Appendix C

MODELLING METHODOLOGY REPORT AND MODEL REPORTS

70009115-50604-TN01

MODELLING METHODOLOGY TECHNICAL NOTE

EAST HERTFORDSHIRE SWMP

Public:

MODELLING METHODOLOGY TECHNICAL NOTE

EAST HERTFORDSHIRE BOROUGH SWMP

Hertfordshire County Council

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APPENDICES

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 East 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 by the project stakeholders 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:

- Buntingford (site 1);
- Bengeo (site 40);
- Hadham Road, Bishop's Stortford (site 43);
- Benhook's Avenue, Bishop's Stortford (site 44);
- Potter Street / South Street, Bishop's Stortford (site 60).

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 3.5.7.

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, East Hertfordshire Council and Anglian Water/Thames Water 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 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 (TUFLOW_2016-03-AA).

2.2.1 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.

2.2.2 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 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).

2.2.3 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. 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.

2.2.4 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.

[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)

2.2.5 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

2.2.6 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.

2.2.7 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

2.2.8 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.

2.2.9 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:

2.2.10 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.

2.2.11 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.

2.2.12 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.

2.2.13 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.

2.2.14 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.

2.2.15 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].

2.2.16 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.

2.2.17 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.

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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)

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

2.2.18 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.

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

2.2.20 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.

2.2.21 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), 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 manholes 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) where water can flow both ways (i.e. in to and out of the manholes/pipes at ground level) 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 mechanisms/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.

2.2.22 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 was then checked and adjusted if necessary to ensure pipe fall gradients were suitable and that pipes were 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 was then checked

	and adjusted if necessary to ensure pipe fall gradients were suitable and that pipes were not above ground. Presence of flap valves have been assumed in the pipes discharging into a watercourse.

2.2.23 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.

2.2.24 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.

2.2.25 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

2.2.26 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.

2.2.27 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.

2.2.28 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.

2.2.29 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

2.2.30 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 2.2.17.

GENERIC DATA REQUIREMENTS

2.2.31 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

2.2.32 WSP 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:

- Stakeholder 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

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

2.2.34 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).

HYDRAULIC MODELLING SCENARIOS

2.2.35 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

2.2.36 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.

2.2.37 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.

[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)

2.2.38 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.

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

HYDRAULIC MODEL REVIEW AND ACCEPTANCE

2.2.40 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 2.2.32.

2.2.41 Each hydraulic model will be subject to an independent internal review at specific points in the modelling process by a member of WSPs hydraulic modelling team who will not be involved with the development of the model.

2.2.42 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 | Parsons Brinckerhoff; 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.

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 BUNTINGFORD (SITE 1)

FLOOD RISK OVERVIEW

3.2.1 A combination of river levels, flooding of the River Rib and flood locking of the surface water sewers influences heavily the surface water flooding of the area.

3.2.2 The surface water is largely restricted to the highway network and flows East along Baldock Road and also Monk's Walk which is a residential area onto the High Street. Monk's Walk and the High Street are known to be historic flooding sites included reported flooding in July 2015.

3.2.3 The Environment Agency Flood Zone 2 is based on historic flooding, however the 0.1% AEP (1 in 1,000 year) fluvial flood mapped extent of the Rive Rib by Mott MacDonald is more closely aligned to the channel. As a result, some places of the Food Zone 2 extent, the ground level is 2-3m above the river channel.

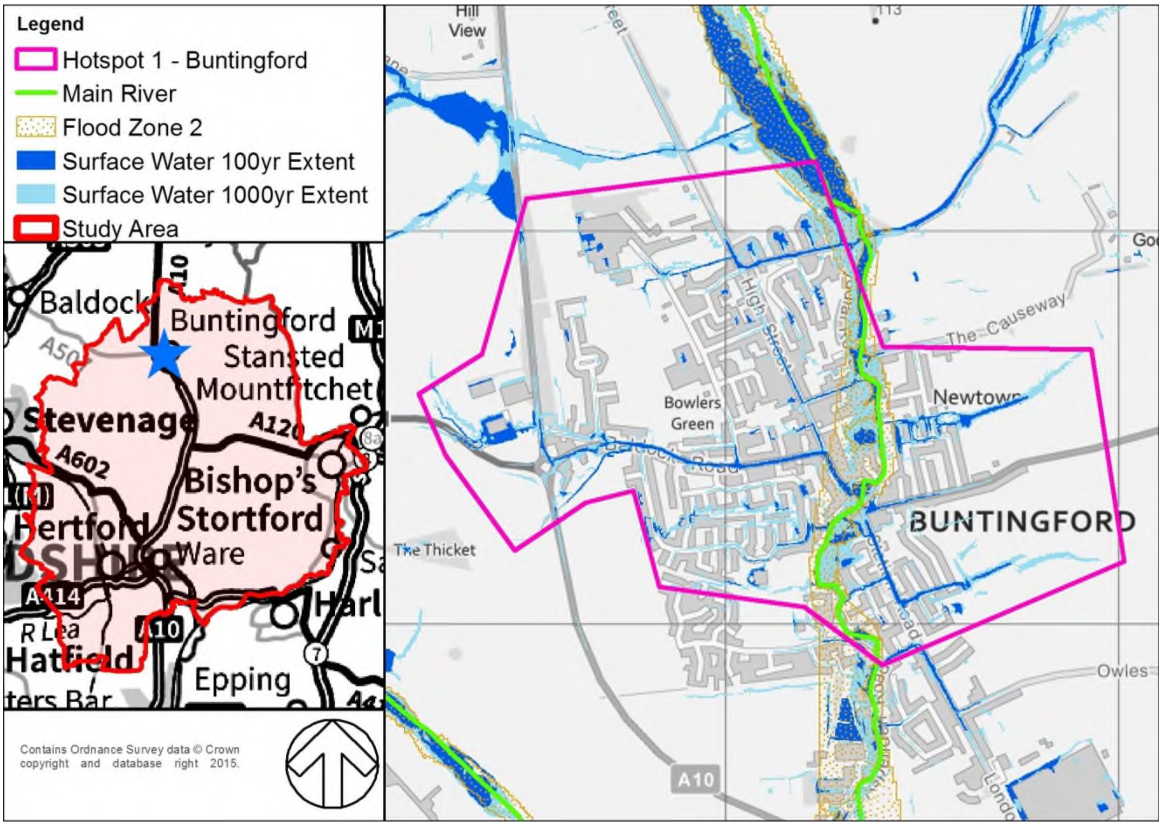

Figure 1 : Buntingford - Site 1

AVAILABLE INFORMATION AND DATA GAPS

3.2.4 The model will cover the existing urban area, the proposed development areas are excluded as these are outside of the main flow paths and will be required to attenuate flows to the greenfield rates as part of the planning requirements.

3.2.5 LiDAR is available for the whole of the study areas and will be preferentially used.

3.2.6 The water company sewer asset data is available for the catchment and held by WSP | Parsons Brinckerhoff.

PROPOSED MODELLING APPROACH

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

3.2.8 This hotspot will be modelled as two different models, one covering the area to the west of River Rib and the other covering the area east of the river. These models will be developed in ESTRY-TUFLOW with a direct rainfall approach utilising a LiDAR based DTM for the whole study area. The downstream boundary conditions of these models will be based on the 20 % AEP fluvial levels for the River Rib, extracted from the model provided by the Environment Agency.

3.2.9 A model for each bank of the River Rib was deemed to be the most suitable approach for this hotspot, given the current mapping shows that the main surface water risks are associated with relatively constrained flow paths as opposed to significant fluvial flood extents.

3.3 BENGEO (SITE 40)

FLOOD RISK OVERVIEW

3.3.1 There are two flow paths within this site, one from the area around Church Road flowing South down Byde Street towards Port Vale and the River Bean, the other from Bengeo Street flowing east through residential areas towards Globe Court and the River Rib.

3.3.2 Flooding was reported in August – September 2015 at Globe Court, Port Vale with water flowing from Byde Street.

3.3.3 Globe Court has reported flooding historically, some of which can be attributed to tree roots blocking pipes, foul flooding has also occurred. Surface water ponding has also affected properties by flowing off into the properties.

3.3.4 According to residents of the areas concerned, short duration, high intensity rainfall events were found to be the cause of flooding in the area of Globe Court, they reported problems with gullies and also previous sewer blockages which have been cleared by Thames Water.

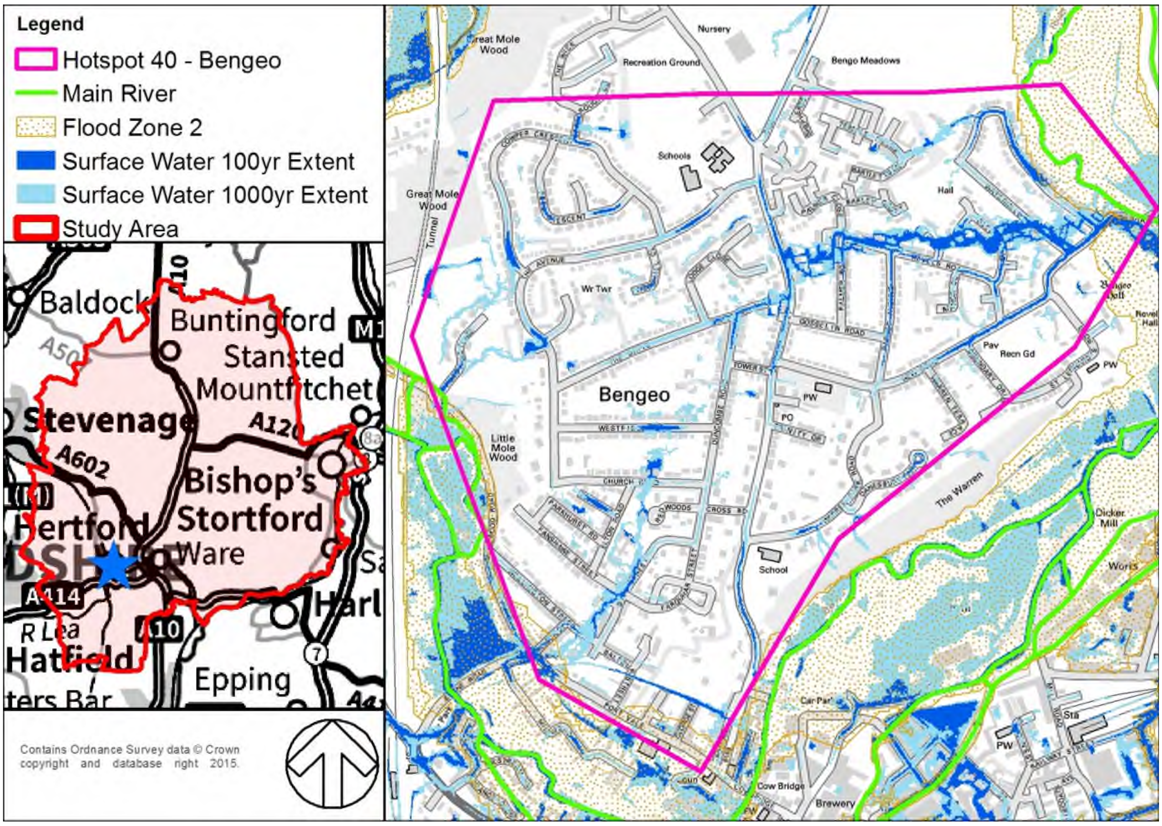

Figure 2 : Bengeo - Site 40

AVAILABLE INFORMATION AND DATA GAPS

3.3.5 The model will cover the existing and recently developed areas to determine whether there has been any change in risk to Bengeo Street as well as the properties downstream (to the east). The flow path to the south is to be excluded.

3.3.6 The uFMfSW DTM is available for the whole of the study areas and will be preferentially used.

3.3.7 The water company sewer asset data is available for the catchment and held by WSP | Parsons Brinckerhoff.

PROPOSED MODELLING APPROACH

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

3.3.9 The model will be focused on Globe Court on Bengeo Street and the impact of a new development on this area.

3.3.10 The new development will be assessed by a hydraulic model of the area and assessing the following scenarios:

- Scenario 1: Mimic of on-site soakaways failure

  This was modelled by including the development as an impermeable area. A new material layer was used in the model called “2d_mat_Hotspot40_EastHerts_NewDev_v11_R.shp” and this was assigned an imperviousness of 0.9 (which is the same as that applied to roads within the model).

- Scenario 2: Mimic of on-site soakaways partial failure

  This was modelled by applying less rainfall over the development area. The event applied over the development area was the difference between the 1:100 year and the 1:30 year event.

- Scenario 3: Mimic of on-site soakaways fully functional

  This was modelled by applying no rainfall over the development area.

3.4 HADHAM ROAD, BISHOP'S STORTFORD (SITE 43)

FLOOD RISK OVERVIEW

3.4.1 The flow path through this hotspot travels to the west through properties before reaching Matching Lane where it flows through further residential areas before reaching Hadham Road (A1250) where it then appears to be well contained on the highway.

3.4.2 To the east of Hadham Road, near the river Stort, finished floor levels appear to be below ground level from desk analysis.

3.4.3 The mapped surface water flow paths indicate lots of properties and obstructions through which the surface water flows.

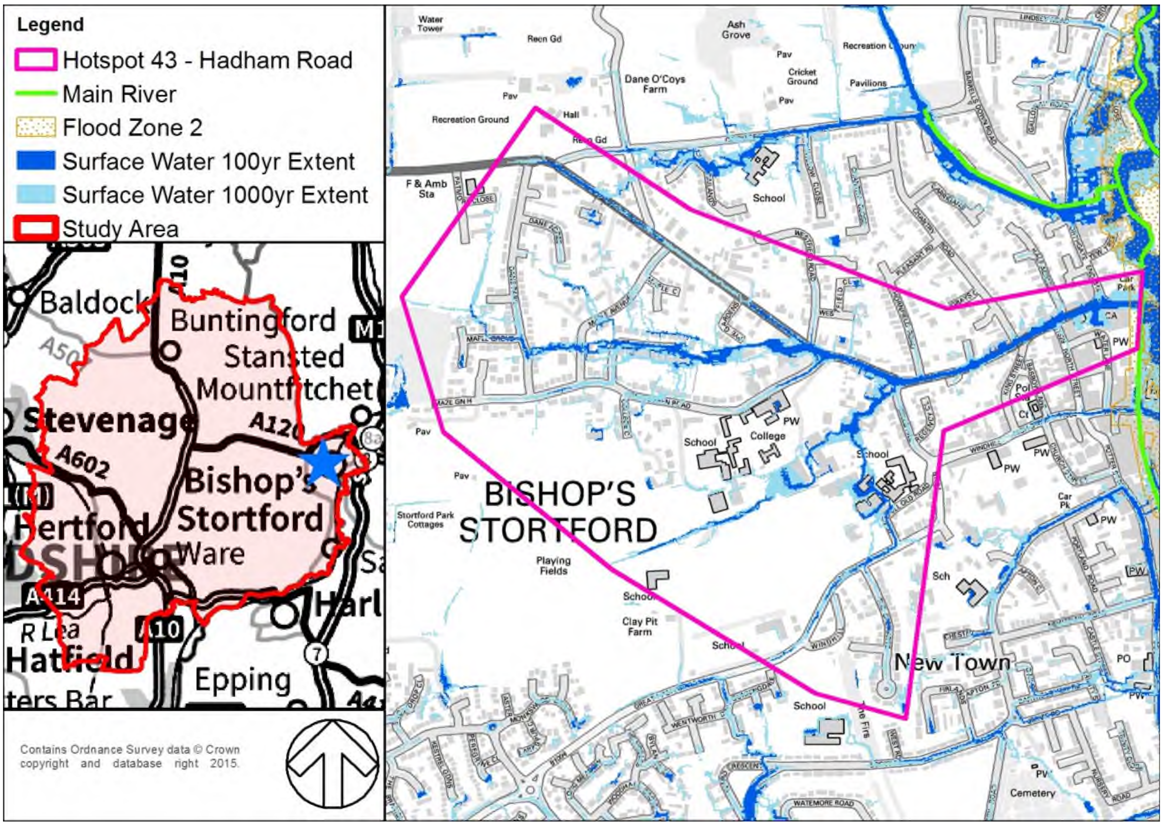

Figure 3 : Hadham Road - Site 43

AVAILABLE INFORMATION AND DATA GAPS

3.4.4 The model will assess the surface water flow path which begins in the residential area to the west, surface water flows through properties before reaching Matching Lane where it flows through further residential areas before reaching Hadham Road (A1250).

3.4.5 A LiDAR DTM is available for the whole of the study areas and will be preferentially used.

3.4.6 The water company sewer asset data is available for the catchment and held by WSP | Parsons Brinckerhoff.

PROPOSED MODELLING APPROACH

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

3.4.8 This hotspot will be modelled with Hotspot 44 (Benhook's Avenue) as they are both located within the same catchment.

3.5 BENHOOK'S AVENUE, BISHOP'S STORTFORD (SITE 44) AND POTTER STREET / SOUTH STREET, BISHOP'S STORTFORD (SITE 60)

FLOOD RISK OVERVIEW

3.5.1 Surface Water flows east along Benhook's Avenue and past the cemetery, in some locations, the flow is confined to the highway. However, in other locations, the surface water flows through residential areas as can be seen in Figure 4.

3.5.2 Potter Street / South Street (Site 60) to the north produces some inflows into Benhook's Avenue.

3.5.3 Flooding was reported in August 2015 at Wharf Road at the downstream (easterly) extent of site 44. This follows the Risk of Flooding from Surface Water flow path as it flows towards Flood Zone 2.

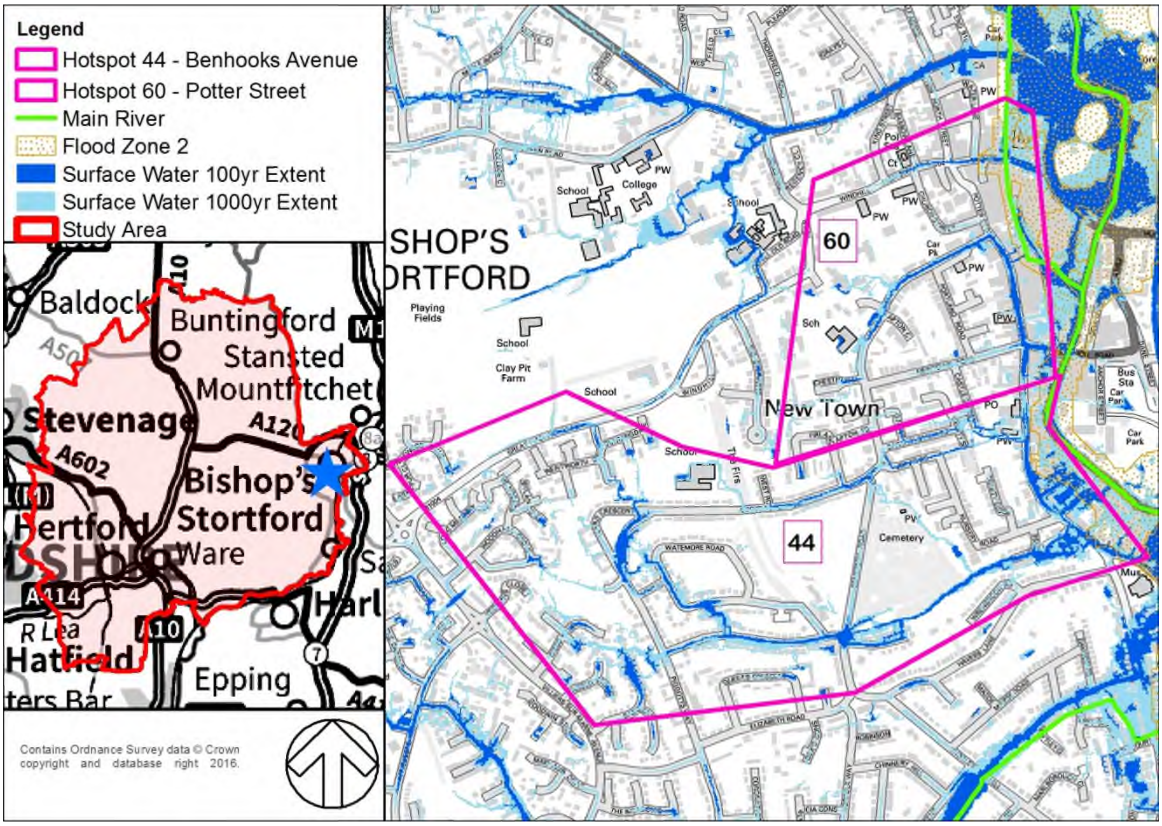

Figure 4 : Benhook's Avenue - Site 44

AVAILABLE INFORMATION AND DATA GAPS

3.5.4 The model will assess the surface water flow path which is shown to be along Benhook's Avenue and past the cemetery towards the River Stort. In some locations, the flow is confined to the highway and in other locations, the surface water flows through residential areas.

3.5.5 A LiDAR DTM is available for the whole of the study areas and will be preferentially used.

3.5.6 The water company sewer asset data is available for the catchment and held by WSP | Parsons Brinckerhoff.

PROPOSED MODELLING APPROACH

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

3.5.8 This hotspot will be modelled with Hotspot 44 (Benhook's Avenue) as they are both located within the same catchment.

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/DTM	Sewer Network data	Railway Data	Existing hydraulic models availability
Buntingford (Site 1)	100%	Available	No railway crossing	Environment Agency model held by WSP | Parsons Brinckerhoff
Bengeo (Site 40)	100%	Available		
Hadham Road, Bishop's Stortford (site 43)	100%	Available	No railway crossing	
Benhook's Avenue (Site 44) and Potter Street/South Street (Site 60)	100%	Available	No railway crossing	

Key

Colour	Meaning
	Most/all available
	Some available
	Little/none available
	Not required
	To be confirmed

Appendix I

TOPOGRAPHICAL / CHANNEL SURVEY SPECIFICATION

SURVEY BRIEF COVERSHEET

TO	Prospective Surveyors	
FROM	Lorena Ramirez	
COPIES TO	Project File	
DATE	22/12/2015	
REF	70009115 – East Hertfordshire and Broxbourne SWMP	

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

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 East Hertfordshire District and Broxbourne Borough as part of their programme of undertaking such studies across the county.

To enable hydraulic modelling to be undertaken at the key locations across East Hertfordshire District and Broxbourne Borough, watercourse survey and road level survey is required at a number of locations as detailed in the accompanying figures.

There is potential for minor variations in this brief as the Environment Agency are currently providing copies of their hydraulic models, of which some modification is expected to be required.

Survey is required at the following locations:

- Rye House, North Hoddesdon (Site 9);
- Cheshunt (Site 52);
- Rosedale North and Rosedale South, Flamstead End (Sites 62 and 63);
- Cozens Lane East, Wormley (Site 55);
- Buntingford (Site 1);
- Hadham Road, Benhook's Avenue and Potter Street / South Street, Bishop's Stortford (Sites 43, 44 and 60);
- Raynham Road, Bishop's Stortford (Site 47);
- Bengeo, Hertford (Site 40).

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.

Key - Legend

Levels will be needed for some roads, the kerb levels are represented in the figures below as grey thick lines with blue outline, and the central line of road with a grey dotted line. The properties where threshold levels are required are represented as red polygons. River banks are represented as pink polylines.

The locations of cross sections in ditches are indicated by yellow points. In some instances OS mapping and Water Company records provide contradictory information as to the presence/absence of a watercourse, in these instances the potential location of the ditch is represented by a blue dotted line. The locations of pipes to be surveyed are indicated with red arrows whereas manholes are indicated with purple dots; note that this is based on Thames Water information not a site inspection. The approximate NGR of these is provided.

Rye House, North Hoddesdon (Site 9)

The approximate grid reference for the central area is NGR 537300, 210000.

- Road levels of Bridle Way (South), Danemead, and Glenster Close, including kerb levels and levels of the central line – as indicated in Figure 1 – in order to confirm the flowpaths. These should include the levels of the kerbs around the roundabout and underneath the roundabout located in Bridle Way, and kerb levels to the south of Beyers Gardens.
- Kerb levels to the east of Ware Road (A1170), as indicated in Figure 1, Figure 2 and Figure 3.
- Threshold levels of the properties indicated in Figure 1.

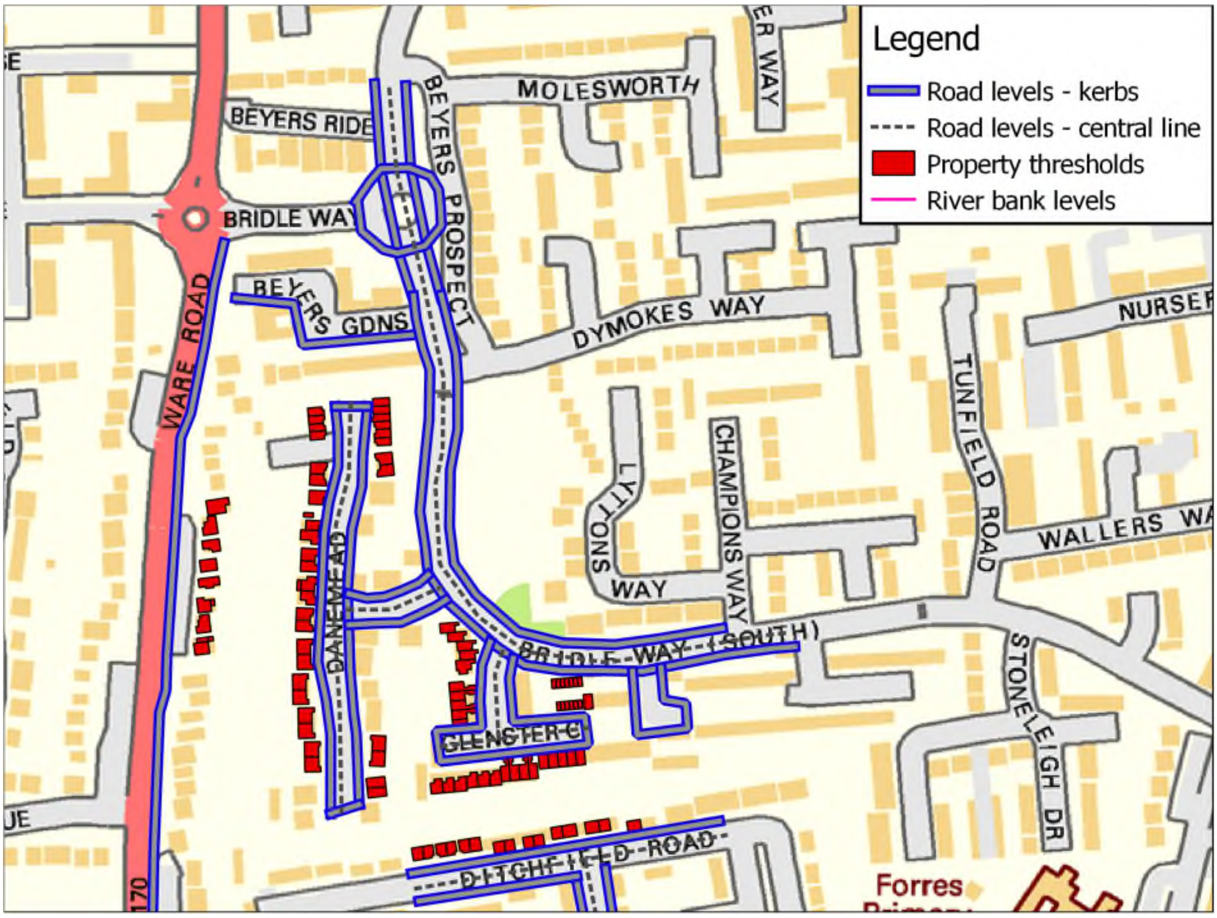

Figure 1

- Road levels of Ditchfield Road, Tregelles Road, Dorchester Avenue, Tovey Avenue and Thurgood Road, including kerb levels and levels of the central line – as indicated in Figure 2– in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 2.

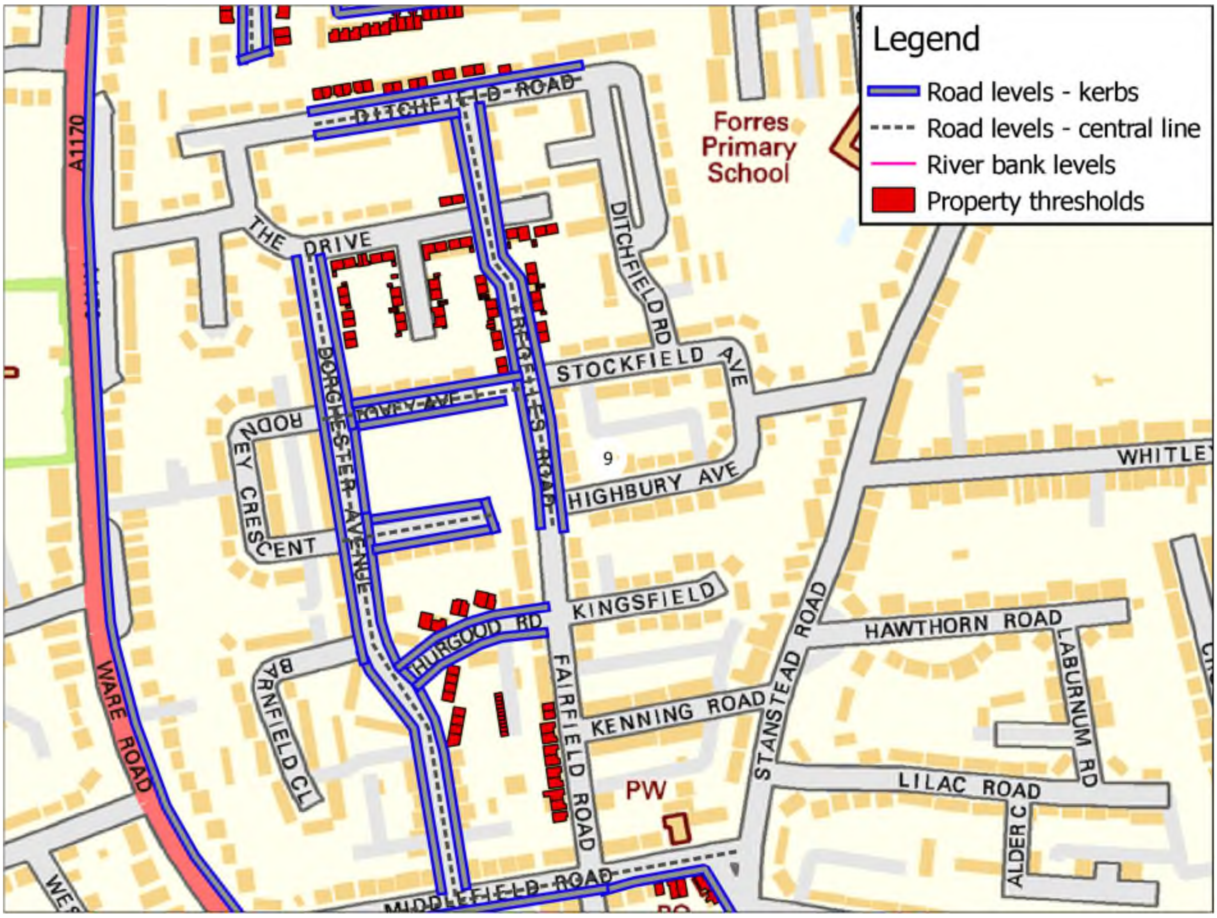

Figure 2

Survey Brief Continuation

- Road levels of Middlefield Road, Essex Road, Marston Road and Parrotts Field, including kerb levels and levels of the central line for the locations indicated in Figure 3, in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 3.
- Levels of the north bank of Woollens Brook for the reach of watercourse running to the west of Parrotts Field, as indicated in Figure 3.
- Levels of both north and south banks of Woollens Brook for the reach of watercourse running to the east of Parrotts Field, as indicated in Figure 3.

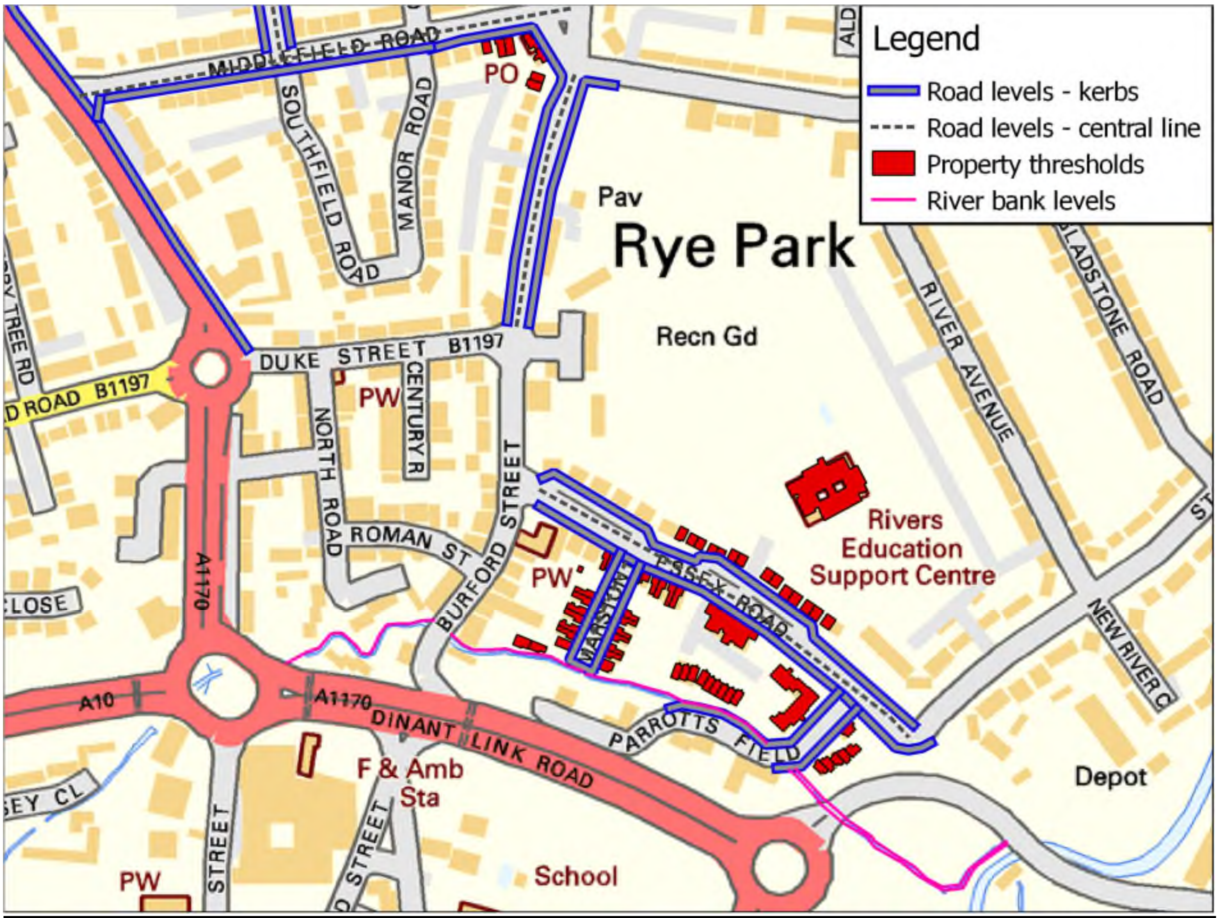

Figure 3

Cheshunt (site 52)

The approximate grid reference for the central area is NGR 535300, 202900.

- Kerb levels to the south of Church Lane, as indicated in Figure 4, in order to understand the level of the road in relation to the watercourse running underneath.
- Cross section in the location indicated in Figure 4, in order to compare them against the road level.

Figure 4

Rosedale North and Rosedale South, Flamstead End (Sites 62 & 63)

The approximate grid reference for the central area is NGR 534300, 202900.

- Road levels of Rosedale Way and Andrew's Lane and Andrew's Lane footpath, including kerb levels and levels of the central line – in the locations indicated in Figure 5 – in order to confirm the flow paths. Dimensions of the underpass under Rosedale Way leading to Andrews Lane footpath.
- Two cross sections in the ditch running across the Recreation Ground if access is possible, from analysis in Google Street View, the area of the Recreation Ground looks to be undergoing development (residential house building). The two cross sections should be approximately in the locations indicated by yellow points in Figure 5.

Figure 5

- Cross sections in the locations indicated by yellow points in Figure 6.

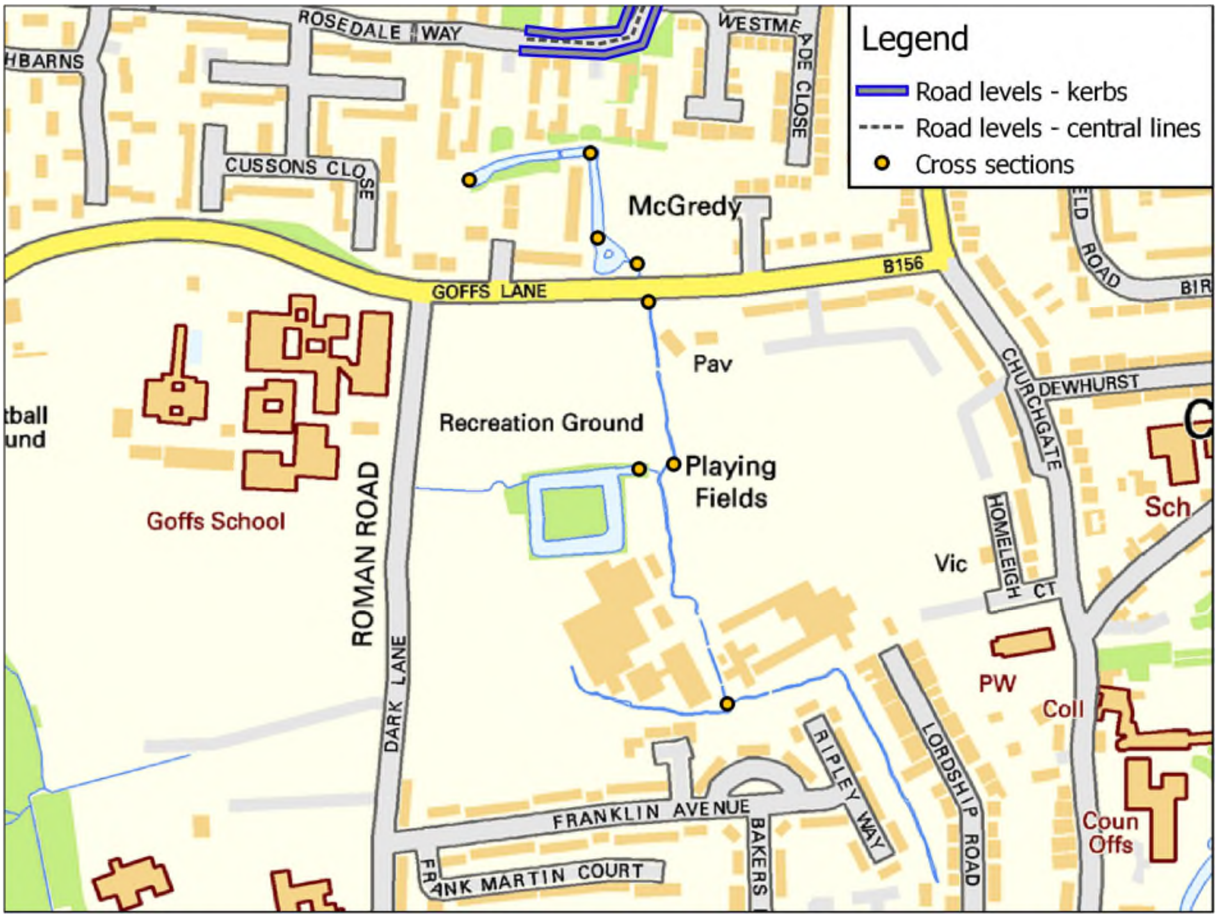

Figure 6

<u>Additional cross sections may be required at a later stage for other watercourses in the area. We are currently unable to confirm the scope as we are waiting for the Environment Agency to provide us with their models for review.</u>

Cozens Lane East, Wormley (Site 55)

The approximate grid reference for the central area is NGR 536700, 205700.

Confirmation on the presence of a sewer shown by the red arrow in Figure 7, crossing the railway near Boat House (approx. NGR 537134, 206513). Details should include soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

- Cross sections of the ditch crossing the railway at this point, approx. every 30 metres as per the locations indicated by yellow points in Figure 7.

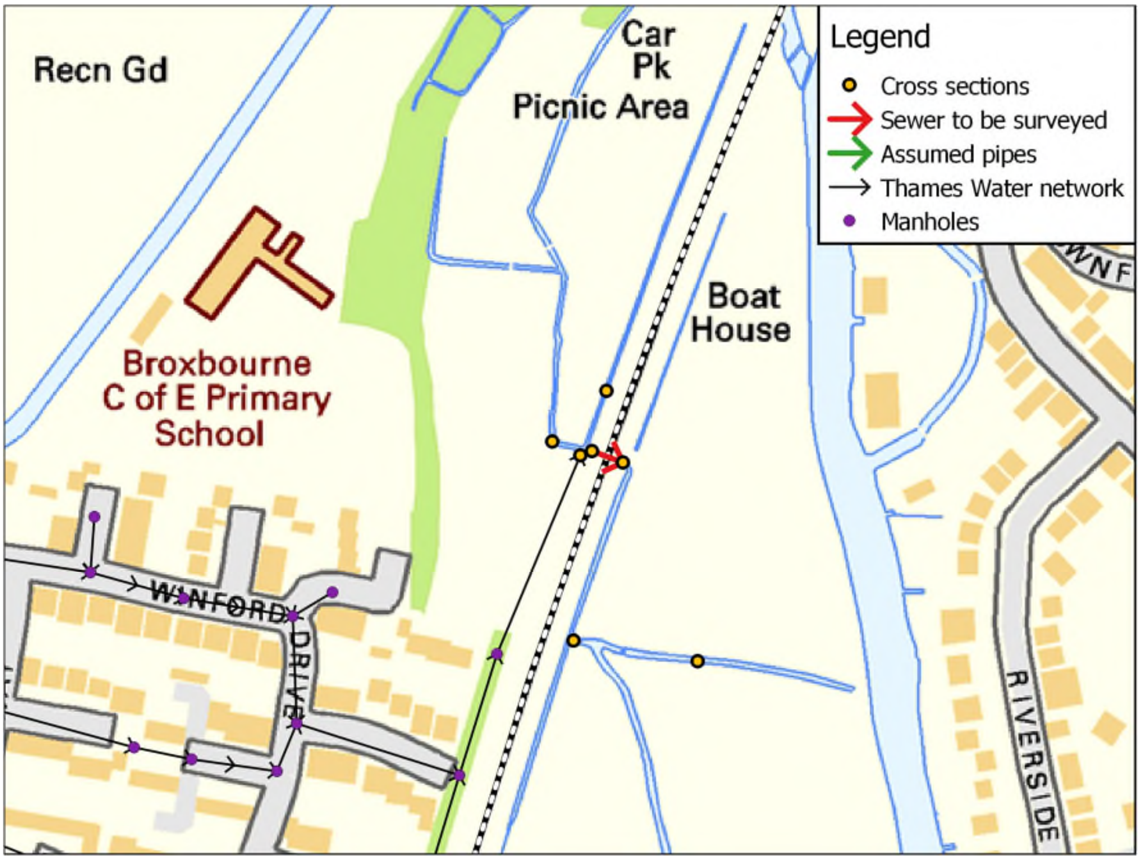

Figure 7

- Confirmation on the presence of a surface water sewer crossing the railway near Cozens Lane East (approx. NGR 536932 205782), as indicated in Figure 8. Details should include downstream soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.
- Details of the Thames Water sewer crossing the railway (approx. NGR 536897 205600) as detailed in Figure 8. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Visual confirmation of the existence of a culvert crossing underneath the path running parallel to the railway (approx. NGR 536918, 205592). If existing, details on this culvert, including downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.
- Details of the Thames Water sewer crossing the railway (approx. NGR 536865 205389), as detailed in Figure 8. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.
- Cross section on the ditches where these three sewers discharge into, in the locations indicated by yellow points in Figure 8.
- Road levels of Wharf Road, including kerb levels and levels of the central line in order to confirm the flow paths, in the section of road indicated in Figure 8.

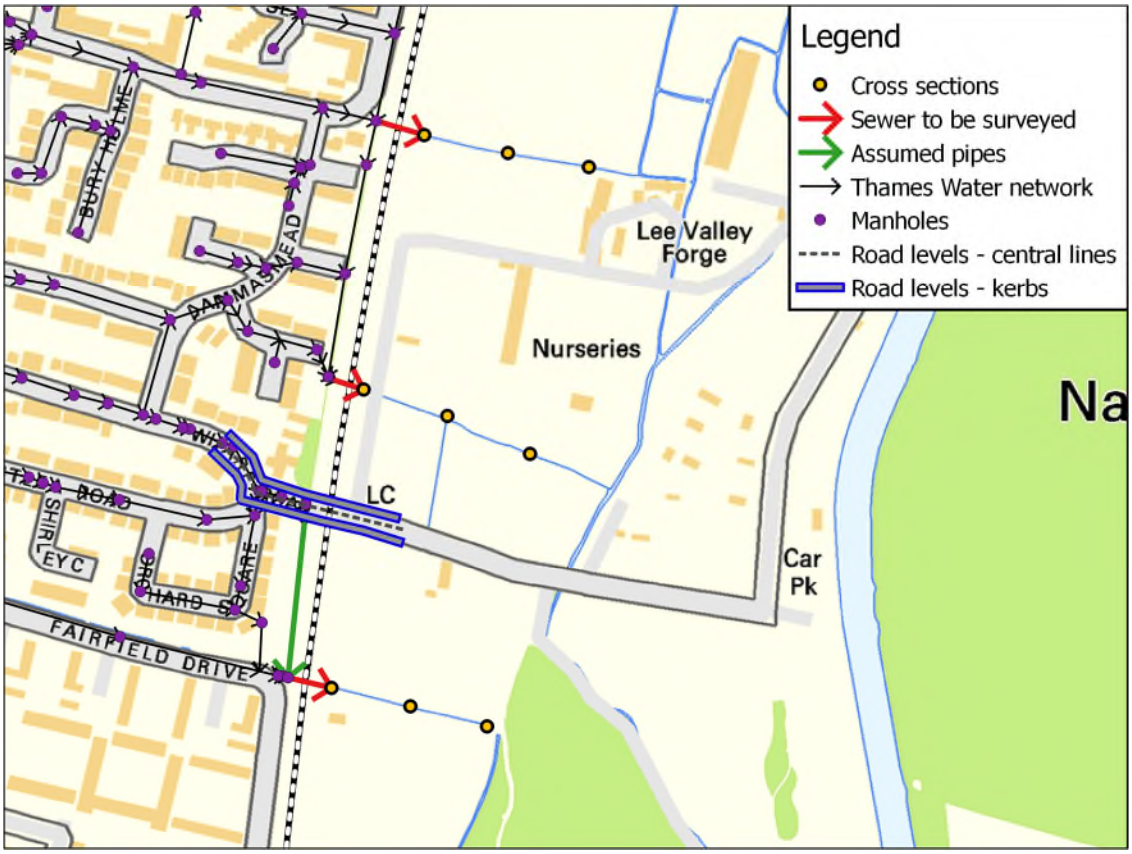

Figure 8

- Details of the Thames Water sewer crossing the railway near Sorbus Road (approx. NGR 536818 204777), as detailed in the Figure 9. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.
- Visual confirmation on the presence of a surface water sewer (blue arrow in Figure 9) immediately downstream from the Thames Water sewer mentioned above (approx. NGR 536838, 204774). If existing, details on this sewer including soffit and invert levels of the culvert, dimensions, shape, material and the presence of any flap valves.
- Cross sections on the ditch where this sewer discharges into, in the locations indicated by yellow points in Figure 9.

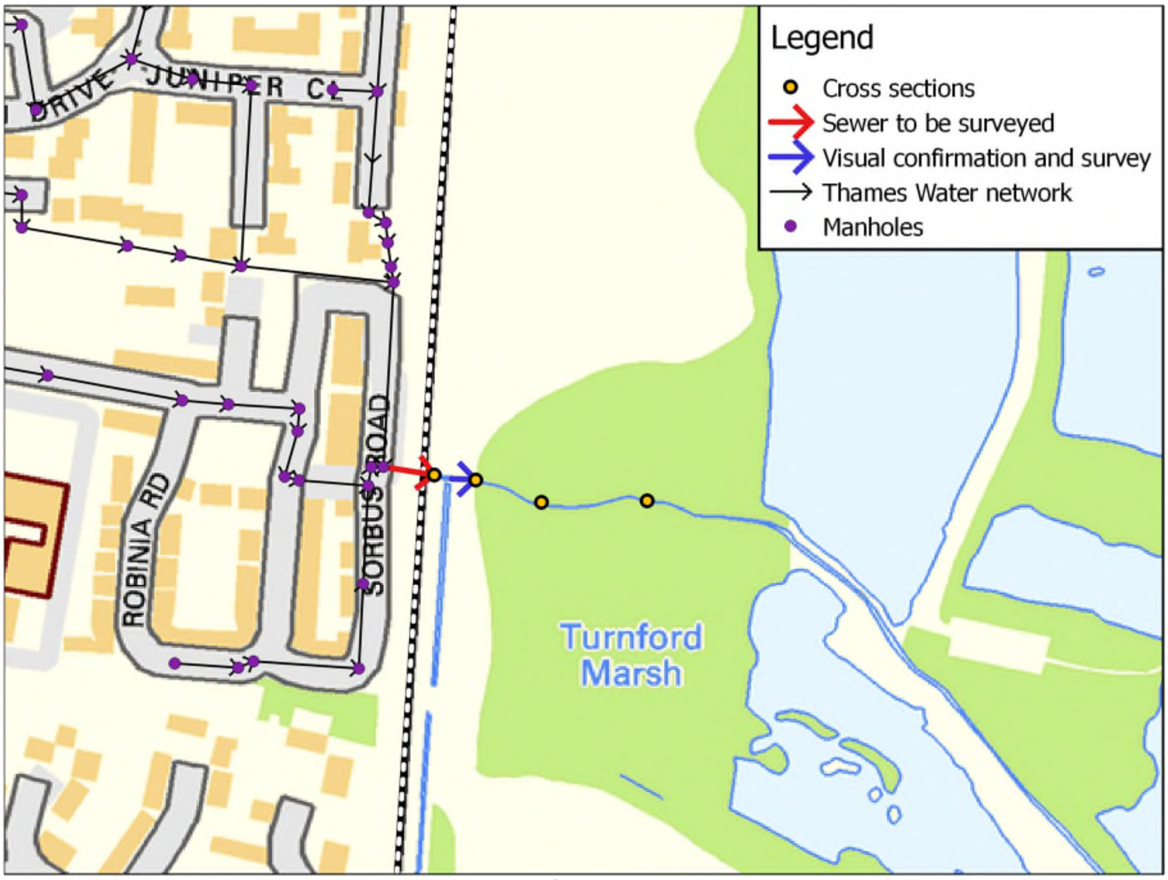

Figure 9

Buntingford (Site 1)

The approximate grid reference for the central area is NGR 536030, 229400.

- Cross sections on the ditch running across Monks Walk, in the locations indicated by yellow points in Figure 10. These cross sections are needed to estimate the slope of the ditch acting as a flow path rather than detailed cross sections of the ditch.

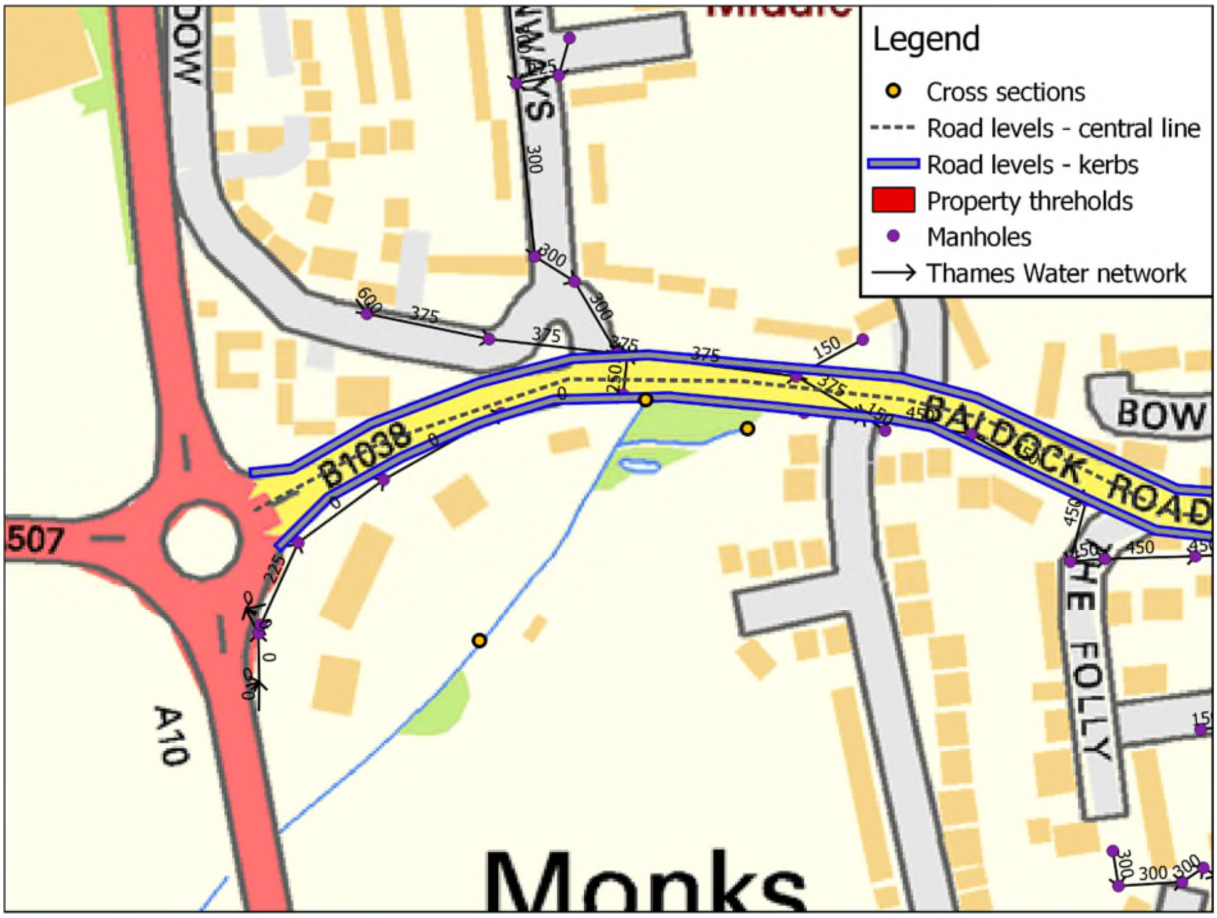

Figure 10

- Road levels of Baldock Road (B1038), Chapel End, Monks Walk and High Street, including kerb levels and levels of the central line in order to confirm the flow paths in the locations indicated in Figure 11.
- Threshold levels of the properties indicated in Figure 11.
- Details on the width of the alleyways as indicated by green stars in Figure 11. Details of the location of these are provided in the list below, starting from the south west of the street, up north and back to the south east of the street:
  - Alleyway next to 41 High Street;
  - Alleyway between Vanilla Boutique Ltd and Skin Deep stores, opposite to Days of Ashwell bakery;
  - Alleyway between 59A High Street and Animal Attraction Ltd, opposite to Touch of Glamour;
  - Alleyway between The Buntingford Coffee Shop and The Dentist;
  - Alleyway between Brunel's restaurant and 71 High Street;
  - Alleyway next to Damian's Barber Shop;
  - Alleyway between Isabel Hospice Shop and Country Properties estate agents;
  - Alleyway between 30 High Street and Days of Ashwell bakery;
  - Alleyway between Days of Ashwell bakery and Interior Solutions;
  - Alleyway next to 22 High Street;
  - Alleyway for Trax cycles, next to The Black Bull pub.

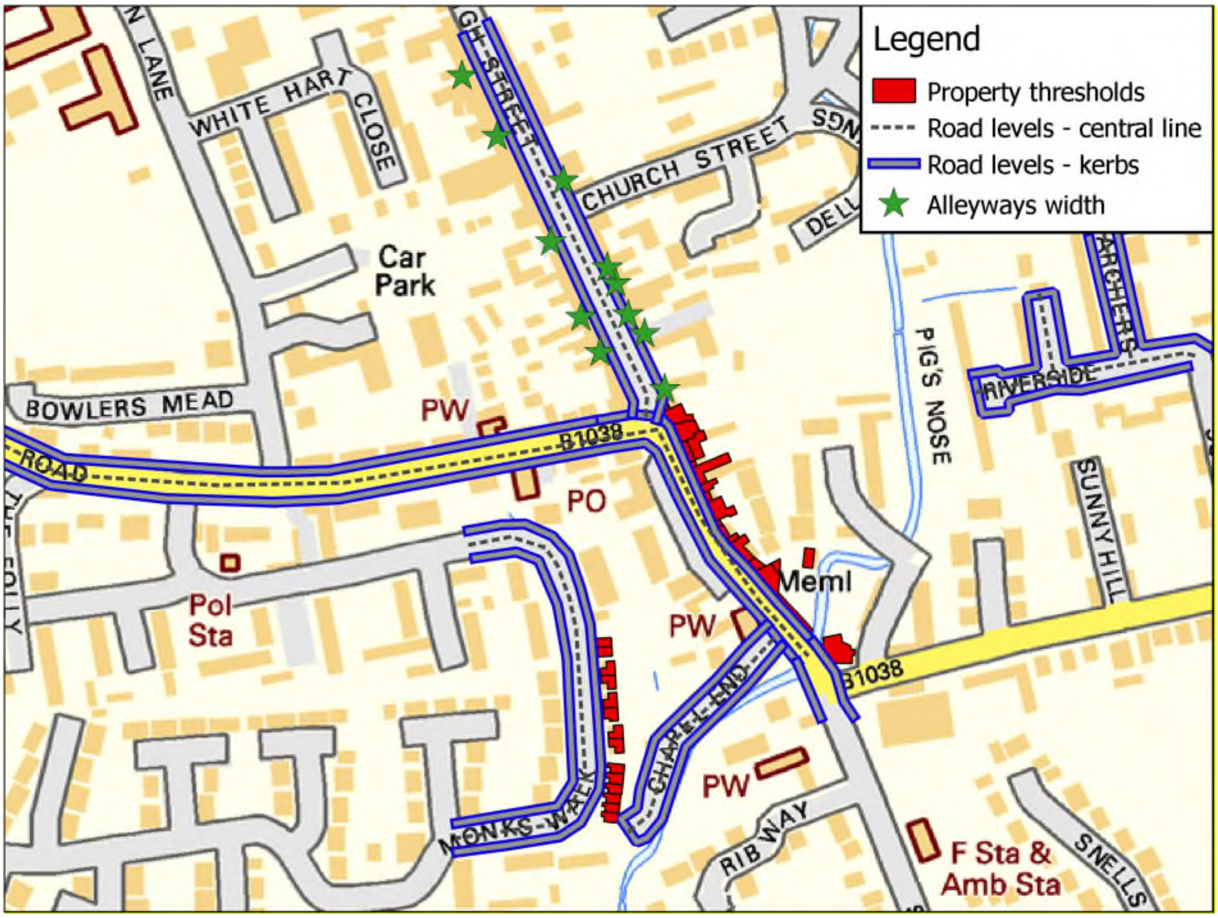

Figure 11

- Road levels of Archers and Riverside, including kerb levels and levels of the central line – as indicated in Figure 12 – in order to confirm the flow paths.

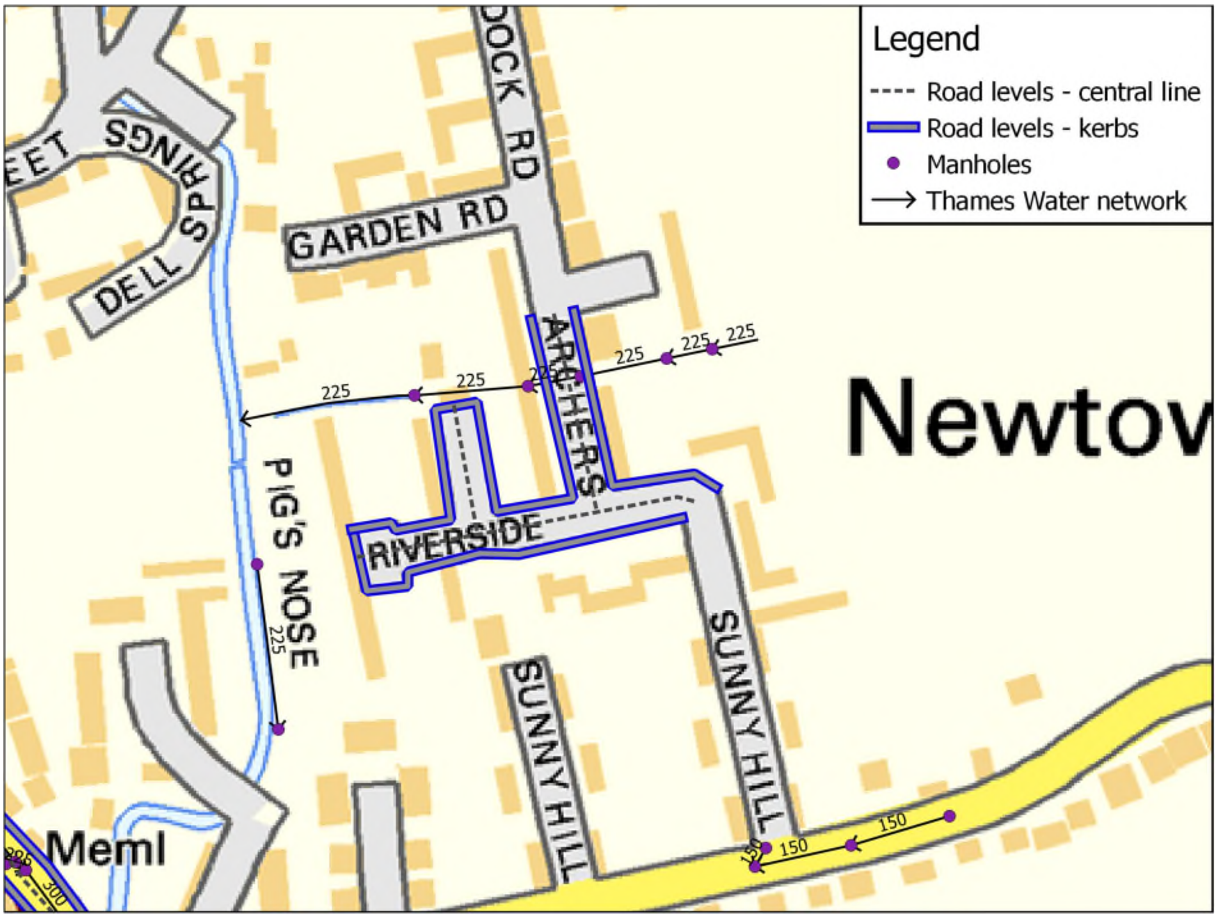

Figure 12

- Road levels of Vicarage Road including kerb levels and levels of the central line – as indicated in Figure 13 – in order to confirm the flow paths.

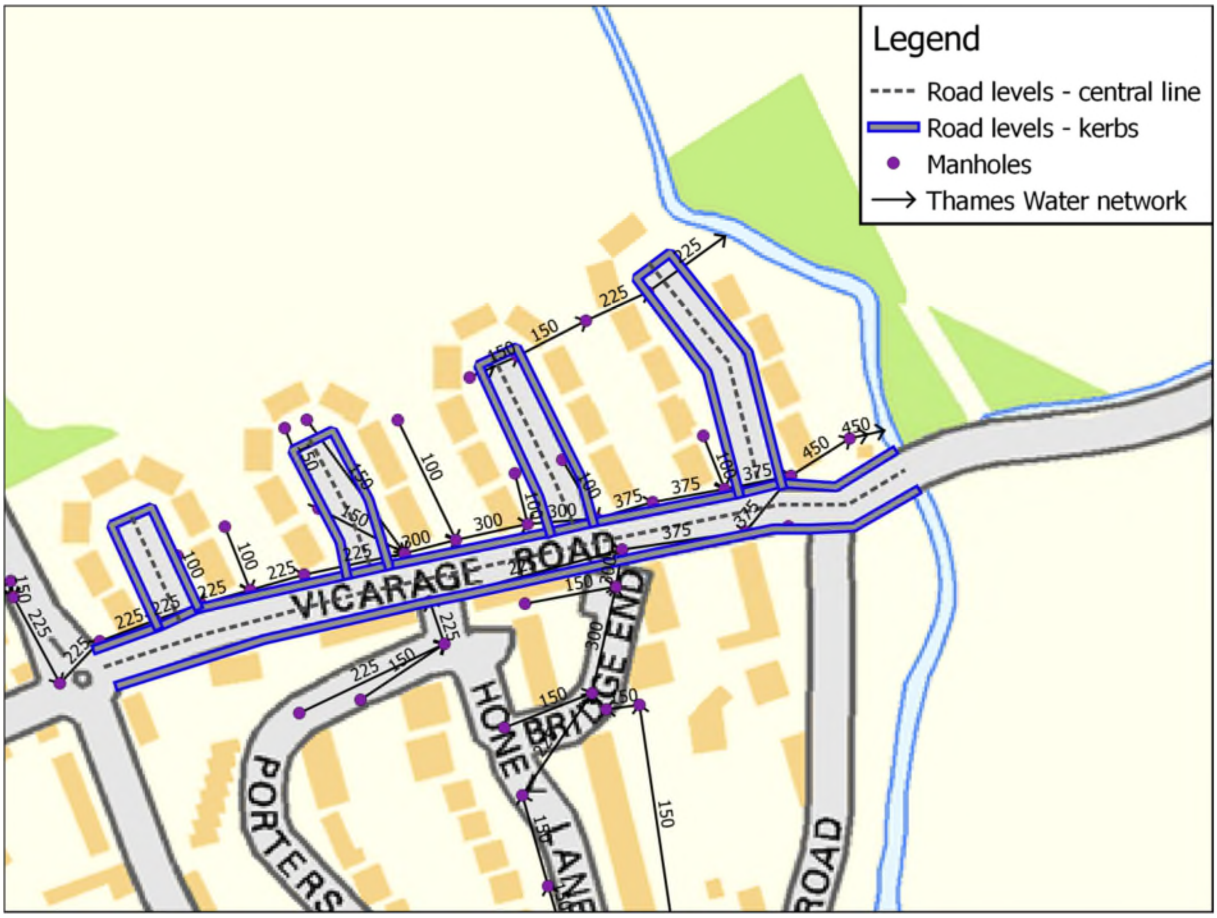

Figure 13

<u>Hadham Road, Benhooks Avenue and Potter Street / South Street, Bishop's Stortford (Sites 43, 44 & 60)</u>

The approximate grid reference for the central area is NGR 548300, 221200.

- Road levels of Dane Park, Maple Avenue and Matching Lane including kerb levels and levels of the central line – as indicated in Figure 14 – in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 14.

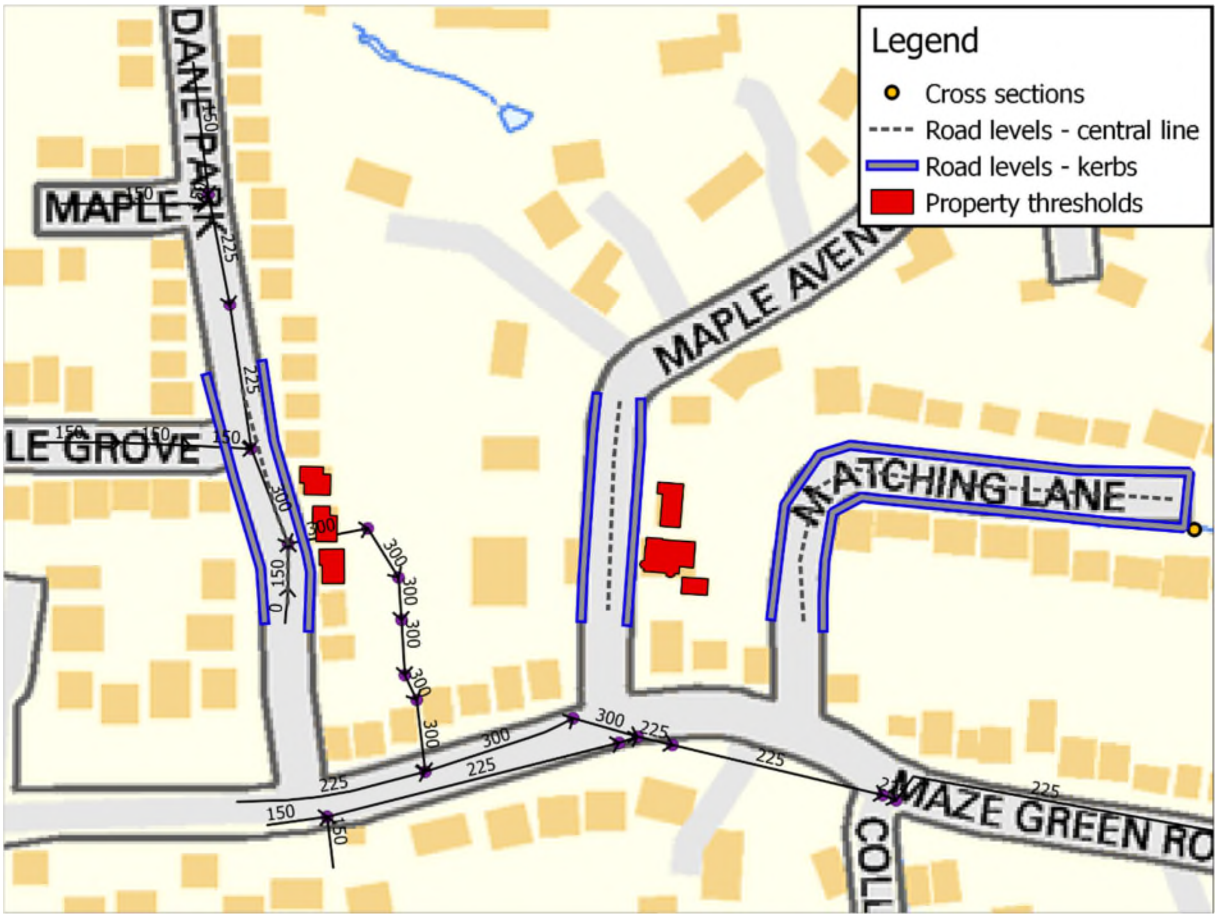

Figure 14

- Cross sections on the ditches running between Matching Lane, Maze Green Road and Pye Gardens, in the locations indicated by yellow points in Figure 15.
- Details on the Thames Water sewer discharging into this drain (visual confirmation on this connectivity) from Maze Green Road (approx. NGR 547948, 221436), as detailed in Figure 15. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.
- Details on the Thames Water sewer linking this drain to the Thames Water network (visual confirmation on this connectivity) running along Hadham Road (A1250) (approx. NGR 548596, 221132), as detailed in Figure 15. Details should include upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.
- Two cross sections on the ditch running across Saint Mary's Catholic School, in the locations indicated in Figure 15.
- Details on the Thames Water sewers linking this ditch (visual confirmation on this connectivity) to the Thames Water network, indicated by red arrows (approx. NGR 548290 221295 and 548283 221336) in Figure 15. Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.
- Visual connectivity of the drain running in an eastern direction to the west of Saint Mary's Catholic School, which seems to connect to the Thames Water network (approx. NGR 548200 221253).

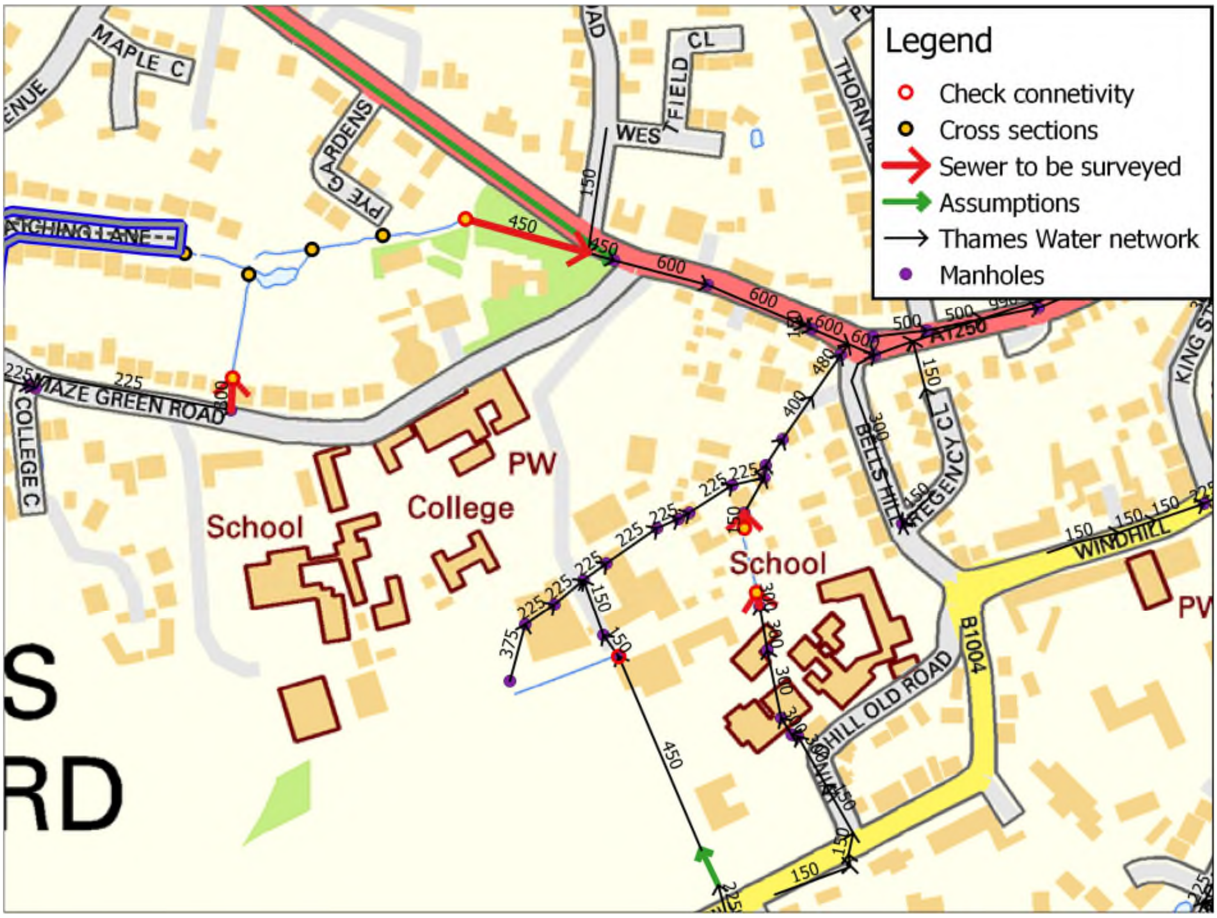

Figure 15

- Visual confirmation of the connectivity of the ditch running between Beechlands and The Chase, with the Thames Water network as indicated in Figure 17.

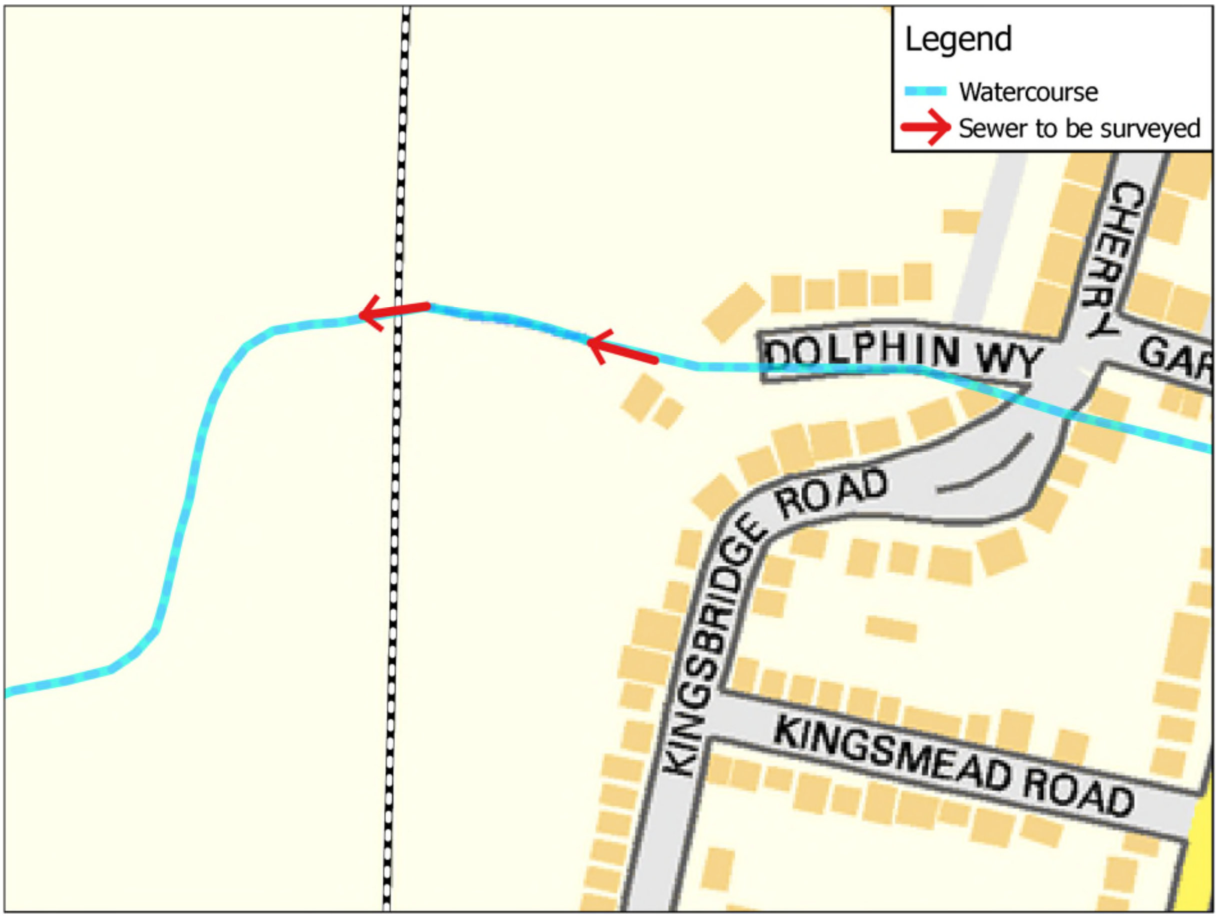

Figure 16

- If the ditch and Thames Water network are connected, cross sections on the two locations indicated in Figure 17.
- Details on the Thames Water sewer discharging to this drain from Beechlands (approx. NGR 548621, 220477), as detailed in Figure 17. Details should include downstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

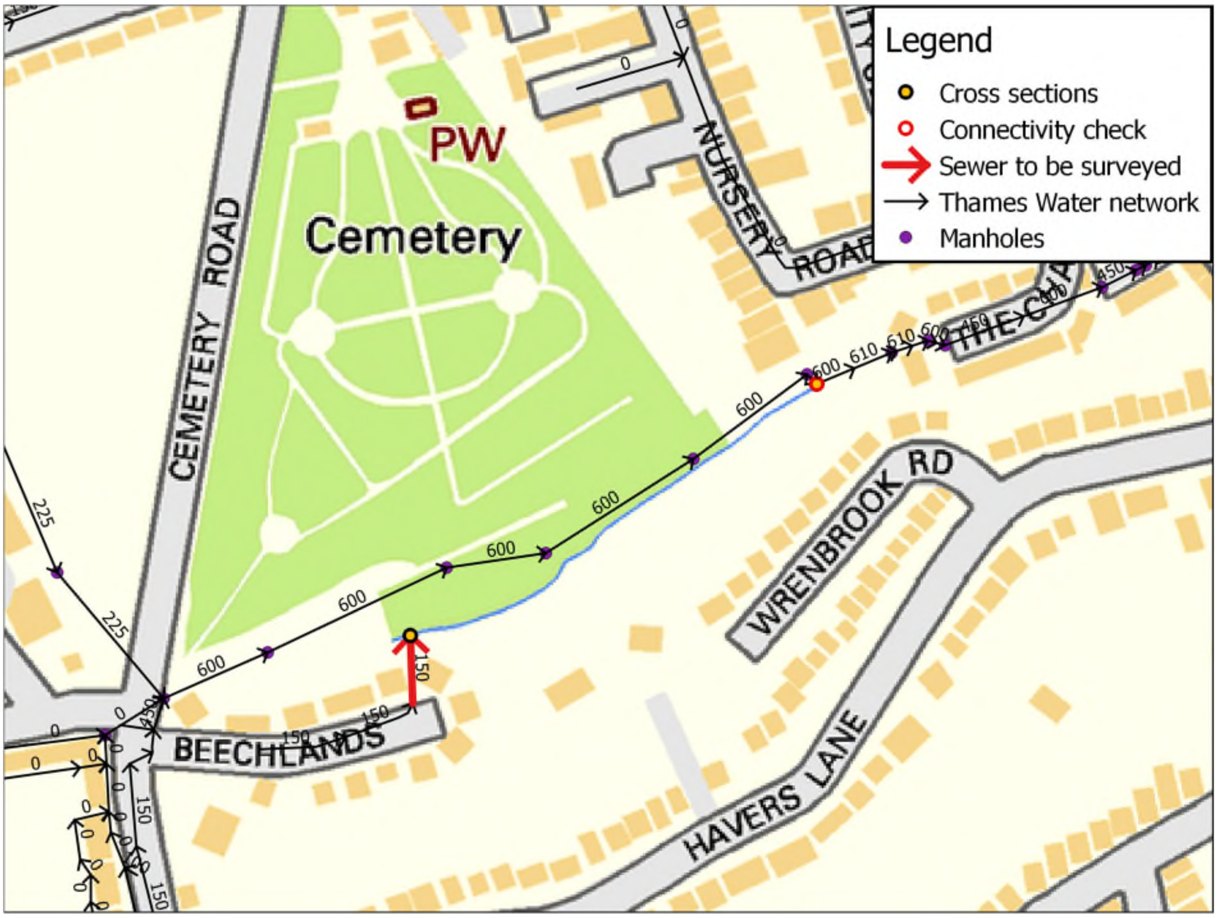

Figure 17

Raynham Road, Bishop's Stortford (Site 47)

The approximate grid reference for the central area is NGR 550100, 221500.

- Kerb levels of Raynham Road, Stortford Hall Park road and Parsonage Lane as indicated in Figure 18, in order to confirm the flow paths.
- Threshold levels of the properties indicated in Figure 18.

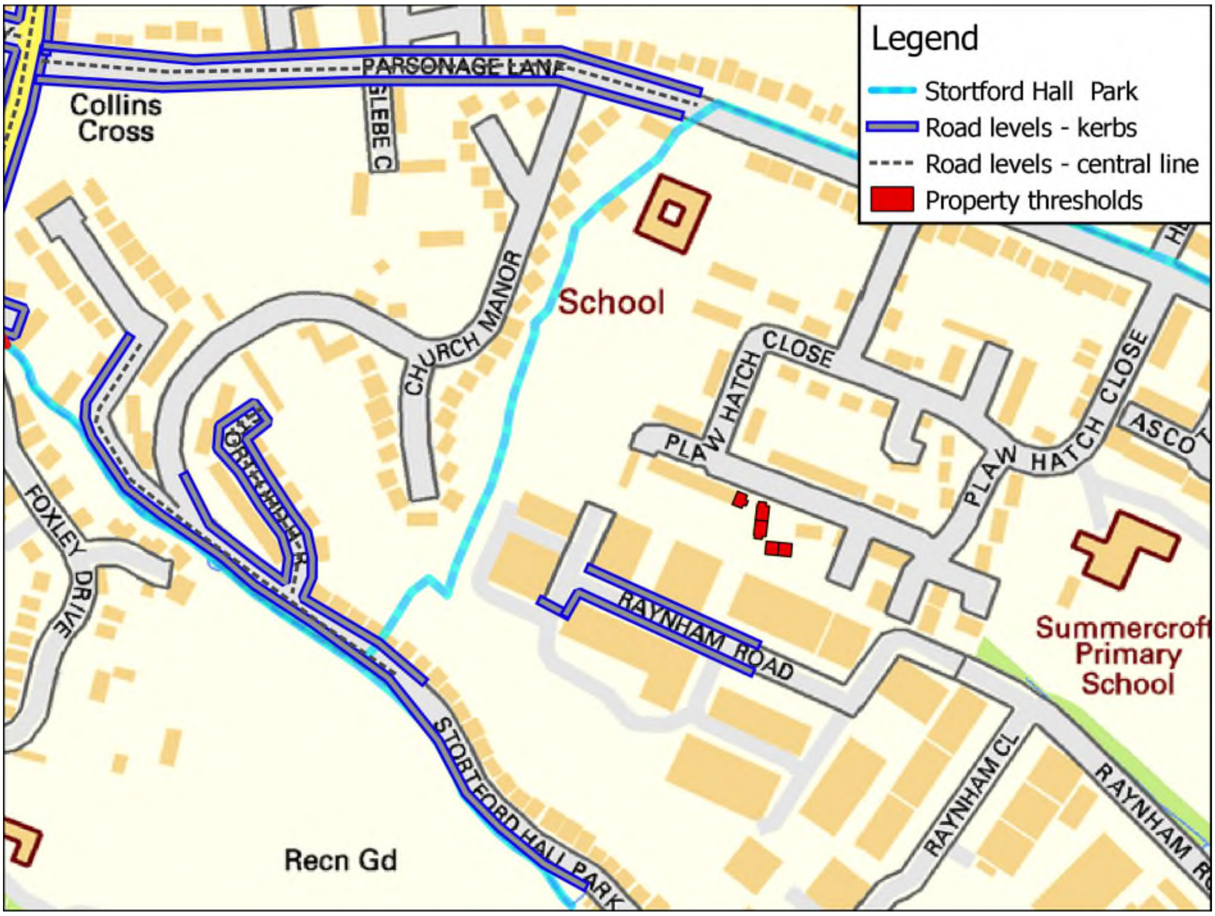

Figure 18

- Details on the culvert connecting Parsonage Lane Ditch to the Thames Water network (approx. NGR 549490, 221776). Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and confirmation of the presence of any flap valves.
- Road levels of Legions Way and Stansted Road (B1383) – including kerb levels and levels of the central line – as indicated in Figure 19 – in order to confirm the flow paths.

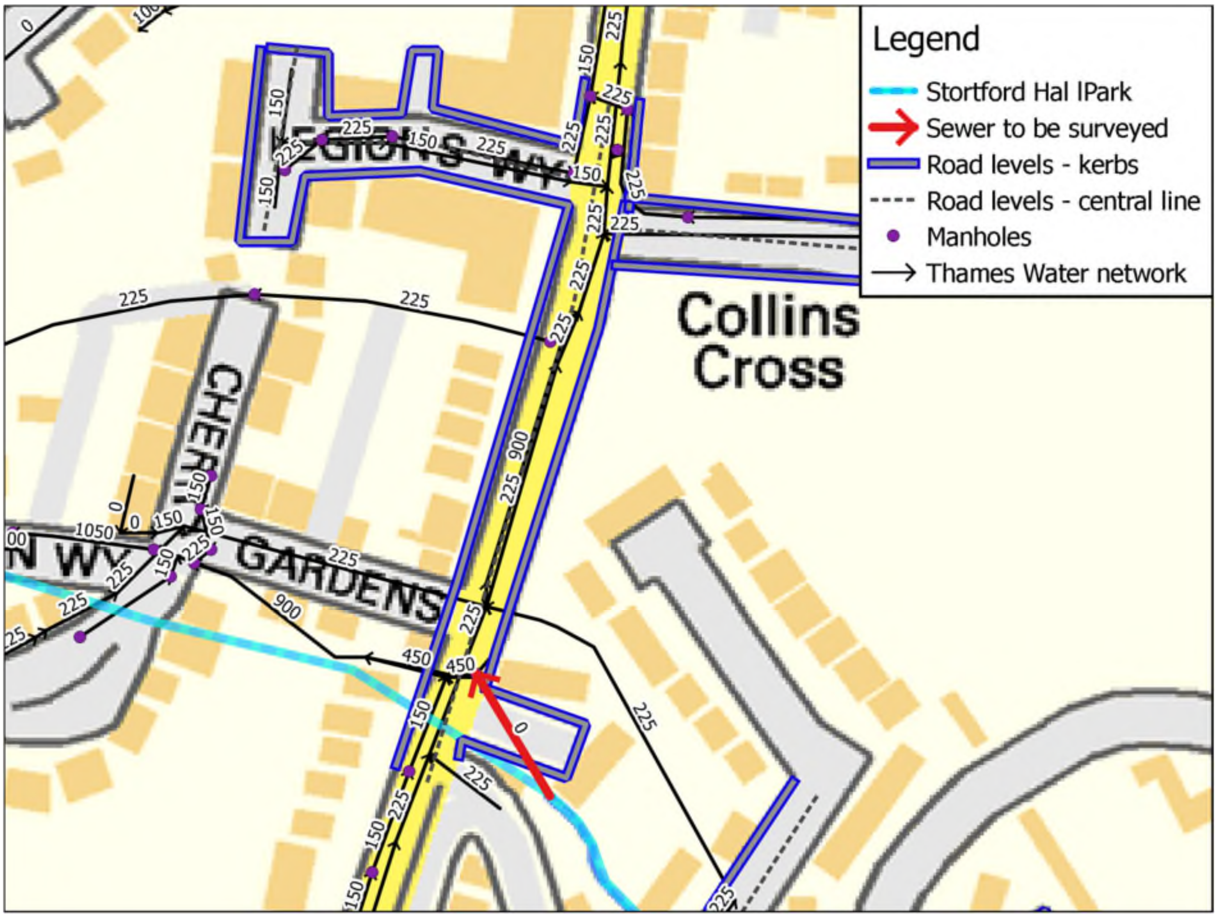

Figure 19

- Cross sections on the ordinary watercourse running parallel to the disused railway, which acts like a flowpath, in the locations indicated in Figure 20 by yellow points.
- Cross sections on the drain running to the south west of Brooke Gardens, in the locations indicated in Figure 20 by yellow points.

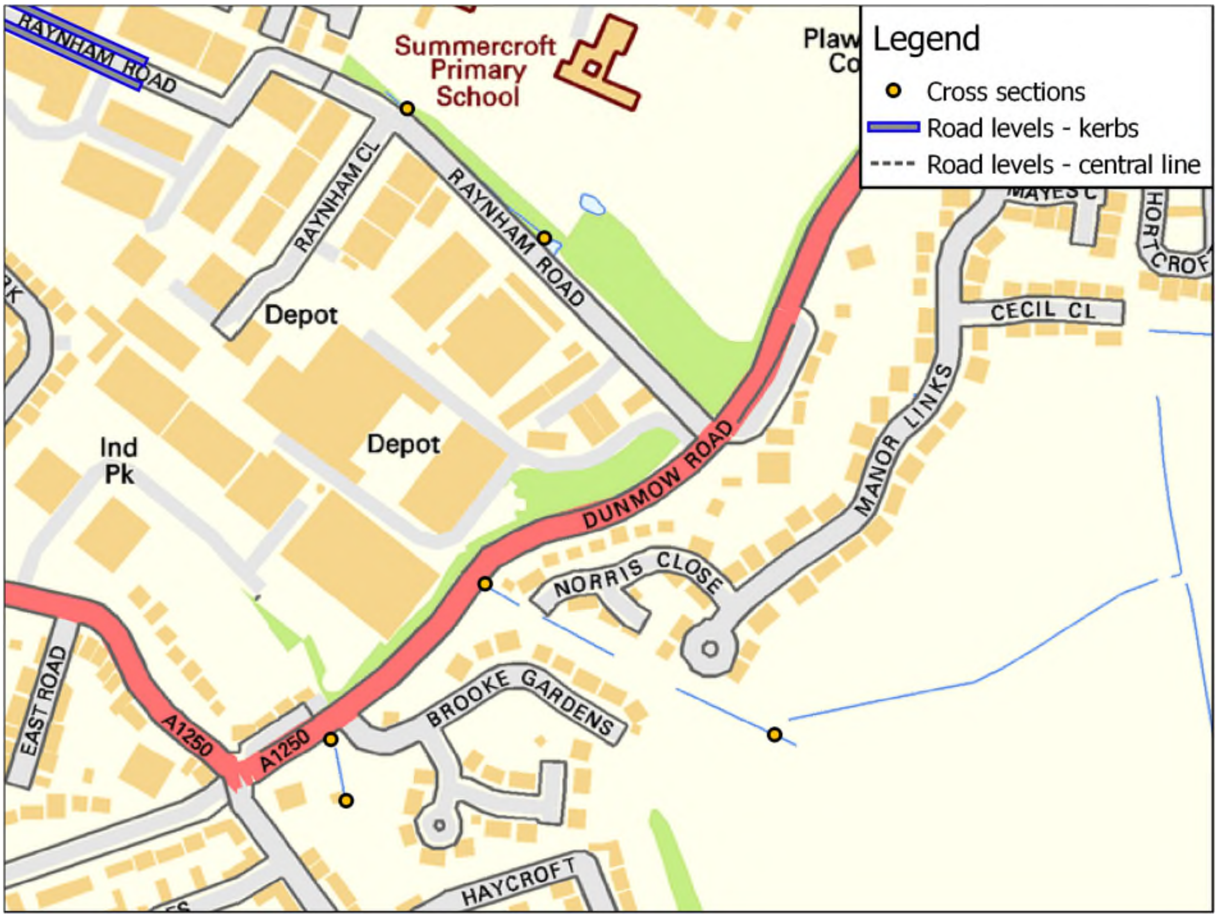

Figure 20

Survey Brief Continuation

- Details on the sewers represented by red arrows (approx. NGR 549162, 221863 and NGR 549227, 221848). Details should include downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves. Where access to Network Rail land is not possible, estimates of the culvert characteristics (i.e. dimensions and soffit level) along with photographic evidence should be provided in order to help with the assumptions.

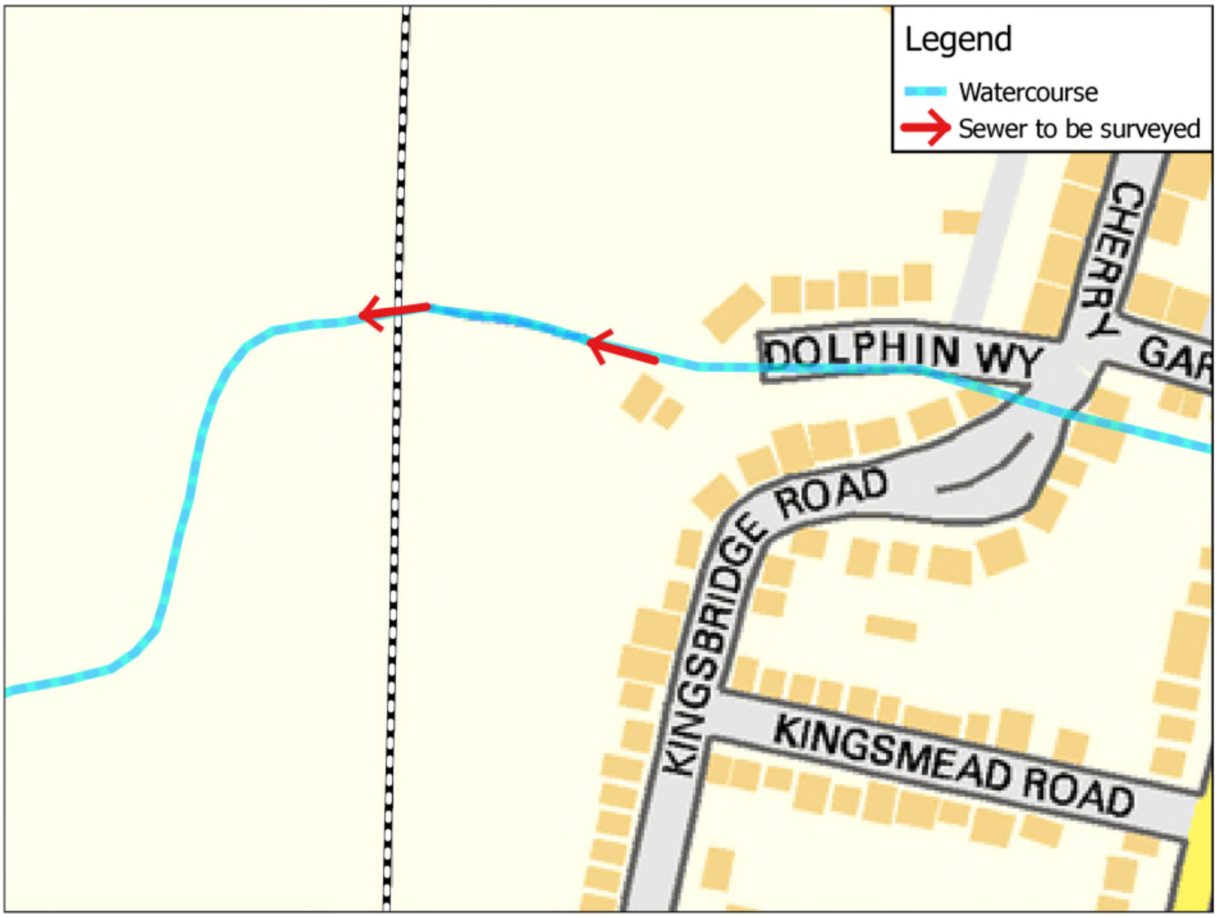

Figure 21

- Visual confirmation on a pipe running under the footpath (Figure 22) and if existing, details including downstream and upstream soffit and invert levels, dimensions, shape, material and the presence of any flap valves.

Figure 22

Survey Brief Continuation
Bengeo, Hertford (Site 40)

The approximate grid reference for the central area is NGR 532400, 213800.

- Road levels of Bengeo Street, Sacombe Road, Palmer Road, Revels Road, Glebe Road, Watermill Lane, Rib Vale, Ware Park Road, including kerb levels and levels of the central line in order to confirm the flow paths in the locations indicated in Figure 23.
- Threshold levels of the properties at Globe Court and surrounding properties as indicated in Figure 23.

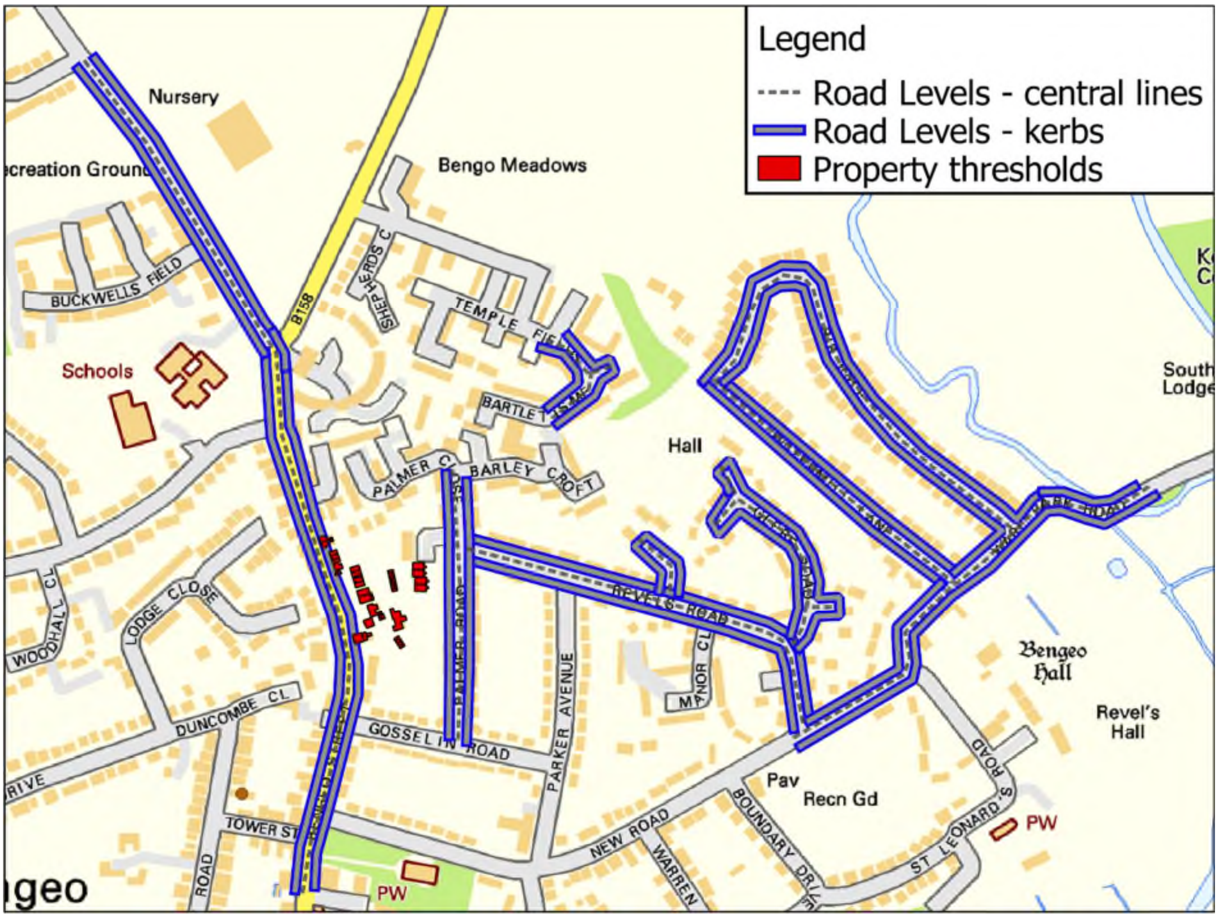

Figure 23

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 and/or desk based analysis. 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.

<u>Access</u>

The surveyor will be responsible for arranging access to any third party land and any consents/licences that are required (i.e. Thames Water).

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

Survey Contact
Lorena Ramirez
Graduate Hydrologist

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Tel: +44(0)117 930 2055
Email: Lorena.ramirez@wspgroup.com

Appendix II

FLOOD MODELLING SUMMARY REPORTS

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 1E

BUNTINGFORD / EAST HERTS

Modeller:	S Cheng	27-06-2016
Reviewer:	A Chowdhury	28-06-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	Levels of the Environment Agency River Rib Model have been used as a downstream boundary of the 2D model. EA 1m and 2m LiDAR used
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as Hotspot1E_Buntingford_~s1~_~e1~_~e2~_v07.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 3.25hr: 3.25hr 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. “Hotspot1E_Buntingford_Baseline_3.25hr_Q0100CC_v07”
2. 2D Reference data	
2.1 Final DEM	The Environment Agency 1m and 2m LiDAR DTM – tiles: TL3631, TL3630, TL3629, TL3628, TL3731, TL3730, TL3729

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 of Riverside and Archers: • Hotspot1E_surveygrid.asc Threshold levels for surveyed buildings: • 2d_z_THL_Hotspot1E_EastHerts_v01_R.shp The roads were lowered by 0.125 m (the height of a British Standard kerb) to better delineate the important pathways and ensure that the principal flood pathways along roads are better represented in the 2 m model grid. The building polygons were also raised by 300 mm. These are consistent with the approach adopted to produce the uFMfSW.
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_TW_pipes_Hotspot1E_EastHerts_v03_L.shp • 1d_nwk_TW_pitchannels_ Hotspot1E_EastHerts_v03_P.shp Any changes to the 1d nwk have been included into the 'Assumption' column in the layers above.
3.2 Watercourse Structures	No 1d watercourse represented within the model.
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in the ReFH1 methodology to derive rainfall hyetographs for a critical storm duration.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	12	19	21	28	30	42	59
Total rainfall (mm)	16	24	27	36	39	54	75
Storm duration (hr)	3.25						

4.2 Downstream boundaries	The downstream boundaries have been defined as the 20 % AEP fluvial boundary for the River Rib; extracted from the Environment Agency River Rib model.
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	No channel manning's values needed as no 1d open channel have been modelled.
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 this hotspot.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	<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 but base-rich 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>4 – Clay Loam</td></tr></table>
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	TUFLOW version 2016-03-AA-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
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	4.5 hours

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
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. 54% and -0.55% for all scenarios.
7.5 Number of messages / warnings etc.	24 warnings / 91 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
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 1W

BUNTINGFORD / EAST HERTS

Modeller:	S Cheng	27-06-2016
Reviewer:	A Chowdhury	28-06-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	Levels of the Environment Agency River Rib Model have been used as a downstream boundary of the 2D model. EA 1m and 2m LiDAR used
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as Hotspot1W_Buntingford_~s1~_~e1~_~e2~_v09.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 3.25hr: 3.25hr 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. “Hotspot1W_Buntingford_Baseline_3.25hr_Q0100CC_v09”
2. 2D Reference data	
2.1 Final DEM	The Environment Agency 1m and 2m LiDAR DTM – tiles: TL3631, TL3630, TL3629, TL3628, TL3731, TL3730, TL3729

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 of Riverside and Archers: • Hotspot1W_surveygrid.asc Threshold levels for surveyed buildings: • 2d_z_THL_Hotspot1W_EastHerts_v01_R.shp The roads were lowered by 0.125 m (the height of a British Standard kerb) to better delineate the important pathways and ensure that the principal flood pathways along roads are better represented in the 2 m model grid. The building polygons were also raised by 300 mm. These are consistent with the approach adopted to produce the uFMfSW.
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_TW_pipes_Hotspot1W_EastHerts_v03_L.shp • 1d_nwk_TW_pitchannels_ Hotspot1W_EastHerts_v03_P.shp Any changes to the 1d nwk have been included into the 'Assumption' column in the layers above.
3.2 Watercourse Structures	No 1d watercourse represented within the model.
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in the ReFH1

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	methodology to derive rainfall hyetographs for a critical storm duration.

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	12	19	21	28	30	42	59
Total rainfall (mm)	16	24	27	36	39	54	75
Storm duration (hr)	3.25						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.2 Downstream boundaries	The downstream boundaries have been defined as the 20 % AEP fluvial boundary for the River Rib; extracted from the Environment Agency River Rib model.
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	No channel manning's values needed as no 1d open channel have been modelled.
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 ELEMENT	ACTION TAKEN DURING MODELLING
	model for this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Loamy	Freely draining slightly acid but base-rich 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

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
6.1 Version	TUFLOW version 2016-03-AA-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
6.5 Hazard	UK Hazard Land Use - Conservative

7. Modelling Log

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
7.1 Model duration	4.5 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds
7.4 Mass balance check	Peak Cumulative Mass Balance error (Qi+Qo > 5%) is 0.88% for all scenarios.
7.5 Number of messages / warnings etc.	29 warnings/ 520 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
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 40

BENGEO

Modeller:	S. Collier	17-06-2016
Reviewer:	A.Chowdhury	27-06-2016

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.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot40_EastHerts_~s1~_~e1~_~e2~_v22.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 2.6hr: 2.6hr 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. “Hotspot40_EastHerts_Baseline_2.6hr_Q0100_v22”
2. 2D Reference data	
2.1 Final DEM	The Environment Agency’s updated Flood Map for Surface Water (uFMfSW) DTM was used – tile t131sw

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2.2 Changes to DEM	Surveyed levels were used in specific areas of Bengeo Street, Palmer Road, Revels Road, Glebe Road, Ware Park Road, Rib Vale and Watermill Lane. The surveyed points were imported as points: • *2d_zsh_Hotspot40_EastHerts_v15_P.shp* A z_shape polygon was drawn around them to provide interpolation between the points: • *2d_zsh_Hotspot40_EastHerts_v15_R.shp* The DTM. Z_shp lines were not used as these caused errors. Surveyed building thresholds were also imported into the model as: • *2d_z_THLs_Hotspot40_EastHerts_v10_R.shp*
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layer: • *1d_nwk_TW_pipes_Hotspot40_EastHerts_v10_L.shp* The pitchannels layers: • *1d_nwk_TW_pitchannels_Hotspot40_EastHerts_v11_P.shp*
3.2 Watercourse Structures	No 1d watercourse represented within the model.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4. Hydrology	
4.1 Inflow boundaries	(see table below)
4.2 Downstream boundaries	The downstream boundaries have been defined as the 20% AEP fluvial boundary for the River Rib; extracted from the River Rib and River Lee draft model (defended scenario) where the 1D network flows into the River Rib. Within the 2D domain the downstream boundaries have been defined by a free flow HQ boundary based on the slope.
4.3 Historical records of flooding	Flooding was reported at Globe Court and Bengeo Street on 24 August 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	No channel manning's values needed as no 1d channel have been modelled.
5.3 Soil loss definition	The soil types in the study area have been defined based on National UK Soils Maps. The soil type in the majority of the hotspot has been identified as freely draining slightly acid but base-rich soils. The soil type in some parts of the lower hotspot has been identified as loamy and clayey floodplain soils with naturally high groundwater. 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.

4.1 Inflow boundaries:

	20.0%	**5.0%**	**3.3%**	**1.3%**	**1.0%**	**1%+40%**	**0.1%**
Peak rainfall intensity (mm/hr)	31	47	53	70	76	107	151
Total rainfall (mm)	24	37	41	55	59	83	117
Storm duration (hr)	2.6						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	<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 but base-rich soils</td><td>8 – Loam</td></tr><tr><td>Loamy and clayey</td><td>Loamy and clayey floodplain soils with naturally high groundwater</td><td>4 – Clay Loam</td></tr></table>
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	TUFLOW version 2016-03-AA-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, XMDF – d v q h ZUK0
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	2.6 hours

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
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%) range between 0.10% and 0.12% for all scenarios
7.5 Number of messages / warnings etc.	43 warnings/ 211 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	
8.5 Inflows	
8.6 Impact of soakaway system along Sacombe Road	Sensitivity was undertaken to assess the impact on potential downstream receptors as a result of a complete and partial failure of the soakaway system within the Recreation Ground located along the west side of Sacombe Road, just north of Bengeo Primary School. Results of the sensitivity testing are shown in the flood difference maps below.

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 43, 44 & 60

HADHAM ROAD, BISHOP'S STORTFORD / EAST HERTS

Modeller:	S Cheng	20-07-2016
Reviewer:	G Feliziani	22-07-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	Levels of the Environment Agency River Stort Model have been used as a downstream boundary of the 2D model. EA 50cm LiDAR used
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as Hotspots_43_44_60_~s1~_~e1~_~e2~_v18.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 1.95hr: 1.95hr 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. " Hotspots_43_44_60_Baseline_1.95hr_Q0100CC_v18"

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency 50 cm LiDAR DTM – tiles: TL4922, TL4721, TL4921, TL4920, TL4822, TL4821, TL4820, TL4722, TL4720.
2.2 Changes to DEM	Surveyed road levels were used to create Triangular Irregular Networks (TINS) in specific areas of Riverside and Archers: • Hotspot43_44_60_roadsurveytin_c.asc Threshold levels for surveyed buildings: • 2d_z_THL_Hotspots_43_44_60_v15_R.shp Z shapes, z lines and z points were used to represent the Matching Lane/Maze Green Road drains and balancing pond: • 2d_z_openchannels_Hotspots_43_44_60_v17_P.shp • 2d_z_openchannels_Hotspots_43_44_60_v17_L.shp • 2d_zsh_pond_Hotspots_43_44_60_v15_P.shp • 2d_zsh_pond_Hotspots_43_44_60_v15_R.shp The roads were lowered by 0.125 m (the height of a British Standard kerb) to better delineate the important pathways and ensure that the principal flood pathways along roads are better represented in the 2 m model grid. The building polygons were also raised by 300 mm. These are consistent with the approach adopted to produce the uFMfSW.
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_ sw_Hotspots_43_44_60_v18_L L.shp

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	• 1d_nwk_ pitchannel_Hotspots_43_44_60_v19_P.shp Any changes to the 1d nwk have been included into the 'Assumption' column in the layers above.
3.2 Watercourse Structures	No 1d watercourse represented within the model.
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in the ISIS FEH module to derive rainfall hyetographs for a critical storm duration.
4.2 Downstream boundaries	The downstream boundaries have been defined as the 20 % AEP fluvial boundary for the River Stort; extracted from the Environment Agency River Stort model.
4.3 Historical records of flooding	Flooding has been recorded along Wharf Road in August 2015. Blocked drains are thought to have caused the flooding.
5. Materials and Soils	

Table for 4.1 Inflow boundaries:

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	39	61	69	91	99	138	198
Total rainfall (mm)	23	35	40	53	58	81	115
Storm duration (hr)	1.95						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
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 open channel have been modelled.
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 this hotspot.
5.4 Changes to coefficients from normal	No

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Clayey_some loamy	Lime-rich loamy and clayey soils with impeded drainage	1 - Clayey
Loamy and clayey	Slowly permeable seasonally wet slightly acid but base-rich loamy and clayey soils	4 – Clay Loam
Loamy	Freely draining slightly acid but base-rich soils	8 – Loam
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	4 – Clay Loam

6. Software

6.1 Version	TUFLOW version 2016-03-AA-W64

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
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
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	3.0 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%) range between 0.85% and 2.54% for all scenarios
7.5 Number of messages / warnings etc.	85 warnings / 1099 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc.
8. Sensitivity testing	
8.1 Culvert blockage	

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
8.2 Structural coefficients	
8.3 Roughness coefficients	(see below)
8.4 Runoff coefficients	
8.5 Inflows	

Depth varying roughness for the buildings	
Change in levels (m)	
Max	0.046
Mean	-0.001
Min	-0.119
Standard Deviation	0.005

Sensitivity was undertaken to assess the impact of using depth varying roughness coefficients for the buildings on the flood levels (m). The baseline uses a single roughness coefficient of 0.3 for the buildings. For the sensitivity, roughness varies with depth in the following format:

- Depth < 0.03m; roughness = 0.02
- Depth > 0.1m; roughness = 0.3
- Depth between 0.03m and 0.1m; roughness is an interpolation between 0.02 and 0.3

The table above indicate the maximum, minimum and mean difference in levels as well as the standard deviation between baseline and sensitivity scenarios for 1 in 100 year event.

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 47

RAYNHAM ROAD, BISHOP'S STORTFORD / EAST HERTS

Modeller:	S Cheng	12-10-2016
Reviewer:	G Feliziani	18-10-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenario: • Models labelled as *HS47_BshpStort_~s1~_~e1~_~e2~_016.tcf* • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 2.2hr 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. "*HS47_BshpStort_Baseline_2.2hr_Q0100CC_016*"

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	The Environment Agency 50 cm LiDAR DTM – tiles: TL4822, TL4821, TL4820, TL4922, TL4921, TL4920, TL5022, TL5021, TL5020, TL5122, TL5121.
2.2 Changes to DEM	Surveyed road levels were used to create Triangular Irregular Networks (TINs) in specific areas of Riverside and Archers: • Hotspot47_surveygrid_c.asc Threshold levels for surveyed buildings: • 2d_z_THL_BSHPS_001_R.shp Z lines and z points were used to set the bank elevations of the 1D channel: • 2d_zln_banks_channel_BSHPS_004_L.shp • 2d_zln_banks_channel_BSHPS_004_P.shp Z lines and z points were used to represent the ditches adjacent to Norris Close and along Raynham Road: • 2d_z_openchannels_BSHPS_001_L.shp • 2d_z_openchannels_BSHPS_001_P.shp A z shape is used to set the road elevation of the Dunmow Road Bridge: • 2d_z_DunmowRd_BSHPS_001_R.shp The roads were lowered by 0.125 m (the height of a British Standard kerb) to better delineate the important pathways and ensure that the principal flood pathways along roads are better represented in the 2 m model grid. The building polygons were also raised by 300 mm. These are consistent with the approach adopted to produce the uFMfSW.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
3. 1D Reference data	
3.1 Sewer network	The surface water drainage network has been based on data provided by Thames Water. Surface Water Network Layers: • 1d_nwk_TW_pipe_BSHPS_003_L.shp • 1d_nwk_TW_pitchannels_BSHPS_003_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 ISIS-TUFLOW model for Stortford Hall Park/Parsonage Lane Ditch (September 2015).
4. Hydrology	
4.1 Inflow boundaries	FEH CD ROM (not web based FEH) was used to extract catchment characteristic which was later used in the ISIS FEH module to derive rainfall hyetographs for a critical storm duration.

AEP	20.0%	5.0%	3.3%	1.3%	1.0%	1%+40%	0.1%
Peak rainfall intensity (mm/hr)	34	53	60	79	86	121	171
Total rainfall (mm)	24	36	41	54	59	83	118
Storm duration (hr)	2.2						

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
4.2 Downstream boundaries	The downstream boundaries have been defined as the 20% AEP fluvial boundary for the River Stort; extracted from the Environment Agency River Stort model
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 varies from 0.02 to 0.07 for the 1D watercourse and a roughness value of 0.013 was used for all the pipes/culverts in the model.
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 this hotspot.

National UK Soil Maps Classification	Description	Green-Ampt Soil Type
Clayey, some loamy	Lime-rich loamy and clayey soils with impeded drainage	1 - Clayey
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	4 – Clay Loam
Loamy	Freely draining slightly acid but base-rich soils	8 – Loam

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
5.4 Changes to coefficients from normal	No
6. Software	
6.1 Version	TUFLOW version 2016-03-AA-W64
6.2 Precision	Double precision used for direct rainfall modelling
6.3 Defaults	Cell wet/dry depth changed from 0.002 to 0.0002, as recommended 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	3.5 hours
7.2 Grid size	2 m
7.3 Timestep	0.5 seconds for the 2D domain and 0.25 seconds for the 1D

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) range between 2.64% and 11.93% for all scenarios
7.5 Number of messages / warnings etc.	84 warnings / 1130 checks relating to invert levels interpolation, SX ZC lowering, null shapes etc
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
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.	✓