Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Bishops Cleeve	**Ref**	WBGCTS
Author	M Green, M Grogan		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the Dean Brook and tributaries at Bishops Cleeve.

1.2 Existing Models & Data

1.2.1 A number of watercourses flow through the Bishops Cleeve study area; the largest being the Dean Brook. An existing 1D-2D ISIS/ESTRY-TUFLOW model for the Dean Brook and its tributaries downstream of the A435 was available for use in this study. This model was developed by Peter Bretts Associates (PBA) (2010) for the purposes of a Flood Risk Assessment (FRA) at Dean Farm. As part of their study, PBA undertook a detailed hydrological analysis, which was assessed as part of this project before being used in the combined Dean Brook model.

1.2.2 The model for this study was created by linking the existing Dean Brook model to an upstream 2D grid representing the watercourses upstream of the A435.

1.3 Site Visit

1.3.1 A site visit to the Dean Brook area was undertaken prior to the commencement of any analysis of the watercourse to obtain a more detailed understanding of structures within the modelled extents and identify possible floodplain flow routes. Particular attention was paid to the structures which were to be included in the 2D only sections of the model.

2 Hydrological Analysis

2.1 Introduction

2.1.1 The existing 1D-2D linked ISIS-TUFLOW model of Bishops Cleeve (PBA, 2010) was provided for use within this study. Consultation with the Environment Agency indicated that the model had not yet been signed-off by the Environment Agency at the time of this study, therefore, a detailed review of the existing hydrological analysis was undertaken prior to its adoption.

2.2 Hydrological appraisal

2.2.1 PBA undertook an in-depth hydrological analysis, compliant with the latest FEH guidelines, as part of the FRA study. PBA estimated peak flows for the study area using a number of methodologies including the ReFH rainfall-runoff model, the FEH rainfall-runoff model and FEH statistical analysis. The FEH rainfall-runoff flood frequency curve was selected as the most appropriate on the basis of consistency with historic flooding.

2.2.2 PBA undertook a detailed schematisation of the catchment using the FEH CD-ROM DTM and sewer data in order to provide inflows at each of the upstream model extents. After requesting and reviewing outfall and sewer data from Severn Trent Water and the FEH-CD ROM version 3, it was concluded that the PBA schematisation was robust. However, due to the fact that the Level 2 SFRA model extents were different from those used in the PBA study, alterations were made to the schematisation to provide appropriate inflow points for this Level 2 SFRA (see Figure 2.1).

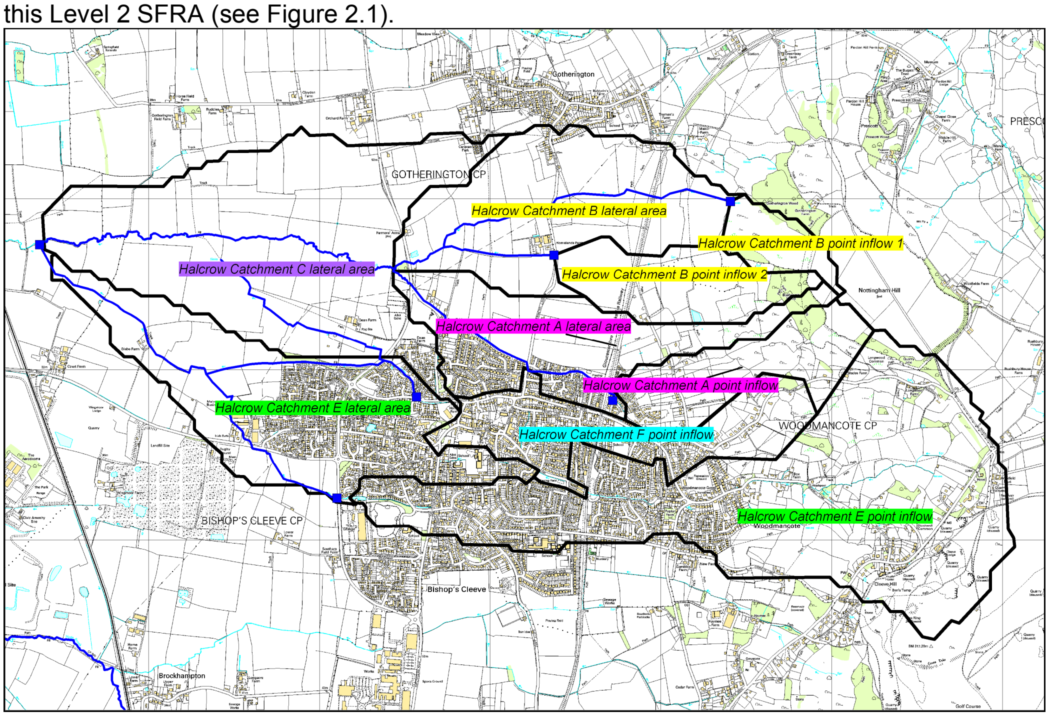

Figure 2.1: Catchment schematisation

2.2.3 Review of the PBA modelling report indicated that there is no record of the validation of the catchment descriptors taken from the FEH-CD ROM. Prior to use in this study a review was therefore undertaken using LiDAR data. FARL values were checked using OS mapping and soil parameters were checked against mapped soil types on the SoilScapes website. It was concluded that no alterations to the catchment descriptors were required and those selected within the PBA analysis were taken forward for use within this study.

2.2.4 A model verification was completed as part of the PBA study using observed rainfall from the July 2007 event. Using FEH rainfall-runoff boundaries created for the July 2007 event, PBA found that the fluvial outlines did not correspond well with the July 2007 observed flood outline by a large margin, even when inflows were scaled up by a factor of 10. Investigations into the reasons for the differences were investigated and it was concluded that the observed flood extent was from predominantly pluvial flooding on waterlogged land, rather than fluvial flooding. The SoilScapes website indicates peat-type soils north-west of Bishops Cleeve, and the BGS website suggests that these are underlain by Lower Lias type clay, which are largely impermeable. The July 2007 event occurred less than a month after the June 2007 event, which was also significant. Taking the soil conditions and antecedent conditions into consideration, water logging is a reasonable explanation.

2.2.5 It was concluded that the PBA hydrology was suitably robust to enable the adoption of the same flow estimation methodology (FEH rainfall-runoff) studying the Level 2 SFRA, with adaptations made for differences in model inflow boundary locations and the associated catchment schematisation.

2.2.6 Storm duration sensitivity runs were carried out using the 1% AEP event in order to arrive at the critical storm duration for the Bishops Cleeve site. It was found that the critical storm duration in terms of modelled levels and flood extents through the site was 5.25 hours, which was therefore adopted for all return periods. This corresponded with the critical storm duration derived in the PBA hydrological analysis.

2.2.7 Flow-sensitivity model runs were undertaken for the 1% AEP event with plus 20% flow (used to identify sensitivity to climate change) and minus 20%. The results showed that the flood outlines are sensitive to flow (see Figure 2.2).

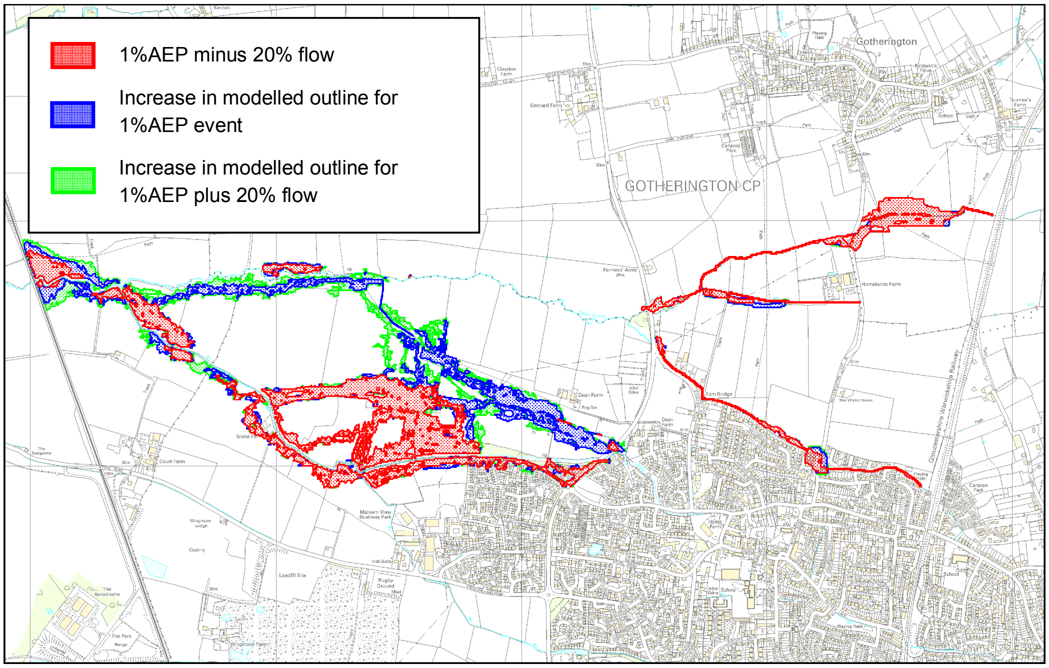

Figure 2.2: Flow sensitivity modelled outlines

2.3 Conclusions

2.3.1 The final peak flows adopted in the model are as shown in Table 2.1.

Table 2.1: Final peak flows adopted in the model

			Maximum flows in m^3/s			
Boundary location	**Watercourse name**	**Node label**	**5% AEP fluvial**	**1% AEP fluvial**	**1% AEP fluvial with climate change**	**0.1% AEP fluvial**
Lateral inflow	Dean Brook	Catch_A_la_1	1.1	1.8	2.2	3.3
SO 9671 2781	Dean Brook	Catch_A_pt_1	0.7	1.0	1.2	1.9
Lateral inflow	Dean Brook	Catch_B_la_1	1.2	1.8	2.2	3.4
SO 9740 2898	Dean Brook	Catch_B_pt_1	0.2	0.3	0.4	0.5
SO 9637 2866	Dean Brook	Catch_B_pt_2	0.5	0.8	0.9	1.4
Lateral inflow	Dean Brook	Catch_C_la_1	0.9	1.4	1.7	2.8
Lateral inflow	Dean Brook	Catch_E_la_1	1.3	2.1	2.5	4.4
SO 9510 2724	Dean Brook	Catch_E_pt_1	2.4	4.0	4.8	8.2
SO 9556 2784	Dean Brook	Catch_F_pt_1	1.2	2.0	2.4	4.0

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment for Dean Brook and tributaries at Bishops Cleeve.

3.2 Model extent

3.2.1 The Dean Brook model developed for this study extends from just upstream of the A435 (SO 95642 28667, SO 95552 28490, SO 95419 28042) to downstream of the railway (SO 92900 28738). Three channels have been modelled in 2D within the upstream section of the study area. These channels extend from downstream of the Gloucestershire Warwickshire Railway (SO 96919 29026, SO 96625 27913) to upstream of the A435 (SO 95642 28667, SO 95552 28490) and downstream of Cleeve Road/Gotherington Lane (SO 96372 28670) to upstream of the A435 (SO 95552 28490). Figure 3.1 below shows the extents of the 1D-2D model covering the study area.

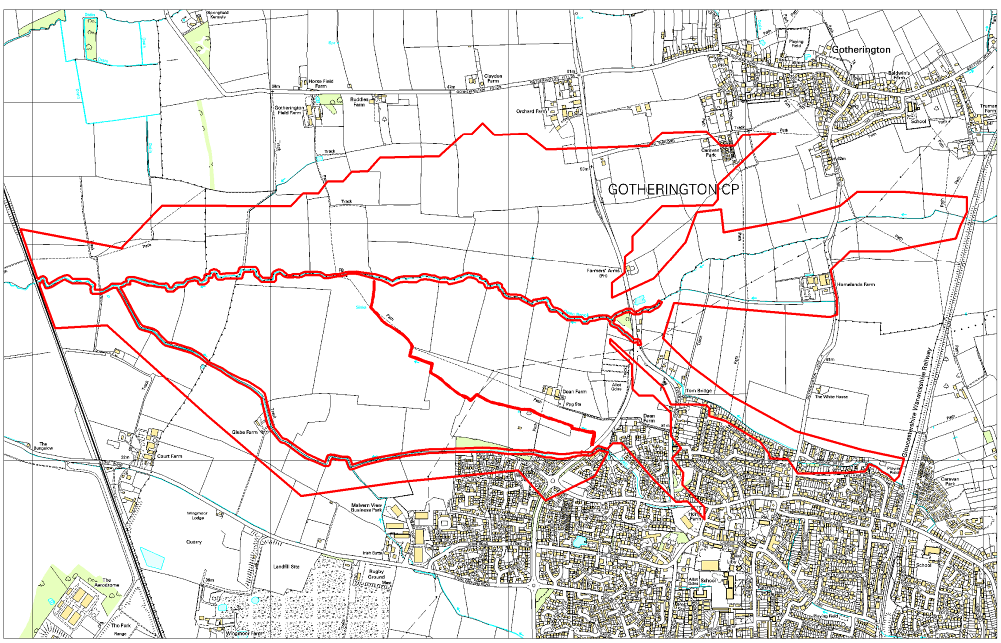

Figure 3.1: Bishops Cleeve model extents

3.3 Methodology

3.3.1 The existing Dean Brook model was reviewed and was determined to be suitable for the purposes of this study.

3.3.2 The existing 1D-2D Dean Brook model 2D domain was extended upstream to encompass the additional channels to be modelled. The available LiDAR data did not extend sufficiently far upstream to cover this area, therefore the ground model for the upstream area has been constructed from topographical survey obtained for this purpose. While this ground model does not have the resolution of LiDAR data, it does have the advantage of clearly defining the channel bed and banks allowing for more accurate definition of the channel than usual for 2D channels. Hydraulically significant structures along the 2D channels were modelled using 1D ESTRY. The dimensions of the structures along the 2D channels were based on observations made on the site visit (see modelling summary table for estimated culvert dimensions).

3.3.3 A 5m resolution was used for the grid size in this model. This allows for accurate representation of the floodplain while keeping model run times and result file sizes manageable.

3.3.4 There are no formal or de-facto defences in the study area.

3.3.5 The in-channel roughness in the existing Dean Brook model was left as it was in the original model; and, the floodplain roughness was redefined using polygons extracted from OS Mastermap data and observations made on the site visit. The upstream 2D channel and floodplain roughnesses were assigned using polygons extracted from OS Mastermap data and observations made on the site visit.

3.3.6 Inflow boundaries in the existing Dean Brook model have been left as they were with the exception of two of the upstream boundaries which have been redistributed between the upstream extents of the 2D channels.

3.3.7 The downstream boundary on the Dean Brook has been modelled as a normal slope.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to roughness (Manning's 'n'), flow and blockage was carried out. The results of this analysis are summarised below.

Manning's 'n'

3.4.2 Changing the Manning's 'n' values in the ISIS component of the model causes the model to develop instabilities which result in either unsatisfactory or incomplete model runs. This implies that the model is very sensitive to changes in roughness and care needs to be taken when adjusting these parameters.

Flow

3.4.3 Increasing the flow by 20% causes an average rise in water level of 33mm while decreasing the flow causes an average decrease in water level of 30mm.

Blockage

3.4.4 Blockage analysis was performed at several locations in the study area; all of the structures blocked were blocked by 75%. The blockage analysis was performed at four locations, at Cleeve Road culvert (SO 96365 28972), two on the A435 culverts (SO 95524 28625, SO 95539 28504) and on the railway culvert (SO 93017 28750).

3.4.5 Blocking the Cleeve Road culvert causes negligible increase in stage upstream of the culvert. Blocking the Northern A435 culvert results in a 177mm increase in stage upstream of the culvert; and, blocking the Southern A435 culvert causes a 292mm increase in stage upstream of the culvert. With a blockage applied to the railway culvert, an increase in stage of 782mm is experienced upstream of the culvert.

3.5 Assumptions & Limitations

3.5.1 A number assumptions have been made in the hydraulic modelling undertaken as part of this study.

3.5.2 The model has been constructued using existing survey data provided at the start of the study. It has been assumed that the survey used to create the existing Dean Brook model is accurate and suitable for use.

3.5.3 It is assumed that the filtered LiDAR used in the study is accurate and has no errors. Where channel has been modelled as 2D it has been assumed to be a trapezoidal shape.

3.5.4 Structure dimensions within the 2D channel have been defined from observations on the site visit and have not been extensively surveyed.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are sensitive to roughness and for watercourse of this character. It is therefore recommended that regular channel maintenance is undertaken to ensure the channel is kept free of obstructions.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Brockworth	**Ref**	WBGCTS
Author	M Green, H Gebre		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the Horsbere Brook at Brockworth.

1.2 Existing Model & Data

1.2.1 There is an existing model for the Horsbere Brook watercourse. Review of this model indicated that the model did not extent far enough upstream to cover the area of interest. Consultation with the Environment Agency indicated that a 1D-2D linked model constructed by Capita Symonds (2009) covering the study area was available, however, there were a number of concerns of the suitability of this model for use in this study.

1.2.2 It was therefore decided to construct a new 1D-2D linked ISIS-TUFLOW model of the Horsbere Brook at Brockworth using available channel survey data (Halcrow 2008), to enable flood extent and hazard classification to be determined for the range of modelled events. The hydrological analysis undertaken for the existing Horsbere Brook study (Halcrow 2007) was considered appropriate and taken forward for use in this study (Section 2)..

1.3 Site Visit

1.3.1 A site visit to the Horsbere Brook at Brockworth was undertaken prior to the commencement of any analysis of the watercourse to obtain a more detailed understanding of structures within the modelled extents and identify possible floodplain flow routes.

2 Hydrological Analysis

2.1 Introduction

2.1.1 The existing 1D-2D linked ISIS-TUFLOW SFRM model for the Horsbere Brook through Gloucester was adopted for this study. The model was developed by Halcrow for the Environment Agency after the summer 2007 floods.

2.2 Hydrological appraisal

2.2.1 The 2007 SFRM Horsbere Brook model was originally produced for the purposes of replicating the July 2007 floods. During the model calibration and flow reconciliation process it was found that the FEH rainfall-runoff model gave the best estimate of peak flows. During the 2007 study only the 1% AEP (1 in 100 year) design hydrology was used to compare with the observed flood extent outline. Using the same hydrological model, flow hydrographs for the 5% and 0.1% AEP events have been derived for this Level 2 SFRA.

2.2.2 The upstream limit of the existing model is at NGR SO 8669 1867, which is approximately 2km downstream of the area of interest at Brockworth. To enable mapping of the current study area, the existing upstream model inflow was relocated approximately 5km upstream to the new upstream model extent (at SO 9031 1595). No adjustments to the inflow boundaries were made, except for storm duration as described below.

2.2.3 Storm duration sensitivity runs were carried out using the 1% AEP event in order to determine the critical duration for the Brockworth study area. A storm duration of 10.25 hours was identified as critical and subsequently used in all design model runs.

2.3 Design Flows

2.3.1 The final peak flows adopted in the model are as shown in Table 2.1.

Table 2.1: Final peak flows adopted in the model

			Maximum flows in m^3/s			
Boundary location	**Watercourse name**	**Node label**	**5% AEP**	**1% AEP**	**1% AEP with climate change**	**0.1% AEP**
SO 8669 1867	Horsbere Brook	Horsb_Upper	11.5	17.0	20.4	29.9

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment of the Horsbere Brook at Brockworth.

3.2 Model extent

3.2.1 The Horsebere Brook model developed for this study extends start from a point 250m upstream of the A46 Shurdington Road (SO 90275, 16112) to 150m downstream of the M5 motorway (SO 87941, 17667) (Figure 3.1).

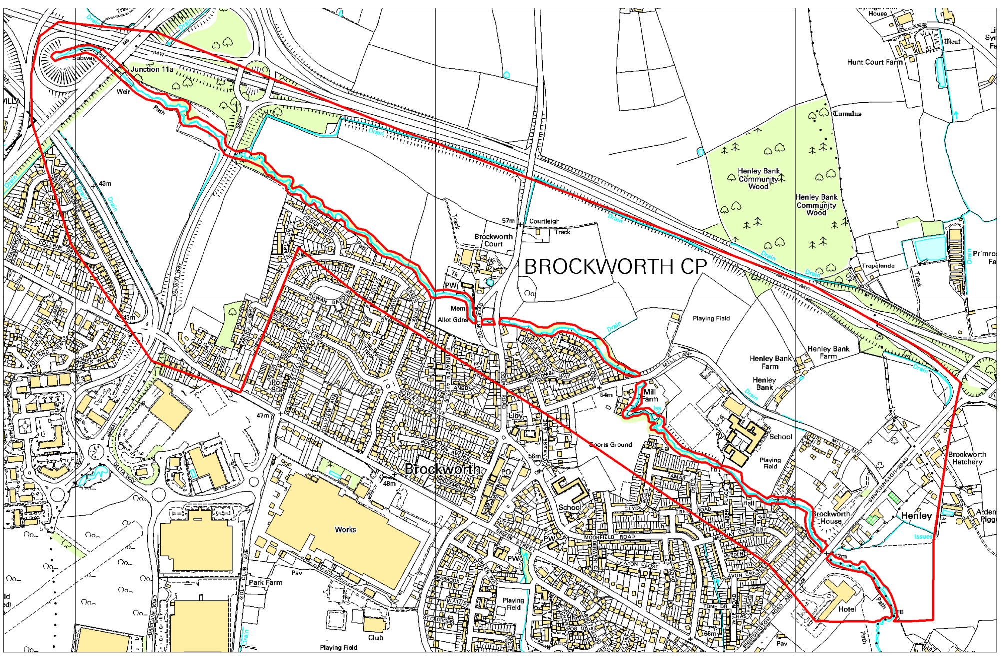

Figure 3.1: Brockworth model extents

3.3 Methodology

3.3.1 The model developed for this study is a 1D-2D ISIS-TUFLOW linked model. This will enable flood extent and hazard maps to be created for the range of modelled design events. All in bank structures with in the watercourse have been included in the model and their backwater effect taken in to account.

3.3.2 The grid resolution used for the 2D model is 5m. This grid size not only allows for accurate representation the floodplain part of the model but also ensures a reasonable model run time so that the final model result files are of a manageable size.

3.3.3 Along the watercourse there are seven culverts, eight bridges and one weir and all of those units added in to the model based on the Halcrow survey with an appropriate units.

3.3.4 A global value for the hydraulic roughness, based on the local land use and observations from the site visit has been selected. This value is 0.04. The exception to this is buildings where OS Mastermap polygons have been used to define areas where a higher roughness value is more appropriate within the building area. The selected roughness value for this study is manning n value of 0.8.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to the roughness (Manning's 'n'), flow, storm duration and structural blockage was carried out. The results of this analysis are summarised below.

Roughness

3.4.2 Applying a 20% increase to roughness (Manning's 'n') showed an maximum increase in water level of 259mm. This was observed at location HB9026CULD. For the 20% decrease on roughness, the maximum water level reduction of 513mm, observed at cross-section HB10286. This demonstrates that the model is sensitive to changes in model roughness.

Flow

3.4.3 Increasing the flow into them model by 20% resulted in a maximum increase in water level of 923mm. This was observed at cross-section HB7254SU. With a 20% decrease to the flow, the maximum reduction in water level was 736mm at cross-section HB10536.

Storm Duration

3.4.4 Three storm durations were considered as part of the sensitivity analysis to determine the critical storm duration for the 1% AEP event (Section 2.2). The storm durations selected for analysis were 4.25hrs, 10.25hrs and 16.25hrs. The model results demonstrated that 10.25hrs is generally the critical storm duration as it resulted in higher water levels throughout the modelled extent.

Blockage

3.4.5 Structural blockage was performed at two key locations: Mill Lane Culvert (HB9566) and Court Road Bridge (HB9079). Each of the structures were blocked by 75% and the blockage to both structures was undertaken simultaneously.

3.4.6 The results of this model run show that the water level increases as a result of 75% blockage to the culvert at Mill Lane (HB9566) increased the flood level by 250mm; however this increase did not result in out-of-bank flow and no properties were affected. However, with a 75% blockage applied to the bridge at Court road (HB9079), there was a significant increase in the water level (1.45m) resulting in a number of properties adjacent to Court Road being affected (Figure 3.2 overleaf).

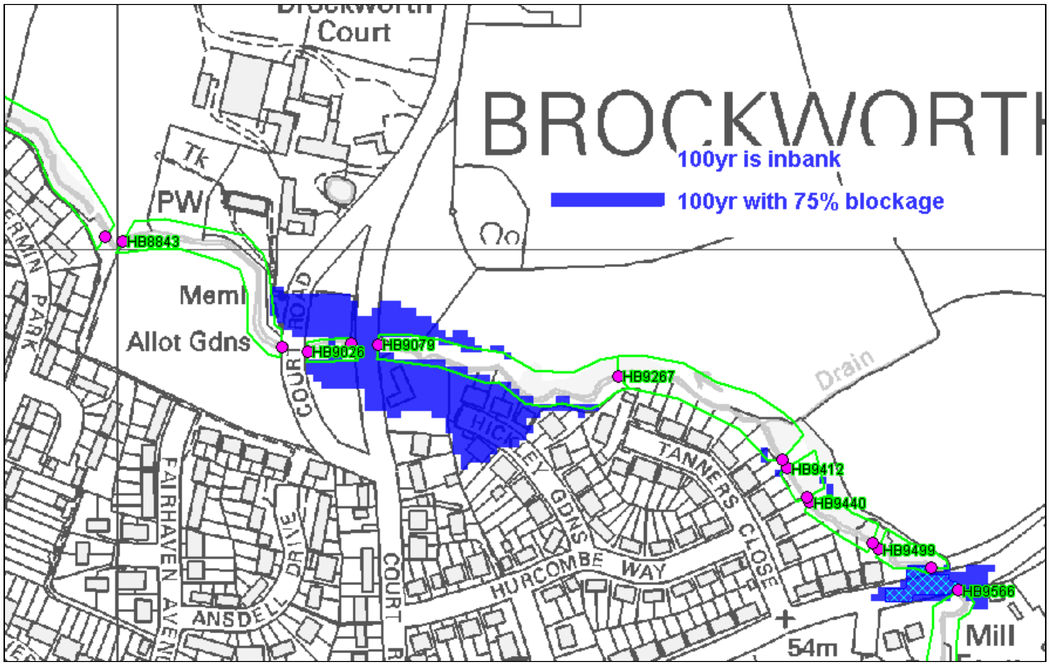

Figure 3.2: Comparison of model extents for blockage scenario at Court Road

3.5 Assumptions & Limitations

3.5.1 A number of assumptions have been made in the hydraulic modelling undertaken as part of this study.

3.5.2 The model has been constructed using existing survey data provided at the start of the study. It has been assumed that this information is accurate and suitable for use.

3.5.3 A key limitation with this study is the lack of information with which to calibrate and verify the model with. If such information had been available, this would have provided a more detailed assessment of the overall model performance.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are sensitive to roughness and flows and for watercourse of this character. It is therefore recommended that regular channel maintenance is undertaken to ensure the channel is kept free of obstructions.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	November 2010
Note	Hydrological & Hydraulic Modelling Methodology – Cheltenham	**Ref**	WBGCTS
Author	M Grogan		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the River Chelt at Cheltenham.

1.2 Existing Models & Data

1.2.1 The River Chelt flows through the Cheltenham study area. The watercourse has an existing model, the River Chelt SFRM model (Black and Veatch 2009). The model has its own hydrological assessment which was assessed as part of this project.

1.3 Site Visit

1.3.1 A site visit to the River Chelt was undertaken prior to the commencement of any analysis of the watercourse Cheltenham was visited to obtain a more detailed understanding of structures within the modelled extents so that hydraulic coefficients could be checked in the model and possible flow routes could be identified, particular attention was paid to floodplain structures which may have been missing from the existing models.

2 Hydrological Analysis

2.1 Hydrological appraisal

2.1.1 The Black and Veatch hydrology was used because it is derived using the most up to date methodologies and has undergone an extensive QA process during previous studies.

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment of the River Chelt through Cheltenham. A brief description of the data used, study extents, the adopted methodology and further model sensitivity/result validation.

3.2 Model extent

3.2.1 The River Chelt model extends from Dowdswell reservoir (SO 99373 19807) to the M5 (SO), the Lilley Brook a tributary of the Chelt is also included in the model from Moor End (SO 95960 20136) to it's confluence with the Chelt (SO 95872 21143). The sections of the model linked to 2D extend from Cox's Meadow (SO 95872 21143) to Honeybourne Way (SO 94152 22653), B4633 (SO 93960 22908) to St Peter's Close (SO 93437 23372), and A4013 (SO 93211 23833) to Downstream of Uckington (SO 91085 24702).

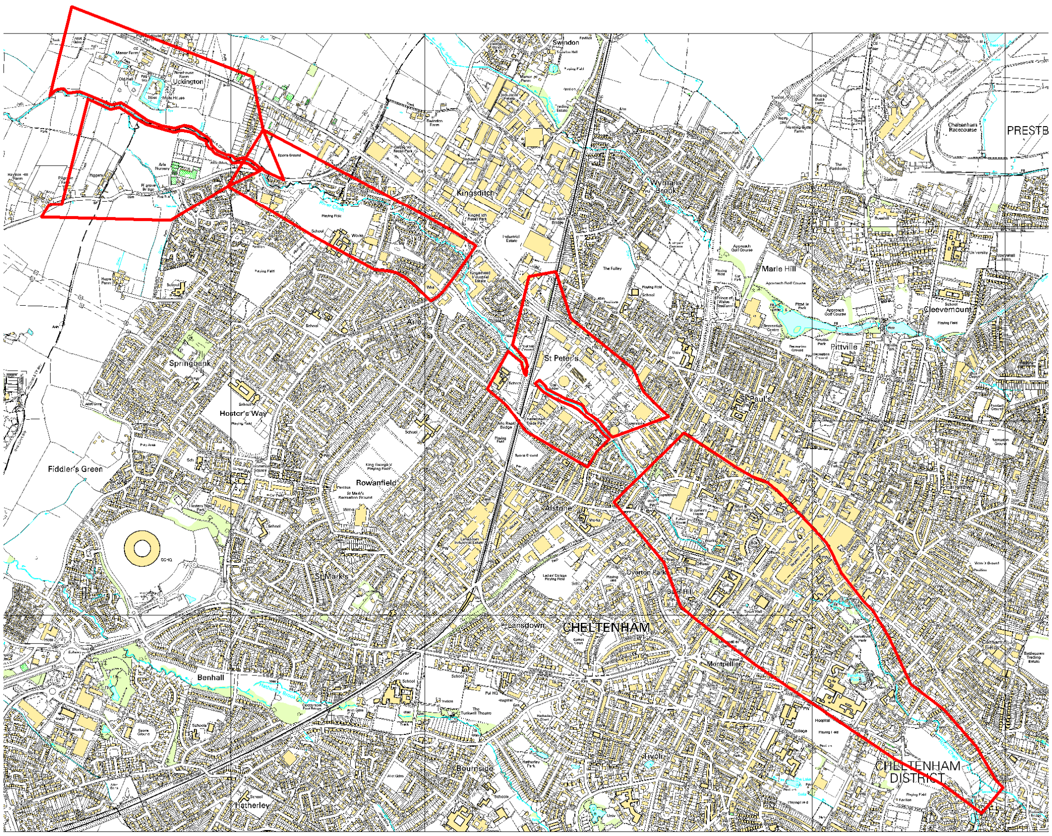

Figure 3.1: Chelt model extents

3.3 Methodology

3.3.1 The existing Environment Agency River Chelt model was taken and modified slightly to make it suitable for use in this study. Modification of the model involved linking two additional discrete areas to a 2D domain to allow floodplain flows and flow routes to be examined in more detail and classification of the flood hazard.

3.3.2 The additional areas linked to 2D are adjacent to Uckington and Cheltenham trade park in St Peter's.

3.3.3 All hydraulic parameters in the new 2D sections were kept consistent with the parameters in the existing 2D sections to maintain consistency throughout the model.

3.4 Sensitivity Analysis

3.4.1 Sensitivity analysis on hydraulic parameters has not been carried out as this model has been extensively tested in previous studies.

Structural Blockage

3.4.2 Blockage analysis was performed on the culverts under Rodney Road and St Peters Railway culvert. A model was run for each culvert which was blocked by 75%. Neither blockage scenario caused any significant changes in local flood extents, however blocking Rodney Road caused a 580mm increase in water level immediately upstream of the culvert and blocking St Pauls railway culvert caused 600mm increase in water level upstream of the culvert.

3.5 Assumptions & Limitations

3.5.1 It is assumed that the River Chelt model is suitable for the purposes of this study and has been hydraulically calibrated.

3.5.2 It is assumed that the filtered LiDAR used in the study is accurate and has no errors.

3.6 Model Confidence

3.6.1 This model has been extensively tested in previous studies which convey a good degree of confidence in the model.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Gloucester	**Ref**	WBGCTS
Author	M Green, H Gebre		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the watercourses in Gloucester.

1.2 Existing Model & Data

1.2.1 For Gloucester Urban Area level 2 SFRA study, there are a number of models developed by different consultants at different times. The first challenge was to integrate them in to one model with an extent sufficient to evaluate the flood risk for the area of interest. The models are, the River Seven tidal interface (JBA 2007), the River Twyver 1D ISIS model (Halcrow 2006), Sud brook 1D ISIS model (Halcrow 2006), Gloucester and Sharpness canal 1D ISIS model (British Waterways 2007). Daniels brook and Whaddon brook were reviewed but they were not included in this study as they do not affect the area of interest.

1.2.2 The SFRA model will be built from integrating all the above mentioned models and trimmed to the right extent. This model is developed in hybrid ISIS-TUFLOW linked format to enable hazard ratings output in addition to the depth and velocity grid output for all design return periods.

1.2.3 NFCDD data set has been used to define the crest level of defence where the elevation is available, where there is no data the LiDAR level has been used. There is a new defence downstream of Llanthony Bridge (SO 82073 18111), the defence crest has been surveyed using a Smart Rover by Halcrow.

1.3 Site Visit

1.3.1 A site visit to the watercourses in Gloucester was undertaken prior to the commencement of any analysis of the Gloucester watercourses so that structures on the watercourses could be observed and that possible floodplain flow routes could be identified.

2 Hydrological Analysis

2.1 Model background & approach

2.1.1 A new 1D/2D Gloucester model has been constructed by combining:

- Selected reaches of existing 1D models of the Lower Severn, River Twyver, Sud Brook and the Gloucester and Sharpness Canal
- New 2D floodplain representations to simulate floodplain interactions between the watercourses through Gloucester.

The extent of the new model is shown in Figure 3.1.

2.2 Hydrological appraisal

2.2.1 Inflow boundaries for a range of design events were provided for each of the four existing 1D models. To provide inflow boundaries at the required locations for the new Gloucester model, the existing models on the River Twyver, Sud Brook, and the Gloucester and Sharpness canal were run separately and flow-time series extracted. Where a 5% AEP (Annual Exceedance Probability) hydrology (1 in 20 year return period) was not available, the 4% (1 in 25 year return period) was adopted instead, adopting a precautionary approach in agreement with the Environment Agency.

2.2.2 The flood response characteristics of the River Severn differ from those in the Gloucester tributaries with flood levels on the River Severn being heavily influenced by tidal conditions and the fluvial hydrograph rising and receding over an extended period (see Figure 2.1). The Gloucester model was run for a 12 hour period with peak levels on the tributaries coincident with the peak level on the River Severn. There is a risk that this phasing would constitute an overly conservative approach. Analysis of historical events indicates that extreme rainfall events can comprise slow moving widespread frontal events where coincidence of heavy rainfall over Gloucester with high levels in the Severn could occur. Using the coincident phasing, the 1% AEP fluvial modelled flood extent matched closely with the July 2007 flood outline which has been assessed by March and Hannaford (2007) as having a severity of approximately 1% AEP event in the vicinity of Gloucestershire[1]. Comparison with the July 2007 event indicates that the adopted design flows and phasing with the Severn is reasonable.

[1] See Table 6 on page 19 of MARSH T AND HANNAFORD J (2007), *The summer 2007 floods in England & Wales – a hydrological appraisal*, CEH.

2.2.3 To determine the extent of Flood Zone 3a on the River Severn two scenarios have been considered: the 1% AEP fluvial event with the 50% AEP tidal; and the 0.5% AEP tidal event with the 20% AEP fluvial event.

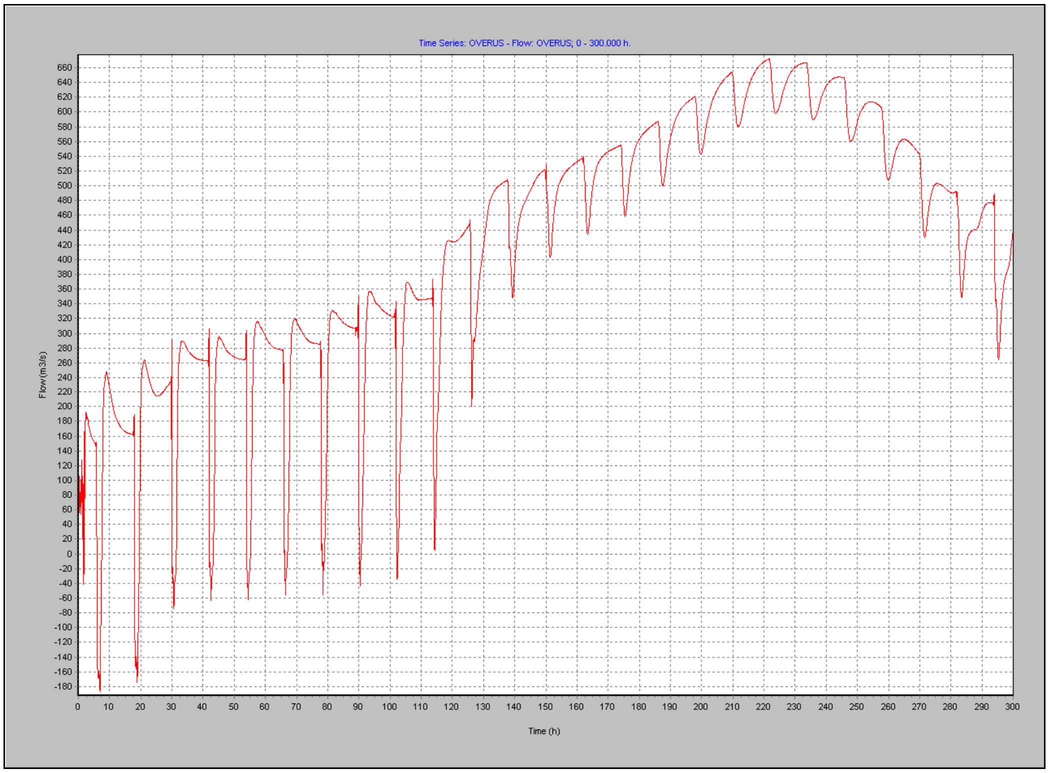

Figure 2.1: Flow-time series on River Severn model upstream of Gloucester

2.2.4 A sensitivity test on flows was carried out using the 1% AEP (50% tidal) event by varying the flow by ±20%. The resulting modelled peak water levels indicated that the River Twyver and Sud Brook are sensitive to flows, whilst the River Severn and the Gloucester and Sharpness Canal are not.

2.3 Design Flows

2.3.1 The adopted peak flows are as shown in Table 2.1.

Table 2.1: Final peak flows adopted in the model

Maximum flows in m^3/s			50% AEP tidal event			
Boundary location	**Watercourse name**	**Node label**	**5% AEP fluvial**	**1% AEP fluvial**	**1% AEP fluvial with climate change**	**0.1% AEP fluvial**
SO 8217 1969	River Severn	LCR18	342.0	517.0	567.0	779.0
SO 8164 1963	River Severn	OVERUS	517.0	576.0	666.0	784.0
SO 8447 1746	River Twyver	CO42D	0.2	0.3	0.4	1.6
Lateral Inflow	River Twyver	H_default	7.7	11.6	13.9	24.4
SO 8409 1696	Sud Brook	SB02025	6.1	8.7	9.3	11.0
Lateral Inflow	Sud Brook	SU_07	5.9	8.9	10.3	19.6
SO 8170 1533	Whaddon Brook	Tuffley	3.8	5.0	6.0	9.3
SO 8144 1503	Daniels Brook	Daniels	6.7	9.3	11.1	17.3

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment of the Gloucester Urban Area.

3.2 Model extent

3.2.1 The Severn model upstream extent starts in the middle of the Alney Island just upstream of A40, there are two arms the Western arm (SO 81660 19690) and the Eastern arm (SO 82173 19687). River Twyver and Sud brook both start immediately upstream of the rail way culverts (SO 84468 17476 and SO 84161 16877). The River Twyver discharges into the River Severn while the Sud Brook discharge into the Gloucester and Sharpness canal. The Gloucester and Sharpness Canal starts at the Gloucester Docks with a series of locks downstream of the confluence with eastern arm of the River Severn. The canal flows south carrying flows from a number of smaller watercourses including the Daniels Brook, the Tuffley, the Sud Brook, the Cam and others. For this study, the canal model is trimmed downstream of the A430 Secunda Way (SO 81062 15621). For the full extent upstream and downstream of the model and full watercourse location see Figure 3.1 below.

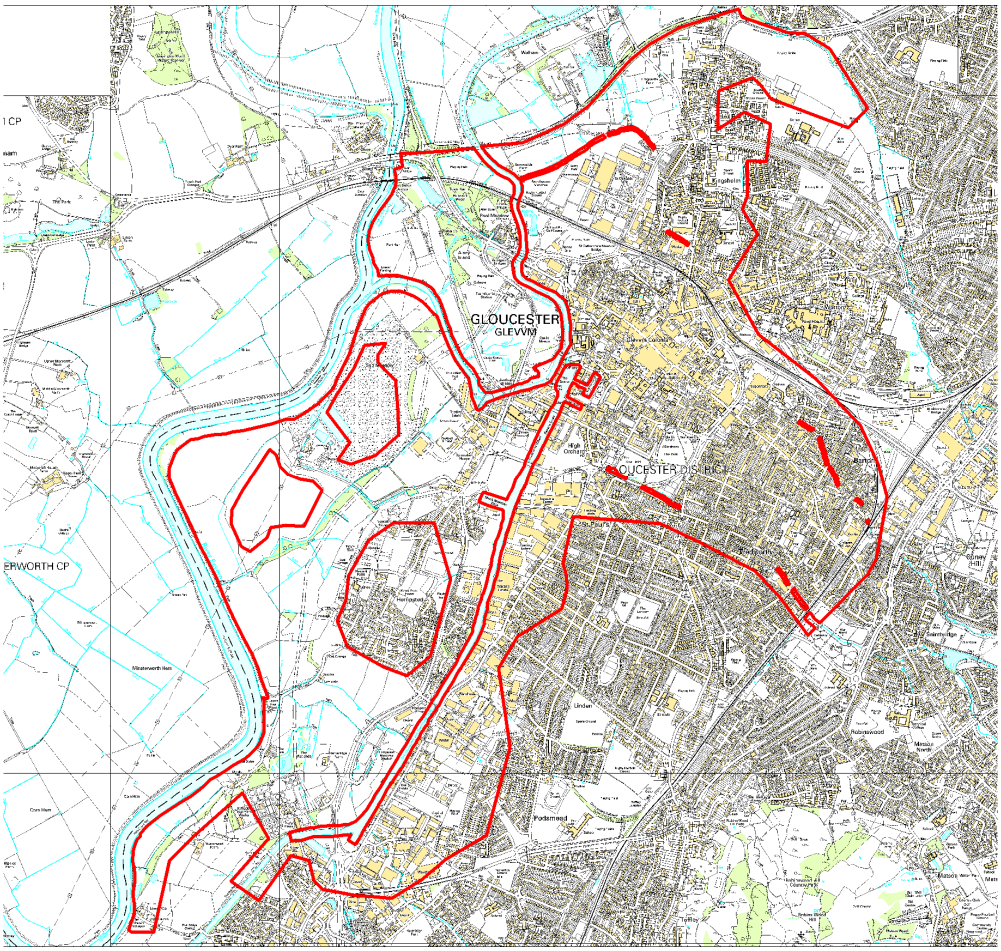

Figure 3.1: Gloucester model extents

3.3 Methodology

3.3.1 The model was built in ISIS-TUFLOW to enable the production of hazard outputs.

3.3.2 The a 5m resolution was used for the 2D grid. This grid size allows for accurate representation the floodplain part of the model and keeps model run times and results file sizes reasonable.

3.3.3 Along the watercourses there are number of culverts, bridges and weirs and all of those structures are kept as they were in their original format except for some of the Arch bridges where advances in ISIS have allowed for an orifice functionality switch to numerically support the model at the transition period between a free flows to surcharges flow.

3.3.4 A global Manning's 'n' value for hydraulic roughness has been chosen, this has been based on the local land use and observations from the site visit, a value of 0.04 has been chosen. A higher value has been chosen to represent buildings in the model, the selected roughness value for this study is Manning's 'n' value of 0.8, the buildings have been defined using OS Mastermap polygons.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to roughness, flow, storm duration and structural blockage were. The results of this analysis are summarised below.

Roughness

3.4.2 Sensitivity to roughness was analysed by running the model with an increase and reduction in Manning's 'n' of 20%. Increasing the roughness by 20% caused a maximum increase in stage of 368mm at C006 in the River Twyver. Decreasing the roughness by 20% caused a maximum decrease in stage of 572mm at C039RESA in the River Twyver.

Flow

3.4.3 Sensitivity to flow was analysed by running the model with an increase and reduction in flow of 20%. Increasing the flow by 20% caused a maximum increase in stage of 559mm at C006. Decreasing the flow by 20% caused a maximum decrease in stage of 831mm at SB1931 on the Sud Brook.

Structural Blockage

3.4.4 Sensitivity to blockage was carried out on two key structures, both of hich where blocked by 75% for the 1% AEP event. The structures selected were the culvert under Trier Way (SB00674R_i) on the Sud Brook and the Rose Cottages Culvert (C016cu) on the River Twyver, both structures were blocked during the same model run. The results of this analysis show an increase in stage of 135mm at Trier Way, however water is still in bank and has not affected properties in the area. The blockage of the Rose Cottages Culvert resulkted in a 34mm rise in stage upstream of the culvert. This rise in flood level has not changed the flood outline.

Cory Environmental Future Landfill

3.4.5 Cory Environmetal was invited to supply an up to date level data of the land fill area for comparison with the LiDAR and to get an understanding of how the topography of the site is proposed to change in the future. Comparison between the current Cory topo survey and the LiDAR found that there was very little difference between the two ground models, as such the LiDAR was adopted for the model build.

3.4.6 Sensitivity analysis was carried out with Cory Environmental's existing consented area raised to its final proposed level to gauge the impact of the any future land fill. The analysis shows that the water level has not changed significantly. The only change being that the current low lying areas within the landfill which currently flood would no longer flood as can be seen in Figure 3.2 below.

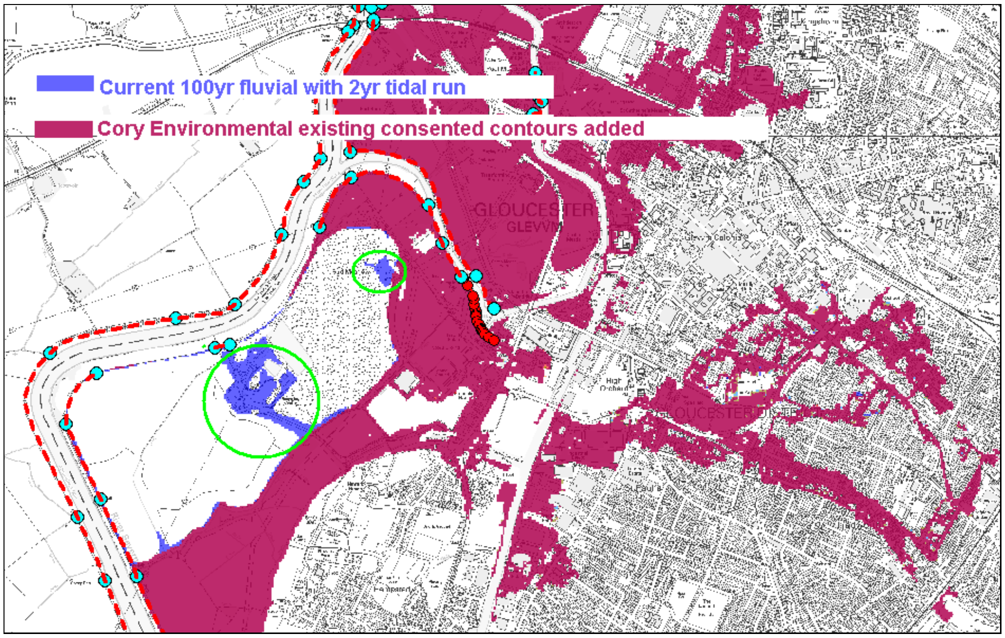

Figure 3.2: Comparison of outlines for future development of landfill

3.5 Assumptions & Limitations

3.5.1 Model is constructed with the assumptions that the survey data used to build all the models used on this study are reasonably accurate.

3.5.2 The key limitation with this study is the luck of good calibration data against which the model performance would have been tested to.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are sensitive to roughness and flows and for watercourse of this character. It is therefore recommended that regular channel maintenance is undertaken to ensure the channel is kept free of obstructions.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Innsworth	**Ref**	WBGCTS
Author	M Green, M Grogan		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the Horsbere brok and Hatherly Brook in the Innsworth area.

1.2 Existing Models & Data

1.2.1 The Innsworth study area has two large watercourses flowing through it, the Hatherly Brook and the Horsbere Brook. Both watercourses have existing models, the Horsbere Brook SFRM model (Halcrow 2008) a 1D-2D ISIS-TUFLOW model and the Hatherly Brook SFRM model (Capita Symonds 2009) a 1D ISIS model. Each model has its own hydrological analysis, which was assessed as part of this project before being used in the combined Innsworth model.

1.2.2 The model for this study was created by combining both of the existing models to create on large integrated 1D-2D ISIS-TUFLOW model, enabling hazard to be mapped.

1.3 Site Visit

1.3.1 A site visit to the Horsbere Brook and Hatherly Brook was undertaken prior to the commencement of any analysis of the watercourse the Innsworth area was visited to obtain a more detailed understanding of structures within the modelled extents so that hydraulic coefficients could be checked in the model and possible flow routes could be identified, particular attention was paid to floodplain structures which may have been missing from the existing models (i.e. the culvert under Innsworth Lane was estimated based on the channel size in the LiDAR, however after the site visit accurate dimensions could be estimated for it).

2 Hydrological Analysis

2.1 Hydrological appraisal

2.1.1 The inflows in the existing models were compared with those quoted in the reports. It was found that, while the Horsbere Brook 100 year design flows in the model matched that reported, there was some discrepancy between the Hatherley Brook inflows in the model and those in the report, which was not easily quantifiable. The Agency project manager for the Hatherley Brook SFRM confirmed that the flows in the model are correct, and these were therefore used in this study.

2.1.2 The 2007 SFRM Horsbere Brook model was originally produced for the purposes of replicating the July 2007 floods. During the model calibration and flow reconciliation process it was found that the FEH rainfall-runoff model gave the best estimate of peak flows. During the 2007 study only the 1% AEP (1 in 100 year) design hydrology was to compare this outline with the observed. Using the same hydrological model, flow hydrographs for the 5% and 0.1% AEP events have been derived for the current study.

2.1.3 The full existing 1D model extents were used in this study, which meant that the majority of inflow boundary locations did not change. There were two exceptions to this as follows.

(a) Three inflow boundaries were added to the Horsbere Brook model during the 2007 study to take account of cross-catchment overland flow from the Hatherley Brook catchment into the Horsbere Brook catchment across the A40 in order to better replicate the July 2007 event. These were removed from the model for the purposes of this study in order to avoid double-counting flows from the Hatherley Brook catchment.

(b) Flow boundary HA_03 in the Hatherley Brook model was removed from the 1D model (location SO 8452 2134) and added to the upstream extent of the 2D domain (location SO 8582 2070). This meant that flows in the vicinity of the Innsworth Technology Park were more accurately represented.

2.1.4 The fact that the Hatherley Brook inflows in the model did not match those in the report introduced an element of uncertainty in the adopted flows. Flow sensitivity model runs were therefore undertaken (plus and minus 20%) to assess the sensitivity of flood extents, depths and hazard to flow. It was found that modelled flood extents were relatively insensitive to changes in flow, although differences were observed in some areas (see Figure 2.1).

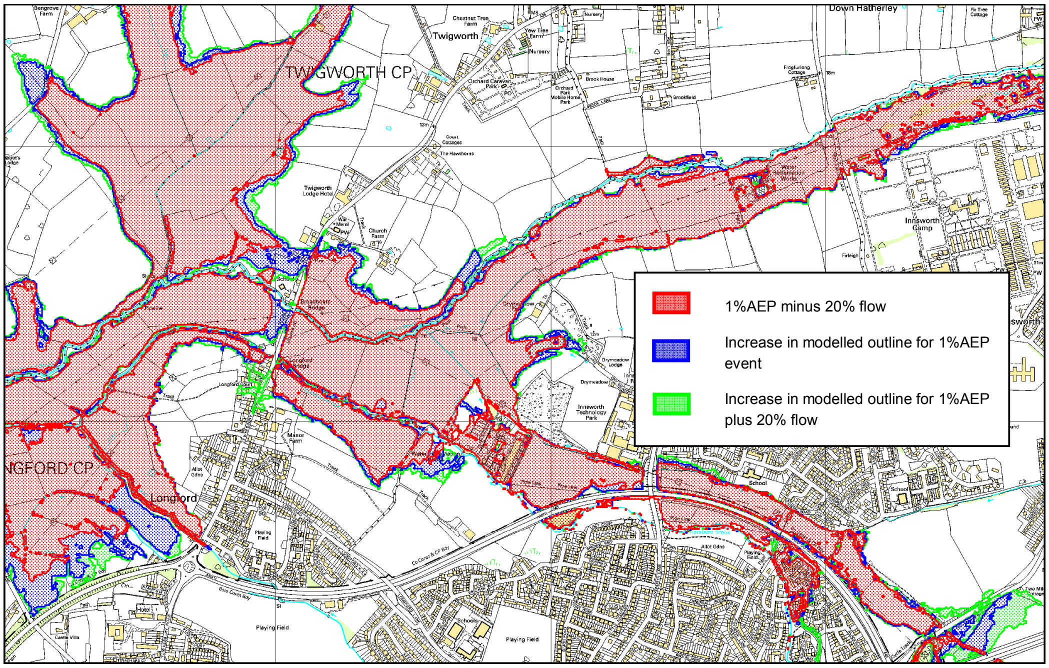

Figure 2.1: Flow sensitivity modelled outlines

2.1.5 Storm duration sensitivity model runs using the 1% AEP event were undertaken to identify the critical duration for the Innsworth site. It was found that the critical storm duration was 8.67 hours and this was therefore adopted for all design model runs.

2.2 Conclusions

2.2.1 The final peak flows adopted in the model are as shown in Table 2.1.

Table 2.1: Final peak flows adopted in the model

			Maximum flows in m^3/s			
Boundary location	**Watercourse name**	**Node label**	**5% AEP fluvial**	**1% AEP fluvial**	**1% AEP fluvial with climate change**	**0.1% AEP fluvial**
SO 8669 1867	Horsbere Brook	Horsb_Upper	11.3	16.8	20.2	29.8
Lateral inflow	Horsbere Brook	Horsb_Lower	3.7	6.4	7.7	11.2
SO 8399 2039	Wotton Brook	WottonBrk	13.9	23.9	28.7	41
SO9376720355	Burrow's Hill Tributary	BR_01	1.6	2.4	2.9	4.4
SO9441619709	Hatherley Brook	BR_02	3.1	4.4	5.3	7.7
SO9332521339	Hatherley Brook	HA_01a	0.2	0.3	0.4	0.6
SO9327921394	Hatherley Brook	HA_01	1.7	2.4	2.9	4.2
SO9285720855	Warden's Hill Tributary	WH_01	2.2	3.1	3.7	5.5
SO9202921628	Hatherley Brook	HA_01b	1.7	2.4	2.9	4.2
SO8898022519	Hatherley Brook	HA_02	6	8.6	10.3	15.4
SO8602022092	Hatherley Brook	HA_02a	1.6	2.2	2.6	3.9
SO8745122064	Norman's Brook	NB_01	17.5	24.2	29.0	41.7
SO 8582 2070	Hatherley Brook	HA_03	4.3	6.6	7.9	11.7
SO8355821480	Cox's Brook	SO_01	7.1	9.9	11.9	17.2
SO8264821040	Hatherley Brook	HA_04	2.5	3.6	4.3	6.5

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment of the Hatherly Brook and Hosbere Brook in the Innsworth area. A brief description of the data used, the study extents, the adopted methodology and further model sensitivity/result validation.

3.2 Model extent

3.2.1 The Hosbere Brook model extends from adjacent of the junction of the A40 and A417 (SO 86699 28674) to it's confluence with the River Severn (SO 82802 20852). The Hatherly Brook model extends from Church Road in Leckhampton (SO 94416 19711) to it's confluence with the River Severn (SO 82590 20976). A section of the 1D Hatherly Brook model had its floodplain stripped out so that it could be linked to TUFLOW through the study area, this area extended from Ashville Business Park (SO 87755 22194) to the confluence with the River Severn. Figure 3.1 below shows the extents of the 1D-2D model covering the study area.

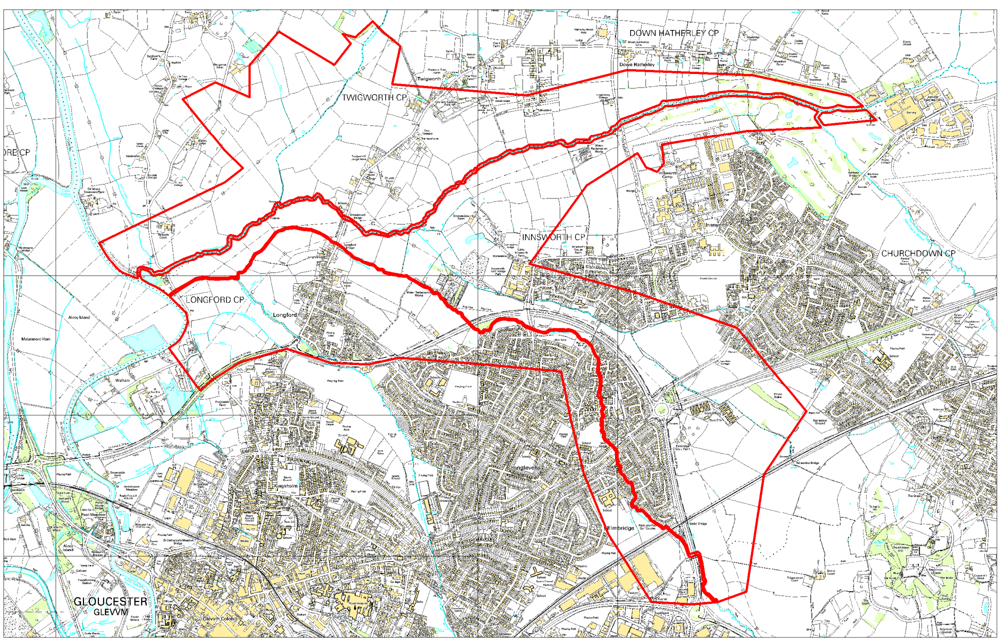

Figure 3.1: Innsworth model extents

3.3 Methodology

3.3.1 A 1D-2D ISIS-TUFLOW model, for the study area, was constructed from two existing models. The Horsbere Brook model, an existing 1D-2D model and the Hatherly Brook model an existing 1D ISIS model.

3.3.2 Through the study area the 1D floodplain of the Hatherly Brook was removed and it was coupled with the 2D TUFLOW grid. This was to allow for more accurate modelling of the floodplain flows in the area. A 5m resolution was used for the grid size in this model. This allows for accurate representation of the floodplain while keeping model run times and result file sizes manageable. Floodplain structures where represented using 1D ESTRY (see modelling summary table for estimated culvert dimensions).

3.3.3 There are no formal or de-facto defences in the study area.

3.3.4 The in-channel roughness was left as it was in the original models and the floodplain roughness was assigned using polygons extracted from OS Mastermap data.

3.3.5 The inflow boundaries are located as they were in the original models.

3.3.6 The downstream boundary on the Severn has been modelled as a normal slope to allow the flooding due to the watercourses themselves to be examined, rather than any flooding from the River Severn.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to roughness (Manning's 'n'), flow and downstream boundary was carried out. The results of this analysis are summarised below.

Manning's 'n'

3.4.2 Raising the Manning's 'n' values by 20% causes an average increase in stage of 60mm through the study area while decreasing Manning's 'n' by 20% causes an average decrease in stage of 85mm.

Flow

3.4.3 Increasing the flow by 20% causes an average rise in water level of 60mm while decreasing the flow causes an average decrease in water level of 85mm.

Downstream boundary

3.4.4 The sensitivity of the model to the downstream boundary was tested by modelling a 100yr water level on the Severn. It was found that a 100yr level on the River Severn causes flooding up to Tewkesbury Road, with any additional flooding upstream of Tewkesbury Road being caused by the Hatherly and Horsbere Brooks backing up.

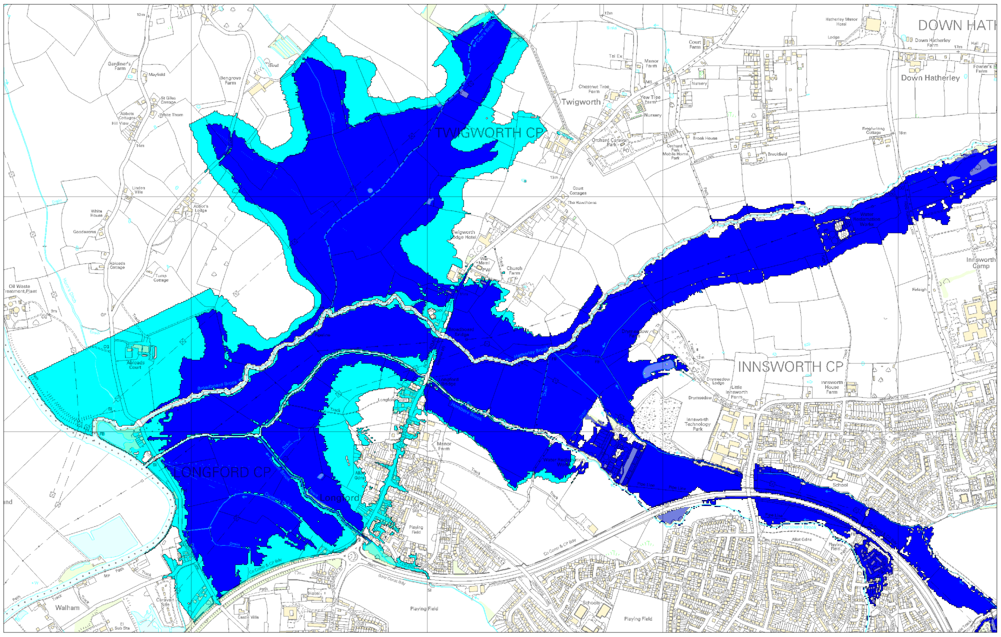

Figure 3.2: Comparison of 100yr design flow with (light blue) and without (dark blue) a 100yr level on the River Severn

Structural Blockage

3.4.5 Blockage analysis was performed on the culverts under Tewkesbury Road. For this analysis both culverts on the Horsbere and Hatherly Brooks were blocked by 75%. This blockage causes an increase in stage, upstream of Tewkesbury Road, of 645mm on the Horsbere Brook and an increase of 218mm on the Hatherly Brook.

3.5 Assumptions & Limitations

3.5.1 It is assumed that both the Hatherly Brook and Horsbere Brook SFRM models are suitable for the purposes of this study and have both been hydraulically calibrated.

3.5.2 It is assumed that the filtered LiDAR used in the study is accurate and has no errors.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are not sensitive to roughness and flows however if the land use and type changes then this should be reanalysed to ensure that this is still valid and that regular channel maintenance is not required.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Leckhampton & Shurdington	**Ref**	WBGCTS
Author	M Green, M Grogan		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the Hatherly Brook and Ham Brook at Leckhampton & Shurdington area.

1.2 Existing Models & Data

1.2.1 The Leckhampton & Shurdington study area has several watercourses flowing through it, the largest being the Hatherly Brook in the Leckhampton area. There is an existing 1D ISIS model for the Hatherly Brook (SFRM model Capita Symonds 2009). The model has its own hydrological analysis, which was assessed as part of this project before being used in the combined Leckhampton & Shurdington model.

1.2.2 The Hatherly Brook model only cover one channel in the study are, this channel was linked to 2D. The other channels in the area were modelled as 2D TUFLOW channels with 1D ESTRY structures.

1.3 Site Visit

1.3.1 A site visit to Leckhampton & Shurdington area was undertaken prior to the commencement of any analysis of the watercourse to obtain a more detailed understanding of structures within the modelled extents and identify possible floodplain flow routes, particular attention was paid to the structures which were to be included in the 2D only sections of the model.

2 Hydrological Analysis

2.1 Introduction

2.1.1 The existing 1D ISIS SFRM model of the Hatherley Brook (Capita Symonds 2007) was provided for use in this study by the Environment Agency. Two of the upstream boundaries for this model (BR01 and BR02 – see Figure 2.1) correspond with the Leckhampton site.

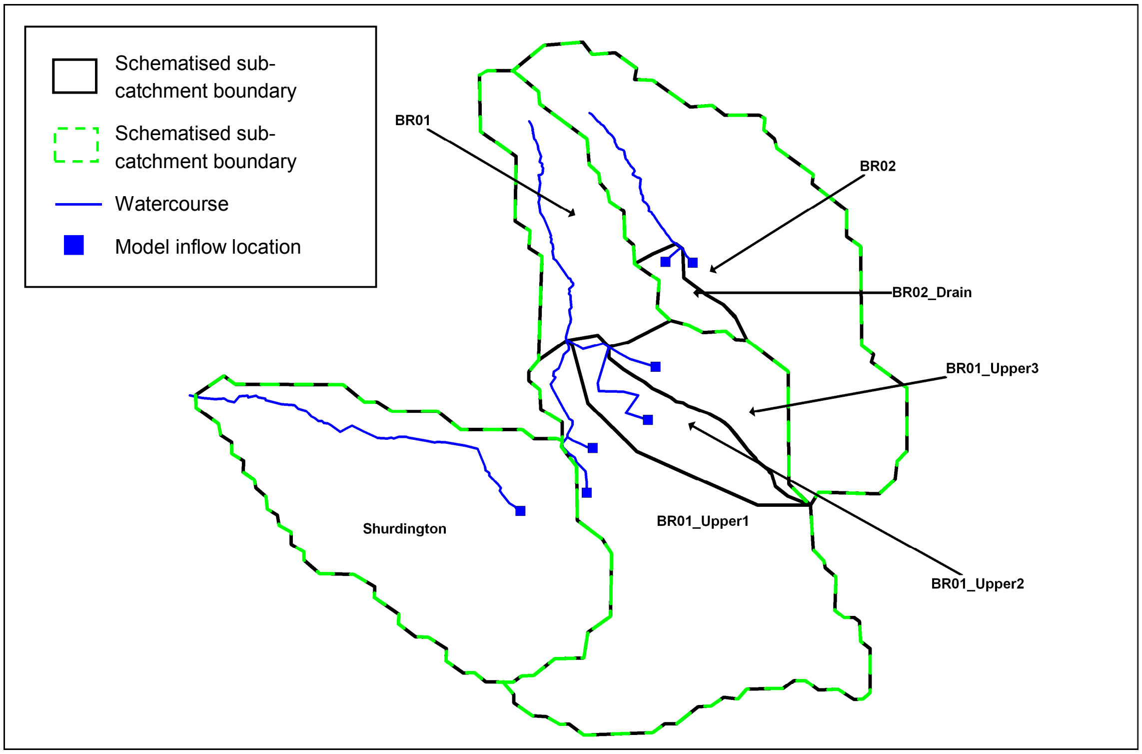

Figure 2.1: Catchment schematisation

2.2 Hydrological appraisal

2.2.1 The flow boundaries in the 2007 SFRM Hatherley Brook model were checked. BR01 was a FEH rainfall-runoff boundary, and BR02 was a flow-time boundary derived using the Modified Rational Method. An error was found in the calculation spreadsheet used to estimate the flows for BR02 such that the flows for this boundary were over-estimated by around 30% in the existing Hatherley Brook model. This was corrected in the derivation of flows in this study. A sensitivity run was also undertaken using the 1% AEP event with flows in BR02 reduced by 30% compared with those in the original model. The results can be seen in Figure 2.2. There was little difference in the modelled outlines with the decrease in flow.

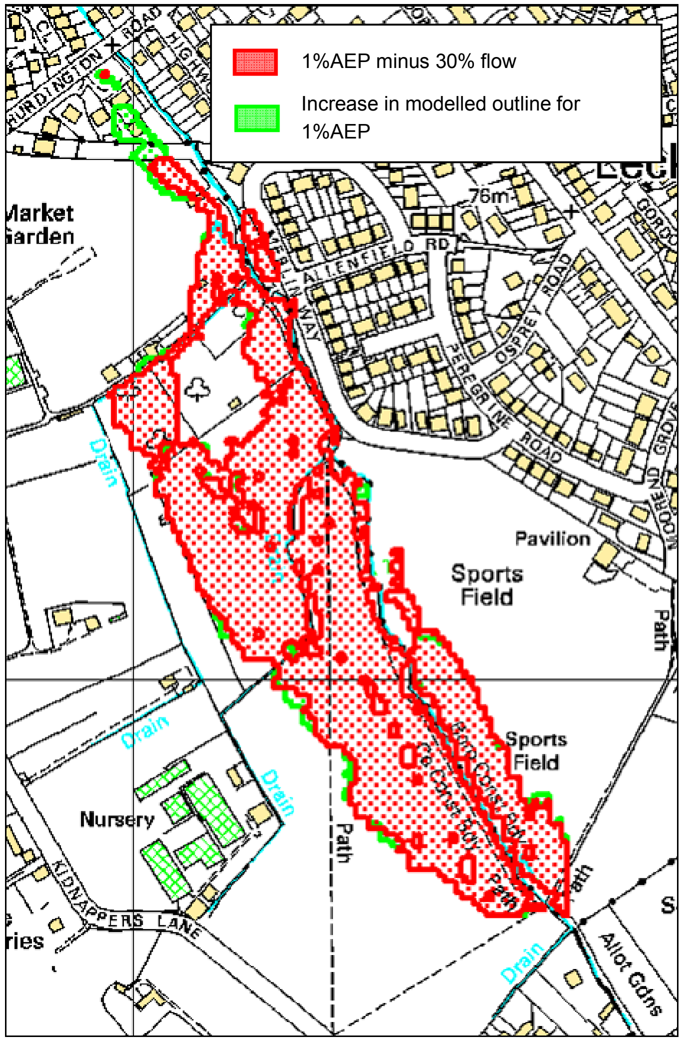

Figure 2.2: Difference in modelled outlines for BR02 with 30% less flow

2.2.2 In addition to flows BR02 and BR01, the Shurdington area falls within a separate catchment, that of the Ham Brook (see Figure 2.1). Given the similarity of the Shurdington and BR01 catchments in terms of topography, geology and land use, flows for the Shurdington catchment were derived in the same way those for the BR01 catchment in the Hatherley Brook model (FEH rainfall-runoff) in order to maintain an approach consistent with previous hydrological studies.

2.2.3 Given that both the Shurdington and Leckhampton catchments are ungauged, there is a degree of uncertainty in the final flows produced. A test on the sensitivity of model outlines to flow was therefore undertaken for the 1% AEP (1 in 100 year) event by increasing and reducing the flow by 20%. The results are shown in Figure 2.3. It can be seen that flood extents are more governed by the topography than flow, and the flood extents are relatively insensitive to flows.

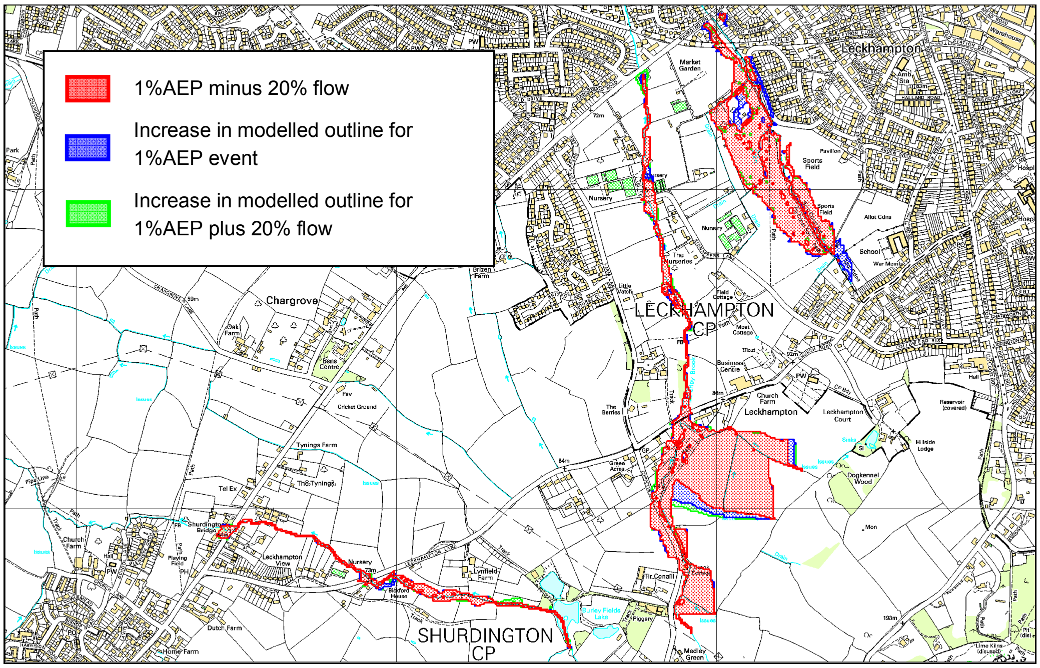

Figure 2.1: Flow sensitivity modelled outlines

2.2.4 Seven upstream model inflow boundaries were required for the hydraulic model. This meant that dividing catchments from the FEH CD ROM using the LiDAR DTM and tools in GIS was required. The resultant sub-catchments (shown in Figure 2.1) were manually verified against OS data and the LiDAR data. BR01 and BR02 inflows were therefore divided between the various upstream model boundaries shown in Figure 2.1 using area-weighting. ‘BR01 Upper1’ flows were divided equally between the two relevant upstream model boundaries, as interrogation of the LiDAR in this region did not indicate any clear catchment delineation.

2.2.5 Storm duration sensitivity runs were carried out using the 1% AEP event in order to arrive at the critical storm duration for the Leckhampton and Shurdington site. It was found that the critical storm duration, in terms of modelled levels and flood extents through the site, was 5.25 hours, which was therefore adopted for all return periods.

2.3 Conclusions

2.3.1 The final peak flows adopted in the model are as shown in Table 2.1.

Table 2.1: Final peak flows adopted in the model

			Maximum flows in m^3/s			
Boundary location	**Watercourse name**	**Node label**	**5% AEP fluvial**	**1% AEP fluvial**	**1% AEP fluvial with climate change**	**0.1% AEP fluvial**
SO 9369 1831	Ham Brook	Shurdington	1.21	1.90	2.28	3.62
SO 9442 1970	Hatherley Brook	BR02	2.84	4.32	5.18	7.82
SO 9430 1970	Hatherley Brook	BR02 Drain	0.16	0.25	0.30	0.45
SO 9397 1842	Hatherley Brook	BR01 Upper1a	0.61	0.96	1.15	1.83
SO 9399 1866	Hatherley Brook	BR01 Upper1b	0.61	0.96	1.15	1.83
SO 9423 1882	Hatherley Brook	BR01 Upper2	0.35	0.55	0.66	1.05
SO 9426 1912	Hatherley Brook	BR01 Upper3	0.37	0.59	0.71	1.12

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment of the Hatherly Brook and Ham Brook in the Leckhampton & Shurdington area.

3.2 Model extent

3.2.1 The section of the Hatherly Brook model which has been used in this area extends from Church Road in Leckhampton (SO 94416 19711) to Merestones Road (SO 93666 20776). A section of the Hatherly Brook was also modelled as a 2D channel, this reach extended from its sources (SO 93920 18611, SO 93999 18672, SO 94193 18963, SO 94266 19121) to upstream of Shurdington Road (SO 93769 20349). In the Shurdington area the Ham Brook has been modelled as a 2D channel from (SO 93546 18564) to downstream of Shurdington Bridge (SO 92453 18942). Figure 3.1 below shows the extents of the 1D-2D model covering the study area.

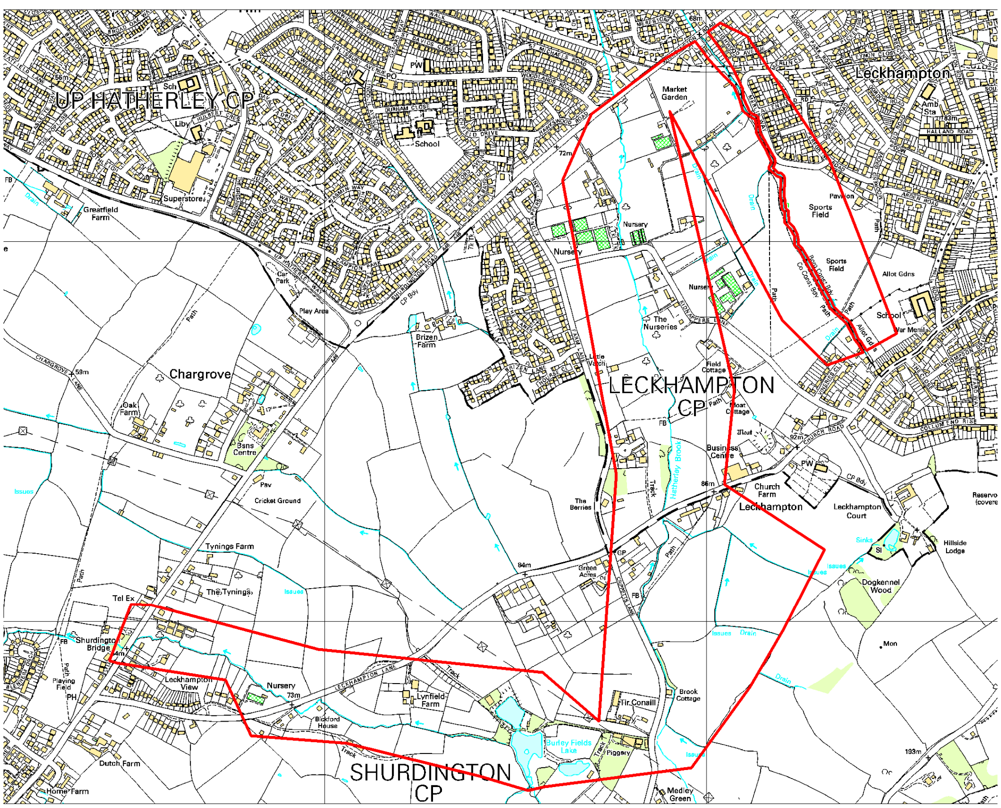

Figure 3.1: Leckhampton & Shurdington model extents

3.3 Methodology

3.3.1 The existing Hatherly Brook model was reviewed and was determined to be suitable for the purposes of this study.

3.3.2 Through the study area the 1D floodplain of the Hatherly Brook was removed and it was coupled with the 2D TUFLOW grid, the downstream extent of the Hatherly Brook model was also removed to improve model run times as it has no effect on the study area. The 2D channels were observed from LiDAR and were reinforced using z-lines to ensure that they are accurately represented in the 2D channel, this method creates idealised trapezoidal channels. Structures in the channels were represented using 1D ESTRY, with dimensions taken from the site visit (see modelling summary table for estimated culvert dimensions).

3.3.3 A 5m resolution was used for the grid size in this model. This allows for accurate representation of the floodplain while keeping model run times and result file sizes manageable.

3.3.4 There are no formal or de-facto defences in the study area.

3.3.5 The in-channel roughness in the 1D model was left as it was in the original models and the 2d channel and floodplain roughness was assigned using polygons extracted from OS Mastermap data and observations made on the site visit.

3.3.6 Inflow boundaries have been located at the upstream extent of each channel, there are no lateral inflows in the model.

3.3.7 The downstream boundary on the Ham Brook has been modelled as a normal slope, based on the LiDAR in the area, while the boundary on the Hatherly Brook is a normal slope boundary far enough downstream that it has no effect on the study area.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to roughness (Manning's 'n'), flow and blockage was carried out. The results of this analysis are summarised below.

Manning's 'n'

3.4.2 Raising the Manning's 'n' values by 20% causes an average increase in stage of 5mm through the study area while decreasing Manning's 'n' by 20% causes an average decrease in stage of 4mm.

Flow

3.4.3 Increasing the flow by 20% causes an average rise in water level of 12mm while decreasing the flow causes an average decrease in water level of 8mm.

Blockage

3.4.4 Blockage analysis was performed at several locations in the study area, all of the structures blocked were blocked by 75%. The blockage analysis was performed at six locations, at Leckhampton Lane (SO 92911 18782) and Shurdington Bridge (SO 92480 18928) on the Ham Brook, and at Leckhampton Lane (SO 93888 19284), Kidnappers Lane (SO 93783 19969) and two blockages on Shurdington Road (SO 93760 20369, SO 93986 20539) on the Hatherly Brook.

3.4.5 Blocking Leckhampton Lane culvert on the Ham Brook causes an increase in stage of 39mm upstream of the culvert. Blocking the Shurdington Bridge on the Ham Brook results in an increase in stage of 19mm upstream of the culvert.

3.4.6 Blocking Leckhampton Lane culvert on the Hatherly Brook causes an increase in stage of 16mm upstream of the culvert. Blocking Kidnappers Lane culvert on the Hatherly Brook causes an increase in stage of 11mm upstream of the culvert. Blocking the Shurdington Road culvert on the west channel of the Hatherly Brook results in an increase in stage of 720mm upstream of the culvert. Blocking the Shurdington Road culvert on the east channel of the Hatherly Brook causes an increase in stage of 97mm upstream of the culvert.

3.5 Assumptions & Limitations

3.5.1 It is assumed that both the Hatherly Brook SFRM model is suitable for the purposes of this study and has been hydraulically calibrated.

3.5.2 It is assumed that the filtered LiDAR used in the study is accurate and has no errors.

3.5.3 Where channel has been modelled as 2D it has been assumed to be a trapezoidal shape.

3.5.4 Structures dimensions in the 2D channel have been defined from observations on the site visit and have not been extensively surveyed.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are not sensitive to roughness and flows however if the land use and type changes then this should be reanalysed to ensure that this is still valid and that regular channel maintenance is not required.

Project	Gloucestershire JCS Level 2 SFRA	**Date**	September 2010
Note	Hydrological & Hydraulic Modelling Methodology – Swilgate	**Ref**	WBGCTS
Author	S Bilby, M Grogan		

1 Overview

1.1 Introduction

1.1.1 This technical note details the hydrological and hydraulic modelling approach taken for the Level 2 SFRA assessment of the River Swilgate at Swindon.

1.2 Existing Models & Data

1.2.1 The Swilgate study area has several watercourses flowing through it, including the River Swilgate, Hyde Brook, Swindon Brook and Leigh Brook. Existing 1D ISIS models for the River Swilgate and its tributaries (Black & Veatch 2009) and for the Leigh Brook (Black & Veatch 2009) were available for use in this study. A review of the models indicated that the River Swilgate model did not extend far enough downstream within the study area. There was therefore a requirement to extend the model to incorporate the full study extents. The floodplain representation within the existing models was also improved by linking the existing 1D sections to a 2D TUFLOW domain (refer to Section 3 for further details).

1.2.2 The models have their own hydrological analysis, which was reviewed prior to commencing the hydraulic modelling to determine its suitability for use in the study..

1.3 Site Visit

1.3.1 A site visit to the River Swilgate and Leigh Brook was undertaken prior to the commencement of any analysis of the watercourse to obtain a more detailed understanding of the structures within the modelled extents and identify possible floodplain flow routes.

2 Hydrological Analysis

2.1 Introduction

2.1.1 A study of the required study area was undertaken by Black and Veatch for JS Bloor (Tewkesbury) Ltd and Persimmon Homes South Midlands. The hydrological approach used by Black and Veatch has been adopted for use in this Level 2 SFRA.

2.2 Review of Existing Model

Selecting Design Flow

2.2.1 Black and Veatch (B&V) investigated the use of three standard hydrological methods to determine inflows for watercourses:

- The statistical approach
- The rainfall runoff method originally developed within the Flood Studies Report (FSR) and modified in the FEH, and
- The revitalised rainfall runoff (ReFH) methodology

2.2.2 B&V noted that their experience, gained from looking at similar catchments, indicated that the statistical approach and ReFH methodology often under predict flows for catchments of this type. B&V noted that under prediction was attributable to:

- The limited number of similarly steep catchments available for inclusion in a pooling group in order to generate a weight averaged flood growth curve.
- As the ReFH methodology was calibrated against the FEH pooling group results poor representation of steep catchments was carried forward from statistical analysis to the ReFH method.

2.2.3 Black and Veatch compared peak flows produced using the three methods, and found, as expected, that the FEH rainfall runoff gave largest results.

2.2.4 Calibration data for the study area are limited. B&V performed a simulation of the July 2007 event using observed rainfall data, and found that this provided a good fit to observed flood level and outline data. It was however noted by Black and Veatch that there is some uncertainty in both the accuracy of these levels and the rainfall profile for the catchment, so it was considered unwise to adjust any parameters within the model.

2.3 Hydrological Appraisal

Catchment Schematisation

2.3.1 The schematisation performed by Black and Veatch was unavailable for review. Halcrow therefore re-extracted the catchment descriptors from the FEH CD – ROM for the same locations as used by Black and Veatch. The schematisation completed by Halcrow is shown in Figure 2.1.

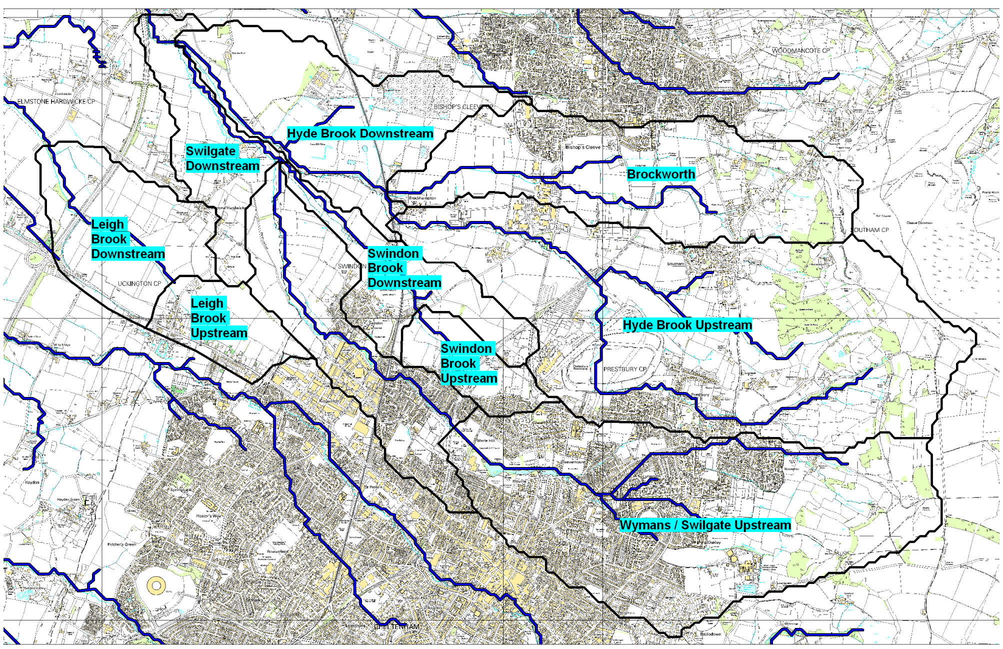

Figure 2.1: Halcrow schematisation of study area

2.3.2 The following checks on model schematisation and catchment descriptors were undertaken:

- A validation of the contours in the FEH CD ROM using LiDAR and drainage paths as shown on OS 10k maps.
- FARL values were checked using OS mapping
- Soil parameters were checked against mapped soil types on the SoilScapes website. No alterations in the catchment descriptors were required.

2.3.3 Black and Veatch noted that no changes to catchment descriptors had been necessary, with the exception of modifications to the sub-catchment area of Leigh Brook. This modification was made to reflect the construction of Tewkesbury Road and some field drainage not accurately represented in the FEH DTM. The same conclusions have been drawn within this study on the basis of the above checks, that no changes to catchment descriptors were necessary, with the exception of making the same area change which Black and Veatch had made to Leigh Brook.

Statistical Analysis

2.3.4 A new statistical analysis was performed at the downstream extent of the catchment, as the statistical analyses performed by Black and Veatch were unavailable for review. When compared with the results generated by distributed FEH units input to the hydraulic model, this repeated the conclusion drawn by Black and Veatch that a distributed FEH unit approach provides higher flow estimates. Comparative results are shown in Table 2.1.

Table 2.1: Comparison of peak flows from distributed FEH units with statistical analysis at downstream extent of catchment

Return Period	Distributed FEH units (preferred approach)	Statistical Analysis
20	20.457	16.93
100	28.48	22.95
1000	73.846	33.76

Time to Peak Checks

2.3.5 The time to peak (Tp) generated by FEH units was checked against observed data from Manor Road level gauge. It was found that observed Tp is slightly shorter than that generated by FEH units, as shown in Table 2.2.

Table 2.2: Comparison of Time to Peak (Tp) at Manor Road Level Gauge using 1) FEH unit with default catchment descriptors and 2) observed data

	Tp (hours) at Manor Road Level Gauge
FEH unit	1.46
OBSERVED MEAN	0.55
Observed Jul 28th & 29th 2008	0.67
Observed Nov 8th & 9th 2008	0.67
Observed Jun 26th 2009	0.45
Observed Nov 22nd 2009	0.45

2.3.6 A sensitivity test was performed, comparing the hydrographs generated by an FEH unit at Manor Road level gauge using the average observed Tp (0.55hr) and the FEH default Tp (1.4hr). Resulting hydrographs are shown in Figure2.2. As expected, it was found that flood peaks are higher with the shorter observed Tp but that the increase in flows was small. The FEH default Tp was retained for final design because:

- All the event used in the Tp analysis were relatively small in bank events and might not be representative of larger events.
- It is not clear whether data from Manor Road could be adopted as a donor site to adjust Tp across the catchment.
- Sensitivity to peak flow tests show that flood outlines are relatively insensitive to peak flow.

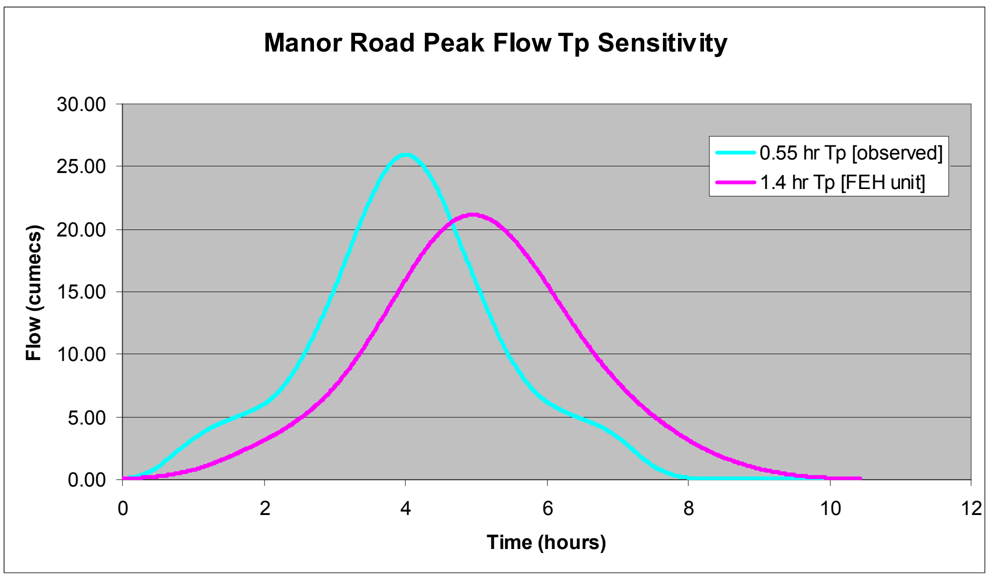

Figure 2.2: Comparison of hydrographs generated with varying Time to Peak (Tp) at Manor Road Level Gauge

Storm Duration Sensitivity Checks

2.3.7 It was found that the critical storm duration for the study area varies between 5.5 hours in the upstream part of the catchment and 8.5 hours at the downstream part of the catchment. Final design runs were therefore performed with storm duration of 5.5 and 8.5 hours, and the outlines combined to give a worst case scenario.

Flow Sensitivity Checks

2.3.8 The 100 year event was run with -20% and +20% flows to check the sensitivity of outlines to changes in flow. It was found that outlines are relatively insensitive to changes in flow.

Conclusion to sensitivity checks

2.3.9 The sensitivity checks performed have shown that flood outlines are relatively insensitive to peak flows, storm duration and time to peak.

2.4 Design Flows

2.4.1 Final design hydrology for the River Swilgate study area is based on the hydrological assessment performed by Black and Veatch, with no modifications. Distributed FEH units have been input to the hydraulic model, using storm durations of 5.5 and 8.5 hours, and the outlines from these storm durations combined.

2.4.2 The final peak flows adopted in the model are as shown in Table 2.3.

Table 2.3: Final adopted peak flows at downstream extent of hydraulic model

				Maximum flows in m^3/s			
Boundary location	**Watercourse name**	**Storm Duration (hours)**	**Node label**	**5% AEP**	**1% AEP**	**1% AEP with climate change**	**0.1% AEP**
SO 91585 27743	River Swilgate	5.5	1Y	20.547	28.48	36.183	73.846
SO 91585 27743	River Swilgate	8.5	1Y	19.422	28.032	35.377	73.973

3 Hydraulic Modelling

3.1 Hydraulic Modelling

3.1.1 This section outlines the hydraulic modelling approach taken for the Level 2 SFRA assessment for the River Swilgate and Leigh Brook at Swindon.

3.2 Model extent

3.2.1 The existing River Swilgate model extends from Pitville Park on the Wynans Brook (SO 95315 23493), downstream of Hyde Lane on the Swindon Brook (SO 94122 25079) and downstream of Brockhampton on the Hyde Brook (SO 93880 25991) to upstream of the M5 culvert (SO 91585 27743). The existing Leigh Brook model extends from Uckington Farm (SO 91855 25046) to downstream of the M5 (SO 90447 26687).

3.2.2 The extents of the River Swilgate model which have been converted to linked 1D-2D are from Manor Road on the River Swilgate (SO 93229 24826), from the railway on the Swindon Brook (SO 93973 25388) and the entire length of the Hyde Brook. The Leigh Brook has been linked to a 2D domain down to the M5 (SO 90778 25994). The River Swilgate model has also been extended at the downstream end to a point downstream of the M5 (SO 91241 28260). Figure 3.1 below shows the extents of the 1D-2D model covering the study area.

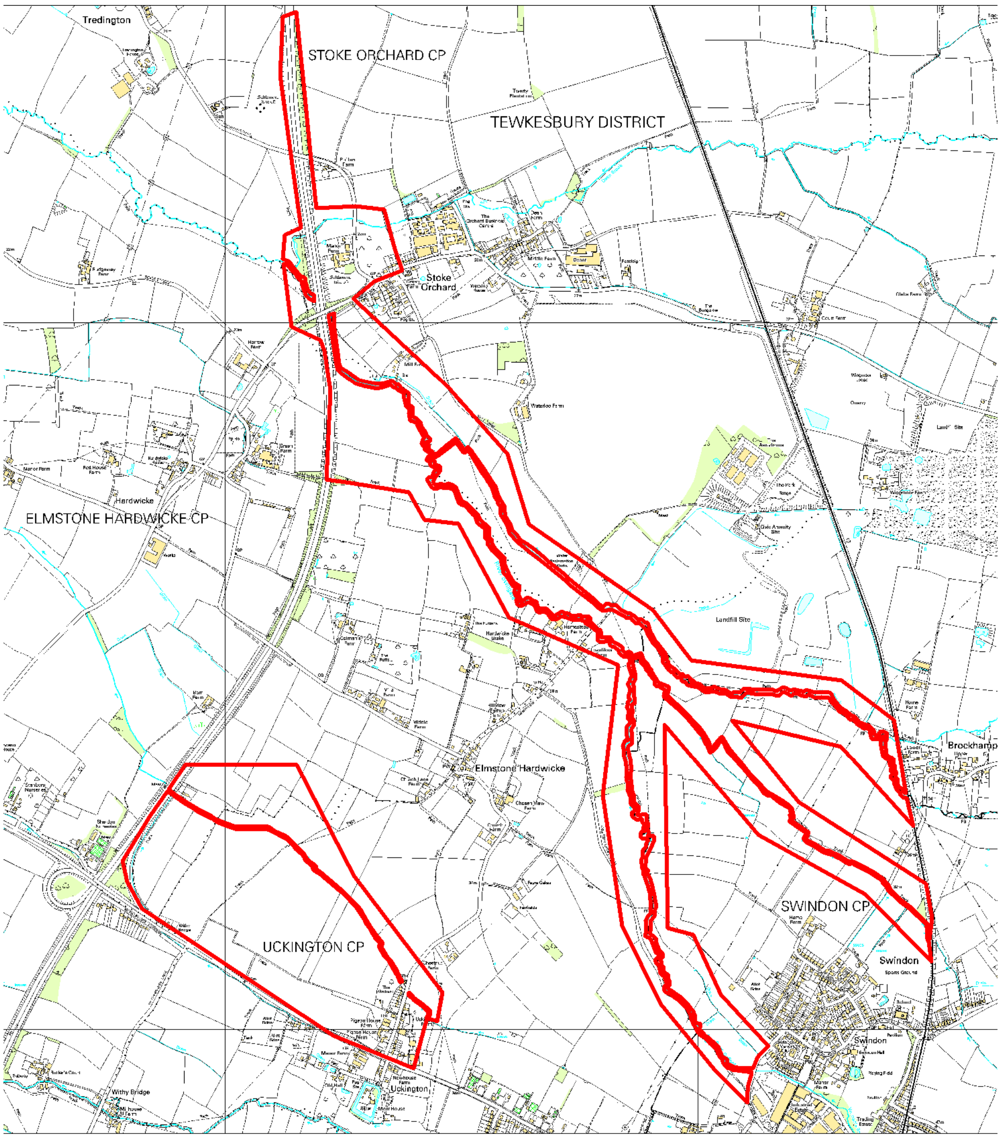

Figure 3.1: River Swilgate and Leigh Brook model extents

3.3 Methodology

3.3.1 The existing River Swilgate and Leigh Brook models were reviewed and determined to be suitable for the purposes of this study.

3.3.2 The River Swilgate and Leigh Brook models were combined into one ISIS model with two separate channels. The river sections through the study area were trimmed down to the channel banks and this 1D ISIS model was then linked to a 2D TUFLOW domain to model the floodplain flows. The River Swilgate channel was extended 700m downstream to cover the entire study area and allow the downstream boundary to be modelled without any effect on the study area. The model was extended by assuming that the last surveyed section at the end of the River Swilgate model is representative of the channel in the area. This section was then copied with the bank and bed levels adjusted according to the ground slope in the LiDAR. The geometry of the culvert under the M5 has been based on observations made during the site visit.

3.3.3 A 5m resolution was used for the 2D grid size in the model. This allows for accurate representation of the floodplain while keeping model run times and result file sizes manageable.

3.3.4 There are no formal or de-facto defences in the study area.

3.3.5 The in-channel roughness in the existing Swilgate and Leigh Brook models have been left as identified in the original model and the floodplain roughness has been defined using polygons extracted from OS Mastermap data and observations made on the site visit.

3.3.6 Inflow boundaries have been kept where they were located in the original models.

3.3.7 The downstream boundaries on the Swilgate and Leigh Brook have been modelled as normal slopes.

3.4 Sensitivity Analysis

3.4.1 Analysis of the models sensitivity to roughness (Manning's 'n'), flow and blockage was carried out. The results of the analysis are summarised below.

Manning's 'n'

3.4.2 Increasing the Manning's 'n' by 20% causes an average rise in water level of 47mm while decreasing Manning's 'n' by 20% causes the model to become unstable, this is due to the increased flow rate causing the channel to suddenly drying out in some locations during low flow conditions.

Flow

3.4.3 Increasing the flow by 20% causes an average rise in water level of 88mm while decreasing the flow causes an average decrease in water level of 71mm.

Blockage

3.4.4 Blockage analysis was performed at several locations in the study area; all of the structures blocked were blocked by 75%. The blockage analysis was performed at three locations, at Uckinton (SO 91767 25166) and the M5 culvert (SO 90757 26008) on the Leigh Brook. The M5 culvert on the Swilgate (SO 91433 28050) was also blocked as well.

3.4.5 Blocking the Uckinton culvert results in a 230mm increase in stage upstream of the culvert. Blocking the M5 culvert on the Liegh Brook results in an 874mm increase in stage upstream of the culvert and blocking the M5 culvert on the Swilgate results in a 732mm increase in stage upstream of the culvert.

3.5 Assumptions & Limitations

3.5.1 It has been assumed that the survey used to create the existing River Swilgate and Leigh Brook models is accurate.

3.5.2 It is assumed that the filtered LiDAR used in the study is accurate and has no errors.

3.5.3 Dimensions of the culvert under the M5 on the River Swilgate have been defined from observations on the site visit and have not been extensively surveyed.

3.6 Model Confidence

3.6.1 In the absence of a good and reliable calibration data, sensitivity analysis should be used to set the perspective in terms of how models results should be interpreted. As can be seen from the sensitivity analysis, model results are sensitive to roughness and flows and for watercourse of this character. It is therefore recommended that regular channel maintenance is undertaken to ensure the channel is kept free of obstructions.