Paul Murphy

Wegnall's Mill, Presteigne, LD8 2LD Flood Report

Report K0813A/1

February 2019

Prepared and submitted by

Hydro-Logic Services (International) Ltd
(part of Hydro International)
Unit 6 Commerce Park , Brunel Way,
THEALE, Berkshire, RG7 4AB

T: 01189 331 325
F: 01189 331 486

enquiries@hydro-logic.co.uk

www.hydro-logic.co.uk

EXECUTIVE SUMMARY OF REPORT

This report documents work undertaken by Hydro-Logic Services for Paul Murphy between December 2018 and January 2019. The purpose of the work was to refine the findings of a previously submitted Report upon which the Environment Agency had commented (Appendix A).

The purpose of the work was to:

- Refine the calculation of design flows for the Site (hydrological modelling);
- Use topographic survey to confirm ground levels;
- Refine the hydraulic analysis in order that design flood levels can be confirmed;
- Provide a Flood Warning and Emergency Plan.

The summary and conclusions are presented in Section 4 of this Report.

The work delivered the following outputs:

- site-specific topographic survey;
- hydrological and hydraulic analysis for the Hindwell Brook;
- this Report.

Contributors for Hydro-Logic Services:

Alan Corner	Project Director
Dr Paul Webster	Project Manager & Hydrological Specialist
Robbie Swan	Hydrologist and Reviewer

Document Status and Revision History:

Version	Date	Author(s)	Authorisation	Status/Comment
0	Feb 2019	P Webster	P Webster	Draft for client review
0 (issue)	Feb 2019	P Webster	P Webster	Issue version

Limitation of liability and use

The work described in this report was undertaken for the party or parties stated; for the purpose or purposes stated; to the time and budget constraints stated. No liability is accepted for use by other parties or for other purposes, or unreasonably beyond the terms and parameters of its commission and its delivery to normal professional standards.

TABLE OF CONTENTS

1. Introduction

1.1 Background

This report presents the results of further hydraulic analysis undertaken by Hydro Logic Services International (HLSI) in January 2019 in support of a planning application at Wegnalls Mill, Presteigne. The application relates to the conversion of one of the outbuildings (The Barn) for short let holiday accommodation (Figure 1-1). The Barn is the most northerly of the four principal buildings at Wegnalls Mill, denoted by the orange text box on the Figure.

HLSI had previously undertaken flood investigations at this Site (HLSI, 2018), for the then owner to define flood risk for the existing residential buildings. The HLSI Report was submitted in support of the current application and has been commented on by the Environment Agency (Appendix A).

In their response to the Planning Application, the Environment Agency recognised the hydraulic complexity of the Site and that the only way to establish beyond reasonable doubt the flood risk would be through detailed modelling. However, it was noted that such modelling would be expensive and out of proportion with the scale of the Planning Application.

The Environment Agency has therefore sought additional work to better define flood risk for the Barn. This Report provides that response.

1.2 Scope of Work

The response of the Environment Agency has been helpful in scoping the required work. The suggested response to comments on the hydraulic modelling is shown in Table 1-1. Two principal tasks emerge from the Table, namely:

- More rigorous hydrological calculations in support of the hydraulic modelling (see Section 2 and Appendix B ;
- Detailed topographic survey (Appendix C).

In addition, a Flood Warning and Emergency Plan (FWEP) has been prepared (Section 3). A summary of the main findings is provided in Section 4.

Table 1-1 Review of Comments on modelling by Environment Agency

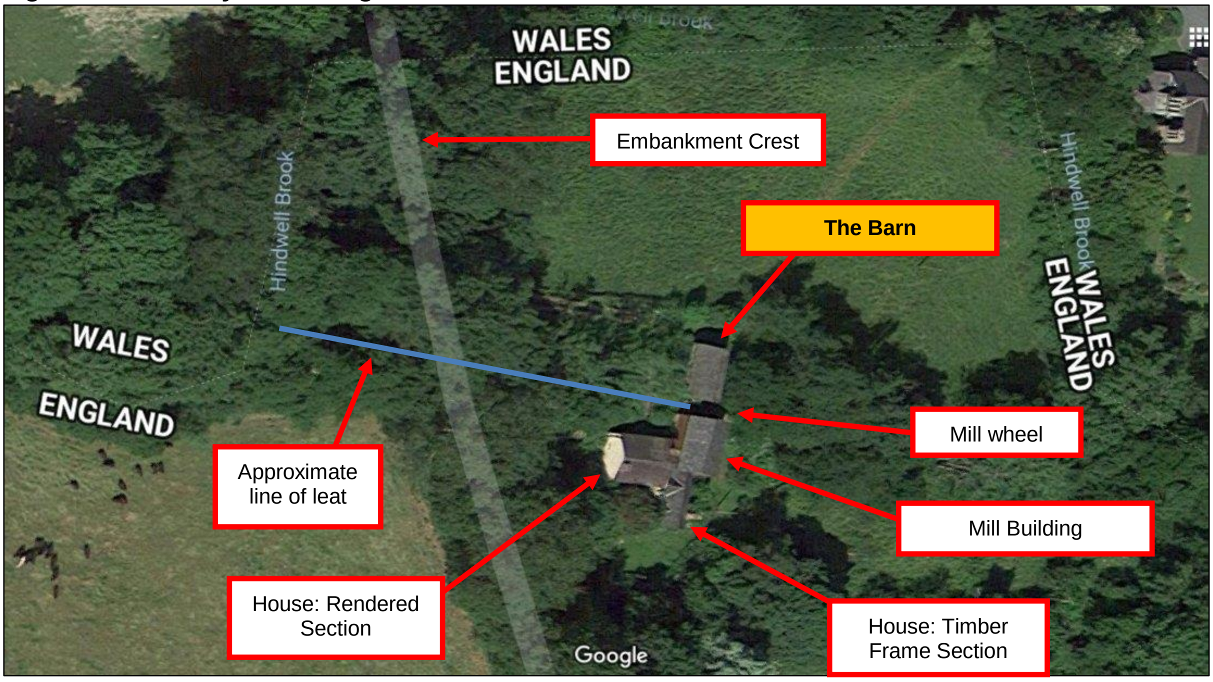
Ref	Comment	Response
1	*The flow has been determined using the ReFH procedure*	Undertake more rigorous hydrological calculations using the Statistical procedure, following Environment Agency Guidance.
2	*Level data is derived entirely from LiDAR, some of which has been collected below a canopy of vegetation.*	Commission surveyors to confirm property floor and threshold levels to mAOD and to demonstrate the accuracy of LiDAR data.
3	*The effect of Back Brook has been ignored.*	Its omission is conservative but expected to be small. **No further action is suggested.**
4	*Topographic mapping shows that the valley to the east of Wegnall's Mill continues to widen; it appears unlikely that any obstacle downstream would significantly affect flood levels at the mill*	This remains a plausible conceptualisation of the flow mechanisms. **No further action is suggested.**

1.3 Sources of Information and Consultation

This Report has been informed by the following:

- The HLSI 2018 Report including a Site Visit on 12th July 2017;
- Topographic survey undertaken by Invar Mapping on 9th January 2019;
- Information on publicly accessible internet sites.

Figure 1-1: The layout of Wegnalls Mill



From HLSI (2018)

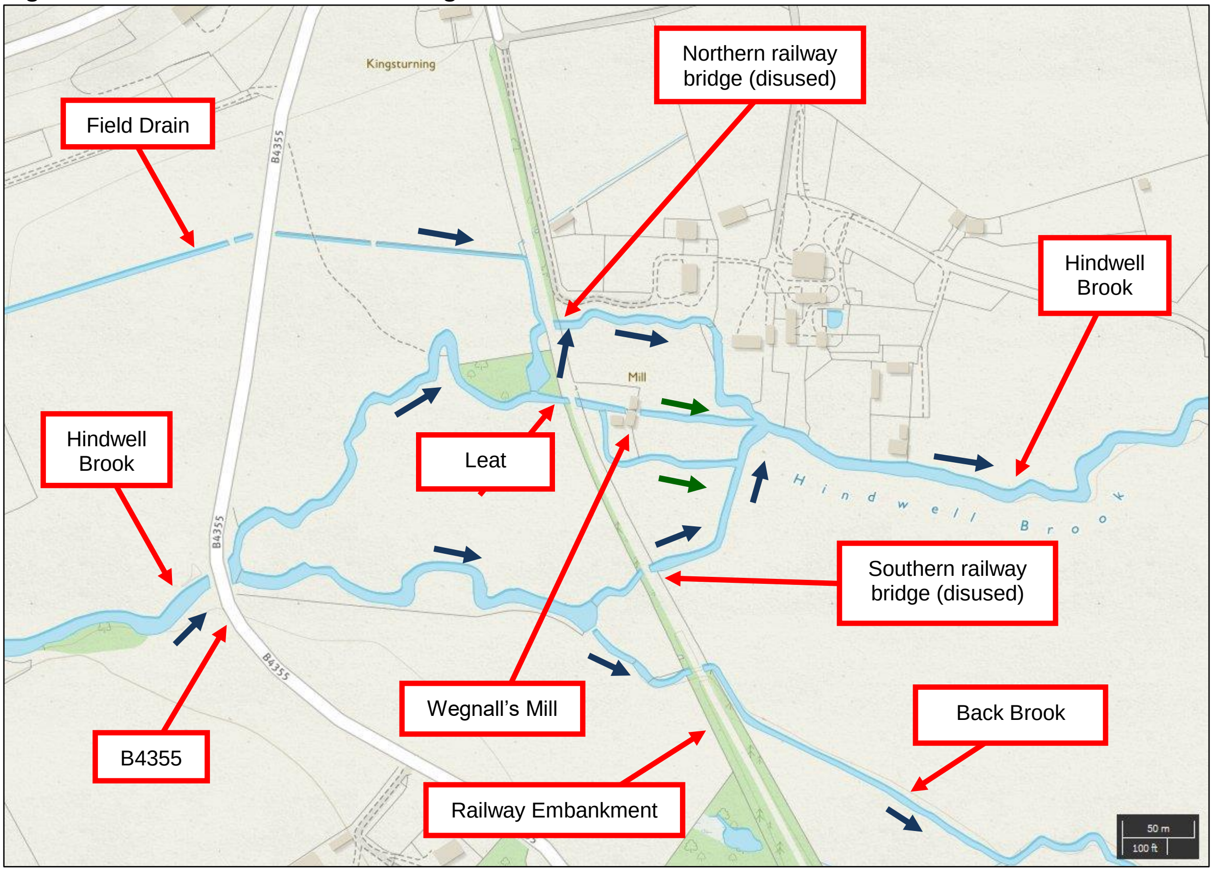
2. Hydrological and Hydraulic Modelling

2.1 Flood Mechanisms

Flood Risk is well described in the previous Report (HLSI, 2018). The flood mechanisms at the Site are complex (Figure 2-1), as is generally the case with Mills. However, under conditions of extreme flooding, the complex flow paths around the Mill are largely drowned as shown by extracts from the NRW (Natural Resources Wales) flood mapping (Figure 2-2) and flood extent from the 1947 flood event provided by NRW (Figure 2-3).

Under these condition of extreme flooding, the flood water levels are controlled by the channel and flood plain at and downstream of the Site. The precise elevation of the channels illustrated in Figure 2-1 is not of importance. It is the broader levels across the flood plain that are important. This was recognised in the earlier HLSI Report and underpinned the method used to establish flood levels. This method has been used in this updated analysis, though with some improvements to the hydrology and the hydraulics as noted in the remainder of this Section.

Figure 2-1 Flow Mechanisms at Wegnalls Mill



Reproduced under Licence 100041271

Figure 2-2 Product 4 Flood Map from NRW

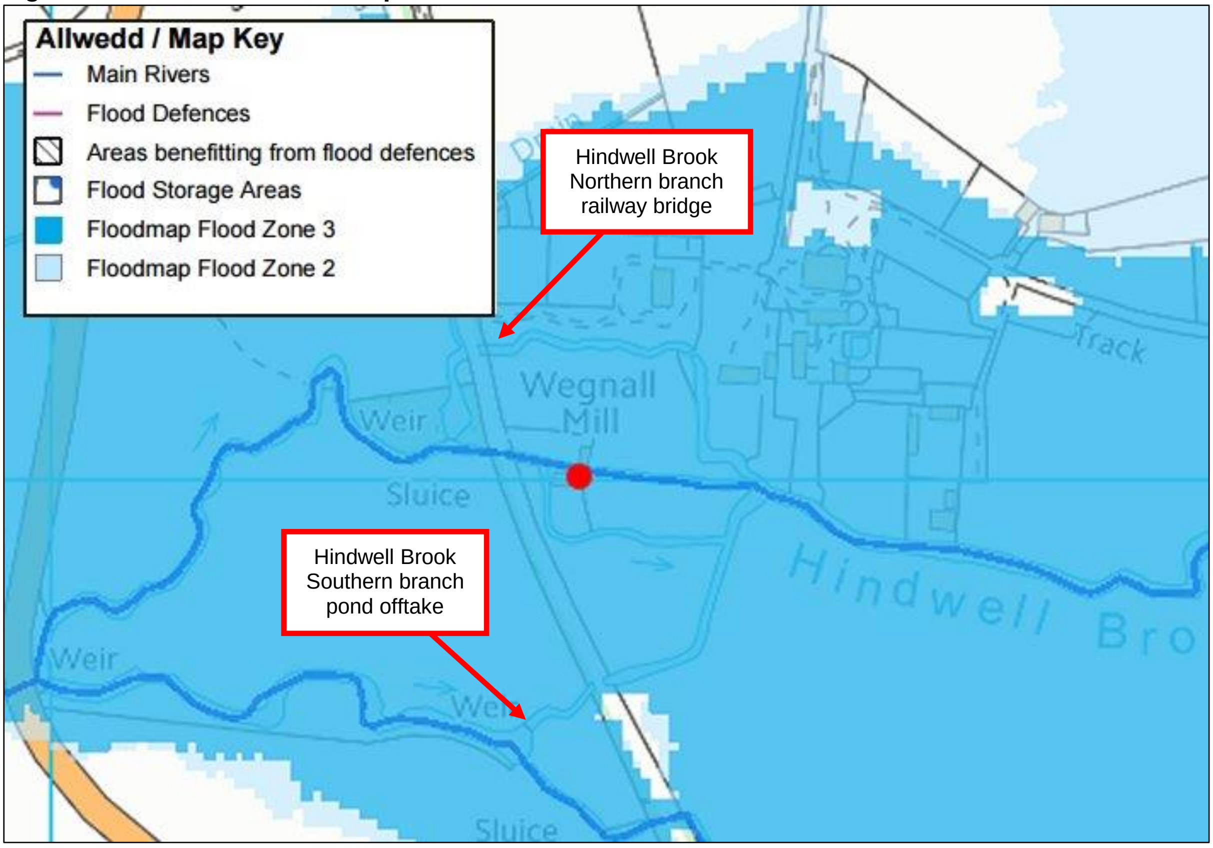
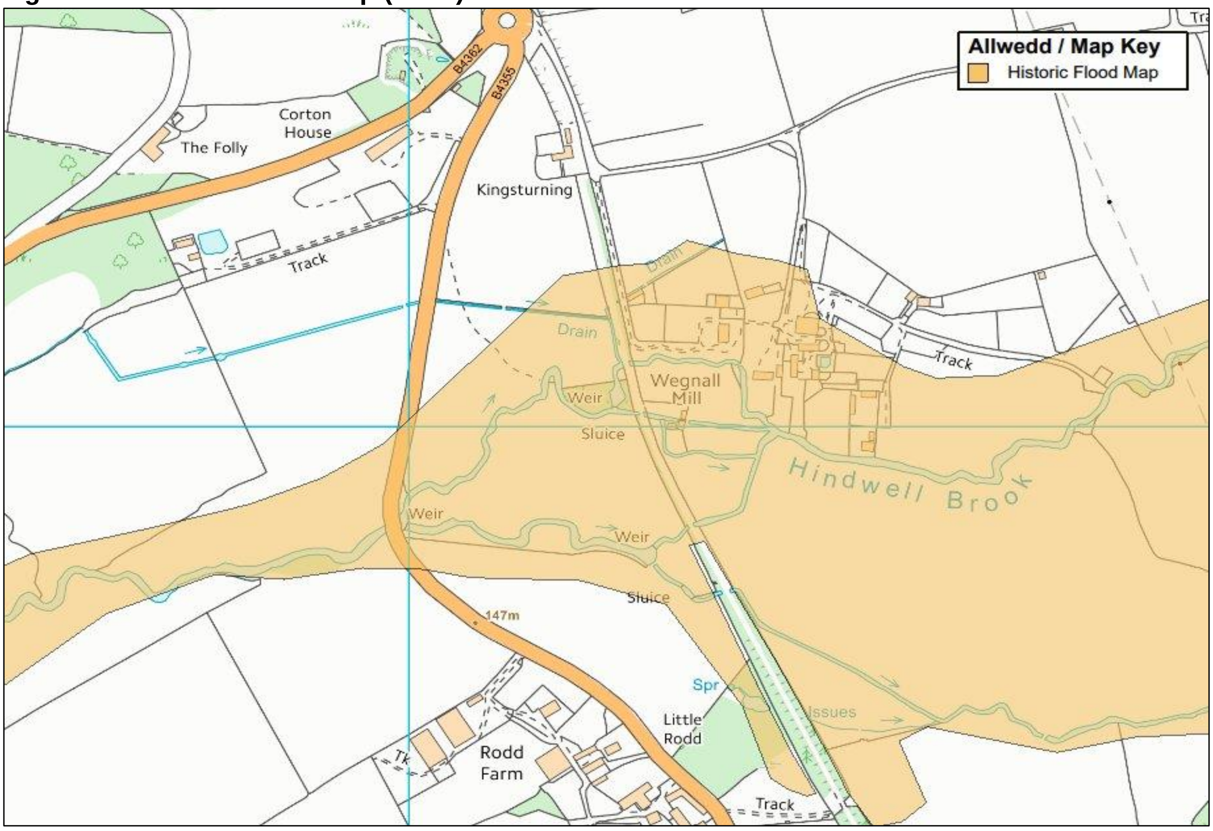


Figure 2-3 Historic Flood Map (NRW)



2.2 Hydrological Modelling

Hydrological modelling is the calculation of the peak flow rate in m^3/s for different return periods. In the earlier HLSI Report, the peak flows were calculated using the ReFH2 method. Whilst this is an acceptable methodology within the Flood Estimation Handbook (FEH) suite, it is generally considered less reliable than the FEH Statistical Method. The favoured method of hydrological modelling is to use a range of methods which then provides the basis for a refined set of flood estimates.

In the current hydrological modelling, which is presented in Appendix B , the original calculations (using the ReFH2 procedure) have been augmented by using the Statistical Method. These are for the catchment area shown in Figure 2-4 with catchment descriptors shown in Table 2-1.

The peak flow estimates for the two methods are given in Table 2-2. These show that the FEH Statistical Method gives higher flows than the ReFH2 method, as used in the Earlier HLSI Report. The difference is consistent for the key Annual Probabilities, the FEH Statistical Estimates being around 20% higher than those from ReFH2.

In the hydraulic analysis that follows, preference has been given to the higher estimates from the FEH Statistical Method. This is for the following reasons:

- The Statistical Method is generally considered to be the more reliable method;
- The estimate for QMED (the so called index flood and which is based on a robust nationally applied equation) is higher;
- Given the attendant uncertainty at this Site, a precautionary approach, using the higher flow estimates, is generally preferred.

Figure 2-4 Catchment area from FEH Web Service

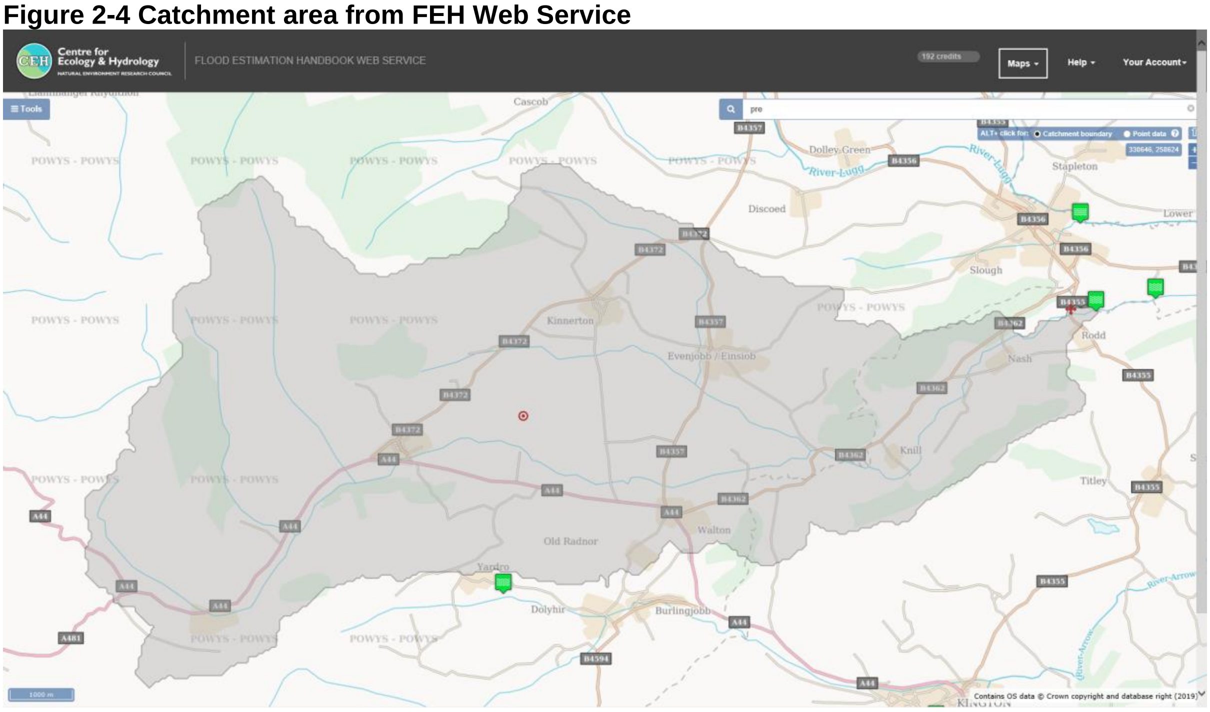


Table 2-1 Catchment Descriptors

	Location:	Wegnalls Brook
AREA	**Catchment area (km2)**	73.105
ALTBAR	Mean elevation (m)	309
ASPBAR	Mean aspect	124
ASPVAR	Variance of aspect	0.26
BFIHOST	Base flow index	0.565
DPLBAR	**Mean drainage path length (km)**	13.6
DPSBAR	Mean drainage path slope	159.3
FARL	Index of lakes	0.992
FPEXT	Prop. Of catchment in1% FP	0.0692
FPDBAR	Mean flood depth (catchment)	0.623
FPLOC	Avg dist of FP to outlet	0.714
LDP	**Longest drainage path (km)**	23.99
PROPWET	Proportion of time soil is wet	0.49
RMED-1H	Median 1-hour rainfall (mm)	9.7
RMED-1D	Median 1-day rainfall (mm)	36.8
RMED-2D	Median 2-day rainfall (mm)	48.2
SAAR	Average annual rainfall (mm)	987
SAAR4170	Ditto for 1941-1970 (mm)	1067
SPRHOST	Percentage runoff	34.15
URBEXT1990	Urban extent 1990	0.0014
URBEXT2000	**Urban extent 2000**	0.0013

Table 2-2 Comparison of Peak Flow Estimates

Annual Probability (%)	Return period (yrs)	ReFH	FEH Statistical	Ratio
50 (QMED)	2	15.48	17.504	0.88
1	100	40.84	49.075	0.83
0.1	1,000	67.55	81.83	0.83

2.3 Hydraulic Modelling

As noted previously, it is only through detailed hydraulic modelling that flood levels can be rigorously established. Since such modelling cannot be justified at this Site, a simpler approach must be adopted. In the earlier analysis, flood levels were established by applying the Manning equation to cross-sections obtained from LiDAR imagery.

In this Report, a similar approach has been followed, with the following changes:

- Survey work undertaken by Invar mapping demonstrated the good correspondence between ground levels estimated from LiDAR and those from topographic Survey (Appendix D);
- The flow estimates from the Statistical Method (Table 2-2) were used in preference to those from the ReFH2 method;
- A more refined hydraulic calculation was possible through assigning different values of Manning roughness to the channels as distinct from the flood plain. The previous analysis had used a single value for flood plain and channels; and
- Calculations have only been undertaken for the section labelled “CS1”in Figure 2-5 since peak flood levels for the “CS2” Section were much lower and not relevant to the Site.

The results from this analysis are illustrated in Figure 2-6 with peak levels shown in Table 2-3. This analysis effectively updates the analysis from the earlier HLSI Report but uses similar assumptions (e.g. for climate change allowance of +35%) and channel slope of 0.0039.

Figure 2-5 Locations of Cross-Sections in Earlier Report superimposed on LiDAR image

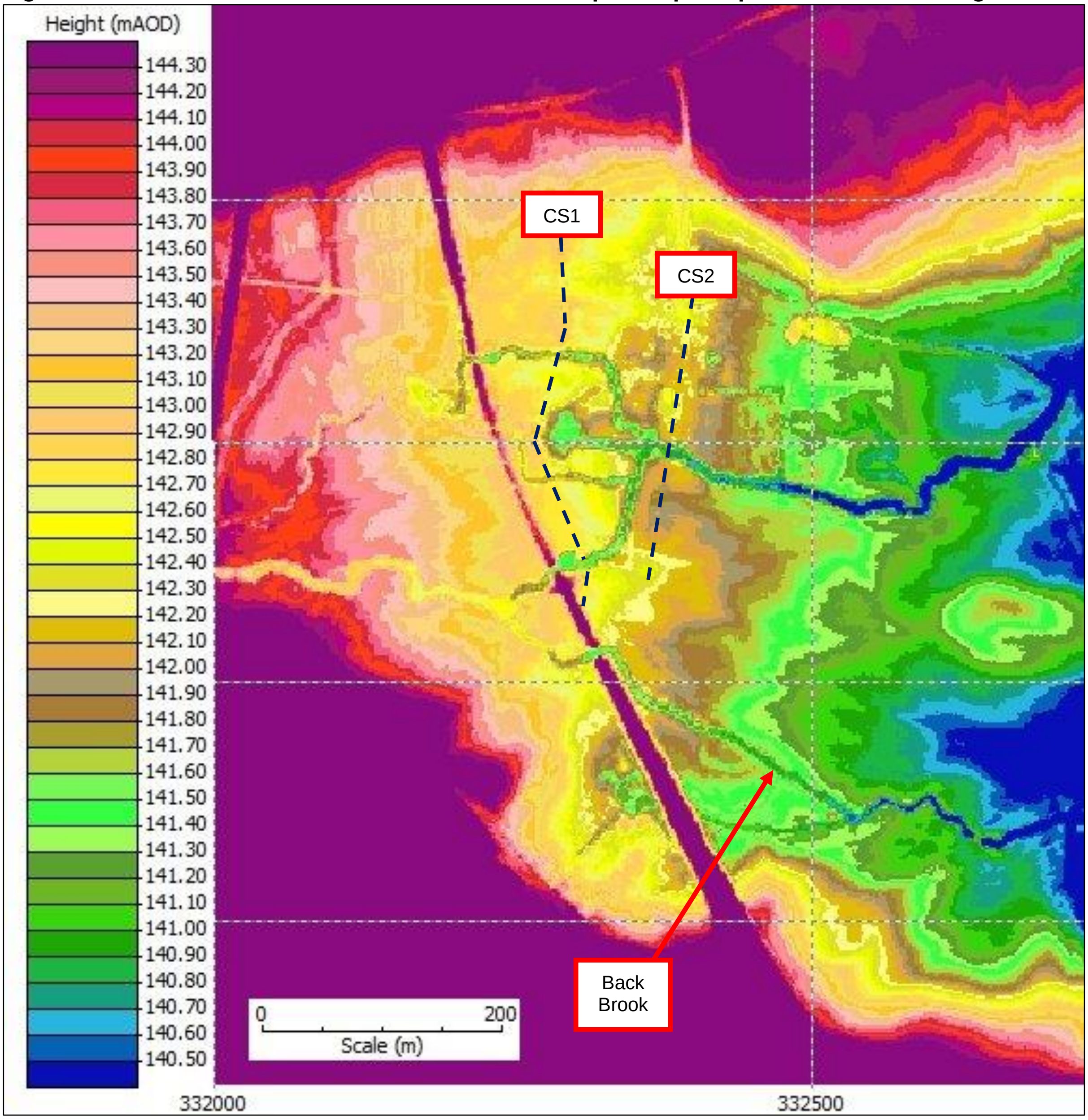


Figure 2-6 Flood Levels at Wegnalls Mill (CS1) (Inset from Earlier HLSI Report)

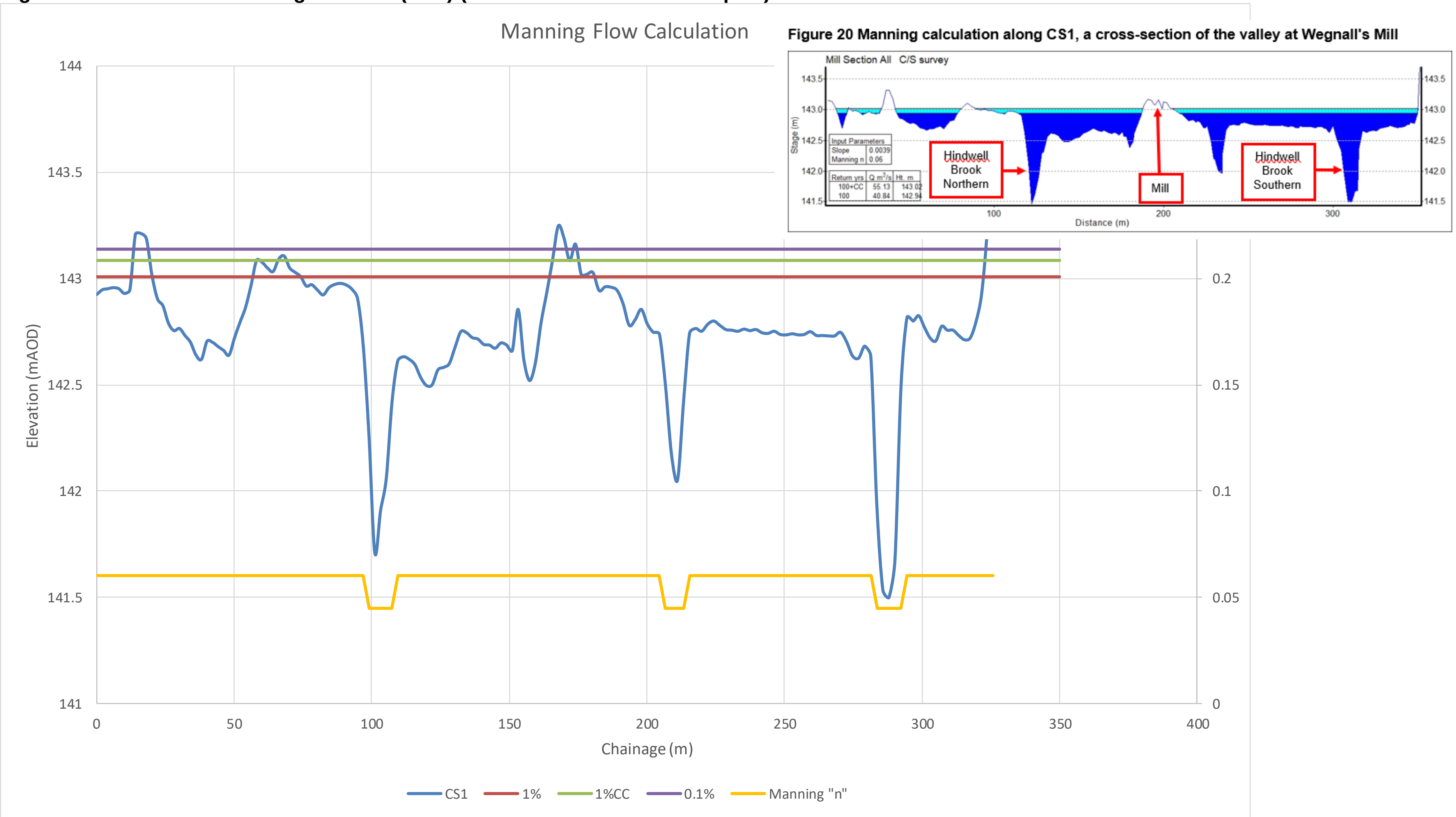


Table 2-3 Comparison of Peak Flow Estimates

Annual Probability	Return period (yrs)	FEH Statistical (m^3/s)	Level (mAOD)
1%	100	49.1	143.01
1% CC	**100 CC**	**64.3**	**143.08**
0.1%	1,000	81.8	143.14

CC refers to Climate Change Allowance (+35% in this case)

The following observations can be made about these levels:

- The “reference flood level” of **143.08 mAOD** is for the 1% Annual Probability with 35% allowance for climate change. This is slightly higher than the value in the Earlier Report of 143.02 mAOD.
- The main reason for the increase in levels is the increase in peak flow used in the analysis – though this is offset in part by the use of a specific value for Manning’s roughness for the channels of 0.045.
- There is a very small increase in level of 0.13 m from the 1% to the 0.1% Annual Probability. This is entirely consistent with the very broad flood plain of over 300 m at the Site.

Whilst the reference flood level of 143.08 mAOD is used in the following Section in comparison with the Finished Floor Levels (FFL), it is considered to be a conservatively high level, for the following reasons:

- The higher of the flow estimates has been used to derive these levels;
- A conservative approach has been adopted for the Manning analysis, e.g. with channel sections defined by LiDAR, rather than topographic survey;

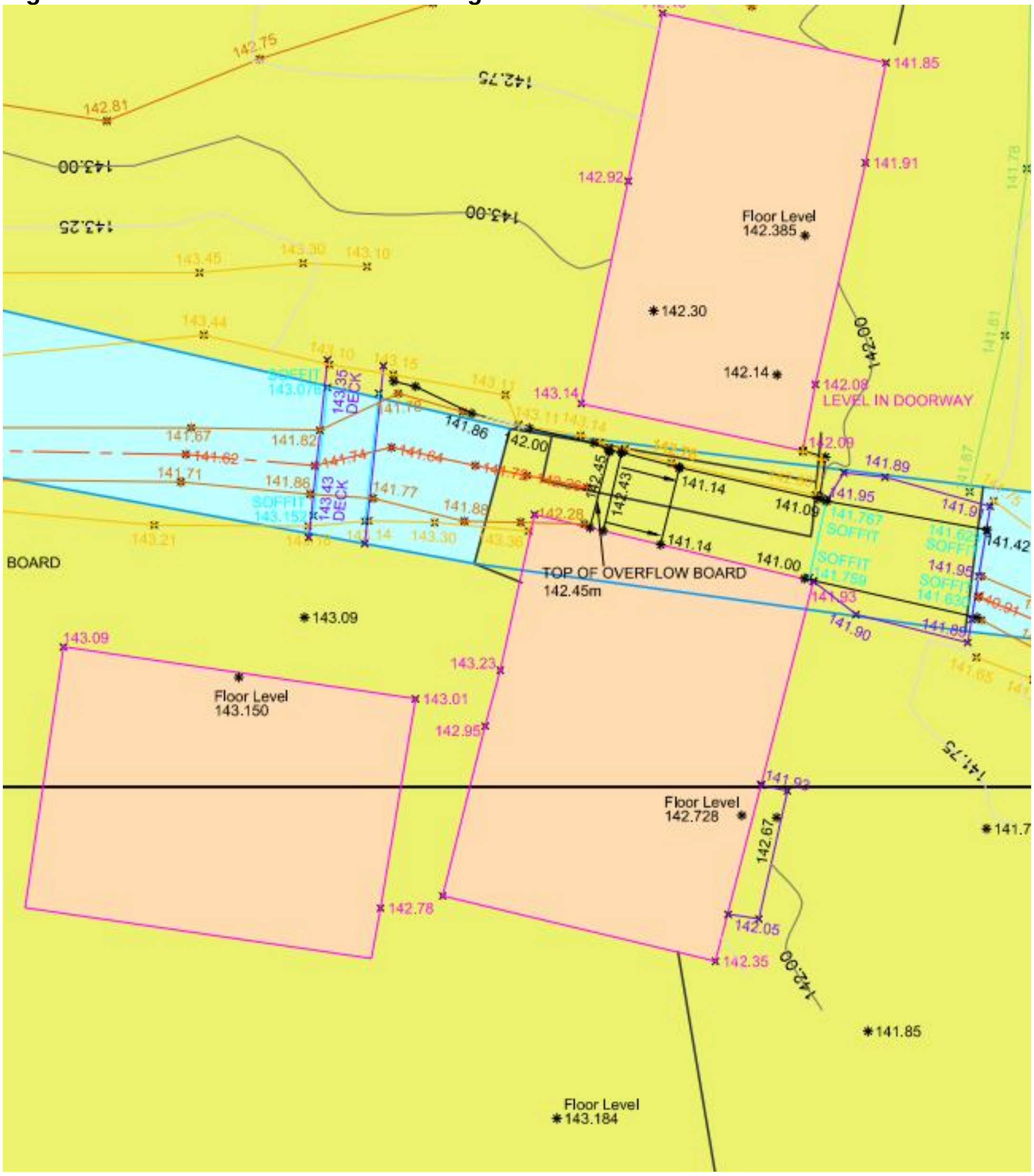
2.4 Comparison with Property Levels

Internal Finished Floor Levels were obtained by Invar for each main building. These are shown in Figure 2-7 and Table 2-4. These show that the Subject Site (The Barn) would suffer flooding to a depth of around 0.79 m whilst both Sections of the Mill House would be flood-free for the reference flood.

Table 2-4 Modelled depths of flooding

Building	FFL (mAOD)	Predicted flood depth (m)
The Barn	142.385	0.79
Mill building	142.728	0.45
Mill House (rendered)	143.150	-
Mil House (timber framed)	143.184	-

Figure 2-7 Finished Floor Levels at Wegnalls Mill



3. Flood Warning and Evacuation Plan

3.1 Introduction

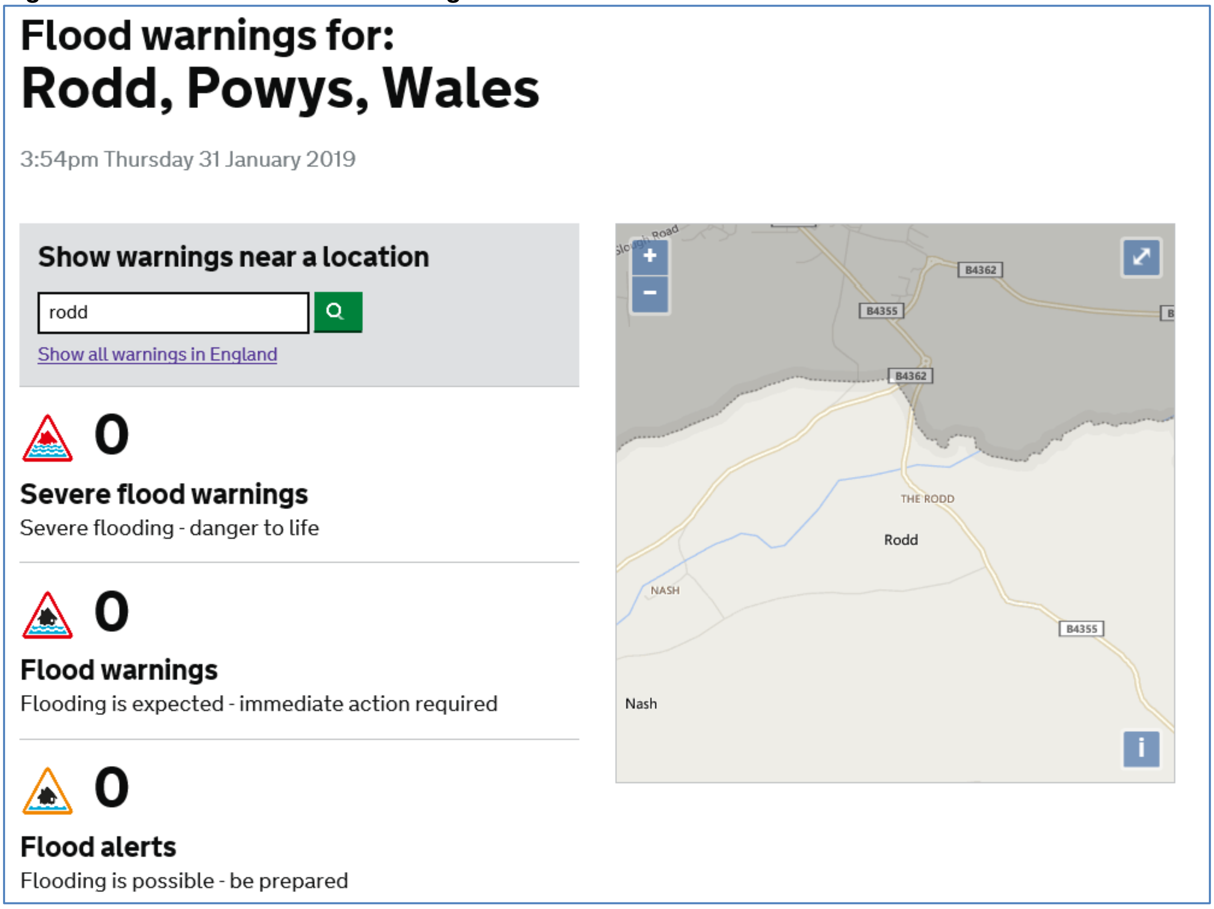
This Flood Warning and Evacuation Plan (FWEP) is intended to provide occupiers of the above site with advice and guidance to manage their safety in the event of flooding. A copy of this FWEP should be available to all users of the site. It should also be regularly updated to ensure that it provides up to date guidance for residents.

3.2 Flood Warnings

The operators of the accommodation should sign up to the Environment Agency Flood Line Service for the area of 'Hindwell Brook", so that they are able to relay any warnings to clients staying at the accommodation (Figure 3-1) and to take such precautions as may be required. The 'Freephone' telephone number for Floodline is:

0345 988 1188

Figure 3-1 Location of flood warning area



If flooding is forecast, the Environment Agency will issue the appropriate warning for the severity of flooding. Three types of warning are issued:

- Flood Alerts
- Flood Warnings; and
- Severe Flood Warnings.

The following tables detail what each type of warning means, and the actions people should take when they are issued. These are general instructions; more specific information is given below.

	**What it means** Flooding is possible. Be prepared. **When it's used** Two hours to two days in advance of flooding.	**EA recommended actions** • Be prepared to act on your flood plan. • Prepare a flood kit of essential items. • Monitor local water levels and the flood forecast on our website.
•		

	**What it means** Flooding is expected. Immediate action required. **When it's used** Half an hour to one day in advance of flooding.	**EA recommended actions** • Move family, pets and valuables to a safe place. • Turn off gas, electricity, and water supplies if safe to do so. • Put flood protection equipment in place.
•		

	**What it means** Severe flooding. Danger to life. **When it's used** When flooding poses a significant threat to life.	**EA recommended actions** • Stay in a safe place with a means of escape. • Be ready should you need to evacuate from your home. • Co-operate with the emergency services. • Call 999 if you are in immediate danger.
•		

EA Flood Warnings No longer in force	**What it means** No further flooding is currently expected in your area. **When it's used** When river or sea conditions begin to return to normal.	**EA recommended actions** • Be careful. Flood water may still be around for several days. • If you've been flooded, ring your insurance company as soon as possible.
•		

3.3 Preparation

There are two principal risks that need to be considered; those to people and those to the property.

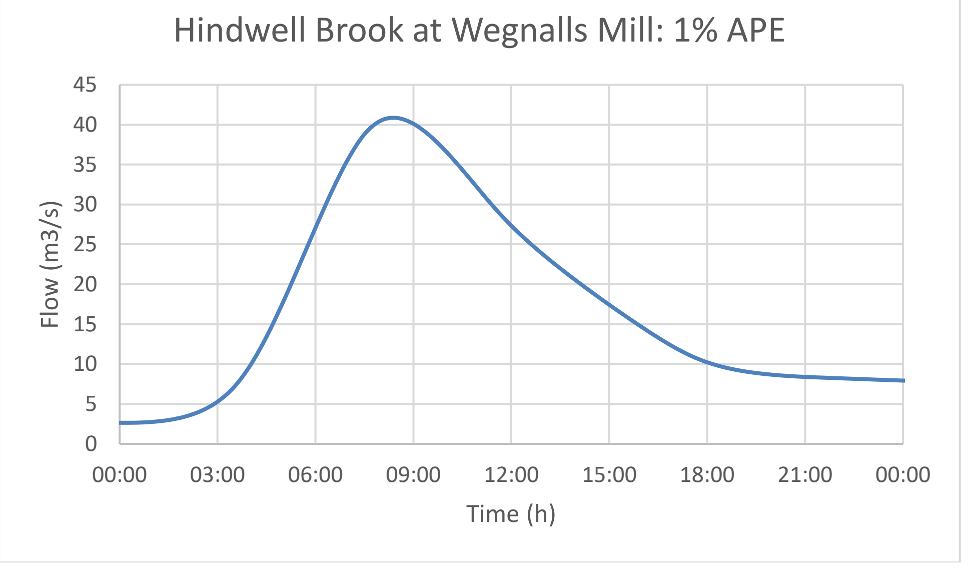
Although the application site is located in an official Flood Zone, the risk to users of the site is considered to be low, because of the hydrology of the Hindwell Brook catchment. The modelled flood hydrograph for the 1% Annual Probability flood is shown in Figure 3-2. The peak occurs 8.5 hours after the start of the storm which is roughly 5 hours after the peak of the storm. This delay reflects the response time of the catchment and provides a time window for such preparations as may be required.

The other defining feature of the site is the small rate of rise with respect to flow – as noted in Section 2.3. This means that even if water levels have exceeded the bank levels, further increases will be both limited and relatively slow.

Preparation should therefore be based on a review of any flood warning information and a decision as to whether the "guests" may decide to vacate the property, in view of the imminent flooding. Any threat to life is considered to be small, since there is land and property (Mill House) where the FFL is above the reference flood level. The decision to vacate may simply be expedient in the sense that a holiday had likely been interrupted.

The greater risk, as inferred from Section 2 is to the property itself, the FFL for which is below the reference flood level. Preparation in this case should comprise actions to minimise damage to the building and to the contents. Although the property will have been constructed in a resilient manner, it may be necessary to relocate some items to upper floors and seek to keep water out of the property in so far as this may be possible.

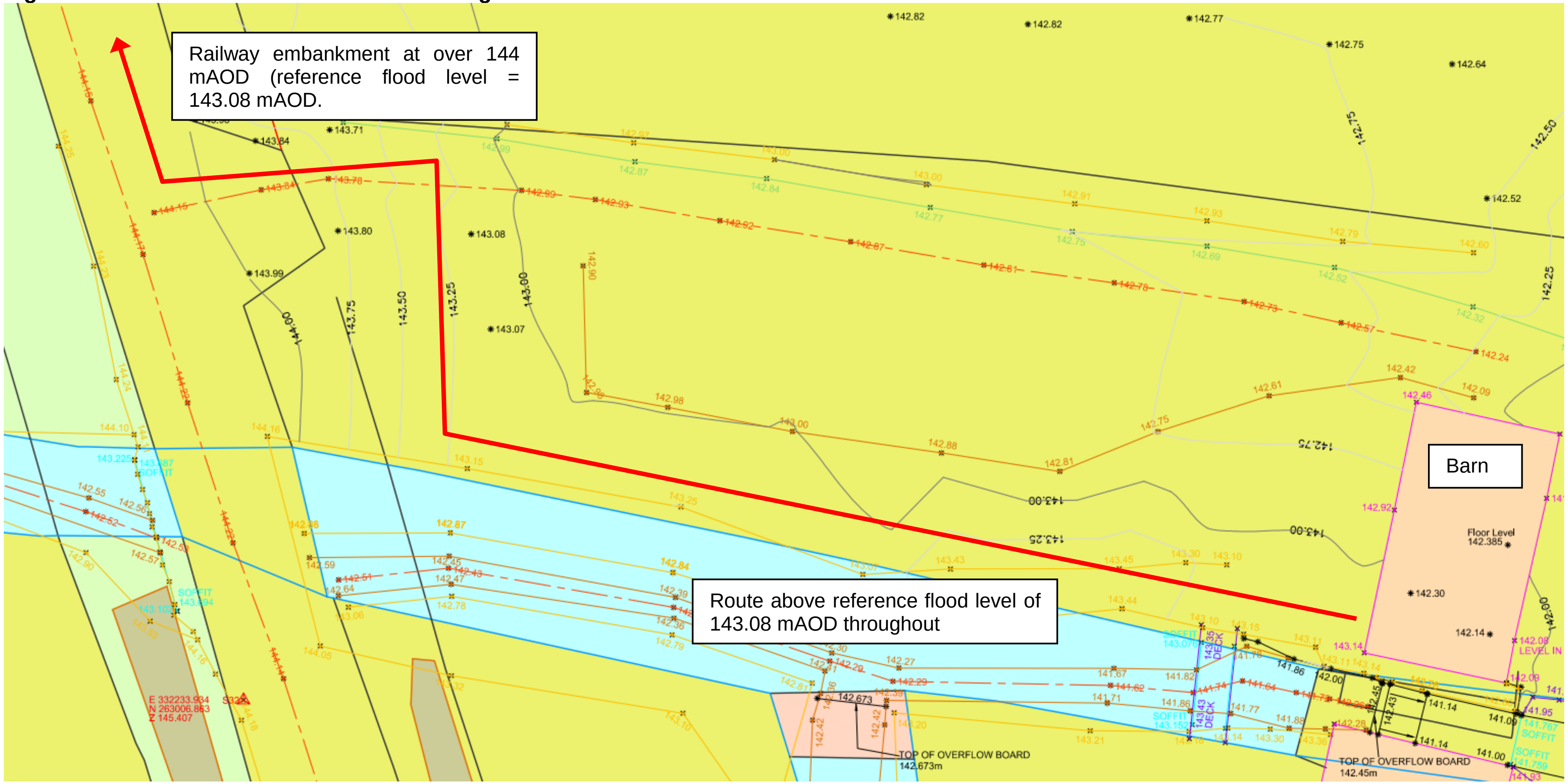
Figure 3-2 Modelled flow hydrograph for Hindwell Brook at Wegnalls Mill



3.4 Evacuation

It is not considered that the site should need to be evacuated. However, a dry route is available as shown in Figure 3-3.

Figure 3-3 Evacuation route from Barn at Wegnalls Mill



3.5 Review

This flood warning & evacuation plan should be reviewed annually to ensure that it is kept up-to-date with any changes to Flood Information. This could include flood map changes and flood policy changes due to updated information that could become available. Any changes to the flood warning & evacuation plan should be noted in this Section of this FRA.

3.6 Roles and Responsibilities

There are many organisations that will play a part in response to a major flooding incident. These include emergency services, utility companies and voluntary agencies.

Below are the roles and responsibilities of some of the principal organisations that may be involved in an emergency response.

Environment Agency

- Predicting flooding from statutory main rivers and the sea including the location, timing, and magnitude
- Issuing of Flood Warnings to partner agencies and ensuring that the public are warned and informed
- Maintenance and operation of sea and river flood defences. Check defences and undertake essential repairs as required.
- Monitor and clear blockages of culverts and repair breaches of defences
- Support the Police and Local Authority by providing materials, equipment, and manpower as far as resources and other duties permit.
- Advisory role in dealing with pollution issues as a result of flooding

MET Office

- The Met office issues severe weather warnings for heavy rain, snow, severe gales etc. These warnings are delivered directly to local authorities, the emergency services, and the media.

Police

- Co-ordination of the emergency services at a major flood event, as well as helping to save lives and protect property
- Establishment of cordons where practical to facilitate the work of the emergency services
- In conjunction with other emergency services, to evacuate people from properties at risk, if necessary
- Collation and dissemination of casualty information

Fire and Rescue

- Saving life and rescuing trapped persons
- Provide monitoring procedures in respect of health and safety of those persons operating within an established cordon

- Carry out essential damage control measures including pumping out flood water and salvage work
- Rendering humanitarian services in support of the local authority

Local Authority

- Providing support to the emergency services
- Mitigation of the effects of an emergency on people, including emergency feeding, accommodation, and welfare.
- Co-ordination of the voluntary sector response
- Information services to the public and media
- Flood alleviation measures where possible
- Environmental health advice
- Rehabilitation of the community and restoration of the environment

Utility Companies

- In the event of a flood, will secure their services and equipment to ensure continuity of supply
- Repair services disrupted by flood
- Provide alternative means of supply during service disruption if life and death health risks are identified

4. Summary

This Report presents an updated statement of flood risk in support of a planning application for the conversion of a Barn to Holiday Let accommodation. This builds on an earlier assessment by Hydro-Logic Services and upon which the Environment Agency had commented as part of their response to the planning application.

The current report has provided more detailed hydrological analysis for the Hindwell Brook. Site specific topographic survey has also been commissioned that has provided improved estimates of ground and floor levels and enabled an assessment of the quality of the LiDAR data. The above factors have also contributed to an improved hydraulic analysis for the Site.

The main findings of the analysis are as follows:

i. Hydrological modelling using the Statistical Method provided peak flows that were around 20% higher than those previously used, which were from the ReFH2 method.

ii. The critical and property ground levels have been established using topographic survey. The current FFL for the Barn, the subject Site, is **142.385 mAOD**.

iii. A comparison has been made between ground levels from the topographic survey and those from the 2 m LiDAR; this for three sections close to the Site. The results confirm that the LiDAR data provides a secure, if slightly conservative, basis for extracting channel cross-sections (Appendix D).

iv. As previously noted, the hydraulics of the Hindwell Brook are complex. It has been recognised by the Environment Agency that detailed hydraulic modelling to obtain design flood levels would not be consistent with overall scale of the planning application. A simplified approach has therefore been used for hydraulic analysis, similar to that used in the earlier analysis and based on the Manning analysis.

v. The estimated flood level for the 1% annual probability flood with 35% allowance for climate change is **143.08 mAOD**. This is slightly higher than from the previous Report; largely due to the increased design flows used for the computation.

vi. A comparison of the design flood levels with property levels shows that the existing Mill House is above the design flood level. However, the Barn would currently be subject to internal flooding of around 0.7 m.

vii. A Flood Warning and Evacuation Plan is presented in Section 3. This indicates that flood warnings, howsoever obtained, should provide time for implementation of any required actions. Further, there is land and property close to the Barn that is safe from flooding. A safe (dry) access/egress route is also available from the Barn.

5. References

Author	Date	Title/Description
Centre for Ecology and Hydrology.		The Flood Estimation Handbook Web Service
Chow, Ven Te	1959	Open Channel Hydraulics. McGraw Hill.
CIRIA	2015	The SUDS Manual – CIRIA Report C753.
Environment Agency	2012	Estimating flood peaks and hydrographs for small catchments: Phase 1, SC090031.
Environment Agency	2016	Flood risk assessments: climate change allowances. (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances)
HLSI	2018	Flood Risk Survey for Wegnall's Mill, Presteigne, LD8 2LD. Report undertaken for Dr Thomas Neal. Report K0813/1.
Institute of Hydrology	1999	Flood Estimation Handbook,
Marshall D.C.W. & Bayliss A.C	1994	Flood estimation for small catchments, IH Report No. 124, Institute of Hydrology, Wallingford and Hall, Hockin & Ellis
WHS	2016a	WINFAP-FEH v4. Technical Guidance.
WHS	2016b	Revitalised Flood Hydrograph Model ReFH2: Technical Guidance.

Appendix A Response from the Environment Agency

Herefordshire Council
PO Box 4
Hereford
HR1 2ZB

Our ref: SV/2018/110046/01-L01
Your ref: 183156

Date: 21 November 2018

F.A.O: Mr. Adam Lewis

Dear Sir

PROPOSED CONVERSION AND EXTENSION INTO HOLIDAY LET ON LAND AT WEGNALLS MILL, PRESEIGNE, HEREFORDSHIRE

Thank you for referring the above application which was received on the 29 October 2018. We **object** to the proposed development, as submitted, and request additional information as detailed below.

Flood Risk: The site lies within Flood Zone 3 (High Probability) of the Hindwell Brook on our Flood Map for Planning as defined in Table 1 of the Planning Practice Guidance. It also falls within the 1947 historic flood outline though there are no records to indicate if it flooded internally during this event.

Sequential Test: The NPPF details the requirement for a risk-based ST in determining planning applications. See paragraphs 157-158 of the NPPF and the advice within the Flood Risk and Coastal Change Section of the government's NPPG.

The NPPF requires decision-makers to steer new development to areas at the lowest probability of flooding by applying a ST. It states that *'Development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower probability of flooding'.*

Further detail is provided in the NPPG; 'Only where there are no reasonably available sites in Flood Zones 1 or 2 should the suitability of sites in Flood Zone 3 be considered, taking into account the flood risk vulnerability of land uses and applying the Exception Test (ET) if required.

Based on the scale and nature of the proposal, which is considered non-major development in accordance with the Development Management Procedure Order (2010), we would not make any bespoke comments on the ST, in this instance at the planning application stage. The fact that we are not providing comments does not mean that there are no ST issues, but we would leave this for the LPA to consider. Providing the LPA are satisfied that the ST has been passed, then we can provide the following

Environment Agency
Hafren House, Welshpool Road, Shelton, Shropshire, Shrewsbury, SY3 8BB.
Customer services line: 03708 506 506
www.gov.uk/environment-agency
Cont/d..

comments on the ET and FRA.

Flood Risk Assessment (FRA): As stated above the site lies within Flood Zone 3, the high risk Zone. However, the Flood Map for Planning at this location has not been produced from a detailed hydraulic model of the Hindwell Brook (classed as Main River) but from a national, generalised mapping technique. We therefore cannot provide modelled flood levels at this location which would inform the flood risk to the proposed development by comparing it to surrounding ground levels and the property threshold level. Also this generalised mapping technique, whilst relatively accurate as it is based on detailed LiDAR (topography), does ignore the impacts of structures such as culverts, bridges, weirs and sluices which are of particular relevance at this location given the previous use of the building as a mill. In addition to the structures, given the historic use, the Hindwell Brook splits into a network of channels at this location so the local flooding regime will be relatively complicated and therefore difficult to assess.

A holiday let is proposed for the mill which is classed as More Vulnerable use though we accept that this vulnerability classification will not have changed if the building has been occupied since 1961 as suggested in the Flood Risk Survey produced by Hydro-Logic Services (Ref K0813/1) dated March 2018. There are two reasons why the potential risk to occupants is increased: firstly, as the visitors will be on holiday, they will not be as aware of or prepared for flooding as someone living permanently at the property. Secondly, bedrooms are proposed on the ground floor of the mill so the occupants are more vulnerable to flooding should this occur, particularly in the night. We do not offer a full flood warning service at this location but the area is covered by a Flood Alert (River Lugg north of Leominster) which is triggered by the gauges at Byton and Butts Bridge on the River Lugg. Therefore the gauges are not actually located on the Hindwell Brook but the Byton gauge is located just downstream of the Lugg/Hindwell Brook confluence so should be impacted by rainfall which affects the Hindwell Brook.

Whilst modelling has not been produced by Hydro-Logic Services a rough estimation of flood risk has been undertaken looking at the structures, various channels using LiDAR data and a Manning's approach. This is a difficult application to comment on in terms of flood risk. On the one hand, it is for a conversion of an existing mill building to a holiday let with bedrooms on the ground floor and a limited flood warning service so there is risk associated with the application should flooding occur. However, given the scale and nature of the proposals, we feel it is unreasonable to ask for full hydraulic modelling on this occasion. As stated above, the area is complex with various bifurcations of the watercourse and a number of in channel structures in addition to the disused railway line upstream of the development so full modelling is likely to cost tens of thousands of pounds. However, it is really the only way of confirming that the proposals would not be vulnerable to flooding over the lifetime of the development.

Hydro-Logic's own document highlights the limitations of the assessment and suggests further work (section 3.6) which could be undertaken to help inform the flood risk at the location. It also contradicts itself as it suggests in section 3.6 that "there is uncertainty around their estimates, which could be tested as part of a more rigorous analysis" and then goes on to list additional work. Yet in the summary at the start of the document it states that the report establishes beyond reasonable doubt that the property lies outside of the 1 in 100 floodplain. We would disagree with the latter statement given the broad brush assessment undertaken, though appreciate why this approach has been adopted due to the scale of the proposals.

Given the risk to occupants, we recommend Hydro-Logic Services' suggested more vigorous analysis is undertaken and the points in sections 3.6 and 4.0 of the report are

Cont/d..

undertaken. We would suggest ground level surveys are undertaken (particularly key for the over vegetated watercourses) and the actual threshold level of the mill building, and proposed finished floor levels, ascertained.

Also as full hydraulic modelling is not being undertaken we strongly recommend that the bedrooms are relocated to the first floor. Depending on the results of this additional work a flood management and evacuation plan may be required for people letting the mill given that it is possible access/egress is affected during times of flooding.

Summary: The mill is located in a location with a complex flooding regime given its historical use and associated structures. We feel it is unreasonable to request full hydraulic modelling as this is a single conversion to a holiday let but we do not believe that the report is detailed enough to rule out internal flooding of the property at this stage. We therefore recommend that the additional work outlined in Hydro-Logic Services' Flood Risk Survey is undertaken and that the bedrooms are moved to the first floor.

Yours faithfully

Mr. Graeme Irwin
Senior Planning Advisor
Direct dial: 02030 251624
Direct e-mail: graeme.irwin@environment-agency.gov.uk

Appendix B Flood Estimation Calculation Record (EA Template)

Introduction

This document is a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future. This version of the record is for studies where flood estimates are needed at a single location.

Contents

Approval

	Signature	Name and qualifications	For Environment Agency staff: Competence level (see below)
Calculations prepared by:	P Webster	BSc, MSc, PhD, DIC, FCIWEM, C.WEM	
Calculations checked by:	Alison Clare-Dalgleish	MA, MSc, DIC	
Calculations approved by:	P Webster	BSc, MSc, PhD, DIC, FCIWEM, C.WEM	

Environment Agency competence levels are covered in Section 2.1 of the flood estimation guidelines:

- Level 1 – Hydrologist with minimum approved experience in flood estimation
- Level 2 – Senior Hydrologist
- Level 3 – Senior Hydrologist with extensive experience of flood estimation

Abbreviations

AEP	Annual Exceedance probability
AM	Annual Maximum
AREA	Catchment area (km^2)
BFI	Base Flow Index
BFIHOST	Base Flow Index derived using the HOST soil classification
CFMP	Catchment Flood Management Plan
CPRE	Council for the Protection of Rural England
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
HOST	Hydrology of Soil Types
NRFA	National River Flow Archive
POT	Peaks Over a Threshold
QMED	Median Annual Flood (with return period 2 years)
ReFH	Revitalised Flood Hydrograph method
SAAR	Standard Average Annual Rainfall (mm)
SPR	Standard percentage runoff
SPRHOST	Standard percentage runoff derived using the HOST soil classification
Tp(0)	Time to peak of the instantaneous unit hydrograph
URBAN	Flood Studies Report index of fractional urban extent
URBEXT1990	FEH index of fractional urban extent
URBEXT2000	Revised index of urban extent, measured differently from URBEXT1990
WINFAP-FEH	Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

1.1 Overview of requirements for flood estimate

Item	Comments
Give an overview which includes: • Purpose of study • Peak flow or hydrograph? • Range of return periods • Approx. time available	*The purpose of this study was to refine flood levels that had previously been computed for the Wegnalls Mill. Since these were based on the ReFH analysis the Environment Agency sought further confirmation using the FEH Statistical Method.*

1.2 Overview of catchment

Item	Comments
Brief description of catchment, or reference to section in accompanying report	*Wegnalls Mill lies adjacent to the Hindwell Brook. It has a catchment area of 73 km^2) to the Mill. Further description is provided in Section 2.*

1.3 Source of flood peak data

Was the HiFlows UK dataset used? If so, which version? Record any changes made.	*V7 of the WIN-FEH files were used in the Statistical Analysis.*

1.4 Gauging stations (flow or level)

(at the site of the flood estimate or nearby at potential donor sites)

Water-course	Station name	Gauging authority number	NRFA number (used in FEH)	Grid reference	Catch-ment area (km²)	Type (rated / ultrasonic / level…)	Start and end of flow record
None							

1.5 Data available at each flow gauging station

Station name	Start and end of data in HiFlows-UK	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow data quality – e.g. information from HiFlows-UK, trends in flood peaks, outliers.
n/a						
Give link/reference to any further data quality checks carried out			*None*			

1.6 Rating equations

Station name	**Type of rating** e.g. theoretical, empirical; degree of extrapolation	**Rating review needed?**	**Reasons** – e.g. availability of recent flow gaugings, amount of scatter in the rating.
Give link/reference to any rating reviews carried out			

1.7 Other data available and how it has been obtained

Type of data	**Data relevant to this study?**	**Data available ?**	**Source of data and licence reference if from EA**	**Date obtained**	**Details**
Check flow gaugings (if planned to review ratings)	No				
Historic flood data – give link to historic review if carried out.	Yes		Previous Owner	Aug 2017	Confirmation of "no flooding" since 1961 when he moved there.
Flow data for events	No				
Rainfall data for events	No				
Potential evaporation data	No				
Results from previous studies (e.g. CFMPs, Strategies)	No				
Other data or information (e.g. groundwater, tides)	No				

1.8 Initial choice of approach

Is FEH appropriate? (it may not be for very small, heavily urbanised or complex catchments) If not, describe other methods to be used.	*FEH Statistical Method considered appropriate for this small to medium sized catchment and certainly to compare with the previous results.*
Outline the conceptual model, addressing questions such as: • What is likely to cause flooding at the site (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might the site flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	*Flooding at the Site is due to conventional rainfall-runoff over the catchment. The complexity of flood mechanisms is due to the wide flood plain of the Hindwell Brook as it approaches the River Lugg.*
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, use permeable catchment adjustment for statistical method if SPRHOST<20%	*The catchment on the FEH Web Service and at the subject site are quite elongated. Normally, this leads to a longer time base for the hydrograph and accordingly lower peak discharge than for a catchment with more regular shape. Since catchment shape is not*

• highly urbanised – avoid ReFH if URBEXT1990>0.125; consider FEH Statistical or other alternatives • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	*parameterised in the methods used, we suspect that the results include a degree of conservatism.*
Initial choice of method(s) and reasons	*ReFH2 had previously been used. This analysis is a logical development in using the FEH Statistical Method.*
Software to be used (with version numbers)	*FEH Web Service* *WINFAP v4 urban adjustment procedure*

1.9 Site details

Watercourse	Site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
Hindwell Brook	*Wegnalls Mill, located to east of former railway embankment (SO3224763070)*			*73.1*	*n/a*

1.10 Catchment descriptors (incorporating any changes made)

Hindwell Brook

FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT	FPEXT
0.99	*0.49*	*0.565*	*13.6*	*159.3*	*987*	*34.15*	*0.0013*	*0.0692*

1.11 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (refer to maps if needed)	*Boundary checked using OS and found to be reasonable.*
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	*The descriptors for the Subject Site are given in Table 2-1. Descriptors are reasonable given inspection of maps and site visit.*
Source of URBEXT	*Very low and plausible*
Method for updating of URBEXT	*None since we are dealing with flood mapping for the existing situation.*

2 Statistical method

2.1 Overview of estimation of QMED

Method		Data transfer	

	Initial estimate of QMED (m^3/s)	NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Power term, a	Moderated QMED adjustment factor, $(A/B)^a$	Final estimate of QMED (m^3/s)
n/a	17.474	n/a	n/a	n.a	n.a	17.474

Notes
Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer; CD – Catchment descriptors alone.

When QMED is estimated from POT data, it should also be adjusted for climatic variation. Details should be added below.

When QMED is estimated from catchment descriptors, the revised 2008 equation from Science Report SC050050**Error! Bookmark not defined.** should be used. If the original FEH equation has been used, say so and give the reason why.

The data transfer procedure is the revised one from Science Report SC050050. The QMED adjustment factor A/B for each donor site is given in Table 3.3. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is $(A/B)^a$ times the initial estimate from catchment descriptors.

If more than one donor has been used, give the weights used in the averaging.

2.2 Search for donor sites for QMED

Comment on potential donor sites Mention: • Number of potential donor sites available • Distances from subject site • Similarity in terms of AREA, URBEXT, FARL and other catchment descriptors • Quality of flood peak data Include a map if necessary. Note that donor catchments should usually be rural.	*Two potential donors were considered, 55013 (Arrow @ Titley Mill) which is 6.77 km from the Subject Site and 55021 (Lugg @ Butts Bridge) which is 11.29 km from the subject Site. The QMED equation performed well for these donors. However, the QMED from the donors was slightly lower than from the CDs and was therefore rejected.*

2.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing or rejecting	Method (AM or POT)	Adjust-ment for climatic variation?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
n/a						

2.4 Derivation of pooling group

Target return period (years)	100	
Changes made to default pooling group, with reasons Note also any sites that were investigated but retained in the group.	**Distribution and reason for choice**	**Parameters (before urban adjustment)** Note any permeable catchment adjustments
No stations were rejected from the initial Pooling Group and which is given below in Section 5 of this Appendix. The Pooling Group was described as "heterogenous" with a review being "desirable". However, there were no obvious candidates for station removal.		
Note: Pooling groups were derived using the procedures from WINFAP-v4		

2.5 Derivation of flood growth curves

Method: SS – Single site P – Pooled J – Joint analysis	**If SS, distribution used and reason for choice** **If J, details of averaging**	**If SS, parameters of distribution** (location, scale and shape)	**Growth factor for 100-year return period**
Pooled using GL on basis of Goodness of fit			*2.804*
Note: Growth curves were derived using the revised procedures from Science Report SC050050 (2008).			

2.6 Flood estimates from the statistical method

Hindwell Brook at Wegnalls Mill

Flood peak (m^3/s) for the following return periods (in years)								
2	5	10	*25*	50	100	200	500	1000
17.504	23.962	28.752	35.805	41.976	49.075	57.289	70.206	81.832

- *The as-rural QMED, based on catchment descriptors was 17.474 m^3/s.*
- *The UAF (urban adjustment factor) for URBEXT = 0.0014 using default values was 1.002*
- *The urban QMED is the product of as-rural QMED and the UAF.*

3 Revitalised flood hydrograph (ReFH) method

3.1 Parameters for ReFH model

Note: If parameters are estimated from catchment descriptors, they are easily reproducible so it is not essential to enter them in the table.

Method: OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer (give details)	**Tp (hours)** Time to peak	**C_{max} (mm)** Maximum storage capacity	**BL (hours)** Baseflow lag	**BR** Baseflow recharge
Brief description of any flood event analysis carried out (further details should be given below or in a project report)				

3.2 Design events for ReFH method

Urban or rural	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)
Rural	Winter	7.0	

3.3 Flood estimates from the ReFH method

Flood peak (m^3/s) for the following return periods (in years)								
2	**5**	**10**	**20**	**30**	**50**	**75**	**100**	**1000**
15.48	20.61	24.45	-	31.24	34.98	38.29	40.84	67.55

4 Discussion and summary of results

4.1 Comparison of results from different methods

This table compares peak flows from various methods with those from the FEH Statistical method for two key return periods. Blank cells indicate that results were not calculated using that method.

Ratio of peak flow to FEH Statistical peak					
Return period 2 years			Return period 100 years		
ReFH	**Other method**	**Ratio**	**ReFH**	**Other method**	**Other method**
15.48	17.504	0.88	40.84	49.075	0.83

4.2 Final choice of method

Choice of method and reasons – include reference to type of study, nature of catchment and type of data available.	*Preference has been given to the more rigorous Statistical Method over the ReFH2 method for this catchment.*

4.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	*This is a routine application of the FEH methodology.*
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed	
Give what information you can on uncertainty in the results – e.g. confidence limits for the QMED estimates using FEH **3** 12.5 or the factorial standard error from Science Report SC050050 (2008).	*The factorial standard error from Science Report SC050050 (2008) is 1.431.*
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	*These results are appropriate for flood estimation in the catchment.*
Give any other comments on the study, for example suggestions for additional work.	*See above*

4.4 Checks

What do the results imply regarding the return periods of floods during the period of record?	*n/a.*

What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 to 4.0)	*The factor of 2.804 for the Statistical Method is reasonable.*
If 1000-year flows have been derived, what is the ratio for 1000-year flow over 100-year flow?	*Ratio of 1.67 is reasonable.*
What specific runoff (l/s/ha) does the design flow equate to?	*1% annual probability flow of around 6.7 l/s/ha for the catchment is reasonable, given the SPRHOST/BFIHOST values.*
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	*None previously as detailed as this.*
Are the results compatible with the longer-term flood history?	*Results presented herein considered to be conservative but suitable for the intended analysis.*
Describe any other checks on the results	*Following hydraulic modelling, the results were consistent with the lack of flooding at the inlet to the culvert in over 50 years.*

4.5 Final results

Flood peak (m^3/s) for the following return periods (in years)								
2	5	10	*25*	50	100	200	500	1000
17.504	23.962	28.752	35.805	41.976	49.075	57.289	70.206	81.832

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, name of ISIS model, or reference to table below)	*Not needed for proposed analysis.*

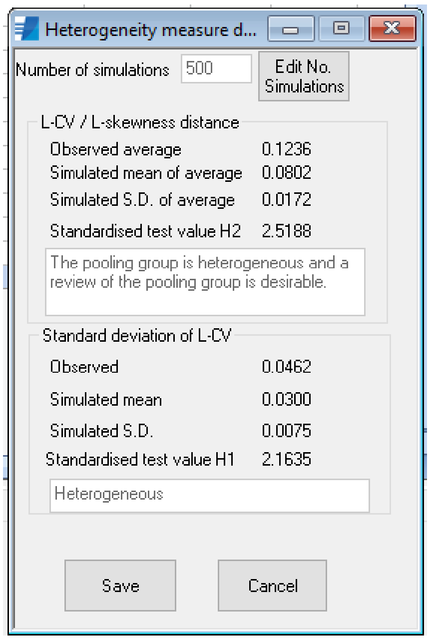
5 Annex - supporting information

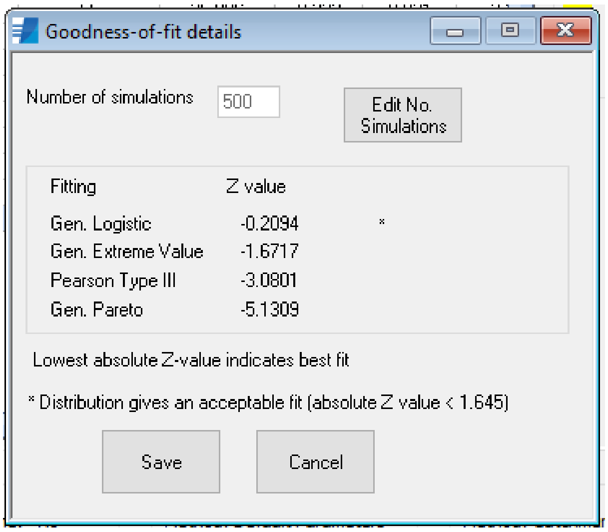
Initial and Final Pooling Group: Statistics

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
205008 (Lagan @ Drumiller)	0.217	42	27.098	0.14	-0.036	1.868
76019 (Roe Beck @ Stockdalewath)	0.242	18	41.711	0.236	0.318	1.156
203043 (Oonawater @ Shanmoy)	0.308	31	31.249	0.169	0.086	0.551
42006 (Meon @ Mislingford)	0.309	58	2.947	0.26	0.216	0.593
27059 (Laver @ Ripon Laver Weir)	0.329	40	22.024	0.231	0.334	0.498
53023 (Sherston Avon @ Fosseway)	0.334	41	7.28	0.229	0.193	0.095
52004 (Isle @ Ashford Mill)	0.366	55	35.806	0.222	0.021	2.24
51001 (Doniford Stream @ Swill Bridge)	0.38	51	11.71	0.322	0.387	1.528
42008 (Cheriton Stream @ Sewards Bridge)	0.386	46	1.35	0.255	0.408	1.01
7010 (Muckle Burn @ Brodie)	0.408	12	18.249	0.188	0.273	1.231
67009 (Alyn @ Rhydymwyn)	0.437	61	8.78	0.264	0.306	0.431
19004 (North Esk @ Dalmore Weir)	0.457	45	19.489	0.21	0.208	0.797
Total		500				
Weighted means				0.227	0.218	

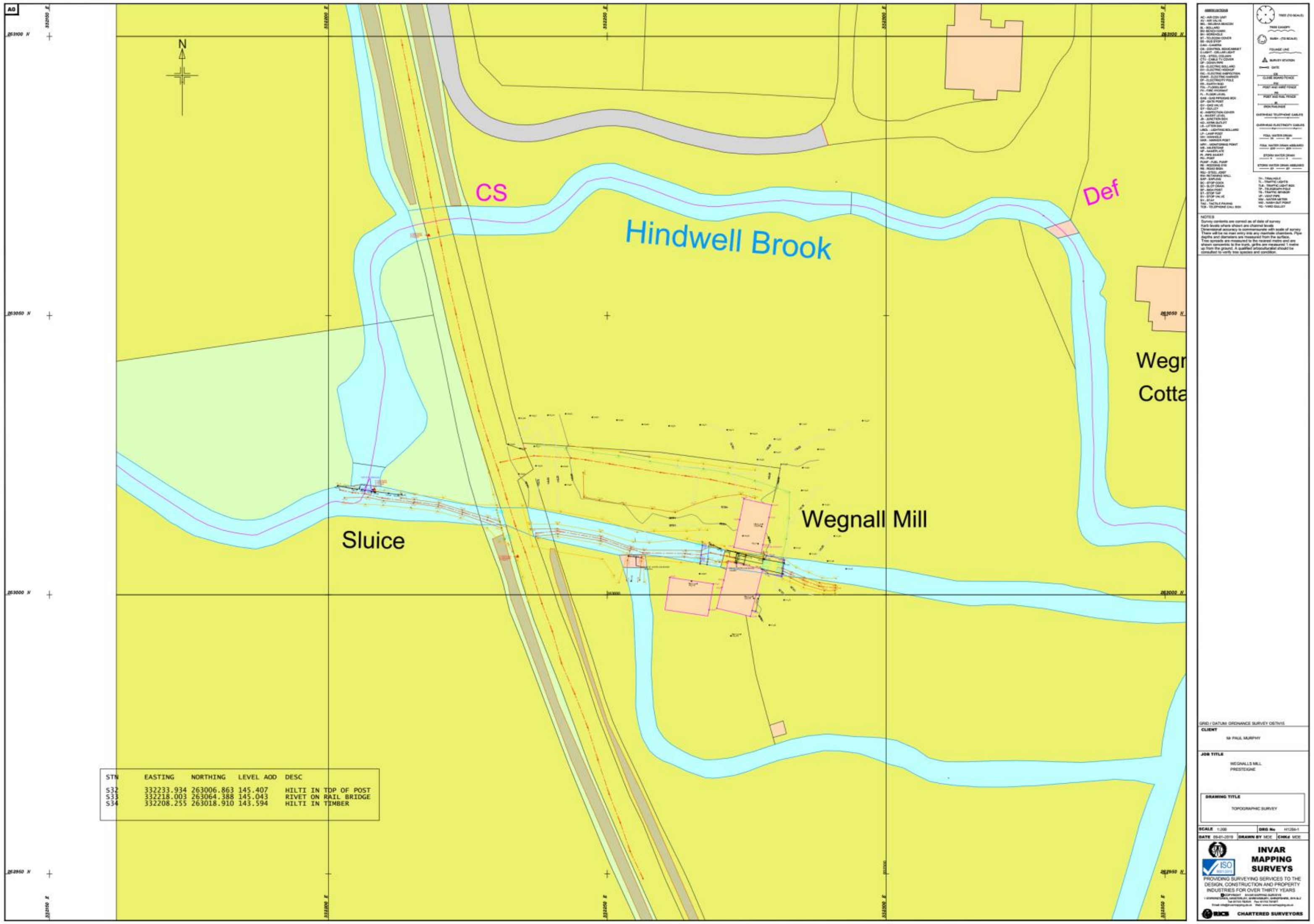
Initial and Final Pooling Group: Descriptors

Station	Distance SDM	AREA	SAAR	FPEXT	FARL	URBEXT 2000
205008 (Lagan @ Drumiller)	0.217	84.97	1016	0.069	0.992	0.001
76019 (Roe Beck @ Stockdalewath)	0.242	63.09	983	0.08	1	0
203043 (Oonawater @ Shanmoy)	0.308	88.59	1003	0.078	0.974	0.002
42006 (Meon @ Mislingford)	0.309	75.85	896	0.049	0.979	0.009
27059 (Laver @ Ripon Laver Weir)	0.329	78.44	912	0.045	0.982	0.01
53023 (Sherston Avon @ Fosseway)	0.334	77.73	835	0.07	0.999	0.009
52004 (Isle @ Ashford Mill)	0.366	87.41	891	0.084	0.979	0.026
51001 (Doniford Stream @ Swill Bridge)	0.38	74.23	911	0.038	0.988	0.011
42008 (Cheriton Stream @ Sewards Bridge)	0.386	74.34	885	0.04	0.995	0.009
7010 (Muckle Burn @ Brodie)	0.408	80.68	810	0.065	0.984	0
67009 (Alyn @ Rhydymwyn)	0.437	81.6	968	0.033	0.99	0.002
19004 (North Esk @ Dalmore Weir)	0.457	79.85	949	0.032	0.975	0.018

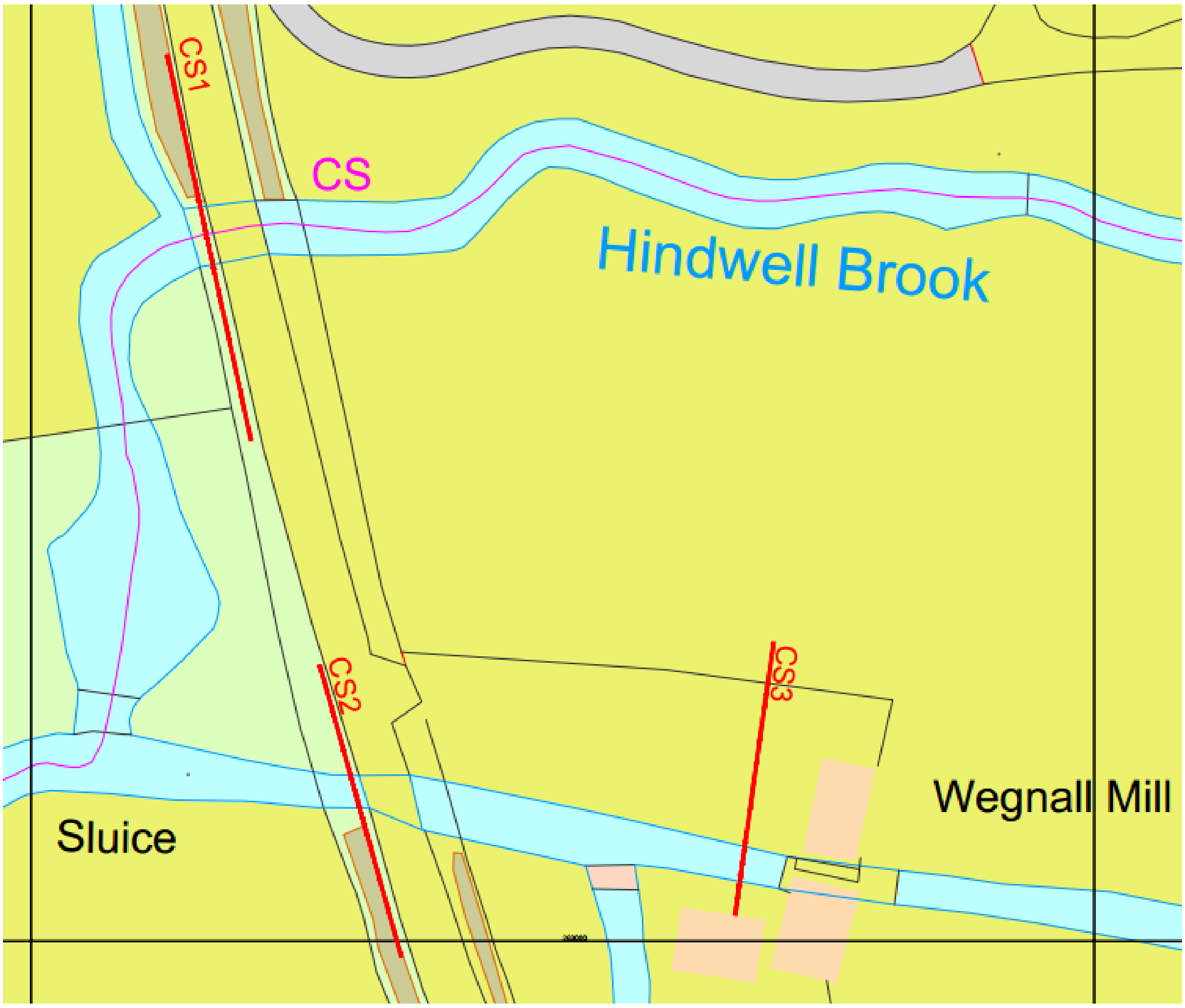

Heterogeneity measure d...
Number of simulations 500
Edit No. Simulations
L-CV / L-skewness distance
Observed average 0.1236
Simulated mean of average 0.0802
Simulated S.D. of average 0.0172
Standardised test value H2 2.5188
The pooling group is heterogeneous and a review of the pooling group is desirable.
Standard deviation of L-CV
Observed 0.0462
Simulated mean 0.0300
Simulated S.D. 0.0075
Standardised test value H1 2.1635
Heterogeneous
Save
Cancel

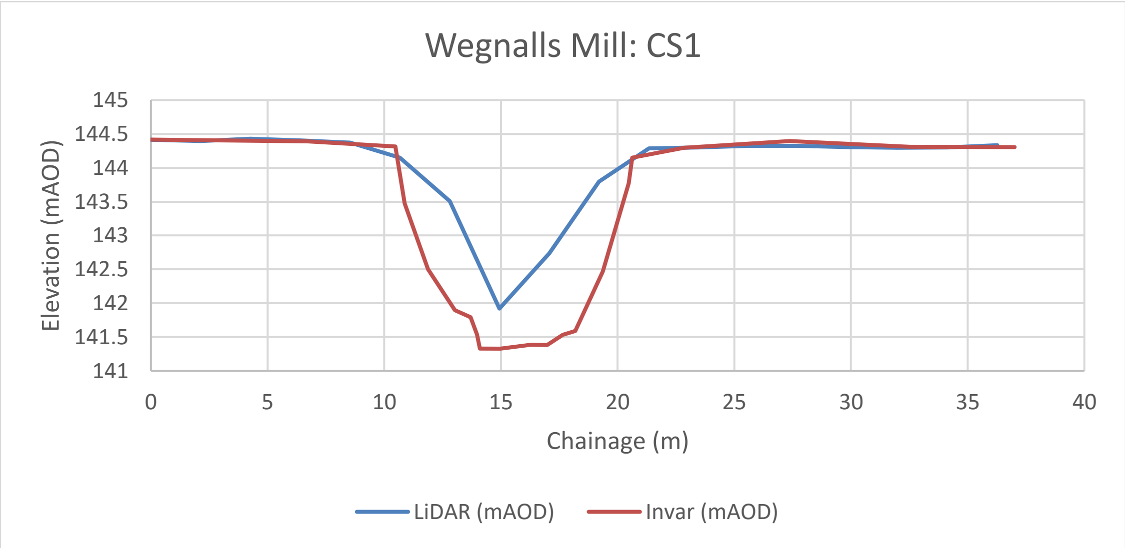

Goodness-of-fit details
Number of simulations 500
Edit No. Simulations
Fitting Z value
Gen. Logistic -0.2094 *
Gen. Extreme Value -1.6717
Pearson Type III -3.0801
Gen. Pareto -5.1309
Lowest absolute Z-value indicates best fit
* Distribution gives an acceptable fit (absolute Z value < 1.645)
Save
Cancel

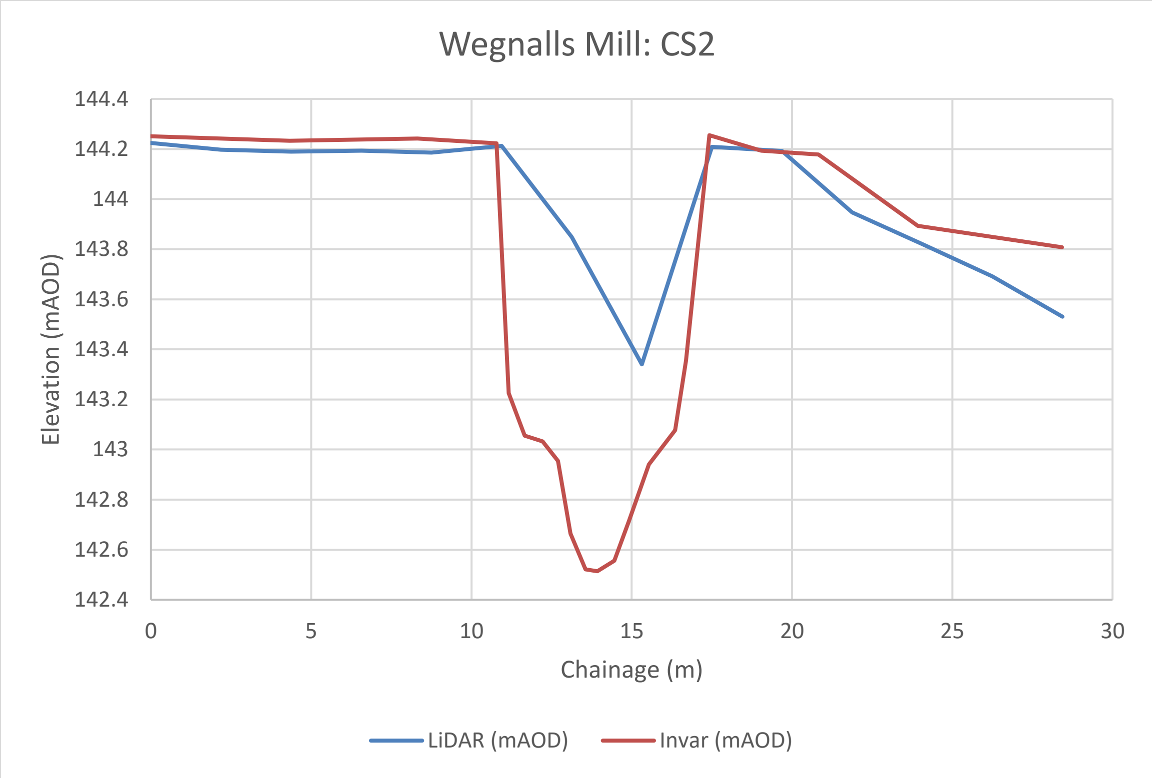
Appendix C Extract of Topographic Survey undertaken by Invar Mapping

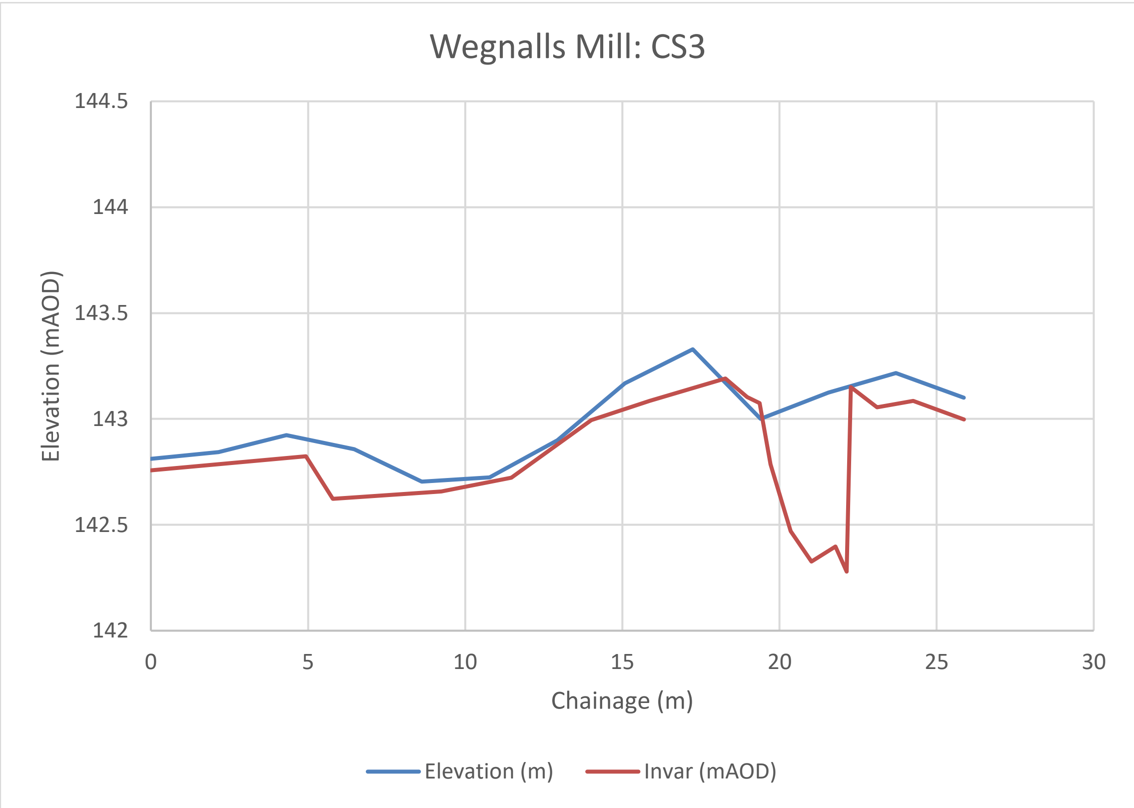


Appendix D Comparison of Levels from LiDAR with Topographic Survey






Wegnalls Mill: CS2
144.4
144.2
144
143.8
143.6
143.4
143.2
143
142.8
142.6
142.4
Elevation (mAOD)
0
5
10
15
20
25
30
Chainage (m)
LiDAR (mAOD)
Invar (mAOD)


Wegnalls Mill: CS3
144.5
144
143.5
143
142.5
142
Elevation (mAOD)
0
5
10
15
20
25
30
Chainage (m)
Elevation (m)
Invar (mAOD)

Offices at

Bromyard

Clevedon

Exeter

Reading

Sheffield

Stirling

Warrington

Registered office

Hydro-Logic Services (International) Ltd
Shearwater House,
Clevedon Hall Estate,
Victoria Road,
Clevedon,
BS21 7RD

Registered in England 03036787