Appendix C

MODELLING METHODOLOGY REPORT AND MODEL REPORTS

70006808-50604-TN01

MODELLING METHODOLOGY TECHNICAL NOTE

NORTH HERTFORDSHIRE SWMP

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NORTH HERTFORDSHIRE SWMP

Hertfordshire County Council

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WSP | Parsons Brinckerhoff
Unit 9,
The Chase,
John Tate Road,
Foxholes Business Park,
Hertford,
SG13 7NN

Tel: +44(0) 1992 526000
www.wsp-pb.com

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Prepared by	Pete Harrison and Giuliano Feliziani	Andy Smith	Andy Smith	Andy Smith	Lorena Ramirez-Romero and Chris Brammeier
Signature					
Checked by	Stephanie Knowles	Stephanie Knowles	Stephanie Knowles	Stephanie Knowles	Andy Smith
Signature					
Authorised by	Andy Smith	Andy Smith	Andy Smith	Andy Smith	James Berryman
Signature					
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1 OVERVIEW

1.1.1 This technical note sets out the proposed modelling methodology for the highest risk hotspots selected for hydraulic modelling as part of the Strategic and Intermediate Report for the North Hertfordshire Surface Water Management Plan (SWMP).

1.1.2 The approach is outlined in terms of the generic approach (Section 2) which will apply to all models and those elements of the approach that are specific to each hotspot (Section 3).

1.1.3 This modelling methodology has been prepared for review and comment to enable agreement to the proposed approach to be reached at the project outset, thereby avoiding unnecessary delay in later stages of the project.

1.1.4 The SWMP hotspots discussed in this Modelling Methodology are:

- Hitchin (site 6)
- Oakfield (site 7)
- Baldock (site 12)
- Clothall Common (site 13)
- Knebworth (site 17)
- Cambridge Road (A505), Purwell and Walsworth areas of Hitchin (site 30)

2 GENERIC MODELLING APPROACH

2.1 STAGE 1: DATA COLLATION AND WALKOVER SURVEYS

2.1.1 The first stage in the development of each hydraulic model will be to collate the data necessary for the development of the models. Data required for the development of the models are presented in the specific modelling approaches for each hotspot (Section 3) and summarised in Section 4.

2.1.2 The aim of the data collation and walkover surveys is to collect all the available data/information for the hotspot area and establish what other information is required for the detailed assessment and modelling. This technical note has been informed through the following steps:

- Liaise with Hertfordshire County Council (HCC) and project stakeholders outlining the proposed methodologies for the hydraulic modelling associated with each hotspot;
- Consult with the Environment Agency, North Hertfordshire District Council and Anglian Water/Thames Water Utilities Ltd to obtain and review the provided flooding and drainage data;
- Identify the extent of the LiDAR available for the study area and review topographical survey requirements for each hotspot;
- Review any appropriate CCTV/manhole/sewer survey data and sewer records available for the vicinity of the study area;

- Undertake site visits to assess flow mechanisms, status of hydraulic structures, physical obstructions to overland flood routes in the vicinity of the site and confirm topographic survey requirements;
- Confirm the hydraulic modelling approach with Hertfordshire County Council and project stakeholders in light of the available data.

2.1.3 This technical note provides the summary of the findings of Stage 1 and any outstanding requests, along with constituting the outline of the proposed hydraulic modelling approach, for confirmation by Hertfordshire County Council and project stakeholders. Following this approval any variations will be identified in the early stages of hydraulic model development and agreement sought.

2.2 STAGE 2: HYDRAULIC MODELLING

HYDRAULIC MODELLING PLATFORM SELECTION

2.2.1 Following a review of the currently available data and the objectives of the modelling studies, WSP|PB propose to preferentially use a direct rainfall methodology (with some inflows for larger watercourses, where relevant) in ESTRY-TUFLOW; using the latest double precision version of TUFLOW (currently 2013_12_AD).

2.2.2 The ESTRY-TUFLOW hydraulic model utilises a two-dimensional (2D) representation of flow across the floodplain and a one-dimensional (1D) representation of flow in the sewers, culverts and watercourses. The 1D and 2D components of the model are dynamically linked, such that water can flow from the channel or sewers into the floodplain, and vice-versa.

2.2.3 ESTRY-TUFLOW is an industry standard hydraulic modelling package, widely used for floodplain modelling in areas also served by arterial drainage networks. ESTRY-TUFLOW has been successfully used by WSP|PB previously for similar SWMP studies. In some areas it may be necessary to extend the model to use Flood Modeller Pro to represent the in-channel flows; however, this is largely likely to be limited to the areas where one of the stakeholders holds an existing fluvial model. Flood Modeller Pro (which replaces ISIS hydraulic modelling software) is widely used across the industry to model the in-channel flows of fluvial networks. However, it is not as stable as ESTRY for direct rainfall modelling, as the channels cannot run dry (i.e. at the start and end of rainfall events as the flows are conveyed through the catchment).

2.2.4 In some instances other packages will be utilised, this may be a result of the project stakeholders undertaking other studies which will inform or be informed by this study. An example of this includes the models previously developed for the North Hertfordshire Strategic Flood Risk Assessment (SFRA), in this instance the models were developed in InfoWorks CS (Collection Systems). To ensure that the models can be developed in an economic and timely manner these will be reviewed and where possible developed in their original hydraulic modelling software package.

2.2.5 Since the development of the North Hertfordshire SFRA InfoWorks CS model, InfoWorks ICM (Integrated Catchment Modelling) has been developed, this now supersedes InfoWorks CS (which has now been retired). ICM incorporates additional functionality, such as a better 2D representation of the ground surface and enabling direct rainfall modelling.

2.2.6 All the modelling platforms used within this SWMP have been assessed by the Environment Agency as part of their benchmarking exercise[1] and all are considered to be acceptable for this type of study. An advantage of using ESTRY-TUFLOW over ICM is the speed in which multiple mitigation scenarios can be assessed.

2.2.7 The models produced for this SWMP will be developed to facilitate submission to the Environment Agency to update the Risk of Flooding from Surface Water map. This will be undertaken in accordance with Environment Agency guidance "*Updated Flood Map for Surface Water – National Scale Surface Water Flood Mapping Methodology*", May 2013 and "*Submitting Locally Produced Information for Updates to the Risk of Flooding from Surface Water Map"* December 2014.

MODEL GEOMETRY DEVELOPMENT

2.2.8 The approach to the development of geometry for the ESTRY-TUFLOW models is to use the best available data wherever possible. Specifically the 1D and 2D component parts of the hydraulic models will be developed as detailed below.

2.2.9 Model boundaries will be governed by the position of historical flooding sites within the hotspot, and where the hotspot sits within its drainage catchment and the catchment's size. Model boundaries will also be reviewed in terms of their impact on model run times and the objective of maximising model size/coverage. Consideration will also be given to the likely position of potential flood alleviation options for assessment in Stage 3 (Section 2.3).

2D MODEL COMPONENT

2.2.10 The primary source of topographic data that will be used for construction of the Digital Terrain Model (DTM) element of the 2D component of the hydraulic models will be the Environment Agency's uFMfSW DTM. As this is based upon previously merged LiDAR (Light Detection And Ranging) and where there is Intermap NEXTMap Synthetic Aperture Radar (SAR) dataset for Britain. The benefit of this is that the merger process which includes smoothing and checking for anomalies, has already been undertaken. However, given that some time has passed since the completion of this dataset, checks have been undertaken to ensure that there is no more extensive LiDAR coverage, given that this is at a much higher resolution and accuracy than the NEXTMap data. These checks established that LiDAR should not be preferentially used for any hotspot.

2.2.11 Where multiple terrain data is to be used the chances of anomalies and differences are increased, in these locations inspections for these will be undertaken. Following a satisfactory review, steps may remain between the data sources, given the varying methods and associated accuracy of data collection, therefore the following approach will be adopted:

2.2.12 In instances where steps in elevation data occur at the boundary of two data sources (i.e. between the boundaries of one or more of LiDAR, NEXTMap (SAR) and topographical survey data) these will be smoothed as far as is practicable within a determined merger area. This will be achieved by generating a TIN over the boundary of the two datasets and averaging/linearly extrapolating elevation data along the junction based on the two datasets.

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[1] Environment Agency Research and Analysis: Benchmarking the latest generation of 2D hydraulic flood modelling packages (Published reports available at: https://www.gov.uk/government/publications/benchmarking-the-latest-generation-of-2d-hydraulic-flood-modelling-packages)

2.2.13 Where possible the LiDAR and NEXTMap data will be replaced with more detailed topographic survey data to be collected in the field. Predominantly this will be confined to surveying of channel cross sections for watercourses through particular areas of interest and/or hydraulic structures, culverts and weirs etc. In areas where the preferential flow paths are shown to break from flowing along the highway or where properties have low threshold levels, topographical survey data will also be collected. The scope for this is detailed at the individual hotspot level.

2.2.14 The individual hotspot modelling approach summaries (provided in Section 3) identify the likely topographic survey that it is anticipated will be collected; the exact requirements are detailed in a separate specification (Appendix B). Should further site inspections identify additional features and structures that could have an influence on local flooding these will be identified and captured where possible. However, the extents of topographic survey need to be considered against the available budget and the strategic nature of this assessment. In locations where topographic survey is not possible, expert knowledge will be utilised to determine the best approach, if flow conveyance is more important than flow restriction, then watercourse routes/holes in embankments will be enforced by lowering appropriate areas of the DTM. In other instances where flow restriction is more important than structure dimensions, invert levels etc. will be estimated based upon information gained through site visits, local knowledge and engineering judgement.

2.2.15 Model resolution/grid size will be determined on a model by model basis. The highest possible model resolution will be sought whilst considering model complexity, modelling objectives and model run times. Wherever possible model resolution/grid size will be less than 5*5m. In instances where a larger surface water catchment drains into an area of interest, a catchment wide model will be developed with a larger cell size to ensure appropriate run times; flows will then be abstracted from the larger cell size model and entered into the more detailed area of interest model. Multi domain grids will not be used within TUFLOW for surface water modelling due to the potential for inaccuracies to develop at the barrier on significant flow paths. For other modelling platforms such as InfoWorks ICM we would seek to avoid issues between changes in significant cell size by restricting the maximum cell size to around 5*5m and run the model on a high specification server, with GPU, to significantly reduce run times.

2.2.16 Roughness values to be utilised in the 2D component of the models will be determined using Ordnance Survey (OS) MasterMap. Table 1 shows the values proposed.

2.2.17 To ensure the influence of buildings on overland flood flow routes is accounted for building footprints will be raised, however, this is not necessary when using the uFMfSW DTM as these changes have already been implemented. The footprints of buildings will be identified using Ordnance Survey (OS) MasterMap data and will be modelled as ‘stubby’ buildings and raised 300mm above the average ground level (LiDAR bare earth) within the footprint area. An upstand height of 300mm is selected in accordance with the Updated Flood Map for Surface Water National Scale Surface Water Flood Mapping Methodology (May 2013). This guidance states that an upstand height of 300mm is selected because flooding at this depth will certainly exceed the level of any damp-proof course and result in property flooding in many cases. Where property thresholds at specific hotspot sites are known (i.e. as a result of site survey) to be lower than 300mm, this value will be reviewed where appropriate. The Manning’s ‘n’ roughness value within the model shall be increased to 0.3 for the footprint of the building. The use of a higher Manning’s ‘n’ value is used in order to represent the energy dissipation caused by buildings on floodwater[2].

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[2] Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences (Syme, 2008). (Published article available at: http://www.tuflow.com/Downloads/Publications/2008.09%20-%202D%20Modelling%20Approaches%20for%20Buildings%20and%20Fences.Syme.pdf)

2.2.18 To ensure that the preferential flow routes that frequently operate along the highways will be maintained within the model, the highway will be lowered by 125mm, as recommended in the National Scale Surface Water Flood Mapping Methodology (May 2013). A value of 125mm is selected as it is the height of a British Standard kerb; this ensures the important highway pathway is represented. The highway extent will be identified from OS MasterMap.

2.2.19 Infiltration losses will be assessed within the hydraulic model rather than through hydrological models as variances between soil types and losses can be altered more easily at a local scale. These will be addressed through the Green-Ampt method in ESTRY-TUFLOW and in InfoWorks ICM through varying the permeability of the underlying soil types within the 2D Zone using 2D infiltration surfaces and fixed coefficient valued (the exact value is to be agreed as the modelling progresses, to ensure constancy between the packages) for a range of soil types in conjunction with the pervious and sub-catchment creation tool.

2.2.20 In InfoWorks ICM, the hydraulic boundary of the 2D zone will be adjusted where necessary to ensure the areas do not “glass wall” and that overland flows are able to freely drain away from the study areas, as they would under normal conditions.

Table 1 – Roughness coefficients by OS MasterMap land use category

OS MasterMap Land Use Category	Manning’s ‘n’ Roughness Coefficient
Buildings	0.3
General surface (residential yards)	0.04
Step	0.025
General surface (unknown)	0.035
General surface (natural)	0.04
General surface (manmade)	0.03
Glasshouse	0.2
Inland water	0.03
Woodland (coniferous/non coniferous trees)	0.06
Manmade surface or step	0.03
Paths (tarmac or dirty tracks)	0.03
Railway surfaces (natural and manmade)	0.035
Roads (tarmac)	0.02
Roadside (natural and manmade)	0.02
Structures	0.3
Unclassified	0.04

1D MODEL COMPONENT

2.2.21 It is understood the following data will be available for construction of the 1D component of the hydraulic models includes:

- Water company GIS Asset data,
- Flood and Water Management Act (2010) asset registers,
- Ordnance Survey MasterMap data,
- LiDAR, and

- Topographic (and channel) survey of key elements of the watercourses and structures.

2.2.22 Where topographic survey data for open channel sections and associated structures is required, this will be collected to the Environment Agency's specification.

2.2.23 It is proposed that the majority of the 1D component of the public surface water sewer element of the hydraulic models will be constructed using data from GIS databases of the local water companies' networks, where these are available.

2.2.24 In the instances where it is important/necessary to incorporate the public surface water sewers (no consideration will be given to the combined or foul sewers – unless there are no surface water network in the area, thus combined will be included and the approach documented in the relevant hotspot), they will be incorporated into the model with the following approach:

- Only pipes greater or equal to 225mm diameter will be incorporated into the 1D component of the hydraulic models. In areas with limited sewer systems the minimum threshold for pipes to be incorporated within the model will be evaluated. This means that the flood maps in certain areas may give a more conservative estimate of the flood depths, as a small amount of storage in the smallest pipes is not being considered. However, as with any form of modelling, the model is a conceptualisation of reality; thus assumptions and simplifications of the real world have to be made, in order for the hydraulic model to be fit for the purpose that it is has been designed to achieve, and in a form where reality is suitably represented.
- Connectivity between the 1D and 2D components of the sewer models will be via pitchannels (zero length channels with no storage associated, where water can flow both ways between the underground 1D pipe network and the above ground 2D domain)) and sewer outfalls (where sewer outfalls have flap valves, pipes representing these flap valve outfalls in the model will be set as one way flow). Flap valves have been assumed at the sewer outfalls to watercourses. No consideration will be given to gully pots as the pipes connecting these to the main sewer are uncertain. Spill levels from the 1D to the 2D and vice versa will be based on asset data provided by the water companies with comparison to topographic data/LiDAR data.
- Roughness values to be utilised. for the pipe network, will be 0.013.
- No CCTV surveys will be undertaken.

2.2.25 It is anticipated that some of the water company sewer asset records will be missing data necessary for the construction of a network model in ESTRY-TUFLOW or ICM. Ideally, topographic/sewer/channel surveys would be conducted to collect the missing data; however the time and costs associated with survey for the number of sites under consideration are prohibitive at this time. Therefore, some key engineering judgement principles (set out in Table 2) will be applied in the first instance to address data gaps. Where data gaps are so severe that the degree of engineering judgement applied would give rise to concern regarding the accuracy of hydraulic model results, surveys shall be considered and this noted within the relevant section of the report.

Table 2 – Standard assumptions to address sewer record data gaps

Modelling Parameter	Assumption
Pipe network – Shape	Will be determined from pipe shapes upstream and downstream.
Pipe network – Length	Will be measured in GIS.
Pipe network – Invert levels (upstream & downstream)	Will be interpolated from the inverts of upstream and downstream adjoining pipes / manhole chambers. Where no adjoining pipes were available to interpolate from, invert levels were taken as 1.2m+pipe diameter below ground model. This was then checked and adjusted if necessary to ensure pipe fall gradients were suitable and that pipes were not above ground.

Pipe network – Diameter or width and height	Will be interpolated from the diameter of upstream and downstream pipes. Where different pipe sizes are recorded at the upstream and downstream manhole chamber, the pipe size will be assumed from the nearest pipes with a documented size.
Pipe network – Number of Culverts	Will be interpolated from the characteristics of upstream and downstream manholes in tandem with Sewers for Adoption (7th edition).
Pit Channel Chamber – Invert level	The lowest level will be utilised or alternatively it will be interpolated from the inverts of connecting pipes.
Pit Channel Chamber – ground level	Will be interrogated from LiDAR data (in the absence of asset data) and will be used as 2D flood level.
Upstream Pipe Network	Where invert levels are missing at the upstream end of the network, it will be assumed that the pipe is running at 1.2m below ground levels. This will then be checked and adjusted if necessary to ensure pipe fall gradients were suitable and that pipes are not above ground.
Downstream Pipe Network	When invert level are missing at the downstream end and where the pipe discharges into a watercourse, it is assumed that the invert level is 300mm above bed level. This will then be checked and adjusted if necessary to ensure pipe fall gradients are suitable and that pipes are not above ground. Presence of flap valves will be assumed in the pipes discharging into a watercourse.

2.2.26 Where the hotspot model includes a reach of open watercourse that is considered significant as a control or influence on local flooding, this will be represented in the hydraulic model. Where these watercourses are Main Rivers and the Environment Agency has a river model, the channel geometry will be extracted from the Environment Agency's models for inclusion in the hotspot model. This will be undertaken based on the availability of Environment Agency models.

2.2.27 Where channel geometry data is not available an attempt will be made to collect topographic/channel data, the extent of survey is detailed on a site by site basis in Section 3.

2.2.28 Where the hotspot model includes a reach of open watercourse but this reach is sufficiently distant from the hotspot flooding itself and is also considered insignificant with respect to the influence on local flooding, the river reach will not be represented in the model as a separate reach. In these situations available hydraulic models will be interrogated for flood stage hydrographs which will be used as a downstream boundary condition for all outfalls discharging into the watercourse.

HYDROLOGICAL INPUTS DEVELOPMENT

RIVER FLOWS

2.2.29 In most cases, the area represented in each hotspot hydraulic model extends to encompass the entire upstream catchment, including the watercourses flowing through an area of interest.

2.2.30 In cases where a modelled area includes a watercourse which crosses an upstream boundary and has been previously modelled, the hydraulic model will be interrogated for a flood flow hydrograph which will be used as the upstream boundary condition (i.e. inflow) on the watercourse in the model.

2.2.31 In cases where a modelled area includes a watercourse which crosses an upstream boundary and has not been previously modelled a Flood Estimation Handbook (FEH) Statistical or Revitalised Flood Hydrograph (ReFH) flow boundary will be derived. Instances of where these approaches will be applied are detailed in Section 3.

2.2.32 The concept of Joint Probability is one where the peak of the river flow and the peak of the surface water runoff occur simultaneously. The focus of this SWMP is on surface water (pluvial) flooding rather than fluvial flooding from Main Rivers. Main Rivers frequently have larger (and often more rural) catchments, where flow in the river takes longer to peak (as opposed to surface water catchments, which can be smaller, flashier, more urbanised and quicker to peak). It is not comparable to use design flows/boundary levels for the same event (for the river and the rainfall), as this would provide a significantly conservative estimate of the flood regime. This situation (the concept of same magnitude events, not being comparable) has occurred for many years when modelling tidal and fluvial interactions, in these instances where there is a significant risk, a joint probability analysis to determine the combination of return periods has been undertaken. However, in the instance of this SWMP, the focus is on surface water flooding and therefore an agreed combination of return periods will be used for the assessment for all the return periods for surface water identified in Table 3, and the method for selecting the fluvial return period event to use for joint probability will be assessed via the following method:

- All fluvial boundaries will be preferentially assessed with a 1 in 5 year return period.
- Should the models have not previously been run with a 1 in 5 year return period, a 1 in 20 year return period event will be used (this should be available with any models issued by the Environment Agency, as the definition of a functional floodplain uses this event).
- Existing hydrology in previously built models will be preferentially used (e.g. the 1 in 20 year event), rather than revising flow estimates. This is because, depending on the scale of the model (significant numbers of flow points could be involved) and model age (methodologies regarding flow estimation have changed), altering flow estimates may impact on the model's calibration (in previously calibrated fluvial models).

RAINFALL PROFILES

2.2.33 Hydrological inputs to the models will be derived by extracting the catchment descriptors from the FEH CD-ROM (v3), with revisions made to the URBEXT values and utilisation of the flow estimation tools within ISIS to determine the critical storm duration and the resultant hyetograph (rainfall profiles) with runoff addressed through the use of the Green-Ampt method (detailed in Hydraulic Modelling, Section 2.2.19).

GENERIC DATA REQUIREMENTS

2.2.34 The data required to develop hydraulic models for each hotspot are detailed in Section 3. In addition, data held by any stakeholder relating to flood defences and/or flood incidents would be advantageous in development of the hydraulic models, in order to gain an understanding of local flooding issues and for verification of model results.

HYDRAULIC MODEL VERIFICATION

2.2.35 WSP|PB have not been provided with any photographic evidence of recorded surface water flood incidents. Therefore attempts to verify the flood outlines with historical information will be limited to comparison of the flood outlines with:

- Local knowledge (e.g. Section 19 Investigations, flood event extents, flood incident record or DG5 records of flooding, along with Environment Agency rainfall data where available)
- The Environment Agency's Risk of Flooding from Surface Water Map

- Any other available flood outlines

SENSITIVITY ANALYSIS

Model Sensitivity: Blockages, coefficients, percentage runoff and inflows

2.2.36 In order to test the robustness of the hydraulic model results, a sample of the models will be subjected to sensitivity analysis.

2.2.37 Sensitivity analysis will be undertaken on one return period event (i.e. the 1 in 100 year, as per current best practice) for each selected model and will include variation of up to three model parameters. This will include testing of the Manning's 'n' roughness coefficients (up to ±20% of the baseline value) and boundary conditions (up to ±20% of the baseline value) applied to the model. The remaining model parameters to be tested will be left to the discretion of the hydraulic modeller based on their appreciation of the data used to develop the hydraulic model. Parameters that may be tested through the sensitivity analysis include:

- Culvert blockage (50 and 75%) – standard practice is to block all culverts, in one or two situations, during the course of the SWMP study, the methodology may be reviewed to only block selected culverts depending on the baseline modelling results and the historic flooding situation at certain hotspots,
- Structural coefficients (up to ±20% of the baseline value),
- Roughness coefficients (Manning's 'n') (±20% of the baseline value)
- Percentage runoff (up to 100% runoff in areas of groundwater emergence); and,
- Inflows (up to ±20% of the baseline value).

Model Sensitivity: Catchment characteristics

2.2.38 Depending upon the outcome of the baseline modelling for North Hertfordshire, at least one hotspot will be adopted for further sensitivity assessment on catchment characteristics. This sensitivity assessment has been chosen to assess the impacts of both the storm duration and antecedent conditions on the chalk catchments (i.e. saturation) and how this alters the flood extents and depths. This will be assessed through running the model with three different initial wetness conditions, through altering the parameters in the Green-Ampt method and running an additional two (longer) storm durations.

2.2.39 A further sensitivity run will be undertaken on a selected hotspot (to be agreed with HCC, following the baseline modelling) to assess the impacts of removing the underground drainage network and representing this through a constant 12mm reduction in the hyetograph (i.e. to facilitate a direct comparison with the approach adopted in the Environment Agency's Risk of Flooding from Surface Water map).

2.2.40 One hotspot model will be selected (in conjunction with HCC) for sensitivity with the fluvial downstream boundary where the 1 in 5 year and 1 in 20 year boundary conditions will be assessed in terms of impact on the surface water flooding regime.

HYDRAULIC MODELLING SCENARIOS

2.2.41 All hydraulic models will be run for the scenarios (storm return period events) presented in Table 3. Justification for these events is provided in the table, in addition to that required to provide input to the economic analysis.

Table 3 – Return periods for hydraulic modelling

Rainfall Probability	Justification
1 in 5 (20% AEP)	■ Of benefit in verifying hydraulic models. ■ Of interest to Hertfordshire County Council.
1 in 30 (3.3% AEP)	■ Of interest to water companies for assessment of benefit for capital investment schemes. ■ Use to define 'very significant' flood risk for assessment of outcome measures. ■ Consistent with Environment Agency Risk of Flooding from Surface Water Map return periods.
1 in 75 (1.3% AEP)	■ Threshold at which insurance for losses from flooding may not feature as part of a standard household or small business insurance policy.
1 in 100 (1% AEP)	■ Typical standard of protection sought for flood alleviation schemes ■ Consistent with NPPF flood zone 3A for fluvial flooding. ■ Used to define 'significant' flood risk for assessment of outcome measures.
1 in 100 +40% (climate change scenario[3])	■ Of interest to the Environment Agency.
1 in 1000 (0.1% AEP)	■ Consistent with NPPF flood zone 2 for fluvial flooding. ■ Of interest to Hertfordshire County Council.

HYDRAULIC MODEL OUTPUTS

2.2.42 The results of the hydraulic models will be utilised to generate maps of the modelled domain, with due consideration to the minimum depth represented illustrating the following:

- Maximum flood extent,
- Peak flood depth bands,
- Peak flood water velocity bands, and
- Flood hazard maps.

2.2.43 Where model sensitivity testing is undertaken and results documented in a simple tabular form for these scenarios to demonstrate the differences in:

- Maximum flood extent, and
- Peak flood depth bands.

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[3] Flood and coastal risk guidance: Climate change allowances (Published guidance available at: https://www.gov.uk/government/publications/flood-and-coastal-risk-guidance-climate-change-allowances)

2.2.44 In the areas where parts of the model are developed using NEXTMap data or there are uncertainties over the accuracy of the input data, this may result in limited parts of the model having a lower degree of accuracy. These areas may potentially be comparable to the Environment Agency's Risk of Flooding from Surface Water map, where NEXTMap data was used for areas missing LiDAR coverage). Regarding the results of this SWMP, to ensure that any areas which may have a lower degree of accuracy are considered in future use and interpretation of the maps, polygons covering these areas will be provided to HCC as part of the GIS delivery. Any PDF maps produced which show these areas of uncertainty will be clearly marked to ensure that this uncertainty is conveyed such as overlying this area with a polygon with reduced transparency.

2.2.45 Hydraulic model outputs will be issued to HCC as GIS files (ESRI compatible).

HYDRAULIC MODEL REVIEW AND ACCEPTANCE

2.2.46 The development of all hydraulic models will be captured in a 'baseline' hydraulic model build report for each hotspot. Due to the data limitation, calibration of the model may not be possible. However, attempts will be given to use historic data upon availability to validate the model results, see Model Verification Section 2.2.35.

2.2.47 Each hydraulic model will be subject to an independent internal review at specific points in the modelling process by a member of WSP|PB's hydraulic modelling team who will not be involved with the development of the model.

2.2.48 The hydraulic models with their accompanying build reports will be submitted to Hertfordshire County Council for their review and acceptance. This will follow an internal review by WSP|PB; all models will be reviewed by our lead modeller on this project to ensure consistency. This review will be documented in an audit sheet that will be submitted as a standalone element with the report and models.

2.3 STAGE 3: OPTIONS ASSESSMENT

2.3.1 Following completion of the baseline modelling, results will be reviewed and flood alleviation scheme options identified for discussion with stakeholders.

2.3.2 Should it be agreed with HCC that flood alleviation options for selected hotspots are to be assessed within the hydraulic model, either the approach will be discussed or a technical note will be prepared to accompany the baseline model build reports describing how the baseline model will be amended to reflect the preferred options. In this instance, the option modelling technical note will be submitted for review, comment and acceptance by Hertfordshire County Council and stakeholders (where appropriate) prior to commencing with option analysis.

3 SPECIFIC MODELLING APPROACHES

3.1 INTRODUCTION

3.1.1 The following sections detail the hotspots identified for assessment through hydraulic modelling. Appendix A illustrates the location of the sites relative to each other.

3.1.2 The following sections document the justification for proceeding (or not proceeding) with hydraulic modelling of each hotspot and the modelling aims and objectives.

3.1.3 The location and extent(s) of the hydraulic models are defined (based on understanding from the currently available data).

3.1.4 The availability of the data required to develop the hydraulic models are identified along with the anticipated topographic survey requirements for each site.

3.1.5 The hotspots should not be viewed solely as the area within which hydraulic model results are required or desired.

3.1.6 For each hotspot, the proposed hydraulic modelling methodology has been developed to ensure the area for which a refined understanding of flood risk is required is adequately represented.

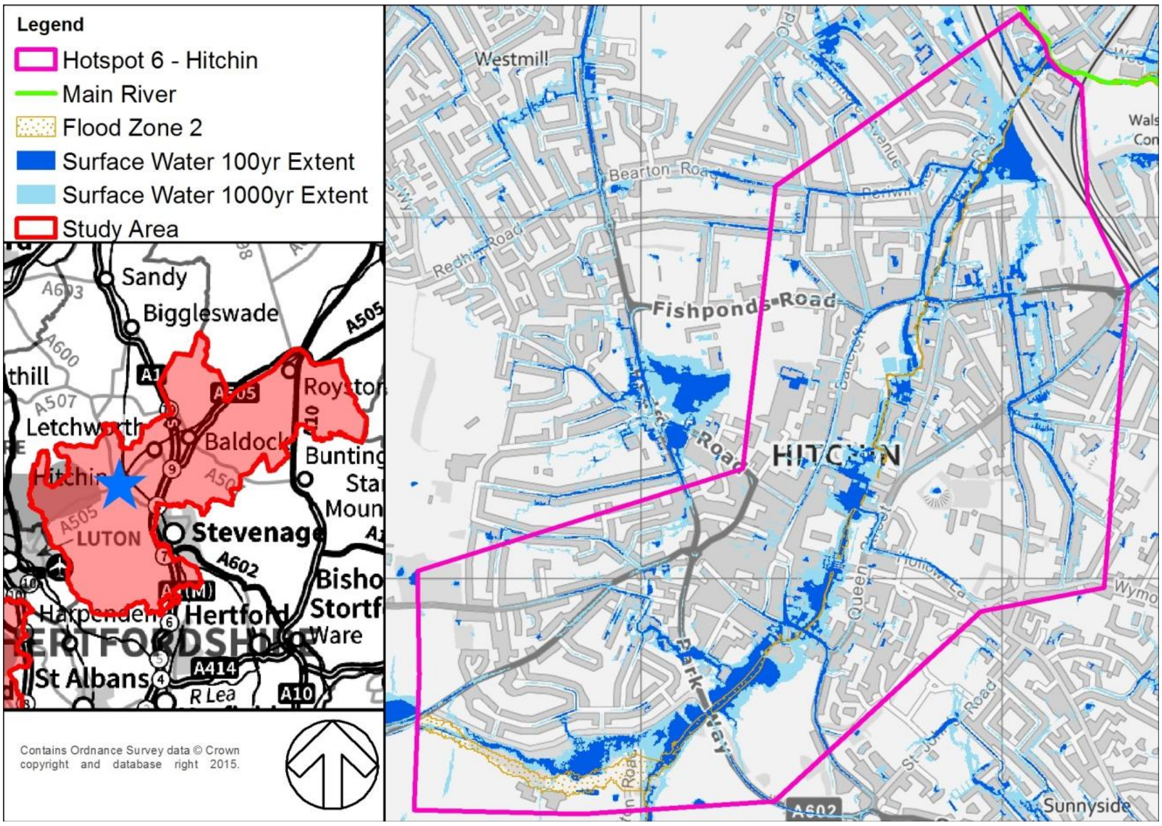
3.2 HITCHIN (SITE 6)

FLOOD RISK OVERVIEW

3.2.1 The Environment Agency Risk of Flooding from Surface Water map shows a medium to high risk area of surface water flooding around the upstream face of the culvert underneath the railway line associated with the River Hiz. The Environment Agency's Flood Map for Planning (Flood Zone 2) shows a smaller floodplain for the River Hiz than the surface water flood maps.

3.2.2 In addition, there may be a risk in relation to blocking of the culvert underneath the A505.

3.2.3 In order to maximise the number of hotspots which could be assessed through the use of hydraulic modelling, it was agreed that the modelling would not seek to duplicate that previously undertaken by others. Therefore, as the Environment Agency hold flood mapping for the River Hiz this model will be used further modelling.



AVAILABLE INFORMATION AND DATA GAPS

3.2.4 The topographical data for the model would ideally consist of LiDAR data where available and NEXTMap data where LiDAR is missing. The Environment Agency ESTRY-TUFLOW model for the River Hiz is available, which was built in April 2010. The purpose of utilising the Environment Agency model is that the topographical survey requirements are significantly reduced, making this an economically feasible model. However, depending upon the model review, additional topographical survey may be required to refine some of the model assumptions.

3.2.5 LiDAR data is available for 97.8% of the catchment. NEXTMap data is available for the whole catchment.

3.2.6 Anglian Water sewer asset data is available for the catchment and held by WSP|PB.

PROPOSED MODELLING APPROACH

3.2.7 The proposed modelling will be undertaken largely in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach. However, given that the River Hiz flows through the centre of Hitchin, the existing model will be used as the basis for the assessment.

3.2.8 The aim of this modelling is to refine the surface water flood risk close to the watercourse as the existing surface water modelling does not show extensive risk areas elsewhere within this catchment. Therefore, inclusion of the conveyance routes is considered to be of more importance than precision or distributed storage when considering how to incorporate the surface water sewers in the wider catchment. Following review of the Environment Agency model and Anglian Water sewer asset data it may be decided that a larger threshold for surface water sewers is appropriate in this instance.

3.2.9 As there is an existing model, the proposed modelling approach at Hitchin is to upgrade the existing model into a 1D-2D Estry- Tuflow model and adopt a direct rainfall approach for applying boundary conditions. The existing model is assumed be suitable for use in this study, given that it was developed for the Environment Agency and will provide the connectivity between open and close stretches of watercourse.

3.2.10 It may be necessary to extend the 1D model (although depending on the location and required accuracy this may be undertaken in 2D) to cover the required extents as follows:

- The 2D domain of the model will be extended to include a coarse representation of entire length of the River Hiz from its origin near Wellhead Farm to its confluence with the River Purwell, however, the accuracy in areas which are not included within the original model will be lower, as additional topographical survey will not be extensively sought and limited to significant crossings, with channel characteristics obtained from the LiDAR DTM.
- The downstream end of the 1D model will be set on the River Hiz at a watercourse cross section immediately upstream of the confluence with the River Purwell. The downstream boundary condition will consist of a fixed stage, based upon an estimate from the Environment Agency's flood maps.

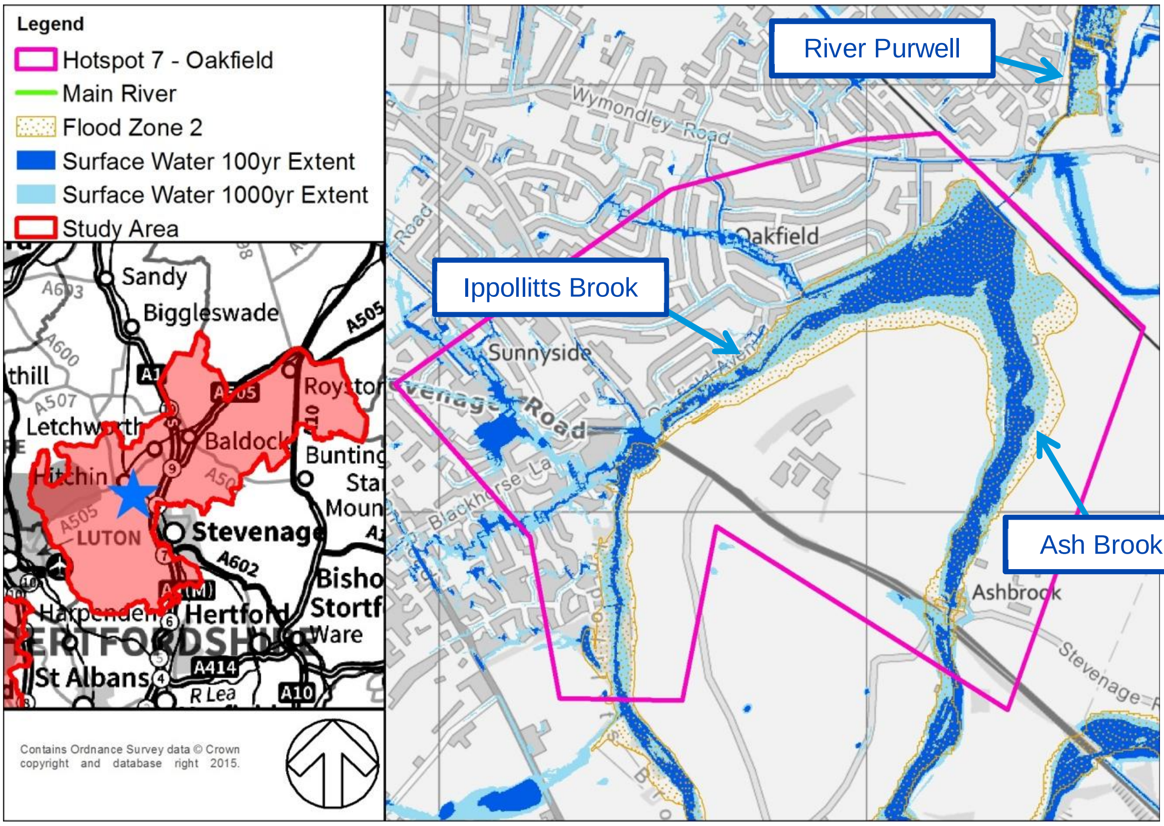
3.2.11 Topographical data for the model will consist of uFMfSW DTM supplemented by topographical survey in the key areas.

3.3 OAKFIELD (SITE 7)

FLOOD RISK OVERVIEW

3.3.1 The Environment Agency Risk of Flooding from Surface Water Map demonstrate a medium to high risk of surface water flooding around Ippollitts Brook and Ash Brook, which are also in the Environment Agency's Flood Map for Planning (Flood Zone 2).

3.3.2 In addition, there may be a risk in relation to blocking of the culvert underneath the A602 and/or railway.



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AVAILABLE INFORMATION AND DATA GAPS

3.3.3 An existing Environment Agency 1D InfoWorks model is available, which was built in 2008 and covers Ippollitts Brook but not Ash Brook (i.e. the western watercourse which flows to the north is covered but the eastern watercourse which joins Ippollitts Brook is not).

3.3.4 LiDAR data is available for 100% of the catchment.

3.3.5 Anglian Water sewer asset data has been obtained for this hotspot site.

3.3.6 To enhance the existing hydraulic model, additional topographical survey is required. In particular, this may include structure survey on the eastern culvert running underneath the A602 in addition to the railway culvert downstream.

PROPOSED MODELLING APPROACH

3.3.7 As there is an existing InfoWorks model, the proposed modelling approach is to build a 1D-2D InfoWorks Integrated Catchment Model (ICM) and adopt a direct rainfall approach for applying boundary conditions. The existing model would be critically reviewed to confirm the suitability for SWMP modelling.

3.3.8 It is anticipated that the Ash Brook will not be included in the model but represented as an inflow instead. The model extents will be the same as the InfoWorks model. The culvert capacity of Ash Brook would be assessed through spreadsheet calculations and if these demonstrate the potential for significant flooding, then this will determine if modelling of the Ash Brook is to be undertaken

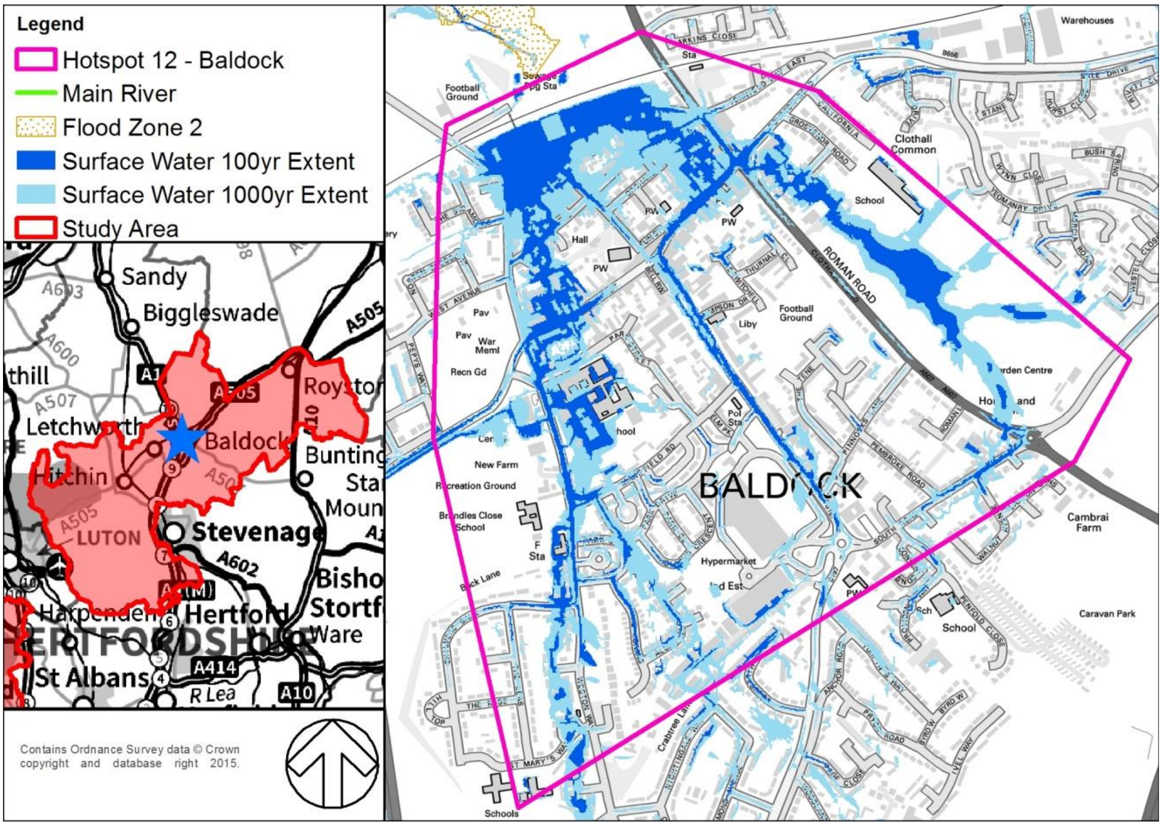
3.3.9 Topographical data for the model will consist of LiDAR data supplemented with the topographical survey.

3.4 BALDOCK (SITE 12)

FLOOD RISK OVERVIEW

3.4.1 The Environment Agency (EA) Risk of Flooding from Surface Water map demonstrate an extensive area at medium to high risk of flooding from surface water on the northern part of the hotspot, to the south of the railway track. This would be the focus of the modelling. Whilst other areas are shown to be at risk there is insufficient topographical information to support further modelling of these areas.

3.4.2 Other areas shown to be at medium to high risk of surface water flooding within the extent of the hotspot are related to the overland flow paths along Weston Way plus the flow path on High Street (B197). In addition, there appears to be an overland flowpath which develops to the east of Station Road / Clothall Road (A507) and joins the main flooding area in the north of the hotspot after having overtopped Station Road / Clothall Road (A507) upstream of the railway track.



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AVAILABLE INFORMATION AND DATA GAPS

3.4.3 No existing hydraulic models are known to be available.

3.4.4 LiDAR data is available for only 38.5% of the catchment (mainly in the downstream area and to the west). NEXTMap data is available for the whole catchment. This raises concerns on the lack of highly accurate topographical data in a significant portion of the urban area and its likely impact on the accuracy of the model and its results. Therefore, this modelling would incorporate the NEXTMap data to ensure that flow conveyance routes are incorporated within the model rather than trying to refine the risks, within these areas.

3.4.5 Anglian Water sewer asset data is available for the catchment and held by WSP|PB.

3.4.6 Additional topographical survey is required to provide input to the model. In particular, it is anticipated that topographical survey coverage will be limited to refine the representation of the flow paths adjacent to and under the railway (the site visit identified a pedestrian underpass as the primary flow route).

PROPOSED MODELLING APPROACH

3.4.7 This hotspot will be modelled together with Clothall Common (Site 13) as these hotspots are hydraulically linked through Anglian Water surface water network.

3.4.8 The modelling at this hotspot will be focused on refining the street level risk between Hitchin Street/Whitehorse Street and the railway, given the limitations with the available LiDAR data. This model will be developed as a direct rainfall ESTRY-TUFLOW model (in accordance with Section 2.2).

3.4.9 Topographical data will be obtained to refine the flow paths along and beneath the railway, including a limited number of sections in the downstream watercourse, to ensure that the boundary is suitably represented.

3.4.10 1D elements of the hydraulic model (i.e. culverts and the subway) will be added within the extent of the 2D floodplain model to simulate by-pass structures along the railway track. The downstream end of the model will be a suitable distance downstream of the culvert beneath the railway, at this point it is considered that the downstream boundary condition of the 1D model will consist of a normal depth boundary condition.

3.4.11 The site visit particularly focused on the railway culvert and potential bypass structures.

3.5 CLOTHALL COMMON (SITE 13)

FLOOD RISK OVERVIEW

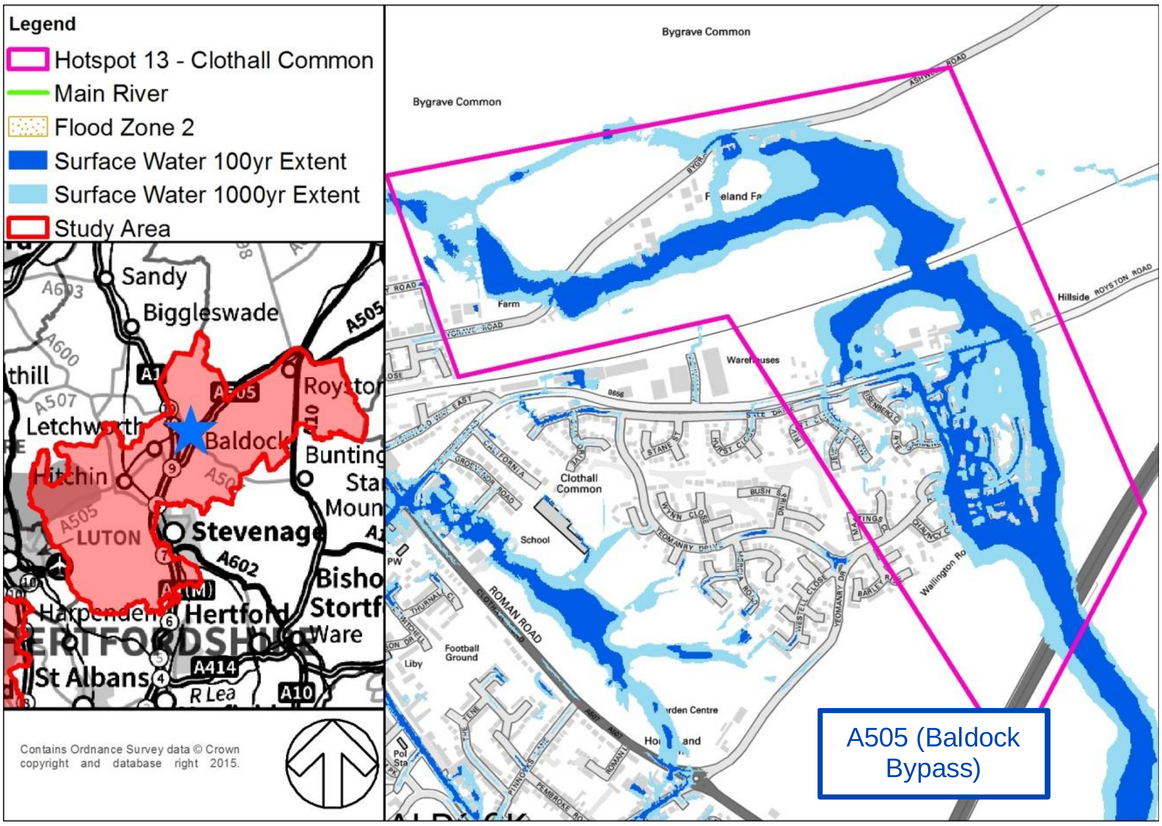
3.5.1 The Environment Agency's Risk of Flooding from Surface Water map shows an extensive area at medium to high risk of surface water flooding to the eastern part of Clothall Common. The map also shows that the risk of flooding is in relation to the overland flowpath across the A505 dual carriageway highway to the south. However, this is considered to be unrealistic given the nature of the cutting and associated embankments in which this section of the highway sits. These features have not been included within the DTM used for the Environment Agency Risk of Flooding from Surface Water maps.

3.5.2 The A505 Baldock bypass opened in 2006, as such design drawings were readily available, whilst we have not assessed the capacity/performance of the highway drainage, given its age and nature of the road, it is highly likely to have been designed in accordance with the Design Manual for Roads and Bridges. This means that the safety of highway users from surface water runoff from the highway would have been considered and addressed through suitable drainage design.

3.5.3 To understand the implications of the A505 on surface water runoff from the wider hotspot catchment we have reviewed the design drawings for the relevant section of the road. This confirms that this flow path is served by two infiltration basins (which also accommodate the highway drainage). Any waters which are in excess of the capacity of these basins are conveyed under the A505 in a 300mm diameter culvert which discharges into a swale immediately upstream of the footpath adjacent to the eastern boundary of the existing residential development at Clothall Common. It is considered that there is no scope for any waters in exceedance of the capacity of this pipe to be conveyed beyond the A505.

3.5.4 Whilst the flow path shown on the Environment Agency's Risk of Flooding from Surface Water map across the A505 is thought to be diminished, there remains the risk to the residential properties to the north of the A505 and that future development is being considered in the agricultural area between the existing residential area, Royston Road (B656), and the A505.

3.5.5 Local knowledge gained during meetings refers to flooding occurrences in the Clothall Common area in 2009 and 2014.



AVAILABLE INFORMATION AND DATA GAPS

3.5.6 A preliminary investigation of the Environment Agency LiDAR demonstrates that coverage; is less than 20% of the proposed model extents with this being limited to a small area to the north-west corner. The lack of the LiDAR for the majority of the area prevents the construction of a robust hydraulic model to assess the risks across the whole hotspot. NEXTMap data is available for the whole catchment, which will assist in the generation of hydrographs at the key study area.

3.5.7 Anglian Water sewer asset data has been obtained by WSP|PB for this hotspot site.

3.5.8 As a result of the low LiDAR coverage more extensive topographical survey will be required to identify the likely flow paths and areas of ponding. Therefore, to avoid significant topographical survey costs, this model will not be developed to the same level of accuracy as those with LiDAR but instead will focus on improving the existing model accuracy for the properties on Merchants Walk, which have little to no freeboard.

PROPOSED MODELLING APPROACH

3.5.9 3.4.7 This hotspot will be modelled together with Baldock (Site 12) as these hotspots are hydraulically linked through Anglian Water surface water network

3.5.10 The rainfall will be applied immediately downstream of the A505 and assume that any exceedance flood waters from the highway drainage and the chalk catchment are restricted to a 300mm pipe (which for the purposes of this hotspot model will initially be run full bore, the accuracy of this will be assessed during the model build and verification process, and any timings/pipe capacity calculations adjusted accordingly). This model is considered to be an interim model to enable HCC to have informed discussions (to inform a further more detailed site specific model) with the developer of the land south of Royston Road (B656) and north of the A505, in addition to the existing residential area which has been allocated within the Local Plan.

3.5.11 Topographical data for the model will consist of LiDAR data where available (around 14.5% coverage) and topographical survey data or NEXTMap data where LiDAR is missing. In terms of the topographical data a grid of points will be obtained covering the area around Merchants Walk, as well as key cross sections of the swales along the edge of the development area. This will enable the swales to be incorporated into the model and enhanced through the use of interpolated sections to ensure that the flow paths are represented.

3.5.12 Additional topographical survey will be obtained to confirm the site visit observations that the general catchment south of Merchants Walk is relatively flat. The site visit indicated that a fair section of the swale from Royston Road (B656) to Merchants Walk falls towards the south rather than the north as indicated by the OS mapping. Therefore, it is likely that the topographical survey will be required to extend to the B656, with levels beyond this falling towards the railway, i.e. away from the hotspot.

3.5.13 Downstream end of the model to be located in the portion of land between Royston Road (B656) and the railway line with 2D boundary units set to enable flow discharging freely downstream.

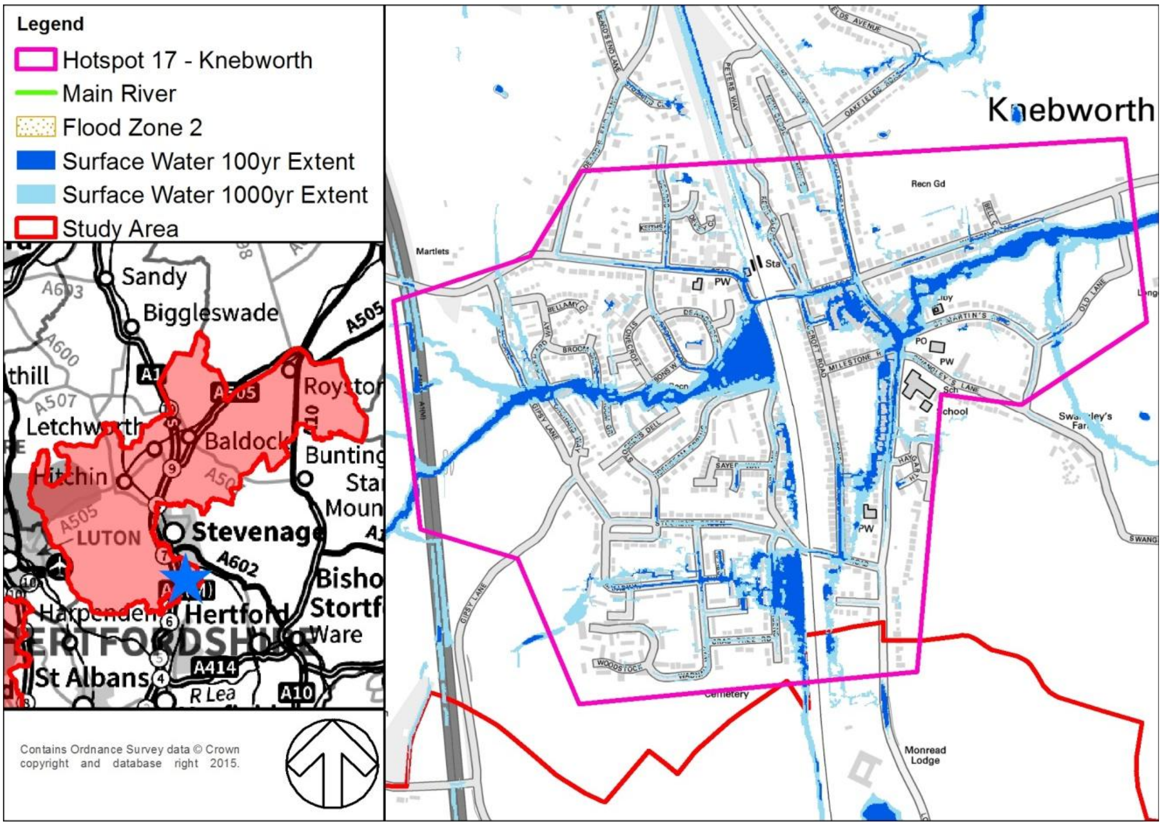
3.6 KNEBWORTH (SITE 17)

FLOOD RISK OVERVIEW

3.6.1 The Environment Agency Risk of Flooding from Surface Water map shows areas at medium to high risk of surface water flooding. These include two areas along the western side of the railway track, a large area just south of Station Road and a second area further to the south, approximately located to the back of the properties on Gun Road Gardens. The map also indicates the presence of flooding to the east of the railway track.

3.6.2 Given the approach adopted in the Updated Flood Map for Surface Water National Scale Surface Water Flood Mapping Methodology (May 2013), flooding to the east of the railway track is largely constrained to surface water runoff generated within the area to the east of the hotspot. Once flow paths under the railway are incorporated, flooding in this area may be shown to be more significant. Additionally, the maps indicate a flow route across the A1(M) motorway to the west, in practice this would not occur, however, a culvert exists beneath the road, so as this culvert is known to exist, the flow path into the Knebworth hotspot is partly represented (flow would enter Knebworth from this direction).

3.6.3 Local knowledge indicates the occurrence of historical flooding events associated with several storms in short succession resulting in a suitable runoff coefficient for the larger events to be around 85% for the chalk agricultural land.



AVAILABLE INFORMATION AND DATA GAPS

3.6.4 Topographical data for the model will consist of LiDAR data where available (78% coverage) and NEXTMap data where LiDAR is missing.

3.6.5 Thames Water sewer asset data is available for the catchment. This demonstrates that there is no extensive surface water network within this area. Hertfordshire County Council as Local High Authority have detailed that the majority of the highway drainage in Knebworth is drained by soakaways.

3.6.6 It is anticipated that additional topographical survey may be required to provide input to the model, to confirm preferential flow paths or barriers to overland flow. The site visit and OS MasterMap does not show any open watercourses in this area, which is in-line with the chalk nature of this small catchment.

PROPOSED MODELLING APPROACH

3.6.7 The proposed modelling will be undertaken in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach.

3.6.8 At this stage WSP|PB are not aware of any open watercourses within this catchment, therefore the approach to modelling is restricted to a direct rainfall model, with topographical data obtained for key sections under the railway.

3.6.9 The downstream end of the model is to be based on free flow discharge.

3.6.10 Topographical data for the model will consist of LiDAR data for the majority of areas.

3.6.11 Constraints at the highways under the railway will be assessed as part of the modelling.

3.6.12 Appropriate soil infiltration parameters will be adopted on the basis of soil maps and sensitivity on soil infiltration parameters or runoff coefficients will be undertaken to demonstrate the potential impacts of antecedent wet conditions.

3.7 CAMBRIDGE ROAD (A505), PURWELL AND WALSWORTH AREAS OF HITCHIN (SITE 30)

FLOOD RISK OVERVIEW

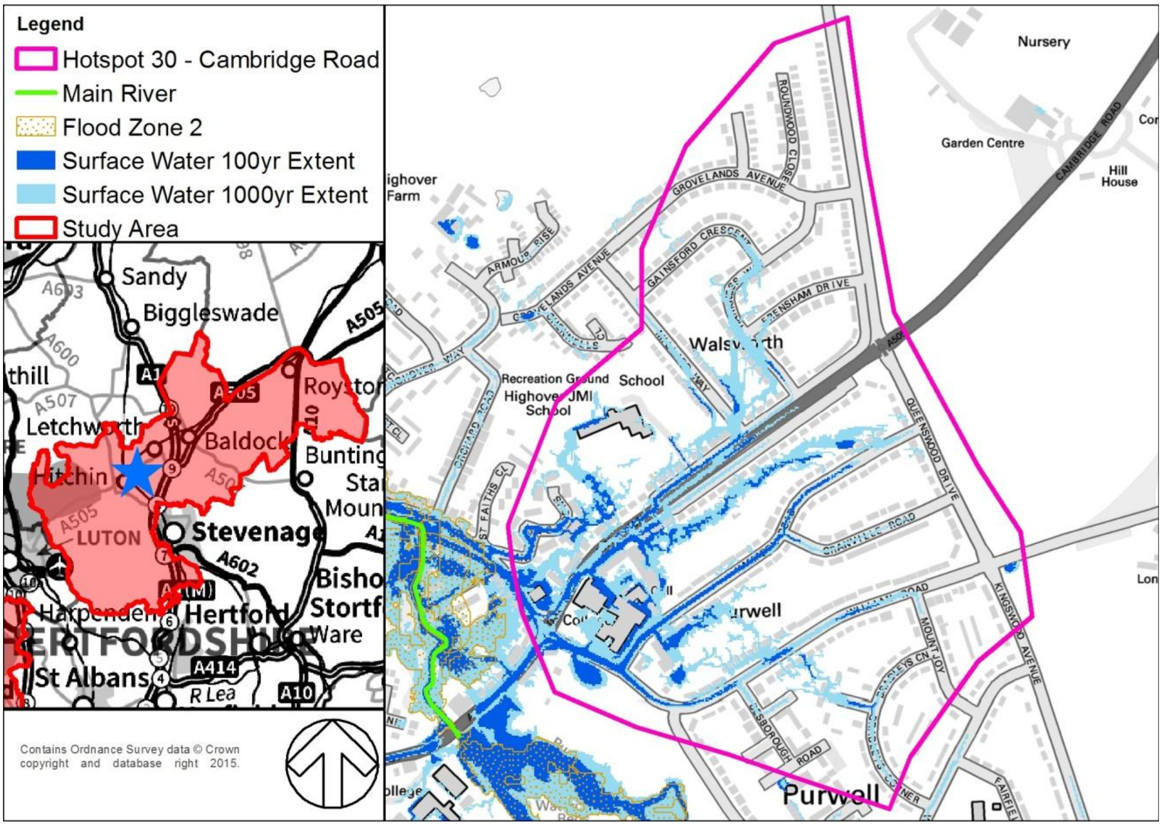
3.7.1 This hotspot has been put forward for consideration based upon several flooding incidents. This hotspot is centred around Cambridge Road (A505), along the first residential section of Cambridge Road, as you enter Hitchin from Letchworth Garden City to the east. This was selected because there have historically been several incidents of flooding around this section of the road.

3.7.2 The Environment Agency Risk of Flooding from Surface Water map shows areas at medium to high risk of surface water flooding at the downstream part of the hotspot. Surface water flood risk appears to be mainly in relation to an overland flowpath along Cambridge Road (A505) and there is an additional overland flowpath to the south.

3.7.3 There is the potential that the overland flowpath along Willian Road has been overestimated as a result of routing flows purely based on terrain gradient. An ordinary watercourse potentially flows under Willian Road to the east of the hotspot figure, with a network of field ditches likely to drain into this area.

3.7.4 It is believed that at least one property has been flooded on several occasions and a side wall and temporary barrier are reported to be in place at the property to reduce the effects of flooding.

3.7.5 Information currently available suggests that the capacity of gullies and the surface water sewer network are likely to fail in heavy rainfall, with the worst effects near the property where two flowpaths meet on Cambridge Road (A505), and the Walsworth crossroads (Cambridge Road, Willian Road and Woolgrove Road junction).



AVAILABLE INFORMATION AND DATA GAPS

3.7.6 Topographical data for the model will consist of LiDAR data where available (59% coverage) and NEXTMap data where LiDAR is missing, as contained within the uFMfSW DTM.

3.7.7 Anglian Water sewer asset data has been obtained for this hotspot site.

3.7.8 It is anticipated that additional topographical survey may be required to provide input to the model. In particular, it is expected that topographical data may include road levels to be taken at various points on the section of Cambridge Road (A505) and this road's residential offshoot road near the historically flooded property. Levels may also be required on pathways and at the edge of the carriageway.

PROPOSED MODELLING APPROACH

3.7.9 The proposed modelling will be undertaken in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach.

3.7.10 Topographical data for the model will consist of uFMfS DTM.

3.7.11 The downstream end of the fine mesh 2D model will be set at the River Purwell. The river levels from the Environment Agency's 1 in 5 year event from the River Purwell model will be used as the downstream boundary of the 2D model extents .

4 SUMMARY OF DATA REQUIREMENTS

4.1.1 Table 4 provides a summary of the availability of the data required to progress the hydraulic modelling for each hotspot.

Table 4 - Summary of data availability and requirements

Hotspot	LiDAR	Network data	Existing hydraulic models availability
Hitchin (site 6)	🟩	🟩	🟩 Existing Environment Agency ESTRY-TUFLOW model available to use and enhance
Oakfield (site 7)	🟩	🟩	🟩 Existing Environment Agency 1D InfoWorks model available to use and enhance
Baldock (site 12)	🟧	🟩	▨
Clothall Common (site 13)	🟥	🟩	▨
Knebworth (site 17)	🟩	🟩	▨
Cambridge Road, Purwell and Walsworth areas of Hitchin (site 30)	🟨	🟩	▨

Key

Colour	Meaning
🟩	Most/all available
🟧	Some available
🟥	Little/none available
▨	Not required
🟨	To be confirmed

Appendix I

TOPOGRAPHICAL SURVEY SPECIFICATION

SURVEY BRIEF COVERSHEET

Kings Orchard
1 Queen Street
Bristol
BS2 0HQ
Tel: +44 (0)117 930 3789
www.wspgroup.co.uk

TO	Prospective Surveyors
FROM	Andy Smith
COPIES TO	Project File
DATE	30/06/2015
REF	70006808 – North Hertfordshire and Dacorum SWMP

SURVEY REQUIREMENTS

Introduction

Hertfordshire County Council in their role as Lead Local Flood Authority commissioned WSP│Parsons Brinckerhoff to undertake a surface water management plan for North Hertfordshire and Dacorum as part of their programme of undertaking such studies across the county.

To enable hydraulic modelling to be undertaken at the key locations across North Hertfordshire and Dacorum, watercourse survey is required at a number of locations as detailed in the accompanying figures.

There is potential for minor variations in this brief as Hertfordshire County Council are currently providing their comments on the modelling methodology.

Survey is required at the following locations:

- Hitchin
- Baldock
- Clothall Common
- Knebworth
- Tring
- Berkhamsted
- Bovingdon
- Cambridge Road, East of Hitchin
- Aldbury
- Oakfield
- Kings Langley

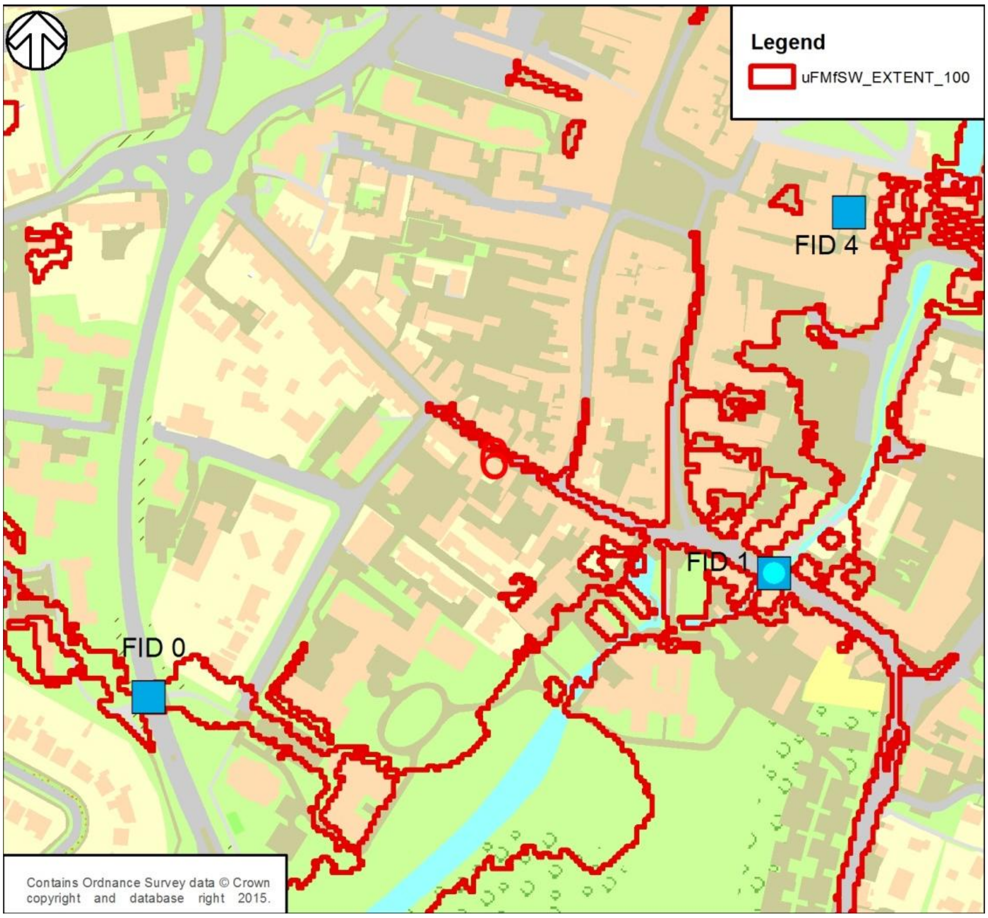
This document outlines the key requirements of the survey for which we require a competitive quotation for your services. It must be read in conjunction with WSP standard specifications for watercourse survey (in particular refer to the accompanying document named "*WSP RICS Jan 2013 ISSUED - Annex K only.pdf*"), which accompanies this document and provides more explicit instructions of the survey requirements. It is worth noting that this survey should also be undertaken to Environment Agency standards, of which I believe you are familiar.

The specific requirements for each location are detailed below, with indicative locations shown in the relevant figures.

Hitchin

The approximate grid reference for the central area is NGR 518200, 229000.

- Details on the pedestrian footpath underpass beneath Park Way (A602), details should include (Ref FID0):
  - cross sections of any open watercourse and culverts beneath Park Way,
  - soffit, invert and dimensions, slope of the pedestrian underpath
  - string of levels along the embankment on the upstream face (20 m either side of underpass)
- Bridge Street/Tilehurst Street – A string of levels for 300m between the B656/Queens Street and the Priory, picking up road level and kerb height, threshold/FFL of the properties fronting the road. We also require details on the upstream and downstream face of the road bridge and levels along the downstream banks (Ref FID1)
- Further works may be required to tie in to existing Environment Agency model – to be agreed as an additional element, if required.



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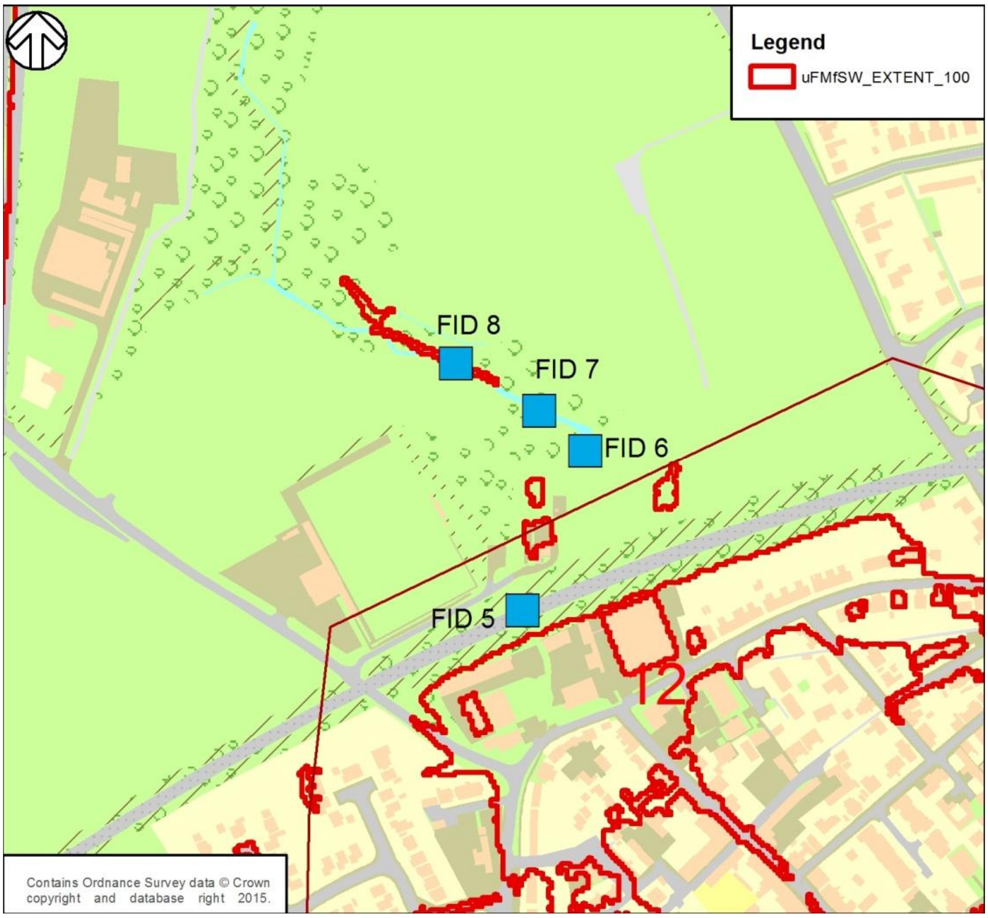
Survey Brief Continuation

Baldock



The approximate grid reference for the footpath under the railway is 524191, 234165.

FID 5 (footpath from Icknield Way): Details on the footpath beneath the railway upstream and downstream dimensions

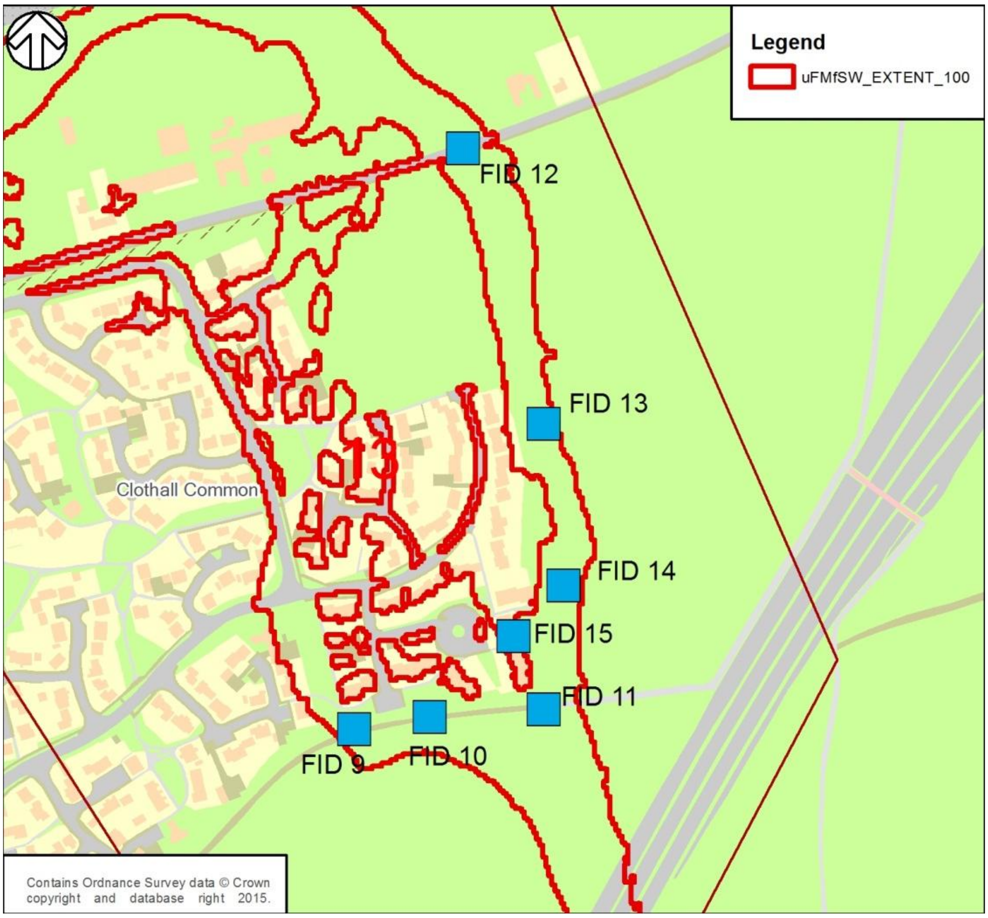
FID 6: Culvert outlet details (soffit, invert and dimensions) and watercourse cross section

FID 7: Cross section 100 m downstream from FID6

FID 8: Cross section 100 m downstream from FID7

Survey Brief Continuation

Clothall Common



The approximate grid reference for FID 11 is 525837, 234040.

FID 9 and **FID10:** Are not required at this stage

FID 11: Swale cross section and sump details

FID 12 (Royston Rd B656): Swale cross section and road culvert details to include soffit, invert and dimensions

FID 13 (525831, 234204): Swale cross section – this is to be at the high point – site visit indicated that the preferential flow path will split at the crest at this indicative location

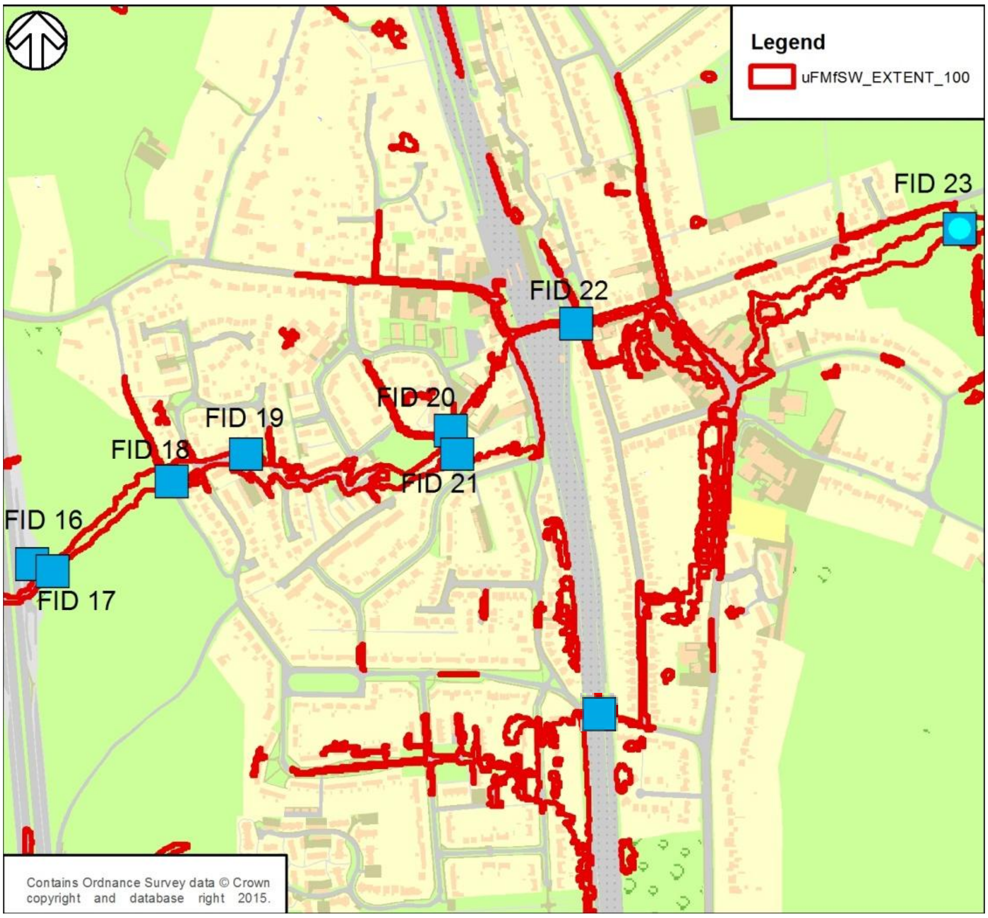
FID 14: Swale cross section

FID 15: Property threshold survey of approximately 20 properties to include the properties shown in the drawing below:

Survey Brief Continuation

Survey Brief Continuation

Knebworth



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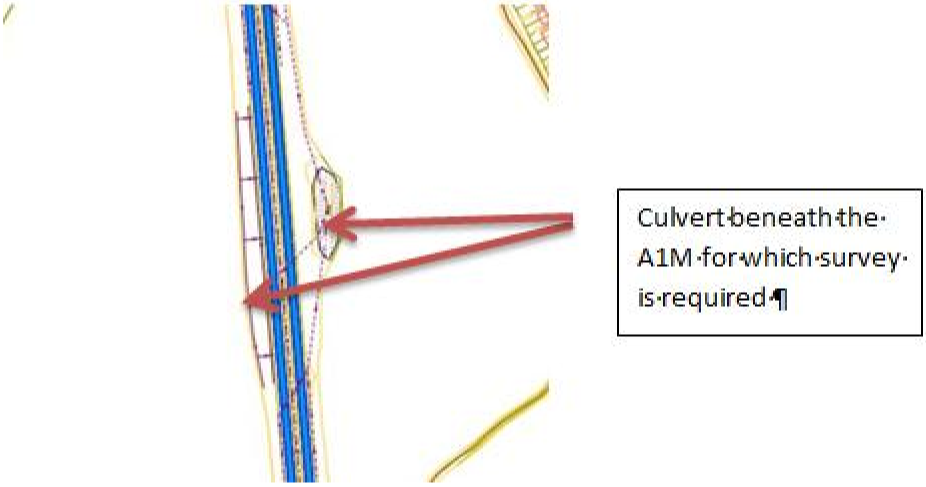
The approximate grid reference for the railway station is 524925, 220263.

FID 16 (A1(M)): Culvert details beneath the highway – for both the upstream and downstream sections to include soffit, invert and dimensions the outfall location is to the highway pond – see image below. Note we are not requiring survey of the pipes from the highway just the one from the toe of the embankment (this runs along the pipe run shown in maroon as indicated by the western most arrow) – see image below .



Culvert beneath the A1M for which survey is required ¶

FID 17: String of levels around pond – if possible depth and extent of pond

FID 18 (Gipsy Lane): Swale cross section and culvert details

Survey Brief Continuation

FID 19: Kerb heights at footpath between Orchard Way and Broom Close

FID 20 and 21: String of levels between the highways - Lytton Fields and Hornbeam Spring to demonstrate road and kerb levels

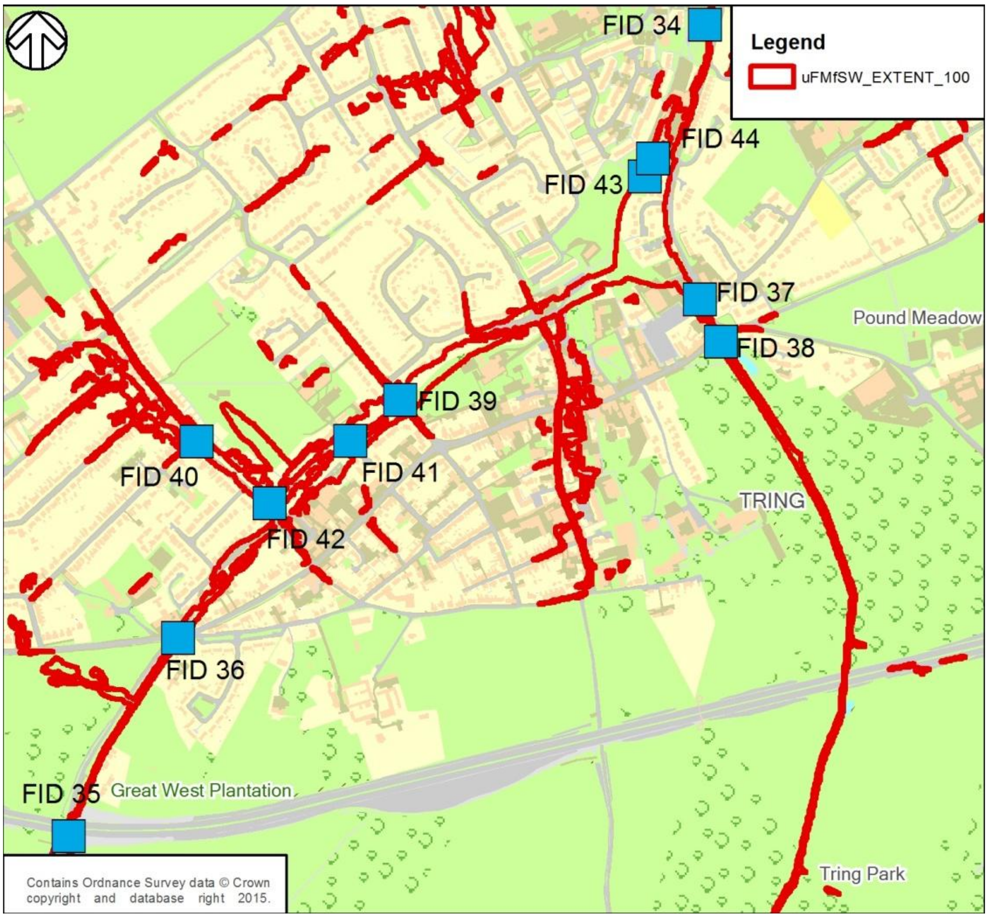
FID 22 (Station Road): Details on both faces of railway crossing width, soffit, road and invert levels

FID 23 (Old Lane): Several Levels on the highway and adjacent ground to ensure that we can tie into LiDAR

Additional – **Gun Lane** leading to Gun Road - Details on both faces of railway crossing width, soffit, road and invert levels

Survey Brief Continuation

Tring



The approximate grid reference for the centre of the study area is 492124, 211313.

FID 34: Watercourse cross section, to include outfall dimensions/soffit/invert from the pond at FID 44/43

FID 35: Not required at this stage

FID 36: Road and kerb levels along the flow path between Duckmore Lane and Park Road along the B4635

FID 37: Not required at this stage

FID 38: String of road and kerb levels to cover the junction of London Road/Brook Street and High Street. Details are also required of the pedestrian footpath in front of the Robin Hood and neighbouring properties along with their threshold levels along with the wall and associated ground levels either side of the wall on the opposite side of the road – see image below

Survey Brief Continuation

Wall and ground levels either side of

Highway and kerb levels across the junction – to extend past the Robin Hood and associated properties to the east

Footpath levels

FID 39: Not required at this stage

FID 40: Not required at this stage

FID 41: Not required at this stage

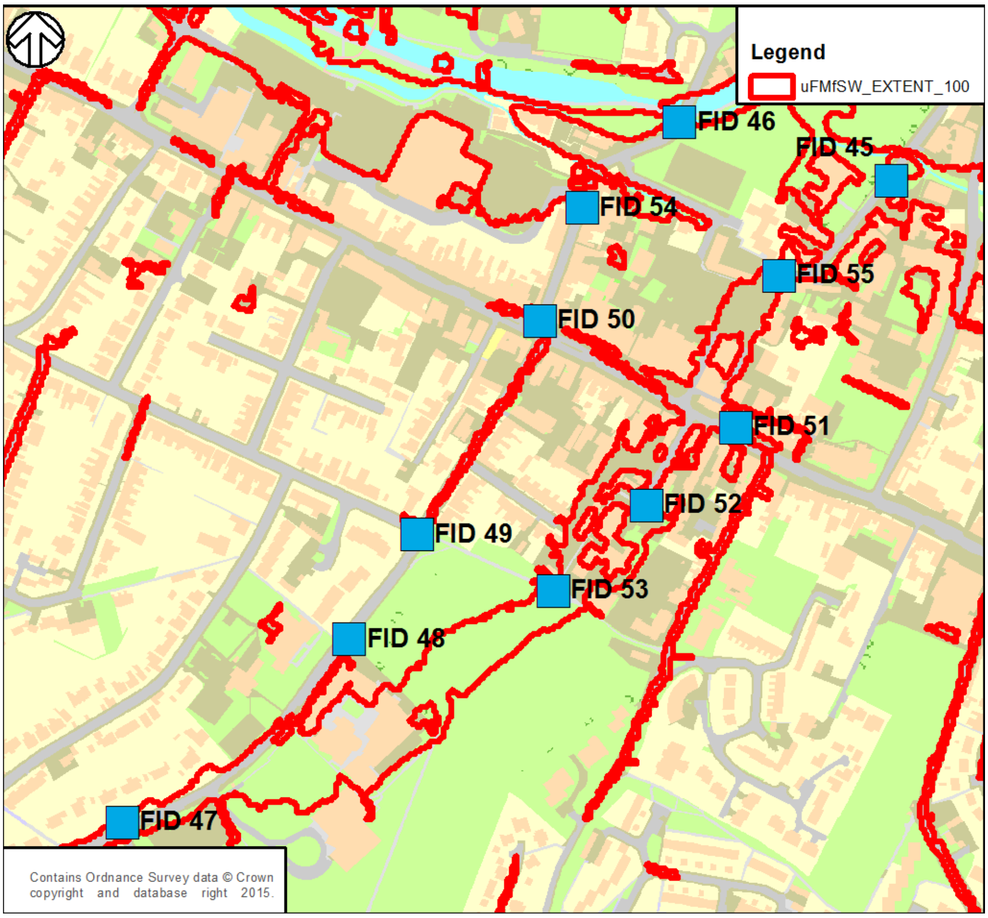
FID 42: Not required at this stage

FID 43: Pond sizes and depth, current water level

FID 44: Pond outfall details to include soffit, invert and dimensions

Survey Brief Continuation

Berkhamsted



The approximate grid reference for the centre of the study area is 498866, 207493.

FID 45 (Mill Street): String of road levels to cover how waters would spill from the highway in to the watercourse

FID 46 (Lower Kings Road): String of road levels to cover how waters would spill from the highway in to the watercourse

FID 47 and **FID 48** (Kings Road): String of road and kerb levels between the two points ensuring that the spill route into the school grounds are detailed

FID 49 and **FID 50**: String of road and kerb levels between the two points

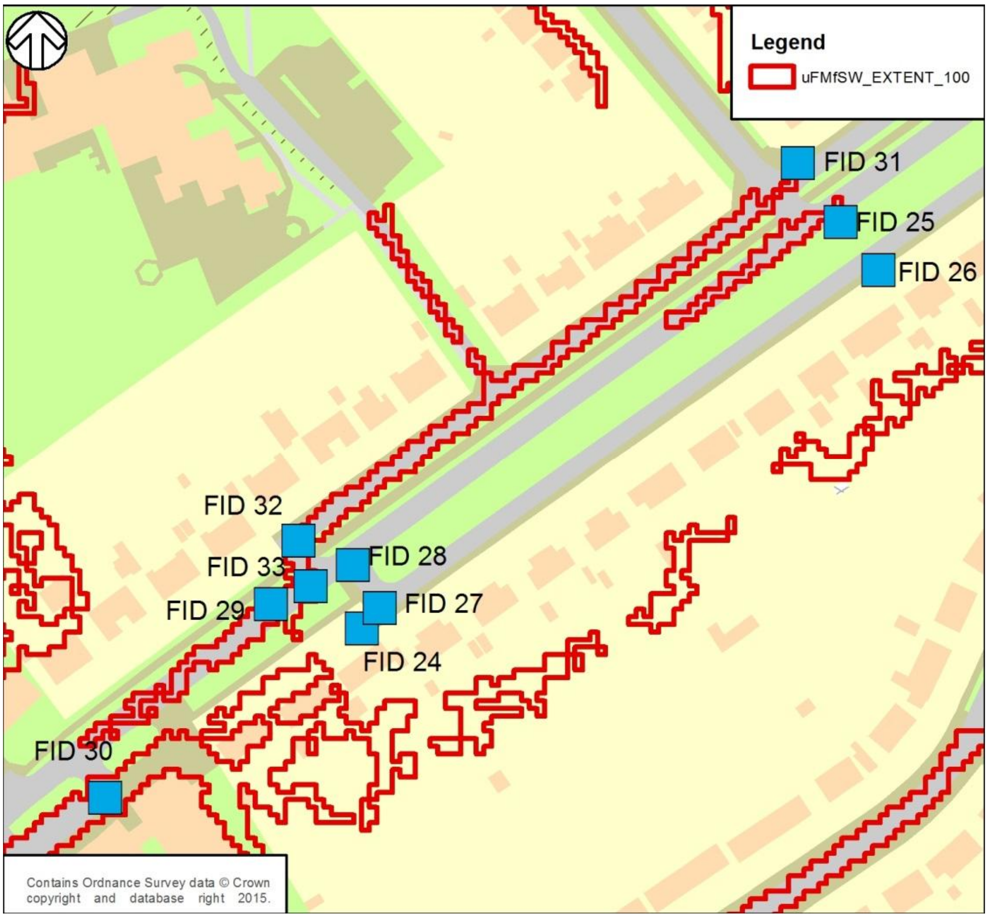
FID 50 and **FID 51** (High Street): String of road and kerb levels between the two points

FID 52: Not required at this stage

FID 53: Ground levels along school boundary

FID 54: Not required at this stage

Cambridge Road, East of Hitchin



The approximate grid reference for the centre of the study area is 520062, 230268 and is focused on 158 Cambridge Road

FID 24: Property Finished Floor Level (FFL) and surrounding wall levels along with Property Level Protection (PLP) details across drive

FID 25: Levels on the highway and kerb

FID 26: Levels on the highway and kerb

FID 27: Levels on the highway, kerbs and drainage infrastructure

FID 28: Levels on the highway and kerb

FID 29: Levels on the highway and kerb

FID 30: Levels on the highway and kerb

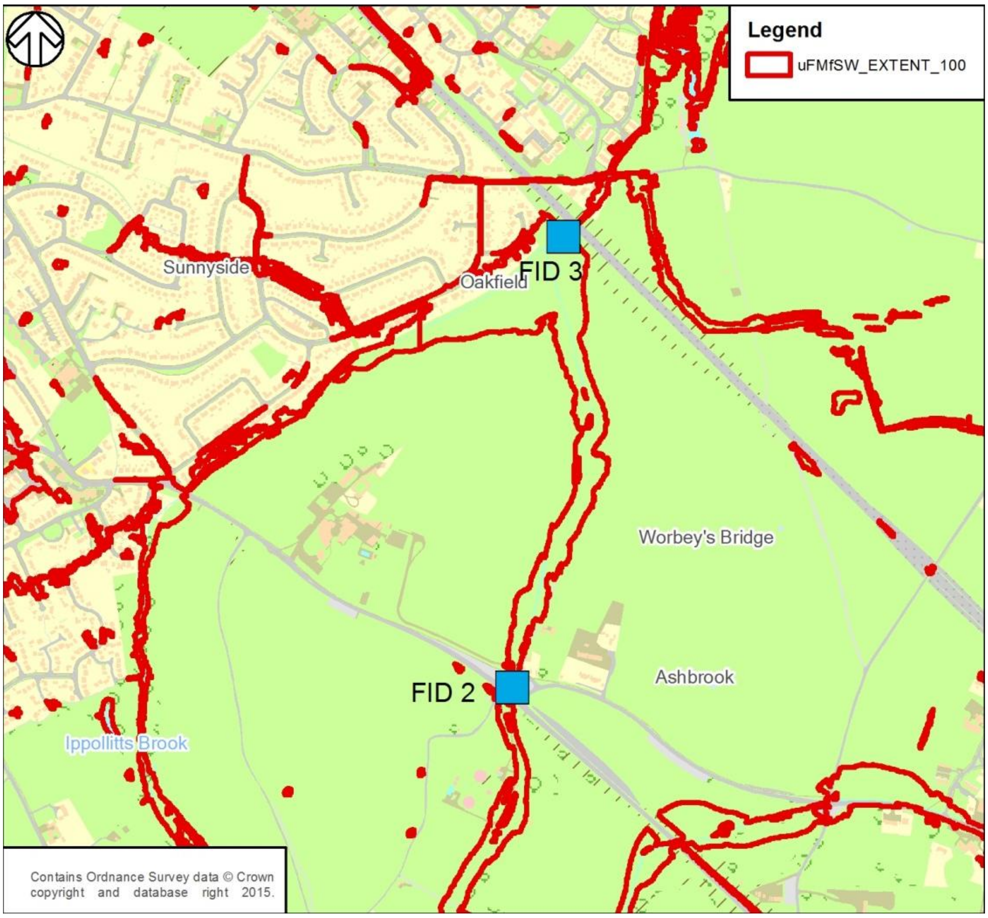
FID 31: Levels on the highway and kerb

FID 32: Levels on the highway and kerb

FID 33: Levels on the highway and kerb

Survey Brief Continuation

Oakfield



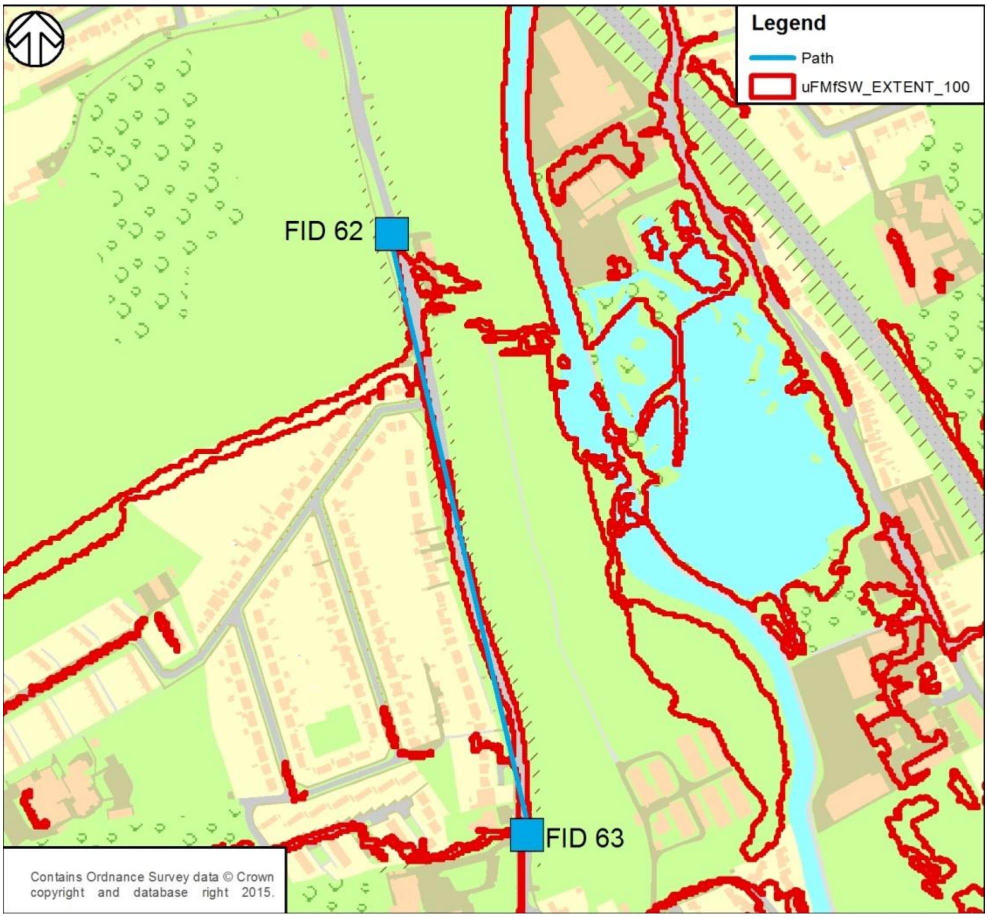
The approximate grid reference for the study area (FID3) is 520306, 228682.

FID 2 (520178, 227748): Details on the culvert (invert, soffit and dimensions) and cross sections obtained 50m upstream and downstream

FID 3 (520295, 228708): Scope/requirements to be confirmed prior to commission, following provision of data from the Environment Agency to WSP

Survey Brief Continuation

Kings Langley

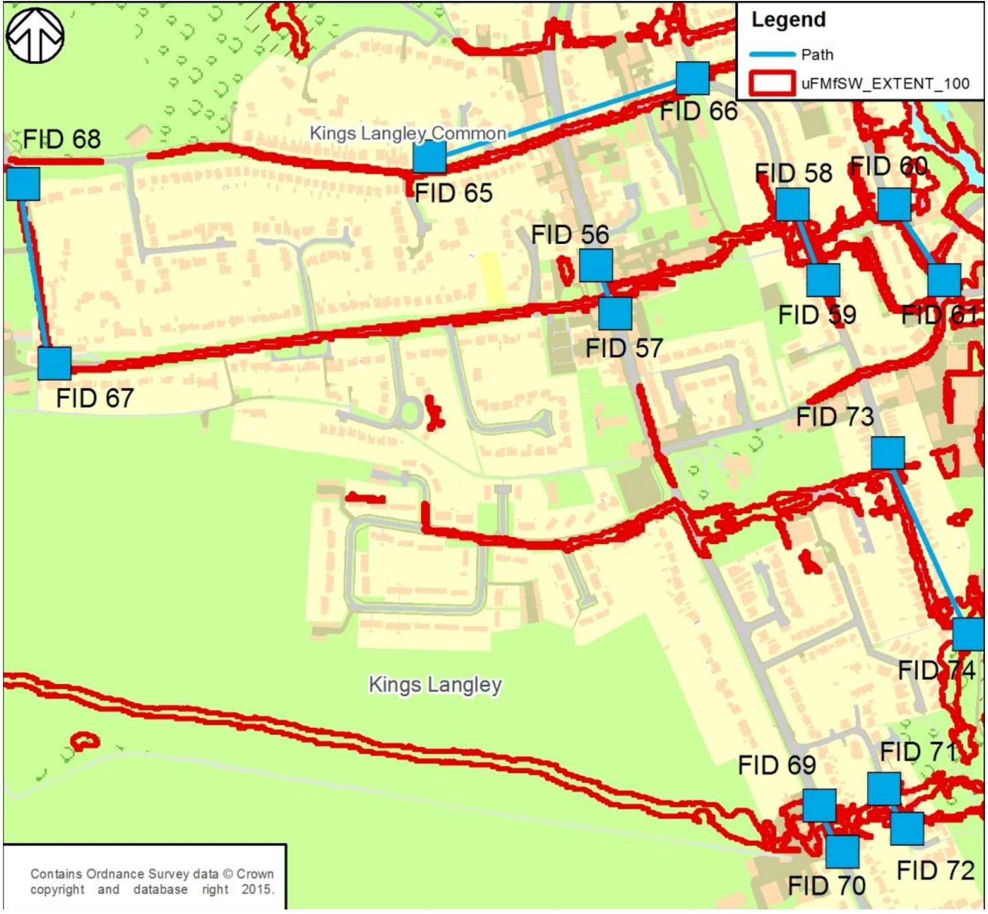


The approximate grid reference for the centre of the study area is 507502, 202504.

Strings of levels are required between the points shown on the two maps to demonstrate likely flow paths and should therefore aim to detail any low spots or constraints to flow particularly focusing on the highway and kerbs

FID 62 – 63

Survey Brief Continuation



Contains Ordnance Survey data © Crown copyright and database right 2015.

FID 56 – 57

FID 58 – 59

FID 60 – 61

FID 65 – 66

FID 67 – 68

FID 69 – 70

FID 71 – 72

FID 73 – 74: String of road levels (Alexandra Road) and levels around the pond to demonstrate how waters would flow into the pond. These levels will need to extend on to Station Footpath (FID 74), which is a pathway around the pond.

Survey Brief Continuation

Watercourse survey requirements

The locations of the required highway and watercourse cross sections have been indicated in the attached plans. The WSP standard specifications for watercourse survey provide details of how these should be surveyed, which includes example cross sections of river sections, structures and long sections. Please allow for the survey of additional cross sections where changes occur in cross section geometry and/or channel slope, which may not be captured by the locations specified.

Some of the cross sections are located at in-channel culvert structures, which have been informed through a site visit. Further detail on the specifications is below:

- The cross sections must be surveyed in accordance with WSP and Environment Agency standard specifications for watercourse survey, as must all of the remaining cross sections.
- For culverts: Survey data will include culvert type (including material), culvert dimension, invert and soffit level at inlet/outlet location, road/deck levels, parapet levels, culvert conditions and approximate estimation of silt if present. For a culvert inlet, it must include survey of the watercourse cross section immediately upstream of the culvert inlet. For a culvert outlet, it must include survey of the watercourse cross section immediately downstream of the culvert outlet;
- For bridges: Survey data will include type, dimension, invert and soffit level at inlet/outlet location, road/deck level, parapet levels, condition and approximate estimation of silt if present. Surveyed cross sections must be provided at each location identified being both the watercourse cross section immediately upstream or downstream (as marked) of the bridge feature;
- For weirs: Survey data will include length of the structure, angle with respect to direction of flows, upstream and downstream bed level, weir level; two surveyed cross sections may be required to define the weir accurately. An indication of whether the weir is natural or manmade would also be useful.

It is possible that key information was not identified during our site visit, such as additional culverts, weirs, ditches, so please ensure that any additional features that may be relevant are also captured during the survey.

The survey should be undertaken in accordance with the WSP standard specifications for watercourse survey (refer to the accompanying document named "*WSP RICS Jan 2013 ISSUED - Annex K only.pdf*"). Any major deviation from these standards may result in deliverables being rejected, where this is not possible this should be identified in your quote.

Access

The surveyor will be responsible for arranging access to any third party land and any consents/licences that are required.

We trust this information is useful and if you have any queries please do contact us.

Survey Contact
Andy Smith
Associate Hydrologist

WSP UK, Kings Orchard, 1 Queen Street, Bristol, BS2 0HQ
Tel: +44(0)117 930 2082

Survey Brief Continuation
Email: andy.smith@wspgroup.com

Appendix II

FLOOD MODELLING SUMMARY REPORTS

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 6

HITCHIN

Modeller:	S Cheng	11/08/2016
Reviewer:	A Chowdhury	12/08/2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The updated Flood Map for Surface Water (uFMfSW) DTM was used as there was no more recent LiDAR flown after the production of the uFMfSW (the most recent EA LiDAR is the 1m, which was flown in 2006).
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as Hotspot6_NorthHerts_~s1~_~e1~_~e2~_011.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 0.99hr: 0.99hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. Model results, logs, checks labelled using above convention, eg. “Hotspot6_NorthHerts_Baseline_0.99hr_Q0100CC_011”
2. 2D Reference data	
2.1 Final DEM	The Environment Agency’s updated Flood Map for Surface Water (uFMfSW) DTM was used for this model – tiles tl12ne, tl13se, tl22nw, tl23sw.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2.2 Changes to DEM	Surveyed road levels were used to create Triangular Irregular Networks (TINS) in specific areas around the road underpass on Parkway A602 and along Tilehouse Street/Bridge Street. • Parkway_Survey_TIN.asc • Tilehouse_Bridge_Street_Survey_TIN_clip.asc Alterations were made to the Grove Road structure as it was represented as a single culvert with the Railway blocking off the 2D Domain in the EA model. Whereas in reality it is a twin arch bridge, 1 arch for the road and 1 for the watercourse. This was represented as a large rectangular culvert for the watercourse, and for the road, a z-shape was used to set the road at better level or geometry.
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Anglian Water. Surface Water Network Layer: • 1d_nwk_AW_SWS_Hotspot6_NorthHerts_010_L.shp • 1d_nwk_AW_SWS_Pit_Hotspot6_NorthHerts_010_P.shp Any changes to the 1d nwk have been included into the ‘Assumption’ column in the layers above.
3.2 Watercourse Structures	Existing watercourse structures were extracted from the Environment Agency’s ESTRY TUFLOW model for the extent of the River Hiz to its confluence with the River Purwell.
4. Hydrology	
4.1 Inflow boundaries	The model uses direct rainfall over the town of Hitchin based on catchment descriptors from a representative catchment of the town at 518750, 229650. The whole catchment of the River Hiz is much larger and would therefore not represent the true urbanised nature of the catchment. The Design Rainfall was taken from the ISIS FEH module as the catchment for the Direct rainfall is highly urbanised. Two point inflows were used upstream of the town, at the A505 and at Charlton Road. The hydrograph flows were generated using

the ISIS ReFH module. The 20 % AEP flows were inputted into the model.

The peaks of each of the hydrographs for the point inflows and the direct rainfall were matched to provide a worst case scenario.

AEP	**20.0%**	**5.0%**	**3.3%**	**1.3%**	**1.0%**	**1%+40%**	**0.1%**
Peak rainfall intensity(mm/hr)	57	91	104	140	154	216	325
Total rainfall (mm)	17	28	32	43	48	67	100
Storm duration (hr)	0.99						
Inflow A505 Peak (m^3/s)	0.058	0.13	0.163	0.271	0.317	0.4438	1.12
Inflow Charlton Road Peak (m^3/s)	0.06	0.134	0.168	0.28	0.329	0.4606	1.171

4.2 Downstream boundaries

The downstream boundaries have been defined as

- A normal slope boundary based on the overall slope of the catchment;
- 1d downstream boundary QH curve generated from channel geometry.

4.3 Historical records of flooding

Environment Agency Recorded Flood Outlines show no recorded events in the area.

5. Materials and Soils

5.1 2D Manning’s n

The Manning’s n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.

5.2 1D Manning’s n

In-channel roughness generally set to 0.038 for 1d watercourse element.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The table below shows the National UK Soil type classification and the Green-Ampt Soil Type used in the TUFLOW model for this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Loamy some clayey	Slightly acid loamy and clayey soils with impeded drainage	4 - Clay Loam
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	5 – Silty Clay Loam
Loamy	Freely Draining lime-rich loamy soils	8 – Loam
Loamy	Freely Draining slightly acidy loamy soils	8 – Loam
Clayey some loamy	Lime-rich loamy and clayey soils with impeded drainage	4 – Clay Loam

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	Tuflow version 2013-12-AE-iDP-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling
6.4 Outputs	DAT – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	10 hours
7.2 Grid size	2m
7.3 Timestep	0.5 seconds for the 2D domain and 0.25 seconds for the 1D

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>7.4 Mass balance check</td><td>Peak Cumulative Mass Balance errors range between 0.33% and 2.97% for the scenarios from Q0005 and Q0100. Peak Cumulative Mass Balance errors for Q0100CC and Q1000 are 7.87% and 9.59% respectively.</td></tr>
<tr><td>7.5 Number of messages / warnings etc.</td><td>862 checks and 113 warnings related to Anglian Water sewer network, lowering of ZC points for pit channels, null shapes, pipe inverts lower than ds connecting pipe etc</td></tr>
<tr><td colspan="2">8. Sensitivity testing</td></tr>
<tr><td colspan="2">8.1 Culvert blockage</td></tr>
<tr><td colspan="2">8.2 Structural coefficients</td></tr>
<tr><td colspan="2">8.3 Roughness coefficients</td></tr>
<tr><td colspan="2">8.4 Runoff coefficients</td></tr>
<tr><td>8.5 Inflows</td><td>
<table>
<tr><th colspan="3">Change in levels (m)</th></tr>
<tr><td>Change in inflows</td><td>20%</td><td>20%</td></tr>
<tr><td>Max</td><td>0.012</td><td>0.028</td></tr>
<tr><td>Mean</td><td>-0.014</td><td>-0.003</td></tr>
<tr><td>Min</td><td>0.000</td><td>0.000</td></tr>
<tr><td>Standard Deviation</td><td>0.001</td><td>0.007</td></tr>
</table>
Sensitivity was undertaken to assess the impact of an increase and decrease of 20% in the inflows on the flood levels (m). The table above indicate the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for 1 in 100 year event; and standard deviation.</td></tr>
</table>

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 7

OAKFIELD

Modeller:	M Islam	22/03/2016
Reviewer:	M Zornitta	24/03/2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	N/A
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Model network: HS7_NorthHerts_ICM_Update_#01 (Version 30)
2. 2D Reference data	
2.1 Final DEM	The Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM was used for this model – already processed DTM data was made available in GIS under TUFLOW where topographic survey data was stamped onto.
2.2 Changes to DEM	N/A
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Anglian Water.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
3.2 Watercourse Structures	Rectangular culvert representing Queensway Bridge • Culverts under the Stevenge Road –Details has been taken from ISIS model • Culvert under railway to the north east of Brookview road – details of diameter and location taken from Network Rail data, no springing levels given so assumed based on ISIS model data (converted from RS) • Culvert under Wymondley road – details of dimension and invert levels taken from 1d ISIS model (converted from RS)

4. Hydrology

4.1 Inflow boundaries

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	29	19	14	13	9	8	5
Total rainfall (mm)	9	6	4	4	3	3	2
Storm duration (hr)	0.45						
Ippollits Brook inflow (m^3/s)	2.145 (1 in 5yr)						
Ashfield Brook inflow(m^3/s)	2.533 (1in 5yr)						

4.2 Downstream boundaries

The downstream boundaries have been defined as a normal boundary used in 2d zone. For fluvial (Ippollits Brook) downstream boundary has been set to “Outfall 2D”

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.3 Historical records of flooding	Environment Agency Recorded Flood Outlines show no recorded events in the area.
5. Materials and Soils	
5.1 2D Manning's n	The Manning's n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning's n	In-channel roughness generally set to 0.045 for 1d watercourse element.
5.3 Soil loss definition	SPR host value within the Study Area has been utilised from http://geoservergisweb2.hrwallingford.co.uk/uksd/greenfieldrunoff_js.htm The average SPR host value of 0.37 has been assigned as fixed runoff coefficients for the nonurban areas in 2d Infiltration zone in ICM.
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	Tuflow version 2013-12-AE-iDP-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
6.4 Outputs	DAT, XMDF – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	30 hours to ensure peaks of all flooding within the hotspot are reached
7.2 Grid size	Maximum triangle area is 15m^2 and minimum element area is 10m^2 defined in active 2d zone
7.3 Timestep	10 sec time step generally used except 1000yr run where time step used as 5 secs.
7.4 Mass balance check	N/A
7.5 Number of messages / warnings etc.	N/A
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 unoff coefficients	
8.5 Inflows	

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOTS 12 & 13

BALDOCK & CLOTHALL COMMON

Modeller:	C Goode	09/03/2016
Reviewer:	M Islam	09/03/2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	Hotspots 12 & 13 have been modelled together as drainage network was connecting both hotspots. The two hotspots are hydraulically linked through the surface water sewer network and as the catchments are adjacent it was suitable to join the two models together. The updated Flood Map for Surface Water (uFMfSW) DTM was used as there was no more recent LiDAR flown after the production of the uFMfSW. A 4m grid size was used in order to improve instabilities.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot12_13_NorthHerts_~s1~_~e1~_~e2~_004.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 2_09hr: 2.09hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC40; Q0100; Q0075; Q0030; Q0020; Q0005. Model results, logs, checks labelled using above convention, eg. “Hotspot12_13_NorthHerts_Baseline_2_09hr_Q0020_004”

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency’s updated Flood Map for Surface Water (uFMfSW) DTM was used for this model – tiles tl21ne, tl21nw, tl22se, tl22sw. The model has commenced immediately downstream of the A505 and it has been assumed that any exceedance flood waters from the highway drainage and the chalk catchment are restricted to a 300mm pipe, which for the purposes of this hotspot model will initially be run full bore.
2.2 Changes to DEM	Surveyed levels were used to change the DTM in levels around the road culvert to the southeast of Clothall Common due to poor DTM data in this region. A zline was used from the existing road to the west along the path of the track to tie in with the surveyed levels at the culvert. A Z line gully was also created using low points of swale survey flowing north from the culvert. • Road_Culvert_TIN.asc • 2d_zsh_track_Hotspot12_13_03_L.shp | 2d_zsh_track_Hotspot12_13_03_P.shp • 2d_zln_gully_Hotspot12_13_01_L.shp | 2d_zln_gully_Hotspot12_13_01_P.shp Survey data was used to lower cells through railway underpass in Baldock with additional flow constriction layer to represent the culvert geometry. 2d z shape used to block “punched through” area of railway at location of culvert east of Clothall Common. • 2d_zln_underpass_Hotspot12_13_01_L.shp | 2d_zln_underpass_Hotspot12_13_01_P.shp • 2d_fcsh_rail_underpass_02_L.shp • 2d_zsh_railway_Hotspot12_13_NorthHerts_01_R.shp | 2d_zsh_railway_Hotspot12_13_NorthHerts_01_P.shp • 2d_z_banks_Hotspot12_13_NorthHerts_01_L.shp | 2d_z_banks_Hotspot12_13_NorthHerts_01_P.shp
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Anglian Water.

Surface Water Network Layers:

- 1d_nwke_AW_SW_Sewer_Hotspot12_13_NorthHerts_01_L.shp
- The pitchannels layer: 1d_nwk_AW_SW_MH_Pit_Hotspot12_13_NorthHerts_03_P.shp

Any changes to the 1d nwk have been included into the ‘Assumption’ column in the layers above.

3.2 Watercourse Structures

A short section of 1d watercourse represented within the model at the downstream end, north of the railway.

Cross section data taken from topographical survey defined shape of channel at one location, this was replicated and levels were lowered for the downstream section based on levels at the DTM in these locations.

2No. 1D culverts inserted to the model.

- Culvert under railway to the east of Clothall Common – details of diameter and location taken from Network Rail Data, no invert levels given so assumed as ground level either side. 1d_nwke_rail_Culvert_Hotspot12_13_NorthHerts_01_L.shp
- Culvert under track to southeast of Clothall Common – details of dimension and invert levels taken from topographical survey. 1d_nwke_road_Culvert_Hotspot12_13_NorthHerts_01_L.shp

4. Hydrology

4.1 Inflow boundaries

AEP	**20.0%**	**5.0%**	**3.3%**	**1.3%**	**1.0%**	**1%+40%**	**0.1%**
Peak rainfall intensity (mm/hr)	33	51	58	76	83	116	167
Total rainfall (mm)	21	33	38	50	54	76	109
Storm duration (hr)	2.09						
Inflow – Rail	0.068						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	<table><tr><td>North culvert (m^3/s)</td><td></td></tr><tr><td>Inflow A5 South Culvert (m^3/s)</td><td>0.060</td></tr></table> Inflow to the south of the A5 is based on a 300mm pipe with a 1:250 gradient.
4.2 Downstream boundaries	The downstream boundaries have been defined as: • A normal slope boundary based on the overall slope of the catchment; • 1d downstream boundary QH curve generated from channel geometry, as there was no discharge to existing 1d network to interrogate levels from.
4.3 Historical records of flooding	Environment Agency Recorded Flood Outlines show no recorded events in the area. Local knowledge refers to flooding occurrences in the Clothall Common area in 2009 and 2014.
5. Materials and Soils	
5.1 2D Manning's n	The Manning's n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning's n	In-channel roughness set to 0.04 for 1d watercourse element
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The table below shows the National UK Soil type classification and all the Green-Ampt Soil Type used in the TUFLOW model for

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Loamy	Shallow lime-rich soils over chalk or limestone	8 – Loam
Loamy	Loamy soils with naturally high groundwater	8 – Loam
Loamy	Freely Draining lime-rich loamy soils	8 – Loam
Loamy some Clayey	Slightly acid loamy and clayey soils with impeded drainage	4 – Clay Loam
Clayey some loamy	Lime-rich loamy and clayey soils with impeded drainage	4 – Clay Loam

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.4 Changes to coefficients from normal	No

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
6. Software	
6.1 Version	Tuflow version 2013-12-AE-iDP-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling
6.4 Outputs	DAT – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	10 hours
7.2 Grid size	4 m, smaller grid size produced prohibitively long model runs due to catchment size
7.3 Timestep	2 second timestep used for 2D domain with 1 second timestep in 1D.
7.4 Mass balance check	Peak Cumulative Mass Balance errors in different event scenarios range between 0.61% and 0.78 %

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>7.5 Number of messages / warnings etc.</td><td>128 warnings and 860 checks prior to simulation relating to surface water sewer network data. Manhole inverts below upstream channel, lowering of ZC points for 2d connection etc. This is as a result of the data received from Anglian Water. 9 warnings during simulation relating to a very small area of instability causing a negative depth, but does not affect the overall model results.</td></tr>
<tr><td colspan="2">8. Sensitivity testing</td></tr>
<tr><td colspan="2">8.1 Culvert blockage</td></tr>
<tr><td colspan="2">8.2 Structural coefficients</td></tr>
<tr><td>8.3 Roughness coefficients</td><td>
<table>
<tr><th colspan="3">Change in levels (m)</th></tr>
<tr><td>Change in inflows on A5 south</td><td>50%</td><td>75%</td></tr>
<tr><td>Max</td><td>0.005</td><td>0.004</td></tr>
<tr><td>Mean</td><td>0.000</td><td>0.000</td></tr>
<tr><td>Min</td><td>-0.021</td><td>-0.019</td></tr>
<tr><td>Standard Deviation</td><td>0.000</td><td>0.000</td></tr>
</table>

Sensitivity was undertaken to assess the impact on levels (m) of blocking the culvert to crossing the A505 in the vicinity of Wallington Road in Baldock. This was undertaken by reducing the inflows applied on this culvert in the baseline scenario by 50% and 75%. The table above indicates the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for the 1 in 100 year event, and the standard deviation.</td></tr>
<tr><td colspan="2">8.4 Runoff coefficients</td></tr>
<tr><td colspan="2">8.5 Inflows</td></tr>
</table>

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 17

KNEBWORTH

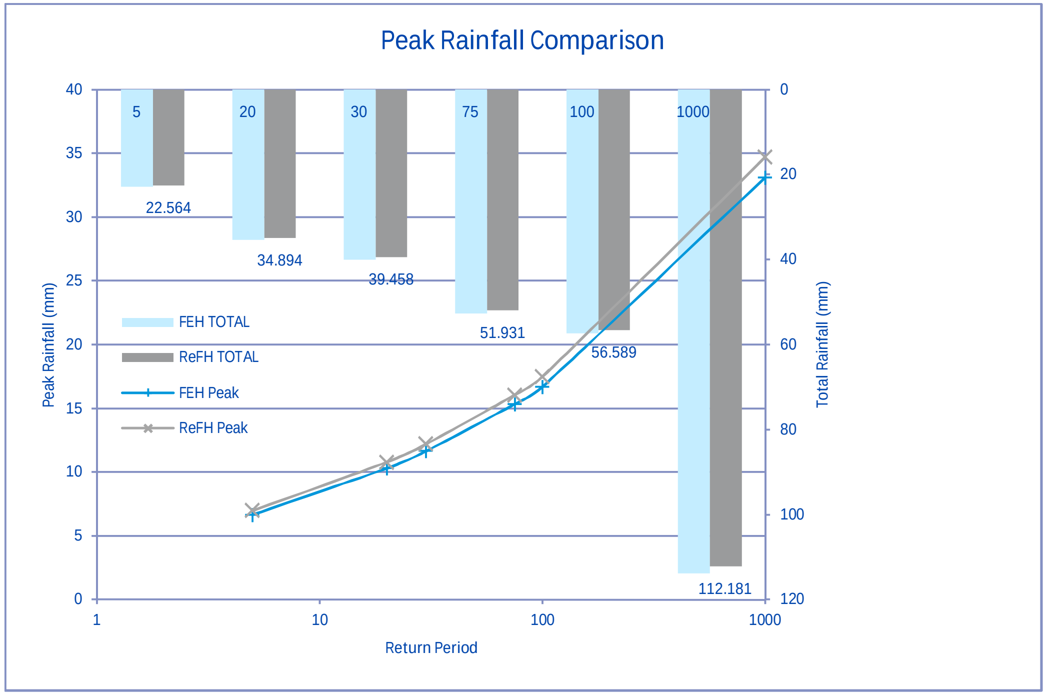
Modeller:	C Goode	29/02/2016
Reviewer:	S Brown	03/03/2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The DTM used to produce the updated Flood Map for Surface Water (uFMfSW) DTM was used the whole catchment, as there was no most recent LiDAR available for the catchment. A grid size of 2.5 m was used, as model run times were prohibitively long when using smaller grid sizes.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as Hotspot17_NorthHerts_~s1~_~e1~_~e2~_v01.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 2_42hr: 2.42hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC40; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. Model results, logs, checks labelled using above convention, eg. “Hotspot17_NorthHerts_Baseline_2_42hr_Q100_v01”

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency’s updated Flood Map for Surface Water (uFMfSW) DTM was used for this model – tiles tl21ne, tl21nw, tl22se, tl22sw.
2.2 Changes to DEM	Surveyed levels were used to create Triangular Irregular Networks (TINS) in specific areas of the model. The Orchard Way footpath was reinforced with a z-line to ensure the levels are picked up. The A1 (M) was originally “cut through” in the DTM to allow flows. This was blocked off with a variable z-shape and the flows are via the 1D culvert No 1D elements included in the model as no surface water sewer network present. However, 2 culverts have been included in the model, under the A1(M) and Railway. See section 2 for details.
3. 1D Reference data	
3.1 Sewer network	No sewer network represented within this hotspot model, as information provided by Thames Water shows no surface water sewers in the area. However two 1D culverts have been inserted to the model: • Culvert under A1(M) – details of diameter and d/s invert level taken from survey, no u/s invert level given so assumed as 1m above d/s with DTM lowering to allow flow. 1d_nwke_Hotspot17_NorthHerts_A1Mcul_01_L.shp • Culvert under Railway – details of dimension and construction material included in Network Rail information. No exact location of start or end of culvert so positions assumed from centre point given and inverts set at existing ground level from DTM. 1d_nwke_Hotspot17_NorthHerts_RailCul_01_L.shp
3.2 Watercourse Structures	No 1d watercourse represented within the model.
4. Hydrology	
4.1 Inflow boundaries	The direct rainfall model has used the Design Rainfall from the ISIS ReFH module, based on the catchment descriptors from 525600, 220300

MODEL ELEMENT	ACTION TAKEN DURING MODELLING

The ReFH1 model has been used, due to concerns regarding the accuracy of the ReFH2, and values of URBEXT2000 have been considered in place of URBEXT1990. This led to an increase of URBEXT to over 0.125, however comparison of FEH 50% Summer Areal Rainfall and ReFH Summer Design Rainfall was done and ReFH was used as it is slightly more conservative (see below).



The predicted catchment from FEH has been compared to the LiDAR data and found to be generally accurate. The model catchment and subsequent model extents and rainfall area were refined using Global Mappers “Watershed Analysis” tool.

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity(mm/hr)	46	49	52	69	75	98	149
Total rainfall (mm)	35	37	40	52	57	74	113
Storm duration (hr)	2.42						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.2 Downstream boundaries	The downstream boundaries have been defined as a 2D HQ normal slope boundary based on the overall slope of the catchment; No direct watercourse downstream of model extents to extract 1d water levels from to use ass downstream boundary, surface water free flows out along floodplain.
4.3 Historical records of flooding	In February 2014 18 properties had internal flooding, with a further two properties suffering external flooding, all in the London Road area. This was as a result of heavy rainfall over an extended period of time saturating the surrounding catchment prior to the event. Other factors identified include possible overspill of the A1(M) attenuation storage pond and the existing highway drainage being unable to cope with the volume of flood water.
5. Materials and Soils	
5.1 2D Manning’s n	The Manning’s n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.
5.2 1D Manning’s n	No channel manning’s values needed as no 1d channel have been modelled.
5.3 Soil loss definition	The table below shows the National UK Soil type classification and the Green-Ampt Soil Type used in the TUFLOW model.

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td></td><td><table>
<tr><th>National UK Soil Maps Classification</th><th>Description</th><th>Green-Ampt Soil Type</th></tr>
<tr><td>Loamy</td><td>Freely draining slightly acid loamy soils</td><td>8 – Loam</td></tr>
<tr><td>Loamy some Clayey</td><td>Slightly acid loamy and clayey soils with impeded drainage</td><td>4 – Clay Loam</td></tr>
</table></td></tr>
<tr><td>5.4 Changes to coefficients from normal</td><td>No</td></tr>
<tr><td colspan="2">6. Software</td></tr>
<tr><td>6.1 Version</td><td>Tuflow version 2013-12-AE-iDP-W64</td></tr>
<tr><td>6.2 Precision</td><td>Double precision used for direct rainfall modelling</td></tr>
<tr><td>6.3 Defaults</td><td>Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling</td></tr>
<tr><td>6.4 Outputs</td><td>DAT – d v q h ZUK0, MB1, MB2</td></tr>
<tr><td>6.5 Hazard</td><td>UK Hazard Land Use - Conservative</td></tr>
<tr><td colspan="2">7. Modelling Log</td></tr>
</table>

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>7.1 Model duration</td><td>4 hours. Model initially tested with 6 hour duration, and was cut back to 4 hours after interrogating the Times.dat results file which showed peaks were reached between 1.5-3 hours.</td></tr>
<tr><td>7.2 Grid size</td><td>2.5m grid size used, as model run times were prohibitively long when using smaller grid sizes.</td></tr>
<tr><td>7.3 Timestep</td><td>1.25 second timestep used (1/2 model grid size in m)</td></tr>
<tr><td>7.4 Mass balance check</td><td>Final Cumulative Mass Balance errors are between -0.34% and 0.52% for all models.</td></tr>
<tr><td>7.5 Number of messages / warnings etc.</td><td>16 warnings/checks relating to geometry changes within the model, sx zc lowering etc</td></tr>
<tr><td colspan="2">8. Sensitivity testing</td></tr>
<tr><td>8.1 Culvert blockage</td><td></td></tr>
<tr><td>8.2 Structural coefficients</td><td></td></tr>
<tr><td>8.3 Roughness coefficients and soil</td><td>
<table>
<tr><th colspan="4">Change in levels</th></tr>
<tr><th>Change in roughness</th><th>-20%</th><th>+20%</th><th>Soil</th></tr>
<tr><td>Max</td><td>0.022</td><td>0.032</td><td>0.014</td></tr>
<tr><td>Min</td><td>-0.043</td><td>-0.015</td><td>-2.499</td></tr>
<tr><td>Mean</td><td>-0.0014</td><td>0.0013</td><td>-0.0272</td></tr>
<tr><td>Standard Deviation</td><td>0.0027</td><td>0.0024</td><td>0.1342</td></tr>
</table>
</td></tr>
</table>

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	Sensitivity was undertaken to assess the impact on flood levels (m) of changing the soil type from Clay Loam and Loam to Loamy Sand in the whole area. Sensitivity was also undertaken to assess the impact of an increase and decrease of 20% in manning coefficients on the flood levels (m) for the Clay Loam soil scenario. The table above indicates the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for the 1 in 100 year event, and the standard deviation.
8.4 Runoff coefficients	
8.5 Inflows	

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 30

CAMBRIDGE ROAD

Modeller:	L Ramirez	28-07-2016
Reviewer:	T. Ashby	29-07-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	Anglian Water data shows a surface water sewer running down Cambridge Road and ending around The Anchor Inn, with no information on connections. It has been assumed that the surface water drainage connects to the culverted watercourse via a 450mm surface water culvert and drain to the River Purwell.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot30_NorthHerts_~s1~_~e1~_~e2~_v18 ~.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 1.5hr: 1.5hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. Model results, logs, checks labelled using above convention, eg. “Hotspot30_NorthHerts_Baseline_2.2hr_Q0100_v18”

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	Elevations based on the Environment Agency's updated Flood Map for Surface Water (uFMfSW) DTM was used (tiles l12ne, tl13se, tl22nw, tl23sw)
2.2 Changes to DEM	Surveyed levels were used to create Triangular Irregular Networks (TINS) in specific areas of Cambridge Road. • 2d_zsh_road_levels_Hotspot30_NorthHerts_v18_R.shp • 2d_zsh_road_levels_Hotspot30_NorthHerts_v18_L.shp • 2d_zsh_road_levels_Hotspot30_NorthHerts_v18_P.shp Added z-shape to represent a wall in Cambridge Road based on topographical survey. • 2d_zsh_wall_Hotspot30_NorthHerts_v18_L.shp • 2d_zsh_wall_Hotspot30_NorthHerts_v18_P.shp Added z-shape to include property threshold levels based on topographical survey. • 2d_z_property thresholds_Hotspot30_NorthHerts_v15_R.shp
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Anglian Water. Surface Water Network Layers: • 1d_nwk_AW_pipes_Hotspot30_NorthHerts_v17_L.shp • 1d_nwk_pitchannels_Hotspot30_NorthHerts_v17_P.shp Any changes to the 1d nwk have been included into the 'Assumption' column in the layers above.

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>3.2 Watercourse Structures</td><td>No 1d watercourse represented within the model.</td></tr>
<tr><td colspan="2">4. Hydrology</td></tr>
<tr><td>4.1 Inflow boundaries</td><td>The model uses direct rainfall over the town of Hitchin based on catchment descriptors from a representative catchment at 519800, 230050. The design rainfall was taken from the ISIS FEH module as the catchment for the direct rainfall is highly urbanised.
<table>
<tr><th>AEP</th><th>20.0%</th><th>5.0%</th><th>3.3%</th><th>1.3%</th><th>1.0%</th><th>1%+40%</th><th>0.1%</th></tr>
<tr><td>Peak rainfall intensity (mm/hr)</td><td>46</td><td>73</td><td>83</td><td>111</td><td>121</td><td>169</td><td>247</td></tr>
<tr><td>Total rainfall (mm)</td><td>20</td><td>32</td><td>36</td><td>48</td><td>52</td><td>73</td><td>107</td></tr>
<tr><td>Storm duration (hr)</td><td colspan="7">1.5hr</td></tr>
</table>
</td></tr>
<tr><td>4.2 Downstream boundaries</td><td>The downstream boundaries have been defined as the 20% AEP fluvial boundary; based on the level outputs for the River Purwell, for 1 in 5 year event provided by the Environment Agency from their Ivel model on 1st March 2016.</td></tr>
<tr><td>4.3 Historical records of flooding</td><td>Environment Agency Recorded Flood Outlines show the downstream area of the hotspot around Green Lane as affected by flooding in October 1993.</td></tr>
<tr><td colspan="2">5. Materials and Soils</td></tr>
<tr><td>5.1 2D Manning’s n</td><td>The Manning’s n values used for the floodplain areas (2D domain) are specified in the modelling methodology report.</td></tr>
</table>

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>5.2 1D Manning’s n</td><td>No channel manning’s values needed as no 1d channel have been modelled.</td></tr>
<tr><td>5.3 Soil loss definition</td><td>The soil types in the study area have been defined based on National UK Soils Maps.
The table below shows the National UK Soil type classification and all the Green-Ampt Soil Type used in the TUFLOW model for this hotspot.
<table>
<tr><th>National UK Soil Maps Classification</th><th>Description</th><th>Green-Ampt Soil Type</th></tr>
<tr><td>Loamy</td><td>Freely draining lime-rich loamy soils</td><td>8 – Loam</td></tr>
<tr><td>Clayey, some loamy</td><td>Lime-rich loamy and clayey soils with impeded drainage</td><td>1 – Clay</td></tr>
</table></td></tr>
<tr><td>5.4 Changes to coefficients from normal</td><td>No</td></tr>
<tr><td colspan="2">6. Software</td></tr>
<tr><td>6.1 Version</td><td>Tuflow version 2013-12-AE-iDP-W64</td></tr>
<tr><td>6.2 Precision</td><td>Double precision used for direct rainfall modelling</td></tr>
</table>

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
6.3 Defaults	Cell wet/dry depth changed to 0.0002 from default of 0.002 for direct rainfall modelling
6.4 Outputs	DAT – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	3 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) in different event scenarios range between -0.75% and -0.22%
7.5 Number of messages / warnings etc.	28 warnings/ 419 checks relating mostly to Zpts lowered by SX and structure invert levels. These have been checked and are considered appropriated.
8. Sensitivity testing	
8.1 Culvert blockage	

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
8.2 Structural coefficients	
8.3 Roughness coefficients	See table and text below
8.4 Runoff coefficients	
8.5 Inflows	

Change in levels (m)		
Change in roughness	-20%	+20%
Max	0.080	0.063
Mean	-0.001	0.001
Min	-0.060	-0.057
Standard Deviation	0.004	0.003

Sensitivity was undertaken to assess the impact of an increase and decrease of 20% in manning coefficients on the flood levels (m). The table above indicates the maximum, minimum and mean difference in levels between baseline and sensitivity scenarios for the 1 in 100 year event, and the standard deviation.

The model review is complete and this model meets WSP|Parsons Brinckerhoff requirements and it is suitable for mapping and release.	✓