ARUP

Bristol City Council, Environment Agency

Bristol Avon Flood Strategy

Options Development Report

Reference: 285982-ARP-XX-RP-CIV-003

| 30 January 2024

Job number 285982-04

Ove Arup & Partners Limited
63 St Thomas Street
Bristol
BS1 6JZ
United Kingdom
arup.com

Contents

Tables

Figures

Appendices

1. Introduction

Bristol City Council is working with the Environment Agency and other partners to create a vital long-term strategy for managing the flood risk from the River Avon, supported by The Capital Strategic Partner (consisting of Arcadis, Arup and Mott Macdonald), referred to as the Bristol Avon Flood Strategy (the Strategy, BAFS). The Strategy will outline actions to be taken in phases to reduce the chance and impact of flooding from the River Avon, and how each phase will be funded. The Strategic Outline Case (SOC) for the Bristol Avon Flood Strategy was consulted on in 2020 prior to adoption by Bristol City Council and adoption by the Environment Agency.

The preferred option for the Strategy comprises raised defences along the River Avon including new tidal stop gates for the Floating Harbour.

The standard of protection (SoP) provided by this strategy considers two epochs – 2069 and 2130. To develop the costing of the defences, the Strategy assumes an adaptive approach to defences which means:

• an initial phase of construction (Phase 1) with delivery starting in the 2020s

• a subsequent phase of construction of additional defences and defence raising in the 2060s (Phase 2).

The Strategy consists of defences designed to protect properties from flooding, and defences designed to prevent detriment. For the purposes of design and ease of reference the defences have been split into twelve geographical areas:

1. Pill – from the western end of Avon Road to the northern tip of Watch House road.
2. Shirehampton – from the western end of Wellington Mews to the sports pitches south of Nibley Road.
3. Sea Mills – from the northern bank of the River Trym to the allotments on the respective south bank.
4. Bower Ashton – from south of the Clifton Suspension Bridge, following along the western bank of the Avon to Coronation Road.
5. Entrance Lock – from Hotwell Road, around the Tongue Head and end of Spike Island to the Brunel Way flyover, including new lock gates.
6. Spike Island – from the Brunel Way flyover along the north bank of the River Avon to the eastern end of the Chocolate Path, including a new flood gate under Cumberland Rd.
7. Redcliffe – from God's Garden along the north Bank of the River Avon to Bristol Temple Meads.
8. Feeder Road – from Bristol Temple Meads along the south bank of the Feeder Canal.
9. St Philip's Marsh - from Bristol Temple Meads to Sparke Evans park on the north bank of the River Avon.
10. Netham Lock – from the Avon railway bridge along the north bank of the River Avon to Netham Lock, including a new flood gate.
11. St. Anne's – from St. Anne's Road following the River Avon around the north end of Brislington including both banks, to Crew's Hole Road.
12. Upstream defences – isolated areas upstream of St Anne's as far upstream as Swineford.

Figure 1 to Figure 5 show the extent of the defences.

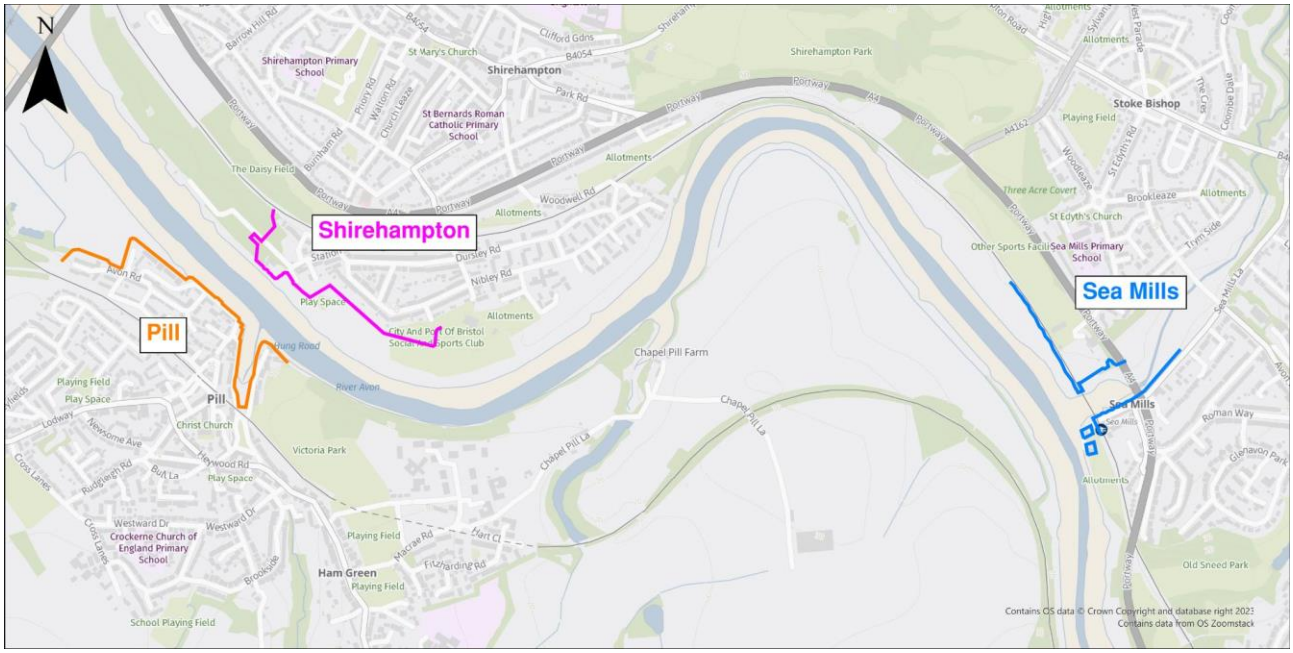

Figure 1: Pill, Shirehampton and Sea Mills Defence Areas

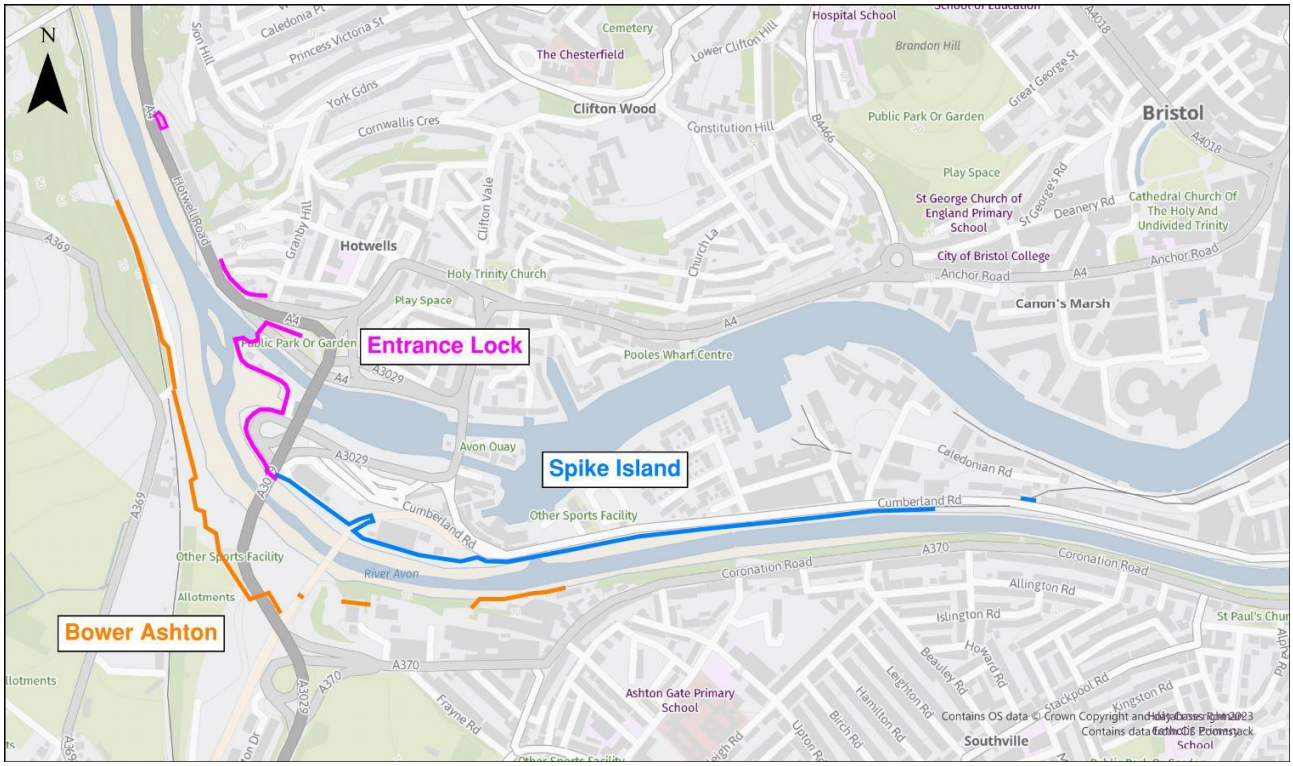

Figure 2: Bower Ashton, Entrance Lock and Spike Island Defence Areas

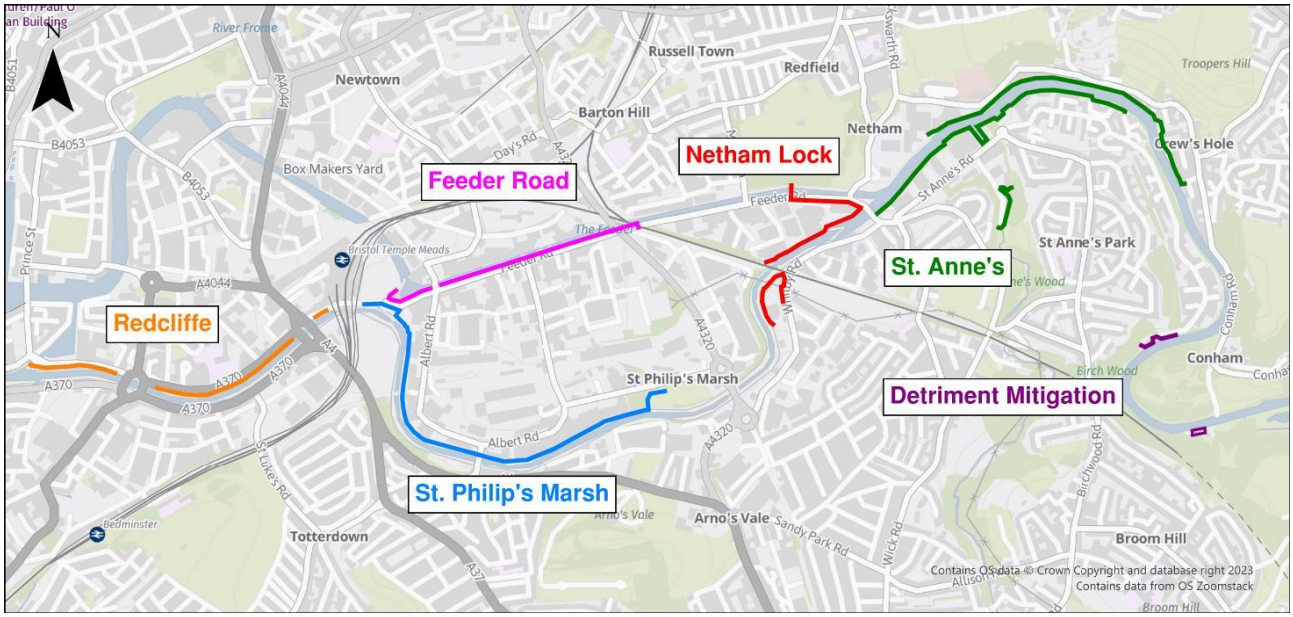

Figure 3: Redcliffe, Feeder Road, St. Philip's Marsh, Netham Lock and St. Anne's Defence Areas (including some detriment mitigation)

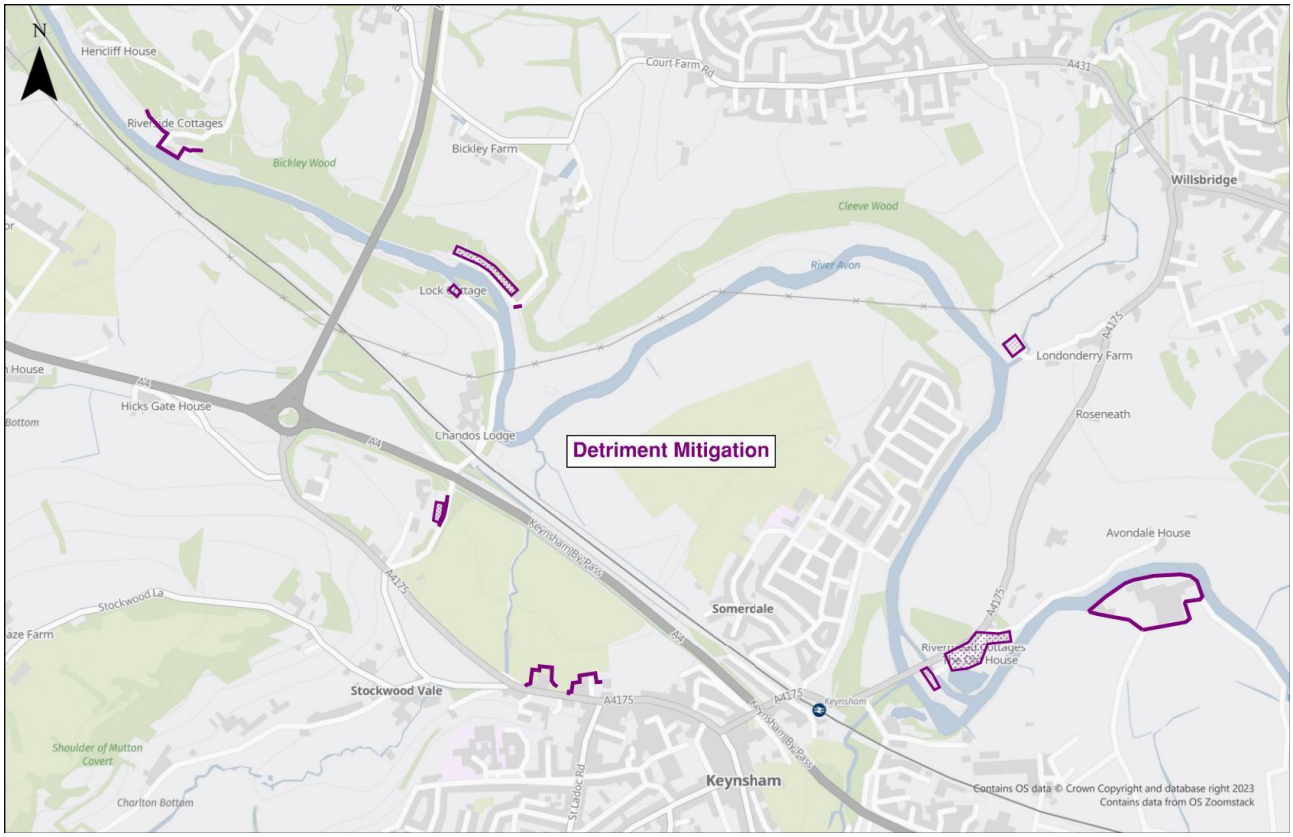

Figure 4: Keynsham Detriment Mitigation Areas

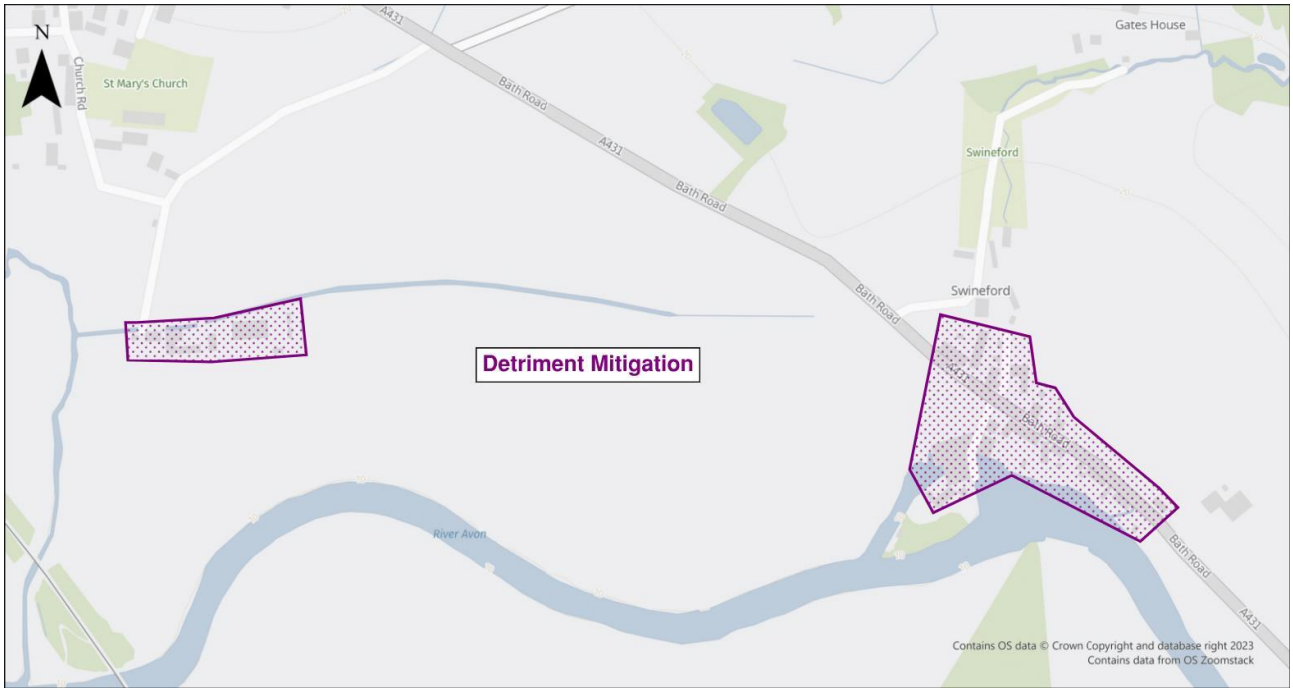

Figure 5: Swineford Detriment Mitigation Areas

This report builds upon work completed as part of the Strategic Outline Case (SOC). The purpose of this report is to demonstrate the options development process and resulting findings that have been completed since the SOC stage. The objectives of this stage of the process were to:

- Identify and record constraints and opportunities associated with the design, including through stakeholder consultation.
- Refine the proposed alignment and design, and where necessary develop options at key areas.
- Compile an updated preferred alignment and associated concept design (including placemaking input) to inform a more robust cost estimate to take forward to subsequent stages.

Further information on the constraints, in particular regarding environmental and heritage issues, are available in specific studies produced as part of the Outline Business Case (OBC). Given the extent of defences, level of design development and information available, not all constraints or opportunities are included in this report. It is intended to describe the options used to give a robust cost estimate in the OBC, and justify these decisions, as well as setting out where further work is required. It should be noted that the design of the proposed defences are not final and that public consultation will be carried out in the next stage to help further inform the design development.

2. Background

2.1 Strategy Summary

Bristol and its neighbouring communities have grown and thrived on the banks of the River Avon. However, people and property face an increasing risk of flooding. Storms can increase flows coming down the river or can force tidal water to surge up the Severn Estuary. Large parts of Bristol's centre are vulnerable to the River Avon overtopping low spots and also causing water within the harbour to flood properties. Flood risk is increasing due to climate change causing sea levels to rise and causing storms to increase in frequency and severity.

Bristol City Council (BCC), the Environment Agency (EA) and the West of England Combined Authority (WECA) are working together to deliver a long-term plan to better protect homes, businesses and

infrastructure from flooding from the River Avon. This is a unique opportunity to enhance the river for all by creating a more resilient, active and sustainable city that can meet the future needs of its residents, businesses and visitors.

2.2 Flood mechanisms and historic events

2.2.1 Flood mechanisms

Bristol is positioned near the mouth of the River Avon as it connects with the Severn Estuary, which has the second highest tidal range in the world. It is therefore subjected to flood risk caused by extreme tidal events (from the sea) and extreme fluvial events (from the inland waterways) and probabilistic combinations of both types of events occurring at the same time.

The predominant flood risk and potential for the most severe damage to much of the city centre is from high tides combined with storm surges. This forces water up the river, overtopping many low spots around the harbour and causing the Floating Harbour to flood properties. Around 1,000 homes and businesses near the city centre and 400 properties in neighbouring communities are currently at risk of being flooded in either a severe river or tidal flood from the River Avon, severing the region's transport network causing gridlock to the city centre, and putting the operation of the existing flood risk management systems at risk.

The influence of climate change has since 1900, seen UK sea levels rise by more than 16cm. Studies of records at Avonmouth found between 1993 to 2007 sea levels on average increased by 0.2cm every year. As a consequence of climate change, the observed increasing sea levels and peak river flows are predicted to continue and to accelerate. Without action, by the end of this century over 3,100 existing properties could be at risk in the event of a severe tidal flood.

2.2.2 Historic flood events

Bristol has a long history of flooding, as suggested by numerous place names throughout the city centre, such as Temple Meads and St Philip's Marsh. The extent of tidal dominance in the New Cut channel changes depending on tide conditions. Under extreme conditions the tide can extend far upstream of Netham Weir.

Bristol has been lucky in recent years and has avoided severe flooding. However, there have been more than twenty minor tidal floods in the last decade. Properties and infrastructure around the river have been flooded including at Pill, Sea Mills, the Portway, Cumberland Basin, Avon Crescent, Coronation Road and Cattle Market Road.

A 1.6m tidal surge in December 1981 caused levels to reach 8.8mOD and flood many properties at Pill, Shirehampton, Avon Crescent and across St Philip's. Subsequently flood defences were constructed by the Environment Agency at Pill, Shirehampton and St Philip's. Despite this defence, there was still localised flooding of St Philip's in 2014 and 2020.

There have been many recent near misses. Levels reached 8.8mOD in February 1990 and 8.7mOD in January 2014 when flooding closed key roads including the A4 Portway, Cattle Market Road and Cumberland Road. Good weather in 2014 reduced forecast surge levels by 0.8m and the proactive use of a temporary barrier protected properties at Avon Crescent.

2.3 Basis of Design

Since the SOC stage a significant change has been made regarding the purpose of the proposed defences. At SOC, the 'main scheme' defences were those between Netham Lock upstream and Entrance Lock downstream. These defences were set at the required SoP to protect receptors behind the defence, including freeboard for residual uncertainties. Other defences (generally those up- and downstream of the city centre) were set at the height required to prevent detriment with the phase 1 defences in place and climate change allowances applied to 2130.

During the modelling for this OBC, it was determined that the required defence height to provide flood protection in 2069 (including freeboard allowance) was at or above the level required to prevent detriment in 2130 (which does not include freeboard). It was therefore agreed with BCC and the EA that all defences downstream of (and including) St Anne's should have a consistent design basis as below:

- All Phase 1 flood defences to provide the required SoP based on 2069 epoch year and include freeboard allowance.
- All Phase 2 flood defences to provide the required SoP based on 2130 epoch year and include freeboard allowance.
- Phase 1 and Phase 2 flood defences to be sufficiently high to prevent detriment to properties based on agreed detriment criteria (given in the OBC modelling report, Appendix D of OBC). This includes the need to prevent detriment for defences constructed in phase 1 against a 2130 climate, and therefore some defences are requiring construction to their final height in phase 1, without raising in Phase 2.

The advantages of this approach are a clear narrative on the purpose of defences whilst a greater number of properties will be better protected for either no increase or a marginal increase in cost. During detriment mitigation modelling, some defences were locally increased to ensure compliance with the design basis. Upstream of St Anne's, an analysis of receptors was carried out to determine where detriment mitigation measures were required, extending as far upstream as Swineford. Further information is available in the OBC modelling report (Appendix D of the OBC).

Following detriment mitigation modelling, an analysis of the required measures showed that upstream of Bristol, the flood depths in 2130 before any defences are built are predicted to be over 3m in places. Any detriment caused by the construction of defences was relatively small in comparison (between 100 and 300mm). As these areas are undefended, constructing raised defences to prevent all detriment in 2130 would result in some cases in prohibitively high defences (up to 3.5m in some areas). The majority of the affected receptors were either properties where the views of the river would be entirely blocked by a defence (significantly reducing property values and having a high likelihood of challenge) or businesses requiring waterfront access (such as marinas). It was therefore agreed in conjunction with the Environment Agency that this was likely to be unacceptable to the affected homes and businesses, so a 'practical betterment' approach could be taken with agreement from those landowners. In these instances, defences could be constructed or measures put in place to reduce the risk of flooding in more frequent (lower return-period) events, but not preventing detriment in 2130 to the design events. For more information refer to section 3.5 of the OBC.

2.4 Work completed to date/summary of recent engagement

Significant optioneering work has been carried out for the Strategy. These were summarised in the Strategic Outline Case (SOC), where the preferred option was selected as raised defences, with defences constructed in the 2020s to a chosen standard of protection in 2069, and then raised to provide protection in 2130.

Costs were based on a bottom-up approach, including optimism bias and an allowance for public realm enhancements. These are described in detail in the SOC and an engineering baseline report (285982-ARP-XX-RP-CIV-001) was produced in June 2022 to summarise the preferred SOC option.

The design of the defences at this OBC stage has been influenced by a wide range of factors and inputs, including:

- Significant hydraulic modelling to understand the required extents and heights of defences, explained further in the baseline modelling report 285982-ARP-XX-RP-MOD-002 and OBC modelling report 285982-ARP-XX-RP-MOD-003.
- Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).
- Preliminary Ecological Appraisal (PEA) Report (285982-ARP-XX-RP-ENV-002).
- Geotechnical desk studies and feasibility reports (285982-ARP-XX-RP-GEO series).
- Workshops with Bristol City Council and the Environment Agency, including stakeholder working group sessions and those with knowledge of the Bristol Temple Quarter and Western Harbour developments.
- Workshops with BCC's harbourmaster and operations team.

- Buildability workshop with ESE contractor BAM Nuttall.
- Carbon study and workshops (285982-ARP-XX-RP-ENV-008).
- Updated topographical surveys in some areas.
- Harbour condition surveys by Bristol City Council.
- Site visit to the Cumberland Road stabilisation works.
- EIA draft scoping report.

3. Option Development Areas

The proposed engineering design for each area is set out in the sections below including a summary of the relevant constraints and opportunities that were used to inform the option development process. More detailed constraints and opportunities are included within individual options matrices for further clarity where relevant. The lists of constraints are not exhaustive and further constraints may be identified at later stages of the strategy development. Further information is also available in individual specialist reports.

The constraints and opportunities summary is followed by a description of the proposed defence, and the alternatives considered. Table 1 is a summary of the options (note that PFR refers to property flood resilience measures). It should be noted that some of the maximum defences heights are from areas with limited topographical information, or are limited to very isolated areas on a defence section. The defence heights refer to the total height from ground level to the top of the defence, unless stated where they are above an existing defence. Refer to Section 2.3 with regards to the chosen Phase 1 and Phase 2 defence levels.

It should also be noted that all defence layouts and types are subject to change at the Full Business Case (FBC) stage and detailed design, in particular as a result of further surveys, investigations and consultation.

Table 1. Summary of all preferred defence options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
1	SoP	Avon Road Embankment	Raise existing embankment	10.29	10.29	530	0.79	1.29
2	SoP	Marine Parade	Raise existing sheet pile wall **– note height is above existing defence**	10.3	10.3	440	**0.9**	1.3
3	SoP	Watch House Road Floodwall	New floodwall (piled and gravity)	10.31	10.31	320	1.31	2.31
4	SoP	Lamplighters Embankment	New embankment	10.3	10.3	320	1.6	2.9
5	SoP	Station Road Floodwall	New gravity floodwall	10.31	10.31	80	1.61	2.01
6	SoP	Sports Field Embankment	New embankment	10.32	10.32	490	0.62	1.12
7	SoP	Railway Floodwall North	New gravity floodwall	10.38	10.38	300	0.28	1.38
8	SoP	North of Tyrm Embankment	New embankment	10.38	10.38	120	2.08	2.68
9	SoP	Railway Bridge Parapet Retrofit	Bridge parapet retrofit	10.38	10.38	100	0.4	0.4
10	SoP	Properties adjacent to allotment	Raise existing floodwalls	10.38	10.38	170	0.5	0.5
11	SoP	Railway Defence	New piled floodwall	10.38	10.38	30	0.48	0.48
12	SoP	Sea Mills Lane Embankment	New embankment	10.38	10.38	310	1.98	3.18
13	SoP	Riverside Path Floodwall	New gravity floodwall	10.43	10.43	410	1.53	2.53
14	SoP	Brunel Open Space Embankment	New embankment	10.2	10.93	460	0.4	1.6

15	SoP	Brunel Way Viaduct Floodwall	New gravity floodwall	10.2	10.93	25	0.4	0.6
16	SoP	Metrobus Road Raising	New road raising	10.2	10.93	10	0.8	0.9
17	SoP	Pump Station Floodwall	New gravity floodwall	10.44	10.44	50	0.84	1.14
18	SoP	Payne's Shipyard Floodwall	New piled floodwall	10.45	10.45	160	1.35	3.55
19	SoP	Hotwell Road PFR	New PFR	10.43	10.43	N/A	1.03	1.43
20	SoP	Hotwell Road Floodproofing	New floodproofing	10.43	10.43	120	1.43	2.13
21	SoP	Bennet Way Floodwall	New gravity floodwall	10.08	10.8	60	0.08	0.68
22	SoP	Cumberland Basin Road Raising	New road raising	10.08	10.8	10	0.78	0.78
23	SoP	Entrance Lock Gates	New lock gates	10.08	10.8	25	n/a	n/a
24	SoP	The Knuckle Floodwall	New piled floodwall	10.08	10.8	180	1.88	1.98
25	SoP	Brunel Dam	Raise existing structure and floodproof	10.07	10.81	20	n/a	n/a
26	SoP	Off Ramp	New gravity floodwall	10.06	10.8	45	1.06	1.26
27	SoP	Bonded Warehouses	New floodwall (piled and gravity) and road raising	10.3	10.8	500	1.5	1.9
28	SoP	Chocolate Path Floodwall	New piled floodwall	10.29	10.85	770	1.89	1.99
29	SoP	Cumberland Road Rail Bridge	New floodgate	10.11	10.83	10	1.81	1.81
30	SoP	Bathurst Dam	Raise existing structure – **note height is above existing dam**	10.09	10.82	10	**1.75**	1.75
31	SoP	Commercial Road Floodwall	New floodwall (piled and gravity)	10.21	10.93	320	0.81	1.41
32	SoP	Clarence Road Floodwall	New piled floodwall	10.25	10.82	620	1.25	1.85
33	SoP	Cattle Market Road Floodwall	New piled floodwall	10.12	10.79	90	0.62	2.12
34	SoP	Coronation Road Floodwall (Phase 2 Only)	New gravity floodwall	10.08	10.8	60	n/a	n/a
35	SoP	Albert Road Floodwall	New minipile floodwall	10.25	10.92	1520	1.25	1.95
36	SoP	Sparke Evans Park Embankment	New embankment	10.2	10.83	250	0.9	1.1
37	SoP	West of Avon Street Floodwall	New piled floodwall	8.76	9.21	200	0.06	0.96
38	SoP	East of Avon Street Floodwall	New piled floodwall	8.76	9.21	740	0.86	1.56

39	SoP	Tie into Railway Bridge Abutment	New road raising	8.76	9.21	10	0.86	0.86
40	SoP	Feeder Canal Flood Gate	New floodgate	10.91	11.66	50	n/a	n/a
41	SoP	Feeder Road Raising	New road raising	10.91	11.66	10	0.91	0.91
42	SoP	Netham Lock Floodwall	New gravity floodwall	10.91	11.66	250	1.41	1.91
43	SoP	Netham Weir Floodwall	New sheet pile floodwall	10.5	11.2	400	1.4	1.7
44	SoP	Avon Bank Floodwall	New gravity floodwall	10.54	10.54	240	0.34	0.44
45	Detriment mitigation	Whitby Road Floodwall	New gravity floodwall	10.54	10.54	100	0.24	0.54
46	SoP	North Bank	New minipile floodwall	11.29	11.98	1200	2.39	2.99
47	SoP	South Bank	New sheet pile floodwall	11.29	11.98	1100	1.29	1.79
48	Detriment mitigation	Chapel Way Floodwall	New gravity floodwall	11.15	11.15	220	0.85	1.15
49	Practical betterment	Pump House Lane Floodwall	New piled floodwall	10.5	10.5	70	2.2	2.4
50	Practical betterment	Beese's Bar	New PFR	n/a	n/a	n/a	n/a	n/a
51	Practical betterment	Riverside Cottages Embankment	New embankment	10.5	10.5	190	1.27	2
52	Practical betterment	Hanham Mills	New PFR	n/a	n/a	n/a	n/a	n/a
53	Practical betterment	Ferry Road	New road raising	10	10	75	0.31	0.47
54	Practical betterment	Lock Cottage	New PFR	n/a	n/a	n/a	n/a	n/a
55	Practical betterment	Durley Lane	New PFR and wall floodproofing	n/a	n/a	60	n/a	n/a
56	Detriment mitigation	Bristol Road West	New gravity floodwall	11.7	11.7	140	1.4	1.5
57	Detriment mitigation	Bristol Road East	New gravity floodwall	11.7	11.7	140	1.4	1.5
58	Practical betterment	Siston Brook	New PFR	n/a	n/a	n/a	n/a	n/a
59	Practical betterment	Marina	New PFR	n/a	n/a	n/a	n/a	n/a
60	Practical betterment	Lock Keeper Pub	New PFR	n/a	n/a	n/a	n/a	n/a
61	Detriment mitigation	Broadmead Industrial Estate	New piled floodwall	12.1	12.1	800	1.1	1.1
62	Practical betterment	The Meadows Livery	New PFR	n/a	n/a	n/a	n/a	n/a
63	Practical betterment	Bath Road, Swineford	New PFR	n/a	n/a	n/a	n/a	n/a

4. Pill

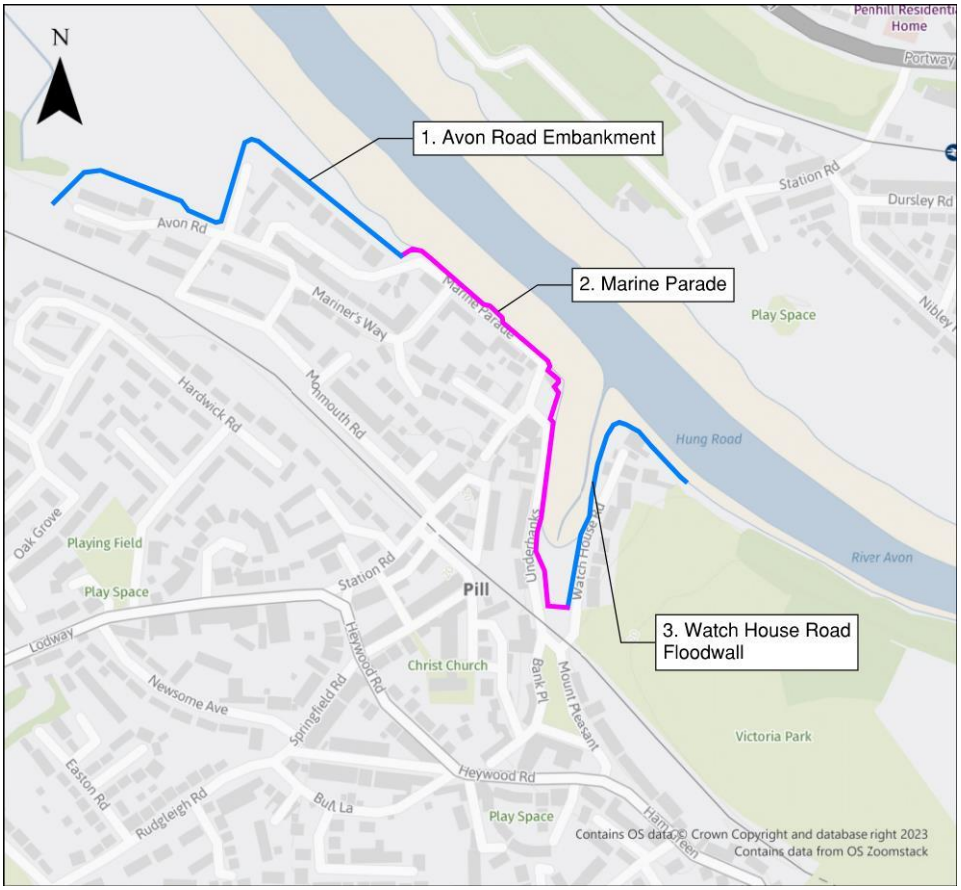

Figure 6 - Pill Defence Area (blue and pink lines delineate between defence sections)

4.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plan - 285982-ARP-XX-DR-CIV-106.

4.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- There are two Grade II listed structures in this area - Mulberry House and Cottage, and the Watch House and retaining walls to the river. With the latter, the extent of curtilage needs to be confirmed with North Somerset Council.
- There is a viaduct that although not listed, is a historic structure. Therefore, the design in this area will need to be respectful to it both physically and in terms of in keeping character.
- Archaeological remains relating to the historic harbour, river crossing and settlement are also likely to be present and their mitigation will need to be considered in the development of the design.
- The finish and cladding of flood defences should be in keeping with the local character of the area.

4.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- Construction of the defence near Avon Road has potential to disrupt and damage saltmarsh and intertidal habitats present here. Saltmarsh and mudflat are Habitats of Principal Importance. Additionally, a SSSI, SPA, SAC, and Ramsar site are in this area, so work in European and national sites will be strictly controlled and should avoid any negative ecological impact. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- Annex I habitats are present adjacent and potentially within the works area. Consultation is advised with Natural England (NE) to understand design constraints and opportunities.
- It should be checked if raising the existing embankment and other works would impact the Site of Nature Conservation (SNCI) in this area, which overlaps the alignment.
- There are also saltmarsh and intertidal habitats on the banks of the Avon near the Grade II listed watch house. This is a particularly sensitive area and works should minimise any disruption or damage here.
- There is an area of green space between Underbanks and Watch House Road, just north of the viaduct. The preferred solution should minimise impact in this area.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with biodiversity net gain (BNG) guidance and legislation.
- There may be opportunities to integrate nesting opportunities for birds and invertebrates, and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and incorporate the findings into the strategy.

4.1.3 Buildability

- Multiple sections of the proposed route include existing floodwalls. Near Marine Parade and Underbanks these walls tie into embankments. The condition of these in places is unknown.
- There is a pumping station in the area of green space between Underbanks and Watch House Road.
- North of Watch House Road construction will be very close to the riverbank and near houses.

4.1.4 Landscape

- There are multiple sections of the defences close to residential areas, mainly along Marine Parade and Underbanks road. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme's SoP.
- There are two pocket parks, one next to Myrtle Hill and the other north of the viaduct. The preferred solution should aim to minimise disruption and provide opportunities for environmental enhancements.

[1] Arup, 2023. Bristol Avon Flood Strategy: Preliminary Ecological Appraisal. Bristol City Council. August, 2023.

- National Cycle Network Route 41 and the River Avon Trail Long Distance Footpath pass close to the proposed defences. The flood walls should not cut this path off or affect its accessibility.
- The Public Right of Way, PROW, LA8 5/10 and LA8 6/5 cross over the proposed South Avon Road Embankment, access must be maintained here.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

4.1.5 Transport

- Proposed flood defences pass near to or along existing roads and paths.
- There is a railway viaduct and existing highway network near the defences south of the area of green space.
- Where possible, the defences should provide enhancement to active travel and interface appropriately with crossings and other adjacent travel routes.

4.1.6 Interfaces

- There is an existing flood gate near Portishead Cruising Club. It is likely that this will need to be incorporated into the new defences to maintain current access routes.
- Environment Agency owned and operated coastal flood defences were built in 1992 as part of the Pill Tidal Defence Scheme. Markham Brook discharges through the tidal defences at the head of the tidal creek, and a pump station (part of the 1992 scheme) can overpump if high fluvial flows occur at times of high tide.
- Bank erosion has been an issue, with emergency works completed along a section of the flood embankment in 2006/07 and further improvement works in 2010/11. The Environment Agency commenced appraising options and the 2020 Strategic Outline Case notes: *"Along the sea wall there is evidence of increasing erosion of the sloping river bank, exposing the sheet piling below the masonry cladding, which may de-stabilise it and the piles are showing signs of corrosion. FRM assets are showing signs of deterioration, such as the seawall and Markham Brook culvert, others are close to, or at the end of their expected life, such as the pumps in Markham Brook pump station, or substandard such as the security screen at the entrance to Markham Brook culvert."*
- The Environment Agency SOC identified a 'Do Refurbish/Replace' preferred way forward in the short term, and Do Sustain for future investment. The works to the tidal defences by the Bristol Avon Flood Strategy here would address the need for refurbishment of the tidal defences but improvements to Markham Brook, such as to a trash screen and pumping station, may continue. Discussions will be ongoing throughout the next stage of the project.
- There is a slipway leading on from the flood gate.
- A desk study has identified services in this area, including utilities owned by National Grid Electricity Distribution (NGED) and Wales and West Utilities (WWU). Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

4.2 Option Development

4.2.1 General

The proposed defences at Pill would largely be upgrading and raising existing flood defences in the area with some additional new sections of raised defences. The line of defence runs from the end of the existing embankment downstream, along Marine Parade and Underbanks Rd until it reaches the viaduct and Markham Brook pumping station, before following and protecting properties along Watch House Rd.

4.2.2 Avon Road Embankment

This section follows the existing line of defence, and it is proposed to increase the height of the existing embankment. The additional height would be achieved by moving the crest closer to the river, where possible using as much existing material as possible. This runs in front of properties along Avon Rd and Marine Parade until it ties in with the floodwall on Marine Parade.

4.2.3 Marine Parade

Along Marine Parade the existing sheet-pile defence and adjacent promenade would be raised by constructing a new line of sheet-piles. There is potential, with further investigation required, to repair the existing line of sheet-piles depending on their condition but at this stage it is assumed that they would not last for the design life of the scheme.

At the eastern end of Marine Parade a new floodgate would be required to replace the existing gate which maintains access to the Portishead Cruising Club. The wall follows the riverbank as it turns into the estuary fed by Markham Brook and around an area of open space. This connects to the wall and promenade of Underbanks Road up to the viaduct and Markham Brook pumping station via another small floodgate. The existing defence level would be raised by constructing a new line of sheet-piles, and where the ground level increases, a new gravity foundation wall to reach the required defence level. This connects into the Watch House Road section of defence on the eastern side of Markham Brook.

The Environment Agency scheme to 'sustain' the existing defences at Pill has identified potential repair options, but has suggested that raising the existing sheet piles would be difficult due to the capacity of existing anchors. Hence, new sheet piles have been assumed in this area, including the associated erosion protection. However, it is recommended that this is reviewed at future stages to reduce costs and impacts.

4.2.4 Watch House Road Floodwall

Following Watch House Road back towards the Avon, a new piled foundation floodwall would form the line of defence between the road and the river. When it reaches the properties, a new sheet-pile wall is proposed to pass around the perimeter of the properties, two of which are Grade II listed.

4.3 Summary of preferred options

Table 2. Pill - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
1	SoP	Avon Road Embankment	Raise existing embankment	10.29	10.29	530	0.79	1.29
2	SoP	Marine Parade	New sheet pile wall	10.3	10.3	440	0.9	1.3
3	SoP	Watch House Road Floodwall	New floodwall (piled and gravity)	10.31	10.31	320	1.31	2.31

5. Shirehampton

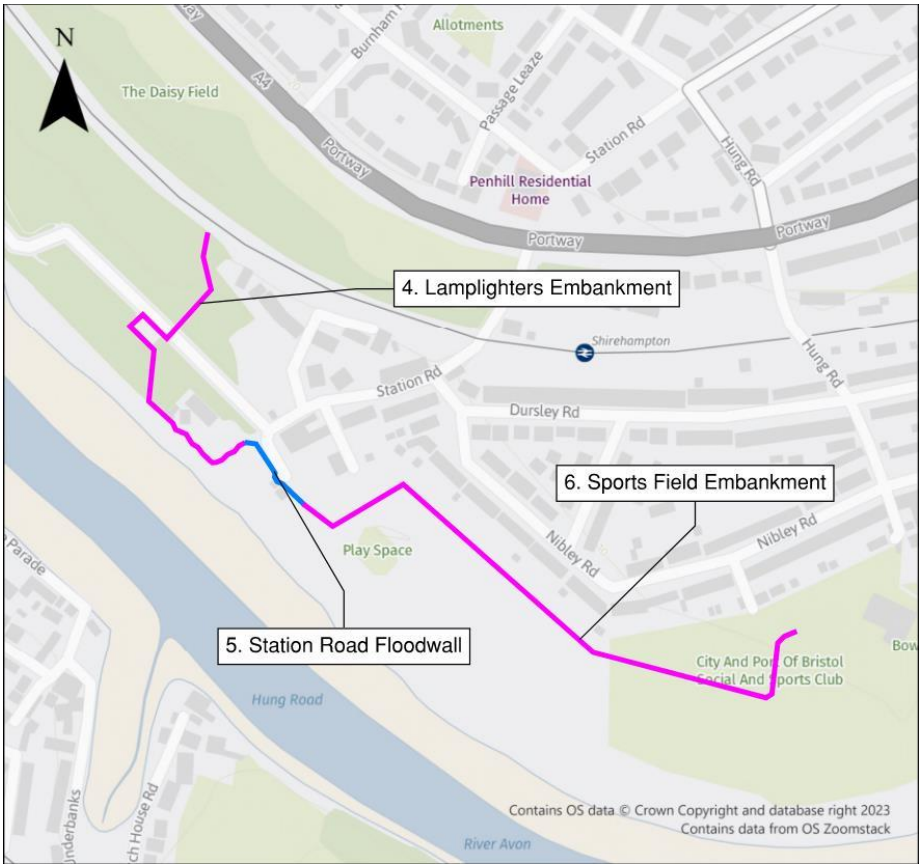

Figure 7 - Shirehampton Defence Area (blue and pink lines delineate between defence sections)

5.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plan– 285982-ARP-XX-DR-CIV-106.

5.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- Parts of Shirehampton conservation area, including several listed buildings along Station Road, are currently protected by the scheme. Defences could be positioned to maximise this benefit.
- Lamplighters Public House is Grade II listed, the historic tin structure associated with the old ferry nearby and the unlisted Haven Master's Station are currently protected by the scheme. The setting of the listed building should be considered in the development of the design.
- There are likely to be archaeological remains along the line of the defence which would be impacted by its construction.

5.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- Lamplighters Marsh Local Nature Reserve (LNR) has statutory designation and is close to large sections of the proposed defences, and areas are currently protected by the scheme. Designs should aim to incorporate protection of the LNR from future flooding and consultation should be

undertaken with NE to understand how designs best achieve protection, whilst minimising any potential harm. Alternative alignment options could avoid or protect the reserve based on this.

- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- There is a Bristol Wildlife Network Site in this area, as well as an SNCI; design should follow the mitigation hierarchy and reduce impacts to these sites.
- There is the opportunity to allow saltmarsh and coastal habitat expansion inland, with the setback of defences.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

5.1.3 Buildability

- One of the sections in Shirehampton crosses over a road – a flood gate or road raising may have to be installed here to allow traffic to pass.
- Some of the proposed works are near the riverbank and in some places access is tightly constrained between the riverbank and buildings or highways.

5.1.4 Landscape

- There are multiple sections of the flood defences close to residential areas, mainly along Station and Nibley Road. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.
- The accessibility of PROW BCC 54/10, BCC 594/10, and the Severn Way Long Distance Footpath should not be adversely affected by their proximity to the proposed flood defences here.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.
- The Sports Field Embankment lies within the City and Port of Bristol Social and Sports Club pitches. The preferred solution should aim to minimise disruption and maximise the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible.
- Lamplighters Marsh Local Nature Reserve (LNR) is in close proximity to the proposed Lamplighters Embankment. The preferred solution should aim to minimise visual impact and vegetation removal caused by the embankment and be in keeping with the local character of the area.

5.1.5 Transport

- There is an access road which will need to be maintained.

5.1.6 Interfaces

- Environment Agency owned and operated coastal flood defences were built in 1990 consisting of two sections of earth embankment, a stone flood wall and flood gates. In 2015 refurbishment included new gate, new flood gate cill, repairs to cracks in wall, and replacing redundant flood gate with new section of wall. The existing floodgate near Shirehampton Sailing Club will need to be incorporated into the scheme to maintain current access routes.
- There are opportunities to incorporate the embankment into the layout of the sports and social club and children's play area.
- A desk study has identified a low concentration of services in this area, including utilities owned by NGED. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

5.2 Option Development

5.2.1 General

For this section of the defence, the alignment has been shortened significantly from the SOC proposal at the downstream end. It now begins at the high ground at the western end of Wellington Mews properties rather than further downstream nearer to the boatyard, which significantly reduces the length of the alignment. When the alignment reaches the open space the defence would be formed of an embankment that runs along the landward side close to the properties on Nibley Road and behind the sports pitches. This is a change from the SOC proposal where the embankment was close to the river. This would reduce cost and embodied carbon as well as buildability and maintenance risks. At the upstream end the embankment ties into high ground near to the sports club car park.

5.2.2 Lamplighters Embankment

The embankment starts by tying into the high ground at the western end of Wellington Mews, cuts across the Lamplighters nature reserve towards the river. It then crosses the road and around the outside of the pumping station before passing between the Avonmouth Sea Cadets property and the river. The upstream end of the embankment ties into the existing floodwall that runs past Shirehampton Sailing Club. This change of the alignment from SOC was to shorten the alignment and reduce the amount of vegetation that would have had to be cleared from the nature reserve. It also minimises the length of defence running along the riverbank and potentially encroaching on protected habitats while still protecting the same number of receptors.

5.2.3 Station Road Floodwall

The existing floodwall between the Sea Cadets and the Sailing Club at the end of Station Road would be raised. This is expected to require a piled foundation due to the defence heights required. There is an existing floodgate here that would also have to be replaced to be of sufficient height.

5.2.4 Sports Field Embankment

In the open space, upstream of Station Road, a new embankment is proposed. At SOC stage this was proposed to run along the high ground close to the riverbank but is now proposed to be set back behind the open space, running in front of the properties on Nibley Road. This would reduce the relative defence height slightly due to the higher ground levels. It would also significantly improve buildability and reduce maintenance health and safety risks as it is set back from the riverbank. It would also remove the encroachment on the riverbank and sensitive habitats.

5.3 Summary of preferred options

Table 3. Shirehampton - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
4	SoP	Lamplighters Embankment	New embankment	10.3	10.3	320	1.6	2.9
5	SoP	Station Road Floodwall	New gravity floodwall	10.31	10.31	80	1.61	2.01
6	SoP	Sports Field Embankment	New embankment	10.32	10.32	490	0.62	1.12

6. Sea Mills

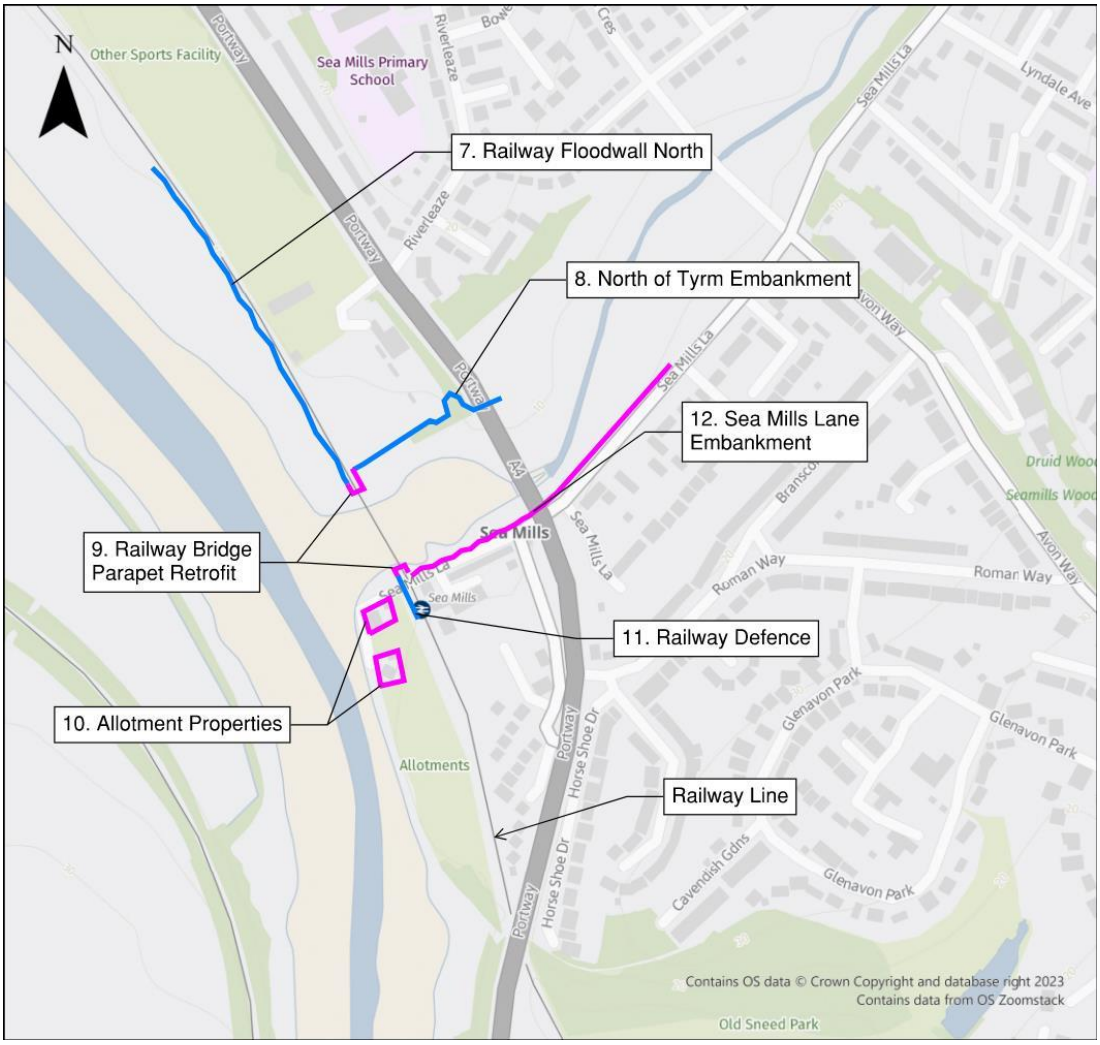

Figure 8 - Sea Mills Defence Area (blue and pink lines delineate between defence sections)

6.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-107.

6.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- The harbour walls of historic harbour are located between the banks of the River Trym in Sea Mills. The scheme should be mindful of this feature.
- Much of the southern portion of this area is part of the Roman settlement of Abonae which is designated as a Scheduled Monument. There may also be remains associated with the Roman settlement beyond the designated area, which have the potential to be of equivalent significance and grant them protection under NPPF.

6.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- There is a Bristol Wildlife Network Site in this area; design should follow the mitigation hierarchy and reduce impacts to this site.
- There is a high tide roost for waterbirds known on the coast here; design impacts should minimise disturbance and avoid loss of coastal habitats. This coastal habitat is viewed as functionally linked land to the SPA/Ramsar. However, there could be opportunity for enhancement as part of the strategy.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- It should be checked if raising the existing embankment and other works would impact the Site of Nature Conservation (SNCI) in this area, which overlaps the alignment.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

6.1.3 Buildability

- There is a railway embankment near Sea Mills station, which could be incorporated as part of the defence, but would require significant consultation and agreement with Network Rail. Works within Network Rail operational land would require a Basic Asset Protection Agreement (BAPA).
- There is a level crossing across the railway and restricted headroom under the Portway which may impact construction access.
- There are allotments located behind the proposed flood walls.

6.1.4 Landscape

- The accessibility of PROW BCC 598/10, BCC 599/10, and the Severn Way Long Distance Footpath should not be adversely affected by their proximity to the proposed flood defences here.
- There are multiple sections of the flood defences close to residential areas, mainly near Sea Mills Lane. The visual impact of defences should be mitigated where possible, for instance by raising

areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme's SoP.

- Access to and from the Sea Mills train station platform must be maintained, and opportunities explored to enhance public amenities here.
- The proposed material of the flood walls and public surfacing should be in keeping with the local character of the area.

6.1.5 Transport

- There is a railway bridge that passes over the River Trym. The defence alignment crosses the railway, and the proposed defence will need to be agreed with Network Rail and any works within railway operational land will require BAPA.
- Access to the properties on the west of the railway line will need to be considered with any new defences. Currently access is across the railway crossing at Sea Mills station, during a flooding event this may be compromised, and a defence will need to consider adequate access and escape routes or operational/early warning systems to avoid cutting off the properties.

6.1.6 Interfaces

- There are existing properties with surrounding walls near the Sea Mills Signal Station Allotments.
- A desk study has identified a potentially medium level of services in this area, including utilities owned by NGED and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

6.2 Option Development

6.2.1 General

The Sea Mills section of defences has changed significantly from what was proposed at SOC. The defence north of the River Trym follows the river side of the railway line. This was proposed as an embankment at SOC but now is proposed to be a small gravity floodwall, closer to the railway line. The line of defence then passes round the outside of the football pitch with an earth embankment and ties in with high ground on the eastern side of the Portway Road. On the south side of the river Trym, the defence is formed of multiple individual defences rather than the single line of defence proposed at SOC. These are described in more detail below.

6.2.2 Railway Floodwall North

At SOC an embankment was proposed on the river side of the railway. To reduce the footprint of the defences in the riverside location, improve buildability and maintenance, and utilise as much as possible the high ground provided by the railway embankment, it is proposed that a floodwall would be built as close as possible to the boundary of the railway line.

6.2.3 North of Trym Embankment

To the east of the railway line, an earth embankment is proposed to provide the line of defence running south of the football ground and underneath the A4 Portway road before tying into high ground adjacent to the road bridge. The earth embankment would be able to match the existing setting of the historic port more suitably than a floodwall.

6.2.4 Railway Bridge Parapet Retrofit

When the defence reaches the northern end of the railway bridge across the river Trym, due to the track level being ~0.6m below the required defence height, the current proposal allows for the bridge parapets to be floodproofed to continue the line of defence and prevent flooding of the railway line. This relies significantly on the assumption of the current and future structural integrity of the railway bridge, especially with regard

to floatation of the bridge from its foundations during flood events and other potential adverse loading scenarios. This would require significant further investigation and may result in an alternative alignment option being developed in conjunction with Network Rail.

6.2.5 Properties adjacent to allotment

There are two existing properties that are located amongst the allotments on the south side of the river Trym. At SOC stage it was proposed that a floodwall would pass around the outside of these and the allotments themselves. However, to mitigate the potential impact on the Scheduled Ancient Monument, and to limit construction close to the riverbank, these properties would be individually protected. Both already have existing walls that surround them, the extent to which these provide flood protection is currently unknown. Further consultation with property owners would be required to set a practical defence height which limits visual impact but protects the properties from flooding.

6.2.6 Railway Defence

The SOC alignment was changed to avoid the Scheduled Ancient Monument. To maintain the line of defence a floodgate and small connecting gravity floodwall on the western side of the railway is required to prevent outflanking. The location of the floodgate in plan can be seen in Appendix J. The defence heights here are low due to the level of the railway line. Further consultation with Network Rail would be required to properly interface these elements of the defence with the track and station. There are existing gates across the railway but these are not floodgates and therefore require replacement as part of the flood defence. Consideration of access and escape routes across the railway line would need to be considered further at FBC.

6.2.7 Sea Mills Lane Embankment

This section of defence runs from where the railway meets the riverbank on the south side of the River Trym, north-east along the river side of Sea Mills Lane. To preserve the setting as much as possible this would be formed of an earth embankment.

Due to the relative heights at the western end of the alignment, there is limited space so a hybrid floodwall/embankment is an alternative option that could be explored at detailed design stage. The western end of the alignment has a higher ground level than the eastern end (lowest elevation is 8.1mAOD where space is severely limited), so a floodwall for the most constricted sections would have a maximum height of 2.28m. The visual impact of this wall could be reduced by incorporating glazing into its top sections, raising the area behind this wall to reduce relative height and using materials sympathetic with the local area.

As with the embankment on the north side of the river Trym it would finish approximately 140m to the east of the A4 Portway where the ground levels reach the required defence height and prevent outflanking. The embankment would either tie into the A4 structure, or more likely deviate around the structure to maintain one line of defence that is isolated from the structure.

At SOC this defence was proposed to carry on west along Sea Mills Lane, and follow the river bank of the Avon upstream to protect the properties and allotments to the west of the railway line. This has been changed at OBC stage to mitigate interference with the Scheduled Ancient Monument that sits within this area. To still maintain a line of defence the following sections of alignment have been proposed.

6.3 Summary of preferred options

Table 4. Sea Mills - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
7	SoP	Railway Floodwall North	New gravity floodwall	10.38	10.38	300	0.28	1.38
8	SoP	North of Tyrm Embankment	New embankment	10.38	10.38	120	2.08	2.68

9	SoP	Railway Bridge Parapet Retrofit	Bridge parapet retrofit	10.38	10.38	100	0.4	0.4
10	SoP	Properties adjacent to allotment	Raise existing floodwalls	10.38	10.38	170	0.5	0.5
11	SoP	Railway Defence	New piled floodwall	10.38	10.38	30	0.48	0.48
12	SoP	Sea Mills Lane Embankment	New embankment	10.38	10.38	310	1.98	3.18

7. Bower Ashton

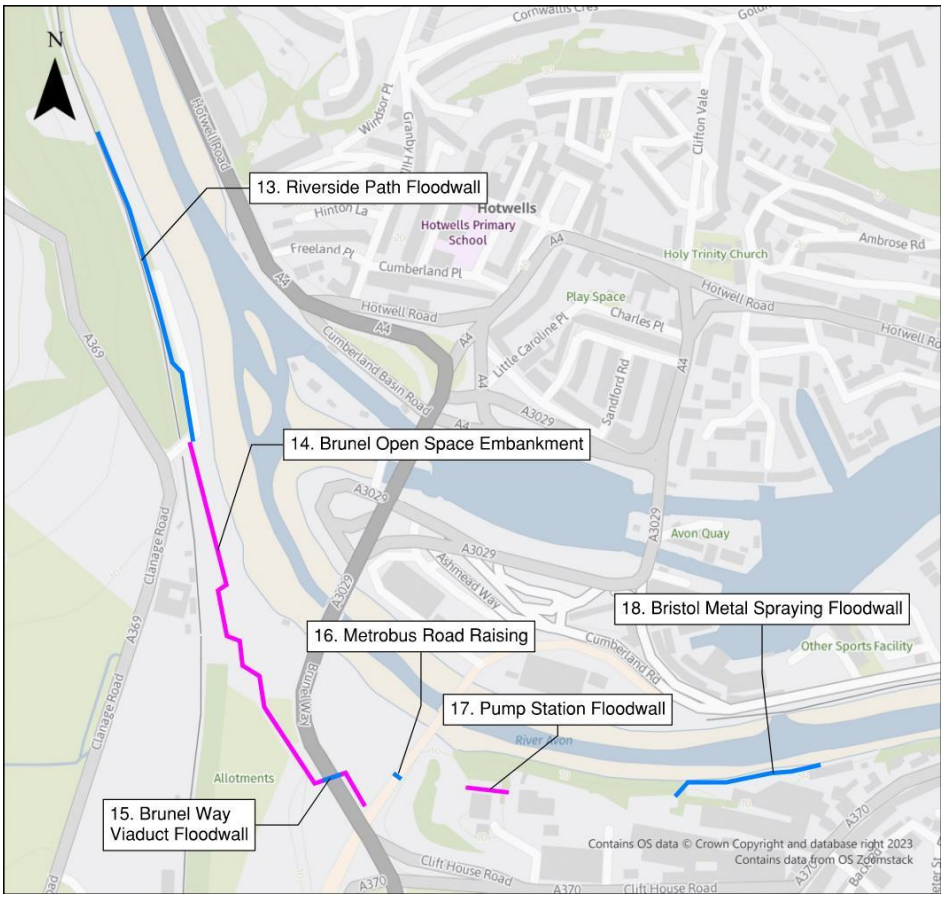

Figure 9- Bower Ashton Defence Area (blue and pink lines delineate between defence sections)

7.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plan - 285982-ARP-XX-DR-CIV-108.

7.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- The impact of the scheme on the setting and views of Clifton Suspension Bridge must be considered, due to its cultural significance and Grade I listing.
- Much of the site is within the City Docks Conservation area.
- The Ashton Avenue Bridge is a Grade II listed structure.

- There are also likely to be archaeological remains along the defence line which would be impacted by construction.

7.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- There is an area of ancient woodland near the proposed defence on the west bank of the Avon. In this area there is also the Avon Gorge Woodlands SAC/SSSI & NNR, which is designated for, in part, woodland and grassland. Impacts to these habitats are protected by legislation and design should follow the mitigation hierarchy.
- Works are within/adjacent to the Avon New Cut LNR, as well as an SNCI; design should follow the mitigation hierarchy and reduce impacts to these sites.
- There are Bristol Wildlife Network sites in the area near the proposed defence by Brunel Way.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

7.1.3 Buildability

- Brunel Way Flyover passes above Brunel Open Space and near the proposed defence alignment. There will be headroom limitations for the plant required to construct the section of floodwall underneath the flyover and the foundations of the flyover will need to be considered in the design and construction. Agreement and consultation with highways stakeholders will be required.
- There are various structures in the riverbank on the south side of the Avon, some of which may be required for supporting the riverbank.
- Potentially constrained access to and construction along the riverside path area close to the riverbank.

7.1.4 Landscape

- The accessibility of the Avon River Trail Long Distance Footpath, National Cycle Network Route 41 and PROW 200A/20 should not be adversely affected by their proximity to the proposed flood defences here.
- The flood defences along the riverbank should be designed to minimise their impact and maintain the riverside views characteristic to this area.
- The Brunel Open Space is located at the centre of this area. The preferred option should aim to minimise disruption and maximise the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible. It should be noted that there is a skate park in this location that could be enhanced as part of the proposals.

- There are key views from this area of the Clifton Suspension Bridge and Avon Gorge, the relative height of the flood defences should be considered so views can be maintained.
- The existing treeline along the riverbank must be reinstated if any trees are removed during construction.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

7.1.5 Transport

- The existing MetroBus route intersects the line of defence. This goes across Ashton Avenue Bridge.
- The Portishead railway line passes close to the Avon in this location – the track is also to be upgraded in future, providing a potential works interface.
- Brunel Way Flyover crosses the New Cut from Greville Smythe park.

7.1.6 Interfaces

- Regeneration as part of the Western Harbour strategic growth and regeneration area. A masterplan has not been developed at the time of this study so the locations and types of development are not known. Any proposed developments will be considered further as details become available. The current design has been based on the current situation, however there is opportunity for defences in this area to be developer-led rather than by the Strategy.
- Redevelopment at Payne's Shipyard has been granted planning permission subject to conditions. This overlaps with some defences, and should the development be constructed, there is an opportunity that defences will not need to be developed by the Strategy.
- A desk study has identified a potentially high level of services in this area, including utilities owned by NGED, Wessex Water and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

7.2 Option Development

7.2.1 General

The Bower Ashton group of defences starts on the western bank of the Avon tying into high ground at south of the Clifton Suspension Bridge. The defence follows the riverside path south, between the river and the railway line before reaching Brunel Open Space where the defence is set back. At the south-eastern edge of this area, it crosses the MetroBus road and in front of the sewage pumping station and Payne's Shipyard. This is a significant change from the SOC where it was proposed that the defence followed the riverbank from the southern end of the riverside path and in front of the Brunel Open Space.

7.2.2 Riverside Path Floodwall

This section would consist of a ~410m gravity floodwall that runs between the riverside path and the railway embankment to the west until the defence reaches the footbridge at the bottom of Rownham Hill. An earth embankment was considered that would be placed between the path and the river but due to the defence height required, and the riverbank gradient, a suitable embankment would be difficult and potentially unsafe to construct and it would also encroach significantly onto the riverbank which includes protected habitats.

7.2.3 Brunel Open Space Embankment

South of Rownham Hill footbridge the area joins Brunel Open Space and the defence would consist of a ~460m long earth embankment that is set back from the river. Initially it was proposed for the line of defence to run along the riverbank but to improve buildability, reduce encroachment on protected habitats and utilise the existing high ground to minimise the height of the defence it would follow the landward boundary of this space. Setting the line of defence back also retains the key views from this space looking down Avon Gorge

towards the Clifton Suspension Bridge. In some places, the existing ground level is sufficient to act as the line of defence and so the embankment would not be continuous. This would also reduce the volume of materials required for construction. There is a break in the embankment underneath Brunel Way Viaduct (see next section) but to the east of the Viaduct the embankment continues until it ties in with existing embankment/cutting created for the Metrobus route.

7.2.4 Brunel Way Viaduct Floodwall

Underneath the Brunel Way Viaduct, a small floodwall is required to connect the two embankments either side. This section is ~25m long and would likely be a gravity foundation due to the low defence heights required and the limited ability to use a piling rig underneath the Viaduct. The interaction with the Viaduct's foundations would need to be considered but the flood defence structure would not rely on the existing bridge structure to form the line of defence. The existing path underneath the viaduct would be maintained, which may require raising in Phase 2.

7.2.5 Metrobus Road Raising

To connect the line of defence across the cutting created for the MetroBus route, road raising is proposed across the road between the two embankments either side. A floodgate across Ashton Avenue Bridge was initially considered but to ensure the defence is passive and to reduce cost and maintenance requirements, road raising is the preferred option. The exact position of the crest of the road raising would need to consider ramp gradient requirements as well as clearance underneath the footbridge in this area.

7.2.6 Pump Station Floodwall

Between the river and the sewage pumping station the ground level is lower than the surrounding area so a ~50m floodwall is required to connect the high ground either side. This floodwall would likely be a gravity floodwall with a maximum defence height of 1.14m. There would likely be constraints below ground as the structure may interfere with the pumping station infrastructure. There is an opportunity to reduce the extent and heights of defences should the pumping station infrastructure be floodproof.

7.2.7 Payne's Shipyard Floodwall

On the river bank at Payne's Shipyard, there would be a ~160m piled floodwall to protect the buildings to the south. There is limited space for construction and so a piled solution would be the most space efficient construction method, and due to defence heights required, a gravity floodwall would not be suitable in some areas of this defence.

7.3 Summary of preferred options

Table 5. Bower Ashton - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
13	SoP	Riverside Path Floodwall	New gravity floodwall	10.43	10.43	410	1.53	2.53
14	SoP	Brunel Open Space Embankment	New embankment	10.2	10.93	460	0.4	1.6
15	SoP	Brunel Way Viaduct Floodwall	New gravity floodwall	10.2	10.93	25	0.4	0.6
16	SoP	Metrobus Road Raising	New road raising	10.2	10.93	10	0.8	0.9
17	SoP	Pump Station Floodwall	New gravity floodwall	10.44	10.44	50	0.84	1.14
18	SoP	Payne's Shipyard Floodwall	New piled floodwall	10.45	10.45	160	1.35	3.55

8. Entrance Lock

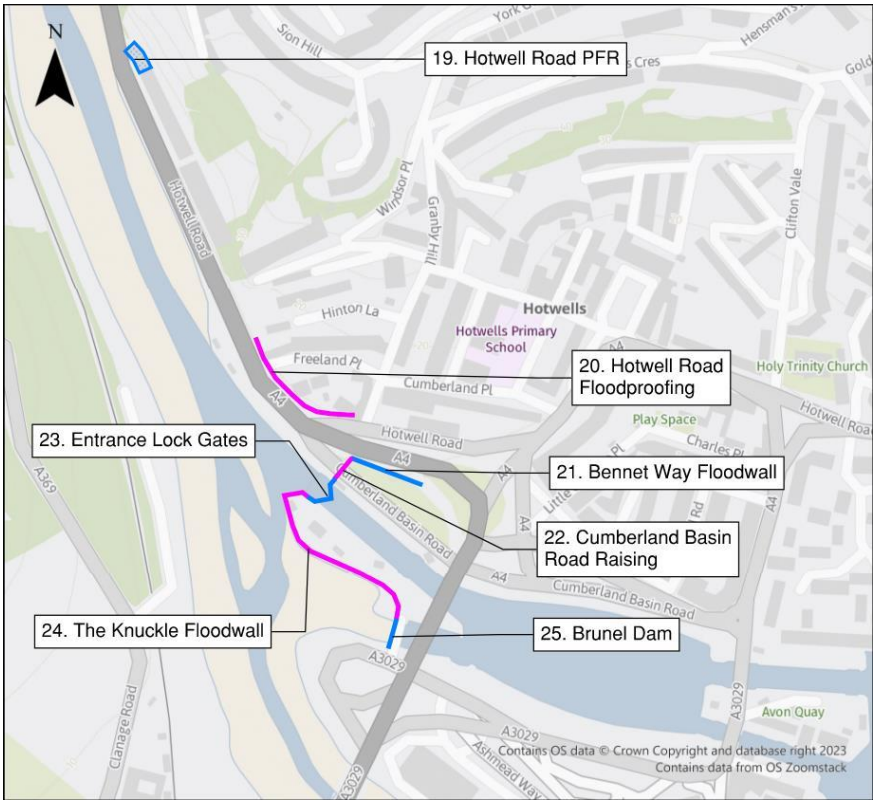

Figure 10 - Entrance Lock Defence Area (blue and pink lines delineate between defence sections)

8.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plan - 285982-ARP-XX-DR-CIV-100.

8.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- The Entrance Lock area sits entirely within conservation areas – the lock area within the City Docks and Hotwells in Clifton.
- There are several Grade II and II* listed buildings and structures in this area. These include but are not limited to Brunel's south entrance lock and swing bridge, Brunel's swing bridge alongside north entrance lock, the Cumberland Basin walls and associated features including Junction Lock swing bridge, and buildings along Hotwell Road. Works are directly proposed along several of these listed structures.
- 414-420 Hotwell Road are Grade II* listed buildings.
- 19 Freeland Place, 20 Freeland Place, and the front area walls and piers of Freeland Court and Numbers 302 and 304 are Grade II listed.
- Ensure that where possible, the proposed defences enhance the specific heritage setting of the Entrance Lock area and the public realm within its vicinity.

8.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- Avon New Cut is a Site of Nature Conservation Importance and Local Nature Reserve.
- There is a Bristol Wildlife Network Site in this area; design should follow the mitigation hierarchy and reduce impacts to this site.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- The EA have confirmed that "*improvements to eel passage will not be required as part of [replacement of the flood gates] and [they] would not be seeking improvements to passage for migratory salmonids into the Feeder Canal or Floating Harbour*."
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- There is the potential to encounter contaminated ground as part of the proposed works.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

8.1.3 Buildability

- Most of the proposed works are near the riverbank and in some places are tightly constrained between the riverbank and buildings or highways.
- There are limited locations for adequate access routes (in particular for large plant) and construction compounds.
- Some areas that will require construction equipment have limited access to plant. For instance, there is a three tonne limited bridge across Brunel Swing Bridge onto the Knuckle. There are also limited locations for adequate access routes and construction compounds, including from the A4 Portway.
- Multiple existing services, foundations and structures are present around this area, due to its operational requirements. These will require further investigation prior to construction. Many of these are non-statutory and unrecorded services and coordination with the harbour operations team will be required throughout the design and construction phases.
- Some sections of floodwall are positioned closely to the basements of properties – it should be ensured that basement access is maintained (Hotwell Road).
- Harbour operations and vessel navigation during construction need to be considered in the design and construction sequencing of the defences to ensure that any adverse impacts are minimised and mitigated as best as possible.

8.1.4 Landscape

- The flood defences along the riverbank and at the lock gate should be designed to minimise their impact and maintain the riverside views characteristic to this area.
- There are key views from this area of the Clifton Suspension Bridge and Avon Gorge, the design of the flood defences in this area should be such that these views can be maintained.

- There are multiple sections of the flood defences close to residential areas, mainly along Hotwell Road. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.
- There are opportunities to enhance active travel across this area, and to create a space that allows for gathering of groups, events, promotion of the city's heritage and recreation. From here, one can afford some of the most iconic views of Bristol towards the Clifton Suspension Bridge and the colourful terraced houses of Clifton Wood and Hotwells. The space is used by runners and walkers, mostly passing by without stopping for too long. There is a lack of seating areas and other general amenities.
- Flood defences are located in close proximity to Cumberland Piazza. The preferred option should aim to minimise disruption and maximise the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

8.1.5 Transport

- This area includes multiple important transport links into the centre of Bristol including highways, specific bus routes and active travel routes. In this area the A4 Portway (improvements to which are currently being investigated and developed) reaches the city centre and splits into multiple routes that run adjacent to or over the Entrance Lock area. Active travel routes around this area of public realm should be enhanced if possible, improving connectivity across Entrance Lock towards Brunel Open Space and Spike Island.
- Current active travel links often involve crossing over the lock gates and near other operational areas, increasing risks to members of the public as well as interfering with operations.
- There are several footpaths, cycle paths and other PROWs in the Entrance Lock area, namely the Severn Way.

8.1.6 Interfaces

- Regeneration as part of the Western Harbour strategic growth and regeneration area. A masterplan has not been developed at the time of this study so the locations and types of development are not known. Any proposed developments will be considered further as details become available. The current design has been based on the current situation, however there is opportunity for defences in this area to be developer-led rather than by the Strategy.
- This area is within the working area of the Floating Harbour and therefore the defences must integrate and not adversely impact the requirements of the harbour and the harbour operations team including operation of lock gates and bridges. Discussions with the harbour operations team have taken place about ensuring that the operational capability of the harbour is maintained, and opportunities for it to be enhanced (reducing maintenance requirements, operational liabilities and risk) should be explored.
- A desk study has identified a potentially high level of services in this area, including utilities owned by Bristol Water (BW), NGED, Virgin, WW and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence. It is expected that non-statutory services related to the operation of the gates will also be present.

8.2 Option Development

8.2.1 General

The Entrance Lock section includes defences starting at the A4 Hotwell Road running south across the western edge of the Floating Harbour infrastructure and joining up with the Spike Island section starting at the Off Ramp of Brunel Way. The alignment and design of defences in this section remains similar to those proposed at SOC. During this options development process a more precise alignment has been agreed through consultation with stakeholders and where there have been significant changes to the alignment or assumptions, these are detailed below.

8.2.2 Hotwell Road PFR

At the northern end of Hotwell Road, The Colonnade and adjacent properties 410-412 Hotwell Road are proposed to be protected with PFR measures to ground level and basement thresholds.

8.2.3 Hotwell Road Floodproofing

As Hotwell Road curves to the east around Freeland Place, the existing wall would require floodproofing and two new floodgates would be required at either end of the wall. At this stage it is assumed that the wall would not need replacing, but allowance has been made for strengthening and floodproofing. It may be found at detailed design that a new wall is more cost effective or agreed with stakeholders.

8.2.4 Bennet Way Floodwall

The defence would be a ~60m-long gravity foundation floodwall that follows the south side of Bennet Way until the ramp up to the flyover is at the required defence height. This stub wall would connect to the road raising to the south on Cumberland Basin Road (see next section).

8.2.5 Cumberland Basin Road raising

Road raising would be used on Cumberland Basin Road to maintain a passive line of defence and ensure that access outside of flood events is maintained on this important part of the road network. On the south side of this carriageway the pavement would also need to be raised and tie into the flood defences that connect to the lock gates.

8.2.6 Entrance Lock Gates

Two pairs of flood stop gates are deployed by BCC at Junction Lock (the downstream entry point to the harbour) to restrict water from flowing from the River Avon channel into Cumberland Basin and then into the harbour. The stop gates are operated and maintained by BCC under a Memorandum of Understanding with the Environment Agency who pay for their operation. The Junction Lock stop gates are operated around 200 times every year but are otherwise left open. The outer set of lock gates Entrance Lock are used only to retain the levels in the floating harbour, and to provide locking services between that and the Avon.

The defence across Entrance Lock itself would remain the same as proposed at SOC. The outer lock gates would be replaced with new gates and the required operational infrastructure that goes with them. These gates would need to protect the floating harbour from high water levels in the Avon, as well as maintaining the water level inside the lock during operation, unlike the current gates which are only designed to maintain levels in the harbour. The design would include a walkway across the lock gates to maintain access in the closed position.

As part of the option development process, BAM Nuttall were consulted on the proposed option to help understand buildability opportunities, constraints and risks as well as help provide an indicative cost estimate due to the large cost and significance of this part of the defence. This highlighted the significant enabling works required to install these new gates considering the bi-directional loading on hinges (as opposed to the single direction hinges currently in place). The main constraint on construction programme would be the ability to allow full closure of the lock gates to navigation. If navigation through the locks could be completely closed for a period this would significantly reduce construction time. The full list of assumptions from the BAM consultation can be found in Appendix E.

An opportunity has been noted that both sets of lock gates at Entrance Lock could be replaced with higher flood gates (rather than just the outside set), and the walls of the lock itself raised, to allow 'locking in' of vessels to the floating harbour even in flood events. This could provide an extra safety measure for vessels on the river and could allow the decommissioning of the existing junction lock gates, but would increase capital costs and carbon, with no increase in flood benefit. The opportunity will be explored further at FBC.

8.2.7 The Knuckle floodwall

Through consultation with the Harbour Operations team, a 2m wide working corridor at the existing ground level is to be kept around the perimeter of The Knuckle to allow access for operations and maintenance, and for vessels to moor up while waiting for the lock to open. The relocation of certain infrastructure such as bollards would be needed to facilitate this. A further advantage of this is to create separation between the operational and publicly accessible areas, especially as is it expected that footfall would increase to the Knuckle following placemaking enhancements. The operations team have expressed concerns that members of the public have free access to enter the harbour working areas during locking operations already and would like to create a physical separation to either mitigate, or reduce the risk to the public. For example, fencing to create a 2m wide working corridor around the lock itself could be incorporated into the works.

The concept of terracing up to the defence height on the 'inside' of the Knuckle to reduce relative defence heights and maintain views, first developed during the SOC, would remain. Further investigation of the interface between the defence and terracing with lock gate infrastructure would be required at the next stage.

From the eastern side of The Knuckle, the alignment would not follow the edge of The Tongue (as proposed in the SOC) as this was considered to be too small a site to justify the complex buildability of building along the edge of the wall on a tight corner. It would also create an uninviting space for the public with a large wall surrounding it. Instead, the alignment cuts across the eastern side of The Tongue to tie into the Brunel Dam section of the alignment and terracing up and over the line of defence would retain access across to the Tongue, where there is opportunity to install further landscape enhancements. Setting the proposed wall back further from the river also reduces the interaction with the listed harbour walls and protected habitats.

8.2.8 Brunel Dam

At SOC stage it was assumed that the Brunel Dam (the former lock that is now permanently sealed closed with non-functioning sluice gates) would be raised to the required defence level by concreting over the top and raising the bridge that goes over the top of the dam. Specific constraints in this area include:

- Grade II* listed Brunel Lock (formerly wrought iron caisson lock, gates now removed)
- Grade II* listed swing bridge over the top of Brunel Lock
- A large area of intertidal silt/mudflat on the river side of Brunel Lock

As part of this phase of work alternative options to concreting over the dam and raising the swing bridge have been considered in more detail to try to mitigate the impact of works on the heritage assets and on the intertidal silt/mudflat. These options consisted of different alignments and construction methods. These are described below and a summary of the options appraisal is provided below with the full appraisal in Appendix I and sketches in Appendix F. The options are illustrated in Figure 11.

As part of the option development process, BAM Nuttall were consulted on the proposed option to help understand buildability opportunities, constraints and risks as well as help provide an indicative cost estimate of the preferred option due to the large cost and significance of this part of the defence.

<u>Option 1</u>

Option 1, developing the SOC option, is to use the Swing Bridge parapets as the line of defence (including remedial works to ensure that they are floodproof) by raising the whole bridge by 0.4m, and then raise and infill Brunel Dam so that it can support the Swing Bridge.

<u>Option 2</u>

Option 2 uses a new sheet pile wall as the line of defence which would be located on the western (river) side of the Brunel Dam and Swing Bridge. This would be constructed with two lines of sheet pile walls infilled to form the line of defence.

Option 3

Option 3 uses a new sheet pile wall as the line of defence which would be located on the eastern (harbour) side of the Brunel Dam and Swing Bridge. This would be constructed with two lines of sheet pile walls infilled to form the line of defence.

Option 4

Option 4 uses the pedestrian bridge within the floating harbour as the line of defence to avoid interfacing with the heritage assets. This would likely be achieved with a sheet pile wall infilled with concrete along the line of the pedestrian bridge. This would pass underneath the Plimsoll Bridge and rejoin the line of defence on the southern side of Brunel Dam.

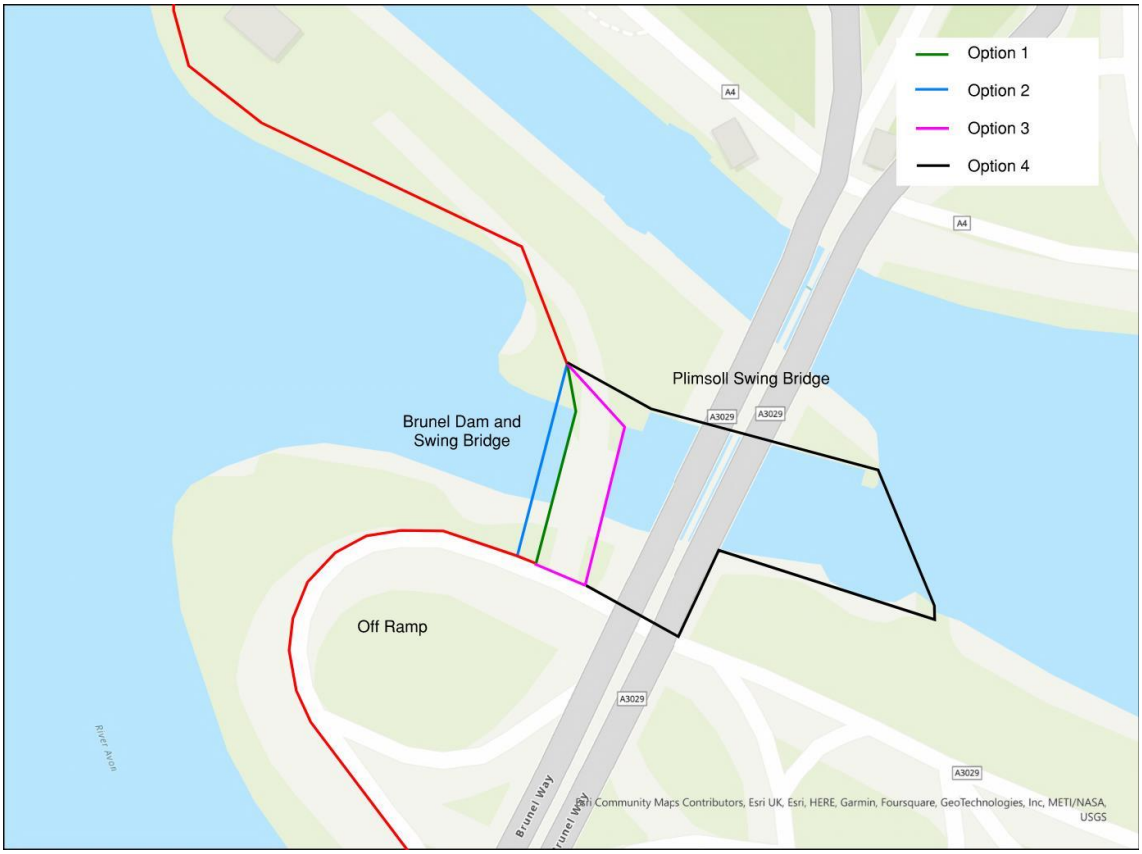

Figure 11 - Brunel Dam Defence Line Options

Table 6. Brunel Dam Appraisal Summary

Option	Summary of key benefits	Summary of key disadvantages
1. Raise and infill Brunel Dam and raise swing bridge (developed SOC option)	• Best maintains the existing setting and views of the area as no new structures are built, only modifications to existing ones. • Limited encroachment into the protected silt habitat and after construction, which can reform around the structure to the same extent following the works. • Strengthening of the bridge as part of construction can provide a valuable upgrade to the access onto the Knuckle which can aid	• Construction would involve direct work to heritage structures and rely on them to form the line of defence. Significant and complex remedial works may be required. • The construction area would encroach upon the protected silt habitat, some of which would be permanently displaced. • Working within tidal area.

	construction and ongoing operation and maintenance. • Limited impact on listed harbour walls • Opportunity to bring sluice gates back into operation, if beneficial for harbour operations	
2. Sheet pile wall adjacent to Brunel Dam (on river side)	• Flood defence line does not rely on existing heritage structures. Potential to make more of a feature out of heritage assets once protected. • The solution is relatively simple and quick to construct.	• Significant encroachment into protected habitat that would be unrecoverable post construction. • Significantly changes the setting and views in the area, including a 'dead space' between the structures • Impact on listed harbour walls • Working within tidal area. • Removes opportunity to bring sluice gates back into operation
3. Sheet pile wall adjacent to Brunel Dam (on harbour side)	• Flood defence line does not rely on the existing and heritage structures. • No impact on protected tidal habitats and no construction in tidal area. • Limits the impact on views and setting.	• Very complicated tie in on southern side of Brunel Dam (likely would prevent this option being feasible) • Very constrained construction zone. • Removes opportunity to bring sluice gates back into operation • Includes creation of 'dead space' between new crossing and existing dam.
4. Use pedestrian bridge within Floating Harbour as line of defence.	• Flood defence line does not rely on the listed structures. • No impact on protected tidal habitats and no construction in tidal area. • Limits the impact on views and setting.	• Very complicated tie in on southern side of Brunel Dam (likely would prevent this option being feasible). • Potential interference with Plimsoll Bridge • Very constrained construction zone. • Cutting off an area of the Floating Harbour permanently. • Impact on listed harbour walls • Removes opportunity to bring sluice gates back into operation

Following consultation with multiple stakeholders, it was agreed that Option 1 (developed SOC option) would be taken forward as the preferred option with further investigations required at later stages to mitigate some of the outstanding risks, particularly related to the existing heritage structures. This was primarily due to the reduced heritage and environmental impact of this option, as well as the improvements to access. It should be noted that, following consultation with BAM that Option 1 has significant cost and carbon implications due to the complex construction method of the option and that if some heritage and environmental constraints could be mitigated further then Option 2 would provide opportunities to reduce the cost and carbon impact of the option. This should be considered further at FBC with reference to Appendix E.

8.3 Summary of preferred options

Table 7. Entrance Lock - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
19	SoP	Hotwell Road PFR	New PFR	10.43	10.43	N/A	1.03	1.43

20	SoP	Hotwell Road Floodproofing	New floodproofing	10.43	10.43	120	1.43	2.13
21	SoP	Bennet Way Floodwall	New gravity floodwall	10.08	10.8	60	0.08	0.68
22	SoP	Cumberland Basin Road Raising	New road raising	10.08	10.8	10	0.78	0.78
23	SoP	Entrance Lock Gates	New lock gates	10.08	10.8	25	n/a	n/a
24	SoP	The Knuckle Floodwall	New piled floodwall	10.08	10.8	180	1.88	1.98
25	SoP	Brunel Dam	Raise existing structure and floodproof	10.07	10.81	20	n/a	n/a

9. Spike Island

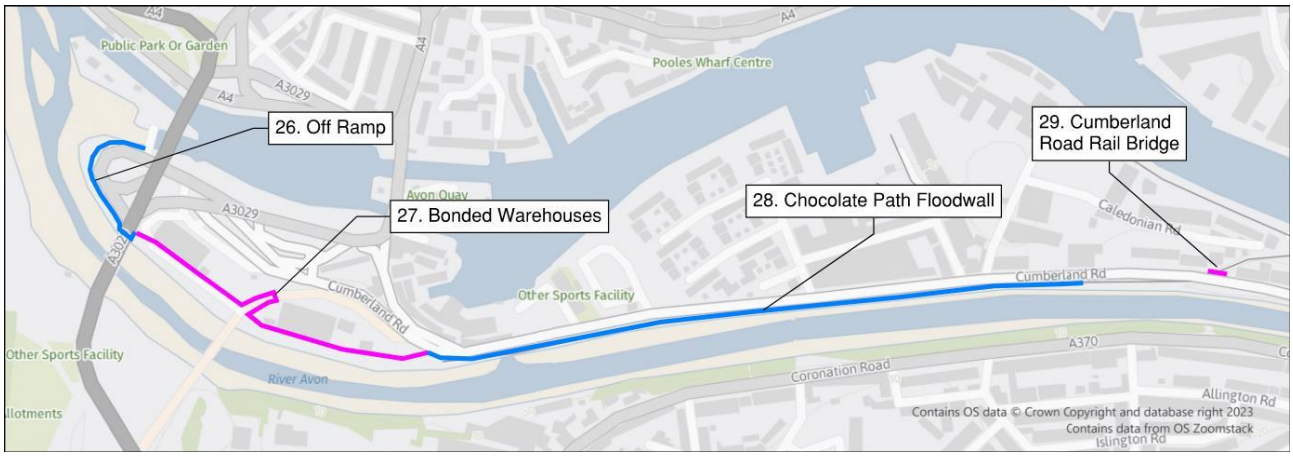

Figure 12 - Spike Island Defence Area (blue and pink lines delineate between defence sections)

9.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-100 and 285982-ARP-XX-DR-CIV-101.

9.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- The Spike Island area sits entirely within the City Docks conservation area.
- There are several grade II and II* listed buildings and structures in the study area. These include but are not limited to Ashton Avenue Swing Bridge, the Bonded Warehouses and Vauxhall Bridge.
- Underfall Yard is a Scheduled Monument located on Spike Island near Cumberland Road and containing multiple listed buildings. It was damaged by a substantial fire in May 2023.
- There is a heritage railway running along the southern edge of Spike Island between Cumberland Road and the Chocolate Path. This railway is not currently running to the Chocolate Path due to the path collapse (9.2.4) but is expected to be reinstated following completion of those works. It should also be noted that this is not a Network Rail asset, and is instead operated by M Shed museum.

9.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- Avon New Cut is a Site of Nature Conservation Importance and Local Nature Reserve.
- A small area of the defences is partly within a Bristol Wildlife Network Site.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.
- There is the potential to encounter contaminated ground as part of the proposed works.

9.1.3 Buildability

- Most of the proposed works are near the riverbank and in some places are tightly constrained between the river and buildings or highways.
- There are limited locations for adequate access routes and construction compounds.
- Along some sections existing foundations or structures are present which may interfere with the flood defence structure e.g. the foundations of the Bonded Warehouses.
- There is a significant section of collapsed wall along the Chocolate Path which was repaired between 2020 and 2023. This reflects the risk of further collapse along the riverbank which must be mitigated for the flood defences to be effective and structurally stable.
- There is a severely corroded metal bridge over the Underfall Sluices which would require remediation prior to flood wall construction. This is likely to form part of the ongoing repair works package at Cumberland Rd.
- Cumberland Rd is likely to require partial or full closure for the works, the latter being extremely unlikely due to level of disruption this would cause. More available space (and likely more traffic disruption) will make construction quicker and potentially cheaper, but this will require careful consideration against the proposed impacts.

9.1.4 Landscape

- The accessibility of the River Avon Trail Long Distance Footpath and PROW BCC 392/10 should not be adversely affected by their proximity to the proposed flood defences here. The floodwall lies along the Chocolate Path. The preferred option should aim to minimise disruption and maximise the creation of inviting multifunctional spaces along the pathway where possible. There are multiple sections of the flood defences close to residential areas, mainly along Cumberland Road. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.

- There are key views along the Chocolate Path and from Ashton Avenue and Vauxhall Bridge. The relative height of flood defences should be considered so views and access can be maintained.
- The existing treeline along the Avon riverbank must be reinstated if any trees are removed during construction. This will help to screen views of the flood defences for nearby residential properties.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

9.1.5 Transport

- This area includes multiple important transport links into the centre of Bristol including highways, specific bus routes and active travel routes.
- There are several footpaths, cycle paths and other PROWs in the Spike Island area, namely the Chocolate Path and the Severn Way.

9.1.6 Interfaces

- Regeneration as part of the Western Harbour strategic growth and regeneration area. A masterplan has not been developed at the time of this study so the locations and types of development are not known. Any proposed developments will be considered further as details become available. The current design has been based on the current situation, however there is opportunity for defences in this area to be developer-led rather than by the Strategy.
- There are several businesses that may be impacted by the flood defence, especially underneath the Off Ramp and around the Bonded Warehouse area.
- This area includes the area of the Chocolate Path and Cumberland Rd which collapsed in 2020 and has subsequently been repaired. The foundations for the repaired 113m-long section have been constructed to allow future raising of the flood wall by the flood scheme. There has also been discussions with the contractor team to learn lessons from that scheme that have been applied to this design.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BW, NGED, Virgin, WW and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

9.2 Option Development

9.2.1 General

The Spike Island section of defences runs from the tie-in to Brunel Dam, around the Off Ramp of the Brunel Way flyover, past the Bonded Warehouses and along the Chocolate Path before tying into the bridge over the historic railway at 80/81 Cumberland Road. The main developments from the SOC stage have been refining how the alignment interfaces with the listed Bonded Warehouses and Ashton Avenue Bridge as well as refining the structural design of the flood defences to mitigate the potential poor ground conditions along the riverbank.

It should be noted that the defences outlined here in particular are subject to interaction with the Western Harbour development area, and are therefore likely to change based on this rather than be delivered exactly as described below. However this section describes a viable option should the development not be progressed, or delivered in time, and has formed the basis of the updated cost estimate.

9.2.2 Off Ramp

The SOC stage design was for a floodwall to follow the riverbank around this area. Through further development and consultation, the alignment would use the off ramp as the line of defence rather than running along the riverbank. This would reduce cost and carbon by using an existing structure for much of this section (a small wall and ramp would be required to tie in to the Brunel Dam defence at the northern

end). This alignment would also maintain views to the river with the path and green space remaining on the riverside of the defence, ensuring that this space remains accessible to the public. There are significant opportunities for biodiversity enhancements in this area of amenity grassland.

The off ramp is not supported by a wall for the entirety of its length. Some parts are supported by columns, which means there are gaps underneath which would need to have new walls constructed in them for the off ramp to be used as part of the line of defence. There are approximately 101m of existing wall, with around 29m of empty space which would require new construction. The construction of these sections would need to consider the foundations of the ramp.

As water levels rise, the area on the river side of the defence may transition from grassland to silt/mudflat and the amount of public space may reduce. It was concluded that maintaining access and views was more of a priority for this area than defending it, as well as the cost and carbon savings of using the existing structure as the line of defence. Similarly, this is an opportunity for habitat enhancement.

On the eastern side of Brunel Way Flyover, the defence would tie into the floodwall that forms the Bonded Warehouses section of defence. The Bonded Warehouses wall is proposed on the landward side of the access road in this location and so either a wall or a usually closed floodgate is proposed here, subject to further development of the Western Harbour masterplan and what would best interface with development. Due to other access roads being available or modified, a passive, or mostly passive defence is preferred here.

9.2.3 Bonded Warehouses

The SOC proposal was for a floodwall that ran along the river side of the access road behind the Bonded Warehouses (the same layout as option 1 in Figure 13), with a raised path behind the wall to maintain views.

As part of this phase of work alternative options, primarily to remove the need for a large floodgate across Ashton Avenue bridge, have been considered in more detail to try and improve the proposed solution in this area. These are described below with the full appraisal in Appendix J and sketches in Appendix G.

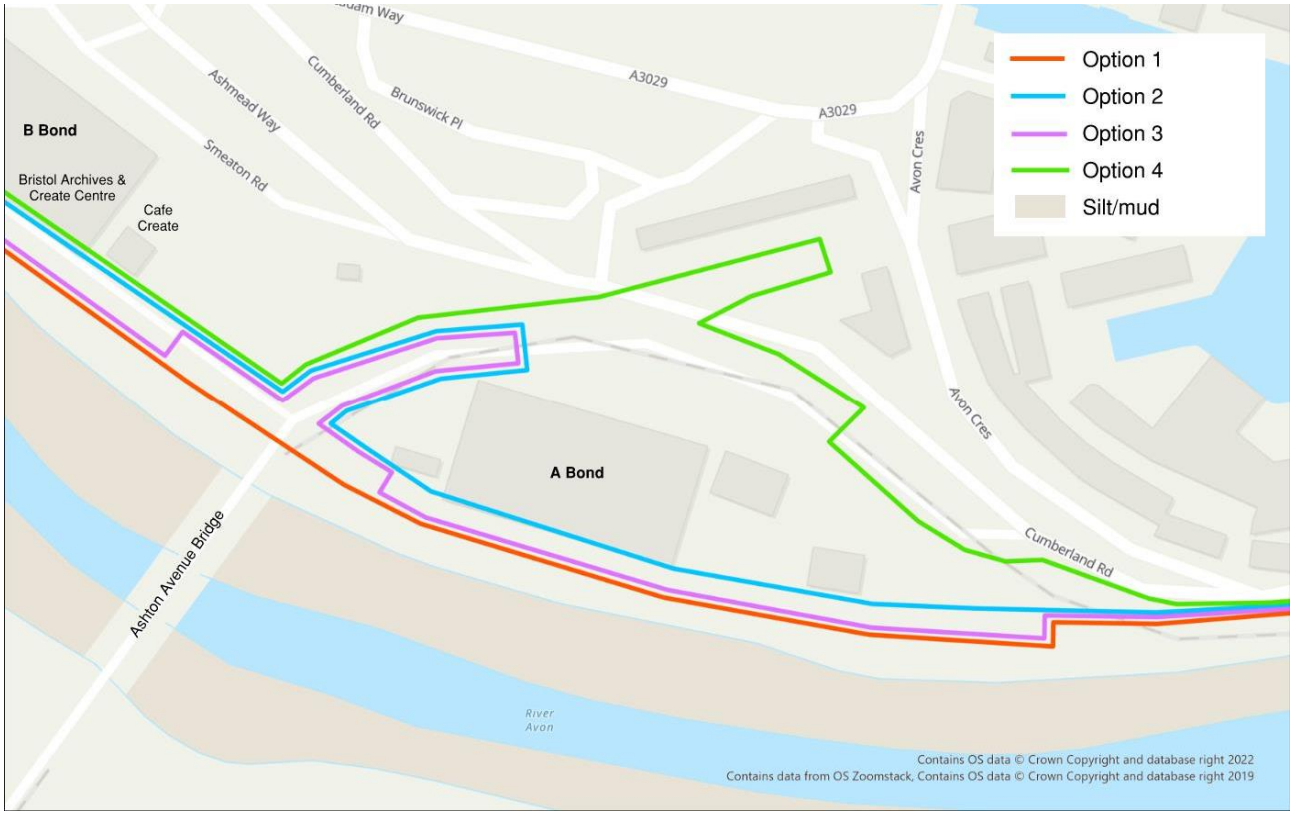

Figure 13 - Bonded Warehouse Defence Line Options

Option 1

Option 1, proposed in the SOC, is to construct a flood wall following the Avon New Cut from the Brunel Way flyover, crossing the Ashton Avenue busway with a ~12m wide flood gate and tying in with the defences along the Chocolate Path. The wall would be on the river side of the access road behind the Bonded Warehouses, with the path raised behind the wall. At the Eastern end of this section, the line of defence would comprise either a further gate or ramps to meet the Chocolate Path defence, which is inland of the path itself.

Option 2

Option 2 proposes a river-side path option where the floodwall is on the landward side of the access road behind the Bonded Warehouses. When it reaches the guided busway, the roads would be raised to provide a passive line of defence. The pavement running on the northern side of the guided busway would also have to be raised to maintain access under Smeaton Road Bridge. The floodwall would tie into the Chocolate Path defences and continue the river-side path along the south side of Spike Island. In Phase 2 a smaller floodgate across the guided busway at the crest of the road raising may be required.

Option 3

Option 3 is a combination of Option 1 and Option 2. This option proposes a floodwall on the riverside of the access road but as the access road approaches the guided busway, road raising is used to form the line of defence and remove the need for a floodgate. The road between the bonded warehouse and proposed wall would require raising, as at Option 1. The pavement running on the northern side of the guided busway would also have to be raised to maintain access under Smeaton Road Bridge. When the access road meets the Chocolate Path the wall would transition to the inland side of the path again with a ramp.

Option 4

Option 4 is a set-back option that primarily uses existing structures as the line of defence. It involves using a combination of flood walls, flood-proofing existing walls, road raising and a small flood gate to form the line of defence. A floodwall would run along the landward side of the Eastern access road (similar to Option 2) and follow the guided busway into the existing wall that leads to the pedestrian underpass. It is proposed that a ramp would be constructed along the access road to B Bond warehouse to provide additional access to the Bristol Archives and Café Create. A small floodgate would be located on the north side of Smeaton Road Bridge where the existing cycle gate is to mirror the current arrangement. Road raising would be required on Ashton Avenue with the peak located towards the Cumberland Road junction. This measure would not protect the A Bond warehouse, so Property Flood Resilience (PFR) may be required including safe routes of access and egress.

Table 8. Bonded Warehouses Appraisal Summary

Option	Summary of key benefits	Summary of key disadvantages
1. Riverside floodwall, floodgate over guided busway (SOC option)	• Protects largest area of land. • Floodwalls are not directly adjacent to Bonded Warehouses.	• More complex construction closer to the riverbank. • Likely to lead to loss of riparian species and vegetation. • Obstructed view of river from path (potential to mitigate with promenade). • Large floodgate is not passive and would incur maintenance and operational costs, as well as significant residual risk. • Significant amounts of path raising required behind floodwall increasing cost and carbon. • Gate closure causing entrapment of metrobus on bridge or approaches.
2. Landward side floodwall, road raising over guided busway	• Protects large area of land. • Floodwall is set back from river edge which reduces impact on riparian species and vegetation.	• Floodwalls would be adjacent to Bonded Warehouses, potential interference with views. • Riverside path would require maintenance after flood event and closure during events –

	• Views of the river from the path are maintained. • Road raising provides a passive solution. • No path raising required, reducing cost and carbon	noting this is the case in a 'do nothing' scenario.
3. Mostly riverside floodwall, road raising over guided busway	• Protects large envelope of developable land. • Road raising provides a passive solution. • Floodwalls are not directly adjacent to Bonded Warehouses.	• More complex construction closer to the riverbank. • Likely to lead to loss of riparian species and vegetation. • Obstructed view of river from path (potential to mitigate with promenade). • Significant amounts of path raising required behind floodwall increasing cost and carbon.
4. Set back flood defence	• Lowest cost and carbon solution by maximising use of existing structures. • Floodwall is set back from river edge which reduces impact on riparian species and vegetation. • Views of the river from the path are maintained. • Largely passive with one small floodgate	• Large area of land would be within the flooded area. A Bond Warehouse would be cut off without additional raised access. • Riverside path and flooded area would require maintenance after flood event and potential closure for short time - noting this is the case in a 'do nothing' scenario.

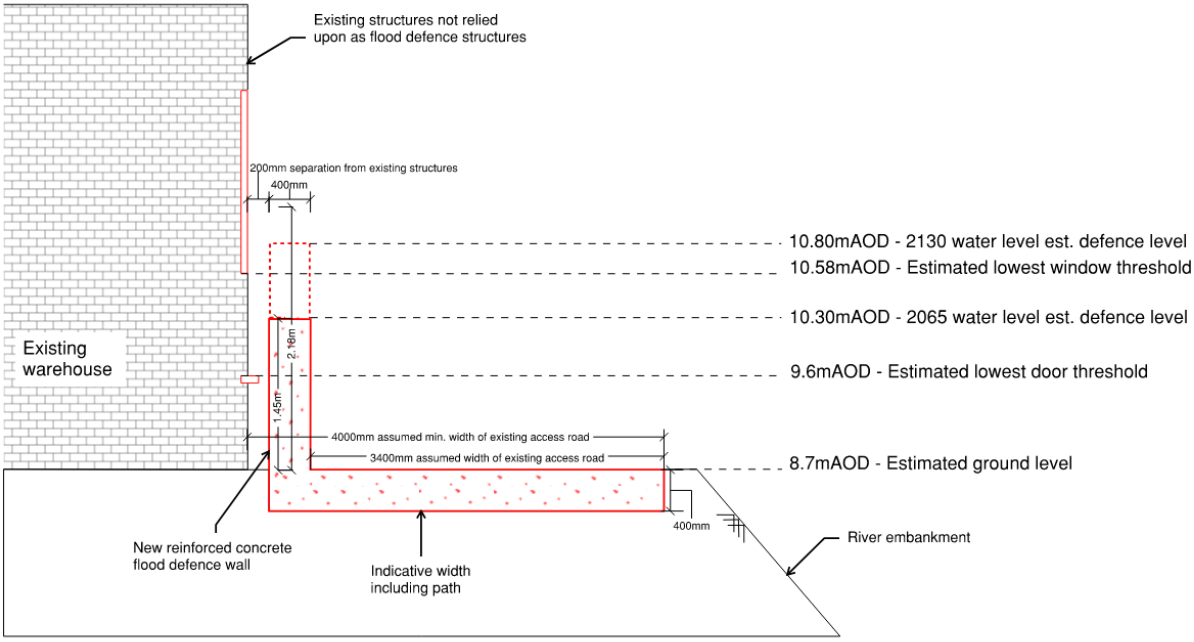

Figure 14 - Typical section of Phase 1 & 2 flood defences proposed in Option 3

Following multiple iterations of option development and appraisal, it was agreed that Option 2 would be taken forward as the preferred option at OBC. It is noted that the option is likely to be influenced by the emerging plans for Western Harbour, which can contain flood defence options not considered here.

Road raising is suggested in all four options and, in each case, the safety implications of this must be considered. Appropriate signage must be installed to provide warning and prevent road users from entering the flood zone during a flood event as well as any other necessary measures. The physical barrier of a flood gate is effective for this purpose but demands manual intervention to secure the defence line which is avoidable with road raising. The flood gate requires active management and operational resources

(monitoring, deployment of barrier, increased maintenance demand) compared to a passive barrier such as road raising.

9.2.4 Chocolate Path Floodwall

The Chocolate Path section of the alignment remains largely similar to the design at SOC. This would be a linear defence with the active travel infrastructure and the historic railway on the river side of the defence with a wall separating those from Cumberland Road. Through consultation with contractors who are carrying out remedial work on the section of the path that collapsed into the river in 2020, and expert geotechnical review, the structural design for this section has been revised to better reflect the requirements and conditions expected. In summary, the number and size of piles required for the foundations has been significantly reduced however significant further ground investigation and geotechnical analysis is required, the current design is based on assumptions and limited available information.

Multiple rows of piles to safely build out from the road side of the defence are still proposed to mitigate the risk of further bank erosion, in the same manner as was used to repair the collapsed section of wall. This design utilises construction from the land, rather than using marine plant.

At the eastern end of the Chocolate Path the wall would taper in height as the road rises along Cumberland Road to the required defence height.

9.2.5 Cumberland Road Rail Bridge

To prevent floodwater passing through the bridge underneath Cumberland Road (north towards Wapping Wharf), a floodgate is proposed so that access along the Chocolate Path for pedestrians, cyclists and users of the heritage railway remains outside flood events. It is expected that the flood gate over the railway itself would normally be closed, but the section over the pedestrian path may need to be normally open. Operation would be the responsibility of BCC.

9.3 Summary of preferred options

Table 9. Spike Island - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
26	SoP	Off Ramp	New gravity floodwall	10.06	10.8	45 (180)	1.06	1.26
27	SoP	Bonded Warehouses	New floodwall (piled and gravity) and road raising	10.3	10.8	500	1.5	1.9
28	SoP	Chocolate Path Floodwall	New piled floodwall	10.29	10.85	770	1.89	1.99*
29	SoP	Cumberland Road Rail Bridge	New floodgate	10.11	10.83	10	1.81	1.81

*This height is measured from the existing Chocolate Path, not Cumberland Road.

10. Redcliffe

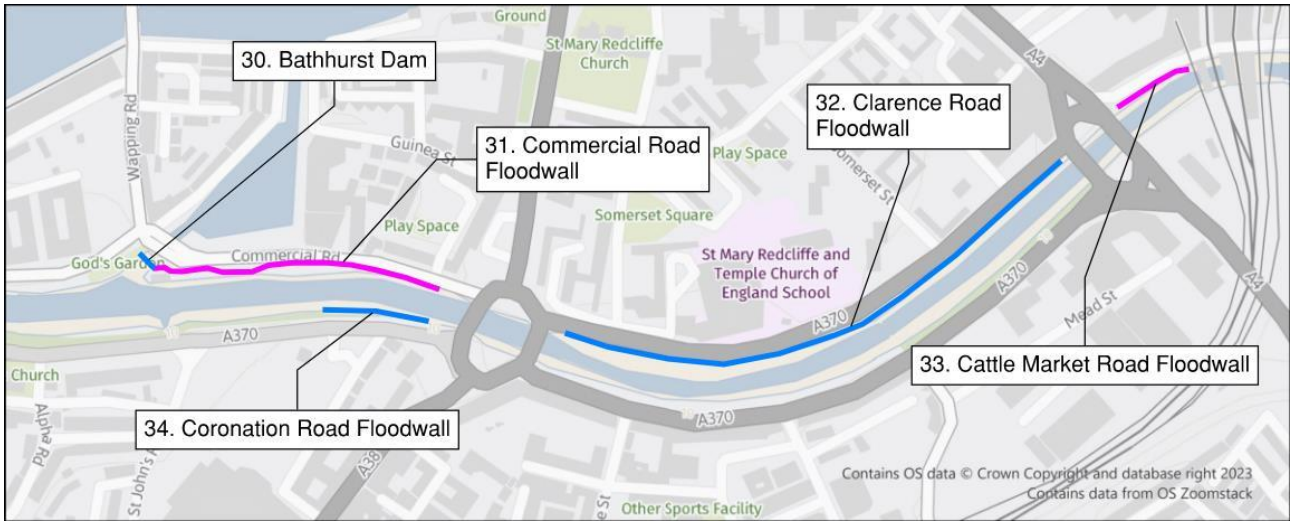

Figure 15 - Redcliffe Defence Area (blue and pink lines delineate between defence sections)

10.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plan - 285982-ARP-XX-DR-CIV-102.

10.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- Redcliffe and City Docks Conservation Areas span across this location.
- There are several Grade I and II listed buildings and structures in the study area. These include but are not limited to: Bathurst Basin which includes Bathurst, Bristol general hospital, drinking water fountain near Bedminster bridge, Bedminster bridge, Langton Street bridge, Bristol Temple Meads (National Rail bridge is grade I listed (main concern is platforms and deck) – must be considered when tying in defences to the bridge)

10.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- The River Avon New Cut is a site of Nature Conservation Importance (SNCI) and a Local Nature Reserve.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- There are several mature trees within this area.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.

- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

10.1.3 Buildability

- Construction of flood defences is likely to require road or lane closures along an important part of the highway network.
- There are significant spatial restrictions for works to Bathurst Dam due to proximity to the new Metrobus road bridge.
- Stone arches along the river support the eastern end of Commercial Road. The proposed flood defence layout suggests that the wall be built on the south edge of the pavement which likely relies on the stone arches for structural support. Further investigation is required to understand whether they can accommodate additional load from flood defences. If not, then additional works may be required to avoid loading bearing on the arches. The adjacent sections of retaining wall are also key to the flood wall design since it is proposed that the current design is built on top of the existing wall.
- Further structural and geotechnical investigation will be required to determine the feasibility of using Langton Street bridge abutments to tie the defences into.
- A section of riparian wall between Langton Bridge and Bath Bridge roundabout is known to have collapsed in 2014 due to a tidal surge. This has since been repaired but the construction details, like with the rest of the stretch of wall in this study area, are unknown which will have a large impact on the flood defence design. Furthermore, the location of competent bedrock is uncertain which will determine the size of foundations and piling technique. Further ground investigation is required at a later stage.

10.1.4 Landscape

- There are multiple sections of the flood defences close to residential areas along Commercial and Clarance Road. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.
- The stones arches on the existing riparian wall along Commercial Road and bollards on Clarence Road are not listed but are an important part of the character of the area. Therefore, the proposed materiality of the flood walls and public surfacing should be high quality and be in keeping with the local character of the area.
- The existing treeline along the riverbank must be reinstated if any trees are removed during construction. This will help to screen views of the flood defences for nearby residential properties and create a more attractive and comfortable public space.
- There are key views from the pavement towards the New Cut, the relative height of flood defences should be considered so views and access can be maintained.
- Active travel routes in this area should not be adversely affected by their proximity to the proposed flood defences here and should be maintained or improved where possible.

10.1.5 Transport

- This area includes multiple important transport links into the centre of Bristol including highways, specific bus routes and active travel routes.

10.1.6 Interfaces

- The area adjacent to Bristol Temple Meads Station, specifically a railway bridge over the proposed flood defence area, would require consideration so as not to impact the railway. A BAPA is likely to be required, and there is potential need for track possession, which will need to be minimised.
- Langton Street Bridge will intersect with the proposed flood defence.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BW, NGED, Sky, Virgin, WW and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.
- The riparian walls are vulnerable to overtopping during a surge, followed by rapid drawdown at low tide, and so maintenance of and improvements to drainage is essential.

10.2 Option Development

10.2.1 General

It is proposed that the Redcliffe section of the defence runs on the northern bank of the River Avon from Bathurst Dam in the west, along Commercial Road and Clarence Road to Cattle Market Road and the underpass beneath Temple Meads Station in the east. This section of the defence alignment has largely remained the same from the SOC stage alignment with most changes being to the structural design of the flood defences.

10.2.2 Bathurst Dam

The alignment starts tying into the high ground at the perimeter of God's Garden, a small area of public space at the entrance to the now disused lock into Bathurst Basin. The SOC design proposed to encase the existing dam that runs across the disused lock in concrete and raise its height to the required defence level.

As part of the option development process, BAM Nuttall were consulted on the proposed option to help understand buildability opportunities, constraints and risks as well as help provide an indicative cost estimate of the preferred option due to the large cost and significance of this part of the defence.

In line with the assumptions made at Brunel Dam, it was decided that the SOC option would be taken forward as the preferred option with further investigations required at later stages to mitigate some of the outstanding risks. It should be noted that, following consultation with BAM that this option has significant cost implications due to the complex construction method of the option and that if some heritage and environmental constraints could be mitigated further then a sheet pile wall across the old lock would provide a significantly easier and cheaper option to build. This should be considered further at FBC with reference to the BAM report that is found in Appendix E.

10.2.3 Commercial Road Floodwall

From the end of Bathurst Dam the defence follows the edge of Commercial Road following the line of the existing railings. The defence would be comprised of piled foundations with a pre-cast reinforced concrete section for the floodwall on top to form the floodwall.

There is a private property on the river side of the defence, adjacent to Bathurst Dam, with an access road that comes off the south side of Commercial Road. To maintain access here a floodgate across this access road may be required, as road raising is impractical due to the required height and limited distance to a bridge downstream. The ownership, operation and maintenance of this would need to be carefully considered as well as engagement with the property owner.

Continuing east along Commercial Road the defence follows the existing railings along the riverbank. On the dry side of the defence, to maintain views for pedestrians, there would be a raised promenade built adjacent to the defence with steps down to the pavement and cycleway before reaching the carriageway.

The option of setting the defence back on the northern side of the carriageway was considered to avoid interfacing and potentially damaging the mature trees and riverbank but this would mean more likely

interaction with services and complex road raising arrangements to accommodate the network of roads that join Commercial Road. It would also mean the defence is closer to the existing buildings on the northern side of the road and this may compromise views from these buildings and the northern side pavement.

Careful consideration of mitigation and/or protection of the mature trees should be considered at the next stage, including construction methods, detailed design and tree replacement, in this specific area.

As the defence carries on east along Commercial Road, the ground profile gradually increases towards the Bedminster Bridge roundabout. The riverbank also turns from natural sloping ground to a section of arched/vaulted walls. The ground level at the start of this section is at ~9.9m and therefore the defence height required for the Phase 1 and Phase 2 levels is ~0.4m and ~1.3m respectively which would decrease further east and the defence would eventually taper out. It is assumed that the defence along this section can be comprised of a gravity floodwall due to the lower defence height required so as to limit interaction with the vaulted walls below. There are no defences required that interface with the Bedminster Bridge roundabout due to the ground levels at this location.

10.2.4 Clarence Road Floodwall

The line of defence resumes to the east of Bedminster Bridge roundabout on Clarence Road. This section of defence would likely be constructed with a similar design to the Commercial Road section, using a piled foundation and pre-cast reinforced concrete floodwall section on top. There would also be a raised promenade level adjacent to the floodwall to maintain views with steps down to the pavement and cycleway before reaching the carriageway.

Along this section of the defence there is a key interface with the Langton Street (Banana) Bridge. The design of the interface with this bridge would be considered in future stages of the project but consultation and alignment with the planned works to repair the bridge would be considered.

Similar to Commercial Road, as the road runs east towards the Bath Bridge roundabout, the ground profile gradually increases. As the ground rises the relative defence height would taper off and a gravity floodwall instead of the piled foundation used across the majority of this section could potentially be used. The exact point at which the defence type changes would be considered at a later stage of the scheme.

10.2.5 Cattle Market Road Floodwall

On the eastern side of the Bath Bridge roundabout the defence continues along the south side of Cattle Market Road towards the underpass beneath Temple Meads station. The ground level of the road slopes down from west to east and the floodwall would be constructed using a gravity floodwall for the western section and then as the relative defence height tapers up a piled foundation solution with precast reinforced concrete floodwall would be used.

The alignment of the defence along this section has been moved slightly north to avoid, as far as reasonably possible, the need to remove the mature trees and vegetation that separates the carriageway and the riverbank. This would mean that the carriageway and cycle path would be moved north by ~2m and the pavement width would be reduced by the same amount to accommodate this.

The eastern end of this section ties in with the Grade I listed railway bridge that supports the tracks and platforms of Temple Meads station. At this stage it is assumed that the floodwall would tie into the bridge abutment, the exact design of this has not been considered at this stage of the project.

10.2.6 Coronation Road Floodwall (Phase 2 Only)

There is a small section of raised defence required on the south bank of the Avon, along Coronation Road. A 60m gravity floodwall is required in Phase 2. This defence is no taller than 0.5m and on average 0.3m at Phase 2 height.

10.3 Summary of preferred options

Table 10. Redcliffe - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
30	SoP	Bathurst Dam	Raise existing structure	10.09	10.82	10	1.75	1.75
31	SoP	Commercial Road Floodwall	New floodwall (piled and gravity)	10.21	10.93	320	0.81	1.41
32	SoP	Clarence Road Floodwall	New floodwall (piled and gravity)	10.25	10.82	620	1.25	1.85
33	SoP	Cattle Market Road Floodwall	New floodwall (piled and gravity)	10.12	10.79	90	0.62	2.12
34	SoP	Coronation Road Floodwall (Phase 2 Only)	New gravity floodwall	10.08	10.8	60	n/a	n/a

11. St Philip's Marsh

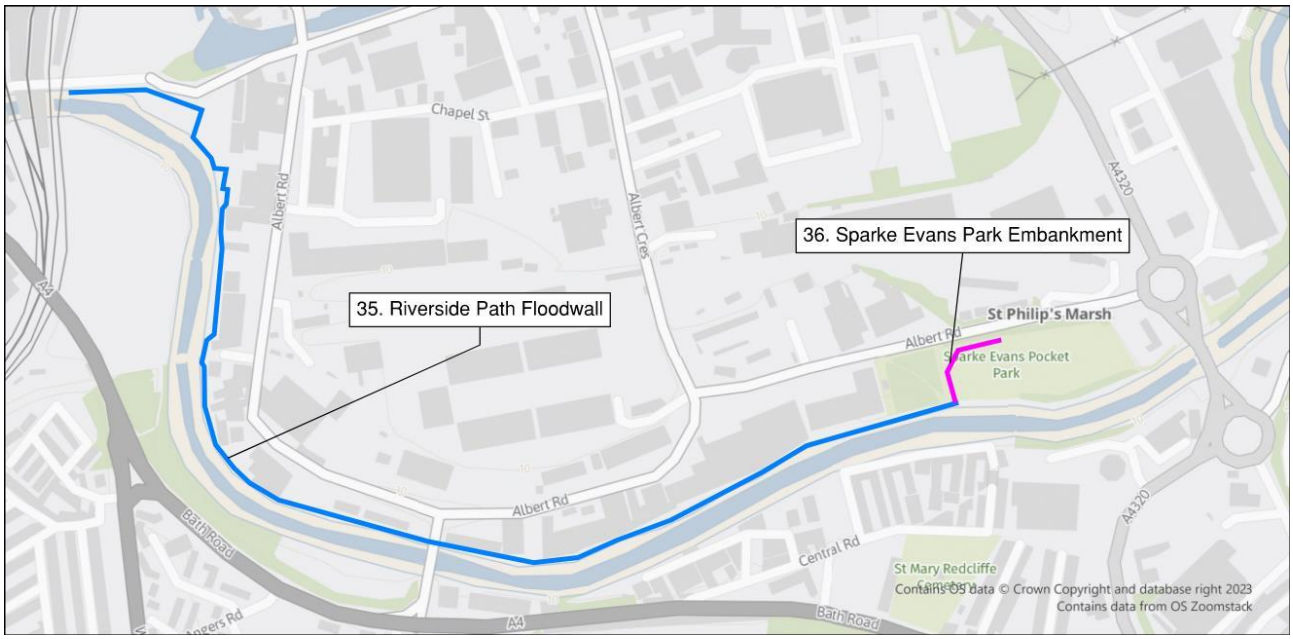

Figure 16 - St Philip's Marsh Defence Area (blue and pink lines delineate between defence sections)

11.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-103.

11.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- Bristol Temple Meads (National Rail bridge is Grade I listed).

- There are multiple locally listed heritage assets within this area including but not limited to Albert Road Relief Line Viaduct and Sparke Evans Bridge.
- The Silverthorne Lane Conservation Area intersects the north west corner of this area near to the Feeder Canal.
- There are likely to be extensive areas of industrial archaeological remains within this area.

11.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- The River Avon New Cut is a site of Nature Conservation Importance (SNCI) and a Local Nature Reserve.
- There is a Bristol Wildlife Network Site in this area; design should follow the mitigation hierarchy and reduce impacts to this site.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

11.1.3 Buildability

- Most of the proposed works are near the riverbank and in some places are tightly constrained between the riverbank and buildings or highways. Typically, the path width in this area is ~1.5-3m.
- There are limited locations for adequate access routes and construction compounds.
- Along some sections existing foundations or structures are present which may interfere with the flood defence structure. There are also multiple river crossings within this section of the defences including rail, road and footbridges.
- There is an opportunity to assess and potentially utilise the existing ad-hoc defences in the area, however as none of these are currently designated as flood defences it has been assumed that none are suitable.

11.1.4 Landscape

- The accessibility of the River Avon Trail Long Distance Footpath and National Cycle Network Route 3 should not be adversely affected by their proximity to the proposed flood defences here. In addition to PROW BCC 405/10 along the foot and rail bridge towards Totterdown and the PROW BCC 409/10 near Sparkes Evans Pocket Park.
- There are sections of the flood defences close to residential areas, mainly Paintworks apartments. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.

- Flood defences intersect Sparks Evans Pocket Park, an 'Important Open Space'. The preferred option should aim to minimise disruption here and maximise the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible.
- The existing tree cover within Sparkes Evans Pocket Park and along the riverbank must be reinstated if any trees are removed during construction.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

11.1.5 Transport

- The riverside pathway adjacent to the majority of the defence in this area forms part of the River Avon Trail and is Cycle Route NCN3.
- There are a number of PROWs and bridges that intersect this area.

11.1.6 Interfaces

- BCC, working in partnership with WECA, Network Rail and Homes England are currently working on a long-term plan to guide how Temple Quarter and St Philip's Marsh develop in the future. This includes a detailed plan for the transformation of Temple Meads station, as well as a long-term vision for the surrounding 70ha area which will heavily influence the final proposal.
- The area adjacent to Bristol Temple Meads Station, specifically a railway bridge over the proposed flood defence area, will require consideration so as not to impact the railway. Significant further consultation with Network Rail is expected.
- St Philips Footbridge crosses the River Avon within this section and will require consideration of the design of the flood defences at this point to interface adequately with the structure.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BW, NGED, Virgin and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

11.2 Option Development

11.2.1 General

As outlined in section 11.1.6, this area is included under the Temple Quarter masterplan. The surrounding area is therefore likely to change significantly from the current arrangements, which would then lead to a change in the required flood defences. However, this section describes a viable option should the development not be progressed, or delivered in time, and has formed the basis of the updated cost estimate. Sections of defences being delivered by developers is a significant opportunity for the scheme and will likely lead to better overall outcomes as the space constraints are likely to be less severe.

The St Philip's Marsh section starts by tying into the eastern abutment of the Grade I listed railway bridge that forms part of Temple Meads station, runs along the southern side of Cattle Market Road, beneath Brock's Bridge before following the riverbank path along the northern riverbank of the Avon. Along this section the path is very narrow, and the floodwall would be situated between the path and the adjacent buildings that back onto the path. At the eastern end of this section the path opens out into Sparke Evans Park where an earth embankment would form the line of the defence along the western and northern sides of the park.

11.2.2 Albert Road Floodwall

The proposed defence would start by tying into the eastern abutment of the Grade I listed railway bridge of Temple Meads station.

The defence then follows the southern side of Cattle Market Road running east towards Brock's Bridge. Due to the required relative defence heights of ~1.6m and ~2.4m for the Phase 1 and Phase 2 levels respectively it is assumed that a floodwall using minipiles would be used in this section.

At Brock's Bridge the defence would tie in either side and the height of the bridge would form the line of defence at Phase 1 to avoid the need for a floodgate. For Phase 2 levels either a ~0.5m floodgate across the bridge or road raising may be required.

Along this section the riverside path, which is designated as a 'greenway' rather than a PROW has part of recreational and national cycle network routes along it. This section remains largely the same as the solution developed at SOC stage where it is assumed that a reinforced concrete floodwall built on minipiles, with the path remaining on the riverside side of the defence, which itself is adjacent to the buildings behind. In a preliminary study, including in consultation with a mini-piling specialist contractor, it was concluded that this design is feasible and that the path width reduction caused by building the defence could be compensated via cantilevering the defence over the riverbank if needed.

11.2.3 Sparke Evans Park Embankment

As the defence reaches the end of the path constrained by the adjacent buildings, the path opens out into Sparke Evans Park. For the first ~80m of this section the path would stay on the river side of the defence until it reaches the eastern end of an area of mature trees and vegetation. At this point the park opens out into open grass and the defence would take the form of an earth embankment that passes around the western and northern sides of this open area of grass. At the end of this it tapers out into high ground along Albert Road. The embankment would include access ramps as necessary to cross it.

11.3 Summary of preferred options

Table 11. St Philip's Marsh - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
35	SoP	Albert Road Floodwall	New minipile floodwall	10.25	10.92	1520	1.25	1.95
36	SoP	Sparke Evans Park Embankment	New embankment	10.2	10.83	250	0.9	1.1

12. Feeder Road

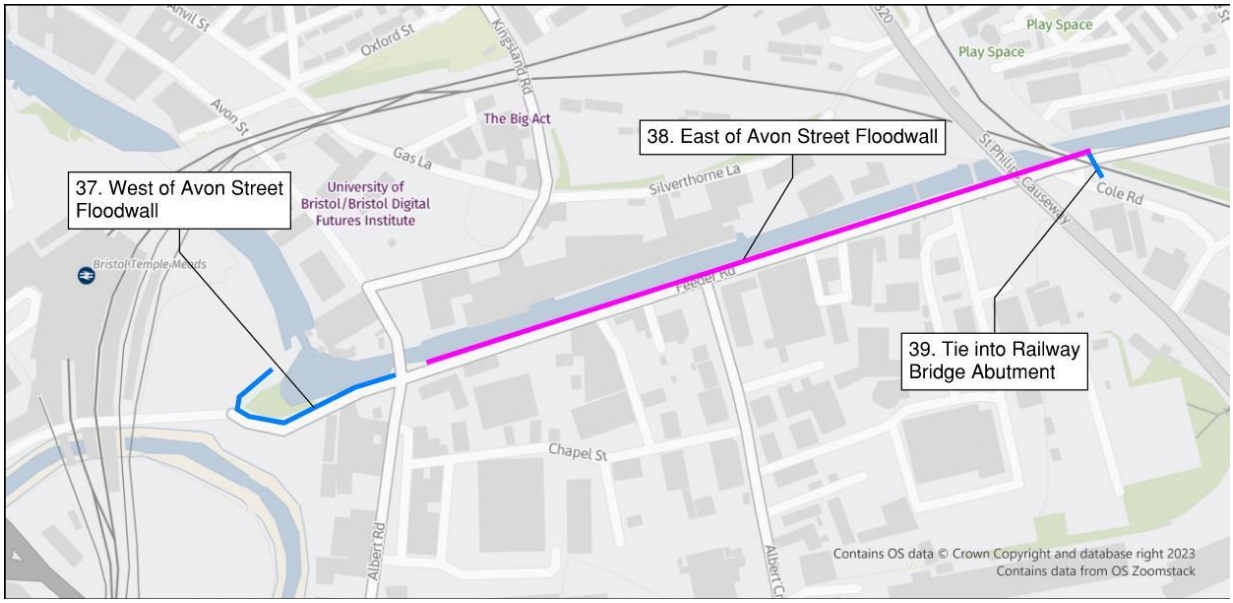

Figure 17 - Feeder Road Defence Area (blue and pink lines delineate between defence sections)

12.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-104.

12.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- Between Avon Street and the St Philips Causeway bridge, the site lies within Silverthorne Lane Conservation Area. The conservation area is largely on the north side of the Floating Harbour with just the river banks adjacent to Feeder road within the boundary, meaning that the flood defences are likely to be implicated. There should be a focus on historic materials within this area as a result.
- There are several Grade II and II* listed industrial warehouses.
- At the west end of the feeder road stretch there is a previous cholera burial ground within the University of Bristol development site. The defences around this development will be incorporated into their design.
- The Feeder canal is an integral part of the complex of historic features associated with the Floating Harbour.

12.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- The Feeder Canal is a Site of Nature Conservation Importance (SNCI).
- The open green space between the Feeder Road pavement and the Feeder has many mature trees along it. The impact on these will be determined following detailed design and arboricultural assessment, but would require mitigation.
- Any works that cause loss or degradation of vegetation along the watercourse will require mitigation.

- Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and incorporate the findings into the strategy.

12.1.3 Buildability

- There are dredging pipes for the Feeder Canal leading to the Avon New Cut where Cattle Market Road and Feeder Road meet.
- The Avon Street Bridge and Bath Line Railway Bridge require investigation to determine whether it is feasible to tie-in to the abutments and foundations.
- A section of the riparian wall along Feeder Road has been damaged and the construction details are unknown.

12.1.4 Landscape

- The accessibility of the PROW BCC 407/10 across the footbridge to Feeder Road should not be adversely affected by its proximity to the proposed flood defences here.
- Areas of 'Important Open Space' here present the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible.
- The flood defences along the riverbank here should be designed to minimise their impact and maintain the riverside views characteristic to this area.
- Active travel routes along Feeder Road should not be adversely affected by their proximity to the proposed flood defences here and should be maintained or improved where possible.
- If possible, the existing treeline along the riverbank must be reinstated if any trees are removed during construction.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

12.1.5 Transport

- Feeder Road is an important transport link into the City Centre and includes a non-continuous bike path along its length.

12.1.6 Interfaces

- BCC, working in partnership with WECA, Network Rail and Homes England are currently working on a long-term plan to guide how Temple Quarter and St Philip's Marsh develop in the future. This includes a detailed plan for the transformation of Temple Meads station, as well as a long-term vision for the surrounding 70ha area which will heavily influence the final proposal.
- Construction of the Temple Quarter Enterprise Campus ties in to the western (downstream) end of the proposed defences. This development includes flood defences sufficiently high that the site itself does not require defences.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BT, Neos, Network Rail, NGED, Sky, Virgin and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

12.2 Option Development

12.2.1 General

The Feeder Road section runs from the western end of Feeder Road, where it meets Cattle Market Road, and along the southern edge of the Feeder Canal up to the railway bridge at the intersection of Cole Road. This

defence included primarily to protect new developments from flooding from within the Floating Harbour rather than from the River Avon. The design is largely unchanged from the SOC option, the major refinements are around incorporating active travel into the design of the floodwall.

On the south side of the defence, the pavement and cycle way would be raised to maintain views towards the canal and provide separation from vehicles on the carriageway. In some places along Feeder Road there is a cycle path but not for the entire length. Where there is currently not a cycle path, the parking spaces on the opposite side of the road could be removed to create more space so there is a continuous active travel route along Feeder Road.

12.2.2 West of Avon Street Floodwall

West of Avon Street, the defence would start by tying into the flood defence being incorporated into the development of Temple Quarter adjacent to Temple Meads station. The defence would then run around the area of vegetation to the west of Totterdown Basin and along the northern side of Feeder Road before tying into the high ground at Avon Street Bridge. As the defence gets closer to Avon Street Bridge, the ground levels increase and the relative defence height would decrease.

12.2.3 East of Avon Street Floodwall

East of Avon Street, the ground level along Feeder Road decreases from ~9.9m to a low point of ~7.4m before rising to ~8.0m at the intersection of Cole Road. If ground conditions permit, the required defence heights mean that the western end of this section can be constructed using a gravity floodwall and as the relative defence height increases defence would transition to using a contiguous piled wall to form the line of defence. For both elements the line of defence would follow the existing railings at the edge of the carriageway.

12.2.4 Tie into Railway Bridge Abutment

At the eastern end of this section, the defence would tie into the railway bridge abutment and road raising would be used across Feeder Road.

12.3 Summary of preferred options

Table 12. Feeder Road - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
37	SoP	West of Avon Street Floodwall	New piled floodwall	8.76	9.21	200	0.06	0.96
38	SoP	East of Avon Street Floodwall	New piled floodwall	8.76	9.21	740	0.86	1.56
39	SoP	Tie into Railway Bridge Abutment	New road raising	8.76	9.21	10	0.86	0.86

13. Netham Lock

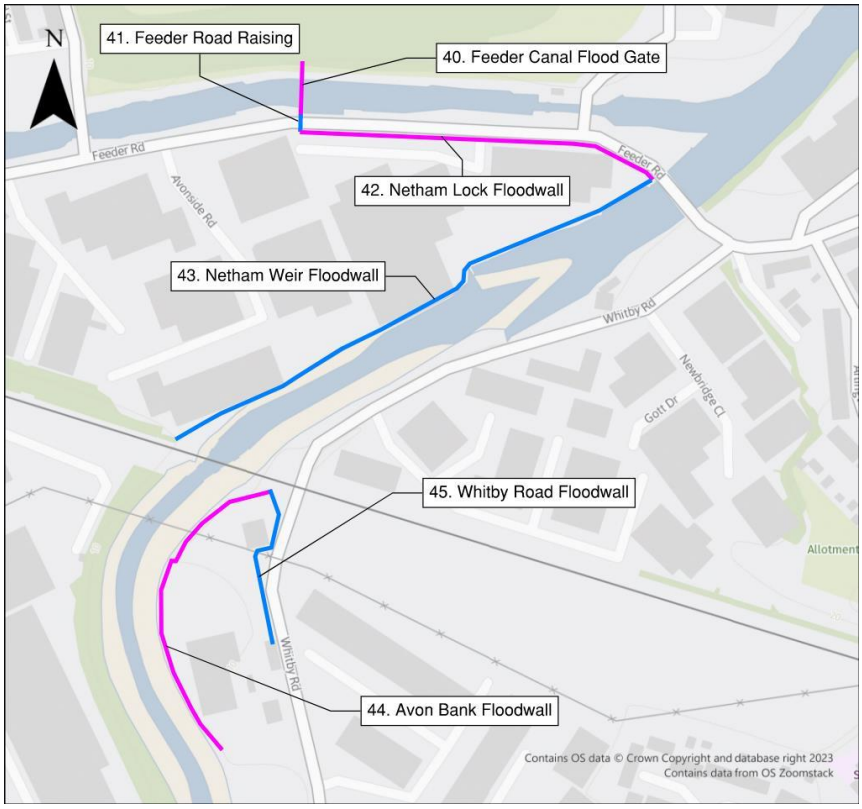

Figure 18 - Netham Lock Defence Area 1 (blue and pink lines delineate between defence sections)

13.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-104.

13.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- This area sits within the Avon Valley Conservation Area.
- There are various listed assets associated with Netham Lock including the grade II listed Lock keeper's House and grade II listed Netham Lock and remains of the bridge.
- The entrance to a, now infilled, canal which crossed St Phillip's March is located on the southern side of the Feeder just west of Netham Lock.
- There is a Grade I listed Masonry Arch Bridge that forms part of the railway crossing the River Avon.

13.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- The area is a site of Nature Conservation Importance (SNCI) and a Bristol Wildlife Network Site.
- There are various areas of intertidal mudflats and coastal saltmarsh across this area. Saltmarsh and mudflat are Habitats of Principal Importance. Coastal habitats, including the River Avon, may be viewed as functionally linked land, required to support the European Sites.

- Much of the proposed works is near the riverbank which contains multiple habitat types. Any works that cause losses to saltmarsh or intertidal mudflats must also provide the same replacement habitat. Similarly, loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation.
- The EA have confirmed that "*improvements to eel passage will not be required as part of [replacement of the flood gates] and [they] would not be seeking improvements to passage for migratory salmonids into the Feeder Canal or Floating Harbour*."
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.
- Fish passage should be maintained and promoted especially considering the migratory species associated with the Severn Estuary Special Area of Conservation (SAC) travelling upstream the Bristol Avon. Opportunities to improve fish passage at Netham Weir would be welcomed.
- Netham Park is an important public open space so PROW and inclusive access must be maintained.

13.1.3 Buildability

- A short section of Feeder Road is a bridge built over a historic lock gate entrance. Further investigation will be required to determine if remedial works to this bridge are needed to support defences.
- Flood defences in this location will have to maintain public rights of way and consider construction methods which will be feasible in this constrained location such as in-river working and working close to highway infrastructure.
- The sheet-piling surrounding the entrance to Netham Lock (directly upstream of the lock) is failing. If the sheet piling fails, the channel leading to the lock may narrow and require repairs to maintain access to the Floating Harbour.

13.1.4 Landscape

- The accessibility of Monarchs Way Long Distance Footpath and PROW BCC 192/10 should not be adversely affected by their proximity to the proposed flood defences here.
- The flood defences lie close to Netham Park. The preferred option should aim to minimise disruption and maximise the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible.
- There are key views of Netham Lock and Netham Weir. The relative height of flood defences along the riverbank should be designed to minimise their impact and maintain views.
- The existing tree cover along Netham Park boundary must be reinstated if any trees are removed during construction.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

13.1.5 Transport

- There are access roads leading off Feeder Road to various businesses based in the warehouse buildings, these access routes must be maintained or, if this is not possible, new accesses must be provided.
- There are existing footpaths along the River Avon on either side of Netham Lock, public rights of way must be maintained on these routes.

- There is a complex road junction above the lock, and any diversionary routes are likely to be complex and disruptive.

13.1.6 Interfaces

- Lock operations at Netham Lock must be able to continue unimpeded. This includes operation of the manually operated lock gates as well as access to the existing lock-keeper's house and existing telemetry and other infrastructure. It is noted that these would benefit from being within the Strategy's protected area to keep them operable during and after flood conditions.
- Any waterside interventions must be able to withstand boat collisions since boats will regularly be manoeuvring near the lock where the channel narrows.
- The sluices at Netham Weir are currently operated approximately 3 times per year however, this is expected to increase in future if the upper section of the river becomes flooded more frequently. The footpath which is used to access the sluices near Netham Weir is particularly constrained.
- There is a potential interface with a proposed hydropower scheme on Netham Weir, although that has been paused indefinitely.[2]
- Throughout 2024, an OBC is to be developed by BCC to review the strategic options for Brislington New Bridge including major refurbishment and on- or offline replacement. There is significant interface with the design of the defences for the Strategy and this bridge, and potential works provide an opportunity to integrate flood defences into the bridge works. This could lead to upgrading the existing lock gates at Netham to provide flood protection, with associated cost savings.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BT, NGED, Sky, Virgin and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

13.2 Option Development

13.2.1 General

The line of defence is largely unchanged from the SOC proposal, but the majority of this section was subject to a more detailed options appraisal to ensure that the proposal was the most suitable. The defence starts by tying into the high ground of Netham Park north of the Feeder Canal. Using a normally open floodgate across the canal the defence then follows the south side of Feeder Road before running along the northwestern bank of the River Avon and tying into the railway embankment. South of the railway line on the eastern bank of the River Avon, a line of defence adjacent to, and surrounding buildings on Whitby Road is required.

13.2.2 Netham Lock Floodwall

As part of the options development process, various other options beyond the SOC proposal have been explored at this location with the aim of ensuring that the defences proposed in this complex area were the most appropriate to the scheme's objectives. These are described below, and a summary of the options appraisal is provided with the full appraisal in Appendix I and sketches in Appendix H.

[2] Bristol Energy Cooperative, "*Huge disappointment as we press pause on the Netham hydropower project*, [online] available: https://bristolenergy.coop/pause-on-the-netham-hydro/

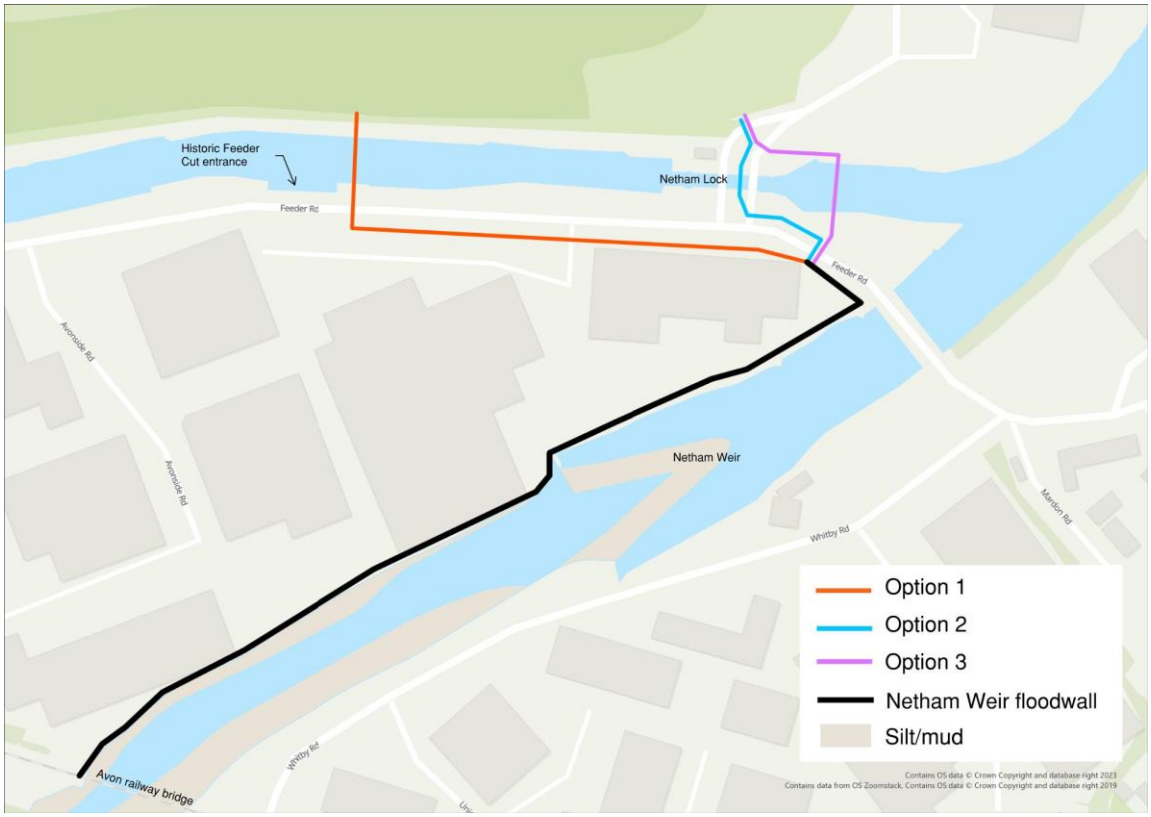

Figure 19 - Netham Lock Defence Line Options

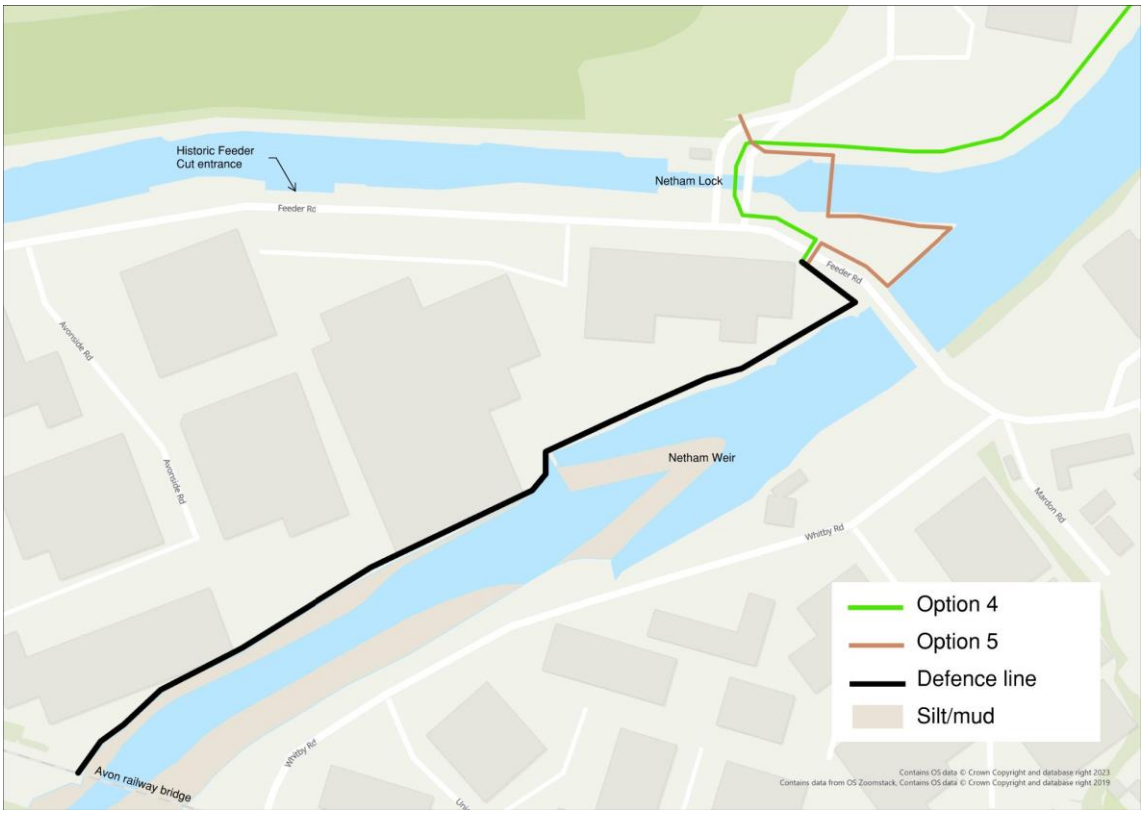

Figure 20 - Netham Lock Options Deemed Unfeasible

Option 1

Option 1, proposed in the SOC, includes a flood wall along the south side of Feeder Road. The entrance to the industrial park to the south, which is intersected by the wall would be relocated further west allowing the businesses to maintain access during a flood event. The road currently ramps up towards the historic Feeder

Cut entrance which is now blocked off and connected by a road bridge. The bridge marks the high point of the road. To utilise the natural higher ground, road raising is proposed here to form the defence line and avoid the need for a flood gate across the road.

The alignment continues on the north side of the road with a short flood wall tying into a normally open flood gate crossing the Feeder Canal. This flood gate would only shut in flood events and would not act as a lock gate when closed. On the north bank, a flood wall ties into the gate and crosses the public footpath then ties into the high ground of Netham Park. The footpath here would be adapted to pass over the top, or be diverted around, the wall.

Option 2

Option 2 crosses the Feeder Road west of Feeder Road Bridge and uses road raising, to form a line of defence across the road. A floodwall would run west along the northern side of the road until it reaches the eastern most of the two bridges across the Netham Lock. Some road and/or bridge raising may be required to achieve the required defence height. A small floodwall would connect this to new lock gates that would be replaced with new gates with sufficient height to provide flood defence, as well as any structural improvements to the wall to ensure they can resist large head differences across them. North of the Lock, a floodwall would connect the lock gates to road raising on Netham Road and tie into the wall of Netham Park.

Option 3

Option 3 crosses the Feeder Road west of Feeder Road Bridge and uses road raising, to form a line of defence across the road. Some bridge raising may be required to achieve the required defence height. Rather than using the existing lock infrastructure to form the line of defence a new, usually open, flood gate would be built on the river side of Netham Lock. This would then tie in with a floodwall and road raising on the north side of Netham Lock.

Option 4

Option 4 is largely the same as Option 2 but on the north side of Netham Lock, rather than tying in to the wall of Netham Park a floodwall would run along the riverbank and protect the area to the northwest currently occupied by Carbase.

Option 5

Option 5 is largely the same as Option 3 but rather than directly connecting the road raising on Feeder Road to the new floodgate, a new sheet-pile floodwall would pass around the perimeter of the promontory of land where the Avon splits to form the entrance to Netham Lock and the Feeder Canal.

Table 13. Netham Lock Appraisal Summary

Option	Summary of key benefits	Summary of key disadvantages
1. Floodwall along south side of Feeder Rd, road raising across Feeder Rd, floodgate across Feeder Canal (SOC option).	• Protects all residential receptors. • Floodwall buildability is relatively simple, floodgate constructed in controlled non-tidal/river environment. • No need for interference with complex Netham Lock area. • Limited changes required to existing road and bridge infrastructure.	• Does not protect all receptors (Lock House and Lock infrastructure unprotected but can be floodproofed independently). • Longest alignment. • Significantly changes the setting of the area. • Increased operations and maintenance requirements and costs of new flood gate.
2. Road raising across Feeder Rd near Feeder Rd Bridge, new lock gates across Netham Lock, road raising on Netham Rd.	• Protects all receptors with the shortest alignment. • Uses existing infrastructure as much as possible, no new assets for Harbour Authority to manage. • No additional gates across Feeder Canal/Avon, reducing O&M costs.	• Complex road and bridge raising to ensure road levels are useable around Netham Lock area. • Increasing the size of Netham Lock gates which are manually operated, poses risk operational issues (health & safety and reliability), or installation of electrical infrastructure for automatic operation would be required.

		• Would likely rely on a floodgate at Phase 2 levels across Feeder Rd near Feeder Road Bridge.
3. Road raising across Feeder Rd near Feeder Rd Bridge, new floodgate east of Netham Lock, road Raising Netham Rd.	• Protects all receptors. • Flood protection not relying on existing lock infrastructure as new gate provides protection.	• Complex construction of new floodgate in River Avon. • Complex road and bridge raising to ensure road levels are useable around Netham Lock area. • Would likely rely on a floodgate at Phase 2 levels across Feeder Rd near Feeder Road Bridge. • Entry and exit of Netham Lock potentially impacted by new structure.
4. Road raising across Feeder Rd near Feeder Rd Bridge, new lock gates across Netham Lock, floodwall around Carbase.	• Protects all receptors. • Uses existing infrastructure as much as possible. • No additional gates across Feeder Canal/Avon.	• Long alignment. • Increasing the size of Netham Lock gates which are manually operated, poses risk operational issues (health & safety and reliability), or installation of electrical infrastructure for automatic operation would be required. • Would likely rely on a floodgate at Phase 2 levels across Feeder Rd near Feeder Road Bridge.
5. Road raising across Feeder Rd near Feeder Rd Bridge, new sheet-pile wall around promontory, new floodgate east of Netham Lock, road Raising Netham Rd.	• Protects all receptors. • Flood protection not relying on existing lock infrastructure as new gate provides protection. • Additional protection of shoreline area at entrance to Netham Lock.	• Complex construction of new floodgate in River Avon and around end of promontory. • Complex road and possible bridge raising to ensure road levels are useable around Netham Lock area. • Would likely rely on a floodgate at Phase 2 levels across Feeder Rd near Feeder Road Bridge.

Following initial development of the options, workshops to understand the opportunities and constraints, and discuss the merit of options took place with key stakeholders (incl. BCC and Harbour Authority) as well as further detailed discussions with technical leads to appraise the options against the critical success factors of the scheme.

The conclusion of the options appraisal process was that the SOC option (Option 1) should be taken forward as the preferred option. This is primarily due to the required changes to the existing roads and bridges surrounding Netham Lock that are needed by the other options in order to reach the required defence height. The cost of this would be significant and would require greater involvement of other stakeholders, in particular raising the existing bridges and adjacent highways. Insufficient information is available about their condition to determine whether significant remedial works or replacement are required to these structures in the near future. If works are planned to these structures that could align with the flood defence construction programme, then utilising them for flood defence could be included in the works and bring significant advantages. However, with the information known at this point, the appraisal of options led to Option 1 being proposed as the preferred option.

The concerns of the harbour operations team are noted with regards to the increased operations and maintenance effort (including dredging) and that the existing infrastructure is not protected from flooding. Additionally, it is likely that navigation through the Feeder Canal would need to be closed for a period of time to facilitate construction, although this is likely with all options. Further consultation during detailed design would be carried out to mitigate these concerns.

As part of the option development process, BAM Nuttall were consulted on the proposed option to help understand buildability opportunities, constraints and risks as well as help provide an indicative cost estimate due to the large cost and significance of this part of the defence. The full list of assumptions and conclusions from the BAM consultation can be found in Appendix E.

13.2.3 Netham Weir Floodwall

This section of the alignment ties into the Netham Lock section and follows the northern riverbank past Netham Weir through a very constrained section between the river and warehouses and tying into the high ground of the railway embankment and bridges (the central bridge is Grade I listed).

There is an existing sheet pile wall that follows the length of this section. The condition of this sheet pile was investigated by BCC in March 2020 and rated in places as “poor” and “serious”. Given the information known at this stage, and without an understanding of the requirement to provide remedial works to bring the asset up to a standard where it is adequate for the additional loading of a floodwall built on top as well as remaining robust for the design life of the scheme, it is proposed that a new sheet pile wall is installed in front of the existing one for a length of ~400m to create the line of defence. There is a significant opportunity to repair or partially replace the existing sheet piled wall which could lead to significant cost and carbon savings, but further investigation on-site would be required for this to be considered as a viable option at this stage.

13.2.4 Avon Bank Floodwall

A short (0.34m average height) wall is proposed for ~240m along the Avon riverbank south of the railway line to protect the industrial area between the River Avon and Whitby Road.

13.2.5 Whitby Road Floodwall

Along Whitby Road, a short (0.24m average height) wall is proposed for ~100m along the Whitby Road pavement to prevent detriment to the Boc Gas & Gear site from increased overland flow along Whitby Road from the north.

13.3 Summary of preferred options

Table 14. Netham Lock - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
40	SoP	Feeder Canal Flood Gate	New floodgate	10.91	11.66	50	n/a	n/a
41	SoP	Feeder Road Raising	New road raising	10.91	11.66	10	0.91	0.91
42	SoP	Netham Lock Floodwall	New gravity floodwall	10.91	11.66	250	1.41	1.91
43	SoP	Netham Weir Floodwall	New sheet pile floodwall	10.5	11.2	400	1.4	1.7
44	SoP	Avon Bank Floodwall	New gravity floodwall	10.54	10.54	240	0.34	0.44
45	Detriment Mitigation	Whitby Road Floodwall	New gravity floodwall	10.54	10.54	100	0.24	0.54

14. St Anne's

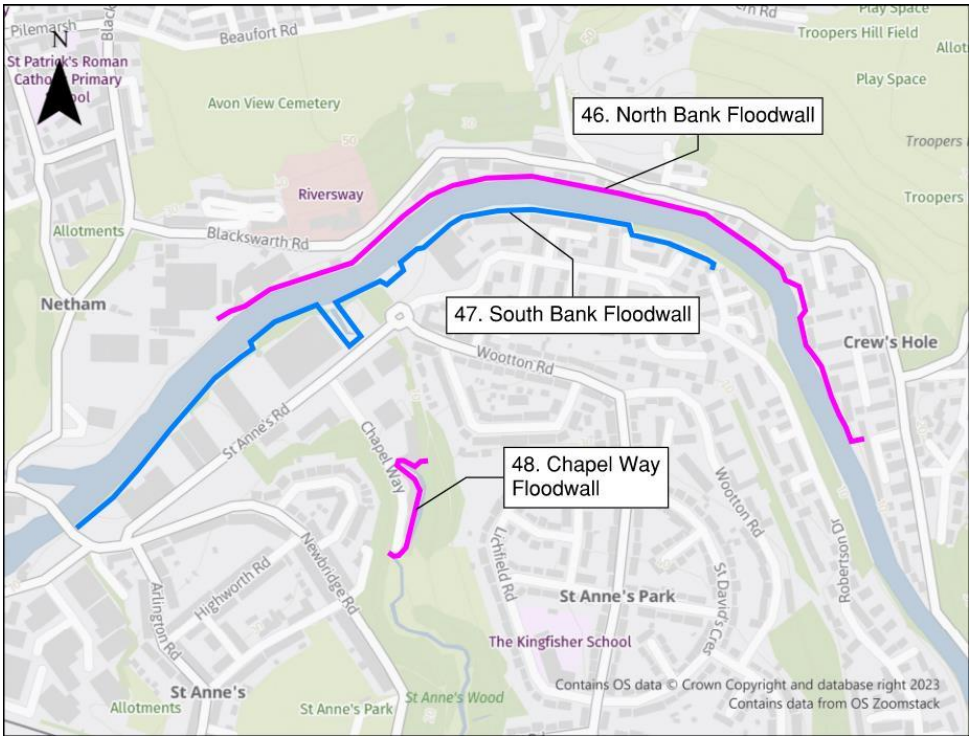

Figure 21 - St. Anne's Defence Area (blue and pink lines delineate between defence sections)

14.1 Constraints and Opportunities

Reference should be made to the constraints and opportunities plans - 285982-ARP-XX-DR-CIV-109.

14.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below, for full details refer to the Heritage desk-based assessment (285982-ARP-XX-RP-ENV-005).

- North of Blackswarth Road is the Avon Valley Conservation Area.
- There are likely to be archaeological remains, potentially including features associated with the St Anne's ferry crossing and St Anne's Well.

14.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1].

- This stretch of river and St Annes is an SNCI, and in part a Bristol Wildlife Network Site.
- There are multiple areas of vegetation between sections of concrete walkway near St. Anne's Road. There are multiple mature trees within this area.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation. Impacts to river units, in BNG terms, are difficult to mitigate. The design mitigation hierarchy should be followed.
- Opportunities should be sought to improve St Annes ecologically, where possible.

- Species surveys will be required at a later stage to monitor the presence of wildlife such as otters and incorporate the findings into the strategy.

14.1.3 Buildability

- The condition of the riverside infrastructure along this section is unknown.
- Near Crew's Hole there is a constrained corridor between buildings and the river. There are also gardens here which may need reinstatement where flood defences will be at the end of the garden wall.

14.1.4 Landscape

- The accessibility of Monarchs Way Long Distance Footpath and PROW BCC 192/20, 192/30, 192/40 and 192/50, which run parallel to Crews Hole Road, as well as PROW BCC 608/10 through St Annes Wood, should not be adversely affected by their proximity to the proposed flood defences here.
- There are multiple sections of the flood defences close to residential areas, mainly along Crews Hole Road and surrounding St Annes Park. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area, whilst maintaining the height required to provide the scheme SoP.
- The river corridor on the south side of the River Avon here provides the opportunity for environmental enhancement and creation of inviting multifunctional public spaces where possible. An outfall in the defences here may also be appropriate for naturalisation.
- The defences along the riverbank should be designed to minimise their impact and maintain the riverside views characteristic to this area, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area.
- The proposed materiality of the flood walls and public surfacing should be in keeping with the local character of the area.

14.1.5 Transport

- The proposed floodwall along the north bank crosses near and over multiple access points.
- There is a PROW to the east of the brook in St. Anne's Woods.
- Monarch's way footpath and cycle way are on the route of the entire North Bank defences.

14.1.6 Interfaces

- There is an interface with a footbridge crossing the Avon between Crew's Hole Road and Wyatts View.
- A desk study has identified a potentially high level of services in this area, including utilities owned by BT, NGED, Sky, Virgin and WWU. Note that this information does not describe the location of buried services accurately and an on-site utility investigation will need to be carried out before works commence.

14.2 Option Development

14.2.1 General

This section of the defence runs either side of the river Avon, upstream of Netham Lock and Netham Weir. Either side of the river the defence follows the riverside path which in places is very narrow and constrained by existing structures. There is an additional section of defence in this area that is protecting properties on Chapel Way flooding from Brislington Brook.

14.2.2 North Bank Floodwall

The North Bank section of the alignment would consist of a raised defence on the land side of the path that follows the river. This runs from Satellite Business Park along to Butlers Walk. Topographic and threshold surveys have allowed this section of defence to be reduced in length by approximately 250m at the upstream end compared with the alignment at SOC.

For most of this section, the defence would follow the line of existing walls and fences which would be replaced with walls founded on mini-piles due to the restricted space and impact on nearby properties. Depending on the condition of the existing walls, in some places these may be able to be raised rather than replaced. In some places there are existing buildings that are adjacent to the riverside path. The defence in these locations is assumed to not rely on these existing buildings and so a raised defence would be constructed. Through further investigation it may be possible to provide additional flood-proofing measures to the buildings so they can act as the line of defence.

14.2.3 South Bank Floodwall

The alignment of the south bank would be formed of a new line of sheet pile floodwall along the edge of the existing path and jetty areas. At present there is no information on the existing condition and remaining lifespan of the existing riverside infrastructure which includes a riverside path, overhanging jetty structure and sheet pile walls. It is therefore assumed that to provide adequate protection for the design life of the scheme, a new sheet pile floodwall would be installed along the length of this alignment. There is an opportunity for cost and carbon savings should further investigation into the existing structures find that they can be utilised as part of the defences.

14.2.4 Chapel Way Floodwall

In the baseline 'Do Minimum' option, which is used to represent the existing situation, the Brislington Brook overtops at Chapel Way (upstream of where it becomes culverted) during fluvial events. This overtopping causes overland flows to travel north contributing to flooding in the St Anne's Road area. Further information is included in the options modelling report 285982-ARP-XX-RP-MOD-003 as to the need for the defence and the development of the option.

This defence runs along the downstream end of Brislington Brook before it enters a culvert and joins the main River Avon. The design of this defence has changed from the assumptions made at SOC stage, which proposed a large earth embankment, and would have come under the Reservoirs Act due its storage capacity. Instead, the height of the defence has been reduced to allow some residual overtopping in storm events. However, this has been shown to drain through the flood wall on the south bank with a limited number of low-level outfalls into the Avon without causing flooding to properties. These outfalls would require non-return valves, and have been included in the cost buildup.

The proposed defence is a gravity floodwall that replaces an existing fence and masonry wall between the properties on Chapel Way and the left bank of Brislington Brook.

14.3 Summary of preferred options

Table 15. St Anne's - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
46	SoP	North Bank	New minipile floodwall	11.29	11.98	1200	2.39	2.99
47	SoP	South Bank	New sheet pile floodwall	11.29	11.98	1100	1.29	1.79
48	Detriment Mitigation	Chapel Way Floodwall	New gravity floodwall	11.15	11.15	220	0.85	1.15

15. Upstream defences

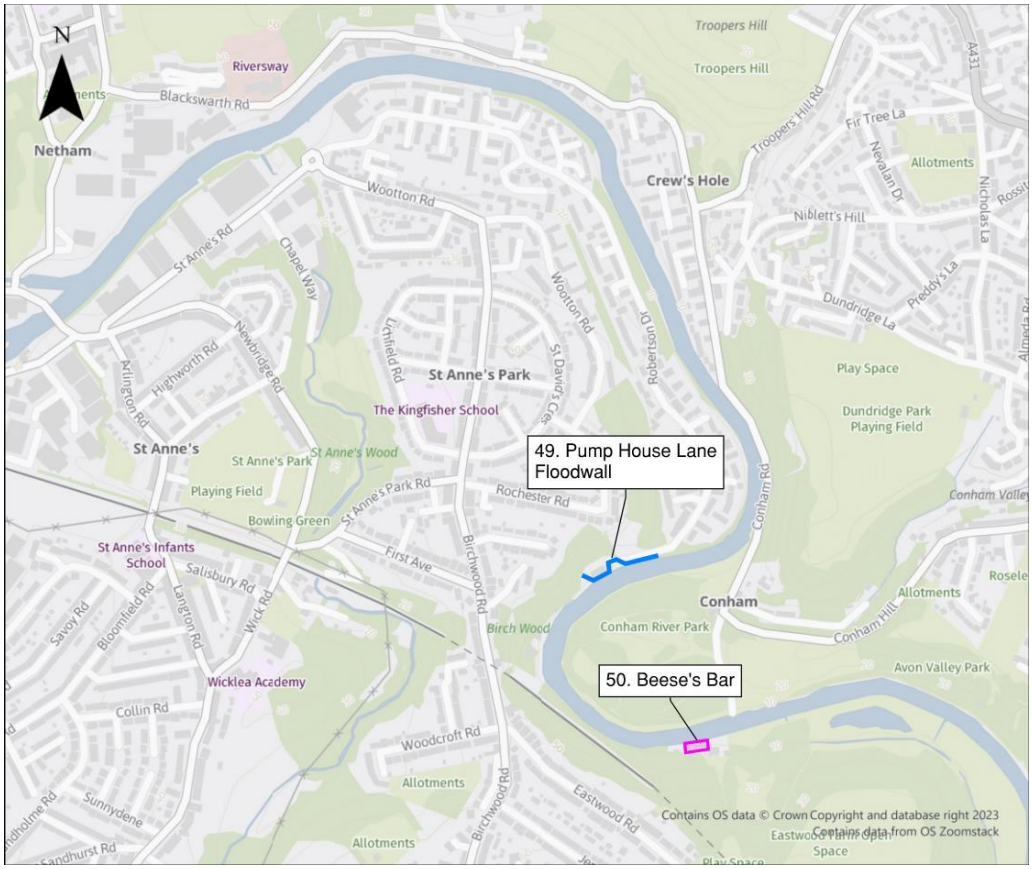

Figure 22 – Upstream of St Anne's (blue and pink lines delineate between defence sections)

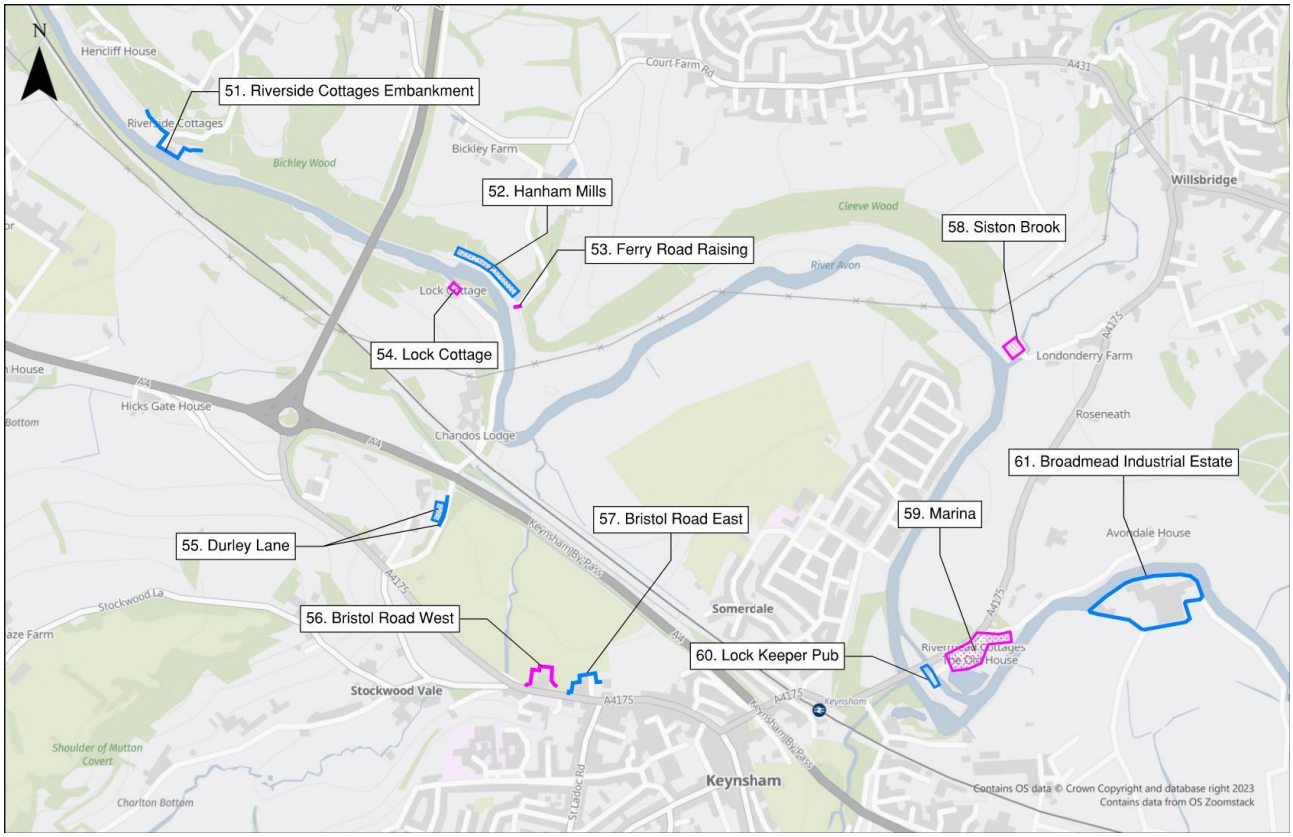

Figure 23 - Keynsham (blue and pink lines delineate between defence sections)

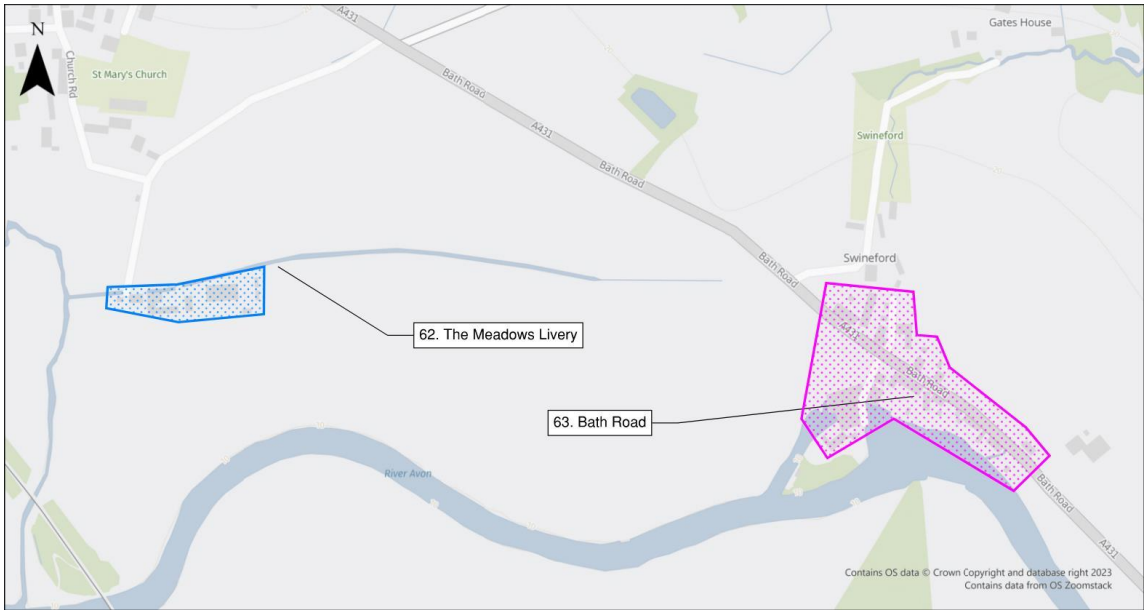

Figure 24 - Swineford (blue and pink lines delineate between defence sections)

15.1 Constraints and Opportunities

15.1.1 Heritage

A summary of the heritage constraints and opportunities is shown below:

- 13 Riverside Way, one of the Riverside Cottages, is a Grade II listed building.
- 1-4 Hanham Mills Road are Grade II listed. The 'Picnic House' on the same road is also Grade II listed.
- There are two Grade two listed structures on Durley Lane, Durley Lane Rail Bridge and Chandos Lodge.
- There are two Grade II listed structures that could possibly be affected by the scheme in Keynsham, the Lock Keeper Public House and the causeway and lock bridge beside it.
- There is a Grade II listed structure, a Weighhouse, just south of Siston Brook.
- There is a large amount of Grade II listed structures, and one Grade I listed, north of The Meadows Livery.
- There are five Grade II listed structures in Swineford.

15.1.2 Environment and Ecology

A summary of the environmental and ecological constraints and opportunities is shown below, for full details refer to the Preliminary Ecological Appraisal (PEA)[1]. These sites have however not been visited and some sites not included within the PEA report; design recommendations are limited to this extent. Further information should be sought before design detail is progressed.

- Pump House Lane is within an area of ancient woodland and is within an SNCI.
- The site of the Beese's Public House is next to a Local Nature Reserve and is within an SNCI.
- The Riverside Cottages site is near to ancient woodland, a Local Nature Reserve, and a SSSI, and is within an SNCI.
- The Hanham Mills houses back onto a Local Nature Reserve near to an area of ancient woodland and is within an SNCI.

- Some of Swineford is included within the Cotswolds Area of Outstanding Natural Beauty.
- The River Avon is a link for migratory fish (which are features of the Severn Estuary SAC and Ramsar) between the Severn Estuary and upper reaches where fish may spawn.
- Much of the proposed works is near the riverbank which contains multiple habitat types. Any loss or degradation of habitats along the river will require mitigation, in line with BNG guidance and legislation. Impacts to river units, in BNG terms, are difficult to mitigate. The design mitigation hierarchy should be followed.
- Integrate nesting opportunities for birds, invertebrates and saltmarsh creation into the proposed structures. Species-specific surveys will be required at a later stage to assess the presence of wildlife, including protected species and to incorporate the findings into the Strategy.

15.1.3 Buildability

- Some of the proposed works are near the riverbank and in some places are tightly constrained between the riverbank and buildings or highways.
- There are limited locations for adequate access routes and construction compounds.
- A large number of properties and businesses in the area rely on access to the river frontage. Limiting the impact of the defences in the permanent and temporary case on these stakeholders will be key.

15.1.4 Landscape

- The accessibility of the River Avon Trail Long Distance Footpath and PROW Bridleway 192A/10 near Pump House Lane, Beese's Bar, River Side Cottages and Hanam Mills, should not be adversely affected by their proximity to the proposed flood defences here. In addition to multiple PROWs near Keynsham Road, at the confluence between Siston Brook and the River Avon as well as Swineford.
- Flood defences lie close to Conham River Park and Eastwood Farm. The preferred options should aim to minimise disruption and maximise the opportunity for environmental enhancement at these locations.
- There are multiple sections of the flood defences close to residential areas, mainly towards Keynsham and Swineford. The visual impact of defences should be mitigated where possible, for instance by raising areas behind defences to reduce relative heights, utilising natural high ground and using materials sympathetic to the local area.
- The proposed materiality of the flood walls, public realm and PFR should be in keeping with the local character of the area.
- The defences along the riverbank should be designed to minimise their impact and maintain the riverside views characteristic to this area.

15.1.5 Transport

- Raising at Ferry Road may cause accessibility issues during construction due to this being the only vehicle access route for the Hanham Mills properties.
- There is limited space on Durley Road where the existing flood wall will be extended. This may cause issues accessing the site and for vehicles passing through to get to the properties past the floodwall.
- Construction on Bristol Road East/West may disrupt traffic on Bristol Road.
- Works near constrained single access roads, carriageways and property entrances may cause accessibility issues for members of the public. Alternative means of access should be provided.
- There are foot and cycle paths along the riverbank which may interfere with the line of defence.

15.1.6 Interfaces

- The proposed defences are alongside with Portavon Marina in Keynsham.
- North Keynsham was identified as a strategic development location as part of Bath and North East Somerset Council work to develop their Local Plan, as part of the wider West of England Joint Spatial Plan (JSP). A 2017 initial strategic planning framework identified the potential (circa 1,400 new homes with supporting mixed land uses over the 150ha site). The site slopes to the River Avon and a riverside park was proposed for areas within the functional floodplain. Whilst the JSP was halted at the Examination stage and the Plan withdrawn in January 2020, technical assessments for the area have commenced to inform the future emerging Local Plan Review.

15.2 Option Development

15.2.1 General

These defences are in place to mitigate detriment (an increase in flood risk) caused by the construction of the flood defences described in previous sections. Hydraulic modelling has shown that, in some areas identified in the sections below, the scale of defences required to mitigate detriment would be impractical from a usability, cost, carbon, buildability or visual perspective. Generally, these would be large raised defences (>2m) to protect a small number of properties (or single property) which are reliant on being at the riverside, such as a marina or restaurant; or properties with a riverside view and access. In these areas it has been agreed that 'practical betterment' measures are likely to be preferable to landowners and can be assumed as the preferred options at this stage, subject to landowner agreement and further investigation. In this case, measures could be put in place to better protect against flooding in more frequent flood events, but not to the design event.

Where property flood resilience (PFR) measures are proposed, specific measures have not been assessed or costed. Instead, an allowance per property has been made. Specific measures would be developed following survey at FBC stage, but could include flood doors, smart air bricks, non-return valves or property-level flood walls.

Design of defences in this area have been developed considerably since SOC as the definition of the hydraulic model has been improved, allowing for specific defences to be designed rather than generic defence types applied to areas. The following defences have been assumed and costed as the preferred option for the OBC.

15.2.2 Pump House Lane Floodwall

This defence consists of approximately 70m of piled foundation floodwall that would pass between the property and the river with a defence height to match the existing ground level behind the single property being protected. To comply with the agreed detriment criteria, the height of the defence would need to be more than 3.2m above ground level, obscuring the windows from lower floors at this riverside property, and likely requiring substantial foundations. Therefore, this practical betterment measure has been allowed for at a height that would not obscure views whilst still increasing flood protection to the property.

15.2.3 Beese's Bar

Beese's Bar is made up of several buildings – three of which were identified as being at risk by modelling. Modelling showed that a 3.5m high, 83m long defence would be required between the property and the river to comply with the agreed detriment criteria, blocking their characteristic riverside views and likely harming the business value. It should be noted that during summer, the bar is served by ferry from Bristol city centre. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to their current flood risk. Of these three, two are a marquee and an outbuilding, which should not require PFR as they are not commercial or residential properties. However, the third building makes up part of the pub and being a commercial property would require PFR to mitigate flood risk.

15.2.4 Riverside Cottages Embankment

The proposed defence is ~190m of new earth embankment protecting a number of residential properties adjacent to the River Avon. Modelling showed that the height of defence would need to be 3.1m high to comply with the agreed detriment criteria, which would block the riverside views for these properties and likely reduce property values. Therefore, a 1.2-2m high embankment is proposed as a practical betterment measure, at a level that would not obscure views whilst still increasing flood protection. The exact level and layout would be subject to stakeholder consultation. A wall could be installed but is thought to be less in keeping with the riverside setting.

15.2.5 Hanham Mills

Hanham Mills is an area to the south of Longwell Green. The road along the riverbank, Ferry Road, has both commercial property (a pub) and multiple homes. Modelling showed that a 2.2m high wall would be required to provide the agreed detriment criteria, which would obscure riverside views and likely reduce property values, as well as likely being impractical to construct. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to properties instead to provide a practical betterment to flood risk. In total, there are eight properties at risk in this area. PFR was installed at four of these in 2015/16 by the EA. Additional PFR would be installed at the remaining properties, and the existing PFR assessed and upgraded or replaced if required.

15.2.6 Ferry Road Raising

To improve access to properties along Ferry Road, the corner of the road is proposed to be raised to 10mAOD to reduce the frequency that this section is impassable during flood events. This measure was proposed during previous studies by the Environment Agency in this area.

15.2.7 Lock Cottage

Lock Cottage is a property located next to Hanham Lock. Modelling showed that a 1.5m high, 36m long defence would be required between the cottage and the river to comply with the agreed detriment criteria, blocking riverside views and access to the river. Therefore, it was agreed with the EA and BCC that PFR measures be offered to this property instead to provide a practical betterment to flood risk.

15.2.8 Durley Lane

Durley Lane is a road to the north of Keynsham. Modelling showed that the two properties at risk here would require a defence height of 1.5m to comply with the agreed detriment criteria. Construction of a defence here would cover the ground floor windows of the properties and block off access to properties further up Durley Lane. In addition, the nearby stream and road have severely restricted the available space.

Therefore, it was agreed with the EA and BCC that PFR measures and floodproofing of an existing wall are to be offered to these properties instead to provide a practical betterment to their current flood risk. The defences here would be installation of PFR on two residential properties and the floodproofing of ~60m of floodwall to the required defence levels.

15.2.9 Bristol Road West

This defence consists of ~140m of gravity foundation floodwall surrounding a property north of Bristol Road. Modelling showed that a defence height of 1.4m would be required to comply with the agreed detriment mitigation criteria, but further development of this defence would require the specific alignment to be agreed with the landowner.

15.2.10 Bristol Road East

This defence consists of ~140m of gravity foundation floodwall surrounding multiple properties north of Bristol Road. Modelling showed that a defence height of 1.4m would be required to comply with the agreed detriment mitigation criteria, but further development of this defence would require the specific alignment to be agreed with the landowner.

15.2.11 Siston Brook

Siston Brook is a tributary of River Avon. There is a riverside property at risk here where the two watercourses confluence, comprised of two buildings. These appear to be an outbuilding and a residential property respectively. Modelling showed that a 2.4m high defence surrounding both buildings would be required to comply with the agreed detriment criteria, which would obscure the ground floor windows and require a floodgate for access, as well as riverside habitats in the temporary and permanent case. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to their current flood risk. This would involve installing PFR at the residential property.

15.2.12 Marina

The Marina is an area just off Keynsham Road, on the banks of the Avon. There are several buildings here, many at risk of flooding. They comprise of three residential properties and three commercial properties, which modelling showed would need to be surrounded by a 2.1m high, 550m long defence to comply with the agreed detriment mitigation criteria. This would block access to the river from the marina and other businesses as well as to properties here and would obscure ground floor windows. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to flood risk.

15.2.13 Lock Keeper Pub

The Lock Keeper is a pub located next to the Marina. It has two buildings on its grounds, one of which is the pub itself. The other appears to be an additional commercial property. The pub building itself is currently above the necessary defence height, so would not require any works to protect it. However, the commercial building is within the area of risk. Modelling showed that a defence height of 1.3m surrounding this would be required to comply with the agreed detriment criteria, which would obscure ground floor windows and require a floodgate to be installed for access, as well as disrupting riverside habitats in the temporary and permanent case. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to their current flood risk.

15.2.14 Broadmead Industrial Estate

This defence consists of ~800m of piled floodwall surrounding Broadmead Industrial Estate, as well as a floodgate installed at its entrance. It is noted that this area forms part of the North Keynsham area mentioned in 15.1.6, and so flood defences in this area may be developer-led. These defences are proposed to provide detriment mitigation, however there are existing moorings, and the proposed use of this area is under review, which may lead to design changes.

15.2.15 The Meadows Livery

The Meadows Livery is an equestrian centre in the south of Bitton. It is a compound made up of several buildings – five of which are at risk of flooding. Modelling showed that a 2.5m high 650m long defence around the eastern, southern, and western sections of the centre would need to be installed to comply with the agreed detriment mitigation requirements. This would obscure ground floor windows and likely reduce property values. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to their current flood risk.

15.2.16 Bath Road, Swineford

Swineford is a hamlet in South Gloucestershire, close to the city of Bath. Based on flood models, initial estimates show 44 buildings at risk of flooding – 31 of which were assessed as commercial and residential properties requiring flood protection. Modelling showed that a 1.4m high, 916m long defence between most of the village and the river would be required to comply with the agreed detriment mitigation criteria, which would obscure the ground floor windows of these riverside properties, as well as restricting river access and disrupting riverside habitats in the temporary and permanent case. Therefore, it was agreed with the EA and BCC that PFR measures are to be offered to these properties instead to provide a practical betterment to their current flood risk. These 36 buildings appear to be comprised of 23 residential (including a school) and eight commercial properties.

15.3 Summary of preferred options

Table 16. Detriment Defences - summary of preferred options

Plan Ref	Defence Group	Name	Description	Phase 1 Level (mAOD)	Phase 2 Level (mAOD)	Length (m)	Avg. Phase 1 Height (m)	Max. Phase 1 Defence Height (m)
49	Practical Betterment	Pump House Lane Floodwall	New piled floodwall	10.5	10.5	70	2.2	2.4
50	Practical Betterment	Beese's Bar	New PFR	n/a	n/a	n/a	n/a	n/a
51	Practical Betterment	Riverside Cottages Embankment	New embankment	10.5	10.5	190	1.27	2
52	Practical Betterment	Hanham Mills	New PFR	n/a	n/a	n/a	n/a	n/a
53	Practical Betterment	Ferry Road	New road raising	10	10	75	0.31	0.47
54	Practical Betterment	Lock Cottage	New PFR	n/a	n/a	n/a	n/a	n/a
55	Practical Betterment	Durley Lane	New PFR and wall floodproofing	n/a	n/a	60	1.3	n/a
56	Detriment Mitigation	Bristol Road West	New gravity floodwall	11.7	11.7	140	1.4	1.5
57	Detriment Mitigation	Bristol Road East	New gravity floodwall	11.7	11.7	140	1.4	1.5
58	Practical Betterment	Siston Brook	New PFR	n/a	n/a	n/a	n/a	n/a
59	Practical Betterment	Marina	New PFR	n/a	n/a	n/a	n/a	n/a
60	Practical Betterment	Lock Keeper Pub	New PFR	n/a	n/a	n/a	n/a	n/a
61	Detriment Mitigation	Broadmead Industrial Estate	New piled floodwall	12.1	12.1	800	1.1	1.1
62	Practical Betterment	The Meadows Livery	New PFR	n/a	n/a	n/a	n/a	n/a
63	Practical Betterment	Bath Road, Swineford	New PFR	n/a	n/a	n/a	n/a	n/a

16. Next Steps

This report sets out the significant option development work that has been carried out on the preferred option design for the Strategy to produce a cost for the OBC. It should be noted that the proposed design solutions are not finalised, and are likely to change prior to construction – in some areas this may be considerable. To enable consenting and ultimately construction, further work will be needed to develop the design in detail. Proposed next steps to inform the detailed design include:

- Ground investigation and structural surveys.
- Additional topographic and utilities surveys to facilitate detailed design, in particular in areas introduced in this OBC stage.
- Further contractor involvement.

- Environmental surveys.
- Land agent support to secure access and construction areas on third-party land.
- Ongoing consultation with interfacing projects, in particular at Pill, Western Harbour and Bristol Temple Quarter.
- Additional stakeholder and public engagement and landowner agreement.

Appendix A

Summary Alignment Plan

Appendix B

Opportunities and Constraints Plans

Appendix C

Engineering Drawings

Appendix D

Placemaking Drawings

Appendix E

BAM Consultation Report

Appendix F

Brunel Dam Sketches

Appendix G

Bonded Warehouses Sketches

Appendix H

Netham Lock Sketches

Appendix I

Option Appraisal Sketches

Appendix J

Gate Layout Plan

Appendix K

Geotechnical Desk Studies