Appendix C

MODELLING METHODOLOGY REPORT AND MODEL REPORTS

70006808-50604-TN01

MODELLING METHODOLOGY TECHNICAL NOTE

DACORUM SWMP

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DACORUM SWMP

Hertfordshire County Council

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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 Dacorum Borough 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:

- Tring (site 0)
- Berkhamsted (site 20)
- Highfield – Hemel Hempstead (site 24)
- Kings Langley (site 53)

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, Dacorum Borough Council and 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 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 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 there is 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 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.

2.2.5 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.

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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)

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. These checks established that LiDAR should be preferentially used for hotspots 24 (Highfield – Hemel Hempstead) and 53 (Kings Langley). The LiDAR will be obtained from the Environment Agency who has a significant programme of checking the data for anomalies and ground truthing.

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 I). 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. 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.

2.2.14 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 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 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. 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 – Invert level	The lowest level will be utilised or alternatively it will be interpolated from the inverts of connecting pipes.
Pit Channel – Cover 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 are 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.

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 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:

- 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

2.2.33 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).

Model Sensitivity: Catchment characteristics

2.2.35 Depending upon the outcome of the baseline modelling for Dacorum, 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.

2.2.36 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).

2.2.37 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

2.2.38 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

2.2.39 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.

2.2.40 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)

2.2.41 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.

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

HYDRAULIC MODEL REVIEW AND ACCEPTANCE

2.2.43 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.

2.2.44 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.

2.2.45 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 TRING (SITE 0)

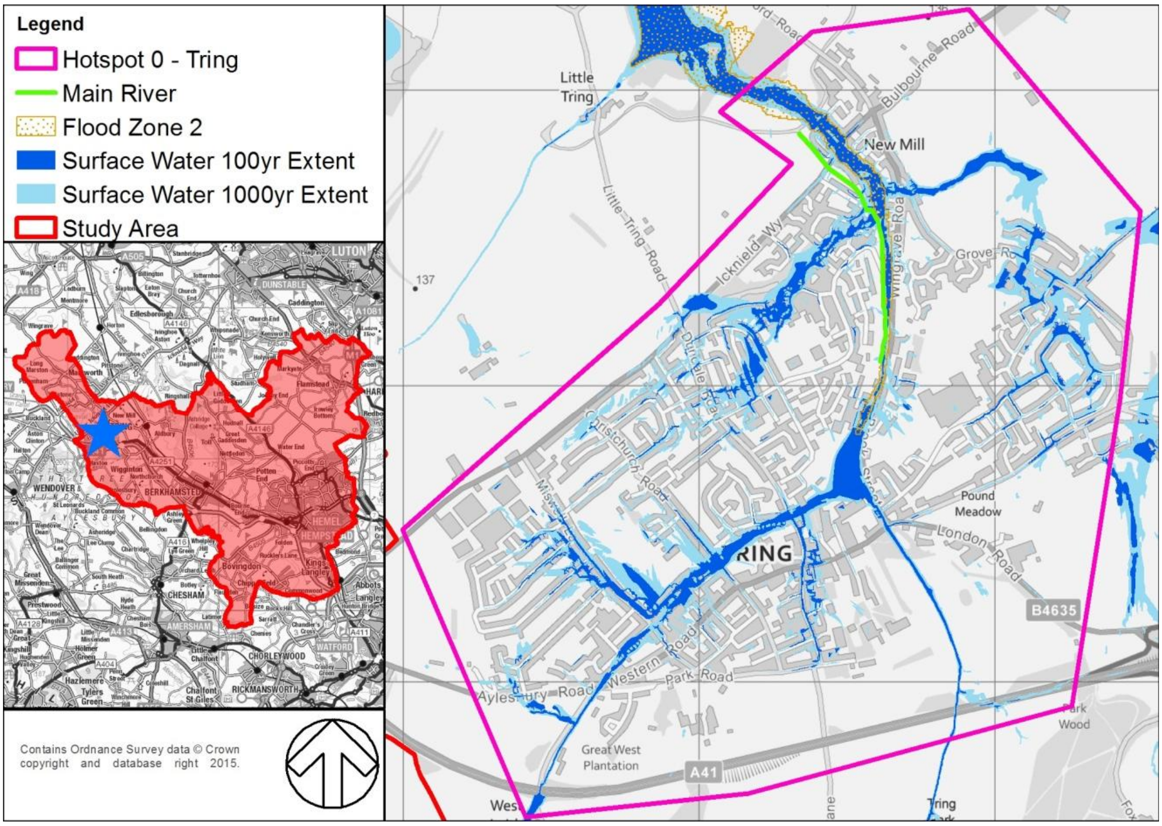
FLOOD RISK OVERVIEW

3.2.1 The Environment Agency Risk of Flooding from Surface Water map shows several areas at medium to high risk of surface water flooding within the hotspot. These include areas of surface water flooding along Brook Street (B488) with an extensive area of surface water flooding identified near Mill Gardens. The surface water flood map also shows two distinctive overland flow paths from the west and east converging to an area to the south and east of Icknield Way (B488).

3.2.2 There is an additional overland flow path entering the hotspot along the southern hotspot boundary through what appears to be a highway/culvert underneath the A41 dual carriageway, this flowpath joins the flow path coming from the west near Mill Gardens. This flow path is considered to be a result of the lower resolution of the NEXTMap data, as reviews of imagery of the area around the Robin Hood public house on the junction of the B4365/London Road and the B488 indicate that waters are unlikely to reach the highway. This is because the local topography shows depressions behind a solid wall, after which the topography grades to the east and provides further areas for ponding.

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 EA hold flood mapping for the central area of Tring and there are no significant surface water flow paths in this area, this section has been discounted from further modelling.

3.2.4 The flow path along the north western boundary (which is an ordinary watercourse from the pond north of Eggleton Drive) has been discounted from requiring further modelling as much of this flowpath is through a green area with ponds, which would provide further attenuation.



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AVAILABLE INFORMATION AND DATA GAPS

3.2.5 The modelling will therefore encompass the south western ordinary watercourse and flow path until the pond immediately north of Mill Gardens. The topographical data for the model would ideally consist of LiDAR data where available and NEXTMap data where LiDAR is missing However, given that LiDAR only exists for the northern part of the hotspot which is of less interest to the stakeholders, given the previous modelling and that there are major discrepancies between the LiDAR and the uFMfSW DTM (differences in height of ±2m) two models will need to be developed to avoid significant reprofiling or jumps in height. The uFMfSW DTM is to be adopted for a hotspot wide model, with flows extracted at pertinent locations on the key flow paths and used as inflows to a inset model based upon LiDAR to provide higher accuracy for the central area.

3.2.6 Thames Water sewer asset data is available for the catchment and held by WSP | Parsons Brinckerhoff.

3.2.7 It is anticipated that additional topographical survey may be required to provide input to the model. However, as no open watercourses are shown in the area to be modelled on the OS mapping, it is expected that survey will be limited to the area around the pond and the downstream culvert, which discharges into the head of the ordinary watercourse.

PROPOSED MODELLING APPROACH

3.2.8 The proposed modelling will be undertaken in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach. For the uFMfSW model a 4*4m grid will be adopted, given the resolution of the NEXTMap data.

3.2.9 The 2D model will include the pond, providing connectivity of the pond with the drainage network is confirmed and information on the inlet/outlet features is made available, pond features will be linked to the modelled network as appropriate.

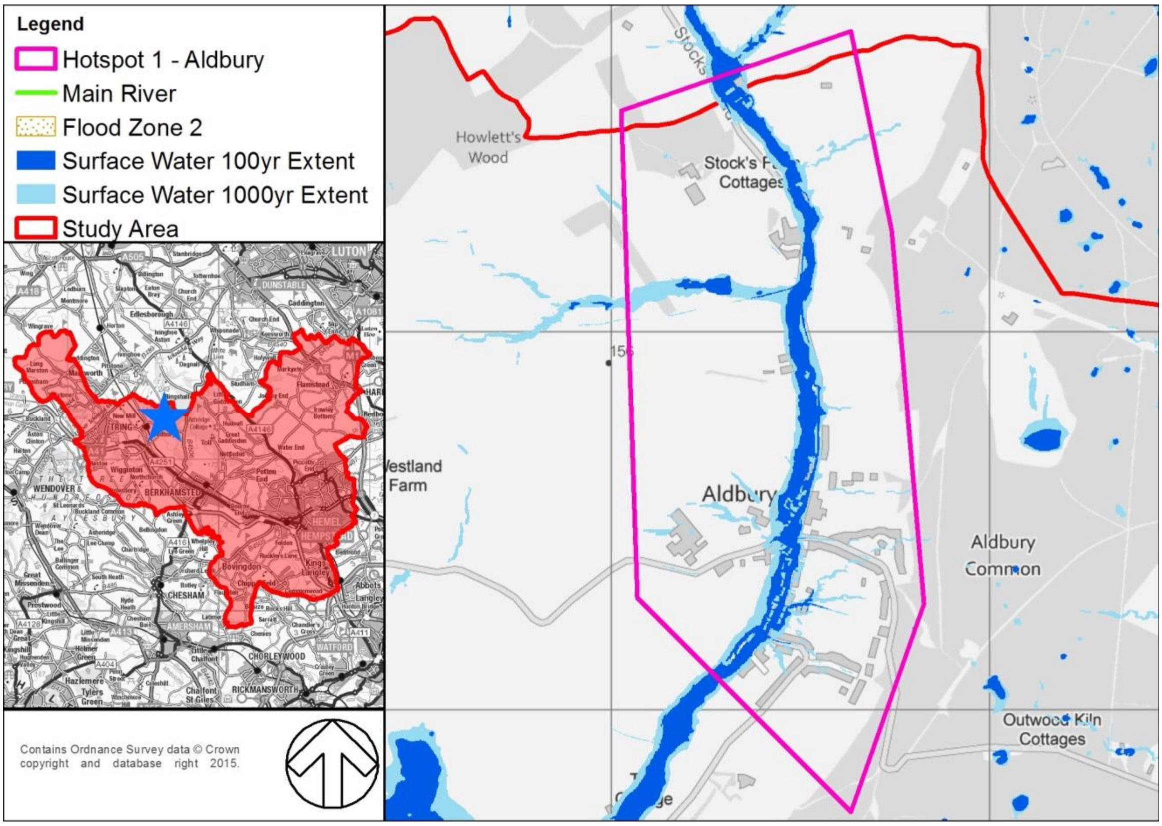
The downstream boundary of the model will be set as the outfall from the culvert (i.e. adjacent to Tring Community Centre), this will be a normal boundary based on free flow.

3.3 ALDBURY (SITE 1)

FLOOD RISK OVERVIEW

3.3.1 There are no records of historical flooding within this hotspot. The Environment Agency Risk of Flooding from Surface Water Map shows that a significant surface water flow path is expected to occur on and off the highway into and out of the village of Aldbury.

3.3.2 This hotspot was selected to investigate how a better representation of the preferential flow paths could be obtained in rural areas and what measures could be considered and installed to manage or reduce the risks of flooding.



AVAILABLE INFORMATION AND DATA GAPS

3.3.3 No detailed topographical information is available.

PROPOSED MODELLING APPROACH

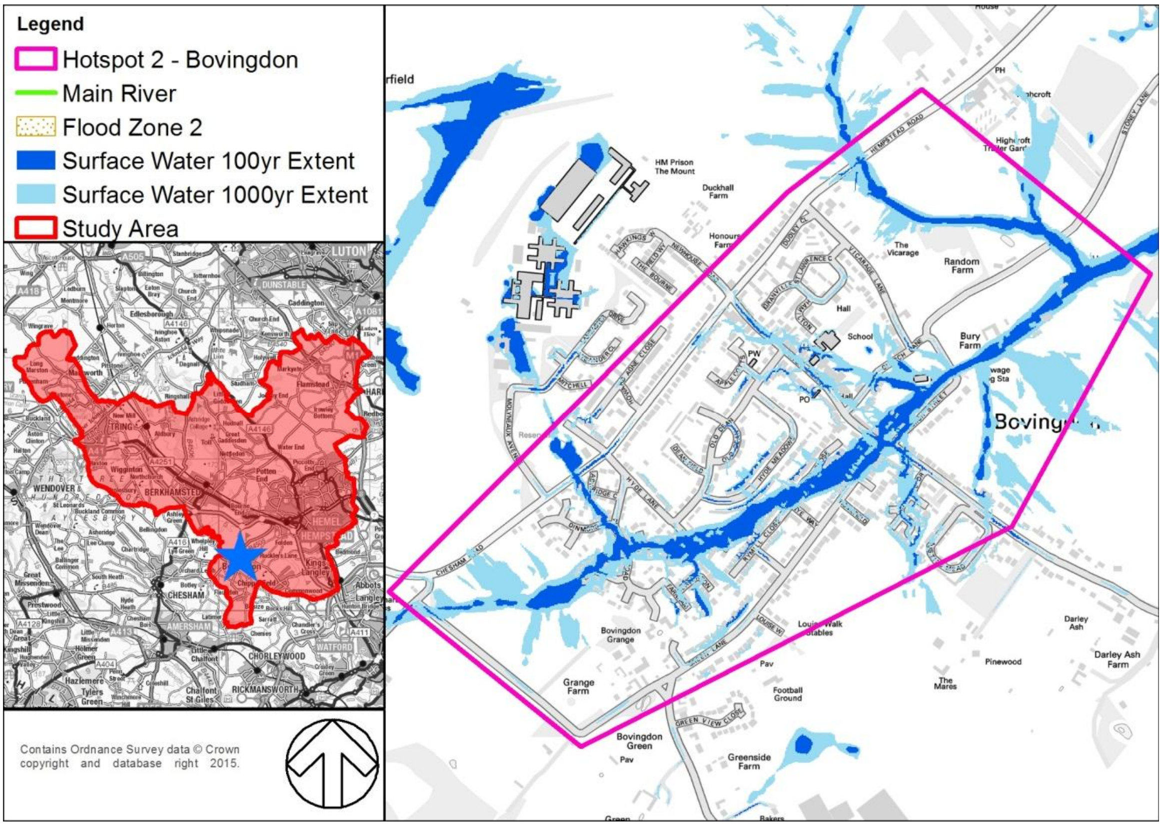
As no LiDAR is available to enable hydraulic modelling to be undertaken that would provide any improvement over the existing flood outlines, an extensive topographical survey of the highway and agricultural land as well as the village would be required. It is therefore considered not to be cost effective to model this hotspot, given the extensive topographical data that would be required and the lack of historical flooding information, when little improved understanding would be gained over the current Environment Agency Risk of Flooding from Surface Water Map.

3.4 BOVINGDON (SITE 2)

FLOOD RISK OVERVIEW

3.4.1 The Environment Agency (EA) Risk of Flooding from Surface Water map shows that surface water flooding is predicted to occur across Bovingdon. However, the stakeholders were not aware of any records of flooding in this location and there is no LiDAR coverage.

3.4.2 It is considered likely that the NEXTMap data (used in the EA's Risk of Flooding from Surface Water modelling) is showing an over representation of the likely flood outline, given that the catchment is largely chalk and has an extensive surface water sewer system that drains to boreholes and tanks. These have been installed in the past to reduce flood risk.



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AVAILABLE INFORMATION AND DATA GAPS

3.4.3 No LiDAR or alternative data exists for this hotspot; extensive topographical survey would therefore be required.

3.4.4 Thames Water sewer asset records are available.

PROPOSED MODELLING APPROACH

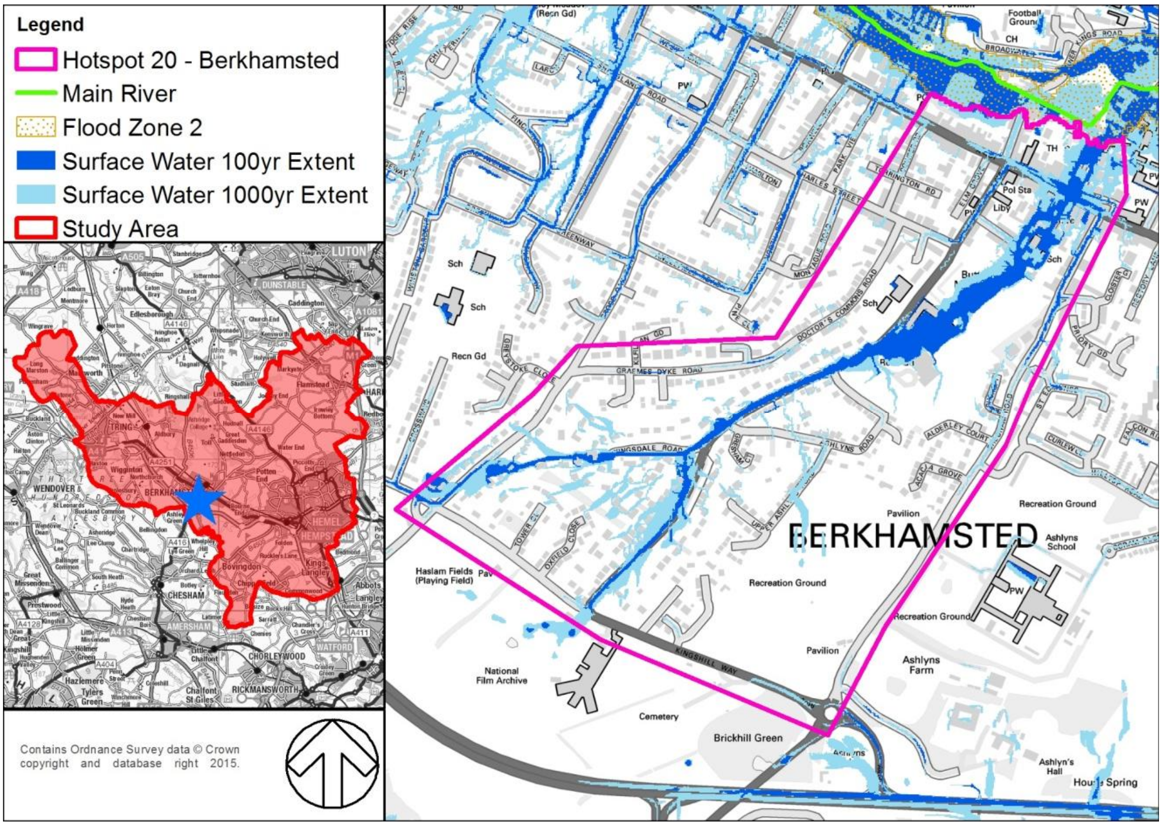
The original aim was to take this hotspot forward to provide an increased understanding of the flood risk within a relatively flat catchment. However, based on the cost and time implications of undertaking an appropriate terrain (topographic) survey, it was decided not to progress this hotspot further at this stage.

3.5 BERKHAMSTED (SITE 20)

FLOOD RISK OVERVIEW

3.5.1 The Environment Agency Risk of Flooding from Surface Water map shows that the preferential flow path for surface water diverges from Kings Road (A416) towards the location of Berkhamsted School. The stakeholders decided that it was important to understand the accuracy of this diversion given the grade on the road and the implications of this to be repeated in other locations across the county. Along with the ability of householders to protect themselves, should further more detailed modelling demonstrate that the properties at risk of flooding are actually elsewhere.

3.5.2 The main aim of undertaking hydraulic modelling in this location is to refine the understanding of the approach to interpreting the national strategic scale surface water flood mapping on a local scale, and the associated risks. Therefore, this modelling is to focus on the representation and associated accuracy of the flood waters leaving Kings Road (A416) (shown in the figure below) and flowing through the school, assessing if the water remains on the highway or flows into the school as currently suggested.



AVAILABLE INFORMATION AND DATA GAPS

3.5.3 The topographical data for the model will consist of the uFMfSW as it combines the most appropriate LiDAR data. LiDAR is only available from approximately Ashlyns Road to the hotspot's boundary north of the High Street (A4251). NEXTMap data, where LiDAR data is missing, is used within the uFMfSW where flow conveyance rather than risk identification is required.

3.5.4 Additional topographical survey will be required to provide input to the model. However, as no open watercourses are shown on the OS mapping within the hotspot, it is expected that survey will be limited to the area around the school and the highway to provide additional street specific information to confirm the preferential flow path routes.

PROPOSED MODELLING APPROACH

3.5.5 The proposed modelling will be undertaken in accordance with Section 2.2 and will use ESTRY-TUFLOW with a direct rainfall approach. The uFMfSW DTM will be used as this include the most recent LiDAR supplemented by NEXTMap) and site specific survey to gain the local details of specific flow routes into the school.

3.5.6 The 2D model will focus on demonstrating the flow routes and potential for mitigation within the school grounds should the modelling demonstrate that the flow routes remain the same. If they do not remain the same, then the 2D sections of the model will enable potential future mitigation measures to be targeted more effectively.

3.5.7 The downstream boundary of the model will be set using river levels from the existing Environment Agency model of the River Gade.

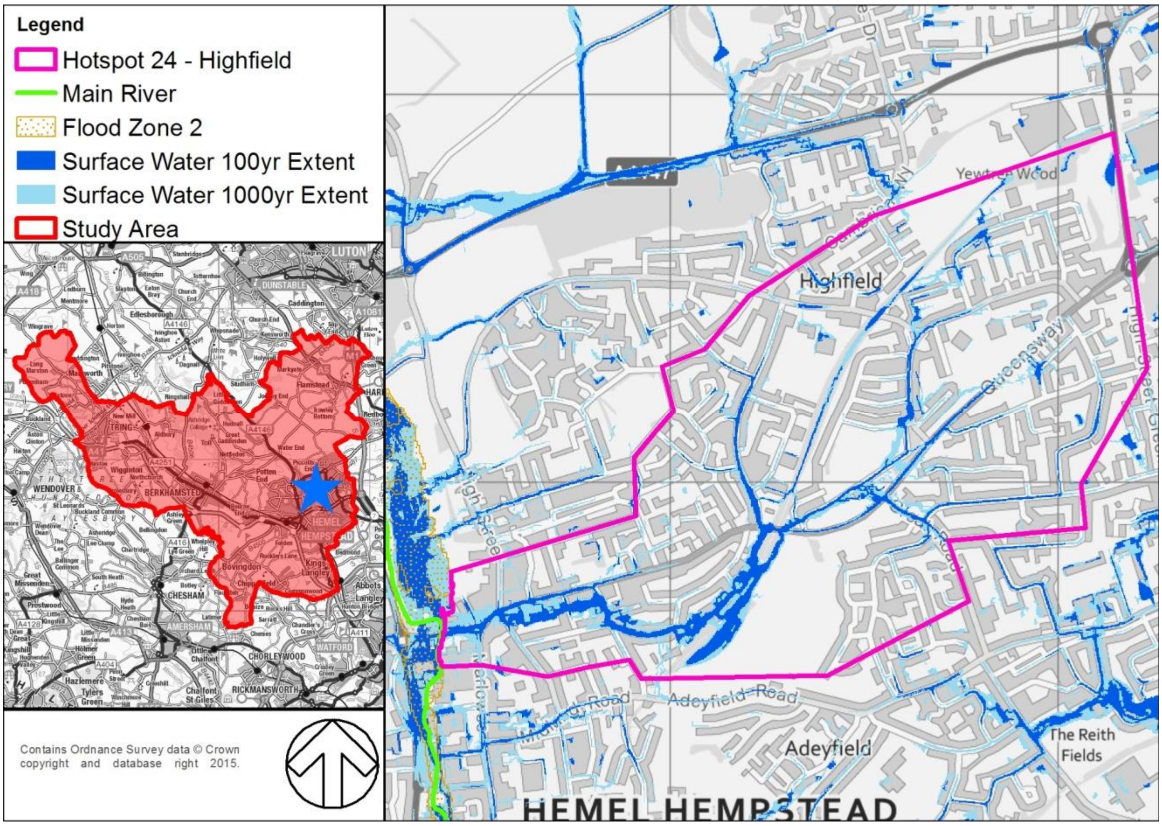
3.6 HEMEL HEMPSTEAD (SITE 24)

FLOOD RISK OVERVIEW

3.6.1 During the stakeholder meeting Hemel Hempstead was prioritised as a location which should be included for consideration for further assessment.

3.6.2 The published Environment Agency Risk of Flooding from Surface Water maps demonstrate a medium to high risk of surface water flooding from overland flow paths across the hotspot, these are shown to utilise the highway network as preferential flow paths and spill into residential areas south of Queensway (B487) and the disused railway crossing (The Nickey Line). There is also an Environment Agency mapped fluvial floodplain (Flood Zone 2) to the west of the hotspot (forming the downstream boundary).

3.6.3 In addition, there may be a risk of locking of the surface water sewer system as the water levels within the River Gade rise during a flood event potentially preventing surface water runoff to discharge at normal rates.



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AVAILABLE INFORMATION AND DATA GAPS

3.6.4 The focus of this model is not in the vicinity of the River Gade (Main River); therefore maximum flood depths from the Environment Agency hydraulic model/flood map for planning will be used.

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

3.6.6 Thames Water sewer asset data has been obtained for this hotspot site.

3.6.7 Topographical survey will be required to provide input to the hydraulic model. In particular, this may include further details on the highway junctions and kerb levels around Queensway (B487) and the disused railway particularly at their intersection.

PROPOSED MODELLING APPROACH

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

3.6.9 Topographical data for the model will consist of LiDAR data for the majority of areas supplemented with topographical survey and NEXTMap.

3.6.10 The downstream boundary of the model will be set using river levels from the existing Environment Agency model of the River Gade.

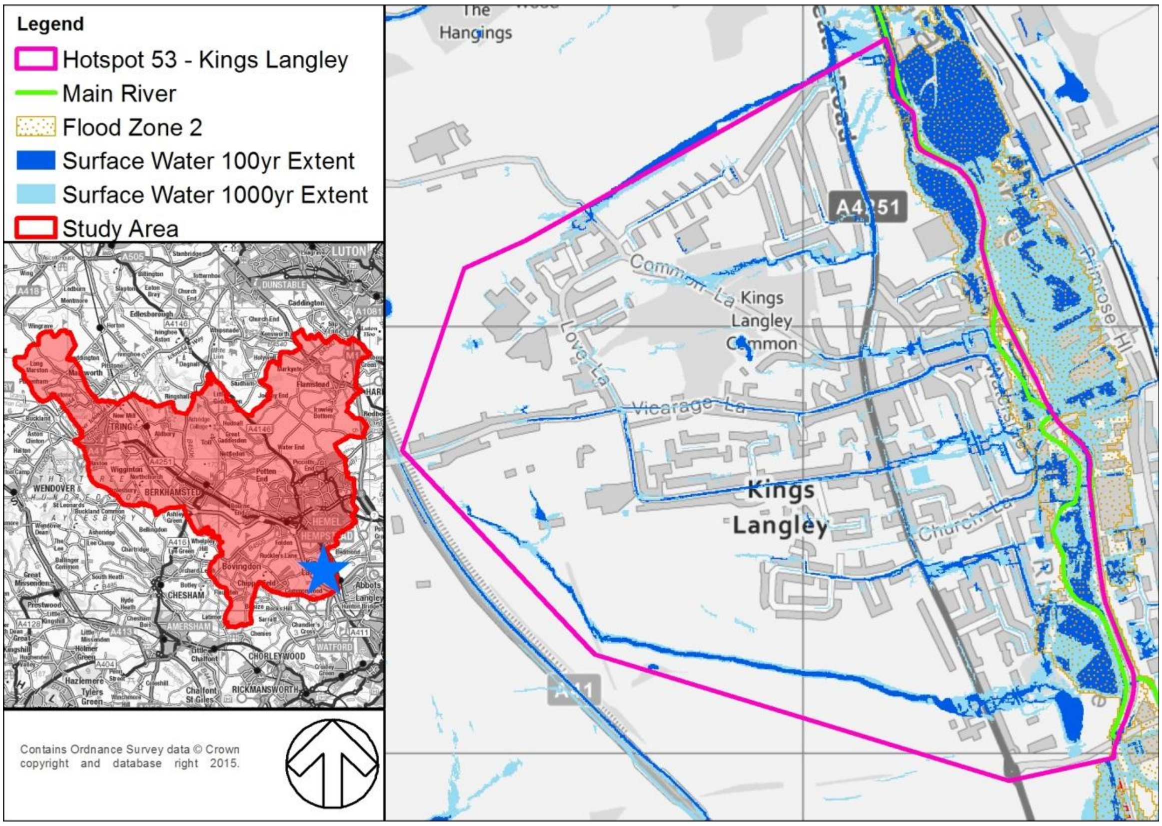
3.7 KINGS LANGLEY (SITE 53)

FLOOD RISK OVERVIEW

3.7.1 During the stakeholder meeting Kings Langley was identified as a location which is subject to flooding and should be included for consideration for further assessment.

3.7.2 The published Risk of Flooding from Surface Water maps demonstrate a medium to high risk of surface water flooding from overland flow paths across the hotspot, these are shown to utilise the highway network as preferential flow paths. There is also an Environment Agency mapped fluvial floodplain (Flood Zone 2) to the east of the hotspot (forming the downstream boundary).

3.7.3 In addition, there may be a risk of locking of the surface water sewer system as the water levels within the River Gade / Grand Union Canal are controlled, and so may affect the ability of surface water runoff to get into the system during flood events.



AVAILABLE INFORMATION AND DATA GAPS

3.7.4 We understand that the Environment Agency have a hydraulic model for the River Gade which can either be used as a downstream boundary or should further detail need to be incorporated within the model, then a suitable reach will be adapted for use within this model (e.g. an ISIS-TUFLOW model).

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

3.7.6 Thames Water sewer asset data has been obtained for this hotspot site.

3.7.7 Depending upon the detail included within the model, additional topographical survey may be required to provide input to the model. In particular, this may include further details on the highway junctions along Hempstead Road (A4251) and areas around the interactions with the River Gade/Grand Union Canal.

PROPOSED MODELLING APPROACH

3.7.8 The downstream boundary of the model will be set using river levels from the existing Environment Agency model of the River Gade.

3.7.9 The surface water sewers will also be incorporated in accordance with the Generic Modelling Approach detailed in Section 2. The model will be run as a direct rainfall model with an upstream boundary on the river extracted from the existing model, alternatively the surface water outfalls will be modelled with a set stage should they discharge into a controlled watercourse.

3.7.10 Topographical data for the model will consist of LiDAR data.

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
Tring (site 0)	🟧	🟩	▨
Aldbury (site 1)	🟥	Not to be taken forward	
Bovingdon (site 2)	🟥	Not to be taken forward	
Berkhamsted (site 20)	🟧	🟩	Draft outputs of the Environment Agency's Gade and Bulbourne modelling (2015) were used as downstream boundary
Hemel Hempstead (site 24)	🟩	🟩	Draft outputs of the Environment Agency's Gade and Bulbourne modelling (2015) were used as downstream boundary
Kings Langley (site 53)	🟩	🟩	Draft outputs of the Environment Agency's Gade and Bulbourne modelling (2015) were used as downstream boundary

Key

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

Appendix I

TOPOGRAPHICAL SURVEY SPECIFICATION

SURVEY BRIEF COVERSHEET

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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

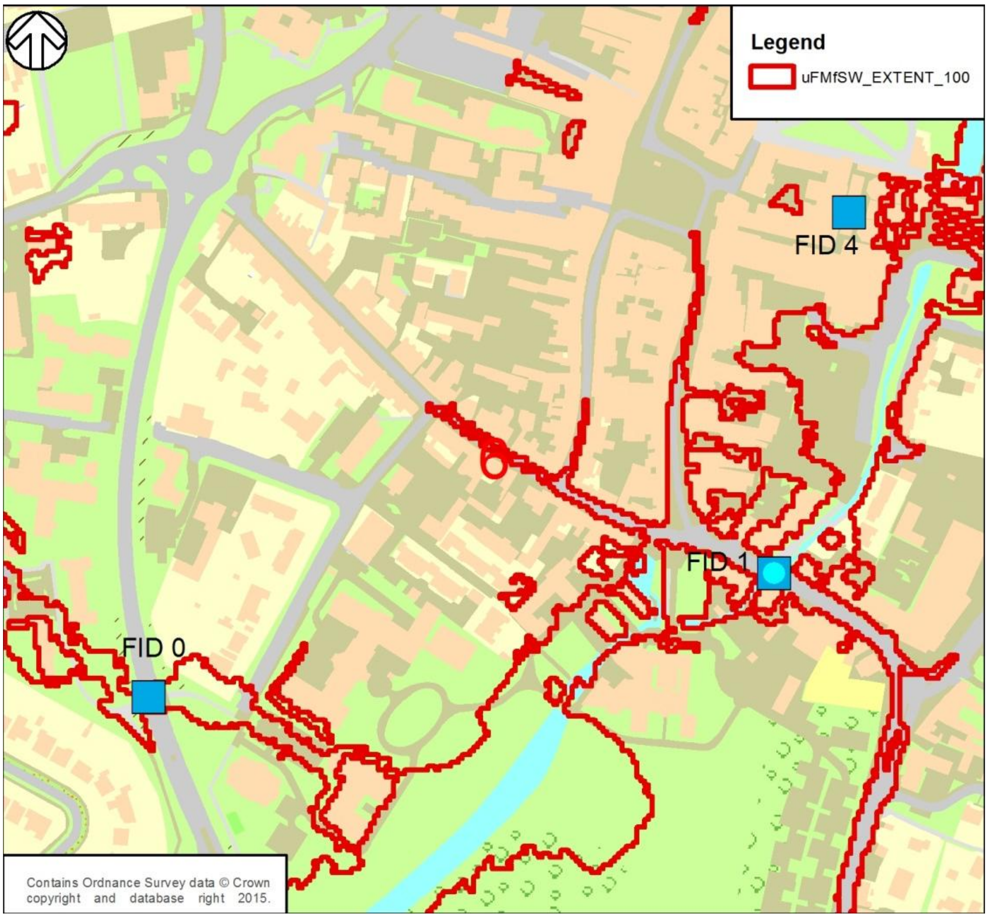
This document outlines the key requirements of the survey for which we require a competitive quotation for your services. It must be read in conjunction with WSP standard specifications for watercourse survey (in particular refer to the accompanying document named "*WSP RICS Jan 2013 ISSUED - Annex K 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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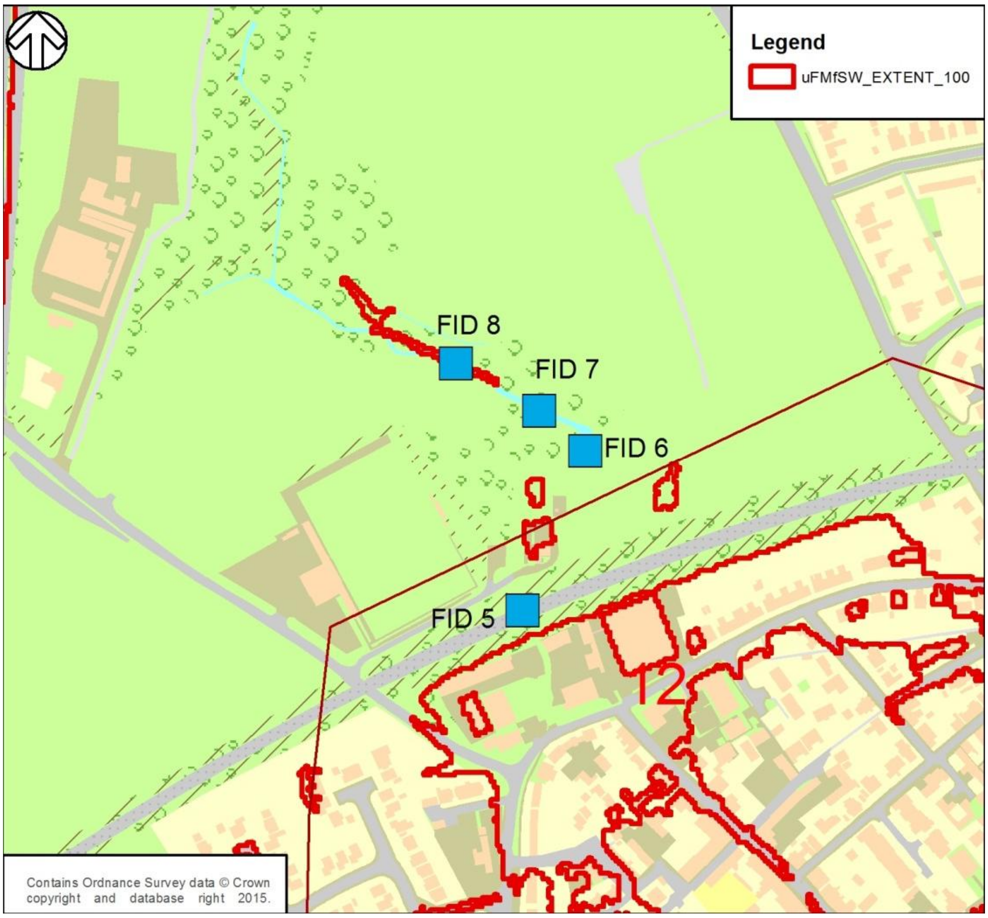
Baldock



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

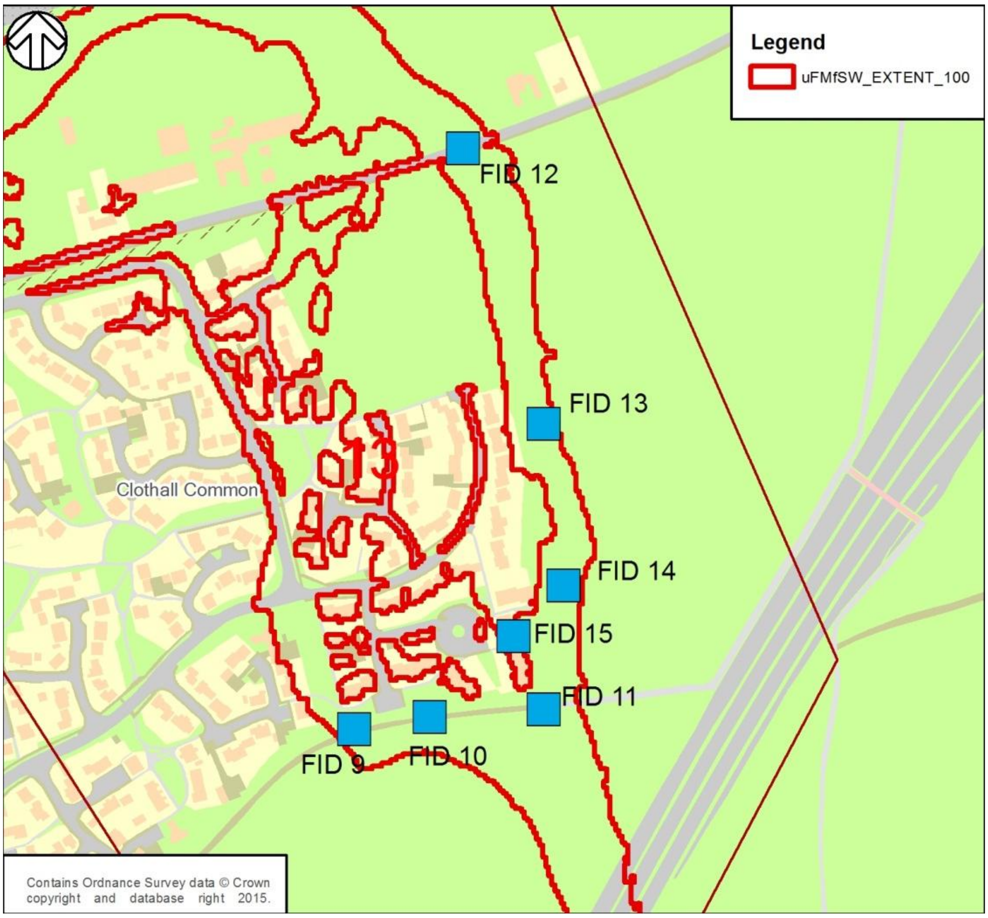
FID 5 (footpath from Icknield Way): Details on the footpath beneath the railway upstream and downstream dimensions

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

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

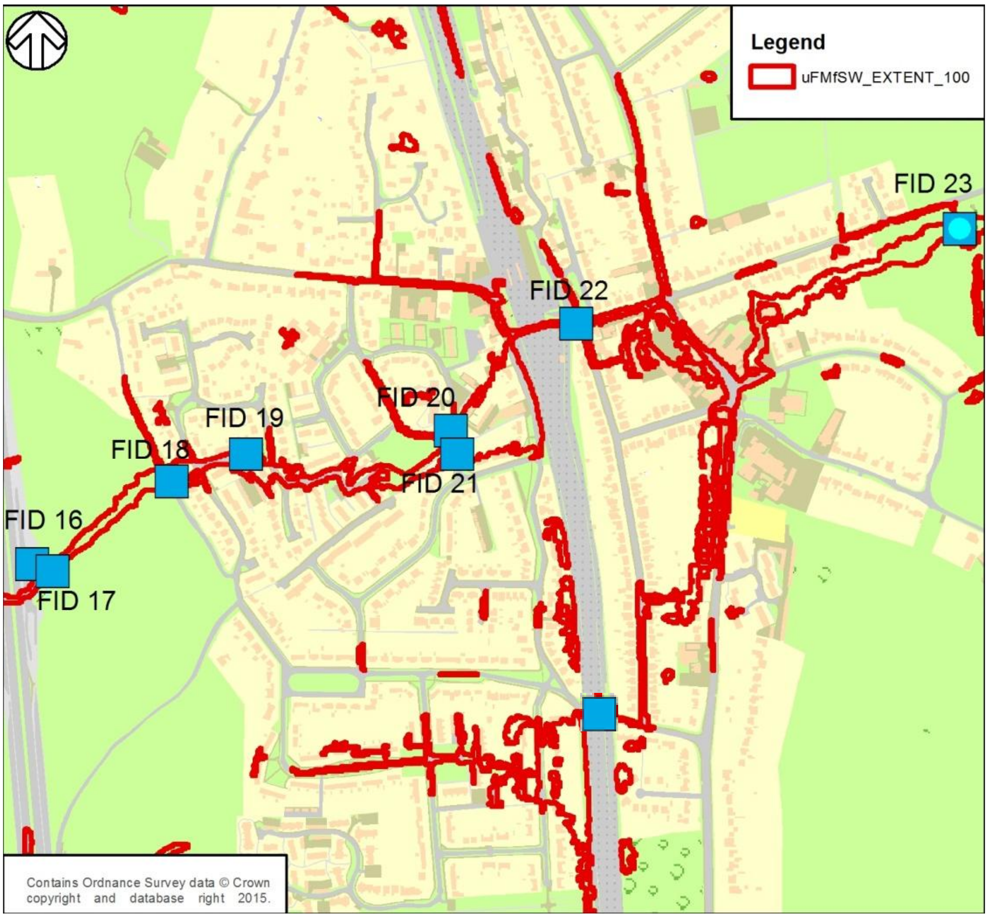
FID 14: Swale cross section

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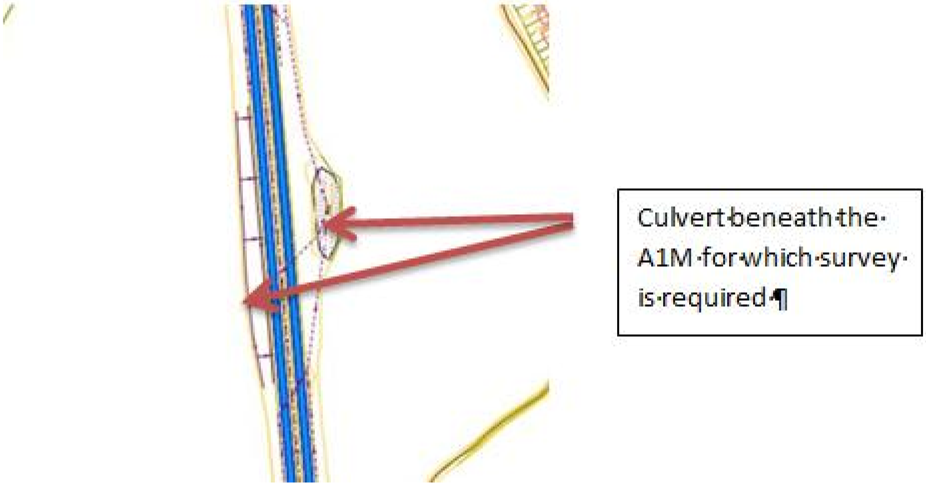
The approximate grid reference for the railway station is 524925, 220263.

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

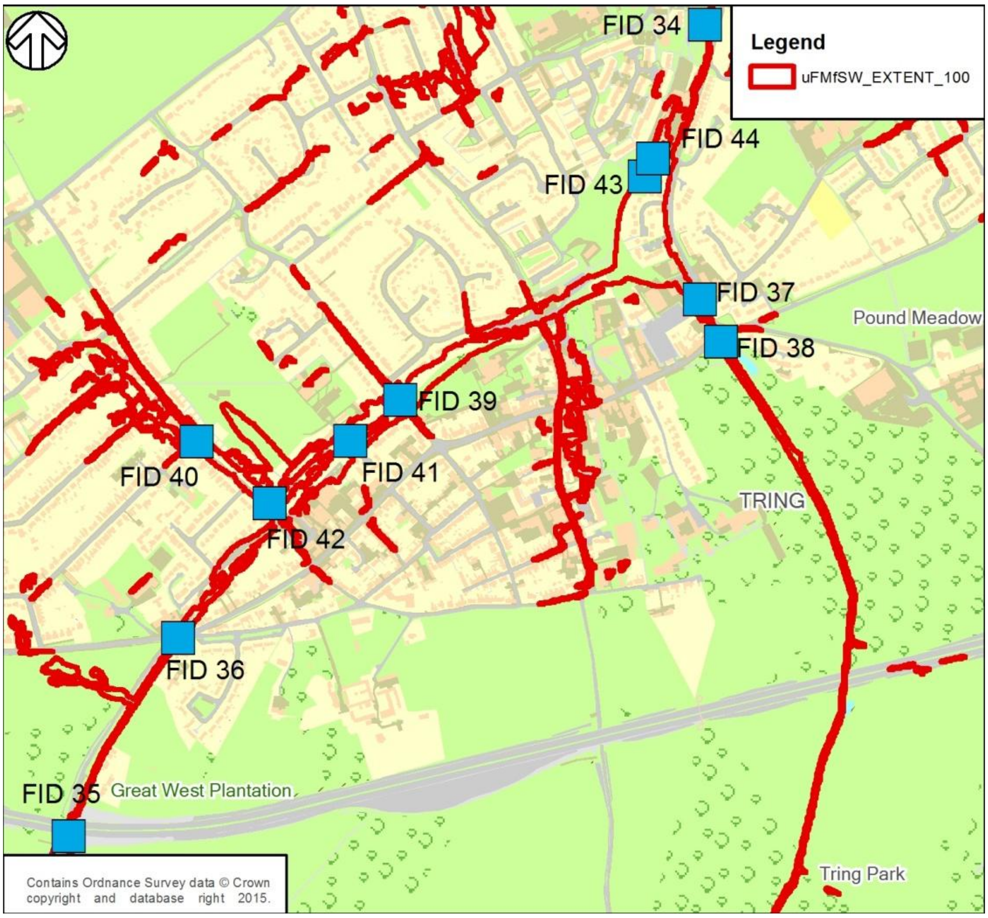
FID 22 (Station Road): Details on both faces of railway crossing width, soffit, road and invert levels

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

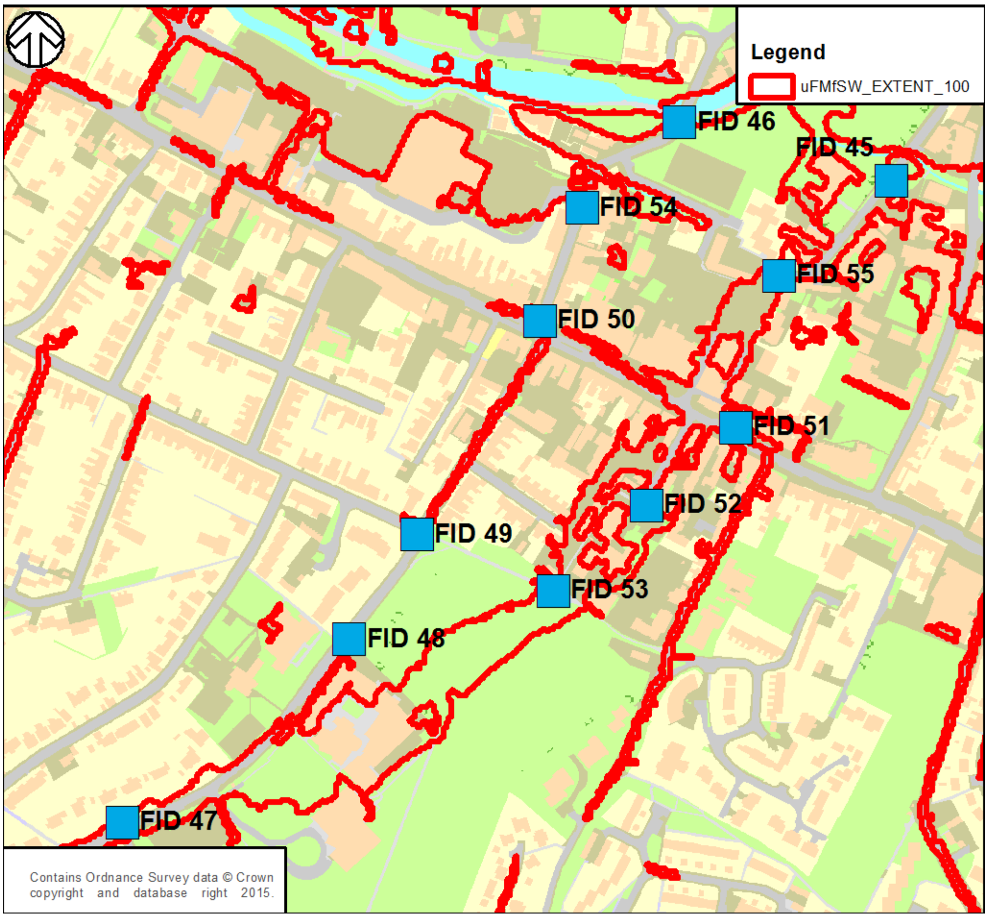
FID 41 not required at this stage

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

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

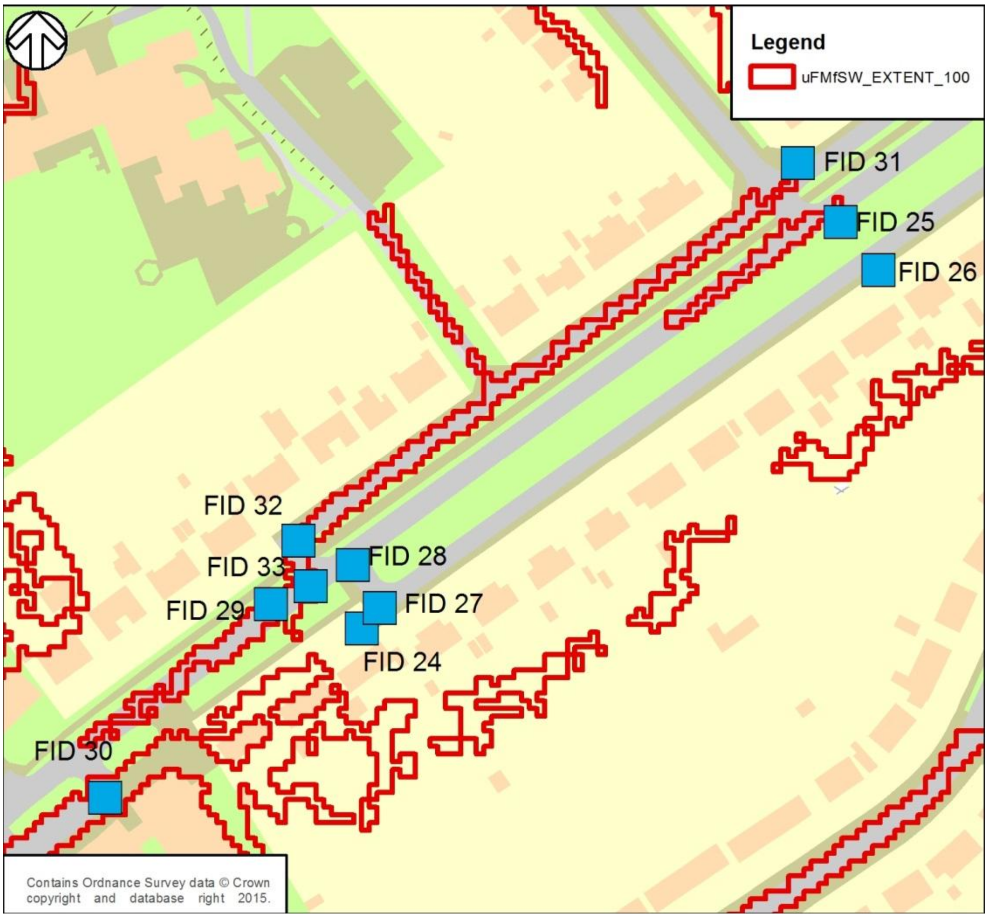
FID 52: Not required at this stage

FID 53: Ground levels along school boundary

FID 54 Not required at this stage

Survey Brief Continuation

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

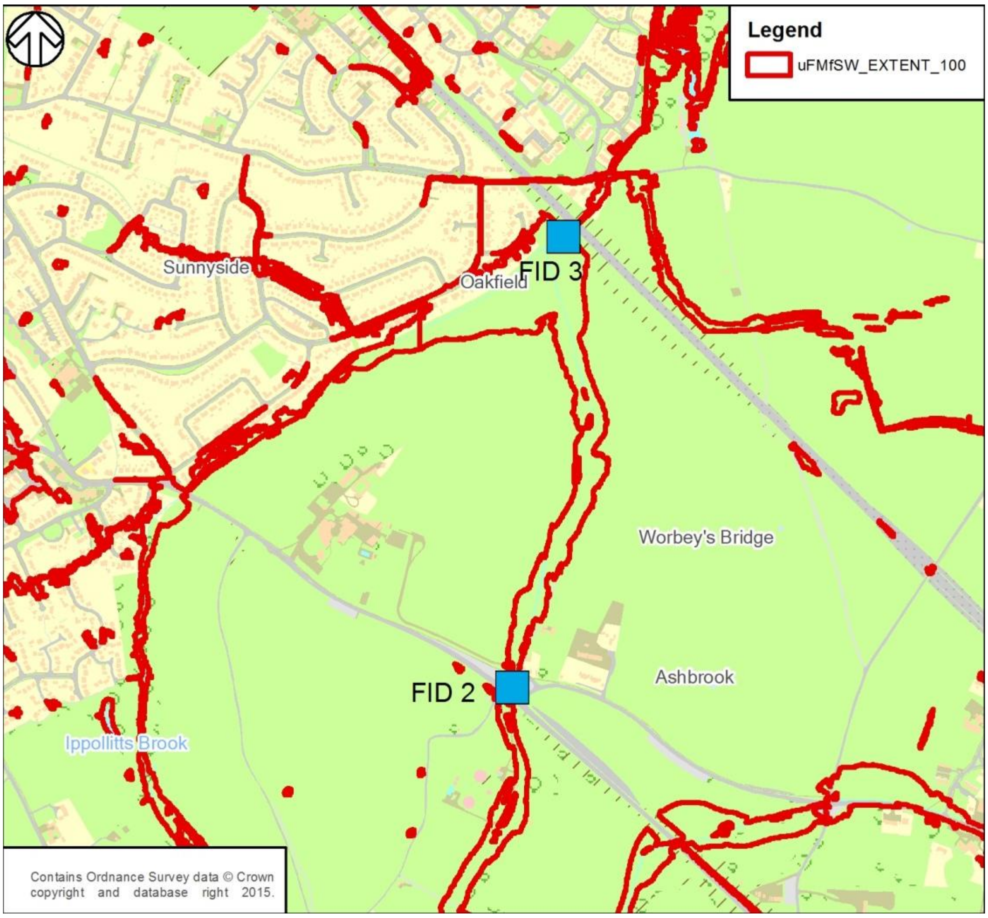
FID 31: levels on the highway and kerb

FID 32: levels on the highway and kerb

FID 33: levels on the highway and kerb

Survey Brief Continuation

Oakfield



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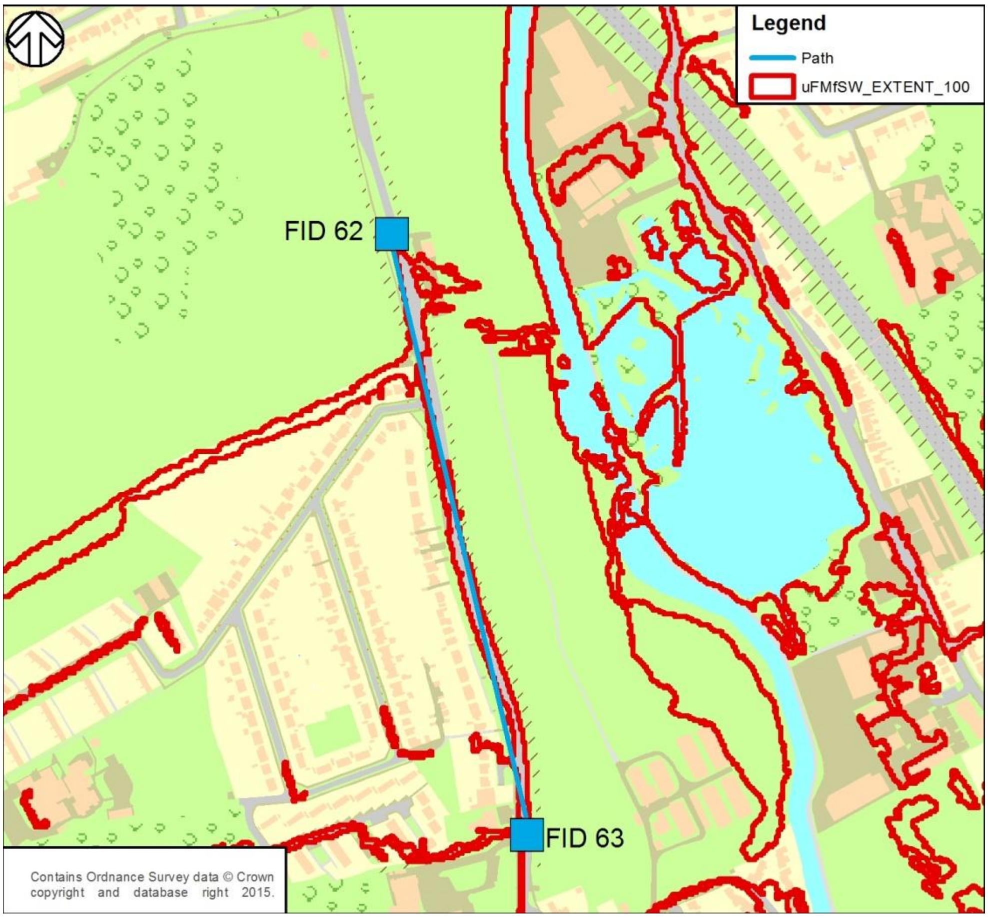
The approximate grid reference for the study area (FID3) is 520306, 228682.

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

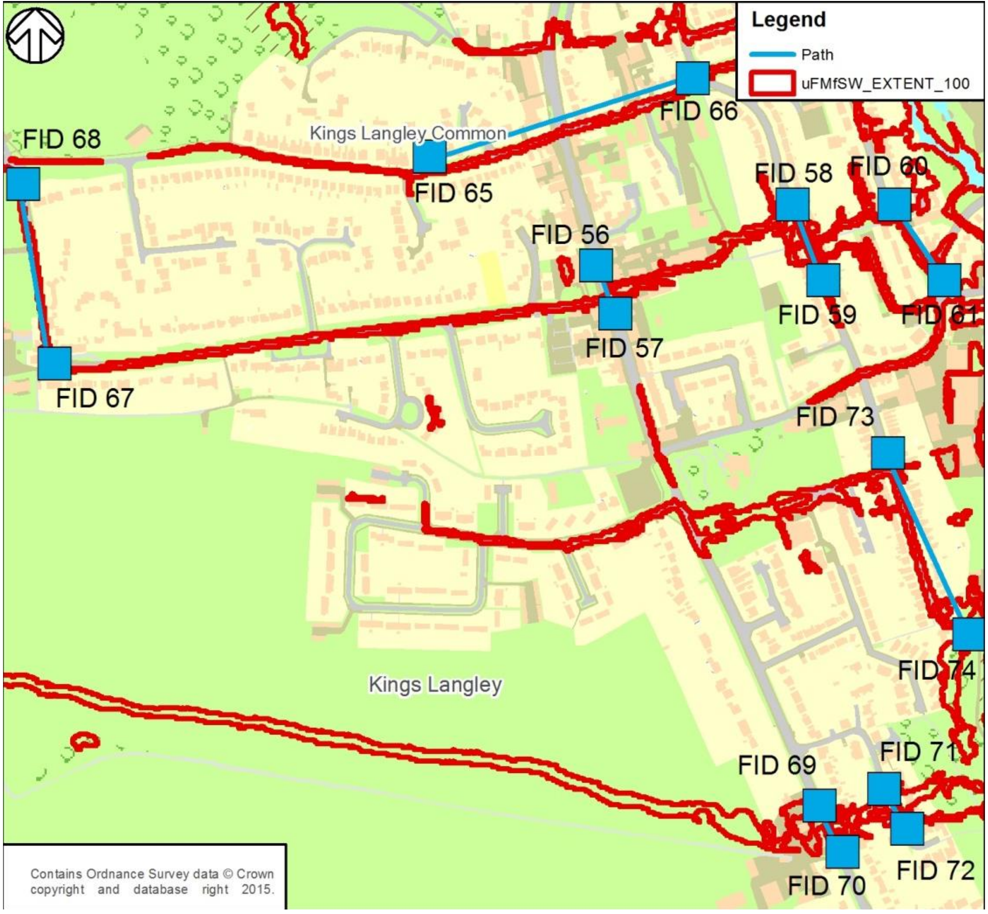


The approximate grid reference for the centre of the study area is 507502, 202504.

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



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

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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 0

TRING

Modeller:	M Grabowiecka	05-07-2016
Reviewer:	A Chowdhury	07-07-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The modelling is based on a two-phased approach. The objective was to create two separate models to be run in cascade and using variable grid resolution to achieve the desired level of accuracy across the various parts of the model domain whilst maintaining reasonable model run times. The Phase 1 model is a coarse resolution (4m grid cell size) 2D ESTRY-TUFLOW model for the whole catchment to simulate overlandflow patterns contributing to surface runoff towards the hotspot area and to accurately estimate the overland flows that are conveyed through the southern boundary of the hotspot model. The Phase 2 model is a fine resolution (2m grid cell size) 1D-2D ESTRY-TUFLOW model focusing on the hotspot area with flow outputs from the Phase 1 model being used as boundary conditions to this more detailed model. The topographical input of the Phase 1 model is based on the UfMfSW DTM whilst the Phase 2 model is based on a DTM built using 1m LiDAR data. This choice was dictated by the fact that 1m LiDAR being was made available only on the northern part of the catchment. A 1d network layer was incorporated into the Phase 1 model to enable the representation of the bypass road underneath the A41 to the south of the hotspot.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot_0_NorthHerts_~s1~_~e1~_~e2~_003.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 4_65hr: 465hr 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. “Hotspot_0_NorthHerts_~s1~_~e1~_~e2~_003”
2. 2D Reference data	
2.1 Final DEM	1m LiDAR was used for the hotspot.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2.2 Changes to DEM	Surveyed levels were used to create Triangular Irregular Networks (TINs) in specific areas of the model: • SURVEY_TIN_CLIP_convert.asc Z-shape polygons were used to raise buildings footprint 300mm above the underlying DTM; a z-shape layer was also created to lower roads by 125mm (the height of a kerb as derived from British Standard). • 2d_za_Hotspot0_NorthHerts_buildings_+300mm.shp • 2d_za_Hotspot0_NorthHerts_roads_-125mm.shp At the downstream end of the model, a Z-line was used to lower the elevation of 2D cells along the ditch to the west of the Gran Union Canal; this was to enable flow release from the pipe network into the 2D modelled floodplain ; • 2d_z_bed_Hotspot0_NorthHerts_01_L.shp • 2d_z_bed_Hotspot0_NorthHerts_01_P.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 Layers: • 1d_nwk_Hotspot0_NorthHerts_12_L.shp, and • 1d_nwk_pitchannels_Hotspot0_NorthHerts_10_v2_P.shp
3.2 Watercourse Structures	No 1d open channel represented within the model.

MODEL ELEMENT **ACTION TAKEN DURING MODELLING**

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)	11	17	19	24	26	37	50
Total rainfall (mm)	20	30	34	44	47	66	90
Storm duration (hr)	4.65						
QT1 (m^3/s)	0.0002	0.0005	0.001	0.478	0.824	3.070	9.365
QT1 (m^3/s)	0.119	0.234	0.281	0.483	0.671	1.825	3.583
QT1 (m^3/s)	0.004	0.015	0.021	0.051	0.103	0.555	1.122

A series of PO lines were added to the Phase 1 TUFLOW model to intercept overland flows derived from the upper catchment. Flows are intercepted upstream of the hotspot area with PO lines being drawn along the southern boundary of the Phase 2 model. This allowed a series of flow hydrographs to be used as hydrological input of the Phase 2 model.

4.2 Downstream boundaries

The downstream boundary condition is based on a head versus flow boundary unit that was applied to a section along the north-west corner of the 2D model domain. This was to enable flow release from the 2D model. The head versus flow curve adopted is automatically generated from TUFLOW on the basis of the terrain slope defined by the user (based on available LiDAR data)

4.3 Historical records of flooding

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

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
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 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
Loamy	Shallow lime-rich soils over chalk or limestone	8 – Loam
Loamy	Freely draining slightly acid but base rich soils	8 – Loam
Loamy some Clayey	Slightly acid loamy and clayey soils with impeded drainage	4 – Clay Loam

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	8 hours
7.2 Grid size	2 m
7.3 Timestep	2D time step: 0.5 second , 1D time step: 0.25 second
7.4 Mass balance check	Peak Cumulative Mass Balance errors (Qi+Qo > 5%) in different event scenarios range between -1.69% and 0.28 %
7.5 Number of messages /	102 warnings/ 188 checks relating to geometry changes within the model, sx zc lowering etc

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
warnings etc.	
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	
8.5 Pipe size	Sensitivity was undertaken to assess the impact of varying on the size of the outlet pipe from the pond located near Mill Gardens; as part of this, pipe diameter was changed from 100mm to 750mm. Model results show no significant impact in flood levels; this was expected as the 100mm diameter pipe from the pond was shown to convey only 13% of its maximum capacity at the peak. The table below 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..

Change in levels (m)	
Max	0.003
Min	-0.022
Mean	0.000
Standard Deviation	0.000

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 20

BERKHAMSTED

Modeller:	L. Ramirez	15-04-2016
Reviewer:	P. Harrison	18-04-2016

MODEL ELEMENT	**ACTION TAKEN DURING MODELLING**
1. General	
1.1 Variations to agreed Methodology	The downstream boundary of the model has been set using the draft levels outputs of the Environment Agency's Gade and Bulbourne modelling (2015), as these was the best information available at the time of building the model. 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 Hotspot20_Dacorum_~s1~_~e1~_~e2~_v26.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 0.9hr: 0.9hr 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. "Hotspot20_Dacorum_Baseline_0.9hr_Q0100_v26"

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 – tile sp90ne.
2.2 Changes to DEM	Surveyed levels were used to create Triangular Irregular Networks (TINS) in specific areas of Kings Road, A4251 and Mills Street: • Survey_levels_1m_grid_trimmed_Hotspot20_v11_converted3.asc The uFMfSW DTM represented roads lowered by 0.125m (*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, this principle was adopted for this model. • 2d_z_Survey_levels_Hotspot20_Dacorum_v19.shp A zline was used to represent the footpath to the north of Butt Meadows: • 2d_zln_footpath_Hotspot20_Dacorum_v12_L.shp | 2d_zln_footpath_Hotspot20_Dacorum_v12_P.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 Layers: • 1d_nwk_TW_Hotspot20_Dacorum_v26_L.shp • 1d_nwk_pitchannels_Hotspot20_Dacorum_v26_P.shp • 1d_nwk_pitchannels2_Hotspot20_Dacorum_v25_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.

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td colspan="2">4. Hydrology</td></tr>
<tr><td>4.1 Inflow boundaries</td><td>
<table>
<tr><th></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>76</td><td>122</td><td>139</td><td>186</td><td>204</td><td>286</td><td>425</td></tr>
<tr><td>Total rainfall (mm)</td><td>20</td><td>32</td><td>36</td><td>49</td><td>53</td><td>74</td><td>111</td></tr>
<tr><td>Storm duration (hr)</td><td colspan="7">0.9</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 for the River Bulbourne; extracted from the Environment Agency River Gade draft model (defended scenario)</td></tr>
<tr><td>4.3 Historical records of flooding</td><td>Environment Agency Recorded Flood Outlines show no recorded events in the area.</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>
<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>
</table>

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 all the Green-Ampt Soil Type used in the TUFLOW 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
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	4 – Clay Loam

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, XMDF – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	2.24 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. 56% and -0.65% for all scenarios.

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td>7.5 Number of messages / warnings etc.</td><td>38 warnings/ 246 checks relating to invert levels interpolation, SX ZC lowering, null shapes 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</td><td>
<table>
<tr><th colspan="3">Change in levels (m)</th></tr>
<tr><th>Change in roughness</th><th>-20%</th><th>+20%</th></tr>
<tr><td>Max</td><td>0.061</td><td>0.063</td></tr>
<tr><td>Min</td><td>-0.086</td><td>-0.045</td></tr>
<tr><td>Mean</td><td>-0.001</td><td>0.001</td></tr>
<tr><td>Standard Deviation</td><td>0.005</td><td>0.004</td></tr>
</table>
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 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>
<tr><td>8.4 Runoff coefficients</td><td></td></tr>
<tr><td>8.5 Inflows</td><td></td></tr>
</table>

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

WSP | PARSONS BRINCKERHOFF

FLOOD MODELLING SUMMARY REPORT

HOTSPOT 24

HIGH FIELD, HEMEL HEMPSTEAD

Modeller:	D. Hughes	27-04-2016
Reviewer:	S. Brown, P. Harrison	03-05-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The downstream boundary of the model has been set using the draft levels outputs of the Environment Agency's Gade and Bulbourne modelling (2015), as these was the best information available at the time of building the model. No survey undertaken as it was considered that LiDAR demonstrated gaps in the railway embankment and thus flow paths suitably.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot24_Hemel_Hempstead_v05_~s1~_~e1~_~e2~.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 0.55hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change 40%): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. • Model results, logs, checks labelled using above convention, e.g. "Hotspot24_Hemel_Hempstead_v05_Baseline_0.55hr_Q0100"

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2. 2D Reference data	
2.1 Final DEM	Elevations based on 50cm LiDAR where available, supplemented by 1m LiDAR coverage for the upper part of the catchment.
2.2 Changes to DEM	Z-shapes used to set building pad elevations at 300mm higher than the average underlying DTM level and to set roads 15mm higher: • 2d_zsh_buildings_Hotspot24_Hemel_Hempstead_v03_R.shp • 2d_zsh_roads_Hotspot24_Hemel_Hempstead_v05_R.shp The river was carved into the LiDAR • 2d_zsh_River_Gade_Hotspot24_Hemel_Hempstead_v03_P.shp • 2d_zsh_River_Gade_Hotspot24_Hemel_Hempstead_v03_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 Layers: • 1d_nwk_TW_Hotspot24_Hemel_Hempstead_v05_L.shp • 1d_nwk_TW_Hotspot24_Hemel_Hempstead_v05_P.shp
3.2 Watercourse Structures	No 1d watercourse represented within the model. Rectangular culverts represented in the layer below. Dimensions have been extracted from the EA model (structure TMS0214, Gd0873BrU). • 1d_nwk_structures_Hotspot24_Hemel_Hempstead_v01_L.shp

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td colspan="2">4. Hydrology</td></tr>
<tr><td>4.1 Inflow boundaries</td><td>
<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>88</td><td>146</td><td>168</td><td>231</td><td>255</td><td>357</td><td>565</td></tr>
<tr><td>Total rainfall (mm)</td><td>15</td><td>25</td><td>29</td><td>40</td><td>44</td><td>61</td><td>97</td></tr>
<tr><td>Storm duration (hr)</td><td colspan="7">0.55</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 draft level outputs from the Environment Agency Gade and Bulbourne modelling (2015).</td></tr>
<tr><td>4.3 Historical records of flooding</td><td>Environment Agency Recorded Flood Outlines show no recorded events in the area.</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>
<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.</td></tr>
</table>

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	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
6. Software	
6.1 Version	Tuflow version 2013-12-AE-iDP-W64
6.2 Precision	Double precision used for direct rainfall modelling

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	Freely draining lime-rich loamy soils	8 – Loam
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	4 – Clay Loam

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, XMDF – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	1.35 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 0.36 to -1.25%
7.5 Number of messages / warnings etc.	262 warnings/ 1474 checks relating to invert levels interpolation, SX ZC lowering etc
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	

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 53

KINGS LANGLEY

Modeller:	D. Hughes	03-05-2016
Reviewer:	S. Brown/P.Harrison	08-04-2016

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
1. General	
1.1 Variations to agreed Methodology	The downstream boundary of the model has been set using the draft levels outputs of the Environment Agency's Gade and Bulbourne modelling (2015), as these was the best information available at the time of building the model.
1.2 Scenarios used in TUFLOW model	The following naming convention has been used for developing the Scenarios: • Models labelled as Hotspot53_Kings_Langley_v07_~s1~_~e1~_~e2~.tcf • Scenario ~s1~ = Baseline: Model baseline conditions • Event ~e1~ = 1.5hr critical storm duration • Event ~e2~ = 4 digit reference for return period (plus additional for climate change 40%): Q1000; Q0100CC; Q0100; Q0075; Q0030; Q0020; Q0005. • Model results, logs, checks labelled using above convention, e.g.“ Hotspot53_Kings_Langley_v07_Baseline_1.5hr_Q0100”
2. 2D Reference data	
2.1 Final DEM	Elevations based on 50cm LiDAR available for the whole catchment.

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
2.2 Changes to DEM	Surveyed levels were used to create Triangular Irregular Networks (TINS) in specific areas of the model: • 2d_ztin_topo_Hotspot53_Kings_Langley_v01_P.shp • 2d_ztin_topo_Hotspot53_Kings_Langley_v01_R.shp Z-shapes used to set building pad elevations at 300mm higher than the average underlying DTM level and to set roads 125mm lower. • 2d_zsh_buildings_Hotspot53_Kings_Langley_v01_R.shp • 2d_zsh_roads_Hotspot53_Kings_Langley_v07_R.shp A 2D channel has been carved into the DTM to represent the downstream channel due to the lack of survey data. • 2d_zsh_River_Bulbourne_Hotspot53_Kings_Langley_v02_P.shp • 2d_zsh_River_Bulbourne_Hotspot53_Kings_Langley_v02_R.shp Added z-shape from EA model to include accurate bank levels along River Bulbourne banks. • 2d_zsh_banks_Hotspot53_Kings_Langley_v02_L.shp Introduced "cress beds" z-shape from existing EA model. • 2d_zsh_cress_beds_Hotspot53_Kings_Langley_v02_R.shp Added z-shape to represent the lock gates: • 2d_zsh_lock_gates_Hotspot53_Kings_Langley_v01_L.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 Layers: • 1d_nwk_TW_Hotspot53_Kings_Langley_v07_L.shp • 1d_nwk_TW_Hotspot53_Kings_Langley_v07_P.shp
3.2 Watercourse Structures	No 1d watercourse represented within the model. Rectangular culvert representing Queensway Bridge. Dimensions hav been extracted from the EA model (structure RG002bu).

<table>
<tr><th>MODEL ELEMENT</th><th>ACTION TAKEN DURING MODELLING</th></tr>
<tr><td></td><td>• 1d_nwk_structures_Hotspot24_Hemel_Hempstead_v01_L.shp</td></tr>
<tr><td colspan="2">4. Hydrology</td></tr>
<tr><td>4.1 Inflow boundaries</td><td>
<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>84</td><td>112</td><td>122</td><td>171</td><td>252</td></tr>
<tr><td>Total rainfall (mm)</td><td>20</td><td>32</td><td>36</td><td>48</td><td>53</td><td>74</td><td>109</td></tr>
<tr><td>Storm duration (hr)</td><td colspan="7">1.5</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 draft level outputs from the Environment Agency Gade and Bulbourne modelling (2015).</td></tr>
<tr><td>4.3 Historical records of flooding</td><td>Environment Agency Recorded Flood Outlines show no recorded events in the area.</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>
<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.</td></tr>
</table>

MODEL ELEMENT	ACTION TAKEN DURING MODELLING
	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
6. Software	
6.1 Version	Tuflow version 2013-12-AE-iDP-W64
6.2 Precision	Double precision used for direct rainfall modelling

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	Freely draining slightly acid loamy soils	8 – Loam
Loamy and clayey	Loamy and clayey floodplain soils with naturally high groundwater	8 – Loam

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, XMDF – d v q h ZUK0, MB1, MB2
6.5 Hazard	UK Hazard Land Use - Conservative
7. Modelling Log	
7.1 Model duration	2 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 -1.04% and 0.59 %
7.5 Number of messages / warnings etc.	9 warnings/ 116 checks relating to invert levels interpolation, SX ZC lowering etc
8. Sensitivity testing	
8.1 Culvert blockage	
8.2 Structural coefficients	
8.3 Roughness coefficients	
8.4 Runoff coefficients	

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