Bath & North East Somerset Council

BATH RIVER AVON OPTIONS APPRAISAL
Phase 1b and 2

FINAL REPORT

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BATH RIVER AVON OPTIONS APPRAISAL
Phases 1b and 2

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BATH RIVER AVON OPTIONS APPRAISAL
Phase 1b and 2

1. INTRODUCTION

1.1 Phase 1b and 2 Appraisal

This report summarises the work completed under Phase 1b and 2 of the Bath River Avon Options Appraisal. Initially the intention was to complete this study as two separate phases, with Phase 1 covering the sluice gates at Pulteney and Twerton and Phase 2 the flood defences along the river. As part of the initial work into Phase 1 it was agreed that there was significant benefit in combining the two phases. This was partly due to feedback from stakeholders and partly to maximise the possibility of an overall scheme being funded.

The Phase 1a report summarised the initial investigations into the options for the long term future of Pulteney and Twerton sluice gates. It recommended a number of options at both locations that were worth investigating further. This has been undertaken during Phase 1b providing further details and confidence in the overall benefits, costs and viability of each option.

The Phase 2 work is largely building on previous studies completed both for the Environment Agency (Bath Flood Defence Scheme, 2005) and for B&NES (Core Strategy, 2014). These studies considered the optimum approach to reducing flood risk from the River Avon in Bath.

The 2005 study divided the areas in Bath that flood from the River Avon into a number of flood cells. This assessment has revisited the costs and benefits of schemes within the key flood cells. In the 2005 study 31 flood cells were identified. However 9 of these were identified as being ‘sole interest’ cells where there was one or more properties under a single ownership. It was agreed that these would not be looked at again. Of the 22 remaining cells there are 4 cells where significant redevelopment has either already occurred or is planned to occur shortly. These are:

- 3L – Stable Yard
- 5L – Bath Western Riverside
- 6L – Lower Bristol Road
- 11R – Green Park Road and Corn Street

Further analysis was undertaken in this study on the remaining 18 cells, which are:

1L, 2L, 8L, 9L, 10L, 11L, 3R, 4R, 6R, 7R, 8R, 10R, 12R, 14R, 15R, 16R, 17R and 18R.

Refer Figure 1 for location of Twerton Sluices, Pulteney Radial Gate and the Flood Cells.

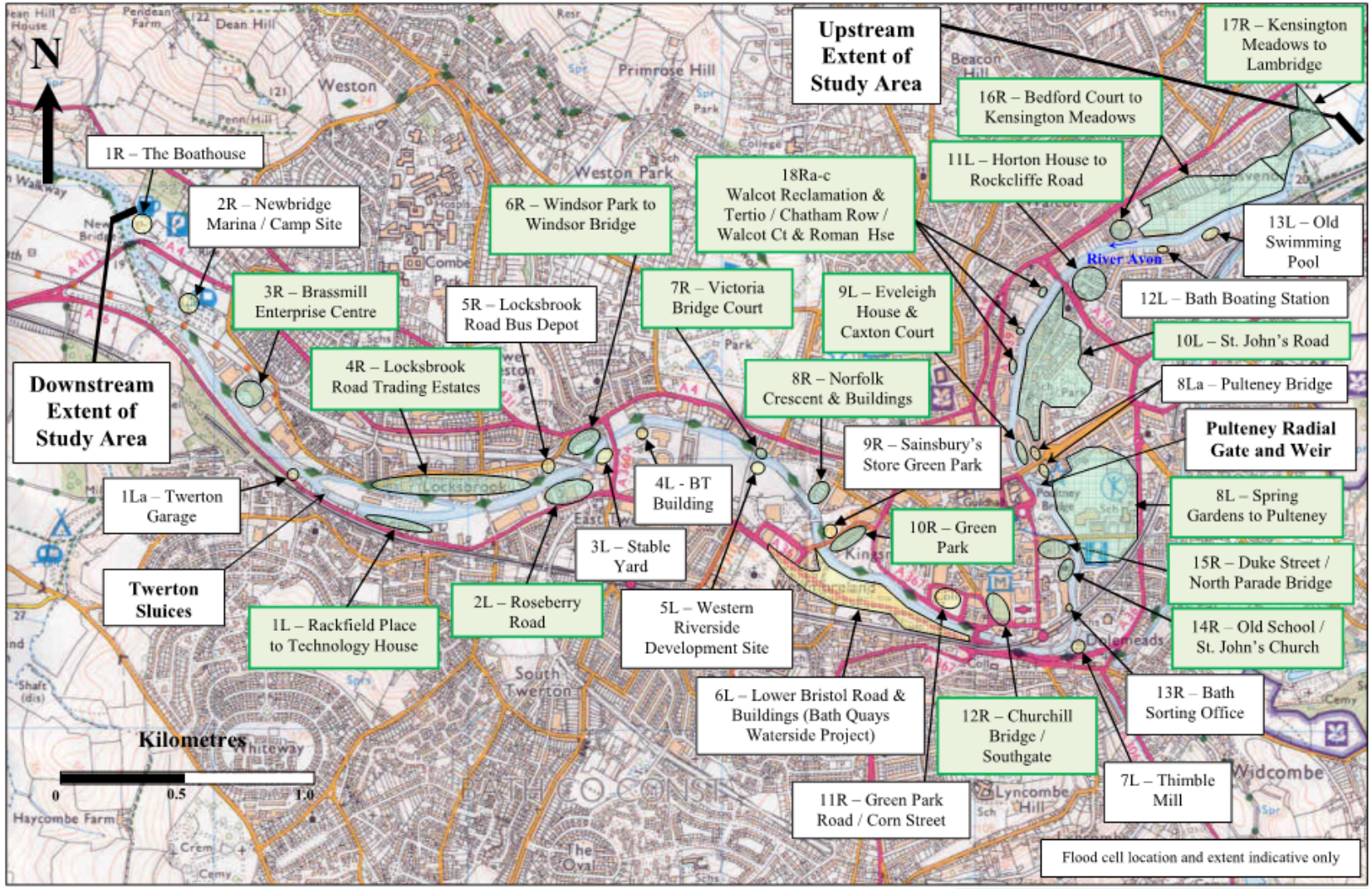

Figure 1 - Location Plan of Twerton Sluices, Pulteney Radial Gate and Bath Flood Cells

1.2 Data Gathering

The following previous studies and reports were reviewed during the Phase 1a work, and are summarised in Section 2 of the Phase 1a Report:

- DRAFT Twerton Sluices and Pulteney Radial Gate Bath Flood Defence Scheme Structural and Mechanical Assessment (Environment Agency, 2014)
- Bath City Riverside, Enterprise Area Masterplan 2014-2029 (B&NES Council, 2014)
- Twerton Gates Hydraulic Modelling (B&V 2014)
- B&NES Core Strategy (Supporting Evidence Base) (B&V 2014)
- Grand Parade and Undercroft Flood Risk Assessment (B&V 2013-14)
- Pulteney Gate Hydraulic Modelling (B&V 2013)
- Bath Flood Defence Assessment - Phase 3 (Halcrow 2013)
- Bath Flood Defence Assessment - Phase 2 Inspection Report (Halcrow 2012)
- Bath Flood Defence Assessment - Phase 1 Report (B&V 2012)
- Bath Avon River Economy (Bath Avon River Corridor Group, 2011)
- Water Safety Review, River Avon, Bath (RoSPA, 2011)
- Creating the Canvas for Public Life in Bath (B&NES/CityID 2010)
- Bath Flood Defence Scheme, Addendum to Option Identification Appraisal (B&V 2005)
- Bath Flood Defence Scheme, Option Identification Appraisal (B&V 2004)
- Pulteney Weir Micro Hydroelectric Study (B&V 2003)
- Pulteney Radial Gate Outline Emergency Access Plan (LFP/B&V 2003)
- Pulteney Radial Gate Risk Assessment (LFP 2003)
- Operation & Maintenance Manual for Pulteney Radial Sluice Gate (LFP 2002)
- Pulteney Physical Modelling Study (LFP 2002)
- Reports on Inspection and Testing of Pulteney Sluice in “Wet” Conditions (LFP 2001)
- Twerton Gate Refurbishment Project Appraisal Report (Halcrow 2000)
- Twerton and Pulteney Gates Feasibility Study (Halcrow 1999)

The following have additionally been reviewed during Phases 1b and 2:

- Operation & Maintenance Manual for Twerton Sluices
- Bath City Riverside, Enterprise Area Masterplan 2014-2029, Masterplan Vision Report (Bath & North East Somerset Council)
- Creating the Canvas for Public Life in Bath, Pattern Book: Volume 1 Public Realm Framework, Consultation Draft (Bath & North East Somerset Council and Landscape Projects, October 2014)
- Creating the Canvas for Public Life in Bath, Pattern Book: Volume 2 Technical and Operational Guidance, Consultation Draft (Bath & North East Somerset Council and Landscape Projects, October 2014)

1.3 Silt survey

One of the recommendations from the Phase 1a work was that there needed to be better understanding of the degree of siltation upstream of Pulteney weir. As part of this phase of work a detailed channel section and silt topographic survey was undertaken from Pulteney upstream to Bathampton weir to quantify current soft and hard bed levels. The results from the Silt Survey have been used to improve the assessment of siltation when considering potential works downstream and to update the current hydraulic model for Bath.

Part of the original justification for having sluice gates at both the Twerton and Pulteney sites is the ability to flush through silt and other debris, which otherwise might build up

upstream of structures. Generally the build up of silt immediately upstream of a weir has little impact on flood risk as water levels remain controlled by the crest level of the weir structure. However the siltation analysis also requires an understanding of how far upstream there is an effect of the silt build up due to any structure.

Monitoring of the channel between Pulteney weir and Twerton Gates has shown minimal change in the channel profile since the Bath Flood Alleviation Scheme was constructed. This would suggest that there is currently minimal siltation in this reach which is also supported by other detailed observations, including the recent survey. However if there was to be siltation it would occur close to the Twerton Gates where, when the gates are closed, the velocity at the bed of the river is low.

Upstream of Pulteney weir there was less information on the changes in river bed level due to siltation. A cross-section survey of the River Avon Channel upstream from Pulteney Gate and Pulteney Weir to Bathampton Weir was commissioned to identify the extent of silt within the river channel and understand how it affects flood risk, to determine how any future structure should address silt movement.

The survey concluded that the River Avon between Bathampton weir and Pulteney weir can be considered as 'in regime'. This means that the channel section is relatively stable and there has been minimal change over time. The sediment load that reaches the top of the reach passes through to the lower reach with minimal accretion. This is expected due to the fact that any coarse sediment in the river is deposited at upstream weir structures before reaching Bath. The velocities in the river are high enough, especially during higher flows, to flush through any fine sediment.

As a result the flood risk between Bathampton and Pultney weir has not changed over time due to any siltation within the channel.

The one area where there is softer bed material is just upstream of Pulteney Bridge on the left bank. However the bed profile does not appear to have changed since the Bath Flood Alleviation Scheme was completed. The channel is at its deepest in the middle and right arch which indicates that this is also where there is the greatest flow.

If Pulteney sluice gate was having a major benefit in preventing upstream siltation then one would expect to see the largest flow depths on the left bank and no build up of silt on this bank upstream. As the opposite is observed it could be inferred that the sluice gate is doing little in preventing upstream siltation.

The full report on the survey is included as Appendix B.

Previous physical modelling studies in 2002 and 2003 attempted to assess the impacts of changes to the Pulteney Gate structure on sedimentation. The 2003 Hydrolab study, as discussed in the final report, was of a qualitative nature and it states that "the depths of sediment recorded in the study are likely to represent an upper band". One of the key factors that was not taken into account in the study was the effect of boats' motors in agitating the silt. The study also showed that under the existing conditions more siltation would occur in the gate channel than has been observed. Of all the current options being considered only one (the fixed crest weir on the alignment of the radial gate) was tested in the 2003 physical modelling study.

The remaining two options (infilling the land, and removing the island and extending the weir) will not suffer from having localised lower velocities in the gate channel. The 2003 study (and all other studies) also show that siltation upstream of the weir does not extend far upstream. The 2002 physical modelling study went further in assessing flood risk

impact due to siltation occurring upstream of a new weir at the location of the existing radial gate. It showed no change in upstream water levels during flood events.

Whilst the impact on siltation upstream of any structure at Pulteney does need further consideration as part of the next stage of this study, it is considered unlikely that it would have any detrimental flood risk impact in the upstream reach.

At Twerton all options proposed in this study involve structures that can be either raised out of the channel or lowered into the bed during high flows. Therefore, if there was any siltation upstream of the structure it would be flushed through at high flows as it is currently.

1.4 Phase 1a Report

The Phase 1a Outline review report (GBV, May 2015) was a high level appraisal which assessed the worth of the different replacement options for the sluice gates in Bath. It concluded that the gates perform different functions and the needs and justifications for their replacement differ.

Twerton Gates perform a vital role in alleviating flood risk in Bath and any scheme which looks at its replacement will need to be focussed on this flood risk function. This could be through a more efficient structure, potentially combined with a high level bypass channel. There is potential for further economic benefits if a revised structure can reduce upstream flood levels. There is also the potential for environmental enhancements, with new fish and eel passes being included in the new structure.

The short-listed options to be taken forward at Twerton were as follows. The justification for these is contained within Section 10.2 of the Phase 1a report.

- Option 1: Do minimum
- Option 4: Replace both gates (potentially in conjunction with Option 9 - a new high level channel)
- Option 7: Replace both gates with a variable height weir (potentially in conjunction with Option 9 - a new high level channel)

At Pulteney, whilst it is essential that any scheme does not increase overall flood risk, the opportunities to reduce flood levels are small. Any scheme will be driven by the visual and amenity requirements of the area. As with Twerton, there is potential for any new scheme to provide environmental enhancements through improved fish and eel passage. There is also the opportunity to improve the landscape, visual, amenity and ecological value of the area.

The short-listed options to be taken forward at Pulteney were as follows. The justification for these is contained within Section 10.1 of the Phase 1a report.

- Option 1: Do minimum
- Option 4: Replace with a fixed crest weir
- Option 6: Infill the land

Overall it is key that the impacts of any potential scheme are seen in the wider context of works on the River Avon in Bath and integrated into ongoing and future strategic studies for the wider area.

This report builds on the Phase 1a outline review report to provide an economic appraisal of the various options. The short-listed options from Phase 1a have been developed as described in Section 2 of this report.

2. OPTION DEVELOPMENT

2.1 Single Options

(a) Do Nothing

To quantify the likely scale of central government funding it is necessary to compare options against the 'Do Nothing' scenario. This should represent a likely future condition if there was no further investment in maintenance. For the purposes of this appraisal we have assumed the following would happen:

- Twerton and Pulteney Sluice Gates would fail in the closed position and would no longer open during flood events.

Additionally, it is expected that the combination of debris in the channel and material from failed walls or components of structures would result in some blockage of bridge arches/openings. The following scenario has therefore also been assessed as part of the Do Nothing option:

- Grosvenor Bridge - right opening blocked
- Pulteney Bridge - right arch blocked
- St James Railway Bridge - left arch blocked
- Stanier Road Bridge (Sainsburys) openings blocked by 25%

Whilst other scenarios could be legitimately suggested, the above remains consistent with other recent studies, such as the Bath Quays Waterside project, which has been approved by the Environment Agency's Project Approvals Board (now the National Project Assurance Service).

The make-up of the Do Nothing scenario may be revised in future work if further information is available to justify an alternative approach. It should be noted that the majority of the economic damages under the above scenario are generated by Twerton Gates failing in a closed position and therefore changes to the assumptions on bridge blockage for example is unlikely to make a significant difference overall.

(b) Do Minimum

This option assumes that investment is made to ensure that the current standard of protection provided by the existing Bath Flood Alleviation Scheme is maintained through Bath. This does not account for the fact that the standard may reduce due to climate change predictions.

For Twerton and Pulteney Gates this assumes that improvements are made as identified in the Phase 1a report. This will extend the life of both structures, although at this stage this is only expected to extend the life of Twerton sluice gates by 5 years before replacement is required (compared to 30 years for Pulteney). These estimates have been made in advance of a more detailed condition inspection survey which may result in the remaining life estimates being adjusted in future work.

The works at Pulteney will include the need for new gantry bridges across the channel upstream and downstream of the sluice gate which will be expensive, visually intrusive and may not gain planning approval within this World Heritage Site

(c) Improvement Options

Hydraulic modelling has been carried out to understand the implications of the possible options at Pulteney and Twerton Sluice Gates short-listed in Phase 1a, and the interaction with proposed raising of flood defences identified in Phase 2. This has informed option development and has led, at the Twerton site, to further short-listing of sub-options as described below.

A full report on the hydraulic modelling and how the various options have been represented is included as Appendix C and summarised in Section 3.

Twerton Sluice Gates

There are a number of possible sub-options (number of gates, type of gates, with or without high level channel) under the two main improvement options short-listed during Phase 1a for this site. These have been reviewed and further short-listed as presented in Twerton RAG Options Appraisal Matrix in Appendix D. This process has been informed by our previous experience, discussions with specialist gate manufacturers, site visits and information from the Environment Agency on their preferred gate types and other operational and maintenance requirements. The improvement sub-options that are short-listed are:

- Option 4c, d, e, and f (replace with 2 or 3 vertical lift or radial gates with tilting crests, in new sub-structure, with or without high level channel), and
- Option 7c, d, g and h (replace with 2 or 3 tilting weirs, in new sub-structure, with or without high level channel).

The options that have not been taken forward are those which provide no or limited flood risk improvements (e.g. options which involve replacement with 2 gates of a similar size to the existing) or are not acceptable from an operational perspective (e.g. replacement with a single gate).

An arrangement for 3 gates is illustrated on Drawing 122369-TWE-1 in Appendix A. A two gate arrangement (not shown on the drawings) would comprise one small (10m wide) and one large (20m wide) gate in order to facilitate maintenance of flows during construction. This is explained further, along with the various design and construction consideration for options at this site, in 'Twerton – Design and Construction Issues' in Appendix D and with reference to 122369-TWE-2 Draft Reconstruction Sequence drawings in Appendix A.

For the high level channel Drawing 122369-TWE-1 shows a 10m wide channel. This is based on the maximum likely width that could be constructed without affecting the current hydropower proposals for the site. However an assessment of the additional benefits of constructing a wider channel has also been undertaken. There will be a limit to the width than can be constructed due to other physical constraints, but the analysis showed there would be additional flood risk benefits in further widening this high level channel. As part of future work, when there is better understanding of the final hydropower proposals it may be possible to refine this high level channel width.

Pulteney Sluice Gate

The options short-listed during Phase 1a have been developed as follows:

Option 4 - Replace with a fixed crest weir
Two sub-options are being considered, (i) removal of the radial gate and replacement with a straight weir at the location of the existing gate and (ii) removal of radial gate and replacement with an extension of the existing weir across the full width of the channel, incorporating the lowered island.

Option 6 - Infill the land
This option comprises removal of the radial gate and infilling of the gate channel, providing an extended area of public open space next to the river.

Drawings 122369-PUL-1 to 3 in Appendix A show possible arrangements for each of these options for this site. 'Pulteney – Design and Construction Issues' provide further information on design and construction considerations for this site.

(d) Flood Cell Defences

The defences identified for the various flood cells are based on previous work for the Environment Agency (Bath Flood Defence Scheme, 2005) and for B&NES (Core Strategy, 2014). The heights of the proposed flood defences have been updated based on the latest modelling results.

In the initial study for the Environment Agency, 31 flood cells were identified. However 9 of these were identified as being 'sole interest' cells where there was one or more properties under a single ownership. These have not been considered as part of the current study. Of the 22 remaining cells there are 4 cells where significant redevelopment has either already occurred or is planned to occur shortly (3L, 5L, 6L and 11R). The current study has therefore considered improvements to defences at the following 18 flood cells only.

1L, 2L, 8L, 9L, 10L, 11L, 3R, 4R, 6R, 7R, 8R, 10R, 12R, 14R, 15R, 16R, 17R and 18R.

For the purposes of this appraisal, flood defence improvements have been identified for a standard of 1 in 100 annual probability without any climate change allowance. These comprise a combination of new and raised flood walls, new or raised flood embankments, flood gates, flood-proofing of windows and other associated works as shown on Drawings 122369-PD-392 to 405.

A 1 in 100 annual probability standard without climate change has been selected to represent a realistic target level to compare options only. As part of future work the location, type and standard (height), including an appropriate allowance for adaptation to climate change, should be optimised to provide the best benefit cost ratio. This more detailed work may well lead to different standards of defence being recommended for different flood cells, due to the feasibility, acceptability or buildability of defences in some locations.

In Flood Cell 8L, which covers the Recreation Ground and Spring Gardens an alternative option has been considered where the recreation ground and cricket ground are left to flood as currently but the properties surrounding them and Spring Gardens are protected. This was looked at primarily due to the significant detrimental impact on flood risk from the full option. This option, which is shown on drawings 122369-PD-400 and 401, would involve a new flood wall along the North side of Ferry Lane from the river to the railway

line. This option would also include a ramp near the river and either flood gates or the facility to install demountable defences across the A36. This option will need to be investigated further in future work. The costing and benefits analysis currently assumes that this alternative option is the one constructed for this flood cell.

2.2 Combined Option

An overall final scheme for Bath may involve a combination of options for Twerton, Pulteney and the Flood Cell Defences. The individual components will vary (e.g. in terms of standard provided or nature of improvements) such that there could be a range of different combined solutions.

For the purposes of this appraisal, this has been simplified by identifying an 'illustrative preferred' option for each component of the overall combined option, as follows:

Twerton: Replacement of the sluice gates with three vertical sluice gates, in conjunction with a 10m wide high level channel.
Pulteney: Remove the radial gate and lower the island to create an extended weir.
Flood Cell Defences: Flood defences constructed at all of the flood cells to a 1 in 100 annual probability flood level, without climate change. At flood cell 8L (Spring Gardens to Pulteney) is it assumed that the cricket ground and recreation ground would still be allowed to flood.

The Twerton and Pulteney 'illustrative preferred' options have been selected based on hydraulic performance, buildability, cost and benefits (economic, amenity and biodiversity) in order that a realistic option is used in the appraisal. The results of the hydraulic modelling for these options are presented in Section 3 below and a full report provided in Appendix C.

The eventual Preferred option (i.e. the option that is recommended for implementation) for each element of an overall scheme will be optimised based on a wider range of criteria to be confirmed in future appraisal work. A decision has not been made at this time on which of the short-listed options for each part of the scheme is Preferred.

When appraising any flood defence scheme that involves multiple components it is necessary to first assess the most beneficial single option and then build up the scheme from this initial option, showing that at each stage there is an incremental benefit cost ratio greater than unity for further improving the option.

Option 1- Twerton

For this scheme the greatest benefits come from the 'illustrative preferred' option at Twerton and therefore this is the base option. This option includes the 'Do Minimum' costs for the remainder of the scheme area.

Option 2 - Twerton and Flood Cell Defences

This option combines the 'illustrative preferred' options at Twerton and the Flood Cell defences. This option includes the 'Do Minimum' costs for Pulteney Gate.

Option 3 - Twerton and Flood Cell Defences and Pulteney

This last combined option considers the 'illustrative preferred' options for works at Twerton, the Flood Cell defences and at Pulteney.

3. HYDRAULIC MODELLING

3.1 Results

A full report on the hydraulic modelling and how the various options have been represented is included as Appendix C. This includes results for all of the options tested, with comparisons made between the different sub-options. The following table shows the changes in peak water level for the 1 in 100 annual probability event at selected locations within the model for the 'illustrative preferred'[1] options described in Section 2 above.

Location	Do Minimum (mAOD)	Difference to Do Minimum Level (m)*					
		Do Nothing	Twerton Illustrative Preferred[1] Option	Pulteney Illustrative Preferred[1] Option	All Flood Cell Defences Illustrative Preferred[1] Option	Combined Twerton & Flood Cell Defences Illustrative Preferred[1] Options	Combined Twerton, Flood Cell Defences & Pulteney Illustrative Preferred[1] Options
Bathford	22.92	0.38	-0.01	-0.03	0.04	0.02	-0.01
Upstream of A4 Bridge	22.33	0.60	-0.01	-0.05	0.06	0.03	-0.01
Upstream of Cleveland Bridge	21.43	0.79	-0.02	-0.09	0.08	0.04	-0.04
St Johns Road	21.34	0.85	-0.02	-0.10	0.05	0.02	-0.08
Downstream of Pulteney bridge	20.82	0.79	-0.02	-0.13	0.07	0.02	-0.10
Downstream of Pulteney Weir	20.76	0.81	-0.03	0.01	0.07	0.02	0.03
Upstream of North Parade Bridge	20.69	0.85	-0.03	0.00	0.04	0.01	0.02
Downstream of Churchill Bridge	19.37	0.97	-0.04	0.00	0.02	-0.02	0.00
Bath Western Riverside	18.61	0.57	-0.06	0.00	0.02	-0.04	-0.01
Upstream of Twerton	17.68	0.94	-0.10	0.00	0.02	-0.08	-0.03
Downstream of Twerton	17.09	-0.04	0.00	0.00	0.01	0.02	0.02
New Bridge	16.53	-0.06	0.00	0.00	0.01	0.01	0.01

*** - When representing a complex system such as this within a hydraulic model there will be a number of uncertainties which will impact on the accuracy of the results. Whilst results have been quoted in the table to the nearest centimetre, in reality the model cannot be considered that accurate. Any difference less than 3cm (i.e. +/-0.03m) should be considered within the accuracy of the model and should be considered as no change.**

Table 3.1 1 in 100 flood event model results

[1] Refer Section 2.2 for description and content of 'illustrative preferred ' options.

3.2 Property Counts

The following table summarises the number of properties at risk for a selection of modelled events for both residential and commercial properties.

Property Type	Approximate Number of Properties at Risk of Flooding				
	Do Minimum	**Do Nothing**	**Twerton Illustrative Preferred[1] Option**	**Combined Twerton & Flood Cell Defences Illustrative Preferred[1] Options**	**Combined Twerton, Flood Cell Defences & Pulteney Illustrative Preferred[1] Options**
Residential	322	1122	314	46	46
Commercial	191	556	187	100	100

Table 3.2 Properties at Risk 1 in 100 flood event

3.3 Conclusions

The modelling work demonstrates that there is hydraulic benefit in the 'illustrative preferred'[1] option at Twerton and there is some certainty in this. The modelling also shows there may be some benefit in the 'illustrative preferred'[1] option at Pulteney, but there is less certainty in the model outputs for this, and it is recommended that there is further, more detailed analysis including the other short-listed options as part of any later stage of this study.

Constructing flood defences throughout the city is shown to have a detrimental impact on flood levels, although any increase could potentially be offset by increased wall heights where these are proposed. However the main impacts come from the construction of any flood defences on the left (east) bank of the river from Cleveland Bridge to Spring Gardens (flood cells 8L and 10L). Defences constructed elsewhere have a minimal impact on flood levels.

The modelling of a combined option demonstrates that it may be possible to develop a combined option that does not show a detrimental flood risk impact. The works at the sluice gates, in particular at Twerton, are critical in offsetting any impacts from any flood defences to protect flood cells in Bath.

Flood risk is not increased downstream of Twerton Sluices as a result of any of the options presented in Table 3.1 above.

4. OPTIONS APPRAISAL

4.1 Appraisal Period

When considering appraisal of flood defence schemes it is necessary to consider over what timescale the appraisal should cover. This is generally considered to be until the next major investment is required. In the case of the sluice gates this is estimated to be fifty years and therefore all of the economic analyses in this study used this time period.

4.2 Costing

(a) General

Costing of flood defences for the various flood cells and for works to Pulteney and Twerton Gates has been undertaken at a high level, suitable for this feasibility study in order to direct the next stage of this study and allow high level future investment profiling to be undertaken.

The non-construction costs have been taken as percentage additions to the construction cost, based on previous experience of similar flood defence work. These non-construction costs include site investigations, detailed design, B&NES / Environment Agency promotion, contract and cost management, land purchase / compensation and design support during construction / construction supervision. The percentages assumed are shown in Table 4.1.

Cost Element	% Addition to Construction Cost
Site investigations	2*
Detailed design	10
B&NES / Environment Agency staff	15
Contract and Cost Management	5
Land Purchase and Compensation	5
Design support / supervision	10

* for the Pulteney and Twerton Gate options, a site specific allowance has been made for site investigations

Table 4.1 Assessment of Non-Construction Costs

In accordance with Defra guidelines, a 60% Optimism Bias allowance has been applied to all costs, this percentage addition being commensurate with the current stage of this project.

(b) Do Minimum

The Do Minimum Present Value costs for the three elements of the scheme are:

1. Flood Cell Defences – No cost assumed as in the locations where new walls are proposed there are currently no assets to maintain
2. Pulteney - £2M
3. Twerton - £4M

The high cost for Twerton is a reflection that of the gates needing to be replaced in five years time even under the Do Minimum scenario. There other Do Minimum costs associated with the River Avon in Bath (e.g. maintaining the channel), however as these are the same across all options they will not affect the calculations.

(c) Flood Cell Defences

The defences for the various flood cells have been included at the locations and levels shown on Drawings 122369-PD-392 to 122369-PD-405. A summary of scheme costs by flood cell is given in Table 4.2.

Flood Cell	Estimated Construction Cost
1L	£1.2M
2L	£1.8M
8L	£4.0M (full option £5.1M)
9L	£0.4M
10L	£6.6M
11L	£2.0M
3R	£0.2M
4R	£2.2M
6R	£0.6M
7R	£0.5M
8R	£0.6M
10R	£0.6M
12R	£0M
14R	£0.6M
15R	£1.4M
16R	£2.7M
17R	£3.2M
18R	£0M
TOTAL	**£29.6M**

Notes:
Increases in costs compared with the 2004 work will be due mainly to increases in the cost of materials
Flood defences are not required to cells 12R and 18R for a 1 in 100 standard

Table 4.2 Flood Cell Defences Construction Costs

Estimates of construction costs have been prepared for each major component of the proposed works, for one defence standard of 1 in 100 annual probability without climate change, based on a combination of the following:

- Unit costs for labour, plant and materials taken from Spon's Civil Engineering and Highway Works Price Book 2015 (price base date 2013) for flood walls and flood embankments. This approach has been used for the majority of the defences.
- Estimates made during the 2004 appraisal work, based on in-house experience and contractor's tender returns for similar work; these have been uplifted for inflation based on construction indices. This approach has been used for the more complicated defences (e.g. asymmetrical embankments, piled flood walls, steps and access ramps).
- Cost estimates made for the recent Bath Quays Waterside project for bespoke items such as flood gates and flood-proofing of windows.

An allowance has been made in the basic construction costs for miscellaneous items. To the basic construction costs a 20% allowance for the Contractor's general costs to cover such items as insurance, site accommodation, general facilities, supervision, access, administration, mobilisation/demobilisation of plant and labour have been included. A fee allowance of 10% has then been made.

The following assumptions, which will need to be investigated further during future stages of work, have been made:

- works to all of the flood cells will be undertaken as a single scheme in year 1
- no services diversions required
- all surplus excavated material will be disposed on site within landscaping mounds/features
- the impervious cohesive clay material for the flood embankments will be imported from a local source, being surplus to other construction work, and not available within the site
- there are no contaminated ground issues
- the tonnage of reinforcement has been estimated assuming 0.11 tonnes per cubic metre of structural concrete
- all built works have high quality finishes e.g. Bath stone facing, ornate railings, glass panels
- reinstatement of public or private accesses where disrupted by proposed flood defence works
- landscaping of flood defences in private gardens to minimise visual intrusion
- the proposed permanent works and accesses are acceptable to the various adjacent landowners on whose land the works are to be constructed.

As part of the economic assessment described later it is necessary to calculate the Whole Life Cost of each option. This includes all expenditure to maintain the asset over the appraisal period (50 years). For the flood cell defences this has been assumed to equate to an annual inspection and maintenance cost of £5K, with an assumption that every 10 years £1.5M is spent on structural repairs.

This gives the following costs for the construction of all defences:

- Cost to construct - £30M
- Present Value cost - £32M

(d) Pulteney Gate

The scheme costs for the short-listed options for this site are summarised in Table 4.3.

Option	Estimated Construction Cost
Fixed Crest Weir within Existing Gate Channel	£1.9M
Existing Weir Extension	£3.7M
Infill Gate Channel	£4.4M

Table 4.3 Pulteney - Summary of Construction Costs for Short-listed improvement options

Estimates of construction costs have been made based on previous experience of similar works elsewhere.

The design and construction assumptions for each of the short-listed options are described in Pulteney – Design and Construction Issues in Appendix D. This includes the following key assumptions, which will need to be investigated further during future stages of work:

- Works are programmed between April and September
- Fishery interests do not impose programme or method constraints on the works (refer Section 5.1 below)

- Steel sheet piled cofferdams can be installed upstream and downstream of the radial gate, utilising existing recesses in the river walls, to allow the structure to be dewatered
- It is acceptable to use Twerton sluices to lower downstream water levels temporarily during parts of the construction period
- It is acceptable to lower the upstream water level temporarily during parts of the construction period
- Crane access can be taken through the Recreation Ground or beneath Argyle Street
- The realigned left bank wall under "infill the land" and "extend existing weir" options is founded on the base slab to the existing retaining wall
- The location of the new weir under the "replace with fixed crest weir" option is within the extent of the existing base slab to the radial gate, i.e. does not need a new foundation
- High quality finishes are required to new works, which are in-keeping with B&NES's general placemaking proposals
- Fish pass improvements are as described in Table 5.2 in Section 5.1
- It is necessary to maintain access across the weir for small vessels and an area for leisure boats to turn upstream of the weir
- Means of lowering the upstream river level is required for maintenance of the weir
- Physical and CFD modelling will be undertaken to inform option development during the next stage of the appraisal (i.e. modelling costs not included in the scheme costs).

As discussed in Section 2.2 the 'illustrative preferred'[1] option for the purposes of this appraisal is the extended weir option. To calculate the whole life costs for this option it has been assumed that an inspection, operation and maintenance expenditure of £1,000 per year will be required due to the extended weir.

This gives the following costs for the 'illustrative preferred'[1] option:

- Cost to construct - £4M
- Present Value cost - £4M

(e) Twerton Sluice

The scheme costs for the short-listed options for this site (refer RAG Options Appraisal Matrix in Appendix D) are all relatively similar due to them being dominated by the civil infrastructure costs, with a range of £13.8M to £15.9M.

Estimates of construction costs for the civil engineering elements of the works have been made based on previous experience of similar schemes.

Estimates of construction costs for the MEICA elements of the works have been made based on advice provided by specialist MEICA Contractors.

The design and construction assumptions for works at this site are described in Twerton – Design and Construction Issues in Appendix D.
This includes the following key assumptions, which will need to be investigated further during future work:

[1] Refer Section 2.2 for description and content of 'illustrative preferred ' options.

- In order to deliver the required operation and maintenance improvements it will be necessary to demolish and reconstruct the reinforced concrete support structure. This is different to the assumption in the Phase 1a report. This is necessary to allow for wider gates
- The existing sub-structure does not have sufficient structural strength to take new, thinner piers and therefore it is assumed these will need to be broken out and replaced. This represents the key cost difference between this and the Phase 1a cost estimates
- The existing power supply to the site is sufficient for the new gates
- That the existing Wessex Water attenuation tank / wet well structures located on the left bank downstream of the gates, are capable of supporting new structurally reinforced cover slabs and imposed loads arising from the assumed construction methodology and maintenance activities. In addition, that the associated sewer which runs along the left bank in parallel with the structure is located far enough from the improvement works to not need to be protected or diverted.
- The construction sequence detailed on Drawing 122369-TWE-2 is acceptable – works are undertaken over 2 years in order to avoid increasing flood risk in the winter months
- Mitigation for temporary reduction in hydraulic capacity resulting from construction of a new pier (prior to removal of the existing pier) is provided by (i) temporarily fixing a flow control mechanism to the new partially reconstructed fish pass in the left bank, (ii) constructing a new high level by-pass to the adjacent right bank island and (iii) installing a temporary flow control mechanism between the new pier and the existing central pier. This assumes that fish passage (except eels) can be suspended between Spring year 1 and Autumn year 2. Alternative arrangements could reduce the period that fish passage is affected, but would be more costly – these have not currently been allowed for (see also Section 5.1, final bullet point)
- A 10m wide high level channel is constructed
- Fish pass improvements are as described in Table 5.1 in Section 5.1.

As discussed in Section 2.2the 'illustrative preferred'[1] option for the purposes of this appraisal is the three vertical sluice gates. To calculate the whole life costs for this option it has been assumed that an inspection, operation and maintenance expenditure of £15,000 per year will be required for the new structure. In addition it is assumed the ultrasonic gauges are replaced every 10 years at a cost of £10K and more extensive maintenance is undertaken on the gates every 20 years at a cost of £25K.

This gives the following costs for the 'illustrative preferred'[1] option:

- Cost to construct - £14M
- Present Value cost - £14M

4.3 Benefits

(a) Flood defence funding from central government and local levy

The benefits of the proposed scheme have been assessed using GBV's Flood Damage Economic Model (FDEM) GIS tool. This allows quick analysis of the impacts to both residential and commercial properties over a range of flood events, climate change scenarios and option scenarios.

[1] Refer Section 2.2 for description and content of 'illustrative preferred ' options.

There would be additional damages incurred to other infrastructure during flood events that is not included in this analysis. This would mainly be damage to roads and utility services and disruption to travel and supply of utility services. There should also be an allowance for any impacts on health and wellbeing.

Based on experience from elsewhere and knowledge of the assets at risk in Bath we have included an uplift of 10% on the damages produced from FDEM for the Do Minimum and Options assessments to cover the items listed in the above paragraph. For the Do Nothing an uplift of 20% is included.

As part of future work a more detailed economic assessment will be required. At that stage there should be further discussions with the Environment Agency's National Project Assurance Service over what they would consider acceptable to be included in the Do Nothing scenario especially. The value quoted below for Do Nothing is likely to represent a lower bound as there are a number of items that could be considered that currently have not (e.g. permanent road diversion, reconstruction of electricity sub-station).

The following table contains the Present Value Damages (based on a 50 year appraisal period) for the options assessed. The numbers have been rounded to the nearest million pounds to reflect the current level of accuracy.

Option	Present Value Damages	Present Value Benefits over Do Nothing	Present Value Benefits over Do Minimum
Do Nothing	£209M	-	-
Do Minimum	£54M	£155M	-
Twerton Illustrative Preferred[1] Option	£48M	£160M	£5M
Twerton and Flood Cell Defences Illustrative Preferred[1] Options	£35M	£174M	£18M
Twerton, Flood Cell Defences and Pulteney Illustrative Preferred[1] Options	£35M	£174M	£19M*

*Numbers are to nearest £1M. Difference between last two options is less than £500K

Table 4.4 Benefit analysis

(b) Council funding

Significant funding for this scheme, if it were to be constructed, would come from other council funding, and would be subject to separate justifications. For the central government funding only losses to the nation can be considered. However, for council funding losses to the local area should also be considered. This would primarily be loss of business and disruption to public services. The losses to business would in turn be primarily based on loss of tourism. If a flood were to occur during a key tourism period (e.g. Christmas Market) then this could represent a major economic loss.

In addition the benefits that a scheme could bring in terms of job creation, regeneration and increased tourism should also be considered. The way to present these considerations depends on the requirements of the different funding sources.

[1] Refer Section 2.2 for description and content of 'illustrative preferred ' options.

4.4 Partnership Funding Opportunities

Whichever option is taken further would be considered a high cost scheme and is unlikely to be funded from central government sources (Flood Defence Grant in Aid – FDGiA) alone. There will therefore need to be additional funding which could be from a variety of sources, such as:

- Local Levy – additional public funds to fund local flood defence schemes. Funds are limited but form an important contributor, especially in funding the pre-construction costs.
- B&NES River Corridor Fund – Small fund that may assist with initial pre-construction costs.
- Economic Development Funding – Significant potential funding source for part of the construction costs.
- Community Infrastructure Levy – Funding source available for the council to use for different schemes. Potential for significant contribution but would need to be bid for.
- Site specific developments (i.e. S106 payments) – Some potential where the options directly benefit, or are located on a development site. Maybe the case for some of the Flood Cell defences.
- Local Development Framework Infrastructure funding – Smaller funding source that could assist with some construction costs.
- Homes and Communities Agency – a potential funding source especially if opportunities to facilitate provision of social housing
- Private funding – There is potential funding from private sources either where there is a direct benefit to residential or commercial properties, or where it can form part of their wider scheme. For now this funding source has been considered to be small.

4.5 Economic Summary

(a) Incremental benefit cost ratios

There are two key steps in justifying central government funding for a flood reduction scheme. The first is determining that there will be a return on any investment (i.e. the benefits outweigh the costs). This is done by comparing options against the next best option. However when considering the cost of the scheme, this only includes the costs that can be met by FDGiA and local levy funding. It ignores the costs that would need to be met from other funding sources, including the council.

There is therefore a theoretical maximum combined FDGiA and Local Levy funding that a scheme could attract based on a benefit cost ratio being greater than unity. The following summarises this analysis for the 'illustrative preferred'[1] options. As before the values have been rounded to the nearest £1M to represent the level of accuracy at this stage.

Option Number	**2**	**3**	**4**	**5**
Option description	**Do Minimum**	**Twerton Illustrative Preferred[1] Option**	**Twerton and Flood Cell Defences Illustrative Preferred[1] Options**	**Twerton, Flood Cell Defences and Pulteney Illustrative Preferred[1] Options**
PV Damages	£54M	£48M	£35M	£35M
PV Benefits over Do Minimum		£5M	£18M	£19M
PV Cost of scheme to give benefit cost ratio of 1 over Do Minimum *(including allowance for PV Cost of Do Minimum being £6M)*	-	£11M	£24M	£25M
Actual calculated PV Costs	£6M	£16M	£47M	£49M
Funding shortfall	-	£5M	£23M	£25M

Table 4.5 Maximum FDGiA/Local Levy funding

(b) Partnership Funding scores

The second test to determine the actual FDGiA funding a scheme may attract uses the 'partnership funding' (PF) calculator developed by DEFRA. Within this the actual costs and benefits of the scheme are taken into account. The exact FDGiA funding amount depends on the PF score required at the time of the assessment to give it sufficient national priority. For this assessment it was assumed that a figure of 100% is required.

The outputs from the PF calculators are contained in Appendix E. The following table gives a summary.

Option	**Present Value Cost**	**Initial Capital Cost**	**Maximum FDGiA funding**	***Maximum additional Local Levy funding****	**Additional funding required (including Local Levy)**
Twerton Illustrative Preferred Option[2]	£16M	£14M	£9M	*£2M*	£7M
Twerton and Flood Cell Defences Illustrated Preferred Options	£47M	£43M	£10M	*£14M*	£37M
Twerton, Flood Cell Defences and Pulteney Illustrative Preferred Options	£49M	£47M	£10M	*£15M*	£39M

* This is calculated based on the maximum available funding in Table 4.5. This is provided for reference only and it is recognised that the actual available Local Levy funding will be less than this.

Table 4.6 Partnership Funding summary

[1] Refer Section 2.2 for description and content of 'illustrative preferred ' options.
[2] Refer Section 2.2 for description and content of 'illustrative preferred ' options.

Table 4.6 demonstrates that it is the partnership funding criteria that will dictate the maximum potential FDGiA funding. Based on the need to still show a positive benefit cost ratio of the combined FDGiA and Local Levy funding the total possible amount of Local Levy funding will be limited to that shown in Table 4.6 (assuming the maximum amount of FDGiA is achieved). However, in reality the available Local Levy funding will be substantially less than this and therefore there will be an overall robust benefit cost ratio because a greater proportion of funds will need to be sourced from elsewhere.

Table 4.6 also demonstrates the degree of additional funding that would be required for the schemes to be constructed.

5. ENVIRONMENT

The environmental baseline conditions are described in Appendix C of the Phase 1a Report (GBV, 2015). As part of this stage of the study two key elements of work have been undertaken looking at fish and eel passage and integrating proposals at Pulteney with those suggested in the draft Pattern Book for Bath.

5.1 Fish and Eel Passage

A technical note on fish passage can be found in Appendix D. This summarises available fish data sources, the existing fish pass arrangements at the Twerton and Pulteney sites, potential options for fish passage improvement and comments on the implementation of improvements.

Key points are as follows:

- There are existing pool and traverse fish passes at each of the sites. The effectiveness of these arrangements for fish passage is not fully understood due to a lack of data, however the provisions are generally considered to be sub-optimal for both the species they were originally intended to cater for (salmonids) and other fish species. There is therefore an opportunity to make improvements which will benefit an increased range of species.

- Eel passage is not currently provided at either of these sites. There is a requirement under the Eels (England and Wales) regulations 2009 to install an eel pass on all structures that form a barrier to passage by 2021.

- A number of options for fish passage are available under each of the short-listed gate options for each site. The optimum arrangement will need to be considered in more detail during outline and detailed design and will depend on the preferred gate option, the proposed operational regime and the fish species that are using the river. At Pulteney one of the short-listed options (replace gate with fixed weir) is, however, considered to be particularly unfavourable for fish passage.

- The selected fish pass option, for costing purposes only, is summarised in the following tables. No allowance for fish pass improvements are made in the do nothing or do minimum options, however under the do minimum option it will be necessary to comply with the Eel Regulations by 2021.

Option	Fish pass provision for costing purposes	Eel pass provision for costing purposes
Rebuild structure and replace gates with 2 or 3 new gates, potentially in combination with high level channel	New Larinier fish pass in by-pass channel on left bank.	Install eel brushes within fish pass through left bank or built into pier adjacent to left gate, and built into pier adjacent right gate (i.e. aligned with river margins).

Table 5.1 Twerton - Fish and Eel Passage Arrangements for Costing Purposes

Option	Fish pass provision for costing purposes	Eel pass provision for costing purposes
Remove gate and extend existing weir	Block off existing fish pass and install new Larinier fish pass adjacent to existing boat ramp.	Install eel brushes at side of Larinier fish pass and on western end of weir
Remove gate and infill gate channel	Block off existing fish pass and install new Larinier fish pass adjacent to existing boat ramp.	Install eel brushes at side of Larinier fish pass and on western end of weir
Replace with fixed crest weir	New Larinier fish passed on both the new weir and adjacent to existing boat ramp on existing weir and blocking off notches in existing fish pass.	Install eel brushes on new weir and at western end of existing weir

Table 5.2 Pulteney - Fish and Eel Passage Arrangements for Costing Purposes

- Implementation of gate improvements will need to consider impacts on fish arising from activities such as in-river piling which will cause noise and vibration impacts and maintenance of fish passage, particularly during the salmonid migration period (August/September to November approximately).

- Implementation of gate improvement works at the Pulteney site is assumed to take place between April and September, i.e. during low flows. In-river piling works will be required under certain gate options. The proposed construction sequence (refer Appendix D) will require temporary lowering of the downstream water level using Twerton Sluices for part(s) of the works, depending on the gate option. It is considered likely that the in-river piling works can be completed and the downstream water level returned to normal before the start of the salmonid migration season, however there is a risk that the early part of the season is affected by the works. As noted in Section 4.2, for the purposes of costing it is assumed that this is acceptable.

- In order to avoid increasing flood risk during the winter months it is proposed that in river works at the Twerton site be undertaken between April and September, with all temporary works removed from the river between October and March. The proposed construction programme and sequence currently requires the suspension of fish passage from Spring year 1 to Autumn year 2. There are options to reduce the length of time that passage is prevented but this would incur additional construction costs which are not currently allowed for. The Environment Agency has confirmed that a pragmatic approach will be taken in terms of maintenance of fish passage during construction if costs are such that the feasibility of the scheme is affected. Options to minimise the time that fish passage is prevented will need to be considered further during outline and detailed design.

5.2 Integration of Pulteney Works with Wider Setting

The landscape drawings produced for the gate options at Pulteney (refer Appendix A) have taken into account proposals within the Pattern Book and other public realm strategies. In particular, improvements to the amenity, ecological and landscape value of public realm spaces, improvements to pedestrian movement and increasing connectivity with the river. These drawings were presented as part of the drop-in surgery in June 2015, described in the next section.

5.3 In-river ecological improvements

In addition to ecological improvements, such as tree planting, in public realm spaces, ecological improvements to the river shall also be considered during outline and detailed design. These may include improvements to the diversity of the marginal form of the river and marginal planting, if appropriate and compatible with other river uses. It will be important to confirm any changes such as these do not increase flood risk.

6. CONSULTATION

Through this phase of work there has been ongoing regular consultation with Environment Agency and Council staff. During Phase 1a of this study there was a workshop where a group of stakeholders and residents groups were invited to discuss the needs for replacing the structures and the different options available. The following table summarises the key comments from this workshop along with details of how this was addressed in this phase of the study.

Option	Comments from October 2014 workshop	Update from work undertaken since October 2014 workshop
	General	
Do Minimum	• Would allow time to holistically review management of river and catchment.	• Study is now looking at wider river flooding issues. Catchment issues and benefits considered under other studies.
	• Must consider impact of climate change and full impact on residents.	• Potential climate change impacts have been fully considered in appraisal of flood risk.
Other	• Flood risk is most important issue	• Agreed
	• Costs and maintenance also important	• Agreed
	• Public realm at Pulteney more important than Twerton	• Agreed and scheme at Pulteney will be led by landscape designers
	• Consider the impact the lack of maintenance, dredging and bank clearance has had on flow	• Has been assessed as part of assessment of benefits of work. Silt survey undertaken to assess benefits of dredging.
	• Opportunity at both sites to improve biodiversity	• Agreed
	• Opportunity for increased future river use	• Agreed
	• Potential to meet amenity use in combined projects	• All Pulteney options are including considerations of bringing more people to the river
	• Need to consider potential solution's impact on water supply/sewerage network – building resilience for the future.	• Options will only impact water levels during flood conditions, however any options to reduce ingress into the sewer system from the river will be investigated
	• Need to consider structures at Pulteney and Twerton together	• Structures being considered as part of combined study

Option	Comments from October 2014 workshop	Update from work undertaken since October 2014 workshop
	Pulteney	
Refurbishment	• Consider future maintenance and access	• Has been assessed in the options
Replace with sluice gate	• Have respect for the setting • Consider future maintenance and access	• Option rejected at end of first phase of study
Replace with fixed crest weir	• Step back in time • Potential for increased sediment risk.	• New weir can have various forms. Potential to extend existing weir • Silt survey shows limited if any silt.
Replace with lock gates	• Concerns on technical failure • Examples of suitable lock gates used elsewhere (e.g. Cardiff Bay) • Concern over safety of navigation above the weir • Public transport opportunities	• Option rejected at end of first phase of study
Infill the land	• Seen as a risk to hydro opportunities • No fish/biodiversity improvements • Safety impacts on people	• Hydropower unlikely to be economically viable at Pulteney • Option will include new fish and eel passes • Safety concerns are very valid and being discussed. Option will also make it easier for people to get out of the water.
Others	• Just remove platform over sluice and celebrate the engineering • Heritage and aesthetic equally important • Educational value of hydropower • Solution should be innovative • Must look to reduce flood risk • Retain the canoe/boat rollers.	• Would be a missed opportunity • Agreed • This would be the main reason for a hydropower scheme at Pulteney • Agreed • Agreed. Analysis is showing this is possible. • They are retained in all options.
	Twerton	
Lowered retained water level	• Negative impact on hydro • Impact on navigation • Visual impact	• Option rejected at end of first phase of study

Option	Comments from October 2014 workshop	Update from work undertaken since October 2014 workshop
Others	• Need to address safety	• Safety concerns considered lower at Twerton, however new scheme will include provision for preventing boats reaching the gates
	• Hydro links to heritage of the area (make the structure work for its living)	• Hydropower being considered by BWCE, although the projects are sharing information
	• Link with future regeneration	• Linked fully with the proposed regeneration sites
	• Connection of Twerton to the river	• Considered to be limited opportunities
	• Potential for biodiversity improvements	• New fish and eel passes included in the design
	• Not so visible	• Agreed
	• Potential for improved public realm access	• Considered to be limited opportunities.

Table 6.1 October 2014 workshop comments

A further 'drop in' surgery was held in June 2015 as part of this phase of work. The key comments that were raised are summarised in the table below.

Comments from June 2015 surgery
A well-presented surgery with knowledgeable presenters. Options for Pulteney can only enhance this area. The concern is with Twerton and it remaining fully operational until it has funding for its replacement.
Good to see you are looking at a holistic approach to Bath now rather than prioritising 'new build' areas.
Displays are helpful. Very useful discussion. It would further help if communications anticipated the question: "if Pulteney sluice gate can be removed, it would it not have been built in the first place". A core objective of the sluice gate is to maintain minimum water levels upstream, i.e. prevent the water levels dropping. Whichever option is chosen must continue to fulfil this purpose.
Anything to reduce flood risk, and improve views and access to the weir at Pulteney gardens would be welcome. Again hydroelectric scheme would be welcome as long as flood risk is not increased.
There should be a fourth option: 1 Fix the Twerton gate 2 Leave Pulteney Weir radial gate and maintain it. 3 use the monies which would have been spent on re-vamping the weir to build flood prevention walls on the Southside upstream of Pulteney Weir.
All very worrying, especially for residents upstream. Looks aren't everything!
I am very concerned at the removal of the radial gate as it protects us upstream from flooding. I fear its removal is driven, not by flood alleviation, but by civic amenity possibly to suit the Rec/rugby Ground
Option 1 (infill gate channel) is a public health hazard in terms of unauthorised swimming and drunken behaviour at night time.

Option 4 – keep the radial gate!!! Option 2 (Pulteney) may be safer (in terms of flood risk upstream) of the three options but it does not show emergency access for emergency boat launching etc.
Option 1 (infill gate channel) will reduce river capacity and may increase flood risk to the east of Pulteney Bridge (i.e. London Road & St Johns Road).
I like the idea of Archimedean screws generating electricity in Twerton, but object strongly to the benefits going to the bus depot unless First Bus pay for the whole of the plant and installation costs. It is Bath's river and Bath should reap the benefit.
The Twerton tilting Crest scheme is claimed to be low(ish) cost to maintain. To an accountant under budget constraints 'cheap' equates to 'unimportant' and I fear that essential maintenance will be neglected. The tilting mechanism will be under stress the whole life of the installation and the maintenance budget needs to be ring-fenced.
I hoped there would be more information about the other developments along the river - Bath Quays, Bath Riverside, etc.
Pulteney – I like mix of options (ii) & (iii) – widening path (ii) and island (iii) whilst incorporating eel passes and enabling more fish to pass. Twerton – allow turbine for hydro-electricity.
Of the three options on show, option 1 should be discarded; the infilled platform area is a perfect location for drunken youngsters to drive off into the turbulence of the weir. This scheme screams night-time drownings. Option 3 is far better than option 2 aesthetically, especially if the island is planted or decorated with sculptures. Option 2 makes the shape of the weir hugely unbalanced and the extended weir will collect floating timber because of its slower flow.
Eels are important but so are the residents of St Johns Road & Henrietta street etc. Please do not forget us!
Twerton sluice: no major objection to the replacements with a 3-gate design as the existing are not highly visible. The insert if screws to provide hydro-power is also a plus; it is just a shame they will be hidden from the public. Pulteney Gate: still major concerns over the removal of the gate; however, if it is removed there are merits in the options proposed. The two best are the removal of the island and extended weir or the hard landscaping OR a variation of both. It would be of benefit if water could be made to flow through the boat dock. Any proposals should enhance.
Looking forward to seeing them in more detail on your website.
Feedback from last workshop – response about river safety should also include reference to wider safety work Council is doing. Interested in hearing the response reference Henrietta gardens.
I attended the showing of proposed changes to Pulteney Weir at the Guildhall on Thursday. I have a real interest in this as my company runs the tripping boats from Pulteney Weir to Bathampton & I also run the Bath Boating Station in Forester Road, on the same stretch of river. I agree that something needs to be done, it would be catastrophic for us if the gate failed during major flooding but of course I have my reservations as to how the business will be affected. I was pleased to see that you have considered us, having the boat turning point in each plan. It appears on all plans that the steps we use to load passengers will remain in the same place, I hope this is the case. I am a little concerned that the flood gate will no longer be there as it has worked so well for a long time, but I was told that removing it would make the flooding upstream of the weir no worse, is this correct? I should like to be kept informed of any developments in the plans & especially how I will be affected if building works went on over the summer. Please could I be informed of any future meetings concerning this development?
A more neutral analysis of the Pulteney gate options would have been valuable: the current wording is clearly intended to create the impression that maintaing the existing radial gate is not a financially viable option. This amounts to making a judgement before the case has been heard.
there is only one option:

to repair or replace the Radial Gate , because a) it is essential for flood control upstream b) other proposals would achieve NOTHING, except to block access for emergency vehicles. c) it's design is mid 20th century Brutalism which is a valid style, and therefore should be listed. I hear there is a meeting on Wednesday 17 June at Keynsham, why was this not publicised at the so-called workshop last week? why was the workshop also not publicised? Please inform me of the times and venue of the meeting at Keynsham.
Yesterday I visited the presentation on the Bath River Avon Options Study and I have to say the proposed options do absolutely nothing to reduce the flood risk upstream of Pulteney Weir. There are over 150 properties at risk in the 1 in 100 area and considerably more of you expand this to 1 in 100 plus 10% for climate change. The majority of these properties are Listed and are of significant historic interest. The total value is well in excess of £300M probably far greater than those properties affected last year in the Somerset Levels. All of the options presented involved removing the Radial Gate at Pulteney Weir and redesigning the Weir. The cost was quoted as around £3M. I further understand that the Radial Gate is not yet at the end of its life and could continue for at least a further 10 years with an annual maintenance cost of around £300K. There must therefore be a fourth option. The work on the Twerton Gate is vital as if that fails most of the centre of Bath is at risk. However, the fourth option for the Pulteney Weir area must be to provide flood defences, probably a walled defence, upstream of Pulteney Bridge. BANES has embarked on a number of expensive studies over the years all of which have confirmed the risk to properties upstream of Pulteney Weir. It is time to actually take some action to alleviate the problem.

Table 6.2 June 2015 drop in surgery comments

7. CONCLUSIONS

Key Conclusions

1. The modelling work indicates that it would be possible to develop a combined flood reduction option consisting of works at Twerton and Pulteney Gates and improved or new flood defences throughout the city which does not detrimentally impact flood risk from the River Avon through Bath. Looking at options in combination provides better flood risk benefit than looking at them individually.

2. If there was no future investment in flood defences in Bath then there would be an unacceptable increase in flood risk over time. This is most marked for the more frequent events where the number of properties at risk of flooding would increase substantially (e.g. for the 1 in 10 annual probability event it would increase from 6 to 201).

3. Any major capital flood defence scheme for Bath cannot be fully funded through central government Flood Defence Grant in Aid. A partnership funding approach will be essential to enable delivery of any new flood defence scheme. Other funding sources have been listed in this report and these will need to be investigated further in the next stages of the appraisal.

4. The 'illustrative preferred' option is the sub-option or standard that has been selected for this appraisal so that a realistic combined scheme can be assessed. This avoids the need to assess numerous possible combinations which would not add value to the appraisal at this stage. The 'illustrative preferred' option is not necessarily the 'Preferred' option, i.e. the option which would eventually be recommended for implementation. Refer to section 2.2 for details of the 'illustrative preferred' option for each scheme component.

5. Engagement with stakeholders was undertaken for all the options . Whilst there is support for the overall principles of a flood risk reduction scheme, there were some reservations about the justification for flood works at Pulteney and any resulting impacts. It is vital that as part of future work these concerns are addressed by undertaking further engagement and consultation.

Siltation

6. Monitoring of the channel through Bath since the 1970s has shown minimal change in the channel profile over time. As anticipated, there has been minimal siltation and therefore the flood risk in Bath has not changed over time due to siltation.
    a. Any new structure at Twerton will not alter sediment dynamics.
    b. If a new structure were to be constructed at Pulteney then even if there was an increase in upstream siltation it would not increase flood risk in the upstream reach.

Twerton Gates

7. Were Twerton gate to fail in a closed position and coincide with a major flood event, such as the 1 in 100 annual probability event (1% chance of occurring in any one year), many additional properties would be put at risk. Under the Do Nothing scenario, which includes Twerton Gates failing closed (as well as blockages occurring in the channel), approximately 1,100 residential properties would be at risk of flooding in this 1 in 100 event, which is an increase of 800 over the Do Minimum scenario. It is likely that around a quarter of these additional properties are directly from the impacts of Twerton Gates. If the sluice gates were to fail shut during a flood event there will be significant disruption to the city of Bath.

8. Even with the planned investment to repair the existing structure at Twerton there would still be a requirement to replace it in the near future (5-10 years time).

9. Several options were presented for Twerton and evaluated against flood risk benefits, costs and operational benefits. The key future decision comes from whether or not wider gates are beneficial to reduce flood risk. With new slimmer piers a new sub-structure would be required to take the different loadings from the new gates, and this would come with a large cost. It is possible that the existing sub-structure could be retained along with the existing pier, however this would require further detailed structural investigation and outline design development to define flood risk benefits and costs.

10. The Twerton options incorporate a 10m wide high level channel to allow flow to bypass the gates during flood events with a 1 in 5 annual probability or rarer. Depending on the future hydropower proposals for Weston Island it may be possible to make this channel wider which would increase flood risk benefit.

11. A preferred option has been taken forward involving three new identical vertical sluice gates at Twerton. As with all preferred options this is to explore indicative economic scenarios. As part of the next stage of detailed appraisal options may be need to be developed further.

12. The construction cost for this option would be £14M with a Whole Life Cost of £16M.

13. Hydraulic modelling of this option demonstrates a significant benefit in terms of level reduction with a reduction in flood risk throughout the city.

14. The current arrangement for fish passage at Twerton is sub-optimal and it is assumed that a new Larinier fish pass would be constructed in the by-pass channel on the left bank, along with two eel brushes.

15. There would potentially be a reduction in fish passage past Twerton during construction.

Pulteney Gate

16. The consequences of Pulteney Gate failing shut during a flood event are considered minimal. The increased flood risk upstream and downstream of the structure are within modelling tolerances, but further investigation of this risk is needed. There is a greater impact if the gate were to fail in the “open position” as this would lower the river level thus impacting on the natural and built environment

17. At Pulteney the life of the structure could be extended for a longer period (25 years) with some initial improvement investments. However these investments are quite significant with the need for visually intrusive gantries which may not obtain planning permission in this World Heritage Setting.

18. For Pulteney the option of extending the weir was presented as the preferred option on the basis that it could have the greatest flood risk benefits, however this will require further investigation in future work.

19. The construction cost for this option would be £3.7M with a Whole Life Cost of £4M.

20. Hydraulic modelling demonstrated that all options at Pulteney have little impact on flood levels, with the majority of the results being within the accuracy of the model. However it is recognised that the complex flow mechanism at Pulteney Weir may not be fully represented in the current model and therefore it is recommended that either computational

three dimensional modelling or reduced scale physical modelling (or both) are undertaken as part of future work.

21. The current fish passage provision at Pulteney is sub-optimal and it is assumed that a new Larinier fish pass would need to be constructed adjacent to the existing boat pass and that the existing fish pass would be blocked off. Two new eel brushes would be installed on either side of the channel.

Flood Walls

22. For the flood walls it was assumed that a current day 1 in 100 annual probability of flooding standard of protection would be provided. If this standard was provided then it would result in the future standard of protection being lower due to the climate change impact. In some locations it may be feasible to provide a higher standard of protection which would include an allowance for climate change, however at other locations this is unlikely to be viable due mainly to visual impacts. In the future work the standard of protection should be refined with consideration given to providing a variable standard throughout the city.

23. The construction cost for this option would be £30M with a Whole Life Cost of £32M.

24. Hydraulic modelling demonstrated that constructing flood defences has little impact on flood levels at any location within the river, except if defences were to be constructed on the left bank from Cleveland Bridge to Spring Gardens. This would result in an increased flood risk upstream which would need to be mitigated for a scheme to be acceptable.

Appraisal of Combined Schemes

25. Two combined schemes were considered further. Both include the preferred option at Twerton and the flood walls, with the second scheme also including the preferred option at Pulteney.

26. Hydraulic modelling of these combined schemes demonstrates that any potential negative impact from one individual part (i.e. flood walls) can be offset by the inclusion of other parts (i.e. reduced afflux at the sluice gates).

27. To enable a comprehensive flood defence scheme to be developed there is a need to demonstrate the incremental benefits of each additional element over the basic option. It was assumed that a combined scheme option would involve one of the following:
    i. Twerton Gates replacement
    ii. Twerton Gates replacement and Flood Cell Defences
    iii. Twerton Gates replacement, Flood Cell Defences and Pulteney Gate replacement

28. For the appraisal options the whole life costs would be:
    i. Do Minimum - £6M
    ii. Twerton Gates replacement - £16M
    iii. Twerton Gates replacement and Flood Cell Defences - £47M
    iv. Twerton Gates replacement, Flood Cell Defences and Pulteney Gate replacement - £49M

29. The likely maximum Flood Defence Grant in Aid funding for the three improvement options is:
    i. Twerton Gates replacement - £9M
    ii. Twerton Gates replacement and Flood Cell Defences - £10M

iii. Twerton Gates replacement, Flood Cell Defences and Pulteney Gate replacement - £10M

30. The difference between these two sets of costs demonstrates the scale of additional funding required.

8. THE WAY AHEAD/RECOMMENDATIONS

This phase of the study demonstrated that there are viable engineering options that could be taken forward and estimated the degree of FDGiA funding that may be available for them. The next stage of work should start to provide the necessary detail on these options such that investment decisions can be made.

To secure FDGiA funding a Project Appraisal Report (PAR) will be required. However decisions need to be made on how this will be undertaken. A PAR could be undertaken now for the scheme at Twerton based on the available information. However, if this is completed on its own it may make it harder to justify any further schemes in Bath, partly as the majority of Do Nothing damages in Bath come from the Twerton sluice gates failing. Also if a new 'baseline' set of water levels is produced following the works at Twerton it may make it harder to demonstrate that any further works do not have a detrimental impact on flooding.

It may be better to produce a Strategic Appraisal Report (StAR). Unlike a PAR this does not require certainty on all funding sources to be approved. As part of the StAR the optimum combined scheme would be developed which may involve a different combination of options than the ones presented in this report. It would identify the costs and benefits of the entire scheme and the overall level of FDGiA funding available. It would also then set a framework for the programme of delivery of each element of the scheme as well as its funding mechanism.

As each element of the scheme is progressed a PAR would still be required but this would be much simplified and follow the guidelines in the StAR. Importantly a new set of 'baseline' water levels would not be achieved until all elements are completed.

The key difficulty in this approach is that there can be no guarantee that the requirements to obtain funding will not change in the future.

There is a proposed scheme at Twerton which will need further evaluation, especially in regard to the high level channel and the means of construction. The scheme is unlikely to meet much opposition.

Based upon stakeholder feedback it is clear that any work at Pulteney may be more controversial and it is therefore necessary during the early stages of the next phase of work to undertake a more detailed hydraulic analysis that demonstrates the impacts on water levels of the preferred options. This will also need to evaluate the potential siltation within the channel and also what impact this could have on flood risk. To build on the work done to date it is recommended that a combination of Computational Fluid Dynamics (CFD) and physical modelling is undertaken. The CFD modelling represents the system in three dimensions and could be used to assess the relative benefits of each option. Ideally, if budget is available, a physical model should also be constructed for the final preferred option to give further confidence in the assessment. This should be at a sufficiently small scale so that impacts are fully represented. It may require an exaggerated vertical scale.

For the flood walls the next stage of work should identify the optimum location, type and height of defence. The greatest risk that could prevent the defence options being constructed is agreement from landowners. In some locations the proposed defences would need to be constructed through multiple different property boundaries and there would be considerable disruption both during and after construction. At an early stage there should be consultation with affected landowners to determine how they may react to a flood alleviation scheme through their land.

B&NES and the Environment Agency should continue to work in partnership to support the development of a holistic flood risk solution for Bath. The Environment Agency may elect to lead the next phase of work as it will need to focus upon the principal flood structures at Twerton and Pulteney as the drivers for a whole scheme solution. B&NES should support this to ensure a joined up approach across community, regeneration and economic development.

APPENDICES

APPENDIX A: OPTION DRAWINGS

APPENDIX B: SILT SURVEY REPORT

APPENDIX C: HYDRAULIC MODELLING REPORT

APPENDIX D: SUPPORTING TECHNICAL INFORMATION

Twerton RAG Option Appraisal Matrix
Pulteney - Design and Construction Issues
Twerton - Design and Construction Issues
Technical Note: Twerton Sluices and Pulteney Weir and Radial Gate Fish Passage

APPENDIX E: PARTNERSHIP FUNDING CALCULATORS