highways england

A1 Birtley to Coal House

Scheme Number: TR010031

Applicant's Responses to ExA's Second Written Questions - Appendix 2.10B - Flood Modelling response to Environment Agency Comments

Planning Act 2008

Rule 8(1)(b)

Infrastructure Planning (Examination Procedure Rules) 2010

Volume 7

April 2020

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Examination Procedure Rules) 2010

A1 Birtley to Coal House Development Consent Order 20[xx]

Applicant's Response to ExA's Second Written Questions - Appendix 2.10B - Flood Modelling response to Environment Agency Comments

Rule number:	Rule 8(1)(b)
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Author:	A1 Birtley to Coal House Project Team, Highways England

Version	**Date**	**Status of Version**
Rev 0	20 April 2020	Application Issue

TECHNICAL NOTE

DATE:	28 January 2020	**CONFIDENTIALITY:**	Public
SUBJECT:	Flood Modelling Response to EA Comments		
PROJECT:	A1 BCH	**AUTHOR:**	Chris Parker
CHECKED:		**APPROVED:**	Andy Smith

INTRODUCTION

This note has been prepared to provide responses to the clarifications requested by JBA on behalf of the Environment Agency, to enable the approval of the hydraulic models that support the FRA for the Highways England A1 Birtley to Coal House scheme. This note is intended to be read in conjunction with the JBA review sheet that provides the comments in line. The ID from the JBA comment sheet has been used in the section headings in this technical memo to identify where a comment has been addressed. Only points identified in our Technical Note 1 dated 29th October and agreed with the Environment Agency (email from Lucy Mo, 14th November 2019) have been covered, in this Technical Note.

Each of the three topics in the Environment Agency review have been addressed in turn these are Hydrology, Hydraulics - River Team and Hydraulics – Allerdene Burn. This review has been supported by the provision of the following documents information have been provided to support this note:

1. JBA review sheet (2018s0387-57_A1_BCH_Review_v2
2. Updated ICM model files
3. River Team DTM
4. Allerdene Burn DTM

HYDROLOGY

ID: A-6: NO FURTHER REPORTING GIVEN ON HOW THE CHANGE IN CATCHMENT AREA INFLUENCES OTHER KEY CATCHMENT DESCRIPTORS. DPLBAR SHOULD INCREASE, AND THERE COULD BE SIGNIFICANT CHANGES TO URBEXT2000 FROM THE CHANGE IN CATCHMENT BOUNDARY. BOTH OF THESE NEED TO BE ALTERED, AND COULD HAVE A BIG EFFECT ON CALCULATED FLOWS.

The catchment area has been delineated in GIS and has been compared to the URBEXT coverage, both of which are shown in Figure 1. The catchment descriptors have been updated in line with the identified change in catchment area, these are documented in Table 1

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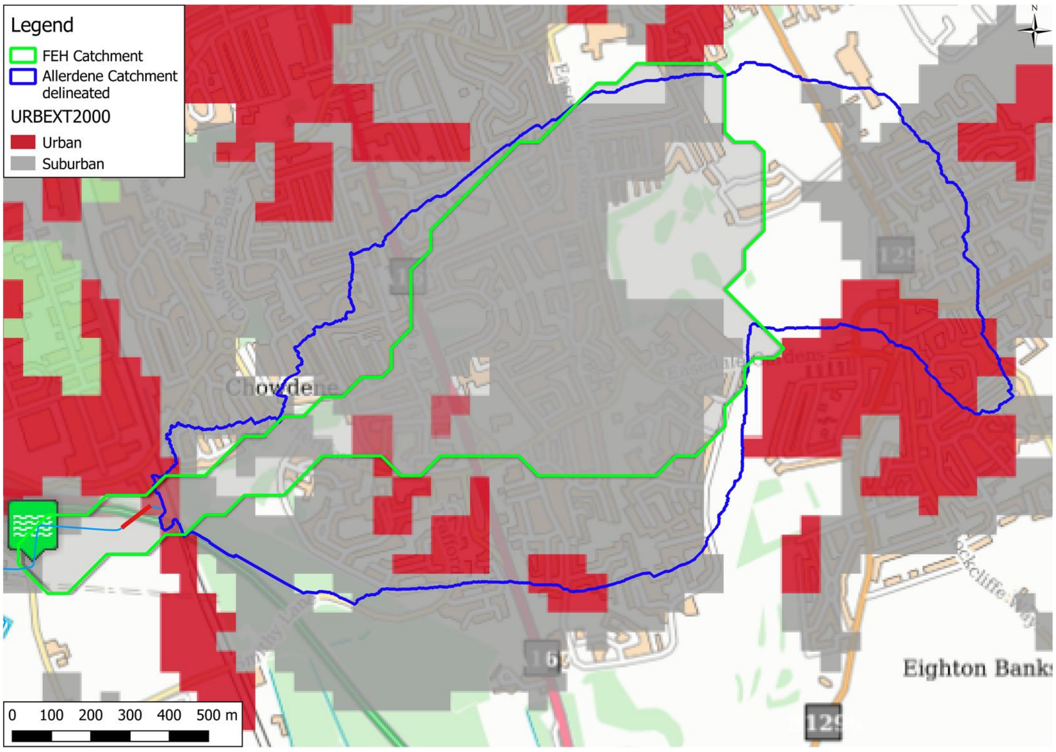

Figure 1: URBEXT Map

Table 1: Updated catchment descriptors (refined descriptors shown in red)

Descriptor	FEH Catchment	Adopted Catchment
AREA	0.9075	1.688
BFIHOST	0.682	0.682
DPLBAR	1.65	**2.31**
DPSBAR	82	82
FARL	1	1.000
SPRHOST	12.12	12.12
$URBEXT_{1990}$	0.2948	**0.4600**
$URBEXT_{2000}$	0.3747	**0.5620**

The approach and reasons for the updates to the catchment descriptors are detailed below:

- **DPLBAR** updated based on formula within FEH calc-sheet (new DPLBAR = New Area^0.548). 0.9075^0.548 = 0.948. 1.65 / 0.948 = 1.741. 1.688^0.548 = 1.33. 1.33 x 1.741 = 2.31.

- **URBEXT** updated based on determining the extent of urban / suburban areas are in the additional part of the catchment, using the URBEXT map from the FEH Webservice. Work out total percentage of urban/suburban area $URBAN_{50K}$.
- $\mathbf{URBEXT_{2000}}$ = 0.629 x $URBAN_{50K}$.
- $\mathbf{URBEXT_{2000}}$ then multiplied by UEF_{2000} for 2019 (1.04).
- **FARL** checked against online mapping and no changes are needed as there are no lakes in the additional area.
- **BFIHOST** and **SPRHOST** checked against online BGS Geology mapping and online soil mapping (soil scape). The geology and soils in the larger catchment area is still the same. Sandstone with bands of Coal measures, overlain by slowly permeable loamy and clayey soils.

The potential impact of these changes on the calculated flows is considered in response to comment A-12 which presents the latest ReFH2 flow estimates.

A-12: ADD A TABLE COMPARING FEH99 AND FEH13 RAINFALLS TO BACK UP THE ARGUMENT GIVEN IN CHAPTER 2 OF APPENDIX A. RUN THE REFH2 MODEL FOR THE 100 AND 1,000YR EVENTS WITH THE FEH13 RAINFALL ALSO, TO TEST IF THIS GIVES LARGER PEAK FLOWS, DUE TO THE "ALPHA" ISSUE.

The ReFH2 derived flows have been recalculated (within the ReFH2 software v2.2 and not within ICM) with the refined catchment descriptors as detailed in A-6, the revised flows are detailed in Table 2 and the growth curves in Figure 2, both are below, the key aspects / findings are:

- A comparison of 2013 and 1999 rainfall models along with the winter and summer storms was undertaken.
- The use of summer rainfall substantially increases flows – this has been adopted given the urban nature of the catchment.
- Flows estimated using the 1999 rainfall are marginally higher than the 2013 rainfall, as shown in Table 2.

Table 2 ReFH Flow Estimates

Peak Flow (m^3/s) at given Return Period	FEH 1999 Rainfall			FEH 2013 Rainfall		
	2.5hr	3.5hr	8.5hr	2.5hr	3.5hr	8.5hr
2	0.86	0.943	0.944	0.755	0.839	0.84
20	1.67	1.795	1.725	1.527	1.627	1.52
100	2.53	2.691	2.521	2.221	2.357	2.2
1000	4.57	4.786	4.333	4.005	4.193	3.77
Growth factor at given Return Period						
2	1	1	1	1	1	1
20	1.93	1.9	1.83	2.02	1.94	1.8
100	2.93	2.85	2.67	2.94	2.81	2.61
1000	5.29	5.08	4.59	5.3	5	4.46

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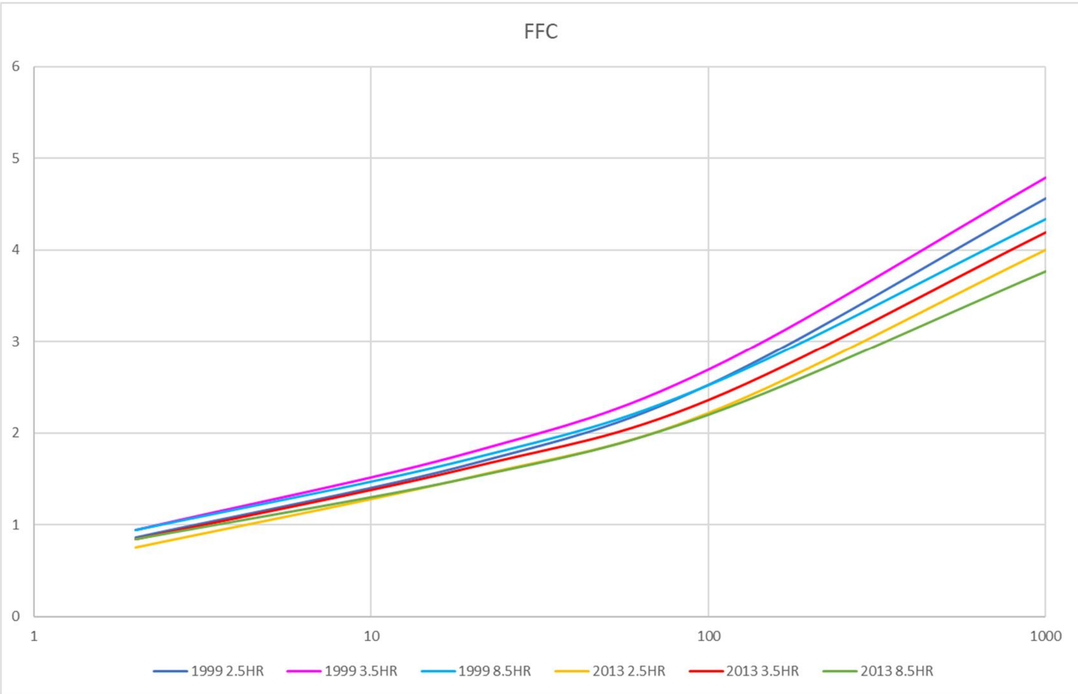

Figure 2 ReFH2 Growth Curves

A-23 (CHOICE OF DESIGN STORM): RUN THE REFH2 MODEL FOR A RANGE OF STORM DURATIONS TO SEE WHICH GIVES THE LARGEST PEAK FLOWS FOR ALLERDENE BURN.

As shown in Table 2 the ReFH2 model was run with a range of storm durations, the design duration is 3.5 hrs, as the highest flows are observed here. The impacts of different durations have been tested using 2.5-hour and 8.5-hour storms.

A-15-A-20: RUN THE FEH STATISTICAL METHOD AS A CHECK IN REFH2 RESULTS.

The FEH Statistical method has been undertaken as a check against the ReFH2 results the approach to this is outlined below:

<u>FEH STATISTICAL</u>

This has been undertaken using:
- Winfap v4.1
- NRFA Peak Flow Dataset V8

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QMED

- The Team Valley gauge is located just downstream of the catchment; however, the catchment area of this gauge is 61.9 km^2 (approximately 36x larger than the subject catchment), so it is not considered to be a suitable donor.
- The Ouse Burn at Woolsington is located approximately 13km northwest of the subject catchment, and has an area of 9km^2, however BFIHOST at this catchment is 0.312, which is significantly lower than the subject site, so it is not considered to be an appropriate donor.
- Other nearby catchments: 23007, 24009, &, 23001 are all significantly larger than the subject catchment so are not suitable donors.
- Stations 23016 and 22081 are marked as not suitable for QMED on the NRFA website.
- Therefore, QMED for the Allerdene Burn catchment has been calculated through the catchment descriptors approach, which gives 0.184 m^3/s and 0.418 m^3/s once urbanised.

POOLING GROUP

- Table 3, below, sets out the initial pooling group from WINFAP and the adjustments made to the pooling group (PG1 is the adopted group).

Table 3: Pooling group composition

Station	Distance	Years of data	QMED AM	AREA	SAAR	FPEXT	FARL	URBEXT 2000	BFIHOST	SPRHOST	PG0	PG1	Notes
76011	1.063	41	1.84	1.63	1096	0.074	1	0	0.196	58.93	Yes	No	BFI Too Low
27051	2.266	46	4.539	8.17	855	0.013	1	0.006	0.309	40.77	Yes	Yes	
45816	2.275	25	3.456	6.81	1210	0.011	1	0.005	0.59	31.27	Yes	Yes	
28033	2.564	43	4.205	7.92	1346	0.007	1	0	0.403	42.5	Yes	Yes	
25019	3.093	40	5.384	15.09	830	0.019	1	0.004	0.524	38.58	Yes	Yes	
26802	3.139	19	0.109	15.85	757	0.03	1	0	0.959	5.67	Yes	Yes	Permeable adjustment applied
27073	3.163	37	0.82	8.06	721	0.237	1	0.008	0.887	17.77	Yes	Yes	Permeable adjustment applied
91802	3.215	34	6.35	6.54	2554	0.003	0.992	0	0.397	53.31	Yes	Yes	
25011	3.216	32	15.533	12.79	1463	0.012	1	0.001	0.237	58.21	Yes	No	BFI Too Low
47022	3.254	25	6.18	13.43	1403	0.023	0.942	0.014	0.431	44.18	Yes	Yes	
71003	3.266	37	10.9	10.71	1882	0.016	1	0	0.276	54.51	Yes	No	BFI Too Low
49005	3.268	8	6.511	16.08	1044	0.023	0.991	0.006	0.627	31.92	Yes	No	Record Length too short
25003	3.346	45	15.12	11.4	1905	0.041	1	0	0.227	59.86	Yes	No	BFI Too Low
54022	3.422	38	14.988	8.75	2481	0.01	1	0	0.323	52.68	Yes	Yes	
27010	3.463	41	9.42	18.82	987	0.009	1	0.001	0.341	50.58	Yes	Yes	
206006	3.503	48	15.33	14.44	1704	0.023	0.981	0	0.336	51.72	No	Yes	
44008	3.565	39	0.448	20.18	1012	0.015	1	0.004	0.811	19.53	No	Yes	Permeable adjustment applied
27032	3.894	52	3.923	22.25	1433	0.021	0.997	0	0.252	57.36	No	No	BFI Too Low
36010	3.911	51	7.5	27.58	588	0.045	0.999	0.007	0.387	44.57	No	Yes	
49003	3.968	52	13.985	21.61	1628	0.064	0.998	0	0.379	47.75	No	Yes	

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PERMEABLE ADJUSTMENTS

As the subject catchment has an SPRHOST of 12.12%, permeable adjustments are necessary (based on guidance detailed in FEH Volume 3, which states this is required for catchments with an SPRHOST less than 20%). In the adopted pooling group (PG1), three catchments were identified as needing permeable adjustments (26802, 27073 & 44008). The final growth and flood frequency curves are detailed in Table 4.

Table 4: PG1 Permeable Adjustment Results

Return Period	**2**	**10**	**20**	**30**	**50**	**100**	**200**	**500**	**1000**
Growth Curve	1.00	1.744	2.088	2.308	2.610	3.072	3.604	4.437	5.183
Flood Frequency Curve	0.418	0.729	0.873	0.965	1.091	1.284	1.506	1.855	2.166

REFH1

As a further check the ReFH1 method has also been used the findings are below:

PARAMETERS FOR REFH MODEL – FEH1999 RAINFALL

Site code	**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
Allerdene_001	CD	0.736	545.275	14.854	1.646

DESIGN EVENTS FOR REFH METHOD

Site code	**Urban or rural**	**Season of design event (summer or winter)**	**Storm duration (hours)**	**Storm area for ARF** (if not catchment area)
Allerdene_001	Urban	Summer	1.25	-

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FLOOD ESTIMATES FROM THE REFH METHOD

Site code	Flood peak (m^3/s) for the following return periods (in years)			
	2	**20**	**100**	**1000**
Allerdene_001	0.491	0.941	1.342	2.718
Growth curve_001	*1*	*1.916*	*2.733*	*5.536*

COMPARISON OF METHODS

To ensure that the most appropriate flows are used within the hydraulic model to understand the potential impacts of the Scheme on the flood regime a comparison of the methods, as refined, in light of the discussion in the previous sections, is presented below:

Table 5: Flood Frequency Curve comparison

Peak Flow (m^3/s) at given Return Period	ReFH2		ReFH1	FEH Statistical Method	Results from previous study
	FEH 1999	FEH 2013			
2	0.943	0.839	0.491	0.418	-
20	1.795	1.627	0.941	0.729	-
100	2.691	2.357	1.342	1.204	1.996
1000	4.786	4.193	2.718	2.166	3.576

Table 6: Comparison of the effect of FEH 1999 and 2013 winter and summer rainfall on Growth factors of ReFH2 flows

Growth Factor at given Return Period	ReFH2		ReFH1	FEH Statistical Method
	FEH 1999	FEH 2013		
2	1.000	1.000	1.000	1.000
20	1.904	1.940	1.916	2.088
100	2.854	2.810	2.733	3.072
1000	5.076	4.998	5.536	5.183

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The tables outline the differences between the results from the different ReFH2 runs and the FEH statistical method, this demonstrates that:

- The flows from the FEH statistical method are significantly lower.
- Whilst the growth curves for ReFH2 and FEH Statistical are similar, the QMED (derived from the statistical method) is significantly lower hence the lower flows at the higher return periods.

In light of this assessment we have adopted the ReFH2 flows with FEH 2013 rainfall for use within the assessment because:

- Given the permeable nature of the catchment, ReFH flows are unreliable.
- The FEH Statistical method is often preferred for permeable catchments and a permeable adjustment was undertaken, however the flows from this method are substantially lower than the ReFH2 flows, therefore the ReFH2 flows are preferred as a more conservative approach.
- Although using the FEH1999 rainfall within ReFH2 does give slightly larger flows than FEH2013 rainfall, the FEH1999 rainfall uses the alpha factor which is not reliable in permeable catchments. Given that the subject site is permeable, using the FEH2013 rainfall is deemed more appropriate.

As part of the addressing the hydraulics comments the models have been re-run with the adopted flows. Any significant changes / implications are discussed in the relevant sections below.

ID: A-1 WHY WAS FLUVIAL MODELLING NOT UNDERTAKEN AT LONGACRE DEAN; AND

ID: A-32 THERE IS NO INFORMATION GIVEN ON THE RANGE OF STORM DURATIONS USED IN THIS DIRECT RAINFALL MODELLING IN THE REPORT.

The Scheme has the potential for significant impacts on the Allerdene Burn as the culvert will be replaced (Allerdene Embankment Option) or a new channel will be constructed (Allerdene Viaduct Option), greater certainty in the flows and associated impacts were required.

In the Longacre Dean catchment a direct rainfall model was utilised, a separate fluvial model was not deemed necessary as:

- The risks to the scheme as a result of fluvial flooding were not considered to be significant
- The proposals do not impact the main channel.

This is because at Longacre Dean the culvert is substantially lower than the road, with no flow route on to the A1. The surface flow routes to the channel are of interest and the main risk to the Scheme in this area was identified as being surface water related associated with the slip road for which the potential flow routes and depths were assessed.

The ReFH2 software was used to develop the net hyetographs for use within the model, as part of this the 1, 3, 6 & critical duration (hr) storms were assessed for both the 1999 and 2013 rainfall. The model has been run with the 1, 3 and 6 hour durations, which confirm that the 1 hour produces the most flooding, in

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the area of interest. However, as requested all the durations have been run and the results merged to obtain the greatest flood depths. The resultant 1 in 100 year flood map is shown on Figure 3.

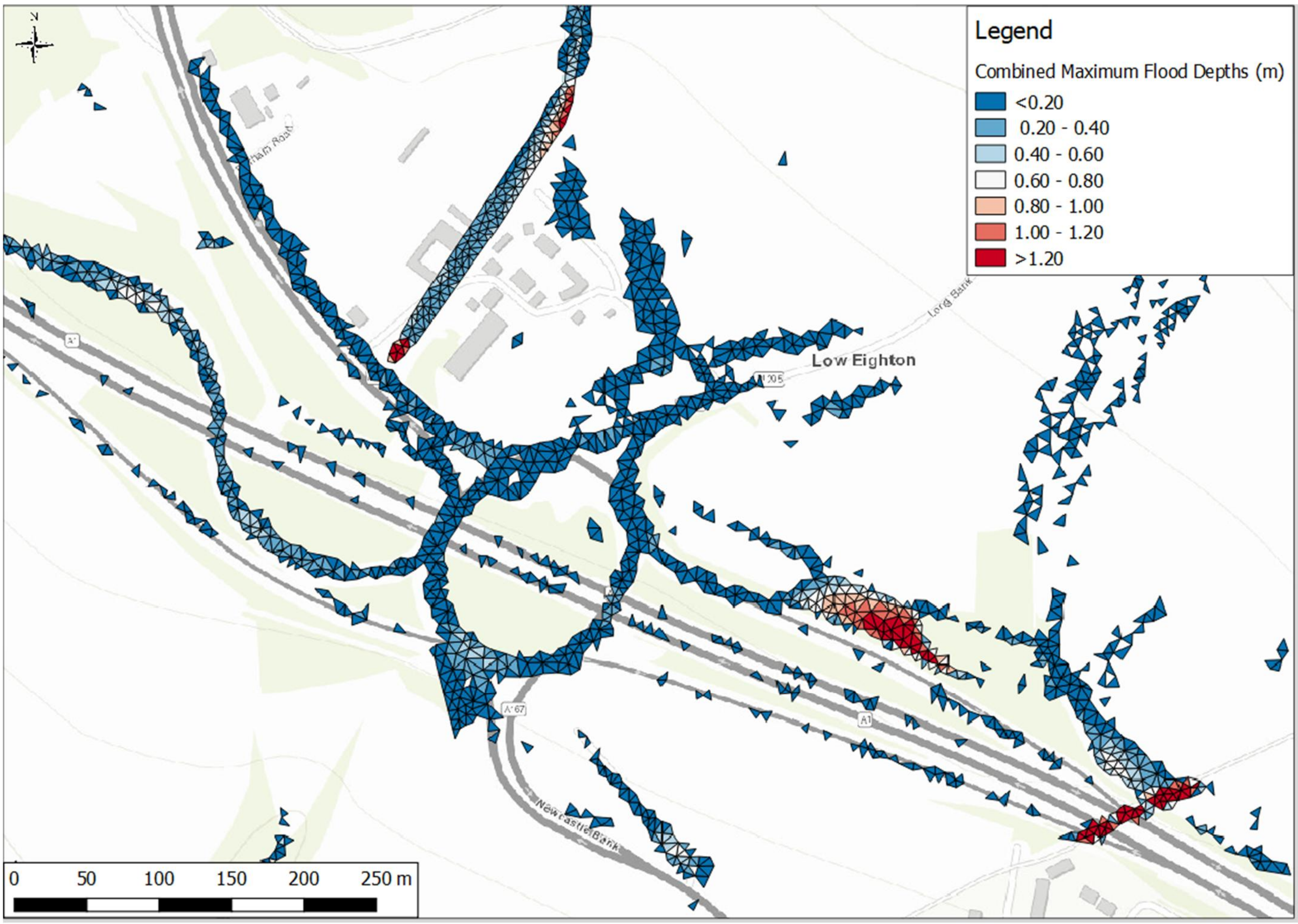

Figure 3: J66 Flood Depths for the 1 in 100 year (1%) event

The hyetograph's were developed using the catchment descriptors for the Allerdene Burn FEH catchment (after undertaking checks against the available online mapping, which identified that the values for BHIHOST, SPRHOST and FARL were deemed appropriate) with AREA, DPLBAR & URBEXT adjusted as described below, with the resultant descriptors contained in Table 7.

Table 7 Junction 66 Catchment Descriptors

Descriptor	Allerdene FEH Catchment	LiDAR J66 catchment
AREA	0.9075	0.817
BFIHOST	0.682	0.682
DPLBAR	1.65	**1.56**
DPSBAR	82	82
FARL	1	1.000
SPRHOST	12.12	12.12
URBEXT2000	0.3747	**0.236**

- **DPLBAR** updated based on formula within FEH calc-sheet (new DPLBAR = New Area^0.548). 0.9075^0.548 = 0.948. 1.65 / 0.948 = 1.741. 0.817^0.548 = 0.895. 0.895 x 1.741 = 1.558.
- **URBEXT** updated based on determining the extent of urban / suburban areas are in the additional part of the catchment, using the URBEXT map from the FEH Webservice. Work out total percentage of urban/suburban area $URBAN_{50K}$
- $\mathbf{URBEXT_{2000}}$ = 0.629 x $URBAN_{50K}$.
- $\mathbf{URBEXT_{2000}}$ then multiplied by UEF2000 for 2019 (1.04).
- **FARL** checked against online mapping and no changes are needed as there are no lakes in the additional area.
- **BFIHOST** and **SPRHOST** checked against online BGS Geology mapping and online soil mapping (soil scape). The geology and soils in the larger catchment area is still the same. Sandstone with bands of Coal measures, overlain by slowly permeable loamy and clayey soils.
- For **URBEXT** there are 0.295km^2 of urban / suburban area as measured from the georeferenced UBREXT map in QGIS.
- $URBAN50k$ = 0.295/0.817 × 100 = 36.11%
- **URBEXT** = 0.227 pre UEF adjustment and 0.236 post UEF adjustment

HYDRAULICS - RIVER TEAM

ID: B-16 PROVISION OF DIGITAL TERRAIN MODELS

A digital terrain model that incorporate topographic survey has been provided.

ID: B-29 MODEL STABILITY AND B-143 OUT OF BANK OSCILLATIONS

Lowering the bank line modular limit to 0.6 for the TEAM_5156.1 river reach improved left bank flow for the option model, as shown in Figure 4, but caused the original basemodel provided by the EA to fail. The change in modular limit had no impact on in channel flows. The stability problem seems to be a wider issue with the model for example, river reach TE05820.1 directly upstream of the Kingsway Viaduct, shown in Figure 5, shows significant oscillations to in channel and left bank flows. Resolving stability issues with the wider approved and provided Environment Agency model (as developed by JBA) is not required as part of the evidence base for the Scheme. This is because the A1 is significantly elevated above the River Team and its associated floodplain at this point on a viaduct and the only impacts occur in the future climate change scenarios when the additional bridge piers require a small amount of floodplain compensation ($12m^3$). The model is therefore considered suitable to assess the scale and nature of the proposed impacts.

An attempt was made to improve channel conveyance of river reach TEAM_5156.1 however, this resulted in the model failing to run.

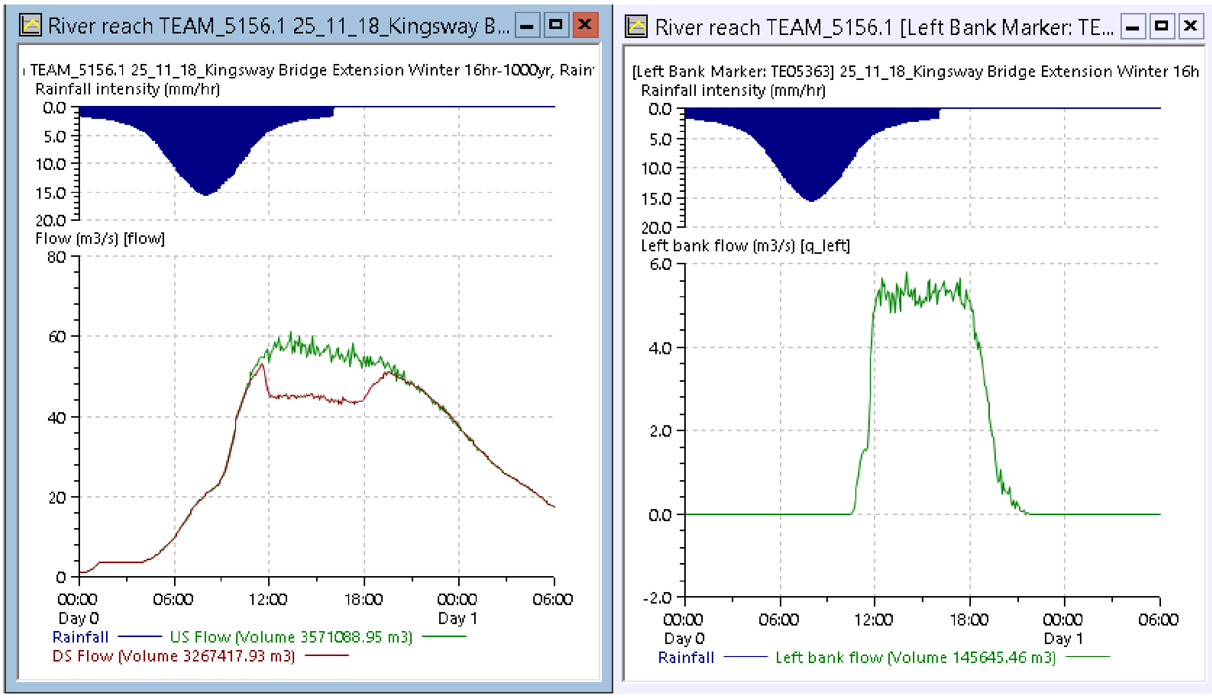

Figure 4: Improvements to channel and left bank flows for the Kingsway Viaduct river reach (TEAM_5156.1) because of lowering the bank modular limits to 0.6 (option model)

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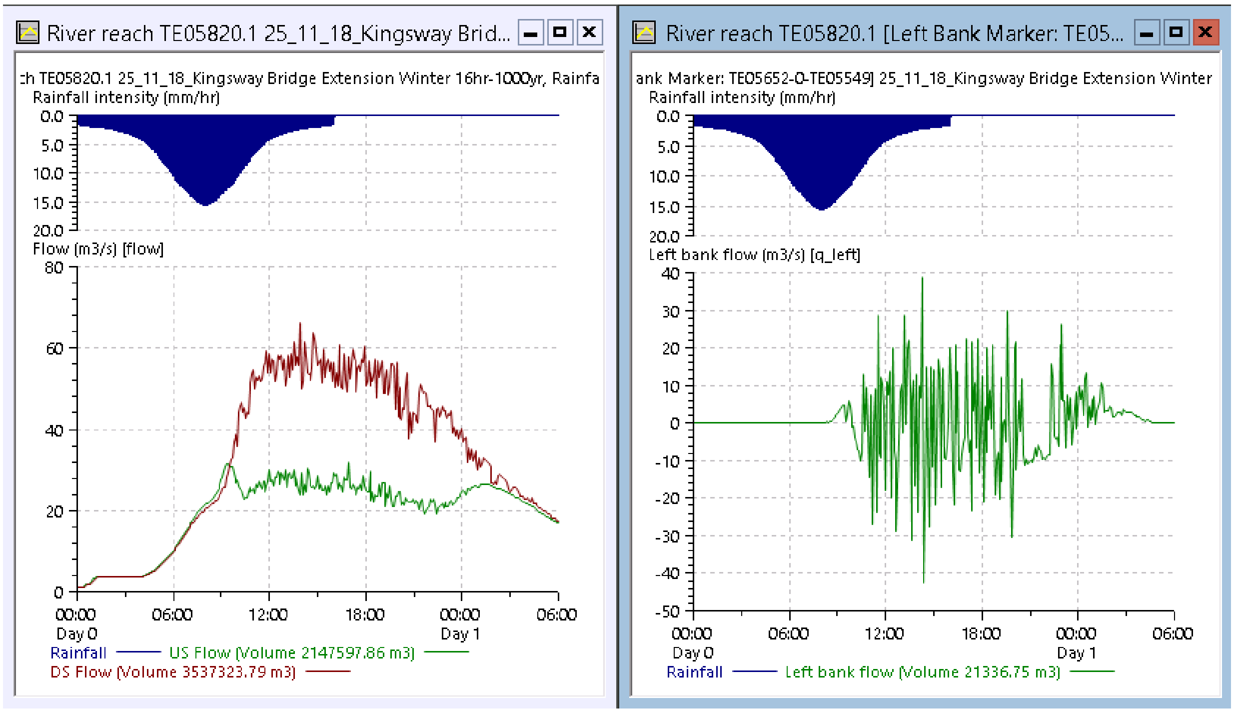

Figure 5: Channel and left bank flows for the river reach TE05820.1, directly upstream of the Kingsway Viaduct, showing stability issues for the 1 in 1000 year flow event highlighting the stability issue with the wider model (option model)

ID: B-137 SENSITIVITY TESTS

The sensitivity tests were not originally provided however, only sensitivity of channel roughness was undertaken and this is summarised below:

Table 8: Sensitivity Analysis for the River Team at the Kingsway Viaduct

Sensitivity Test	Model changes	Description of sensitivity test and outcome
Downstream Boundary	Channel Roughness Mannings +/- 20%	Channel Mannings roughness value in the model was varied by +/- 20%. Increasing channel roughness has minimal impact on maximum predicted depths at the Kingsway Viaduct reach (Team_5156.1), shown in Figure 10, with depth varying by +0.034m to -0.045m. This is considered to be within the acceptable model tolerance limits.

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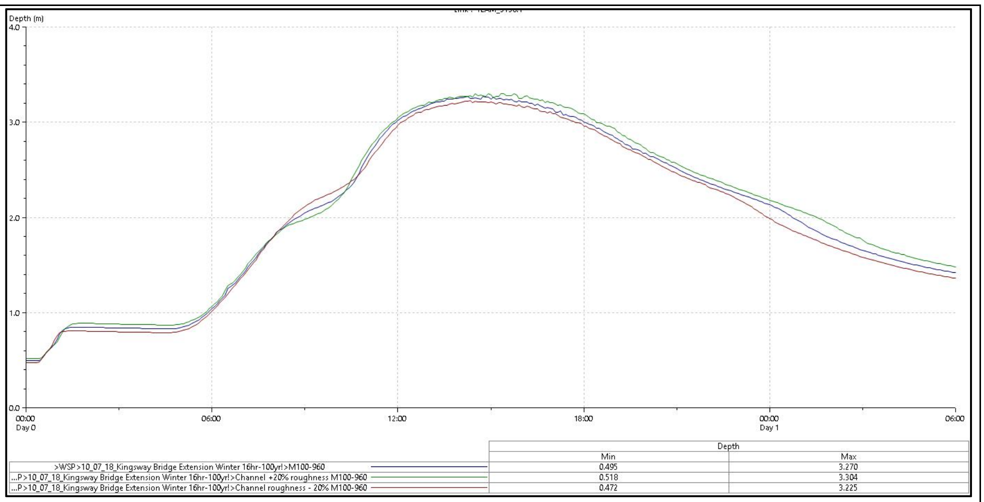

Figure 6: Flow hydrographs (top) and water depth (bottom) at the Kingsway Viaduct river reach for 1 in 100 year flows.

ID: B-139 BASELINE 0.1% EVENT

The baseline 0.1% event has now been run to completion, this required changes to the tolerances, however, it did not establish any issues.

ID: B-137 MODEL PERFORMANCE TESTS

No calibration was undertaken as this was deemed outside of the scope of the project considering both the minor amendments made to the model and the proposed A1 scheme. As outlined above only approximately 12m^3 of flood plain compensation is required for the additional bridge piers

HYDRAULICS - ALLERDENE BURN

INTRODUCTION

The updates to the hydrology as detailed previously have resulted in increases to the peak flows, unfortunately this means that the original mitigation options no longer perform as intended. Therefore, the mitigation options have been refined to maintain or improve current flood risk.

Error! Reference source not found. shows the modelled predicted peak flows prior to and following the revision to the hydrology. The refinements to the mitigation has included the incorporation of additional flow controls within the proposed channels to maximise channel storage. Full descriptions of the options can be found in the Scenario Clarification section below. These mitigation options have been progressed to the same level of detail as those originally proposed within the FRA and the Road Drainage and Water Resources ES Chapter, in that they are appropriately designed for this stage and will require refinement during the detail design phase.

Table 9 : Predicted peak flows at river reach ST02 DS.1 for the Baseline Scenario and Options 1 and 2, grey and green cells show the predicted peak flows prior and following the hydrology revision respectively.

Hydrology	Scenario	Flood Peaks Flow (m^3/s)			
		1 in 100 year (1% AEP)	1 in 100 year (1% AEP+25%)	1 in 100 year (1% AEP +50%)	1 in 1000 year (0.1% AEP)
Original	Baseline	2.16	2.53	2.68	2.85
	Option 1	2.10	2.51	2.65	2.83
	Option 2	2.14	2.53	2.70	2.82
Revised	Baseline	2.36	2.63	2.80	2.94
	Option 1	2.28	2.63	2.64	2.65
	Option 2	2.21	2.44	2.47	2.47

ID: B-8 SCENARIO CLARIFICATION

Two options have proposed in the ES with respect to the Allerdene Bridge replacement and the modifications to the Allerdene Culvert:

1. Allerdene embankment option, whereby the Allerdene Culvert will be lengthened downstream to accommodate the bridge replacement and the upstream section will be daylighted to reduce the length of the resulting culvert. Furthermore, an approximate 300m of the open section of the watercourse downstream will be realigned parallel to the new bridge.
2. ii. Allerdene viaduct option: whereby the Allerdene Culvert will be replaced by an engineered open channel and the existing watercourse downstream will be realigned to accommodate the new viaduct. The proposed channel (new section and realignment) will be approximately 620m in length and will run under one of the bridge spans of the new structure.

The model scenarios have been simplified in the ICM model with only the baseline model and two option models being provided. The option scenarios have been renamed Option 1 and Option 2 in ICM for simplicity.

- Option 1 – Allerdene Embankment Option
- Option 2 – Allerdene Viaduct Option

Figure 7 shows the baseline configuration / model schematisation.

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CHECKED:		**APPROVED:**	Andy Smith

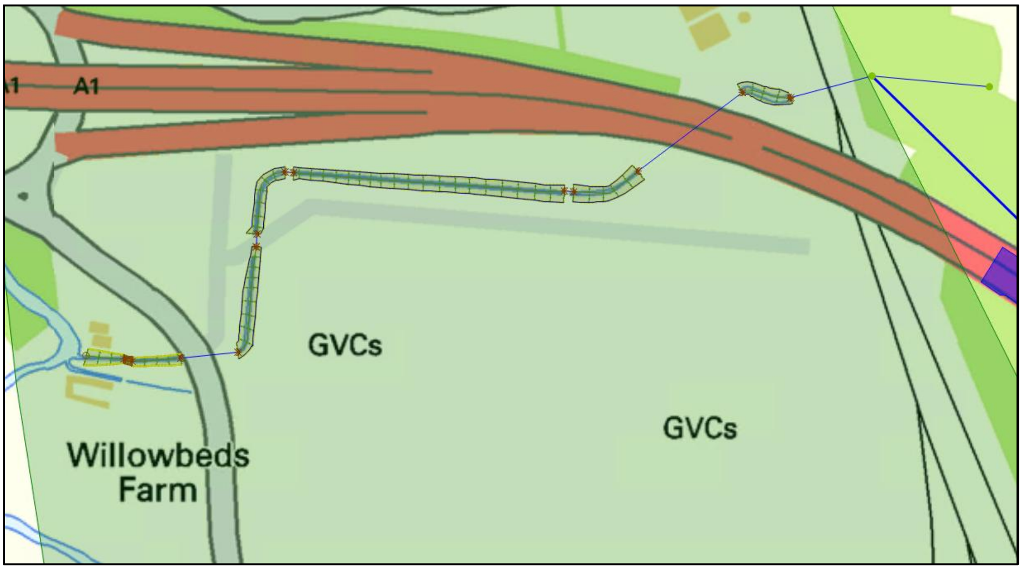


Figure 7: Existing model channel configuration

Option 1: requires the extension of the existing Allerdene culvert and realignment of the drainage channel. The proposed drainage channel includes the replacement of four culverts, these are to be replaced with, a 1200mm diameter circular culvert at the downstream end of the channel and a 1350mm and two 1200mm circular culvert at intervals along the channel. In addition, a 900mm diameter circular orifice plate at the upstream end of the existing culvert. These are designed to mimic the existing channel structure, which has three 1350mm culverts, to attenuate peak flows and maximise the available channel storage. The locations and sizes of the flow control structures are shown in Figure 8.

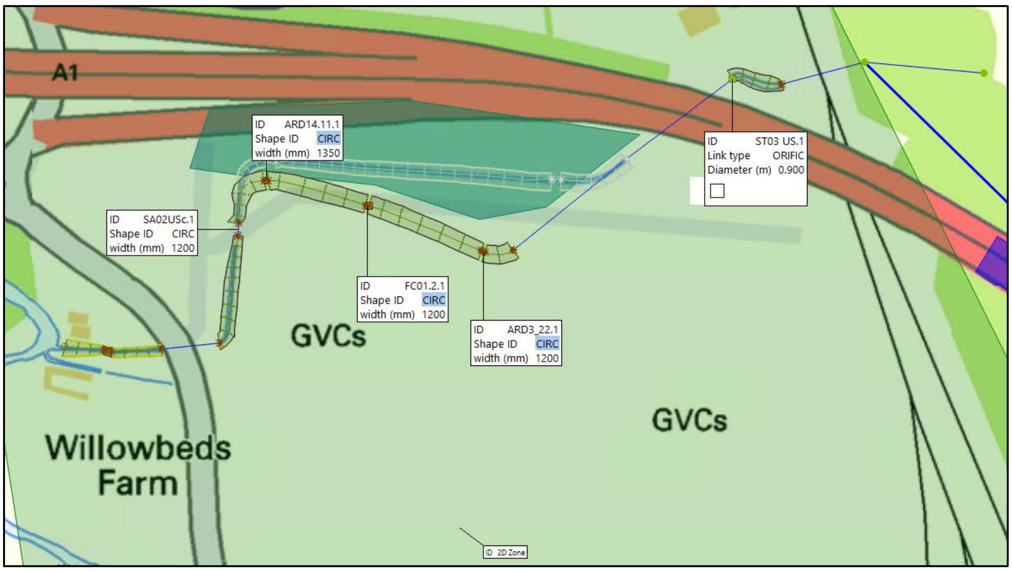


Figure 8: Option 1 channel alignment and flow control locations

Option 2: Requires the daylighting and replacement of Allerdene culvert with a new section of open channel and realignment of the existing channel to accommodate the construction of a new viaduct over the adjacent railway line. Like Option 1 the new drainage channel includes four 1200mm diameter circular flow control culverts, one at the downstream end and three at intervals along the new channel to attenuate peak flows. Figure 9 shows the alignment of the new channel and location of the flow control culverts.

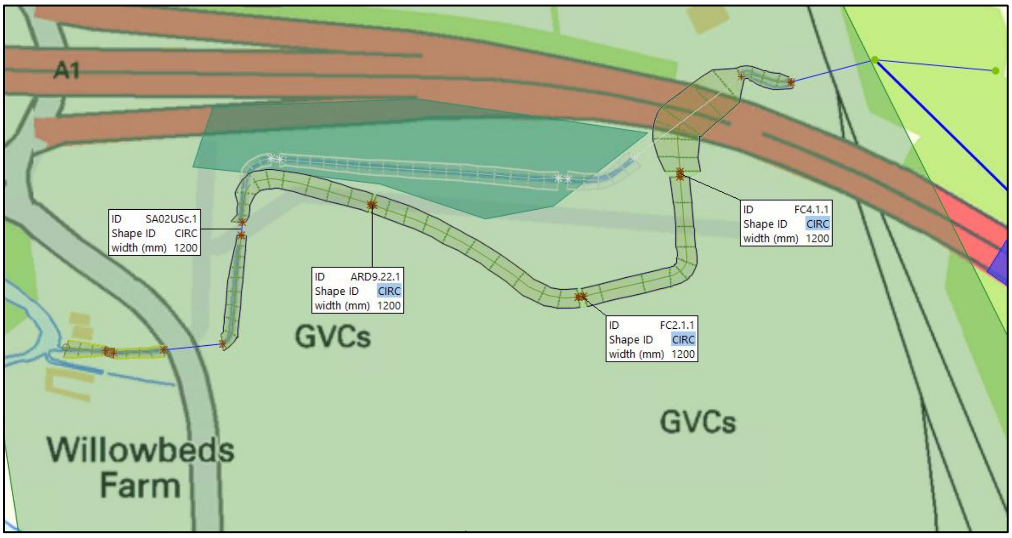


Figure 9: Option 1 channel alignment and flow control locations

ID: B-14 PROVISION OF DIGITAL TERRAIN MODELS

Digital terrain models of the existing model and two options have been provided.

ID: B-31 WATERCOURSE BANK LINES (EXISTING MODEL)

For the existing model the banklines were interpolated between survey sections, as the existing channel (for most of its length) is a uniform shape. At the time of survey, the channel was mainly within dense scrub and woodland therefore there is low confidence in the Lidar data which is one of the main reasons for using interpolation of survey data.

ID: B-42 REPRESENTATION OF ROADS AND BUILDINGS

The Allerdene model covers a small area and this level of detail is not required in this instance.

ID: B46 & B47 WATERCOURSE CONVEYANCE (OPTION MODELS)

For the option models the watercourse cross sections have been trimmed to top of banks at the sections identified and panel markers added to improve conveyance at higher flows.

TECHNICAL NOTE

DATE:	28 January 2020	**CONFIDENTIALITY:**	Public
SUBJECT:	Flood Modelling Response to EA Comments		
PROJECT:	A1 BCH	**AUTHOR:**	Chris Parker
CHECKED:		**APPROVED:**	Andy Smith

ID: B145 & B152 SENSITIVITY TESTING

Sensitivity testing has been undertaken on the Allerdene Burn for the downstream boundary, the channel roughness and flow duration, these are summarised in Table 10.

Table 10: Sensitivity Analysis for the Allerdene Burn

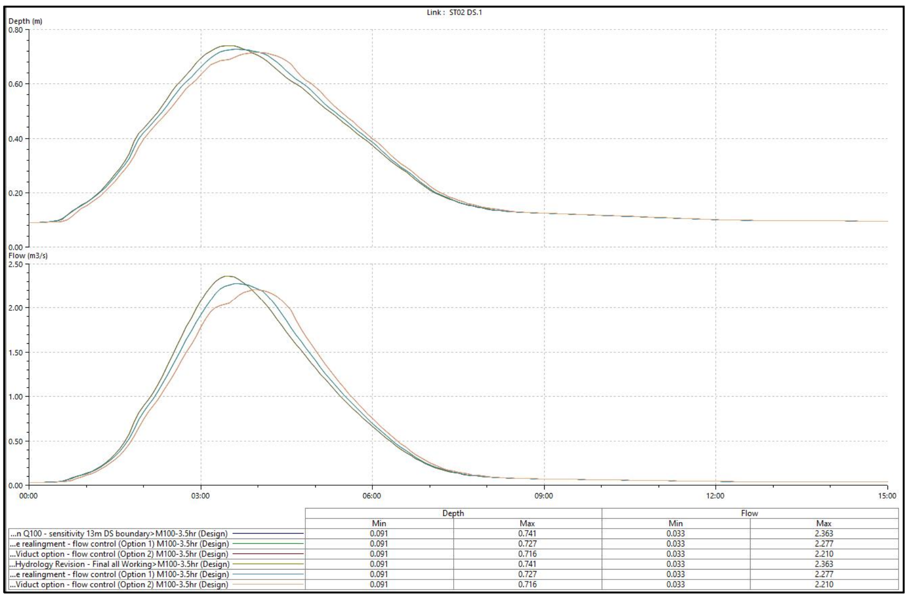
<table>
<tr><th>Sensitivity Test</th><th>Model changes</th><th>Description of sensitivity test and outcome</th></tr>
<tr><td>Downstream Boundary</td><td>Set downstream boundary to 13m AOD</td><td>
The original downstream boundary was taken from the River Team model for the matching critical duration for the closest cross section to the confluence with the Allerdene Burn. To test the impact of the downstream boundary on the model a boundary level of 13m AOD has been applied. The River Team model demonstrates that this is approximately the highest level predicted for the 1 in 1000 year critical duration event at the confluence with the Allerdene Burn.
Results indicate that an extreme downstream boundary has no impact on the 1 in 100 year flows or depths. Figure 10 shows peak flows and depth for the 1 in 100 year event at the river reach ST02 DS.1. As there is negligible difference between the design and boundary test runs, the test run results mirror the design run, hence no impact and thus it is not visible.


Figure 10: Flow hydrographs (top) and water depth (bottom) at river reach ST02 DS.1 for 1 in 100 year flows.
</td></tr>
</table>

TECHNICAL NOTE

DATE:	28 January 2020	**CONFIDENTIALITY:**	Public
SUBJECT:	Flood Modelling Response to EA Comments		
PROJECT:	A1 BCH	**AUTHOR:**	Chris Parker
CHECKED:		**APPROVED:**	Andy Smith

<table>
<tr>
<td>Channel Roughness</td>
<td>Channel Roughness Mannings +/- 20%</td>
<td>
Increasing channel roughness by ±20% has no impact on peak flows (Figure 10). However, for channel depths it does cause the maximum depth to vary by approximately 140-150mm (Figure 11) or approximate ±70-80mm compared with the baseline roughness values. This is considered to be within the acceptable model tolerance limits.

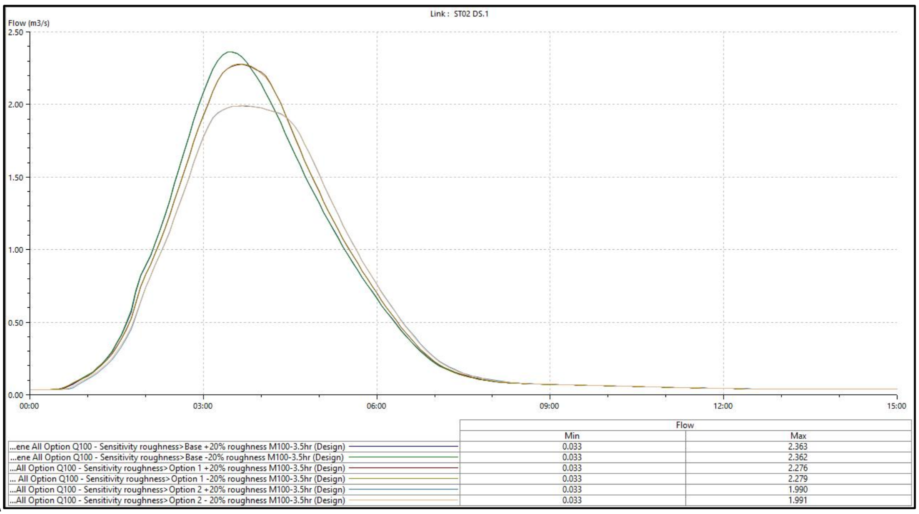


Figure 11: Flow hydrographs at river reach ST02 DS.1 for 1 in 100 year flows with varying roughness

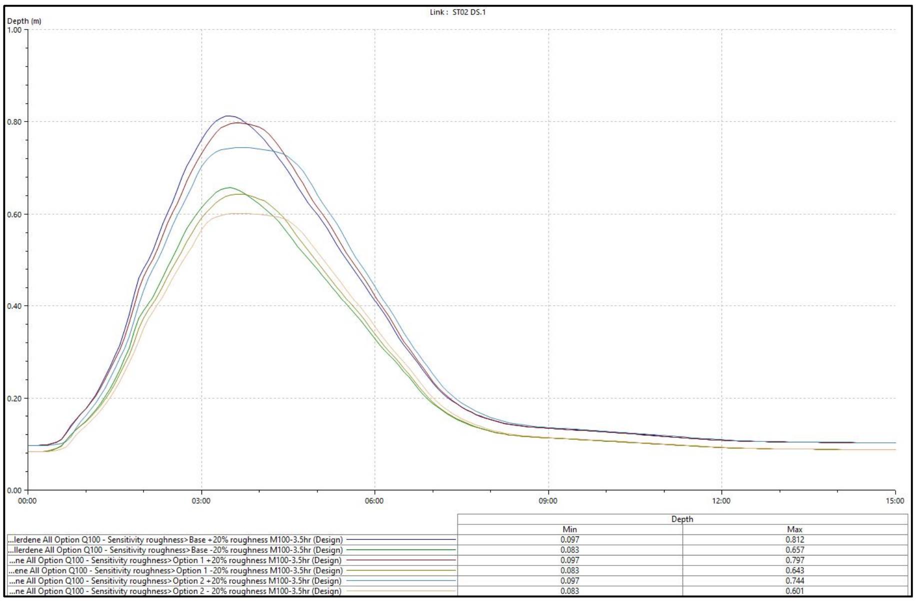


Figure 12: Water depth at river reach ST02 DS.1 for 1 in 100 year flows with varying roughness.
</td>
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</table>

TECHNICAL NOTE

DATE:	28 January 2020	**CONFIDENTIALITY:**	Public
SUBJECT:	Flood Modelling Response to EA Comments		
PROJECT:	A1 BCH	**AUTHOR:**	Chris Parker
CHECKED:		**APPROVED:**	Andy Smith

<table>
<tr><th></th><th></th><th></th></tr>
<tr>
<td>Flow duration</td>
<td>Run 1 in 100 year 2.5 and 8.5 hour duration flows</td>
<td>
Flows for the 1 in 100 year 2.5 hour and 8.5 hour duration where run to test the model sensitivity to different length flood events (Figure 13). Results show that the highest flow is achieved for the 3.5 hour duration flow hydrograph which was used as the critical design event.

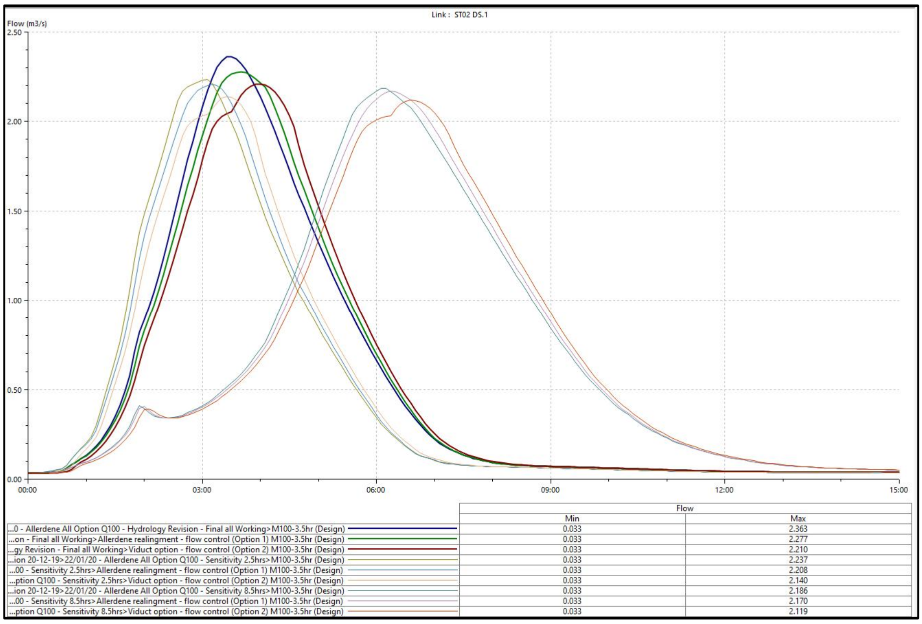


*Figure 13: Flow hydrographs at river reach ST02 DS.1 for 1 in 100 year flows for 2.5, 3.5 (**shown in bold**) and 8.5 hour durations.*
</td>
</tr>
</table>

ID: B-153 MODEL PERFORMANCE TESTS

As the Allerdene burn is a minor watercourse with no available event data for calibration. The model performs well for all flow conditions modelled including the extreme 1 in 1000 year and 1 in 100 +50% climate change allowance.

Technical Model Review Report		
Client	Environment Agency	
Single project or WEM package?	WEM Package	
Package name (if applicable)	2018-19 National Modelling and Forecasting Technical Support Contract	
Project name	Review No. 57 - A1 Birtley to Coal House	
JBA Project Number (or overarching project)	2018s0387	
JBA Sub-Project Number (if applicable)	57	
Review requirements	A) Previous project - hydrology	
	B) Previous project - hydraulic	
	C) New project - hydrology	Yes
	D) New project - hydraulics	Yes
	E) Survey data	
	F) Reporting	

"RAG" key	
Major issue	Omission that could make the findings subject to challenge and which requires correction/further work.
Minor issue	Non-standard method or method not following guidance but unlikely to have impacted on results
Clarification required	The approach used is unclear and requires further clarification before it can be reviewed
Recommendations	Suggestion for improved / good practice but which is unlikely to change the project outcomes.
Acceptable (but does not meet best practice)	The approach is acceptable, however it is not in line with standard industry best practice
Acceptable	Suggestion for improved / good practice but which is unlikely to change the project outcomes.

Summary of 1st hydrology review findings

Hydrology review

A few suggestions have been given below, which may give more conservative results. The reporting in Appendix A regarding the inflow calculations would benefit from additional detail , but is generally well written. The maps provided are excellent and are very helpful.

There are a few omissions that should be addressed, see individual comments below.

Summary of 1st hydraulics review findings

Allerdene Burn model:

Minor issues have been identified. Generally the baseline model and option 1 are well constructed. There were some issues identified in Option 2 that could be impacting the results. Therefore it is recommended that this model is revised.

As for all modelling studies, results of the sensitivity testing and model proving, should be provided for review.

Kingsway Viaduct model:

As the baseline model was constructed by JBA, only the described changes at the viaduct have been reviewed to avoid a conflict of interest. The representation of the existing and proposed viaduct has been done well. However, the stability of out of bank flows in the area of interest is a concern in the 0.1% AEP event, proposed scenario examined.

A	Hydrology Review
Date of hydrology analysis	Dec-18
Name of reviewer	James Molloy BE(Hons) MEngSc
Date of review	08/07/2019
Revision	V1
Applicable standards or guidance	Flood Estimation Handbook (IH, 1999) updates including Kjeldsen (DEFRA, 2008), and recent outputs from the FEH Local project ReFH1 and/or ReFH2 guidance documents EA Flood Estimation Guidelines (Operational instruction 197_08, V6)
Nature of study watercourse(s)/constraints	The study looks at various sources of flood risk along a reach of the A1 road, to the south of Allerdene near Newcastle. Various proposed engineering works along the road require an assessment of (a) fluvial flood risk from Allerdene Burn, a small tributary of the River Team and (b) surface water flood risk around Longacre Dean a short distance to the south-east. **The report also looks at flood risk from the River Team, however as no changes have been applied to the hydrology used in the underlying model for this watercourse (previously signed off by the Environment Agency), this aspect is not reviewed in this document.**
Study objectives	The aim of the analysis is to determine if the proposed changes to the road layout have any effect on local flood risk. Information provided in Appendix A of the provided modelling report is used as the basis of this review.
Summary of 1st review	A few suggestions have been given below, which may give more conservative results. The reporting in Appendix A regarding the inflow calculations would benefit from additional detail , but is generally well written. The maps provided are excellent and are very helpful. There are a few omissions that should be addressed, see individual comments below.

JBA consulting

Key
Purple - no change
Red - changes made

Category	Detail	ID	1st review: Comment	Suitability	Suggested actions	Consultants Response (if required)
General comments						
General comments	Method statement	A-1	Quite detailed in places, as various sources of flood risk need to be considered in the analysis. The maps provided alongside the report are very useful and clear. Some of the details regarding the hydrological inflows are quite sparse however, see individual comments below.	Clarification required	Reasoning is given in the main report text (Chapter 3) for the study requirements at each watercourse crossing of the A1 road. It seems an unusual decision why fluvial modelling was carried out on Allerdene Burn, but only pluvial modelling around Longacre Dean (why not carry out fluvial modelling at the latter site also?)	Significiant works are proposed on the channel at Allerdene Burn, no works are proposed at Longacre Dean. Therefore, fluvial modelling was not required at Longacre Dean due to the proposals not impacting the main channel. At Long acre dean the culvert is substantially lower than the road, with no flow route on to the A1 and no changes are proposed but the surface flow routes to the channel are of interest.
	Previous studies	A-2	It is understood that there are no previous studies looking at flood risk for Allerdene Burn, and that only broad-scale pluvial mapping has been carried out in the region surrounding Longacre Dean, which the authors correctly point out does not account for local drainage features that would affect local flood risk.	Acceptable		N/A
	Catchment description (any unusual features such as pumps, reservoirs, heavy urbanisation?)	A-3	Small catchments, some of which drain densely urbanised areas.	Recommendations	Has the Urban ReFH2 method been considered adequately? Checked in further detail below.	This is addressed within the accompanying technical note
Method statement						
Flow estimation points and descriptors	Location of FEPs / catchment descriptors provided?	A-4	Yes in Section 3.3.	Acceptable		N/A
	Unusual catchment features (which may influence choice of approach)	A-5	The Allerdene catchment is heavily urbanised, and also has a moderately high BFIHOST, noted by the authors.	Recommendations	It may also be useful to obtain sewer drainage information for the area around the Allerdene Burn catchment, in case there are sewered areas outside the topographic catchment draining into this watercourse. However, this is unlikely given the steep slope in the urban area, but still would be a useful to check.	Sewer plans were not available for use within the project, we agree that additional inflows are unlikely given the local topography.
	Checks on catchment descriptors	A-6	The catchment area has been correctly checked using LIDAR data, noted that this gives a larger area compared to the "default" FEH catchment.	Major issue	No further reporting given on how the change in catchment area influences other key catchment descriptors. DPLBAR should increase, and there could be significant changes to URBEXT2000 from the change in catchment boundary. Both of these need to be altered, and could have a big effect on calculated flows.	This is addressed within the accompanying technical note
Data review	Hiflows-UK version	A-7	NRFA V7 is the latest version	Recommendations	Should be used in FEH statistical as an independent check on ReFH2, see below.	This is addressed within the accompanying technical note
	Review of hydrometric data	A-8	No local hydrometric data available to calibrate hydrological methods unfortunately.	Acceptable		N/A
	Rating reviews	A-9	n/a, no local gauges in the area apart from on the River Team, not reviewed here.	Acceptable		N/A
	Flood history	A-10	Yes, the authors have queried data held by the Environment Agency and briefly reported this in Chapter 4 of the main report, giving some details of recent floods. This shows that the region assessed here is vulnerable to a range of flood mechanisms.	Acceptable - but does not meet best practice	There are other useful sources of flood history as well. I would recommend having a look on the CBHE website (http://www.cbhe.hydrology.org.uk/index.php), and a general internet search also.	No changes proposed
Initial choice of methods	Approaches suggested	A-11	Only the ReFH2 method is proposed for use for the Allerdene modelling. Depending on the software implementation used, urbanisation adjustments may/may not have been automatically applied given the very high URBEXT200 values.	Major issue	Confirm whether or not the ICM implementation of ReFH2 automatically applies the urban adjustment, giving faster response times and peak flows on highly urbanised catchments. There is no mention anywhere in the document of the FEH statistical method, which should also be applied here, given the uncertainty from catchment-descriptor methods. This at least would be useful as ball-park check on the peak flow produced from ReFH2.	The ReFH2 analysis was undertaken outside of ICM within the ReFH2 software. This is addressed within the accompanying technical note

	Justification of approach	A-12	A sensible argument is given for using FEH99 rainfalls over FEH13 (although it's hidden in a footnote!), given that the former is reported to give higher rainfall totals in this case. For the purposes of construction options modelling this is a good idea. Some data needs to be presented in the Appendix however to back this up, perhaps a table comparing rainfall totals across multiple storm durations. However using FEH99 rainfall in the ReFH2 model may have an unforeseen drawback. In this situation with FEH99 rainfall, ReFH2 applies the "alpha" factor when calculating runoff (essentially a fudge factor that reduces runoff for increasing return periods - introduced to try to match FEH statistical peaks, but conceptually does not make a lot of sense!). So even though FEH99 might give more rainfall, the "alpha" factor may cancel out the effect. This factor is not used with FEH13 rainfall in the model.	Major issue	Add a table comparing FEH99 and FEH13 rainfalls to back up the argument given in Chapter 2 of Appendix A. Run the ReFH2 model for the 100 and 1,000yr events with the FEH13 rainfall also, to test if this gives larger peak flows, due to the "alpha" issue discussed to the left.	This is addressed within the accompanying technical note
	Lumped / distributed	A-13	n/a, as a single inflow to the model is sufficient for this case for the Allerdene model.	Acceptable		N/A
		A-14				
Flow estimation						
FEH Statistical	Suitable for statistical?	A-15	Yes, as a check on ReFH2 results, but not used, see above.	Major issue	See above	As above
	QMED estimation - CDs	A-16				
	QMED estimation - AMAX / POT	A-17				
	Choice of donors	A-18				
	Growth curve methodology	A-19				
	Hydrology shape	A-20				
ReFH method	Suitable for ReFH?	A-21	Yes with caution given the heavy urbanisation	Acceptable		N/A
	Calibration	A-22	n/a, the small catchment assessed here is ungauged.	Acceptable		N/A
	Choice of design storm	A-23	Summer rainstorm profile is suitable in this case. However only very little discussion given for the choice of design storm duration, choosing the value used in the existing River Team model, simply assuming this will also be critical for Allerdene Burn.	Major issue	Run the ReFH2 model for a range of storm durations to see which gives the largest peak flows for Allerdene Burn. Assuming the same critical storm duration as the downstream River Team model could under-estimate peak flows on this small and fast-responding stream, especially important when testing models needed to size culverts, bridges, etc (in this case I think it's OK to mix and match durations from the main Team model and the Allerdene model, to give conservative results). Give a table of peak flows from ReFH2 versus storm duration in the text.	This is addressed within the accompanying technical note
Urban ReFH variant	Suitable for urban ReFH?	A-24	Yes, see previous comments	Major issue	Clarify in the text if the ICM implementation applies the urban adjustments from ReFH2.	This is addressed within the accompanying technical note
	Catchment delineation	A-25	n/a, a lumped approach is OK here.	Acceptable		N/A
	Calibration	A-26	n/a, no gauges available to calibrate the ReFH2 model on these small streams.			N/A
	Choice of URBEXT values	A-27	See comments above	Major issue	See adjustments for URBEXT200 required above.	This is addressed within the accompanying technical note
	Choice of percentage runoff	A-28	ReFH2 defaults are presumably applied for the Allerdene Burn model, this should be OK (but should be reported, e.g. was urbanised %runoff left at the default 70%?)	Acceptable		This is addressed within the accompanying technical note
Final choice of method	Final flows	A-29	N/A as only one method used. Given reliance on (uncertain) catchment descriptor methods, it is important to look at both FEH statistical and ReFH2.	Recommendations		N/A
Miscellaneous						
	Direct rainfall modelling - 2D domain extent	A-30	The model domain for the direct-rainfall modelling around Longacre Dene looks sensible, based on LIDAR. The plot in Table 6 in Appendix A is very useful to demonstrate this.	Acceptable		N/A
	Direct rainfall modelling - 2D downstream boundary condition	A-31	The authors state that there was no need to apply a 2D downstream boundary condition to remove excess ponding at the southern edge of the model.	Minor issue	It is usually best practice to place a downstream boundary on a direct rainfall model, to stop any glasswallng affecting results. This might be more important if longer rainstorms are being tested.	To clarify, a normal flow boundary condition was applied to the 2D mesh in ICM rather than no boundary condition.
	Direct rainfall modelling - range of storm durations tested	A-32	There is no information given on the range of storm durations used in this direct rainfall modelling in the report. The EA national-scale pluvial mapping runs separate models for storm durations of 1hr, 3hrs and 6hrs, then merges the modelled maximum depths in a final grid. This allows for runoff rates on regions with different topography to influence the results. A similar method needs to be adopted for this more detailed assessment.	Major issue	Run the direct rainfall model for a range of storm durations, then merge the results taking the maximum from each individual model grid.	The model has been tested against the critical duration for the catchment, the national modelling was undertaken at a significantly larger scale and therefore wasn't looking at an individual catchment and couldn't be certain on the impacts /cirtical duration in scheme specific terms. In this instance, we are assessing the potential flow routes and flood depths on a slip road which will need to be managed, it is not considered necessary to undertake further analysis, as no changes to surfaces or flow routes or buildings are proposed This is addressed within the accompanying technical note
	Direct rainfall modelling - Percentage runoff	A-33	Not much detail given on this, other than use of the ReFH rainfall. Not clear from the text if this is before or after application of the ReFH2 loss model (i.e., is gross or net rainfall used)? Another issue is the use of different percentage runoff on different parts of the model. Has base mapping been used to inform where percentage runoff should be increased on urban surfaces? This is typically set at 70% but can be altered in some cases, with the ReFH model used to inform %runoff on other surfaces.	Major issue	See list of issues to the left.	This is addressed within the accompanying technical note

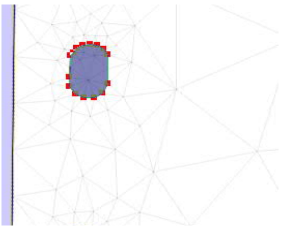
Climate change	Consistent with latest guidance?	A-34	The text in Section 3.3.4 of Appendix A suggests an unusual method was used to apply climate change allowances, altering the rainfall applied to ReFH2. As the Allerdene part of the study is a fluvial analysis, it is standard practice to simply multiply the final fluvial hydrographs by the percentage increase.	Minor issue	(Minor issue) For climate change runs on the Allerdene catchment, recommend instead simply multiplying the initial flow hydrographs using the fluvial uplift factors, instead of altering the input rainfall to ReFH2. As the results of this unusual method are not too far off the required percentages, this is a minor issue only. However this complicated method is needed for applying climate change uplifts for the pluvial analysis (the ReFH loss model is non-linear). (comment for EA) The EA also had a query on use of UKCP18 outputs instead of UKCP09 for climate change analysis. While some UKCP18 outputs are now available, research is ongoing to convert these large datasets to simple uplift factors for fluvial / rainfall inputs, due to be released later this year by CEH. Data from UKCP18 can be used manually to inform updated uplift factors, but current guidance recommends this is only needed on very high-risk areas (e.g. power stations). Therefore the use of uplift factors from the current EA guidance (2016 document) using UKCP09 is suitable in this case. (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances)	The River Team model is direct rainfall so therefore the normal fluvial approach is not available. As the reveiwer outlines this approach gives very similar answers, therefore no change is required. The approach to climate change was agreed with Caroline seperatly.
Reporting and follow up actions						
Reporting and Results.	Suitability of reporting	A-35	Quite detailed in places, but lacking detail in others, see the list above. The maps given alongside the report are very well put together and are very helpful.	Minor issue		No changes other than above are proposed
	Results	A-36	Some issues and omissions spotted, as listed above.	Major issue	See above	No changes other than above are proposed
	Recommendations	A-37	Key recommendations as follows: - Consider if fluvial modelling on Longacre Dene is needed as well as general pluvial modelling? - Carry out FEH statistical method as an independent ball-park check on the ReFH2 fluvial calculations - Consider sensitivity of using FEH13 rainfall due the "alpha" issue discussed above - Look at sensitivity of results to storm duration, for both fluvial and pluvial analysis.	Major issue	See above	No changes other than above are proposed

B	**Review of River Team Viaduct**
Date of model	August 2018
Name of reviewer	Jenny Hill
Date of review	24/07/2019
Revision	v2
Applicable standards or guidance	
Nature of study watercourse(s)/constraints	Allerdene Burn
Study objectives	The reporting states: Flood Risk Assessment (FRA) to support the Environmental Impact Assessment (EIA) and DCO Application for the A1 Birtley to Coal House Scheme. Three areas were identified for further modelling: - Hydraulic modelling to the River Team at Junction 67 to assess the impact of the extension of the Kingsway Viaduct. This modelling utilises an existing Environment Agency hydraulic model of the River Team constructed by JBA in 2014. - Hydraulic modelling of the Allerdene Burn to understand the impact of the A1 realignment which will require either: a. the extension of the existing Allerdene culvert and replacement of the existing section of the Burn; b. or daylighting of the existing culvert and replacement and realignment of the existing burn to accommodate a new viaduct over the existing railway line. - Hydraulic modelling of the surface water flood risk at Junction 66. **This review focusses on the River Team at Junction 67**
Summary of 1st review	As the baseline model was constructed by JBA, only the described changes at the viaduct have been reviewed to avoid a conflict of interest. The representation of the existing and proposed viaduct has been done well. However, the stability of out of bank flows in the area of interest is a concern in the 0.1% AEP event, proposed scenario examined.

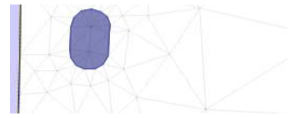
Key
Purple - no change
Red - changes made

Category	Detail	Prompts	ID	Comment	Suitability	Suggested actions	Consultants Response (if required)
Data to be reviewed							
Data to be reviewed	Software	~ Versions	B-1	InfoWorks ICM v6	Acceptable		N/A
			B-2	Updated to v8 for the purpose of this review	Acceptable		N/A
	AEPs provided / reviewed		B-3	1% AEP + 20 or 40% and 0.1% AEP.	Acceptable		N/A
			B-4	1% AEP event reviewed.	Acceptable		N/A
	Scenarios provided / reviewed		B-5	Base and 'Kingsway Bridge Extension'. The Kingsway Bridge Extension scenario has been the focus of this review.	Acceptable		N/A
	Reports	~ Reference versions ~ Technical reporting ~ General reporting	B-6	FRA report with technical appendices	Acceptable		N/A
Reporting							
Reporting	Reporting	~ Objectives ~ Constraints ~ Approach Justification (both model scale and structure scale) ~ Clarity ~ Assumptions	B-8	The report states that Modelling changes are confined to the A1 junction 67 roundabout 424950, 558550 and included the modelling of the existing Kingsway Viaduct and the proposed widening of the viaduct to include an additional pillar.	Acceptable		N/A
			B-9	Reporting generally clear and thorough	Acceptable		N/A
			B-10	Results discussed	Acceptable		N/A
General comments							
General comments	File organisation / naming convention	~ Scenarios ~ Naming ~ Flags	B-12	Flags ED and AD have been used at the changed structure, although flags have not been included in the model describe what this means.	Clarification required	In future include a CSV export of flags or a table of flags in the report	ED = Engineering Design, based upon Scheme drawings AD = Assumed Data, engineering judgement used
			B-13	The viaduct option has been created as a scenario from the base model, which follows best practice.	Acceptable		N/A
			B-14	The scenario is clearly named which is helpful for future users.	Acceptable		N/A
	Survey / topographic data	~ Age ~ Quality	B-15	Source of data is unknown as flag not included, although it is assumed that ED refers to Engineering Drawings.	Clarification required		See B-12 response
	Other	~ Any significant missing data	B-16	DTM was not provided although the commit history suggests a custom DTM which included topographic survey was used.	Clarification required	In future, provide the DTM used	DTM issued
General modelling approach							
General modelling approach	Model extents	~ Domain boundaries ~ Upstream/downstream boundaries ~ Potential downstream influences on water levels ~ Glass walling	B-18	Domain is unchanged from the base model	Acceptable		N/A
	Modelling approach	~ 1D / 2D / Linked ~ georeferenced (ixy/gxy/2d links)	B-19	A 1D-2D approach has been used for the watercourse and a 2D representation of the viaduct pillars has been used.	Acceptable		N/A
			B-20	The model is fully geo-referenced.	Acceptable		N/A
	Application of hydrological estimates	~ Lumped / distributed ~ Applied to 1D or 2D domain ~ Lateral or point inflows ~ Consistency with reporting	B-21	The application of the hydrology is unchanged from the base model	Acceptable		N/A
InfoWorks ICM							
InfoWorks ICM	Model build	~ Hard bed / soft bed ~ Accuracy of modelled channel length	B-23	The model is an adapted version of the JBA built, Environment Agency approved model. The changes made to the existing model have been documented in the commit history. Changes listed are all in relation to Kingsway Viaduct. The 'compare network' tool has been run on the WSP and existing EA model. This concluded that WSP's description of the changes was accurate.	Acceptable		N/A
			B-24	The modelling report does not comment on whether hard or soft bed have been modelled. However, as the is a proposed design, it is assumed a hard bed level was implemented.	Acceptable		N/A
			B-25	The modelled length has been calculated from the centre line and the centre line matches the mapped watercourse well.	Acceptable		N/A
	Watercourses	~ Deactivation ~ Interpolates ~ Bank level and DTM matchup ~ Bank coefficients ~ Baseflow	B-26	1D river reaches have been voided from the 2D zone to avoid double counting	Acceptable		N/A
			B-27	Based on the cross section naming convention, it is not thought that any interpolates have been applied. The resolution of cross sections in the study area mean no interpolates were necessary.	Acceptable		N/A
			B-28	Discharge coefficient of 1 and modular limit of 0.9 consistently used.	Acceptable		N/A
			B-29	The 1D river banks generally track the DTM level well. However, at chainage 50m on river reach TEAM_5156.1 the 1D bank is 1m higher than the 2D level. The 0.1% AEP water level predicted to exceed bank tops so this has potential to impact the results.	Minor issue	Modify 1D or 2D water levels to allow a better match of levels in area of interest	This is addressed within the accompanying technical note
			B-30	River sections look sensible but few panel markers have been used.	Acceptable		N/A
			B-31	Conveyance plots for TE05365 and TE05340 are kinked at higher depths.	Minor issue	Update panel markers and channel roughness to smooth conveyance plots at deeper flows.	See B-29 response
	Watercourse structures	~ Bridges ~ Culverts ~ Screens ~ Weirs ~ Flap valves ~ Sluices	B-32	25 mesh zones have been used to represent viaduct pillars in the flood plain	Acceptable		N/A
			B-33	In the proposed scenario, all the pillars use a level of 20mAOD. This is 7.5m above ground level which seems appropriate. In the base scenario, the proposed pillars are included but with a level change of 0m.	Acceptable		N/A
			B-34	Notes have been used to describe which pillars are existing and which are proposed, which is helpful.	Acceptable		N/A
	Mesh	~ Mesh optimisation ~ Infiltration surfaces ~ Initial conditions ~ Rainfall applied to the mesh. Use of sub catchments ~ 1D/2D linking: bank lines, manhole flood types, inline banks	B-35	The use of mesh zones with small footprints is causing the generation of small triangles (Figure 1) around the area of interest which could slow model run times.	Minor issue	In future models, simplify the geometry of 2D features (while retaining area) to avoid small triangles.	We havent had a significant issue with model run times, therefore no changes have been made
	Mesh modifications	~ Representation of roads and buildings	B-36	See watercourse structures above	Acceptable		N/A
	Scenarios	~ Do minimum (baseline) ~ Do nothing ~ Do something	B-38	As the baseline model was constructed by JBA, only the described changes at the viaduct have been reviewed to avoid a conflict of interest.	Acceptable		N/A
			B-39	Only Kingsway Bridge Extension scenario has been reviewed.	Acceptable		N/A

Figure 1: Small triangles around pillars



	Run parameters and output data	~ Results generated ~ Temporal resolution of results ~ Run parameters	B-40	Results are saved every 5 minutes.	Acceptable		N/A
			B-41	Timestep used was 4 seconds	Acceptable		N/A
			B-42	Simulation was run for 30-hours which allows the full storm to pass in the area of interest.	Acceptable		N/A
Runs							
	Model simulations	Model simulation runs ~ Existing (baseline) ~ Climate change ~ Sensitivity	B-136	Sims provided for the base and scenario for the 1, 1 +20 or 40% and 0.1% AEP events.	Acceptable		N/A
			B-137	No sensitivity tests were provided.	Minor issue	Run sensitivity tests	This is addressed within the accompanying technical note
Model results, interpretation, verification and stability							
Model results, interpretation, verification and stability	Model stability	~ zzd, eof, tlf ~ Model warnings and errors ~ Non-convergence ~ Mass balance ~ unrealistic oscillations (water level / flow / boundaries / dVol).	B-139	The base 0.1% AEP event ended incomplete.	Minor issue		See response to B-29
			B-140	Total mass error = 9.9 m3	Acceptable		N/A
			B-141	Volume balance error = 0.9 %	Acceptable		N/A
			B-142	There is some oscillation in the peak flows in the area of interest during a 0.1% AEP event (Figure 2)	Minor issue	Make updates to conveyance and bank lines to improve stability	See response to B-29
			B-143	There is some significant oscillations in the out of bank flows in the area of interest during the 0.1% AEP event (figure 3)	Major issue	Make updates to conveyance and bank lines to improve stability. If appropriate, lower bank co-efficient	See response to B-29
	Sensitivity testing	~ Suitability of sensitivity testing undertaken ~ Results & interpretation of sensitivity testing	B-144	Sensitivity tests not provided for review	Minor issue	Run sensitivity tests	See response to B-137
	Calibration / performance		B-145	No model performance testing was provided for review.	Minor issue	Use the model report to provide commentary on the sensibility of predicted flooding.	This is addressed within the accompanying technical note



Acceptable
Acceptable - but does not meet best practice
Clarification required
Minor issue
Major issue
Recommendations

Figure 2: In channel flows ate TEAM_5156.1

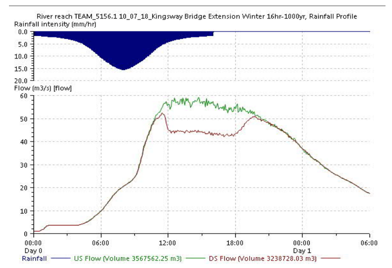
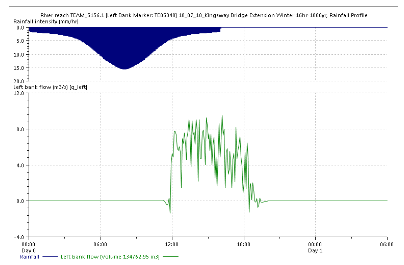


Figure 3: : Left bank flows at TEAM_5156.1



B	Review of Alledene Burn
Date of model	August 2018
Name of reviewer	Jenny Hill
Date of review	19/07/2019
Revision	v1
Applicable standards or guidance	
Nature of study watercourse(s)/constraints	Alledene Burn
Study objectives	The reporting states: Flood Risk Assessment (FRA) to support the Environmental Impact Assessment (EIA) and DCO Application for the A1 Birtley to Coal House Scheme. Three areas were identified for further modelling: - Hydraulic modelling to the River Team at Junction 67 to assess the impact of the extension of the Kingsway Viaduct. This modelling utilises an existing Environment Agency hydraulic model of the River Team constructed by JBA in 2014. - Hydraulic modelling of the Alledene Burn to understand the impact of the A1 realignment which will require either: a. the extension of the existing Alledene culvert and replacement of the existing section of the Burn; b. or daylighting of the existing culvert and replacement and realignment of the existing burn to accommodate a new viaduct over the existing railway line. - Hydraulic modelling of the surface water flood risk at Junction 66. **This review focusses on the Alledene Burn options**
Summary of 1st review	Minor issues have been identified. Generally the baseline model and option 1 are well constructed. There were some issues identified in Option 2 that could be impacting the results. Therefore it is recommended that this model is revised. As for all modelling studies, results of the sensitivity testing and model proving, should be provided for review.

JBA consulting

Key
Purple - no change
Red - changes made

Category	Detail	Prompts	ID	Comment	Suitability	Suggested actions	Consultants Response (if required)
Data to be reviewed							
Data to be reviewed	Software	~ Versions	B-1	InfoWorks ICM v8	Acceptable		N/A
	AEPs provided / reviewed		B-2	0.1% AEP model files and results	Acceptable		N/A
	Scenarios provided / reviewed		B-3	Base, Option 1 ditch realignment, Option 1 realignment flow control, Option 2 and Option 3	Acceptable		N/A
	Reports	~ Reference versions ~ Technical reporting ~ General reporting	B-4	FRA report with technical appendices	Acceptable		N/A
Reporting							
Reporting	Reporting	~ Objectives ~ Constraints ~ Approach Justification (both model scale and structure scale) ~ Clarity ~ Assumptions ~ Interpretation of results	B-6	Objectives clearly stated in the reporting	Acceptable		N/A
			B-7	Reporting generally clear and thorough	Acceptable		N/A
			B-8	The scenarios are a bit unclear - more models provided than options discussed.	Clarification required	Check consistency between model and reporting provided for review.	This is addressed within the accompanying technical note
			B-9	Results discussed	Acceptable		
General comments							
General comments	File organisation / naming convention	~ Scenarios ~ Naming ~ Flags	B-11	Scenarios and files well labelled although it was a bit confusing to establish what is the base scenario. One model network with all options as scenarios could have been a neater way to organise the options.	Acceptable - but does not meet best practice	In future, use one model network with a series of scenarios to represents options	N/A
			B-12	Flags have not been included although data has been flagged.	Acceptable - but does not meet best practice	In future include a CSV export of flags or a table of flags in the report	N/A
			B-13	Naming conventions are clear and descriptive	Acceptable		N/A
			B-14	The DTM has not been provided which makes comparisons more difficult. A lidar clip has been made but it understood that the model DTM was a composite of three sources	Clarification required	In future, provide the DTM used	DTM provided
	Survey / topographic data	~ Age ~ Quality ~ Suitability	B-15	According to the report, Channel survey for Alledene Culvert was undertaken by Longdin and Browning in March 2018	Acceptable		N/A
			B-16	Lidar data was supplemented by topo survey in the study area.	Acceptable		N/A
	Other	~ Any significant missing data	B-17	NextMap 5m has been used to north east of the A1 which has partial or no Lidar coverage.	Acceptable		N/A
General modelling approach							
General modelling approach	Model extents	~ Domain boundaries ~ Upstream/downstream boundaries ~ Potential downstream influences on water levels ~ Glass walling	B-19	The Alledene Burn is not mapped. However, a check against 1m Lidar suggests that the full length of the watercourse has been modelled in 1D with 2D linking.	Acceptable		N/A
			B-20	A check on the maximum flood extent for the 0.1% AEP event showed no glass walling. Therefore the extent of the 2D model is considered appropriated.	Acceptable		N/A
	Modelling approach	~ 1D / 2D / Linked ~ georeferenced (ixy/gxy/2d links)	B-21	1D river reaches are linked to the 2D domain at banks.	Acceptable		N/A
			B-22	Model is fully georeferenced	Acceptable		N/A
	Application of hydrological estimates	~ Lumped / distributed ~ Applied to 1D or 2D domain ~ Lateral or point inflows ~ Consistency with reporting	B-23	Inflows have been applied at the upstream extent of the model	Acceptable		N/A
			B-24	No lateral inflows are made, but it is not anticipated that these would be required for a watercourse of this size.	Acceptable		N/A
			B-25	A downstream water level from the River Team for the same AEP has bee applied.	Acceptable		N/A
InfoWorks ICM							
InfoWorks ICM	Model build	~ Hard bed / soft bed ~ Accuracy of modelled channel length	B-27	Hard bed/ soft bed not specified in the reporting	Clarification required	Specify if hard or soft bed levels were used..	Hard bed levels used.
			B-28	All river reach lengths have been calculated based on the length of the centre line and the centreline follows the channel indicated in the DTM well.	Acceptable		N/A
	Watercourses	~ Deactivation ~ Interpolates ~ Bank level and DTM matchup ~ Bank coefficients ~ Baseflow	B-29	1D river reaches have been voided from the 2D zone to avoid double counting	Acceptable		N/A
			B-30	Interpolates have been used excessively, with on interpolate every 10m. The interpolates have not caused any kinks in the conveyance plots so it is concluded that this is unlikely to impact results.	Acceptable - but does not meet best practice		N/A
			B-31	Bank levels are interpolated between survey points rather than updated from the DTM. In some cases this can make the 1D bank 2m above the 2D level	Minor issue	In future, update bank levels from DTM in between surveyed cross sections if there is good confidence in the DTM levels.	This is addressed within the accompanying technical note
			B-32	Discharge coefficient of 1 and modular limit of 0.8 consistently used.	Acceptable		N/A
			B-33	No inflow applied to the river reach link as inflow hydrograph has been used.	Acceptable		N/A
	Watercourse structures	~ Bridges ~ Culverts ~ Screens ~ Weirs ~ Flap valves ~ Sluices	B-34	7 culverts have been modelled. The data flags suggested 6 of these 7 have been modelled from survey data and 1 from As Built drawings. The size and roughness looks sensible although I would recommend that Manning's n is used for fluvial culverts over Colebrook White.	Acceptable		N/A
			B-35	Culvert inlets and outlets consistently used with appropriate coefficients applied.	Acceptable		N/A
			B-36	1 bridge has been modelled. The bridge opening (flagged as survey data) and deck look sensible compared to the river cross section. Bank coefficient and discharge coefficient have been left as default.	Acceptable		N/A
			B-37	Summary on none modelled: flap valve, orifice, pump, screen, weirs	Acceptable		N/A
	Mesh	~ Mesh optimisation ~ Infiltration surfaces ~ Initial conditions ~ Rainfall applied to the mesh. Use of sub catchments ~ 1D/2D linking: bank lines, manhole flood types, inline banks	B-38	Max triangle area was 20m² and minimum element was 10m² which is appropriate for a model of this scale. The general roughness was 0.035 which is within typical range.	Acceptable		N/A
			B-39	No mesh warnings have were produced.	Acceptable		N/A
			B-40	No rainfall was applied to the mesh, despite rainfall being applied in the run set up. It is understood that this was a fluvial model, and therefore the rainfall was not required. However, clarification on why rainfall files have been included is required.	Clarification required	Clarify if rainfall was an intended inflow to this model.	Rainfall was only applied in a small sub catchment, with the model being predominantly fluvial.
			B-41	1D-2D linking happens at bank lines which has been successfully achieved.	Acceptable		N/A
	Mesh modifications	~ Representation of roads and buildings ~ Roughness	B-42	There is no representation of the conveyance in highways or the resistance caused by buildings.	Minor issue	Represent buildings, road, woodland, scrub as roughness zones in the 2D model.	This model covers a small area and this level of detail is not required in this instance
			B-43	However, the raised highway embankment are represented in the DTM and therefore the mesh.	Acceptable		N/A
			B-44	Option 1a: Ditch re-alightment A Mesh Level Zone has been added over the existing watercourse. This adjusts the DTM elevation to give a minimum elevation of 16 mAOD and maximum elevation of 17.5 mAOD. A 3D view indicates that this level zone has lowered the existing embankment. There has been no modification of the ground levels to tie in worth the proposed bank heights. In some locations this can cause a 1m discrepancy between 1D and 2D bank level. This is not shown to impact 0.1% AEP results. The extended culvert has been connected to the proposed culvert with a break node. I would think it more likely that a manhole chamber would be installed to connect these. A manhole would have the potential to flood whereas a break node does not. However, the pipe is not surcharged at the peak of the 0.1% AEP event so this is not thought to impact results. The roughness of the proposed culvert has not been updated from default. The The new cross sections mainly look sensible but ARD1 - ARD4 all have left bank lower than the highest point, allowing for premature flooding (Figure 1). However, the max water level doesn't exceed left bank level in the 0.1% AEP event so this is not thought to impact results. The conveyance of the new cross sections is kinked at higher depths (Figure 2). However, the max water depth doesn't reach this level in the 0.1% AEP event so this is not thought to impact results.	Acceptable - but does not meet best practice		N/A

Figure 1: Bank top higher than left bank

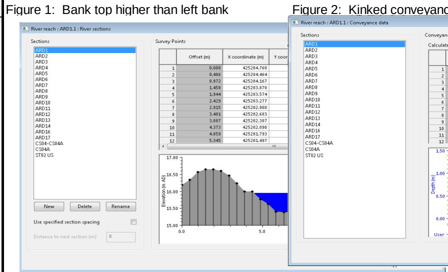
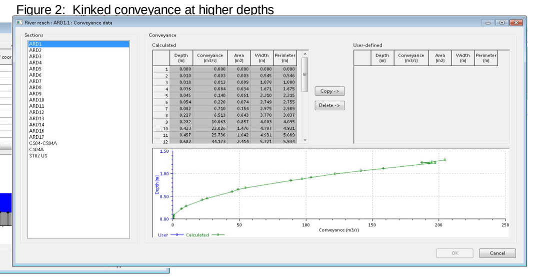
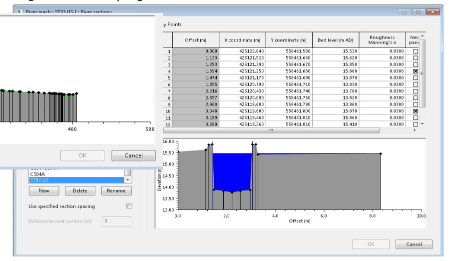


Figure 2: Kinked conveyance at higher depths



	Scenarios	~ Do minimum (baseline) ~ Do nothing ~ Do something	B-45	Option 1b: Ditch realignment + flow control A Mesh Level Zone has been added over the existing watercourse, as before (for comments see Option 1a). Pipe size of SA02USc.1 has been reduced from 1.35 to 1.2m in diameter. No other apparent changes made from Option 1a so same comments stand.	Acceptable - but does not meet best practice		N/A
			B-46	Option 2: Viaduct A Mesh Level Zone has been added over the existing watercourse, as before (for comments see Option 1a). There is no apparent level change in the model to account for lowering the highway embankment which is present in the DTM JBA imported (no DTM provided). As a result, in some places there is a 9m miss match between the 1D and 2D bank levels modelled. In channel water levels do not exceed bank top during the 0.1% AEP so this is not impacting results. The open channel has been extended to replace the culvert. As per Option 1a, sections ARD1-ARD4 have lower left bank to the bank top (Figure 1). The same is true for ARD14-17 and ST02 US. Here channel flow does exceed bank top in the 0.1% AEP event (Figure 4) so this is impacting results. As per Option 1a, conveyance plots are kinked in at greater depths, which in this instance could impact the results as in channel depths exceed 1m.	Minor issue	Trim 1D cross sections to the highest point on the left bank. Update panel markers and channel roughness to smooth conveyance plots at deeper flows.	This is addressed within the accompanying technical note
			B-47	Option 3: Viaduct There are no apparent changes between Options 2 and 3 so the same comments stand unless clarification of changes is provided.	Minor issue	Trim 1D cross sections to the highest point on the left bank. Update panel markers and channel roughness to smooth conveyance plots at deeper flows.	See response to B-47
	Run parameters and output data	~ Results generated ~ Temporal resolution of results ~ Run parameters	B-48	Results saved at a 1minute interval which is high but acceptable.	Acceptable		N/A
			B-49	Model is run for 12 hours which allows the full storm to pass	Acceptable		N/A
			B-50	Run use a GPU card but don't link 1D and 2D calculations at minor timesteps.	Acceptable		N/A
Runs							
	Model simulations	Model simulation runs ~ Existing (baseline) ~ Climate change ~ Sensitivity	B-144	The model has been run and reviewed for the baseline and options. All results use the 0.1& AEP event.	Acceptable		N/A
			B-145	There were no sensitivity tests provided.	Minor issue	Run sensitivity tests	This is addressed within the accompanying technical note
Model results, interpretation, verification and stability							
Model results, interpretation, verification and stability	Model stability	~ zzd, eof, tlf ~ Model warnings and errors ~ Non-convergence ~ Mass balance ~ unrealistic oscillations (water level / flow / boundaries / dVol).	B-147	Total mass error = 0.0 m3	Acceptable		N/A
			B-148	Volume balance error = 0.0 %	Acceptable		N/A
			B-149	In channel flows raise and fall in a smooth hydrograph	Acceptable		N/A
			B-150	Out of bank flows are generally stable	Acceptable		N/A
			B-151	There is some instability at the downstream boundary due to the backing up of the River Team 0.1% AEP level but this is not impacting the results in the area of interest.	Acceptable		N/A
	Sensitivity testing	~ Suitability of sensitivity testing undertaken ~ Results & interpretation of sensitivity testing	B-152	Sensitivity tests not provided for review	Minor issue	Run sensitivity tests	See response to B-145
	Calibration / performance		B-153	No model performance testing was provided for review.	Minor issue	Use the model report to provide commentary on the sensibility of predicted flooding.	This is addressed within the accompanying technical note

Figure 4: Bank top higher than left bank



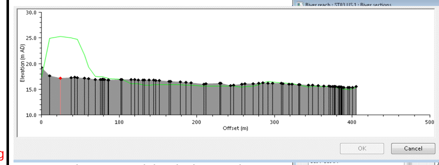


Figure 3: Bank level miss match

Acceptable
Acceptable - but does not meet best practice
Clarification required
Minor issue
Major issue
Recommendations

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