological, and geomorphological impacts on designated sites adjacent to works.	Visual, landscape impacts Possible ongoing ecological and geomorphological impacts
F	High Defences-	Significant construction impacts in terms of noise,	Visual, landscape impacts	

	High - High	traffic disruption. Visual, landscape and archaeological impacts local to the walls.		
G	Do Min – Do Min – High Defences	Significant social impacts due to flood risk	Significant social impacts due to flood risk	Significant construction impacts in terms of noise, traffic disruption. Visual, landscape and archaeological impacts local to the walls.

The Strategic Environmental Assessment has found that there is no single clear 'best option'.

All of the Options have negative impacts, either temporary or permanent, which will require mitigation, but also positive impacts such as improving the quality of life of residents through reduced frequency of flooding. All Options also bring an opportunity to incorporate enhancements to the built environment.

0.5.5 **Development**

Options D, E and F all provide a 1 in 200 yr (0.5%) SoP from 2015, and a commitment to maintain a high standard for the life of the Strategy. Therefore these Options support development aspirations.

Options A, B and C all provide a 1 in 200 yr (0.5%) SoP from 2030, and a commitment to maintain a high standard for the life of the Strategy. Therefore these Options support development aspirations from 2030.

Option G provides a SoP much less than 1 in 200, and reducing over time. It does not support development aspirations.

0.5.6 **Economic Appraisal**

Table 6 summarises benefits and costs for the Options. Options have been ranked from top to bottom in order of increasing cost and benefits (used as indicators of the overall standard of protection). Option G has the highest benefit-cost ratio.

Table 6 Economic summary

Strategic option	Sequence of measures	Costs PV (£M)	Economic benefits PV (£M)	Average B/C Ratio
NA	Do Min – Do Min – Do Min	23.7	1,316	56:1
G	Do Min – Do Min – High Def	56.8	1,430	25:1
A	PLP – Low Def – High Def	112.7	1,546	14:1
B	PLP – High Def – High Def	130.3	1,560	12:1
D	Low Def – Low Def – High Def	166.3	1,576	9:1
F	High Def – High Def – High Def	202.0	1,598	8:1
C	PLP – Tidal Barrier – Tidal Barrier	471.1	1,572	3:1
E	Low Def – Tidal Barrier – Tidal Barrier	595.2	1,599	3:1

0.5.7

Comparison of Options

Taking account of incremental benefit-cost ratios (the additional benefit derived from moving to a higher cost option) the leading option is Option A: PLP - Low Defences – High Defences. This has the highest incremental benefit-cost ratio of any option when compared to Do Minimum or Option G.

However, all of the wall options - Options A, B, D and F – have incremental benefit-cost ratios greater than unity when compared to Option G so any might be selected.

Table 7 Incremental Benefit-Cost Ratios

Strategic option	Sequence of measures	Economic costs PV (£M) Relative to Option G	Economic benefits PV (£M) relative to Option G	Incremental Benefit-Cost Ratio
G	Do Min – Do Min – High Def	-	-	-
A	PLP – Low Def – High Def	55.9	116	2.08
B	PLP – High Def – High Def	73.5	130	1.77
D	Low Def – Low Def – High Def	109.5	146	1.33
F	High Def – High Def – High Def	145.2	168	1.16
C	PLP – Barrier – Barrier	414.3	142	0.34
E	Low Def – Barrier - Barrier	538.4	169	0.31

Options C and E – the two options which include a Tidal Barrier - have substantially greater costs than any of options AB.D and F- and correspondingly very poor incremental benefit cost ratios.

There is no economic case for the additional investment (over and above a wall option) in Tidal Barrier options and no specific additional wider benefit identified. Therefore Options C and E are rejected.

Taking account of issues beyond benefit-cost ratios, the following issues were considered:

- Option G would lead to a significant deterioration in standards of protection over the next 50 years. Very large numbers of properties would remain at risk of flooding and this number would substantially increase over the 50 year period. Option G does not meet the Strategy Objectives and is therefore rejected.
- Options A and B would provide a measure of protection to homes and businesses over the next 15 years, but significant risks would remain until 2030. There would be something like a 1 in 12 chance of a 1 in 200 year (0.5%) flood occurring in those 15 years, causing widespread damage. Development would continue to be constrained for 15 years. At 2030, the business case for a flood wall (whether low or high) would be very similar to the case for building it in the present day. Assuming the rules for Grant in Aid are unchanged then the eligibility for Grant in Aid would be virtually unchanged.
- Options D and F would provide an immediate improvement in standards of protection. Development would be facilitated.

Based on these considerations it is concluded that Options D and F would better meet the Objectives of the Strategy.

Given that Option D has a lower cost, lesser or equal environmental impact and is more adaptable to future sea level rise than Option F, Option D is considered the better of the two.

Therefore Option D is the preferred Option, subject to funding availability.

0.5.8 Wider Opportunities – Second Avon Crossing, Tidal Power Generation and Synergies

Synergies of a second Avon Crossing combined with a tidal barrier, and a Tidal Power Generation scheme combined with a tidal barrier have been considered. For both there are potential cost saving synergies which would be created. However, the cost saving for both is far less than the cost differential between the barrier and wall options considered in the Strategy and therefore the potential cost savings have no impact on the choice of the preferred option.

Furthermore, the wall options also have potential cost saving synergies should replacement / refurbishment of the existing riparian walls be required; combining upgrades to the existing frontline structures with raising of the crest level to improve the standard of protection could provide significant cost savings for all.

Considering the wider opportunities, Option D remains preferred Option.

0.5.9 Uncertainty

Sensitivity tests have been undertaken, considering possible uncertainties in option costing and sea level rise projections, and the results indicate that the selection process for the preferred option is robust. Sensitivity tests include increasing / decreasing the Present Value costs for various options, delaying the implementation period of the barrier in the barrier options and considering the impact of sea level rise occurring faster or slower than currently projected.

0.6 Funding

Funding of any of the Options is challenging. For each option a partnership funding score for the initial scheme has been calculated. Each score indicates the proportion of the scheme cost which can be expected to be funded by public grant monies. None of the Options generates a high Partnership Funding score, so all will require a significant degree of contributions.

Partnership Funding scores are set out below for the works that the Options would require in Epoch 1 or 2. Two calculations have been undertaken, one assuming Do Nothing as a baseline, and one assuming Do Minimum. The Do Nothing scenario is considered an appropriate baseline and provides the most favourable results. However confirmation is needed that the Environment Agency and Defra see the Do Nothing baseline as the more appropriate.

Table 8 Partnership Funding scores for the strategic options. Do Nothing baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	64%	£82m	£46m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	60%	£99	£66m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	59%	£71m	£57m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	51%	£84m	£81m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	16%	£108m	£575m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.	As above			

Table 9 Partnership Funding scores for the strategic options. Do Minimum baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	10%	£13m	£115m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	9%	£15m	£150m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	6%	£8m	£120m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	8%	£14m	£151m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	3%	£22m	£661m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.	As above			

The funding gap for Low Defences in Epoch 1 is £57m (best case) to £120m (worst case). To implement these works, this gap would need to be filled by contributions from BCC, LEP, other public funding sources and beneficiaries from the defences.

In some areas there is an opportunity to integrate the defence works with site raising and redevelopment, potentially gaining contributions from developers (in cash or in kind) and reducing costs.

Nonetheless, it is very unlikely that the works could go ahead without a substantial contribution from BCC. Before the Preferred Option is confirmed BCC's appetite for funding the shortfall will need to be ascertained.

A review of potential funding sources has been undertaken to identify the means of BCC finding the shortfall in funding to implement the preferred option, assuming that GiA is successfully drawn down from the EA via Partnership Funding. This is reported in the Funding Strategy report.

The review found that:

- The LEP Economic Development Fund (EDF) and Revolving Infrastructure Fund (RIF) provide the most significant potential contributions. This comprises £10m from EDF delivered in two tranches; 2023-24 and 2032-33 and, purely indicatively based on previous successful applications, £5m from the RIF.
- The most important 'regular' contribution to flood defences should come from the Community Infrastructure Levy (CIL). The exact contribution would need to be determined by BCC, reconciling the needs of other infrastructure projects.
- The City Centre BID proposal provides an opportunity to secure monies from harbourside businesses.
- The Coastal Communities Fund is worth investigating to make a case for submitting an expression of interest; flood defence schemes have received funding in the past
- The Metro Mayor funding deal provides BCC with another source of money, but the relative portion that BCC would receive compared to South Gloucestershire Council and Bath & North East Somerset will not become clear until next year. The implementation of the proposal may be affected by post-Brexit decision plans.
- The funding mechanism for most contributions is via payback i.e. the money will not be made available to BCC upfront. The Council will need to commit its own money and claim the contribution back via, for example, uplift in business rates.
- There is currently no Local Levy available from the Wessex Regional Flood Defence Committee. This could change when the EA 6 year capital programme is next reviewed.
- Potential contributions from developers / landowners / beneficiaries are likely to be very limited based on BCC's significant land ownership of the areas proposed for defence works (unless land deals are exercised with developers).

The conclusion was that whilst BCC may be able to source significant contributions, the Council may need to commit at least £20m to the implementation of the preferred strategic option in Epoch 1 and possibly as much as £85 million.

The FCERM economic analysis only assesses losses to the national economy. Dynamic impacts reflect the outcomes for a local economy over time as businesses respond to changes in flood risk. Strategic tidal flood risk management intervention is likely to:

- Support business continuity and sustainability of business activity in an area;
- 'Unlock' investments that might otherwise have been constrained or unattractive given the flood risk; and,
- Lead to 'spill over' impacts which reflect interdependencies or other intangible impacts on economic activity.

By evaluating the potential contribution to the local economy of investing in flood risk management measures it helps build an understanding of their potential impacts on the local economy. This would be expected to increase the propensity for local partners to contribute funding to FCERM as part of the government's Partnership Funding approach.

From the evaluation of direct impacts undertaken for the preferred Option, implementation could deliver something like a multiple of 2.5 times the FCERM benefits.

0.7

Preferred Option

Option D has been identified as the Preferred Option. The selection of Option D as the preferred option is a result of the economic analysis (where the generic barrier options were ruled out) and consideration of the wider objectives of the Strategy (where option D was considered the best wall option to support the wider objectives). Option D comprises the following:

- Construction of 5.3 km of flood defence walls with an average height of 1m in 2015 (or as soon thereafter as the option can be implemented)
- Construction of a further 1.9 km of flood walls in 2065, predominantly at Pill/Shirehampton, with existing walls raised. The 2065 date is based on current projections for sea level rise, and would be kept under review and brought forward or delayed to suit actual rates of sea level rise and required standard.
- Continued maintenance and refurbishment of existing defences and operation of the gates and control structures associated with the floating harbour. Due to sea level rise the cost of these Do Minimum activities increases over time.

The initial capital cost of the low defences for this Option is estimated at £128 million.

Table 10 Non-discounted (cash) costs for the preferred strategic option

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Low defences - construction	128.3	135.8
	Maintenance of low defences	6.0	
	Do Minimum activities	1.5	
Epoch 2 (2030 – 2065)	Maintenance of low defences	41.8	45.3
	Do Minimum activities	3.5	
Epoch 3 (2065 – 2115)	High defences - upgrade	50.6	123.2
	Maintenance of high defences	62.9	
	Do Minimum activities	9.7	
Total			304.2

Option D's main environmental impacts have been identified as a potential for disruption, noise, pollution, dust etc. during construction, and a risk of adverse visual impact in the longer term.

It is expected that significant adverse effects can be avoided or mitigated through sensitive design measures. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

Option D also presents an opportunity to incorporate enhancement, for example improving access to the riverside, improving biodiversity and integrating the flood defence with public realm improvements.

0.8

Next steps

Stage 1

- Agreement in principle of Preferred Option by Project Board.
- Provisional agreement on funding availability from BCC – this would need to take the form of a confirmation that BCC could in principle meet the scale of funding shortfall identified, or if that could not be confirmed, what range of funding shortfall BCC could meet.
- Agreement of EA development control that in principle adoption of the Preferred Strategic Option and implementation of the Epoch 1 Low Defence would be sufficient to allow development to proceed in the City, subject to an investigation of residual risk to specific developments and incorporation of corresponding proportionate local measures.
- Agreement of EA on suitability of Partnership Funding calculation approach, and use of Do Nothing as a baseline, determining GiA eligibility.

Stage 2

- Refinement of Preferred Option, including confirmation of standard, review of defence alignments and costs, and potentially prioritisation of Low Defences to match funding availability
- Funding Strategy

Stage 3

- Development of Public Consultation document and Business Case
- Preparation of statutory environmental reporting
- Public Consultation
- Strategy Finalisation

1. PROJECT BACKGROUND

Effective strategic tidal flood risk management is essential for the city of Bristol, not just because of the threat to lives and property, but also because of the risk of long-term reputational damage to the city's attractiveness and economic prosperity.

This project will deliver a Tidal Flood Risk Management Strategy (TFRMS) (the 'Strategy') for the area of Bristol at risk of flooding from the River Avon, including the city centre (between Cumberland Basin and Netham) Shirehampton and Pill. Downstream and upstream impacts will be considered, including Pill and Portbury. The study area is shown in **Figure 1**, with a zoomed-in view of the Floating harbour in **Figure 2**.

The flood risk in the study area is dominated by tidal events and this is the focus of the study. The development of the Strategy will be underpinned by an appraisal of management options of 'strategy alternatives' to address present and future tidal flood risk. The Strategy will recommend the preferred programme of adaptive measures identifying when measures are needed and how they will be funded.

1.1 Strategy objectives

The objectives of the Tidal Flood Risk Management Strategy, as set out in the Baseline Review are as follows:

1. To develop an agreed understanding of flood risk from now until 2115 and to quantify the impact of this risk on the existing development and infrastructure, and future proposals.
2. To confirm intervention options that form components of an adaptive strategic approach to maintain an acceptable level of flood risk from now until 2115 (subject to review on the basis of the preferred intervention(s) timing and type).
3. To evaluate the justification for investment and recognise the different drivers and priorities of BCC and the Environment Agency.

1.2 Previous studies

Prior to the Strategy a number of studies investigating the flood risk in Bristol have been undertaken. In 2010 Bristol City Council commissioned the Bristol Central Area Flood Risk Assessment (CAFRA) to develop an understanding of flood risk on tidally-influenced watercourses within the Bristol City boundary. CAFRA was divided into four workstreams, and also included a parallel harbour study.

- Workstream 1 collected and reviewed existing hydraulic models, studies and survey data.
- Workstream 2 considered joint probability to derive boundary conditions for the CAFRA numerical modelling.
- Workstream 3 detailed the hydrodynamic model build and assessment of the predicted flood risk.
- Workstream 4, alongside the harbour study, scoped fluvial and tidal flood risk management options. Recent updates to the CAFRA study have been carried out in 2014 and 2015.

In 2013 the First Phase Feasibility Study was undertaken to appraise strategic options to manage the flood risk in central Bristol, from present day to 2110. The study identified strategic interventions, undertook a high level economic appraisal of options and recommended a strategic flood risk approach. Given the changing flood risk profile over the next century, an adaptive approach that progressively improves flood risk management by building on the outcomes of previous interventions was advocated by the study.

Based upon the shortlist of options, a series of interventions were recommended by the First Phase Feasibility study:

- Improved flood forecasting, warning and planning;
- Early raised defences at low spots along the riverside to reduce the risk of inundation and overtopping into the floating harbour;
- Local interventions and improved operational resilience to lower residual fluvial and pluvial flood risk as part of a wider flood risk management strategy; and
- Longer term strategic protection against storm tides with an allowance for sea level rise, the most likely measure being a city wide solution involving a tidal barrier.

The CAFRA studies and First Phase Feasibility Study were undertaken at high level strategic scales, with a number of limitations and constraints. These are described in the Baseline Review Briefing Note.

This report outlines the preferred option phase of the Strategy. Prior to this phase the baselining, longlisting and shortlisting phases have been completed. Refer to section 3.4 for more details on the Strategy appraisal to date.

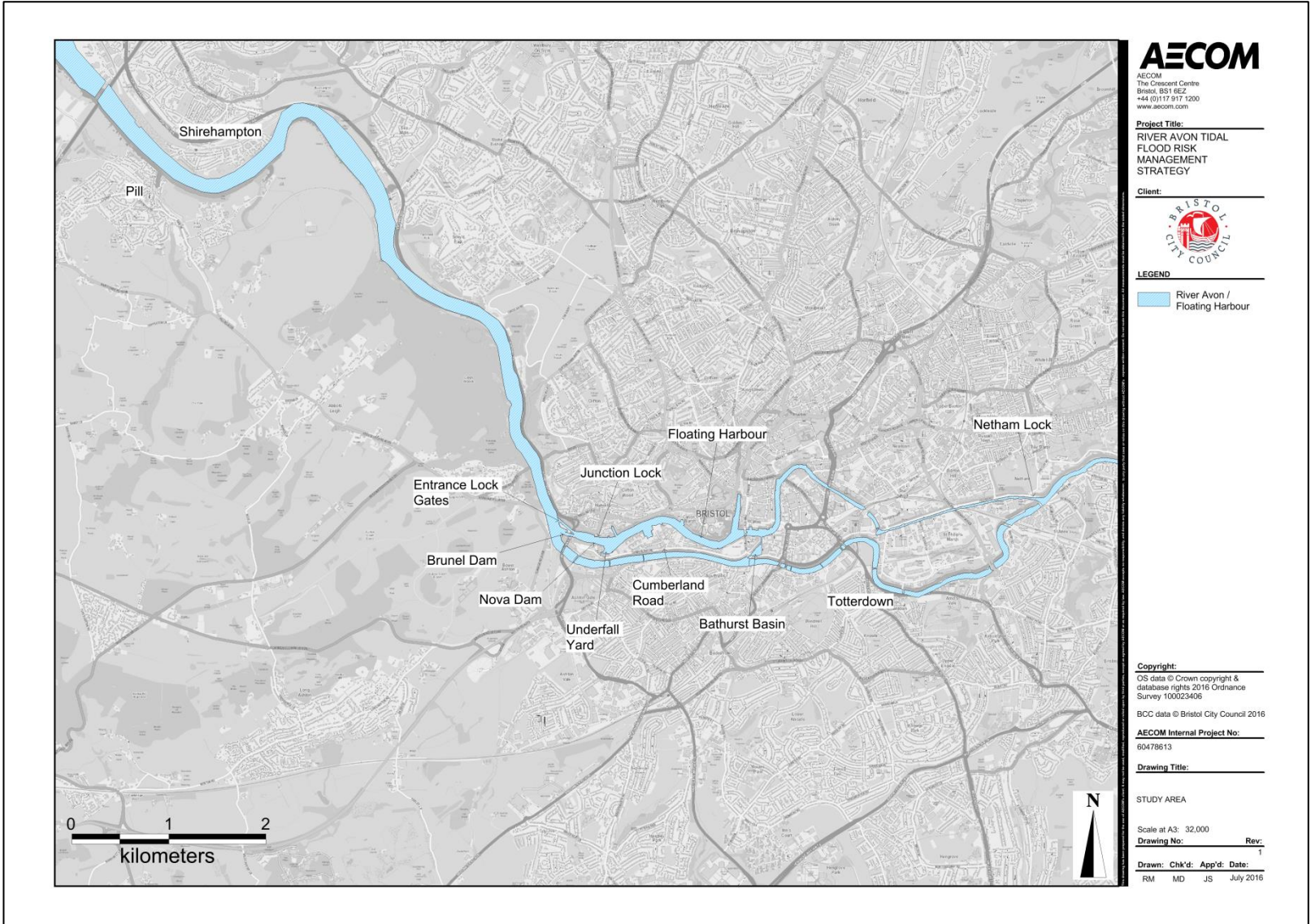
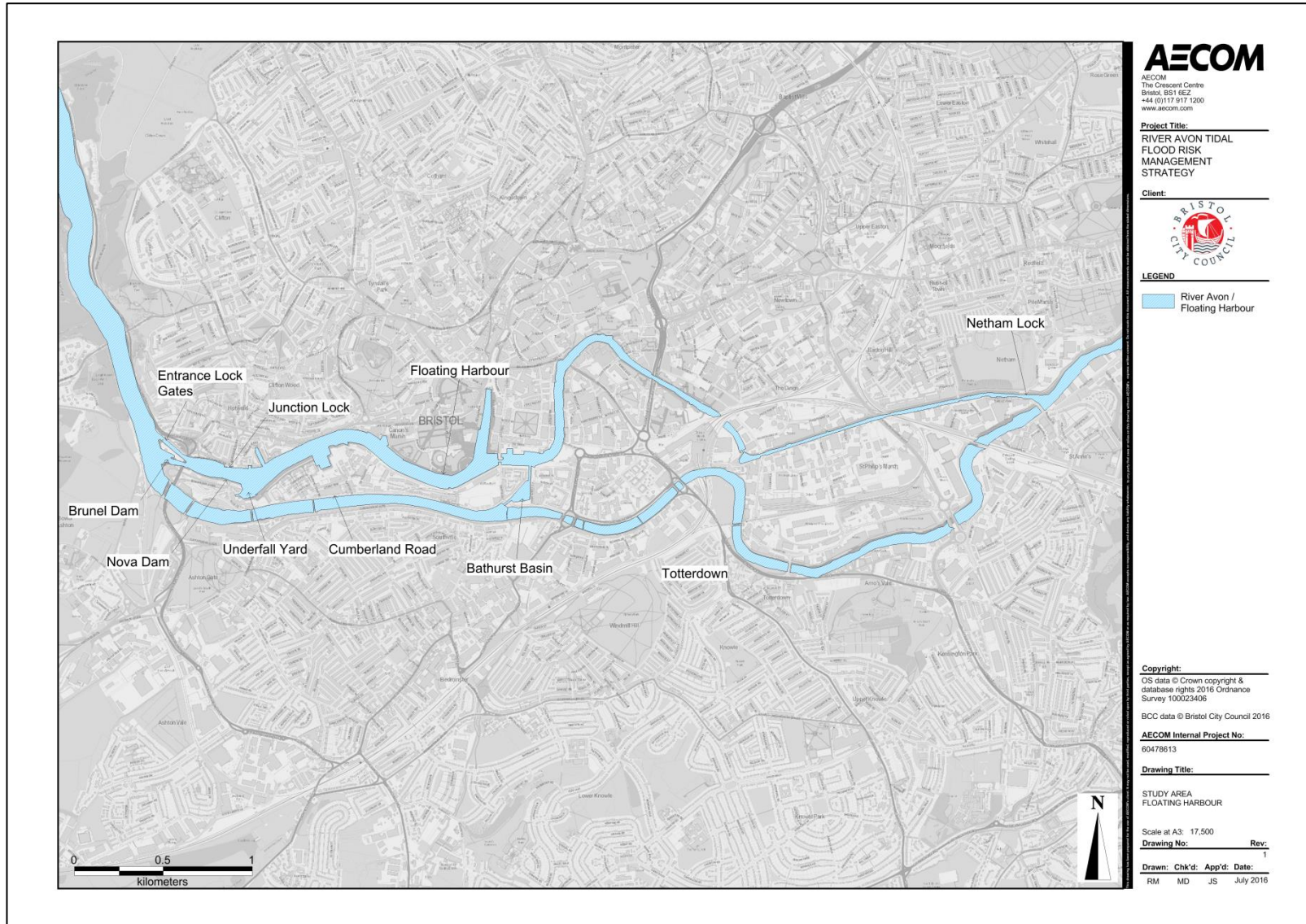


Figure 1 Overview map of study area



1.3

Structure of this report

Chapter 3 sets out the flood risk baseline for the study area, describing the results of the numerical modelling which has been undertaken to underpin the option appraisal process.

Chapter 4 provides an overview of the option appraisal process, outlining the steps undertaken prior to this report and the process that has been undertaken. This chapter also defines the 'measures' and 'strategic options'.

Chapter 5 provides an introduction to the flood defence measures which are included within the short list of strategic options. More details of the measures can be found in the Appendices.

Chapters 6 to 12 provide an in-depth description of each of the 7 strategic options on the short list (a chapter for each option). Within each chapter the following points are considered:

- A description of the Strategic option and what it involves. The reader should refer to further information presented in Appendix 1 for more details.
- Cost breakdown of the strategic option; including a breakdown of non-discounted (cash) costs (capital, maintenance and other costs), a cost profile over time and whole life present value costs.
- Economic benefits of the strategic option; including the whole life flood risk benefits of the option, overview of the benefit areas and the standard of protection over time.
- Overview of funding; including the potential of the strategic option to attract government Grant-in-Aid (GiA) funding, partnership funding score and the potential funding shortfall.
- Environmental impacts; including potential environmental constraints and opportunities associated with the strategic option.
- Wider issues and opportunities; including the potential impact on fluvial risk, residual risk and future development opportunities.

In Chapter 13, the evidence for each strategic option is combined and used to appraise the 7 short list strategic options and identify the preferred strategic option. This involves appraising the options against a decision making process that has been agreed. More details of the decision making process are provided in this chapter.

Chapter 14 presents the preferred strategic option.

Chapter 15 outlines the next steps to be taken in the finalisation of the Strategy.

The Appendices to this report present information on costings of options, and diagrams of feasible alignments, indicative cross sections and indicative defence heights (from ground level). Information presented in the Appendices is referred to throughout the report.

This report should also be read in conjunction with the following technical reports:

- Strategic Environmental Assessment, August 2016, AECOM
- Economic Assessment Report, August 2016, AECOM
- Hydraulic Modelling Report (Option Phase), August 2016. AECOM
- Funding note, August 2016, AECOM

2. FLOOD RISK

2.1 Overview of tidal flood risk in Bristol

Hydraulic modelling has been undertaken for the Do Nothing scenario and Do Minimum scenarios. The model results show current flood risk and how risk is expected to evolve over time, identifying the number of properties that are at risk.

An overview of the tidal flood risk in the Strategy study area is provided in the Hydraulic Modelling Report (Short Listing Phase), July 2016, AECOM.

Low spots along the banks of the River Avon, notably at Avon Crescent, Junction Lock and Bathurst Basin are the first pathways for flood water to inundate a significant number of properties in central Bristol. Other areas, such as Baltic Wharf are also at risk as water levels become raised in the Floating Harbour and overtop low spots in the defences. At present (i.e. with no allowance for climate change considered), a number of low lying areas at St. Phillips Marsh, the Cumberland Basin and Netham are at risk of flooding. This flood risk is expected to evolve in the future due to rising sea levels.

Based upon the results of the hydraulic modelling it is estimated that the Do Nothing damages will reach approximately £1.65 billion over the appraisal period (2015-2115). A breakdown of the Do Nothing damages is presented in **Table 11** below.

In **Table 11** write off and capping damages are presented, alongside PV 'other' damages. For reference, write off refers to the damage associated with assets being 'lost' due to flooding too frequently. Capping is a technique used to ensure the total PV damages do not exceed the risk-free market value of the asset. PV 'other' damages describe indirect damages associated with flooding, such as loss of life impacts.

Table 11 PV flood Damages for the appraisal period (2015-2115)

PV Flood Damages (£m)		PV Flood Damages – Write Off and Capping (£m)		PV Other (£m)	PV Total (£m)
Residential	Commercial	Residential	Commercial		
295.7	1,030.7	181.8	113.8	28.6	1,650.5

2.2 Extreme water levels adopted by the Strategy

It has been agreed with the project team to adopt the Medium Emissions 95th percentile scenario as the change factor for future tide levels. This has been decided to ensure that the options and economic appraisal is consistent with other Flood and Coastal Erosion Risk Management (FCERM) projects and therefore potential grant-in-aid eligibility of the options can be assessed in accordance with FCERM appraisal guidance. Therefore, unless otherwise stated, the extreme water levels referred to in this report have been determined using the Medium Emissions scenario.

Table 12 below presents the extreme water levels for the Strategy under a range of climate change emission scenarios; the Medium Emissions scenario, the High Emissions scenario and the Upper End emissions scenario. Water levels for a range of return period events across the different Strategy time epochs are shown. More details of the combined fluvial and tidal sources to determine the joint probability events are presented in the Hydraulic Modelling Report.

Throughout this report the terminology on the following lines is used for flood risk:

1 in 200 (years) (0.5%)

This indicates an event with an annual probability of exceedance of 0.5%, more commonly referred to as a 1 in 200 year event.

It should be noted that LPAs consider more precautionary allowances for sea level rise and climate change compared to the Medium Emissions 95th percentile scenario. This is important when considering the wider objectives of the Strategy (i.e. planning regulations feed into objectives relating to future economic growth and sustainability). For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

Table 12 Extreme tide levels (medium emissions 95thtile scenario adopted by the Strategy). The levels provided are for the downstream boundary of the numerical model.

Epoch	Probability	Tide Level (m AOD)		
		Upper End SLR	Medium Emissions 95 th ile SLR	High Emissions 95 th ile SLR
2015	1 in 20yr (5%)	8.69	8.69	8.69
	1 in 75yr (1.33%)	8.94	8.94	8.94
	1 in 200yr (0.5%)	9.13	9.13	9.13
	1 in 1000yr (0.1%)	9.45	9.45	9.45
2030	1 in 20yr (5%)	8.78	8.77	<i>Not considered</i>
	1 in 75yr (1.33%)	9.03	9.02	<i>Not considered</i>
	1 in 200yr (0.5%)	9.22	9.21	<i>Not considered</i>
	1 in 1000yr (0.1%)	9.54	9.53	<i>Not considered</i>
2065	1 in 20yr (5%)	9.11	9.01	9.08
	1 in 75yr (1.33%)	9.36	9.26	9.33
	1 in 200yr (0.5%)	9.55	9.45	9.52
	1 in 1000yr (0.1%)	9.87	9.77	9.84
2115	1 in 20yr (5%)	9.84	9.43	9.59
	1 in 75yr (1.33%)	10.09	9.68	9.84
	1 in 200yr (0.5%)	10.28	9.87	10.03
	1 in 1000yr (0.1%)	10.60	10.19	10.35

2.3

What is at risk in Do Nothing?

Do Nothing represents a hypothetical baseline against which all other measures and strategic options can be compared. Under the Do Nothing approach, all maintenance, repair and renewal work of existing flood defences would cease immediately. It is also assumed that the operation of all water level management assets which help to control flood risk would cease (e.g. lock gates, sluices and lock systems). Under normal operating conditions the Junction Lock stop gates resting position is open and stopping operations would result in the lock gates at Entrance and Junction Lock mitre being forced open. Therefore, under the Do Nothing scenario the water level management assets default to fail-open positions for the duration of the appraisal period.

There would be no investment in asset maintenance from the present day onwards. If this approach were adopted, existing flood defences would deteriorate, and any damage would not be repaired. This would result in the defence system being in a poor condition and would further deteriorate over time.

Table 13 presents the asset representation for the Do Nothing scenario.

Table 13 Do Nothing asset representation

Time Period	Asset Location and Description	Comments/Assumptions	Failure Representation / Model Commentary
2015 to 2065	Albert Road, Totterdown – Mid Section	Poor condition, failing. Local issues/gaps in defences. EA FRM asset.	Modelling to assume failure across all epochs.
	Pill and Shirehampton; Raised Flood Gates	Manually operated. EA FRM asset.	Location of defence within 1D domain. As such, this defence is represented as 'left open' within both the Do Nothing and Do Minimum model setup for all epochs.
	Netham Lock Gates and Sluices	Lock gates retain Floating Harbour water level and provide safe haven for mariners New lock gate – Good condition. Sluice paddles and operating system – Poor condition. Resilience of operation system believed to be poor.	Modelling to assume failure in 'open' position across all epochs.
	Totterdown Dam	No available info. Construction form unknown having been infilled and covered. Assume condition is fair.	Assume solid structure with minimal chance of failure. This structure has been represented as 'not failed' for all epochs.
	Nova Dam and Sluices	Nova Dam – Fair condition. Sluices and electrical system – very good condition. Standby generator may be vulnerable to flooding.	Modelling to assume failure to sluices only in 'open' position across all epochs.
	Junction Lock Gate and Sluices	New stop gates, upper gates and sluices – Very good condition. Old backup gates – Poor condition (inundated during spring tides).	Modelling to assume failure in 'open' position across all epochs.
	Entrance Lock Gates	Resilient against flooding. Lock gates stowed at times of surge tide and are unable to hold back high river levels.	Modelled as 'open' in both Do Nothing and Do Minimum scenario.
	Underfall Yard: Culverts, Sluices and Gates	High vulnerability to flooding –Poor condition.	Modelling to assume failure in 'open' position across all epochs.
	Brunel Dam Sluices / Gates	High vulnerability to flooding –Poor condition.	Modelling to assume failure in 'open' position across all epochs.

2065 to 2115	1 - Marine Parade (Pill); Masonry Flood Wall 2 - Marine Parade (Pill); Embankment 3 - Shirehampton Sailing Club; Embankment 4 - Shirehampton Sailing Club; Flood Wall	EA FRM asset. 1 - Good condition. 2 - Fair condition. 3 - Good condition. 4 - Good condition.	1-4: Location of defences within 1D domain. As such, this defence is represented as 'failed' within both the Do Nothing and Do Minimum model setup for all epochs.
	Albert Road, Totterdown – North Section	Fair condition. EA FRM asset.	Modelling to assume failure for this epoch only.
	Totterdown – Defences adjacent Bristol RSPCA (concrete wall)	Fair condition. Current failure experienced through breaching. EA FRM asset.	Modelling to assume failure for this epoch only.
	Totterdown – Defences downstream of Bristol RSPCA (embankment)	Constructed in 2003. Good condition. EA FRM asset.	Modelling to assume failure for this epoch only.
	Cumberland Road Wall Defence	New structure with less than 50 year design life without maintenance.	Modelling to assume failure for this epoch only.
	New Cut: Retaining Wall and Drainage (900m).	Risk to Cumberland Road Wall.	Modelling to assume failure for this epoch only (by breach).
	Netham Weir masonry sub-structure, concrete crest and rock apron.	Netham Weir helps retain Floating Harbour water level. Netham Weir is retained due to legal navigation duty and enables a safe haven for mariners. Sub-structure and concrete crest currently in fair condition. Rock apron in poor condition. Consequence of rock apron failure likely to lead to undermining and failure of weir.	Assumed that the rock apron will fail in 2065, which will undermine and lead to failure of the weir itself. However in the Do Nothing model simulations the weir structure will not be breached as the flood risk arising from failure of the structure will be represented by the failure of Netham gates and sluices.

Do Nothing is not considered a feasible approach to flood risk management and is not incorporated into any of the short-listed strategic options. BCC have a legal safe haven duty which is assumed to include the operation of the lock gates of the floating harbour but only have permissive powers for the operation of stop gates. However, to establish the benefits of various 'Do Something' options it is important to develop a Do Nothing scenario and to establish what would happen if no further work was undertaken to address flood risk in Bristol (i.e. the walk away option).

As sea levels rise and defence condition deteriorates, flood risk would increase significantly from both failure of the defences and through inundation over areas of low lying topography. Defence failure would increase as the severity and frequency of overflowing increased.

Eventually many of the existing residential and commercial assets within Bristol would be written off. Economic prosperity, opportunities for growth and community viability in Bristol would significantly decrease, and therefore a Do Nothing approach would be politically unacceptable. Doing Nothing would likely result in the escalation of uncertainty and this, with the loss of investor confidence, and lack of policy or infrastructure solution would result in the whole city and environs being prejudiced, and investment blocked or withdrawn.

Table 14 and **Table 15** present the numbers of properties within the study that are expected to be at risk of inundation under the Do Nothing scenario. For the present day approximately 2720 properties are at risk from a 1 in 200 year joint probability event. Approximately 64% of these properties are residential properties, with the remainder being non-residential or commercial. By 2115 the total number of properties at risk from a 1 in 200 year event is expected to have risen to 4344. Approximately 63% of these properties are residential.

As can be seen, the number of commercial properties at risk from a 1:1000 year event between 2030 and 2065 actually decreases. This is a result of write-off with the properties flooding very frequently in 2030 considered to be 'lost' and therefore not counted in 2065 and 2115.

The evolution of flood risk in the study area under the Do Nothing scenario is presented below in **Figure 3** and **Figure 4**. The flood risk for a 1 in 200 year event for the present day (2015) and 2115 is shown. Within Bristol city centre the areas exposed to the greatest level of flood risk are located at Cumberland Basin, Cumberland Road, St. Phillips marsh, Totterdown (Victor Street), Albert Road and downstream of Netham.

Table 14 Properties at risk under the Do Nothing scenario; Residential and Commercial

Epoch	1:2yr (50%)		1:20yr (5%)		1:75yr (1.33%)		1:200yr (0.5%)		1:1000yr (0.1%)	
	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial
2015	486	225	883	476	1245	678	1743	977	2290	1315
2030	625	264	992	576	1308	712	1874	1063	2447	1381
2065	777	421	1706	909	1308	713	2092	1232	2291	1323
2115	1318	738	1876	1001	2061	1198	2724	1620	3740	2010

Table 15 Properties at risk under the Do Nothing scenario; Total

Epoch	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)	1:1000yr (0.1%)
	Total	Total	Total	Total	Total
2015	711	1359	1923	2720	3605
2030	889	1568	2020	2937	3828
2065	1198	2615	2021	3324	3614
2115	2055	2877	3259	4344	5750

It should be noted that these figures do not include any properties built in the city since 2011 (as these are not eligible for Defra Grant in Aid flood defence funding) nor any of the 9052 homes planned to be built in the city between 2015-2026 in the housing trajectory assessment as set out in the current Local Plan document entitled *Bristol City Council Five Year Housing Land Supply 2015 – 2020*.

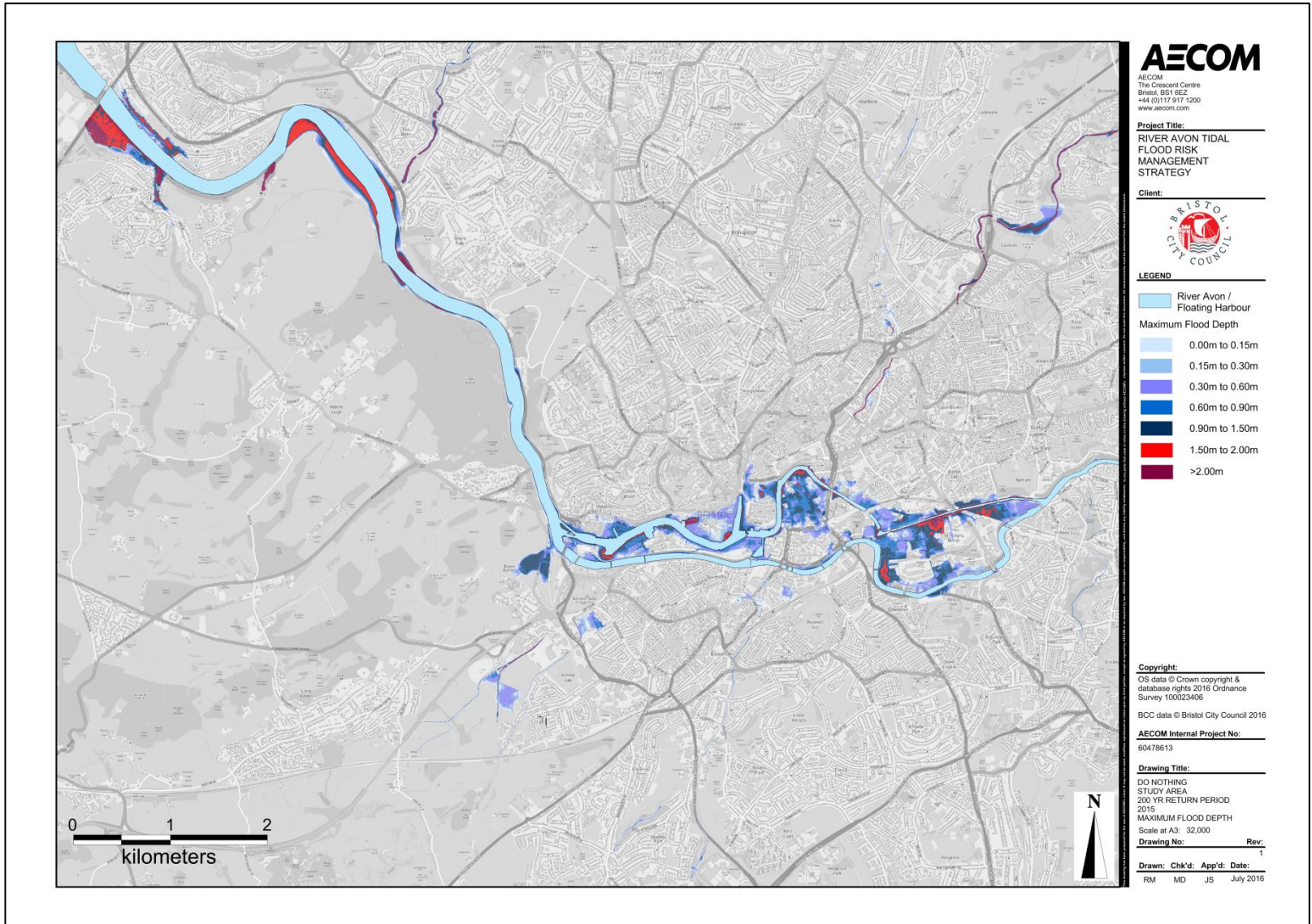


Figure 3 Do Nothing flood extent 1 in 200 year, 2015

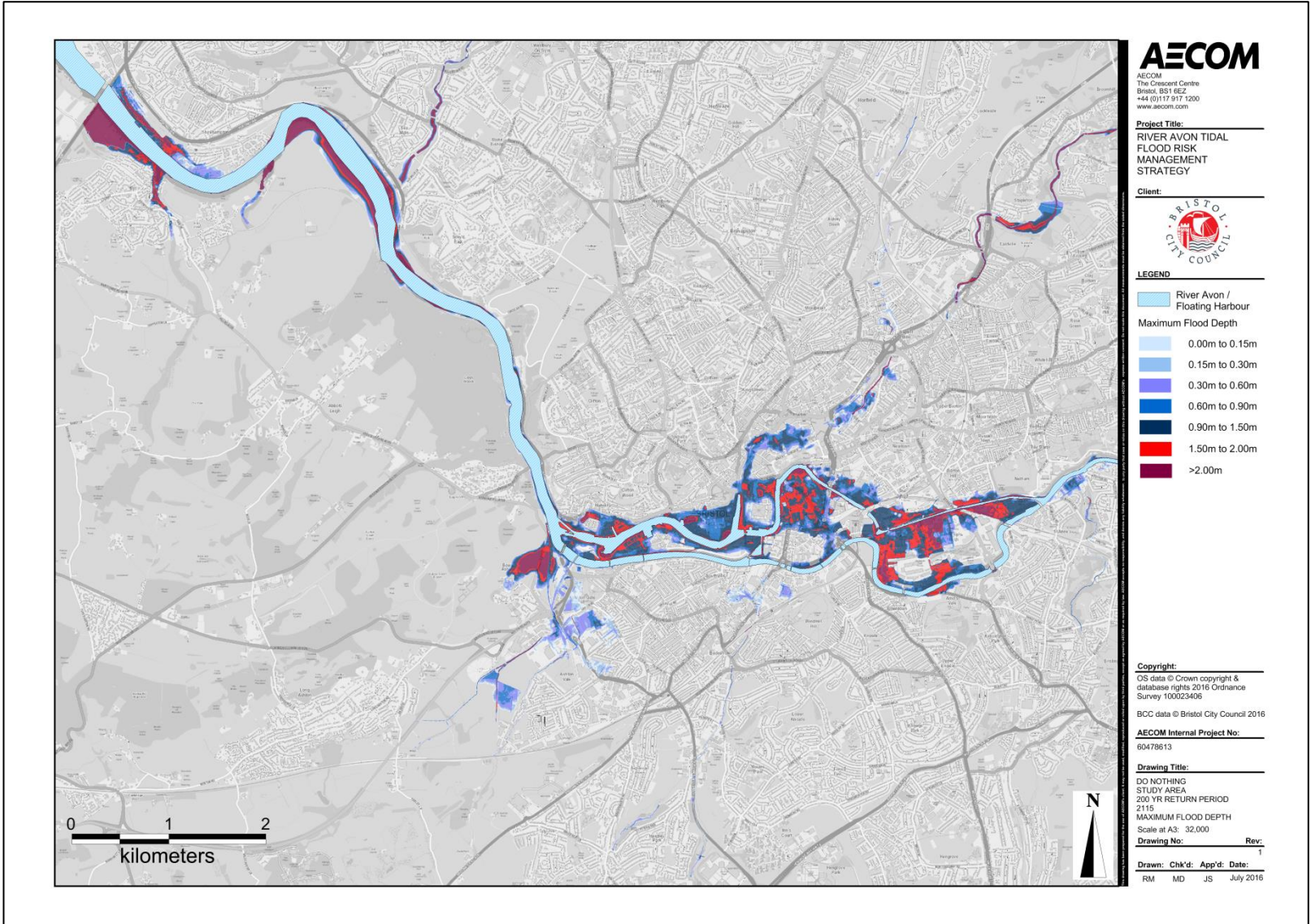


Figure 4 Do Nothing flood extent 1 in 200 year, 2115

2.4

What is at risk in Do Minimum?

Do Minimum represents what happens if the 'status quo' is maintained. This involves a continuation of maintenance to both the existing Floating Harbour water level control structures and raised defences throughout the duration of the Strategy period.

It is assumed that under the Do Minimum scenario the functioning of the Floating Harbour water level control structures would be sustained until 2115, and maintenance would incorporate improvements to the resilience of MEICA control and electrical systems to flooding (i.e. by raising the elevation of controls to reduce vulnerability to flooding). Do Minimum is considered a feasible approach to managing tidal flood risk.

Under Do Minimum it is assumed that like-for-like replacement of mechanical infrastructure e.g. lock gates would be undertaken but with no improvements in performance to account for sea level rise. The raised defences within the city and at Avonmouth (including Pill and Shirehampton) would be maintained to ensure their flood defence function continues; however, the defences would not be raised and consequently the standard of flood protection would be expected fall over time in response to sea level rise.

Table 16 and **Table 17** below present the numbers of properties at risk under the Do Minimum scenario. For the present day approximately 1008 properties are at risk from a 1 in 200 year joint probability event. Approximately 54% of these properties are residential properties, with the remainder being non-residential or commercial. By 2115 the total number of properties at risk from a 1 in 200 year event is expected to have risen to 3689. Approximately 63% of these properties are residential.

The evolution of flood risk in the study area under the Do Minimum scenario is presented in **Figure 5** and **Figure 6**. The flood risk for a 1 in 200 year event for the present day (2015) and 2115 is shown. The areas exposed to the greatest level of flood risk are located at Cumberland Basin, Cumberland Road, St. Phillips Marsh, Totterdown (Victor Street), Albert Road and downstream of Netham.

Table 16 Properties at risk under the Do Minimum scenario; Residential and Commercial

Epoch	1:2yr (50%)		1:20yr (5%)		1:75yr (1.33%)		1:200yr (0.5%)		1:1000yr (0.1%)	
	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial	Residential	Commercial
2015	49	7	94	120	124	199	488	486	1673	963
2030	52	20	104	163	127	238	579	497	2101	1074
2065	91	111	129	239	340	358	1673	964	2128	1084
2115	131	245	783	467	1499	820	2342	1347	3412	1896

Table 17 Properties at risk under the Do Minimum scenario; Total

Epoch	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)	1:1000yr (0.1%)
	Total	Total	Total	Total	Total
2015	56	214	323	974	2636
2030	72	267	365	1076	3175
2065	202	368	698	2637	3212
2115	376	1250	2319	3689	5308

It should be noted that these figures do not include any properties built in the city since 2011 (as these are not eligible for Defra Grant in Aid flood defence funding) nor any of the 9052 homes planned to be built in the city between 2015-2026 in the housing trajectory assessment as set out in the current Local Plan document entitled *Bristol City Council Five Year Housing Land Supply 2015 – 2020*.

A figure showing the location of the properties at risk for a present day 1:2 year event is provided in Appendix 4.

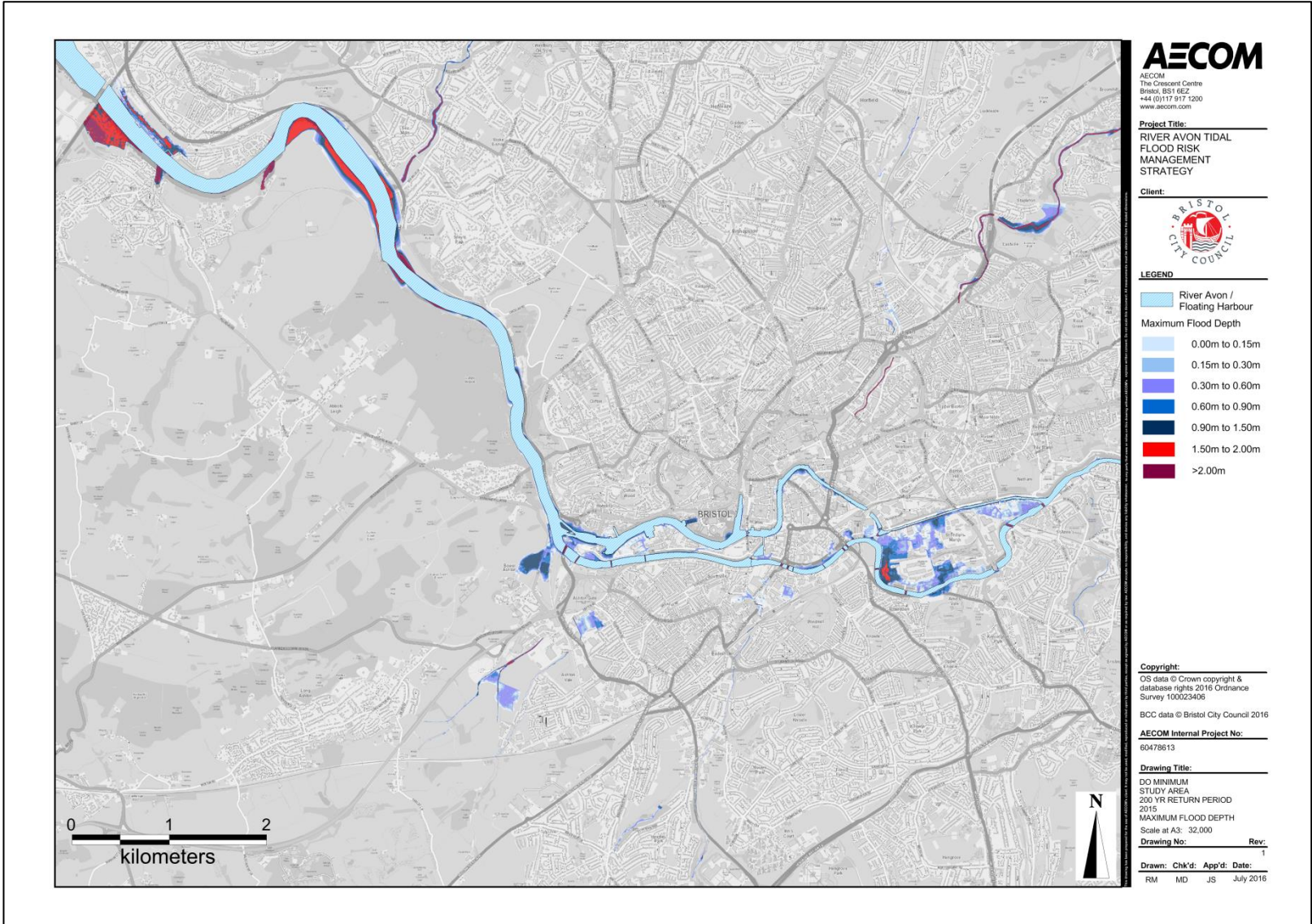


Figure 5 Do Minimum flood extent 1 in 200 year, 2015

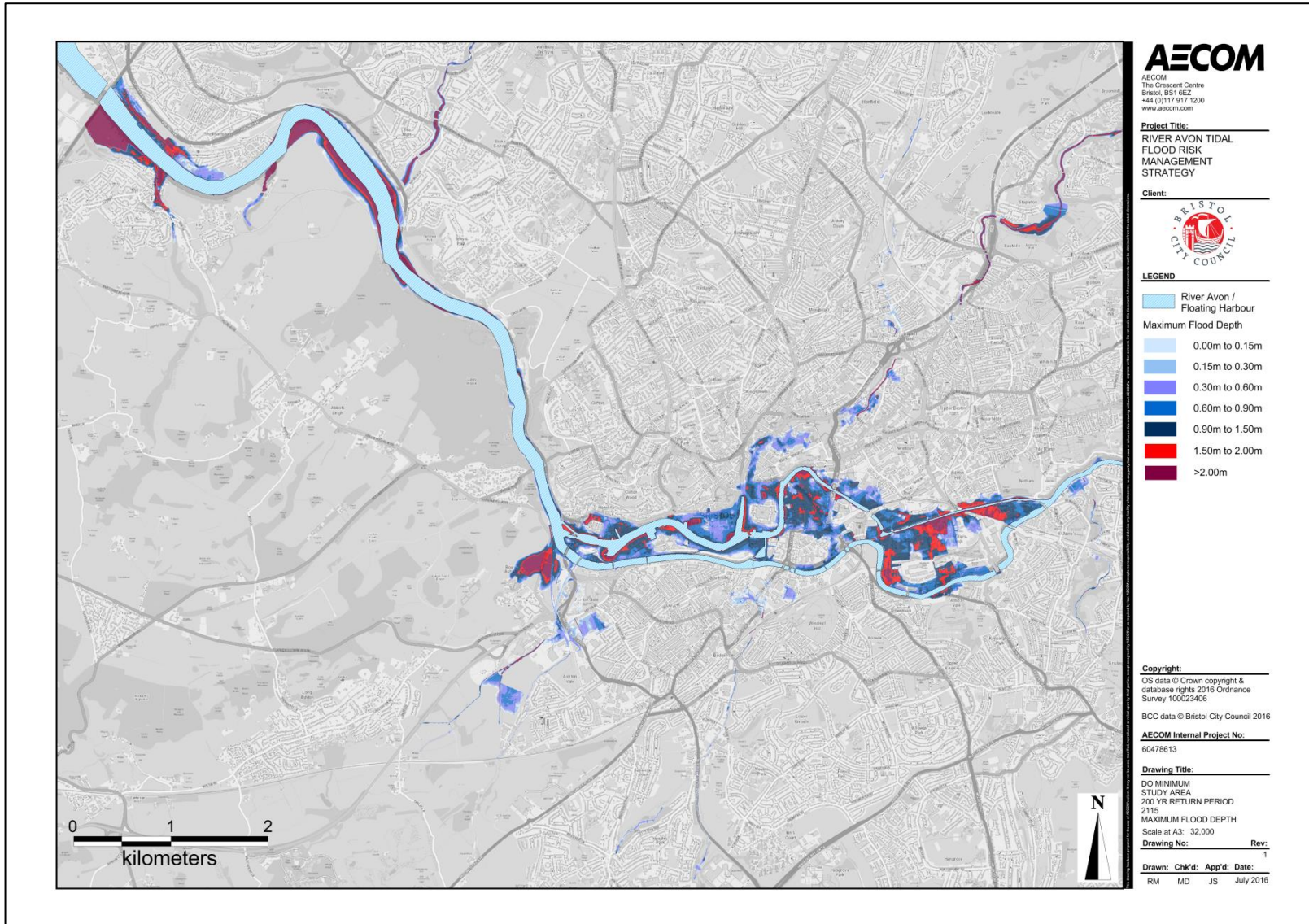


Figure 6 Do Minimum flood extent 1 in 200 year, 2115

3. OPTION APPRAISAL OVERVIEW

3.1 Purpose of this report

To date, the option appraisal has developed a short list of 7 strategic options. This report describes the process by which the preferred strategic option has been selected from the short list.

3.2 Option objectives

To facilitate the option appraisal process, the objectives for the flood risk management options have been agreed with the project team. The objectives provide a means of considering multiple factors for the options to achieve a balanced Strategy and outcome. However, it is recognised that the principal aim for the Strategy is to reduce flood risk and the restrictions it may bring to future development. The option objectives are as follows:

1. To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks
2. To facilitate the sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure
3. To maintain, and where possible enhance, natural, historic, visual and built environments
4. To reduce whole life costs
5. To ensure navigation of the River Avon and marine activities can continue
6. Ensure the Strategy is technically feasible and deliverable over its duration

3.3 Strategy time epochs

To facilitate the development of the Strategy and appraisal of options the 100 year appraisal period (2015-2115) has been split into three time epochs:

- 2015 to 2030 (short term);
- 2030 to 2065 (medium term); and
- 2065 to 2115 (long term)

By developing management options in accordance with these time epochs it will allow for an adaptive approach to management to be developed that keeps pace with climate change and potential sea level rise. In addition, the approach has sufficient flexibility to address uncertainty thereby ensuring the most appropriate strategic choices are taken now and in the future. As the Strategy is implemented, to help inform the best time to implement the recommended management interventions, various risk 'thresholds' and 'tipping points' will be outlined. For instance, the Strategy may initially recommend that a scheme is implemented at the start of epoch 2, but, if sea level rise occurs more slowly than expected and the exceedance of the risk threshold does not occur, the scheme could be delayed until a later stage.

3.4 Appraisal to date

In previous work, 7 short list strategic options have been established, from an original long list of 39 options. Each of the strategic options comprises a sequence of feasible, coherent and logical measures to be implemented over the duration of the Strategy appraisal period (2015-2115).

For each strategic option a 'measure' was assigned to each time epoch, so for instance one of the strategic options suggests Property Level Protection (PLP) in the short term (2015-2030), implementing Low Defences in the medium term (2030-2065) and then raising these defences to High Defences in the long term (2065-2115). For the purpose of the appraisal, it has been assumed that the measure for each time epoch will be constructed / implemented at the start of each time epoch.

The measures from which the strategic options were developed included:

- Do Minimum
- Property Level Protection / temporary defences
- Low Defences
- High Defences

- Narrow Tidal Barrier
- Wide Tidal Barrier

During the short listing phase of the appraisal the strategic options which included the 'Wide Tidal Barrier' were scoped out. As a result, this measure is no longer a consideration for the Strategy and does not feature in any of the 7 strategic options on the short list. The 'Narrow Tidal Barrier' was taken forward and included in two short listed options. For the remainder of this report the 'Narrow Tidal Barrier' measure is simply referred to as 'Tidal Barrier'.

Since the short listing phase of the appraisal, and to support the selection of the preferred option, the remaining measures have been developed in more detail.

The short list of 7 strategic options comprises:

- **Option A:** Property Level Protection / temporary defences in epoch 1 (short term; 2015-2030), Low Defences in epoch 2 (medium term; 2030-2065), High Defences in epoch 3 (long term, 2065-2115).
- **Option B:** Property Level Protection / temporary defences in epoch 1 (short term, 2015-2030), High Defences in epoch 2 (medium term; 2030-2065), High Defences in epoch 3 (long term, 2065-2115).
- **Option C:** Property Level Protection / temporary defences in epoch 1 (short term, 2015-2030), Tidal Barrier in epoch 2 (medium term; 2030-2065), Tidal Barrier in epoch 3 (long term, 2065-2115).
- **Option D:** Low Defences in epoch 1 (short term, 2015-2030), Low Defences in epoch 2 (medium term, 2030-2065), High Defences in epoch 3 (long term, 2065-2115).
- **Option E:** Low Defences in epoch 1 (short term, 2015-2030), Tidal Barrier in epoch 2 (medium term, 2030-2065), Tidal Barrier in epoch 3 (long term, 2065-2115).
- **Option F:** High Defences in epoch 1 (short term, 2015-2030), High Defences in epoch 2 (medium term, 2030-2065), High Defences in epoch 3 (long term, 2065-2115).
- **Option G:** Do Minimum in epoch 1 (short term, 2015-2030), Do Minimum in epoch 2 (medium term, 2030-2065), High Defences in epoch 3 (long term, 2065-2115).

The short list of 7 strategic options can be categorised by their approach to flood risk management; being either adaptive or precautionary.

Options A, D, and G represent an adaptive approach to flood risk management whereby the measures which provide the greatest standard of flood protection (i.e. the Tidal Barrier or High Defences) are delayed until later on in the appraisal period (i.e. in epoch 3). The adaptive approach provides flexibility in terms of adjusting to rates of sea level rise and climate change and delays large capital construction costs until later in the appraisal period (generally resulting in a lower present value cost of the option). Of the adaptive options, option A represents the most adaptive approach.

Options B, C, E and F represent a precautionary approach to flood risk management whereby the measures which provide the greatest standard of flood protection (i.e. the Tidal Barrier or High Defences) are undertaken early in the appraisal period (i.e. in epochs 1 or 2). The precautionary options ensure that the risk posed by sea level rise in the future is addressed early on in the Strategy appraisal period (assuming sea levels rise as projected) and the protection to a high standard is provided for the duration of the Strategy. However, should sea levels rise slower than expected over the next 100 years, there is a risk that the precautionary options will be overdesigned and may represent wasted investment. Of the precautionary options, options E and F represent the most precautionary approaches.

3.5

Assumptions

Table 18 sets out the key assumptions that have been made during the selection process of the preferred option. These assumptions are discussed in more detail throughout the report but are included for reference here for the reader's benefit.

Table 18 Key assumptions during the selection of the preferred option

List of key assumptions	
Aspect	Assumption
Do Nothing scenario	Water level control structures and assets default to a fail-open position
Do Minimum scenario	Water level control assets continue to be operated and closed during periods of increased tidal flood risk
Climate change and sea level rise	Medium emissions scenario 95 th tile has been adopted for modelling simulations
Strategy implementation	For each strategic option the flood risk measures assumed to be implemented as earliest possible opportunity from the start of the strategy time epochs
Costing and design assumptions	Refer to separate sections in the report which provide more detail for each measure
Standard of protection	Low Defences constructed to 1:200 year standard for 2030
Standard of protection	High Defences constructed to 1:200 year standard for 2115

4. OVERVIEW OF MEASURES

This chapter provides an overview of the various measures which comprise the short list of options. The measures include do minimum, property level protection, low defences, high defences and a tidal flood barrier (referred to previously as the narrow barrier in the long and short listing phase of the appraisal). This chapter should be read in conjunction with the Appendices at the end of this report.

4.1 Do Minimum

Do Minimum involves maintaining the existing defence assets, the floating harbour water level control infrastructure and ensuring that the operation of the floating harbour is continued. In essence, Do Minimum represents what happens if the current 'status quo' is maintained.

Under the Do Minimum scenario the existing defences would be maintained but would not be raised or lengthened, nor the standard of protection increased. As a result, with sea level rise, the standard of protection of the existing defences would be expected to decrease over the duration of the Strategy. Under Do Minimum there is therefore increased risk in the future that the existing defences would be inundated / overtopped during tidal flood events.

Despite the fall in the standard of protection under Do Minimum, the maintenance works that would be carried out are assumed to preserve the structural integrity of the existing defences. In this respect, Do Minimum provides a flood risk benefit compared to the Do Nothing scenario, in which it is assumed that many of the defences would breach or are operationally abandoned.

In the development of the strategic options it has been assumed that the Do Minimum measure can act as a 'stand-alone' measure and also as a measure which will be carried out in support of the other 'do something' measures (PLP, low defences, high defences and tidal barrier). For example, if a strategic option outlines the implementation of PLP in epoch 1, it is assumed that the activities of the Do Minimum measure (e.g. lock gate maintenance and operation) would also be undertaken during this epoch. This would ensure that the maintenance of the existing defences in the study area and the ongoing operation of the floating harbour would be continued.

4.2 Property Level Protection / temporary defences

4.2.1 Overview

This measure groups together Property Level Protection (PLP) approaches and use of temporary / demountable flood defences.

Property Level Protection is a generic term for permanent flood defences such as individual property barriers (fitted to any property openings such as front doors, windows and garden gates), non-return valves (fitted to drains to prevent floodwater backing up into a home) and airbrick/vent covers (placed over existing airbricks and vents to prevent the ingress of water). PLP can also take the form of community flood defences, for example low walls built to protect blocks of flats or close housing groups.

PLP is typically retro-fitted to existing building stock, but the same measures can be designed into new developments.

Typically PLP can provide protection from flooding to individual properties up to approximately 600mm of water depth (though greater depths can be accommodated through use of customised flood barriers). For flood depths greater than 600mm, PLP is unlikely to form an effective defence. PLP can provide only a relatively low standard of protection.

The Environment Agency issued guidance for the design and management of temporary / demountable flood defence products and systems in 2011 and information from this guidance is provided below. A temporary flood defence is defined as (Environment Agency, 2011):

"A temporary flood protection system is formed by removable flood protection products that are wholly installed during a flood event and removed completely when levels have receded, its connection with the underlying surface, and its connections."

A demountable flood defence is defined as (Environment Agency, 2011):

"A demountable flood protection system is a moveable flood protection system that is fully pre-installed and required operation during a flood event, or a system that required part-installation into pre-installation guides or sockets within a pre-constructed foundation."

Temporary or demountable flood defences can be used in a variety of situations and to perform different task including; raising the level of protection, strengthening existing defences, containing flood water from either overtopping or breaching of permanent defences, and diverting or directing water elsewhere on the floodplain.

4.2.2 **Design Assumptions**

PLP / temporary defences is a measure which is only used in the short term (epoch 1) in the short listed strategic options. To determine the properties which may be suitable for PLP / temporary defences within the study area the zones which fall within the 1:75 year flood extent and have water depths less than the 600mm threshold have been identified. The 1:75 year flood extent was used as this represents a flood event which is not unlikely to occur within the next 15 years. It is considered unlikely that a 1:200 year event or greater will occur before the end of epoch 1 and therefore a larger flood event such as this was not used as protecting additional properties within this extent may represent a wasted investment. The 600mm threshold was used because this represents the typical flood water depth in which PLP / temporary defences is most effective.

The number of properties within the PLP / temporary defence zones for epoch 1 is 245. For the purpose of this appraisal it has been assumed that each of these properties is suitable for PLP / temporary defences. Further studies and individual property threshold surveys will be required to investigate this in more detail. The majority of the properties which are considered suitable for PLP / temporary defences are located in the area east of Temple Meads station and in the Totterdown and St. Philips Marsh area.

4.2.3 **Costing**

Cost estimates for the property level / temporary defence measure have been built up by considering the number of properties which may be suitable for PLP measures. An average cost per property for PLP measures has been assumed based on costs provided by other PLP schemes elsewhere. In further work that is beyond the scope of the Strategy it will be necessary to undertake individual property and threshold surveys to determine the scope of PLP measures which will be required at each property. This will allow the costs of this measure to be refined.

As part of the PLP / temporary defences measure, potential alignments for temporary defences have been investigated and are presented in **Figure 8**. It has been assumed that these temporary defences would remove the need for individual property level protection measures to the properties that would benefit. It has also been assumed that the cost of the temporary defences would be similar to the overall cost of implementing individual property protection measures to the protected properties.

For the purpose of the Strategy costing, the cost of the PLP / temporary defence measure is considered to be unchanged irrespective of whether the preferred approach comprises property protection measures to the individual properties or a utilising temporary defences to benefit a number of properties simultaneously.

4.3 **Low Defences**

4.3.1 **Overview**

The Low Defence measure comprises linear defences – walls or embankments – to provide a high standard of protection, but for a limited period only, not to 2115. At a future point in time the defence would be raised further or an alternative measure implemented. Low Defences represent an adaptive solution to manage tidal flood risk and sea level rise.

The implementation of Low Defences involves identifying low spots or gaps in the existing defences and then raising the existing defence levels or constructing new floodwalls or similar defences (e.g. embankments) in these locations.

Low Defences will be constructed to a 1:200 year standard for 2030 and are intended to provide a standard of protection that is robust against short to medium term levels of sea level rise before a defence upgrade is needed.

Note that during previous stages of the option appraisal (i.e. long listing and short listing) it was envisaged that low defences could be constructed to either the 1:200 year standard for 2015 or the 1:200 year standard in 2030. However, during further appraisal work in the preferred options stage it became clear that the difference between these standards is minimal (i.e. often less than 0.1m in defence crest level required and only very marginal changes to the defence length). As a result it is impractical to assume that low defences in epoch 1 would be constructed to the 1:200 2015 standard, when in reality with only a marginal increase in defence crest level and length, the 2030 1:200 standard could be achieved for similar costs.

To provide the 1:200 year standard in 2030 approximately 5.3km of new flood defences will be required across the study area. The low defences will be required at Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown / St. Phillips, Netham and Bath Road. As part of the low defences measure new tidal stop gates and supporting infrastructure will also be required at Entrance Lock and Netham Lock.

No raised defences have been identified for the Ashton Gate area on the south side of the River Avon. This is despite there being a flood risk in this location. However, the flood risk is not tidally dominated

and raised defences along the Avon do not improve the standard of protection to the properties at risk. Other means of protection, such as property level protection are more suitable to improve the standard of protection in this area.

4.3.2 Alignments and Design Assumptions

For costing purposes in this strategic level study it has been assumed that Low Defences will follow a frontline alignment. Potentially feasible frontline alignments at each location are presented in Appendix 2, alongside the required heights from ground level and indicative cross sections.

A walkover survey of the defence locations was carried out to assess the viability of the various potential alignments. Consideration was given to:

- buildability;
- visual and landscape impact;
- operational issues (i.e. favouring passive defences over gates or demountables); and
- unknown site conditions (services, existing structures, ground conditions UXO).

In some locations there were a number of alignments which could be technically feasible, whilst at others the route alignments are constrained and more limited. In particular the proposed wall heights, in some cases up to 2m above existing ground level, could create “dead” areas and / or cut off views of and access to the river or other infrastructure.

Access through or over new defences was also considered both for pedestrians and traffic. Ramped accesses are preferable due to the reduced operational risks associated with them but in most cases these would not be feasible due to the heights involved. Flood gates or demountable barriers offer an alternative but increase the operational requirement on the Council or its partners. Additional analysis and appraisal is required during future feasibility studies to identify the preferred alignment in each location.

It has been assumed that the existing riparian walls cannot be relied upon for support to new structures nor to provide a watertight defence against raised water levels throughout the life of the strategy. It has therefore been assumed that the proposed defences will be built as independent walls placed in front of the existing Avon / New Cut retaining structures. This is a conservative approach and will provide the most robust cost estimate. In future feasibility studies, assessments can be carried out on existing walls and other structures to identify their residual life and ability to withstand additional loading. Consideration of their permeability and ability to withstand tidal and fluvial flood loads will also be included in these assessments. These assessments can then be used to refine the designs and wherever possible offer cost savings or environmental improvements (mostly heritage, amenity and visual).

It should be noted that although the costing of the walls allows for a self-supporting design, capable of taking earth pressures from dead loads, the designs have not been tested for their ability to take additional loads from adjacent highways or railways, and thereby totally negate the need for replacement of existing structures. It is likely that this will be the case in some areas, but not all.

Although the alignments and structure types have not been confirmed, unless otherwise stated, for the purpose of costing the options a conservative worst-case frontline alignment has been followed. The alignments generally follow the river bank and, in most cases, are positioned riverward from the existing structures. This alignment position has been chosen to avoid any services which may exist behind the wall and reduce the risk of hitting the foundations of the wall during construction. It would also enable the defences to be installed from barges within the river to minimise disruption during the construction phase. The frontline alignments are provided in Appendix 2 at the end of this report.

The top level of the walls has been determined from the modelled design standard return period for the relevant epoch. The heights of the wall have been estimated from available Lidar and topographical data for adjacent ground levels and are presented later in the report.

The preferred scheme alignments will be confirmed during future phases of work, and in instances where a frontline alignment is taken forward as the preferred alignment then there is potential for a loss of intertidal habitat due to coastal squeeze. This will occur when a new frontline structure is constructed in place of an existing riverbank. It is expected that the impact will be localised and small scale but HRA scoping will be required to assess the impact in more detail.

4.3.3 Numerical Modelling

Results of numerical modelling of low and high walls are presented in Hydraulic Modelling Report (Option Phase), August 2016, AECOM.

Flood defence walls were shown to be effective at reducing flood risk for the City. As a result of adopting defence walls, a minor increase in flooding to the Bower Ashton, Ashton and upstream of Netham could

be expected. The low and high defences options also bring about a significant reduction of flood depth and extent at a number of locations across the City, in an extreme fluvial event.

4.3.4 Costing

For costing purposes it is assumed that the new tidal defence walls will be a cantilevered sheet piled wall offset from the existing river bank by approximately 2-3m. No structural calculations have been carried out in these walls but a rule of thumb estimate of pile length has been assumed to retain and unit rates have been benchmarked against EA actual cost data. An optimism bias of 60% has been applied.

The unit rates are assumed to include for ancillary items such as back of wall drainage, cladding, edge protection and reinstatement. A percentage uplift on the unit rates has also been applied to account for design, preliminaries and scale of works.

It has been assumed that no maintenance works would be required in the ten years immediately after the construction of low or high defences. This is a reasonable assumption to make as it would be expected that new defences would be constructed to a high quality and that initial maintenance activities such as the replacement of cathodic protection (for sheet piled solutions) would not be required for a number of years post construction.

In strategic options where low defences are upgraded to high defences, the upgrade to high defences involves a significant capital investment and it has been assumed that maintenance/local refurbishment of the existing low defences would be incorporated into the upgrade works. Therefore, no maintenance allowance has been included for the ten years immediately after upgrades from low to high defences.

The cost estimate for the raised defences is sufficiently conservative (in addition to the 60% optimism bias) to cover localised method related issues and designs, such as specific cladding / facings and new defence mitigation measures (i.e. landscape and environmental). At the Strategy stage it is not appropriate to consider local construction methodology and design in more detail and this will be done during the scheme design stage.

4.4 High Defences

4.4.1 Overview

The high defence measure comprises linear defences – walls or embankments – to provide a high standard of protection in a single implementation phase.

The implementation of high defences involves identifying low spots or gaps in the existing defences and then raising the defence crest levels or constructing new floodwalls or similar defences (i.e. embankments) in these locations.

The design standard of protection for the high defences is a 1:200 year standard for 2115 and therefore the high defences represent a precautionary approach and would provide long term protection from tidal flood risk by considering sea level rise and climate change projections until 2115. Being a precautionary measure, high defences could be constructed in epochs 1, 2 or 3 and irrespective of the timing the protection provided by the defences will exceed the 1:200 year standard for the duration of the strategy period (the defences are designed so that the standard gradually falls to a 1:200 year standard by 2115 due to sea level rise).

To provide a 1:200 year standard in 2115, approximately 7.2km of new flood defences will be required across the study area. This length is approximately 1.9km greater than that required for the low defences measure. The locations of the high defences are similar to that of low defences, focussed at Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown / St. Phillips, Netham and Bath Road. Stop gates and operational infrastructure at Entrance Lock and Netham Lock would also be required.

No raised defences have been identified for the Ashton Gate area on the south side of the River Avon. This is despite there being a flood risk in this location. However, the flood risk is not tidally dominated and raised defences along the Avon do not improve the standard of protection to the properties at risk. Other means of protection, such as property level protection are more suitable to improve the standard of protection in this area.

4.4.2 Alignments and Design Assumptions

As discussed previously, for costing purposes in this strategic level study it has been assumed that low defences will follow a frontline alignment. Potentially feasible frontline alignments at each location are presented in Appendix 2, alongside the required heights from ground level and indicative cross sections.

A walkover survey of the defence locations was carried out to assess the viability of the various potential alignments. Consideration was given to:

- buildability;
- visual and landscape impact;
- operational issues (i.e. favouring passive defences over gates or demountables); and
- unknown site conditions (services, existing structures, ground conditions UXO).

In some locations there were a number of alignments which could be technically feasible, whilst at others the route alignments are constrained and more limited. In particular the proposed wall heights, in some cases up to 2m above existing ground level, could create “dead” areas and / or cut off views of and access to the river or other infrastructure.

Access through or over new defences was also considered both for pedestrians and traffic. Ramped accesses are preferable due to the reduced operational risks associated with them but in most cases these would not be feasible due to the heights involved. Flood gates or demountable barriers offer an alternative but increase the operational requirement on the Council or its partners. Additional analysis and appraisal is required during future feasibility studies to identify the preferred alignment in each location.

It has been assumed that the existing riparian walls cannot be relied upon for support to new structures nor to provide a watertight defence against raised water levels throughout the life of the strategy. It has therefore been assumed that the proposed defences will be built as independent walls placed in front of the existing structures. This is a conservative approach and will provide the most robust cost estimate. In future feasibility studies, assessments can be carried out on existing walls and other structures to identify their residual life and ability to withstand additional loading. Consideration of their permeability and ability to withstand tidal and fluvial flood loads will also be included in these assessments. These assessments can then be used to refine the designs and wherever possible offer cost savings or environmental improvements (mostly heritage, amenity and visual).

It should be noted that although the costing of the walls allows for a self-supporting design, capable of taking earth pressures from dead loads, the designs have not been tested for their ability to take additional loads from adjacent highways or railways, and thereby totally negate the need for replacement of existing structures. It is likely that this will be the case in some areas, but not all.

Although the alignments and structure types have not been confirmed, unless otherwise stated, for the purpose of costing the options a conservative worst-case frontline alignment has been followed. The alignments generally follow the river bank and, in most cases, are positioned riverward from the existing structures. This alignment position has been chosen to avoid any services which may exist behind the wall and reduce the risk of hitting the foundations of the wall during construction. It would also enable the defences to be installed from barges within the river to minimise disruption during the construction phase. The frontline alignments are provided in Appendix 2 at the end of this report.

The top level of the walls has been determined from the modelled design standard return period for the relevant epoch. The heights of the wall have been estimated from available Lidar and topographical data for adjacent ground levels and are presented later in the report.

4.4.3 Numerical Modelling

Results of numerical modelling of low and high walls are presented in Hydraulic Modelling Report (Option Phase), August 2016, AECOM.

Flood defence walls were shown to be effective at reducing flood risk for the City. As a result of adopting defence walls, a minor increase in flooding to the Bower Ashton, Ashton and upstream of Netham could be expected. This has been shown to occur during a combined 200yr tidal and 2yr fluvial event, as well as the 200yr fluvial event (Netham only).. This adverse consequence would need to be resolved, either by localised wall raising as part of the tidal strategy, or as part of a fluvial strategy. Whilst it is possible that any existing tide lock impacts may increase over time as a consequence of sea level rise, the Strategy has not addressed whether the introduction of walls will alter existing tide lock effects. The Strategy will consider, where relevant, detriment from a fluvial perspective.

The low and high defences options also bring about a significant reduction of flood depth and extent at a number of locations across the City, in an extreme fluvial event.

4.4.4 Costing

For costing purposes it is assumed that the new tidal defence walls will be a cantilevered sheet piled wall offset from the existing river bank by approximately 2-3m. No structural calculations have been carried out in these walls but a rule of thumb estimate of pile length has been assumed to retain and unit rates have been benchmarked against EA actual cost data. An optimism bias of 60% has been applied.

The unit rates are assumed to include for ancillary items such as back of wall drainage, cladding, edge protection and reinstatement. A percentage uplift on the unit rates has also been applied to account for design, preliminaries and scale of works.

It has been assumed that no maintenance works would be required in the ten years immediately after the construction of low or high defences. This is a reasonable assumption to make as it would be expected that new defences would be constructed to a high quality and that initial maintenance activities such as the replacement of cathodic protection (for sheet piled solutions) would not be required for a number of years post construction.

In strategic options where low defences are upgraded to high defences, the upgrade to high defences involves a significant capital investment and it has been assumed that maintenance/local refurbishment of the existing low defences would be incorporated into the upgrade works. Therefore, no maintenance allowance has been included for the ten years immediately after upgrades from low to high defences.

4.5 Tidal flood barrier

4.5.1 Overview

The tidal flood barrier would operate to exclude the highest surge or astronomical tides which otherwise could cause flooding in the city centre. For most of time the barrier gates would be in the open position, allowing largely unimpeded flow of water in the tidal Avon and normal tidal variation.

The proposed barrier location is across the River Avon between the amenity grassland area adjacent to Nibley Road, Shirehampton and the river bank immediately downstream of the Chapel Pill confluence at Ham Green – a so-called ‘Narrow’ barrier location, to distinguish it from the much wider barrier configuration that would be required downstream.

This location was chosen as it sits within a straight reach of the river, a requirement for navigational safety, provides close to the maximum fluvial flood storage capacity while still being considered as “Narrow”, and has sufficient space for the barrier land-side facilities and potential for the required access routes..

A ‘Wide’ barrier, located further downstream, was discounted at the shortlisting stage due to its significantly higher cost and greater potential for negative environmental impact. An alternative ‘Narrow’ location immediately downstream of Cumberland Basin was also discounted at shortlisting stage as numerical modelling suggests it could increase fluvial flood risk in the city centre.

The location is indicative as this stage of Strategy development and, if the preferred option includes a barrier, alternative locations between Cumberland Basin and Nibley Road – Ham Green would need to be investigated to identify the optimum position.

4.5.2 Design Assumptions

The barrier concept has been developed further since the short listing phase of the Strategy to take into consideration information generated at a second barrier workshop held between AECOM, BCC, the Environment Agency and BCC’s barrier advisor, CH2M HILL, and also information obtained from further modelling of the impacts of the barrier on tidal and fluvial flood risk. The issues/changes arising were:

- Rising sector gates similar to those used at the Thames Barrier were confirmed as preferred. This type of gate will sit flush with the bed in normal operation and will revolve to the upright position in advance of a high tide. Consideration was given to horizontal sector gates, lifting gates and sliding gates but all were discounted due to space requirements, navigational difficulties or the shape of the channel.
- The gate arrangement has been modified to reduce the number of gates to 3, 2 at 40m width and 1 at 20m width, varying in height from 10m to 18m.
- The barrier width, from one abutment to the other, is approximately 140m.
- Confirmation of a barrier gate crest level of 10.9m AOD. This allows for a 1 in 1000 year 2115 (0.1%) water level plus a freeboard of 300mm, to take account of uncertainties in modelling, and wave action.
- To accommodate the increase in gate size, pier width has been increased to 10m. Numerical modelling has demonstrated that the increase in pier width does not significantly impede fluvial flows and does not increase upstream flood risk. Additional, more detailed, modelling will need to be carried out to assess the velocity profiles and flowstreams to understand the impact of the barrier on navigation and geomorphology.
- Additional thought has been given to construction as well as operational access requirements. Compound areas are now shown on both banks of the barrier with vehicular access from existing highways. Compounds will need to be permanent to provide parking and welfare facilities as well as a control building. Access to the piers for operators and services will be provided by an underground service tunnel within the barrier foundations.

The increase in pier and gate width has widened the channel in the location of the barrier and the tie in details up and downstream will require further consideration during the future design phases to minimise the geomorphological impacts. An approximate location of the barrier is shown in **Figure 17** later in the report.

The gates will be fitted within a concrete superstructure supported on piles which extend to bedrock. The need for a cut-off to prevent seepage beneath the structure will need investigation in future design phases. No structural calculations have been carried out on any of the elements and sizing has been based on other similar structures. It is envisaged that there will be scope to reduce the volume of concrete in the structure and improve the visual impact during the detailed design phases.

The configuration includes defence tie-ins at each side of the river to ensure flood water does not outflank the barrier.

Navigation requirements have been a key factor in the change to the gate alignment. The existing main low flow channel has a single gate across it with two gates towards the right (north) bank. Bed levels mimic the existing channel levels as much as possible and offer more consistent depths over a wider width than the current channel profile. The need for and type of navigational aids to guide boats will be fully determined at a later stage. Further discussion will be required with the Port Authority and Harbourmaster to ensure that the proposed gate widths and bed levels meet the current requirements and any future aspirations for the type and number of craft using this section of the Avon. The impacts of any velocity changes and gate operation will also need further assessment.

4.5.3 Numerical Modelling

Results of numerical modelling of a barrier option are presented in Hydraulic Modelling Report (Option Phase), August 2016, AECOM.

The modelling results suggest that when the barrier option is closed for a short duration during an extreme tidal event (200 year return period) in conjunction with a moderate fluvial event (2 year return period) in 2115, compared to the Do Minimum, there is a decrease in water levels at all cross sections upstream of the barrier. This indicates that there is a benefit during a predominantly tidal inundation event. In terms of fluvial storage, when the barrier is closed for a similar, relatively short duration, during a 200 year fluvial event combined with a 2 year tide in 2115, the modelling found a reduction in water levels at all cross sections upstream of the barrier, demonstrating storage benefits during a high fluvial event. This also indicates a benefit during a predominantly fluvial event.

A tidal flood barrier has been shown to be effective at reducing flood risk for the City. In the open position the barrier piers have been shown to have an insignificant impact on upstream water levels up to a 20% impedance. Operation of the barrier to the closed position on a high tide has been simulated and been shown not to cause an increase in upstream water levels, providing that an appropriate operating regime is followed.

4.5.4 Costing

Due to the unique nature of the barrier solution estimating the cost is a challenge. Previously barrier costs have been estimated based on the approved PAR cost of the Boston Barrier. However, the proposed tidal barrier is closer in scale to the Thames Barrier and it is considered more appropriate to benchmark against this.

The outcome of the benchmarking provided a range of values from £386m to £926m depending on which values were used, what they were assumed to include (e.g. associated defences, design costs etc.) and how they were pro-rated. Ultimately the following approach has been adopted to arrive at a single value for the barrier cost:

- The cost of the Thames Barrier is reported to be £534m (1984 cost base) not including associated defences. This has been updated to a 2012 cost base using BIS construction indices (2012 being the latest available online).
- The cost has then been pro-rated using the ratio of the respective gate widths to get the construction cost and allowances added for upfront costs (20%) and optimism bias (60%).
- Following this approach the estimate for the total non-discounted (cash) cost for design and construction of the tidal barrier is **£683m**.

Ongoing operation and maintenance costs depend on the frequency of operation and whether the barrier becomes a device to mitigate fluvial flood risk as well as tidal (as has happened with the Thames Barrier). To derive an operation cost estimate it has been assumed that operation includes a monthly full lift to ensure all systems are working correctly. Only two lifts per annum have been assumed to protect against tidal flooding.

It is likely that regular maintenance dredging will be required to keep the navigation channels clear. The extent and frequency of dredging will be determined as part of the geomorphological assessments at a later stage. Gates and operating mechanisms will also require regular maintenance to ensure that they continue to operate satisfactorily. It is anticipated that every 25 years there is likely to be a need for a major refurbishment, particularly of the mechanical and electrical components.

Based on the above it has been assumed for the purposes of this costing exercise that annual operation and maintenance costs would be **£1m**. Every 25 years it is estimated **£50m** would be required for refurbishment.

In the final assessment of Options, the selection of the recommended Preferred Option has been checked with a number of sensitivity tests to allow for the uncertainty in costing.

The tidal barrier measure does not provide protection against tidal flooding in downstream areas at Pill and Shirehampton. In order to protect these areas from tidal flood risk, raised defences will be required at an additional cost. It is also possible that new raised defences may be required upstream of the barrier location (i.e. in the city centre) to account for fluvial risk if barrier operation provide impossible to provide sufficient storage capacity for a fluvial flood event. Barrier operation has not been investigated at this stage and therefore potential costs for raised defences upstream of the barrier to account for fluvial risk have not been included.

5. STRATEGIC OPTION A (PLP – LOW DEFENCES – HIGH DEFENCES)

5.1 Description

This strategic option involves undertaking Property Level Protection / temporary defences in epoch 1 (2015-2030), constructing low defences in epoch 2 (2030-2065) and then upgrading the defences to high defences by raising and lengthening in epoch 3 (2065-2115).

The term 'low' defences denotes defences which provide a good initial Standard of Protection (1 in 200 year or 0.5%), but have an extent and crest level such that if no further raising or extensions were implemented the SoP would be significantly lower than 1 in 200 year (0.5%) by the end of the 100-year study period.

The term 'high' defences denotes defences which are sufficiently high and of such an extent that they provide at least a 1 in 200 year (0.5%) SoP to 2115.

The sequence of using PLP / temporary defences, low defences and then high defences represents an adaptive approach to managing the flood risk in the study area. An advantage of the adaptive approach is that the proposed heights and lengths of the low and high defences can be adjusted in the future according to the magnitude of sea level rise that is occurring. The potential to adjust the proposals in the future will help to prevent overdesign and wasted investment.

5.1.1 *Epoch 1 (PLP / temporary defences)*

In epoch 1 property level protection / temporary defences will be undertaken on a city wide scale and also in the Pill / Shirehampton area.

The zones suitable for PLP / temporary defences in epoch 1 have been identified in GIS using the 1:75 year flood mapping extent and considering a 600mm water depth threshold. The largest of the zones are located east of Bristol Temple Meads rail station, at St. Phillips and Bath Road. There are also a number of smaller zones located adjacent to the New Cut, opposite Cumberland Basin, adjacent to Cumberland Basin, Ashton Gate and at Pill. **Figure 7** shows the PLP / temporary barrier zones that have been identified.

A total of 245 properties are located within the PLP / temporary barrier zones and it has been assumed that PLP can be used for each of the properties to effectively mitigate the flood risk.

Potential routes for temporary defence alignments have also been investigated and are presented in **Figure 8**. Opportunities for temporary barrier alignments have been identified where a short length of temporary defence could protect a comparatively large number of properties and provide a substantial flood risk benefit. If the temporary defences were to be installed and operated it would ensure that property protection measures to the individual properties that would benefit would not be required.

The feasible temporary barrier alignments that have been identified are located at St. Phillips, running along the edge of Feeder Road and would benefit approximately 43 properties in the PLP / temporary barrier zones. Approximately 283m of temporary defences would be required.

Table 19 below presents the number of properties within the PLP / temporary barrier zones for epoch 1.

Table 19 Properties suitable for PLP / temporary defences within epoch 1

PLP / temporary barrier zone	Number of properties
Feeder Road East (St. Phillips)	35
Feeder Road West (St. Phillips)	11
Bath Road	59
St. Phillips (S. Temple Meads)	62
Temple Meads	5
Cumberland Basin Road	21
Cumberland Basin Bridge	11
Cumberland Road	6
Ashton Gate	7
Smeaton Road	16
Hotwell Road	3
Pill	9
Total	245

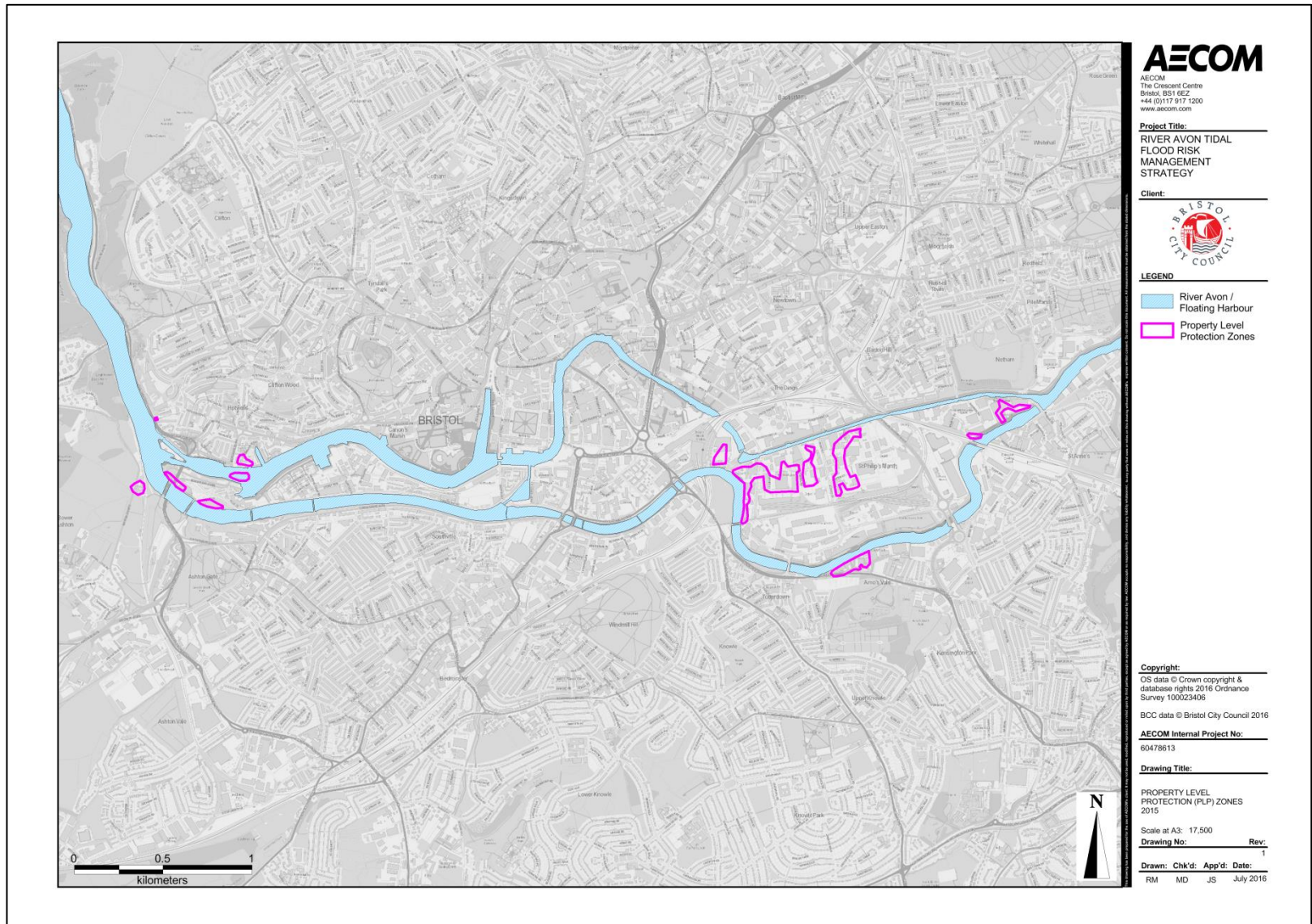


Figure 7 PLP zones 2015

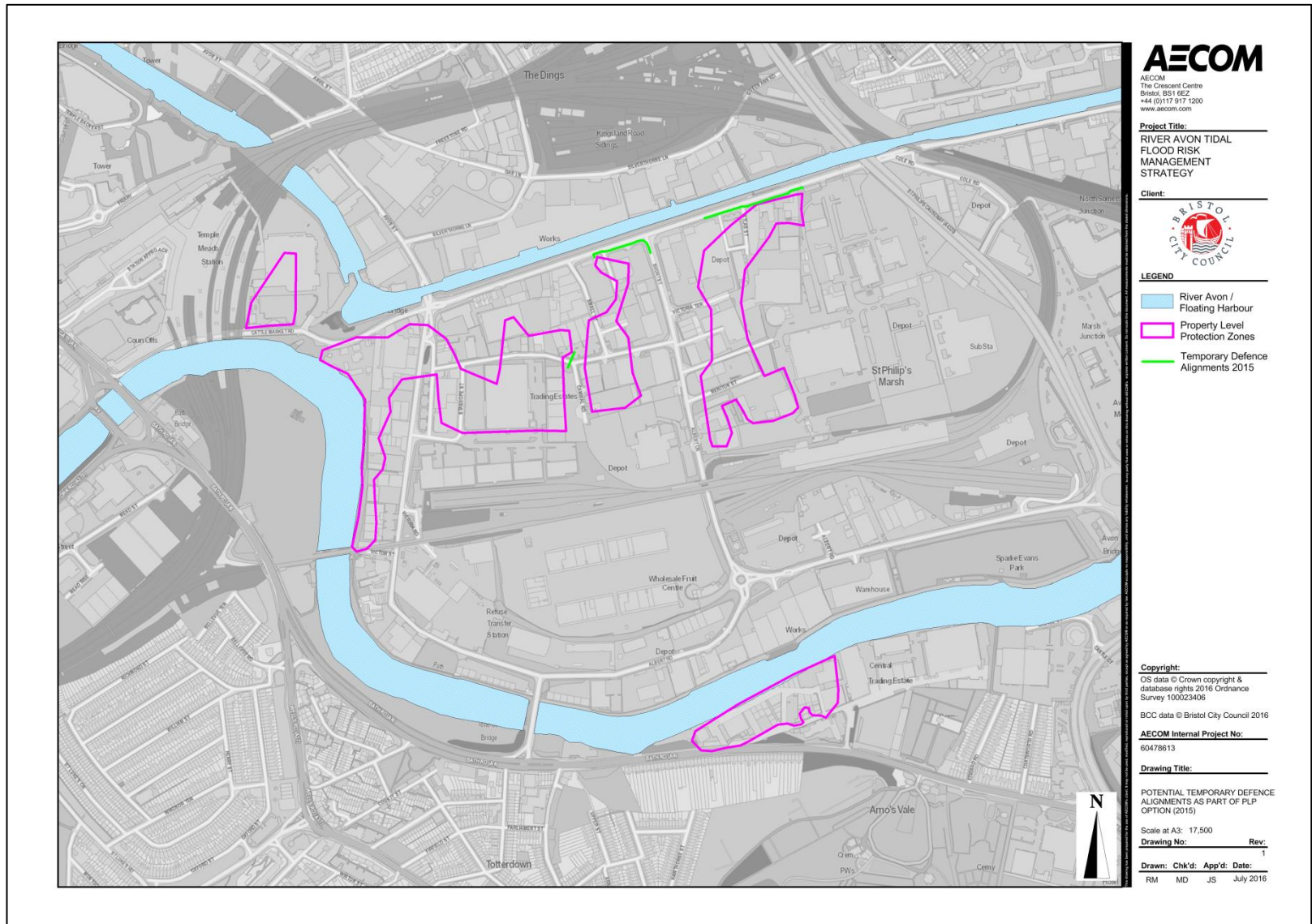


Figure 8 Potential temporary defence alignments

5.1.2 **Epoch 2 (Low Defences)**

In epoch 2 low defences would be constructed on a city wide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2030. Including freeboard this requires a crest level of approximately 9.5m AOD.

Approximately 5.3km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock.

The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment. As part of developing a conservative cost estimate the low defences have been 'future-proofed' in their concept design to enable the raising of the defences in the future (i.e. upgrading to high defences in epoch 3).

For the frontline alignments the indicative defence lengths and heights have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the defences relative to the adjacent pavement / road levels.

The design crest level of the low defence alignments were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. A freeboard allowance of 0.15m has been applied.

Table 20 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the low defences in central Bristol are shown in **Figure 9**, and at Pill and Shirehampton in **Figure 10**. The 1 in 200 year flood extent (2030) with the low defences in place is shown in **Figure 11**. Indicative cross sections of the defences are found in Appendix 2.

Table 20 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 0.44m (Commercial Road) and 1.62m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 0.7 to 1.3m.

Table 20 Low defences 2030; lengths and heights of frontline alignments

Location	Design crest level (including 0.15m freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	9.50	1090	7.42	3.31	2.10	8.44	5.57	1.10
Cumberland Road	9.50	432	8.55	8.46	1.00	8.63	8.37	0.90
Cumberland Road East	9.50	18	8.71	8.44	0.80	8.71	8.44	0.80
Commercial Road	9.50	218	8.73	7.78	0.80	9.07	8.74	0.40
Clarence Road	9.50	515	7.60	5.70	1.90	8.72	8.00	0.80
Cattle Market Road	9.50	42	8.65	7.84	0.90	8.77	7.92	0.80
Totterdown	9.60	1471	8.87	7.38	0.70	8.84	7.21	0.70
Netham	9.60	553	7.45	3.62	2.20	7.99	3.89	1.60
Bath Road	9.60	402	6.91	5.45	2.70	8.35	6.86	1.20
Pill	9.40	294	7.56	6.39	1.90	8.14	6.64	1.30
Shirehampton	9.57*	309	8.09	6.64	1.50	8.54	7.36	1.00

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

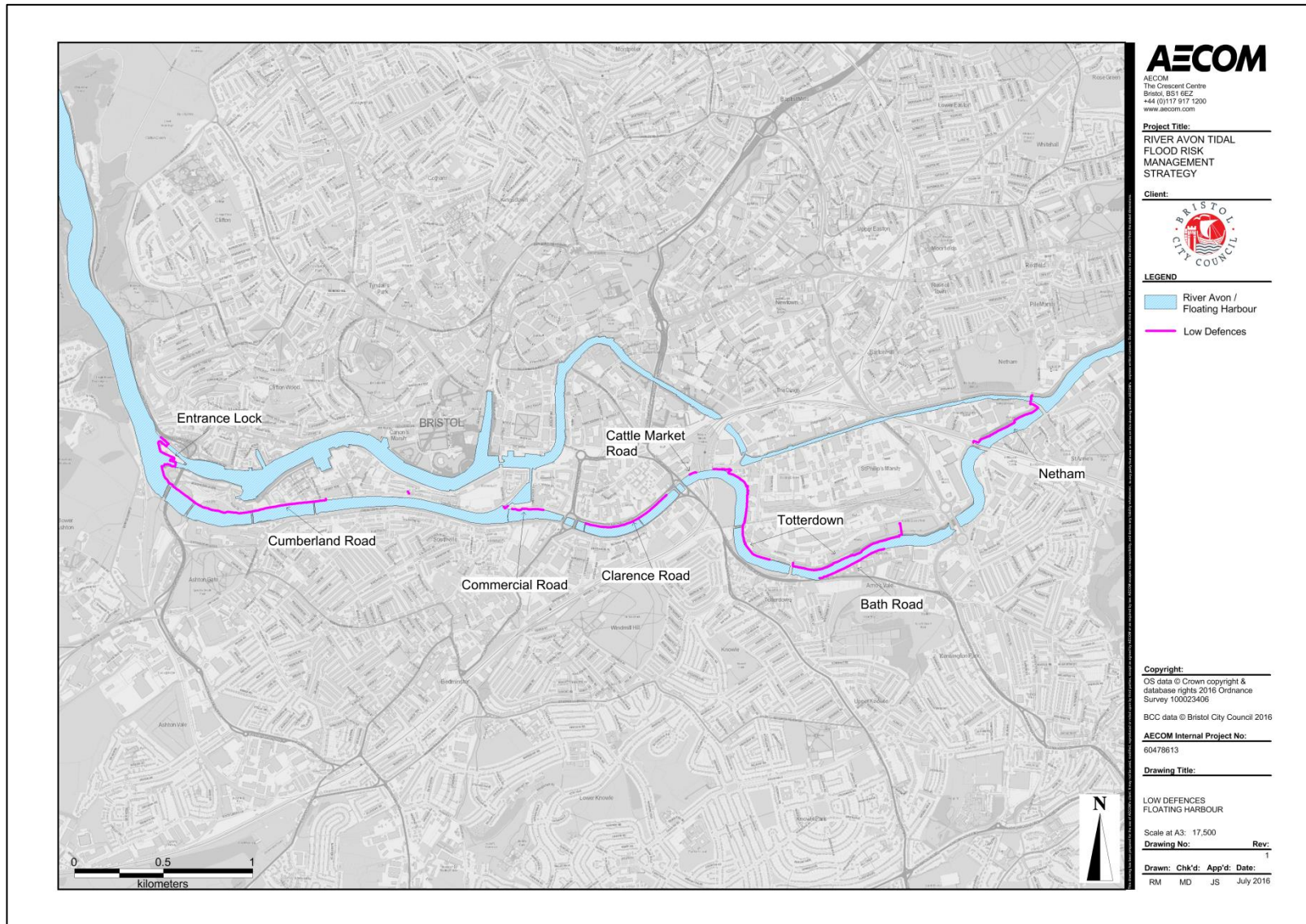


Figure 9 Overview of low defence areas in central Bristol

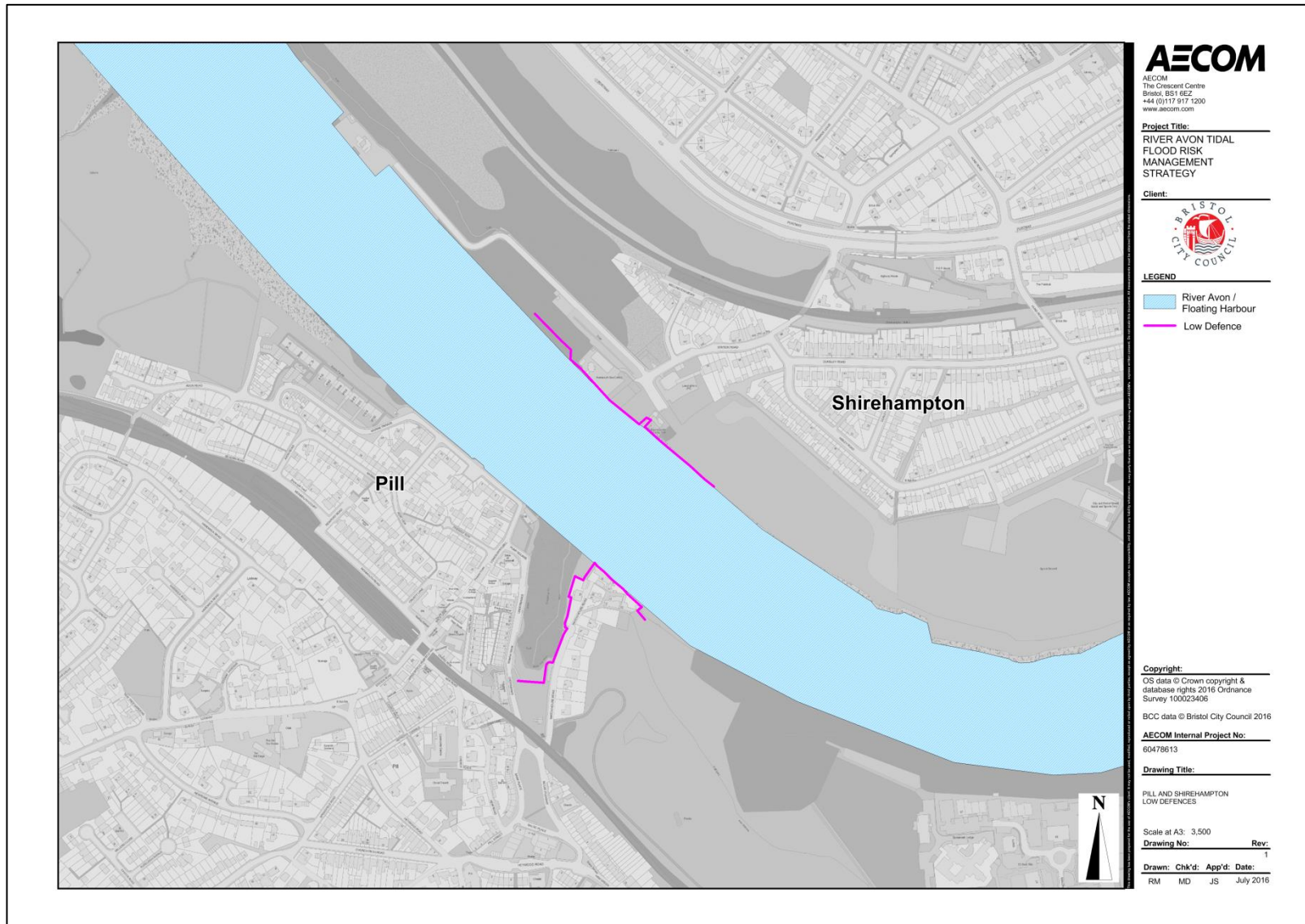


Figure 10 Overview of low defence areas at Pill / Shirehampton

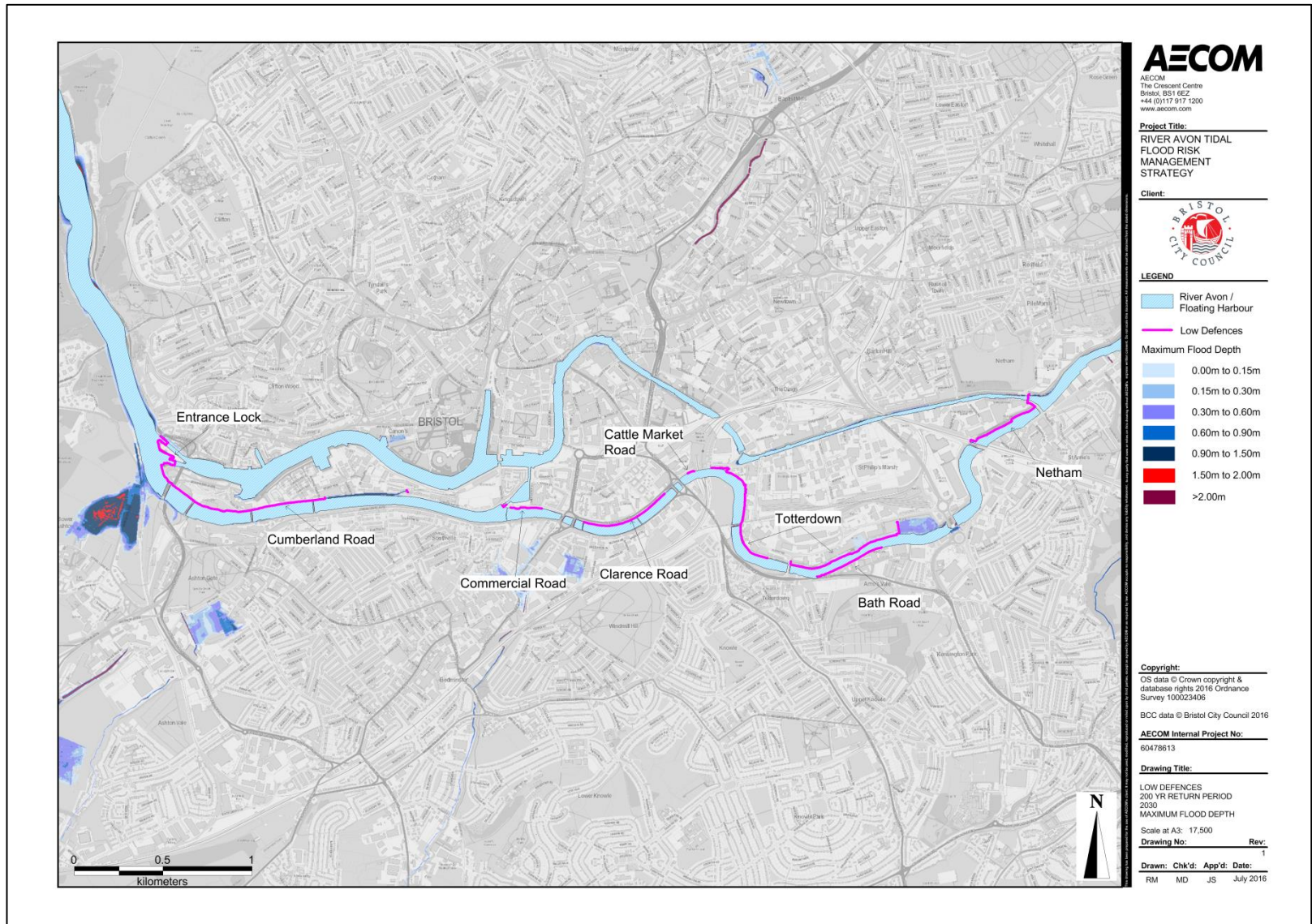


Figure 11 1 in 200 year flood extent (2030) with low defences in place

5.1.3

Epoch 3 (High Defences)

In epoch 3 the defences constructed during epoch 2 would be raised / lengthened to high defences. The upgrade would ensure a 1:200 year standard of protection until 2115. Including freeboard this requires a crest level of approx. 10.15m AOD to 10.25m AOD (9.95m AOD at Pill).

The total length of raised defences across the study area after this upgrade (including the length of low defences constructed in epoch 2) would be approximately 7.2km. Of this, approximately 1.9km will be from new defences and 5.3km would be from raising the defences constructed in epoch 2. The low defences constructed in epoch 2 will have been 'future proofed' in their design to allow for the raising.

As part of the upgrade to high defences new lengths of defence will be required at Cumberland Road (188m), Commercial Road (43m), Clarence Road (60m), Cattle Market Road (16m), Totterdown (118m), Bath Road (62m), Pill (889m) and Shirehampton (477m). Crest raising of the existing low defences at these locations will also be required. No new lengths of defence will be required at Entrance Lock, Cumberland Road East or at Netham. In these locations only crest raising of the existing low defences is necessary.

For the purpose of the preferred option costing, it has been assumed that the new lengths of defences required for the high defences will follow a frontline alignment. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case scenario). Further information and analysis will be required to select the preferred route alignments at feasibility stage. This assumption has been made for costing purposes but it is anticipated that at feasibility stage alignments and designs will be reviewed and modified, generating cost savings the preferred route alignments at each location have yet to be chosen.

For the new lengths of frontline alignment required as part of the high defences measure the indicative lengths and heights have been established. Land levels along the alignment have been extracted in GIS using LIDAR data and topographic data if available. Topographic data was available and considered for the new defences at the following locations; Commercial Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the new lengths of defences relative to the adjacent pavement / road levels.

The design crest levels for the high defences (raised sections and new lengths) were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. The high defences are designed to a 2115 1:200 standard and therefore to avoid an overly precautionary design the freeboard allowance that has been applied is less than that applied to the low defence measure (0.15m). This is considered acceptable given that the low defences were designed to present day conditions (constructed in 2030, and designed to a 2030 standard) whereas the high defences for epoch 3 consider future conditions (2115 standard but constructed in 2065).

Table 21 presents the length, design crest level, land/bank levels and indicative heights of the new lengths of defences required for the high defences measure. **Table 22** presents the lengths and design crest levels for the raising of the low defences which would have been constructed in epoch 2 for this strategic option. The locations of the high defences within central Bristol are shown in **Figure 12**. The locations at Pill and Shirehampton are shown in **Figure 13**. The 2115 1 in 200 year flood extent with the high defences in place is shown in **Figure 14**. Indicative cross sections of the defences are found in Appendix 2.

Table 21 High defences 2065; heights and lengths of the new sections of defences (to be constructed in addition to the raising of the existing low defences which would have been constructed in epoch 2 as part of this strategic option).

Location	Design crest level (including freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	No new length required. Raising of low defences only							
Cumberland Road	10.15	188	8.55	8.50	1.60	8.63	8.42	1.52
Cumberland Road East	No new length required. Raising of low defences only							
Commercial Road	10.15	43	6.39	4.45	3.76	8.69	7.72	1.46
Clarence Road	10.15	60	8.08	6.33	2.07	9.81	9.20	0.34
Cattle Market Road	10.20	16	9.83	9.56	0.37	9.86	9.61	0.34
Totterdown	10.20	118	9.64	9.61	0.56	9.61	9.54	0.59
Netham	No new length required. Raising of low defences only							
Bath Road	10.20	62	8.90	7.36	1.30	9.65	9.25	0.55
Pill	9.95	889	8.53	5.04	1.42	8.73	6.38	1.22
Shirehampton	10.25*	477	7.70	7.15	2.55	8.83	7.44	1.42

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

Table 22 High defences 2065; lengths and heights of crest raising required to raise the low defences (constructed in epoch 2 as part of this strategic option) to high defences

Location	Crest level of existing low defence alignment (including freeboard) (m ODN)	Length of existing low defence alignment that requires raising (m)	Design crest level of high defence alignment (including freeboard) (m ODN)	Height of crest raising required to achieve high defence design level (including freeboard) (m)
Entrance Lock	9.50	1090	10.15	0.65
Cumberland Road	9.50	432	10.15	0.65
Cumberland Road East	9.50	18	10.15	0.65
Commercial Road	9.51	218	10.15	0.64
Clarence Road	9.51	515	10.15	0.64
Cattle Market Road	9.54	42	10.20	0.66
Totterdown	9.56	1471	10.20	0.64
Netham	9.61	553	10.25	0.64
Bath Road	9.56	402	10.20	0.64
Pill	9.42	294	9.95	0.53
Shirehampton	9.57*	309	10.25	0.68

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

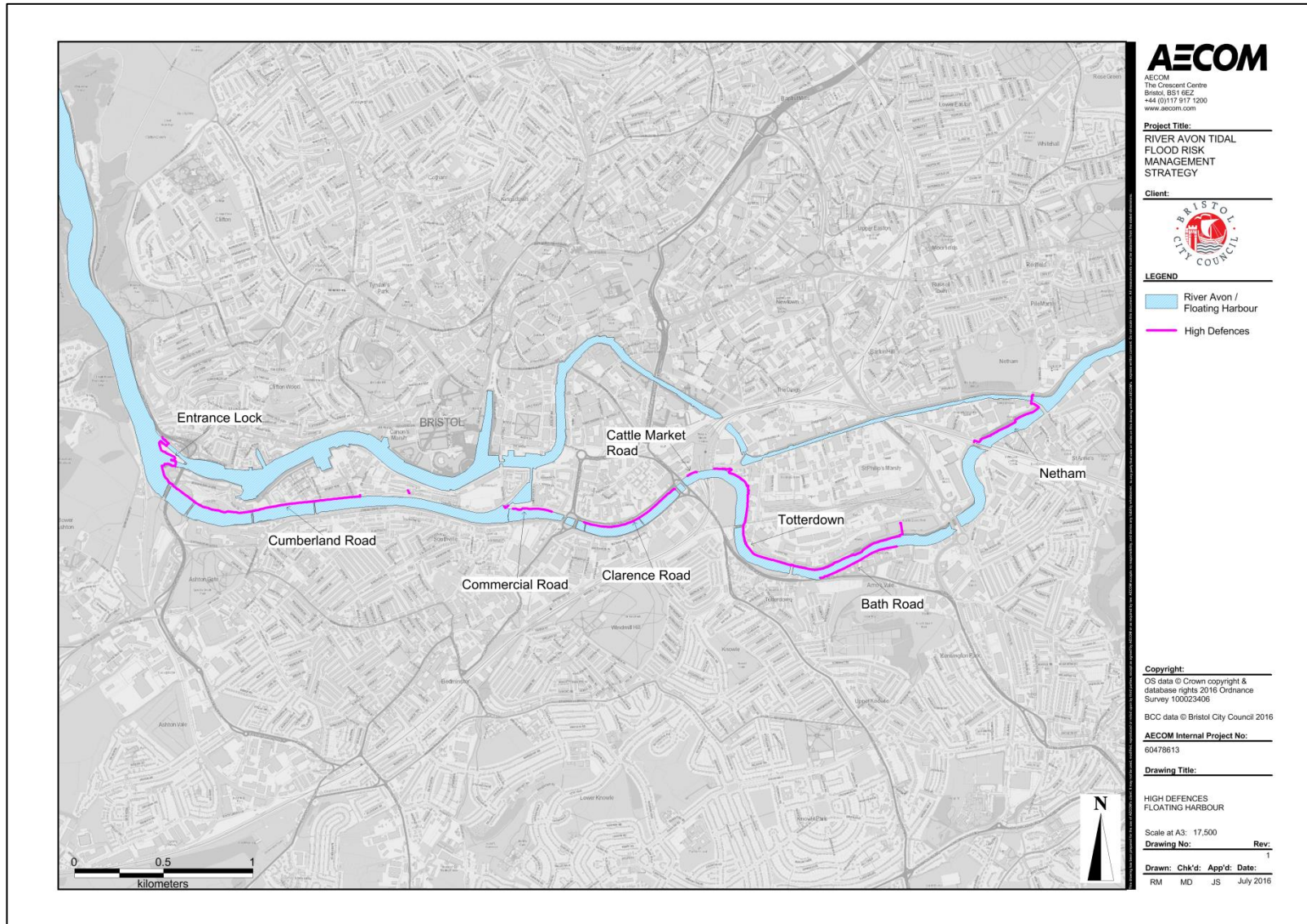


Figure 12 Overview of high defence areas in central Bristol

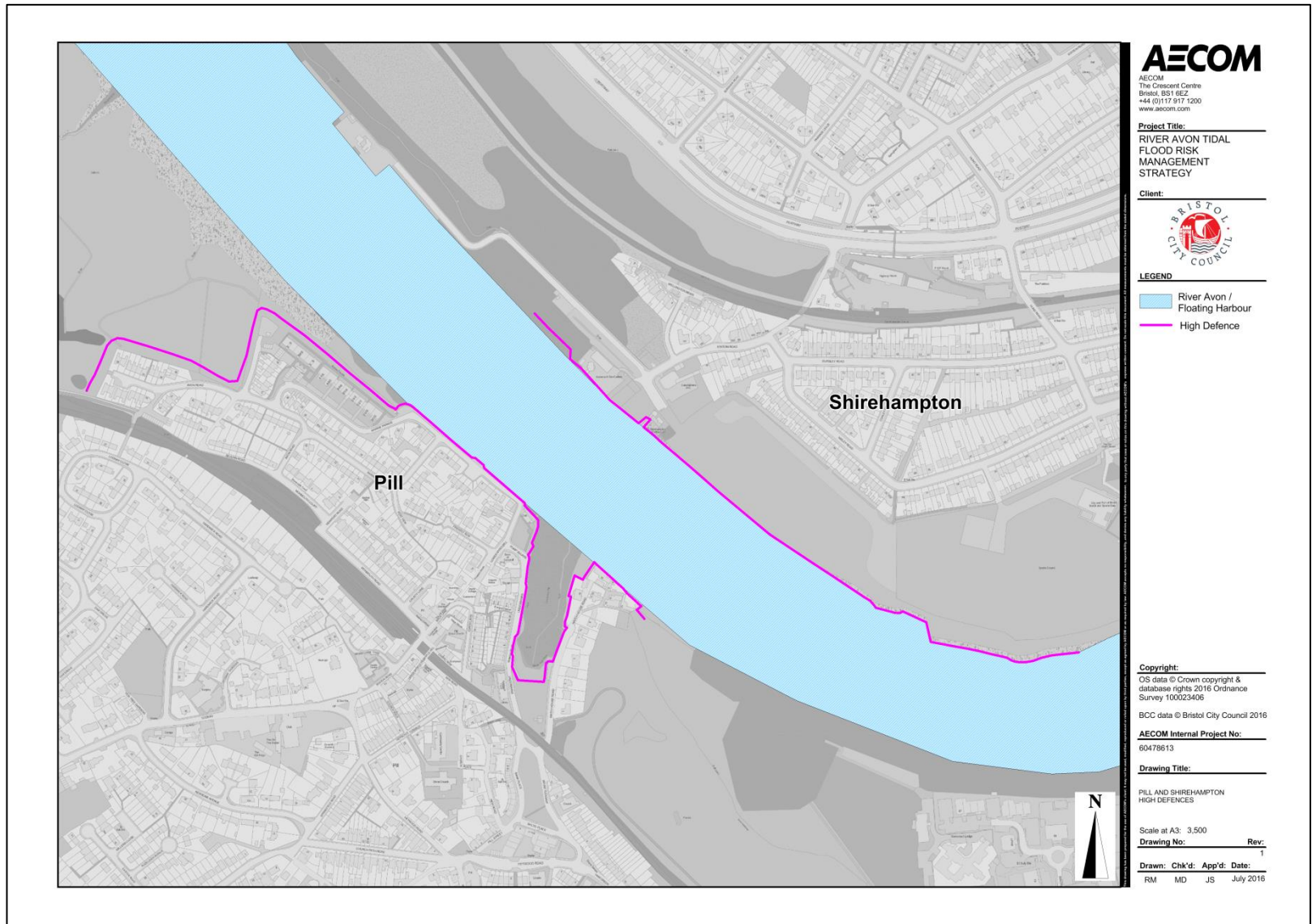


Figure 13 Overview of high defence areas at Pill and Shirehampton

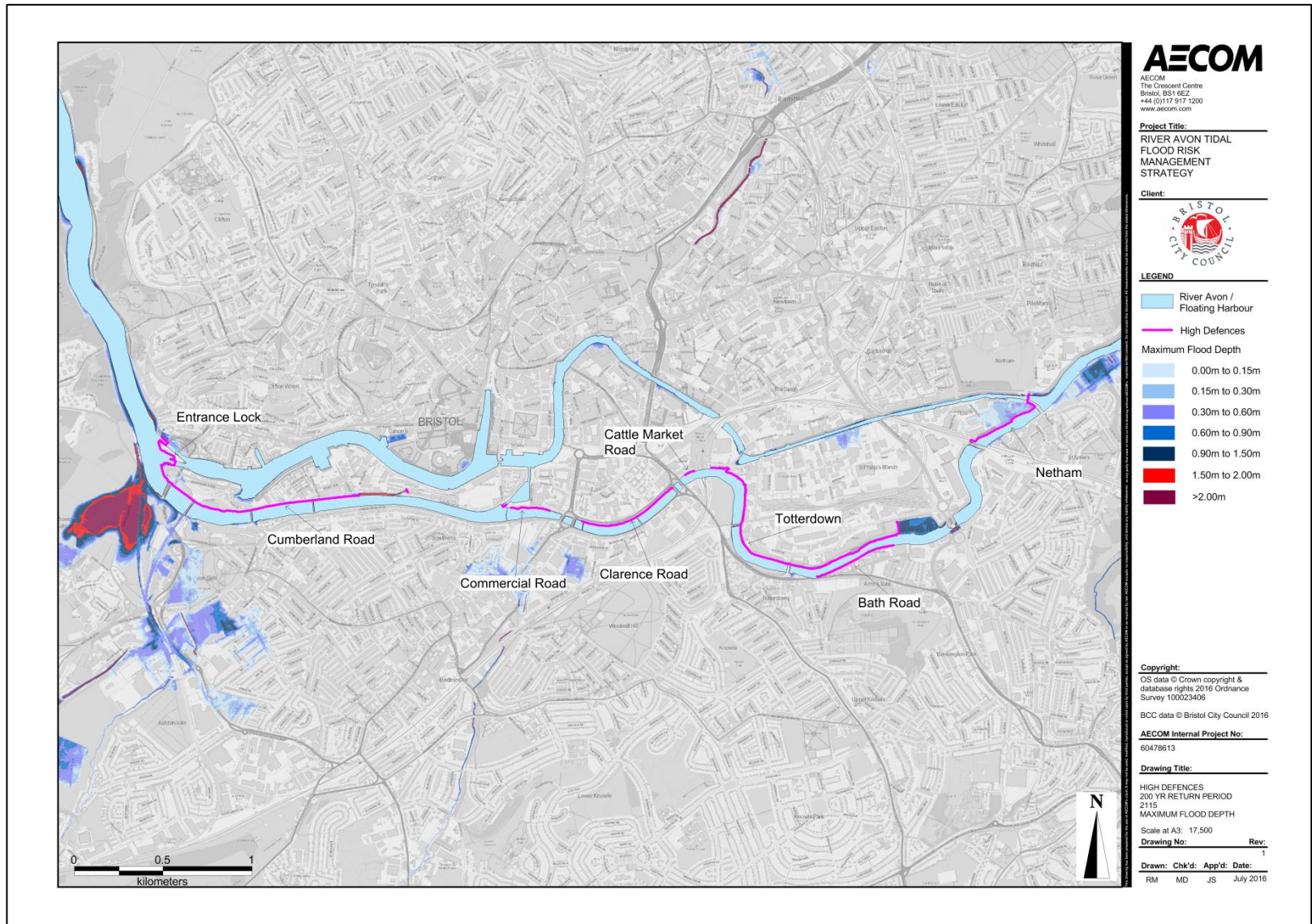


Figure 14 1 in 200 year flood extent (2115) with high defences in place

5.1.4 **All Epochs (Do Minimum and Maintenance)**

Alongside the primary measures outlined for this strategic option (PLP, low and high defences) it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115).

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the implementation of PLP and the construction of raised defence measures. The raised defence measure includes the installation of new stop gates at Entrance lock and Netham Lock. Once these features are installed the do minimum activities from epoch 2 onwards should include the operation and upkeep of the gates in addition to the existing water level control assets in the floating harbour.

Following the installation of PLP measures in epoch 1, to ensure their continued flood defence function it will be necessary for these measures to be maintained throughout the epoch, between 2015 and 2030. Likewise, when the new raised defences are constructed in epoch 2, and subsequently upgraded in epoch 3, it will be necessary to maintain these structures to sustain their flood defence function. Regular condition inspections are recommended alongside the development and implementation of a maintenance strategy.

It will also be necessary to operate any flood gates that may have been included as part of the raised defence alignments. It is recommended that Bristol City Council employ a specialist team or a specially trained team from Docks/Marine services to operate the gates during flood conditions to limit the residual risk of the gates being left open or other failures from occurring.

Further details of the do minimum activities and maintenance of PLP and the low and high defences are found in Appendix 1.

5.2 Economic Costs and Benefits

5.2.1 Non-discounted (cash) costs

High level costs have been developed. Costs for installing property level protection, constructing low defences and upgrading to high defences have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance of these measures and also undertaking the do minimum activities have also been developed.

A summary table outlining the estimated cash costs for this strategic option A is presented in **Table 23** below. In total, the cash cost is approximately £296million. The vast majority of this cost will come in epochs 2 and 3, when the Low and High Defence measures are constructed.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 23 Summary of non-discounted (cash) costs for strategic option A

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Property level protection - installation	2.1	11.3
	Maintenance of property level protection	0.3 (average 0.02 per annum)	
	Do Minimum activities	8.9 (average 0.60 per annum)	
Epoch 2 (2030 – 2065)	Low defences – construction	128.3	161.7
	Maintenance of low defences	29.9 (average 1.194 per annum)	
	Do Minimum activities	3.5 (average 0.100 per annum)	
Epoch 3 (2065 – 2115)	High defences – construction (upgrade from low defences)	50.6	123.2
	Maintenance of high defences	62.9 (average 1.573 per annum)	
	Do Minimum activities	9.7 (average 0.130 per annum 2065-2089, 0.257 per annum 2090+)	
Total			296.2

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 24** to **Table 26** below.

Table 24 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option A

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Property level protection	Installation – 245 properties	2.1	0	2.4	11.3
	Maintenance – 245 properties	0	0.021 (total 0.289 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.098 (total 1.473 over epoch 1)	8.9	
	Maintenance of existing defences	0	0.498 (total 7.474 over epoch 1)		

Table 25 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option A

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Low defences	Entrance Lock – new defence, capital works	24.6	0	158.2	161.7
	Cumberland Road – new defence, capital works	10.1	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	4.6	0		
	Clarence Road –new defence, capital works	11.7	0		
	Cattle Market Road – new defence, capital works	1.0	0		
	Totterdown – new defence, capital works	34.8	0		
	Netham – new defence, capital works	12.5	0		
	Bath Road – new defence, capital works	8.9	0		
	Pill – new defence, capital works	6.7	0		
	Shirehampton – new defence, capital works	0.4	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.2 (total 29.9 over epoch 2)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 26 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option A

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Entrance Lock – defence raising, capital works	3.5	0	113.5	123.2
	Cumberland Road – new defence length, capital works	4.5	0		
	Cumberland Road – defence raising, capital works	1.4	0		
	Cumberland Road East – defence raising, capital works	0.1	0		
	Commercial Road – new defence length, capital works	1.0	0		
	Commercial Road – defence raising, capital works	0.7	0		
	Clarence Road – new defence length, capital works	1.4	0		
	Clarence Road – defence raising, capital works	1.7	0		
	Cattle Market Road – new defence length, capital works	0.4	0		
	Cattle Market Road – defence raising, capital works	0.1	0		
	Totterdown – new defence length, capital works	2.9	0		
	Totterdown – defence raising, capital works	4.7	0		
	Netham – defence raising, capital works	1.8	0		
	Bath Road – new defence length, capital works	1.5	0		
	Bath Road – defence raising, capital works	1.3	0		
	Pill – new defence length, capital works	21.4	0		
	Pill – defence raising, capital works	0.9	0		
	Shirehampton – new defence length, capital works	0.9	0		
	Shirehampton – defence raising, capital works	0.3	0		

	Maintenance – all locations	0	1.5 (total 62.9 over epoch 2)		
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

5.2.2

Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option A to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option A has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. PLP, low and high defences) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented. As such, for costing purposes, it has been assumed that PLP will be implemented in year 2015, low defences in year 2030 and upgrading to high defences in year 2065. For maintenance and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 27** below. As shown, the total present value cost is estimated to be approximately £113million. Of this, the majority of the investment (in present value terms) is required in epoch 2, with the construction of the Low Defences. In epoch 3, despite there being a large cash investment required to upgrade the defences to High defences and to maintain these structures, the larger discount rate applied in epoch 3 ensures that the present value cost of doing so is comparably much smaller than in epoch 2.

Table 27 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option A

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	2.1	0.3	9.0	11.3	2.1	0.2	7.1	9.4
Epoch 2	128.3	29.9	3.5	161.7	76.6	8.9	1.3	86.7
Epoch 3	50.6	62.9	9.7	123.2	10.0	5.6	0.9	16.5
	Total			296.2	Total			112.7

5.2.3

Economic benefits

Table 28 below presents the minimum standard of protection provided by the strategic option for five year time intervals throughout the appraisal period. For PLP / temporary defences in epoch 1 an SoP of 1:20 year has been assumed, although this is likely to vary on a property by property basis.

Table 28 Minimum standard of protection; strategic option A

Epoch	Time interval	Measure	Standard of protection	Epoch	Time interval	Measure	Standard of protection
1	2015-2019	PLP	1:20 yr	3	2065-2069	High defences	Higher than 1:200 yr
1	2020-2024	PLP	1:20 yr	3	2070-2074	High defences	Higher than 1:200 yr
1	2025-2029	PLP	1:20 yr	3	2075-2079	High defences	Higher than 1:200 yr
2	2030-2034	Low defences	1:200 yr	3	2080-2084	High defences	Higher than 1:200 yr
2	2035-2039	Low defences	1:150 yr	3	2085-2089	High defences	Higher than 1:200 yr
2	2040-2044	Low defences	1:100 yr	3	2090-2094	High defences	Higher than 1:200 yr
2	2045-2049	Low defences	1:100 yr	3	2095-2099	High defences	Higher than 1:200 yr
2	2050-2054	Low defences	1:75 yr	3	2100-2104	High defences	Higher than 1:200 yr
2	2055-2059	Low defences	1:75 yr	3	2105-2109	High defences	Higher than 1:200 yr
2	2060-2064	Low defences	1:50 yr	3	2110-2115	High defences	1:200 yr

Table 29 to **Table 31** below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option A in addition to the Do Minimum scenario.

Table 29 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	16	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	15	54	71	418
2065	42	73	277	1380
2115	76	706	142	2011

Table 30 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	7	48	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	14	149	224	413
2065	97	225	339	831
2115	230	445	790	1190

Table 31 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	29	203	295	831
2065	139	298	616	2211
2115	306	1151	2210	3201

The economic benefit of strategic option A in present value terms is summarised in **Table 32** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,546m benefits in PV terms. The average benefit cost ratio of the option is 14:1.

Table 32 Strategic option A whole life PV benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
6	Epoch 1 – PLP Epoch 2 – Low Defences Epoch 3 – High Defences	1,546.0	112.7	14:1

5.3

Development

Strategic option A provides PLP / temporary defences for epoch 1. This measure provides protection to individual properties at risk and temporary protection during periods of flooding. As a result of this measure there will be no areas benefiting from permanent flood defences during epoch 1 and therefore this measure does not facilitate the development or redevelopment opportunities within the city centre or elsewhere within the study site.

However, from epoch 2 onwards the raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 2 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are aspirations for development and redevelopment of the city centre. Whilst the PLP / temporary defences approach in epoch 1 does not support this, the medium and long term approach from epoch 2 does. As such, in the context of the full appraisal period, this option can be considered as beneficial to development and redevelopment of the city centre.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

5.4 Environmental impacts

5.4.1 *Epoch 1 (PLP)*

This flood defence measure is considered to have a relatively limited environmental impact as the measures are local to the façade of buildings or roads, and erected temporarily; and therefore unlikely to interact with most aspects of the environment.

As these measures are small in scale, the landscape and visual impact is expected to be negligible. Likewise, a negligible impact on traffic and transport would be expected due to the limited and highly dispersed trip generation which the delivery of these defences would necessitate. This measure may take the form of community flood defences which would involve low walls built to protect blocks of flats or close housing groups. This would lead to a diversion of traffic, however the effect is considered to be no different to if the roads were flooded and rendered unusable by flood water.

A minor adverse direct impact is expected on archaeology and heritage as this flood defence measure may temporarily change the appearance of any Listed Buildings which they are used to protect, as described in **Table 33**. The impact is short term (during the period of flood risk) and reversible, however.

A negligible impact is expected on terrestrial and riverine ecology as this flood defence measure is local to the façade of buildings or roads, where ecology is generally absent or of low interest. As these defence measures are local to structures and infrastructure they are also expected to result in a negligible impact to geomorphology and water quality and soil and groundwater.

This measure is unlikely to have a noticeable impact on air quality and noise. There will be some very minor and localised noise and dust generation during initial installation (and possibly the removal), but no more severe than that caused by general building maintenance and the impacts should be adequately managed through appropriate control measures.

This measure is considered to have no overall impact on socio-economics, as although the defences will provide a benefit to the communities through provision of flood protection, local communities are likely to still feel vulnerable and stressed during periods of high flood waters. People may also be discouraged from investing in property or business by the continued high risk flood status, particularly in residential, ground floor dwellings.

Table 33 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 33: Potential Receptors affected by PLP in Epoch 1

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Cultural Heritage	PLP will be installed on the following Grade II Listed Buildings: Watch house, Mulberry House/Cottage, 16-19 Freeland Place, The Pump House, Old Dock Cottages, A Bond Tobacco Warehouse, B Bond Tobacco Warehouse.	PLP installed on the property	Direct	The mechanism for attaching PLP to these buildings will be permanent, however would also be subtle and should not materially change the appearance of these buildings. When erected, this flood defence measure would materially change the appearance of any Listed Buildings which they are used to protect. However this change would be infrequent and temporary, with the flood gates on buildings removed following dissipation of the flood risk.

5.4.2

Epoch 2 (Low Defences)

During the construction of the Low Defences a negligible impact is predicted for air quality and noise, as any noise impacts are likely to be temporary and will be managed through measures contained within a Construction Environmental Management Plan (CEMP). There are also unlikely to be noticeable long-term or detrimental short-term impacts on geomorphology and water quality. There may be temporary and localised entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water.

This flood defence measure is likely to have minor landscape and visual impacts. The majority of the defences will be less than a metre in height and therefore less visually intrusive compared to the High Defence measure.

This measure is expected to have a minor impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as a section of this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology. Negligible impacts are predicated for soil and groundwater as the Low Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences. The Listed Buildings which are likely to be impacted by the defence alignment are identified in **Table 34**. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as Underfall Yard which is a Scheduled Ancient Monument.

The Low Defences measure is likely to have a minor impact on traffic and transport as there will be some additional trips associated with bringing in the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts.

This flood defence measure will reduce the risk of extreme flooding and promote investment in the city centre and therefore a minor positive impact would be expected for socio-economics.

Table 34 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 34: Potential Receptors affected by Low Defences in Epoch 2

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar, SPA, SAC, and SSSI	A section of the low defence alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>The defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is the Lamplighters Public House.</p> <p>Within the city centre the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct and Indirect	There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially where there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.
Landscape and visual	<p>Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

5.4.3 *Epoch 3 (High Defences)*

The implementation of High Defences in Epoch 3 will involve raising the defence crest levels or constructing new floodwalls or similar defences (i.e. embankments).

During construction a negligible impact is predicted for air quality and noise as these impacts are likely to be temporary and can be adequately managed through measures contained within a CEMP. There are also unlikely to be impacts on geomorphology and water quality. There will be temporary entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water and therefore the impact is expected to be negligible.

This measure is expected to have a minor negative impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as a section of this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary and once constructed this measure is unlikely to have a noticeable impact on terrestrial ecology and estuarine/riverine ecology.

There is the potential for significant adverse impacts on archaeological and heritage receptors listed in **Table 35** This is because the High Defences have the potential to cause a significant indirect impact on the setting of heritage assets, especially if there are high value receptors in close proximity to the high defences, such as Underfall Yard which is a Scheduled Ancient Monument. The final design of the defences should be sympathetic to these heritage assets in order to mitigate this impact to some extent.

The High Defences measure is likely to have a minor impact on Traffic and Transport as there will be some additional trips associated with bringing the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts. Negligible impacts are predicated for soil and groundwater as the High Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There is the potential for significant landscape and visual impacts as the high defences will be visually prominent and therefore likely to have a substantial impact on key views and on the Landscape Character of the area.

The level of protection that the High Defences measure will provide is likely to have a significant positive impact on socio-economics as this flood defence measure represents a long term approach to managing the impacts of sea level rise which will encourage individuals and developers to invest in the city in the future.

Table 35 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 35: Potential Receptors affected by High Defences in Epoch 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar, SPA, SAC, and SSSI.	A section of the alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment this is: The Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct/Indirect	<p>There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the high defences.</p> <p>When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.</p>
Landscape and visual	<p>In Reach 2 Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

5.4.4 Summary

In summary, it is expected that significant adverse effects can be avoided or mitigated through sensitive design measures. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

5.5 Risks

5.5.1 Ground conditions

A conservative approach has been taken at this stage, with the assumption that the defences will need to be founded on fully continuous piled walls, designed as if the walls were retaining the full height from river bed level to defence crest.

Therefore acquisition of detailed ground investigation data should result in cost savings. Nonetheless there is a risk that unfavourable ground conditions may exist in some locations which could limit the feasibility of the defences following certain route alignments. Should this Strategic Option be taken forward as the preferred strategic option, ground conditions will need to be investigated in subsequent design stages and the appraisal of potential route alignments.

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of ground information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Following this a targeted campaign of investigations on the preferred alignment will be needed.

5.5.2 Services accommodation

The design of the raised defences scheduled for epochs 2 and 3 will need to consider potential impacts on services and utilities, such as electricity cables, telecommunications cables and water, gas oil and fuel pipelines.

An Optimism Bias of 60% has been added to estimated scheme costs, in part to cover these currently unquantified costs.

Should the Strategic Option be taken forward as the preferred strategic option then depending on the proximity of potential alignments to key services, suitable mitigation will need to be agreed with the bodies responsible for managing the services / utilities. If mitigation is not possible, services and utilities could limit the feasibility of the defences following certain route alignments.

Typically, water companies will ask for a 6m easement to be observed (3m either side of the centreline of the sewer). Other expectations generally include:

- No damage would occur during construction
- No increase in structural loads on the assets
- Access would be maintained for future maintenance, including replacement if necessary
- Easements are maintained
- Diversions or protection works may be required

Mitigation measures with electricity and telecommunication companies will also have to be agreed upon to ensure that the functionality of the of the services is maintained. If defence alignments cannot be modified to account for key services, it is often possible to divert the services (but this is generally the more expensive option).

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of key services / utilities information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Should gaps in the information be found, or further information be required it may be necessary to obtain key services and utilities data comprising key utility company record plans.

A full up-to-date services assessment will be required prior to developing designs.

5.5.3 Transport links issues

Consideration will be needed with regards to the impact of alignments on bridges (and operational infrastructure) and transport links. For example, works adjacent to railway structures will need to comply with strict requirements on ground disturbance. There is a risk of cost increase as a result, again covered by the use of 60% Optimism Bias.

5.5.4 Lack of confidence in long-term

This option comprises PLP / temporary defences in epoch 1 and will provide only a relatively low standard of protection during this period. Stakeholders and the general public may hold aspirations for a

higher standard of protection being provided. Development aspirations for Bristol city are of importance to the Strategy and PLP / temporary defences will not facilitate development or redevelopment during epoch 1 (they will only provide a benefit to existing properties). For these reasons there is potential for concern to be raised regarding this option's short term approach in epoch 1.

However, in the long term this option provides robust flood defences from epoch 2 onwards in the form of low and high defences which will provide upwards of a 1:200 year standard of protection. The epoch 1 PLP / temporary defences measure can therefore be considered as a 'stop-gap' solution until more robust defences are delivered. Within this context, the option as a whole is likely to be accepted by the public and stakeholders. If this option is taken forward as the preferred option it will be essential to communicate this with the public, stakeholders and developers; that PLP / temporary defences are only being proposed for the short term and that more substantial investment in permanent defences is forthcoming from epoch 2 onwards. Effective communication is likely to provide reassurance and potentially increase developer confidence for future investment in the area.

There may be some issues around the robustness of proposals to provide additional works in 2065 that do not currently have secured funding. However, in our experience issues that are so far into the future are not considered significant by either the public or investors.

5.5.5 *Visual and landscape impact of permanent defences*

The low and high defences scheduled for epochs 2 and 3 have the potential to impact the landscape and visual character of the study area. Within Bristol city centre this impact is likely to be of particular significance as the city's landscape and architecture is a highly valued aspect of the city's culture and tourism value. Bristol's architecture includes many examples of medieval, gothic, modern industrial and post-war architecture. The visual appeal and continued access to the waterfront along the floating harbour is also important to businesses and tourism for the city and is considered integral to the city's development.

The average height of low defences in epoch 2 relative to ground levels behind the frontline alignments is typically within the range of 0.7 to 1.3m. For the high defences this increases to between 1.3 to 1.7m. There are some exceptions to these ranges, for example at the alignment at Netham but generally speaking these ranges are representative. The introduction of defences of this height to the waterfront could be seen as compromising the visual character of the city and therefore mitigation may be necessary to reduce the impact and gain public, political and stakeholder support for the option.

5.5.6 *Impact on fluvial flood risk*

The primary role of the low and high defence measures in epochs 2 and 3 is to provide protection against tidal flood risk. However, being located along the New Cut and Floating Harbour, the defences may also have an impact on the fluvial flood risk within the study area. A number of model simulations have been undertaken to simulate the impact of the defences on the fluvial flood risk.

Three key areas within or adjacent to the study site have been identified as having a fluvial flood risk impact due to the proposed new defences. The three locations are Easton (Newfoundland Way), Lower Easton (M32 underpass) and Netham.

For Easton, there is a marginal increase in flood depths (0.01-0.02m) for the 2015 epoch, however, flood depths generally decrease for the later epochs.

For Netham, there is a significant increase in flood depths during the 2065 epoch and 2115 epoch when flood walls are introduced. During the 2065 epoch there are areas at Netham (in the location where Brislington Brook discharges into the River Avon) which were not initially at risk of flooding, but that are now simulated to be at risk. During the 2115 epoch the flood depths are simulated to increase in areas of residential / commercial landuse by up to 0.24m.

For areas adjacent to the Floating Harbour, comparison of flood extents have shown that although the new flood defences do not completely remove fluvial flood risk, it is not made any worse. If anything, there is a reduction in both flood extents and depths.

Whilst it is possible that any existing tide lock impacts may increase over time as a consequence of sea level rise, the Strategy has not addressed whether the introduction of walls will alter existing tide lock effects. The Strategy will consider, where relevant, detriment from a fluvial perspective.

For more information on the potential impact on fluvial flood risk, refer to the Options Modelling Report.

5.5.7 *Operation and disruption – temporary and demountable defences*

The PLP / temporary defences that are scheduled for epoch 1 of this option are likely to include temporary defence measures which will need deployment during periods of high tidal water levels. Depending on the preferred route alignments of temporary defences, during periods of deployment there may be disruption to receptors such as infrastructure, transport links and other services. However, given that flooding to the receptors protected by the temporary defences would otherwise occur if the defences were not deployed, the impact of disruption is not considered to be significant.

In epochs 2 and 3 low and high defence measures are scheduled for this strategic option. The preferred route alignments for these measures have yet to be determined, but it is possible that the preferred alignments may pass over transport, service and infrastructure links, such as main roads, rail links and public walkways. During the design of the defences, it is recommended that passive sections of defence are provided in these areas, such as road raising. However, should this be unfeasible it is likely that demountable flood gates in these areas may be needed. Demountable defences, such as flood gates, require operation (often manual) during times of flooding and the closure of roads and rail links will be required during periods of deployment. Operation and deployment has the potential to cause local disruption but, similar to temporary defences with the PLP measure, the impact of the disruption is not considered to be significant given that the receptors would otherwise be flooded (and disrupted anyway) if the demountable defences were not deployed.

The deployment of temporary defences (PLP / temporary defences) and potentially demountable defences (low and high defences) carries with it a risk that the defences will not be deployed or operated successfully. This increases the chance of residual flood damages from occurring as part of this option. To limit this risk it is recommended that a specialist team or a specially trained team from Docks/Marine services is set-up and supported, and should be responsible for the deployment and operation of temporary and demountable defences during periods of flooding.

5.5.8 *Private property and landowner support*

The measures recommended for each epoch as part of this strategic option are likely to require support from private landowners in order to be successfully delivered. For instance, whilst the preferred alignments for low and high defences are yet to be identified, it is possible that the alignments may pass through privately owned land or property. During the planning phase of the defences it will be imperative to achieve 'buy-in' from these landowners and to work alongside the landowners to ensure that the scheme design is in line with the landowners aspirations and future plans for the area, and to build upon opportunities which may arise with regards to funding. Failure to consult and work alongside private landowners could create planning issues and increase the risk of schemes not being delivered.

5.5.9 *Commitment to maintenance*

The raised defence measures constructed in epochs 2 and 3 will require maintenance from the time of construction to sustain the flood defence function. To facilitate this Bristol City Council and partners should develop a long term maintenance strategy, which should include regular and periodic defence condition assessments and repair works. The strategy will allow for maintenance works to be prioritised across the Strategy frontage and to help ensure that funding streams for maintenance are secured in the long term. There is a risk that should maintenance not be undertaken on a regular basis, then defences may fall into disrepair and be more likely to fail during times of flooding, increasing the residual flood risk to the city. A long term commitment to maintenance is essential for this option to be an effective flood risk management approach.

5.5.10 *Commitment to flood forecasting and warning systems*

Property level protection / temporary defences scheduled for epoch 1 and manually operated sections of raised defences (potentially) constructed in epochs 2 and 3 require flood forecasting and warning systems to ensure that the measures are operated successfully. Currently the EA and partners operate flood warning systems in the area and it is essential that this is sustained with the delivery of the strategic option. Should forecasting and warnings stop (i.e. due to funding constraints) then the residual risk of operable defences being left open or not being deployed significantly increases.

The reliability of surge forecasting is variable as the surge magnitude is susceptible to wind direction which can change suddenly with little warning. However, with advances in flood forecasting techniques likely to occur in the future, it is recommended that the forecasting and warning systems are updated over the Strategy period to account for the latest technologies.

5.6 *Wider opportunities*

5.6.1 *Adaptive approach to flood risk management*

This Strategic Option provides an adaptive approach to managing the tidal flood risk over the Strategy appraisal period. This provides opportunities to refine the proposals during a series of design stages over the appraisal period; for the PLP works in epoch 1, before low defence construction in 2030 and again prior to the upgrade to high defences in 2065. Changes to the proposals can be made, taking into account the latest climate change information and design guidance to ensure that the defence are not 'over-designed' or represent wasted investment.

For example, if sea level rise is found to occur at a slower rate than presently projected, the move to defences in 2065 could be deferred for a number of years.

The ability to revisit the proposals at numerous stages during the appraisal period will open up a number of opportunities to get achieve stakeholder and public support of the option designs. Over time it is

possible that political, stakeholder and public aspirations may change and therefore each design period provides an opportunity to reassess the defence requirements (i.e. in terms of landscaping, visual considerations, and access opportunities).

5.6.2 ***Facilitate development and redevelopment opportunities***

The raised defences scheduled for epoch 2 and 3 will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas. This is in line with the political aspirations for the city and is a major advantage of this option.

By providing robust defences, it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

5.6.3 ***Environmental enhancement***

Raised defence schemes in epochs 2 and 3 could provide opportunities to locally enhance the environment, mainly in terms of the visual/landscape aspect of the waterfront.

Landscaping of the new defences could be carried out which could enhance the character and visual appeal of some areas. Enhancement might include improved surfacing for existing routes, better lighting to improve safety, addition of marked cycleway, provision of ramps in place of stepped accesses and provision of seating and viewing areas.

Potential approaches to mitigate impacts of walls on the visual environment would be to include 'softer' structure types as part of the raised defence measures, such as reinforced glass walls which could help to sustain the views and connection to the waterfront, or use of self-raising walls which in normal use are lower than the required crest level. Some examples of these techniques are provided in **Figure 15** and **Figure 16**.



Figure 15 Example of a reinforced glass floodwall (image courtesy of Flood Control International. Available at www.floodcontrolinternational.com)



Figure 16 Example of landscaping that could be used as part of the raised defences measures

5.7

Next steps

Should this Strategic Option be the preferred Strategic Option the following next steps will be required:

- Feasibility study for PLP including threshold and property surveys for individual properties within the PLP / temporary barrier zones, plus operational protocols for the temporary barriers.
- Engagement with stakeholders for the PLP scheme – principally building owners and tenants.
- Feasibility study for Low Defences scheme - including identifying preferred alignments in each location. Identifying preferred alignments should be done following a full review of the available supporting information, such as the ground condition and services data that is available. Full topographic surveys and ground investigation will be required to support the design. Broader outcomes will need to be considered – access, amenity and recreation benefits that can be built in, such as improved cycleways or lighting, access for the disabled.
- Engagement with stakeholders for the Low Defences scheme – BCC city docks (as harbour authority), affected landowners and businesses, residents, community groups, statutory organisations.
- Should approval / funding from the Environment Agency be required it will be necessary to develop Outline Business Case(s) (OBC) and Full Business Case(s) (FBC). This should be done once the project has been included on the Environment Agency's programme of flood and coastal erosion risk management schemes. In order to get approval it will be necessary to use the correct EA template to align with the HM Treasury's Five Case Model.
- Development of design for PLP and temporary defences, followed by procurement and installation. PLP may be undertaken on a design and install basis by a suitably accredited company.
- Development of Low Defences designs, including landscape and amenity elements
- Environmental assessment of Low Defences at scheme level
- Ecological surveys and related issues will need to be addressed
- Planning consent for Low Defences scheme (technically may not be required, but recommended)

- Procurement and construction of Low Defences scheme

6. STRATEGIC OPTION B (PLP – HIGH DEFENCES – HIGH DEFENCES)

6.1 Description

This strategic option involves undertaking property level protection measures in epoch 1 (2015-2030), constructing high defences in epoch 2 (2030-2065) and then maintaining these defences in epoch 3 (2065-2115).

The term 'high' defences denotes defences which are sufficiently high and of such an extent that they provide at least a 1 in 200 year (0.5%) SoP to 2115.

The sequence of using PLP to high defences represents a precautionary approach to managing the flood risk in the study area. High defences will be constructed to a 1:200 year standard of protection for 2115 and will therefore provide a standard of protection in excess of this for epochs 2 and 3 (the standard will gradually fall over time due to sea level rise, expected to drop to a 1:200 year standard by 2115). An advantage of this approach is that a very high standard of protection will be provided to the study area from 2030 onwards and the flood risk benefits will be significant. However the decision to commit to providing a high standard of protection will need to be taken early on in the appraisal period (i.e. within the next 15 years during epoch 1) and there is a risk that the high defences may end up being 'over designed' if sea levels rise at a reduced rate compared to projections. Should this occur, at the end of the appraisal period the option may represent wasted investment compared to more adaptive, flexible options.

6.1.1 Epoch 1 (PLP / temporary defences)

In epoch 1 property level protection / temporary defences will be undertaken on a city wide scale and also in the Pill / Shirehampton area.

The zones suitable for PLP / temporary defences in epoch 1 have been identified in GIS using the 1:75 year flood mapping extent and considering a 600mm water depth threshold. The largest of the zones are located east of Bristol Temple Meads rail station, at St. Phillips and Bath Road. There are also a number of smaller zones located adjacent to the New Cut, opposite Cumberland Basin, adjacent to Cumberland Basin, Ashton Gate and at Pill.

Figure 7 in the previous chapter shows the PLP / temporary barrier zones that have been identified for epoch 1.

A total of 245 properties are located within the PLP / temporary barrier zones and it has been assumed that PLP can be used for each of the properties to effectively mitigate the flood risk.

Potential routes for temporary defence alignments in epoch 1 have also been investigated and are presented in **Figure 8**. Opportunities for temporary barrier alignments have been identified where a short length of temporary defence could protect a comparatively large number of properties and provide a substantial flood risk benefit. If the temporary defences were to be installed and operated it would ensure that property protection measures to the individual properties that would benefit would not be required.

The feasible temporary barrier alignments that have been identified are located at St. Phillips, running along the edge of Feeder Road and would benefit approximately 43 properties in the PLP / temporary barrier zones. Approximately 283m of temporary defences would be required.

Table 36 below presents the number of properties within the PLP / temporary barrier zones for epoch 1.

Table 36 Properties suitable for PLP / temporary defences within epoch 1

PLP / temporary barrier zone	Number of properties
Feeder Road East (St. Phillips)	35
Feeder Road West (St. Phillips)	11
Bath Road	59
St. Phillips (S. Temple Meads)	62
Temple Meads	5
Cumberland Basin Road	21
Cumberland Basin Bridge	11
Cumberland Road	6
Ashton Gate	7
Smeaton Road	16
Hotwell Road	3
Pill	9
Total	245

6.1.2 *Epoch 2 (High Defences)*

In epoch 2 high defences would be constructed on a citywide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2115, with crest levels between 10.15m AOD and 10.25m AOD (9.95m AOD at Pill).

Approximately 7.2km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock.

The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment.

For the frontline alignments the indicative lengths and heights for the high defences have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the high defences relative to the adjacent pavement / road levels.

The design crest levels for the high defences were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. The high defences are designed to a 2115 1:200 (0.5%) standard and therefore to avoid an overly precautionous design the freeboard allowance that has been applied is less than the typical 0.15m (i.e. that applied to the low defence measure within the Strategy). This is considered an acceptable approach given that the high defences are designed for future conditions and are therefore already conservative by design (designed to 2115 1:200 (0.5%) standard but constructed in 2030).

Table 37 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the high defences are shown in **Figure 12** and **Figure 13**.

Table 37 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 1.14*m (Cattle Market Road) and 2.26*m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 1.3 to 1.7m.

Table 37 High defences; lengths and heights of high defences, 2030

Location	Design crest level (including freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	10.15	1090	7.42	3.31	2.73	8.44	5.57	1.71
Cumberland Road	10.15	620	8.55	8.46	1.69	8.63	8.37	1.52
Cumberland Road East	10.15	18	8.71	8.44	1.44	8.71	8.44	1.44
Commercial Road	10.15	261	8.29	4.45	1.86	9.00	7.72	1.15
Clarence Road	10.15	575	7.65	5.70	2.50	8.85	8.00	1.30
Cattle Market Road	10.20	58	8.97	7.84	1.23	9.06	7.92	1.14
Totterdown	10.20	1589	8.92	7.38	1.28	8.89	7.21	1.31
Netham	10.25	553	7.75	3.62	2.50	7.99	3.89	2.26
Bath Road	10.20	464	7.18	5.45	3.02	8.53	6.86	1.67
Pill	9.95	1183	8.29	5.04	1.66	8.58	6.38	1.37
Shirehampton	10.25*	786	7.86	6.64	2.39	8.71	7.36	1.54

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence

6.1.3 **All epochs (Do Minimum and Maintenance)**

Alongside the primary measures outlined for this strategic option (PLP and high defences) it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115). No further capital works are planned in epoch 3 as High Defences provide a 1:200 year standard of protection to the end of the appraisal period.

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the implementation of PLP and the construction of

raised defence measures. The raised defence measure includes the installation of new stop gates at Entrance lock and Netham Lock. Once these features are installed the do minimum activities from epoch 2 onwards should include the operation and upkeep of the gates in addition to the existing water level control assets in the floating harbour.

Following the installation of PLP measures in epoch 1, to ensure their continued flood defence function it will be necessary for these measures to be maintained throughout the epoch, between 2015 and 2030. Likewise, when the new raised defences are constructed in epoch 2, it will be necessary to maintain these structures during epoch 2 and in epoch 3 to sustain their flood defence function. Regular condition inspections are recommended alongside the development and implementation of a maintenance strategy.

It will also be necessary to operate any flood gates that may have been included as part of the raised defence alignments. It is recommended that Bristol City Council employ a specialist team or a specially trained team from Docks/Marine services to operate the gates during flood conditions to limit the residual risk of the gates being left open or other failures from occurring.

Further details of the do minimum activities and maintenance of PLP and the low and high defences are found in Appendix 1.

6.2 Economic Costs and Benefits

6.2.1 Non-discounted (cash) costs

High level costs for strategic option B have been developed. Costs for installing property level protection, and constructing high defences and have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance of these measures and also undertaking the do minimum activities have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option B are presented in **Table 38** below. In total, the cash cost for implementing strategic option A is approximately £308million. The vast majority of this cost will come in epoch 2, when the high defences are constructed.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 38 Summary of non-discounted (cash) costs for strategic option B

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Property level protection - installation	2.1	11.3
	Maintenance of property level protection	0.3 (average 0.02 per annum)	
	Do Minimum activities	9.0 (average 0.60 per annum)	
Epoch 2 (2030 – 2065)	High defences – construction	165.3	208.1
	Maintenance of low defences	39.3 (average 1.573 per annum)	
	Do Minimum activities	3.5 (average 0.100 per annum)	
Epoch 3 (2065 – 2115)	Maintenance of high defences	78.6 (average 1.573 per annum)	88.3
	Do Minimum activities	9.7 (average 0.130 per annum 2065-2089, 0.257 per annum 2090+)	
Total			307.7

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 39** to **Table 41** below.

Table 39 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option B

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Property level protection	Installation – 245 properties	2.1	0	2.4	11.3
	Maintenance – 245 properties	0	0.021 (total 0.289 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.098 (total 1.473 over epoch 1)	8.9	
	Maintenance of existing defences	0	0.498 (total 7.474 over epoch 1)		

Table 40 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option B

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Entrance Lock – new defence, capital works	25.2	0	204.6	208.1
	Cumberland Road – new defence, capital works	14.9	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	5.7	0		
	Clarence Road – new defence, capital works	13.4	0		
	Cattle Market Road – new defence, capital works	1.4	0		
	Totterdown – new defence, capital works	38.4	0		
	Netham – new defence, capital works	12.8	0		
	Bath Road – new defence, capital works	10.6	0		
	Pill – new defence, capital works	28.3	0		
	Shirehampton – new defence, capital works	1.5	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.6 (total 39.3 over epoch 2)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 41 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option B

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Maintenance – all locations	0	1.6 (total 78.7 over epoch 3)	78.7	88.3
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

6.2.2 Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option B to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option B has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. PLP and high defences) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented. As such, for costing purposes, it has been assumed that PLP will be implemented in year 2015 and high defences in year 2030. For maintenance and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 42** below. As shown, the total present value cost for strategic option B is estimated to be approximately £130million. Of this, the majority of the investment (in present value terms) is required in epoch 2, with the construction of the high defences. In epoch 3, despite there being a large cash investment required to maintain these structures, the larger discount rate applied in epoch 3 ensures that the present value cost of doing so is comparably much smaller than the capital costs in epoch 2.

Table 42 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option B

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	2.1	0.3	9.0	11.3	2.1	0.2	7.1	9.4
Epoch 2	165.3	39.3	3.5	208.1	98.7	11.7	1.3	111.6
Epoch 3	0	78.6	9.7	88.3	0	8.4	0.9	9.3
	Total			307.7	Total			130.3

6.2.3

Economic benefits

Table 43 below presents the minimum standard of protection provided by the strategic option for 5 year time intervals throughout the appraisal period. For PLP / temporary defences in epoch 1 an SoP of 1:20 year has been assumed, although this is likely to vary on a property by property basis.

Table 43 Minimum standard of protection; strategic option B

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	PLP	1:20 yr	3	2065-2069	High defences	Higher than 1:200 yr
1	2020-2024	PLP	1:20 yr	3	2070-2074	High defences	Higher than 1:200 yr
1	2025-2029	PLP	1:20 yr	3	2075-2079	High defences	Higher than 1:200 yr
2	2030-2034	High defences	Higher than 1:200 yr	3	2080-2084	High defences	Higher than 1:200 yr
2	2035-2039	High defences	Higher than 1:200 yr	3	2085-2089	High defences	Higher than 1:200 yr
2	2040-2044	High defences	Higher than 1:200 yr	3	2090-2094	High defences	Higher than 1:200 yr
2	2045-2049	High defences	Higher than 1:200 yr	3	2095-2099	High defences	Higher than 1:200 yr
2	2050-2054	High defences	Higher than 1:200 yr	3	2100-2104	High defences	Higher than 1:200 yr
2	2055-2059	High defences	Higher than 1:200 yr	3	2105-2109	High defences	Higher than 1:200 yr
2	2060-2064	High defences	Higher than 1:200 yr	3	2110-2115	High defences	1:200 yr

Table 44 to **Table 46** below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option B in addition to the Do Minimum scenario.

Table 44 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	16	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	15	54	71	418
2065	42	73	277	1380
2115	76	706	1420	2011

Table 45 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	7	48	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	14	149	224	413
2065	94	225	339	831
2115	230	445	790	1190

Table 46 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	29	203	295	831
2065	139	298	616	2211
2115	306	1151	2210	3201

The economic benefit of strategic option B in present value terms is summarised in **Table 47** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,560m benefits in PV terms. The average benefit cost ratio of the option is 11:1.

Table 47 Strategic option B whole life benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
9	Epoch 1 – PLP Epoch 2 – High Defences Epoch 3 – High Defences	1,560	130.3	11:1

6.3

Development

Strategic option B outlines PLP / temporary defences for epoch 1. This measure provides protection to individual properties at risk and temporary protection during periods of flooding. As a result of this measure there will be no areas benefiting from permanent flood defences during epoch 1 and therefore this measure does not facilitate the development or redevelopment opportunities within the city centre or elsewhere within the study site.

However, from epoch 2 onwards the raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 2 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are aspirations for development and redevelopment of the city centre. Whilst the PLP / temporary defences approach in epoch 1 does not support this, the medium and long term approach from epoch 2 does. As such, in the context of the full appraisal period, this option can be considered as beneficial to development and redevelopment of the city centre.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

6.4 Environmental impacts

6.4.1 Epoch 1 (PLP)

This flood defence measure is considered to have a relatively limited environmental impact as the measures are local to the façade of buildings or roads, and erected temporarily; and therefore unlikely to interact with most aspects of the environment.

As these measures are temporary and small in scale, the landscape and visual impact is expected to be negligible. Likewise, a negligible impact on traffic and transport would be expected due to the limited and highly dispersed trip generation which the delivery of these defences would necessitate. This measure may take the form of community flood defences which would involve low walls built to protect blocks of flats or close housing groups. This would lead to a diversion of traffic, however the effect is no different to if the roads were flooded and rendered unusable by flood water.

A minor adverse direct impact is expected on archaeology and heritage as this flood defence measure may temporarily change the appearance of any Listed Buildings which they are used to protect (as described in **Table 48**). The impact is short term (during the period of flood risk) and reversible, however.

A negligible impact is expected on terrestrial and riverine ecology as this flood defence measure is local to the façade of buildings or roads, where ecology is generally absent or of low interest. As these defence measures are local to structures and infrastructure they are also expected to result in a negligible impact to geomorphology and water quality and soil and groundwater.

This measure is unlikely to have a noticeable impact on air quality and noise. There will be some very minor and localised noise and dust generation during initial installation (and possibly the removal), but no more severe than that caused by general building maintenance and the impacts should be adequately managed through appropriate control measures.

Finally, this measure is considered to have no overall impact on socio-economics, as although the defences will provide a benefit to the communities through provision of flood protection, local communities are likely to still feel vulnerable and stressed during periods of prolonged or high flood water levels. People may also be discouraged from investing in property or business by the continued high risk flood status, particularly in residential, ground floor dwellings.

Table 48 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 48: Potential Receptors affected by PLP in Epoch 1

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Cultural Heritage	Grade II Listed Buildings: Watch house, Mulberry House/Cottage, 16-19 Freeland Place, The Pump House, Old Dock Cottages, A Bond Tobacco Warehouse, B Bond Tobacco Warehouse.	PLP installed on the property	Direct	The mechanism for attaching PLP to these buildings will be permanent, however would also be subtle and should not materially change the appearance of these buildings. When erected, this flood defence measure would materially change the appearance of any Listed Buildings which they are used to protect. However this change would be infrequent and temporary, with the flood gates on buildings removed following dissipation of the flood risk.

6.4.2 Epoch 2 and Epoch 3 (High Defences)

During construction a negligible impact is predicted for air quality and noise as these impacts are likely to be temporary and can be adequately managed through measures contained within a CEMP. There are also unlikely to be impacts on geomorphology and water quality. There may be temporary entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water and therefore the impact is expected to be negligible.

This measure is expected to have a minor negative impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as a section of this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary and once constructed this measure is unlikely to have a noticeable impact on terrestrial ecology and estuarine/riverine ecology.

There is the potential for significant adverse impacts on archaeological and heritage receptors (see **Table 49**). This is because the High Defences have the potential to cause a significant indirect impact on the setting of heritage assets, especially if there are high value receptors in close proximity to the high

defences, such as Underfall Yard which is a Scheduled Ancient Monument. The final design of the defences should be sympathetic to these heritage assets in order to mitigate this impact to some extent.

The High Defences measure is likely to have a minor impact on Traffic and Transport as there will be some additional trips associated with bringing the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts. Negligible impacts are predicated for soil and groundwater as the High Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There is the potential for significant landscape and visual impacts as the high defences will be visually prominent and therefore likely to have a substantial impact on key views and on the Landscape Character of the area.

The level of protection that the High Defences measure will provide is likely to have a significant positive impact on socio-economics as this flood defence measure represents a long term, precautionary approach to managing the impacts of sea level rise which will encourage individuals and developers to invest in the city in the future.

Table 49 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 49: Potential Receptors affected by High Defences in Epoch 2 and 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar Site, SPA, SAC, and SSSI	A section of the alignment at Pill borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is the Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct/Indirect	There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.
Landscape and visual	<p>In Reach 2 Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the alignment is located in the LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

6.4.3

Summary

In summary, it is expected that significant adverse effects can be avoided or mitigated through sensitive design measures. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

6.5 Risks

6.5.1 Ground conditions

A conservative approach has been taken at this stage, with the assumption that the defences will need to be founded on fully continuous piled walls, designed as if the walls were retaining the full height from river bed level to defence crest.

Therefore acquisition of detailed ground investigation data should result in cost savings. Nonetheless there is a risk that unfavourable ground conditions may exist in some locations which could limit the feasibility of the defences following certain route alignments. Should this Strategic Option be taken forward as the preferred strategic option, ground conditions will need to be investigated in subsequent design stages and the appraisal of potential route alignments.

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of ground information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Following this a targeted campaign of investigations on the preferred alignment will be needed.

6.5.2 Services accommodation

The design of the raised defences scheduled for epoch 2 will need to consider potential impacts on services and utilities, such as electricity cables, telecommunications cables and water, gas oil and fuel pipelines.

An Optimism Bias of 60% has been added to estimated scheme costs, in part to cover these currently unquantified costs.

Should the Strategic Option be taken forward as the preferred strategic option then depending on the proximity of potential alignments to key services, suitable mitigation will need to be agreed with the bodies responsible for managing the services / utilities. If mitigation is not possible, services and utilities could limit the feasibility of the defences following certain route alignments.

Typically, water companies will ask for a 6m easement to be observed (3m either side of the centreline of the sewer). Other expectations generally include:

- No damage would occur during construction
- No increase in structural loads on the assets
- Access would be maintained for future maintenance, including replacement if necessary
- Easements are maintained
- Diversions or protection works may be required

Mitigation measures with electricity and telecommunication companies will also have to be agreed upon to ensure that the functionality of the services is maintained. If defence alignments cannot be modified to account for key services, it is often possible to divert the services (but this is generally the more expensive option).

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of key services / utilities information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Should gaps in the information be found, or further information be required it may be necessary to obtain key services and utilities data comprising key utility company record plans.

A full up-to-date services assessment will be required prior to developing designs.

6.5.3 Transport links issues

Consideration will be needed with regards to the impact of alignments on bridges (and operational infrastructure) and transport links. For example, works adjacent to railway structures will need to comply with strict requirements on ground disturbance. There is a risk of cost increase as a result, again covered by the use of 60% Optimism Bias.

6.5.4 Lack of confidence in long-term

This option comprises PLP / temporary defences in epoch 1 and will provide only a relatively low standard of protection during this period. Stakeholders and the general public may hold aspirations for a higher standard of protection being provided. Development aspirations for Bristol city are of importance to the Strategy and PLP / temporary defences will not facilitate development or redevelopment during epoch 1 (they will only provide a benefit to existing properties). For these reasons there is potential for concern to be raised regarding this option's short term approach in epoch 1.

However, in the long term this option provides robust flood defences from epoch 2 onwards in the form of high defences which will provide upwards of a 1:200 year standard of protection. The epoch 1 PLP /

temporary defences measure can therefore be considered as a 'stop-gap' solution until more robust defences are delivered. Within this context, the option as a whole is likely to be accepted by the public and stakeholders. If this option is taken forward as the preferred option it will be essential to communicate this with the public, stakeholders and developers; that PLP / temporary defences are only being proposed for the short term and that more substantial investment in permanent defences is forthcoming from epoch 2 onwards. Effective communication is likely to provide reassurance and potentially increase developer confidence for future investment in the area.

There may be some issues around the robustness of proposals to provide additional works in 2065 that do not currently have secured funding. However, in our experience issues that are so far into the future are not considered significant by either the public or investors.

6.5.5 *Visual and landscape impact of permanent defences*

The high defences scheduled for epoch 2 have the potential to impact the landscape and visual character of the study area. Within Bristol city centre this impact is likely to be of particular significance as the city's landscape and architecture is a highly valued aspect of the city's culture and tourism value. Bristol's architecture includes many examples of medieval, gothic, modern industrial and post-war architecture. The visual appeal and continued access to the waterfront along the floating harbour is also important to businesses and tourism for the city and is considered integral to the city's development.

The average height of high defences in epoch 2 relative to ground levels behind the frontline alignments is typically between 1.3 to 1.7m. There are some exceptions to this range, for example at the alignment at Netham but generally speaking the range is representative. The introduction of defences of this height to the waterfront could be seen as compromising the visual character of the city and therefore mitigation may be necessary to reduce the impact and gain public, political and stakeholder support for the option.

6.5.6 *Impact on fluvial flood risk*

The primary role of the high defence measures in epoch 2 is to provide protection against tidal flood risk. However, being located along the New Cut and Floating Harbour, the defences may also have an impact on the fluvial flood risk to the study area. A number of model simulations have been undertaken to simulate the impact of the defences on the fluvial flood risk.

Three key areas within or adjacent to the study site have been identified as having a fluvial flood risk impact due to the proposed new defences. The three locations are Easton (Newfoundland Way), Lower Easton (M32 underpass) and Netham.

For Easton, there is a marginal increase in flood depths (0.01-0.02m) for the 2015 epoch, however, flood depths generally decrease for the later epochs.

For Netham, there is a significant increase in flood depths during the 2065 epoch and 2115 epoch when flood walls are introduced. During the 2065 epoch there are areas at Netham (in the location where Brislington Brook discharges into the River Avon) which were not initially at risk of flooding, but that are now simulated to be at risk. During the 2115 epoch the flood depths are simulated to increase in areas of residential / commercial landuse by up to 0.24m.

For areas adjacent to the Floating Harbour, comparison of flood extents have shown that although the new flood defences do not completely remove fluvial flood risk, it is not made any worse. If anything, there is a reduction in both flood extents and depths.

For more information on the potential impact on fluvial flood risk, refer to the Options Modelling Report.

6.5.7 *Operation and disruption – temporary and demountable defences*

The PLP / temporary defences that are scheduled for epoch 1 of this option are likely to include temporary defence measures which will need deployment during periods of high tidal water levels. Depending on the preferred route alignments of temporary defences, during periods of deployment there may be disruption to receptors such as infrastructure, transport links and other services. However, given that flooding to the receptors protected by the temporary defences would otherwise occur if the defences were not deployed, the impact of disruption is not considered to be significant.

In epoch 2 high defence measures are scheduled for this strategic option. The preferred route alignments for these measures have yet to be determined, but it is possible that the preferred alignments may pass over transport, service and infrastructure links, such as main roads, rail links and public walkways. During the design of the defences, it is recommended that passive sections of defence are provided in these areas, such as road raising. However, should this be unfeasible it is likely that demountable flood gates in these areas may be needed. Demountable defences, such as flood gates, require operation (often manual) during times of flooding and the closure of roads and rail links will be required during periods of deployment. Operation and deployment has the potential to cause local disruption but, similar to temporary defences with the PLP measure, the impact of the disruption is not considered to be significant given that the receptors would otherwise be flooded (and disrupted anyway) if the demountable defences were not deployed.

The deployment of temporary defences (PLP / temporary defences) and potentially demountable defences (low and high defences) carries with it a risk that the defences will not be deployed or operated successfully. This increases the chance of residual flood damages from occurring as part of this option. To limit this risk it is recommended that a specialist team or a specially trained team from Docks/Marine services is set-up and supported, and should be responsible for the deployment and operation of temporary and demountable defences during periods of flooding.

6.5.8 *Private property and landowner support*

The measures recommended for each epoch as part of this strategic option are likely to require support from private landowners in order to be successfully delivered. For instance, whilst the preferred alignments for low and high defences are yet to be identified, it is possible that the alignments may pass through privately owned land or property. During the planning phase of the defences it will be imperative to achieve 'buy-in' from these landowners and to work alongside the landowners to ensure that the scheme design is in line with the landowners aspirations and future plans for the area, and to build upon opportunities which may arise with regards to funding. Failure to consult and work alongside private landowners could create planning issues and increase the risk of schemes not being delivered.

6.5.9 *Commitment to maintenance*

The raised defence measures constructed in epoch 2 will require maintenance from the time of construction to sustain the flood defence function. To facilitate this Bristol City Council and partners should develop a long term maintenance strategy, which should include regular and periodic defence condition assessments and repair works. The strategy will allow for maintenance works to be prioritised across the Strategy frontage and to help ensure that funding streams for maintenance are secured in the long term. There is a risk that should maintenance not be undertaken on a regular basis, then defences may fall into disrepair and be more likely to fail during times of flooding, increasing the residual flood risk to the city. A long term commitment to maintenance is essential for this option to be an effective flood risk management approach.

6.5.10 *Commitment to flood forecasting and warning systems*

Property level protection / temporary defences scheduled for epoch 1 and manually operated sections of raised defences (potentially) constructed in epoch 2 require flood forecasting and warning systems to ensure that the measures are operated successfully. Currently the EA and partners operate flood warning systems in the area and it is essential that this is sustained with the delivery of the strategic option. Should forecasting and warnings stop (i.e. due to funding constraints) then the residual risk of operable defences being left open or not being deployed significantly increases.

The reliability of surge forecasting is variable as the surge magnitude is susceptible to wind direction which can change suddenly with little warning. However, with advances in flood forecasting techniques likely to occur in the future, it is recommended that the forecasting and warning systems are updated over the Strategy period to account for the latest technologies.

6.5.11 *Precautionary approach to flood risk management*

This option represents a precautionary approach to flood risk management whereby high defences are constructed to a 2115 standard from epoch 2 onwards (2030). At the time of construction the design information for the defences (to establish crest level and defence length) will rely on using information from long term climate change projections. Climate change projections over this length of time (i.e. 85 years from 2030 to 2115) are characteristically uncertain and in reality it is possible that sea levels and other sources of flood risk may rise at a different rate to what the projections suggest. If, for example, sea levels were to rise slower than expected, the high defence measures are likely to be considerably 'overdesigned' and may represent a wasted investment.

6.6 *Wider opportunities*

6.6.1 *Facilitate development and redevelopment opportunities*

The raised defences scheduled for epoch 2 will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas. This is in line with the political aspirations for the city and is a major advantage of this option.

By providing robust defences, it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

6.6.2 *Environmental enhancement*

Raised defence schemes in epoch 2 could provide opportunities to locally enhance the environment, mainly in terms of the visual/landscape aspect of the waterfront.

Landscaping of the new defences could be carried out which could enhance the character and visual appeal of some areas. Enhancement might include improved surfacing for existing routes, better lighting to improve safety, addition of marked cycleway, provision of ramps in place of stepped accesses and provision of seating and viewing areas.

Potential approaches to mitigate impacts of walls on the visual environment would be to include 'softer' structure types as part of the raised defence measures, such as reinforced glass walls which could help to sustain the views and connection to the waterfront, or use of self-raising walls which in normal use are lower than the required crest level. Some examples of these techniques are provided in **Figure 15** and **Figure 16**.

6.7 **Next steps**

Should this Strategic Option be the preferred Strategic Option the following next steps will be required:

- Feasibility study for PLP including threshold and property surveys for individual properties within the PLP / temporary barrier zones, plus operational protocols for the temporary barriers.
- Engagement with stakeholders for the PLP scheme – principally building owners and tenants.
- Feasibility study for High Defences scheme - including identifying preferred alignments in each location. Identifying preferred alignments should be done following a full review of the available supporting information, such as the ground condition and services data that is available. Full topographic surveys and ground investigation will be required to support the design. Broader outcomes will need to be considered – access, amenity and recreation benefits that can be built in, such as improved cycleways or lighting, access for the disabled.
- Engagement with stakeholders for the High Defences scheme – BCC city docks (as harbour authority), affected landowners and businesses, residents, community groups, statutory organisations.
- Should approval / funding from the Environment Agency be required it will be necessary to develop Outline Business Case(s) (OBC) and Full Business Case(s) (FBC). This should be done once the project has been included on the Environment Agency's programme of flood and coastal erosion risk management schemes. In order to get approval it will be necessary to use the correct EA template to align with the HM Treasury's Five Case Model.
- Development of design for PLP and temporary defences, followed by procurement and installation. PLP may be undertaken on a design and install basis by a suitably accredited company.
- Development of High Defences designs, including landscape and amenity elements
- Environmental assessment of High Defences at scheme level
- Ecological surveys and related issues will need to be addressed
- Planning consent for High Defences scheme (technically may not be required, but recommended)
- Procurement and construction of High Defences scheme

7. STRATEGIC OPTION C (PLP – TIDAL BARRIER – TIDAL BARRIER)

7.1 Description

This strategic option involves undertaking property level protection measures in epoch 1 (2015-2030), constructing a tidal barrier so that it is in place for epoch 2 (2030-2065) and then maintaining the barrier in epoch 3 (2065-2115).

The tidal barrier would be a 'narrow' barrier located on the river reach at Pill-Shirehampton, as described in Section 5.5.

The sequence of using PLP for epoch and then switching to a tidal barrier represents a precautionary approach to managing the flood risk in the study area. The tidal barrier would be constructed to a very high standard of protection for 2115 (expected to be in excess of a 1:200 to 1:1000 year, 0.5% to 0.1%) and would therefore provide a standard of protection in excess of this for epochs 2 and 3 - the standard would gradually fall over time due to sea level rise, expected to drop to its design standard by 2115. Should the barrier be taken forward as part of the preferred option, additional studies following the Strategy will be required to define the optimal design standard of protection for the scheme.

An advantage of the precautionary approach to flood risk management is that a very high standard of protection will be provided to the study area from 2030 onwards and the flood risk benefits will be significant.

However, the decision to commit to providing the tidal barrier and a high standard of protection will need to be taken shortly if the barrier is to be in place and operational by 2030.

7.1.1 Epoch 1 (PLP / temporary defences)

In epoch 1 property level protection / temporary defences will be undertaken on a city wide scale and also in the Pill / Shirehampton area.

The zones suitable for PLP / temporary defences in epoch 1 have been identified in GIS using the 1:75 year flood mapping extent and considering a 600mm water depth threshold. The largest of the zones are located east of Bristol Temple Meads rail station, at St. Phillips and Bath Road. There are also a number of smaller zones located adjacent to the New Cut, opposite Cumberland Basin, adjacent to Cumberland Basin, Ashton Gate and at Pill. **Figure 7** shows the PLP / temporary barrier zones that have been identified for epoch 1.

A total of 245 properties are located within the PLP / temporary barrier zones and it has been assumed that PLP can be used for each of the properties to effectively mitigate the flood risk.

Potential routes for temporary defence alignments in epoch 1 have also been investigated and are presented in **Figure 8**. Opportunities for temporary barrier alignments have been identified where a short length of temporary defence could protect a comparatively large number of properties and provide a substantial flood risk benefit. If the temporary defences were to be installed and operated it would negate the need for individual property protection measures.

The feasible temporary barrier alignments that have been identified are located at St. Phillips, running along the edge of Feeder Road and would benefit approximately 43 properties in the PLP / temporary barrier zones. Approximately 283m of temporary defences would be required.

Table 50 below presents the number of properties within the PLP / temporary barrier zones for epoch 1.

Table 50 Properties suitable for PLP / temporary defences within epoch 1

PLP / temporary barrier zone	Number of properties
Feeder Road East (St. Phillips)	35
Feeder Road West (St. Phillips)	11
Bath Road	59
St. Phillips (S. Temple Meads)	62
Temple Meads	5
Cumberland Basin Road	21
Cumberland Basin Bridge	11
Cumberland Road	6
Ashton Gate	7
Smeaton Road	16
Hotwell Road	3
Pill	9
Total	245

7.1.2***Epoch 2 (Tidal barrier)***

In epoch 2 a tidal barrier would be constructed downstream of central Bristol. The barrier would provide an effective flood defence against high tide levels in central Bristol.

An outline design for a tidal barrier at Ham Green – Nibley Road has been developed and consists of 3 gates ranging in width from 25m to 40m and in height from 10m to 18m. The design tide level of the barrier in this location is 10.9m AOD. On the south (left) bank the barrier will tie into the cliffs whilst on the north (right) bank the barrier will tie into high ground across the playing field / allotments. The details are presented in section 5.5. The proposed barrier location is shown in **Figure 17**.

The major disadvantage of a barrier located in this position is that the barrier does not provide flood protection to Pill, the Severn Beach railway line further downstream and parts of Shirehampton. Although the barrier is outside of the Severn Estuary environmentally designated sites, it is still close-by so the impacts of the barrier on these designations would need to be taken into account. There is also likely to be significant visual intrusion and amenity impacts in the locality.



Figure 17 Tidal barrier location

7.1.3

All epochs (Do Minimum and Maintenance)

Alongside the primary measures outlined for this strategic option (PLP and tidal barrier) it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115). No further capital works are planned in epoch 3 as the tidal barrier provides a very high standard of protection to the end of the appraisal period.

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the implementation of PLP and the construction of the tidal barrier.

Following the installation of PLP measures in epoch 1, to ensure their continued flood defence function it will be necessary for these measures to be maintained throughout the epoch, between 2015 and 2030. Likewise, the tidal barrier measure includes a requirement to maintain and operate the barrier. The safe operation of the barrier would require a permanent staff working to a detailed operation and maintenance plan with periodic refurbishment.

Further details of the do minimum activities and maintenance of PLP and the low and high defences are found in Appendix 1.

7.2

Economic Costs and Benefits

7.2.1

Non-discounted (cash) costs

High level costs for strategic option C have been developed. Costs for installing property level protection, and constructing the tidal barrier have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance, undertaking the do minimum activities and also operating the tidal barrier have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option C are presented in **Table 51** below. In total, the cash cost for implementing strategic option C is approximately £959million. The vast majority of this cost will come in epoch 2, when the tidal barrier is constructed.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 51 Summary of non-discounted (cash) costs for strategic option C

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Property level protection - installation	2.1	11.3
	Maintenance of property level protection	0.3 (average 0.02 per annum)	
	Do Minimum activities	9.0 (average 0.60 per annum)	
Epoch 2 (2030 – 2065)	Tidal barrier – construction	683.0	788.5
	Tidal barrier maintenance and operation	102.0 (average 3.0 per annum)	
	Do Minimum activities	3.5 (average 0.1 per annum)	
Epoch 3 (2065 – 2115)	Tidal barrier maintenance and operation	150.0 (average 3.0 per annum)	159.7
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			959.5

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 52** to **Table 54** to below.

Table 52 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option C

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Property level protection	Installation – 245 properties	2.1	0	2.4	11.3
	Maintenance – 245 properties	0	0.02 (total 0.3 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 1.4 over epoch 1)	8.9	
	Maintenance of existing defences	0	0.5 (total 7.5 over epoch 1)		

Table 53 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option C

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Tidal barrier	Construction	683.0	0	785.0	788.5
	Operation and maintenance	0	3.0 (total 102.0 over epoch 2)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 54 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option C

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Tidal barrier	Operation and maintenance	0	3.0 (total 150.0 over epoch 3)	150.0	159.7
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

7.2.2 Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option C to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option C has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to implemented.

Within the cost profile the cost of the capital works (i.e. PLP and tidal barrier) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented. As such, for costing purposes, it has been assumed that PLP will be implemented in year 2015 and a tidal barrier in year 2030. For maintenance/operation and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 55** below. As shown, the total present value cost for strategic option C is estimated to be approximately £471million. Of this, the majority of the investment (in present value terms) is required in epoch 2, with the construction of the tidal barrier. In epoch 3, despite there being a large cash investment required to maintain and operate this structure, the larger discount rate applied in epoch 3 ensures that the present value cost of doing so is comparably much smaller than the capital cost of construction in epoch 2.

Table 55 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option C

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	2.1	0.3	9.0	11.3	2.1	0.2	7.1	9.4
Epoch 2	683.0	102.0	3.5	788.5	407.7	35.9	1.3	444.9
Epoch 3	0	150.0	9.7	159.7	0	16.0	0.9	16.9
	Total			959.5	Total			471.1

7.2.3

Economic benefits

Table 56 below presents the minimum standard of protection provided by the strategic option for five year time intervals throughout the appraisal period. For PLP / temporary defences in epoch 1 an SoP of 1:20 year has been assumed, although this is likely to vary on a property by property basis.

Table 56 Minimum standard of protection; strategic option C

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	PLP	1:20 yr	3	2065-2069	Tidal barrier	Higher than 1:1000 yr
1	2020-2024	PLP	1:20 yr	3	2070-2074	Tidal barrier	Higher than 1:1000 yr
1	2025-2029	PLP	1:20 yr	3	2075-2079	Tidal barrier	Higher than 1:1000 yr
2	2030-2034	Tidal barrier	Higher than 1:1000 yr	3	2080-2084	Tidal barrier	Higher than 1:1000 yr
2	2035-2039	Tidal barrier	Higher than 1:1000 yr	3	2085-2089	Tidal barrier	Higher than 1:1000 yr
2	2040-2044	Tidal barrier	Higher than 1:1000 yr	3	2090-2094	Tidal barrier	Higher than 1:1000 yr
2	2045-2049	Tidal barrier	Higher than 1:1000 yr	3	2095-2099	Tidal barrier	Higher than 1:1000 yr
2	2050-2054	Tidal barrier	Higher than 1:1000 yr	3	2100-2104	Tidal barrier	Higher than 1:1000 yr
2	2055-2059	Tidal barrier	Higher than 1:1000 yr	3	2105-2109	Tidal barrier	Higher than 1:1000 yr
2	2060-2064	Tidal barrier	Higher than 1:1000 yr	3	2110-2115	Tidal barrier	1:1000 yr

Table 57 to **Table 59** below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option C in addition to the Do Minimum scenario.

Table 57 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	16	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	46	97	120	520
2065	84	122	281	1417
2115	124	529	1216	2037

Table 58 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	7	48	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	20	163	238	494
2065	111	239	355	943
2115	245	446	798	1325

Table 59 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	9	64	NA (PLP standard undefined)	NA (PLP standard undefined)
2030	66	260	358	1014
2065	195	361	636	2360
2115	369	975	2014	3362

The economic benefit of strategic option C in present value terms is summarised in **Table 60** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,572m benefits in PV terms. The average benefit cost ratio of the option is 3:1.

Table 60 Strategic option C whole life benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
10	Epoch 1 – PLP Epoch 2 – Tidal Barrier Epoch 3 – Tidal Barrier	1,571.5	471.1	3:1

7.3

Development

Strategic option C outlines PLP / temporary defences for epoch 1. This measure provides protection to individual properties at risk and temporary protection during periods of flooding. As a result of this measure there will be no areas benefiting from permanent flood defences during epoch 1 and therefore this measure does not facilitate the development or redevelopment opportunities within the city centre or elsewhere within the study site.

From epoch 2 onwards strategic option C schedules the construction and operation of a tidal barrier. The barrier would provide a high standard of protection from flooding to the entire city centre area and with multiple levels of redundancy put in place for barrier operation, as is the case with the Thames Barrier, it would be reasonable for the tidal flood zone upstream of the barrier to be effectively reclassified as suitable for all types of development, albeit with appropriate measures for dealing with residual risk. This would allow a much freer approach to development in the flood zone.

Given that the tidal barrier will facilitate development, opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the barrier. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are political aspirations for development and redevelopment of the city centre. Whilst the PLP / temporary defences approach in epoch 1 does not support this, the medium and long term approach from epoch 2 does. As such, in the context of the full appraisal period, this option can be considered as beneficial to development and redevelopment of the city centre.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

7.4 Environmental impacts

7.4.1 Epoch 1 (PLP)

PLP is considered to have a relatively limited environmental impact as the measures are local to the façade of buildings or roads, and erected temporarily; and therefore unlikely to interact with most aspects of the environment.

As these measures are temporary and small in scale, the landscape and visual impact is expected to be negligible. Likewise, a negligible impact on traffic and transport would be expected due to the limited and highly dispersed trip generation which the delivery of these defences would necessitate. This measure may take the form of community flood defences which would involve low walls built to protect blocks of flats or close housing groups. This would lead to a diversion of traffic, however the effect is considered to be no different to if the roads were flooded and rendered unusable by flood water.

A minor adverse direct impact is expected on archaeology and heritage as this flood defence measure may temporarily change the appearance of any Listed Buildings which they are used to protect (see **Table 61**). The impact is short term (during the period of flood risk) and reversible, however.

A negligible impact is expected on terrestrial and riverine ecology as this flood defence measure is local to the façade of buildings or roads, where ecology is generally absent or of low interest. As these defence measures are local to structures and infrastructure they are also expected to result in a negligible impact to geomorphology and water quality and soil and groundwater.

This measure is unlikely to have a noticeable impact on air quality and noise. There will be some very minor and localised noise and dust generation during initial installation (and possibly the removal), but no more severe than that caused by general building maintenance and the impacts should be adequately managed through appropriate control measures.

Finally, this measure is considered to have no overall impact on socio-economics, as although the defences will provide a benefit to the communities through provision of flood protection, local communities are likely to still feel vulnerable and stressed during periods of prolonged or high flood water levels. People may also be discouraged from investing in property or business by the continued high risk flood status, particularly in residential, ground floor dwellings.

Table 61 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 61: Potential Receptors affected by PLP in Epoch 1

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Cultural Heritage	Grade II Listed Buildings: Watch house, Mulberry House/Cottage, 16-19 Freeland Place, The Pump House, Old Dock Cottages, A Bond Tobacco Warehouse, B Bond Tobacco Warehouse.	PLP installed on the property	Direct	The mechanism for attaching PLP to these buildings will be permanent, however would also be subtle and should not materially change the appearance of these buildings. When erected, this flood defence measure would materially change the appearance of any Listed Buildings which they are used to protect. However this change would be infrequent and temporary, with the flood gates on buildings removed following dissipation of the flood risk.

7.4.2 Epoch 2 and Epoch 3 (Tidal Barrier)

The Tidal Barrier measure will be visually prominent and is likely to have a substantial negative impact on local key viewpoints and the Landscape Character of the area, although it will be fairly localised.

The Tidal Barrier measure has the potential to result in significant impacts on terrestrial ecology and estuarine/riverine ecology, particularly during the construction phase; however these impacts will be temporary and be managed through measures contained within a CEMP. Once the barrier is constructed this flood defence measure may have a negative impact on transient species i.e. fish as when the barrier is closed these species will be prevented from moving up and down the river. There is also the potential for some habitat loss which may affect sensitive habitats such as the Severn Estuary SPA, SAC, Ramsar and SSSI sites even though the barrier sits outside of these areas.

There are five Grade II Listed Buildings within 500 m of the Tidal Barrier location (Powder Houses and Jetty, Myrtle Hall and Attached Wall, Eighteenth Century Watergate and Ham Green Hospital Buildings). Even though there are no Listed Buildings which will be directly impacted by this measure there is the potential for a negative impact on the setting of these heritage receptors.

Minor impacts are expected on geomorphology and water quality as the Tidal barrier could alter the water flow and introduce sediment during riverbed disturbance in the construction phase. Minor impacts would also be likely for Traffic and Transport as there will be some additional trips associated with bringing in the defences to site, but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately avoid any significant impacts.

Negligible impacts are predicted for air quality and noise as these impacts are only likely during the construction phase but they will be temporary in nature and will be managed adequately through measures contained within a CEMP. Once constructed, this measure is unlikely to have any impact on air quality and noise. Negligible impacts are predicated for soil and groundwater as the barrier measures may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

In terms of flood risk the Tidal Barrier will reduce flood risk to a Standard of Protection until 2115. This reassurance is likely to have a significant positive impact on socio-economics as individuals and developers are not discouraged from investing in the city centre because of flood risk.

Table 62 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 62: Potential Receptors affected by Tidal Barrier in Epoch 2 and 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	<p>The northern extent of the Tidal Barrier is likely to be situated in Nibley Road Open Space and just to the south of Myrtle Hall Allotments which are both wildlife corridors.</p> <p>The southern extent of the barrier is not located in an area of biodiversity value. Although there are several strips of woodland nearby (approx. 150 m away).</p> <p>There are a number of designated sites in close proximity to the tidal barrier. The Severn Estuary SPA and SAC is located approximately 1.5 km west of the tidal barrier. Ham Green SSSI is located approximately 500 m south east of the barrier location. Horseshoe Bend SSSI is located approximately 500 m north east of the barrier. Avon Gorge SSSI and Avon Gorge and Woodlands SAC are located approximately 1.5 km east of the barrier. There are also a number of European protected species recorded within this Reach.</p>	<p>Within the affected area for wildlife corridors</p> <p>Within 1.5 km for designated habitat sites and European protected species records.</p>	Direct/Indirect	<p>There may be temporary impacts on associated with construction activity, either directly or indirectly. Transient river species would also be adversely affected during this phase.</p> <p>Once operational there may be a temporary impact on transient species such as fish, eels and birds as these species will be prevented from moving up and down the river when the barrier is closed. This is expected to be an infrequent occurrence however.</p>
Cultural Heritage	<p>There are three Grade II listed buildings within 500 m of the northern extent of the Tidal Barrier. These are: Powder Houses and Jetty and Myrtle Hall and Attached Wall.</p> <p>There are three further Grade II Listed Buildings within 500 m of the southern extent of the Tidal Barrier. These are for: an Eighteenth Century Watergate, Gazebo and Ham Green Hospital Buildings.</p>	Within 500 m.	Indirect	The tidal barrier has the potential to change the setting of these designated assets. This is likely to be an adverse impact although the opportunity does also exist for a high quality design that complements these existing heritage assets.
Landscape and visual	The Tidal Barrier is located in Shirehampton Conservation Area to the east and Avon Rolling Valley Farmland to the west.	Within the conversation areas.	Direct	The Tidal Barrier may affect the Landscape Character of the area during construction and operation. An opportunity does also exist for a high quality design that complements or enhances the existing landscape and visual amenity.

7.4.3 Summary

In summary, the PLP in epoch 1 is unlikely to lead to any significant effects on the environment, but the tidal barrier in epoch 2 will have the potential for a number of significant adverse effects on landscape and visual, heritage, and ecology. It may be possible to mitigate these to some extent during detailed design and the EIA process would explore this further. The tidal barrier is anticipated to lead to a significant positive effect on socio-economics as a result of the high level of flood protection it should provide.

7.5 Risks

7.5.1 Ground conditions

No ground investigation has been undertaken at this stage. A marine ground investigation using a jack-up barge would be needed to drill boreholes deep into the river bed to provide sufficient information for design of the civil infrastructure. At this stage a conservative view on conditions has been taken, assuming a need for closely spaced, deep piles. Ground investigation information may lead to a need to re-site the barrier or change its configuration.

7.5.2 Hydraulic performance

Flow velocity and velocity patterns around the piers are important for marine safety, siltation and scour. Detailed modelling may lead to design modifications.

7.5.3 Geomorphology and siltation

The Avon has a relatively heavy sediment load and detailed modelling at local and area scale will be needed to ascertain the likely impacts of sedimentation on the barrier, and the impacts of the barrier on geomorphology. This work may lead to design modifications.

7.5.4 Environment

The barrier will potentially have a wide range of impacts on the natural environment and on local archaeology. A full EIA will be required and a range of mitigation measures can be expected to be required to make the proposal acceptable. For example a fish pass or eel pass may be needed.

7.5.5 Land acquisition

A barrier will need significant compound space, room for a control building and access roads on both banks. There are risks associated with land acquisition.

7.5.6 Planning Consent and other Consenting Issues

The barrier may be taken through the major projects planning process or a Transport and Works Act Order will be required as the barrier will impact on river navigation. If there are objections to the proposals a public enquiry may be required. There are likely to be a need for other consents also such as MMO.

7.5.7 Water Quality, Outfalls and Watercourses

The barrier may impact on water quality due to alteration of flows in the river and discharges from Wessex Water outfalls, requiring design modifications. Similar considerations apply to the River Pill which has an outlet just upstream of the proposed barrier site.

7.5.8 Precautionary approach to flood risk management

There is a risk that the barrier may end up being 'over designed' if sea levels rise at a reduced rate compared to projections. Should this occur, at the end of the appraisal period the option may represent wasted investment compared to more adaptive, flexible options (such as a sequence of low to high defences).

7.5.9 Costs

A cost estimate has been made using the Thames Barrier as a benchmark. The barrier is considerably larger (by a factor of 5 at least) bigger than any other barrier built or currently planned in the UK, other than the Thames Barrier, and the Thames Barrier itself was built 40 years ago. Therefore it is inevitable that there is a significant risk of cost escalation despite the adoption of a 60% optimism bias in addition to estimates. Because of the long time-scales required to develop the barrier from concept to operation, cost inflation is also a real risk despite the UK's recent record of low inflation.

7.5.10 Lead Time

A barrier project of this magnitude might theoretically be implemented within 6 years, but more realistically will take 10-15 years. An early decision is required, with realistic allocation of funding, if the project is to be operational by 2030. The 2030 target date could be pushed back, but with only PLP/temporary barrier defences being put in place in the interim, Bristol would remain at risk from a major tidal flood event.

7.6 Wider opportunities

7.6.1 High standard of flood protection

The barrier would provide a very high standard of protection from 2030. The benefits to the local economy of a robust, high-standard defence would be significant.

7.6.2 Development opportunities

With multiple levels of redundancy put in place for barrier operation, as is the case with the Thames Barrier, it would be reasonable for the tidal flood zone upstream of the barrier to be effectively reclassified as suitable for all types of development, albeit with appropriate measures for dealing with residual risk. This would allow a much freer approach to development in the flood zone.

7.6.3 Tidal energy production opportunities

There are possibilities to combine a barrier with tidal energy production and /or with a second crossing of the Avon. High-level studies have suggested that the benefits of integrated solutions are modest in comparison to the additional costs but if the barrier were to be identified as the preferred option on flood risk grounds then further investigation would be warranted.

7.6.4 Tourism benefits

Potential for the barrier to act as a tourist attraction. Could increase public awareness of area and draw visitors to the area.

7.6.5 Separate schemes at Pill and Shirehampton

Potential for separate protection to Pill and Shirehampton, not included in this Option

7.6.6 Fluvial flood mitigation by storage

Potential to improve protection against fluvial flooding by lowering the river downstream of Bristol (this is now a common practice for London with the Thames Barrier).

7.7 Next steps

Should this Strategic Option be the preferred Strategic Option the following next steps will be required:

PLP Scheme

- Feasibility study for PLP including threshold and property surveys for individual properties within the PLP / temporary barrier zones, plus operational protocols for the temporary barriers.
- Engagement with stakeholders for the PLP scheme – principally building owners and tenants.
- Business Case
- Design / Procurement / Installation / Purchase

Tidal Barrier:

- Feasibility Study to confirm location and outline design, including
 - Engagement with stakeholders – wide range of affected and interested parties including the Port of Bristol, river users groups, local residents, statutory bodies, public at large
 - Develop design parameters
 - Ground Investigation, Topographic survey, Ecological survey
 - Sediment modelling and geomorphological modelling
 - Hydraulic modelling and possibly computational fluid dynamics modelling
 - Navigation assessment and possibly modelling
 - Environmental assessment
 - Cost review, Buildability assessment including plan for temporary works and partial river closures during construction, Operational aspects
- Business Case/Funding Application
- TWAO (or equivalent consent), EIA and Design Development, possibly Public Inquiry
- Detailed Design
- Procurement and Construction
- Commissioning

- Operation
- Ecological surveys and related issues will need to be addressed

8. STRATEGIC OPTION D (LOW DEFENCES – LOW DEFENCES – HIGH DEFENCES)

8.1 Description

This strategic option involves constructing low defences in epoch 1 (2015-2030), maintaining these low defences in epoch 2 (2030-2065) and then upgrading the defences to high defences by raising and lengthening in epoch 3 (2065-2115).

The sequence of using low defences and then high defences represents an adaptive approach to managing the flood risk in the study area. An advantage of the adaptive approach is that the proposed heights and lengths of the low and high defences can be adjusted in the future according to the magnitude of sea level rise that is occurring. The potential to adjust the proposals in the future will help to prevent overdesign and wasted investment.

8.1.1 Epoch 1 (Low Defences)

In epoch 1 low defences would be constructed on a city wide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2030.

Approximately 5.3km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock. The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment. As part of developing a conservative cost estimate the low defences have been 'future-proofed' in their concept design to enable the raising of the defences in the future (i.e. upgrading to high defences in epoch 3).

For the frontline alignments the indicative defence lengths and heights have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the defences relative to the adjacent pavement / road levels.

The design crest level of the low defence alignments were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. A freeboard allowance of 0.15m has been applied.

Table 63 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the low defences are shown in **Figure 9** and **Figure 10**.

Table 63 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 0.44m (Commercial Road) and 1.62m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 0.7 to 1.3m.

Table 63 Low defences 2015; lengths and heights of frontline alignments

Location	Design crest level (including 0.15m freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	9.50	1090	7.42	3.31	2.08	8.44	5.57	1.06
Cumberland Road	9.50	432	8.55	8.46	0.95	8.63	8.37	0.87
Cumberland Road East	9.50	18	8.71	8.44	0.79	8.71	8.44	0.79
Commercial Road	9.51	218	8.73	7.78	0.78	9.07	8.74	0.44
Clarence Road	9.51	515	7.60	5.70	1.91	8.72	8.00	0.79
Cattle Market Road	9.54	42	8.65	7.84	0.89	8.77	7.92	0.77
Totterdown	9.56	1471	8.87	7.38	0.69	8.84	7.21	0.72
Netham	9.61	553	7.45	3.62	2.16	7.99	3.89	1.62
Bath Road	9.56	402	6.91	5.45	2.65	8.35	6.86	1.21
Pill	9.42	294	7.56	6.39	1.86	8.14	6.64	1.28
Shirehampton	9.57*	309	8.09	6.64	1.48	8.54	7.36	1.03

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

8.1.2

Epoch 3 (High Defences)

In epoch 3 the low defences constructed during epoch 1 would be raised / lengthened to high defences. The upgrade would ensure a 1:200 year standard of protection until 2115. The total length of defences across the study area after this upgrade (including the length of low defences constructed in epochs 1&2) would be approximately 7.2km. Of this, approximately 1.9km will be from new defences constructed in epoch 3 and 5.3km would be from a raise of the existing defences constructed in epochs 1 and 2. The low defences constructed in epochs 1 and 2 will have been 'future proofed' in their design to allow for the raising of these defences to occur.

As part of the upgrade to high defences new lengths of defence will be required at Cumberland Road (188m), Commercial Road (43m), Clarence Road (60m), Cattle Market Road (16m), Totterdown (118m), Bath Road (62m), Pill (889m) and Shirehampton (477m). Crest raising of the existing low defences at these locations will also be required. No new lengths of defence will be required at Entrance Lock, Cumberland Road East or at Netham. In these locations only crest raising of the existing low defences is necessary.

For the purpose of the preferred option costing, it has been assumed that the new lengths of defences required for the high defences will follow a frontline alignment. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignments.

For the new lengths of frontline alignment required as part of the high defences measure the indicative lengths and heights have been established. Land levels along the alignment have been extracted in GIS using LIDAR data and topographic data if available. Topographic data was available and considered for the new defences at the following locations; Commercial Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the new lengths of defences relative to the adjacent pavement / road levels.

The design crest levels for the high defences (raised sections and new lengths) were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. The high defences are designed to a 2115 1:200 standard and therefore to avoid an overly precautionary design the freeboard allowance that has been applied is less than that applied to the low defence measure (0.15m). This is considered acceptable given that the low defences were designed to present day conditions (constructed in 2030, and designed to a 2030 standard) whereas the high defences for epoch 3 consider future conditions (2115 standard but constructed in 2065).

Table 64 presents the length, design crest level, land/bank levels and indicative heights of the new lengths of defences required for the high defences measure. **Table 64** presents the lengths and design crest levels for the raising of the low defences which would have been constructed in epoch 2 for this strategic option. The locations of the high defences are shown in **Figure 12** and **Figure 13**.

Table 64 High defences 2065; heights and lengths of the new sections of defences (to be constructed in addition to the raising of the existing low defences which would have been constructed in epoch 2 as part of this strategic option).

Location	Design crest level (including freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	No new length required. Raising of low defences only							
Cumberland Road	10.15	188	8.55	8.50	1.60	8.63	8.42	1.52
Cumberland Road East	No new length required. Raising of low defences only							
Commercial Road	10.15	43	6.39	4.45	3.76	8.69	7.72	1.46
Clarence Road	10.15	60	8.08	6.33	2.07	9.81	9.20	0.34
Cattle Market Road	10.20	16	9.83	9.56	0.37	9.86	9.61	0.34
Totterdown	10.20	118	9.64	9.61	0.56	9.61	9.54	0.59
Netham	No new length required. Raising of low defences only							
Bath Road	10.20	62	8.90	7.36	1.30	9.65	9.25	0.55
Pill	9.95	889	8.53	5.04	1.42	8.73	6.38	1.22
Shirehampton	10.25*	477	7.70	7.15	2.55	8.83	7.44	1.42

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

Table 65 High defences 2065; lengths and heights of crest raising required to raise the low defences (constructed in epoch 2 as part of this strategic option) to high defences

Location	Crest level of existing low defence alignment (including freeboard) (m ODN)	Length of existing low defence alignment that requires raising (m)	Design crest level of high defence alignment (including freeboard) (m ODN)	Height of crest raising required to achieve high defence design level (including freeboard) (m)
Entrance Lock	9.50	1090	10.15	0.65
Cumberland Road	9.50	432	10.15	0.65
Cumberland Road East	9.50	18	10.15	0.65
Commercial Road	9.51	218	10.15	0.64
Clarence Road	9.51	515	10.15	0.64
Cattle Market Road	9.54	42	10.20	0.66
Totterdown	9.56	1471	10.20	0.64
Netham	9.61	553	10.25	0.64
Bath Road	9.56	402	10.20	0.64
Pill	9.42	294	9.95	0.53
Shirehampton	9.57*	309	10.25	0.68

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

8.1.3 **All Epochs (Do Minimum and Maintenance)**

Alongside the primary measures outlined for this strategic option (low and high defences) it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115).

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the construction of the raised defence measures. The raised defence measures include the installation of new stop gates at Entrance lock and Netham Lock. Once these features are installed the do minimum activities should include the operation and upkeep of the stop gates in addition to the existing water level control assets in the floating harbour.

Following the construction and subsequent upgrades of the new raised defences from epoch 1 onwards it will be necessary to maintain these structures to sustain their flood defence function. Regular condition inspections are recommended alongside the development and implementation of a maintenance strategy.

It will also be necessary to operate any flood gates that may have been included as part of the raised defence alignments. It is recommended that Bristol City Council employ a specialist team or a specially trained team from Docks/Marine services to operate the gates during flood conditions to limit the residual risk of the gates being left open or other failures from occurring.

Further details of the do minimum activities and maintenance of the raised low and high defences are found in Appendix 1.

8.2 Economic Costs and Benefits

8.2.1 *Non-discounted (cash) costs*

High level costs for strategic option D have been developed. Costs for constructing low defences, minor low defence upgrades in epoch 2 and then a large upgrade to high defences in epoch 3 have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance and undertaking the do minimum activities have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option D are presented in **Table 66** below. In total, the cash cost for implementing strategic option D is approximately £304million. The majority of this cost will come in epochs 1 and 3, when the initial low defences are constructed and when the major upgrade to high defences is undertaken. In epoch 2, when the low defences are raised by only a relatively modest amount, the total costs are expected to be lower.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 66 Summary of non-discounted (cash) costs for strategic option D

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Low defences - construction	128.3	135.7
	Maintenance of low defences	6.0 (average 1.2 per annum)	
	Do Minimum activities	1.5 (average 1.0 per annum)	
Epoch 2 (2030 – 2065)	Maintenance of low defences	41.8 (average 1.2 per annum)	45.3
	Do Minimum activities	3.5 (average 0.1 per annum)	
Epoch 3 (2065 – 2115)	High defences - upgrade	50.6	123.2
	Maintenance of high defences	62.9 (average 1.6 per annum)	
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			304.2

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 67** to **Table 69** below.

Table 67 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option D

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Low defences	Entrance Lock – new defence, capital works	24.6	0	134.3	135.8
	Cumberland Road – new defence, capital works	10.1	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	4.6	0		
	Clarence Road – new defence, capital works	11.7	0		
	Cattle Market Road – new defence, capital works	1.0	0		
	Totterdown – new defence, capital works	34.8	0		
	Netham – new defence, capital works	12.5	0		
	Bath Road – new defence, capital works	8.9	0		
	Pill – new defence, capital works	6.7	0		
	Shirehampton – new defence, capital works	0.4	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.2 (total 5.9 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 1.5 over epoch 1)	1.5	
	Maintenance of existing defences	0	0*		

* (assumed cost will be covered by the cost of maintaining primary measure)

Table 68 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option D

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Low defences	Maintenance – all locations	0	1.2 (total 41.8 over epoch 2)	41.8	45.3
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 69 Breakdown of non-discounted (cash) costs for epoch 3: Strategic option D

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Entrance Lock – defence raising, capital works	3.5	0	113.5	123.2
	Cumberland Road – new defence length, capital works	4.5	0		
	Cumberland Road – defence raising, capital works	1.4	0		
	Cumberland Road East – defence raising, capital works	0.1	0		
	Commercial Road – new defence length, capital works	1.0	0		
	Commercial Road – defence raising, capital works	0.7	0		
	Clarence Road – new defence length, capital works	1.4	0		
	Clarence Road – defence raising, capital works	1.7	0		
	Cattle Market Road – new defence length, capital works	0.4	0		
	Cattle Market Road – defence raising, capital works	0.1	0		
	Totterdown – new defence length, capital works	2.9	0		
	Totterdown – defence raising, capital works	4.7	0		
	Netham – defence raising, capital works	1.8	0		
	Bath Road – new defence length, capital works	1.5	0		
	Bath Road – defence raising, capital works	1.3	0		
	Pill – new defence length, capital works	21.4	0		
	Pill – defence raising, capital works	0.9	0		
	Shirehampton – new defence length, capital works	0.9	0		
	Shirehampton – defence raising, capital works	0.3	0		

	Maintenance – all locations	0	1.6 (total 62.9 over epoch 3)		
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

8.2.2

Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option D to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option D has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. the raised defence construction and upgrades) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented. As such, for costing purposes, it has been assumed that the raised defences will be implemented in year 2015 and the subsequent upgrades in the years 2030 and 2065. For maintenance/operation and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 70** below. As shown, the total present value cost for strategic option D is estimated to be approximately £166million. Of this, the majority of the investment (in present value terms) is required in epoch 1, with the construction of the initial low defences. In epoch 3, despite there being a large cash investment required to upgrade to high defences, the larger discount rate applied in epoch 3 ensures that the present value cost of doing so is comparably much smaller than the capital cost of the initial construction in epoch 1.

Table 70 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option D

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	128.3	6.0	1.5	135.7	128.1	4.0	1.2	133.4
Epoch 2	0	41.8	3.5	45.3	0	15.0	1.3	16.3
Epoch 3	50.6	62.9	9.7	123.2	10.0	5.7	0.9	16.5
			Total	304.2			Total	166.3

8.2.3

Economic benefits

Table 71 below presents the minimum standard of protection provided by the strategic option for five year time intervals throughout the appraisal period.

Table 71 Minimum standard of protection; strategic option D

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	Low defences	1:200 yr	3	2065-2069	High defences	Higher than 1:200 yr
1	2020-2024	Low defences	1:150 yr	3	2070-2074	High defences	Higher than 1:200 yr
1	2025-2029	Low defences	1:100 yr	3	2075-2079	High defences	Higher than 1:200 yr
2	2030-2034	Low defences	1:200 yr	3	2080-2084	High defences	Higher than 1:200 yr
2	2035-2039	Low defences	1:150 yr	3	2085-2089	High defences	Higher than 1:200 yr
2	2040-2044	Low defences	1:100 yr	3	2090-2094	High defences	Higher than 1:200 yr
2	2045-2049	Low defences	1:100 yr	3	2095-2099	High defences	Higher than 1:200 yr
2	2050-2054	Low defences	1:75 yr	3	2100-2104	High defences	Higher than 1:200 yr
2	2055-2059	Low defences	1:75 yr	3	2105-2109	High defences	Higher than 1:200 yr
2	2060-2064	Low defences	1:50 yr	3	2110-2115	High defences	1:200 yr

Table 72 to Table 74 below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option D in addition to the Do Minimum scenario.

Table 72 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	14	44	69	287
2030	15	54	71	418
2065	42	73	277	1380
2115	76	706	1420	2011

Table 73 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	106	185	381
2030	14	149	224	413
2065	97	225	339	831
2115	230	445	790	1190

Table 74 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	16	150	254	668
2030	29	203	295	831
2065	139	298	616	2211
2115	306	1151	2210	3201

The economic benefit of strategic option D in present value terms is summarised in **Table 75** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,575.9m benefits in PV terms. The average benefit cost ratio of the option is 9:1.

Table 75 Strategic option D whole life benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
17	Epoch 1 – Low Defences Epoch 2 – High Defences Epoch 3 – High Defences	1,575.9	166.3	9:1

8.3

Development

Strategic option D outlines raised defences from epoch 1 onwards, for the duration of the strategy appraisal period. The raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 1 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are political aspirations for development and redevelopment of the city centre. The approach for the duration of the appraisal period can be considered as beneficial to development and redevelopment of the city centre and in support of the political aspirations. Compared to other options which delay implementing the raised defences and the tidal barrier until epoch 2 or later, strategic option D can be considered favourable in the context of development as it will help development redevelopment / development opportunities from year 0 (or immediately following defence construction) of the appraisal period.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

8.4 Environmental impacts

8.4.1 *Epoch 1 and Epoch 2 (Low Defences)*

A negligible impact is predicted for air quality and noise as any noise impacts are likely to be temporary and will be managed through measures contained within a CEMP. There are also unlikely to be noticeable long-term or detrimental short-term impacts on geomorphology and water quality. There will be temporary and localised entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water.

This flood defence measure is likely to have minor landscape and visual impacts. The majority of the defences will be less than a metre in height and therefore less visually intrusive compared to the High Defence measure or barriers.

This measure is expected to have a minor impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology. Negligible impacts are predicated for soil and groundwater as the Low Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as and Underfall Yard which is a Scheduled Ancient Monument.

The Low Defences measure is likely to have a minor impact on traffic & transport as there will be some additional trips associated with bringing in the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts.

This flood defence measure will reduce the risk of flooding and promote investment in the city centre and therefore a minor positive impact would be expected for socio-economics.

Table 76 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 76: Potential Receptors affected by Low Defences in Epoch 1 and 2

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar Site, SPA, SAC, and SSSI.	A section of the alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is: the Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct and Indirect	<p>There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences.</p> <p>When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.</p>
Landscape and visual	<p>In Reach 2 Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

8.4.2

Epoch 3 (High Defences)

During construction a negligible impact is predicted for air quality and noise as these impacts are likely to be temporary and can be adequately managed through measures contained within a CEMP. There are also unlikely to be impacts on geomorphology and water quality. There may be temporary entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water and therefore the impact is expected to be negligible.

This measure is expected to have a minor negative impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary and once constructed this measure is unlikely to have a noticeable impact on terrestrial ecology and estuarine/riverine ecology.

There is the potential for significant adverse impacts on archaeological and heritage receptors. This is because the High Defences have the potential to cause a significant indirect impact on the setting of heritage assets, especially if there are high value receptors in close proximity to the high defences, such as Underfall Yard which is a Scheduled Ancient Monument. The final design of the defences should be sympathetic to these heritage assets in order to mitigate this impact to some extent.

The High Defences measure is likely to have a minor impact on Traffic and Transport as there will be some additional trips associated with bringing the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts. Negligible impacts are predicated for soil and groundwater as the High Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There is the potential for significant landscape and visual impacts as the high defences will be visually prominent and therefore likely to have a substantial impact on key views and on the Landscape Character of the area.

The level of protection that the High Defences measure will provide is likely to have a significant positive impact on socio-economics as this flood defence measure represents a long term approach to managing the impacts of sea level rise which will encourage individuals and developers to invest in the city in the future.

Table 77 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 77: Potential Receptors affected by High Defences in Epoch 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar Site, SPA, SAC, and SSSI.	A section of the alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is: The Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct/Indirect	There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the high defences. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.
Landscape and visual	<p>Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. Conservation Areas which may be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

8.4.3

Summary

In summary, it is expected that significant adverse effects can largely be avoided or mitigated through sensitive design measures, although localised residual impacts on landscape and visual amenity may still exist in places. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

8.5 Risks

The risks associated with this Option are set out in Section 6.6. The issues related to PLP obviously do not apply, but all other aspects are relevant.

8.6 Wider opportunities

8.6.1 *Adaptive approach to flood risk management*

This Strategic Option provides an adaptive approach to managing the tidal flood risk over the Strategy appraisal period. This provides opportunities to refine the proposals at Epoch 3. Changes to the proposals can be made, taking into account the latest climate change information and design guidance to ensure that the defences are not 'over-designed' or represent wasted investment.

For example, if sea level rise is found to occur at a slower rate than presently projected, the move to defences in 2065 could be deferred for a number of years.

The ability to revisit the proposals at numerous stages during the appraisal period will open up a number of opportunities to get achieve stakeholder and public support of the option designs. Over time it is possible that political, stakeholder and public aspirations may change and therefore each design period provides an opportunity to reassess the defence requirements (i.e. in terms of landscaping, visual considerations, and access opportunities).

8.6.2 *Facilitate development and redevelopment opportunities*

The raised defences scheduled for epoch 1 and 3 will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas. This is in line with the political aspirations for the city and is a major advantage of this option.

By providing robust defences, it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

8.6.3 *Environmental enhancement*

Raised defence schemes in epochs 1 and 3 could provide opportunities to locally enhance the environment, mainly in terms of the visual/landscape aspect of the waterfront.

Landscaping of the new defences could be carried out which could enhance the character and visual appeal of some areas. Enhancement might include improved surfacing for existing routes, better lighting to improve safety, addition of marked cycleway, provision of ramps in place of stepped accesses and provision of seating and viewing areas.

Potential approaches to mitigate impacts of walls on the visual environment would be to include 'softer' structure types as part of the raised defence measures, such as reinforced glass walls which could help to sustain the views and connection to the waterfront, or use of self-raising walls which in normal use are lower than the required crest level. Some examples of these techniques are provided in **Figure 15** and **Figure 16**.

8.7 Next steps

Should this Strategic Option be the preferred Strategic Option the following next steps will be required:

- Feasibility study for Low Defences scheme - including identifying preferred alignments in each location. Identifying preferred alignments should be done following a full review of the available supporting information, such as the ground condition and services data that is available. Full topographic surveys and ground investigation will be required to support the design. Broader outcomes will need to be considered – access, amenity and recreation benefits that can be built in, such as improved cycleways or lighting, access for the disabled.
- Engagement with stakeholders for the Low Defences scheme – BCC city docks (as harbour authority), affected landowners and businesses, residents, community groups, statutory organisations.
- Should approval / funding from the Environment Agency be required it will be necessary to develop Outline Business Case(s) (OBC) and Full Business Case(s) (FBC). This should be done once the project has been included on the Environment Agency's programme of flood and

coastal erosion risk management schemes. In order to get approval it will be necessary to use the correct EA template to align with the HM Treasury's Five Case Model.

- Development of Low Defences designs, including landscape and amenity elements
- Environmental assessment of Low Defences at scheme level
- Ecological surveys and related issues will need to be addressed
- Planning consent for Low Defences scheme (technically may not be required, but recommended)
- Procurement and construction of Low Defences scheme

9. STRATEGIC OPTION E (LOW DEFENCES – TIDAL BARRIER – TIDAL BARRIER)

9.1 Description

This strategic option involves constructing low defences in epoch 1 (2015-2030), constructing a tidal barrier in epoch 2 (2030-2065) and then maintaining the tidal barrier in epoch 3 (2065-2115).

The sequence of using low defences initially and then constructing a tidal barrier represents a precautionary approach to managing the flood risk in the study area and will secure a high standard of protection throughout the next 100 year period. Initially the low defences will provide a 1:200 year standard for 2015, but this will gradually drop over the duration of epoch 1 as a result of sea level rise. However from 2030 the tidal barrier will be constructed, re-raising the standard of protection to a very high standard (to be in excess of the 1:200 to 1:1000 year SoP for 2115) for the remainder of the appraisal period.

Should the barrier be taken forward as part of the preferred option, additional studies following the Strategy will be required to define the optimal design standard of protection for the scheme.

Due to the precautionary approach to flood risk management the flood risk benefits to the area will be significant. However the decision to commit to providing the tidal barrier and a high standard of protection will need to be taken early on in the appraisal period (i.e. within the next 15 years during epoch 1) and as a result there is a risk that the barrier may end up being 'over designed' if sea levels rise at a reduced rate compared to projections. Should this occur, at the end of the appraisal period the option may represent wasted investment compared to more adaptive, flexible options (such as a sequence of low to high defences).

9.1.1 Epoch 1 (Low Defences)

In epoch 1 low defences would be constructed on a city wide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2030. Approximately 5.3km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock. The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment. As part of developing a conservative cost estimate the low defences have been 'future-proofed' in their concept design to enable the raising of the defences in the future (i.e. upgrading to high defences in epoch 3).

For the frontline alignments the indicative defence lengths and heights have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the defences relative to the adjacent pavement / road levels.

The design crest level of the low defence alignments were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. A freeboard allowance of 0.15m has been applied.

Table 78 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the low defences are shown in **Figure 9** and **Figure 10**.

Table 78 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 0.44m (Commercial Road) and 1.62m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 0.7 to 1.3m.

Table 78 Low defences 2015; lengths and heights of frontline alignments

Location	Design crest level (including 0.15m freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	9.50	1090	7.42	3.31	2.08	8.44	5.57	1.06
Cumberland Road	9.50	432	8.55	8.46	0.95	8.63	8.37	0.87
Cumberland Road East	9.50	18	8.71	8.44	0.79	8.71	8.44	0.79
Commercial Road	9.51	218	8.73	7.78	0.78	9.07	8.74	0.44
Clarence Road	9.51	515	7.60	5.70	1.91	8.72	8.00	0.79
Cattle Market Road	9.54	42	8.65	7.84	0.89	8.77	7.92	0.77
Totterdown	9.56	1471	8.87	7.38	0.69	8.84	7.21	0.72
Netham	9.61	553	7.45	3.62	2.16	7.99	3.89	1.62
Bath Road	9.56	402	6.91	5.45	2.65	8.35	6.86	1.21
Pill	9.42	294	7.56	6.39	1.86	8.14	6.64	1.28
Shirehampton	9.57*	309	8.09	6.64	1.48	8.54	7.36	1.03

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence.

9.1.2 **Epoch 2 (Tidal barrier)**

In epoch 2 a tidal barrier would be constructed downstream of central Bristol. The barrier would, in principle, provide an effective flood defence against high tide levels in central Bristol.

A concept design for a tidal barrier at Ham Green – Nibley Road has been developed and consists of 3 gates ranging in width from 25m to 40m and in height from 10m to 18m. The design tide level of the barrier in this location is 10.9m AOD. On the south (left) bank the barrier will tie into the cliffs whilst on the north (right) bank the barrier will tie into high ground across the playing field / allotments. The details are discussed further in section 5.5. The proposed barrier location is shown in **Figure 17**.

The major disadvantage of a barrier located in this position is that the barrier does not provide flood protection to Pill, the Severn Beach railway line further downstream and parts of Shirehampton. Although the barrier is outside of the Severn Estuary environmentally designated sites, it is still close-by so the impacts of the barrier on these designations would need to be taken into account. There is also likely to be significant visual intrusion and amenity impacts in the locality.

9.1.3

All epochs (Do Minimum and Maintenance)

Alongside the primary measures outlined for this strategic option (low defences and tidal barrier) it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115). No further capital works are planned in epoch 3 as the tidal barrier provides a very high standard of protection to the end of the appraisal period.

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the construction of low defences and of the tidal barrier.

In epoch 1 following the construction of the low defences it will be necessary to maintain these structures to ensure their continued flood defence function. Likewise, from epoch 2 onwards the tidal barrier will need to be maintained and operated and it is recommended that a designated team is established and made responsible for the operation of the barrier. Regular condition inspections are also recommended alongside the development and implementation of a maintenance strategy.

Further details of the do minimum activities and maintenance of and the low defences and tidal barrier are found in Appendix 1.

9.2 Economic Costs and Benefits

9.2.1 Non-discounted (cash) costs

High level costs for strategic option E have been developed. Costs for constructing the low defences and tidal barrier have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance, undertaking the do minimum activities and also operating the tidal barrier have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option E are presented in **Table 79** below. In total, the cash cost for implementing strategic option C is approximately £1,084million. The vast majority of this cost will come in epoch 2, when the tidal barrier is constructed.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 79 Summary of non-discounted (cash) costs for strategic option E

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Low defences - construction	128.3	135.8
	Maintenance of low defences	6.0 (average 1.2 per annum)	
	Do Minimum activities	1.5 (average 0.1 per annum)	
Epoch 2 (2030 – 2065)	Tidal barrier – construction	683.0	788.5
	Tidal barrier maintenance and operation	102.0 (average 3.0 per annum)	
	Do Minimum activities	3.5 (average 0.1 per annum)	
Epoch 3 (2065 – 2115)	Tidal barrier maintenance and operation	150.0 (average 3.0 per annum)	159.7
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			1,083.9

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 80** to **Table 82** below.

Table 80 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option E

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Low defences	Entrance Lock – new defence, capital works	24.6	0	134.3	135.8
	Cumberland Road – new defence, capital works	10.1	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	4.6	0		
	Clarence Road – new defence, capital works	11.7	0		
	Cattle Market Road – new defence, capital works	1.0	0		
	Totterdown – new defence, capital works	34.8	0		
	Netham – new defence, capital works	12.5	0		
	Bath Road – new defence, capital works	8.9	0		
	Pill – new defence, capital works	6.7	0		
	Shirehampton – new defence, capital works	0.4	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.2 (total 6.0 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 1.5 over epoch 1)	1.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 81 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option E

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Tidal barrier	Construction	683.0	0	785.0	788.5
	Operation and maintenance	0	3.0 (total 102.0 over epoch 2)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 82 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option E

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Tidal barrier	Operation and maintenance	0	3.0 (total 150.0 over epoch 3)	150.0	159.7
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

9.2.2

Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option E to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option E has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. the construction of the low defences and tidal barrier) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented. As such, for costing purposes, it has been assumed that the low defences will be implemented in year 2015 and the tidal barrier constructed in 2030. For maintenance/operation and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 83** below. As shown, the total present value cost for strategic option E is estimated to be approximately £595million. Of this, the majority of the investment (in present value terms) is required in epoch 2, with the construction of the tidal barrier.

Table 83 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option E

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	128.3	4.0	1.5	135.8	128.3	4.0	1.2	133.4
Epoch 2	683.0	102.0	3.5	788.5	407.7	35.9	1.3	444.9
Epoch 3	0	150.0	9.7	159.7	0	16.0	0.9	16.9
			Total	1,083.9			Total	595.2

9.2.3

Economic benefits

Table 84 below presents the minimum standard of protection provided by the strategic option for five year time intervals throughout the appraisal period.

Table 84 Minimum standard of protection; strategic option E

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	Low defences	1:200 yr	3	2065-2069	Tidal barrier	Higher than 1:1000 yr
1	2020-2024	Low defences	1:150 yr	3	2070-2074	Tidal barrier	Higher than 1:1000 yr
1	2025-2029	Low defences	1:100 yr	3	2075-2079	Tidal barrier	Higher than 1:1000 yr
2	2030-2034	Tidal barrier	Higher than 1:1000 yr	3	2080-2084	Tidal barrier	Higher than 1:1000 yr
2	2035-2039	Tidal barrier	Higher than 1:1000 yr	3	2085-2089	Tidal barrier	Higher than 1:1000 yr
2	2040-2044	Tidal barrier	Higher than 1:1000 yr	3	2090-2094	Tidal barrier	Higher than 1:1000 yr
2	2045-2049	Tidal barrier	Higher than 1:1000 yr	3	2095-2099	Tidal barrier	Higher than 1:1000 yr
2	2050-2054	Tidal barrier	Higher than 1:1000 yr	3	2100-2104	Tidal barrier	Higher than 1:1000 yr
2	2055-2059	Tidal barrier	Higher than 1:1000 yr	3	2105-2109	Tidal barrier	Higher than 1:1000 yr
2	2060-2064	Tidal barrier	Higher than 1:1000 yr	3	2110-2115	Tidal barrier	1:1000 yr

Table 85 to Table 87 to below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option E in addition to the Do Minimum scenario.

Table 85 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	14	44	69	287
2030	46	97	120	520
2065	84	122	281	1417
2115	124	529	1216	2037

Table 86 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	106	185	381
2030	20	163	238	494
2065	111	239	355	943
2115	245	446	798	1325

Table 87 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	16	150	254	668
2030	66	260	358	1014
2065	195	361	636	2360
2115	369	975	2014	3362

The economic benefit of strategic option E in present value terms is summarised in **Table 88** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,598.8m benefits in PV terms. The average benefit cost ratio of the option is 3:1.

Table 88 Strategic option E whole life benefits

Strategic option	Measures	Whole life PV benefits (£k)	Whole life PV cost (£k)	Average Benefit : Cost ratio
21	Epoch 1 – Low Defences Epoch 2 – Tidal Barrier Epoch 3 – Tidal Barrier	1,598.8	595.2	3:1

9.3

Development

Strategic option E schedules raised defences in epoch 1 and then a tidal barrier from epoch 2 onwards.

The raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 1 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

From epoch 2 the tidal barrier would provide a high standard of protection from flooding to the entire city centre area and with multiple levels of redundancy put in place for barrier operation, as is the case with the Thames Barrier, it would be reasonable for the tidal flood zone upstream of the barrier to be effectively reclassified as suitable for all types of development, albeit with appropriate measures for dealing with residual risk. This would allow a much freer approach to development in the flood zone.

Given that the low defences and tidal barrier will facilitate development, opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the raised defence schemes and barrier itself. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are political aspirations for development and redevelopment of the city centre. The approach for the duration of the appraisal period can be considered as beneficial to development and redevelopment of the city centre and in support of the political aspirations. Compared to other options which delay implementing the raised defences and the tidal barrier until epoch 2 or later, strategic option D can be considered favourable in the context of development as it will help development redevelopment / development opportunities from year 0 (or immediately following defence construction) of the appraisal period.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

9.4 Environmental impacts

9.4.1 *Epoch 1 (Low Defences)*

A negligible impact is predicted for air quality and noise as any noise impacts are likely to be temporary and will be managed through measures contained within a CEMP. There are also unlikely to be noticeable long-term or detrimental short-term impacts on geomorphology and water quality. There will be temporary and localised entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water.

This flood defence measure is likely to have minor landscape and visual impacts. The majority of the defences will be less than a metre in height and therefore less visually intrusive compared to the High Defence measure or Tidal Barrier.

This measure is expected to have a minor impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as this alignment is located adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology. Negligible impacts are predicated for soil and groundwater as the Low Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as and Underfall Yard which is a Scheduled Ancient Monument.

The Low Defences measure is likely to have a minor impact on traffic and transport as there will be some additional trips associated with bringing in the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts.

This flood defence measure will reduce the risk of flooding and promote investment in the city centre and therefore a minor positive impact would be expected for socio-economics.

Table 89 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 89: Potential Receptors affected by Low Defences in Epoch 1

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar, SPA, SAC, and SSSI	A section of the low defence alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>The defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is the Lamplighters Public House.</p> <p>Within the city centre the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct and Indirect	There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially where there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.
Landscape and visual	<p>Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

9.4.2

Epoch 2 and 3 (Tidal Barrier)

The Tidal Barrier measure will be visually prominent and is likely to have a substantial impact on local key viewpoints and the Landscape Character of the area, although it will be fairly localised.

The Tidal Barrier measure has the potential to result in significant impacts on terrestrial ecology and estuarine/riverine ecology, particularly during the construction phase; however these impacts will be temporary and be managed through measures contained within a CEMP. Once the barrier is constructed this flood defence measure may have a negative impact on transient species i.e. fish, as when the barrier is closed these species will be prevented from moving up and down the river. There is also the potential for some habitat loss which may affect sensitive habitats such as the Severn Estuary SPA, SAC, Ramsar and SSSI sites even though the barrier sits outside of these areas.

There are five Grade II Listed Buildings within 500 m of the Tidal Barrier location (Powder Houses and Jetty, Myrtle Hall and Attached Wall, Eighteenth Century Watergate and Ham Green Hospital Buildings). Even though there are no Listed Buildings which will be directly impacted by this measure there is the potential for a negative impact on the setting of these heritage receptors.

Minor impacts are expected on geomorphology and water quality as the tidal barrier could alter the water flow and introduce sediment during riverbed disturbance in the construction phase. Minor impacts would also be likely for traffic and transport as there will be some additional trips associated with bringing in the defences to site, but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately avoid any significant impacts.

Negligible impacts are predicted for air quality and noise as these impacts are only likely during the construction phase but they will be temporary in nature and will be managed adequately through measures contained within a CEMP. Once constructed, this measure is unlikely to have any impact on air quality and noise. Negligible impacts are predicated for soil and groundwater as the barrier measures may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

In terms of flood risk the Tidal Barrier will reduce flood risk to a Standard of Protection until 2115. This reassurance is likely to have a significant positive impact on socio-economics as individuals and developers are not discouraged from investing in the city centre because of flood risk.

Table 90 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 90: Potential Receptors affected by Tidal Barrier in Epoch 2 and 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	<p>The northern extent of the Tidal Barrier is likely to be situated in Nibley Road Open Space and just to the south of Myrtle Hall Allotments which are both wildlife corridors.</p> <p>The southern extent of the barrier is not located in an area of biodiversity value. Although there are several strips of woodland nearby (approx. 150 m away).</p> <p>There are a number of designated sites in close proximity to the tidal barrier. The Severn Estuary SPA and SAC is located approximately 1.5 km west of the tidal barrier. Ham Green SSSI is located approximately 500 m south east of the barrier location. Horseshoe Bend SSSI is located approximately 500 m north east of the barrier. Avon Gorge SSSI and Avon Gorge and Woodlands SAC are located approximately 1.5 km east of the barrier. There are also a number of European protected species recorded within this Reach.</p>	<p>Within the affected area for wildlife corridors</p> <p>Within 1.5 km for designated habitat sites and European protected species records.</p>	Direct/ Indirect	<p>There may be temporary impacts on associated with construction activity, either directly or indirectly. Transient river species would also be adversely affected during this phase.</p> <p>Once operational there may be a temporary impact on transient species such as fish, eels and birds as these species will be prevented from moving up and down the river when the barrier is closed. This is expected to be an infrequent occurrence however.</p>
Cultural Heritage	<p>There are three Grade II listed buildings within 500 m of the northern extent of the Tidal Barrier. These are: Powder Houses and Jetty and Myrtle Hall and Attached Wall.</p> <p>There are three further Grade II Listed Buildings within 500 m of the southern extent of the Tidal Barrier. These are for: an Eighteenth Century Watergate, Gazebo and Ham Green Hospital Buildings.</p>	Within 500 m.	Indirect	The tidal barrier has the potential to change the setting of these designated assets. This is likely to be an adverse impact although the opportunity does also exist for a high quality design that complements these existing heritage assets.
Landscape and visual	The Tidal Barrier is located in Shirehampton Conservation Area to the east and Avon Rolling Valley Farmland to the west.	Within the conversation areas.	Direct	The Tidal Barrier may affect the Landscape Character of the area during construction and operation. An opportunity does also exist for a high quality design that complements or enhances the existing landscape and visual amenity.

9.4.3

Summary

In summary, the Low Defence measure in epoch 1 is unlikely to lead to any significant effects on the environment, but the tidal barrier in epoch 2 and 3 will have the potential for a number of significant adverse effects on landscape and visual, heritage, and ecology. It may be possible to mitigate these to some extent during detailed design and the EIA process would explore this further. The tidal barrier is anticipated to lead to a significant positive effect on socio-economics as a result of the high level of flood protection it should provide.

9.5 Risks

This option presents all of the risk associated with low defences as set out in section 6.6, and all of the risks associated with a tidal barrier as set out in section 8.6.

9.6 Wider opportunities

See sections 6.7 and 8.7.

9.7 Next steps

See section 6.8 and 8.8.

10. STRATEGIC OPTION F (HIGH DEFENCES – HIGH DEFENCES – HIGH DEFENCES)

10.1 Description

This strategic option involves constructing high defences in epoch 1 (2015-2030) and then maintaining these defences in epochs 2 and 3 (2030-2115).

The approach of constructing high defences initially and then maintaining these defences for the remainder of the appraisal period represents a precautionary approach to managing the flood risk in the study area and will secure a high standard of protection throughout the next 100 year period. The high defences will provide a 1:200 year standard of protection for 2115. As a result, for the duration of the appraisal period the defences will exceed the 1:200 year standard and gradually fall to this level in 2115 as a result of sea level rise.

With the precautionary approach to flood risk management the flood risk benefits to the area will be significant. However the decision to commit to providing the high defences and a high standard of protection will need to be taken very early on in the appraisal period in order to construct and implement these defences in epoch 1. As a result there is a risk that the defences may end up being 'over designed' if sea levels rise at a reduced rate compared to projections. Should this occur, at the end of the appraisal period the option may represent wasted investment compared to more adaptive, flexible options (such as a sequence of low to high defences).

10.1.1 Epoch 1 (High Defences)

In epoch 1 high defences would be constructed on a city wide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2115.

Approximately 7.2km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock. The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment.

For the frontline alignments the indicative lengths and heights for the high defences have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the high defences relative to the adjacent pavement / road levels.

The design crest levels for the high defences were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. The high defences are designed to a 2115 1:200 standard and therefore to avoid an overly cautious design the freeboard allowance that has been applied is less than the typical 0.15m (i.e. that applied to the low defence measure within the Strategy). This is considered an acceptable approach given that the high defences are designed for future conditions and are therefore already conservative by design (designed to 2115 1:200 standard but constructed in 2015).

Table 91 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the high defences are shown in **Figure 12** and **Figure 13**.

Table 91 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 1.14*m (Cattle Market Road) and 2.26*m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 1.3 to 1.7m.

Table 91 High defences; lengths and heights of high defences, 2015

Location	Design crest level (including freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	10.15	1090	7.42	3.31	2.73	8.44	5.57	1.71
Cumberland Road	10.15	620	8.55	8.46	1.69	8.63	8.37	1.52
Cumberland Road East	10.15	18	8.71	8.44	1.44	8.71	8.44	1.44
Commercial Road	10.15	261	8.29	4.45	1.86	9.00	7.72	1.15
Clarence Road	10.15	575	7.65	5.70	2.50	8.85	8.00	1.30
Cattle Market Road	10.20	58	8.97	7.84	1.23	9.06	7.92	1.14
Totterdown	10.20	1589	8.92	7.38	1.28	8.89	7.21	1.31
Netham	10.25	553	7.75	3.62	2.50	7.99	3.89	2.26
Bath Road	10.20	464	7.18	5.45	3.02	8.53	6.86	1.67
Pill	9.95	1183	8.29	5.04	1.66	8.58	6.38	1.37
Shirehampton	10.25*	786	7.86	6.64	2.39	8.71	7.36	1.54

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence

10.1.2 **All epochs (Do Minimum and Maintenance)**

Alongside the high defences outlined for this strategic option it will be necessary to undertake do minimum and maintenance activities throughout the appraisal period (2015-2115). No further capital works are planned in epochs 2 and 3 as the high defences constructed in epoch 1 provide a 1:200 year standard of protection to the end of the appraisal period.

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the construction and maintenance of the new high defences. The high defence measure includes the installation of new stop gates at Entrance lock and Netham Lock. Once these features are installed the do minimum activities from epoch 1 onwards should include the operation of the gates in addition to the existing water level control assets in the floating harbour.

For the new high defences it is recommend that regular condition inspections are carried out alongside the development and implementation of a maintenance strategy.

It will also be necessary to operate any flood gates that may have been included as part of the high defence alignments. It is recommended that Bristol City Council employ a specialist team or a specially trained team from Docks/Marine services to operate the gates during flood conditions to limit the residual risk of the gates being left open or other failures from occurring.

Further details of the do minimum activities and maintenance of the high defences are found in Appendix 1.

10.2 Economic Costs and Benefits

10.2.1 Non-discounted (cash) costs

High level costs for strategic option F have been developed. Costs for constructing the high defences have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance and undertaking the do minimum activities have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option F are presented in **Table 92** below. In total, the cash cost for implementing strategic option F is approximately £321million. The majority of this cost will come in epoch 1, when the high defences are constructed. In epochs 2 and 3 the total costs will be lower as no capital investments for construction are required.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 92 Summary of non-discounted (cash) costs for strategic option F

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	High defences - construction	165.3	174.6
	Maintenance of low defences	7.9 (average 1.6 per annum)	
	Do Minimum activities	1.5 (average 0.1 per annum)	
Epoch 2 (2030 – 2065)	Maintenance of high defences	55.0 (average 1.6 per annum)	58.5
	Do Minimum activities	3.5 (average 0.1 per annum)	
Epoch 3 (2065 – 2115)	Maintenance of high defences	78.6 (average 1.6 per annum)	88.3
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			321.5

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 93** and **Table 95** below.

Table 93 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option F

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Entrance Lock – new defence, capital works	25.2	0	173.2	174.6
	Cumberland Road – new defence, capital works	14.8	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	5.7	0		
	Clarence Road – new defence, capital works	13.4	0		
	Cattle Market Road – new defence, capital works	1.4	0		
	Totterdown – new defence, capital works	38.4	0		
	Netham – new defence, capital works	12.8	0		
	Bath Road – new defence, capital works	10.6	0		
	Pill – new defence, capital works	28.3	0		
	Shirehampton – new defence, capital works	1.5	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.6 (total 7.9 over epoch 1)		
Do minimum activities	Floating Harbour operations	0	0.1 (total 1.5 over epoch 1)	1.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 94 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option F

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Maintenance – all locations	0	1.6 (total 55.0 over epoch 2)	55.0	58.5
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	3.5	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

Table 95 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option F

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Maintenance – all locations	0	1.6 (total 78.6 over epoch 3)	78.6	88.3
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

10.2.2 Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option F to a present value cost. According to the FCERM-AG, the following variable discount rates have been used within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option F has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. the construction of the high defences) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented; 2015. For maintenance/operation and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 96** below. As shown, the total present value cost for strategic option F is estimated to be approximately £202million. Of this, the significant majority of the investment (in present value terms) is required in epoch 1, with the construction of the high defences.

Table 96 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option E

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	165.3	7.9	1.5	174.6	165.3	5.2	1.2	171.7
Epoch 2	0	55.0	3.5	58.5	0	19.8	1.3	21.0
Epoch 3	0	78.7	9.7	88.3	0	8.3	0.9	9.3
	Total			321.5	Total			202.0

10.2.3

Economic benefits

Table 97 below presents the minimum standard of protection provided by the strategic option for five year time intervals throughout the appraisal period.

Table 97 Minimum standard of protection; strategic option F

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	High defences	Higher than 1:200 yr	3	2065-2069	High defences	Higher than 1:200 yr
1	2020-2024	High defences	Higher than 1:200 yr	3	2070-2074	High defences	Higher than 1:200 yr
1	2025-2029	High defences	Higher than 1:200 yr	3	2075-2079	High defences	Higher than 1:200 yr
2	2030-2034	High defences	Higher than 1:200 yr	3	2080-2084	High defences	Higher than 1:200 yr
2	2035-2039	High defences	Higher than 1:200 yr	3	2085-2089	High defences	Higher than 1:200 yr
2	2040-2044	High defences	Higher than 1:200 yr	3	2090-2094	High defences	Higher than 1:200 yr
2	2045-2049	High defences	Higher than 1:200 yr	3	2095-2099	High defences	Higher than 1:200 yr
2	2050-2054	High defences	Higher than 1:200 yr	3	2100-2104	High defences	Higher than 1:200 yr
2	2055-2059	High defences	Higher than 1:200 yr	3	2105-2109	High defences	Higher than 1:200 yr
2	2060-2064	High defences	Higher than 1:200 yr	3	2110-2115	High defences	1:200 yr

Table 98 to Table 100 below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option F in addition to the Do Minimum scenario.

Table 98 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	14	44	69	287
2030	15	54	71	418
2065	42	73	277	1380
2115	76	706	1420	2011

Table 99 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	2	106	185	383
2030	14	149	224	413
2065	97	225	339	831
2115	230	445	790	1190

Table 100 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	16	150	254	670
2030	29	203	295	831
2065	139	298	616	2211
2115	306	1151	2210	3201

The economic benefit of strategic option F in present value terms is summarised in **Table 101** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,598.0m benefits in PV terms. The average benefit cost ratio of the option is 8:1.

Table 101 Strategic option F whole life benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
23	Epoch 1 – High Defences Epoch 2 – High Defences Epoch 3 – High Defences	1,598.0	202.0	8:1

10.3

Development

Strategic option F outlines raised defences from epoch 1 onwards, for the duration of the strategy appraisal period. The raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 1 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are political aspirations for development and redevelopment of the city centre. The approach for the duration of the appraisal period can be considered as beneficial to development and redevelopment of the city centre and in support of the political aspirations. Compared to other options which delay implementing the raised defences and the tidal barrier until epoch 2 or later, strategic option D can be considered favourable in the context of development as it will help development redevelopment / development opportunities from year 0 (or immediately following defence construction) of the appraisal period.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

10.4 Environmental impacts

10.4.1 *Epoch 1, 2 and 3 (High Defences)*

During construction a negligible impact is predicted for air quality and noise as these impacts are likely to be temporary and can be adequately managed through measures contained within a CEMP. There are also unlikely to be impacts on geomorphology and water quality. There will be temporary entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water and therefore the impact is expected to be negligible.

This measure is expected to have a minor negative impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as a section of this alignment is located directly adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI (see **Table 102**). However, the construction phase is temporary and once constructed this measure is unlikely to have a noticeable impact on terrestrial ecology and estuarine/riverine ecology.

There is the potential for significant adverse impacts on archaeological and heritage receptors see **Table 102**. This is because the High Defences have the potential to cause a significant indirect impact on the setting of heritage assets, especially if there are high value receptors in close proximity to the high defences, such as Underfall Yard which is a Scheduled Ancient Monument. The final design of the defences should be sympathetic to these heritage assets and mitigate this impact to some extent; however in the absence of a final design this has not been taken into account.

The High Defences measure is likely to have a minor impact on Traffic & Transport as there will be some additional trips associated with bringing the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts. Negligible impacts are predicated for soil and groundwater as the High Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There is the potential for significant landscape and visual impacts as the high defences will be visually prominent and therefore likely to have a substantial impact on key views and on the Landscape Character of the area.

The level of protection that the High Defences measure will provide is likely to have a significant positive impact on socio-economics as this flood defence measure represents a long term, precautionary approach to managing the impacts of sea level rise which will encourage individuals and developers to invest in the city in the future.

Table 102 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 102: Potential Receptors affected by High Defences in Epoch 1, 2 and 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar, SPA, SAC, and SSSI.	A section of the alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment this is: The Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct/Indirect	<p>There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the high defences.</p> <p>When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.</p>
Landscape and visual	<p>In Reach 2 Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

10.4.2

Summary

In summary, it is expected that significant adverse effects can be avoided or mitigated through sensitive design measures. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

10.5 Risks

10.5.1 *Ground conditions*

A conservative approach has been taken at this stage, with the assumption that the defences will need to be founded on fully continuous piled walls, designed as if the walls were retaining the full height from river bed level to defence crest.

Therefore acquisition of detailed ground investigation data should result in cost savings. Nonetheless there is a risk that unfavourable ground conditions may exist in some locations which could limit the feasibility of the defences following certain route alignments. Should this Strategic Option be taken forward as the preferred strategic option, ground conditions will need to be investigated in subsequent design stages and the appraisal of potential route alignments.

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of ground information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Following this a targeted campaign of investigations on the preferred alignment will be needed.

10.5.2 *Services accommodation*

The design of the raised defences scheduled for epoch 1 will need to consider potential impacts on services and utilities, such as electricity cables, telecommunications cables and water, gas oil and fuel pipelines.

An Optimism Bias of 60% has been added to estimated scheme costs, in part to cover these currently unquantified costs.

Should the Strategic Option be taken forward as the preferred strategic option then depending on the proximity of potential alignments to key services, suitable mitigation will need to be agreed with the bodies responsible for managing the services / utilities. If mitigation is not possible, services and utilities could limit the feasibility of the defences following certain route alignments.

Typically, water companies will ask for a 6m easement to be observed (3m either side of the centreline of the sewer). Other expectations generally include:

- No damage would occur during construction
- No increase in structural loads on the assets
- Access would be maintained for future maintenance, including replacement if necessary
- Easements are maintained
- Diversions or protection works may be required

Mitigation measures with electricity and telecommunication companies will also have to be agreed upon to ensure that the functionality of the services is maintained. If defence alignments cannot be modified to account for key services, it is often possible to divert the services (but this is generally the more expensive option).

Owing to the wealth of studies that have previously been undertaken with regards to defence improvements in central Bristol, a variety of key services / utilities information exists for the study site. In the first instance it is recommended that this information is reviewed in detail. Should gaps in the information be found, or further information be required it may be necessary to obtain key services and utilities data comprising key utility company record plans.

A full up-to-date services assessment will be required prior to developing designs.

10.5.3 *Transport links issues*

Consideration will be needed with regards to the impact of alignments on bridges (and operational infrastructure) and transport links. For example, works adjacent to railway structures will need to comply with strict requirements on ground disturbance. There is a risk of cost increase as a result, again covered by the use of 60% Optimism Bias.

10.5.4 *Visual and landscape impact of permanent defences*

The high defences scheduled for epoch 1 have the potential to impact the landscape and visual character of the study area. Within Bristol city centre this impact is likely to be of particular significance as the city's landscape and architecture is a highly valued aspect of the city's culture and tourism value. Bristol's architecture includes many examples of medieval, gothic, modern industrial and post-war architecture. The visual appeal and continued access to the waterfront along the floating harbour is also important to businesses and tourism for the city and is considered integral to the city's development.

The average height of high defences in epoch 1 relative to ground levels behind the frontline alignments is typically between 1.3 to 1.7m. There are some exceptions to this range, for example at the alignment

at Netham but generally speaking the range is representative. The introduction of defences of this height to the waterfront could be seen as compromising the visual character of the city and therefore mitigation may be necessary to reduce the impact and gain public, political and stakeholder support for the option.

10.5.5 *Impact on fluvial flood risk*

The primary role of the high defence measures in epoch 1 is to provide protection against tidal flood risk. However, being located along the New Cut and Floating Harbour, the defences may also have an impact on the fluvial flood risk to the study area. A number of model simulations have been undertaken to simulate the impact of the defences on the fluvial flood risk.

Three key areas within or adjacent to the study site have been identified as having a fluvial flood risk impact due to the proposed new defences. The three locations are Easton (Newfoundland Way), Lower Easton (M32 underpass) and Netham.

For Easton, there is a marginal increase in flood depths (0.01-0.02m) for the 2015 epoch, however, flood depths generally decrease for the later epochs.

For Netham, there is a significant increase in flood depths during the 2065 epoch and 2115 epoch when flood walls are introduced. During the 2065 epoch there are areas at Netham (in the location where Brislington Brook discharges into the River Avon) which were not initially at risk of flooding, but that are now simulated to be at risk. During the 2115 epoch the flood depths are simulated to increase in areas of residential / commercial landuse by up to 0.24m.

For areas adjacent to the Floating Harbour, comparison of flood extents have shown that although the new flood defences do not completely remove fluvial flood risk, it is not made any worse. If anything, there is a reduction in both flood extents and depths.

For more information on the potential impact on fluvial flood risk, refer to the Options Modelling Report.

10.5.6 *Private property and landowner support*

The measures recommended for each epoch as part of this strategic option are likely to require support from private landowners in order to be successfully delivered. For instance, whilst the preferred alignments for low and high defences are yet to be identified, it is possible that the alignments may pass through privately owned land or property. During the planning phase of the defences it will be imperative to achieve 'buy-in' from these landowners and to work alongside the landowners to ensure that the scheme design is in line with the landowners aspirations and future plans for the area, and to build upon opportunities which may arise with regards to funding. Failure to consult and work alongside private landowners could create planning issues and increase the risk of schemes not being delivered.

10.5.7 *Commitment to maintenance*

The raised defence measures constructed in epoch 1 will require maintenance from the time of construction to sustain the flood defence function. To facilitate this Bristol City Council and partners should develop a long term maintenance strategy, which should include regular and periodic defence condition assessments and repair works. The strategy will allow for maintenance works to be prioritised across the Strategy frontage and to help ensure that funding streams for maintenance are secured in the long term. There is a risk that should maintenance not be undertaken on a regular basis, then defences may fall into disrepair and be more likely to fail during times of flooding, increasing the residual flood risk to the city. A long term commitment to maintenance is essential for this option to be an effective flood risk management approach.

10.5.8 *Precautionary approach to flood risk management*

This option represents a precautionary approach to flood risk management whereby high defences are constructed to a 2115 standard from epoch 1 onwards (2030). At the time of construction the design information for the defences (to establish crest level and defence length) will rely on using information from long term climate change projections. Climate change projections over this length of time (i.e. 85 years from 2030 to 2115) are characteristically uncertain and in reality it is possible that sea levels and other sources of flood risk may rise at a different rate to what the projections suggest. If, for example, sea levels were to rise slower than expected, the high defence measures are likely to be considerably 'overdesigned' and may represent a wasted investment.

10.6 *Wider opportunities*

10.6.1 *Facilitate development and redevelopment opportunities*

The raised defences scheduled for epoch 1 will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas. This is in line with the political aspirations for the city and is a major advantage of this option.

By providing robust defences, it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds.

Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

10.6.2 **Environmental enhancement**

Raised defence schemes in epoch 1 could provide opportunities to locally enhance the environment, mainly in terms of the visual/landscape aspect of the waterfront.

Landscaping of the new defences could be carried out which could enhance the character and visual appeal of some areas. Enhancement might include improved surfacing for existing routes, better lighting to improve safety, addition of marked cycleway, provision of ramps in place of stepped accesses and provision of seating and viewing areas.

Potential approaches to mitigate impacts of walls on the visual environment would be to include 'softer' structure types as part of the raised defence measures, such as reinforced glass walls which could help to sustain the views and connection to the waterfront, or use of self-raising walls which in normal use are lower than the required crest level. Some examples of these techniques are provided in **Figure 15** and **Figure 16**.

10.7 **Next steps**

Should this Strategic Option be the preferred Strategic Option the following next steps will be required:

- Feasibility study for High Defences scheme - including identifying preferred alignments in each location. Identifying preferred alignments should be done following a full review of the available supporting information, such as the ground condition and services data that is available. Full topographic surveys and ground investigation will be required to support the design. Broader outcomes will need to be considered – access, amenity and recreation benefits that can be built in, such as improved cycleways or lighting, access for the disabled.
- Engagement with stakeholders for the High Defences scheme – BCC city docks (as harbour authority), affected landowners and businesses, residents, community groups, statutory organisations.
- Should approval / funding from the Environment Agency be required it will be necessary to develop Outline Business Case(s) (OBC) and Full Business Case(s) (FBC). This should be done once the project has been included on the Environment Agency's programme of flood and coastal erosion risk management schemes. In order to get approval it will be necessary to use the correct EA template to align with the HM Treasury's Five Case Model.
- Development of High Defences designs, including landscape and amenity elements
- Environmental assessment of High Defences at scheme level
- Ecological surveys and related issues will need to be addressed
- Planning consent for High Defences scheme (technically may not be required, but recommended)
- Procurement and construction of High Defences scheme

11. STRATEGIC OPTION G (DO MINIMUM – DO MINIMUM – HIGH DEFENCES)

11.1 Description

This strategic option involves doing minimum in epochs 1 and 2 (2015-2065) before constructing high defences in epoch 3 (2065-2115).

The sequence of doing minimum for a significant part of the appraisal period before constructing the high defences later on, from 2065 represents an adaptive approach to managing the flood risk in the study area.

In 2065 the high defences will be constructed to a 1:200 year standard of protection for 2115 and will therefore provide a standard of protection in excess of the 200 year standard for the duration epochs 3 (the standard will gradually fall over time due to sea level rise, expected to drop to a 1:200 year standard by 2115).

An advantage of the adaptive approach is that the proposed heights and lengths of the high defences (as outlined in the Strategy) can be adjusted prior to their construction according to the magnitude of sea level rise that is occurring. This will help to prevent overdesign and wasted investment for this measure.

11.1.1 *Epoch 3 (High Defences)*

In epoch 3 high defences would be constructed on a city wide scale and in the Pill / Shirehampton area. The defences would be constructed to a 1 in 200 year standard of protection for 2115. Approximately 7.2km of new raised defences across the study area will be required alongside the instalment of new tidal stop gates (and operational infrastructure) at Entrance Lock and Netham Lock. The new raised defences will be required at the following locations; Pill, Shirehampton, Entrance Lock, Cumberland Road, Commercial Road, Clarence Road, Cattle Market Road, Totterdown and St. Phillips, Netham and Bath Road. In each location different alignment opportunities and engineering solutions exist and a preferred alignment at each location will be decided upon during future, more detailed appraisal work carried out at the local level.

For the purpose of the preferred option costing it has been assumed that the alignment at each location will be a frontline solution. This assumption has been made in order to provide a conservative cost estimate (i.e. worst case cost scenario). The reader should be aware that this assumption has been made for costing purposes only and the preferred route alignments at each location have yet to be chosen. Further information and analysis is required to select the preferred route alignment.

For the frontline alignments the indicative lengths and heights for the high defences have been established. Land levels along the alignment have been extracted in GIS using LiDAR data and topographic data if available. Topographic data was available and considered for the following locations; Entrance Lock (partial coverage), Cumberland Road, Commercial Road, Cattle Market Road and Totterdown. The ground levels 3-5m behind the frontline alignments have also been extracted to give an indication of the height of the high defences relative to the adjacent pavement / road levels.

The design crest levels for the high defences were established from numerical modelling. Peak water levels at the defence locations were used to estimate the indicative crest levels. Refinements to the design levels were then made after further simulations that included the defences were undertaken. The high defences are designed to a 2115 1:200 standard and therefore to avoid an overly precautionous design the freeboard allowance that has been applied is less than the typical 0.15m (i.e. that applied to the low defence measure within the Strategy). This is considered an acceptable approach given that the high defences are designed for future conditions and are therefore already conservative by design (designed to 2115 1:200 standard but constructed in 2065).

Table 103 presents the length, design crest level, land/bank levels and indicative heights of the defences along their alignments and also the land levels setback 3-5m. For the land level parameters the average and minimum values are presented to give an indication of the maximum defence height that may occur. The locations of the high defences are shown in **Figure 12** and **Figure 13**.

Table 103 shows that the average land level in the position 3-5m setback from the frontline alignments varies with location. Relative to the design crest levels the land elevation falls between 1.14*m (Cattle Market Road) and 2.26*m (Netham) below the crest level. In many locations there are roads / pathways adjacent to the frontline defence alignments and this marker gives an indication of the height of the defences relative to these features. Typically the mean defence height relative to the ground level behind is within the range 1.3 to 1.7m.

Table 103 High defences; lengths and heights of high defences, 2065

Location	Design crest level (including freeboard) (m ODN)	Length (m)	Mean land/bank level along alignment (m ODN)	Min land/bank level along alignment (m ODN)	Indicative mean defence height (m)	Mean land level setback from alignment (3-5m) (m ODN)	Min land level setback from alignment (3-5m) (m DON)	Indicative mean defence height setback from alignment (3-5m) (m)
Entrance Lock	10.15	1090	7.42	3.31	2.73	8.44	5.57	1.71
Cumberland Road	10.15	620	8.55	8.46	1.69	8.63	8.37	1.52
Cumberland Road East	10.15	18	8.71	8.44	1.44	8.71	8.44	1.44
Commercial Road	10.15	261	8.29	4.45	1.86	9.00	7.72	1.15
Clarence Road	10.15	575	7.65	5.70	2.50	8.85	8.00	1.30
Cattle Market Road	10.20	58	8.97	7.84	1.23	9.06	7.92	1.14
Totterdown	10.20	1589	8.92	7.38	1.28	8.89	7.21	1.31
Netham	10.25	553	7.75	3.62	2.50	7.99	3.89	2.26
Bath Road	10.20	464	7.18	5.45	3.02	8.53	6.86	1.67
Pill	9.95	1183	8.29	5.04	1.66	8.58	6.38	1.37
Shirehampton	10.25*	786	7.86	6.64	2.39	8.71	7.36	1.54

*Shirehampton alignment includes 0.3m freeboard allowance. This alignment is likely to be an embankment and a larger freeboard allowance is provided to account for settling of the defence

11.1.2

All epochs (Do Minimum and Maintenance)

For epochs 1 and 2 and alongside the high defences in epoch 3 which are outlined for this strategic option it will be necessary to undertake do minimum and maintenance activities throughout.

Do minimum activities involve the continuing operation and maintenance of the floating harbour water level control assets and infrastructure and maintaining the existing defence assets. It will be necessary to continue these activities for each epoch alongside the construction and maintenance of the new high defences in epoch 3. The high defence measure includes the installation of new stop gates at Entrance lock and Netham Lock. Once these features are installed the do minimum activities from epoch 3 onwards should include the operation of the gates in addition to the existing water level control assets in the floating harbour.

For the new high defences it is recommend that regular condition inspections are carried out alongside the development and implementation of a maintenance strategy.

It will also be necessary to operate any flood gates that may have been included as part of the high defence alignments. It is recommended that Bristol City Council employ a specialist team or a specially

trained team from Docks/Marine services to operate the gates during flood conditions to limit the residual risk of the gates being left open or other failures from occurring.

Further details of the do minimum activities and maintenance of the high defences are found in Appendix 1.

11.2 Economic Costs and Benefits

11.2.1 Non-discounted (cash) costs

High level costs for strategic option G have been developed. Costs for constructing the high defences have been estimated, and on the first basis were built up in cash terms. Costs associated with maintenance and undertaking the do minimum activities have also been developed.

A summary table outlining the estimated cash costs for the measures in strategic option G are presented in **Table 104** below. In total, the cash cost for implementing strategic option G is approximately £276million. The majority of this cost will come in epoch 3, when the high defences are constructed.

More details on the methodology that has been used to estimate the cash costs for the strategic option can be found in Appendix 1.

Table 104 Summary of non-discounted (cash) costs for strategic option G

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Do Minimum activities	8.9 (average 0.6 per annum)	8.9
Epoch 2 (2030 – 2065)	Do Minimum activities	29.2 (average 0.8 per annum)	29.2
Epoch 3 (2065 – 2115)	High defences - construction	165.3	237.9
	Maintenance of low defences	62.9 (average 1.6 per annum)	
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			276.0

A more detailed breakdown of the cash costs associated with the specific measures in each epoch is provided in the **Table 105** to **Table 107** below.

Table 105 Breakdown of non-discounted (cash) costs for epoch 1; Strategic option G

Epoch 1					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Do minimum activities	Floating Harbour operations	0	0.1 (total 1.5 over epoch 1)	8.9	8.9
	Maintenance of existing defences	0	0.5 (total 7.5 over epoch 1)		

Table 106 Breakdown of non-discounted (cash) costs for epoch 2; Strategic option G

Epoch 2					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
Do minimum activities	Floating Harbour operations	0	0.1 (total 3.5 over epoch 2)	29.2	29.2
	Maintenance of existing defences	0	0.7 (total 25.7 over epoch 2)		

Table 107 Breakdown of non-discounted (cash) costs for epoch 3; Strategic option G

Epoch 3					
Measure	Component	One-off cash cost (£m) including 60% optimism bias	Ongoing annual cash costs (£m) including 60% optimism bias	Total cash cost (£m) for measure	Total cash cost (£m) for epoch including 60% optimism bias
High defences	Entrance Lock – new defence, capital works	25.2	0	228.2	237.9
	Cumberland Road – new defence, capital works	14.9	0		
	Cumberland Road East – new defence, capital works	0.1	0		
	Commercial Road – new defence, capital works	5.7	0		
	Clarence Road – new defence, capital works	13.4	0		
	Cattle Market Road – new defence, capital works	1.4	0		
	Totterdown – new defence, capital works	38.4	0		
	Netham – new defence, capital works	12.7	0		
	Bath Road – new defence, capital works	10.6	0		
	Pill – new defence, capital works	28.3	0		
	Shirehampton – new defence, capital works	1.5	0		
	Entrance Lock and Netham Lock gate upgrades	13.0	0		
	Maintenance – all locations	0	1.6 (total 62.9 over epoch 3)		
Do minimum activities	Floating Harbour operations	0	0.1 (2065-2089), 0.3 (2090+) (total 9.7 over epoch 3)	9.7	
	Maintenance of existing defences	0	0*		

*(assumed cost will be covered by the cost of maintaining primary measure)

11.2.2 Present value costs

Present value costs consider discounting to enable the whole life cost of an option to be established in today's cost terms. This enables the cost of the strategic option to be compared to that of the other strategic options. Standard discount rates have been used to convert the cash cost of strategic option G to a present value cost. According to the FCERM-AG, the following variable discount rates have been used

within the economic appraisal; 3.5% for the years 0 to 35, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in an overall PV factor over the 100 years at 29.9.

A present value cost profile for strategic option G has been developed. This has been done by applying the discount factor to the cash cost of the various measures for the year in which they are to be implemented.

Within the cost profile the cost of the capital works (i.e. the construction of the high defences) has been discounted using the discount factor for the year at the beginning of the time epoch in which it is to be implemented; 2065. For maintenance/operation and other costs (other costs representing the costs of do minimum activities), an average annual cash cost has been applied for the duration of the appraisal period and discounted on a yearly basis. The average annual cash cost for these activities differs between time epochs due to the implementation of the primary measures.

The present value cost profile is provided in **Table 108** below. As shown, the total present value cost for strategic option G is estimated to be approximately £57million. Of this, the majority of the investment (in present value terms) is required in epoch 3, with the construction of the high defences.

Table 108 Cost profile of non-discounted (cash) and present value (PV) costs for strategic option G

Epoch	Cash cost (£m) including 60% optimism bias				Present value cost (£m) including 60% optimism bias			
	Capital	Maintenance	Other	Total	Capital	Maintenance	Other	Total
Epoch 1	0	0	8.9	8,947	0	0	7.1	7.1
Epoch 2	0	0	29.2	29,200	0	0	10.5	10.5
Epoch 3	165.3	62.9	9.7	237,868	32.6	5.6	0.9	39.2
	Total			276.0	Total			56.8

11.2.3

Economic benefits

Table 109 below presents the minimum standard of protection provided by the strategic option for five year intervals throughout the appraisal period. For do minimum in epochs 1&2 an SoP of 1:2 year and 1:1 year has been assumed respectively.

Table 109 Minimum standard of protection; strategic option G

Epoch	Time interval	Measure	Target standard of protection	Epoch	Time interval	Measure	Target standard of protection
1	2015-2019	Do Min	1:2 yr	3	2065-2069	High Defences	Higher than 1:200 yr
1	2020-2024	Do Min	1:2 yr	3	2070-2074	High Defences	Higher than 1:200 yr
1	2025-2029	Do Min	1:2 yr	3	2075-2079	High Defences	Higher than 1:200 yr
2	2030-2034	Do Min	1:1 yr	3	2080-2084	High Defences	Higher than 1:200 yr
2	2035-2039	Do Min	1:1 yr	3	2085-2089	High Defences	Higher than 1:200 yr
2	2040-2044	Do Min	1:1 yr	3	2090-2094	High Defences	Higher than 1:200 yr
2	2045-2049	Do Min	1:1 yr	3	2095-2099	High Defences	Higher than 1:200 yr
2	2050-2054	Do Min	1:1 yr	3	2100-2104	High Defences	Higher than 1:200 yr
2	2055-2059	Do Min	1:1 yr	3	2105-2109	High Defences	Higher than 1:200 yr
2	2060-2064	Do Min	1:1 yr	3	2110-2115	High Defences	1:200 yr

Table 110 to **Table 112** below present the number of properties (residential, commercial and total) which would be protected and would benefit from strategic option G in addition to the Do Minimum scenario.

Table 110 Numbers of properties protected in addition to the Do Minimum scenario; residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	0	0	0	0
2030	0	0	0	0
2065	42	73	277	1380
2115	76	706	1420	2011

Table 111 Numbers of properties protected in addition to the Do Minimum scenario; non-residential

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	0	0	0	0
2030	0	0	0	0
2065	97	225	339	831
2115	230	445	790	1190

Table 112 Numbers of properties protected in addition to the Do Minimum scenario; total

Epoch	Return Period			
	1:2yr (50%)	1:20yr (5%)	1:75yr (1.33%)	1:200yr (0.5%)
2015	0	0	0	0
2030	0	0	0	0
2065	139	298	616	2211
2115	306	1151	2210	3201

The economic benefit of strategic option G in present value terms is summarised in **Table 113** below. Also shown is the whole life present value cost and average benefit cost ratio of the option. In total, the option is estimated to produce £1,429.8m benefits in PV terms. The average benefit cost ratio of the option is 25:1.

Table 113 Strategic option G whole life benefits

Strategic option	Measures	Whole life PV benefits (£m)	Whole life PV cost (£m)	Average Benefit : Cost ratio
36	Epoch 1 – Do Minimum Epoch 2 – Do Minimum Epoch 3 – High Defences	1,429.8	56.8	25:1

11.3

Development

Strategic option G outlines Do Minimum for epochs 1 and 2. This measure does not provide additional flood risk protection to any areas above what is already being undertaken (i.e. present day). As a result of this measure there will be no areas benefiting from permanent flood defences during epochs 1 and 2 therefore this measure does not facilitate the development or redevelopment opportunities within the city centre or elsewhere within the study site.

From epoch 3 onwards the raised defences that are scheduled will provide a specified standard of flood protection to the city, benefiting numerous areas which would otherwise be at risk of flooding. This will facilitate development and provide redevelopment opportunities in the benefit areas.

By providing robust defences from epoch 3 it should be possible to develop inside the defence perimeter in a way that is currently not possible, by for example not having to raise individual property thresholds. Given that the defences will facilitate development opportunities are likely to arise for Bristol City Council to work with developers to secure investment to the schemes from epoch 3 onwards. This will be in line with the Environment Agencies 'partnership funding' approach to fund flood risk management schemes and will help to unlock additional grant-in-aid funding and other sources of funding to help the schemes go ahead.

There are political aspirations for development and redevelopment of the city centre. The do minimum approach for epochs 1 and 2 does not support this is therefore, being utilised across half of the appraisal period, this strategic option is unlikely to be considered acceptable in the context of development and aspirations. This is despite the use of high defences in epoch 3 which will facilitate development for this period only.

It should be noted that Local Planning Authorities (LPAs) consider more precautionary allowances for climate change. For more information refer to: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances>.

11.4 Environmental impacts

11.4.1.1 *Epoch 1 and 2 (Do Minimum)*

Overall, this flood defence measure is likely to have a limited environmental impact, compared with the Do Nothing baseline conditions. It is acknowledged that there would be less negative impacts on environmental aspects under this scenario compared with Do Nothing, which is predicted to lead to greater and more frequent flooding, however these are infrequent and short duration events.

There may be a negative impact on socio-economics, as flood defences will not be raised, and as a result of sea level rise the standard of flood protection is expected to fall over time (although still better than the Do Nothing baseline). This may deter developers and individuals from investing in the city in the future.

11.4.1.2 *Epoch 3 (High Defences)*

During construction a negligible impact is predicted for air quality and noise as these impacts are likely to be temporary and can be adequately managed through measures contained within a CEMP. There are also unlikely to be impacts on geomorphology and water quality. There will be temporary entrainment of sediment during riverbed disturbance, but this is unlikely to affect the overall quality of the water and therefore the impact is expected to be negligible.

This measure is expected to have a minor negative impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly in Pill as a section of this alignment is located directly adjacent to the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI (see **Table 114**). However, the construction phase is temporary and once constructed this measure is unlikely to have a noticeable impact on terrestrial ecology and estuarine/riverine ecology.

There is the potential for significant adverse impacts on archaeological and heritage receptors. This is because the High Defences have the potential to cause a significant indirect impact on the setting of heritage assets, especially if there are high value receptors in close proximity to the high defences, such as Underfall Yard which is a Scheduled Ancient Monument, other receptors within 100 m of the defence alignment are presented in **Table 114**. The final design of the defences should be sympathetic to these heritage assets in order to mitigate this impact to some extent.

The High Defences measure is likely to have a minor impact on traffic and transport as there will be some additional trips associated with bringing the materials used for the defences to site but these will be over a relatively short period of time and distributed across large parts of the transport network. A Transport Management Plan should be able to adequately address any negative impacts. Negligible impacts are predicated for soil and groundwater as the High Defences may generate pollutant pathways but these will be managed through an appropriate risk assessment and Ground Investigations, as well as any remediation measures.

There is the potential for significant landscape and visual impacts as the high defences will be visually prominent and therefore likely to have a substantial impact on key views and on the Landscape Character of the area.

The level of protection that the High Defences measure will provide is likely to have a significant positive impact on socio-economics as this flood defence measure represents a long term approach to managing the impacts of sea level rise which will encourage individuals and developers to invest in the city in the future.

Table 114 presents a summary of the environmental and social receptors that have the potential to be affected by this measure, along with a short description of the potential impact.

Table 114: Potential Receptors affected by High Defences in Epoch 3

Environmental / social aspect	Receptor	Location of receptor relative to development	Direct / Indirect Impact	Description of Impact
Ecology	Severn Estuary Ramsar, SPA, SAC, and SSSI.	A section of the alignment at Pill immediately borders the designated site.	Direct	This measure is expected to have a minor adverse impact on terrestrial ecology and estuarine/riverine ecology during the construction stage, particularly if the works take place within an ecologically sensitive area such as the Severn Estuary which is designated as a Ramsar site, SPA and SAC, and SSSI. However, the construction phase is temporary in nature and once constructed this flood defence measure is unlikely to have a discernible impact on terrestrial ecology and estuarine/riverine ecology.
Cultural Heritage	<p>In Reach 2 the defence alignment in Pill extends in front of two Grade II Listed Buildings: Watch House, Retaining Walls to the River and Garage, and Mulberry Cottage Mulberry House.</p> <p>There is one Grade II Listed Building within 100 m of the Shirehampton alignment. This is: The Lamplighters Public House.</p> <p>In Reach 3 the Listed Buildings which have the potential to be affected are: Grade II* Listed Swing Bridge over North Entrance Lock, Grade II* Listed Swing Bridge over Brunel's South Entrance Lock, Grade II* Listed Brunel's South Entrance Lock, Grade II Listed B Bond Tobacco Warehouse, Grade II Listed Ashton Swing Bridge, Grade II Listed A Bond tobacco Warehouse, Grade II Vauxhall Bridge, Grade II Strand Buildings and 6 Grade II Listed buildings on Cumberland Road, Grade II Listed Bedminster Bridge and Grade II Listed Drinking Fountain 3 metres north west of Bedminster Bridge, Grade II Listed Temple Meads Station, Grade II Langton Street Bridge, Grade II Listed Netham Lock and Lock Keepers House.</p> <p>The Conservation Areas which are likely to be affected by this measure are City Docks, Redcliffe, and Bedminster.</p> <p>Underfall Yard which is a Scheduled Ancient Monument also has the potential to be impacted by this measure.</p>	Within 100 m of the defence alignment.	Direct/Indirect	There are likely to be some small and noticeable direct impacts on archaeology and heritage receptors, especially if there are high value receptors in close proximity to the low defences. When considering the setting of archaeology and heritage receptors this may also result in a minor indirect impact, particularly if the defence is built in close proximity to high value receptors such as the Underfall Yard.
Landscape and visual	<p>In Reach 2 Pill is located within Avon Valley Rolling Farmland Landscape Character Area (LCA). The Shirehampton alignment is not located within an LCA.</p> <p>There are no Landscape Character Areas within Reach 3. The Conservation Areas which could be impacted are Bristol Docks and Bedminster.</p>	The western part of the development is within this LCA	Direct	<p>There may be a temporary construction impact, as the presence of construction compounds, working areas, and mobile plant equipment has the potential to temporarily change the character of the area and visual amenity.</p> <p>In the operational stage this defence may impact on local views, particularly views to and from the river.</p>

11.4.2

Summary

In summary, it is expected that significant adverse effects can be avoided or mitigated through sensitive design measures. A significant positive impact on socio-economics will result as a consequence of the improved flood protection associated with the high defences.

11.5 Risks

This Option presents a substantial risk of a major flood event occurring in the 50 year period prior to new defences being implemented, with corresponding impact on Bristol, its residents and businesses.

For the risks associated with the implementation of High Defences in epoch 3, please refer to section 10.5.

11.6 Wider opportunities

No wider opportunities during epochs 1 and 2. In epoch 3 there will be wider opportunities associated with the construction of High Defences. Please refer to section 10.6 for an overview of these opportunities.

11.7 Next steps

During the initial two epochs of this option it will be necessary to engage with stakeholders to explain the Do Minimum approach and the reasoning for it. Later on in the Strategy, to implement the High Defences in epoch 3 it will be necessary to undertake the next steps which are outlined in section 10.7.

12. APPRAISAL OF SHORT LIST OPTIONS

12.1 Decision making process

The process for selecting the preferred strategic option is largely based upon the Environment Agency's Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) decision making criteria.

The approach involves comparing the economic costs and benefits of the strategic options to choose the leading economic option. Additional consideration is then made to the Strategy objectives, contributions and funding and uncertainty to decide whether the leading economic option should change, or whether it should be the preferred strategic option.

The decision making process can be split into five distinct stages which are as follows:

12.1.1 **Stage 1 – whole life costs and benefits**

Establish the whole life costs and benefits of each of the seven strategic options on the shortlist, and the Do Minimum baseline scenario. Ensure that the average benefit cost ratio (ABCR) for each option is >1 . If the ABCR <1 , then that strategic option is removed from the process.

12.1.2 **Stage 2 – organise options**

Based upon the decision making rules set out in FCERM-AG, the options are then organised by the extent to which they reduce the probability of flooding.

Given that each option comprises a sequence of measures whose standard of protection varies, it is difficult to rank the options using an average standard of protection for the full appraisal period. The total costs and benefits of the strategic options have therefore been used as indicators for the standard of protection and the options have been ranked on this basis. Once ranked, the option with the highest ABCR is identified as the provisional leading economic option.

Next, the incremental benefit cost ratio (IBCR) of the options is considered. In FCERM-AG the IBCR is used to inform the cost-effectiveness of different options. It is defined as the difference in benefit between two options, divided by the difference in cost. This is a measure of the return from the additional investment from one option to the next.

The IBCR of each option is calculated and then starting at the provisional leading option, with the options being ordered by reduced probability of flooding, if the IBCR ratio of the next option is sufficient, then this option becomes the new leading economic option. Moving through the options this process is repeated until the next option on the list does not have an IBCR that is sufficient to justify the increase in expenditure.

12.1.3 **Stage 3 – consider Strategy objectives**

The leading economic option is then considered against the objectives of the Strategy, such as stakeholder and community aspirations, environmental impact and development facilitation. The choice of the leading option is reconsidered if an alternative option from the shortlist demonstrates a significantly stronger case in terms of meeting the strategy objectives.

12.1.4 **Stage 4 – accounting for contributions and funding**

Financial contribution and likelihood of funding is considered to evaluate whether this should change the choice of the leading option. Bristol City Council's appetite for making up funding shortfalls will be taken into account. If there is a realistic prospect of funding the leading option it will be selected, otherwise an alternative option from the shortlist with a realistic prospect of funding will be identified and selected as the leading option.

12.1.5 **Stage 5 – testing uncertainty**

In the final stage of decision making a number of sensitivity tests are carried out to assess whether uncertainty changes the selection of the leading option. The sensitivity tests include:

- altering the cost of the options by changing the levels of optimism bias
- altering the level of indirect benefits accrued by the options, such as increasing / decreasing loss of life estimates and benefits arising from protecting heritage features
- consideration of different futures such as varying rates of sea level rise; i.e. how do different rates of sea level rise impact the benefits and the ABCR of the options?

12.2 Appraisal

This section describes the appraisal of the short list options. It is divided into sections relating to the appraisal decision making process; the economic analysis, objectives, contributions and funding, and uncertainty.

12.2.1 *Economic analysis (whole life costs and benefits and ordering options)*

Table 115 presents the 7 short-listed strategic options in order of reduced probability of flooding (i.e. those providing the lowest standard of protection at the top with an increasing standard moving down the list). Also presented is the do minimum scenario whereby only the do minimum measure is undertaken for each epoch during the appraisal period. Implementing the do minimum approach for the next 100 years is not considered to be an acceptable solution to flood risk management and is presented for comparison purposes only.

The option costs and benefits have been used as an indicator of the standard of protection of the options and to order the options in **Table 115**. The minimum standards of protection for each strategic option (broken down into 5-yearly time intervals) are presented in previous sections of this report.

The quoted standard is presented as a guide and plays no part in the preferred option selection process.

Table 115 Strategic option costs and benefits. Ordered by increasing cost and SoP

Strategic option	Sequence of measures	Economic costs PV (£m)	Economic benefits PV (£m)	ABCR	Provisional leading economic option
NA	Do Min – Do Min – Do Min	23.7	1,315.8	56:1	×
G	Do Min – Do Min – High Def	56.8	1,429.8	25:1	✓
A	PLP – Low Def – High Def	112.7	1,546.0	14:1	×
B*	PLP – High Def – High Def	130.3	1,560.0	12:1	×
D	Low Def – Low Def – High Def	166.3	1,575.9	9:1	×
F	High Def – High Def – High Def	202.0	1,598.0	8:1	×
C	PLP – Barrier – Barrier	471.1	1,571.5	3:1	×
E	Low Def – Barrier - Barrier	595.2	1,598.7	3:1	×

As shown in **Table 115**, the provisional leading economic option when based upon the ABCR is strategic option G. This option has the highest ABCR of the options with an estimated PV cost of £57million and PV benefits of £1,430 million (ABCR of 24:1).

The IBCR of the short-listed strategic options has been calculated to determine whether there is an economic case for additional investment to improve the average standard of protection and to select an alternative strategic option as the leading economic option. **Table 116** presents the IBCR of the strategic options.

According to FCERM-AG, in order to justify an increase in the standard of protection from 1:75yr standard to a 1:200yr standard it is necessary to have an IBCR > 3. However, the purpose of the preferred options phase of the Strategy has been to robustly identify a preferred option and to demonstrate how this choice was arrived at, rather than to develop a compliant FCERM-AG business case. In addition, the IBCR threshold of > 3 only applies if there is no significant contribution to from BCC or other sources. As such, for this phase of the Strategy an IBCR ratio > 1 has been used to compare the options and to justify moving between options to select the leading economic option.

Table 116 IBCR of the strategic options

Strategic option	Sequence of measures	Economic costs PV (£m)	Economic benefits PV (£m)	ABCR	Provisional leading economic option	IBCR	Revised leading economic option
NA	Do Min – Do Min – Do Min	23.7	1,315.8	56:1	*	NA	*
G	Do Min – Do Min – High Def	56.8	1,429.8	25:1	✓	NA	*
A	PLP – Low Def – High Def	112.7	1,546.0	14:1	*	2.08	✓
B*	PLP – High Def – High Def	130.3	1,560.0	12:1	*	0.79	*
D	Low Def – Low Def – High Def	166.3	1,575.9	9:1	*	0.44	*
F	High Def – High Def – High Def	202.0	1,598.0	8:1	*	0.62	*
C	PLP – Barrier – Barrier	471.1	1,571.5	3:1	*	(-ve)	*
E	Low Def – Barrier - Barrier	595.2	1,598.7	3:1	*	0.22	*

*note – strategic option B ranked above D as the target SoP of the options are similar but option D has greater economic benefits

The IBCRs are presented in **Table 116**. They demonstrate that the choice of the leading economic option changes to strategic option A when the IBCR is considered. Previously option G was identified as the leading economic option (based on ABCR), but the IBCR demonstrates a strong economic case for additional investment to option A, which has a higher average standard of protection. The IBCR of strategic option A is 2.08 which is greater than 1.0. Relative to option G, the additional investment required for strategic option A is less than the value of additional benefits that it provides.

The option next in the list which provides the next highest option benefits and a higher average standard of protection is strategic option B. The IBCR of moving from option A to option B is 0.79 which is less than 1.0. This demonstrates that relative to option A, the additional investment required for strategic option B is more than the value of additional benefits that it provides.

As a result of the above analysis, the **leading economic option** is identified as strategic **option A**; PLP / temporary defences, low defences, then high defences.

Further investigation of the IBCR's between the options is undertaken below to provide additional evidence and context for the next stages of the decision making process (i.e. considering objectives, funding and uncertainty).

The IBCRs of moving from raised defence options to barrier options (options C and E) are < 1. In fact, moving from option F (high defences option for epochs 1, 2&3) to option C (lowest cost barrier option) has a negative IBCR. This is because option C is significantly higher cost than option F, yet the whole life benefits are actually reduced as the barrier is not constructed until epoch 2 and flood damages can occur before this.

A set of additional IBCR calculations have been undertaken to separately compare the barrier options 10 and 21 to the do minimum option (the scenario whereby do minimum is undertaken in each epoch). In these calculations the costs and benefits of the barrier options are set relative to the do minimum scenario. Rather than calculating the IBCR between barrier options the IBCR has been calculated for each option relative to do minimum. **Table 117** presents the results of these calculations.

Table 117 IBCR of options 10 and 21 relative to the do minimum approach

Strategic option	Sequence of measures	Economic costs PV (£m) (relative to Do Min)	Economic benefits PV (£m) (relative to Do Min)	IBCR (relative to Do Min)
NA	Do Min – Do Min – Do Min	NA	NA	NA
C	PLP – Barrier – Barrier	447.5	255.8	0.57
E	Low Def – Barrier - Barrier	571.5	283.0	0.50

As demonstrated in **Table 117**, the IBCR ratios of the barrier options relative to do minimum are less than 1. This suggests that there is not an economic case to implement either barrier option as the increase in benefits from the barrier options relative to do minimum is less than the increase in cost. On this basis, the barrier options, options C and E are ruled out from the preferred option appraisal process.

The IBCR analysis also shows that there is little to differentiate between the IBCR's of strategic options A, B, D and F. These options have raised defences at their core from epochs 1&2 onwards and have IBCR's ranging from 0.44 to 2.08 in **Table 118**. The cost of these options varies between £113 million and £202 million and the benefits between £1,546million and £1,598million. Of these options, the strategic option with the highest IBCR is option A which involves constructing raised defences from epoch 2 and using PLP / temporary defences in the interim to manage the residual risk. As outlined previously, strategic option A is the leading economic option.

A set of additional IBCR calculations have been undertaken to separately compare the raised defence options A, B, D and F to the do minimum option (the scenario whereby do minimum is undertaken in each epoch). In these calculations the costs and benefits of the raised defence options are set relative to the do minimum scenario. Rather than calculating the IBCR between raised defence options the IBCR has been calculated for each option relative to do minimum. **Table 118** presents the results of these calculations.

Table 118 IBCR of options 6, 9, 17 and 23 relative to the do minimum approach

Strategic option	Sequence of measures	Economic costs PV (£m) (relative to Do Min)	Economic benefits PV (£m) (relative to Do Min)	IBCR (relative to Do Min)
NA	Do Min – Do Min – Do Min	NA	NA	NA
A	PLP – Low Def – High Def	89.0	230.2	2.59
B*	PLP – High Def – High Def	106.6	244.2	2.29
D	Low Def – Low Def – High Def	142.6	260.2	1.82
F	High Def – High Def – High Def	178.3	282.2	1.58

As shown in **Table 118**, the IBCR of each of the raised defence options (A, B, D & F) relative to do minimum is greater than 1. This demonstrates an economic case to undertake each of these options (relative to do minimum) as the additional benefits produced by the options compared to do minimum outweigh the increase in costs. There is little difference between the IBCR's presented in **Table 118**, with the ratios ranging between approximately 1.6 and 2.6. Given how close the IBCRs of the options are there is no clear choice of option with the strongest economic case. However, it is clear that by delaying the construction of the raised defences until epoch 2 the IBCR is improved, with options 6 and 9 having the higher IBCRs in **Table 118**.

12.2.2 **Objectives - Overview**

The following Objectives were set at the outset of the development of the Strategy, against which the Preferred Strategic Option has been tested:

1. To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks
2. To facilitate the sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure
3. To maintain, and where possible enhance, natural, historic, visual and built environments
4. To reduce whole life costs
5. To ensure navigation of the River Avon and marine activities can continue
6. Ensure the Strategy is technically feasible and deliverable over its duration

Based on the economic analysis strategic **option A** is identified as the **leading economic option**. However, as part of the decision making process it is necessary to also consider the objectives of the Strategy to select the **preferred option**. Based on the Strategy objectives the leading economic option may not be selected as the preferred option if other options better meet the objectives and are still economically robust.

The non-economic criteria are focussed on reducing flood risk, technical robustness, continuation of navigation, environmental sustainability and facilitation of growth of Bristol.

Issues related to flood risk and technical robustness have been addressed in the development of the options.

All of the options are considered acceptable from a navigation perspective. The tidal barrier options are the only ones which present any significant potential impact on navigation, and the technical studies undertaken have shown that there are feasible designs which can be implemented without significantly constraining navigation.

The objectives for Environment and Growth are considered below in more detail.

12.2.3 **Objectives - Environment**

Environmental sustainability has been considered in the environmental assessment of each option, and as a whole in the SEA (Strategic Environmental Assessment, August 2016, AECOM)

The SEA has found that although all of the options have a potential for significant adverse impacts on quality of life and natural and built environments, whether temporary or permanently, there is also a potential to mitigate these impacts and an opportunity to provide enhancement as part of the design of all options.

The SEA has identified serious issues that would need to be addressed, but has not identified a 'showstopper' – an issue so serious that it would lead to the outright rejection of an Option.

Overall the SEA has found that there is not a clear 'best option' from an environmental perspective. The reason for this is that the barrier options concentrate their direct impacts on relatively small area, although the intensity of impact may be great. On the other hand the wall options will directly impact receptors over a large area. The impact of the barrier at distance is a current unknown, and would require some detailed investigations to resolve.

Similarly, some of the options have multiple phases, thereby potentially impacting adversely on several occasions, whereas others have fewer occurrences of impacts but these impacts might be more significant.

Whichever option is selected, it will need to go through a formal planning/consenting process, with mitigation measures designed into both the permanent works and the construction plan.

12.2.4 **Objectives - Growth**

One of the key objectives of the strategic options is to facilitate sustainable growth of the Bristol and wider west of England economy. Central to this objective is realising development and redevelopment opportunities within the city centre. The leading economic option, option A, generally supports this objective as raised defences from epoch 2 onwards will provide a specified standard of protection and allow development to occur within the new defence perimeters. Committing to permanent raised

defences is likely to provide investment confidence and encourage redevelopment opportunities to be pursued.

Whilst strategic option A generally supports sustainable growth, a notable exception to this is during epoch 1, when the use of PLP / temporary defences is scheduled. This measure will not facilitate development or redevelopment opportunities within the city centre. In this respect, the raised defence options which construct defences from epoch 1 (present day) are considered to better support this objective. Options D and F for instance schedule low and high defences respectively during epoch 1 and would facilitate earlier development and redevelopment of the city centre.

During the development of the Strategy the timeframes for the options have followed a simplistic epoch by epoch approach. This approach is necessarily rigid to enable conceptual options to be developed and compared. However, in reality, the timings in which options are delivered are likely to deviate from the timeframes set out in the Strategy. For instance, if raised defences are scheduled to be undertaken in epoch 1, for the purpose of comparing the options' costs and benefits it has been assumed that the defences would be constructed in year 0 (i.e. present day). However, in reality it would be likely take 3-5 years to plan, design and construct the raised defences so they would not likely be delivered and start to accrue benefits until 2020. Likewise, if raised defences are scheduled for epoch 2 in 2030 yet funding can be secured before then, then in all likelihood the raised defences would be constructed earlier on to provide an increased number of benefits across their lifespan. In this context, if funding can be secured earlier for the raised defences set out for 2030 which are part of the leading economic option (option A) then the case for using PLP / temporary defences in the interim becomes less compelling. It would not seem appropriate to install PLP / temporary defences on a city wide scale for the present day if new raised defences are forthcoming say in 2025 or even earlier. With this considered, the marginal differences between the four raised defence options' costs and benefits are likely to become even more similar in real world terms.

Given the similarity in economics terms between the raised defence options on the short list, in order to maximally support the strategic growth objective it is considered that the preferred option should implement raised defences in epoch 1. This would help facilitate redevelopment / development of the city centre and further support sustainable growth compared to the leading economic option, which does not specify raised defences until epoch 2. It will also mean that PLP / temporary defences are not required in the interim to manage residual risk.

Bristol's development aspirations include continued development in the Temple Quay Enterprise Zone, expansion of the Enterprise Zone to Totterdown and in the long-term development at Cumberland Basin. All of these areas will directly benefit from flood defences along the Avon, and there is an opportunity to integrate defences into development with advantages in terms of cost reduction and public realm improvements.

12.2.5 Wider Opportunities – Second Avon Crossing, Tidal Power Generation and Synergies

In parallel to the Tidal Flood Risk Management Strategy, BCC has commissioned two high-level studies, one related to a potential Second Avon Crossing, and one related to a potential tidal power plant on the Avon.

AECOM has produced a report for BCC (Second Avon Crossing. High-level Engineering Feasibility Study to inform Joint Transport Strategy, July 2016) which provides a high-level assessment of options for a second Avon Crossing. The report concludes that a second crossing would cost £155-181 million.

Assuming that a second crossing could be located at the site of a tidal barrier, thereby sharing some of the same foundation infrastructure, without imposing additional costs on either project, some cost synergies would be created. The study was actioned to quantify / validate a 20% cost saving synergy estimate so assuming a 20% saving on the crossing cost by combining the two projects would generate synergy savings of £30 million to £40 million. This is far less than the cost differential between the highest cost wall defence option and the lowest cost barrier option. Therefore the assessment in 12.2.1 would not be significantly altered.

WSP Parsons Brinckerhoff has produced a briefing note for BCC ('The potential for tidal power generation from the River Avon operating in conjunction with a tidal flood barrier', July 2016) which provides an initial assessment of tidal power potential. The note concludes that it would be feasible to incorporate a 12MW turbine plant into a tidal barrier, with the potential to generate some 25GWh of energy each year. Capital cost over and above the tidal barrier is estimated at £30million, and operating cost at £0.3m/year. Revenues are estimated at £2.25 million/yr.

Although attractive from a sustainability perspective in terms of emissions avoided, and potentially financially viable when incremental costs and revenues are considered (the identified IRR is 5-7%), the scale of the net revenues is too low to significantly affect the economic assessment made in 12.2.1. Assuming zero additional capital cost and a net revenue of £2m/yr (i.e. neglecting any additional refurbishment costs from operating the barrier every day rather than a few times per year) over the full

100 year strategy period would equate in FCERM terms to a present value of only £70 million – far less than cost differential identified between barrier and wall options.

The cost savings associated with synergies from the second Avon crossing and Tidal Power Generation are less than the cost differential between the barrier and wall options and therefore do not change the selection of the preferred option. Furthermore, the wall options also have potential cost saving synergies should replacement / refurbishment of the existing riparian walls be required; combining upgrades to the existing frontline structures with raising of the crest level to improve the standard of protection could provide significant cost savings for all.

12.2.6 Conclusion

A summary comparing the generic barrier and wall options against the strategy objectives is shown in **Table 119**. It shows the barrier and wall options generally support the strategy objectives. Both groups of options are likely to have an impact on the environment. However, no ‘showstoppers’ were identified in the SEA and both options will need to address potential environmental impacts through suitable mitigation. The barrier options have the potential to impact navigation, although the technical studies which have been undertaken have shown that there are feasible designs which can be implemented without significantly constraining navigation. The main difference between the generic barrier and wall options relates to objective 4 (to reduce whole life costs) where the considerably higher cost of the barrier options means that these options do not support this objective.

There are potentially wider flood risk benefits that may arise with the barrier options, such as changing the risk of tide locking and tributary drainage. However, optimisation/refinement of the barrier design and operation has not been undertaken at this stage and the additional benefits are not considered to be significant with respect to changing the choice of the preferred option.

Table 119 Comparison of generic barrier and wall options against the strategy objectives

Strategy objective	Barrier options (generic)	Wall options (generic)
1. To support the safe living, working and travelling of people in and around central Bristol by ensuring that the flood threat is reduced and that measures are in place to address residual risks	●	●
2. To facilitate the sustainable growth of Bristol and the wider West of England economy by supporting development opportunities for employment and residential land, and associated infrastructure.	●	●
3. To maintain, and where possible enhance, natural, historic, visual and built environments.	●	●
4. To reduce whole life costs	●	●
5. To ensure navigation of the River Avon and marine activities can continue	●	●
6. Ensure the Strategy is technically feasible and deliverable over its duration	●	●
Key ● Supports objectives ● Mitigation required ● Does not support objectives		

For the wall options, based on the considerations set out in sections 12.2.2 to 12.2.4 above it is concluded that Options D and F would better meet the Objectives of the Strategy.

Given that Option D has a lower cost, equal or lesser environmental impact and is more adaptable to future sea level rise than Option F, Option D is considered the better of the two.

Therefore Option D is the preferred Option, subject to funding availability.

12.3 Contributions and Funding

12.3.1 Partnership Funding

Funding of any of the Options is challenging. For each option a partnership funding score for the initial scheme has been calculated. Each score indicates the proportion of the scheme cost which can be expected to be funded by public grant monies. None of the Options generates a high Partnership Funding score, so all will require a significant degree of contributions.

Partnership Funding scores are set out below for the works that the Options would require in Epoch 1 or 2. Two calculations have been undertaken, one assuming Do Nothing as a baseline, and one assuming Do Minimum. Assuming Do Nothing as the baseline provides the most favourable results.

The Do Nothing scenario is considered an appropriate baseline for the PF calculations given the importance of the continued operation of the Floating Harbour to the total flood damages within the study area and the reliance on human interaction to operate the water level control structures within the harbour. However, small changes in the assumptions which comprise the Do Nothing scenario could create large difference in the flood damages and therefore there is uncertainty in this approach. There are also concerns that the Environment Agency and Defra may see the Do Minimum baseline as the more appropriate.

The Partnership Funding scores for the options fall below 100%. There are many reasons for this but the low scores are mainly driven by the type of properties at risk and the development of the flood risk in relation to sea level rise. For instance, a large proportion of the properties at risk (and therefore protected by the schemes) are commercial. The Partnership Funding score calculation is largely driven by risk to residential properties and therefore the significant risk to commercial properties does not carry over into a higher PF score. Due to the propagation of the flood cells within the study area the impact of sea level rise generally leads to the deepening of flood waters rather than a larger flood cell extent which limits the number of properties at risk and has an impact on the overall flood damages in the future.

Table 120 Partnership Funding scores for the strategic options. Do Nothing baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	64%	£82m	£46m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	60%	£99	£66m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	59%	£71m	£57m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	51%	£84m	£81m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	16%	£108m	£575m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.				

Table 121 Partnership Funding scores for the strategic options. Do Minimum baseline

Strategic option	Sequence of measures	Scheme Assessed for PF	Capital cost (cash £)	Raw PF Score	GiA (cash £)	Shortfall (cash £)
G	Do Min – Do Min – High Def	-		-	-	-
A	PLP – Low Def – High Def	Low defences from 2030 with 50 year design life	£128m	10%	£13m	£115m
B	PLP – High Def – High Def	High defences at 2030 with 85 year design life	£165m	9%	£15m	£150m
D	Low Def – High Def- High Def	Low defences 2015 with 50 year design life	£128m	6%	£8m	£120m
F	High Def – High Def – High Def	High defences, 2015 with 100 year design life	£165m	8%	£14m	£151m
C	PLP – Tidal Barrier – Tidal Barrier	Tidal barrier from 2030 with 85 year design life.	£683m	3%	£22m	£661m
E	Low Def – Tidal Barrier – Tidal Barrier	See D for low wall in Epoch 1 and C for Tidal Barrier in Epoch 2.				

As shown in **Table 120** and **Table 121** the funding gap for Low Defences in Epoch 1 is £57m (best case) to £120m (worst case). To implement these works, this gap would need to be filled by contributions from BCC, LEP, other public funding sources and beneficiaries from the defences.

In some areas there is an opportunity to integrate the defence works with site raising and redevelopment, potentially gaining contributions from developers (in cash or in kind) and reducing costs.

Nonetheless, it is very unlikely that the works could go ahead without a substantial contribution from BCC. Before the Preferred Option is confirmed BCC's appetite for funding the shortfall will need to be ascertained.

12.3.2 **Gross Value Added Benefits (GVA)**

Wider economic impacts of Do Nothing

The Environment Agency currently has detailed guidance for appraising the economic, environmental and social impacts of FCERM interventions. Some economic impacts are assessed within that framework such as the expected annual damage to properties. These assessments relate specifically to impacts in the short term post-flood. These are termed 'First Round Impacts' and include losses which are applicable to the economy in a national context.

First Round impacts

The estimated 'first round' damages for a Do Nothing scenario presented earlier in this chapter include:

- Expected damage to residential and commercial properties (premises, inventories, machinery etc.);
- damage to public infrastructure (utilities, for example);
- Education and Schools;
- Vehicle damage;
- Risk to life;
- Emergency clean up and response;
- Accommodation and subsistence ;
- Traffic and business travel disruption;
- Heritage and tourism loss from impacts on bespoke features (e.g. There is no equivalent feature elsewhere, or there is no potential for displacement or transfer of this related tourism).

Where FCERM interventions prevent some or all of these first round impacts, these benefits are included in Partnership funding and Grant in Aid assessments. However, in addition these direct impacts can trigger business responses and in turn, dynamic impacts. The scale and significance of these dynamic impacts on the local economy, in part depends on the geographical area under consideration.

Dynamic Impacts

Dynamic impacts reflect the outcomes for a local economy over time as businesses respond to changes in flood risk. Strategic tidal flood risk management intervention is likely to:

- Support business continuity and sustainability of business activity in an area;
- 'Unlock' investments that might otherwise have been constrained or unattractive given the flood risk; and,
- Lead to 'spill over' impacts which reflect interdependencies or other intangible impacts on economic activity.

By evaluating the potential contribution to the local economy of investing in flood risk management measures it helps build an understanding of their potential impacts on the local economy. This would be expected to increase the propensity for local partners to contribute funding to FCERM as part of the government's Partnership Funding approach.

Overview of approach to GVA Assessment

The contribution to the economy is quantified where possible and measured as Gross Value Added, GVA. This is complemented with qualitative assessments. The full method is described in "TOOLKIT for assessing the impacts of flood and coastal erosion risk management on the local economy" (Frontier Economics, 2014).

The primary focus is on local GVA, and associated key drivers of the impacts on the local economy. As the methodology for assessing GVA impacts of FCERM, and its application, are in their infancy, it is likely that the approach, data and assumptions will need to be reviewed and updated over time as a richer evidence base comes to light.

A high level proportionate GVA assessment was applied in this study estimate the wider impacts on economic activity by explicitly considering businesses' likely responses to flood risk. The assessment has drawn upon a range of available data including:

- GVA toolkit and annexes;
- Business size and sector distribution statistics for Bristol (Office of National Statistics);
- Average salaries for different business sizes and categories in Bristol (www.payscale.com)

- Local Plan (development and employment projections)
- National Receptor Database 2011
- Derived data from Strategic City Planning (Sept 2015).
- Economic Development Needs Assessment (2015)

Typically, a GVA assessment is undertaken using a 10 year period, as this period reflects that where direct impacts can be reasonably attributed or linked to specific interventions. Beyond that the envelope of uncertainty grows significantly and other factors may become more influential in determining the futures experienced. However, in this study a 23 year period from 2015 – 2038 was considered, as estimates of development and employment projections are available or can be extrapolated. The GVA estimations are based on an average annual figure for the period which is then presented as a discounted (Present Value) total for the whole period.

The dynamic impacts focussed on in the quantitative estimations in the assessment included:

- Disruption to existing businesses. A valuation of potential losses from flood risk detrimentally impacting on business continuity and operation.
- Opportunity lost. An estimation of potential development and investment lost out on in a Do Nothing case. Without FRM intervention the development plans and employment increases will not be enabled and therefore the locally economy will not benefit from the investment that could be unlocked by FRM intervention. With the continuation of the status quo and without FRM intervention, the scale and form of development plans and employment increase risk not being enabled and the local economy not benefiting from the investment that could be unlocked by FRM intervention.

It should be noted that this high level GVA assessment, which is suitable for a strategic level appraisal, provides ballpark estimates of dynamic impacts but is underpinned by significant assumptions and uncertainties in the data. Further more detailed assessment and valuation of GVA impacts is recommended in future more detailed appraisals to support potential schemes.

Business responses to flood risk

Using the estimated range of business responses, we can explore the likely dynamic impacts of flooding and FRM. In the absence of FCERM intervention, evidence suggests that disruption to business activity could last many weeks. Based on a review of available evidence, we assume that without the intervention, a business could be disrupted for around 16-24 weeks because of flooding, and 2-4 weeks with the FRM intervention.

Businesses operate in the context of uncertainty about when, how, what scale, how long and how often they may experience flooding. They have to make business decisions to manage the risks they face. In response to flood risk, businesses respond in one of 4 ways: stay and do nothing; stay and adapt; move or shut down. In this case, in Bristol, many premises within the City Centre are national or Regional Headquarters who provide specialist knowledge-intensive, creative or financial services which are not easily transferrable. With this in mind, and without detailed data to underpin an assessment of potential business behaviours (with respect to flood risk) it has been assumed in the valuation of impacts that all businesses will 'Stay and Do Nothing.'

Impacts of Do Nothing on Planned Development and Investment

Development Control and Planning Policy is in place to ensure that new development is safe and appropriate with respect to potential flood risk. A Do Nothing Scenario will lead to an unmitigated increase in tidal flood risk which will become increasingly significant over time. As such this scenario would inhibit planned development within the flood plain, such as the Temple Quay Enterprise Zone. This would lead to lost opportunities and the added investment benefiting the locally economy would be missed. Therefore in the valuation of this lost opportunity it was assumed that the Do Nothing Scenario would lead to none of the planned development and employment being realised, thus representing a 'worst case' estimation.

Headlines from GVA Assessment

The analysis shows that the true potential cost of flooding for the local economy is over £2.5bn (present value) over the next 23 years. Within this figure nearly £505m (PV) can be counted under FCERM-AG as a national economic loss. The remaining £2.0bn is comprised of GVA impacts to the local economy. This total economic loss (£2.5bn PV) relates to total annual loss of £140m (in cash terms) over the period.

Just over £29m of this annual cash loss figure comes from first round impacts which can be valued and counted under FCERM-AG. A key component of this valuation comprises annual damage and write off of

properties due to increasingly frequent flood events as well as significant infrastructure and transport disruption. Other associated or indirect damages are also included in this sum.

The remaining £111m comes from dynamic impacts (those felt by the local economy but not necessarily on a national level, i.e. the impacts have the potential to be displaced or transferred to another area).

A significant proportion (over 90%) of the dynamic impacts (over £1.75bn PV) stem from the likely lost opportunity (development, employment and investment) which would otherwise bring benefit to the local economy if it were not to be inhibited by the unmitigated tidal flood risk. It has been assumed that without flood risk management infrastructure to adequately mitigate flood risk to these developments, the future projected jobs and employment both with the Temple Quay Enterprise Zone and the Wider City area within the floodplain would not occur.

There is also significant disruption to commercial activity already currently located within the floodplain, meaning £10m annual cash loss from business discontinuity and loss of earnings. Without flood risk management intervention this total dynamic impact on existing commercial activity within the floodplain could total over £273m PV by 2038.

A summary graphic from the GVA assessment is provided below.

GVA Assessment – Do Nothing Scenario

2016 - 2038			
Key findings from the GVA assessment			
a) First round impacts nearly £505m (PV) in next 23 years.			
b) Tidal flood risk unmanaged leading to >£2bn (PV) dynamic impacts (local economic loss) in next 23 years.			
c) Unlocked investment exceeding £1.75bn (PV) would not materialise.			
d) Impacts on existing business (discontinuity etc.) totalling £273m (pv) over next 23 years)			
e) Over 4,000 pipeline jobs would not materialise over the next 10 years.			
f) GVA dynamic impacts nearly 4x first round impacts, with total £2.5bn (PV) economic loss over 23 year period.			
g) £170m average annual cash damage (first round + dynamic impacts) over the period under Do Nothing.			
	Estimated undiscounted annual average (cash £k)	Estimated 23-year GVA impact (£k PV)	Qualitative assessment
First Round impacts	29,439	504,735	Significant write off of commercial and residential properties likely due to very high levels of flood risk. Regular and frequent flooding of key enterprise and commercial zones, including financial hub Significant tourism loss due to flooding of key assets and Floating Harbour area. Large areas become uninhabitable due to flood risk. Critical Infrastructure significantly damage, disrupted or lost.
Dynamic impacts	110,353	2,030,067	Area blighted by unmanaged, very significant flood risk. New development currently in the pipeline does not proceed due to level of flood risk. Much of the commercial sector around the Floating Harbour becomes unviable and future pipeline jobs are not created. Wider spillover impacts on regional economy also likely.
Limitations			
Estimates based on a Do Nothing Scenario.			
Estimates based on Defra GVA toolkit 2014 methodologies.			
Estimates of dynamic impacts beyond 2025 extrapolated from data and employment targets up to 2025.			
Assumptions that all businesses 'Stay and Do Nothing' and are unable to operate for 20 weeks following a flood with no FRM in place.			
Figures based on statistics for Bristol (e.g. average salaries, sector distribution, business sizes etc).			

Likely GVA benefits of preferred option

The recommended preferred option will maximise the opportunity to turn the GVA impacts (damages) estimated for a Do Nothing Scenario into benefits. By providing a strategic FRM intervention which delivers a high standard of protection to Bristol, the impacts valued under Do Nothing will almost entirely be claimed as a benefit through significantly improved protection against tidal flooding. Such intervention will also maximise the opportunity to unlock investment through enabling and supporting potential development and regeneration within the current floodplain, also reducing site specific flood risk measures. It is expected that planning guidance will follow from the Strategy, guiding site specific flood risk assessments down a path to deal with residual risk and acceptable ways to fit into the overall strategic approach.

The GVA assessment also identifies significant potential spill over impacts for the regional economy, and improve strategic defence could also enhance the potential for additional development over that currently

planned, or may facilitate different uses e.g. housing. The GVA assessment demonstrates significant local value (beyond simply traditional FCERM valuation of benefits) of the proposed FRM intervention, and this provides a more comprehensive evidence base and greater justification to seek partner funding from the potential beneficiaries thus helping to enable the schemes required.

12.3.3 Contributions

A review of potential funding sources has been undertaken to identify the means of BCC finding the shortfall in funding to implement the preferred option, assuming that GiA is successfully drawn down from the EA via Partnership Funding. This is reported in the Funding Strategy report.

The review, at the time of writing, found:

- The LEP Economic Development Fund (EDF) and Revolving Infrastructure Fund (RIF) provide the most significant potential contributions. The EDF comprises £10m delivered in two tranches; 2023-24 and 2032-33.
- The most important 'regular' contribution to flood defences should come from the Community Infrastructure Levy (CIL). The exact contribution would need to be determined by BCC, reconciling the needs of other infrastructure projects.
- The City Centre BID proposal provides an opportunity to secure monies from harbourside businesses, although this is subject to local support through contributor's votes and a viable contribution is likely to be minimal.
- The Coastal Communities Fund is worth investigating to make a case for submitting an expression of interest; flood defence schemes have received funding in the past
- The Metro Mayor funding deal provides BCC with another source of money, but the relative portion that BCC would receive compared to South Gloucestershire Council and Bath & North East Somerset will not become clear until next year. The implementation of the proposal may be affected by post-Brexit decision plans.
- The funding mechanism for most contributions is via payback i.e. the money will not be made available to BCC upfront. The Council will need to commit its own money and claim the contribution back via, for example, uplift in business rates.
- There is currently no Local Levy available from the Wessex Regional Flood Defence Committee. This could change when the EA 6 year capital programme is next reviewed and a case could be made.
- Potential contributions from developers / landowners / beneficiaries are likely to be very limited based on BCC's significant land ownership of the areas proposed for defence works (unless land deals are exercised with developers).
- Additional central government grant opportunities such as the Growth Deal; where England's 39 LEPs will be able to apply for a share of £1.8 billion to support projects in their areas that boost local economic growth and promote jobs.

Table 122 summarises the impact of potential contributions on the shortfall for the preferred strategic option. This is based on the Epoch 1 intervention of Low Defences and the need to fund a shortfall of £128m. The table is to *illustrate the quantum of potential contributions only* i.e. significant further work is required to secure these amounts. The table shows that whilst BCC may be able to source significant contributions, the Council may need to commit at least £20m to the implementation of the preferred strategic option in Epoch 1 and possibly as much as £85 million.

Table 122 Indicative illustration of potential funding contributions for preferred strategic option construction works in Epoch 1

Strategic Option Scheme /Contributor	Cost / Contribution (£m)	Notes / Assumptions
Low defences (construction cost)	128	Construction in Epoch 1
GiA	8-71	Depending on EA/Defra acceptance of baseline
LEP EDF Tranche 1 (in 2023-24)	5	Fully allocated to Strategy; payback via business rates uplift
LEP EDF Tranche 2 (in 2032-33)	5	Fully allocated to Strategy; payback via business rates uplift
LEP RIF	5	Payback; in line with previous successful bids

City Centre BID	2	Upfront collection of money by 2022; 33% allocation to Strategy
Verve Investments Limited	0	Bath Road works occur in Epoch 2
Community Groups	0	Negligible contributions forecast
Coastal Communities Fund	1	In line with previous successful application for flood defences
WRFC Local Levy	0	Current allocation up to 2021
CIL	7.5	50% of Strategic CIL secured over 5 years (half of £15m)
Metro Mayor	10	20% of BCC share of £900m fund over 30 years secured over 5 years i.e. BCC receive £300m over 30 years (£10m per year)
Balance to find less contributions	21.5-84.5	

12.3.4 **Potential synergies**

Potential cost saving synergies associated with the preferred strategic option could help to reduce the cost of implementing the Strategy and improve the case for funding. The preferred route alignments for raised defences which comprise this option have yet to be confirmed. However, should frontline alignments be identified during the next phases of work then combining the new frontline defences with replacement / refurbishment of the existing riparian walls could provide significant cost savings for all.

12.4 **Uncertainty**

A number of tests have been carried out to assess uncertainty. These are outlined in **Table 123**. The tests indicate whether the preferred Option is sufficiently robust in the face of uncertainty.

Table 123 **Uncertainty tests**

Strategic option	Sequence of measures	Test	Result
C and E	PLP – Barrier – Barrier and Low Def – Barrier - Barrier	Reduce PV cost by 50%	Barrier options remain significantly more costly than Option D, with only marginal benefit advantage
E	Low Def – Barrier - Barrier	Delay barrier to Epoch 3	Reduces PV cost of barrier by around £250 million, but costs still greatly exceed Option D
D	Low Def – Low Def – High Def	Cost increase by 25%	Would affect all Low/High Defences - Options A, B, D, F – to same extent. Relative merits largely unchanged. Funding gap increases.
D	Low Def – Low Def – High Def	SLR occurs more quickly than projected	High defences would need to be built before 2065, but Option D still more optimal than Option F
D	Low Def – Low Def – High Def	SLR occurs more slowly than projected	Option D becomes more optimal as design length increases
	Do Minimum – Do Minimum – Do Minimum	Assumptions on asset failure	Maintenance and operation of assets carried out with all 'Do Something' options so the impact of when assets fail is similar. No impact on choice of preferred option.

Based on the tests outlined in **Table 123** the basis for selecting the Preferred Option is considered robust. Should the PV cost of the barrier options, options C and E, reduce by 50% these options remain at a significantly higher cost than the preferred option, Option D. Likewise, by delaying the barrier until epoch 3, and hence reducing the overall PV cost of the barrier options, the costs still greatly exceed that of Option D.

For the raised defence options, if costs are increased by 25%, the impact would be similar across all four of these options and therefore the relative economic merits of each option would be largely unchanged. Should sea levels rise at a different rate to currently projected then the implementation time of the High Defences may need to be changed but Option D remains preferable in this case.

To account for the uncertainty in future rates of sea level rise (compared to the existing projections) and potential modelling uncertainties (such as channel shape, hydrology, hydraulics etc.) a suitable freeboard allowance has been applied to the strategic options. The freeboard allowance is suitable for this level of assessment but further refinements may be required in subsequent design works. Changing levels of freeboard could impact the cost of the various options, although this is likely to be a consistent change across the options and will not impact the choice of the preferred option.

13. PREFERRED STRATEGIC OPTION

Option D (Low Defences – Low Defences – High Defences) has been identified as the Preferred Option. It is comprised of the following:

- Construction of 5.3 km of flood defence walls, plus flood gates at either end of the Floating Harbour, to a SoP of 1 in 200 yr at 2015 with an average height of 1m in 2015 (or as soon thereafter as the option can be implemented).
- Construction of a further 1.9 km of flood walls in 2065, with existing walls raised, to provide a consistent 1 in 200 yr SoP at 2115. The 2065 date is based on current projections for sea level rise, and would be kept under review and brought forward or delayed to suit actual rates of sea level rise.
- Continued maintenance and refurbishment of existing defences and operation of the gates and control structures associated with the floating harbour.
- Maintenance of all defence elements until 2115.

The initial capital cost of the low defences for this Option is estimated at £128 million.

Table 124 Summary of non-discounted (cash) costs for the preferred strategic option, option D

Epoch	Measure	Cash cost of measures (£m) including 60% optimism bias	Total cash cost (£m) including 60% optimism bias
Epoch 1 (2015 – 2030)	Low defences - construction	128.3	135.7
	Maintenance of low defences	6.0 (average 1.2 per annum)	
	Do Minimum activities	1.5 (average 1.0 per annum)	
Epoch 2 (2030 – 2065)	Maintenance of low defences	41.8 (average 1.2 per annum)	45.3
	Do Minimum activities	3.5 (average 0.1 per annum)	
Epoch 3 (2065 – 2115)	High defences - upgrade	50.6	123.2
	Maintenance of high defences	62.9 (average 1.6 per annum)	
	Do Minimum activities	9.7 (average 0.1 per annum 2065-2089, 0.3 per annum 2090+)	
Total			304.2

14.

NEXT STEPS

The next steps in the Strategy include:

Stage 1

- Agreement in principle of Preferred Option by Project Board.
- Provisional agreement on funding availability from BCC – this would need to take the form of a confirmation that BCC could in principle meet the scale of funding shortfall identified, or if that could not be confirmed, what range of funding shortfall BCC could meet.
- Agreement of EA development control that in principle adoption of the Preferred Strategic Option and implementation of the Epoch 1 Low Defence would be sufficient to allow development to proceed in the City, subject to an investigation of residual risk to specific developments and incorporation of corresponding proportionate local measures.
- Agreement of EA on suitability of Partnership Funding calculation approach, and use of Do Nothing as a baseline, determining GiA eligibility.

Stage 2

- Refinement of Preferred Option, including confirmation of standard, review of defence alignments and costs, and potentially prioritisation of Low Defences to match funding availability
- Consider phasing of the Preferred Option. A phasing plan would require that a) the requirements of development control are clear insofar as they affect required standards b) what standard is required, where, and c) what restrictions there are on filling the funding gap from a BCC perspective.
- Funding Strategy – document to be updated based on the latest understanding of potential 'development futures' e.g. in the Temple Quay Enterprise Zone.

Stage 3

- Development of Public Consultation document and Business Case
- Preparation of statutory environmental reporting
- Public Consultation
- Strategy Finalisation

1. APPENDIX 1: COSTING METHODOLOGY

1.1 Approach to option costing

1.1.1 Approach

This appendix outlines the process by which high level cost estimates have been made for each of the seven short listed strategic options.

Each strategic option is comprised of a sequence of different measures over the duration of the Strategy. Costs for the various strategic options have been developed by following a 'bottom-up' approach, whereby costs for the separate measures in each epoch have been estimated and then summed to derive the total costs for the Strategic Option. Once cash costs were derived it allowed for whole life present value costs to be developed for each of the options.

The measures for which costs have been estimated comprise do minimum, property level protection / temporary defences, low and high Defences (raised defences including lock gate upgrades) and the tidal barrier.

The approach to costing each measure is provided in sections 1.2 to 1.5 below.

1.1.2 Optimism bias

In line with Environment Agency Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG), an optimism bias of 60% has been applied to the costs of the measures / strategic options. Optimism bias:

"is included to account for the tendency for appraisers to be overly optimistic in early assessment of project costs, timescales and benefits in comparison to the final values. This 'optimism' is a result of uncertainty in the final design detail and implementation as a result of the high level strategic approach required at this stage. To counter this, the HM Treasury issued guidance in the form of a percentage to increase the present value costs depending on the uncertainty surrounding the estimates. This guidance has been adopted with FCERM-AG. With regard to coastal Strategies, the FCERM-AG recommends an optimism bias level of 60% as these projects are typically at an early stage and adopt a higher level approach to design and costing" (FCERM-AG, Environment Agency, 2010).

1.1.3 Discounting

Discounting is a technique used to compare costs that occur at different points in time over the appraisal period (i.e. the next 100 years). Standard discount rates have been used to convert all cash costs to 'present values' (PV). This enables the whole life costs of the various strategic options to be compared and also leads to a realistic assessment of the cost implications of the options in today's cost terms. According to FCERM-AG, the following variable discounts rates have been used within the economic appraisal; 3.5% for the years 0 to 30, 2.5% for the years 31 to 75 and 2.5% for the years 76 to 99. This results in a PV factor over the 100 years at 29.9.

Once the cash costs for the individual measures comprising each strategic option were established, the whole life present value costs were derived. This was done by specifying the year in which each measure was to be implemented then applying the suitable discount rate.

For the purpose of option costing it has been assumed that the cost of capital works are applied during the first year of each epoch. For instance, if an option specifies low defences in epoch 1, then the cash cost for this measure has been placed in 2015. If an option specifies a tidal barrier in epoch 2, then the cash cost for this measure has been placed in 2030. Maintenance costs have been applied as an average annual cost and spread evenly throughout each epoch. The exception being after the construction of low or high raised defences when it is assumed that no maintenance will be required for the first ten years after construction.

A detailed breakdown of the PV costs and investment timings are provided in sections 5 to 11.

1.2 Do minimum

The do minimum measure involves maintaining the existing defence assets, the floating harbour water level control infrastructure and ensuring that the operation of the floating harbour is continued. In essence, the do minimum measure represents what happens if the current 'status quo' is maintained.

As part of the strategic options it has been assumed that the Do Minimum measure can act as a 'stand-alone' measure and also as a measure which will be carried out in support of the other 'do something' measures (PLP, low defences, high defences and tidal barrier). For example, if a strategic option outlines the implementation of PLP in epoch 1, it is assumed that the activities of the do minimum measure (e.g. lock gate maintenance and operation) would also be undertaken during this epoch. This would ensure

that the maintenance of the existing defences in the study area and the ongoing operation of the floating harbour would be continued.

Cost estimates for the do minimum measure vary according to the time epoch (costs estimated separately for 2015, 2030, 2065 and 2115) and whether the do minimum measure is being carried out alongside a primary measure (i.e. raised defences) or in isolation. The cost estimate for do minimum has been based upon real life costs for operation of the floating harbour, provided by Bristol City Council (BCC) and the Harbour Master, costs for the emergency deployment and operation of temporary defences, and costs provided by BCC for the maintenance of flood defence assets in central Bristol, Pill and Shirehampton.

In strategic options when the do minimum measure is undertaken alongside another primary measure that involves a large capital investment and associated maintenance activities (i.e. raised defences or a barrier), it has been assumed that the do minimum costs will include only the costs of floating harbour operation and temporary defence deployment and operation.

In strategic options when the do minimum measure is undertaken in isolation (i.e. without another primary measure alongside it), or alongside PLP / temporary defences, it has been assumed that the do minimum costs will include the maintenance costs for existing defences in addition to the costs of floating harbour operation and the deployment and operation of the existing temporary defences.

1.2.1

Floating harbour operation and maintenance and temporary defence deployment

The cost estimate for maintaining and operating the water level controls and floating harbour operations includes:

- Temporary flood barrier deployment
- Flood gate deployment
- Temporary flood barrier parts
- Deployment of stop gates at Junction / Netham locks
- Regular inspection of stop gate pair M&E, dock sill and masonry
- Special inspection of stop gate pair
- Routine sluice gate inspections
- Refurbishment of sluices
- Remote control of Netham sluices
- Temporary flood barrier training
- Planning and coordination
- Pre-event incident planning
- Pre-event harbour water level lowering
- Routine inspection of stop gate pair M&E, dock sill and masonry
- Junction Lock visual inspection
- Special sluice gate inspections
- Stop gate maintenance
- Harbour water level management system

The costs and frequency (present day) for each component were provided and based on this information a total annual cost for the maintenance and operation of the floating harbour and temporary defences was estimated for 2015. Due to sea level rise, the frequency of harbour operations and defence deployment is expected to increase in the future and therefore an uplift was applied to estimate the costs in 2030, 2065 and 2115. The annual costs for 2015 have been estimated as £98k, for 2030 as £100k, for 2065 as £130k and for 2115 as £257k. These annual cost estimates include a 60% optimism bias allowance.

1.2.2

Maintenance of existing flood defence structures

Costs estimates for maintenance works to the existing defences at Pill and Shirehampton have been estimated using a range of available data and reports, including; Pill Sheet Pile Wall Stability and Durability Assessment (Atkins, 2012) and the Initial appraisal of Bristol Tidal Assets (Arup, EA, 2015).

Based upon the information provided in these reports the following assumptions and cost estimate has been made for maintenance at **Pill**:

- Maintenance costs for the next 35 years were estimated to be £650k in cash terms (£1.04million including 60% optimism bias). This cost is comprised of sheet pile berm works, pile protection, replacement of mastic joints and replacement of flood gate seals (every 5 years).
- A similar maintenance cost is assumed to be required again from 2050 onwards and therefore over the full 100 year appraisal period the total cost for maintenance in cash terms is expected to be £1.3million (£2.08million including 60% optimism bias).
- As an average annual cost, this equates to approximately £13k per year. This equates to £21k per year when including a 60% optimism bias allowance.

Based upon the information provided the following assumptions and cost estimate has been made for maintenance at **Shirehampton**:

- No significant maintenance costs outlined for Shirehampton defences in the initial appraisal of Bristol Tidal Assets (Arup, EA, 2015). Only minor costs are outlined including the replacement of gate seals, clearance for inspection, monitoring and replacement of flood gates.
- Assumed that gates will need replacing once every 50 years, seals replacing every 5 years and ongoing vegetation clearance and monitoring an estimate of £320k for total cash maintenance cash costs over the duration of appraisal period (£512k when including a 60% optimism bias allowance).
- As an average annual cost this comes to £3.2k per year which equates to approximately £5.1k per year when including a 60% optimism bias allowance.

Bristol City Council provided a cost estimate to repair an 80m length of defence at Clarence Road in central Bristol. The repair works are following a failure resulting from a tidal surge event in 2014. The estimated cost for repair works is £480k. This equates to a cost per metre length of repair works of approximately £6k.

The Clarence Road retaining / defence structure along the New Cut has been assumed to be representative of other defences within the city centre and therefore the cost per metre for repair works have been applied to raised defences elsewhere at Totterdown and Cumberland Road. This has been used as the basis for maintenance costs for existing defences within **central Bristol**.

Due to sea level rise and the ageing of existing structures within central Bristol, the frequency of repair / maintenance works is expected to increase in the future. For year 2015 it is assumed that repair works to existing structures will be required on average once every 25 years, in 2030 on average one and half times more frequently than this and in 2065 and 2115 on average two times more frequently than in 2015. By considering the total length of raised defences within central Bristol, the cost of repair works per metre length and the estimated frequency of maintenance required the following average annual maintenance costs for raised defences in central Bristol have been assumed; in 2015, £295k; 2030, £443k; 2065 and 2115, £590k. Including a 60% optimism bias allowance these costs equate to 2015, £472k; 2030, £709k; 2065 and 2115, £944k.

The average annual maintenance costs for Pill, Shirehampton and central Bristol have been summed to provide an overall annual cost for maintenance of raised defences within the study site.

1.3 Property level protection / temporary defences

1.3.1 PLP / temporary defences capital works

A cash cost estimate for the property level / temporary defence measure have been built up by considering the number of properties which may be suitable for property level protection measures (PLP) and an average cost of PLP per property.

In GIS the zones suitable for PLP / temporary defences were identified using the 1:75 year flood mapping extent and considering a 600mm water depth threshold. The properties within the flood extent, whose flood depths fell below 600mm were considered suitable for PLP measures.

An average cost per property for PLP measures has been assumed based on real costs from a 49 property resistance scheme at Wallingford (Fareham) on the south coast of the UK. Additional information from Environment Agency published literature, Defra Pilot studies and quotations for commercially available defences from direct contractor discussion (UK Flood Barriers) has also been used. The worked up estimates of the costs are £4,250 per property. This sum also covers the material and fitting costs estimated per property and any liaison/engagement costs that may be associated with installing the protection. However, the engineer fee for undertaking a pre-installation property survey is not included. It should be acknowledged that additional costs associated with the protection works are likely to have to come from alternative sources, such as the Coastal Flood Levy or homeowners.

The average cost of PLP per property was multiplied by the number of properties to derive the overall cost of the measure in cash terms. A 60% optimism bias was then applied to the cost of the measure.

Potential routes for temporary defence alignments have also been investigated. Opportunities for temporary barrier alignments have been identified where a short length of temporary defence could protect a comparatively large number of properties and provide a substantial flood risk benefit. It has been assumed that use of temporary defences would remove the need for individual property level protection measures to the properties that would benefit. The alignments have been assessed at a high level appropriate for a Strategy; therefore rather than providing a specific cost for temporary defences that is based on lengths / heights of the temporary defence alignments, the cost has been assumed to be equal to that of protecting properties on an individual property-by-property basis using PLP measures. As such, the cost of the PLP / temporary defence measure is unchanged irrespective of whether PLP is provided to individual properties or if temporary barriers are utilised to protect numerous properties simultaneously.

1.3.2 **PLP / temporary defences maintenance**

A maintenance cost for the PLP / temporary defence measure has been estimated assuming an annual average maintenance cost of 1% of the capital investment. It is unlikely that maintenance will be required for individual property protection measures, but should temporary defences be used this maintenance cost is expected to cover the storage and deployment of the temporary defences.

1.4 **Raised defences (low and high defences)**

The cost estimates for the low and high defence measures have been developed assuming a worst-case conservative design approach.

At this stage of the option appraisal, no decision has been made regarding the preferred route alignments at each location. A decision regarding the type of defence structure has also yet to be made. These decisions are deferred to later stages of the project or during subsequent appraisal studies when additional information is available for review or additional site surveys are undertaken.

For the purpose of option costing only, it has been assumed that the proposed defences will be designed as frontline solutions placed in front of the existing structures. The structure type used for costing is a cantilevered sheet piled wall offset from the existing river bank by approximately 2-3m. This is a conservative approach and will provide the most robust cost estimate. It is necessary to make this assumption as it is currently unclear as to whether the existing riparian walls can be relied upon for support to new structures, or to provide a watertight defence against raised water levels throughout the life of the Strategy.

Assuming a frontline alignment, indicative raised defence alignments have been established in GIS. Frontline alignments necessary to protect against the following flood events were created:

- Low defences; 1:200 year standard in 2030
- High defences; 1:200 year standard in 2115

For each defence location the crest level of the defences has been obtained using the peak water levels from the modelled design standard events at that location. For the low defences, a freeboard allowance of 0.15m was applied (unless stated otherwise). For the high defences, being constructed to a standard 100 years in the future, a reduced freeboard allowance was used to avoid an overly conservative crest level for the duration of the appraisal period.

An exception to the frontline assumption for costing has been made for the raised defences specified at Shirehampton. At this location there is ample space for a setback solution and there is no reliance on existing structures to support a new flood defence scheme. At this location only, a setback alignment for an earth embankment solution has been identified.

1.4.1 **Sheet piled wall**

For costing purposes it was assumed that the new raised defences will be a cantilevered sheet piled wall offset from the existing river bank by approximately 2-3m. The sheet pile would be capped by a concrete capping beam and the design would be 'future-proofed' to allow for raising of the beam to be undertaken in the future, subject to sea level rise. No structural calculations have been carried out but a rule of thumb estimate of pile length has been assumed to retain and unit rates have been benchmarked against EA actual cost data. An example cross section showing a general solution is provided in **Figure 18**.

Based on the example frontline design (sheet pile, cantilever and capping beam), costing for the raised defences have been built up using the best available information and to a level of detail suitable for a high level strategic study. Values have been estimated from rates provided in civil engineering price books (e.g. SPONS, 2016) coupled with experience of costs from similar projects.

Sheet piles are available in a range of standard lengths and it was necessary to select a suitable length of pile for the Strategy frontage. Evidence considered from the numerical model and LiDAR / topographic survey data suggests a varied bed level relative to the design crest level of the new defences. A 19m pile length was used in the cost build-up, with an AZ48 – 700N pile specification costed.

The cost estimate includes an allowance for the following aspects and materials:

- Piling Rig
- Pile Driving
- Formwork
- Wailing beam
- Anchor plant
- Sheet Piles
- Reinforcement
- Concrete
- Wailing beam installation
- Anchor ties

- Placing of concrete
- Bollards
- Ladders
- Backfill
- Sheet pile coating protection
- Design, preliminaries and scaling of works (25% uplift on total cost)

The cost of piling depends upon the depth to which the pile needs to be driven into the river bank. No recent topographic survey data of the river channel and banks is available and therefore the river bank levels have been assumed to be on average 2m below the land levels immediately adjacent to the indicative alignments. This elevation varies depending on location, and an average cost per metre of the raised defences across the strategy frontage as a whole has been determined by dividing the total cost of the raised piled defences by the total length.

On average, across the Strategy frontage the cost per m of the piled frontline solution was approximately £23,600 per metre. The cost estimate per metre includes a 25% uplift to account for design, preliminaries and scaling of works. In addition, a 60% optimism bias allowance has also been applied.

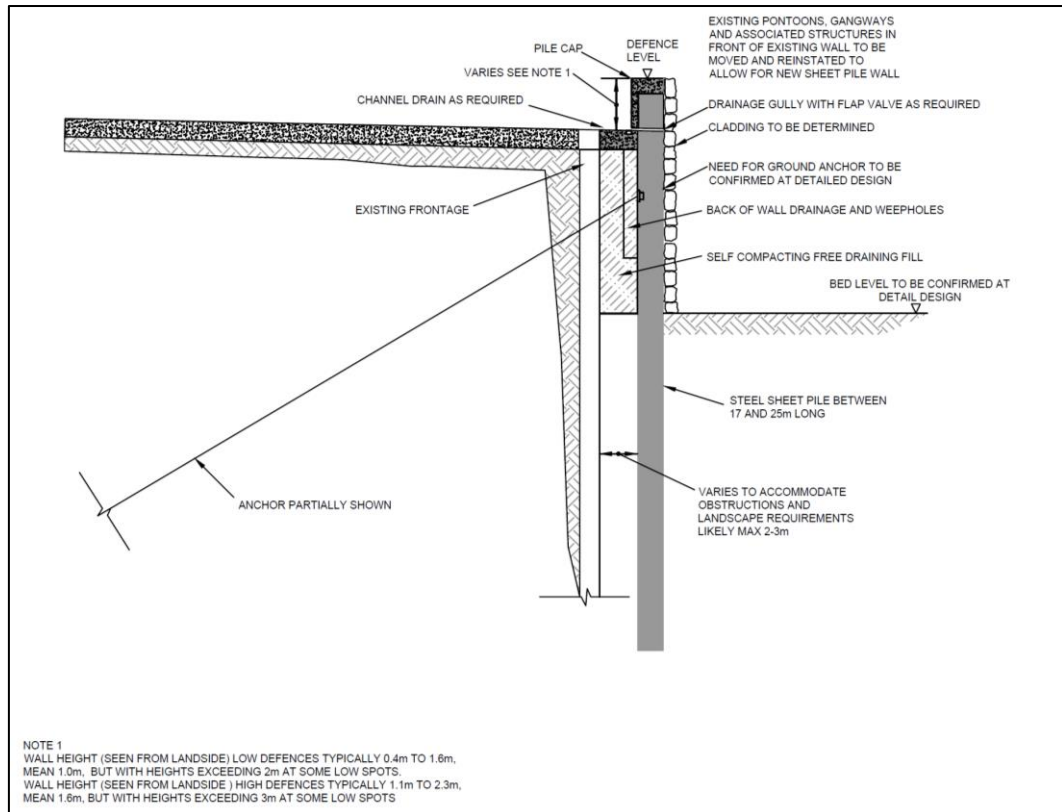


Figure 18 Example frontline pile

1.4.2 Crest raising

As part of some of the Strategic options a defence upgrade from low to high defences is required (via lengthening and raising). It is assumed that the initial sheet pile structure for low defences would be 'future-proofed', allowing for additional height to be added to the structure and to facilitate crest raising. For costing purposes the cost of the crest raising upgrades has been estimated using a cost build-up for a reinforced concrete wall. This is likely to provide a conservative, robust cost estimate for the raising works which is in line with the overall approach for the costing exercise at this stage of the Strategy.

Unit rates per metre for reinforced concrete flood defence walls were estimated using civil engineering price books (e.g. SPONS, 2016) coupled with experience of costs from similar projects. A standard indicative cross section was adopted to cost the structures. The typical setback flood wall cross section assumed for costing is provided in **Figure 19**.

The costing of the walls includes an allowance for the following aspects and materials:

- Excavation and disposal
- Trimming of excavation
- Topsoil
- Reinforcement of concrete
- Formwork
- Trimming of filled surfaces

- Fill
- Facing brickwork
- Engineering brickwork
- Concrete top - Design mix
- Drainage
- Seeding
- Placing of concrete
- Design, preliminaries and scaling of works

The estimated costs per metre of reinforced concrete flood wall range from £1,760 to £3,216 for walls of heights 0.5m to 1m respectively. The cost estimate includes an uplift to account for design, preliminaries and scaling of works. In addition, a 60% optimism bias allowance has also been applied.

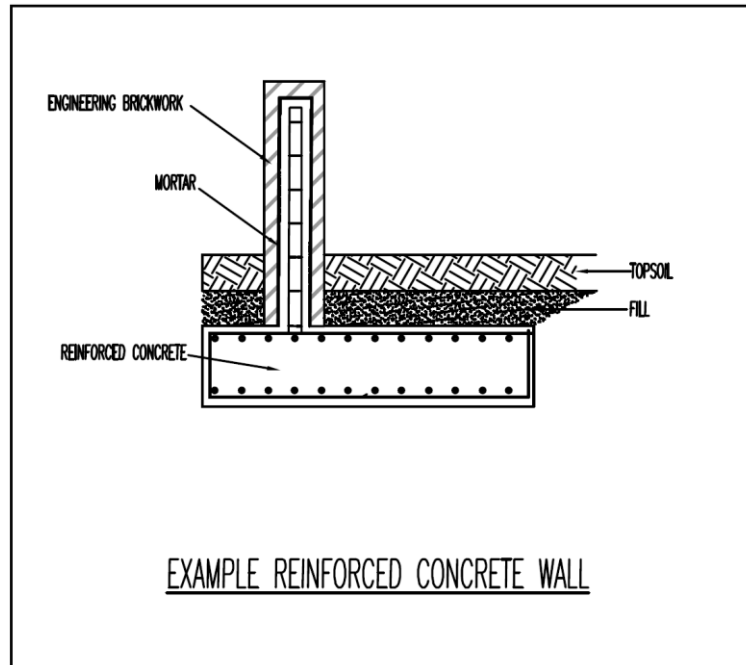


Figure 19 Indicative flood wall cross section

1.4.3

Embankments

At the Shirehampton location only, a setback earth embankment has been used for costing purposes.

Unit rates per metre for earth embankments were estimated using civil engineering price books (e.g. SPONS, 2016) coupled with experience of costs from similar projects and benchmarking against information obtained from the Environment Agency. The typical embankment cross section assumed for costing is provided below in **Figure 20**.

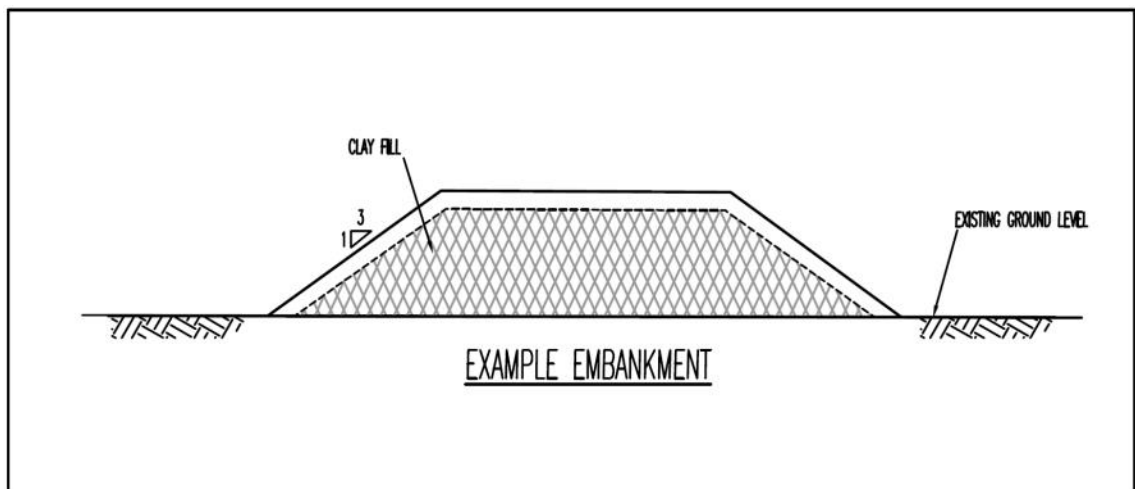


Figure 20 Indicative earth embankment cross section

The costing of the earth embankment included allowance for the following aspects and materials:

- Excavation and disposal
- Fill
- Trimming of filled surfaces
- Seeding
- Topsoil
- Erosion control
- Drainage
- Design, preliminaries and scaling of works

The estimated costs per metre of embankment range from £800 to £1,600 for embankments of heights 0.5m to 2m respectively. The cost estimate includes an uplift to account for design, preliminaries and scaling of works. In addition, a 60% optimism bias allowance has also been applied.

1.4.4 Demountables / flood gates

As part of the raised defence alignments it is possible that demountable / manually operated flood gates will be required in order for the defence to pass over roads / rail / footpaths and other essential infrastructure.

The cost for flood gates has been estimated based on prices provided by various contractors and flood gate suppliers, including *Flood Sense*, *Flood Control International*, *Defence Doors* and *Stoneman Engineering*. Costs for a range of gate sizes, lengths and heights were provided and costs were identified based on the most appropriate gate geometry that was required. In the instance that real costs for the exact gate geometry was not available, costs from similar size gates were scaled. This is considered appropriate for a high level costing exercise as part of a strategic level study.

The estimated cost for two swing gates 5m in length by 1.5m in height is approximately £85,000. This cost includes an allowance for installation and also a 60% optimism bias uplift.

1.4.5 Tidal lock / stop gates upgrades

Lock / stop gate raising and replacement at Entrance Lock and Netham Lock will accompany the construction of raised defences and is included as part of the low and high defence measures.

The costs of lock / stop gate upgrades have been estimated based upon the Environment Agency guidance document 'Cost estimation for control assets – summary of evidence, Report SC080039/R5'. The report provides a summary of indicative costs and guidance on a number of channel, flow and level control assets typical of those used by operating authorities for watercourses in England and Wales. The cost estimates for MEICA systems provided in the report are based on the experience of regional Environment Agency MEICA teams drawing on typical costs experienced for similar types of work. In reality the possible range of actual costs is high and the costs provided are therefore only suitable for use in high level initial assessments (such as a Strategy).

In subsequent studies more detailed cost estimations of lock / stop gate replacement will be necessary.

The cost build-up below is for one replacement of the lock gates and associated infrastructure.

No specific structural dimensions for Entrance Lock or Netham Lock have been used in the costing exercise. Rather, standard unit rates for maximum size gates >10m² and the associated infrastructure have been utilised.

The costing of the lock gate raising and replacement includes an allowance for the following aspects and materials:

Building services

- Electrical systems

Controls

- Common MCC controls

Mechanical

- Actuation
- Engines (over 250 horsepower)
- Gates (over 10m²)
- Gearbox (over 250 horsepower)

Pumps

- Screw pumps

Electrical

- Auto-transformers
- Electronic power components
- High voltage control equipment
- High voltage and power correction capacitors
- Three-phase motors

Lifting and winching

- Cranes over 5 tonnes

Other

- Powered weed screen
- Hydraulic systems

Based on this approach, the capital costs of upgrading one set of lock / stop gates is estimated to be approximately £5.3million. A percentage uplift in cost has been made for design, preliminaries and scale of works in addition to a 60% optimism bias allowance which has also been applied.

1.4.6 **Raised defence maintenance**

Cost estimates for the maintenance of the raised defences vary according to the structure type; general defences at Shirehampton (embankment) and sheet piled solutions elsewhere within the study site.

For the frontline sheet pile structures the maintenance cost includes the cost of providing and replacing the cathodic protection. The cost was based upon a contractor cost estimate obtained in February 2016 and includes the galvanising of steel sheet piles of maximum AZ-48 pile length. The cost includes survey and design, materials, installation, testing and commissioning. It has been assumed that cathodic protection maintenance will be required on average once every 20 years. Per metre of sheet pile defence the annual cost estimate for cathodic protection is approximately £40. This cost includes a 60% optimism bias allowance.

General maintenance costs have also been considered within the maintenance cost build-up for the frontline sheet pile structures. General maintenance costs have been based upon the replacement costs provided by BCC for Clarence Road. As raised defences are new structures, it has been assumed that the general maintenance will be initially required on a less frequent basis.

In total, the average annual cost estimate for frontline sheet piles, including both cathodic protection maintenance and general maintenance, is approximately £230 per metre. This cost includes a 60% optimism bias allowance.

Costs for general maintenance to the embankment at Shirehampton have been estimated to be approximately £130 per metre per year. This cost includes a 60% optimism bias allowance.

1.5 **Tidal Barrier**

1.5.1 **Capital works**

Due to the unique nature of the barrier solution estimating the cost is a challenge. Previously barrier costs have been estimated based on the approved PAR cost of the Boston Barrier. However, the proposed tidal barrier is closer in scale to the Thames Barrier and it is considered more appropriate to benchmark against this.

The outcome of the benchmarking provided a range of values from £386m to £926m depending on which values were used, what they were assumed to include (e.g. associated defences, design costs etc.) and how they were pro-rated. Ultimately the following approach has been adopted to arrive at a single value for the barrier cost:

- The cost of the Thames Barrier is reported to be £534m (1984 cost base) not including associated defences. This has been updated to a 2012 cost base using BIS construction indices (2012 being the latest available online).
- The cost has then been pro-rated using the ratio of the respective gate widths to get the construction cost and allowances added for upfront costs (20%) and optimism bias (60%).
- Following this approach the estimate for the total cash cost for design and construction of the tidal barrier is **£683m**.

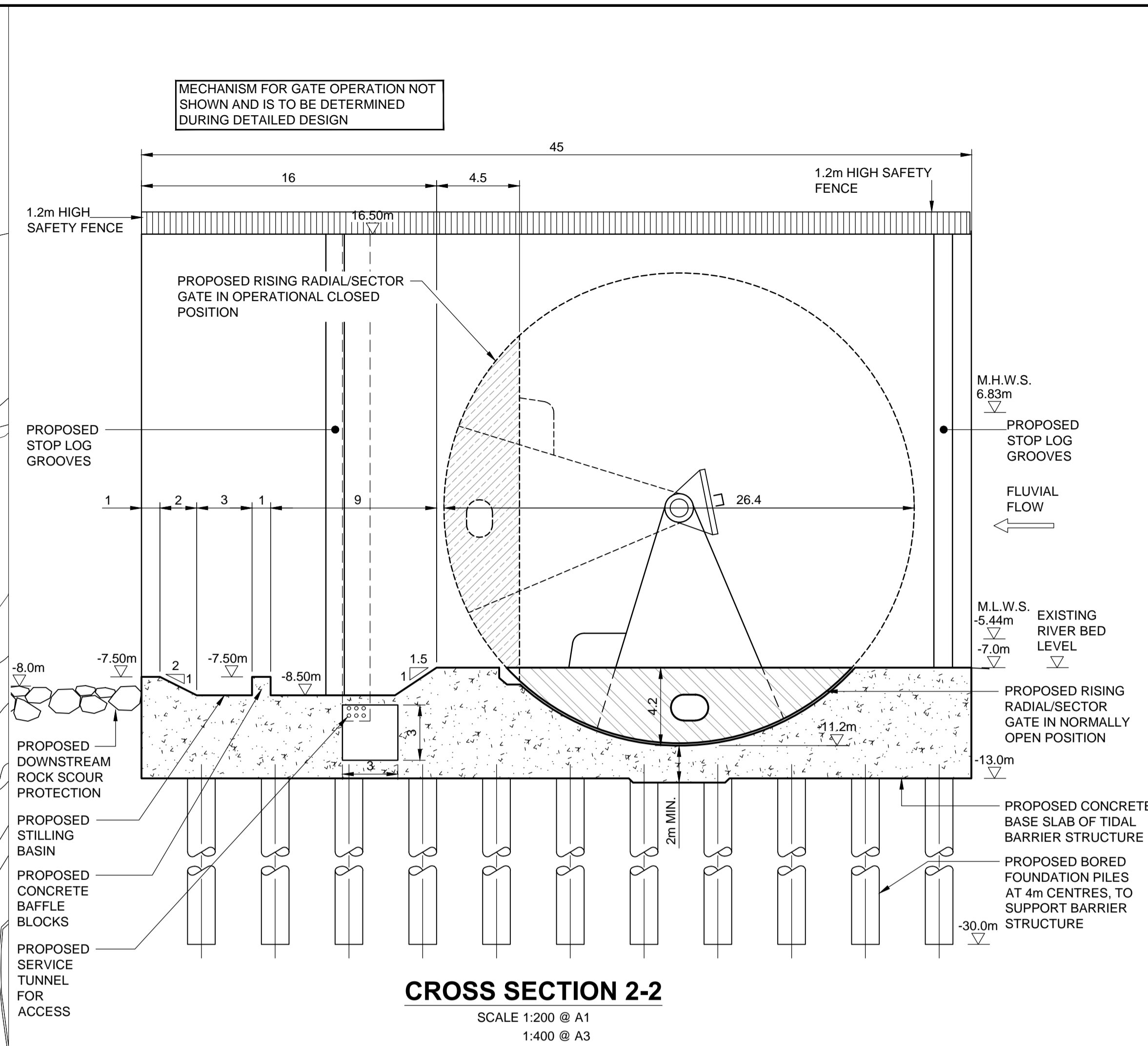
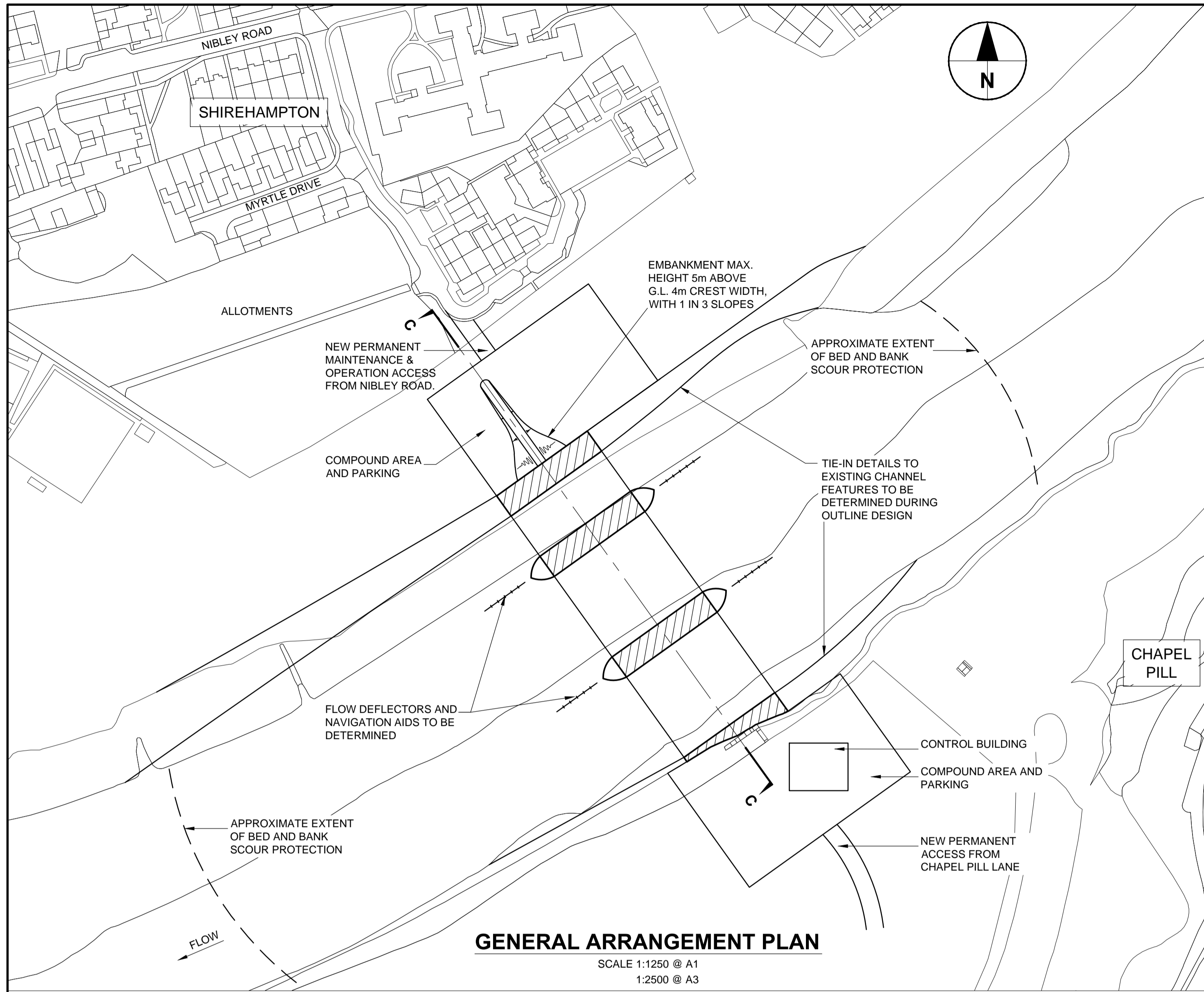
1.5.2 **Maintenance and operation**

Ongoing operation and maintenance costs depend on the frequency of operation and whether the barrier becomes a device to mitigate fluvial flood risk as well as tidal (as has happened with the Thames Barrier). To derive an operation cost estimate it has been assumed that operation includes a monthly full lift to ensure all systems are working correctly. Only two lifts per annum have been assumed to protect against tidal flooding.

It is likely that regular maintenance dredging will be required to keep the navigation channels clear. The extent and frequency of dredging will be determined as part of the geomorphological assessments at a later stage. Gates and operating mechanisms will also require regular maintenance to ensure that they continue to operate satisfactorily. It is anticipated that every 25 years there is likely to be a need for a major refurbishment, particularly of the mechanical and electrical components.

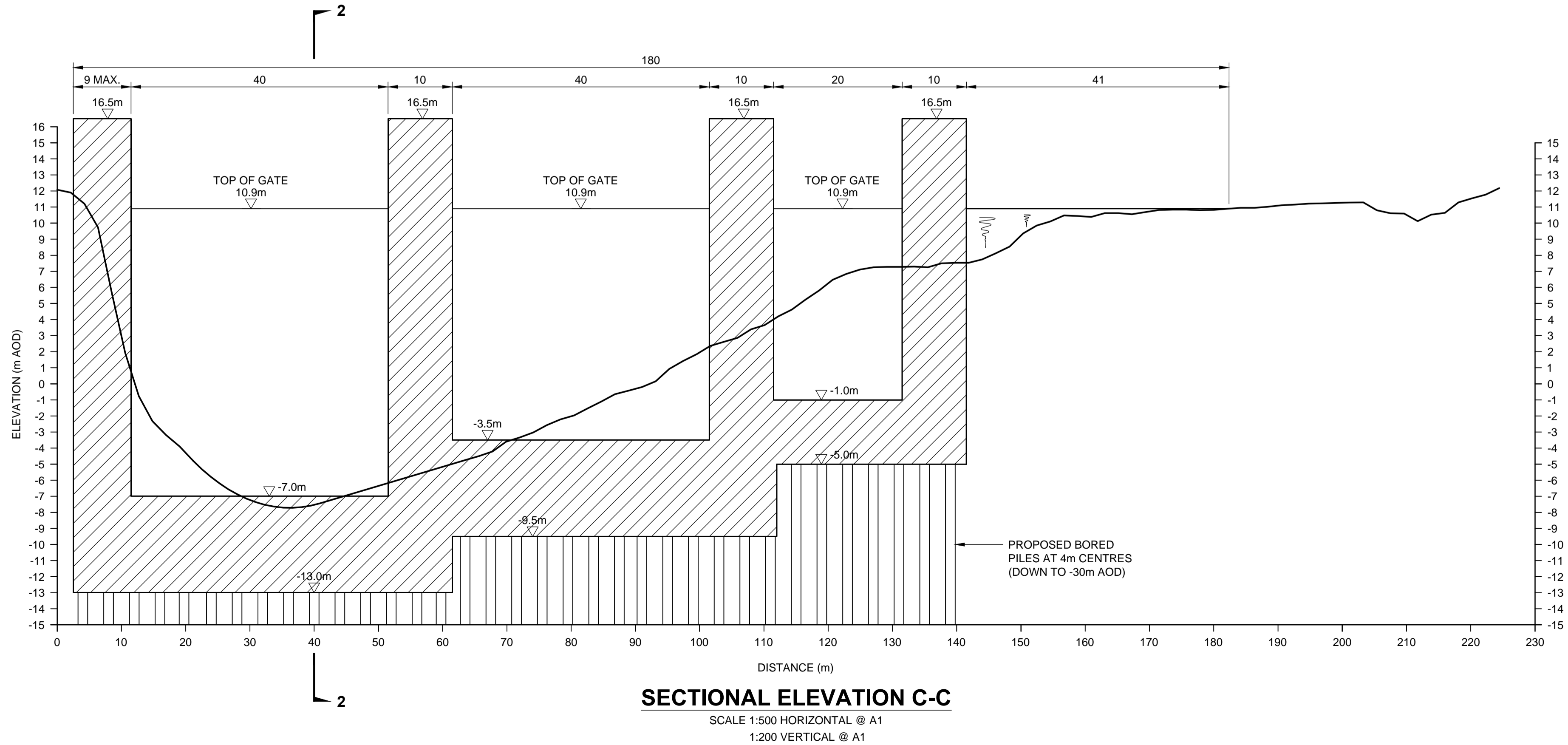
Based on the above it has been assumed for the purposes of this costing exercise that annual operation and maintenance costs would be **£1m**. Every 25 years it is estimated **£50m** would be required for refurbishment.

Figure 21 Tidal Barrier cross section drawing



GATE SCHEDULE			
No.	WIDTH	HEIGHT	INVERT LEVEL
1	40m	17.9m	-7.0m
1	40m	14.4m	-3.5m
1	20m	9.9m	1.0m

PILE SCHEDULE			
No.	LENGTH	TOP LEVEL	BASE LEVEL
165	17.0m	-13.0m	-30m
143	20.5m	-9.5m	-30m
77	25.0m	-5.0m	-30m



- NOTES**
- ALL DIMENSIONS SHOWN ARE IN METRES & ALL LEVELS ARE IN METRES A.O.D.
 - TIDAL DESIGN HEIGHT = 10.9m (10.6m = 1:1000 TIDAL LEVEL, BASED ON THE UPPER END SLR SCENARIO FOR 2115, PLUS 300mm FREEBOARD).
 - FLUVIAL DESIGN HEIGHT = 9.6m (9.3m = WATER LEVEL FOR 2110 F200 T2 CAFRA RUN, PLUS 300mm FREEBOARD).
 - NO CALCULATIONS HAVE BEEN CARRIED OUT TO DETERMINE ANY STRUCTURAL ELEMENT SIZES, AND ALL DIMENSIONS ARE INDICATIVE ONLY AT THIS STAGE.
 - NOT SHOWN BUT TO BE INCLUDED:
 - 1 No. FIXED CRANE ON PIER
 - CONTROL BUILDINGS
 - ALL M&E ASSOCIATED WITH GATE OPERATION
 - PROPOSED PILE LENGTHS TAKEN FROM OUTLINE GEOTECHNICAL ASSESSMENT, ARUP, 30th SEPTEMBER 2013.
 - NEED FOR SEEPAGE CUT-OFFS NOT ASSESSED.
 - NO ENVIRONMENTAL MITIGATION OR ENHANCEMENT CURRENTLY INCLUDED.
 - PEDESTRIAN AND SERVICES ACCESS TO BE VIA A TUNNEL BENEATH GATES.
 - BED LEVEL BASED ON ARUP OUTLINE GEOTECHNICAL ASSESSMENT, 30th SEPTEMBER 2013.
 - BED PROFILE BELOW -4.5m UNKNOWN & ESTIMATED BASED ON ASSUMED BED LEVEL (SEE NOTE 10).
 - PILES ASSUMED TO BE 1.5m DIAMETER.

ISSUE/REVISION

NO.	DATE	DESCRIPTION
A	21.07.2016	REVISED ISSUE
I/R	24.02.2016	PRELIMINARY ISSUE
I/R		DATE DESCRIPTION

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2. **APPENDIX 2: RAISED DEFENCE ALIGNMENTS**

The figures in this appendix present the raised defence alignments used for costing purposes.

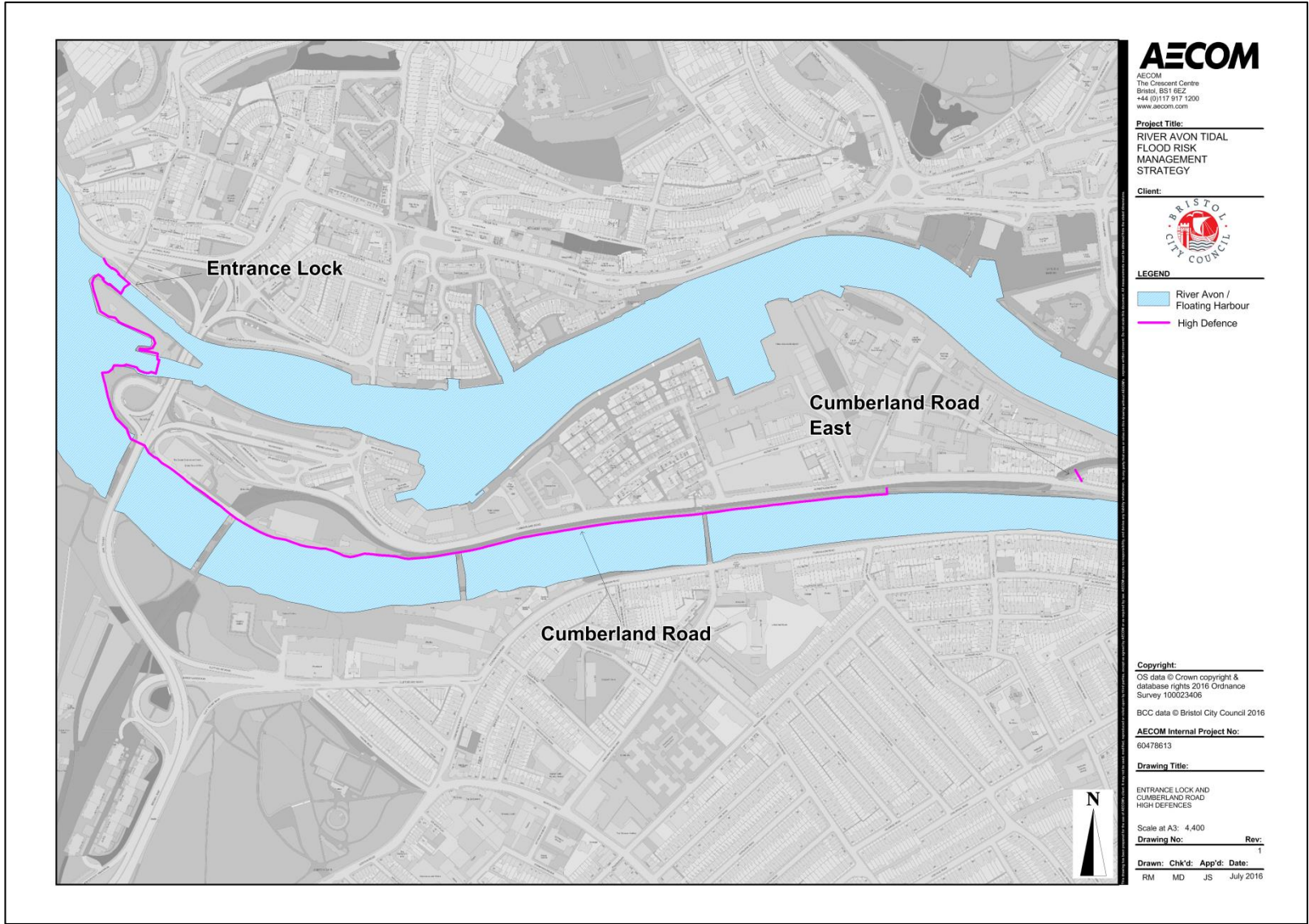


Figure 22 High Defences. Entrance Lock and Cumberland Road

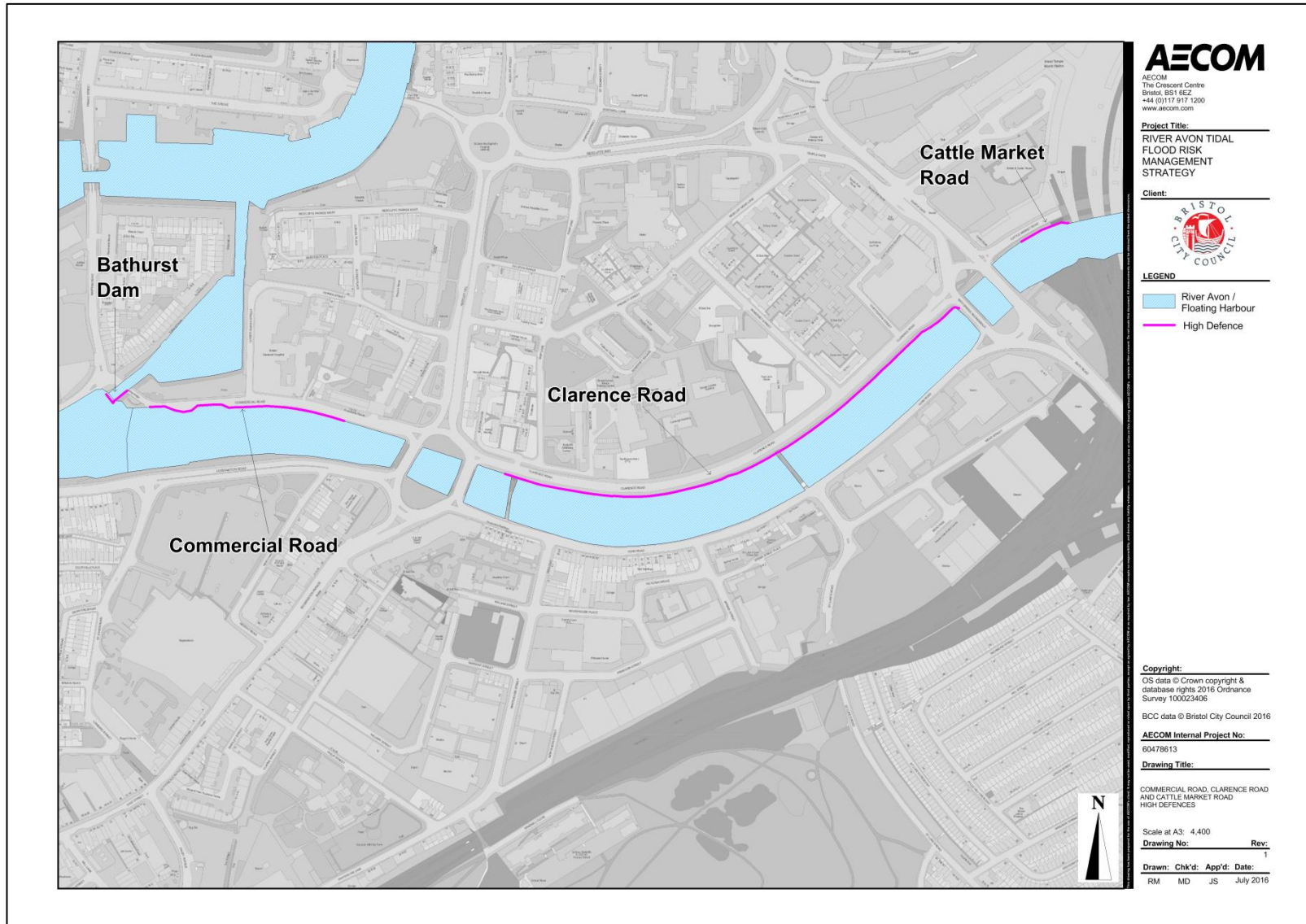


Figure 23 High Defences. Commercial Road, Clarence Road and Cattle Market Road

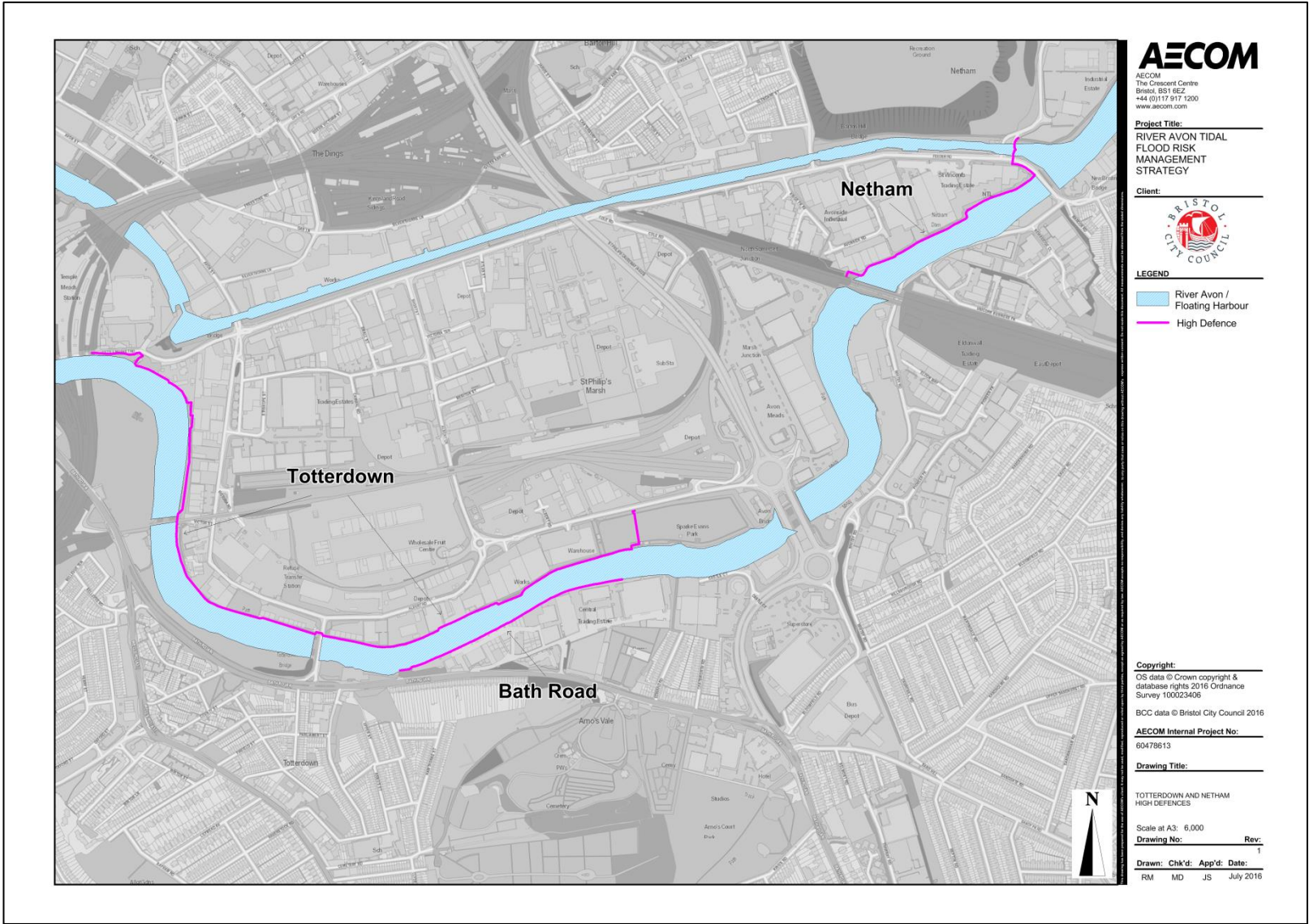


Figure 24 High Defences. Totterdown and Bath Road

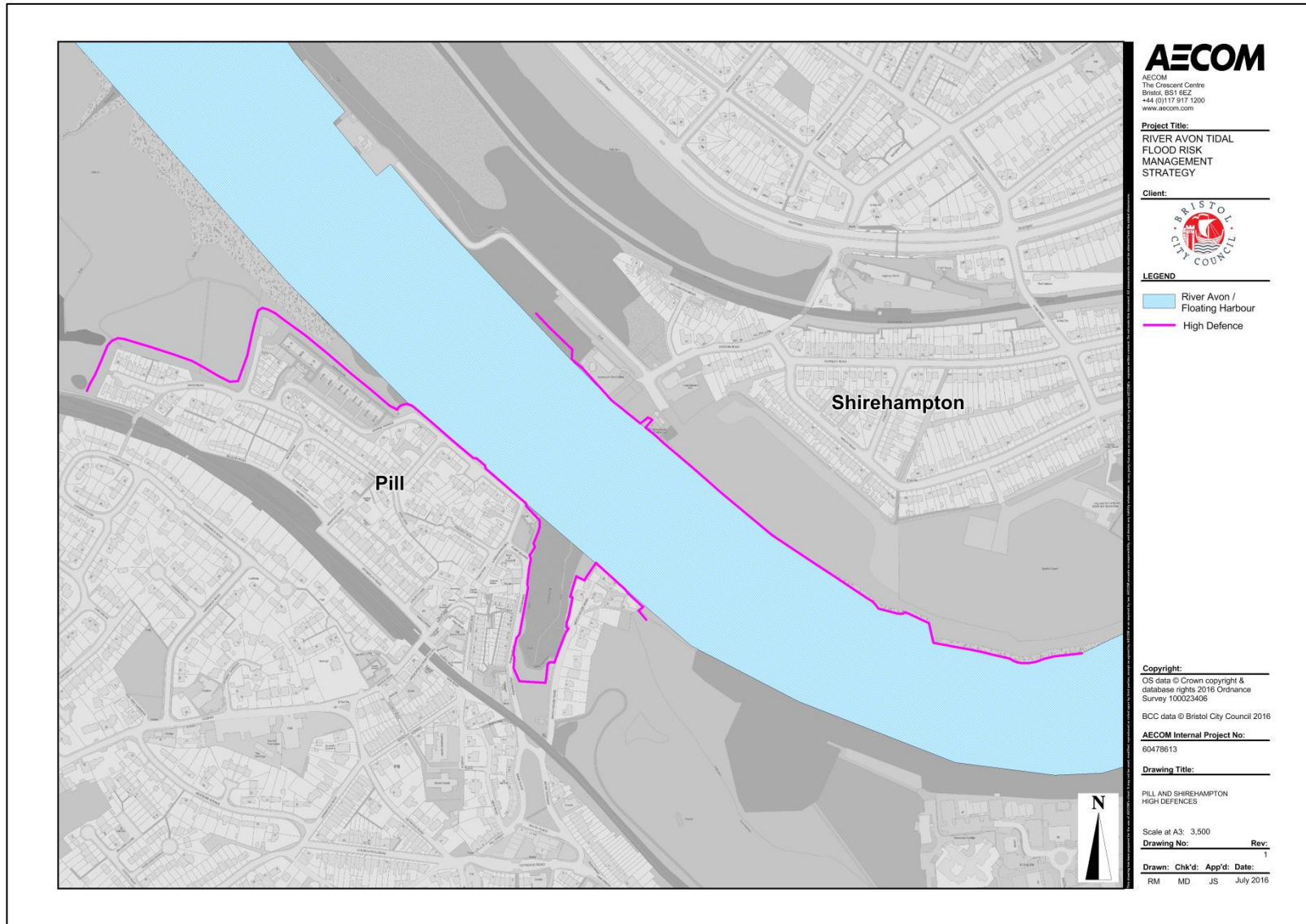


Figure 25 High Defences. Pill and Shirehampton

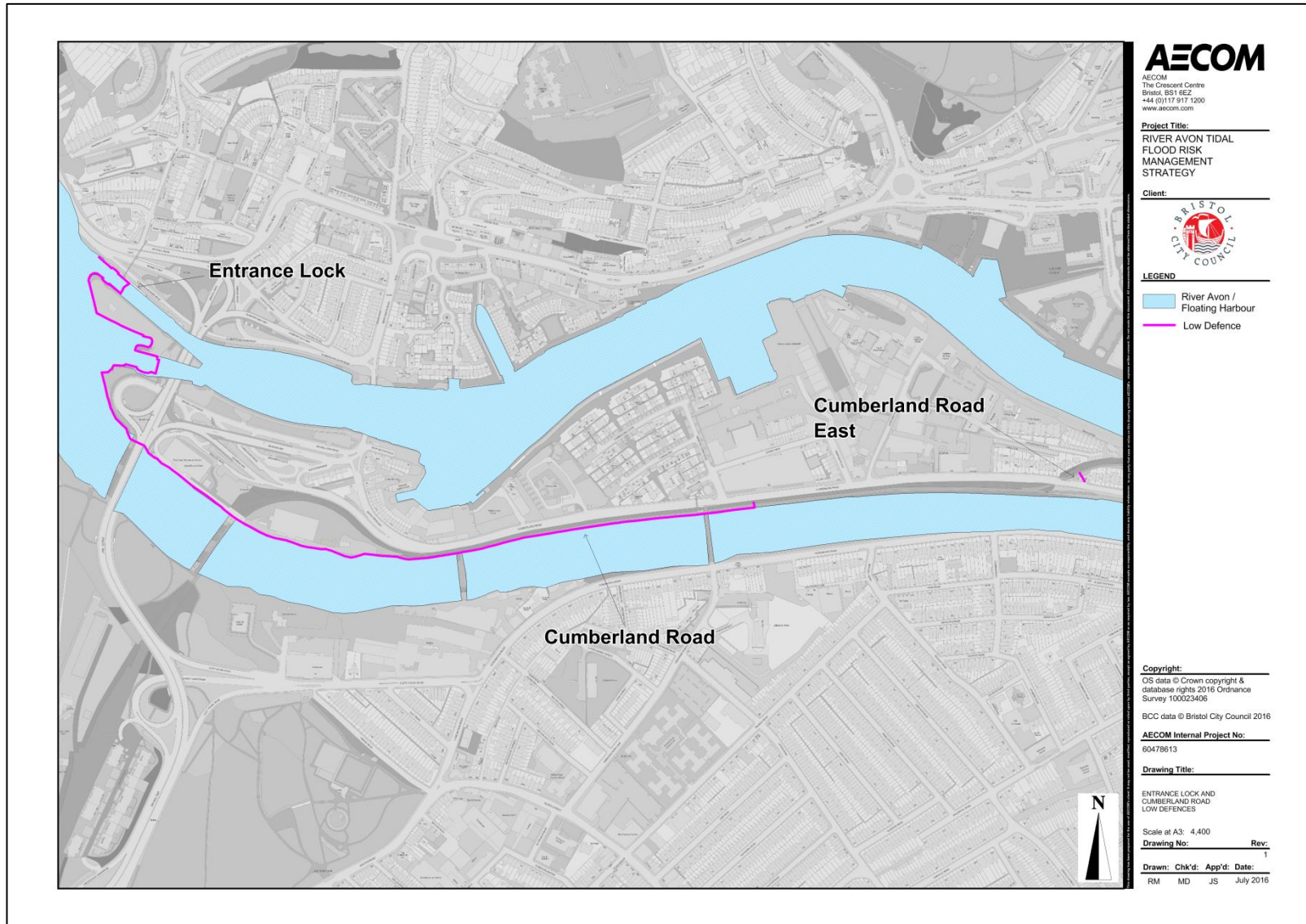


Figure 26 Low Defences. Entrance Lock and Cumberland Road

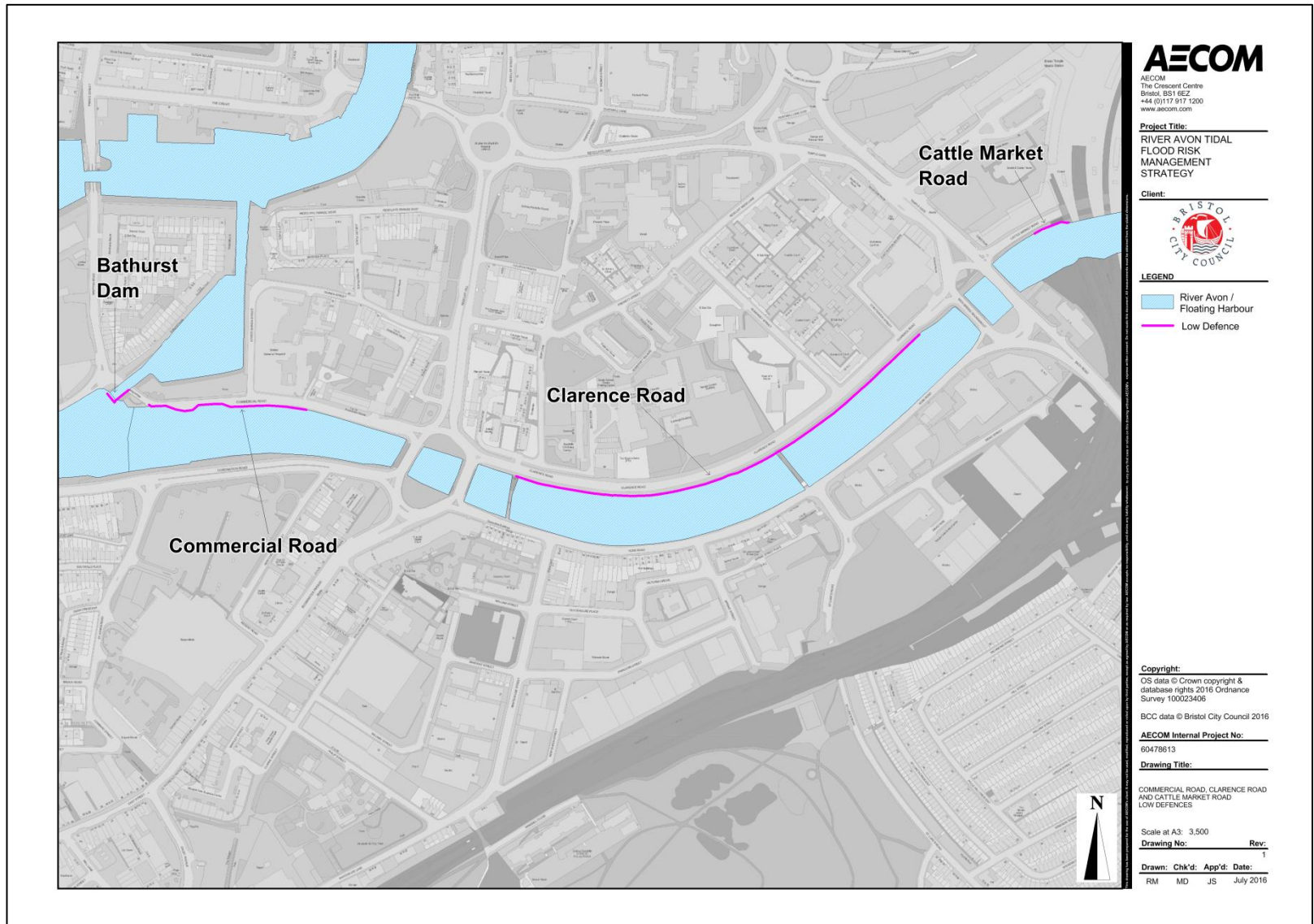


Figure 27 Low Defences. Commercial Road, Clarence Road and Cattle Market Road

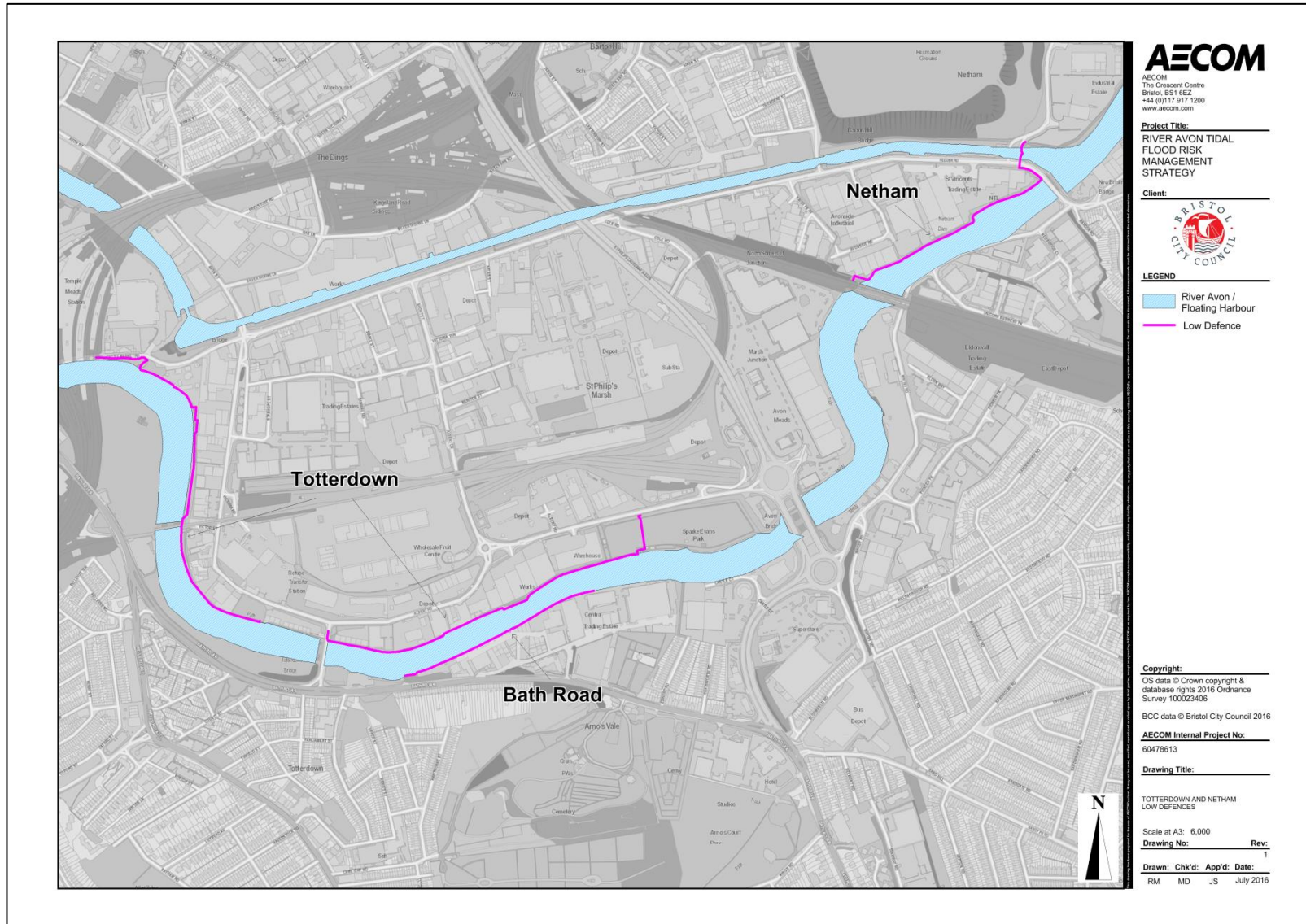


Figure 28 Low Defences. Totterdown and Bath Road

3.

APPENDIX 3: PARTNERSHIP FUNDING CALCULATIONS

Low defences, 2015, Do Nothing baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)
Version 8 January 2014

Project Name Avon TFRMS Low Walls 2015, 50yr design life, Do Nothing Benefits
Unique Project Number 47070074

All figures are in £'s
Figures in Blue to be entered onto Medium Term Plan

SUMMARY: prospect of FCRM GIA funding

Raw Partnership Funding Score	59% (1)	Scheme Benefit to Cost Ratio:	9.04 to 1
External Contribution or saving required to achieve an Adjusted Score of 100%	53,092,579 (2)	Effective return to taxpayer:	9.04 to 1
Adjusted Partnership Funding Score (PF)	59% (3)	Effective return on contributions:	n/a to 1
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval)	- (4)		

Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.

1. Scheme details

Risk Management Authority type of asset maintainer	LA (5)	Yes (6)	Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?
Duration of Benefits (years)	50 (7)		
PV Whole-Life Benefits:	1,353,404,000 (8)		
PV Costs			All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.
PV Appraisal Costs			
PV design & Construction Costs	128,317,000 (10)		
Sub Total - PV Cost for Approval (appraisal,design,construction)	128,317,000 (11)		
PV Post-Construction Costs	21,404,000 (12)		
PV Whole-Life Costs:	149,721,000 (13)		
PV Contributions secured to date			
PV Local Levy secured to date			
PV Public Contributions secured to date			
PV Private Contributions secured to date			
PV Funding from other Environment Agency functions/sources secured to date			
PV Total Contributions secured to date	0 (18)		

WARNING: Contributions less than minimum required in cell (2)

The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.

NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).

2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk

Number of households in:	Before	After	Change due to scheme
20% most deprived areas	1,545	-	0
21-40% most deprived areas	1,187	-	-1,545
60% least deprived areas	845	-	-1,187
			0

Annual damages avoided (£), compared with a household at low risk

Per year	Over lifetime of scheme	Qual. benefits (discounted)
20% most deprived areas	£ -	OM2 (20%) £ -
21-40% most deprived areas	£ -2,084,700	OM2 (21-40%) £ 51,476,598
60% least deprived areas	£ -	OM2 (60%) £ -

3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion

Number of households in:	Before	After	Change due to scheme
20% most deprived areas			£ 6,000
21-40% most deprived areas			£ 6,000
60% least deprived areas			£ 50
			£ 20

Qual. benefits (discounted):

OM3 (20%)	£ -
OM3 (21-40%)	£ -
OM3 (60%)	£ -

4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met

Payments under:	Assumed benefits per unit:	Qual. benefits (discounted):
OM4a: Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b: Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c: Kilometres of protected river improved	£ 80,000	OM4c £ -
		OM4 £ -

5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan

OM deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 1,301,927,402	5.58 p in the £1	£ 72,329,300
OM2	£ -	45.0	£ -
20% most	£ -	30.0	£ -
21-40%	£ 51,476,598	20.0	£ 15,442,979
Least 60%	£ -	45.0	£ -
OM3	£ -	30.0	£ -
20% most	£ -	20.0	£ -
21-40%	£ -	100.0	£ -
Least 60%	£ -		£ -
OM4	£ -		£ -
Total	£ 1,353,404,000		£ 87,772,279

Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.

Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.

Raw Score	Contribution for 100% Score (£k)
59%	53,092,579
21%	179,545,290
57%	54,731,794
59%	53,092,579
11%	114,029,269
58%	54,438,098

As scenario above

Sensitivity 1 - Change in PV Whole Life Cost (25% increase)

Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band

Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss

Sensitivity 4 - Increase Duration of Benefits by 25%

Sensitivity 5 - Reduce Duration of Benefits by 25%

END OF WORKSHEET

Low defences, 2030, Do Nothing baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)		
Version 8 January 2014		
Project Name	Avon TFRMS Low walls 2030, 50yr design life, Do Nothing Benefits	
Unique Project Number	47070074	
		Key
		Input cells
		Calculated cells
All figures are in £'s Figures in Blue to be entered onto Medium Term Plan		
SUMMARY: prospect of FCRM GIA funding		
Raw Partnership Funding Score	64% (1)	Scheme Benefit to Cost Ratio: 8.60 to 1 Effective return to taxpayer: 8.60 to 1 Effective return on contributions: n/a to 1
External Contribution or saving required to achieve an Adjusted Score of 100%	27,763,077 (2)	Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.
Adjusted Partnership Funding Score (PF)	64% (3)	
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval)	- (4)	
1. Scheme details		
Risk Management Authority type of asset maintainer	LA (5)	Yes (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?
Duration of Benefits (years)	50 (7)	
PV Whole-Life Benefits:	746,133,000 (8)	All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.
PV Costs		
PV Appraisal Costs	(9)	
PV design & Construction Costs	76,591,000 (10)	
Sub Total - PV Cost for Approval (appraisal,design,construction)	76,591,000 (11)	
PV Post-Construction Costs	10,139,000 (12)	
PV Whole-Life Costs:	86,730,000 (13)	
PV Contributions secured to date		The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.
PV Local Levy secured to date	(14)	NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).
PV Public Contributions secured to date	(15)	
PV Private Contributions secured to date	(16)	
PV Funding from other Environment Agency functions/sources secured to date	(17)	
PV Total Contributions secured to date	0 (18)	
WARNING: Contributions less than minimum required in cell (2)		
2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk		
Number of households in:	Before	After
20% most deprived areas	1,717	1,248
21-40% most deprived areas		
60% least deprived areas		
At:	Moderate risk	Significant risk
		Very significant risk
		Annual damages avoided (£), compared with a household at low risk
		150 600 1,350
Change in household damages, in:	Per year	Over lifetime of scheme
20% most deprived areas	£ -	£ -
21-40% most deprived areas	£ -2,292,900	£ 114,645,000
60% least deprived areas	£ -	£ -
		Qual. benefits (discounted):
		OM2 (20%) £ -
		OM2 (21-40%) £ 56,617,590
		OM2 (60%) £ -
3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion		
Number of households in:	Before	After
20% most deprived areas		
21-40% most deprived areas		
60% least deprived areas		
	Long-term loss	Medium-term loss
Change in household damages, in:	Year 1 loss avoided:	Over lifetime of scheme:
20% most deprived areas	£ -	£ -
21-40% most deprived areas	£ -	£ -
60% least deprived areas	£ -	£ -
		Qual. benefits (discounted):
		OM3 (20%) £ -
		OM3 (21-40%) £ -
		OM3 (60%) £ -
4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met		
Payments under:		Assumed benefits per unit:
OM4a	Hectares of net water-dependent habitat created	£ 15,000
OM4b	Hectares of net intertidal habitat created	£ 50,000
OM4c	Kilometres of protected river improved	£ 80,000
		Qual. benefits (discounted):
		OM4a £ -
		OM4b £ -
		OM4c £ -
		OM4 £ -
5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan		
OM, deprivation:	Qual. benefits:	Payment rate:
OM1	£ 689,515,410	5.56 p in the £1
OM2	£ -	45.0
20% most	£ -	30.0
21-40%	£ 56,617,590	20.0
Least 60%	£ -	45.0
OM3	£ -	30.0
20% most	£ -	20.0
21-40%	£ -	100.0
Least 60%	£ -	
OM4	£ -	
Total	£ 746,133,000	
		FCRM GIA contribution:
		£ 38,306,412
		£ -
		£ 16,985,277
		£ -
		£ -
		£ -
		£ -
		£ -
		£ -
		£ 55,291,689
Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.		
Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.		
	Raw Score	Contribution for 100% Score (£k)
As scenario above	64%	27,763,077
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)	23%	73,766,185
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band	61%	29,668,007
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss	64%	27,763,077
Sensitivity 4 - Increase Duration of Benefits by 25%	21%	60,395,581
Sensitivity 5 - Reduce Duration of Benefits by 25%	62%	29,287,967
END OF WORKSHEET		

High defences, 2030, Do Nothing baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)			
Version 8 January 2014			
Project Name	Avon TFRMS High Walls 2030, 85 yr design life, Do Nothing Benefits		
Unique Project Number	47070074		
<p>All figures are in £'s Figures in Blue to be entered onto Medium Term Plan</p>			
<p>SUMMARY: prospect of FCRM GIA funding</p>			
Raw Partnership Funding Score	60% (1)	Scheme Benefit to Cost Ratio: 8.37 to 1 Effective return to taxpayer: 8.37 to 1 Effective return on contributions: n/a to 1	
External Contribution or saving required to achieve an Adjusted Score of 100%	39,845,522 (2)	Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.	
Adjusted Partnership Funding Score (PF)	60% (3)		
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval)	- (4)		
<p>1. Scheme details</p>			
Risk Management Authority type of asset maintainer	LA (5)	Yes (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?	
Duration of Benefits (years)	85 (7)		
PV Whole-Life Benefits:	1,011,912,000 (8)		
PV Costs		<p>All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.</p>	
PV Appraisal Costs	(9)		
PV design & Construction Costs	98,670,000 (10)		
Sub Total - PV Cost for Approval (appraisal,design,construction)	98,670,000 (11)		
PV Post-Construction Costs	22,228,000 (12)		
PV Whole-Life Costs:	120,898,000 (13)		
PV Contributions secured to date			
PV Local Levy secured to date	(14)		
PV Public Contributions secured to date	(15)		
PV Private Contributions secured to date	(16)		
PV Funding from other Environment Agency functions/sources secured to date	(17)		
PV Total Contributions secured to date	0 (18)		
<p>WARNING: Contributions less than minimum required in cell (2)</p>			
<p><i>The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.</i></p> <p>NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).</p>			
<p>2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk</p>			
Number of households in:	Before	After	
20% most deprived areas			
21-40% most deprived areas	1,794	1,214	
60% least deprived areas		921	
At:	Moderate risk	Significant risk	Very significant risk
Annual damages avoided (£), compared with a household at low risk:	150	600	1,350
Change in household damages, in:	Per year	Over lifetime of scheme	Qual. benefits (discounted)
20% most deprived areas	£ -	£ -	OM2 (20%) £ -
21-40% most deprived areas	£ -2,240,850	£ -190,472,250	OM2 (21-40%) £ 64,877,309
60% least deprived areas	£ -	£ -	OM2 (60%) £ -
<p>3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion</p>			
Number of households in:	Before	After	
20% most deprived areas			
21-40% most deprived areas			
60% least deprived areas			
Long-term loss	Medium-term loss		
Change in household damages, in:	Year 1 loss avoided:	Over lifetime of scheme:	Qual. benefits (discounted):
20% most deprived areas	£ -	£ -	OM3 (20%) £ -
21-40% most deprived areas	£ -	£ -	OM3 (21-40%) £ -
60% least deprived areas	£ -	£ -	OM3 (60%) £ -
<p>4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met</p>			
Payments under:		Assumed benefits per unit:	Qual. benefits (discounted):
OM4a	Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b	Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c	Kilometres of protected river improved	£ 80,000	OM4c £ -
<p>5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan</p>			
OM, deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 947,034,691	5.56 p in the £1	£ 52,613,038
OM2	£ -	45.0	£ -
20% most	£ -	30.0	£ -
21-40%	£ 64,877,309	20.0	£ 19,463,193
Least 60%	£ -	45.0	£ -
OM3	£ -	30.0	£ -
20% most	£ -	20.0	£ -
21-40%	£ -	100.0	£ -
Least 60%	£ -		£ -
OM4	£ -		£ -
Total	£ 1,011,912,000		£ 72,076,231
<p>Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.</p>			
<p>Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.</p>			
Raw Score	Contribution for 100% Score (£k)		
60%	39,845,522		
21%	96,896,485		
58%	41,840,404		
60%	39,845,522		
#N/A	#N/A		
59%	40,811,894		
<p>As scenario above</p> <p>Sensitivity 1 - Change in PV Whole Life Cost (25% increase)</p> <p>Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band</p> <p>Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss</p> <p>Sensitivity 4 - Increase Duration of Benefits by 25%</p> <p>Sensitivity 5 - Reduce Duration of Benefits by 25%</p>			

Barrier, 2030, Do Nothing baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)			
Version 8 January 2014			
Project Name	Avon TFRMS Barrier 2030, 85yr design life, Do Min Benefits		
Unique Project Number	47070074		
		Key: <input type="text" value="Input cells"/> <input type="text" value="Calculated cells"/>	
All figures are in £'s Figures in Blue to be entered onto Medium Term Plan			
SUMMARY: prospect of FCRM GIA funding			
Raw Partnership Funding Score	16% (1)	Scheme Benefit to Cost Ratio: 2.22 to 1 Effective return to taxpayer: 2.22 to 1 Effective return on contributions: n/a to 1	
External Contribution or saving required to achieve an Adjusted Score of 100%	343,125,746 (2)	Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.	
Adjusted Partnership Funding Score (PF)	16% (3)		
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval)	- (4)		
1. Scheme details			
Risk Management Authority type of asset maintainer	LA (5)	Yes (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?	
Duration of Benefits (years)	85 (7)		
PV Whole-Life Benefits:	1,022,829,000 (8)	All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.	
PV Costs			
PV Appraisal Costs	(9)		
PV design & Construction Costs	407,676,000 (10)		
Sub Total - PV Cost for Approval (appraisal,design,construction)	407,676,000 (11)		
PV Post-Construction Costs	54,057,000 (12)		
PV Whole-Life Costs:	461,733,000 (13)	The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.	
PV Contributions secured to date		NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).	
PV Local Levy secured to date	(14)		
PV Public Contributions secured to date	(15)		
PV Private Contributions secured to date	(16)		
PV Funding from other Environment Agency functions/sources secured to date	(17)		
PV Total Contributions secured to date	0 (18)		
WARNING: Contributions less than minimum required in cell (2)			
2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk			
Number of households in:	Before	After	Change due to scheme
20% most deprived areas	1,819	1,297	926
21-40% most deprived areas			
60% least deprived areas			
At:	Moderate risk	Significant risk	Very significant risk
Annual damages avoided (£), compared with a household at low risk:	150	600	1,350
Change in household damages, in:	Per year	Over lifetime of scheme	Qual. benefits (discounted)
20% most deprived areas	£ -	£ -	OM2 (20%) £ -
21-40% most deprived areas	£ -2,301,150	£ 195,597,750	OM2 (21-40%) £ 66,623,121
60% least deprived areas	£ -	£ -	OM2 (60%) £ -
3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion			
Number of households in:	Before	After	Change due to scheme
20% most deprived areas			
21-40% most deprived areas			
60% least deprived areas			
Long-term loss			
Medium-term loss			
Change in household damages, in:	Year 1 loss avoided:	Over lifetime of scheme:	Qual. benefits (discounted):
20% most deprived areas	£ -	£ -	OM3 (20%) £ -
21-40% most deprived areas	£ -	£ -	OM3 (21-40%) £ -
60% least deprived areas	£ -	£ -	OM3 (60%) £ -
4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met			
Payments under:		Assumed benefits per unit:	Qual. benefits (discounted):
OM4a	Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b	Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c	Kilometres of protected river improved	£ 80,000	OM4c £ -
			OM4 £ -
5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan			
OM, deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 956,205,879	5.56 p in the £1	£ 53,122,549
OM2	£ -	45.0	£ -
20% most	£ -	30.0	£ -
21-40%	£ 66,623,121	20.0	£ 19,986,936
Least 60%	£ -	45.0	£ -
OM3	£ -	30.0	£ -
20% most	£ -	20.0	£ -
21-40%	£ -	100.0	£ -
Least 60%	£ -		£ -
OM4	£ -		£ -
Total	£ 1,022,829,000		£ 73,109,485
			Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.
Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.			
Raw Score	Contribution for 100% Score (£k)		
16%	343,125,746		
6%	480,547,396		
15%	345,295,581		
16%	343,125,746		
#N/A	#N/A		
16%	344,199,308		
As scenario above			
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)			
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band			
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss			
Sensitivity 4 - Increase Duration of Benefits by 25%			
Sensitivity 5 - Reduce Duration of Benefits by 25%			
END OF WORKSHEET			

Low defences, 2015, Do Minimum baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)		
Version 8 January 2014		
Project Name	Avon TFRMS Low Walls 2015, 50yr design life, Do Min Benefits	
Unique Project Number	47070074	
<p>All figures are in £'s Figures in Blue to be entered onto Medium Term Plan</p>		
<p>SUMMARY: prospect of FCRM GIA funding</p>		
Raw Partnership Funding Score	6% (1)	Scheme Benefit to Cost Ratio: 0.97 to 1 Effective return to taxpayer: 0.97 to 1 Effective return on contributions: n/a to 1
External Contribution or saving required to achieve an Adjusted Score of 100%	120,657,583 (2)	Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.
Adjusted Partnership Funding Score (PF)	6% (3)	
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval)	- (4)	
<p>1. Scheme details</p>		
Risk Management Authority type of asset maintainer	LA (5)	Yes (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?
Duration of Benefits (years)	50 (7)	
PV Whole-Life Benefits:	145,238,000 (8)	<p>All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.</p> <p>The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means. NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).</p>
PV Costs		
PV Appraisal Costs	(9)	
PV design & Construction Costs	128,317,000 (10)	
Sub Total - PV Cost for Approval (appraisal,design,construction)	128,317,000 (11)	
PV Post-Construction Costs	21,404,000 (12)	
PV Whole-Life Costs:	149,721,000 (13)	
PV Contributions secured to date		
PV Local Levy secured to date	(14)	
PV Public Contributions secured to date	(15)	
PV Private Contributions secured to date	(16)	
PV Funding from other Environment Agency functions/sources secured to date	(17)	
PV Total Contributions secured to date	0 (18)	
<p>WARNING: Contributions less than minimum required in cell (2)</p>		
<p>2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk</p>		
Number of households in:	Before	After
20% most deprived areas		
21-40% most deprived areas	287	69
60% least deprived areas		44
	At: Moderate risk Significant risk Very significant risk	Moderate risk Significant risk Very significant risk
		Annual damages avoided (£), compared with a household at low risk
		150 600 1,350
Change in household damages, in:	Per year	Over lifetime of scheme
20% most deprived areas	£ -	£ -
21-40% most deprived areas	-£ 143,850	-£ 7,192,500
60% least deprived areas	£ -	£ -
		Qual. benefits (discounted):
		OM2 (20%) £ -
		OM2 (21-40%) £ 3,552,026
		OM2 (60%) £ -
<p>3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion</p>		
Number of households in:	Before	After
20% most deprived areas		
21-40% most deprived areas		
60% least deprived areas		
	Long-term loss Medium-term loss	Long-term loss Medium-term loss
		Damages per household avoided:
		Annual damages avoided
		Loss expected in
		Present value of Year 1 loss (i.e. first year damages, discounted based on when loss is expected)
		£ 6,000 £ 6,000
		-50 20 years
		£ 1,184 £ 3,015
Change in household damages, in:	Year 1 loss avoided:	Over lifetime of scheme:
20% most deprived areas	£ -	£ -
21-40% most deprived areas	£ -	£ -
60% least deprived areas	£ -	£ -
		Qual. benefits (discounted):
		OM3 (20%) £ -
		OM3 (21-40%) £ -
		OM3 (60%) £ -
<p>4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met</p>		
Payments under:		Assumed benefits per unit:
OM4a	Hectares of net water-dependent habitat created	£ 15,000
OM4b	Hectares of net intertidal habitat created	£ 50,000
OM4c	Kilometres of protected river improved	£ 80,000
		Qual. benefits (discounted):
		OM4a £ -
		OM4b £ -
		OM4c £ -
		OM4 £ -
<p>5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan</p>		
OM, deprivation:	Qual. benefits:	Payment rate:
OM1	£ 141,685,974	5.56 p in the £1
20% most	£ -	45.0
21-40%	£ 3,552,026	30.0
Least 60%	£ -	20.0
OM2	£ -	45.0
20% most	£ -	30.0
21-40%	£ -	20.0
Least 60%	£ -	100.0
OM3	£ -	£ -
OM4	£ -	£ -
Total	£ 145,238,000	£ 8,937,051
		Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.
<p>Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.</p>		
As scenario above	Raw Score	Contribution for 100% Score (£k)
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)	6%	120,657,583
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band	2%	156,949,512
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss	6%	120,742,939
Sensitivity 4 - Increase Duration of Benefits by 25%	6%	120,657,583
Sensitivity 5 - Reduce Duration of Benefits by 25%	1%	127,331,107
	6%	120,750,428
<p>END OF WORKSHEET</p>		

High defences, 2015, Do Minimum baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)
Version 8 January 2014

Project Name Avon TFRMS High Walls 2015, 100 yr design life, Do Min Benefits
Unique Project Number 47070074

Key Input cells
 Calculated cells

All figures are in £'s
Figures in Blue to be entered onto Medium Term Plan

SUMMARY: prospect of FCRM GIA funding

Raw Partnership Funding Score (1) Scheme Benefit to Cost Ratio: to 1
Effective return to taxpayer: to 1
Effective return on contributions: to 1

External Contribution or saving required to achieve an Adjusted Score of 100% (2) Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.

Adjusted Partnership Funding Score (PF) (3)

PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval) (4)

1. Scheme details

Risk Management Authority type of asset maintainer (5) (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?

Duration of Benefits (years) (7)

PV Whole-Life Benefits: (8)

PV Costs

PV Appraisal Costs (9)

PV design & Construction Costs (10)

Sub Total - PV Cost for Approval (appraisal,design,construction) (11)

PV Post-Construction Costs (12)

PV Whole-Life Costs: (13)

PV Contributions secured to date

PV Local Levy secured to date (14)

PV Public Contributions secured to date (15)

PV Private Contributions secured to date (16)

PV Funding from other Environment Agency functions/sources secured to date (17)

PV Total Contributions secured to date (18)

WARNING: Contributions less than minimum required in cell (2)

All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.

The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.
NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).

2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk

Number of households in: Before After Change due to scheme

	Before			After			Change due to scheme		
	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk
20% most deprived areas				-	-	-	0	0	0
21-40% most deprived areas	287	68	44	-	-	-	-287	-68	-44
60% least deprived areas				-	-	-	0	0	0

Annual damages avoided (£), compared with a household at low risk:

Change in household damages, in: Per year Over lifetime of scheme Qual. benefits (discounted)

	Per year	Over lifetime of scheme	Qual. benefits (discounted)
20% most deprived areas	£ -	£ -	OM2 (20%) £ -
21-40% most deprived areas	£ -143,250	£ -14,325,000	OM2 (21-40%) £ 4,277,927
60% least deprived areas	£ -	£ -	OM2 (60%) £ -

3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion

Number of households in: Before Damages per household avoided:

	Before		Annual damages avoided	
	Long-term loss	Medium-term loss	Annual damages avoided	Loss expected in Present value of Year 1 loss (i.e. first year damages, discounted based on when loss is expected)
20% most deprived areas			£ 6,000	£ 6,000
21-40% most deprived areas			£ -	£ -
60% least deprived areas			£ 1,184	£ 3,015

Change in household damages, in: Year 1 loss avoided: Over lifetime of scheme: Qual. benefits (discounted):

	Year 1 loss avoided:	Over lifetime of scheme:	Qual. benefits (discounted):
20% most deprived areas	£ -	£ -	OM3 (20%) £ -
21-40% most deprived areas	£ -	£ -	OM3 (21-40%) £ -
60% least deprived areas	£ -	£ -	OM3 (60%) £ -

4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met

Payments under: Assumed benefits per unit: Qual. benefits (discounted):

	Assumed benefits per unit:	Qual. benefits (discounted):
OM4a Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c Kilometres of protected river improved	£ 80,000	OM4c £ -
		OM4 £ -

5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan

OM, deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 278,003,073	5.56 p in the £1	£ 15,444,615
OM2	£ 4,277,927	45.0	£ 1,283,378
OM3	£ -	30.0	£ -
OM4	£ -	45.0	£ -
	£ -	30.0	£ -
	£ -	20.0	£ -
	£ -	100.0	£ -
Total	£ 282,281,000		£ 16,727,993

Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.

Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.

Raw Score	Contribution for 100% Score (£k)
8%	151,616,298
3%	200,472,134
8%	151,714,870
8%	151,616,298
#N/A	#N/A
8%	151,666,041

As scenario above

Sensitivity 1 - Change in PV Whole Life Cost (25% increase)

Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band

Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss

Sensitivity 4 - Increase Duration of Benefits by 25%

Sensitivity 5 - Reduce Duration of Benefits by 25%

END OF WORKSHEET

High defences, 2030, Do Minimum baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)
Version 8 January 2014

Project Name Avon TFRMS High walls 2030, 85yr design life, Do Min Benefits
Unique Project Number 47070074

Key
Input cells
Calculated cells

All figures are in £'s
Figures in Blue to be entered onto Medium Term Plan

SUMMARY: prospect of FCRM GIA funding

Raw Partnership Funding Score 9% (1)
External Contribution or saving required to achieve an Adjusted Score of 100% 116,733,751 (2)
Adjusted Partnership Funding Score (PF) 9% (3)
PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval) - (4)

Scheme Benefit to Cost Ratio: 1.46 to 1
Effective return to taxpayer: 1.46 to 1
Effective return on contributions: n/a to 1

Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.

1. Scheme details

Risk Management Authority type of asset maintainer LA (5) Yes (6)
Duration of Benefits (years) 85 (7) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?
PV Whole-Life Benefits: 220,444,000 (8) All costs and benefits must be on a Present Value (PV) Whole-Life basis over the Duration of Benefits period. Where Contributions are identified these should also be on a Present Value basis.

PV Costs
PV Appraisal Costs (9)
PV design & Construction Costs 128,317,000 (10)
Sub Total - PV Cost for Approval (appraisal,design,construction) 128,317,000 (11)
PV Post-Construction Costs 22,228,000 (12)
PV Whole-Life Costs: 150,545,000 (13)

The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.
NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).

PV Contributions secured to date
PV Local Levy secured to date (14)
PV Public Contributions secured to date (15)
PV Private Contributions secured to date (16)
PV Funding from other Environment Agency functions/sources secured to date (17)
PV Total Contributions secured to date 0 (18)
WARNING: Contributions less than minimum required in cell (2)

2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk

Number of households in:	Before			After			Change due to scheme		
	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk
20% most deprived areas				-	-	-	0	0	0
21-40% most deprived areas	495	71	54	-	-	-	-495	-71	-54
60% least deprived areas				-	-	-	0	0	0

Annual damages avoided (£), compared with a household at low risk: 150 600 1,350

Change in household damages, in:	Per year		Over lifetime of scheme		Qual. benefits (discounted)	
	£		£		OM2 (20%)	£
20% most deprived areas		-		-	OM2 (20%)	£ -
21-40% most deprived areas	-£	189,750	-£	16,128,750	OM2 (21-40%)	£ 5,493,661
60% least deprived areas		-		-	OM2 (60%)	£ -

3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion

Number of households in:	Before		Damages per household avoided:		Qual. benefits (discounted):	
	Long-term loss	Medium-term loss	Annual damages avoided	Loss expected in Present value of Year 1 loss (i.e. first year damages, discounted based on when loss is expected)	Long-term loss	Medium-term loss
20% most deprived areas			£ 6,000	£ 6,000	OM3 (20%)	£ -
21-40% most deprived areas			50	20	OM3 (21-40%)	£ -
60% least deprived areas			1,184	3,015	OM3 (60%)	£ -

4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met

Payments under:	Assumed benefits per unit:	Qual. benefits (discounted):
OM4a Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c Kilometres of protected river improved	£ 80,000	OM4c £ -
		OM4 £ -

5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan

OM, deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 214,950,339	5.56 p in the £1	£ 11,941,686
OM2	£ -	45.0	£ -
20% most	£ -	30.0	£ -
21-40%	£ 5,493,661	20.0	£ 1,648,098
Least 60%	£ -	45.0	£ -
OM3	£ -	30.0	£ -
20% most	£ -	20.0	£ -
21-40%	£ -	100.0	£ -
Least 60%	£ -		£ -
OM4	£ -		£ -
Total	£ 220,444,000		£ 13,589,784

Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.

Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.

Raw Score	Contribution for 100% Score (£k)
9%	116,733,751
3%	155,183,788
9%	116,855,903
9%	116,733,751
#N/A	#N/A
9%	116,819,211

As scenario above
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss
Sensitivity 4 - Increase Duration of Benefits by 25%
Sensitivity 5 - Reduce Duration of Benefits by 25%

END OF WORKSHEET

Barrier, 2030, Do Minimum baseline

FCRM Partnership Funding Calculator for Flood and Coastal Erosion Risk Management Grant in Aid (FCRM GIA)
Version 8 January 2014

Project Name Avon TFRMS Barrier 2030, 85yr design life, Do Min Benefits
Unique Project Number 47070074

Key Input cells
 Calculated cells

All figures are in £'s
Figures in Blue to be entered onto Medium Term Plan

SUMMARY: prospect of FCRM GIA funding

Raw Partnership Funding Score 3% (1) Scheme Benefit to Cost Ratio: 0.50 to 1
Effective return to taxpayer: 0.50 to 1
Effective return on contributions: n/a to 1

External Contribution or saving required to achieve an Adjusted Score of 100% 394,571,860 (2) Cell (2) shows the minimum amount of contributions and/or reductions in scheme cost that are required to raise the Adjusted PF Score to at least 100%. Further increases on this will improve this scheme's chances of an FCRM GIA allocation in the desired year. Planned savings and contributions should be entered into cells(9,10,12) and cells(14-17). See NOTE below.

Adjusted Partnership Funding Score (PF) 3% (3)

PV FCRM GIA towards the up-front costs of this scheme (PV Cost for Approval) - (4)

1. Scheme details

Risk Management Authority type of asset maintainer LA (5) Yes (6) Is evidence available that a Strategic Approach has been taken, and that double counting of benefits has been avoided?

Duration of Benefits (years) 85 (7)

PV Whole-Life Benefits: 231,361,000 (8)

PV Costs

PV Appraisal Costs - (9)

PV design & Construction Costs 407,676,000 (10)

Sub Total - PV Cost for Approval (appraisal,design,construction) 407,676,000 (11)

PV Post-Construction Costs 54,057,000 (12)

PV Whole-Life Costs: 461,733,000 (13)

PV Contributions secured to date

PV Local Levy secured to date - (14)

PV Public Contributions secured to date - (15)

PV Private Contributions secured to date - (16)

PV Funding from other Environment Agency functions/sources secured to date - (17)

PV Total Contributions secured to date 0 (18)

WARNING: Contributions less than minimum required in cell (2)

The total value of any necessary contributions will depend on whether maintenance (ongoing costs) is funded through revenue FCRM GIA, or by other means.
NOTE: This scheme is to be maintained by an RMA other than the EA (ref cell 5). Capital FCRM GIA will fund the appropriate share of the up-front costs (cell 11) with any shortfall needing to be paid for via contributions identified in cells(14-17). Future ongoing costs (cell 12) and any contributions towards them are a matter for local agreement by the RMA and should NOT be included in cells(14-17). It is recommended that the RMA takes the opportunities created during scheme development to separately secure contributions towards future ongoing costs (cell12).

2. Qualifying benefits under Outcome Measure 2: households better protected against flood risk

Number of households in:	Before			After			Change due to scheme		
	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk	Moderate risk	Significant risk	Very significant risk
20% most deprived areas				-	-	-	0	0	0
21-40% most deprived areas	520	120	97	-	-	-	-520	-120	-97
60% least deprived areas				-	-	-	0	0	0

Annual damages avoided (£), compared with a household at low risk: 150 600 1,350

Change in household damages, in:	Per year		Over lifetime of scheme		Qual. benefits (discounted)	
	£	£	£	£	£	£
20% most deprived areas	-	-	-	-	OM2 (20%)	-
21-40% most deprived areas	-£	280,950	-£	23,880,750	OM2 (21-40%)	8,134,092
60% least deprived areas	-	-	-	-	OM2 (60%)	-

3. Qualifying benefits under Outcome Measure 3: households better protected against coastal erosion

Number of households in:	Before		After		Change due to scheme	
	Long-term loss	Medium-term loss	Long-term loss	Medium-term loss	Long-term loss	Medium-term loss
20% most deprived areas					£ 6,000	£ 6,000
21-40% most deprived areas					£ 50	£ 20
60% least deprived areas					£ 1,184	£ 3,015

Annual damages avoided: £ 6,000
Loss expected in Present value of Year 1 loss (i.e. first year damages, discounted based on when loss is expected): £ 50

Change in household damages, in:	Year 1 loss avoided:		Over lifetime of scheme:		Qual. benefits (discounted):	
	£	£	£	£	£	£
20% most deprived areas	-	-	-	-	OM3 (20%)	-
21-40% most deprived areas	-	-	-	-	OM3 (21-40%)	-
60% least deprived areas	-	-	-	-	OM3 (60%)	-

4. Qualifying benefits under Outcome Measure 4: statutory environmental obligations met

Payments under:	Assumed benefits per unit:	Qual. benefits (discounted):
OM4a Hectares of net water-dependent habitat created	£ 15,000	OM4a £ -
OM4b Hectares of net intertidal habitat created	£ 50,000	OM4b £ -
OM4c Kilometres of protected river improved	£ 80,000	OM4c £ -
		OM4 £ -

5. Qualifying benefits arising from the overall scheme, for entry into the Medium-Term Plan

OM, deprivation:	Qual. benefits:	Payment rate:	FCRM GIA contribution:
OM1	£ 223,226,908	5.56 p in the £1	£ 12,401,495
OM2	£ 8,134,092	30.0	£ 2,440,228
OM3	£ -	45.0	£ -
OM4	£ -	100.0	£ -
Total	£ 231,361,000		£ 14,841,722

Maximum for Outcomes delivered. The actual value any scheme is eligible for may be less.

Sensitivity Testing. It is important that users of this calculator appreciate the implications on funding from changes to input data which may become necessary as the project develops and better information is available. Five typical tests are provided below. Users should consider how appropriate these are to their project, what other tests may be appropriate and how best to use the information with all those that may be involved in the project.

As scenario above	Raw Score	Contribution for 100% Score (£k)
Sensitivity 1 - Change in PV Whole Life Cost (25% increase)	3%	394,571,860
Sensitivity 2 - Change in OM2 - 50% of households in Very Significant (Before) risk may already be in Significant Risk band	1%	503,698,137
Sensitivity 3 - Change in OM3 - 50% of households in Medium Term loss (Before) may already be in Long Term loss	3%	394,799,153
Sensitivity 4 - Increase Duration of Benefits by 25%	3%	394,571,860
Sensitivity 5 - Reduce Duration of Benefits by 25%	#N/A	#N/A
	3%	394,702,934

END OF WORKSHEET

4. APPENDIX 4: PROPERTIES AT RISK

A figure showing the location of the properties at risk during a present day 1:2 year event (Do Minimum scenario) is provided overleaf. This figure has been produced to provide clarifications to BCC.

