

Feasibility Restoration Report for By Brook, North East Bath

Document title: Feasibility Restoration Report for By Brook, North East Bath

Status: Final

Date: May 2015

Project name: By Brook Restoration Project

Project number: PB2707

Client: Bristol and Avon Rivers Trust (BART)

Client contact: Ian Mock

Reference: PB2707

Authors / Contributions: Peter Brunner, Clare Rodgers, Robin Parry and Benjamin Rostaing

Checked by: Peter Thornton

Date / initials check: 01/04/2015

Approved by: Peter Brunner

Date / initials approval: 29/05/2015

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1	Introduction	1
1.1	Background	2
1.2	Aims and Objectives of the Project.....	2
1.3	Scope of Project Works.....	3
1.4	Key Guidance and Legislation.....	5
1.5	Structure of this Report	6
2	The Study Area – By Brook.....	8
2.1	Introduction	9
2.2	Topography, Geology and Soils	10
2.3	Hydrology and Hydromorphology	13
2.4	Channel Geomorphology, Modifications and Structures	14
2.5	Designated Sites	43
2.6	Terrestrial Flora and Fauna.....	48
2.7	Freshwater Flora and Fauna with Special Reference to Native Crayfish	49
2.8	Fish Passage Criteria and Target Species	52
2.9	Cultural Heritage and Land Use	53
2.10	Public Interest and Recreational Activities	56
2.11	Past and Present Management Regime.....	58
3	Environmental Conditions of the By Brook Catchment	60
3.1	Introduction	61
3.2	Past Ecological Condition.....	62
3.3	Present Ecological Condition	65
3.4	Present Standards for Good Ecological Condition	67
3.5	By Brook Reach Conditions and WFD Objectives.....	69
4	Proposed Restoration Options for By Brook	74
4.1	Introduction	75
4.2	Assessment Approach	75
4.3	Proposed Restoration Options	75
4.4	Reach 4A1: Ford Mill Weir Restoration Options - Technical Details and Appraisal.....	76
4.5	Reach 4A2: Weir D/S Ford Restoration Options - Technical Details and Appraisal.....	92
4.6	Reach 4A3: Sluice D/S Ford Restoration Options - Technical Details and Appraisal.....	96
4.7	Reach 4A4: Slaughterford Gate Restoration Options - Technical Details and Appraisal.....	104
4.8	Reach 4A5: Rag Mill (Slaughterford) Weir Restoration Options - Technical Details and Appraisal.....	114
4.9	Review of BART Restoration Options for the Remaining Reaches of the By Brook Catchment	123

5	Selection of Preferred Restoration Options for By Book	133
5.1	Introduction	134
5.2	Preferred Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir	134
5.3	Details of Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir	135
5.4	Key Mitigation Measures for Reach 4A River Restoration Solutions	139
5.5	Restoration Solutions for the Remaining Reaches of the By Brook Catchment	141
6	Specific Details of the Preferred Restoration Options for By Brook	144
6.1	Introduction	145
6.2	Preferred Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir	145
7	Conclusions and 4-5 Year Management Plan	150
7.1	Introduction	151
7.2	Next Steps (Licences, Consents) and Challenges	151
7.3	Preliminary Long-Term Restoration Programme for the By Brook Catchment	151
8	References.....	155
9	List of Abbreviations	157
10	Glossary.....	159
	Appendix A: By Brook Project Phase I Report (BART, 2013/2014)	161
	Appendix B: Crayfish Survey of the By Brook, River Avon and St Catherine’s Brook (OHES, 2014).....	163
	Appendix C: By Brook Flood Risk Modelling Study (Backwater Effect of Hydraulic Structures at Low Flows).....	165
	Appendix D: By Brook Catchment Walkover Report – Fluvial Audit (BART, 2015).....	167
	Appendix E: Ecosystem Services Assessment for By Brook	169
	Appendix F: Costings of Preferred Options.....	171

Tables

Table 1.1	Outline of Report.....	6
Table 2.1	Historic Timeline of Anthropogenic Change in the By Brook Catchment.....	16
Table 2.2	Key Fish Migration Barriers of By Brook	20
Table 2.3	Upstream Limit of Impoundment for Key Structures	21
Table 2.4	Target Fish Species and Associated River Flow Rates	53
Table 3.1	Ecological Status of Waterbodies in the By Brook Catchment.....	62
Table 3.2	Overall Ecological Status (Current and Target) in each Waterbody in the By Brook Catchment	68
Table 3.3	By Brook Current Reach Conditions Based On WFD Quality Elements.....	70

Table 3.4	Typical WFD Hydromorphology Measures and Monitoring.....	72
Table 4.1	Restoration Solutions - Ford Mill Weir and Rag Mill Weir	75
Table 4.2	Ford Mill Weir Restoration Options Appraisal (Part 1)	82
Table 4.3	Ford Mill Weir Restoration Options Appraisal (Part 2)	88
Table 4.4	Weir D/S Ford Restoration Options Appraisal.....	97
Table 4.5	Sluice D/S Ford Restoration Options Appraisal	105
Table 4.6	Slaughterford Gate Restoration Options Appraisal	115
Table 4.7	Review of BART Restoration Options for the Remaining Reaches of the By Brook.....	124
Table 5.1	Mitigation Measures for Key By Brook Restoration Solutions.....	139
Table 6.1	Capital Costs - Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A).....	145
Table 7.1	Preliminary Long-Term River Restoration Programme for the By Brook	153

Figures

Figure 2.1	By Brook Catchment and WFD Management Reaches.....	11
Figure 2.2	Soilscape Characteristics of By Brook Catchment	12
Figure 2.3	Environment Agency Flood Risk Map for the By Brook	14
Figure 2.4	Paper Making at Slaughterford.....	15
Figure 2.5	Selected Morphological Changes along the By Brook	17
Figure 2.6	Key Fish Migration Barriers of By Brook	19
Figure 2.7	Key Environmental Features - Burton and Ford.....	22
Figure 2.8	Location Plan of Reach 1	22
Figure 2.9	Key Environmental Features - Pennsylvania and Castle Combe	23
Figure 2.10	Location Plan of Reach 2	24
Figure 2.11	Key Environmental Features of By Brook and Upper Tributaries	25
Figure 2.12	Location Plan of By Brook and Upper Tributaries	25
Figure 2.13	Location Plan of Reach 4A	26
Figure 2.14	Ford Mill Weir.....	27
Figure 2.15	Glide Habitat of Ford Mill Weir.....	28
Figure 2.16	Weir D/S Ford	29
Figure 2.17	Sluice D/S Ford.....	29
Figure 2.18	Upstream of Slaughterford Gate – Flow Impoundment.....	30
Figure 2.19	Slaughterford Gate Sluice	30
Figure 2.20	Rag Mill Weir	31
Figure 2.21	Location Plan of Reach 4B, 4C and Reach 5.....	32
Figure 2.22	Weavert Mill Weir.....	33
Figure 2.23	Key Environmental Features of Weavert Mill Weir Site.....	34
Figure 2.24	Cattle Poaching Upstream of Widdenham Mill Weir	35

Figure 2.25	Widdenham Mill Weir.....	35
Figure 2.26	Key Environmental Features of Widdenham Mill Weir Site.....	36
Figure 2.27	Key Environmental Features of Lid Brook.....	37
Figure 2.28	Drewitts Mill Sluice.....	38
Figure 2.29	Wooded Debris and Drewitts Mill Sluice	38
Figure 2.30	Lid Brook Gravels	39
Figure 2.31	Box Mill Sluice and Key Environmental Features.....	40
Figure 2.32	Middlehill Gauging Weir and Key Environmental Features	41
Figure 2.33	Shockerwick Mill Weir and Key Environmental Features.....	42
Figure 2.34	By Brook Geomorphological Process Between Ford and Shockerwick.....	44
Figure 2.35	Overview of Crayfish Presence / Likely Absence Results (2013 & 2014).....	51
Figure 2.36	Historic Environment	54
Figure 2.37	Public Access Between Ford and Slaughterford	57
Figure 3.1	WFD Surface Waterbodies in the By Brook Catchment.....	63
Figure 3.2	WFD Groundwater Waterbodies in the By Brook Catchment	64
Figure 4.1	Construction of Bottom Ramps and Slopes	78
Figure 4.2	Rock Ramp Concept (Outline Design) for Ford Mill Weir.....	79
Figure 4.3	Bypass Channel Concepts for Ford Mill Weir.....	80
Figure 4.4	Technical Fish Pass Concepts for Ford Mill Weir.....	81
Figure 4.5	Schematic Diagram Illustrating a Bypass Channel Construction Arrangement	93
Figure 4.6	Concept (Outline Design) Layout of the Natural Bypass Channel for Reach 4A2 (Weir D/S Ford)	94
Figure 4.7	Larrier Technical Fish Pass Concept for Weir D/S Ford.....	95
Figure 4.8	Natural Rock Pre-barrage Concept for Sluice D/S Ford.....	103
Figure 4.9	Larrier Technical Fish Pass Concept for Sluice D/S Ford	104
Figure 4.10	Natural Rock Pre-barrage Concept for Slaughterford Gate	111
Figure 4.11	Natural Rock Pre-barrage Concept for Slaughterford Gate – River Long Section.....	112
Figure 4.12	Natural Bypass Channel Concept (Outline Design) for Slaughterford Gate	113
Figure 4.13	Pool and Traverse Style Fish Pass Concepts for Slaughterford Gate	122
Figure 4.14	Pool and Traverse Style Fish Pass Concepts for Rag Mill Weir	123

Executive Summary

Royal HaskoningDHV have been commissioned by the Bristol Avon Rivers Trust (BART) in partnership with the Environment Agency, to undertake a detailed feasibility assessment on restoration solutions for the By Brook, a tributary of the Bristol Avon, located to the north east of Bath. The assessment aims to identify and detail viable solutions (options) that will restore natural geomorphological and ecological processes along the By Brook with the aim of eventually achieving Good Ecological Status (GES) for the river system, while ensuring that all landowners and recreational interests such as angling are fully taken into consideration.

A whole catchment scale approach has been undertaken for this project, although the focus of detailed restoration solutions for this phase has been between Ford Mill and Rag Mill Weir (Slaughterford) (Reach 4A), while a high level assessment of potential restoration solutions has also been undertaken between Rag Mill Weir and Shockerwick Weir. These solutions have included for both minor in-channel works such as the potential placement of wooded debris to create greater flow and morphological diversity to larger scale works such as technical and non-technical fish passes in order to contribute to the long term GES of the By Brook.

In the context of achieving long term GES along the By Brook and based on the outcomes of this feasibility restoration report, the following preferred solutions for Reach 4A which includes the stretch of the By Brook between Ford Mill and Rag Mill Weir have been taken forward to the implementation phase subject to the feasibility of managing key risks:

- Reach 4A1 – Rock Ramp
- Reach 4A2 TBC – Structural Removal or Natural Bypass Channel
- Reach 4A3 TBC – Structural Removal or Natural Bypass Channel
- Reach 4A4 TBC – Natural Bypass Channel or Structural Removal
- Reach 4A5 TBC – Natural Bypass Channel or Pool and Traverse or Structural Removal

In addition, it is proposed that the following potential river restoration solutions be further investigated for Reach 1 to Reach 3 along the upper By Brook and Reach 4B and 5 along the lower sections of the By Brook to ensure the successful implementation of the key river restoration solutions proposed between Ford Mill and Rag Mill Weir.

- Reach 1 – Local landowner consultation to increase buffer strips and employ good land management practises; fencing and in-channel works (e.g. flow deflectors to narrow over widened channels).
- Reach 2 – Local landowner consultation to employ good land management practise; fencing and water provision project; and strategic trapping of signal crayfish.
- Reach 3 – Local landowner consultation to employ good land management practise; fish passage feasibility study; fencing and water provision project; Environment Agency to work with Wessex Water to over low flows and phosphate stripping.
- Reach 4B/C to Reach 5 – Local landowner consultation to employ good land management practise (e.g. fencing, natural buffer strips); bank re-profiling; larger projects such as structural removal and/or construction of bypass channels, low cost fish baffles.

To ensure the long term GES of the By Brook is achieved, a 4-5 year catchment plan has been developed which takes into consideration the different implementation phases for the development of the proposed restoration solutions including monitoring strategies.

Acknowledgements

Royal HaskoningDHV would like to thank all members of the team for producing this feasibility report and D&H Surveys, D & H and Survey Operations Ltd Surveys, Mike and Beach Fish Pass Consultants for providing valuable data for the project. Finally, a special thank you to Ian Mock (BART), Melissa Hoskings (BART), Richard Vivash (Ex-Director of RRC) and the Environment Agency (Wessex Area) in particular Jeremy Taylor, John Phillips and Aly Maxwell for allowing RHDHV to undertake this exciting project which has the potential to improve the ecological condition of the By Brook for all to enjoy.



By Brook downstream of Ford Mill

1 Introduction

1.1 Background

- 1.1.1 The By Brook is a 19km tributary of the Bristol Avon, located to the north east of Bath, with the source of the brook associated with the Burton and Broadmead Brooks which rise in south Gloucestershire at Tormaton and Cold Ashton respectively. The By Brook supports a variety of flora and fauna including European eel (*Anguilla Anguilla*), sea trout (*Salmo trutta*), brown trout (*Salmo trutta*), white-clawed crayfish (*Austropotamobius pallipes*) and otter (*Lutra lutra*). The By Brook has been heavily modified throughout history, primarily for the milling of corn during Roman times, but later for the “fulling” of wool and the production of paper. The last recorded working mill, Chaps Paper Mill, Slaughtford, which included Rag Mill, ceased operations in 1964.
- 1.1.2 Many of the weirs and sluices associated with the industrial heritage of the By Brook still remain today and form major structural barriers to fish migration along the By Brook preventing the brook, in part, from achieving Good Ecological Status (GES) under the European Water Framework Directive (WFD) (see **Section 3** for details). Sustainable natural fish populations contribute to GES and impassable barriers to fish migration (e.g. weirs) can cause failure of the objective. This Directive requires all EU Member States to protect and, where possible, enhance the condition of all bodies of water by 2015 (or, in cases where there are significant pressures to address, 2021 or 2027). In addition, under the EU Eel Regulation, all member states must also prepare and implement Eel Management Plans (EMPs), with the objective of reducing anthropogenic impacts on stocks. Making rivers passable for juvenile and adult eel is a key element of the UK EMPs which are implemented and enforced by the Environment Agency.
- 1.1.3 Other key legislation which requires fish passage for migratory salmonids includes the Salmon and Freshwater Fisheries Act 1975; and the Water Resources Act 1991.
- 1.1.4 Barriers to fish passage are prioritised by scoring against a variety of drivers, dependent on which species are failing the ‘fish element’ of WFD, and whether barriers to migration and free movement of fish are likely to be a contributory or main cause for failure. As mentioned, eel regulations are also a driver for some critical barrier sites. Of the 23 key barriers on the By Brook that are identified on the Environment Agency’s fish passage barrier list for the Bristol Avon and North Somerset Streams, 15 are prioritised in the top 20 out of 88 barriers.

1.2 Aims and Objectives of the Project

- 1.2.1 As such, Royal HaskoningDHV (RHDHV) have been commissioned by the Bristol Avon Rivers Trust (BART) in partnership with the Environment Agency, to undertake a detailed feasibility assessment on restoration solutions for the By Brook.
- 1.2.2 The key aim of the project is to identify and detail viable solutions (options) which deliver improved fish passage through the restoration of natural geomorphic and ecological processes along the By Brook while ensuring the landowners and recreational interests such as angling are fully taken into consideration.
- 1.2.3 The key objectives of the project include the following:
- To provide viable restoration solutions which improve the WFD hydromorphological quality elements along the By Brook, in particular improvement of river continuity, flow quantity and variability, planform and substrate conditions along the By Brook.

- To provide viable restoration solutions which improve the WFD biological quality elements along the By Brook, in particular for fish, benthic invertebrates and aquatic flora.

To provide viable restoration solutions which improve fish passage for European eel (as part of the EU Eel Regulation) and migratory salmonids (as part of the Salmon and Freshwater Fisheries Act 1975).

1.3 Scope of Project Works

1.3.1 The overall approach undertaken for this project is briefly summarised below:

Stage 1 – Site Walkover

- Qualitative geomorphological, ecological and engineering site walkover to characterise the existing environment and gain an appreciation of the constraints and opportunities for the key (pilot) sites scoped into the project along the By Brook between Ford Mill and Rag Mill Weir (Slaughterford) (Reach 4A, see **Figure 2.1**; also see **Appendix A**). This walkover was undertaken on the 5th of September 2014 and also included Chapps Paper Mill (downstream of Rag Mill Weir within Reach 4A) which provided a good ecological and geomorphological bench mark for the restoration of the By Brook. In addition, a site walkover was undertaken on the 23rd of December 2014 between Weavern Mill Weir downstream to Shockerwick Mill Weir (Reach 4B and upper sections of Reach 5, see **Figure 2.1**). This was undertaken as part of a ground-truthing appraisal of recommended BART river restoration solutions (see Stage 3).
- The site walkovers were further verified through a Fluvial Audit undertake by BART between December 2014 – January 2015 of the whole catchment to gain a further appreciation of the existing the environment (geomorphology, ecology) and to ensure a whole of catchment scale strategy was implemented for this project. This was implemented to ensure the successful selection of the preferred solutions for the key sites scoped into the project. Full details of this Fluvial Audit are provided in **Appendix C**.

Stage 2 – Desk-top Review

- A review and validation of existing surveys, data and reports to inform the other stages and overall outcomes of the feasibility report, including baseline information on the following:
 - The geographical setting of the By Brook (and catchment), and general environmental (ecological, geomorphological) information and constraints.
 - Ecological condition of the By Brook.
 - Current and past management practices of the By Brook.

Stage 3 – Proposed Restoration Options for the By Brook

- Specific details on proposed restoration options for the By Brook including:
 - Technical and feasibility details.
 - Environmental constraints and opportunities. The development of the proposed restoration options took into consideration all previous stages of the report and focused on the key (pilot) sites scoped into the study area along the By Brook between Ford Mill and Rag Mill Weir (Slaughterford), although a whole of catchment scale approach was implemented in the development of the restoration solutions supported by the site walkovers as described in Stage 1.

- Restoration solutions between Weavert Mill Weir downstream to Shockerwick Mill Weir and for the rest of the catchment (i.e. Fluvial Audit undertaken by BART, 2015) were investigated at a high level to ensure the successful implementation of the key river restoration solutions proposed between Ford Mill and Rag Mill Weir.

Stage 4 – Selection of Preferred Restoration Options for the By Brook

- Selection of the preferred restoration solutions for the By Brook between Ford Mill and Rag Mill Weir (Slaughterford) based on the outcomes of the detailed appraisal of the proposed options provided in Stage 3. The selection of the preferred options to be confirmed by an Ecosystem Services Assessment (see **Appendix E**).

Stage 5 – Specific Details of the Preferred Restoration Options for the By Brook

- Further specific details including the construction activities and capital costs for the preferred restoration solutions for the By Brook between Ford Mill and Rag Mill Weir (Slaughterford). Recommended complimentary solutions such as soft enhancement works have also been provided.

Stage 6 – Catchment Management Plan

- Recommended way forward, additional considerations and a 4-5 year plan for the whole By Brook catchment based on information provided in this report to ensure the long term GES of the By Brook is achieved.

1.3.2 Sources of data and analysis used to inform this report included:

- Existing reports and data, including:
 - By Brook Project Phase I Report (BART, 2013/2014) (see **Appendix A**). Data comprised of the following:
 - Fish pass feasibility designs 7m;
 - Ford Mill Weir to Shockerwick Weir;
 - Water quality monitoring on the Lid Brook and By Brook;
 - Fish, macrophyte, and invertebrate sampling data;
 - By Brook crayfish monitoring results.
 - A crayfish survey of the By Brook, River Avon and St Catherine's Brook (OHES, 2014) (see **Appendix B**).
 - By Brook Flood Risk Modelling Study: Backwater Effect of Hydraulic Structures at Low Flows (Environment Agency, 2015) (**Appendix C**).
 - Feasibility of river works in relation to weir modification, fish passes and crayfish species in the By Brook, River Avon, Wiltshire (OHES, 2014).
 - By Brook Catchment Walkover Report – Fluvial Audit (BART, 2015).
- Topographic surveys (by D & H and Survey Operations Ltd undertaken between December 2013 and April 2014).
- Digital Elevation Models (using LiDAR data).

- Qualitative site walkover information.
- Latest Water Framework Directive data from the Catchment Data Explorer and other draft “Cycle 2” RBMP documents currently out to consultation. https://consult.environment-agency.gov.uk/portal/ho/wfd/draft_plans/consult.
- MAGIC (UK Government environmental mapping website).
- English Heritage interactive mapping tool.
- National River Flow Archive.
- BART and Cotswolds AONB websites.

1.4 Key Guidance and Legislation

1.4.1 Key guidance documents used in this report include:

- Catchment Based Approach to WFD implementation (CaBA).
(<http://www.environment-agency.gov.uk/research/planning/131506.aspx>).
- Healthy Catchments – Online WFD guidance for the Environment Agency.
(<http://www.restorerivers.eu/RiverRestoration/Floodriskmanagement/HealthyCatchmentsmanagingforfloodriskWFD/tabid/3098/Default.aspx>).
- Water Framework Directive (WFD) Mitigation Measures Online Manual
(<http://evidence.environment-agency.gov.uk/FCERM/en/SC060065.aspx>).
- Mainstone, C. (2007). Rationale for the physical restoration of the SSSI river series in England.
- JNCC (2004). Common Standards Monitoring Guidance. <http://jncc.defra.gov.uk/page-2199>.
- Manual of River Restoration Techniques (River Restoration Centre).
- Guidebook of Applied Geomorphology (Defra, Environment Agency, 2003).
- Weir removal lowering and modification a review of best practice (Environment Agency, 2013).
- River Weirs – Good Practice Guide (Rickard et al., 2003).
- Fish pass manual: Guidance notes on the legislation, selection and approval of fish passes in England and Wales (Environment Agency, 2010).
- Gough, P., Philipsen, P., Schollemma, P. and Wanningen, H. (2012). From sea to source: International guidance for the restoration of fish migration highways.
- Elver and eel passes – A guide to the design and implementation of passage solutions at weirs, tidal gates and sluices (Environment Agency, 2011).
- Solomon, D. J. and Beach, M. H. (2004a). Fish pass design for eel and elver. R&D Technical Report W2- 070/TR1, Environment Agency, Bristol.
- Solomon, D. J. and Beach, M. H. (2004b). Manual for provision of upstream migration facilities for eel and elver. Science Report SC020075/SR2, Environment Agency, Bristol.
- CL:AIRE Definition of Waste Industry - Code of Practice (Version 2, March 2011).
- Waste Hierarchy Guidance Review 2012 (<https://www.gov.uk/waste-legislation-and-regulations> Accessed 08/04/2014).

1.4.2 Key legislation documents taken into consideration in this report include:

- Water Framework Directive (2000/60/EC).
- Biodiversity 2020: A strategy for England's wildlife and ecosystem services.
- European Union (EU) Eel Regulation (1100/2007/EC).
- Salmon and Freshwater Fisheries Act 1975.
- Part 7 (Fisheries), chapter 3 (Migratory and freshwater fish) of the Marine and Coastal.
- Water Resources Act 1991.
- Land Drainage Act 1991 (c.59) section 61 A-D.
- Access Act 2009 (c.51) (The Marine Act).
- EU Waste Framework Directive (2008/98/EC).
- Environmental Permitting (England and Wales) Regulations 2010.
- The Waste (England and Wales) Regulations 2011.
- Environmental Protection Act 1990.

1.5 Structure of this Report

1.5.1 This report is divided into 11 discrete sections including a description and condition assessment of the By Brook (**Sections 2 to 3**), option assessments associated with the restoration of the By Brook (**Sections 4 to 5**), specific details of the preferred restoration solutions for the By Brook (**Section 6**), and recommended way forward, additional considerations and 4-5 year catchment management plan for the By Brook (**Section 7**). **Table 1.1** provides further details on each section of the report and appendices.

Table 1.1 Outline of Report

Sections of Report		Description
1	Introduction	Introduces the project, outlines the main aims and objectives, assessment approach and key guidance and legislation.
2	The Study Area – By Brook	Description of the geographical setting of the By Brook (and catchment), including physical and ecological characteristics and constraints.
3	Environmental Condition Assessment of the By Brook Catchment	An assessment of past and present environmental conditions of the By Brook and key targets required to help achieve Good Ecological Status for the By Brook.

Sections of Report		Description
4	Proposed Restoration Options for the By Brook	Specific details on proposed restoration solutions for the By Brook in particular between Ford Mill and Rag Mill Weir (Slaughterford) (Reach 4A) including: technical and feasibility details; and environmental constraints and opportunities. The development of the proposed restoration solutions will take into consideration all previous sections of the report and detailed options assessment matrices. Restoration solutions between Weavert Mill Weir downstream to Shockerwick Mill Weir (Reach 4B, Reach 5) and for the rest of the catchment (i.e. Fluvial Audit undertaken by BART, 2015) to be investigated at a high level (ground-truthed) to ensure the successful implementation of the key river restoration solutions proposed between Ford Mill and Rag Mill Weir.
5	Selection of Preferred Restoration Options for the By Brook	Selection of the preferred restoration solutions for the By Brook based on Section 4 .
6	Specific Details of the Preferred Restoration Options for the By Brook	Further details including the construction activities and capital costs for the preferred restoration solutions for the By Brook.
7	Conclusions and 4-5 Year Catchment Plan	Recommended way forward including licenses and consents, additional considerations; and a 4-5 year management plan based on information provided in this report for the By Brook catchment.
8	References	Literature used to inform the development of this report.
9	List of Abbreviations	Abbreviations used in this report.
10	Glossary	Glossary of terms used in this report.
Supporting Appendices		
A	By Brook Project Phase I Report (BART, 2013/2014)	
B	Crayfish Survey of the By Brook, River Avon and St Catherine's Brook (OHES, 2014)	
C	By Brook Flood Risk Modelling Study (Low Flows)	
D	By Brook Catchment Walkover Report – Fluvial Audit (BART, 2015)	
E	Ecosystem Services Assessment for By Brook	
F	Costings of Preferred Options	

2 The Study Area – By Brook

2.1 Introduction

2.1.1 This section of report introduces the By Brook catchment in the context of this feasibility report and focuses on describing the physical and ecological characteristics of the By Brook at the catchment scale. This will provide specific background information to inform the environmental condition assessment of the By Brook in **Section 3**. To enable the specific management and ease of identification of key sites along the By Brook, **Figure 2.1** provides a break-down of the By Brook and tributaries into manageable reaches, based on the approach used by the Environment Agency in the identification of WFD waterbody boundaries (see **Section 3.1.2**) and the breakdown of individual reaches based on key in-channel structures within these WFD waterbody boundaries. This includes the two headwater streams as separate reaches for the By Brook:

- Reach 1: Burton Brook.
- Reach 2: Broadmead Brook.
- Reach 3: By Brook - Confluence of Burton Brook and Broadmead Brook to confluence with Doncombe Brook.
- Reach 4A: By Brook – Confluence with Doncombe Brook to Chapps Paper Mill (the Mill House).
- Reach 4B: By Brook – Chapps Paper Mill to confluence with Lid Brook.
- Reach 5: By Brook – Confluence with Lid Brook to confluence with River Avon.

2.1.2 The tributaries have been broken down as follows to compliment the above management reaches of the By Brook:

- Reach 3A: Unnamed tributary - Source to confluence with By Brook.
- Reach 3B: Doncombe Brook - Source to confluence with By Brook.
- Reach 4C: Lid Brook - Source to confluence with By Brook.

2.1.3 The primary focus of this report as stated in **Section 1** is Reach 4A which contains the following key five sites:

- Ford Mill (**Reach 4A1**).
- Weir D/S Ford (**Reach 4A2**).
- Sluice D/S Ford (**Reach 4A3**).
- Slaughterford Gate (**Reach 4A4**).
- Rag Mill (Slaughterford) (**Reach 4A5**).

2.1.4 The other sites specifically detailed in this report include the following:

- Chapps Paper Mill (**Reach 4A6**).
- Weavern Mill Weir (Farm) (**Reach 4B1**).
- Widdenham Mill (Farm) (**Reach 4B2**).
- Drewitts Mill (**Reach 5A1**).

- Box Mill (Real World Studios) (**Reach 5A2**).
- Middlehill Gauging Weir (**Reach 5A3**).
- Shockerwick Mill (old) Weir (**Reach 5A4**).
- D/S of Box Bridge (**Reach 5A5**).
- Railway Sluice (**Reach 5B1**) – Although outside of the BART area of responsibility.
- Bathford Paper Mil (**Reach 5B2**) – Although outside of the BART area of responsibility.

2.2 Topography, Geology and Soils

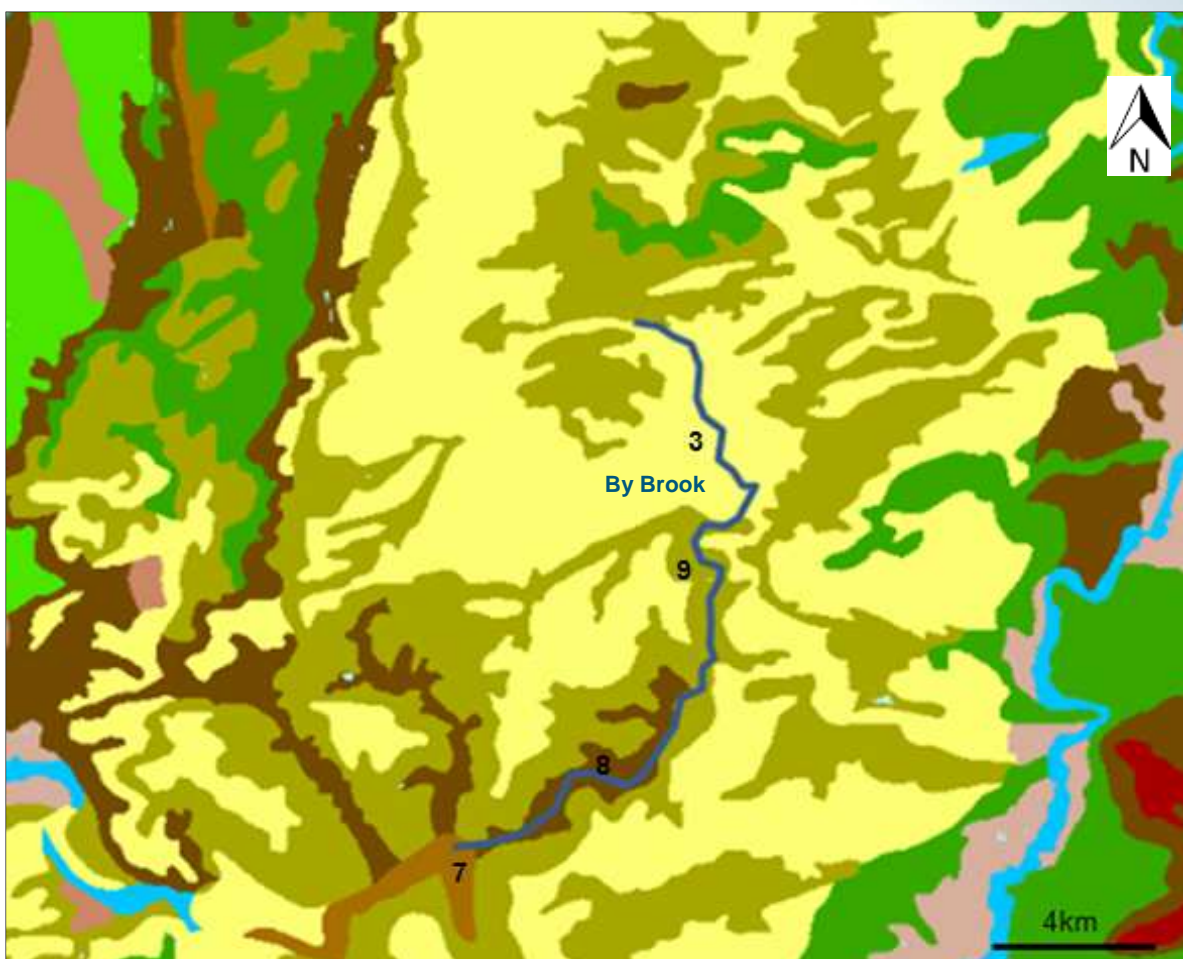
- 2.2.1 The By Brook catchment covers an area of 111 km² between Bath and Chippenham. By Brook was formerly the main headwater of the River Avon, before a major shift along a fault line in recent geological time shifted the surrounding watercourses that had previously drained into the River Thames to flow into the River Avon, creating a series of water-cut gorges and leaving By Brook as a minor tributary of a larger river¹.
- 2.2.2 The topography across the By Brook catchment is characterised by deeply eroded river valleys, a legacy of the geological shift in catchment boundaries. By Brook and its tributaries flow steeply along its 19km length, from over 150mAOD in the upper catchment to the west, to 60mAOD at Slaughterford in the east, and then more gradually southwards to 25mAOD at the confluence with the River Avon.
- 2.2.3 The majority of the By Brook catchment is underlain by limestone from the Chalfield Oolite Formation. Where the river and its tributaries have incised down, they have exposed sections of limestone from the Inferior Oolite and Forest Marble Formations, mudstone from the Fuller's Earth Formation and, downstream of Slaughterford, sections of the Bridport Sand and Charmouth Mudstone Formations². This alternating sequence of limestone and clays produces a multi-layer aquifer system, with some potential hydraulic connection between separate layers due to faulting³.
- 2.2.4 The main soil types in the By Brook catchment are a combination of lime-rich loamy and clayey soils with impeded drainage and shallow lime-rich soils over limestone (CU, 2014). There is also an area of slightly acid loamy and clayey soils with impeded drainage in the lower catchment around Box.
- 2.2.5 **Figure 2.2** provides an overview of the key Soilscape characteristics of the By Brook Catchment based on Soilscales, a soil thematic dataset (<http://www.landis.org.uk/services/soilscales.cfm>) in which the majority of soils are vulnerable to soil erosion, in particular Soilscales 8 and 9 along the middle and lower reaches of the By Brook (i.e. Reach 4A, 4B and 5 in **Figure 2.1**).

1 Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

2 Contains British Geological Survey materials © NERC 2014. Retrieved 28/10/2014 from <http://mapapps.bgs.ac.uk/geologyofbritain/home.html>

3 Environment Agency (2001). Report on the By Brook low flow investigations: Volume I. Report published by the Environment Agency, October 2001.

Figure 2.2 Soilscape Characteristics of By Brook Catchment⁴



Soilscape 3 – Shallow lime-rich soils over chalk or limestone

Particularly vulnerable to leaching of nitrate and pesticides to groundwater; surface capping and erosion of chalk soils on steeper slopes under cereals is linked with eutrophication and silting of chalk streams and their gravel spawning beds.

Soilscape 7 – Freely draining slightly acid but base-rich soils

Groundwater contamination with nitrate; siltation and nutrient enrichment of streams from soil erosion on certain of these soils.

Soilscape 8 – Slightly acid loamy and clayey soils with impeded drainage

Farmed land is drained and therefore vulnerable to pollution run-off and rapid through-flow to streams; surface capping can trigger erosion of fine sediment.

Soilscape 9 – Lime-rich loamy and clayey soils with impeded drainage

Land is drained and nitrate vulnerable; potential for rapid pollutant transport; surface capping can trigger sheet erosion of fine sediment to stream network.

⁴ Source: Land Information System (2015): <http://www.landis.org.uk/services/soilscales.cfm>

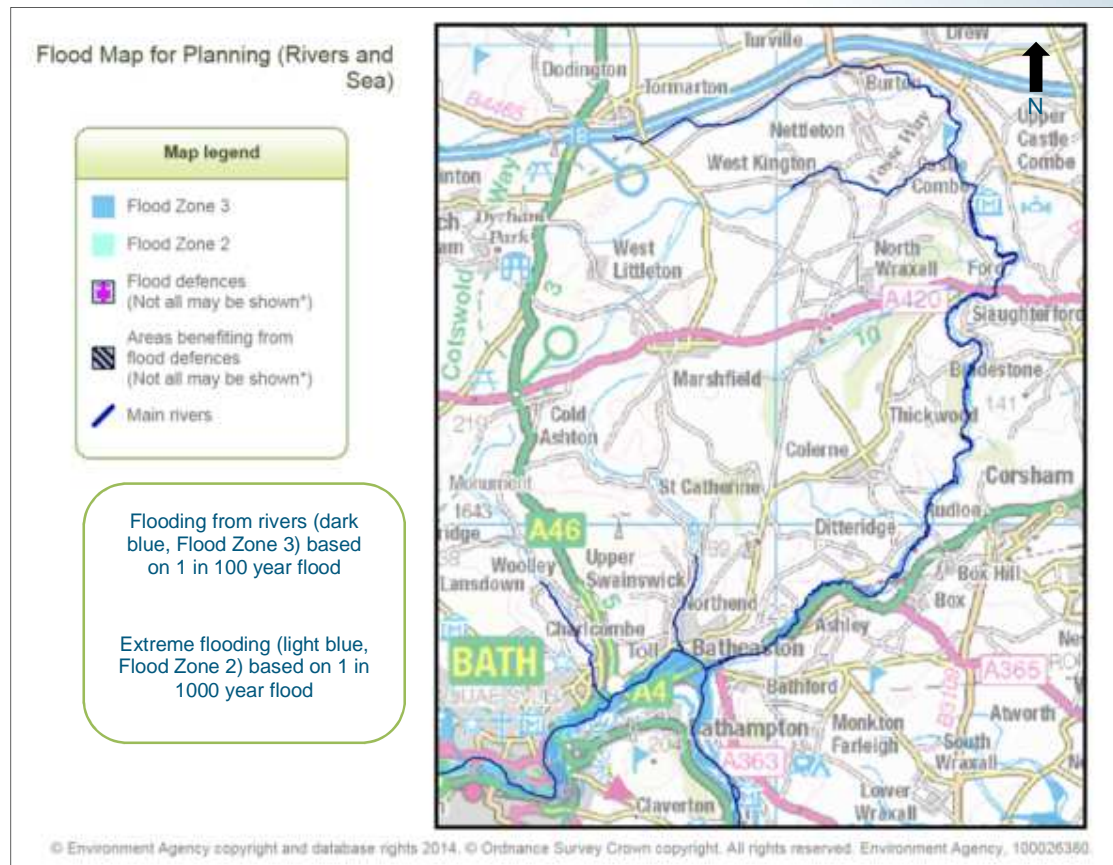
2.3 Hydrology and Hydromorphology

- 2.3.1 By Brook is the main hydrological feature in this catchment (see **Figure 2.1**). The main sources of the river, Burton and Broadmead Brooks, flow from west to east across the catchment to join at Castle Combe in the northeast. Downstream of this confluence, the mainstream By Brook flows from southwards along the eastern side of the catchment down to the confluence with the River Avon. The main tributaries to the By Brook are an unnamed tributary that flows through Danks Down Wood near Ford, Doncombe Brook and Lid Brook (listed in order from upstream to downstream). These tributary streams also flow broadly west to east (see **Figure 2.1**).
- 2.3.2 The average annual rainfall in the By Brook is between 850 and 950mm, highest in the higher elevations to the west and low to the east where the main river channel is located. The prevailing winds are westerly and mean monthly temperatures (based on the nearest monitoring station at Bath) range from 7°C to 14°C⁵. River data for the By Brook are available from one flow gauge at the downstream end of the catchment near Ashley (Gauge 53028 By Brook at Middlehill, NGR ST814688)⁶. The size of the By Brook catchment above this station is 102km². Over the period of record (1982 – 2013), the mean flow in the By Brook was 1.6m³/s, with lows flows (Q95) of 0.25m³/s and high flows (Q10) of 4.0m³/s. For comparison, the nearest flow gauge downstream in the River Avon (Gauge 53018 Avon at Bathford, NGR ST785670) recorded mean flows of 18.3m³/s from a catchment of 1,552km². By Brook has a Base Flow Index of 0.63, indicating that river flows are a combination of groundwater inputs and rainfall run-off, as would be expected for a catchment with permeable geology and areas of impeded drainage. The relatively high peak flows in the By Brook are likely to result from rapid rainfall run-off from the steeply sided valley slopes in the upper catchment.
- 2.3.3 The By Brook catchment is predominantly rural, and flood risks to human habitation are relatively low. **Figure 2.3** presents the flood risk map for the By Brook catchment and immediately downstream of the confluence with the River Avon. This shows that the risk of flooding is largely confined to the narrow floodplains immediately adjacent to the main river channel and tributaries. Changes to high river flows in the By Brook may contribute to flood risk downstream in Batheaston and Bath, although it is noted that high flows in the River Avon (Q10 of 41.7m³/s) are ten times greater than high flows in the By Brook so this effect may not be significant.
- 2.3.4 Water quality in the By Brook catchment is generally good according the WFD assessment, with the exception of Moderate status for phosphate in Doncombe Brook and the By Brook waterbody downstream of the confluence with that tributary (EA, 2013). High levels of phosphate are likely to be associated with agricultural run-off and effluent from sewage treatment works. Water quality monitoring carried out in winter 2013/14 identified high levels of suspended sediment and phosphorus in the main By Brook channel associated with inputs from agricultural sources along Lid Brook. No further issues were identified in the catchment with regards to physico-chemical elements or specific pollutants as part of the WFD assessment.

⁵ The Met Office. Bath: Climate period: 1981-2010. Retrieved 28/10/2014 from <http://www.metoffice.gov.uk/public/weather/climate/gcnk62de6>

⁶ CEH National River Flow Archive for Station 53028. Retrieved 28/10/2014 from <http://www.ceh.ac.uk/data/nrfa/data/station.html?53028>

Figure 2.3 Environment Agency Flood Risk Map for the By Brook⁷



2.4 Channel Geomorphology, Modifications and Structures

Catchment Overview

- 2.4.1 The By Brook is a dynamic morphological system owing in part to its flashy flow regime (as described in **Section 2.3**) and local slope changes which in turn govern the channel form processes along the brook. The variety of geomorphological process and landforms along By Brook and its tributaries (including active meanders, ox bow lakes and islands) in turn support a rich range of plants, fish and invertebrates⁸.
- 2.4.2 The overall average gradient of the By Brook falls approximately 125m over a distance of 19km from the headwaters to the confluence with the River Avon. Between the headwaters of the By Brook and Ford (Reach 1, 2, and 3) the gradient of the By Brook is relatively steep falling from 125m to 60m in which the key fluvial process based on the concept of Schumm (1988) regarding sediment transport-deposition zones is one of sediment transport. Between Ford and the River Avon (Reach 4A, 4B and 5) the gradient is less steep falling from 60m to 25m in which sediment transfer and deposition is the key sediment transport process. It should be noted these process coincide with Soilscales 8

⁷ Source: Environment Agency (2014): <http://maps.environment-agency.gov.uk>

⁸ Tatem, K (1996) A History of the By Brook. Published by the Environment Agency.

and 9 along the middle and lower reaches of the By Brook (see **Figure 2.2**) which are highly susceptible to erosion. **These sediment transport processes are of important consideration regarding the position of potential restoration solutions along the By Brook along with historical changes in the catchment** (described below). See **Figure 2.34** for sources of sediment.

- 2.4.3 The geological shift in the River Avon headwaters from By Brook to capture surrounding watercourses that had previously drained into the River Thames caused the By Brook itself to run deeper and steeper than it would have done otherwise⁹. This in turn has influenced the historic modifications to the catchment by human activity, in particular the use of the steep river for milling, which is evident since at least Roman times¹⁰.
- 2.4.4 A review of historic maps¹¹ indicates that the main activities to influence channel form and processes are mill structures and bridges for road and rail. There is evidence of at least 20 mill sites along the By Brook, a number of which were listed in the Domesday Book (see **Figure 2.4**). Many of these structures and bridges are still in place along the By Brook today; for example, at Chapps Mill the By Brook upstream is artificially widened to provide a reservoir of water. In the tributary of Doncombe Brook, river flow was less reliable and an artificial reservoir was created to regulate supply which is still in place today in the form of a pond behind the mill house¹².

Figure 2.4 Paper Making at Slaughterford



⁹ Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

¹⁰ Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

¹¹ OS Six Inch Map for England and Wales (1888-1913). Retrieved 28/10/2014 from <http://maps.nls.uk/>

¹² Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

2.4.5 The channel planform appears to have undergone relatively little artificial straightening over time, and continues to follow the strongly meandering route evident on historic maps (1185-1920)¹³ (also see **Figure 2.5**). It is claimed that Weavert Mill Weir, downstream of Slaughtertford, is a corruption of “wavering” with reference to the meandering route of the channel¹⁴.

2.4.6 **Table 2.1** provides a summary of anthropogenic changes within the By Brook catchment based on Tatem (1996) while **Figure 2.5** graphically presents selected morphological changes which have occurred over time along the By Brook.

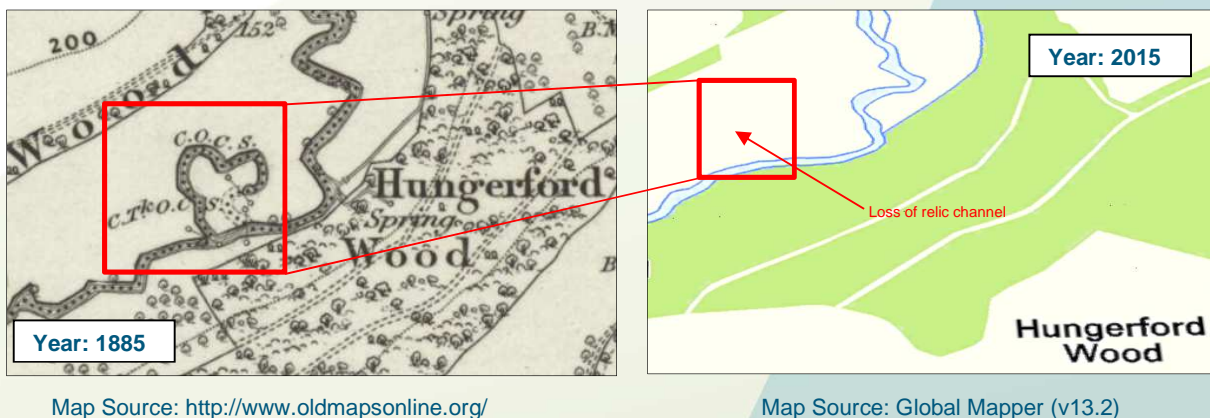
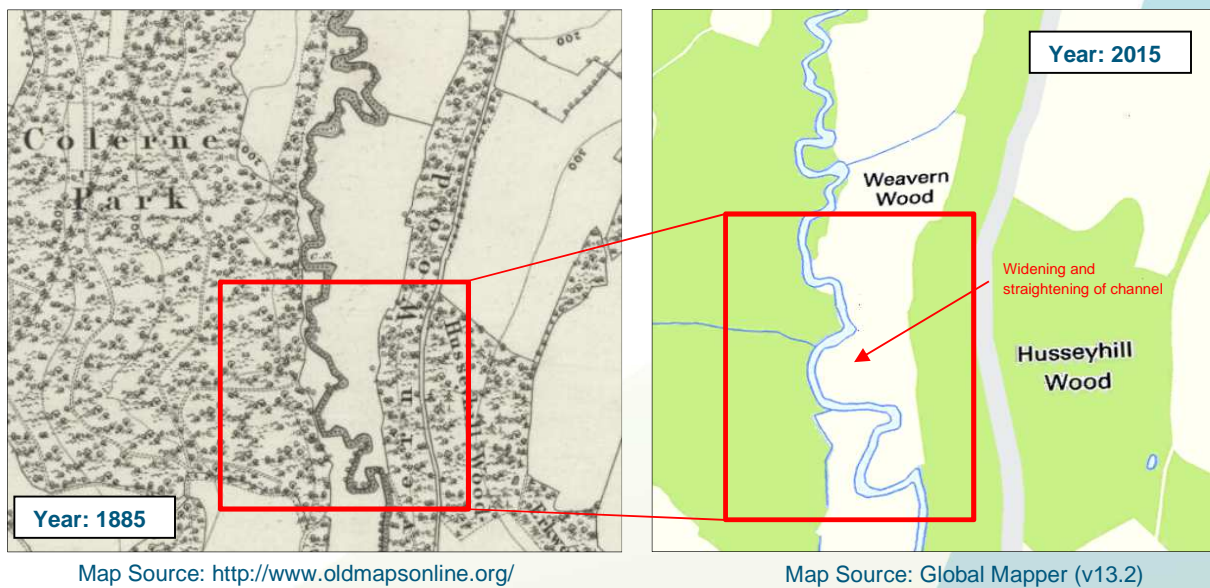
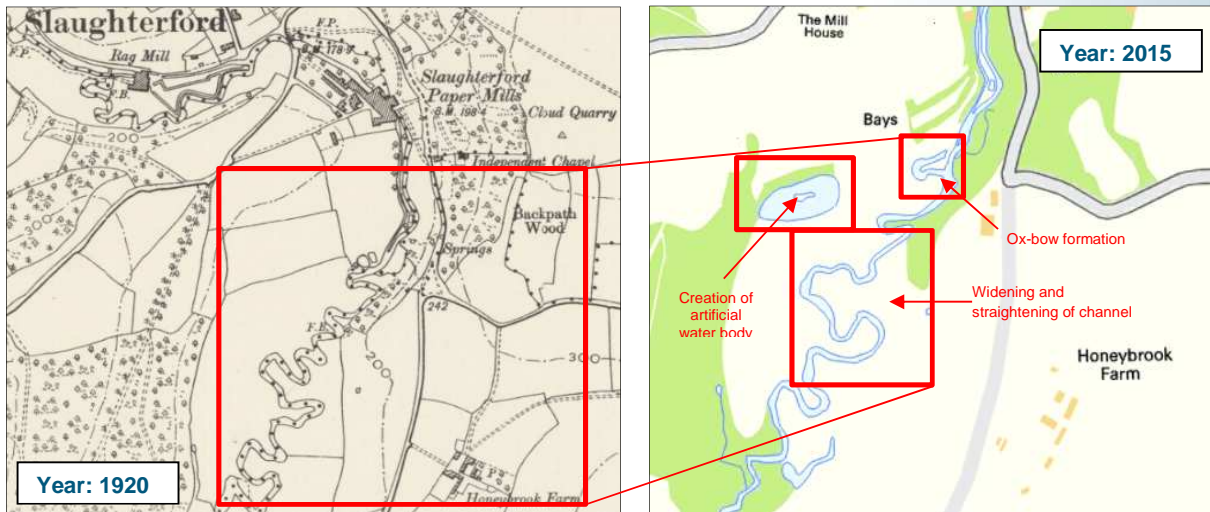
Table 2.1 Historic Timeline of Anthropogenic Change in the By Brook Catchment

Change	1300-1500s	1600s	1700s	1800s	1900s
General trends	<p>This area of Wiltshire becomes important for wool trade – mills built or converted from corn to wool.</p> <p>Rise in demand for paper – many mills converted to paper mills.</p> <p>Decline of wool industry, civil war and plague – mills closed or converted back to corn.</p> <p>Growth of tourism industry.</p>				
Examples	Bathford Mill mentioned in Domesday Book as a wool mill (1500s).	Widdenhams Mill ceases operation as a wool mill (1662). Lower Long Dean Mill built as paper mill (1635).	Ford Mill rebuilt for corn (1778) with paper mill added (1784). Chapps Mills converted from wool to paper (1790).	Rag processing installed at Rag Mill, a wool mill (1890s). Fibres transported to Chapps Mill for paper making.	Box Mill converted from malt-house to recording studios (1987). Rag Mill demolished (1964).
Capital works		Road-bridge built over By Brook at Bathford (1665).	Navigation opened on River Avon and used to export stone from Box (1727).	Great Western Railway Tunnel built (1841), diverting flow from Carsham stream to By Brook.	Steep embankments built along By Brook at Castle Combe, as part of flood attenuation scheme following major flood in 1954.
Other events				Major flood at Bathford (1894).	Castle Combe awarded “prettiest village in England” (1962) and becomes a regular tourist attraction. Quarrying of Box stone ends (1970).

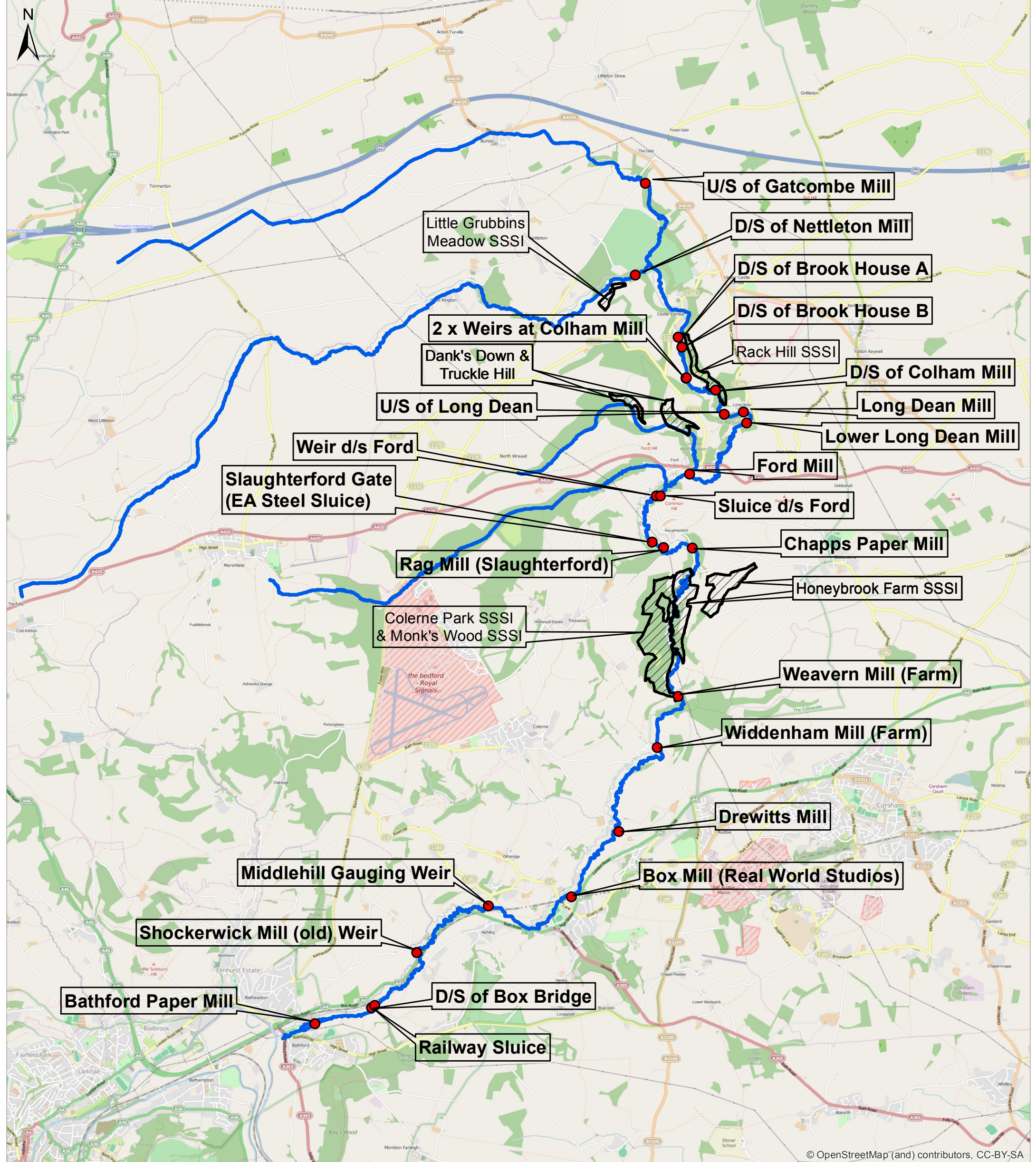
¹³ OS Six Inch Map for England and Wales (1885-1920). Retrieved 28/10/2014 from <http://maps.nls.uk/>

¹⁴ Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

Figure 2.5 Selected Morphological Changes along the By Brook



- 2.4.7 Sediment and water quality monitoring carried out in winter 2013/14 on Lid Brook, a small tributary of the lower By Brook, over two storm events found that three tonnes of soil were lost from the sub-catchment in each 24 hour period and washed into the By Brook (BART, 2013). This coincided with high levels of suspended sediment and phosphorus recorded in the main By Brook channel, and is likely to have a negative impact on downstream ecology. BART has already helped put some measures in place in the Lid Brook sub-catchment to mitigate this risk which have included fencing of the river banks and controlled in-channel cattle drinking access points.
- 2.4.8 As discussed in **Section 2.3**, the steep nature of this catchment and fast flowing waters have led the By Brook to be heavily modified in the past through construction of mills and associated weirs and sluices. Several sections of the river channel have also been artificially widened and straightened. Whilst no longer in use for industry, these historical constructions continue to strongly affect the geomorphology of the By Brook, with subsequent impacts on ecology.
- 2.4.9 Previous work has focussed on the By Brook between Ford and the confluence with the River Avon (the lowest By Brook waterbody) as this is where the greatest WFD issues are and where most of the significant structures are located. The Project Phase 1 – 2013/14 report produced by BART (2013) identified 14 structures along the By Brook that were potentially significant in terms of impeding fish migration. **Figure 2.6** presents the locations of these structures along the By Brook in proximity to designated sites which are further detailed in **Section 2.5**.
- 2.4.10 The most heavily impacted section of the By Brook in terms of structures impeding fish migration is between Ford and Shockerwick (particularly brown trout), shown as Reach 4A1 to Reach 5A4 in **Table 2.2**. The two furthest downstream barriers, **Bathford Paper Mill and the Railway Sluice near Batheaston, are located outside of the BART area of responsibility for its project work**. Two of the upstream structures, Drewitts Mill and Chapps Paper Mill, have been identified as sufficiently dilapidated to no longer present a barrier to fish migration (BART, 2013). **Table 2.3** provides impoundment characteristics of the key structures along the By Brook (EA, 2015).
- 2.4.11 As an additional sensitivity, there is public access to most of these structures. There are also at least eight foot crossings, ten road bridges (including three primary roads and six secondary roads) and three railway bridges providing access across the mainstream By Brook between Castle Combe and the confluence with the River Avon, which may limit the shape and route of the channel. This includes three crossing points on the most heavily impacted reach, between Ford and Slaughterford.
- 2.4.12 Several of these structures have been designated as scheduled monuments or listed buildings and will require special consideration (discussed further in **Section 2.7**).
- 2.4.13 These migration barriers, together with the associated straightening and deepening of the river channel in several locations, can have a negative impact on the WFD hydromorphological and biological quality elements:
- Altering the quality of the habitat available – for example by impeding sediment transport, and encourages sedimentation and macrophyte growth.
 - Limiting the access for fish to these habitats, particularly to the range of different habitats needed for different stages of their life cycle – for example by preventing upstream migration to upper reaches for spawning.
 - Wider ecosystem implications of reduced diversity – for example reducing the numbers of fish fry available as food for other organisms.



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Legend

- Fish Migration Barrier
- Site of Special Scientific Interest (SSSI)
- WFD Surfacewater Waterbodies

Title
By Brook Structures and Designated Sites

Project
Feasibility Restoration Report for By Brook, Bristol Avon, North East Bath

Client
Bristol Avon Rivers Trust (BART)

Date
12/03/2015

Scale
1:50000

Figure
2.6

Drawn by
MCP

Checked by
CR



Table 2.2 Key Fish Migration Barriers of By Brook

Reach	Site Name	NGR	Waterbody	Ownership
1	Upstream of Gatcombe Mill	383599,178866	GB109053027500	-
2	D/S of Nettleton Mill	383456,177586	GB109053027490	-
3	D/S of Brook House (A)	384 056,176 723	GB109053027480	-
3	D/S of Brook House (B)	384104,176585	GB109053027480	-
3	At Colham Mill	384165,176151	GB109053027480	-
3	At Colham Mill	384169,176159	GB109053027480	-
3	D/S of Colham Mill	384577,175985	GB109053027480	-
3	U/S of Long Dean	384700,175651	GB109053027480	-
3	Long Dean Mill	384964,175683	GB109053027480	-
3	Lower Long Dean Mill	385007,175532	GB109053027480	-
4A1	Ford Mill	ST8421274819	GB109053087390 (now part of GB109053027480)	Private
4A2	Weir D/S Ford	ST8374874517	GB109053027380	Ford FFC / Lord King / Environment Agency / ByBrook Ltd
4A3	Sluice D/S Ford	ST8381174512	GB109053027380	Ford FFC
4A4	Slaughterford Gate (Environment Agency Steel Sluice)	ST8369173873	GB109053027380	EA
4A5	Rag Mill (Slaughterford)	ST8385273794	GB109053027380	Ford FFC
4A6	Chapps Paper Mill	ST8425373788	GB109053027380	Private
4B1	Weavern Mill Weir (Farm)	ST8405671729	GB109053027380	Private
4B2	Widdenham Mill (Farm)	ST8376471018	GB109053027380	Private
5A1	Drewitts Mill	ST8322869848	GB109053027380	Private
5A2	Box Mill (Real World Studios)	ST8257168937	GB109053027380	Private
5A3	Middlehill Gauging Weir	ST8141568810	GB109053027380	EA
5A4	Shockerwick Mill (old) Weir	ST8041968165	GB109053027380	TBC
5A5	D/S of Box Bridge	379833,167429	GB109053027380	-
5B1	Railway Sluice	ST7978767394	GB109053027380	EA
5B2	Bathford Paper Mil	ST7899967171	GB109053027380	EA

Table 2.3 Upstream Limit of Impoundment for Key Structures

Reach	Site Name	Distance U/S (m) for Q95	Distance U/S (m) for Q50
4A2	Weir D/S Ford	461	461
4A3	Sluice D/S Ford	157	157
4A4	Slaughterford Gate	801	801
4A5	Rag Mill (Slaughterford)	107	186
4B1	Weavern Mill Weir (Farm)	No Impoundment	
4B2	Widdenham Mill (Farm)	574	574
5A4	Shockerwick Mill (old) Weir	672	1448
5A5	D/S of Box Bridge	No Impoundment	
5A3	Middlehill Gauging Weir	53	69

High Level Overview: Burton to Ford (Reach 1 to 3)

2.4.14 A high level overview regarding the channel geomorphology (fluvial processes), modifications and structures associated with the By Brook between Burton to Ford – Reach 1 to Reach 3 (see **Figure 2.1**) is provided below. Further details are provided in **Appendix D**.

Burton to Castle Combe (Burton Brook) (Reach 1)

2.4.15 Overall this section of the By Brook (Burton brook) between Burton and Castle Combe is characterised by large sections of straightened channel some of which have been modified as a result of road transport, residential housing or old historic milling (see **Figure 2.7a**). The banks are typically steep sided where they have been over deepened and predominantly supports glide flows (see **Figure 2.7b**). There is limited riparian zone and bank vegetation is generally restricted due to grazing of livestock along the upper sections of Reach 1, however downstream sections support a variety of plant species.

2.4.16 There is lack of substrate between Phydomic and Westfield along the middle section of Reach 1 where the river runs through a grass channel (see **Figure 2.7c**), with evidence of general siltation of the channel bed along most of this reach with no evidence of clean gravels. A combination of limited geomorphological diversity and sedimentation has led to localised sections of the reach also becoming choked with vegetation and slowing down flows. Reach 1 contains one in-channel structure (fixed concrete weir approximately 0.8m in height and 0.8m wide) which is only likely to be passed by migratory fish during medium to high flows (see **Figure 2.7d**).

2.4.17 A location overview plan of Reach 1 is provided in **Figure 2.8**.

Figure 2.7 Key Environmental Features - Burton and Ford

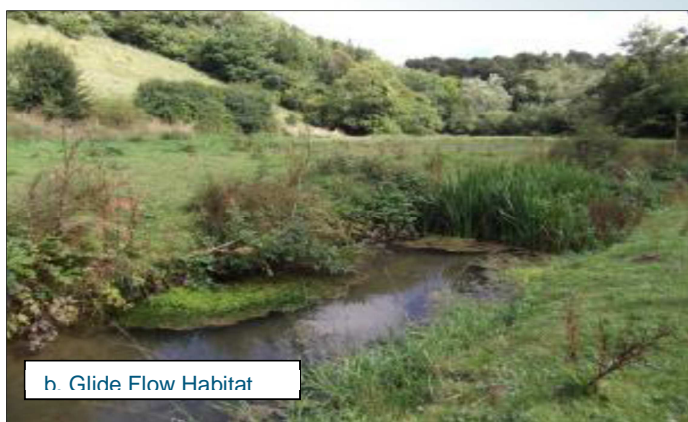
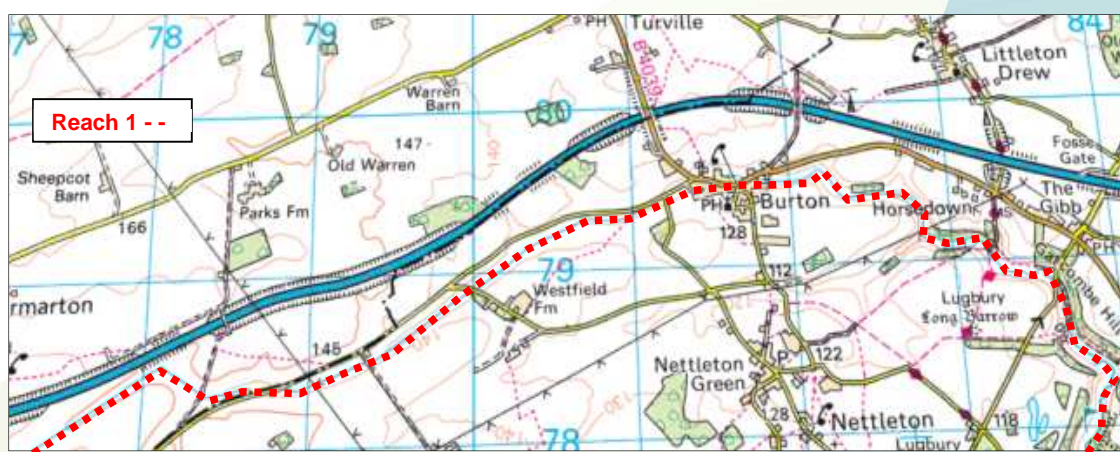


Figure 2.8 Location Plan of Reach 1



Pennsylvania to Castle Combe (Broadmead Brook) (Reach 2)

- 2.4.18 Overall the Broadmead Brook flows through a narrow, shallow valley with a flood plain dominated by pastoral agriculture. The channel planform is characterised by regular meandering with pastoral agricultural areas, whilst within the villages been realigned as a result of historic milling and potential flood defences. There is some evidence of historical channel widening in areas such as West Kingston, which has resulted in an over-wide and uniform channel with a shallow gradient (see **Figure 2.9a**). Fine sedimentation dominates the substrate within the middle sections of this reach, notably between Castle Farm, Marshfield and downstream to West Kingston.
- 2.4.19 Emergent vegetation is present throughout the reach with a dominance of reed species, particularly within areas of glide habitat. Sedges, rushes, and water mint were also noted, whilst water-starwort was recorded in areas with clean gravels and good light penetration. A variety of deciduous tree species are present in a semi-continuous habit throughout the reach which provides shading and areas of open water. Bank vegetation is varied due to the diversity of land management along the river. There is little bank vegetation in areas of pastoral agriculture where livestock graze vegetation down to the water's edge.
- 2.4.20 This reach has a good diversity of flow with riffle-run-glide flows present along the majority of the reach and there is little evidence of active bank erosion (see **Figure 2.9b**). The presence of large woody debris and a number of in-channel structures also contribute to the diversity of flow introducing both chute and rapid flow to some areas. The downstream sections of the reach contain clean stable gravels alongside silt deposits at the channel margins. However the middle reaches exhibit excessive siltation possibly due to the presence of large populations of American signal crayfish burrowing into the soft banks.

Figure 2.9 Key Environmental Features - Pennsylvania and Castle Combe



- 2.4.21 A broad crested weir of approximately 2.3m in height and 5m in width is located downstream of Nettleton Mill, near Castle Combe. The weir is only likely to be passable to migratory fish at high flows only. The reach also contains several other minor in-channel barriers, with large woody debris being the most common type of barrier to fish passage.
- 2.4.22 A location overview plan of Reach 2 is provided in **Figure 2.10**.

Figure 2.10 Location Plan of Reach 2



By Brook and Upper Tributaries (Reach 3, Reach 3a and Reach 3b)

- 2.4.23 Reach 3: Overall the reach between Castle Combe and Ford exhibits a substantial proportion of hydromorphological alteration due to historic milling and flood defence. Downstream of the confluence with the Broadmead Brook, the river is situated within a straight heavily modified channel and exhibits predominant glide flows. As the river flows past Brook House it enters a steep sided valley where the gradient of the river increases and thus the river starts to exhibit more varied flows. The channel in places has been enlarged and realigned and banks heavily modified, most noticeably in Castle Combe and near the weirs which are present throughout the majority of the reach. The banks in the reach are relatively unstable due to a combination of high energy flows from channel gradient, in-channel structures and livestock poaching, with considerable evidence of sedimentation occurring within the river (see **Figure 2.11a**).
- 2.4.24 Reach 3a: This tributary (North Wraxhall to Ford) is dominated by run conditions and swifter flows than the reaches on the main By Brook channel. Sediment transport is the dominant process, with the substrate displaying significant sections of clean gravels and other coarse sediment (see **Figure 2.11b**). Land use is characterised by deciduous woodland with some low intensity grazing in North Wraxhall and on the right-hand bank at the downstream section of the reach.

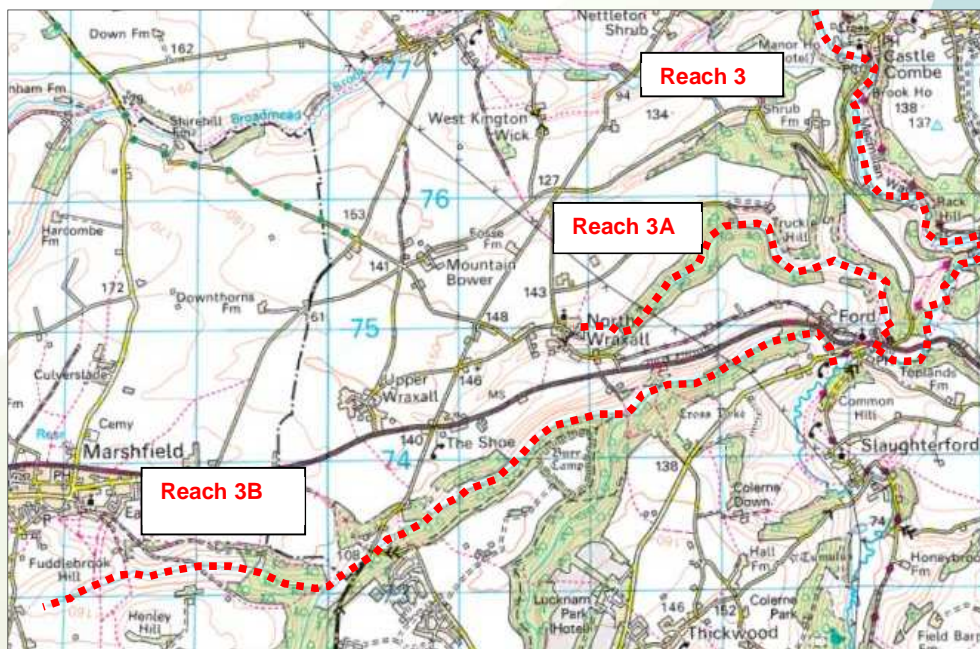
Figure 2.11 Key Environmental Features of By Brook and Upper Tributaries



2.4.25 Reach 3b: This tributary (Marshfield to Ford) displays a good degree of flow and morphological diversity. The channel planform is characterised by a meandering low flow channel with varied bank and bed profiles. Cattle poaching and large scale tree removal from woodland areas has resulted in the substrate character of lower reaches being dominated by fine sedimentation. Gravels and pebbles are cleaner in the upstream sections of the reach but a large proportion of the substrate is covered by filamentous algae in the middle and downstream reaches. Hard bank reinforcement is observed downstream and the channel is disconnected from its floodplain. Land use is dominated by deciduous woodland along the majority of the reach with some areas used as pastoral agriculture.

2.4.26 A location plan of the above reaches is provided in **Figure 2.12**.

Figure 2.12 Location Plan of By Brook and Upper Tributaries

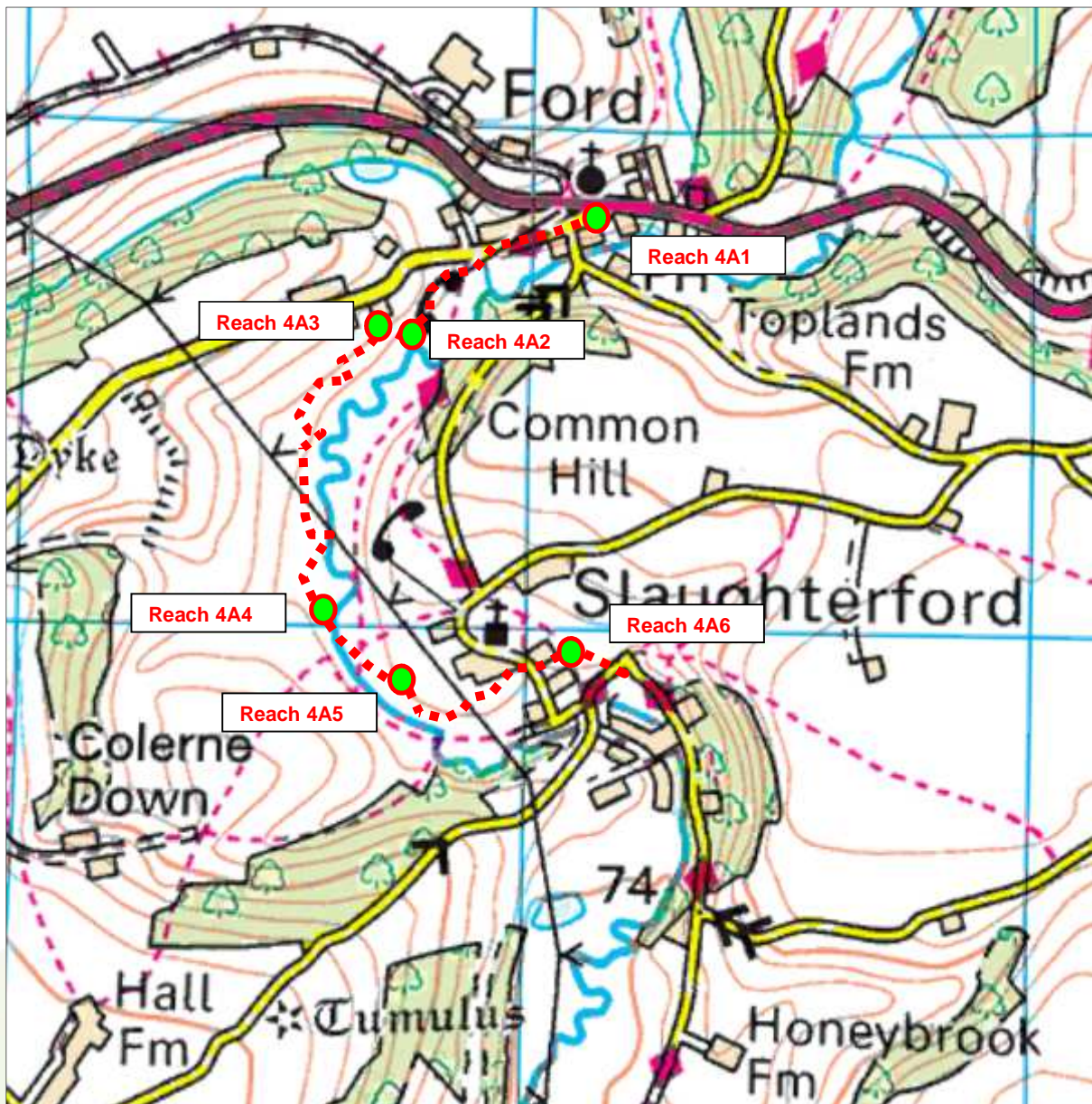


Detailed Overview: Ford Mill Weir to Rag Mill Slaughterford) Weir (Reach 4A)

2.4.27 Specific site details regarding the channel geomorphology (fluvial processes), modifications and structures associated with the By Brook between Ford Mill and Rag Mill Weir (Slaughterford) (see **Figure 2.6**) are provided below. As noted in **Table 2.2**, all the structures associated with the sites present barriers to fish passage.

2.4.28 A location overview plan of Reach 4A is provided in **Figure 2.13**.

Figure 2.13 Location Plan of Reach 4A



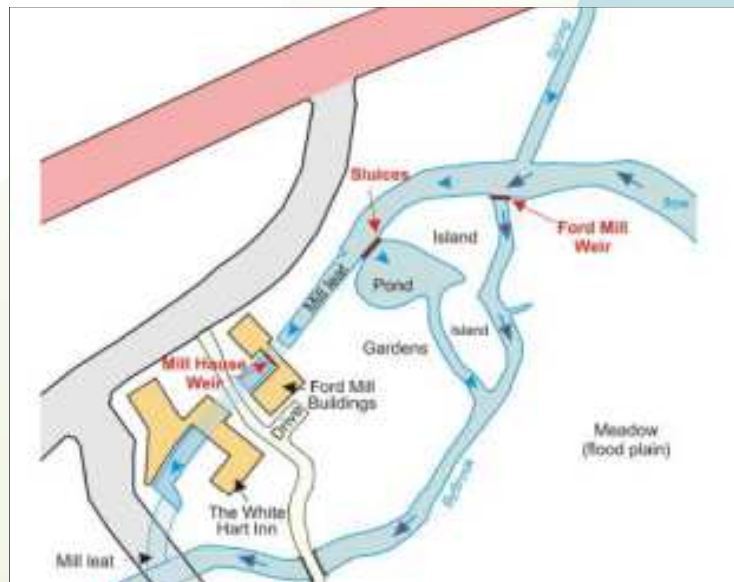
Reach 4A1 - Ford Mill Weir

- 2.4.29 Ford Mill Weir is a privately owned structure upstream of Ford Mill and is in a very poor state. The weir is constructed of masonry and its right abutment has partially collapsed. Whilst it has been temporarily shored up by sandbags, there is leakage behind the structure and in time this leakage will result in further outflanking of the structure. This deterioration process will be exacerbated in the winter when river levels and flows are higher. The condition of this structure is poor and in danger of collapse (see **Figure 2.14**). Overall there is limited access to the weir which is constrained by trees.

Figure 2.14 Ford Mill Weir



- 2.4.30 Within this reach of the By Brook, flows have been impounded in response to the complex historic milling system and the majority of flow is diverted down the main channel of the By Brook and not through the mill leat. However, the mill leat discharges back into the By Brook beneath the road bridge immediately downstream of the White Hart Inn (see inset flow diagram).



- 2.4.31 The impoundment of flows or ponding of water has reduced the overall sediment carrying capacity (velocity) of the watercourse as evident by sediment accumulation on the bed upstream of Ford Mill Weir.

- 2.4.32 Upstream of the weir, the reach is characterised by a slow flowing glide habitat (in response to flow impoundment) within a deep section of channel up to approximately 7m wide (see **Figure 2.15**).

Figure 2.15 **Glide Habitat of Ford Mill Weir**



- 2.4.33 A sluice downstream of Ford Weir used to control water levels is associated with a large pond habitat (see above flow diagram) which has also accumulated large amounts sediments and debris, although it does provide good habitat for flora and fauna such as brown trout which were noted in the pond.

- 2.4.34 Directly downstream of Ford Mill Weir, the habitat is a fast flowing riffle-pool system in which eroded and deposited sediments are being flushed downstream during high flows, although the overall channel habitat is good in places (e.g. good flow / morphological diversity, aquatic plants, and marginal vegetation). However, it was noted some bed sections where relatively armoured or contained large quantities of fine sediment interlocked with coarse bed material decreasing the quality of micro-spawning habitat for fish.



- 2.4.35 The reach of the By Brook between Ford Mill Weir and Weir D/S Ford is generally characterised by a slow flowing meandering glide habitat with good submerged aquatic and marginal vegetation such as Brook water-crowfoot (*Ranunculus penicillatus*) and common reed (*Phragmites australis*) (see insert photo). Evidence of bank instability was observed along this reach potentially in response to changes in water levels causing some sections of bank to collapse thus providing a source of sediment to the system.

Reach 4A2 - Weir D/S Ford

- 2.4.36 Overall the channel and floodplain form and function downstream of Weir D/S Ford has been modified to accommodate flows through widening of channel and floodplain. The actual weir its self (approximately 450m downstream of Ford) which comprises a foot-bridge which forms the river crossing on a public right of way, was built for additional storage capacity to provide flows for an old off-take structure and associated leat that fed Rag Mill Weir further downstream (see **Figure 2.16**).

Figure 2.16 Weir D/S Ford

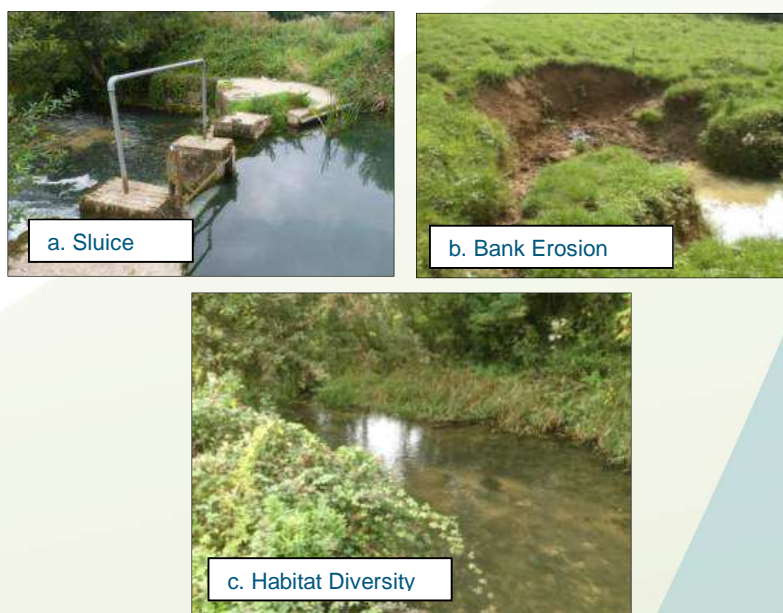


- 2.4.37 Directly upstream of the weir flows are impounded (up to 461m, EA, 2015), while downstream of the weir there is a large scour pool (30m wide) with evidence of bank erosion further contributing to fine sediments into the By Brook (see **Figure 2.16**). Flows are also impounded between Weir D/S Ford and Sluice D/S Ford.

Reach 4A3 - Sluice D/S Ford

- 2.4.38 Directly downstream (175m) of Weir D/S Ford, there is steel sluice (see **Figure 2.17**) potentially constructed to maintain a depth of water at the upstream structure (i.e. Weir D/S Ford) to prevent under-cutting of the weir. Although there are signs of bank slumping (due to cattle poaching) downstream of the sluice further contributing fine sediment to the By Brook, there is a good diversity of flow and morphology habitat in the form of small pool-riffle systems directly downstream for approximately 300m (see **Figure 2.16**).

Figure 2.17 Sluice D/S Ford



2.4.39 Further downstream of Sluice D/S Ford past the small pool-riffle systems, the habitat of the By Brook is characterised by a slow flowing straight glide habitat with good submerged aquatic and marginal vegetation such as common reed (*Phragmites australis*). However, the glide habitat up to 10m wide appears to be in response to channel modifications (e.g. over widening, dredging) and flow impoundment associated with Slaughterford Gate. Flow impoundment upstream of the structure is estimated to be more than 800m (EA, 2015) (see **Figure 2.18**) and appears to have contributed to the settlement of fines on the bed of the By Brook.

Figure 2.18 Upstream of Slaughterford Gate – Flow Impoundment



Reach 4A4 - Slaughterford Gate

2.4.40 Slaughterford Gate which is approximately 900m downstream of Sluice D/S Ford (see **Figure 2.19**), is a steel weir structure currently owned by the Environment Agency (see **Table 2.1**), which was originally constructed to provide a reservoir for the historic rag mill, which formed part of the next structure downstream (Rag Mill Weir). Water level control has been non-operational since an electrically-driven automatic sluice control mechanism became jammed several years ago. Downstream of the structure is a large scour hole (20m wide) with eroded banks.

Figure 2.19 Slaughterford Gate Sluice



Reach 4A5 - Rag Mill (Slaughterford) Weir

- 2.4.41 Directly downstream (160m) of Slaughterford Gate is Rag Mill Weir (see **Figure 2.20**). The weir, which includes a public foot-bridge across the By Brook, comprises a stepped concrete weir with removable boards and is currently in a poor condition with water seeping through the structure. It is unclear if it can actually be repaired to a suitable standard; and a significant proportion (an estimated 60% on the day of walkover) of flows is directed through the structure, instead of over the weir.

Figure 2.20 Rag Mill Weir



- 2.4.42 A large scour hole (12m wide) exists below the weir which has in part undercut and eroded the existing channel bank exposing coarse material and informally developed a recreational freshwater beach for local community (see **Figure 2.20**). Flows upstream of Rag Mill are impounded up to 107m (EA, 2015).

Detailed Overview: Weavert Mill Weir to Shockerwick (Reach 4B, 4C and Reach 5)

- 2.4.43 An overview of the channel geomorphology (fluvial processes), modifications and structures associated with the By Brook between Weavert Mill Weir and Shockerwick is provided below.
- 2.4.44 A location overview plan of Reach 4B, 4C and Reach 5 is provided in **Figure 2.21**.

Figure 2.21 Location Plan of Reach 4B, 4C and Reach 5



Reach 4B1 - Weavern Mill Weir

- 2.4.45 Weavern Mill Weir which is approximately 2km downstream of Rag Mill Weir, is a concrete fixed weir (foot-bridge) structure which is currently in a poor condition and hidden by dense woodland and serves no current use as a water level control structure along the By Brook (see **Figure 2.22**). The weir does present a barrier to fish passage in particular during low flows.

Figure 2.22 Weavern Mill Weir



- 2.4.46 Upstream of the weir, the section of channel varies from relatively diverse flow and geomorphic complexity with good sections of gravel bed including the side branch of the main channel to silt dominated substrates in response to channel banks being significantly poached by cattle and a poorly managed cattle holding area with no hard standing (see **Figure 2.23a**). A scour pool is evident directly downstream of a small weir which is directly upstream (150m) of Weavern Mill Weir in which flows between the two weirs reduce in velocities and silts settle out and along with washed in silts from the cattle holding area provide an environment in which the bed is covered in fine sediments.
- 2.4.47 A scour pool (22m wide) is present directly downstream of Weavern Mill Weir and the channel in places is relatively wide and shallow which allows for cattle to cross the channel during low flows and poach the banks (see **Figure 2.23b**). However, further downstream the channel of the By Brook comprises sections which provide a good flow and geomorphological diversity, comprising of run and slow flowing glide habitat, although the impacts of the upstream sources of sediment are clearly visible on the bed of the channel (see **Figure 2.23c**).
- 2.4.48 Weavern Mill Weir provides access across the By Brook as it incorporates a foot-bridge / access track used by landowners (see **Figure 2.22**).

Figure 2.23 Key Environmental Features of Weavern Mill Weir Site



- 2.4.49 Further downstream of Weavern Mill Weir towards Widdenham Mill Weir, the overall channel is in relatively poor condition in response to channel banks being poached by cattle with large amounts of sediment being washed into the By Brook (see **Figure 2.24**). This was clearly evident during the walkover survey in which the water quality was quite turbid in response to the transport of fine sediments which had been washed into the channel after a rainfall event. Good sections of gravel bed were noted, although the majority the channel bed was dominated by silt deposition. There is evidence directly upstream Widdenham Mill Weir that management has been taking place in response to the local angling club undertaking vegetation improvement works.

Figure 2.24 Cattle Poaching Upstream of Widdenham Mill Weir



Reach 4B2 - Widdenham Mill (Farm)

- 2.4.50 Widdenham Mill Weir which located approximately 900m downstream of Weavert Mill Weir, is a concrete fixed weir which is surrounded by dense woodland and scrub and similar to Weavert Mill Weir appears to serve no current use as a water level control structure along the By Brook (see **Figure 2.25**). The weir does present a barrier to fish passage.

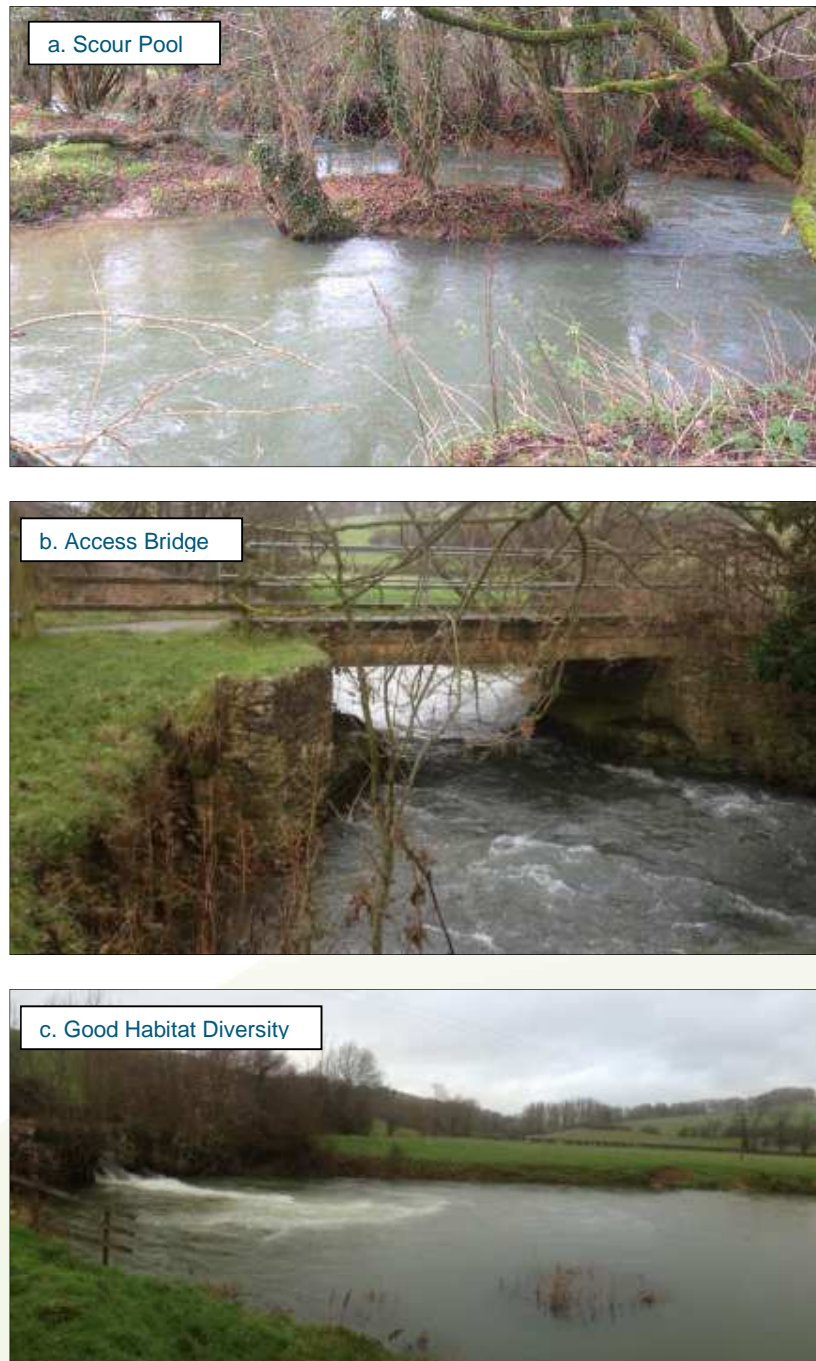
Figure 2.25 Widdenham Mill Weir



- 2.4.51 Downstream of the weir a large scour pool (25m wide) has been formed which has also caused the channel banks to erode and slump in response to fluvial processes (see **Figure 2.26a**), while up to a distance of 574m low flows are impounded upstream of Widdenham Mill Weir (EA, 2015).

2.4.52 Further downstream of Widdeham Mill Weir, the By Brook flows under a small access bridge which constricts flows and increases velocities which has in places eroded the channel banks (see **Figure 2.26b**). However, the downstream section beyond the access bridge is characterised by run habitat with good flow and geomorphological diversity including instream wooded debris (see **Figure 2.26c**).

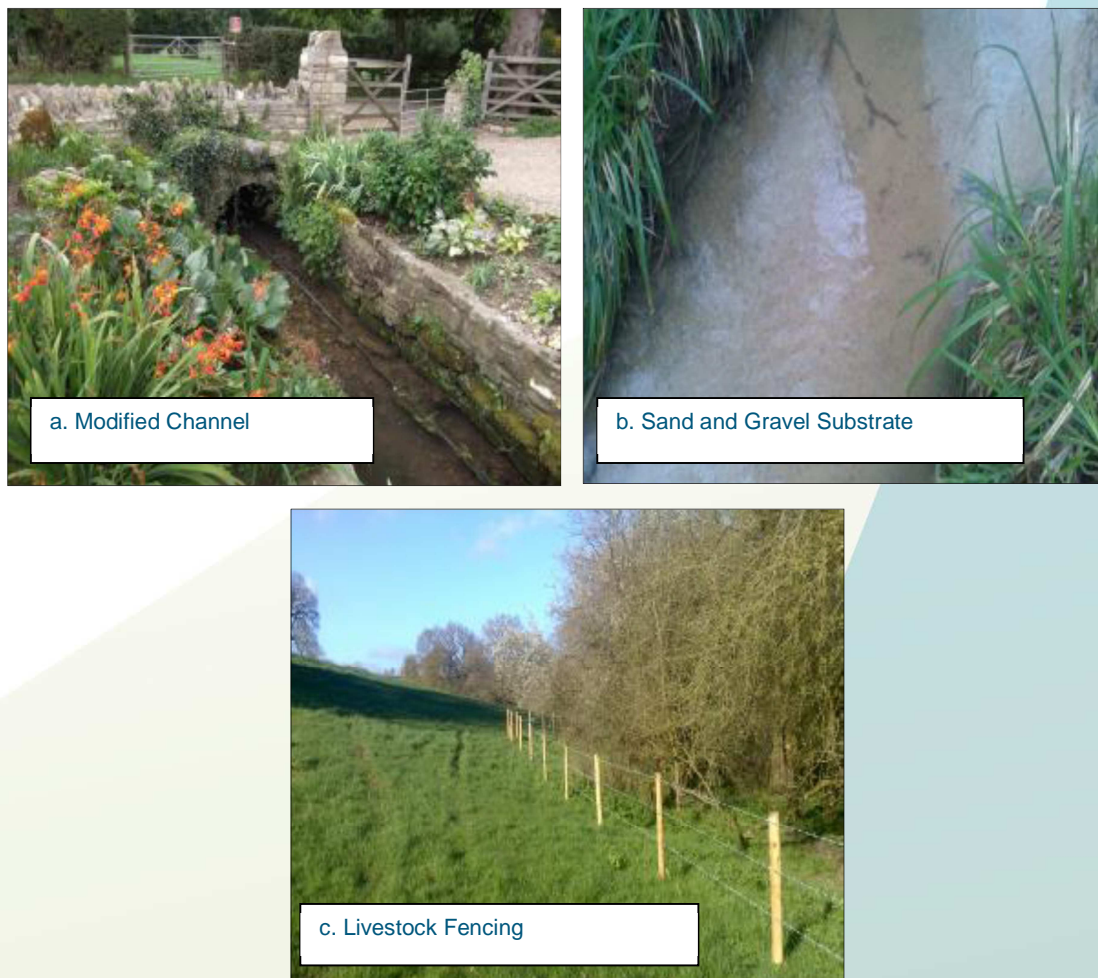
Figure 2.26 Key Environmental Features of Widdeham Mill Weir Site



Reach 4C – Lid Brook

- 2.4.53 The Lid Brook is situated within a high gradient valley and as a result displays a good degree of flow and morphological diversity. The channel planform is characterised by a meandering channel with varied bank and bed profiles. The channel is connected well to the floodplain along the majority of the reach and is present on both banks in the upstream sections of the reach. However, in the middle sections of the reach the river becomes disconnected from the floodplain due to the steep banks and modification (see **Figure 2.27a**), although returns to a wide connected floodplain in the downstream sections of the reach. Land use in the floodplain consists of pastoral agriculture and is dominated by dairy cattle on both banks of the river. Excessive poaching in the past has led to accelerated bank erosion, siltation and destruction of riparian habitat, although good sections of clean gravels do occur along the upstream sections of the reach (see **Figure 2.27b**).
- 2.4.54 Very little riparian vegetation exists along this reach. This is largely due to livestock access to the river and the excessive poaching which has caused damage to bankside structure and vegetation. However, with livestock fencing that has been erected in the past year it is hoped that a good diversity of riparian vegetation begins to establish along this reach (see **Figure 2.27c**).

Figure 2.27 Key Environmental Features of Lid Brook



Reach 5A1 - Drewitts Mill

- 2.4.55 Drewitts Mill consists of a water control structure in the form of a wooded board sluice which controls water levels along the mill stream (By Brook) (see **Figure 2.28**). The sluice is located approximately 1.2km downstream of Widdenham Mill Weir.

Figure 2.28 Drewitts Mill Sluice



- 2.4.56 It was noted in the Bart report (see **Appendix A**) that the sluice is not a barrier to fish passage when no boards are in place. However, during the time of the walkover survey the sluice was completely blocked with large wooded debris which would not have been passable to fish (see **Figure 2.29**).

Figure 2.29 Wooded Debris and Drewitts Mill Sluice



2.4.57 Upstream of the sluice, flows are impounded to approximately 300m. Poached banks and floodplain were noted during the walkover survey, although there are good sections of gravel bed and instream diversity in form of large wooded debris past the extent of the flow impoundment, in which the dominant flow habitat is a combination of glides, runs and riffles. Directly downstream of the sluice there is a large scour pool (18m wide). Clean gravel beds were noted along the Lid Brook during the walkover which provides a good source of coarse sediments to the By Brook (see **Figure 2.30**).

Figure 2.30 Lid Brook Gravels



Reach 5A2 - Box Mill (Real World Studios)

2.4.58 Box Mill is located approximately 1km downstream of Drewitts Mill and comprises of four steel sluices which maintain the hydrostatic head over 2.8m, making this structure the largest fish migration barrier along the By Brook (see **Figure 2.31a**). Although historically used as a water control structure to keep water levels maintained along the mill leat for milling purposes, the sluice now maintains water levels for aesthetic reasons associated with Box Mill Studios owned by Peter Gabriel (see **Figure 2.31b**).

2.4.59 Downstream of the sluice a large scour pool (22m wide) is present (see **Figure 2.31c**), although further downstream towards Box Mill, the channel is characterised by good flow and geomorphological diversity including deposition benches and wooded debris.

Figure 2.31 Box Mill Sluice and Key Environmental Features



2.4.60 Upstream of the sluice there are slow flowing glide sections which are the dominant flow habitat (see **Figure 2.30d**). The section upstream of the sluice is a known white-clawed crayfish habitat and generally the habitat is in good condition in regards to flow and geomorphological diversity with minimal anthropogenic impacts evident during the walkover survey.

Reach 5A3 - Middlehill Gauging Weir

2.4.61 Middlehill Gauging Weir is an Environment Agency Gauging Station comprising of a concrete crump weir (7m wide) (see **Figure 2.32a**) and is located approximately 1.1km downstream of Box Mill. Downstream of the weir the channel is characterised by good flow and geomorphological diversity including deposition benches and wooded debris (see **Figure 2.32b** and **2.32c**). Runs and riffles (which include good sections of gravel beds) are the dominant flow habitats. However, adjacent fields have the potential to provide a large source fine sediments to the By Brook if not managed appropriately (see **Figure 2.32d**).

2.4.62 The weir does appear to present a barrier to fish passage in particular during low flows. Flows upstream of the structure are impounded for a distance of 53m during low flow conditions.

Figure 2.32 Middlehill Gauging Weir and Key Environmental Features



Reach 5A4 - Shockerwick Mill (Old) Weir

- 2.4.63 Shockerwick Mill Weir is located approximately 1.1km downstream of Middlehill Gauging Weir and comprises of a fixed crest weir with a steel sluice (see **Figure 2.33a**). The weir does appear to present a barrier to fish passage in particular during low flows. The current operational purpose and regime of the sluice component of the weir is unknown although there is evidence that it is operated. Flows upstream of the structure are impounded for distance of 672m during low flow conditions (EA, 2015).
- 2.4.64 Overall flow and geomorphological diversity downstream of the weir is good and is generally characterised by run and riffle flow habitats with good sections of gravel bed (see **Figure 2.33b**). There was limited evidence of channel erosion or bank slumping associated with anthropogenic impacts during the walkover survey. Sheep grazing is the dominant livestock being farmed which has had no impacts upon the banks of the By Brook downstream of the weir. The stretch of the By Brook downstream of the weir is also managed by the Bathampton Angling Club.

Figure 2.33 Shockerwick Mill Weir and Key Environmental Features



Geomorphological Conceptual Model

2.4.65 **Figure 2.34** provides a conceptual model of the key geomorphological processes and constraints associated with the By Brook catchment between Ford and Shockerwick based on **Section 2.4** and the By Brook Fluvial Audit undertaken by BART between December 2014 and January 2015. Further geomorphological processes for other section of the catchment are presented in **Appendix D**.

2.5 Designated Sites

- 2.5.1 By Brook itself is not a designated site, although several small SSSIs are located across the catchment that are adjacent to the By Brook and its tributaries (see **Figure 2.6**). In the upper catchment, Little Grubbins Meadow SSSI adjacent to Broadmead Brook, and Rack Hill SSSI adjacent to the By Brook near Castle Combe are both SSSIs designated for calcareous grassland features¹⁵. The nearby river is not mentioned in the reasons for designation, and actions which could impact the river are not considered likely to affect the integrity of these two SSSIs, which have therefore been scoped out of further consideration for this project.
- 2.5.2 Downstream of Slaughterford there are two SSSIs adjacent to the By Brook: Honeybrook Farm SSSI on the east bank, and Colerne Park and Monk's Wood SSSI on the west bank¹⁶. The citations for these two SSSIs explicitly refer to the floral assemblages associated with the wet margins and floodplain, and the list of operations likely to damage these SSSIs includes "**modification of the structure of watercourses (e.g. rivers, streams, springs, ditches, dykes, drains), including their banks and beds, as by re-alignment, re-grading and dredging**". Managing bank vegetation and changing water levels and tables are also listed as actions that may cause deterioration of the SSSIs. For Honeybrook Farm SSSI in particular, clear views about management were set out by Natural England in 2005 which may limit restoration activities in the By Brook, and it is therefore recommended that Natural England are contacted as an early stage to discuss their latest views on the management of this habitat.
- 2.5.3 None of the structures listed in **Section 2.4** are located within the reach of the By Brook covered by the two SSSIs. However, works on structures upstream of the SSSIs (from Chapps Paper Mill at Slaughterhouse to the upper reaches of the catchment) could indirectly have an impact on the SSSIs during construction and operation of the river restoration solutions by changing the quality of the downstream river habitat (see **Section 4**). Downstream of the SSSIs, Weavert Mill is located at the foot-bridge which marks the southern limit of the Colerne Park and Monk's Wood SSSI, thus potential river restoration works at this location could also potentially have a direct localised impact on this section of the SSSI (see **Section 4**).

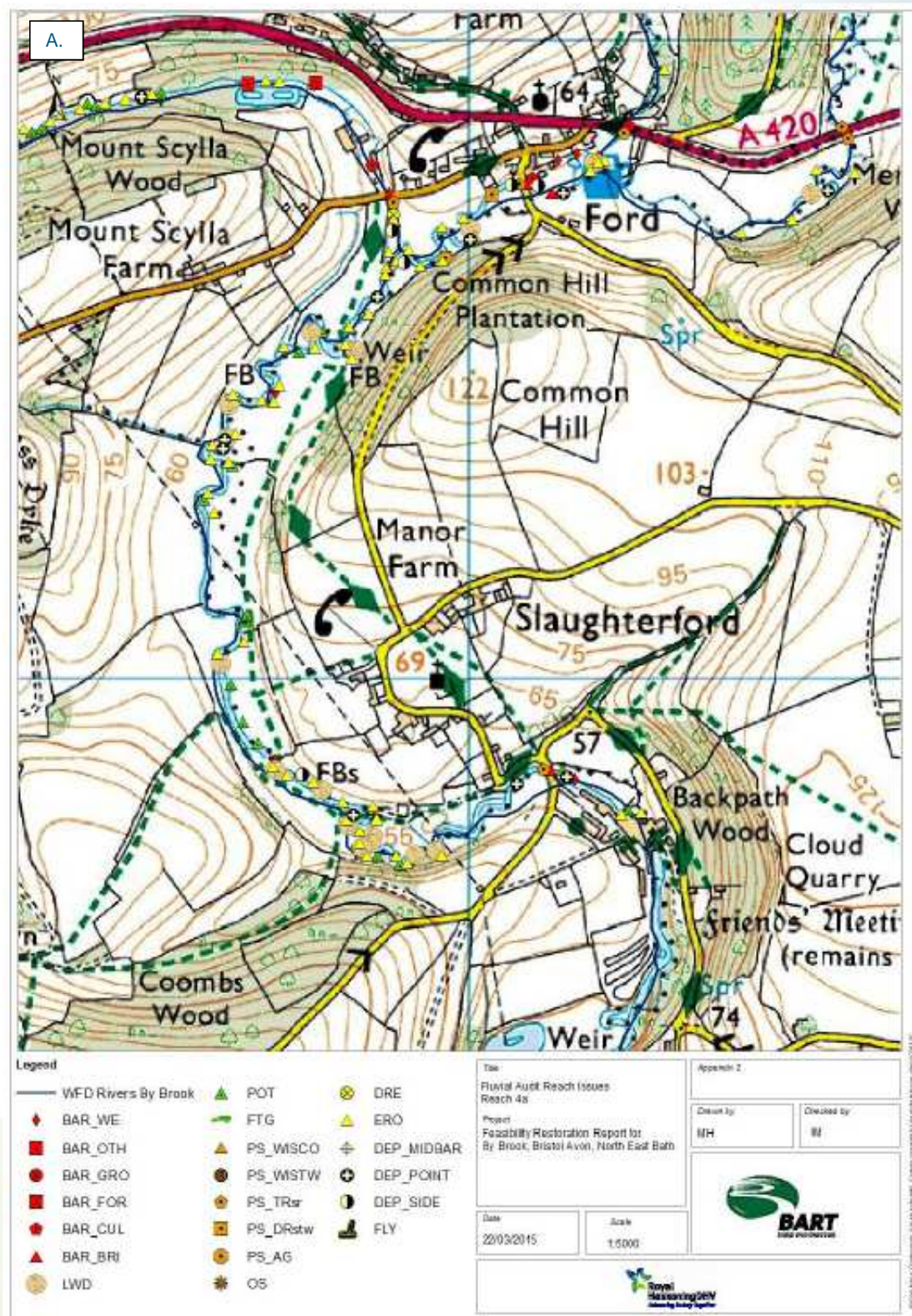
¹⁵ Little Grubbins Meadow SSSI. Retrieved 28/10/2014 from <http://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1004487>

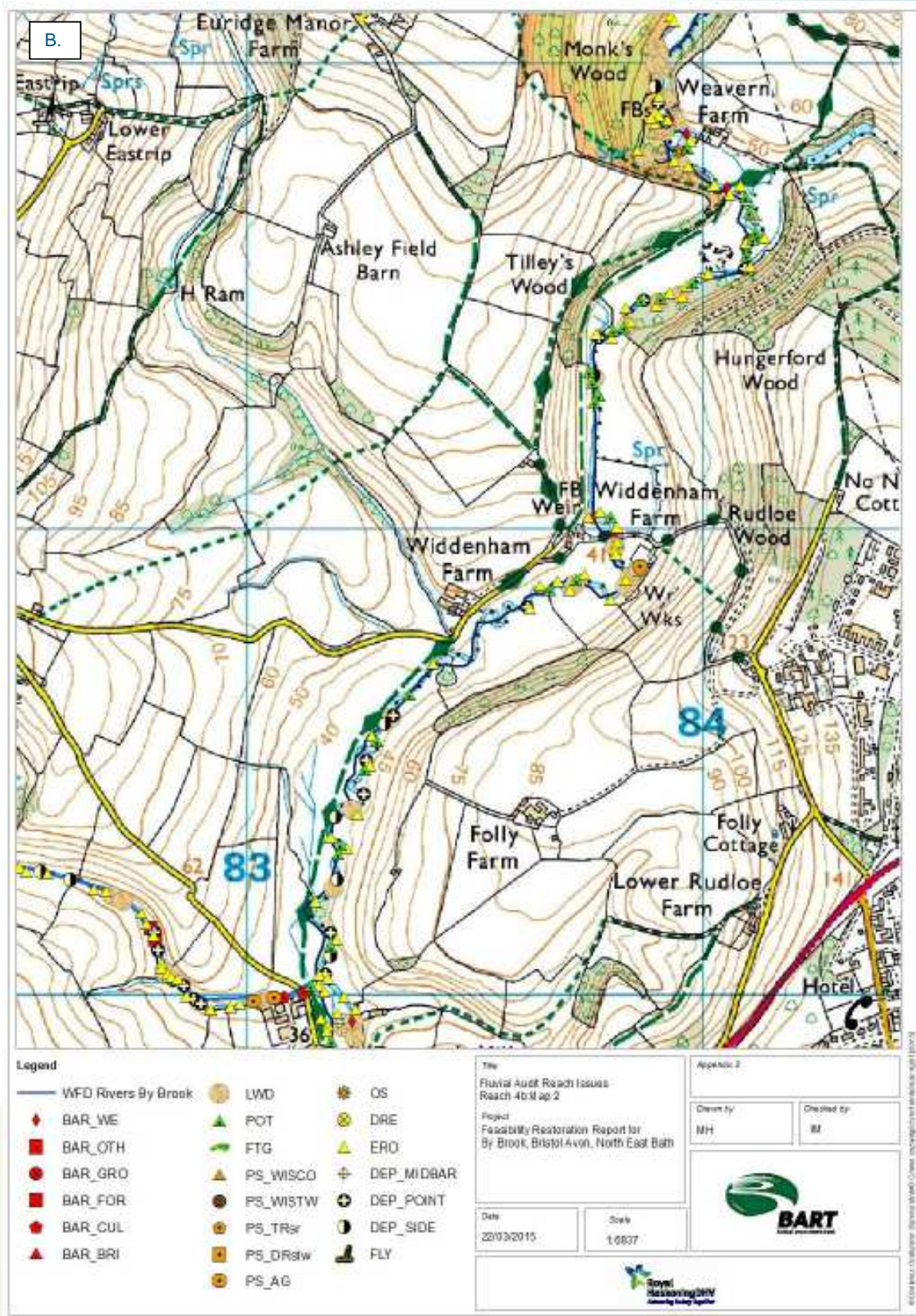
Rack Hill SSSI. Retrieved 28/10/2014 from <http://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1001906>

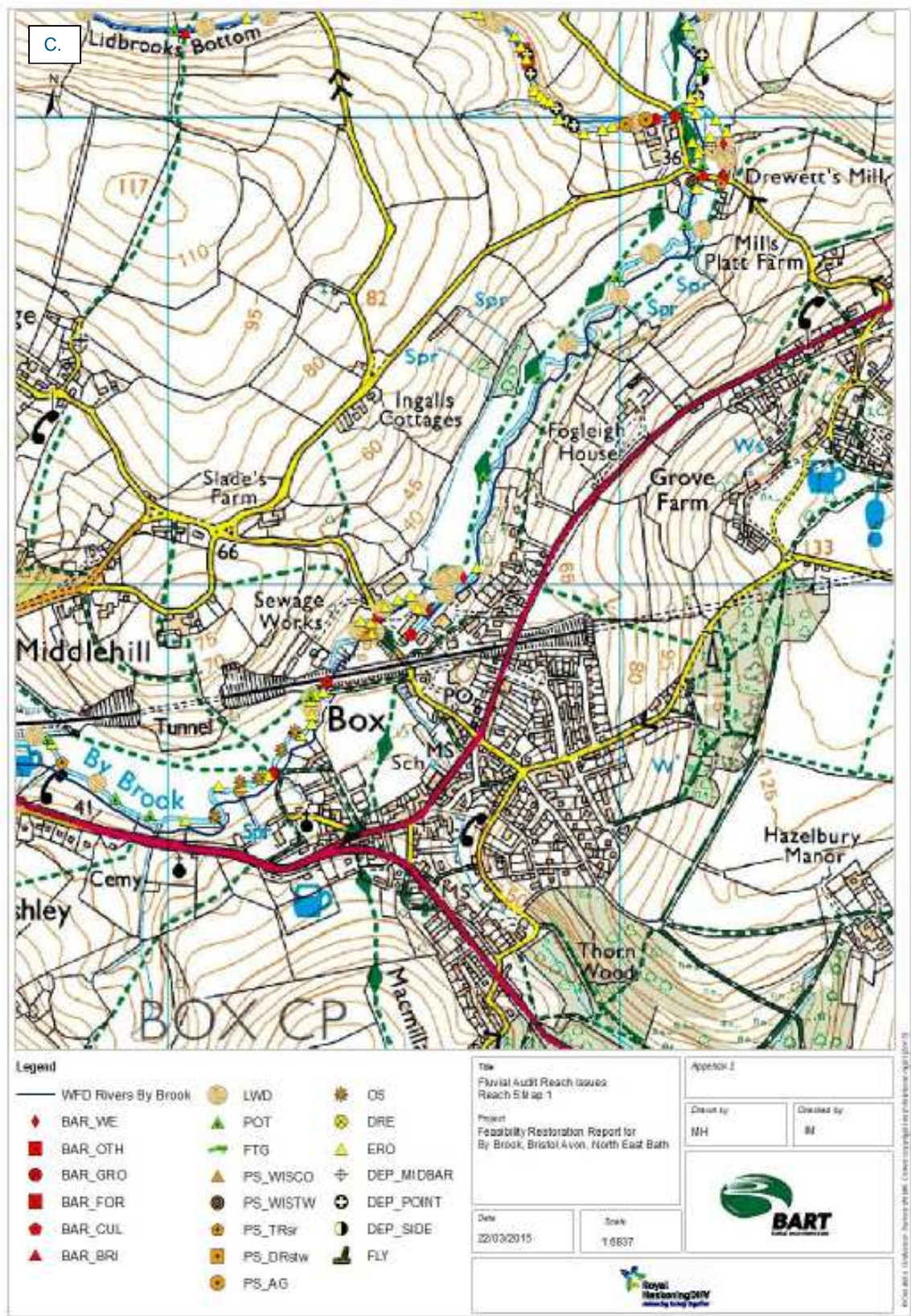
¹⁶ Honeybrook Farm SSSI. Retrieved 28/10/2014 from <http://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1006376>

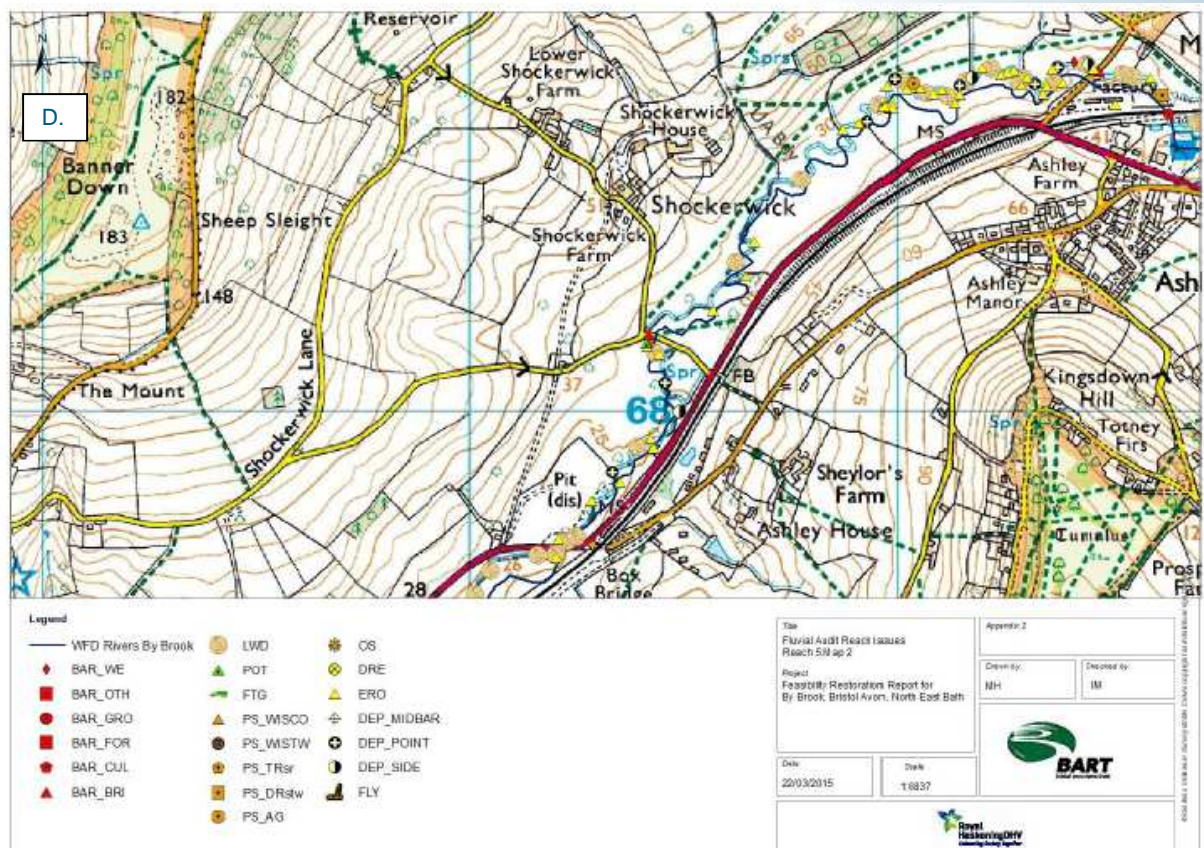
Colerne Park and Monk's Wood SSSI. Retrieved 28/10/2014 from <http://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1003288>

Figure 2.34 By Brook Geomorphological Process Between Ford and Shockerwick









Legend Key for Figure 2.34:

Code	Description
FTG	Farm Tracks and Gateways (as pathways)
POT	General Poaching and Trampling
PS_TRSr	Pipe/Run-off - Transport - Road
PS_DRStw	Domestic and Residential
PS_WlStw	Water Industry
PS_WlCso	Water Industry
PS_Ag	Pipe – Farm
BAR_We	Manmade Barrier – Weirs, sluices or dam across river channel
BAR_Cul	Manmade Barrier – Culvers
BAR_Bri	Manmade Barrier – Bridges
BAR_For	Manmade Barrier – Fords
BAR_Gro	Manmade Barrier – Deflectors
BAR_Oth	Manmade Barrier – Other Structure
ERO	Erosional Features
DEP	Depositional Features
DRE	Dredging
FLY	Drainage Ditch
OS	Other Sources

2.5.4 The By Brook catchment is located at the southern end of the Cotswolds Area of Outstanding Natural Beauty¹⁷. Within the AONB, the By Brook comprises two character areas: dip-slope lowland valley (Upper By Brook Valley) and enclosed limestone valley (Lower By Brook Valley).

2.5.5 There are no other designated sites (i.e. Ramsar, SPA, SAC, NNR or LNR) located within the By Brook catchment (see **Figure 2.6**).

2.6 Terrestrial Flora and Fauna

2.6.1 The variety of geomorphological landforms in the By Brook catchment are known to support a high diversity of terrestrial plant and animal species, including mature trees and lime-loving shrubs, badgers, deer, and bats¹⁸.

2.6.2 The SSSIs adjacent to the By Brook (Honeybrook Farm SSSI, and Colerne Park and Monk's Wood SSSI) are primarily designated for the woodland and grassland habitats they contain. Colerne Park and Monk's Wood SSSI is a floristically rich southern calcareous ash-wych elm wood which supports uncommon woodland plants such as meadow saffron (*Colchicum autumnale*), toothwort (*Lathraea squamaria*), herb-paris (*Paris quadrifolia*), and green hellebore (*Helleborus viridis*). Open areas within the SSSI provide habitats for a diversity of mammals, birds and insects, notably butterflies dingy skipper (*Erynnis tages*) and grizzled skipper (*Pyrgus malvae*), and other species such as Blomer's rivulet (*Discoloxia blomeri*).

2.6.3 Honeybrook Farm SSSI is one of the few remaining non-intensively managed lowland farms in Britain, comprising hay meadows, lime-stone grassland, ancient semi-natural woodland, a small lake and part of the By Brook. The site as a whole supports a rich transitional plant community, from crested dog's-tail (*Cynosurus cristatus*) and red fescue (*Festuca rubra*) in the hay meadow to southern marsh-orchid (*Dactylorhiza praetermissa*), and common meadow-rue (*Thalictrum flavum*) along the wet margins.

2.6.4 Other species of note supported along the By Brook include:

- Brown long-eared bat (*Plecotus auritus*);
- Common pipistrelle (*Pipistrellus pipistrellus*);
- Myotis bat (*Myotis myotis*);
- Lesser horseshoe bat (*Rhinolophus hipposideros*);
- Soprano pipistrelle (*Pipistrellus pygmaeus*);
- Badger (*Meles meles*).

¹⁷ <http://www.cotswoldsaonb.org.uk/>

¹⁸ Tatem, K (1996) A History of the By Brook. Published by the Environment Agency.

2.7 Freshwater Flora and Fauna with Special Reference to Native Crayfish

Fish

- 2.7.1 Based on surveys to date (see BART, 2013), the By Brook supports a variety of fish species including sea trout and brown trout (*Salmo trutta*). Brown trout has been identified as the dominant species along the By Brook, with small numbers of other fish species such as bullhead (*Cottus gobio*) and three-spined sticklebacks (*Gasterosteus aculeatus*) also present. Angling club catch records indicate that brown trout population levels in the By Brook have been relatively stable over the last 40 years, although this may be assisted by annual stocking of brown trout. However, under more natural conditions a greater range of course fish would be expected in the By Brook, including dace, chub, roach, gudgeon and grayling. No European eel have been recorded at any locations upstream of Box since 2003, a single specimen was recorded at Weavert Farm (BART, 2013), although anecdotal evidence from local landowners suggests elvers have been regularly recorded in the By Brook near Ford.

Native Crayfish

- 2.7.2 Under current legislation, the native white-clawed crayfish (*Austropotamobius pallipes*) is a 'protected species' under Schedule 5 of the Wildlife & Countryside Act 1981 (as amended), and a UK Biodiversity Action Plan (BAP) priority species (BART, 2013). The species is included in Appendix III of the Bern Convention and Annexes II and V of the European Habitats and Species Directive 1992, which is implemented in the UK under the Conservation Regulations (Natural Habitats & c.) 1994 (as amended). The species was upgraded with regard to its global status, from *Vulnerable* to *Endangered* in the 2010 review of the IUCN's global Red Data List of Threatened Species, in the assessment of crayfish species (prepared by Zoological Society of London, 2010). Standard practice for river works in the UK is to adopt best ecological practice guidelines to avoid detrimental impacts, killing and injuring, through appropriate Ecological Clerk of Works.
- 2.7.3 Whilst not designated specifically for this purpose, the By Brook has been identified as one of the last local strongholds of the white-clawed crayfish. The watercourse has historically held an extensive native crayfish population and continues to be a regionally important population. However, the native population is under threat from invasive crayfish species, namely the American signal crayfish (*Pascifastacus leniusculus*). Work to understand the population health, pressures (from encroaching non-native species) and geographical spread in the By Brook is on-going, but any works to enable fish passage will have to demonstrate that it will not adversely impact upon the resident white-clawed crayfish population or will have to include mitigation actions, which may include re-location (BART, 2013).
- 2.7.4 The substrate, habitat and water quality of the By Brook offers "ideal environmental conditions" for native crayfish populations (OHES, 2014a & b). Crayfish require calcareous watercourses, within which the species typically occupies sheltered aquatic habitats, ideally with soft vertical banks, overhanging vegetation and suitable areas of shelter from predation and water flow (such as submerged tree roots and man-made constructions including piers, fishing platforms and walls), as can be found at the By Brook (OHES, 2014a & b).

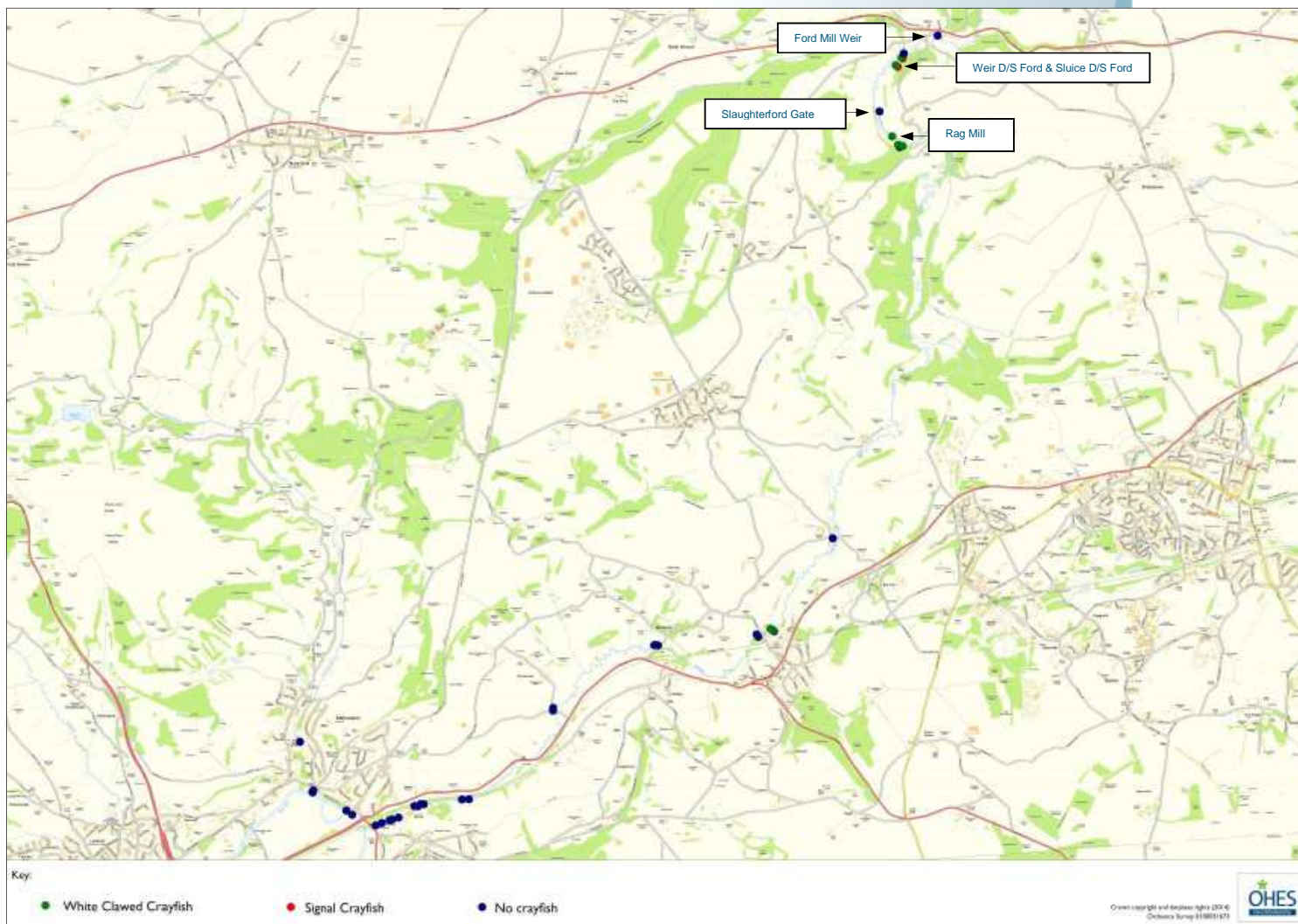
- 2.7.5 Native crayfish have been identified as present in the By Brook since the 1970s. Non-native signal crayfish were introduced to Broadmead Brook in the upper By Brook catchment in the 1970s by a landowner, and gradually migrated downstream to Castle Combe. No further introductions of signal crayfish have been identified since then and it is assumed that the current signal crayfish population in the river consists of descendants of this stock (OHES, 2014a & b).
- 2.7.6 A series of crayfish surveys has been undertaken over the last few years by the Avon Wildlife Trust (BART, 2013) and OHES (OHES, 2014a & b) (see **Figure 2.35**). The initial survey in 2013 found evidence of white-clawed crayfish in the By Brook between Ford and Box, with particularly strong numbers at Slaughterford. Native and invasive crayfish species are considered likely to be absent downstream of Box. Signal crayfish were identified co-existing with the native population between Ford and Slaughterford (including evidence of breeding populations), which is the first time the non-native species has been identified this far downstream. **It was anticipated that the presence of non-native species encroaching on the stronghold for white-clawed crayfish at Slaughterford was likely to lead to signal crayfish out-competing the native population on one to five years** (OHES, 2014a & b). A further survey in April 2014 found no white-clawed or signal crayfish at the locations sampled in the By Brook, although it was considered reasonable to assume that crayfish are present where suitable habitat exists and environmental conditions are appropriate in the river. It was concluded that in the medium to long-term, white-clawed crayfish are highly likely to become extinct within the By Brook, as signal crayfish (and possibly other invasive crayfish species in time) become established throughout the catchment. Environment Agency guidance on the links between white-clawed crayfish and fish passes is available (Diamond, 2013). This brief statement highlights that any benefits of enhanced fish passage may be offset by the damage to native crayfish populations, in situations where a barrier is removed which otherwise impedes the migration of non-native crayfish into a reach supporting native crayfish. Under these situations it is considered likely that invasion of non-native crayfish into an area occupied by native white-clawed crayfish would occur, leading to the eradication of the native population. The guidance states that while this is a matter for local assessment, the precautionary principle should be used.
- 2.7.7 In terms of restoration work between Ford and Slaughterford, the OHES report advises that in the long-term, based on current evidence of signal crayfish spread characteristics, **moderate channel enhancements in this reach would not make a significant negative contribution to declines of white-clawed crayfish** (OHES, 2014a & b). However, there are considerable potential short-term risk from capital works, bank disturbance and siltation. Ecological Clerk of Works and surveys are recommended to minimise risks to native crayfish and other protected species (such as nesting birds and otters) during the works. The report also recommends that translocation of the current native population to a suitable Ark site is considered to safeguard the population in the medium to long-term, potentially as a piece of work undertaken in collaboration with the Environment Agency and local groups such as the West of England Nature Partnership and Avon Wildlife Trust.

Other Invertebrates

- 2.7.8 The By Brook catchment is known to support a range of other invertebrate species due to the range of habitats provided, including butterflies, damselflies, mayflies and caddis flies¹⁹.

¹⁹ Tatem, K (1996) A History of the By Brook. Published by the Environment Agency.

Figure 2.35 Overview of Crayfish Presence / Likely Absence Results (2013 & 2014)



2.7.9 Invertebrate information has been collected by Ahern Ecology, Bath Spa university students (Lid Brook only) and from Fly life data collected by volunteers. Survey data collected by Ahern Ecology (August 2013) from the By Brook at Ford and at Box show a range of invertebrate species present in the watercourse (BART, 2013). The most abundant types of invertebrates were those such as trueflies, beetles, snails and worms with a moderate to high tolerance to organic pollution (BMWP scores of 1 to 5). Overall this indicates a moderate level of organic pollution in the By Brook (ASPT scores of 5.3 to 5.8), with species diversity higher at Box than upstream at Ford. Invertebrate data available from Lid Brook indicate a heavily impacted stream, with ecological quality deteriorating with distance downstream to the confluence with the By Brook.

Aquatic Plants and Diatoms

2.7.10 The range of habitats provided by By Brook and its tributaries also support a rich mosaic of plant life, from ferns and liverworts in shaded areas, to tall herbs such as yellow iris (*Iris pseudacorus*) in more open areas, to characteristic in-channel vegetation such as water starwort (*Callitriche stagnalis*) and water crowfoot (*Ranunculus sp.*) in the channel²⁰.

2.7.11 Macrophyte data were collected by Ahern Ecology (BART, 2013) alongside invertebrate monitoring in 2013. Macrophyte cover was abundant and species present were characteristic of slow flowing waterbodies, with branched bur-reed (*Sparganium erectum*) and perfoliate pondweed (*Potamogeton perfoliatus*) the dominant in-channel macrophytes, and bankside macrophytes dominated by reed canary-grass (*Phalaris arundinacea*).

Mammals

2.7.12 Mammal species of note supported along the By Brook include otter (*Lutra lutra*) and water vole (*Arvicola amphibious*), both identified upstream of Castle Combe and downstream around of Box, but not between Ford and Slaughterford.

2.8 Fish Passage Criteria and Target Species

2.8.1 Extensive empirical trials in France and the U.S.A. indicate that certain fish passes are particularly suitable for certain species. Coarse fish passage can often be accommodated with pool and traverse type fish passes within technical and non-technical (e.g. rock ramp) fish passes if care is taken to reduce the power density in each pool and to maintain a low head loss between pools (Armstrong *et al.*, 2004).

2.8.2 Fish will tend to move in windows of opportunity that will rarely be in a drought or a flood. Coarse fish, for example, will be moving upstream to spawn in the spring when flows will usually be within a certain range around Annual Daily Flow (ADF) (Q50) (Armstrong *et al.*, 2004).

2.8.3 It is important to know the hydrological conditions in which fish are moving so as to define the range of operation of any passage facilities. There is no substitute for knowing or establishing the local conditions for the specific site where it is intended to provide a pass. However, if information on fish migration and flow is not available for the site, then it is suggested that the facility for upstream migration should be designed to operate across a flow range from Q90 to Q10 for salmon; Q95 to Q10 for sea trout and brown trout; Q50 to Q20 for coarse fish and shad; and Q99 to Q70 for eel.

²⁰ Tatem, K (1996). A History of the By Brook. Published by the Environment Agency.

- 2.8.4 Thus, the recommended option identified during this appraisal process should provide passage to the above identified fish in **paragraph 2.7.1** within the defined range of flows as stated in **Table 2.4**. These defined flows are based on flow exceedance values obtained at Gauge 53028 By Brook at Middlehill, NGR ST814688. The Q95 estimated flow is within a similar range estimated for the recent By Brook Flood Risk Modelling Study undertaken for the By Brook (EA, 2015). Variations in low flow values for Q95 do not vary significantly along the By Brook (EA, 2015).

Table 2.4 Target Fish Species and Associated River Flow Rates

Target Species	Lower Design Flow (m ³ /s)	Highest Design Flow (m ³ /s)
Trout	Q95 – 0.25m ³ /s	Q10 – 4.0m ³ /s
Eels	Q99 – 0.2m ³ /s	Q70 – 0.5m ³ /s

Please note: Flows are in cubic metres.

2.9 Cultural Heritage and Land Use

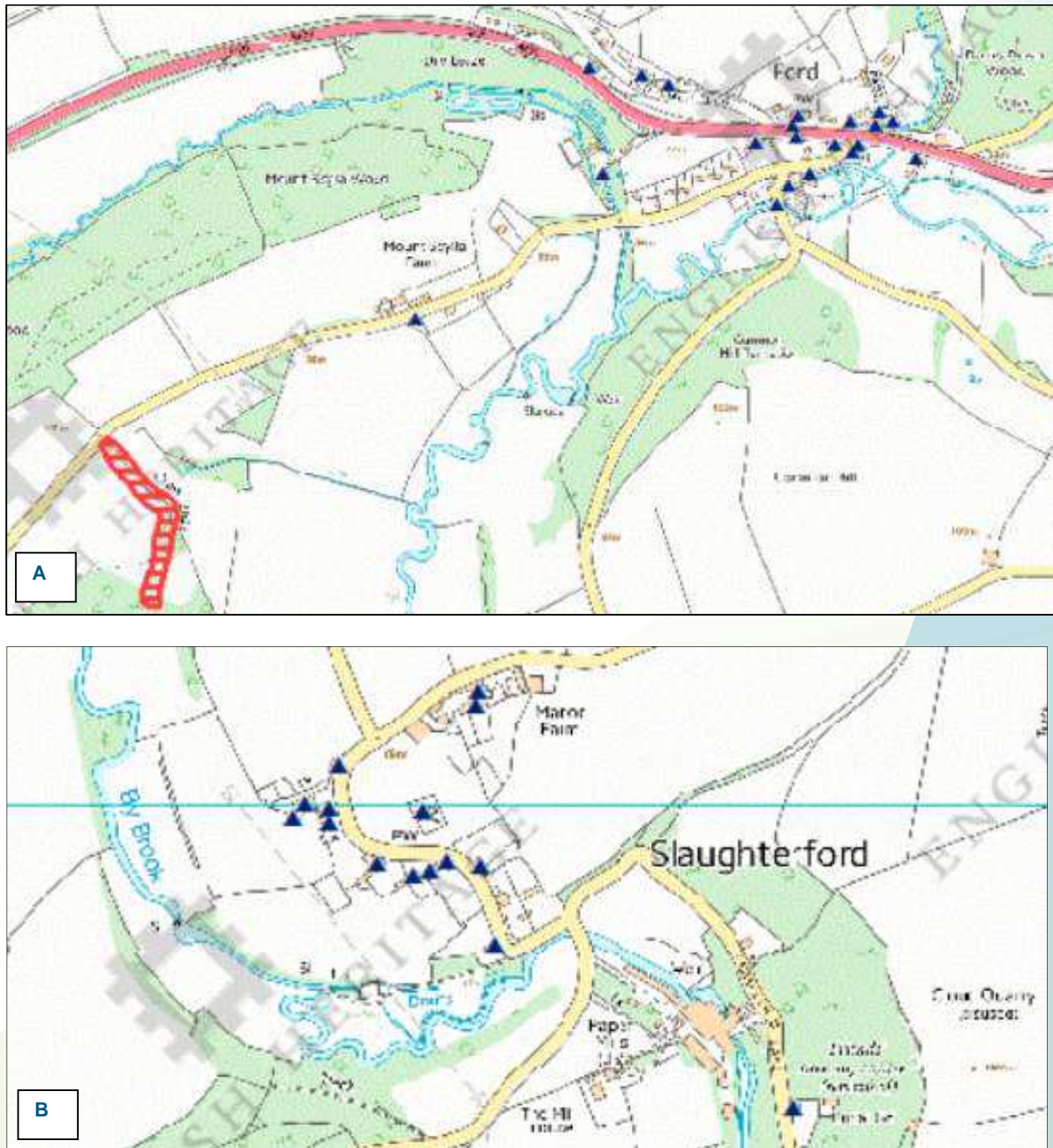
- 2.9.1 Land use in the By Brook catchment is predominantly arable (36%) and grassland (44%), with scattered areas of woodland (14%) particularly along Doncombe Brook and the un-named tributary near Ford, and around the By Brook reach immediately downstream of Slaughterford²¹. Farming in the catchment is predominantly arable in the upper reaches above Castle Combe, and mostly livestock-based (primarily beef and dairy) from Castle Combe to Box (BART, 2013).
- 2.9.2 Urban land use in the catchment is limited, comprising mainly of small villages (Marshfield and Colerne in the upper catchment, Castle Combe, Slaughterford and Ford along the By Brook), with two larger villages in the lower catchment adjacent to the By Brook (Box and Batheaston).
- 2.9.3 Evidence of human activity and land management can be found in the By Brook catchment going back 6,000 years, from Neolithic long barrows to evidence of past agricultural practices²². Sections of a Roman Road cross through the centre of the catchment from north to south. The impact of industry in the Cotswolds region, especially the success of the wool trade from the Middle Ages onwards, is hugely significant. As discussed in **Section 1.1**, the culture heritage of the By Brook catchment, particularly modifications made to support local industry such as flour and wool mills, and grassland for sheep grazing, have had a profound impact in shaping the river and surrounding landscape. Although no longer in operation, many mill structures and associated weirs and sluices are evident along the course of the By Brook today.
- 2.9.4 There are over 20 scheduled monuments located within the By Brook catchment. One of these is located on the By Brook: Bathford Bridge, situated just upstream of the River Avon confluence (see **Figure 2.36e**). The town of Bath downstream is a World Heritage Site.
- 2.9.5 There are well over 100 listed buildings in the By Brook catchment, mostly clustered in small villages. At least eight of these listed buildings have been identified as bridges and mills on the By

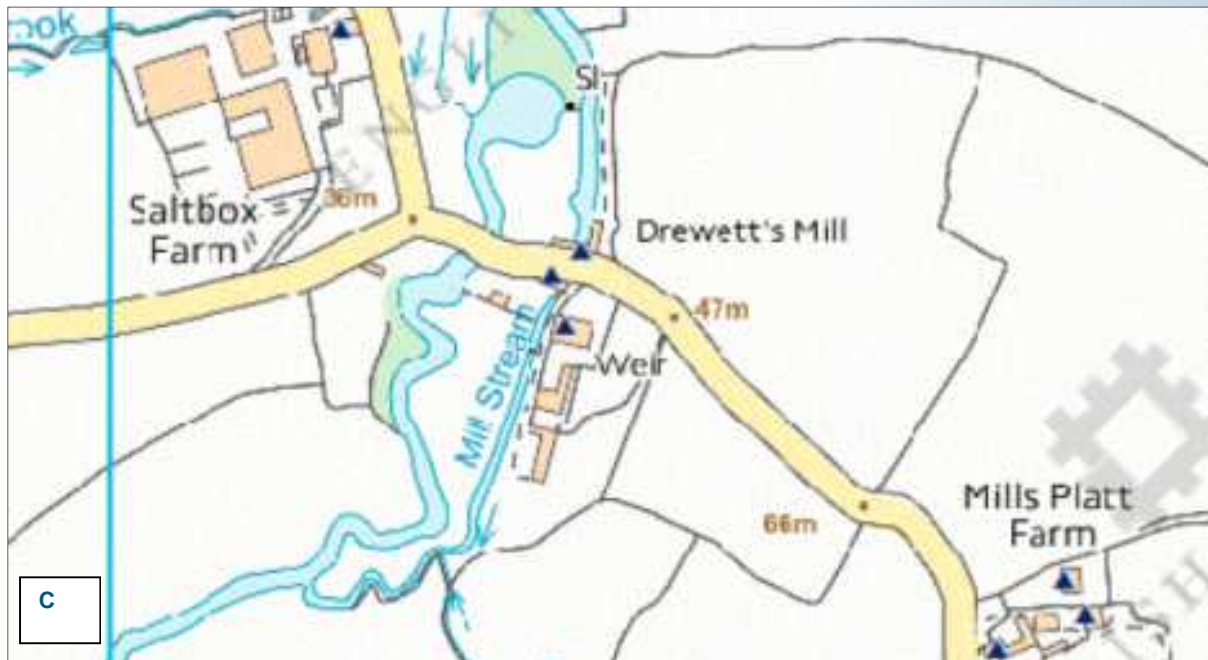
²¹ Percentages based on the catchment upstream of the By Brook gauging station at Middlehill, so does not include lower end of the catchment. Spatial Data for By Brook © NERC (CEH) 2012. Retrieved 28/10/2014 from <http://www.ceh.ac.uk/data/nrfa/data/spatialdata.html?53028>

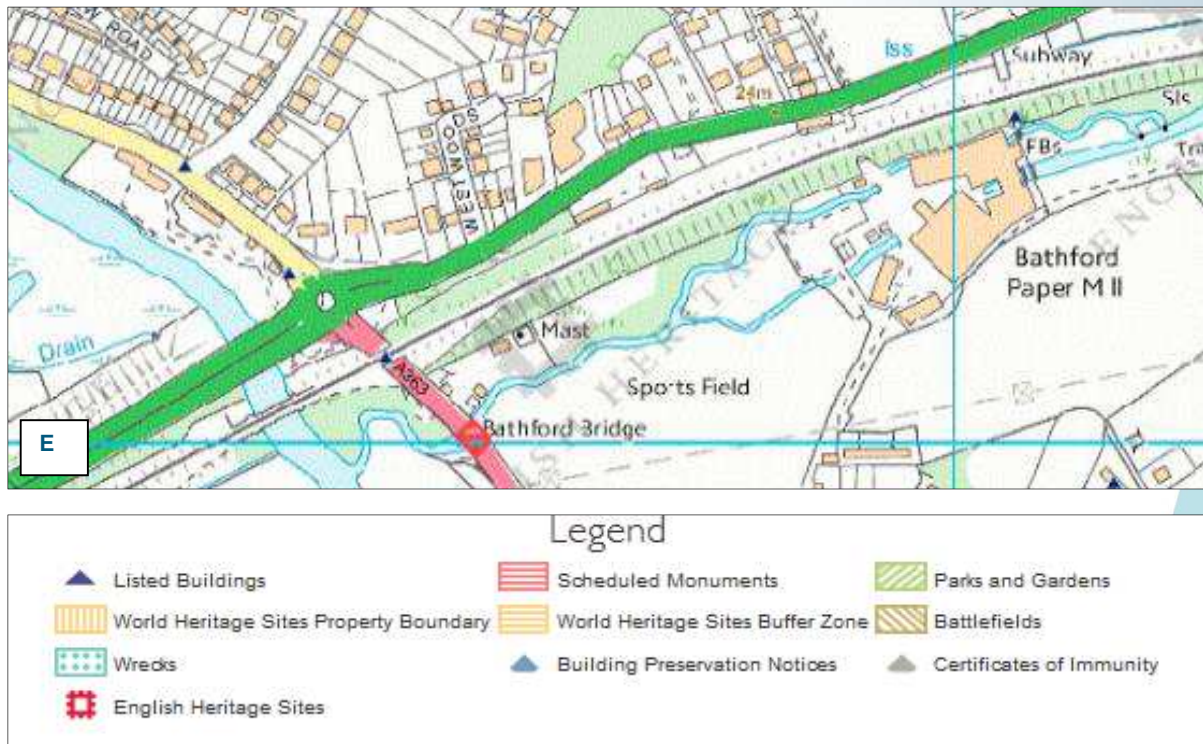
²² Cotswolds AONB: Historic and Cultural Heritage. Retrieved 28/10/2014 from <http://www.cotswoldsaonb.org.uk/about-the-cotswolds/historic-cultural-heritage/>

Brook. One Grade II* structure was identified, Drewitt's Mill (ID 1181097) at Box (see **Figure 2.36c**), which is one of the structures identified by BART as potentially impeding movement of fish (though it now appears to be dilapidated and is no longer thought to present a barrier to fish migration) as discussed in **Section 2.4**.

Figure 2.36 Historic Environment







Map Source: <http://www.english-heritage.org.uk/>

2.9.6 Six Grade II listed structures were identified between Castle Combe and Slaughterford (listed in order from upstream to downstream): Bridge over By Brook about 500m North West of Manor House Hotel (ID 1022861); The Bridge (ID 1022879); Roman Bridge (ID 1199255); The Bridge (ID 1363495); Upper Long Dean Mill (ID 1023022); and Lower Long Dean Mill (ID 1199048). One further Grade II listed structures was identified on by Bridge at Box: By Brook Bridge (MIN110162) (ID 1410949).

2.9.7 Several other listed buildings are mill cottages and farmhouse buildings located adjacent to the By Brook and its tributaries (see **Figure 2.36**), which may be impacted by works to restore the river (see **Section 4**).

2.10 Public Interest and Recreational Activities

2.10.1 As part of the Cotswolds AONB, tourism is an important sector in the By Brook catchment. Castle Combe on the banks of the upper By Brook is a popular tourist destination, with a castle and museum. Other attractions in the catchment include Pound Hill on Broadmead Brook (historic buildings and gardens) and Hazelbury Manor near Box (historic gardens)²³.

2.10.2 Walking and cycling are important recreational activities in the By Brook catchment. There is an extensive network of footpaths across the By Brook catchment, particularly along the river itself. A section of the Macmillan Way (a National Trail) follows the By Brook from Castle Combe to Box. Colerne Park and Monk's Wood SSSI downstream of Slaughterford is managed by the Woodland Trust for recreation. Public access along and across the river, for example particularly between Ford

²³ <http://www.escapetothecotswolds.org.uk>

and Slaughterford (see **Figure 2.37**) where there is the highest density of structures, increases the visual prominence of any restoration work undertaken and would potentially increase the cost of some options, as additional foot-bridges would potentially have to be constructed across restoration the works (BART, 2013).

Figure 2.37 Public Access Between Ford and Slaughterford



Map Source: <https://www.google.com/earth/>

- 2.10.3 There are four fishing clubs that control the fishing in By Brook: Ford Fly Fishers (from Ford to Slaughterford), By Brook Fly Fishers (Slaughterford to Widdenham Farm), Two Mills Fly Fishing Club (Widdenham Farm to Box) and Bathampton Angling Club (from Box Mill to Batheaston) (BART, 2013).
- 2.10.4 Bird and wildlife watching are also popular past time recreational activities enjoyed along the By Brook.

2.11 Past and Present Management Regime

2.11.1 Grasslands and woodlands in the By Brook catchment have developed over centuries in response to influence by human activity. Woodlands were managed for coppicing to provide timber for buildings and fencing, while grasslands were used for sheep grazing to support the wool industry²⁴. As discussed in **Section 2.4**, the By Brook channel itself has been heavily modified throughout history, primarily for the milling of corn during Roman times, but later for the “fulling” of wool and the production of paper (BART, 2013). The last recorded working mill was Chaps Paper Mill and Rag Mill at Slaughterford, which ceased operations in 1964.

2.11.2 By Brook and tributaries are now predominantly managed for wildlife conservation, recreation, farming and flood protection. The main activities are:

- Conservation activities as part of BART’s community engagement and river restoration work. The main activity so far is installation of several hundred meters of stock-proof fencing on the Lid Brook as part of work by BART and landowners to control access for cattle drinking, in order to reduce water quality and soil erosion issues.
- The Ford Fly Fishers club actively manages the section of the By Brook between Ford and Slaughterford by controlling water levels and stocking with farmed brown trout. The club is also responsible for maintenance and repair on three of the four structures impacting on fish migration in their stretch, while responsibly for the remaining site (Slaughterford Gate) is currently with the Environment Agency.
- The Environment Agency carries out basis maintenance activities on flood control structures.

2.11.3 The above are discussed in greater detail below.

2.11.4 The Bristol Avon Catchment Group (BACG) is one of the longest-running Catchment Based Approach (CaBA) partnerships, set up to “to develop a collaborative plan to deliver a healthy, functioning, river environment across the [Bristol Avon and North Somerset Streams] catchment”²⁵. Partnership members include BART, the Avon & Frome Partnership, Avon Wildlife Trust, local councils, the Environment Agency, FWAG South West and Wessex Water. In addition to developing an action plan for the Bristol Avon catchment, BACG aims to collaboratively identify strategies and opportunities across the catchment to achieve the requirements of the WFD, and to facilitate this by developing synergistic and complimentary local government, Local Nature Partnership and private business development / action plans²⁶.

2.11.5 During 2012, BART worked with the Environment Agency to identify and agree a sub-catchment within the Bristol Avon area in which to carry out a collaborative river restoration project to help deliver improvements towards GES. Since summer 2013, BART has been funded by the Environment Agency to lead a Partnership Project on the By Brook²⁷. This work has involved a number of strands with an emphasis on improving By Brook’s WFD classification from “Poor” to “Good” over time.

²⁴ Tatem, K (1996) A History of the By Brook. Published by the Environment Agency.

²⁵ <http://barcmp.webnode.com/>

²⁶ <http://www.bristolavonriverstrust.org/wp-content/uploads/2014/07/What-is-the-Catchment-Based-Approach.docx>.

²⁷ <http://www.bristolavonriverstrust.org/good-news-for-by-brook/>

- 2.11.6 The initial phase involved carrying out ecological survey work and engaging with local stakeholders (farmers, landowners and local interest groups) to determine quick wins that can be delivered in 2013-14. All farmers with riparian frontage within the catchment were contacted and visited by BART's Project Officer and these were followed up with a continuing process of engagement, focussed on encouraging catchment-sensitive farming practices and gaining approval for riparian protection works to be carried out (BART, 2013). This included work on the Lid Brook tributary to engage with landowners and farmers to erect stock-proof fencing, provide controlled access for cattle drinking and to re-locate field access and cattle watering stations, in order to reduce water quality and soil erosion issues. Several hundred meters of fencing was installed in collaboration with landowners and farmers to limit livestock access to the stream. Members of BART also attended meetings of the local Friends of the By Brook Valley (FoBV) group to give regular presentations and updates on the project's progress.
- 2.11.7 The feasibility study for fish passage (river restoration) improvements captured in this report is another important part of this work, to help improve fish mobility in the By Brook catchment and boost the numbers and varieties of fish in the river.
- 2.11.8 As stated previously, the Ford Fly Fishers club actively manages the section of the By Brook between Ford and Slaughterford by controlling water levels and stocking with farmed brown trout. Stocking is required in this reach of the river to maintain it as a fishery, as the five structures in this reach prevent fish accessing the range of habitats needed to maintain the population (BART, 2013). The Ford Fly Fishers club are also responsible for maintenance and repair on three of the four structures impacting on fish migration in their stretch, while responsibly for the remaining site (Slaughterford Gate) is currently with the Environment Agency.
- 2.11.9 The Environment Agency carry out Flood and Coastal Erosion Risk maintenance activities in the By Brook catchment (ID FR/14/S082) in the form of operational inspections, obstruction removal (when flood risk is imminent), grass cutting of flood defences and maintenance and operation of flood defence structures²⁸.
- 2.11.10 The Cotswolds AONB Management Plan 2013-1829 sets out the AONB's plans for that period under three main categories: Conserving and enhancing; Understanding and enjoying; and Fostering economic and social well-being. River valleys such as the Upper and Lower By Brook valley are listed as one of the Special Qualities of the Cotswolds that the plan aims to protect and enhance. The Management Plan makes reference to "compliance with WFD requirements as set out in River Basin Management Plans and Catchment Management Plans" as a delivery mechanism to improve the management of natural resources. A change in "the % of waterbodies achieving "Good" ecological status" was listed as a key monitoring indicator for this target.
- 2.11.11 The Cotswolds AONB Landscape Strategy and Guidelines³⁰ set out the main sensitivities, strategies and indicators for management of the Upper and Lower By Brook Valley (as a Dip-Slope Lowland Valley and Enclosed Limestone Valley, respectively), including measures to improve different aspects of the river habitat. This information is designed to support informed decisions about the suitability of proposed development or change within the Cotswold landscape.

²⁸ <http://maps.environment-agency.gov.uk/wiyby>

²⁹ <http://www.cotswoldsaonb.org.uk/planning-management-advice/management-plan/>

³⁰ <http://www.cotswoldsaonb.org.uk/planning-management-advice/landscapestrategy/>

3 Environmental Conditions of the By Brook Catchment

3.1 Introduction

- 3.1.1 This section of report provides an overview of the past and present condition of the By Brook in order to fully understand the requirements needed to provide appropriate restoration (rehabilitation) options for the By Brook and inform **Sections 4 to 5** of this report.

Water Framework Directive

- 3.1.2 Based on the latest data³¹, the By Brook catchment is situated in the Bristol Avon Rural operational catchment, part of the Avon Bristol and North Somerset Streams management catchment within the Severn River Basin District. The catchment is made up of six surface waterbodies³² and three groundwater waterbodies.

- By Brook - source to conf Broadmead Brook – GB109053027500 (note this is the waterbody referred to as Burton Brook earlier in this report).
- By Brook (Broadmead Brook to Doncombe Brook) – GB109053027480.
- By Brook - conf Doncombe Brook to conf R Avon (Brist) – GB109053027380.
- Broadmead Brook - source to conf By Brook – GB109053027490.
- Tributary - source to conf By Brook – GB109053027460.
- Doncombe Brook - source to conf By Brook – GB109053027400.
- Bath Oolite – GB40901G805500.
- Bristol Avon Forest Marble – GB40902G302900.
- Bristol Triassic – GB40902G804800.

- 3.1.3 Despite the heavily modifications that have been made historically in the By Brook catchment, **none of these waterbodies have been designated as “Heavily Modified Waterbodies”**, so the WFD target of achieving “Good Ecological Status” (GES) applies.

Designated Sites

- 3.1.4 As discussed in **Section 2.5**, the By Brook itself is not a designated site but there are two SSSIs (Honeybrook Farm SSSI and Colerne Park and Monk's Wood SSSI) located on the banks of the By Brook downstream of Slaughterford which may be affected by this restoration project.

Native Crayfish

- 3.1.5 As discussed in **Section 2.7**, native white-clawed crayfish are not designated species in the By Brook, but this river is considered to be a significant habitat for this species.

³¹ Environment Agency “Catchment Data Explorer”. Retrieved 28/10/2014 from <http://environment.data.gov.uk/catchment-planning/>

³² Note that between cycle 1 and cycle 2 of the River Basin Management Plans (RBMPs), two separate waterbodies on By Brook between Broadmead Brook and Doncombe Brook confluences have now been merged to form By Brook (Broadmead Brook to Doncombe Brook), retaining the ID of the upper waterbody GB109053027480. The other waterbody, GB109053027390 (referred to in the list of structures in **Table 2.1**), is now part of this merged waterbody.

3.2 Past Ecological Condition

Water Framework Directive

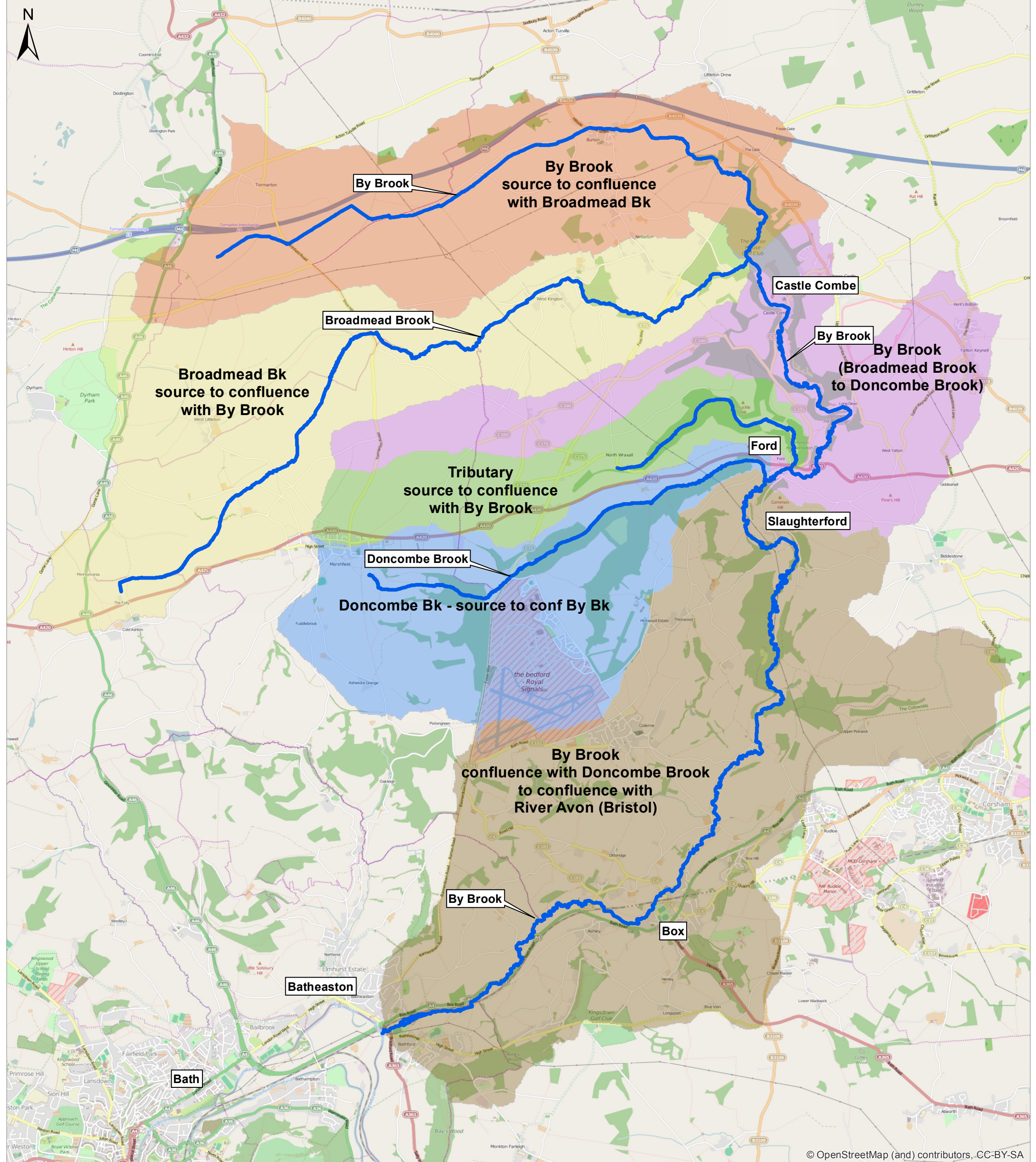
3.2.1 Historic trends in overall ecological status for the waterbodies in the By Brook catchment are shown in **Table 3.1** and their locations presented in **Figure 3.1** and **3.2**.

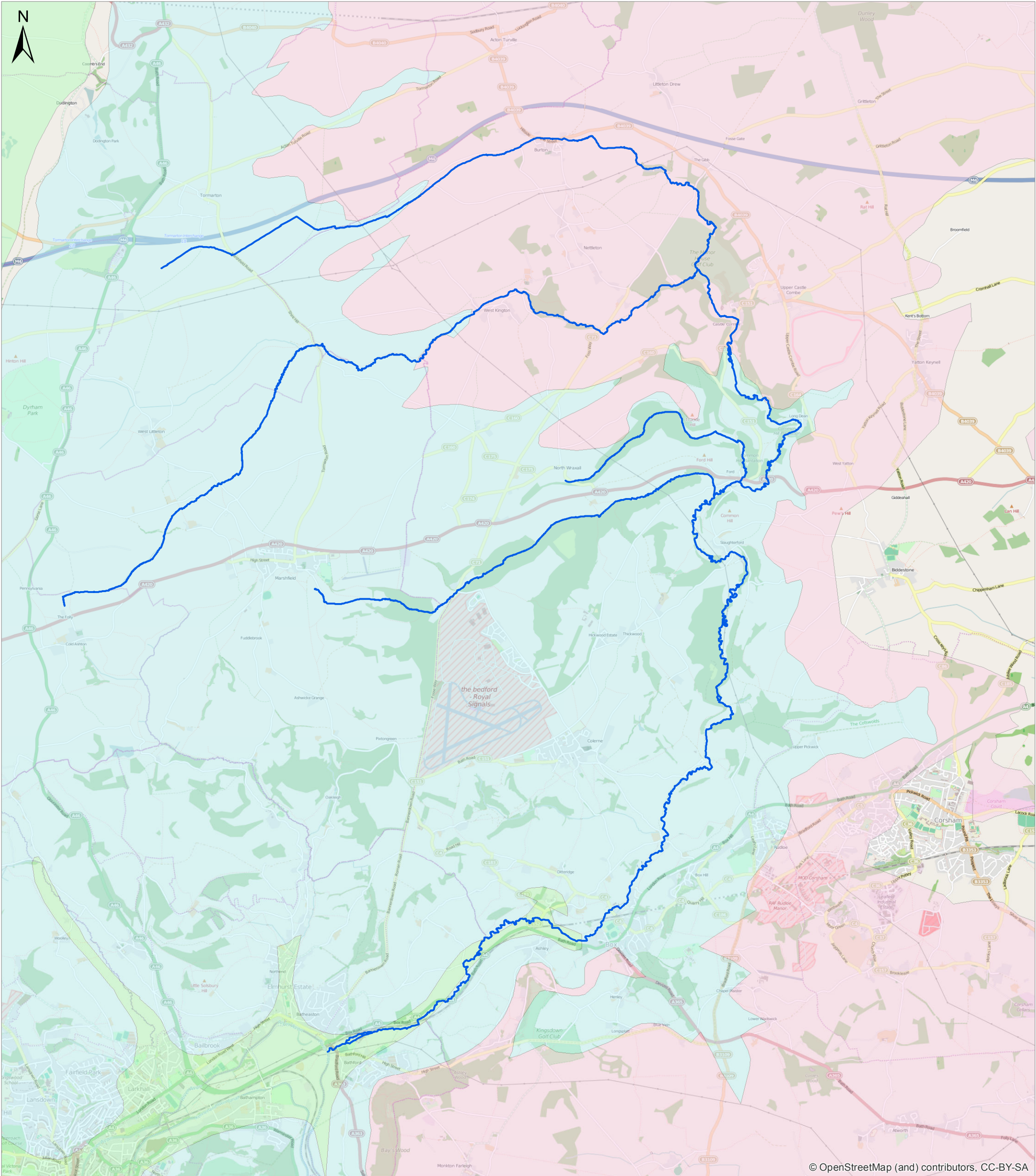
Table 3.1 Ecological Status of Waterbodies in the By Brook Catchment

Year	2009	2010	2011	2012	2013	2014
By Brook - source to conf Broadmead Brook	Good	Good	Good	Good	Good	Mod.
Broadmead Brook - source to conf By Brook	Mod.	Mod.	Good	Good	Good	Mod.
By Brook (Broadmead Brook to Doncombe Brook)	Good	Mod.	Good	Mod.	Mod.	Mod.
Tributary - source to conf By Brook	Mod.	Good	Poor	Poor	Mod.	Mod.
Doncombe Brook - source to conf By Brook	Poor	Poor	Mod.	Mod.	Mod.	Mod.
By Brook - conf Doncombe Brook to conf R Avon (Brist)	Poor	Poor	Mod.	Mod.	Mod.	Mod.
Bath Oolite (Groundwater)	Good	Good	Good	Good	Poor	Poor
Bristol Avon Forest Marble (Groundwater)	Poor	Poor	Poor	Poor	Poor	Poor
Bristol Triassic (Groundwater)	Poor	Poor	Poor	Poor	Poor	Poor

3.2.2 This WFD information shows that surface waterbody status has **generally improved** over time from 2009 to 2014, with no surface waterbodies now classified as poor ecological status. Overall status has historically been better in more upstream, rural waterbodies. Deteriorations in status in the By Brook (from Broadmead Brook to Doncombe Brook) and the un-named tributary appear to have been temporary.

3.2.3 For groundwater waterbodies, the WFD information shows that overall status has changed very little over time, except for a deterioration in status for the Bath Oolite waterbody in 2013. Historically, overall status has been better in the Bath Oolite waterbody, which underlies most of the By Brook catchment, than the Bristol Avon Forest Marble and the Bristol Triassic waterbodies which are located on the periphery to the east of the catchment.





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Legend

WFD River Channels

WFD Groundwater Waterbodies

- Bath Oolite
- Bristol Avon Forest Marble
- Bristol Triassic

Title
WFD Groundwater Waterbodies
in the BY Brook Catchment

Project
Feasibility Restoration Report for
By Brook, Bristol Avon, North East Bath

Client
Bristol Avon Rivers Trust (BART)

Date
06/11/2014

Scale
1:50000

Figure
3.2

Drawn by
MCP

Checked by
CR



- 3.2.4 It is noted that some of the historical changes observed in overall ecological status may reflect changes in monitoring frequency, waterbody boundaries and classification methodology, in addition to changes in ecological conditions on the ground.

Designated Sites

- 3.2.5 Historical information is not available regarding the condition of Honeybrook Farm SSSI and Colerne Park and Monk's Wood SSSIs prior to the last assessment in 2011.

Native Crayfish

- 3.2.6 Native crayfish populations have been recorded in the By Brook since the 1970s, primarily between Ford and Box. Populations of signal crayfish, introduced in Broadmead Brook in the 1970s, appear to have migrated downstream past the confluence at Castle Combe to encroach on the native populations downstream of Ford.

3.3 Present Ecological Condition

Water Framework Directive

- 3.3.1 According to the latest data shown in **Table 3.1** the overall ecological status is currently moderate for all surface waterbodies and poor for the three groundwater waterbodies.
- 3.3.2 Moderate overall ecological status for the lower By Brook and Doncombe Brook was associated with moderate status for fish and phosphate. Moderate overall ecological status for the un-named tributary was associated with moderate status for macrophytes and phytobenthos (aquatic plants and diatoms).
- 3.3.3 Detailed information on the reasons for not achieving good status (or Reasons for Failure) in the lower By Brook (GB109053027380) (Reach 4A to Reach 5, see **Figure 2.1**) has been recently published³³. The failure to achieve good status for fish is confirmed as due to **physical modifications acting as barriers to fish migration**. Details of the sector responsible are “under investigation”, though it is predicted that the waterbody could achieve good status by 2015 (see **Table 3.2**) if this pressure is addressed. Reasons for failure to achieve good status for phosphate were not discussed, however BART has identified Lid Brook (a small tributary which forms part of this waterbody) as a high-risk area in terms of soil erosion from intensive livestock production with unrestricted access to the watercourse, which may be contributing to high phosphate levels in this waterbody, and some mitigation measures for this have already been undertaken.
- 3.3.4 Detailed information on the reasons for not achieving good status in Doncombe Brook has been recently published³⁴. Information on the un-named tributary is not available. For Doncombe Brook the failure to achieve good status for fish is considered “probable” to be due to **physical**

³³ “WFD Water Bodies in England: reasons for not achieving good status data, provided as supporting information for consultation on the draft update to the river basin management plans - Cycle 2”. Retrieved 28/10/2014 from https://consult.environment-agency.gov.uk/portal/ho/wfd/draft_plans/consult?pointId=s1405417965041#section-s1405417965041

³⁴ “WFD Water Bodies in England: reasons for not achieving good status data, provided as supporting information for consultation on the draft update to the river basin management plans - Cycle 2”. Retrieved 28/10/2014 from https://consult.environment-agency.gov.uk/portal/ho/wfd/draft_plans/consult?pointId=s1405417965041#section-s1405417965041

modifications acting as barriers to fish migration. The agriculture and rural land management sector is considered likely to be responsible, though it is predicted that the waterbody would still not achieve good status by 2015 if this pressure is addressed. Reasons for failure to achieve good status for phosphate were confirmed as point source wastewater discharge from a sewage treatment works (which is not named, but is likely to be Marshfield STW). The water industry is identified as responsible, though it is predicted that the waterbody would still not achieve good status by 2015 if this pressure is addressed.

- 3.3.5 The poor status of the Bristol Avon Forest Marble waterbody historically and currently is associated with poor quantitative status. The poor status of the Bristol Triassic waterbody historically and currently is associated with poor quantitative and poor chemical status. The current poor status of the Bath Oolite waterbody, a deterioration from the historically good status, is associated with a deterioration in chemical status.
- 3.3.6 Detailed information on the reasons for not achieving good status in the Bristol Avon Forest Marble and Bristol Triassic waterbodies has been recently published³⁵. Information on the Bath Oolite waterbody is not available. For the Bristol Avon Forest Marble waterbody the failure to achieve good quantitative status is associated with changes to the natural flow and levels of water, and it is considered “probable” that the sector responsible is the water industry. Further details of the pressure are unknown (pending further investigation) and it is predicted that the waterbody would still not achieve good status by 2015 if this issue is addressed. For the Bristol Triassic waterbody the failure to achieve good chemical status is associated with diffuse pollution affecting chemical drinking water quality, and it is considered “probable” that the sector responsible is agriculture and rural land management. Further details of the pressure are unknown (pending further investigation) and it is predicted that the waterbody would still not achieve good status by 2015 if this issue is addressed. The reasons for failing to achieve good quantitative status in this waterbody are not available.
- 3.3.7 According to the draft RBMP documents for the Bristol Avon Rural operational catchment³⁶, the measures proposed for this catchment include “improve modified physical habitats”, with specific mention given to removal or easement of barriers to fish migration, and improvement to condition of channel / bed and / or banks / shoreline. The By Brook restoration project will therefore contribute to delivering these measures and help these waterbodies improve towards GES.
- 3.3.8 BART has identified fish diversity in the middle reaches of the By Brook (the upper end of the most downstream waterbody) as the “primary failing element” for WFD (BART, 2013). Initial investigations, prior to the project’s inception, coupled with more detailed surveying during the project have identified 15 fish migration barriers in the stretch between Ford and Bathampton, which alongside channel straightening and deepening, have impacted fish habitats significantly as discussed in **Section 2.4**. In addition, and as previously stated, of the 23 barriers on the By Brook that are identified on the Environment Agency’s fish passage barrier list for the Bristol Avon and North Somerset Streams, 15 are prioritised in the top 20 out of 88 barriers.

³⁵ “WFD Water Bodies in England: reasons for not achieving good status data, provided as supporting information for consultation on the draft update to the river basin management plans - Cycle 2”. Retrieved 28/10/2014 from https://consult.environment-agency.gov.uk/portal/ho/wfd/draft_plans/consult?pointId=s1405417965041#section-s1405417965041

³⁶ https://consult.environment-agency.gov.uk/portal/ho/wfd/draft_plans/consult?pointId=s1406201384425#section-s1406201384425

Designated Sites

- 3.3.9 The condition of Honeybrook Farm SSSI and Colerne Park and Monk's Wood SSSIs were last assessed by Natural England in 2011.
- 3.3.10 Honeybrook Farm SSSI is made up of three units: Eastern Limestone Coombe, Honeybrook Meadows, and a third unit for the narrow elongate areas of lowland woodland attached to the other two units. The condition of all three units is currently favourable, and the condition threat risk is medium for the first two units and not identified for the third unit.
- 3.3.11 Colerne Park and Monk's Wood SSSI is made up of one unit of lowland broadleaved, mixed and yew woodland. The condition of this unit is currently favourable, and no condition threat risks have been identified.

Native Crayfish

- 3.3.12 As discussed in **Section 2.7**, a series of crayfish surveys has been undertaken recently by the Avon Wildlife Trust (BART, 2013) and OHES (OHES, 2014a & b). These surveys found evidence of native white-clawed crayfish in the By Brook between Ford and Box, with particularly strong numbers at Slaughterford. Non-native signal crayfish were identified co-existing with the native population between Ford and Slaughterford, and it was advised that in the medium to long-term, white-clawed crayfish are highly likely to become extinct within the By Brook, as signal crayfish become established throughout the catchment.

3.4 Present Standards for Good Ecological Condition

Water Framework Directive

- 3.4.1 The aims of the WFD are prevention of deterioration in the status of surface waters and groundwater, and to achieve good status for all waterbodies. The main target is for waterbodies to achieve good status by 2015, and where this is not possible (due to natural conditions, technical infeasibility or disproportionate costs), an extended deadline may be set for 2021 or 2027, or a less stringent objective may be set³⁷.
- 3.4.2 The current and target status of the six surface waterbodies and two groundwater waterbodies is shown in **Table 3.2**.
- 3.4.3 All surface waterbodies of the By Brook have the target of Good status by 2015 or 2027. All three tributary waterbodies have extended deadlines for the target to get to Good status, extended to 2027. In all three cases this is associated with ecological elements (fish) being unlikely to achieve good status until 2027, which is most likely going to be the case for the lower By Brook surface water body (GB109053027380) which as above stated is failing to achieve GES in response to **physical modifications acting as barriers to fish migration along the By Brook**.

³⁷ Environment Agency (2014). Water for life and livelihoods: A consultation on the draft update to the river basin management plan. Part 2: River basin management planning overview and additional information.

Table 3.2 Overall Ecological Status (Current and Target) in each Waterbody in the By Brook Catchment

Waterbody	Overall Ecological Status	
	Currently (2014)	Target ³⁸
By Brook - source to conf Broadmead Brook	Mod.	Good by 2015
Broadmead Brook - source to conf By Brook	Mod.	Good by 2027
By Brook (Broadmead Brook to Doncombe Brook)	Mod.	Good by 2015
Tributary - source to conf By Brook	Mod.	Good by 2027
Doncombe Brook - source to conf By Brook	Mod.	Good by 2027
By Brook - conf Doncombe Brook to conf R Avon (Brist)	Mod.	Good by 2015
Bath Oolite (Groundwater)	Poor	Good by 2015
Bristol Avon Forest Marble (Groundwater)	Poor	Good by 2027
Bristol Triassic (Groundwater)	Poor	Good by 2027

3.4.4 Of the groundwater waterbodies, Bath Oolite has the target of Good status by 2015. Bristol Avon Forest Marble and Bristol Triassic have extended deadlines of Good status by 2027, respectively associated with quantitative elements (water balance) and chemical elements (drinking water quality) being unlikely to achieve good status until 2027.

Designated Sites

3.4.5 For designated sites relevant to this project, two SSSIs, the relevant objective is for the designated features of the SSSIs to achieve favourable condition in line with the standards set out in the relevant Common Standards Monitoring (CSM) Guidance. Separate CSM guidance documents are available for different habitats and species for which the site was designated. For relevant SSSIs in the By Brook catchment, guidance on lowland grassland³⁹ and woodlands⁴⁰ applies.

³⁸ Note that targets are best on the first cycle of RMBPs (published in 2009). Targets with dates have not yet been set in the latest draft documents for cycle 2 (to be finalised in 2015).

³⁹ JNCC (2004) Common Standards Monitoring Guidance for Lowland Grassland Habitats.
http://jncc.defra.gov.uk/PDF/CSM_lowland_grassland.pdf

⁴⁰ JNCC (2004) Common Standards Monitoring Guidance for Woodland Habitats.
http://jncc.defra.gov.uk/pdf/CSM_woodland.pdf

- 3.4.6 It is noted that while CSM guidance on favourable conditions for rivers is available⁴¹, it does not apply to work in the By Brook as the river itself has not been identified as a designated feature (impacts of the SSSIs would relate instead to floral assemblages associated with the wet margins and floodplain).

Native Crayfish

- 3.4.7 There are no specific objectives for the By Brook catchment relating to native crayfish, although it is the aim of this restoration project to consider options to improve native crayfish habitat and limit the spread of non-native crayfish as far as possible. Native white-clawed crayfish are a UK BAP priority species, and best ecological practice guidelines should be followed to avoid detrimental impacts, killing and injuring, through appropriate Ecological Clerk of Works (ECW) (see **Section 7.2**).

3.5 By Brook Reach Conditions and WFD Objectives

- 3.5.1 To ensure the most appropriate restoration solutions are considered for the By Brook which will enable GES to be eventually achieved for the whole river system, **Table 3.3** provides a summary of the current ecological and geomorphological conditions of the By Brook based on **Section 2**, WFD information provided in **Section 3.3 to 3.4**, **Appendix D**; and Cycle 1 Extended Waterbody Summary Reports (March 2015). The main focus of **Table 3.3** is on the condition of the hydromorphology and biological quality elements along the By Brook, although it is acknowledged that the key WFD chemical elements impacting upon the By Brook is associated with high levels of phosphate from agricultural run-off and effluent from sewage treatment works.
- 3.5.2 **Table 3.4** provides typical measures associated with hydromorphology quality elements and selected monitoring techniques which could be implemented for the By Brook catchment. The monitoring techniques are based on the Practical River Restoration Appraisal Guidance for Monitoring Options (PRAGMO) (RRC, 2011).

⁴¹ JNCC (2014). Common Standards Monitoring Guidance for Rivers. Updated from March 2005.
http://jncc.defra.gov.uk/pdf/CSM_rivers_jan_14.pdf

Table 3.3 By Brook Current Reach Conditions Based On WFD Quality Elements

Reach	WFD Hydromorphology and Biological Quality Elements										
	Flow (Quantity and Variability)	Planform	Width / Depth	Substrate	Continuity (lateral)	Continuity (long.)	Riparian	Inverte- brates	Fish	Phyto- benthos	Macrophytes
Reach 1: Burton Brook	L	L	L	L	M	M to H	L	H	-	-	M
Reach 2: Broadmead Brook	M	M	M	L to M	M	L to M	M to H	M	H	-	-
Reach 3: Castle Combe to Ford	L to M	M	M	M	M to H	L to M	M to H	H	-	-	M
Reach 3A: Unnamed tributary	M	M to H	M to H	H	M to H	M	M to H	H	H	M	H
Reach 3B: Doncombe Brook	M	L to M	L to M	L to M	L to M	M	M to H	H	M	-	H
Reach 4A1: Ford Mil Weir	L	H	L	M	L	L	M	H	M	-	M
Reach 4A2: Weir D/S Ford	L to M	M	L to M	L	L to M	L	L	H	M	-	M
Reach 4A3: Sluice D/S Ford	L to M	H	L to M	M	L to M	L	L to M	H	M	-	M
Reach 4A4: Slaughterford Gate	L to M	H	L to M	M	L to M	L	L to M	H	M	-	M
Reach 4A5: Rag Mill	L to M	M	L to M	M to H	L to M	L	M	H	M	-	M

Reach	WFD Hydromorphology and Biological Quality Elements										
	Flow (Quantity and Variability)	Planform	Width / Depth	Substrate	Continuity (lateral)	Continuity (long.)	Riparian	Inverte- brates	Fish	Phyto- benthos	Macrophytes
Reach 4B1: Weavern Mill Weir	L to M	M	L to M	L	L to M	L	L	H	M	-	M
Reach 4B2: Widdenham Mill (Farm)	L to M	M	L to M	M	M	L	M	H	M	-	M
Reach 4C: Lid Brook	H	M to H	M to H	M to H	M to H	M to H	L	H	M	-	M
Reach 5A1: Drewitts Mill	L	L to M	L to M	L to M	H	L	L to M	H	M	-	M
Reach 5A2: Box Mill	L	L to M	L to M	L to M	L to M	L	M	H	M	-	M
Reach 5A3: Middlehill Gauging Weir	M	M	M	L to M	L to M	M	M	H	M	-	M
Reach 5A4: Shockerwick Mill	M	M	M	L to M	M	M	M	H	M	-	M

Note: H: High (or Good Condition), M: Medium (or Moderate Condition), L: Low (or Poor Condition); - Not Assessed.

Table 3.4 Typical WFD Hydromorphology Measures and Monitoring

Measures and Monitoring	WFD Hydromorphology Quality Elements					
	Flow Quantity and Variability	Planform	Width / Depth	Substrate	River Continuity	Riparian
Measures	Removal of hard engineering structures (e.g. naturalisation)			Install silt, sand or gravel traps or artificial wetlands for use as sediment traps	Removal of hard engineering structures (e.g. naturalisation)	
	Create low-flow (2 stage) channels in over-widened or over-deepened rivers to improve morphological diversity (could be meandering, through use of deflectors)			Stock and access management	Reconnect and restore historic aquatic habitats	Retain marginal vegetation; and create reed fringes
	Adopt strategic options and policies promoting natural recovery		River bed raising or lowering (re-grading)		Fish passage solutions	Control or eradicate invasive species causing hydromorphological impact
	Assist natural recovery of water body with use of sympathetic engineering techniques (e.g. replacement of hard defences)					
	Replace existing structures with new structural designs to minimise impact hydromorphological impact (avoid like for like)					
	Change operational regime of structures	Recreate a sinuous river channel (re-meandering)			Change operational regime of structures	Recreate a sinuous river channel (re-meandering)
	Introduce minimum flow limits	Narrow over-wide channels		Land (Cultivation) Management		Stock and access management
	Regulate abstraction and discharge	Recreation of gravel bars and riffles using permanent and / or temporary bed structures (increase morphological diversity)		Establish in-field sediment buffer strips		Introduction of stock-proof fencing (reduce bank side erosion)
	Educate landowners on sensitive management practices					
	Introduce compensatory flows (not just at low flow levels)	Bank re-profiling (rehabilitation)	Replenishment of mobile sediments			Bank re-profiling (rehabilitation); and introduce riparian vegetation / green corridors

Measures and Monitoring	Selected Monitoring Techniques					
	Fixed Point Photography	Geomorphological Mapping	Electric Fishing or Trapping	LiDAR (High Resolution Remote Sensing)	Repeat Cross-Sections or Topographic Surveys	Spot Gauging
Information Provided by Monitoring Technique	Habitat change in terms of aquatic vegetation and sediment type and percentage.	Planform mapping of river, riparian zone and floodplain to provide information about features and sediment characteristics.	<p><i>Electric Fishing:</i> Can provide either a qualitative or quantitative estimate of fish population size, at a local scale (tens of metres up to a few hundred metres).</p> <p><i>Trapping:</i> Trapping is most effective for monitoring migratory species such as adult salmon, trout (usually with fixed-location traps) and eels (usually with fixed traps or fyke nets). Quantitative population estimates can be achieved, usually over extensive river lengths.</p>	Useful information of modelling floodplain water levels changes as a result of river and floodplain restoration.	Can provide details of a specific morphological change over time in river and floodplain.	Provides a snapshot of flow information, and can be used to create accretion profiles. Spot gaugings can also be used to calibrate rainfall-runoff models in ungauged catchments. Knowing the flow regime is vital to determining the appropriate river restoration techniques to apply.

4 Proposed Restoration Options for By Brook

4.1 Introduction

- 4.1.1 This section of the report provides technical details on the proposed restoration options for the By Brook which will be assessed against engineering and environmental criteria to determine the overall effectiveness of the options to meet these criteria. The overall development and assessment of the proposed restoration options takes into consideration all previous sections of this report in particular **Section 3** and the Ecosystem Services Assessment undertaken for this project (see **Appendix E**).
- 4.1.1 Based on the information provided in this section, **Section 5** will further justify the selection of the preferred options to be taken forward to help restore the By Brook to Good Ecological Status.

4.2 Assessment Approach

- 4.2.1 Each option has been assessed against the following six criteria:

- **Hydrology:** Impacts on water levels and the flow regime.
 - **Engineering:** Technical feasibility including health and safety.
 - **Geomorphology:** Impacts on the physical characteristics of the river channel, including the sediment regime and bed and bank conditions.
 - **Environment:** Impacts on wider environmental parameters, including human beings, ecology, water quality and heritage.
- WFD Compliance:** Impacts on the WFD quality elements (biological, hydromorphological and physico-chemical), and on overall compliance with the requirements of the directive. **Includes for fish passage.**
- **Ecosystem Services:** Services provided by the natural environment that benefit people.

4.3 Proposed Restoration Options

- 4.3.1 The proposed restoration options presented in the By Brook Project Phase I Report (BART, 2013/2014) (in **Appendix A**) for the By Brook between Ford Mill Weir and Rag Mill Weir (Reach 4A) are presented in **Table 4.1** and assessed in detail within **Section 4.4** to **4.16**. Alternative river restoration options are also assessed and presented in **Table 4.1**.

Table 4.1 Restoration Solutions - Ford Mill Weir and Rag Mill Weir

Reach (Site)	Options
Reach 4A1: Ford Mill Weir	<ul style="list-style-type: none"> A. Do nothing. B. Structural removal. C. Replacement of structure with rock ramp. D. Bypass channel around the structure. E. Installation of a Larinier fish pass and series of pre-weir structures.
Reach 4A2: Weir D/S Ford	<ul style="list-style-type: none"> A. Do nothing. B. Structural removal. C. Bypass channel to Sluice D/S Ford. D. Installation of a Larinier fish pass or pool and traverse fish pass.

Reach (Site)	Options
Reach 4A3: Sluice D/S Ford	A. Do nothing. B. Structural removal. C. Raising water levels (pre-barrage). D. Bypass channel to Slaughterford Gate. E. Lowering of weir height and installation of a Larinier fish pass or pool and traverse fish pass.
Reach 4A4: Slaughterford Gate	A. Do nothing. B. Structural removal. C. Raising water levels (Rock Riffles). D. Bypass channel to Rag Mill. E. Pool and traverse technical fish pass.
Reach 4A5: Rag Mill	A. Do nothing. B. Structural removal. C. Bypass channel to Slaughterford Gate. D. Pool and traverse technical fish pass.

4.3.2 The restoration options are predominately associated with the changes which deliver improved fish passage through the restoration of natural geomorphic and ecological processes along the By Brook (see **Section 1**). However, significant consideration has been given to the incorporation of other WFD measures such as those presented in **Table 3.4** to ensure key WFD quality elements have been addressed. It should be noted, structural removal should be considered in river restoration projects as potentially the first viable solution which should be assessed in providing fish passage and better geomorphological-ecological conditions along river systems, and if this cannot be undertaken, clear reasoning should be stated.

4.4 Reach 4A1: Ford Mill Weir Restoration Options - Technical Details and Appraisal

Do Nothing

4.4.1 This option maintains the status quo and is based on the present situation. It assumes that the Ford Mill Weir would not be removed and no fish passage solutions constructed. The do nothing option provides a benchmark against which the suggested restoration options for Ford Mill Weir can be assessed.

Structural Removal

4.4.2 This option would consist of breaking out the current structure (Ford Mill Weir) in situ. This would reduce the impoundment effects of the structure which includes ponding of water which has reduced the sediment carrying capacity (velocity) of the watercourse and increased sediment accumulation on the bed upstream of the weir (see **paragraph 2.4.13**). In addition, the option would provide for a greater ability for salmonid fish species (and eels) to migrate upstream and thus contribute towards GES for the biological (fish) element of the downstream water body (see **Section 3.4**).

4.4.3 As stated, structural removal should be considered in river restoration projects as potentially the first viable solution which should be assessed in providing better geomorphological-ecological conditions along river systems. In regards to Ford Mill Weir, and as stated above, the complete structure would be directly removed on site, although this could be undertaken in phases (e.g. small cofferdam & over-pumping) to reduce potential disturbance to the downstream water environment and flora and fauna. In addition, partial excavation of accumulated fine sediment behind the weir prior to removal could be undertaken to reduce the amount of sediment available for downstream transport. Ensuring that the bed is re-graded downstream of the site will also assist in minimising erosion and downstream transport of sediment along the By Brook in response to potentially removing Ford Mill Weir. However, in response to the continuing functionality of the mill leat to provide an aesthetically pleasing watercourse for the White Hart Inn at Ford and the old Ford Mill buildings, which are now residential, the overall option of removing the Ford Mill Weir may not be viable (see **Table 4.3**).

4.4.4 It should be noted the implications of structure removal for bed and bank stability upstream and downstream must be properly assessed prior to consent being approved. This must include consideration of the impact on infrastructure such as bridge supports. Consideration should be given to retaining the structure invert to help check the creation of a runaway erosion 'knick point'.

Replacement of Structure with Rock Ramp

4.4.5 An alternative to completing removing Ford Mill Weir, would be replacing Ford Mill Weir with a "close-to-nature style" fish pass such as a rock ramp similar to **Figure 4.1c** (cascaded construction) which imitates as closely as possible natural river rapids or streams with steep gradients and the construction material chosen corresponds to what is usually present in rivers under natural conditions. Such fish passes meet the biological requirements more satisfactorily than technical fish passes (e.g. such as Larinier, see below). Furthermore, the close-to-nature design enables new flowing-water habitats to be created in a watercourse, while blending into the local landscape. Typical rock ramps or bottom ramp and slope construction style fish passes can be classified as follows, all of which are designed to reduce the hydraulic gradient and velocities to allow for improved fish passage, while maintain upstream water levels (see **Figure 4.1**):

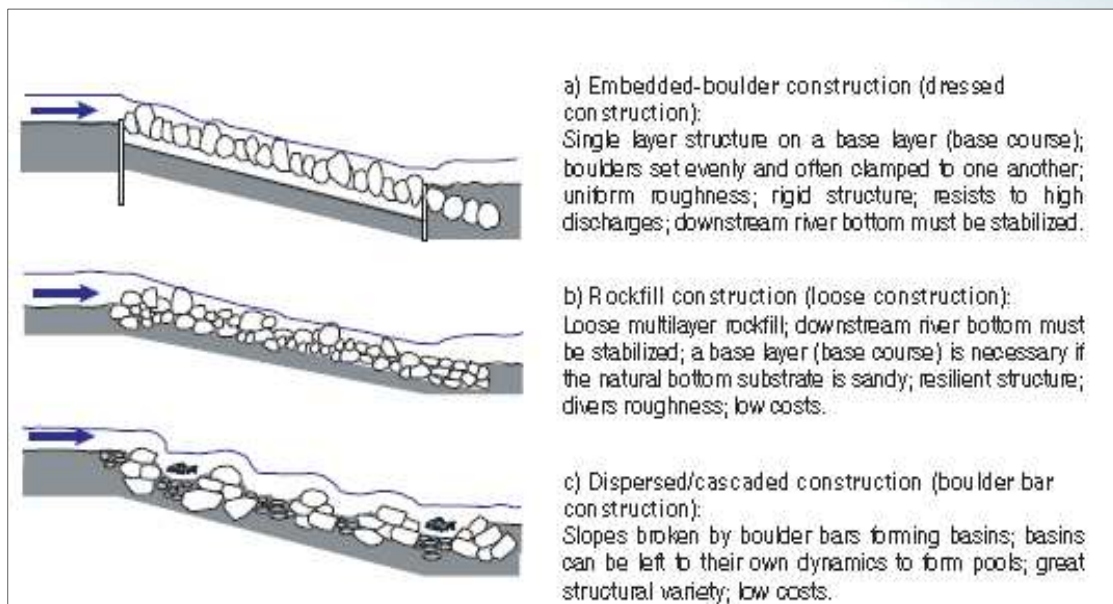
- Set or embedded-boulder constructions (conventional ramps in dressed and ordered construction mode).
- Rock-fill constructions (loose rock construction).
- Dispersed or cascaded constructions (embedded rocky sills construction).

4.4.6 Although rock ramp fish passes are typically installed at a slope of 1:20 (Harris *et al.*, 1998), a 1:25 to 1:30 slope provides more flexibility in design and a more natural looking bypass channel without the need for additional piling or stabilising of banks.

4.4.7 For the proposed rock ramp (cascaded construction style rock ramp) at Ford Mill Weir, this would extend downstream of the existing weir which would be replaced with a solid concrete structure with the same existing weir crest height to which the start of the rock ramp would be incorporated to provide a natural design finish (see **Figure 4.2**). The overall channel depth of the rock ramp would be approximately 0.6m with a bottom width of approximately 2m and side slopes of around 1:1 (to accommodate the cascaded construction style rock ramp – see **Figure 4.1c**). Thus, the total channel (top) width of the rock ramp would be 3.5m. The length of the rock ramp would be approximately 15m to 20m. The upstream entrance level to the rock ramp will be 59.00mAOD and

corresponds to approximately Q95 which is below the lower design limit for trout of Q95 (see **Table 2.4**).

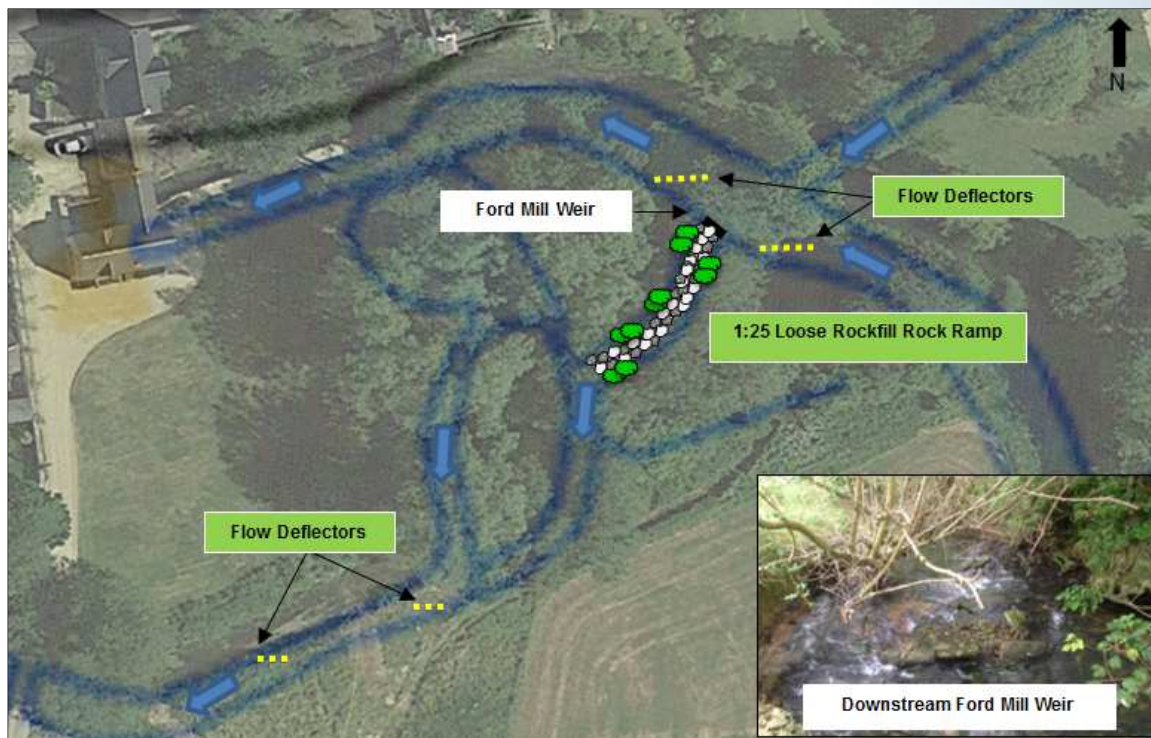
Figure 4.1 Construction of Bottom Ramps and Slopes



Source: DVWK, 2002.

- 4.4.8 The downstream exit level of the rock ramp would be located approximately 15m to 20m downstream of the weir at a level of 57.8mAOD below the downstream water level (based on Survey Operations undertaken in March 2014).
- 4.4.9 The rock ramp would consist of a loose multilayer 'core' fill material (see **Figure 4.1b**), suitably impermeable to ensure sufficient flow is maintained on the surface of the rock ramp to make sure it remains passable for the full range of fish and eel species. This may be further enhanced by incorporating a lower flow 'channel' within the ramp, where flows will be concentrated during periods of lower river flows. The inherent nature of the existing channel downstream of Ford Mill Weir does give rise to the construction of a natural rock ramp style fish pass which will provide sufficient attraction flows for fish (see **Figure 4.2**).
- 4.4.10 In addition, to assist flows being conveyed down the proposed rock ramp, the placement of flow deflectors along the over widened channel section of the By Brook would enable the pinching (narrowing) of the channel. This would provide a more efficient conveyance of flows down the rock ramp while providing greater morphological complexity along the By Brook. It was noted along sections of the river further downstream of the weir, the channel bed was armoured in places with fine sediments, as smaller flow deflectors placed downstream would assist in increasing local flow velocities and reducing siltation along the bed of the By Brook through promoting onward transport of fine sediment material.

Figure 4.2 Rock Ramp Concept (Outline Design) for Ford Mill Weir

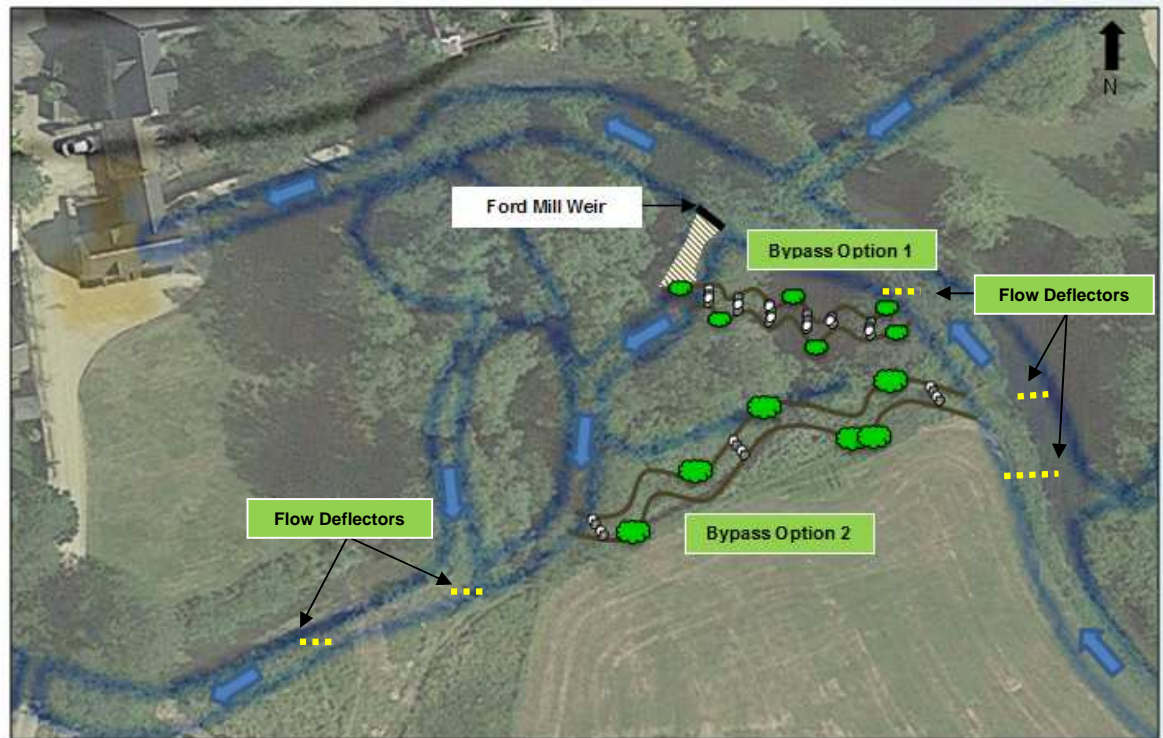


Bypass Channel

- 4.4.11 There is potential to construct another type of “close-to-nature style” fish pass such as a bypass channel. This would bypass Ford Mill Weir and allow for fish passage upstream while creating new flowing-water habitats within the newly created bypass channel while blending into the local landscape.
- 4.4.12 There are two variations to the bypass channel which could be implemented for the Ford Mill Weir site (see **Figure 4.3**):
- Bypass 1: The land directly adjacent the left bank (as you face downstream) of the weir could be used for the construction of the bypass channel (approximately 25m in length and 3m wide) , with excavated material (spoil) used to backfill the existing channel from the start of the bypass channel to the weir. The bank of the weir would be extended across to provide a continued bank face and solid structure which would continue to maintain the current water levels. An array of boulder and vegetation planting arrangements would be incorporated to increase water depth and reduce flow velocity to allow for improved fish passage while reducing potential increased channel erosion and flood risk. An alternative to completely back filling the existing channel would be to create backwater habitat with the weir maintained as a solid structure using the excavated material of the bypass channel.
 - Bypass 2: The use of existing watercourse features downstream of the weir to create a bypass channel (approximately 45m in length and 3m wide), although this would require the weir to be repaired separately (i.e. no direct construction benefits). The bypass would continue to maintain the current water levels, although the design of this particular variation in bypass channel would

need to take into consideration the relationship between fish passage and flow conveyance requirements at this site. An array of boulder and vegetation planting arrangements would be incorporated to increase water depth and reduce flow velocity to allow for improved fish passage while reducing potential increased channel erosion and flood risk.

Figure 4.3 Bypass Channel Concepts for Ford Mill Weir

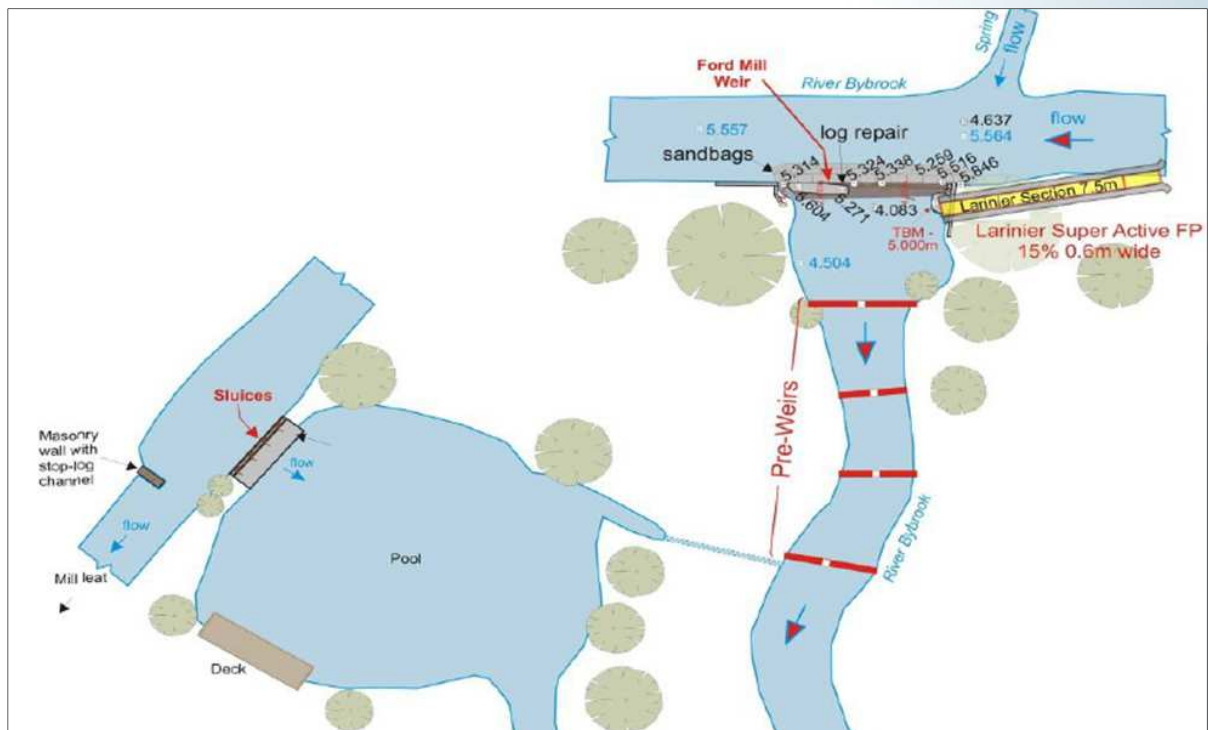


- 4.4.13 In addition, similar to the proposed rock ramp, to assist flows being conveyed down the bypass channels, the placement of flow deflectors along the over widened channel section of the By Brook would narrow the main channel. This would provide a more efficient conveyance of flows down the bypass channels while providing greater morphological complexity along the By Brook. Smaller flow deflectors, rock riffles and gravel bars as per described for the proposed rock ramp could also be placed downstream to enhance fish habitat further downstream along Reach 4A1.

Technical Fish Pass

- 4.4.14 The proposed solution comprises a series of pre-weir structures, constructed from natural stone and a Larinier style fish pass (BART, 2013/2014) (see **Figure 4.4**).
- 4.4.15 Given the maximum operating gradient of 15% for a Larinier fish pass, the minimum length for such a pass to be installed with a head loss of approximately 1.15m, could be between 7m to 8m. The width of a Larinier fish pass is a function of baffle height, and based on a baffle height of 100mm, such a pass installed would be approximately 0.6m wide (see **Figure 4.4**).

Figure 4.4 Technical Fish Pass Concepts for Ford Mill Weir



- 4.4.16 A prerequisite to any works being carried out to facilitate fish passage would be for the weir to be fully repaired by the owner, although this work could be carried out in conjunction with the fish passage works to reduce overall cost by having one set of machinery and a single contractor.

Advantages and Disadvantages

- 4.4.17 **Table 4.2** and **Table 4.3** presents advantages and disadvantages of implementing either a Do Nothing scenario, structural removal, rock ramp, natural bypass or technical fish pass solution for Ford Mill Weir based on the six key criteria presented in **Section 4.2**.

Table 4.2 Ford Mill Weir Restoration Options Appraisal (Part 1)

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
Hydrology & Engineering	<p>Advantages</p> <ul style="list-style-type: none"> No change in upstream water levels and flood extent (or elevated flows) downstream of structure (weir). <p>Disadvantages</p> <ul style="list-style-type: none"> The structure will continue to influence the natural flow and sediment regime promoting upstream flow impoundment (see Section 2), increased siltation upstream, reduction in 'freshest' (flushing flows), and low flows (i.e. reduction in seasonal base flows). Potential collapse of the structure overtime. 	<p>Advantages</p> <ul style="list-style-type: none"> More natural flow regime reinstated upstream and downstream of Ford Mill Weir. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for upstream water levels to lower due to increased conveyance and removal of the weir. Potential for reduced flows along the Mill leat upstream of the Mill house. A key concern of the landowner. Potential for changes in water temperatures following the removal of the weir, although this would be short-term until the natural thermal regime was re-established. Restricted access. 	<p>Advantages</p> <ul style="list-style-type: none"> The rock ramp will be designed to reduce the hydraulic gradient and velocities (to allow for improved fish passage), while maintaining upstream water levels and flows through the Mill leat. Failure of the structure would have minimal long term consequences (e.g. flood risk). Reduced tendency to clog compared to other fish passage solutions (e.g. Larinier fish pass) and therefore more reliable to operate, with reduced maintenance efforts. The inherent nature of the existing channel downstream of the weir does give rise to the construction of a natural rock ramp style fish pass. Local rocks from the existing channel to be used for the rock ramp. <p>Disadvantages</p> <ul style="list-style-type: none"> Material may settle or disintegrate in high flows if not constructed robustly, although this would be mitigated through robust design and construction. Restricted access.

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
Geomorphology	<p>Advantages</p> <ul style="list-style-type: none"> No major benefits for geomorphology. <p>Disadvantages</p> <ul style="list-style-type: none"> Downstream bank erosion and bed scour will continue during high flows (see Section 2). Continued trapping of sediments behind the structure (see Section 2). Disruption to the natural longitudinal profile and channel cross-section upstream and downstream of the structure. Potential sudden release of sediment behind structure if it collapses. 	<p>Advantages</p> <ul style="list-style-type: none"> Natural sediment dynamics and channel morphology will be reinstated over time following a period of adjustment as sediment stored upstream from the weir is remobilised and transported downstream. However, it should be noted that any excess sediment could be removed at the same time as the weir. The removal of impoundment and reinstatement of a more natural flow and sediment regime is likely to result in an increase in in-channel morphological diversity. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for an increase in local stream power and channel incision, although this will depend upon the morphology of the channel directly upstream and downstream of the weir. There is potential for the step created by the weir in the river's long profile to migrate upstream and cause channel erosion. However, such channel erosion can be minimised by re-grading the bed and creating a smooth gradient over the former site of the weir. The banks upstream and downstream of the weir are likely to adjust as a result of lowered water levels. Fine sediment from bank collapse and any material from behind the weir will travel downstream and potentially smother good habitat and infill pools. 	<p>Advantages</p> <ul style="list-style-type: none"> Use of natural substrates. Reduced impoundment and reinstatement of a more natural flow and sediment regime is likely to result in an increase in in-channel morphological diversity downstream of the weir. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for an increase in local stream power, channel incision and bank erosion, although these can be minimised through robust mitigation (e.g. re-grading the bed, soft engineering bank protection works).

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
Environment	<p>Advantages</p> <ul style="list-style-type: none"> No change to the current sensitivity of environmental receptors within close proximity to the structure. <p>Disadvantages</p> <ul style="list-style-type: none"> Locally poor water quality (e.g. lower dissolved oxygen; higher temperature) in response to large sections of impounded water (see Section 2) will be retained. 	<p>Advantages</p> <ul style="list-style-type: none"> Improves in-channel habitats for fish, otter, water vole and other aquatic fauna which inhabit the By Brook (see Section 2). The removal of the structure will increase habitat diversity, reduce siltation, reduce temperature and increase oxygen levels in the river. <p>Disadvantages</p> <ul style="list-style-type: none"> Sediments accumulated behind the weir are likely to consist of coarse material, fines and organic detritus. Removal of the weir is likely to result in the remobilisation of these sediments, which may adversely impact upon downstream habitats. Full or partial removal of this material (and potential reuse for bed re-grading) could, however, mitigate this impact. Potential disturbance during the weir removal phase to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Loss of a historic feature in the landscape (i.e. connection with the Mill House). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> Blends into the landscape (i.e. high aesthetic appeal). Follows the original watercourse and provides a natural setting for local flora and fauna. Use of natural substrates, rather than concrete or other smooth materials, provides roughness and interstitial spaces that allow both small fishes and benthic invertebrates to pass and directly colonise. <p>Disadvantages</p> <ul style="list-style-type: none"> Requires temporary works in the river channel, although impacts upon migratory fish can be minimised through robust mitigation and timing of works. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner.

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
WFD Compliance (and Fish Passage)	<p>Advantages</p> <ul style="list-style-type: none"> No major benefits to WFD compliance <p>Disadvantages</p> <ul style="list-style-type: none"> Does not comply with the objectives of the WFD regarding fish passage. The structure has a large head difference making this structure a major barrier along the By Brook for salmonid fish species (and eels). Does not provide for longitudinal connectivity. This option will therefore not contribute towards Good Ecological Status for the biological (fish) element of the downstream water body (see Section 3). 	<p>Advantages</p> <ul style="list-style-type: none"> Weir removal is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation) during the weir removal phase. However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> Installation of the rock ramp is likely to improve the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. The installation of the rock ramp will be suitable for a wide range of fish species (e.g. salmonids to eels) and sizes. No additional works would be required to facilitate eel passage, as rock ramps provide an effective mechanism for eel passage. <p>Disadvantages</p> <ul style="list-style-type: none"> Variation in upstream water levels may influence the effectiveness of the rock ramp for fish passage during certain flow conditions. However, this could be controlled through the installation of small flow deflectors to help assist in directing flows down the rock ramp.

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
Ecosystem Services	<p>Advantages</p> <ul style="list-style-type: none"> No change in current status of Ecosystem Services. <p>Disadvantages</p> <ul style="list-style-type: none"> No additional positive benefits in regards to Ecosystem Services. 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse for wild food provisions (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). Localised weir removal would have no impact on wet woodland, reedbed, fen or grazing marsh land cover within the catchment. None are directly adjacent to the works. Siltation in the Leat would result in the creation of new reedbed habitats which will create additional water storage capacity (Water and Erosion Regulation Services). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). More naturalised watercourse (Water Cycling Services). <p>Disadvantages</p> <ul style="list-style-type: none"> If the Leat were to run dry there would be a negative impact to the setting of the listed buildings (Cultural Services - Heritage). There may be localised changes to flow upstream of the weir, this will have no impact on the aesthetic value of the river and surrounds. If the Leat were to run dry there would be a negative impact to the aesthetic setting (Aesthetic Value - Physical Landscape). Ford Mill buildings sit on the Mill Leat. The Mill Leat contributes to the setting of the buildings. If the Leat were to run dry there would be a negative impact to the setting of the buildings (Aesthetic Value - Heritage). 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to rock ramp features. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). Localised weir removal would have no impact on wet woodland, reedbed, fen or grazing marsh land cover within the catchment. None are directly adjacent to the works. Siltation in the Leat would result in the creation of new reedbed habitats which will create additional water storage capacity (Water and Erosion Regulation Services). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> If the Leat were to run dry there would be a negative impact to the setting of the listed buildings (Cultural Services - Heritage). There may be localised changes to flow upstream of the weir, this will have no impact on the aesthetic value of the river and surrounds. If the Leat were to run dry there would be a negative impact to the aesthetic setting (Aesthetic Value - Physical Landscape). Ford Mill buildings sit on the Mill Leat. The Mill Leat contributes to the setting of the buildings. If the Leat were to run dry there would be a negative impact to the setting of the buildings (Aesthetic Value - Heritage).

Criteria	Ford Mill Weir Restoration Options		
	Do Nothing	Structural Removal	Rock Ramp
Overview: Potential Restoration Option	Low	Moderate	High

Table 4.3 Ford Mill Weir Restoration Options Appraisal (Part 2)

Criteria	Ford Mill Weir Restoration Options	
	Natural Bypass Channel	Technical (Larinier) Fish Pass
Hydrology & Engineering	<p>Advantages</p> <ul style="list-style-type: none"> Increased flow diversity. Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> Potential uneven split in flows down the Mill leat, By Brook and / or bypass channel, with the current weir crest perhaps requiring to be raised to mitigate the increased flows down the bypass channel (if bypass channel option 2 carried forward) in particular during periods of low river flows. Large land take (footprint) required, in particular for bypass channel option 2, although the bypass channels would generally follow existing drainage and / or field boundaries. Restricted access. Unknown ground conditions. 	<p>Advantages</p> <ul style="list-style-type: none"> A Larinier fish pass will provide the main attracting flows in low flow conditions as all flow will pass through the Larinier. Flexibility in width of Larinier fish passes over other types of passes (0.6m to 3.6m). The existing weir would still function as a water level control structure. Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> Sensitivity to change in head level which means that a Larinier fish pass will not generally remain effective if head rises more than about 200mm to 300mm above normal operating level in 100mm baffle passes, or 400mm to 500mm above normal operating level in 150mm passes. Requirement of pre-weirs downstream of the existing weir in order to raise downstream water levels for fish passage (i.e. to provide resting pools) to enable the successful use of the Larinier fish passes. The approach angle of the proposed Larinier fish pass as presented in Figure 4.4 may not be suited for optimum flow attraction for migrating fish. Restricted access. Unknown ground conditions.

Criteria	Ford Mill Weir Restoration Options	
	Natural Bypass Channel	Technical (Larinier) Fish Pass
Geomorphology	<p>Advantages</p> <ul style="list-style-type: none"> Reinstates some of the natural functioning of river processes, although the weir would still function and regulate flows if not back filled with spoil (if bypass channel option 2 carried forward). Use of natural substrates. <p>Disadvantages</p> <ul style="list-style-type: none"> Initial channel bed and bank erosion along the bypass channel until equilibrium is maintained and there is no net erosion or deposition along the bypass channel. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> Disruption of flow and sediment continuity, in particular during low flows.
Environment	<p>Advantages</p> <ul style="list-style-type: none"> Creation of additional river and floodplain habitat for flora and fauna including spawning nursery grounds within the bypass channel (see Figure 4.3). <p>Disadvantages</p> <ul style="list-style-type: none"> Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> No additional terrestrial habitat or near natural freshwater habitat created. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Temporary minor disturbance (visual, noise and obstructions) to landowner.

Criteria	Ford Mill Weir Restoration Options	
	Natural Bypass Channel	Technical (Larinier) Fish Pass
WFD Compliance (and Fish Passage)	<p>Advantages</p> <ul style="list-style-type: none"> A bypass channel is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats via the bypass channel. No additional works would be required to facilitate eel passage, as the bypass will provide an effective mechanism for eel passage. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation). However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if a technical fish pass is installed. Eel pass required.

Criteria	Ford Mill Weir Restoration Options	
	Natural Bypass Channel	Technical (Larinier) Fish Pass
Ecosystem Services	<p>Advantages</p> <ul style="list-style-type: none"> Creation of a bypass channel will result in a net gain of watercourse which will have a positive impact on water cycling (Recreation and Tourism Services – Bird and Wildlife Watching). The creation of a bypass channel would result in a net gain in watercourse and therefore marginal habitats. This would have a minor positive impact on erosion regulation. More naturalised watercourse (Water Cycling Services). <p>Disadvantages</p> <ul style="list-style-type: none"> There may be localised changes to flow upstream of the weir, this will have no impact on the aesthetic value of the river and surrounds. If the Leat were to run dry there would be a negative impact to the aesthetic setting (Aesthetic Value - Physical Landscape). Ford Mill buildings sit on the Mill Leat. The Mill Leat contributes to the setting of the buildings. If the Leat were to run dry there would be a negative impact to the setting of the buildings (Aesthetic Value - Heritage). The creation of a bypass channel would result in small scale habitat loss of habitat in the woodland and therefore there may be a minor impact to photosynthesis. This would be offset by colonisation of the channel by marginal and macrophyte species so over time there will be no impact (Recreation and Tourism Services – Bird and Wildlife Watching). 	<p>Advantages</p> <ul style="list-style-type: none"> Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> If the Leat were to run dry there would be a negative impact to the setting of the listed buildings (Cultural Services - Heritage). There may be localised changes to flow upstream of the weir, this will have no impact on the aesthetic value of the river and surrounds. If the Leat were to run dry there would be a negative impact to the aesthetic setting (Aesthetic Value - Physical Landscape). Ford Mill buildings sit on the Mill Leat. The Mill Leat contributes to the setting of the buildings. If the Leat were to run dry there would be a negative impact to the setting of the buildings (Aesthetic Value - Heritage). The sluice lies within the Cotswolds AONB. Installation of a Larinier fish pass could result in a visual impact on the landscape character of the AONB as it is a non-natural structure (Cultural Heritage Services).
Overview: Potential Restoration Option	Moderate	Moderate

4.5 Reach 4A2: Weir D/S Ford Restoration Options - Technical Details and Appraisal

Do Nothing

- 4.5.1 This option maintains the status quo and is based on the present situation. It assumes that the Weir D/S Ford would not be removed and no fish passage solutions constructed. The do nothing option provides a benchmark against which the suggested restoration options for Weir D/S Ford can be assessed.

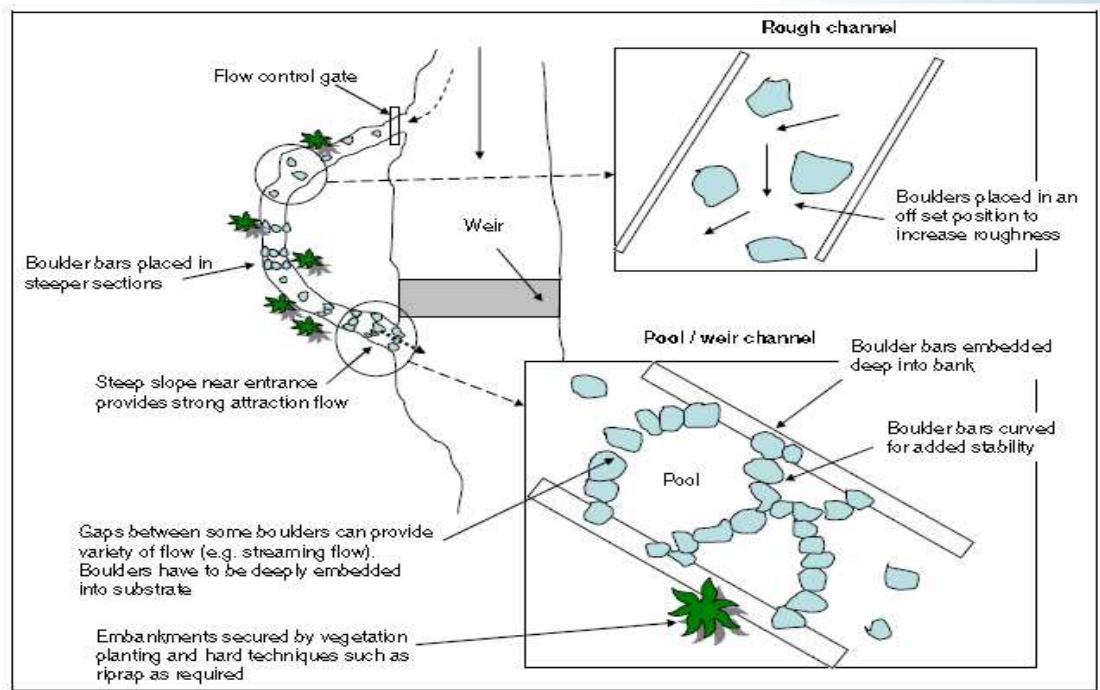
Structural Removal

- 4.5.2 Similar to Ford Mill Weir along Reach 4A1, this option would comprise of removing the water level control structure to alleviate the effects of upstream impoundment caused by the structure while providing a greater ability for salmonid fish species (and eels) to migrate upstream and thus contribute towards GES for the biological (fish) element of the downstream water body (see **Section 3.4**). In regards to Weir D/S Ford, the complete structure would be directly removed on site, although as previously stated structural removal along watercourses can be undertaken in phases to reduce potential disturbance to the downstream water environment and flora and fauna. In addition, partial excavation of accumulated fine sediment behind the weir prior to removal could be undertaken to reduce the amount of sediment available for downstream transport. Ensuring that the bed is re-graded downstream of the site will also assist in minimising erosion and downstream transport of sediment along the By Brook. However, maintenance of the weir is the reasonability of the Ford Fly Fishers (FFF) who rent the fishing rights along this stretch of the By Brook (i.e. Reach 4A) with the weir controlling water levels for the benefits of the FFF in regards to providing long deep pools or slower water upstream of the weir. These modified flows create an artificial flow environment which is favoured for recreational fly fishers, and as such weir removal may not be supported by the FFF if changes in these environments were to alter the recreational experience of fly fishing along the By Brook (see **Table 4.4**). A replacement foot-bridge would be required if the removal of the weir was taken forward.

Natural Bypass Channel

- 4.5.3 During flood events along the By Brook, floodwaters breach the channel banks directly upstream of the Weir D/S Ford and are conveyed along the natural floodplain (valley) depression which appears the original alignment of the watercourse which re-enters the main By Brook again directly downstream of Sluice D/S Ford. As such there is potential to construct a natural bypass channel which incorporates a pool and riffle system which both provides geomorphological and ecological diversity while improving fish passage along Reach 4A2 and Reach 4A3 (detailed below).
- 4.5.4 A natural bypass channel or “close-to-nature style” of fish passes imitates as closely as possible natural river rapids or streams with steep gradients and the construction material chosen corresponds to what is usually present in rivers under natural conditions. Such fish passes meet the biological requirements more satisfactorily than technical fish passes (e.g. Larinier, see **Table 4.4**) with regard to the connectivity of rivers. Furthermore, the close-to-nature design enables new flowing-water biotopes to be created in a watercourse, while blending into the surrounding landscape.
- 4.5.5 Bypass channels can be constructed using an array of boulder and vegetation planting arrangements to increase water depth and reduce flow velocity to allow for improved fish passage (see **Figure 4.5**).

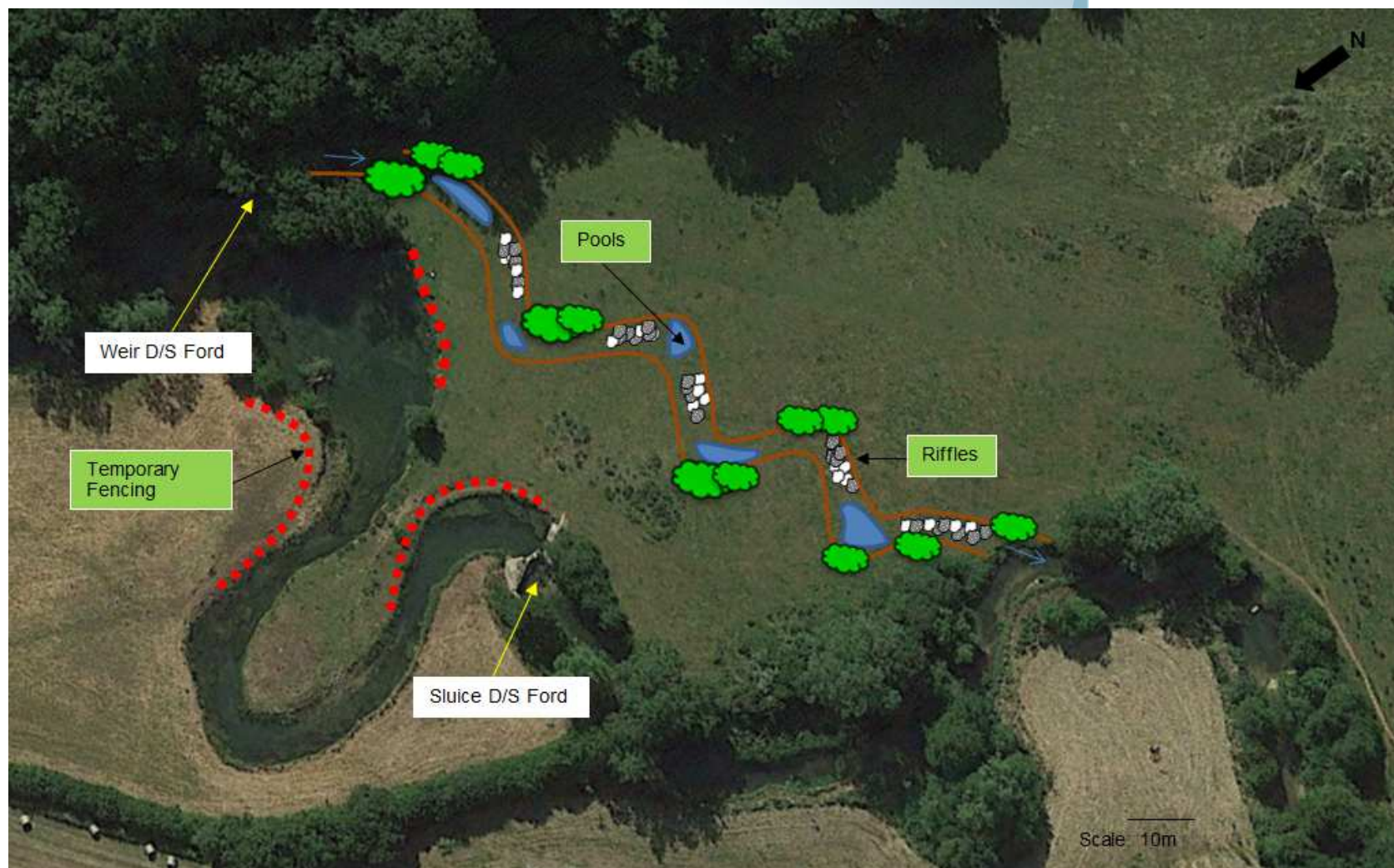
Figure 4.5 Schematic Diagram Illustrating a Bypass Channel Construction Arrangement



Note: This schematic does not relate directly to Reach 4A2 (Weir D/S Ford) and is merely used to illustrate bypass channel design.

- 4.5.6 Although natural bypass channel (rock ramp) fish passes are typically installed at a slope of 1:20 (Harris *et al.*, 1998), a 1:30 slope provides more flexibility in design and a more natural looking bypass channel without the need for additional piling or stabilising of banks.
- 4.5.7 For the proposed bypass channel associated with Weir D/S Ford as presented in **Figure 4.6**, the start or entrance of the bypass could be located near the end of the natural channel alignment at the weir and extended onto the outer left floodplain (facing downstream) with the bed of the bypass being 0.25m below the upstream water level (measured at 56.89mAOD, based on Survey Operations Ltd undertaken in March 2014) to take into consideration variations in flow and ensure effectiveness of the bypass. **The upstream water level of 56.89mAOD corresponds to approximately Q95 which is below the lower design limit for trout of Q95 (see Table 2.4).**
- 4.5.8 The overall channel depth of the bypass channel would be approximately 0.4m with a bottom width of approximately 1m and side slopes of around 1:3. Thus, the total channel (top) width of the bypass channel would be 3.5m. The length of the bypass channel would be approximately 125m, with a pool and riffle spacing around 5 to 7 times the channel width (Knighton, 1998). Based on various fluvial environments, the wavelength and radius of curvature of the meanders associated with the bypass channel should be respectively about 10 to 14 and 2 to 3 times the channel width (Knighton, 1998).
- 4.5.9 The downstream exit level of the bypass channel would be located approximately 125m downstream of Weir D/S Ford at a level of 54.6mAOD below the downstream water level (measured at 55.12mAOD based D & H Surveys undertaken in March 2014).

Figure 4.6 Concept (Outline Design) Layout of the Natural Bypass Channel for Reach 4A2 (Weir D/S Ford)

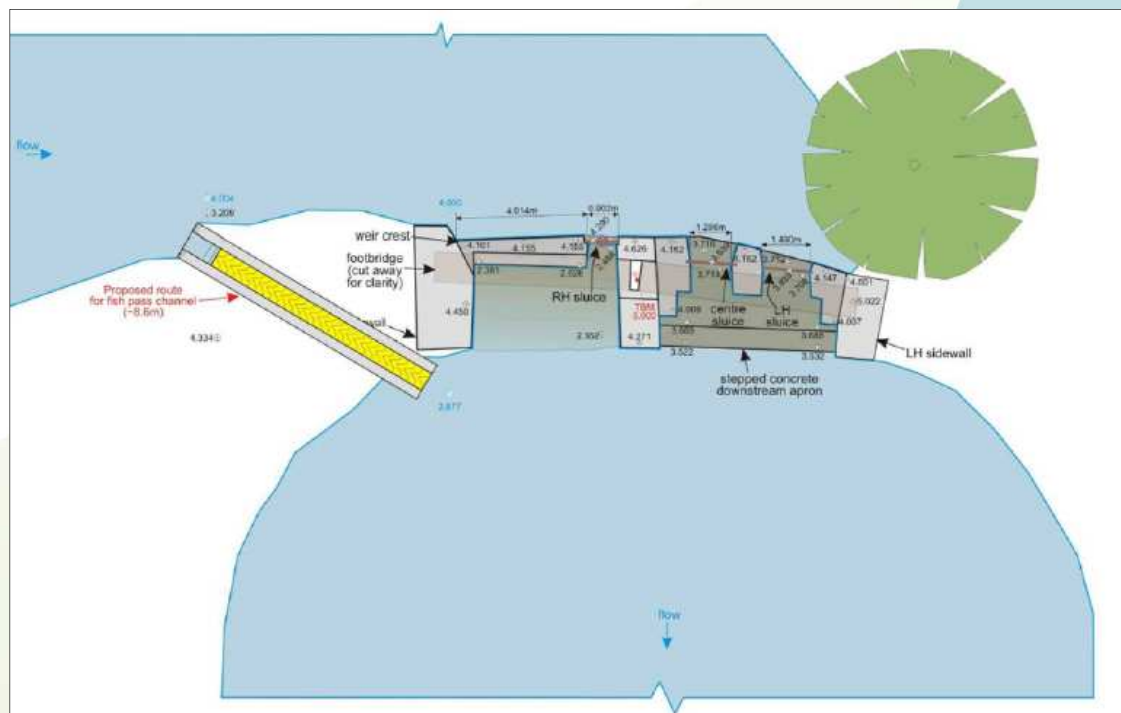


- 4.5.11 In addition, temporary fencing could be incorporated around the banks downstream of Weir D/S Ford to reduce fine sediment input into the main channel of the By Brook from cattle poaching (see **Figure 4.8** – transported fine sediments after a flood event). The fencing should be set back from the banks to allow for continued fluvial process and natural development of the meander bends, although soft bank protection works may be required along the left bank directly downstream of the weir to reduce the expansion of the scour hole.

Technical Fish Pass

- 4.5.12 The proposed solution comprises either a pool and traverse or Larinier style fish pass (BART, 2013/2014) (see **Figure 4.7**). Given the maximum operating gradient of 15% for a Larinier fish pass, the minimum length for such a pass to be installed with a head loss of approximately 1.2m, could be between 8m to 8.5m. The width of a Larinier fish pass is a function of baffle height, and based on a baffle height of 100mm, such a pass installed would be approximately 0.6m wide (see **Figure 4.7**). The pool and traverse fish pass would consist of 5 traverses (2m wide) with low flow notches (0.3m wide by 0.25m deep) and be approximately 13.3m in length and similar to the Larinier pass through the right bank of the By Brook upstream, of the weir (see **Appendix A** for further details).

Figure 4.7 **Larinier Technical Fish Pass Concept for Weir D/S Ford**



Advantages and Disadvantages

4.5.13 **Table 4.4** presents advantages and disadvantages of implementing either a structural removal, natural bypass channel or technical fish pass solution for Weir D/S Ford based on the six key criteria presented in **Section 4.2**. The Do Nothing scenario is similar to that presented in **Table 4.2** and is therefore not included in this table.

4.6 Reach 4A3: Sluice D/S Ford Restoration Options - Technical Details and Appraisal

Do Nothing

4.6.1 This option maintains the status quo and is based on the present situation. It assumes that the Sluice D/S Ford would not be removed and no fish passage solutions constructed. The do nothing option provides a benchmark against which the suggested restoration options for Sluice D/S Ford can be assessed.

Structural Removal

4.6.2 Similar to Weir D/S Ford along Reach 4A2, this option would comprise of removing the sluice to alleviate the effects of upstream impoundment caused by the structure while providing a greater ability for salmonid fish species (and eels) to migrate upstream and thus contribute towards GES for the biological (fish) element of the downstream water body (**see Section 3.4**). However, similar to Weir D/S Ford, the sluice is maintained by the Ford Fly Fishers with the sluice controlling water levels for the benefits of the FFF, and as such structural removal may not be supported by the FFF. In addition, the sluice appears to maintain the depth of water associated with the upstream structure (i.e. Weir D/S Ford) to prevent under-cutting of the structure, although depending on the outcomes of the preferred river restoration solutions along Reach 4A2 and Reach 4A3 this may not have any implications.

Raising Water Levels (Pre-barrage)

4.6.3 Fish passage at small obstructions, in terms of the vertical height which has to be traversed, can often be assisted by provision of a small weir or weirs (pre-barrage) downstream of the main obstruction. These have the effect of splitting the distance required by fish to be traversed into smaller leaps or traverses. As such, a natural rock pre-barrage downstream of Sluice D/S Ford could be constructed to allow either sufficient depth of water for fish to leap, or else to assist in drowning out the sluice structure during flood events to allow fish passage, without impacting upon the exiting function of the sluice in regards to controlling water levels. Further detailed aspects of a pre-barrage are detailed below along with the proposed pre-barrage which could be constructed below Sluice D/S Ford.



4.6.4 A pre-barrage can span the whole channel with minimum lengths of pool being 3m (over a 15% gradient) and the head of the individual weirs (barrages) should not exceed 0.3m – 0.5m for migratory salmonids (Environment Agency, 2010). Guidelines for minimal length of pool and power dissipation values are generally the same for pool passes in that volumetric power dissipation values for migratory salmonids are $\leq 150 \text{ WM}^{-3}$ and $\leq 100 \text{ WM}^{-3}$ for trout (Environment Agency, 2010).

Table 4.4 Weir D/S Ford Restoration Options Appraisal

Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
Hydrology & Engineering	<p>Advantages</p> <ul style="list-style-type: none"> More natural flow regime reinstated upstream and downstream of Weir D/S Ford. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for upstream water levels to lower due to increased conveyance and removal of the weir. Potential to alter the recreational experience of fly fishing along the By Brook due to changes in water levels. Potential for changes in water temperatures following the removal of the weir, although this would be short-term until the natural thermal regime was re-established. 	<p>Advantages</p> <ul style="list-style-type: none"> Increased flow diversity (more natural flow regime). Can be adapted to a wide range of flow regimes. The existing weir would still function as a water level control structure. Reduced tendency to clog and therefore more reliable to operate, with reduced maintenance efforts. Failure of the structure would have minimal long term consequences (e.g. flood risk, etc). <p>Disadvantages</p> <ul style="list-style-type: none"> Potential uneven split in flows down the main channel and bypass channel, although can be controlled. Large land take (footprint) required for bypass channel. Unknown ground conditions. 	<p>Advantages</p> <ul style="list-style-type: none"> A Larinier fish pass will provide the main attracting flows in low flow conditions as all flow will pass through the Larinier. Flexibility in width of Larinier fish passes over other types of passes (0.6m to 3.6m). Low maintenance associated with pool and traverse style fish passes. The existing weir would still function as a water level control structure. Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> Sensitivity to change in head level which means that a Larinier fish pass will not generally remain effective if head rises more than about 200mm to 300mm above normal operating level in 100mm baffle passes, or 400mm to 500mm above normal operating level in 150mm passes. The approach angle of the proposed Larinier fish pass as presented in Figure 4.7 may not be suited for optimum flow attraction for migrating fish. Maximum head loss for pool and traverse style fish passes is 0.3m for brown trout (head loss of Weir D/S Ford is approximately 1.2m based on D & H Surveys (2014)). Established trees and shrubs along the alignment of the technical fish passes. Unknown ground conditions.

Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
Geomorphology	<p>Advantages</p> <ul style="list-style-type: none"> Natural sediment dynamics and channel morphology will be reinstated over time following a period of adjustment. Although, excess sediment could be removed at the same time as the weir. The removal of impoundment and reinstatement of a more natural flow and sediment regime resulting in greater in-channel morphological diversity. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for an increase in local stream power and channel incision, although this will depend upon the morphology of the channel directly upstream and downstream of the weir. There is potential for the step created by the weir in the river's long profile to migrate upstream and cause channel erosion. However, such channel erosion can be minimised by re-grading the bed and creating a smooth gradient over the former site of the weir. The banks upstream and downstream of the weir are likely to adjust as a result of lowered water levels. Fine sediment from bank collapse and any material from behind the weir will travel downstream and potentially smother good habitat and infill pools. 	<p>Advantages</p> <ul style="list-style-type: none"> Reinstates some of the natural functioning of river processes, although the weir would still function and regulate flows. Use of natural substrates to increase morphological diversity. Reduced impoundment and reinstatement of a more natural flow and sediment regime is likely to result in an increase in in-channel morphological diversity downstream of the weir along the main channel. <p>Disadvantages</p> <ul style="list-style-type: none"> Initial channel bed and bank erosion along the bypass channel until equilibrium is maintained and there is no net erosion or deposition along the bypass channel. Potential erosion at the confluence of the bypass and By Brook, although soft bank protections works could be placed. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> Disruption of flow and sediment continuity, in particular during low flows.

Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
Environment	<p>Advantages</p> <ul style="list-style-type: none"> Improves in-channel habitats for fish, otter, water vole and other aquatic fauna which inhabit the By Brook (see Section 2). The removal of the structure will increase habitat diversity, reduce siltation, reduce temperature and increase oxygen levels in the river. <p>Disadvantages</p> <ul style="list-style-type: none"> Sediments accumulated behind the weir are likely to consist of coarse material, fines and organic detritus. Removal of the weir is likely to result in the remobilisation of these sediments, which may adversely impact upon downstream habitats. Full or partial removal of this material (and potential reuse for bed re-grading) could, however, mitigate this impact. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> Creation of additional river and floodplain habitat for flora and fauna including spawning nursery grounds within the bypass channel (e.g. riffles, see Figure 4.6). Use of natural substrates, rather than concrete or other smooth materials, provides roughness and interstitial spaces that allow both small fishes and benthic invertebrates to pass and directly colonise. Blends into the landscape (i.e. high aesthetic appeal). Can follow part of an original watercourse. <p>Disadvantages</p> <ul style="list-style-type: none"> Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> No additional terrestrial habitat or near natural freshwater habitat created. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Temporary minor disturbance (visual, noise and obstructions) to landowner.

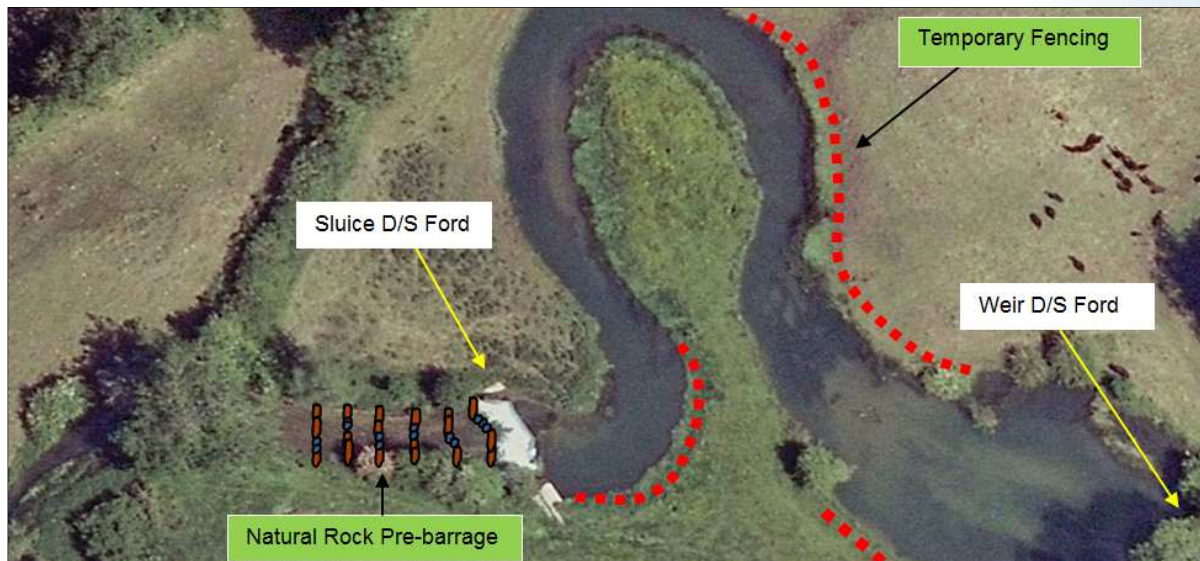
Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
WFD Compliance (and Fish Passage)	<p>Advantages</p> <ul style="list-style-type: none"> Weir removal is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation) during the weir removal phase. However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> A bypass channel is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats via the bypass channel. No additional works would be required to facilitate eel passage, as it will provide an effective mechanism for eel passage. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation) but they are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the SSSI. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if a technical fish pass is installed. Eel pass required.

Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
Ecosystem Services	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). Structure removal would result in a more naturalised watercourse which will have a positive impact on water cycling (Water Cycling Services). <p>Disadvantages</p> <ul style="list-style-type: none"> A PROW passes across the weir structure at this location, removal of the structure would interrupt the PROW network, an alternative river crossing would need to be installed. This would have no impact to rambling, horseriding, cycling (Recreation and Tourism Services). 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). The creation of a bypass channel would result in a net gain in watercourse and therefore marginal habitats. This would have a minor positive impact on water regulation (Water Regulation – Wetlands). The creation of a bypass channel will create additional bird habitats and therefore more opportunities for birdwatching (Recreation and Tourism – Bird Watching). Creation of a bypass channel will result in a net gain of watercourse which will have a positive impact on water cycling and erosion (Water and Erosion Regulation Services). 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling; Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and other Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> A PROW passes across the weir structure at this location, removal of the structure would interrupt the PROW network, an alternative river crossing would need to be installed. This would have no impact to rambling, horseriding, cycling (Recreation and Tourism Services). Installation of a Larinier fish pass could result in a negative impact on visual amenity as it is a non-natural structure (Aesthetic Value). Installation of a Larinier fish pass would result in the small scale loss of in-channel vegetation, and therefore a minor reduction in photosynthesis.

Criteria	Weir D/S Ford Restoration Options		
	Structural Removal	Natural Bypass Channel	Technical Fish Pass
Ecosystem Services (continued)		<p>Disadvantages</p> <ul style="list-style-type: none"> The bypass channel would result in a small area of land take from a field used for grazing. Access would need to be created to ensure the remainder of the field can be utilised (Food, Cultivated Produce and Genetic Resources – Livestock, Wool and Animal Breeding). The creation of a bypass channel would result in small scale habitat loss of grassland habitats and therefore there may be a minor impact to photosynthesis. This would be offset by colonisation of the channel by marginal and macrophyte species so over time there will be no impact. A PROW passes across the weir structure at this location, the creation of a bypass channel would have include a pedestrian bridge to maintain access to the PROW. 	
Overview: Potential Restoration Option	Moderate	High	Moderate
	High		

- 4.6.5 For the proposed pre-barrage below Sluice D/S Ford as presented in **Figure 4.8**, this would consist of six traverses which would cover the width of the channel and include low flow notches (0.35m wide by 0.4m deep). The length of the pre-barrage will be approximately 12m in length.

Figure 4.8 Natural Rock Pre-barrage Concept for Sluice D/S Ford



- 4.6.6 In addition, temporary fencing could be incorporated around the banks downstream of Weir D/S Ford to reduce fine sediment input into the main channel of the By Brook from cattle poaching (see **Figure 4.8** – transported fine sediments after a flood event). The fencing should be set back from the banks to allow for continued fluvial process and natural development of the meander bends, although soft bank protection works may be required along the left bank directly downstream of the weir to reduce the expansion of the scour hole.

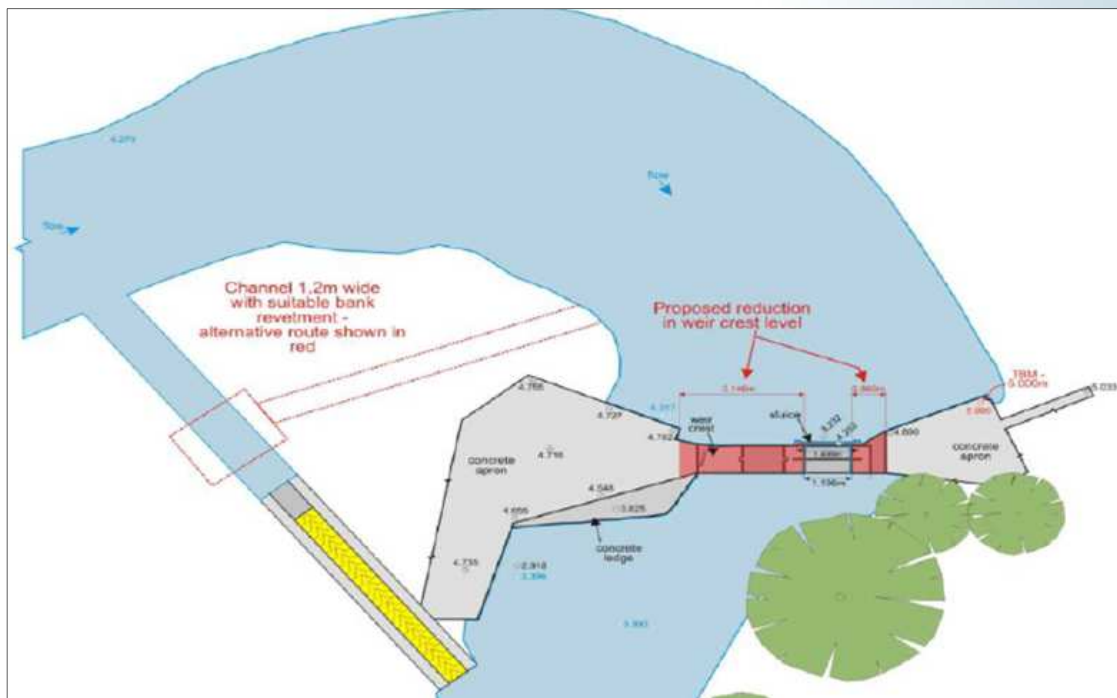
Natural Bypass Channel

- 4.6.7 As introduced for Weir D/S Ford, there is the potential for the construction of a natural bypass channel which bypasses both water level control structures along Reach 4A2 and Reach 4A3 as presented in **Figure 4.6**. In addition, other river restoration works (benefits) could also be undertaken along the main channel of the By Brook as per described in **Section 4.5.11** and shown on **Figure 4.6**.

Technical Fish Pass

- 4.6.8 The proposed solution comprises either a pool and traverse or Larinier style fish pass which include for the lowering of the sluice height (BART, 2013/2014) (see **Figure 4.9**). Given the maximum operating gradient of 15% for a Larinier fish pass, the minimum length for such a pass to be installed with a head loss of approximately 1m, could be between 6m to 7m. The width of a Larinier fish pass is a function of baffle height, and based on a baffle height of 100mm, such a pass installed would be approximately 0.6m wide (see **Figure 4.7**). The pool and traverse fish pass would consist of 4 traverses (2m wide) with low flow notches (0.35m wide by 0.4m deep) and be approximately 15m in length and installed in the same location as the Larinier fish pass (see **Appendix A** for further details).

Figure 4.9 Larinier Technical Fish Pass Concept for Sluice D/S Ford



Advantages and Disadvantages

4.6.9 **Table 4.5** presents advantages and disadvantages of implementing either structural removal, raising water levels, natural bypass channel or technical fish pass solution for Sluice D/S Ford based on the six key criteria presented in **Section 4.2**. The Do Nothing scenario is similar to that presented in **Table 4.2** and is therefore not included in this table. In addition, given the natural bypass channel was assessed in **Table 4.4** as having high restoration potential to be implemented along Reach 4A2 and Reach 4A3, it also is not further assessed in **Table 4.5**.

4.7 Reach 4A4: Slaughterford Gate Restoration Options - Technical Details and Appraisal

Do Nothing

4.7.1 This option maintains the status quo and is based on the present situation. It assumes that Slaughterford Gate would not be removed and no fish passage solutions constructed. The do nothing option provides a benchmark against which the suggested restoration options for Slaughterford Gate can be assessed.

Table 4.5 Sluice D/S Ford Restoration Options Appraisal

Criteria	Sluice D/S Ford Restoration Options		
	Structural Removal	Raising water levels (Pre-barrage)	Technical Fish Pass
Hydrology & Engineering	<p>Advantages</p> <ul style="list-style-type: none"> More natural flow regime reinstated upstream and downstream of Sluice D/S Ford. <p>Disadvantages</p> <ul style="list-style-type: none"> Sluice appears to maintain the depth of water associated with the upstream structure (i.e. Weir D/S Ford) to prevent under-cutting of the structure. Potential for upstream water levels to lower due to increased conveyance and removal of the sluice. Potential to alter the recreational experience of fly fishing along the By Brook due to changes in water levels. Potential for changes in water temperatures following the removal of the weir, although this would be short-term until the natural thermal regime was re-established. 	<p>Advantages</p> <ul style="list-style-type: none"> The main advantage of such pre-barrage structures is their attractiveness for fish, because of the very high percentage of the discharge of the watercourse that is likely to pass through the facility. Low construction material required, with rocks for the pre-barrage sources locally (e.g. Cornbrash Stone). Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> The sluice may require lowering to facilitate the operation of the pre-barrage over all flow conditions which may impact upon upstream water levels and the recreational experience of fly fishing along the By Brook due to changes in water levels. Pre-barrage weirs are generally used for rivers with salmonid populations, although given the key species in the By Brook are trout this may not be an issue. 	<p>Advantages</p> <ul style="list-style-type: none"> A Larinier fish pass will provide the main attracting flows in low flow conditions as all flow will pass through the Larinier. Flexibility in width of Larinier fish passes over other types of passes (0.6m to 3.6m). Low maintenance associated with pool and traverse style fish passes. The existing weir would still function as a water level control structure. Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> Sensitivity to change in head level which means that a Larinier fish pass will not generally remain effective if head rises more than about 200mm to 300mm above normal operating level in 100mm baffle passes, or 400mm to 500mm above normal operating level in 150mm passes. The approach angle of the proposed Larinier fish pass as presented in Figure 4.9 may not be suited for optimum flow attraction for migrating fish. Maximum head loss for pool and traverse style fish passes is 0.3m for brown trout (head loss of Sluice D/S Ford is approximately 0.6m based on D & H Surveys (2014)). Unknown ground conditions.

Criteria	Sluice D/S Ford Restoration Options		
	Structural Removal	Raising water levels (Pre-barrage)	Technical Fish Pass
Geomorphology	<p>Advantages</p> <ul style="list-style-type: none"> Natural sediment dynamics and channel morphology will be reinstated over time following a period of adjustment as sediment stored upstream from the sluice is remobilised and transported downstream. Although, excess sediment could be removed at the same time as the sluice. The removal of impoundment and reinstatement of a more natural flow and sediment regime resulting in greater in-channel morphological diversity. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for an increase in local stream power and channel incision, although this will depend upon the morphology of the channel directly upstream and downstream of the sluice. There is potential for the step created by the sluice in the river's long profile to migrate upstream and cause channel erosion. However, such channel erosion can be minimised by re-grading the bed and creating a smooth gradient over the former site of the sluice. The banks upstream and downstream of the sluice are likely to adjust as a result of lowered water levels. Fine sediment from bank collapse and any material from behind the sluice will travel downstream and potentially smother good habitat and infill pools. 	<p>Advantages</p> <ul style="list-style-type: none"> No additional geomorphological advantages associated with pre-barrage style fish passes, although natural rocks used for construction providing a diversity of micro-habitat flows within and over the pools. <p>Disadvantages</p> <ul style="list-style-type: none"> Disruption of flow and sediment continuity, in particular during low flows. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> Disruption of flow and sediment continuity, in particular during low flows.

Criteria	Sluice D/S Ford Restoration Options		
	Structural Removal	Raising water levels (Pre-barrage)	Technical Fish Pass
Environment	<p>Advantages</p> <ul style="list-style-type: none"> Improves in-channel habitats for fish, otter, water vole and other aquatic fauna which inhabit the By Brook (see Section 2). The removal of the structure will increase habitat diversity, reduce siltation, reduce temperature and increase oxygen levels in the river. <p>Disadvantages</p> <ul style="list-style-type: none"> Sediments accumulated behind the sluice are likely to consist of coarse material, fines and organic detritus. Removal of the sluice is likely to result in the remobilisation of these sediments, which may adversely impact upon downstream habitats. Full or partial removal of this material (and potential reuse for bed re-grading) could, however, mitigate this impact. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> Natural rock features to promote a diversity of aquatic species to use as micro-habitat. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> No additional terrestrial habitat or near natural freshwater habitat created. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Temporary minor disturbance (visual, noise and obstructions) to landowner.

Criteria	Sluice D/S Ford Restoration Options		
	Structural Removal	Raising water levels (Pre-barrage)	Technical Fish Pass
WFD Compliance (and Fish Passage)	<p>Advantages</p> <ul style="list-style-type: none"> Removal of the sluice is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation) during the sluice removal phase. However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if pre-barrage installed downstream of sluice. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if a technical fish pass is installed. Eel pass required.

Criteria	Sluice D/S Ford Restoration Options		
	Structural Removal	Raising water levels (Pre-barrage)	Technical Fish Pass
Ecosystem Services	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). Structure removal would result in a more naturalised watercourse which will have a positive impact on water cycling (Water Cycling Services). <p>Disadvantages</p> <ul style="list-style-type: none"> No major disadvantages to Ecosystem Services. 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> Creation of a pre-barrage could result in the small scale loss of aquatic vegetation and therefore a minor reduction in photosynthesis. 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be an improvement in in-channel habitat for fish and otter (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> Installation of a Larinier fish pass would result in the small scale loss of in-channel vegetation, and therefore a minor reduction in photosynthesis. Installation of a Larinier fish pass could result in a negative impact on visual amenity as it is a non-natural structure (Aesthetic Value).
Overview: Potential Restoration Option	Moderate	Moderate	Moderate
	High	High	

Structural Removal

- 4.7.2 Similar to Sluice D/S Ford along Reach 4A3, this option would comprise of removing the sluice structure associated with Slaughterford Gate to alleviate the effects of upstream impoundment caused by the structure while providing a greater ability for salmonid fish species (and eels) to migrate upstream and thus contribute towards GES for the biological (fish) element of the downstream water body (see **Section 3.4**). However, the upstream stretch which is impounded for approximately 400m although providing no geomorphological and ecological benefits, is favoured by the Ford Fly Fishers for ease of recreational angling. As such structural removal may not be supported by the Ford Fly Fishers in response to changes in water levels if the sluice was removed. A replacement foot-bridge would be required if the removal of the sluice was taken forward. It should be noted, although, structural removal may not be favoured by the Ford Fly Fishers, it is supported by the Environment Agency who currently own Slaughterford Gate. The Environment Agency consider the structure a failing and uneconomic asset that provides no flood risk benefit. The Environment Agency would not want to fund maintenance works to keep this impoundment in place when the WFD benefits of its removal are considerable (see **Table 4.6**). It should be noted that the FFF do not own the structure or land affected by the structure.

Raising Water Levels (Rock Riffles)

- 4.7.3 This option would consist of a series of naturalised rock riffles, using local Cornbrash stone to raise the water levels along the By Brook between Slaughterford Gate and Rag Mill Weir in conjunction with the replacement of Slaughterford Gate steel weir with a notched board and lowering Rag Mill Weir (see **Figure 4.10**). A total of four riffles (between 5m and 9m in length and up to 0.5m high) would be placed along the profile of channel bed to provide an overall rise in water levels of 1m with a proposed 0.5m head difference for low water levels at Slaughterford Gate (see **Figure 4.11**).

Natural Bypass Channel

- 4.7.4 During winter flooding, floodwater bypasses Slaughterford Gate along the outer right floodplain (facing downstream) in which floodwaters escape the channel approximately 100m upstream of the sluice and follows the natural landscape depression re-entering downstream of Rag Mill Weir. As such there is the potential to construct a natural bypass channel which bypasses both structures and provides fish passage.
- 4.7.5 For the proposed bypass channel as presented in **Figure 4.12**, the start or entrance of the bypass could be located upstream of Slaughterford Gate and extended onto the outer right floodplain with the bed of the bypass being 0.25m below the upstream water level (measured at 54.65m AOD, based on based D & H Surveys undertaken in March 2014) to take into consideration variations in flow and ensure effectiveness of the bypass. **The upstream water level of 54.65m AOD corresponds to approximately Q95 which is below the lower design limit for trout of Q95** (see **Table 2.4**).
- 4.7.6 The overall depth of the bypass channel would be approximately 0.6m (below exiting ground level) with a bottom width of approximately 1m and side slopes of around 1:3. Thus, the total channel (top) width of the bypass channel would be 5m. The length of the bypass channel would be approximately 225m, with a pool and riffle spacing around 5 to 7 times the channel width (Knighton, 1998). Based on various fluvial environments, the wavelength and radius of curvature of the meanders associated with the bypass channel should be respectively about 10 to 14, and 2 to 3 times the channel width (Knighton, 1998).

Figure 4.10 Natural Rock Pre-barrage Concept for Slaughterford Gate

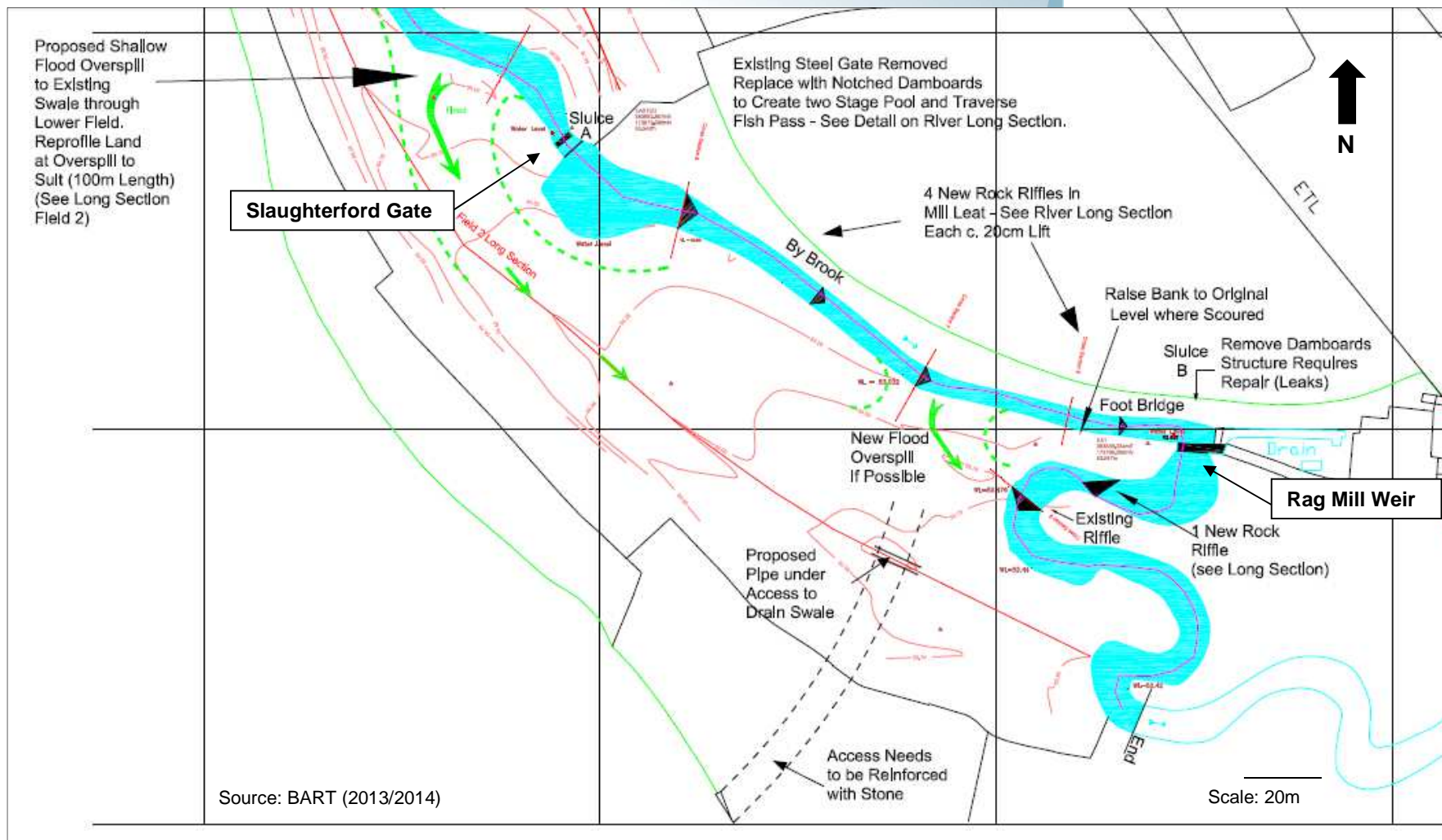
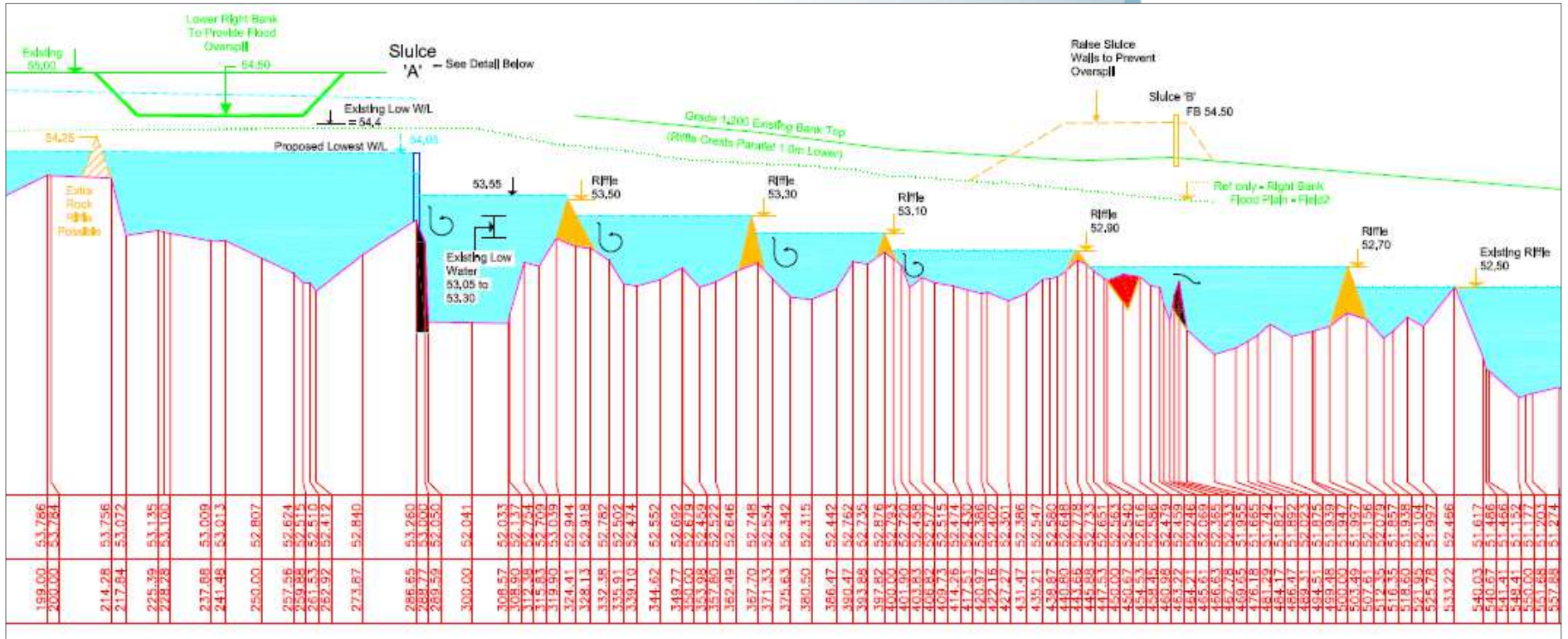
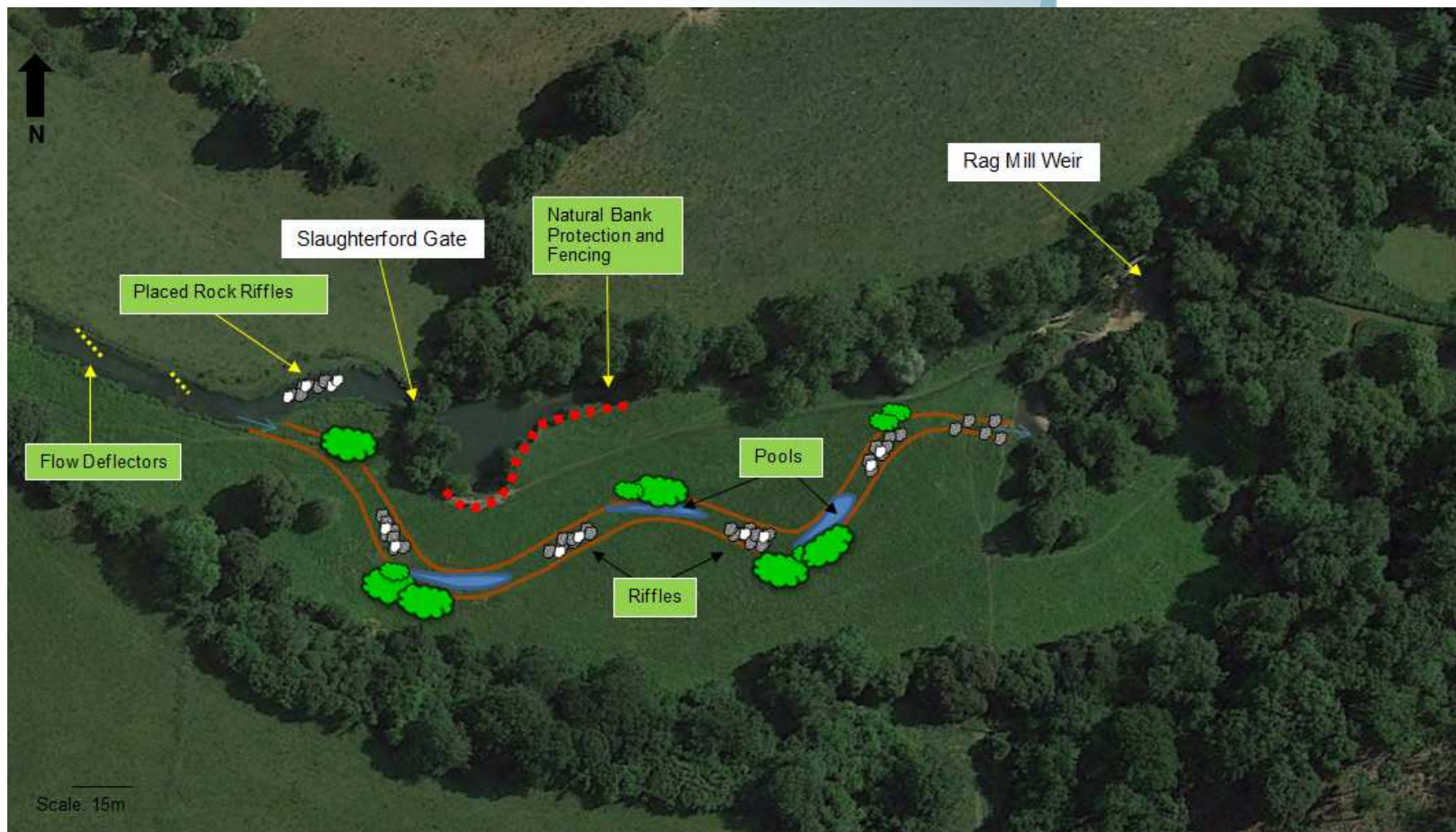


Figure 4.11 Natural Rock Pre-barrage Concept for Slaughterford Gate – River Long Section



Source: BART (2013/2014)

Figure 4.12 Natural Bypass Channel Concept (Outline Design) for Slaughterford Gate



- 4.7.7 The downstream exit level of the bypass channel would be located approximately 225m downstream of Slaughterford Gate at a level of 52.48mAOD below the downstream water level (based on D & H Surveys undertaken in March 2014).
- 4.7.8 A small control structure could be installed at the entrance of the bypass to allow for fine tuning and control of the flows in which it is envisioned that 10% to 15% of the flows would be diverted down the bypass channel. An additional foot-bridge would be placed over the bypass channel to ensure continued access along the By Brook. The rocks themselves will break up the flow of water which will slow it down through this section and create broken water which will act as an attractant flow to fish species.
- 4.7.9 In addition, soft bank protection works (e.g. Hazel Whips) and fencing could be incorporated around the banks downstream of the sluice to reduce fine sediment input into the main channel of the By Brook from fluvial processes and cattle poaching; and ensure the scour pool does not further widen. Rock riffles and gravel bars could also be placed to enhance fish habitat further upstream / downstream of the sluice along with flow deflectors to provide greater morphological diversity (see **Figure 4.12**).

Technical Fish Pass

- 4.7.10 This option comprises a pool and traverse style fish pass to be installed on either the left or right hand bank of the By Brook to provide fish passage (see **Figure 4.13**). The pool and traverse fish passes would consist of 6 traverses and 5 pools and be between 17m and 33m in length (see **Appendix A** for further details). However, given the large head difference at the structure (1.35m based on existing low water levels calculated by D & H Surveys in December 2013), the technical fish passes will be large and require the loss of a small area of grazing; and this combined with the potential visual impact such a fish passage solution is unlikely to be acceptable to landowners (see **Table 4.6**). An alternative foot-bridge would be required for public access if either of the pool and traverse style fish passes were taken forward.

Advantages and Disadvantages

- 4.7.11 **Table 4.6** presents advantages and disadvantages of implementing either structural removal, raising water levels, natural bypass channel or technical fish pass solution for Slaughterford Gate based on the six key criteria presented in **Section 4.2**. The Do Nothing scenario is similar to that presented in **Table 4.2** and is therefore not included in this table.

4.8 Reach 4A5: Rag Mill (Slaughterford) Weir Restoration Options - Technical Details and Appraisal

Do Nothing

- 4.8.1 This option maintains the status quo and is based on the present situation. It assumes that the Rag Mill Weir would not be removed and no fish passage solutions constructed. The do nothing option provides a benchmark against which the suggested restoration options for Rag Mill Weir can be assessed.

Table 4.6 Slaughterford Gate Restoration Options Appraisal

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Hydrology & Engineering	<p>Advantages</p> <ul style="list-style-type: none"> More natural flow regime reinstated upstream and downstream of Slaughterford Gate. Option supported by the Environment Agency. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for upstream water levels to lower due to increased conveyance and removal of the sluice. Potential to alter the recreational experience of fly fishing along the By Brook due to changes in water levels. Potential for changes in water temperatures following the removal of the weir. However, this would be short-term until the natural thermal regime was re-established and would be more appropriate in any case compared to slow moving impounded flow. 	<p>Advantages</p> <ul style="list-style-type: none"> Low construction material required, with rocks for the pre-barrage sources locally (e.g. Cornbrash Stone). Failure of the structure would have minimal long term consequences on flood risk downstream of Slaughterford Gate. <p>Disadvantages</p> <ul style="list-style-type: none"> The sluice may require lowering (notched board) to facilitate the operation of the placed rock riffles over all flow conditions which may impact upon upstream water levels and the recreational experience of fly fishing along the By Brook due to changes in water levels. 	<p>Advantages</p> <ul style="list-style-type: none"> Increased flow diversity (more natural flow regime). Can be adapted to a wide range of flow regimes. The existing weir would still function as a water level control structure. Reduced tendency to clog and therefore more reliable to operate, with reduced maintenance efforts. Failure of the structure would have minimal long term consequences (e.g. flood risk, etc). <p>Disadvantages</p> <ul style="list-style-type: none"> Potential uneven split in flows down the main channel and bypass channel, although can be controlled. Large land take (footprint) required for bypass channel. Unknown ground conditions. 	<p>Advantages</p> <ul style="list-style-type: none"> Low maintenance associated with pool and traverse style fish passes. The existing weir would still function as a water level control structure. Failure of the structure would have minimal long term consequences (e.g. flood risk). <p>Disadvantages</p> <ul style="list-style-type: none"> Maximum head loss for pool and traverse style fish passes is 0.3m for brown trout (head loss of sluice is greater than 1.35m based on D & H Surveys (2014)). Unknown ground conditions.

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Geomorphology	<p>Advantages</p> <ul style="list-style-type: none"> Upstream of Slaughterford Gate, a more natural channel will develop which would have minimal adjustment in response to the bed being already graded. It is anticipated a two-stage channel will develop providing greater enhancement along this over widened section of the By Brook. Natural sediment dynamics and channel morphology will be reinstated over time following a period of minor adjustment as sediment stored upstream from the sluice is remobilised and transported downstream. Although, excess sediment could be removed at the same time as the sluice. The removal of impoundment and reinstatement of a more natural flow and sediment regime resulting in greater in-channel morphological diversity. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential for an increase in local stream power and channel incision, although this will depend upon the morphology of the channel directly upstream and downstream of the sluice. In addition, the bed upstream is already graded and there would be minimal channel erosion. 	<p>Advantages</p> <ul style="list-style-type: none"> Natural rocks used for construction of the riffles providing a diversity of micro-habitat flows and spawning grounds for fish along the main channel of the By Brook. <p>Disadvantages</p> <ul style="list-style-type: none"> No disadvantages, although if not correctly positioned, may increase local erosion of the channel. Creation of a series of impoundments which will reduce the fluvial processes through this reach. 	<p>Advantages</p> <ul style="list-style-type: none"> Reinstates some of the natural functioning of river processes, although the sluice would still function and regulate flows. Use of natural substrates to increase morphological diversity (e.g. riffles and pools). Reduced impoundment and reinstatement of a more natural flow and sediment regime is likely to result in an increase in in-channel morphological diversity downstream of the sluice along the main channel. <p>Disadvantages</p> <ul style="list-style-type: none"> Initial channel bed and bank erosion along the bypass channel until equilibrium is maintained and there is no net erosion or deposition along the bypass channel. Potential erosion at the confluence of the bypass and By Brook, although soft bank protections works could be placed. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> Disruption of flow and sediment continuity, in particular during low flows.

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Geomorphology <i>(continued)</i>	<ul style="list-style-type: none"> The banks upstream and downstream of the sluice are likely to adjust as a result of lowered water levels. Fine sediment from bank collapse and any material from behind the sluice will travel downstream and potentially smother good habitat and infill pools. However, this is a small risk that would not be long-term in any case, as once adjustment has ceased any bank collapse will vegetate if fenced. 	See above.	See above.	See above.

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Environment	<p>Advantages</p> <ul style="list-style-type: none"> Improves in-channel habitats for fish, otter, water vole and other aquatic fauna which inhabit the By Brook (see Section 2). The removal of the structure will increase habitat diversity, reduce siltation, reduce temperature and increase oxygen levels in the river. <p>Disadvantages</p> <ul style="list-style-type: none"> Sediments accumulated behind the sluice are likely to consist of coarse material, fines and organic detritus. Removal of the sluice is likely to result in the remobilisation of these sediments, which may adversely impact upon downstream habitats. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> Natural rock features (riffles) to promote a diversity of aquatic species to use as micro-habitat. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential disturbance to local environmental receptors such as white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> Creation of additional river and floodplain habitat for flora and fauna including spawning nursery grounds within the bypass channel (e.g. riffles, see Figure 4.12). Use of natural substrates, rather than concrete or other smooth materials, provides roughness and interstitial spaces that allow both small fishes and benthic invertebrates to pass and directly colonise. Blends into the landscape (i.e. high aesthetic appeal). Can follow part of an original watercourse. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential disturbance to local environmental receptors such as white-clawed crayfish (see Section 2). Mitigation strategy for white-clawed crayfish will be required (e.g. translocation to Ark sites), if such species are still within the By Brook when the implementation / construction phase is to take place (i.e. they have not been eradicated by signal crayfish). Temporary minor disturbance (visual, noise and obstructions) to landowner. 	<p>Advantages</p> <ul style="list-style-type: none"> No potential advantages associated with technical fish passes. <p>Disadvantages</p> <ul style="list-style-type: none"> No additional terrestrial habitat or near natural freshwater habitat created. Potential disturbance to local environmental receptors such as flora and fauna including white-clawed crayfish (see Section 2). Temporary minor disturbance (visual, noise and obstructions) to landowner.

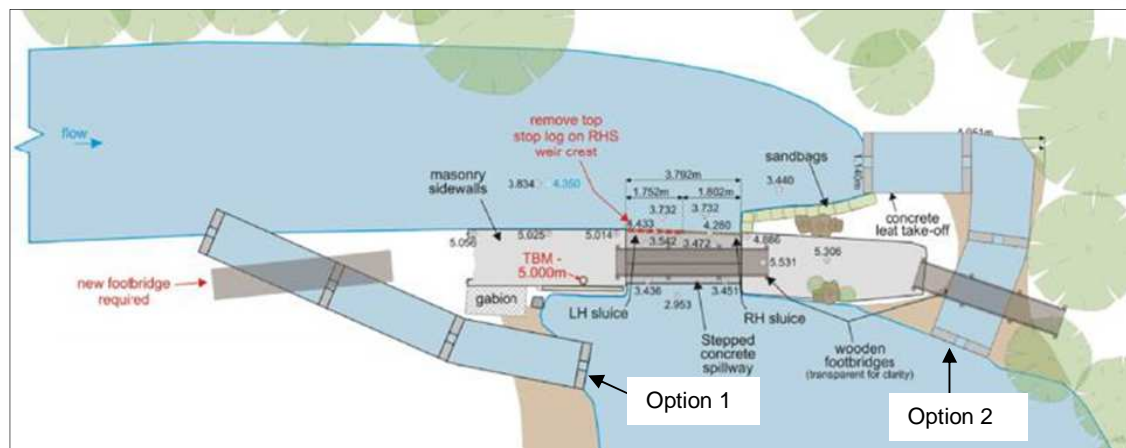
Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
WFD Compliance (and Fish Passage)	<p>Advantages</p> <ul style="list-style-type: none"> Removal of the sluice is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation) during the sluice removal phase. However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if rock riffles placed downstream of sluice. 	<p>Advantages</p> <ul style="list-style-type: none"> A bypass channel is likely to contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body, resulting in an improvement in the biological communities that the physical habitats support. Any changes will not cause deterioration in water body status, and may overall contribute towards an improvement from Moderate to Good Ecological Status for the local water body. Fish passage will be reinstated; and other aquatic organisms such as invertebrates will benefit from being able to access upstream and downstream habitats via the bypass channel. No additional works would be required to facilitate eel passage, as the bypass will provide an effective mechanism for eel passage. <p>Disadvantages</p> <ul style="list-style-type: none"> Potential short term impacts on water quality (e.g. increased turbidity, siltation). However, any impacts are unlikely to be sufficient to cause deterioration in the status of the water body or condition of the By Brook. 	<p>Advantages</p> <ul style="list-style-type: none"> Has the potential to contribute to improving the ecological status of the local water body regarding fish passage under the WFD (i.e. fish passage reinstated). <p>Disadvantages</p> <ul style="list-style-type: none"> Other key WFD objectives not addressed if a technical fish pass is installed. Eel pass required.

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Ecosystem Services	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be improved fish passage (Cultural Services - Wildlife). Structure removal would result in a more naturalised watercourse which will have a positive impact on water cycling (Water Cycling Services). <p>Disadvantages</p> <ul style="list-style-type: none"> Ford Fly Fishers stretch of water would have reduced impoundment which will have a negative impact on fishing. 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be improved fish passage (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> Creation of a pre-barrage could result in the small scale loss of aquatic vegetation and therefore a minor reduction in photosynthesis. 	<p>Advantages</p> <ul style="list-style-type: none"> The creation of a bypass channel would result in a net gain in watercourse and therefore marginal habitats. This would have a minor positive impact on water regulation Water Regulation – Wetlands). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be improved fish passage (Cultural Services - Wildlife). Creation of a bypass channel will result in a net gain of watercourse which will have a positive impact on water cycling and erosion (Water and Erosion Regulation Services). Creation of a bypass channel would result in additional fish habitats for use by Ford Fly Fishers and also maintain upstream impoundment for fishing. <p>Disadvantages</p> <ul style="list-style-type: none"> The bypass channel would result in a small area of land take from a field used for grazing. Access would need to be created to ensure the remainder of the field can be utilised (Food, Cultivated Produce and Genetic Resources – Livestock, Wool and Animal Breeding). 	<p>Advantages</p> <ul style="list-style-type: none"> Improved in channel habitats due to weir removal. Improved fish passage in watercourse (Food Wild Services – Fish; Recreation and Tourism - Freshwater Angling, Social). There will be no impacts to any designated site or BAP habitat as they are too distant from the proposed works. There will be improved fish passage (Cultural Services - Wildlife). <p>Disadvantages</p> <ul style="list-style-type: none"> The pool and traverse fish pass would result in a small area of land take from a field used for grazing. Access would need to be created to ensure the remainder of the field can be utilised (Food, Cultivated Produce and Genetic Resources – Livestock, Wool and Animal Breeding).

Criteria	Slaughterford Gate Restoration Options			
	Structural Removal	Raising water levels (Rock Riffles)	Natural Bypass Channel	Technical Fish Pass
Ecosystem Services (continued)	See above.	See above.	<ul style="list-style-type: none"> A PROW passes across the sluice structure and along the right bank of the By Brook at this location. Creation of a bypass channel would include a pedestrian bridge and diversion of the PROW to maintain access to the PROW network (Recreation and Tourism Services). The creation of a bypass channel would result in small scale habitat loss of grassland habitats and therefore there may be a minor impact to photosynthesis. This would be offset by colonisation of the channel by marginal and macrophyte species so over time there will be no impact. 	<ul style="list-style-type: none"> A PROW passes across the sluice structure and along the right bank of the By Brook at this location. Installation of a pool and traverse fish pass would have include a pedestrian bridge and diversion of the PROW to maintain access to the PROW network Recreation and Tourism Services). Installation of a pool and traverse fish pass would result in the small scale loss of in-channel vegetation, and therefore a minor reduction in photosynthesis.
Overview: Potential Restoration Option	Moderate	Moderate	High	Moderate
	High			

or right bank (facing downstream) of the By Brook (Option 2) (see **Figure 4.14**). The pool and traverse fish pass would consist of 4 traverses (1.5m or 2m wide), 3 pools (3m long) and provision of a foot-bridge to enable continued public access along the By Brook (see **Appendix A** for further details). If these options were to be implemented, the weir would require extensive repair works in response to being in poor condition with water seeping through the structure (see **Figure 2.20**). Such repairs may include grouting the weir and pumping in concrete to fill the holes / leaks; sheet piling or a new weir which could incorporate a small Larinier fish pass and a lower weir crest (Option 3).


Figure 4.14 Pool and Traverse Style Fish Pass Concepts for Rag Mill Weir




Advantages and Disadvantages


- 4.8.5 The Do Nothing scenario is similar to that presented in **Table 4.2**, while the natural bypass channel was previously assessed in **Table 4.6** as having high restoration potential to be implemented along Reach 4A4 and Reach 4A5.
- 4.8.6 The technical fish pass options for Rag Mill Weir would have similar advantages and disadvantages of those pool and traverse style fish passes proposed previously along the By Brook with Option 1 being the favoured pool and traverse style fish pass for Rag Mill Weir. This option would be assessed as moderate to high restoration potential.
- 4.8.7 However, if the bypass channel was not implemented than the preferred option would be for structural removal at Rag Mill. This option would be assessed as moderate to high restoration potential, if minimal changes in upstream water levels could be maintained.
- 4.9 **Review of BART Restoration Options for the Remaining Reaches of the By Brook Catchment**
- 4.9.1 To ensure the selection of the preferred solutions for the above key reaches of this report are successfully implemented and the goal of eventually achieving Good Ecological Status for the whole of the By Brook catchment is attained, **Table 4.7** reviews the recommended options put forward by BART for the remaining reaches of the By Brook Catchment which were ground-truthed during the site walkover undertaken on the 23rd of December 2014 by RHDHV and the Fluvial Audit undertaken by BART between December 2014 – January 2015 (see **Appendix D**).

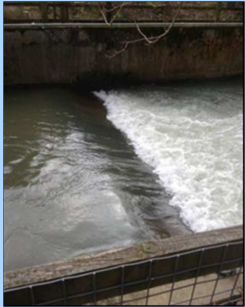

Table 4.7 Review of BART Restoration Options for the Remaining Reaches of the By Brook

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 4B1: Weavern Mill Weir	 <ul style="list-style-type: none"> In-channel structures: Concrete fixed weir (crest of 20m), which is currently in a poor condition and hidden by dense woodland. The weir incorporates a foot-bridge / access track used by landowners. Silt covered spawning beds. Bank erosion due to livestock poaching. 	<ul style="list-style-type: none"> Structural removal. Natural re-alignment of the channel bed and to allow for fish passage. Technical fish pass: Larinier or pool and traverse style fish pass installed on either the right or left hand bank adjacent to the weir (see Appendix A for more details). 	<ul style="list-style-type: none"> Provision to provide a viable fish passage solution would not be constrained by site access, as a gravel track to Weavern Farm is located adjacent to the weir. Removing the structure would require a replacement foot-bridge or public access across the By Brook. At the time of the walkover undertaken by RHDHV, the weir did appear passable at high flows, although velocities were high in response to flows being funnelled through the structure. As such the natural re-alignment of the channel bed via re-profiling through the structure may provide a viable fish passage solution. The banks are relatively steep along the right hand bank (facing downstream) adjacent the weir, and as such the option of a pool and traverse appears the less likely option regarding the technical fish passes, with the Larinier the favoured option. No U/S impoundment. 	<ul style="list-style-type: none"> There is potential for a natural bypass channel upstream of the weir structure along the left hand outer floodplain either as a stand-alone bypass or connected with the existing watercourse networks. Although the management of the cattle holding area (see Figure 2.23a) would need to be addressed as the bypass channel would most likely get impacted upon by the nutrient / sediment run-off of the cattle yard. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. This option appears to be the first stage of restoration which should be implemented along this reach prior to the development of fish passage solutions. Bank re-profiling.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 4B2: Widdenham Mill (Farm)	 <ul style="list-style-type: none"> In-channel structures: A concrete fixed weir which is surrounded by dense woodland and scrub. Silt covered spawning beds. Bank erosion due to livestock poaching. 	<ul style="list-style-type: none"> Technical fish pass: Pool and traverse style fish pass installed on the right hand bank (facing downstream) adjacent to the weir (see Appendix A for more details). 	<ul style="list-style-type: none"> Provision to provide a viable fish passage solution in regards to pool and traverse fish pass would not be constrained by site access, as there is clear access through the fields off the main access road. The pool and traverse fish pass does appear a viable fish passage solution, although would be relatively long (up to 19m) and require considerable land take. Low flows impounded up 574m upstream of structure. 	<ul style="list-style-type: none"> Given the non-functional operation of the weir, open access to the site, low complexity of the structure, the option of removing the weir should be considered first, subject to further feasibility and land owner consultation. There is potential for a natural bypass channel upstream of the weir structure along the left hand outer floodplain, although this would require a larger land take than the pool and traverse pass. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. This option should also be implemented along this reach prior to the development of fish passage solutions. Bank re-profiling.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 5A1: Drewitts Mill	 <ul style="list-style-type: none"> In-channel structures: Water control structure in the form of a wooded board sluice which controls water levels along the mill stream. Agricultural run-off. Steeply eroded banks. 	<ul style="list-style-type: none"> No river restoration solutions have been proposed for fish passage (see Appendix A for more details). 	<ul style="list-style-type: none"> At the time of the walkover the control structure was completely blocked with large wooded debris which would not have been passable to migratory fish (see paragraph 2.4.56). 	<ul style="list-style-type: none"> Given the non-functional operation of the sluice, further landowner consultation should be undertaken in regards to structural removal. Although the sluice may be required for aesthetic purposes and to maintain water levels for angling recreation. A strategy for managing debris along the By Brook upstream of the sluice (e.g. debris boom) needs to be implemented to reduce the frequency in which the sluice becomes unpassable due to debris blockage. There is potential for a natural bypass channel upstream of the sluice along the right hand outer floodplain (facing downstream) either as a stand-alone bypass or connected with the existing drainage network. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. This option should also be implemented along this reach prior to the development of fish passage solutions. Bank re-profiling.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
<p>Reach 5A2: Box Mill (Real World Studios)</p>	 <ul style="list-style-type: none"> In-channel structures: Four steel sluices which maintain the hydrostatic head over 2.8m, making this structure the largest fish migration barrier along the By Brook. Agricultural run-off. Steeply eroded banks. 	<ul style="list-style-type: none"> Two-stage Larinier Super-Active fish pass with elver pipe (see Appendix A for more details). Natural bypass channel using an existing back-channel (see Appendix A for more details). 	<ul style="list-style-type: none"> The construction of the Larinier fish pass does appear feasible, although access to undertake the works would require access tracks down from Drewitts Mill. The construction of the bypass channel also appears feasible, although this would need to take into consideration another in-channel structure upstream of Box Mill sluice. There is no impoundment associated with this structure (see Table 2.3). 	<ul style="list-style-type: none"> It's unlikely that structural removal will be accepted by the landowner who requires water levels to be maintained for ornamental ponds. Another natural bypass channel could be constructed using the existing drainage features along the right hand outer floodplain (facing downstream) which would start approximately 300m upstream of the sluice and re-enter the By Brook directly downstream of the sluice (scour hole). This would bypass both in-channel structures while using the existing drainage network. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. Bank re-profiling.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 5A3: Middlehill Gauging Weir	 <ul style="list-style-type: none"> In-channel structures: Concrete crump weir (7m wide). Agricultural run-off. Steeply eroded banks. 	<ul style="list-style-type: none"> Single Larinier fish pass installed along the left bank (facing down stream) (see Appendix A for more details). 	<ul style="list-style-type: none"> The construction of the Larinier fish pass does appear feasible, although access to undertake the works does appear constrained with access tracks required through the landowner fields. Low flows impounded up 53m upstream of structure. 	<ul style="list-style-type: none"> It's unlikely that structural removal will be accepted as the structure provides gauging data for the Environment Agency. Potential for the installation of low cost baffles which have been successfully used for other similar gauging weirs in the UK. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. This option should also be implemented along this reach prior to the development of fish passage solutions. Bank re-profiling.
Reach 5A4: Shockerwick Mill	 <ul style="list-style-type: none"> In-channel structures: Concrete structure with steel sluice. Agricultural run-off. Steeply eroded banks. 	<ul style="list-style-type: none"> Lowering of weir combined with pool and traverse style fish pass and pre-barrages downstream of the weir channel. Elver pass also installed (see Appendix A for more details). 	<ul style="list-style-type: none"> Provision to provide a viable fish passage solution would not be constrained by site access. However, the location of the proposed pool and traverse is within close proximity to the road bridge which is approximately 10m upstream of the weir. Low flows impounded up 672m upstream of structure. 	<ul style="list-style-type: none"> Potential for structural removal, although a detailed feasibility assessment would be required in response to the upstream road bridge. BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river. Bank re-profiling.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 1: Burton to Castle Combe (Burton Brook)	<ul style="list-style-type: none"> In-channel structures. Algal formation on substrate. Livestock poaching. Dominating glide flows. Heavy siltation of substrate. 	<ul style="list-style-type: none"> No river restoration solutions have been proposed for fish passage (see Appendix D for more details). 	<ul style="list-style-type: none"> See Fluvial Audit (Appendix D). 	<ul style="list-style-type: none"> BART could work with local farmers to increase buffer strips on arable land, employ good practise soil management and possibly introduce sediment traps in areas most at risk of sedimentation. BART / Environment Agency to work with local residents to identify misconnections from private residences. BART could work with farmers to encourage fencing the river and providing a riparian strip to both benefit bank profile and the quality of gravel substrate. BART could introduce some small flow deflectors and channel narrowing to increase flow diversity.
Reach 2: Pennsylvania to Castle Combe (Broadmead Brook)	<ul style="list-style-type: none"> In-channel structures. Siltation of substrate. Algae covered substrate. Domestic outputs of phosphate. Invasive American signal crayfish. Poaching by cattle. 	<ul style="list-style-type: none"> No river restoration solutions have been proposed for fish passage (see Appendix D for more details). 	<ul style="list-style-type: none"> See Fluvial Audit (Appendix D). 	<ul style="list-style-type: none"> Joint BART / Environment Agency project to look at misconnections and public awareness of phosphate in the river. Strategic trapping of American signal crayfish. Potential BART project to look at cattle fencing and water provision.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
	<ul style="list-style-type: none"> Barriers to fish and eel passage. Poaching by livestock. Algae covered sediment. Heavy siltation in areas. Highly eroding banks. Over abstraction & low flows. 	<ul style="list-style-type: none"> No river restoration solutions have been proposed for fish passage (see Appendix D for more details). 	<ul style="list-style-type: none"> See Fluvial Audit (Appendix D). 	<ul style="list-style-type: none"> Potential for BART / Environment Agency project to look at fish passage options throughout this reach. Potential BART project to install livestock fencing and water provision. Potential for BART to work with landowners on livestock management / fencing to reduce cattle access to the river and water provision. Environment Agency to work with Wessex Water to introduce 'phosphate stripping' at Marshfield STW. Environment Agency to work with Wessex Water and landowners over low flows and abstraction for amenity lake.

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 3 and Reach 3B: By Brook and Upper Tributaries	<ul style="list-style-type: none"> No issues were identified for Reach 3A in which restoration solutions required development (see Fluvial Audit (Appendix D)). 			

Reach	Structures and Key Issues	BART Restoration Options for Fish Passage	Site Appraisal	Further Options
Reach 4C: Lid Brook	<ul style="list-style-type: none"> Sedimentation of downstream river gravels. Nutrient influx from nearby farms. 	<ul style="list-style-type: none"> No river restoration solutions have been proposed for fish passage (see Appendix D for more details). 	<ul style="list-style-type: none"> See Fluvial Audit (Appendix D). 	<ul style="list-style-type: none"> BART could work with farmers to improve land management practices, such as bringing cattle in over the winter, reducing compaction and introducing land drainage where required. BART could work with farmers to introduce measures to reduce diffuse pollution on farms, such as the installation of guttering where required and installation of concrete sleeping policeman to reduce the likelihood of dirty water reaching nearby watercourses.

5 Selection of Preferred Restoration Options for By Brook

5.1 Introduction

5.1.1 This section of the report briefly summarises the restoration solutions presented in **Section 4** in order to highlight the selection of preferred options with focus upon the reaches between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A1 to Reach 4A5). Further details regarding technical details, flood risk and environmental assessments (e.g. changes in geomorphological and ecological processes) of the preferred options are also briefly provided in this section, while specific details such as capital costs of the preferred options are presented in **Section 6**.

5.2 Preferred Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir

5.2.1 Based on the detailed assessments provide in **Section 4** and the Ecosystem Services Assessment for the By Brook catchment (see **Appendix E**), the preferred options considered for the By Brook between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A1 to Reach 4A5) include:

- Ford Mill (Reach 4A1):
 - **Rock Ramp** – Construction of a rock ramp downstream of Ford Mill Weir will be designed to reduce the hydraulic gradient and velocities (to allow for improved fish passage), while maintaining upstream water levels and flows through the Mill leat. This option will also blend into the landscape (i.e. have a high aesthetic appeal). The construction of the rock ramp will overall improve the hydromorphology and physico-chemical conditions of the water body.
- Weir D/S Ford (Reach 4A2):
 - **Structural Removal** – Removing Weir D/S Ford will reinstatement a natural flow regime and natural sediment dynamics and hydromorphology along this reach; increase in-channel habitat diversity and ecological connectivity; reinstate fish passage along this reach; and overall improve the hydromorphology and physico-chemical conditions of the water body.
 - **Natural Bypass Channel** – Construction of a bypass channel between Weir D/S Ford and Sluice D/S Ford would reduce flow impoundment and reinstate a more natural flow and sediment regime along tis reach. There would be additional river and floodplain habitat for flora and fauna including spawning nursery grounds created within the bypass channel. Construction of a bypass channel will reinstate fish passage along this reach and overall contribute towards local improvements in the hydromorphology and physico-chemical conditions of the water body.
- Sluice D/S Ford (Reach 4A3):
 - **Structural Removal** – Similar environmental summary benefits as Weir D/S Ford.
 - **Natural Bypass Channel** – Similar environmental summary benefits as Weir D/S Ford.
- Slaughterford Gate (Reach 4A4):
 - **Natural Bypass Channel** – Similar environmental summary benefits as Weir D/S Ford.
 - **Structural Removal** – Similar environmental summary benefits as Weir D/S Ford, in addition Slaughterford Gate is an Environment Agency asset no longer functional and as such removing this asset will be of long term benefit to the Environment Agency.

- Rag Mill (Slaughterford) (Reach 4A5):
 - **Natural Bypass Channel** – Similar environmental summary benefits as Weir D/S Ford.
 - **Pool and Traverse Style Fish Pass** – Construction of pool and traverse style fish pass at Rag Mill would provide a low maintenance technical fish pass which would improve fish passage along this reach.
 - **Structural Removal** – Similar environmental summary benefits as Weir D/S Ford.

5.2.2 Although further detailed in **Section 7**, the proposed order of priority for above sites/solutions based on the outcomes of **Section 4** and baseline data provided in **Section 2** (e.g. impoundment lengths, complexities associated with the solutions e.g. white-clawed crayfish) and potential quick wins (depending on the final options agreed) are as follows:

1. Ford Mill (Reach 4A1) – Rock Ramp
2. Weir D/S Ford (Reach 4A2) – Structural Removal or Natural Bypass Channel
3. Slaughterford Gate (Reach 4A4) – Natural Bypass Channel or Structural Removal
4. Sluice D/S Ford (Reach 4A3) – Structural Removal or Natural Bypass Channel
5. Rag Mill (Slaughterford) (Reach 4A5) – Natural Bypass Channel or Pool and Traverse or Structural Removal

5.3 Details of Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir

5.3.1 Key details of the preferred options regarding the conceptual construction (engineering) details are presented in the following sections of this report:

- Ford Mill (Reach 4A1) – Rock Ramp (see **Section 4.4.7** to **4.4.10**).
- Weir D/S Ford (Reach 4A2) – Structural Removal (see **Section 4.5.2**) or Natural Bypass Channel (see **Section 4.5.7** to **4.5.11**).
- Sluice D/S Ford (Reach 4A3) – Structural Removal (see **Section 4.6.2**) or Natural Bypass Channel (see **Section 4.6.7** and **Section 4.5.7** to **4.5.11**).
- Slaughterford Gate (Reach 4A4) – Structural Removal (see **Section 4.7.2**) or Natural Bypass Channel (see **Section 4.7.5** to **4.7.9**).
- Rag Mill (Slaughterford) (Reach 4A5) – Structural Removal (**Section 4.8.2**) or Natural Bypass Channel (see **Section 4.8.3** and **Section 4.7.5** to **4.7.9**) or Pool and Traverse Style Fish Pass (see **Section 4.8.4**).

5.3.2 Although the preferred options will result in an array of environmental benefits as briefly summarised above and detailed in **Section 4**, there is potential impacts on the following key environmental receptors which are briefly discussed below under the consecutive headings:

- Changes in flow regime and flood risk.
- Adjustment in channel morphology (e.g. planform, bank and longitudinal profile).
- Downstream deposition of fines and potential disturbance to local flora and fauna (including white-clawed crayfish).

Changes in flow regime and flood risk

- 5.3.3 The By Brook catchment is predominantly rural, and flood risks to human habitation are relatively low. As shown in **Figure 2.3 (Section 2.3.3)** the flood risk map for the By Brook catchment and immediately downstream of the confluence with the River Avon shows that the risk of flooding is largely confined to the narrow floodplains immediately adjacent to the main river channel of the By Brook and tributaries. Changes to high river flows in the By Brook associated with such restoration options as structural removal may contribute to flood risk downstream in Batheaston and Bath, although it is noted that high flows in the River Avon (Q10 of 41.7m³/s) are ten times greater than high flows in the By Brook, so changes in high flows along the By Brook may not have a significant effect on downstream flood risk. The implementation of the restoration solutions would further assist in reducing flood risk locally through increasing the capacity of the By Brook channel to convey more efficiently flood flows for example, structural removal of selected weirs which would reduce flow impoundment and potential back flow effects and local flooding. While, construction of bypass channels often assist in reducing flood risk by attenuating flood flows.
- 5.3.4 In addition, although the By Brook is one of the steepest tributaries in the catchment and receives above average rainfall across the Cotswold Hills, its flow contribution is relatively low in the catchment, with a relatively long time-to-peak. This is largely due to the relatively permeable nature of the soil and underlying rock that reduces surface water runoff and overall long term flooding along the By Brook.
- 5.3.5 In overall terms, there would be a **low risk** that the preferred options for the By Brook would have an adverse impact on flood risk, while given the preferred the options would only reinstate a near natural flow regime along the By Brook, there would be a **low risk** of impact upon water dependent habitats such as the riverine, standing water and wet grassland habitats of the Honeybrook Farm SSSI. However, it is recommended that Natural England are contacted as an early stage to discuss their latest views on the management of this habitat prior to the construction of any restoration activities.
- 5.3.6 Further reference should also be made to the By Brook Flood Risk Modelling Study (Environment Agency, 2015).

Adjustment in channel morphology

- 5.3.7 The removal or lowering of a structure such as a weir will typically have a direct impact on sediment transport and geomorphological processes (more so than the construction of bypass channels). It is, however, universally accepted that geomorphological change resulting from weir removal or lowering is site-specific in nature and will depend on the local bed gradient and sediment load (Environment Agency, 2013).
- 5.3.8 Weir removal can have complex, unexpected and long term effects upon a river system including vertical incision (i.e. bed scouring) and lateral degradation (i.e. undercutting and bank erosion) in response to local increases in stream power (the energy the river has to do work, which is expressed as γQS , where γ is specific weight of water, Q is stream discharge, and S is slope) and reduction in water levels. However, based on the local gradient of the reach and previous management in which the key preferred options associated with Reach 4A1 to Reach 4A5 would be implemented, the potential for major morphological adjustments such as channel incision or changes in the local longitudinal profile may be relative low.

5.3.9 As stated above, due to the relatively permeable nature of the soil and underlying rock of the By Catchment, there is a long time-to-peak regarding high flows and thus a reduced ability of the By Brook, in particular along the middle section (compared to the upper / head water sections) to do dynamic geomorphological work over a short timescale.

5.3.10 There is limited published literature on the effectiveness of weir removal, including the degree of channel cross-section adjustments (Roni et al., 2005). However, the removal of a weir can influence both the discharge and bedload along a particular watercourse. Using a + or – sign to denote an increase or decrease, Schumm (1969) suggests the following channel responses (w = channel width, d = channel depth, (w/d) = channel form ratio, λ = meander wavelength, S = sinuosity and s = slope) to changes in discharge (Q) or bedload (Q_{sb}):

$$Q+ \rightarrow w+, d+, (w/d)+, \lambda+, s- \quad (5.1)$$

$$Q- \rightarrow w-, d-, (w/d)-, \lambda-, s+ \quad (5.2)$$

$$Q_{sb} + \rightarrow w+, d-, (w/d)+, \lambda-, S-, s+ \quad (5.3)$$

$$Q_{sb} - \rightarrow w-, d+, (w/d)-, \lambda-, S+, s- \quad (5.4)$$

5.3.11 However, changes in discharge and sediment load rarely occur alone so four other more likely combinations of change are possible:

$$Q+ Q_{sb} + \rightarrow w+, d\pm, (w/d)+, \lambda+, S-, s\pm \quad (5.5)$$

$$Q- Q_{sb} - \rightarrow w-, d\pm, (w/d)-, \lambda-, S+, s\pm \quad (5.6)$$

$$Q+ Q_{sb} - \rightarrow w\pm, d+, (w/d)\pm, \lambda\pm, S+, s- \quad (5.7)$$

$$Q- Q_{sb} + \rightarrow w\pm, d-, (w/d)\pm, \lambda\pm, S-, s+ \quad (5.8)$$

5.3.12 Schumm's predictions, although based on sand bed streams, provide a general insight of what to expect from changes in discharge or bedload along river systems. Equation (5.5) demonstrates that the net effect of an increase in both local discharge and bed-material load which may typically occur in response to weir removal will produce wider, less sinuous channels with a larger wavelength. The expected change in channel depth and slope are less clear but since the form ratio (w/d) increases, depth will remain constant or decrease in response to downstream aggradation. Such changes in cross-sectional adjustments in response to weir removal have been observed by Conly and Martz (2013).

5.3.13 While there is potential for channel widening in response to an increase in both local Q and Q_{sb} downstream of the potential weirs/sluices to be removed along the By Brook, the current width of the channel downstream of these structures is overall relatively wide and along with the cohesive nature of the river banks may be able to accommodate this channel adjustment. It is anticipated that in some reaches for example downstream of Slaughterford Sluice, a two-stage channel will develop providing greater enhancement along over widened sections of the By Brook further allowing for the accommodation of flows.

- 5.3.14 This would limit the need for major lateral adjustment and bank erosion. In addition, historic evidence suggests lateral movement of the channel is not a major mechanism for adjustment along the By Brook. Any minor shifting of channel pattern would expend a certain amount of energy and reduce or slow degradation / bank erosion (Conly and Martz, 2013).
- 5.3.15 Changes in bank profiles in response to a reduction in impounded water levels upstream of removed structures are an important consideration and have implications for downstream sediment supply. This is likely to result in slumping in response to the drop in water levels, although the upstream extent is likely to be relatively confined along the existing extent of upstream impoundment and mitigated through natural bank protection works until any slumped banks become vegetated and stable.
- 5.3.16 The potential for a decrease in channel slope upstream/downstream of structures along the By Brook once removed in response to an increase in Q and Qsb may occur through downstream deposition (aggradation) of upstream eroded sediments. However, as previously stated there is a low probability that dynamic geomorphological work along the By Brook would be progressed over a short timescale and as such the degree of downstream aggradation and changes in channel slope would most likely be of low magnitude. In addition, the bed upstream of some structures such as Slaughterford Gate are already graded and there would be minimal channel erosion.

Downstream deposition of fines and potential disturbance to local flora and fauna

- 5.3.17 Structural removal can often lead to fine sediment that was previously trapped behind structures such as a weir or sluice being transported downstream and potentially smothering good habitat, with a similar scenario associated with the construction of bypass channels regarding the potential increase in fines being transported downstream. As such there is potential disturbance to local aquatic flora and fauna (including white-clawed crayfish) along the By Brook regarding the preferred options of removing structures or the construction of bypass channels / rock ramp.
- 5.3.18 Partial excavation of accumulated fine sediment upstream of structures prior to removal will reduce a significant amount of net sediment available for downstream transport, while ensuring that the bed is regraded at the structural removal sites will minimise erosion and further downstream transport of fines. The wider floodplain and increased connectivity downstream of the removed structures along the By Brook in particular between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A1 to Reach 4A5) may also reduce the effects of siltation through increased floodplain deposition. In addition, mitigation measures such as desilting before removing structures, in-stream silt traps and soft bank protection works would further minimise the risk of disturbance to aquatic flora and fauna (see **Table 5.1**) associated with removing structures or the construction of bypass channels.
- 5.3.19 In overall terms, there would be a **low to medium risk** that removing structures or the construction bypass channels /rock ramp along the By Brook would have an adverse impact on the flora and fauna including white-clawed crayfish regarding increased siltation if appropriate mitigation as detailed in **Table 5.1** was implemented prior to works.
- 5.3.20 In terms of restoration work between Ford and Slaughterford, based on current evidence of signal crayfish spread characteristics, **moderate channel enhancements in this reach would not make a significant negative contribution to declines of white-clawed crayfish** (OHES, 2014a & b). However, there are considerable potential short-term risk from capital works, bank disturbance and siltation. Ecological Clerk of Works and surveys are recommended to minimise risks to native crayfish and other protected species (such as nesting birds and otters) during the works. The OHES

(2014) report also recommends that translocation of the current native population to a suitable Ark site is considered to safeguard the population in the medium to long-term (see **Table 5.1**).

5.4 Key Mitigation Measures for Reach 4A River Restoration Solutions

- 5.4.1 In order to minimise risks associated with implementing the preferred options, potential mitigation measures and enhancement opportunities are outlined in **Table 5.1**.

Table 5.1 Mitigation Measures for Key By Brook Restoration Solutions

Environmental Receptor	Potential Risk	Mitigation Measures
Hydrology & Engineering	Changes in flow regime	<p>Confirmation of no impact upon flood risk in response to removing key structures or the construction bypass channels / rock ramp.</p> <p>Installation of small flow deflectors (or flow control) to help assist in directing flows down the bypass channels or rock ramp.</p> <p>Potential for flow divergence modelling associated with bypass channels and rock ramp to assist in the implementation of the above mitigation (if required).</p>
Geomorphology	Fine and coarse sediment transport and downstream deposition associated with structural removal and/or construction of bypass channels / rock ramp.	<p>Potential assessment in sediment transport dynamics (modelling) to be undertaken to ensure any changes in morphology in response to removing key structures will not impact upon in-stream habitats.</p> <p>Partial excavation of accumulated fine sediment upstream of structures prior to removal. This should reduce a significant amount of net sediment available for downstream transport.</p> <p>Ensuring that the bed is regraded at the site of structures to minimise erosion and downstream transport of fines.</p> <p>Implementation of silt traps (Sedimats) downstream of structures to be removed.</p> <p>Pre and post monitoring to assess magnitude of change regarding downstream sedimentation and associated management (see Table 3.4).</p>

Environmental Receptor	Potential Risk	Mitigation Measures
Geomorphology (<i>continued</i>)	Channel widening and bank erosion associated with structural removal and/or construction of bypass channels / rock ramp.	<p>Geotechnical Investigation (GI) to confirm the composition and cohesion of channel banks prior to structural removal and construction bypass channels.</p> <p>Potential to incorporate river restoration upstream and downstream of the structures to be removed or by pass channels to be constructed, to promote channel stability prior to works (e.g. bioengineering).</p> <p>Regrading the bed and banks to create a more natural channel profile; or allow the banks to collapse if there are no other constraints.</p> <p>Pre and post monitoring to assess magnitude of change regarding changes in channel morphology (see Table 3.4).</p>
Environment	Disturbance to local environmental receptors (e.g. PRoW, flora and fauna, pollutants, landscape setting) associated with structural removal and/or construction of bypass channels / rock ramp.	<p>Clear notification and signage of works and path diversions if required prior to works.</p> <p>Protected species survey (Extended Phase I Habitat Survey) to be undertaken prior to works.</p> <p>Sediment analysis to determine if trapped sediments behind structures contain pollutants prior to removal.</p> <p>Consultation with local historic environment advisor (if required).</p> <p>Detailed photographic recording of the structures before removal.</p> <p>Pre and post monitoring to ensure no impact upon flora and fauna including fish to determine the success of the restoration options.</p>
	Specific disturbance to white-clawed crayfish associated with structural removal and/or construction of bypass channels / rock ramp.	<p>On ground works associated with structural removal or bypass channel to be programmed as late as possible to allow for the succession of invasive American signal crayfish to take over the natural populations of white-clawed crayfish.</p> <p>Mitigation for geomorphology (see above) in particular to reduce the downstream transport of sediment to be implemented prior to works.</p> <p>Monitoring of crayfish to be undertaken prior to works.</p> <p>If required, translocation of white-clawed crayfish to Ark sites.</p>

Environmental Receptor	Potential Risk	Mitigation Measures
WFD Compliance (and Fish Passage)	Low level of upstream fish recruitment along the By Brook.	Monitoring of fish passage, water quality and habitat changes (see Table 3.4).
Practicality	Disturbance to local environmental receptors (e.g. water quality) associated with structural removal and/or construction of bypass channels / rock ramp.	Structural removal could be undertaken in phases (e.g. part cofferdam & over-pumping) to reduce potential disturbance to the water environment and flora and fauna. Appropriate Pollution Prevention Guidelines to be followed.
	Health and safety associated with structural removal and/or construction of bypass channels / rock ramp.	In-channel structure removal and construction of bypass channels will fall under the Construction, Design and Management Regulations 2007 and the Approved Code of Practice (ACoP) should be applied (HSE, 2007).
	Services associated structural with removal and/or construction of bypass channels / rock ramp.	Any contractor potentially doing works shall always verify exact locations of cables using a cable locator and by careful use of hand tools in accordance with HSE guidance note HSG4.

5.5 Restoration Solutions for the Remaining Reaches of the By Brook Catchment

5.5.1 The following is summary of the restoration solutions associated with the other reaches of the By Catchment in which similar mitigation presented in **Table 5.1** can be applied for those solutions in which structural removal or the construction of a bypass channel or channel/bank works is recommended, although please note these solutions have not been assessed in detail compared to those of Reach 4A.

- Reach 4B1: Weavern Mill Weir –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Management of the cattle holding area to reduce the nutrient / sediment run-off of the cattle yard.
 - Bank re-profiling.
 - Natural bypass channel upstream of the weir.
- Reach 4B2: Widdenham Mill (Farm) –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Bank re-profiling.
 - Structural removal or natural bypass channel upstream of the weir.

- Reach 5A1: Drewitts Mill –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Bank re-profiling.
 - Strategy for managing debris along the By Brook upstream of the sluice (e.g. debris boom) needs to be implemented if structure not removed.
 - Structural removal or natural bypass channel upstream of the weir.
- Reach 5A2 – Box Mill (Real World Studios) –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Bank re-profiling.
 - Natural bypass channel upstream of the weir.
- Reach 5A3: Middlehill Gauging Weir –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Bank re-profiling.
 - Low cost fish baffles.
- Reach 5A4: Shockerwick Mill –
 - BART to work with farmers on livestock fencing (or natural vegetated buffer strips) and land management to reduce sediment and nutrient input into the river.
 - Bank re-profiling.
 - Structural removal.
- Reach 1: Burton to Castle Combe (Burton Brook) –
 - BART could work with local farmers to increase buffer strips on arable land, employ good practise soil management and possibly introduce sediment traps in areas most at risk of sedimentation.
 - BART / Environment Agency to work with local residents to identify misconnections from private residences.
 - BART could work with farmers to encourage fencing the river and providing a riparian strip to both benefit bank profile and the quality of gravel substrate.
 - BART could introduce some small flow deflectors and channel narrowing to increase flow diversity.
- Reach 2: Pennsylvania to Castle Combe (Broadmead Brook –
 - Joint BART / Environment Agency project to look at misconnections and public awareness of phosphate in the river.
 - Strategic trapping of American signal crayfish.
 - Potential BART project to look at cattle fencing and water provision.

- Reach 3 and Reach 3B: By Brook and Upper Tributaries –
 - Potential for BART / Environment Agency project to look at fish passage options throughout this reach.
 - Potential BART project to install livestock fencing and water provision.
 - Potential for BART to work with landowners on livestock management / fencing to reduce cattle access to the river and water provision.
 - Environment Agency to work with Wessex Water to introduce 'phosphate stripping' at Marshfield STW.
 - Environment Agency to work with Wessex Water and landowners over low flows and abstraction for amenity lake.
- Reach 4C: Lid Brook –
 - BART could work with farmers to improve land management practices, such as bringing cattle in over the winter, reducing compaction and introducing land drainage where required.
 - BART could work with farmers to introduce measures to reduce diffuse pollution on farms, such as the installation of guttering where required and installation of concrete sleeping policeman to reduce the likelihood of dirty water reaching nearby watercourses.

6 Specific Details of the Preferred Restoration Options for By Brook

6.1 Introduction

6.1.1 This section of the report provides details regarding the preferred options of restoring the By Brook to help achieve Good Ecological Status, with a focus upon providing fish passage and increased river continuity. As such, construction activities and capital costs are specifically provided for the preferred options brought forward in **Section 5** between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A).

6.2 Preferred Restoration Options – Reach 4A: Ford Mill Weir to Rag Mill (Slaughterford) Weir

6.2.1 **Table 6.1** provides specific details on the construction activities and capital costs (exclusive of VAT) for the preferred restoration solutions between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A). The capital costs are based on information provided in **Section 4** such as the concept outline designs, topographic details of the structures, Spon's Civil Engineering and Highway Works Price Book 2015, and engineering expert assessment based on similar projects undertaken by RHDHV. Further details are provided in **Appendix F** regarding the breakdown of the construction activities and associated capital costs.

Table 6.1 Capital Costs - Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A)

Preferred Options and Construction Activity Costs	Costs £
Reach 4A1: Ford Mill	
<i>Option 1: Rock Ramp Concept for Ford Mill Weir</i>	
Construction Costs	36,350
Overhead and Other Costs	10,905
Professional Fees / Associated Costs	31,977
Optimism Bias	47,539
Total Option Cost for Rock Ramp	126,771
Reach 4A2: Weir D/S Ford	
<i>Option 1: Structural Removal</i>	
Construction Costs	56,000
Overhead and Other Costs	14,000
Professional Fees / Associated Costs	24,300
Optimism Bias	56,580
Total Option Cost for Structural Removal	150,880
<i>Option 2: Natural Bypass Channel</i>	
Construction Costs	66,800
Overhead and Other Costs	20,040
Professional Fees / Associated Costs	43,310
Optimism Bias	78,090
Total Option Cost for Natural Bypass Channel	208,240

Preferred Options and Construction Activity Costs	Costs £
Reach 4A3: Sluice D/S Ford	
<i>Option 1: Structural Removal</i>	
Construction Costs	21,476
Overhead and Other Costs	6,443
Professional Fees / Associated Costs	23,100
Optimism Bias	30,611
Total Option Cost for Structural Removal	81,630
<i>Option 2: Natural Bypass Channel</i>	
Construction Costs	66,800
Overhead and Other Costs	20,040
Professional Fees / Associated Costs	43,310
Optimism Bias	78,090
Total Option Cost for Natural Bypass Channel	208,240
Reach 4A4: Slaughterford Gate	
<i>Option 1: Natural Bypass Channel</i>	
Construction Costs	99,200
Overhead and Other Costs	29,760
Professional Fees / Associated Costs	53,840
Optimism Bias	109,680
Total Option Cost for Natural Bypass Channel	292,480
<i>Option 2: Structural Removal</i>	
Construction Costs	41,427
Overhead and Other Costs	12,428
Professional Fees / Associated Costs	23,100
Optimism Bias	46,173
Total Option Cost for Natural Bypass Channel	123,128
Reach 4A5: Rag Mill (Slaughterford)	
<i>Option 1: Natural Bypass Channel</i>	
Construction Costs	99,200
Overhead and Other Costs	29,760
Professional Fees / Associated Costs	53,840
Optimism Bias	109,680
Total Option Cost for Natural Bypass Channel	292,480

Preferred Options and Construction Activity Costs	Costs £
Option 2: Structural Removal	
Construction Costs	18,618
Overhead and Other Costs	5,585
Professional Fees / Associated Costs	21,900
Optimism Bias	27,662
Total Option Cost for Structural Removal	73,766

6.2.2 High level indicative costs (exclusive of VAT) for the remaining reaches of the By Brook Catchment associated with capital works are provided below. The costs are based on RBMP2 WFD cost information for HMWB mitigation measures; similar projects undertaken by RHDHV; and information provided in this feasibility report including **Appendix D** (Fluvial Audit).

- Reach 4B1: Weavern Mill Weir –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £24,000 – £30,000 based on 400 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Natural bypass channel upstream of the weir = £200,000 – £250,000 based on a bypass channel length of 200 m. Further study required to confirm these costs.
- Reach 4B2: Widdenham Mill (Farm) –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £42,000 – £52,500 based on 700 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Structural removal = £120,000 – £180,000; or natural bypass channel upstream of the weir = £100,000 – £125,000 based on a bypass channel length of 100 m. Further studies required to confirm these costs.
- Reach 5A1: Drewitts Mill –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £6,000 – £7,500 based on 100 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Structural removal = £120,000 – £180,000; natural bypass channel upstream of the weir = £250,000 – £300,000 based on a bypass channel length of 300 m (mostly using the existing drainage system). Further studies required to confirm these costs.

- Reach 5A2 – Box Mill (Real World Studios) –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £6,000 – £7,500 based on 100 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Natural bypass channel upstream of the weir = £250,000 – £300,000 based on a bypass channel length of 600 m (mostly using the existing drainage system). Further study required to confirm these costs.
- Reach 5A3: Middlehill Gauging Weir –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £6,000 – £7,500 based on 100 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Low cost baffles (simple structure) = £120,000 – £180,000. Further study required to confirm these costs.
- Reach 5A4: Shockerwick Mill –
 - Consultation with landowners = £400 (based on 1 days consultation @ £400 per day).
 - Bank re-profiling = £6,000 – £7,500 based on 100 m of bank rehabilitation/reprofiling at £60 -£75 per m (which includes for excavator, construction team, planting/seeding and protection matting of the banks). However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
 - Structural removal = £120,000 – £180,000. Further study required to confirm these costs.
- Reach 1: Burton to Castle Combe (Burton Brook) –
 - Consultation with landowners = £1,200 (based on 3 days consultation @ £400 per day).
 - Placement of small flow deflectors and channel narrowing in places to increase flow diversity = £60,000 based on 1000 m of in-channel morphological work at £60 per m. However, a high level study should be undertaken first to review and confirm the key areas to be restored and then the overall capital costs.
- Reach 2: Pennsylvania to Castle Combe (Broadmead Brook) –
 - Consultation with landowners = £1,200 (based on 3 days consultation @ £400 per day).
 - Strategic trapping of American signal crayfish = Costs will depend on the number of sites along Reach 2 and extend of the crayfish survey required to inform the trapping of the American signal crayfish.

Potential BART project to look at cattle fencing and water provision = £80,000 – £100,000. Further study required to confirm these costs.

- Reach 3 and Reach 3B: By Brook and Upper Tributaries –
 - Consultation with landowners = £1,200 (based on 3 days consultation @ £400 per day).
 - Potential for BART / Environment Agency project to look at fish passage options throughout this reach = £25,000.
 - Potential BART project to install livestock fencing and water provision = £80,000 – £100,000. Further study required to confirm these costs.
- Reach 4C: Lid Brook –
 - Consultation with landowners =£400 (based on 1 days consultation @ £400 per day).

7 Conclusions and 4-5 Year Management Plan

7.1 Introduction

- 7.1.1 This section of the report provides a brief overview of the next steps potentially required to implement the river restoration solutions discussed in this report that will contribute to restoring the By Brook to Good Ecological Status by 2021.

7.2 Next Steps (Licences, Consents) and Challenges

- 7.2.1 The following actions are most likely required for works directly associated with the preferred restoration solutions for the By Brook between Ford Mill Weir to Rag Mill (Slaughterford) Weir (Reach 4A in order to ensure the appropriate management of environmental risk and compliance with legislation, policy and environmental management procedures:

- Potential for planning permission and an Environmental Impact Assessment (EIA), as such an EIA screening may be required to be sent to the Local Authorities to determine if a statutory or non-statutory EIA is required for the works (**this feasibility report can assist in this process**).
- Flood Defence Consent, which includes the requirement for an environmental appraisal (**to which this feasibility report can be provided**).
- WFD Compliance Screening and Assessment (generally required with Flood Defence Consent) (**this feasibility report can assist in this process**).
- Landowner Consent (stakeholder consultation).
- SSSI Consent (required if working within or near a SSSI).
- Potential protected species licences.
- Potential Listed Building Consent or permission from English Heritage.

- 7.2.2 Note as the By Brook is a Main River (i.e. those rivers managed by the Environment Agency), the Environment Agency will need to approve any river works under the Water Resources Act 1991, Flood Defence (Land Drainage) Byelaws/Sea Defence Byelaws, Environment Act 1995 and Flood and Water Management Act 2010. **This feasibility report will assist the Environment Agency in accelerating the approval process.**

7.3 Preliminary Long-Term Restoration Programme for the By Brook Catchment

- 7.3.1 **Table 7.1** provides a preliminary long-term programme or plan for the restoration of the By Brook catchment which includes the next essential steps (including licenses, consents) required to help achieve GES by 2021. The programme has been developed so that the key actions can be implemented, if required, at different phases or reaches within the By Brook catchment based on all the information provided in this report when funding becomes available.

- 7.3.2 The plan allows for feasibility studies or confirmation of restoration solutions and costs associated with bank rehabilitation/reprofiling and in-channel works; detailed fish passage feasibility studies (Reach 1 to 3, Reach 4B to 5); landowner consultation for all reaches regarding preferred fish passage solutions and promotion of buffer strips/sediment traps; and cattle fencing/water provision projects to be undertaken within the first and second years of the plan (**Table 7.1**).

- 7.3.3 The third and fourth years of the plan are generally associated with ecological surveys including cray fish surveys and mitigation (if required); on-ground works for quick win solutions and those not associated with fish passage solutions (e.g. bank rehabilitation/reprofiling and in-channel works) and obtaining consents for the complex fish passage solutions along with the undertaking of the detailed design for these solutions.
- 7.3.4 The final year of the plan is associated with the on-ground works of the complex fish passage solutions for all reaches along the By Brook, although some of these can be brought forward into the second year if there is a low complexity associated with the solutions. For example, as stated in **Section 5.2.2**, the proposed order of priority for the fish passage solutions associated with Reach 4 based on baseline data provided in **Section 2** (e.g. impoundment lengths, complexities associated with the solutions e.g. white-clawed crayfish) and potential quick wins (depending on the final options agreed) are as follows:
1. Ford Mill (Reach 4A1) – Rock Ramp
 2. Weir D/S Ford (Reach 4A2) – Structural Removal or Natural Bypass Channel
 3. Slaughterford Gate (Reach 4A4) – Natural Bypass or Channel Structural Removal
 4. Sluice D/S Ford (Reach 4A3) – Structural Removal or Natural Bypass Channel
 5. Rag Mill (Slaughterford) (Reach 4A5) – Natural Bypass Channel or Structural Removal or Pool and Traverse Style Fish Pass
- 7.3.5 Given the relatively low degree of complexity for the preferred fish passage solution associated with Ford Mill i.e. the rock ramp (Reach 4a1) and potential removal of the weir downstream Ford (Reach 4A2), these could be brought forward to the second year of the plan, while those more complex solutions such as the potential removal of large structures (e.g. Slaughterford Gate) or construction of bypass channels would be programmed for the fourth and fifth year plan. This would allow for more on-ground projects to be undertaken such as bank rehabilitation/reprofiling and in-channel works, buffer strips/sediment traps, and cattle fencing/water provision works throughout the catchment which will then compliment the larger restoration works such as the complex fish passage solutions. In addition, programme large restoration works towards the fourth and fifth years of the programme would most likely have lower impact on white-clawed crayfish between Ford and Slaughterford in which it is likely that signal crayfish would have out-competed the native populations of crayfish and as such major mitigation works may not be required for the implementation of the large complex fish passage restoration works. However, updated crayfish surveys are recommend prior to these works to confirm this statement or to ensure a mitigation strategy is in place for native crayfish (e.g. translocation to sites).

Table 7.1 Preliminary Long-Term River Restoration Programme for the By Brook

Year	1				2				3				4				5			
Monthly Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Reach 1 to 3: Burton to Ford Mill Weir																				
Feasibility study to confirm/review restoration solutions (based on the Fluvial Audit. BART 2015) and costs for bank rehabilitation/reprofiling and in-channel works.																				
Consultation with landowners to increase buffer strips and introduce sediment traps.																				
Project to look at cattle fencing and water provisions.																				
Strategic trapping of American signal crayfish.																				
Fish passage feasibility for Reach 3.																				
Protected Species Survey (Phase I Extended Habitat Survey).																				
White-clawed crayfish survey (mitigation/translocation if required).																				
Implementation (& potential minor consents) for the restoration solutions for bank rehabilitation/reprofiling and in-channel works. To include for mitigation measures as mentioned in Table 5.1 for geomorphology and environment prior to any works.																				
Consents for the implementation of fish passage works for Reach 3 (based on the feasibility study). Potential consents include Planning Permission, Flood Defence Consent, WFD Consent, Landowner Consent.																				
Implementation and on-ground works for selected fish passage works for Reach 3 (based on the feasibility study). To include for detail design and mitigation measures as mentioned in Table 5.1 for geomorphology and environment prior to works.																				
Monitoring of fish passage and bank rehabilitation/reprofiling and in-channel works.																				
Reach 4A: Ford Mill Weir to Rag Mill Weir																				
Landowner consultation on the preferred fish passage solutions between Ford Mill Weir and Rag Mill Weir (THIS FEASIBILITY REPORT).																				
Follow up sediment modelling (if required) to inform the detail design.																				
Detailed design of the preferred fish passage solutions between Ford Mill Weir and Rag Mill Weir based on the outline designs provided in this feasibility report.																				
Protected Species Survey (Phase I Extended Habitat Survey).																				
White-clawed crayfish survey (mitigation/translocation if required).																				
Consents for the implementation of the preferred fish passage solutions between Ford Mill Weir and Rag Mill Weir. Potential consents include Planning Permission, Flood Defence Consent, WFD Consent, Landowner Consent.																				
Implementation and on-ground works for selected fish passage works for Reach 3 (based on the feasibility study). To include for detail design and mitigation measures as mentioned in Table 5.1 for geomorphology and environment prior to works.																				
Monitoring of fish passage and any bank rehabilitation/reprofiling and in-channel works.																				

Year	1				2				3				4				5			
Monthly Quarter	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Reach 4B to Reach 5: Weavern Mill Weir to Shockerwick Mill Weir																				
Feasibility study to confirm/review restoration solutions (based on the Fluvial Audit. BART 2015) and costs for bank rehabilitation/reprofiling and in-channel works.																				
Consultation with landowners to increase buffer strips and introduce sediment traps.																				
Project to look at cattle fencing and water provisions.																				
Detailed fish passage feasibility for Reach 4B to Reach 5.																				
Protected Species Survey (Phase I Extended Habitat Survey).																				
White-clawed crayfish survey (mitigation/translocation if required).																				
Implementation (& potential minor consents) for the restoration solutions for bank rehabilitation/reprofiling and in-channel works. To include for mitigation measures as mentioned in Table 5.1 for geomorphology and environment prior to any works.																				
Consents for the implementation of fish passage works for Reach 4B to Reach 5 (based on the feasibility study). Potential consents include Planning Permission, Flood Defence Consent, WFD Consent, Landowner Consent.																				
Implementation and on-ground works for selected fish passage works for Reach 4B to Reach 5 (based on the feasibility study). To include for detail design and mitigation measures as mentioned in Table 5.1 for geomorphology and environment prior to works.																				
Monitoring of fish passage and bank rehabilitation/reprofiling and in-channel works.																				

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9 List of Abbreviations

AOD	Above Ordnance Datum
BAP	Biodiversity Action Plan
EIA	Environmental Impact Assessment
EAP	Environmental Action Plan
cm	centimetre
EU	European Union
GEP	Good Ecological Potential
GES	Good Ecological Status
Ha	Hectares
km	Kilometre
km²	Kilometre squared (or 100ha)
LiDAR	Light Detecting and Ranging
LNR	Local Nature Reserve
m	metre
mm	millimetre
NGR	National Grid Reference
NNR	National Nature Reserve
ODN	Ordnance Datum Newlyn
SAC	Special Area of Conservation
SM	Scheduled Monument
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
UK	United Kingdom
WFD	Water Framework Directive

10 Glossary

Aggradation – The process by which a stream's gradient steepens due to increased deposition of sediment.

Bankfull – This stage is delineated by the elevation point of incipient flooding, indicated by deposits of sand or silt at the active scour mark, break in stream bank slope, perennial vegetation limit, rock discoloration, and root hair exposure.

Bankfull Discharge – The dominant channel forming flow with a recurrence interval seldom outside the 1 to 2 year range.

Channel Slope – Change in elevation divided by the length of channel along a channel distance of 20-30 riffle / pool sequences or two meander lengths. Valley slope / sinuosity.

Competence – A stream's ability to transport sediment. The diameter of the largest sediment grain transported.

Floodplain – Land that is actively (flooded beyond bankfull once every 1-2 years), generally broad, gently sloped valley floor, often bounded by a terrace (abandoned floodplain) or encroaching side slope.

Freshes – A flushing flow.

Knickpoint – A bedrock outcrop that creates an abrupt change in the longitudinal profile of a stream and controls the streambed elevation.

Meander – A bend or curve in the stream that often resembles a sine-generated curve.

Point bar – A crescent-shaped depositional feature with coarse material located on the inside bend of a meander.

Pool – Located on the outside of a meander bend or the bottom of a step, pools are deep flat areas in the stream created by scour. Pools generally contain fine grained bed materials, such as sand and silt.

Reach – A relatively short defined length of stream.

Return interval – The expected frequency of occurrence for a given discharge (i.e. 1½ years).

Riffle – Gravel size or larger bed sediment where the stream is shallow and swift at low flows. Riffles are produced during high flows by the accumulation of large bed materials.

Sediment – The accumulation of abiotic and biotic materials on the beds of waterbodies.

Scour – Erosive action of water in streams by excavating and transporting bed and bank materials downstream.

Sinuosity – Ratio of channel length to valley length. Ratio of valley slope to channel slope.

Water Framework Directive (WFD) – EU legislation that integrates water management through river basin planning.

Watercourse – Any flowing body of water. These include rivers, streams, anabranches, and so forth.

Appendix A: By Brook Project Phase I Report (BART, 2013/2014)

Please see CD-ROM

Appendix B: Crayfish Survey of the By Brook, River Avon and St Catherine's Brook (OHES, 2014)

Please see CD-ROM

Appendix C: By Brook Flood Risk Modelling Study (Backwater Effect of Hydraulic Structures at Low Flows)

Please see CD-ROM

Appendix D: By Brook Catchment Walkover Report – Fluvial Audit (BART, 2015)

Please see CD-ROM

Appendix E: Ecosystem Services Assessment for By Brook

Please see CD-ROM

Appendix F: Costings of Preferred Options

Please see CD-ROM