Appraisal of Flood Levels Upstream of Avoncliff Weir Proposed Hydropower Scheme

April 2013

Environment Agency

Mott MacDonald

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description
A	March 2013	Shan Senthilkumaran	Marianne Piggott	Richard Gamble	First Issue
B	March 2013	Shan Senthilkumaran	Richard Gamble	Richard Gamble	Second issue
C	April 2013	Shan Senthilkumaran 	Sun Yan Evans	Sun Yan Evans 	Third Issue

Content

1. Introduction

1.1 Background

Two hydropower schemes have been proposed by different parties at the Avoncliff weir on the River Avon. The Environment Agency (EA) are obliged to determine both of these applications in accordance with their statutory obligations.

Proposed Scheme at North Mill – Earl Scheme

Mr Ewan Earl has proposed a hydropower generation scheme based on altering the existing weir at North Mill, Avoncliff between National grid references ST 80561 60112 and ST 80560 60103. This scheme includes the following structural elements;

(i) One 3.6 meter diameter 4-blade variable speed Archimedes turbine;

(ii) A 2m wide fish pass;

(iii) One 2.7 metre diameter 4-blade variable speed Archimedes turbine within the existing wheel-pit.

Relevant drawings NORTH MILL EARL Screw Sections 3-5-A3.pdf and NORTH MILL EARL Plan2Screws3-6-A3.pdf are included in Appendix C.

Proposed Scheme at Weavers Mill – Tarrant Scheme

Mr Martin Tarrant has proposed a hydropower generation scheme at Weavers Mill, Avoncliff between National grid references ST 80555 60045 and ST 80555 60054. This scheme includes:

(i) One Kaplan hydropower turbine;

(ii) A fish pass capable of passing 0.16m^3/s as per email received from the Environment Agency on 13th March 2013.

The drawings for the proposed scheme (WEAVERS MILL TARRANT Plan1.pdf and WEAVERS MILL TARRANT Plan2.pdf) are included in Appendix C.

1.2 Objectives

The EA commissioned Mott MacDonald to assess the impacts of these two proposed schemes on flood levels upstream of Avoncliff Weir. In agreement with the EA the existing hydraulic model (model reference BOA_014) developed in 2012 as part of the Bradford on Avon Flood Mapping Model was used for such assessment.

Flooding impacts due to these two schemes, in terms of changes in maximum water level from the baseline case, were assessed for a range of return periods of events (1 in 2, 5 , 10, 20, 50, 75, 100, 200 and 1000 year flood events, as well as the 1 in 100 year plus climate change event).

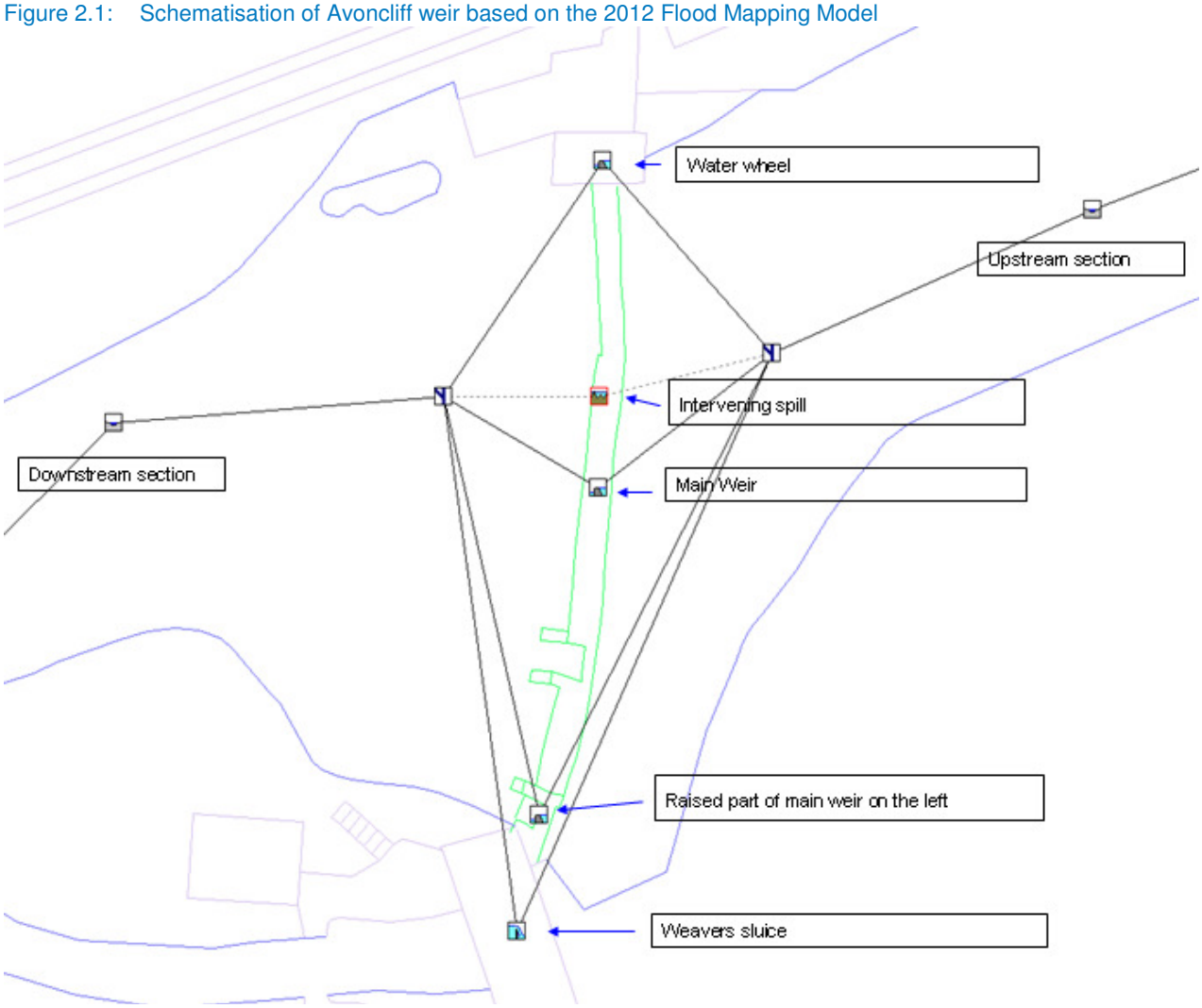
Results were then compared at key locations against the baseline scenario of model version BOA_014 from Bradford on Avon Flood Mapping Study (See Summary Sheets in Appendix A).

2. Assessment of Flood Levels Upstream of Avoncliff Weir

2.1 Existing Baseline Configuration of the Avoncliff Weir

The Avoncliff weir is located in the centre of Avoncliff, approximately 1.6km to the west of Bradford-On-Avon at Ordnance Survey grid reference 380562, 160087. Figure 2.1 shows the schematisation of the existing Avoncliff weir from the 2012 Bradford on Avon Flood Mapping Model.

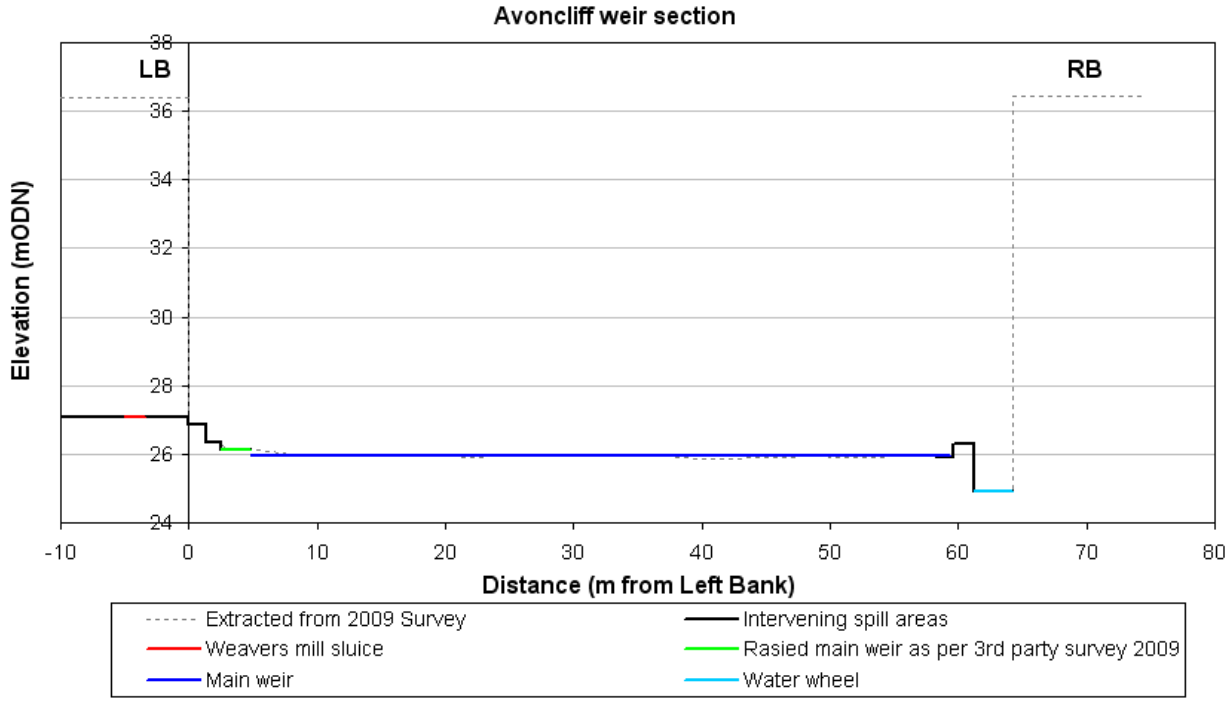
Figure 2.1: Schematisation of Avoncliff weir based on the 2012 Flood Mapping Model



Source: Mott MacDonald, March 2013

The baseline configuration of the weir is illustrated in Figure 2.2 below.

Figure 2.2: Baseline configuration of Avoncliff weir based on flood mapping study in 2012



Source: Mott MacDonald, March 2013

Key dimensions for the Avoncliff weir are shown in drawing ATL 1076 1009.dwg in Appendix C and also summarised in Table 2.1.

Table 2.1: Details of Avoncliff weir as per Mr Martin Tarrant topographic survey

Key components	Elevation of crest (mAOD)	Width of crest (m)
Weavers mill sluice (BOA3409_WR1U)	27.09	1.57
Main weir (BOA3409_WR3U)	25.97*	54.56
Raised part of main weir on the left (BOA3409_WR2U)	26.11	2.30
Intervening spill (BOA3409_SPU)	Variable crest elevations as shown in Figure 2.2	Variable crest elevations as shown in Figure 2.2
Existing water wheel (BOA3409_WR4U)	24.93	2.99

Source: Mott MacDonald, 2013

* Average crest level

ATL 1076 1009.dwg (See Appendix C)

2.2 Methodology and approach

Flow data for all design runs along the rivers was obtained from the 2012 Bradford on Avon Flood Modelling Study. Manning's roughness values and weir coefficients are tabulated in Appendix B.

Model runs have been undertaken to assess the impacts of the two schemes. For each scheme, two model configurations have been used in order to determine the maximum and minimum impact which each of the proposals is likely to have on flood levels. The configurations are:

I. Considering the maximum constriction to the flow; assuming sluice gates are fully shut at high flows to protect the turbines; and

II. Considering the minimum constriction to the flow; assuming sluice gates and turbines removed (as may occur during maintenance conditions).

2.3 Maximum constriction to the flow at North Mill – Earl Scheme

This approach has been adopted in order to assess the most critical (worst case) scenario with this scheme. Dimensions and sources of the information are summarised in Table 2.2. Following units were included in the model to represent the proposed scheme.

- Fish pass (BOA3409_FP1U);
- Top of sluice 3.6m diameter turbine (BOA3409_3.6U);
- Top of sluice 2.7m diameter turbine (BOA3409_2.7U) replaced the existing water wheel (BOA3409_WR4U) from 2012 Bradford on Avon Flood Modelling Study.

Dimensions for the existing spill unit BOA3409_SPU from the 2012 Bradford on Avon Flood Modelling Study were modified to include;

- Support to the fish pass;
- Support to the 3.6m diameter turbine;
- Plinth wall between 2 turbines; and
- Eel pass.

In addition, the length of the existing main weir (BOA3409_WR3U) was modified to match the proposed scheme. Dimensions for the remaining weir units representing the raised main weir as per the 3rd party survey 2009 (BOA3409_WR2U) and the Weavers Mill sluice (BOA3409_WR1U) were unchanged.

Details for the 3.6m diameter turbine, 2.7m diameter turbine, fish pass, plinth wall between 2 turbines and eel pass were abstracted from the survey data provided in the North Mill Earl submission (See Appendix C). Key dimensions are also tabulated in Table 2.2.

Table 2.2: Detail of proposed scheme at North Mill - Earl Scheme

Key components	Elevation of crest (mAOD)	Width of crest (m)	Modelling unit
Support to the fish pass	26.06	1.00	Included with spill unit (BOA3409_SPU)
Fish pass	26.08	2.00	Broad crested weir (BOA3409_FP1U)
Support to the 3.6m diameter turbine	28.88*	0.35	Included with spill unit (BOA3409_SPU)
Top of sluice 3.6m diameter turbine	28.88*	4.10	Broad crested weir (BOA3409_3.6U)
Plinth wall between 2 turbines	28.88*	2.21 (0.35+1.56+0.30)	Included with spill unit (BOA3409_SPU)
Top of sluice 2.7m diameter turbine	28.88*	2.70	Broad crested weir (BOA3409_2.7U)
Eel pass	24.93	0.12	Included with spill unit (BOA3409_SPU)

Source: Mott MacDonald, 2013

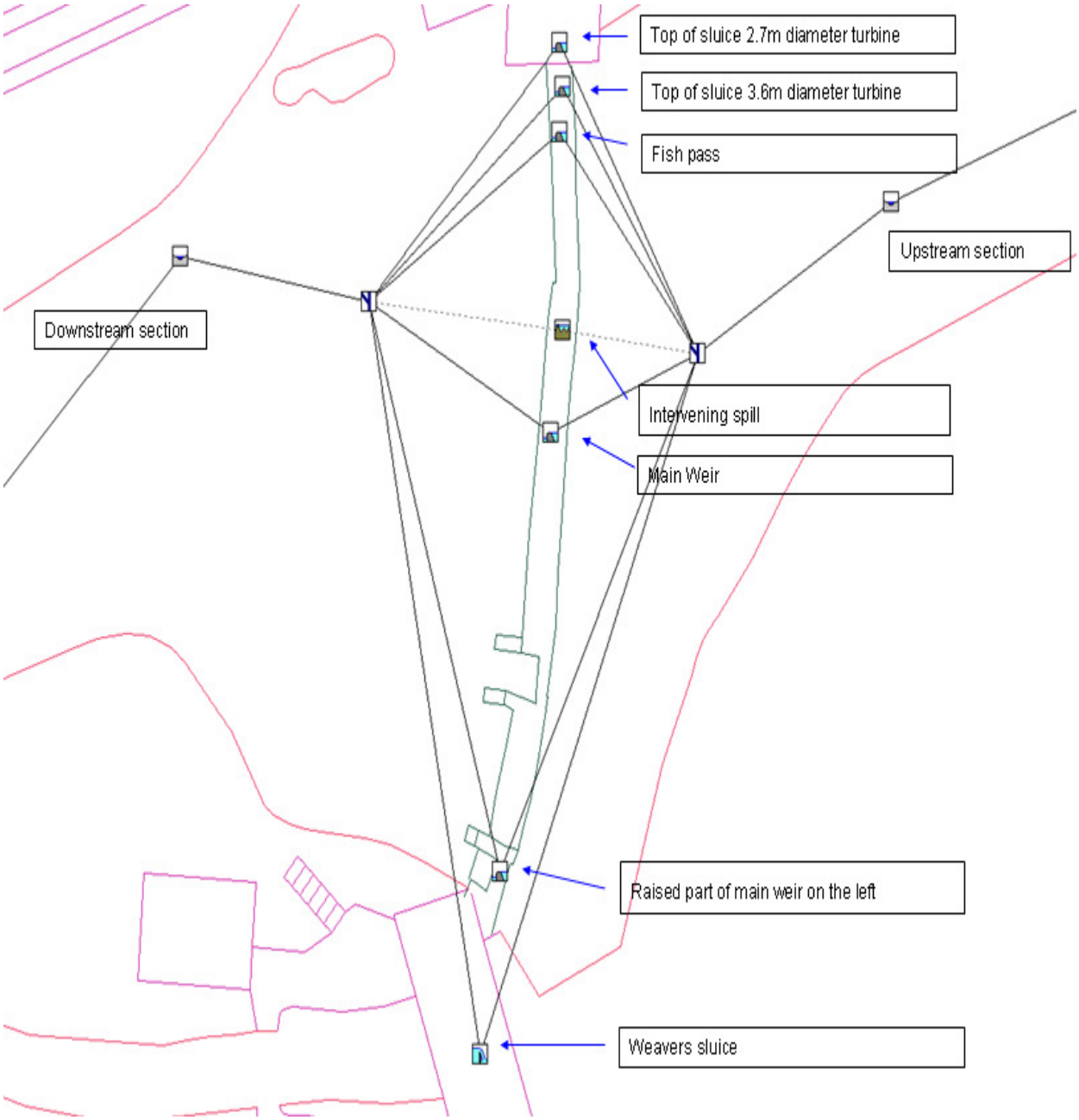
NORTH MILL EARL Plan2Screws3-6-A3.pdf (See Appendix C)

NORTH MILL EARL Hydro Project Elevations 3-5-A3.pdf (See Appendix C)

*Elevations of crest for support to the 3.6m diameter turbine, top of sluice of 3.6m diameter turbine, plinth wall between two turbines, and top of sluice of 2.7m diameter turbines were measured from scale drawings NORTH MILL EARL Hydro Project Elevations 3-5-A3.pdf.

Figure 2.3 shows the schematisation of the North Mill scheme to represent the maximum constriction scenario.

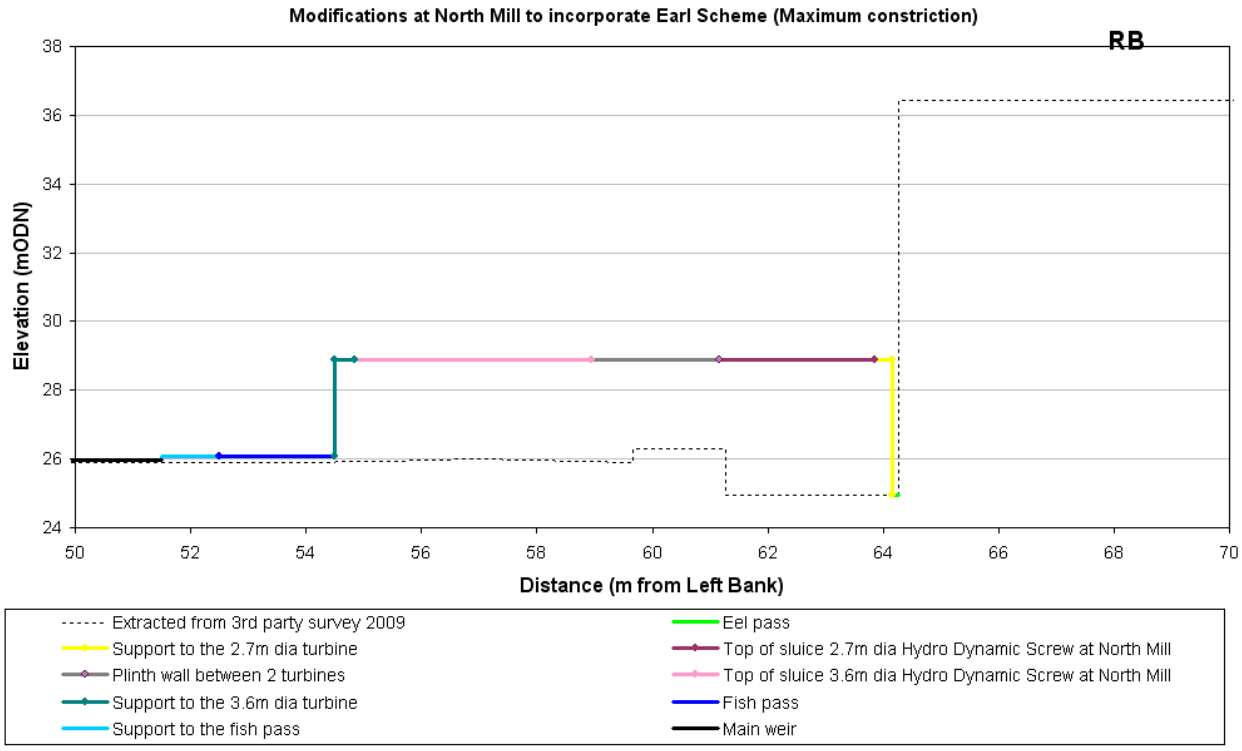
Figure 2.3: Schematisation of the North Mill - Earl Scheme



Source: Mott MacDonald, March 2013

Figure 2.4 indicates the modifications that were made at North Mill to represent the maximum constriction scenario.

Figure 2.4: Modification to the North Mill - Earl Scheme



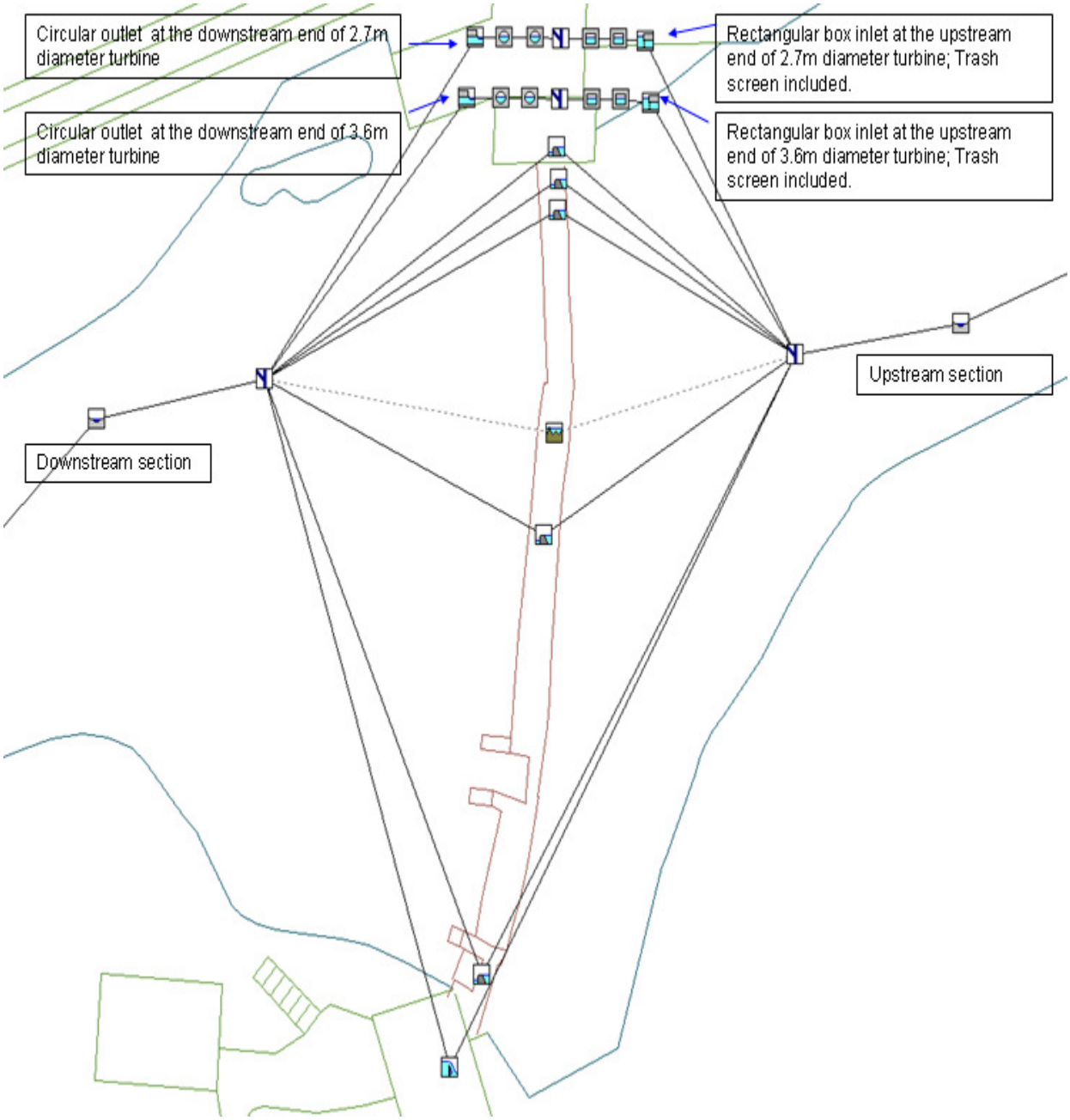
Source: Mott MacDonald, March 2013

2.4 Minimum constriction to the flow at North Mill - Earl Scheme

This modelling includes further details of 3.6m and 2.7m diameter hydrodynamic screws in order to assess the minimum constriction to the flow over the Avoncliff weir by including the openings of the two turbines.

Figure 2.5 shows the schematisation of the North Mill scheme to represent the minimum constriction scenario.

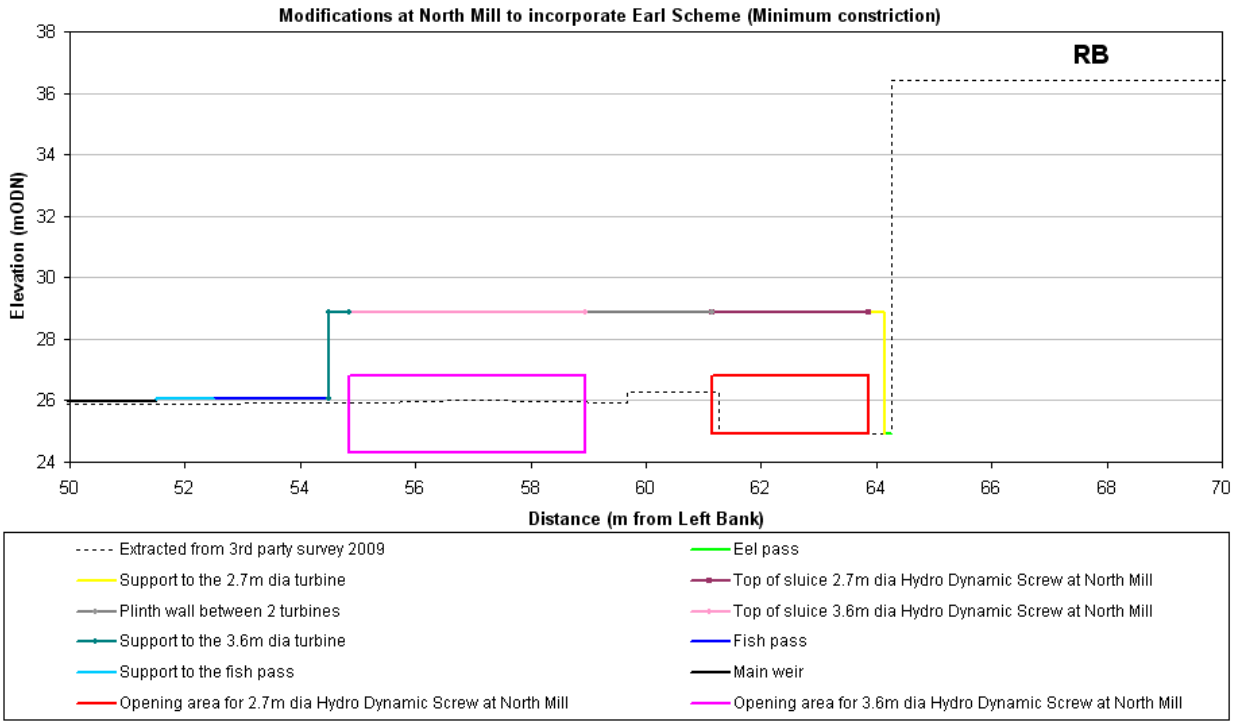
Figure 2.5: Schematisation of the North Mill - Earl Scheme



Source: Mott MacDonald, March 2013

Figure 2.6 indicates the modifications that were made at North Mill to represent the minimum constriction scenario.

Figure 2.6: Modifications to the North Mill – Earl Scheme



Source: Mott MacDonald, March 2013

Details of 3.6m and 2.7m diameter hydrodynamic screws at North Mill were provided in the North Mill Earl submission (See Appendix C). Key dimensions are also tabulated in Table 2.3.

Table 2.3: Detail of proposed scheme at North Mill - Earl Scheme

Key components	Elevation of invert (mAOD)	Dimension of culvert (m)	Modelling unit
Rectangular box inlet at the upstream end of 3.6m diameter turbine	Upstream = 24.29 Downstream = 24.29	Width = 4.10 Height = 2.51 Length = 6.60	Rectangular box culvert
Circular outlet at the downstream end of 3.6m diameter turbine	Upstream = 24.29 Downstream = 21.82	Diameter = 3.60 Length = 6.16	Circular culvert
Rectangular box inlet at the upstream end of 2.7m diameter turbine	Upstream = 24.93 Downstream = 24.93	Width = 2.70 Height = 1.87 Length = 6.60	Rectangular box culvert
Circular outlet at the downstream end of 2.7m diameter turbine	Upstream = 24.93 Downstream = 22.78	Diameter = 2.70 Length = 6.48	Circular culvert

Source: Mott MacDonald, 2013

NORTH MILL EARL Screw Sections 3-5-A3.pdf (See Appendix C)

NORTH MILL EARL Plan2Screws3-6-A3.pdf (See Appendix C)

2.5 Maximum constriction to the flow at Weavers Mill - Tarrant Scheme

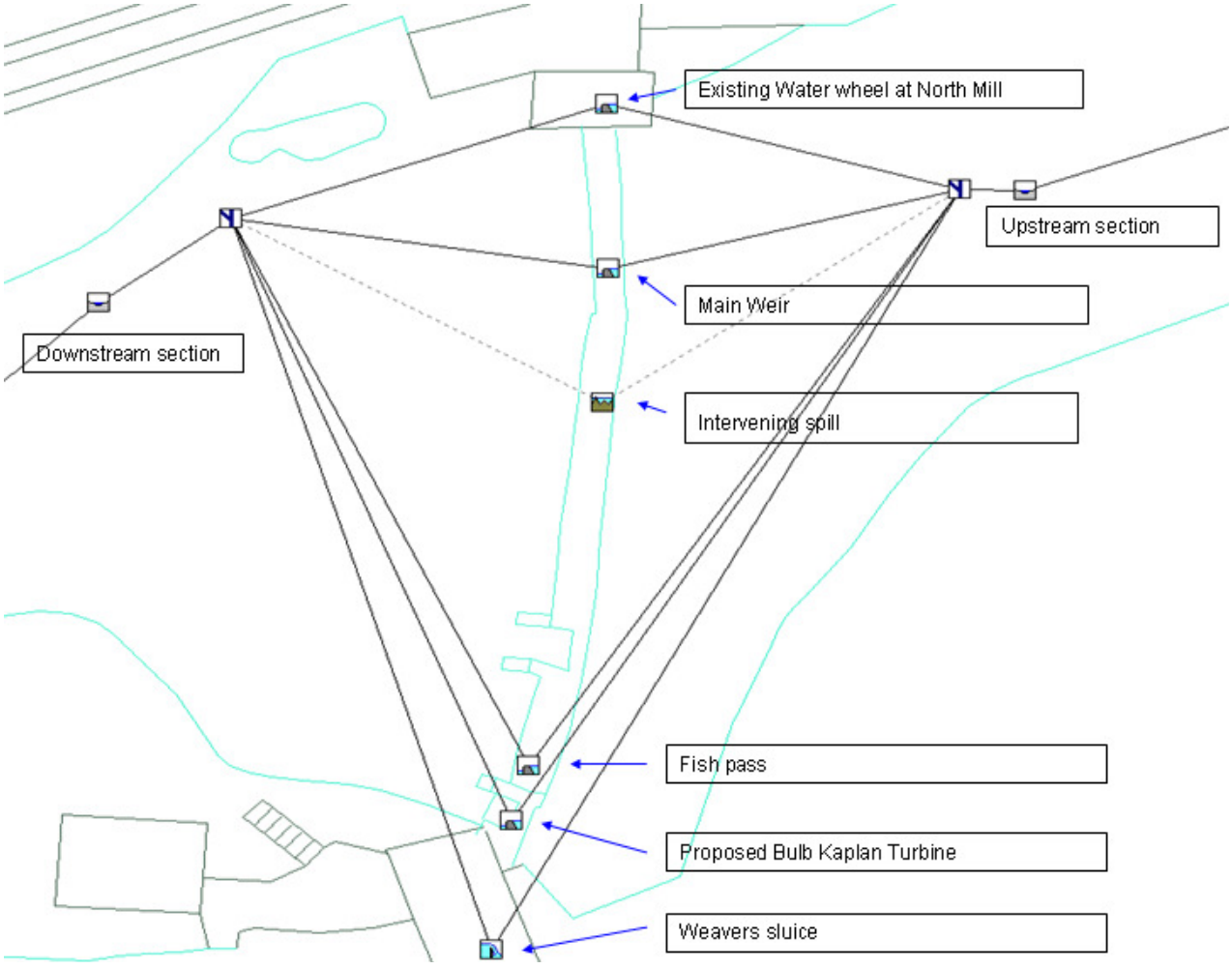
Dimensions and the sources of the drawings are summarised in Table 2.4 . The following units were included in the model to represent the proposed scheme.

- Fish pass (BOA3409_WMFU); and
- Top of sluice 2.5m width sluice (BOA3409_WMU).

Dimensions for the existing spill unit BOA3409_SPU from the 2012 Bradford on Avon Flood Modelling Study were modified to include the support to the Kaplan Turbine.

In addition, the length of the existing main weir (BOA3409_WR3U) was modified to match the proposed scheme. Dimensions for the remaining weir units representing the water wheel as per the 3rd party survey 2009 (BOA3409_WR4U) and Weavers Mill sluice (BOA3409_WR1U) were unchanged. Figure 2.8 shows the schematisation of the Weavers Mill scheme to represent the maximum constriction scenario.

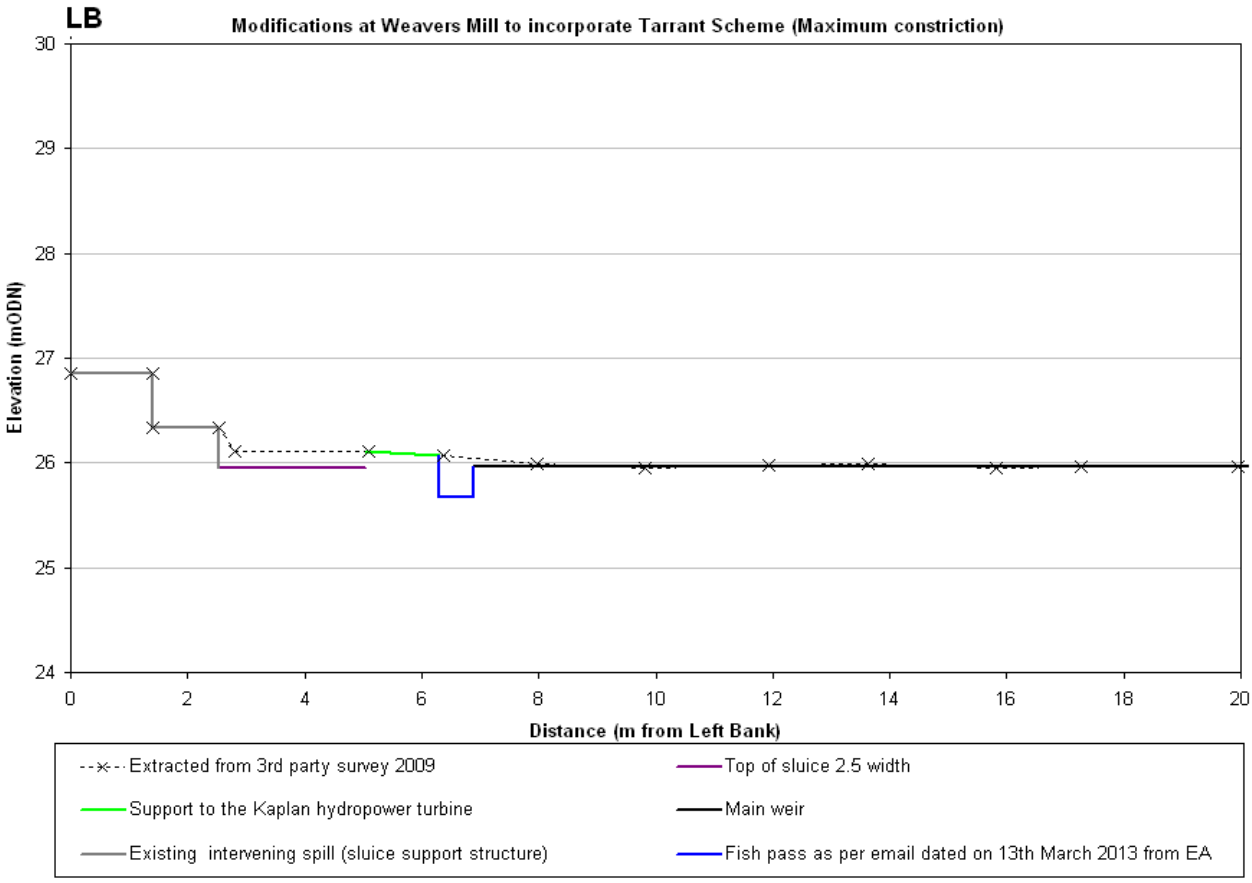
Figure 2.7: Schematisation of the Weavers Mill – Tarrant Scheme



Source: Mott MacDonald, March 2013

Figure 2.8 indicates the modifications that were made at the Weavers Mill to represent the maximum constriction scenario.

Figure 2.8: Modification to the Weavers Mill – Tarrant Scheme



Source: Mott MacDonald, March 2013

Details of the Kaplan hydropower turbine were abstracted from the survey data provided by the Tarrant submission (See Appendix C). Details of fish pass were obtained following discussions with Environment Agency on 13th March 2013. Key dimensions are also tabulated in Table 2.4.

Table 2.4: Detail of proposed scheme at the Weavers Mill - Tarrant Scheme

Key components	Elevation of crest (mAOD)	Width of crest (m)	Modelling unit
Top of sluice 2.5m width	25.95	2.50	Broad crested weir (BOA3409_WMU)
Support to the Kaplan hydropower turbine	Variable crest levels as shown in Figure 2.8	1.27	Include with spill unit (BOA3409_SPU)
Fish pass	25.67	0.58	Broad crested weir (BOA3409_WMFU)

Source: Mott MacDonald, 2013

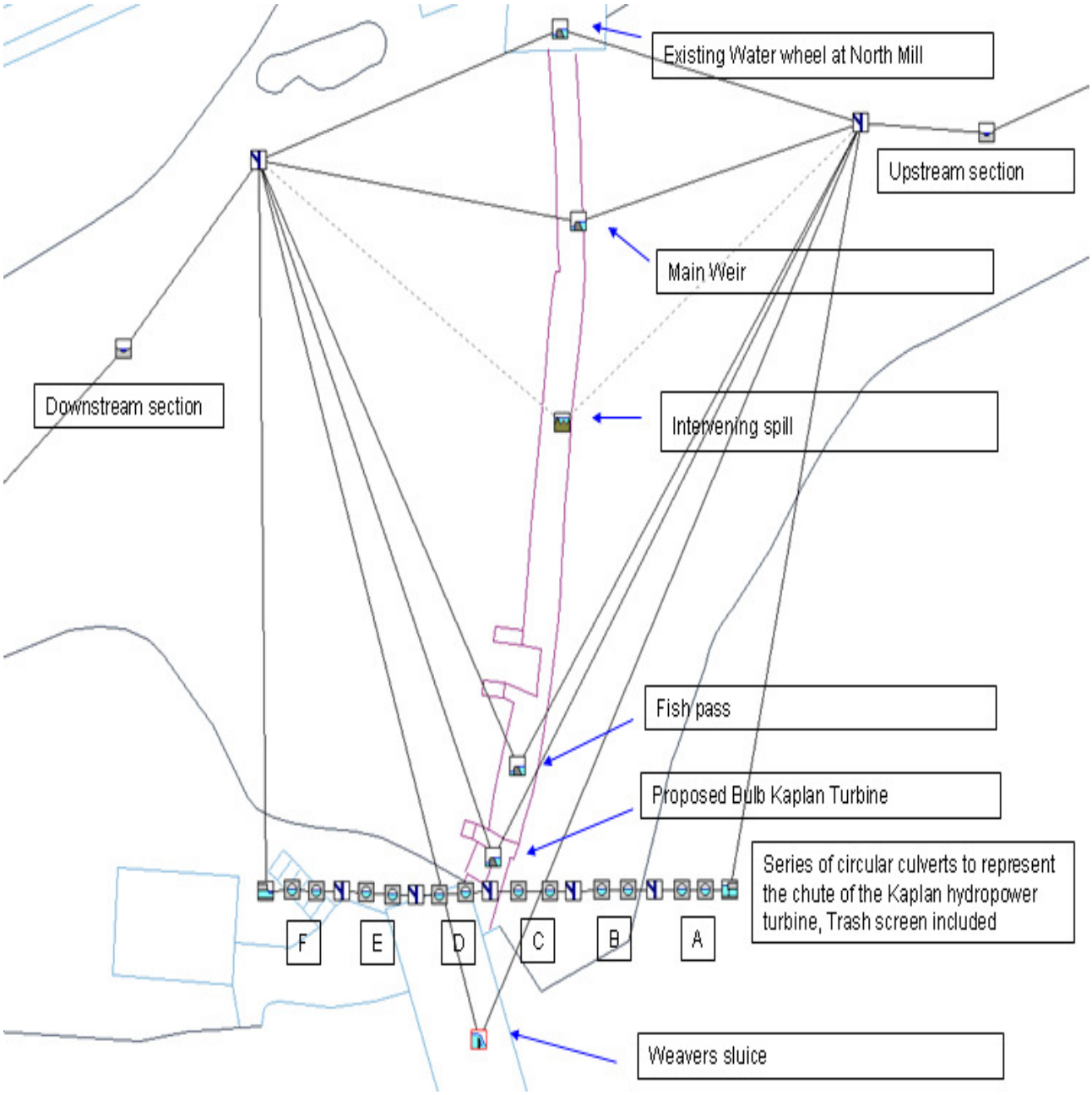
WEAVERS MILL TARRANT Plan1.pdf (See Appendix C)

WEAVERS MILL TARRANT Plan2.pdf (See Appendix C)

2.6 Minimum constriction to the flow at Weavers Mill - Tarrant Scheme

Figure 2.9 shows the schematisation of the Weavers Mill scheme to represent the minimum constriction scenario.

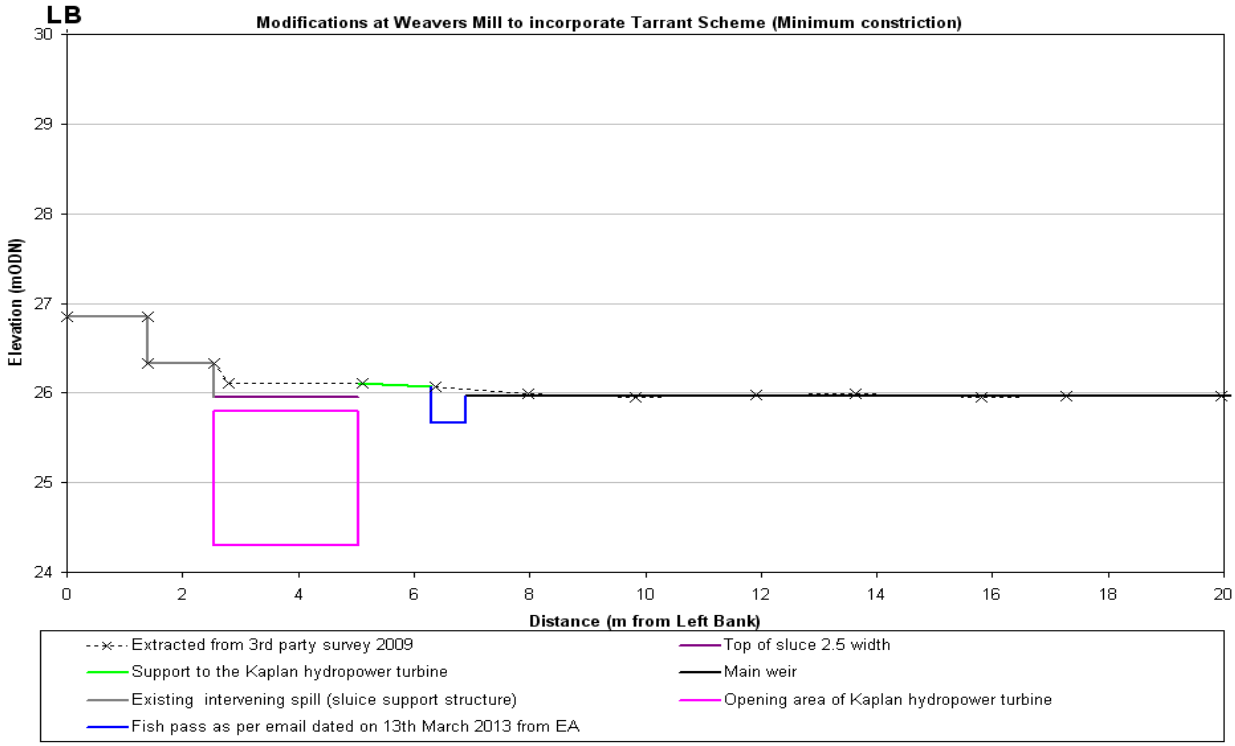
Figure 2.9: Schematisation of the Weavers Mill – Tarrant Scheme



Source: Mott MacDonald, March 2013

The minimum constriction scenario at Weavers Mill includes the open area of the Kaplan hydropower turbine as shown on Figure 2.10.

Figure 2.10: Modifications to the Weavers Mill – Tarrant Scheme



Source: Mott MacDonald, March 2013

In addition to the details included in the Table 2.4, circular culverts were included in the model to represent the chute of the Kaplan hydropower turbine as provided in Table 2.5.

Table 2.5: Detail of proposed scheme at Weavers Mill - Tarrant Scheme

Key components	Elevation of invert (mAOD)	Dimension of culvert (m)	Modelling unit
A	Upstream = 24.30 Downstream = 23.43	Diameter = 2.50 Length = 6.95	Circular culvert (BOA3409WMd1)
B	Upstream = 23.43 Downstream = 23.28	Diameter = 1.85 Length = 1.00	Circular culvert (BOA3409WMdB)
C	Upstream = 23.28 Downstream = 23.21	Diameter = 1.20 Length = 0.50	Circular culvert (BOA3409WMdD)
D	Upstream = 23.21 Downstream = 22.83	Diameter = 1.40 Length = 2.50	Circular culvert (BOA3409WMdE)
E	Upstream = 22.83 Downstream = 22.56	Diameter = 1.92 Length = 1.83	Circular culvert (BOA3409WMdG)
F	Upstream = 22.56 Downstream = 22.28	Diameter = 2.54 Length = 1.83	Circular culvert (BOA3409WMdJ)

Source: Mott MacDonald, 2013

WEAVERS MILL TARRANT Plan2.pdf (See Appendix C)

3. Summary of results

For the two alternative proposals, modelled water levels for the maximum constriction and minimum constriction scenarios were compared with the baseline scenario results.

Both schemes were tested for a range of flood events; i.e. 1 in 2, 5, 10, 20, 25, 50, 75, 100, 200 and 1000 year events as well as the 1 in 100 year plus climate change event. The outputs from these model runs indicate the full range of impacts that each scheme would have on peak water levels during flood events. The following observations can be made from the above tests.

The North Mill Earl Scheme would have the following impacts:

- Over the full range of events tested, the water level could increases by up to 0.20 m and decreases by up to 0.15 m immediately upstream of Avoncliff weir for the maximum restriction to the flow and minimum restriction to the flow scenarios respectively.

- Over the full range of events tested, the water level could increases by up to 0.10 m and decreases by up to 0.07 m in the main river closest to the rowing club for the scenarios of maximum restriction to the flow and minimum restriction to the flow respectively.

The Weavers Mill Tarrant Scheme would have the following impacts:

- Over the full range of events tested, the water level could increases by up to 0.01 m and decreases by up to 0.05 m immediately upstream of Avoncliff weir for the maximum restriction to the flow and minimum restriction to the flow scenarios respectively.

- Over the full range of events tested, the water level could increases by up to 0.01m and decreases by up to 0.03 m in the main river closest to the rowing club for the scenarios of maximum restriction to the flow and minimum restriction to the flow respectively.

Detailed water level comparisons are included in Appendix A.

4. Key assumptions and limitations

Key assumptions and limitations with the input data and the modelling techniques are outlined below:

- Flow data for all design runs along the rivers was obtained from the 2012 Bradford on Avon Flood Modelling Study as agreed with the Environment Agency.
- The sluice gate under Weavers Mill at Avoncliff Weir is assumed to be closed for the entire duration of the events as this structure is not operated by the Environment Agency and not maintained as a flood defence structure.
- The channel geometry, weir crest level and configuration are based on topographic survey captured by ATL Hydro dated 11/10/2009. This topographic survey was not intended for the purpose of hydraulic modelling therefore assumptions have been made in the extraction of spot levels from the plan survey drawing.
- The river channel downstream of the Weir to the upstream face of the Viaduct has been modelled in 1D ISIS between the railway on the left bank and the track in front of the Public House on the right bank assuming a single water level and velocity at the downstream cross-section. Therefore, any variation in water level and velocity in the tail race, which flows under Weavers Mill before rejoining the River Avon downstream of River House, has not been considered in the BOA_014 model.
- The head losses at Barton Bridge have been combined at the rail bridge 95 m upstream to reduce model instability. However, water levels and flows on the adjacent floodplain are not significantly affected as Barton Bridge is quickly drowned out even under QMED flows (approximately a 1 in 2 chance of flooding in any given year) and the results match well with recorded historic flood data.
- All flow would pass through Freshford Rail Bridge. The model results did not predict that flood water would overtop the adjacent railway embankment even during the 1 in 1000 year flood thus validating this assumption.
- All culverts and bridge structures would be blockage free for the design defended scenario as per ABD guidance.
- The competing hydropower schemes are assumed to be independent of one another. Therefore the two schemes will be modelled separately. An assessment of the combined effect of the development both schemes will not be assessed.

Other assumptions made during the modelling process are listed below:

- The flow distribution between Feeder Leat and the main River Avon at Greenlands Weir is based on the geometry of the channels as the actual distribution is unknown. However, as all flow returns to River Avon by the railway bridge it is not expected to affect the model at the Rowing Club, Bradford-on-Avon Gauge and Avoncliff Weir.
- Momentum transfer between the 1D and 2D connections, i.e. between ISIS and TUFLOW, is not fully considered. Although in most simulations this is not of concern, it does influence the model results where a large structure (relative to the 2D grid size) is modelled as a 1D element.
- In areas of super-critical flow through the 2D and 1D domains, the results should be treated with caution, particularly if they are in key areas of interest. Hydraulic jumps and surcharging against obstructions may occur in reality. These highly localised 3D effects could not be adequately modelled using TUFLOW as a 2D modelling software.

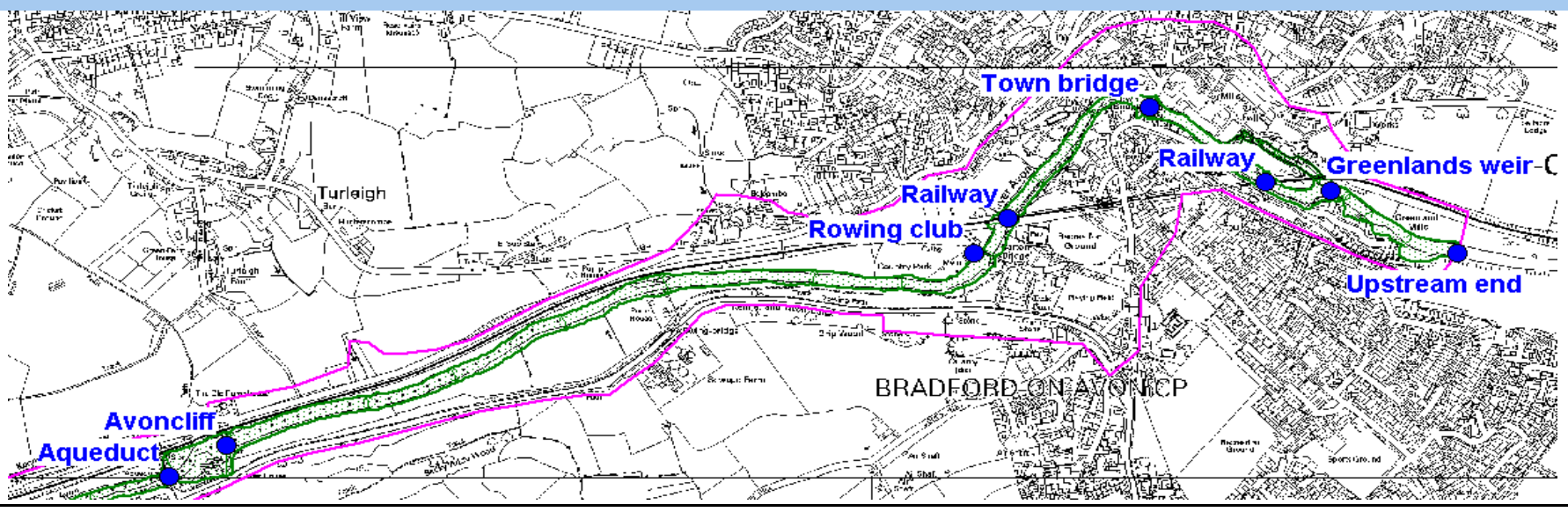
- No attempt has been made to identify areas that are affected by flooding from urban drainage systems. Assessments of areas susceptible to drainage system inadequacies or localised ponding or debris blockage are not included.
- Fences and property walls in the urban areas have not been considered as they are not classified as formal flood defences.
- The 2D model has a grid size of 5 m, which does not necessarily pick up all small-scale features that may have an impact on the flow path and/or conveyance. However, key flow paths have been included in the 2D model as 3D break lines such as the alleyway at the Bullpit.

Appendices

Appendix A. Summary Water Levels Tables

AVONCLIFF HYDROPOWER SCHEME
NORTH MILL SCHEME - EARL

LOCATION PLAN



WATER LEVEL COMPARISON (mAOD)

Description (Distance form Avoncliff weir)	Node Label	Return Period (Years)	BOA baseline scenario, 2012	North Mill Scheme (Earl) - Maximum Constriction	Difference in water level (m)	North Mill Scheme (Earl) - Minimum Constriction	Difference in water level (m)	Return Period (Years)	BOA baseline scenario, 2012	North Mill Scheme (Earl) - Maximum Constriction	Difference in water level (m)	North Mill Scheme (Earl) - Minimum Constriction	Difference in water level (m)
Upstream End (3384 m)	BOA6605	1 in 2 year	29.15	29.15	0.00	29.15	0.00	1 in 5 year	29.58	29.60	0.02	29.58	0.00
Greenlands Weir (3049 m)	BOA6270D		28.64	28.68	0.04	28.62	-0.02		29.15	29.18	0.03	29.14	0.00
Railway Bridge (2909 m)	BOA6130D		28.51	28.55	0.05	28.48	-0.03		28.99	29.03	0.03	28.99	0.00
Town Bridge (2589 m)	BOA5810D		28.14	28.21	0.07	28.10	-0.04		28.58	28.62	0.04	28.57	-0.01
Railway Bridge (2119 m)	BOA5340D		27.84	27.93	0.09	27.78	-0.06		28.23	28.29	0.06	28.22	-0.01
Rowing Club (2024 m)	BOA5245D		27.79	27.89	0.10	27.72	-0.07		28.21	28.27	0.06	28.20	-0.01
Avoncliff	BOA3409U		27.22	27.41	0.20	27.07	-0.15		27.59	27.70	0.12	27.57	-0.02
Aquaduct (188 m - DS)	BOA3246D		26.46	26.46	0.00	26.46	0.00		26.97	26.97	0.00	26.97	0.00
Upstream End (3384 m)	BOA6605	1 in 10 year	29.92	29.94	0.02	29.92	0.00	1 in 20 year	30.24	30.25	0.02	30.24	0.00
Greenlands Weir (3049 m)	BOA6270D		29.49	29.52	0.03	29.50	0.00		29.81	29.84	0.03	29.81	0.00
Railway Bridge (2909 m)	BOA6130D		29.33	29.36	0.03	29.33	0.00		29.63	29.66	0.03	29.64	0.00
Town Bridge (2589 m)	BOA5810D		28.88	28.91	0.04	28.88	0.00		29.12	29.16	0.04	29.12	0.00
Railway Bridge (2119 m)	BOA5340D		28.50	28.56	0.06	28.50	0.00		28.74	28.80	0.06	28.74	0.00
Rowing Club (2024 m)	BOA5245D		28.49	28.55	0.06	28.49	0.00		28.74	28.81	0.07	28.75	0.01
Avoncliff	BOA3409U		27.86	27.98	0.12	27.87	0.00		28.09	28.22	0.13	28.10	0.01
Aquaduct (188 m - DS)	BOA3246D		27.24	27.24	0.00	27.24	0.00		27.42	27.41	-0.01	27.42	0.00
Upstream End (3384 m)	BOA6605	1 in 50 year	30.68	30.70	0.02	30.68	0.00	1 in 75 year	30.90	30.90	0.00	30.88	-0.02
Greenlands Weir (3049 m)	BOA6270D		30.26	30.29	0.03	30.26	0.01		30.45	30.48	0.03	30.46	0.01
Railway Bridge (2909 m)	BOA6130D		30.06	30.09	0.03	30.06	0.00		30.24	30.28	0.03	30.25	0.00
Town Bridge (2589 m)	BOA5810D		29.46	29.50	0.04	29.46	0.01		29.61	29.65	0.05	29.61	0.01
Railway Bridge (2119 m)	BOA5340D		29.07	29.13	0.06	29.08	0.01		29.22	29.28	0.06	29.24	0.01
Rowing Club (2024 m)	BOA5245D		29.08	29.14	0.07	29.09	0.01		29.23	29.30	0.07	29.24	0.01
Avoncliff	BOA3409U		28.40	28.52	0.12	28.43	0.02		28.54	28.67	0.12	28.58	0.04
Aquaduct (188 m - DS)	BOA3246D		27.67	27.67	-0.01	27.67	0.00		27.78	27.79	0.01	27.77	-0.01
Upstream End (3384 m)	BOA6605	1 in 100 year	31.01	31.04	0.04	31.02	0.01	1 in 100 year + Climate Change	31.59	31.61	0.02	31.59	0.01
Greenlands Weir (3049 m)	BOA6270D		30.59	30.63	0.04	30.60	0.01		31.16	31.18	0.02	31.17	0.01
Railway Bridge (2909 m)	BOA6130D		30.38	30.41	0.03	30.38	0.00		30.88	30.92	0.04	30.90	0.02
Town Bridge (2589 m)	BOA5810D		29.72	29.78	0.05	29.73	0.01		30.36	30.43	0.06	30.39	0.02
Railway Bridge (2119 m)	BOA5340D		29.33	29.39	0.07	29.34	0.01		29.81	29.89	0.07	29.84	0.03
Rowing Club (2024 m)	BOA5245D		29.34	29.41	0.07	29.36	0.02		29.85	29.95	0.09	29.89	0.03
Avoncliff	BOA3409U		28.65	28.77	0.13	28.68	0.03		29.17	29.31	0.14	29.23	0.06
Aquaduct (188 m - DS)	BOA3246D		27.86	27.86	0.01	27.86	0.01		28.32	28.32	0.00	28.32	0.00
Upstream End (3384 m)	BOA6605	1 in 200 year	31.44	31.45	0.01	31.44	0.00	1 in 1000 year	32.07	32.08	0.01	32.07	0.00
Greenlands Weir (3049 m)	BOA6270D		30.96	31.00	0.04	30.98	0.02		31.62	31.64	0.02	31.62	0.00
Railway Bridge (2909 m)	BOA6130D		30.69	30.74	0.05	30.71	0.02		31.24	31.27	0.03	31.25	0.00
Town Bridge (2589 m)	BOA5810D		30.12	30.19	0.07	30.15	0.03		30.70	30.78	0.07	30.74	0.04
Railway Bridge (2119 m)	BOA5340D		29.63	29.71	0.08	29.66	0.03		30.40	30.47	0.07	30.42	0.03
Rowing Club (2024 m)	BOA5245D		29.64	29.73	0.09	29.67	0.03		30.40	30.47	0.07	30.42	0.02
Avoncliff	BOA3409U		28.95	29.09	0.15	29.00	0.05		29.74	29.86	0.12	29.79	0.05
Aquaduct (188 m - DS)	BOA3246D		28.08	28.10	0.02	28.10	0.01		28.79	28.79	0.00	28.78	-0.02

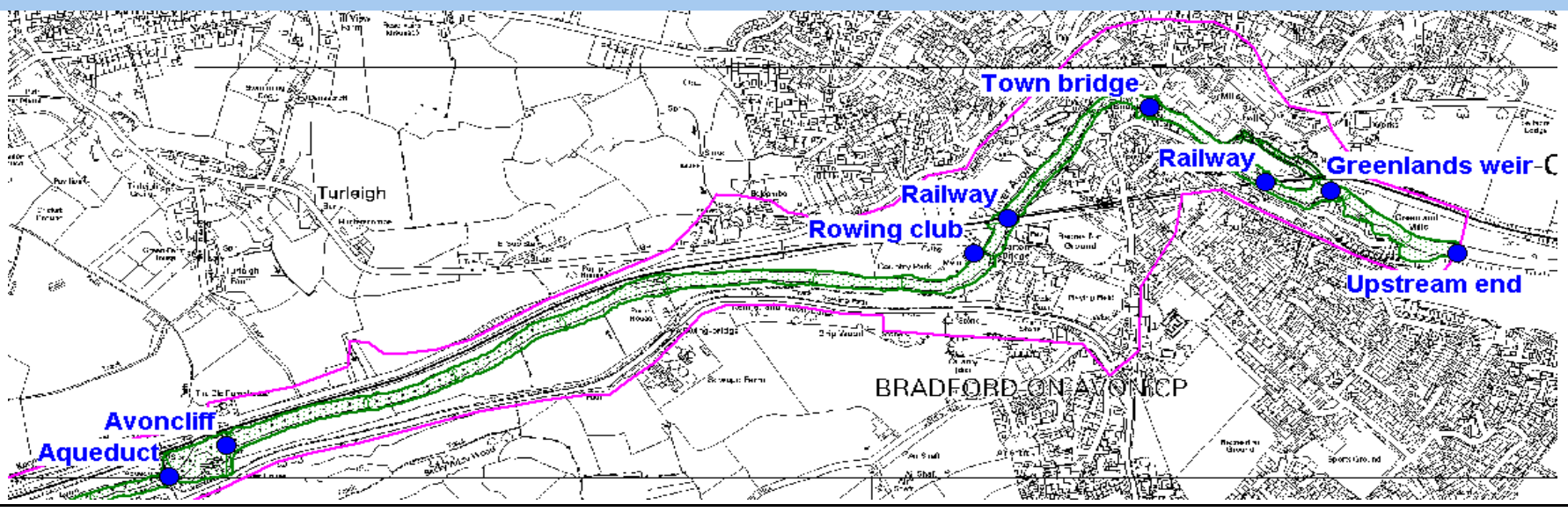
SUMMARY

• Over the full range of events tested, the water level could increases by up to 0.20 m and decreases by up to 0.15 m immediately upstream of Avoncliff weir for the maximum restriction to the flow and minimum restriction to the flow scenarios respectively.
• Over the full range of events tested, the water level could increases by up to 0.10 m and decreases by up to 0.07 m in the main river closest to the rowing club for the scenarios of maximum restriction to the flow and minimum restriction to the flow respectively.
• The impact on water levels upstream of Avoncliff weir is reduced for higher magnitude events.

Revision Record				
Revision	**Date**	**Modeller**	**Checker**	**Approver**
1	21/03/2013	SSK	SYE	RJG
2	22/03/2013	SSK	SYE	RJG

AVONCLIFF HYDROPOWER SCHEME
WEAVERS MILL SCHEME - TARRANT

LOCATION PLAN



WATER LEVEL COMPARISON (mAOD)

Description (Distance form Avoncliff weir)	Node Label	Return Period (Years)	BOA baseline scenario, 2012	Weavers Mill Scheme (Tarrant) - Maximum Constriction	Difference in water level (m)	Weavers Mill Scheme (Tarrant) - Minimum Constriction	Difference in water level (m)	Return Period (Years)	BOA baseline scenario, 2012	Weavers Mill Scheme (Tarrant) - Maximum Constriction	Difference in water level (m)	Weavers Mill Scheme (Tarrant) - Minimum Constriction	Difference in water level (m)
Upstream End (3384 m)	BOA6605	1 in 2 year	29.15	29.15	0.00	29.15	0.00	1 in 5 year	29.58	29.58	0.00	29.58	0.00
Greenlands Weir (3049 m)	BOA6270D		28.64	28.64	0.00	28.63	-0.01		29.15	29.15	0.00	29.14	0.00
Railway Bridge (2909 m)	BOA6130D		28.51	28.51	0.00	28.49	-0.01		28.99	29.00	0.00	28.99	0.00
Town Bridge (2589 m)	BOA5810D		28.14	28.15	0.00	28.13	-0.02		28.58	28.58	0.00	28.57	-0.01
Railway Bridge (2119 m)	BOA5340D		27.84	27.84	0.00	27.81	-0.02		28.23	28.23	0.00	28.22	-0.01
Rowing Club (2024 m)	BOA5245D		27.79	27.79	0.00	27.77	-0.03		28.21	28.21	0.00	28.20	-0.01
Avoncliff	BOA3409U		27.22	27.22	0.00	27.16	-0.05		27.59	27.59	0.00	27.57	-0.02
Aquaduct (188 m - DS)	BOA3246D		26.46	26.46	0.00	26.46	0.00		26.97	26.97	0.00	26.97	0.00
Upstream End (3384 m)	BOA6605	1 in 10 year	29.92	29.92	0.00	29.92	0.00	1 in 20 year	30.24	30.24	0.00	30.23	0.00
Greenlands Weir (3049 m)	BOA6270D		29.49	29.50	0.00	29.49	0.00		29.81	29.81	0.00	29.81	0.00
Railway Bridge (2909 m)	BOA6130D		29.33	29.33	0.00	29.33	0.00		29.63	29.63	0.00	29.63	-0.01
Town Bridge (2589 m)	BOA5810D		28.88	28.88	0.00	28.87	-0.01		29.12	29.12	0.00	29.11	-0.01
Railway Bridge (2119 m)	BOA5340D		28.50	28.50	0.00	28.49	-0.01		28.74	28.74	0.00	28.73	-0.01
Rowing Club (2024 m)	BOA5245D		28.49	28.49	0.00	28.48	-0.01		28.74	28.74	0.00	28.73	-0.01
Avoncliff	BOA3409U		27.86	27.87	0.00	27.84	-0.02		28.09	28.09	0.00	28.07	-0.02
Aquaduct (188 m - DS)	BOA3246D		27.24	27.24	0.00	27.24	0.00		27.42	27.42	0.00	27.42	0.00
Upstream End (3384 m)	BOA6605	1 in 50 year	30.68	30.68	0.00	30.67	0.00	1 in 75 year	30.90	30.88	-0.02	30.88	-0.02
Greenlands Weir (3049 m)	BOA6270D		30.26	30.25	0.00	30.25	0.00		30.45	30.45	0.00	30.45	0.00
Railway Bridge (2909 m)	BOA6130D		30.06	30.05	0.00	30.05	-0.01		30.24	30.24	0.00	30.24	-0.01
Town Bridge (2589 m)	BOA5810D		29.46	29.45	0.00	29.45	-0.01		29.61	29.60	0.00	29.59	-0.01
Railway Bridge (2119 m)	BOA5340D		29.07	29.07	0.00	29.06	-0.01		29.22	29.22	0.00	29.21	-0.02
Rowing Club (2024 m)	BOA5245D		29.08	29.08	0.00	29.07	-0.01		29.23	29.22	-0.01	29.22	-0.01
Avoncliff	BOA3409U		28.40	28.40	0.00	28.39	-0.02		28.54	28.55	0.00	28.53	-0.02
Aquaduct (188 m - DS)	BOA3246D		27.67	27.67	-0.01	27.67	0.00		27.78	27.77	-0.01	27.77	-0.01
Upstream End (3384 m)	BOA6605	1 in 100 year	31.01	31.01	0.00	31.01	0.00	1 in 100 year + Climate Change	31.59	31.59	0.00	31.59	0.00
Greenlands Weir (3049 m)	BOA6270D		30.59	30.59	-0.01	30.59	-0.01		31.16	31.16	0.00	31.16	0.00
Railway Bridge (2909 m)	BOA6130D		30.38	30.38	0.00	30.37	-0.01		30.88	30.89	0.01	30.89	0.01
Town Bridge (2589 m)	BOA5810D		29.72	29.72	0.00	29.72	-0.01		30.36	30.37	0.00	30.36	0.00
Railway Bridge (2119 m)	BOA5340D		29.33	29.33	0.00	29.32	-0.01		29.81	29.82	0.00	29.81	-0.01
Rowing Club (2024 m)	BOA5245D		29.34	29.34	0.00	29.33	-0.01		29.85	29.85	0.00	29.84	-0.01
Avoncliff	BOA3409U		28.65	28.65	0.00	28.63	-0.02		29.17	29.18	0.01	29.16	-0.01
Aquaduct (188 m - DS)	BOA3246D		27.86	27.85	-0.01	27.86	0.01		28.32	28.32	0.00	28.32	0.00
Upstream End (3384 m)	BOA6605	1 in 200 year	31.44	31.42	-0.02	31.43	-0.02	1 in 1000 year	32.07	32.06	-0.01	32.06	-0.01
Greenlands Weir (3049 m)	BOA6270D		30.96	30.96	0.00	30.96	0.00		31.62	31.61	-0.01	31.60	-0.01
Railway Bridge (2909 m)	BOA6130D		30.69	30.69	0.00	30.68	0.00		31.24	31.23	-0.01	31.23	-0.02
Town Bridge (2589 m)	BOA5810D		30.12	30.13	0.01	30.12	0.00		30.70	30.72	0.02	30.72	0.01
Railway Bridge (2119 m)	BOA5340D		29.63	29.63	0.00	29.62	-0.01		30.40	30.39	0.00	30.39	-0.01
Rowing Club (2024 m)	BOA5245D		29.64	29.65	0.01	29.64	0.00		30.40	30.39	-0.01	30.39	-0.01
Avoncliff	BOA3409U		28.95	28.95	0.01	28.94	-0.01		29.74	29.74	0.00	29.73	-0.01
Aquaduct (188 m - DS)	BOA3246D		28.08	28.10	0.01	28.09	0.01		28.79	28.78	-0.01	28.78	-0.02

SUMMARY

• Over the full range of events tested, the water level could increases by up to 0.01 m and decreases by up to 0.05 m immediately upstream of Avoncliff weir for the maximum restriction to the flow and minimum restriction to the flow scenarios respectively.
• Over the full range of events tested, the water level could increases by up to 0.01m and decreases by up to 0.03 m in the main river closest to the rowing club for the scenarios of maximum restriction to the flow and minimum restriction to the flow respectively.
• The impact on water levels upstream of Avoncliff weir is reduced for higher magnitude events.

Revision Record

Revision	Date	Modeller	Checker	Approver
1	21/03/2013	SSK	SYE	RJG
2	22/03/2013	SSK	SYE	RJG

Appendix B. Manning's "n" Values and Loss Coefficients

Note that Manning's roughness values have been taken from the 2012 Bradford on Avon Flood Modelling Study (Refer Table D.1 of technical report of 2012 Bradford on Avon Flood Modelling Study)

Table B.1: Manning's n Values Assigned for Different Land Classification from 2012 Bradford on Avon Flood Modelling Study

Land Classification	Manning's n Value
Natural/Grassland/River Banks	0.055
Roads	0.038
Buildings	0.200
Water	0.035
Woodland	0.080

Weir coefficients for the Avoncliff weir are tabulated in Table 2 of the 2012 Bradford on Avon Flood Modelling Study. Chapter 7 of the technical report from that study explained that how the coefficients for structures were calibrated.

Table B.2: Weir coefficients Classification from 2012 Bradford on Avon Flood Modelling Study

Node	Comment	Crest Elevation (mAOD)	Weir Coefficient
BOA3409_WR1U	Weavers Mill sluice assumed closed for flood events	27.09	1
BOA3409_WR2U	Main weir higher part	26.11	0.8
BOA3409_WR3U	Main weir	25.97	0.8
BOA3409_WR4U	Waterwheel weir	24.93	0.8
BOA3409_SPU	Combined platform levels - (Intervening spill	variable	0.8

Table B.3: Weir coefficients for proposed hydropower scheme at North Mill – Earl Scheme

Node	Comment	Crest Elevation (mAOD)	Weir Coefficient
BOA3409_WR1U	Weavers Mill sluice assumed closed for flood events	27.09	1
BOA3409_WR2U	Main weir higher part	26.11	0.8
BOA3409_WR3U	Main weir	25.97	0.8
BOA3409_FP1U	Fish Pass	26.08	0.8
BOA3409_3.6U	Top of sluice 3.6m diameter turbine	28.88	0.8
BOA3409_2.7U	Top of sluice 2.7m diameter turbine	28.88	0.8
BOA3409_SPU	Combined platform levels - Intervening spill modified to include; a) Support to the fish pass; b) Support to the 3.6m diameter turbine; c) Plinth wall between 2 turbines; and d) Eel pass.	variable	0.8

Table B.4: Weir coefficients for proposed hydropower scheme at Weavers Mill – Tarrant Scheme

Node	Comment	Crest Elevation (mAOD)	Weir Coefficient
BOA3409_WR1U	Weavers Mill sluice assumed closed for flood events	27.09	1
BOA3409_WMFU	Fish Pass	25.67	0.8
BOA3409_WMU	Top of sluice 2.5m width	25.95	0.8
BOA3409_WR3U	Main weir	25.97	0.8
BOA3409_WR4U	Waterwheel weir	24.93	0.8
BOA3409_SPU	Combined platform levels - Intervening spill modified to include support to the Bulb Kaplan Turbine;	variable	0.8

Appendix C. Survey Drawings