TECHNICAL NOTE

JBA Project Code	2017s6220
Contract	Eastleigh Hydrological Study
Client	Eastleigh Borough Council
Day, Date and Time	4th May 2018
Author	Rebecca Thrower BSc MSc
Reviewer	Natasha Todd-Burley BSc PhD
Subject	Hydraulic modelling

1 Introduction

1.1 Terms of Reference

JBA Consulting was commissioned by Eastleigh Borough Council to investigate hydrological and ecological constraints within one of their boroughs, as part of plans to develop housing projects. As part of this commission, JBA Consulting was asked to advise on the alignment of the proposed North of Bishopstoke link road (NBLR) to ensure that it has the least possible impact and that hydrological flows and stream systems can maintain their current functions. This Technical Note summarises the approach taken to modelling the various streams that fall within the study area and presents the draft results of the hydraulic modelling.

2 Modelling Approach

2.1 Overview

Given that the study area covers a number of different catchments, it was decided that developing four separate models to cover the headwater streams would be the best approach. JBA are preparing new flood risk modelling and mapping for fluvial flood risk across the full River Itchen catchment for the Environment Agency, upstream of Wood Mill, Swaythling, including a number of tributaries. One of the models, which represents Bow Lake, covers part of the study area. The draft version of the Bow Lake model has been supplied for use in this study, in order for the model to be extended to cover the small headwater streams that fall within the Bow Lake catchment. The supplied Bow Lake model has been developed using Flood Modeller (4.2) / TUFLOW (2016-03-AD) software. Changes to the model have been confined to the 2D (TUFLOW) part of the model, to extend the model domain and represent inflows to the study watercourses. The draft Bow Lake model used in this study has yet to be approved and signed-off by the Environment Agency, and yet to be finalised. However, the draft model files were licenced to JBA for use in this study due to programme and timescale constraints associated with this project. The model results for Bow Lake will therefore be subject to change, following completion of the flood risk modelling and mapping study of the Itchen catchment.

The remaining headwater streams are not covered by the full Itchen catchment model. Therefore, new models have been developed to represent these watercourses. As with the Bow Lake headwater streams, the study watercourses have been represented in the 2D using TUFLOW (2016-03-AD) software. Adopting 2D-only techniques was agreed at inception stage, given the anticipated costs of procuring detailed channel survey of each of the streams.

An overview of the model extents and where they fall in relation to the study area, is shown in Figure 2-1.

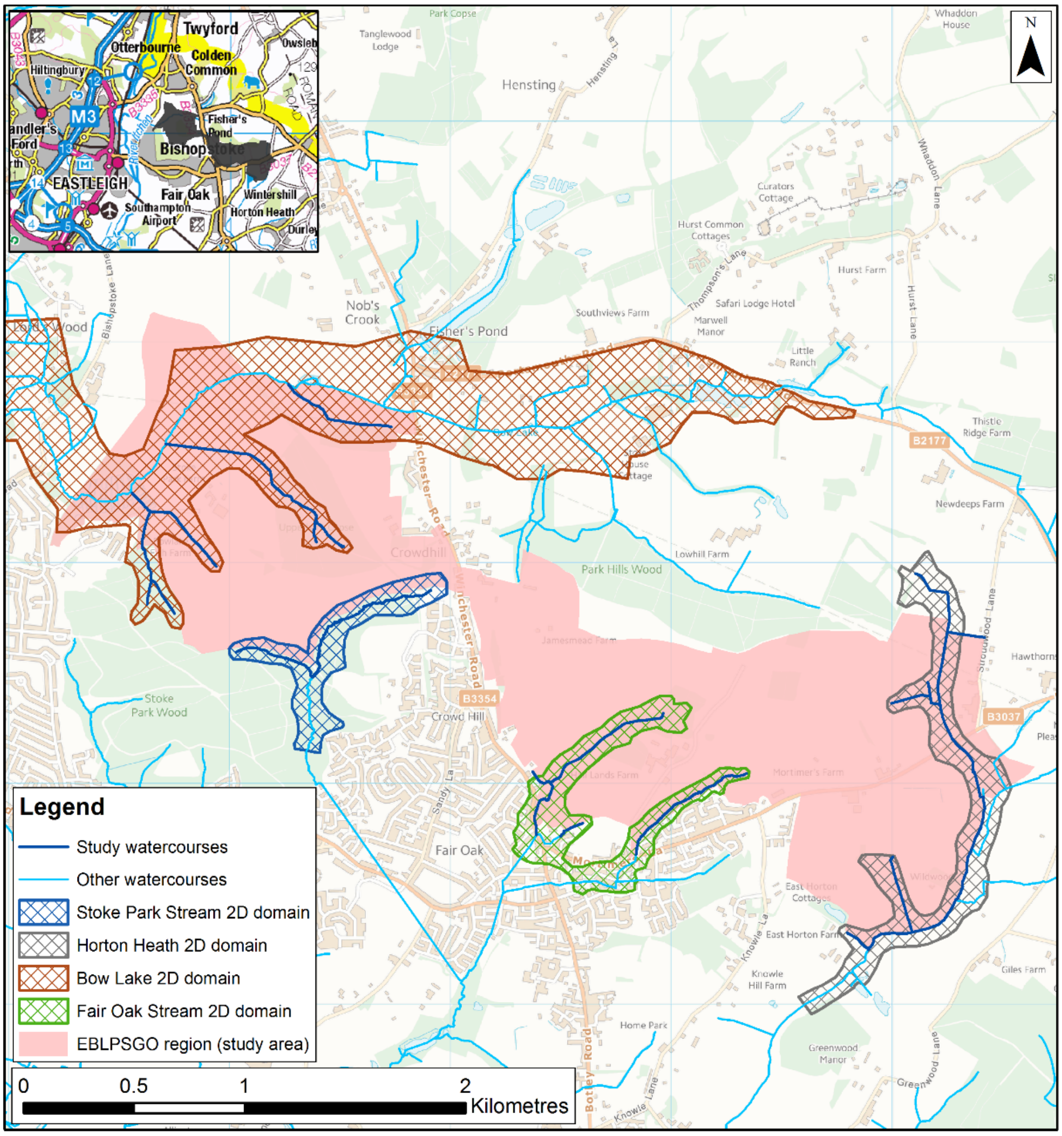

Figure 2-1: Model schematic overview

2.2 2D modelling approach

2.2.1 2D models

Open-source LIDAR data of 1m resolution has been obtained and used to inform ground and channel elevations in each of the 2D models. Where the LIDAR is poorly filtered due to obstructions such as minor footbridges, culverts or in areas of dense vegetation, modifications have been made to the 2D-domain to facilitate a flow route, using TUFLOW z-shapes. A summary of the modifications made to the 2D grid is shown in the appendices. The models were then simulated with a steady flow to ensure the channel as it is represented, is capable of conveying baseflow. A grid cell size of 2m has been used for the three 2D only models, in order to adequately represent flow routes between the channel and the floodplain. In the existing 1D/2D model of Bow Lake, a grid cell size of 3m has been used, which is considered appropriate.

Floodplain roughness has been represented by applying different Manning's *n* values, depending on the dominant land-use. Both mapping and aerial imagery were consulted to inform the choice of Manning's *n* values.

Inflows have been assigned to the 2D grid through the use of 2D boundary conditions at specified locations. Results are available for the 5% AEP, 1% AEP and 0.1% AEP, as well as the 1% AEP with the following three climate change scenarios; 35% (central), 45% (higher central) and 105% (upper end). For information on the hydrology used in this study, refer to the accompanying hydrology reports (2017s6220 Ford Lake FEH calculation record v1.0 and 2017s6220 Itchen Headwater Hydrology Technical Note v1.0).

Model schematics of the Horton Heath, Stoke Park Stream and Fair Oak Stream models are shown in Figure 2-2, Figure 2-3 and Figure 2-4, below.

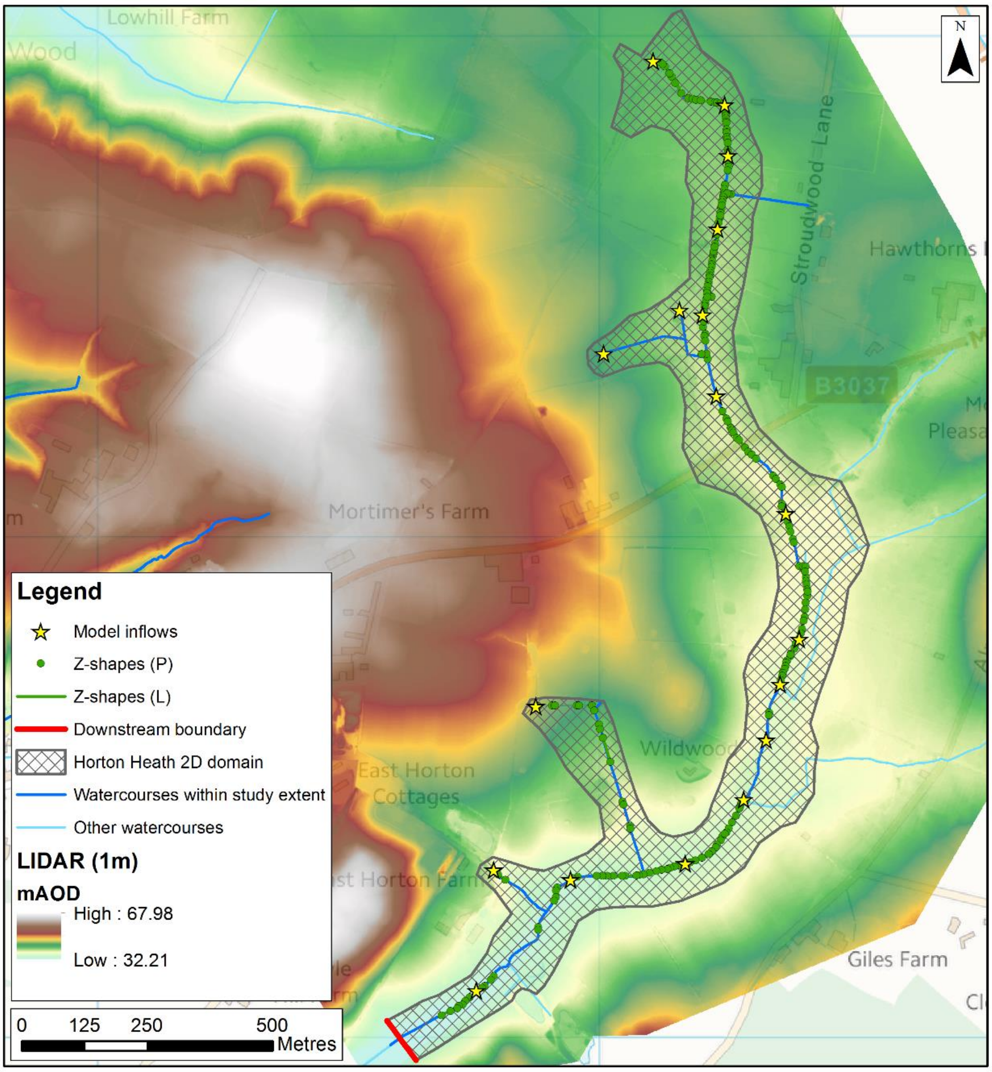

Figure 2-2: Horton Heath 2D model schematic

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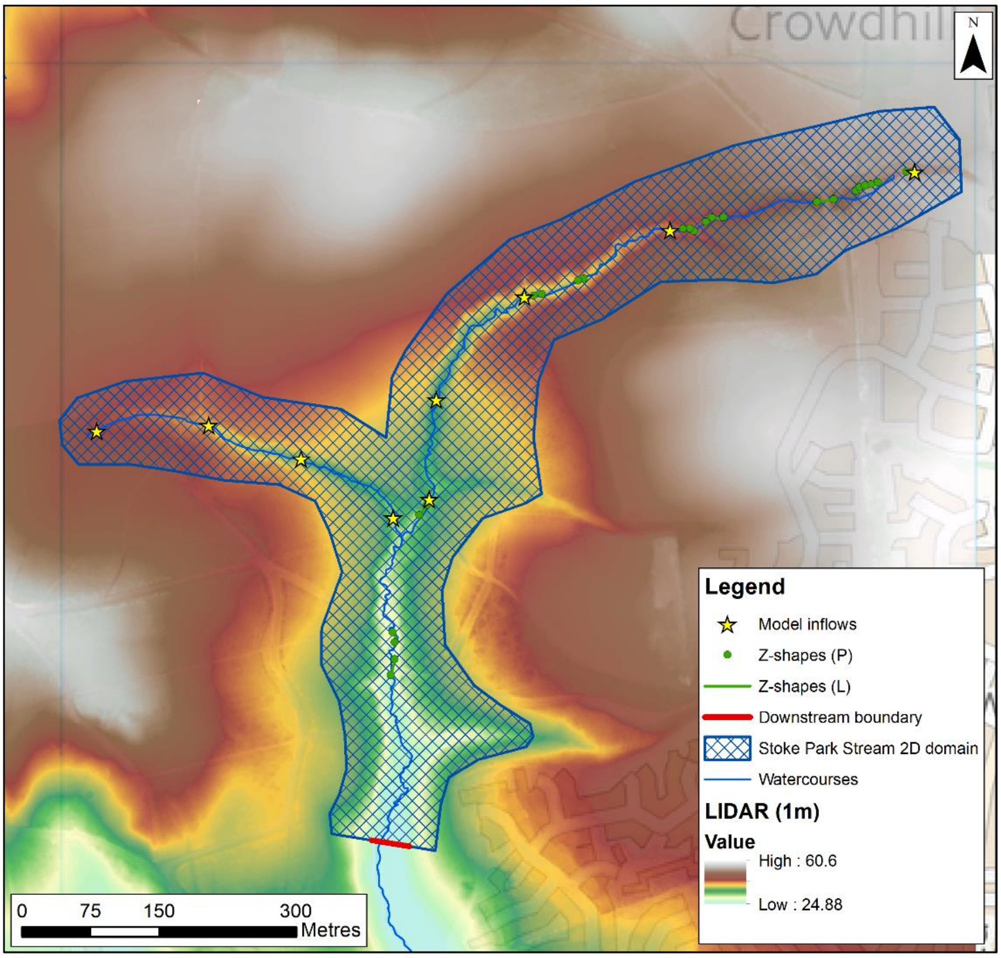

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Figure 2-3: Stoke Park Stream 2D model schematic

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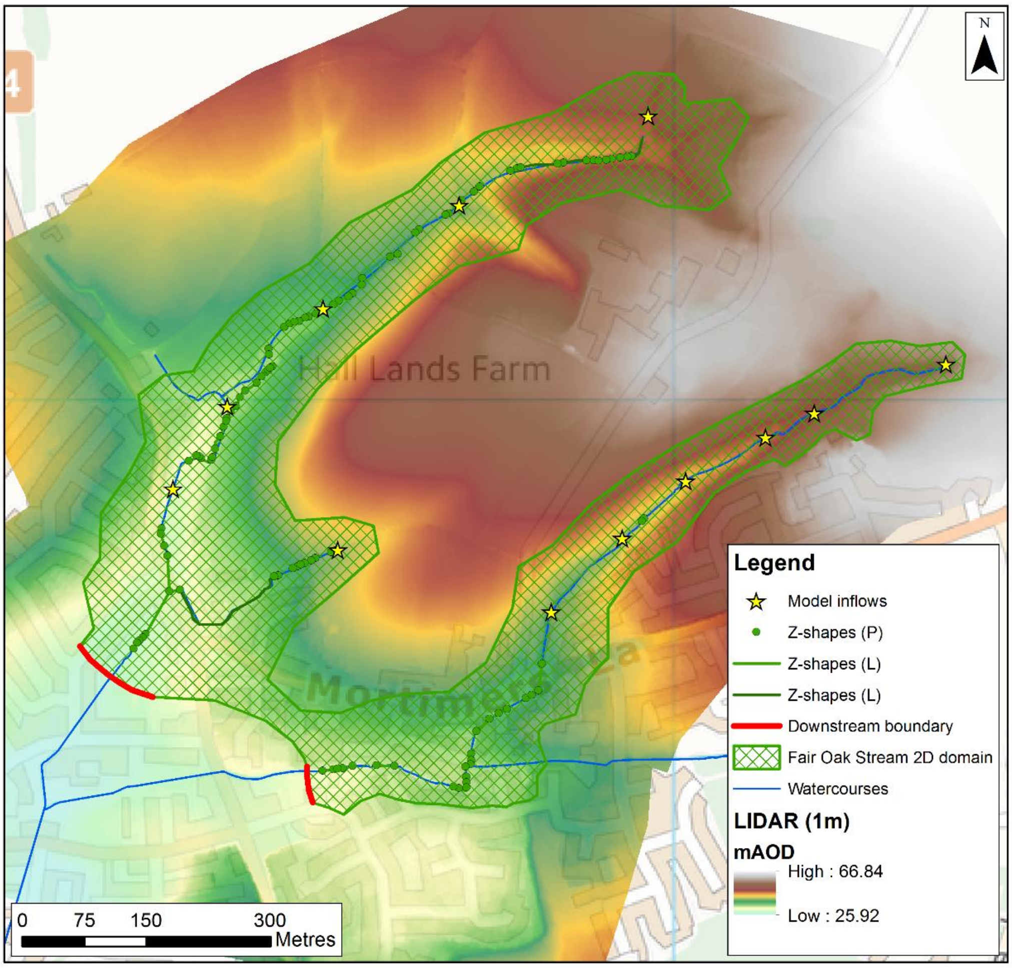

Figure 2-4: Fair Oak Stream 2D model schematic

2.2.2 Bow Lake model

As discussed, the draft Bow Lake model has been supplied by JBA (with permission from the Environment Agency) for use in this study. The 1D part of the model has been used as existing; no modifications have been made. The 2D part of the model has been modified to represent the small study streams; copies were made of the existing TUFLOW files and the following adjustments have been made:

- The 2D domain has been extended to represent the streams within the model extent; this involved modifying the dimensions of the 2D grid, the code layer which defines the active area within the 2D model extent, and the location line which defines the orientation of the grid
- In the existing model, the downstream boundary along the edge of the 2D floodplain has been applied using a 2D_bc (boundary condition) line with a Head-Time control with the same level used in the 1D data file (which represents a fixed

top-of-bank water level within the river Itchen[1]). The elevation used represents the top of bank at the confluence of Bow Lake with the River Itchen. To improve the cumulative mass error value resulting from flood storage at the downstream end of the model, the downstream boundary along the floodplain has been modified.

By raising the elevation in the downstream boundary set across the floodplain more in line with the local bank elevations, it is assumed that interaction exists between the River Itchen and the floodplain. Since the elevation applied is higher than parts of the floodplain, due to the number of small channels that intersect it, out of bank flooding is caused by the downstream boundary at the start of the model simulation. As a sensitivity test, results were compared with the previous model results, which used the existing downstream boundary. The results showed some change in maximum extent and levels in the vicinity of the downstream boundary; however, upstream, minimal change is observed. Given the improvements to the cumulative mass error with the revised downstream boundary, these results have been presented in this report.

The results around the downstream boundary should be treated with caution as the downstream boundary conditions are arbitrary and subject to revision once the full River Itchen model is finalised.

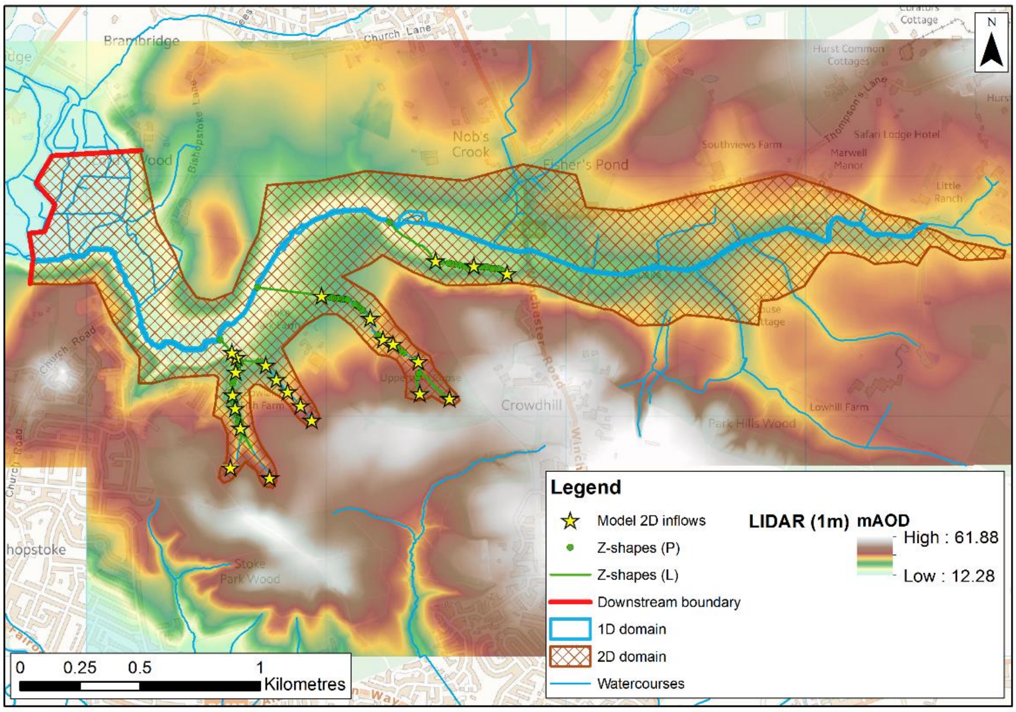

Figure 2-5: Bow Lake (draft) model schematic

[1] *Note:* The Model Operation Manual for the draft Bow Lake model (2016s5115) states the elevation used in the downstream boundary was estimated from inspection of LIDAR data and will be revised to reflect modelled water levels from the River Itchen Model 3 once this is available. Water levels used in the draft version of the model used in this study, are therefore likely to change in the vicinity of the downstream boundary, once the Bow Lake model is updated and finalised.

2.3 Modelling assumptions

Given that channel survey of the modelled streams is not available (due to the anticipated costs involved in surveying such a high number of watercourses), channel capacity has been approximated from LIDAR data. The channel capacity used in each stream has been set to the baseflow of the modelled events.

It is assumed that the Manning's *n* values, defined by land-use according to aerial imagery and open source mapping, are appropriate. Sensitivity testing was beyond the scope of the study.

For the purposes of this study, culverted watercourses have been modelled as open watercourses. Consequently, flood outlines produced for such areas should be treated with caution. In order to better represent these watercourses, an assumption as to the channel capacity would be required as the culvert's channel is not represented directly in the DTM. In some cases, an estimate of the channel capacity may be available or, alternatively, a channel capacity equivalent to the median annual maxima flood (QMED) could be assumed. However, this would require a more detailed modelling approach which is beyond the scope of this study.

Bridges and other structures (weirs and sluices) were not modelled; this could lead to underestimation of flood extent/depth where a structure causes significant afflux.

2.4 Model uncertainty and limitations

The modelling techniques described in this report are suitable for meeting the objectives of this study. They enable an approximation of the flood risk posed by the small streams within the study area. However, 2D-only techniques have a number of limitations which need to be considered when reviewing the model results. The most significant limitation is perhaps the uncertainty surrounding channel capacity, given that it has been approximated based on LIDAR and the depth to which the channel must be to contain baseflow. The results are strategic and should flood extents and depths be required for flood-sensitive purposes (such as to inform planning), detailed modelling would be required and channel survey would need to be commissioned.

3 Model Results

Flood outlines from peak of each modelled flood event have been mapped and presented in the following figures. Flood outlines from each of the models have been presented together and shown in relation to the study area.

The national Flood Zones have been shown on each figure to indicate the most recent, published, flood extent data for the River Itchen. As discussed, the flood extents for the Itchen will be updated once the new River Itchen flood risk modelling and mapping study is complete; however, in the interim the Flood Zones have been used in this report. The proposed road routes have also been presented on the figures. Note, dry islands have been removed from the outlines to a 250m^2 tolerance.

The flood extents for Stoke Park Stream and Fair Oak Stream are minimal, even in the more extreme flood event scenarios. This is thought to result from the fact each catchment contributing flow to the streams covers a small area, and therefore modelled inflows are small. The floodplains of each stream are also thought to be limited, with LIDAR data suggesting confined floodplains in the small headwater valleys.

As part of the fluvial flood risk modelling and mapping study of the River Itchen catchment that JBA are preparing for the Environment Agency under a separate commission, draft outlines have been produced for the Colden Common Stream, situated to the north of the study area. The outputs from this model have been licenced to JBA for use in this study, given that the proposed road route is shown to pass over the Colden Common Stream. Draft flood outlines have been shown alongside the modelling results from this study in the following figures. No changes have been made to the Colden Common model as part of this study. However, as with the draft Bow Lake model, the Colden Common Stream model has yet to be approved and signed-off by the Environment Agency and yet to be finalised. The model results for both the Colden Common Stream and the Bow Lake model will therefore be subject to change following completion of the flood risk modelling and mapping study of the Itchen catchment.

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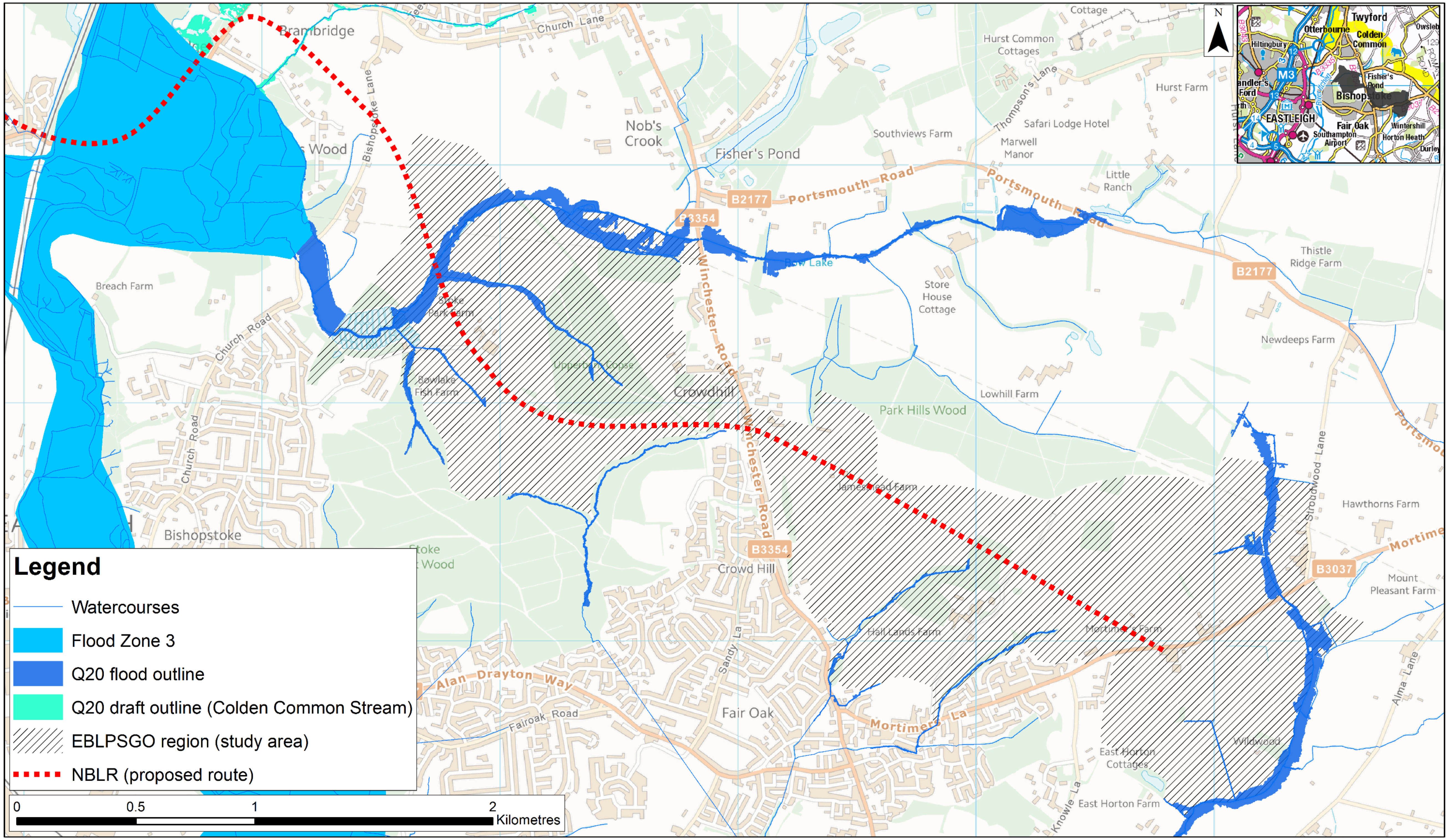

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Figure 3-1: Flood outlines for the 1-in-20-year return period event

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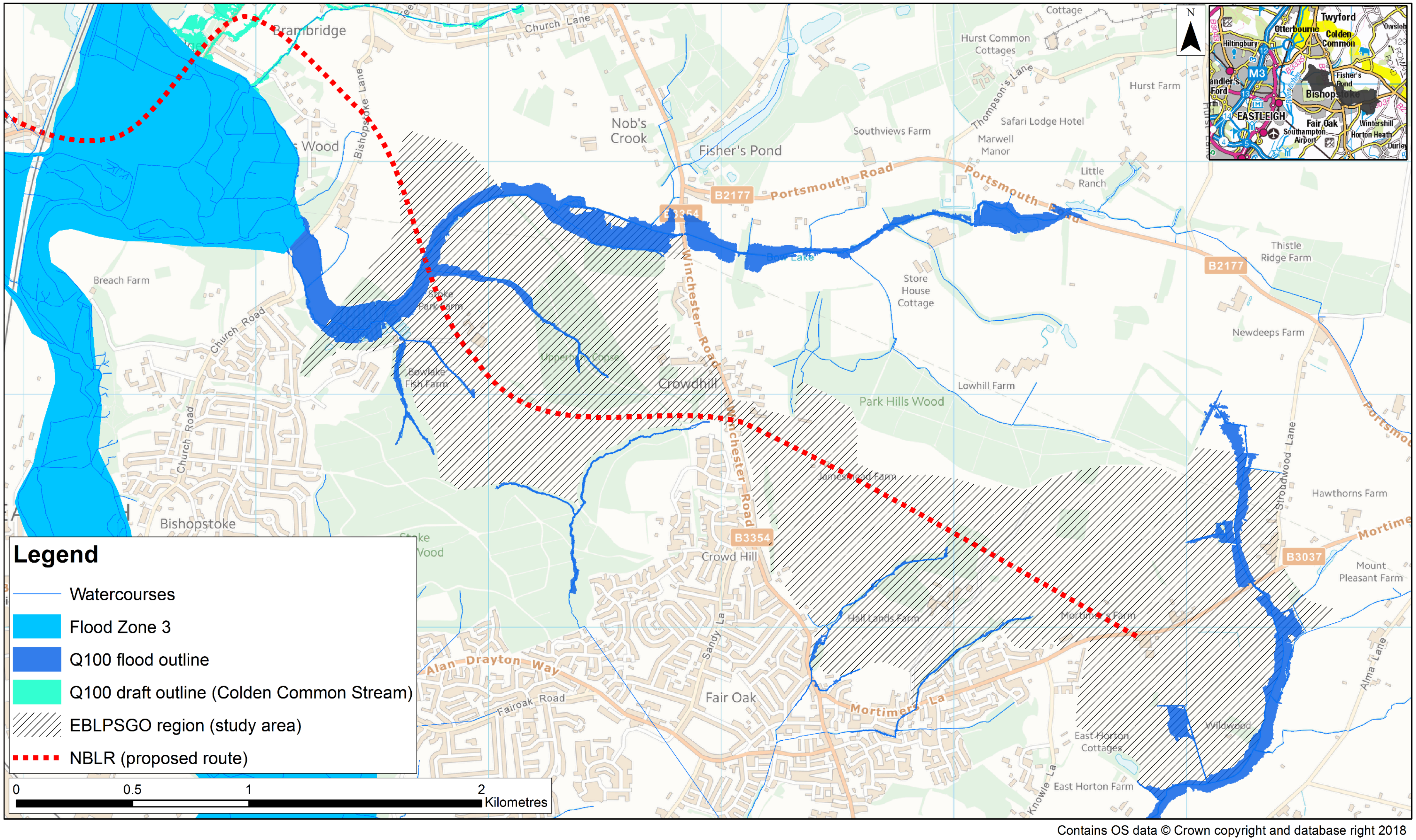

Figure 3-2: Flood outlines for the 1-in-100-year return period event

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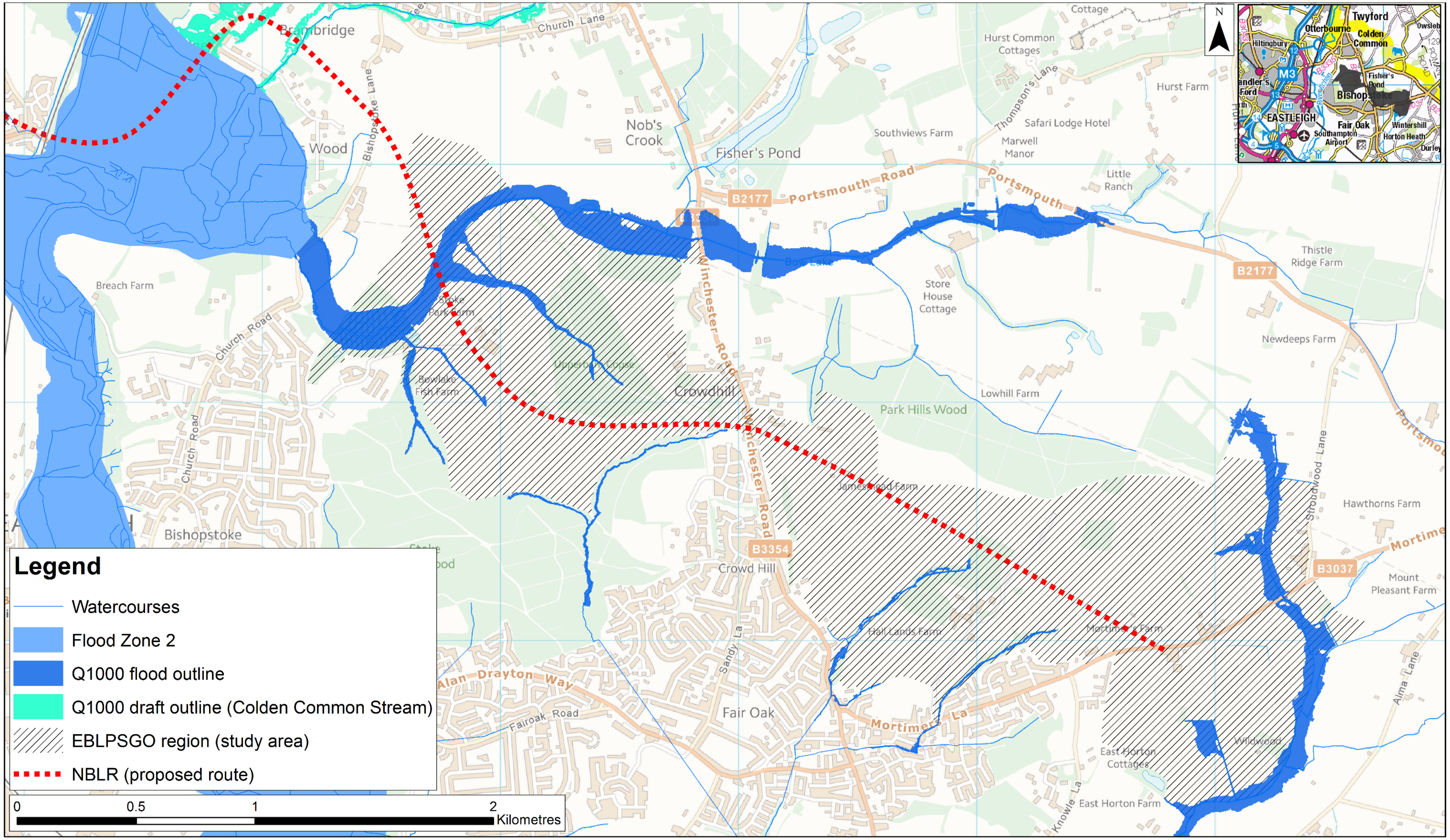

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Figure 3-3: Flood outlines for the 1-in-1,000-year return period event

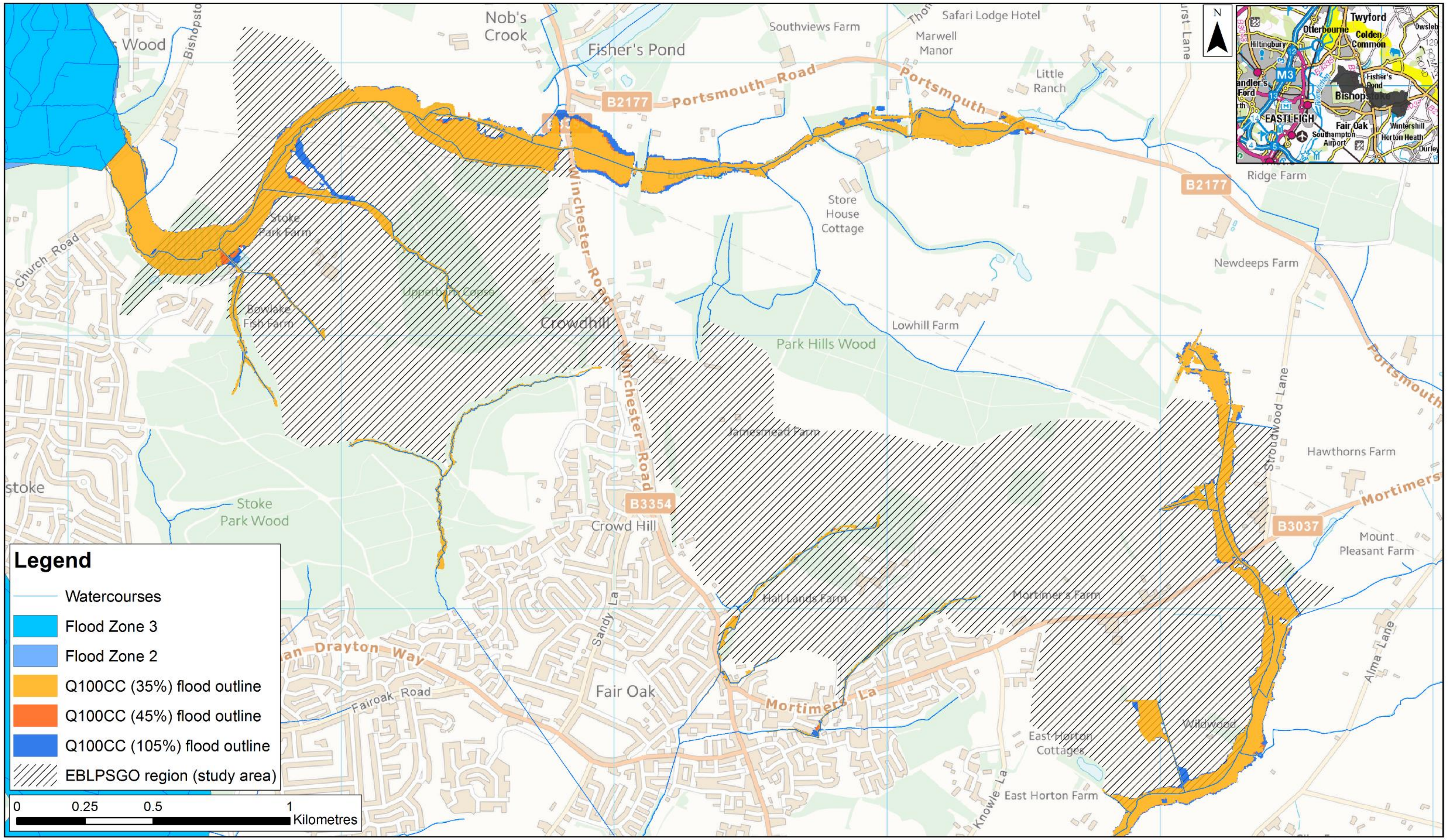

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Figure 3-4: Flood outlines for the 1-in-100-year return period event with allowances for climate change

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4 Conclusions

JBA Consulting was commissioned by Eastleigh Borough Council to investigate hydrological and ecological constraints within one of their boroughs, as part of plans to develop housing projects. This Technical Note summarises the approach taken to modelling the various streams that fall within the study area, and the draft results of the hydraulic modelling.

Four hydraulic models have been developed using 2D-only techniques to represent the small headwater streams. Three of the four models have been created as new models, Fair Oak Stream, Stoke Park Stream and Horton Heath streams. The streams within the Bow Lake catchment have been built into an existing 1D/2D hydraulic model that covers the Bow Lake watercourse. This model is currently in draft format and is being developed by JBA to investigate fluvial flood risk across the full River Itchen catchment for the Environment Agency. It is possible that the results of this study, which have been presented as draft and subject to change, may have to be updated with the final River Itchen model.

Flood outlines from each model have been presented together and shown in relation to the study area for each of the modelled events. The flood extents for Stoke Park Stream and Fair Oak Stream are minimal, even in the more extreme flood event scenarios. This is thought to result from the fact each catchment contributing flow to the streams covers a small area, and therefore modelled inflows are small. The floodplains of each stream are also thought to be limited, with LIDAR data suggesting confined floodplains in the small headwater valleys.

Whilst suitable for the purposes of this study, 2D modelling techniques involve several limitations that produce uncertainty in the model results. Channel capacity has been approximated from LIDAR and does not accurately represent the capacity of the streams nor any structure or obstruction that might influence conveyance of flow. Channel and floodplain characteristics, such as roughness and land-use, have been approximated from aerial imagery and open source mapping; however, localised variations will not be represented. Should flood extents and flood depths be required to inform flood-sensitive purposes (i.e. planning and development), detailed modelling would be required.

Appendices

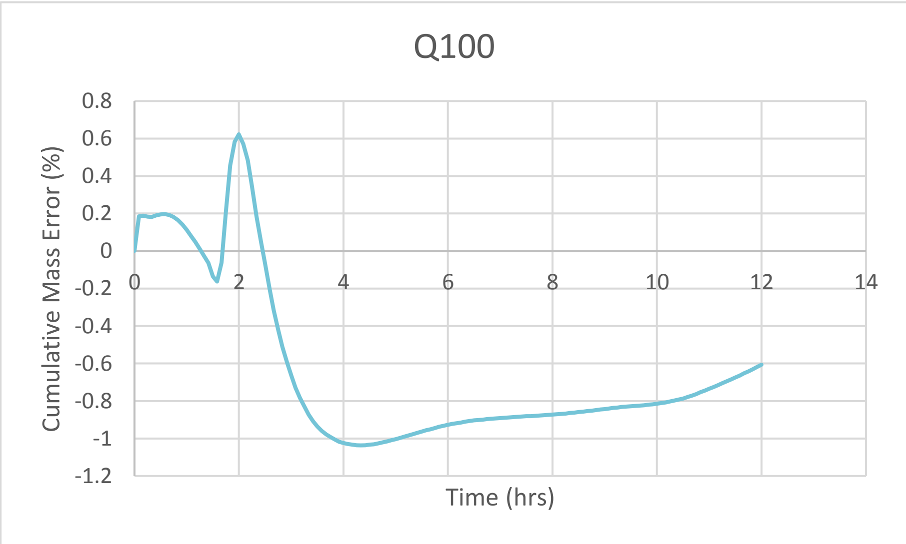
A Technical model overview

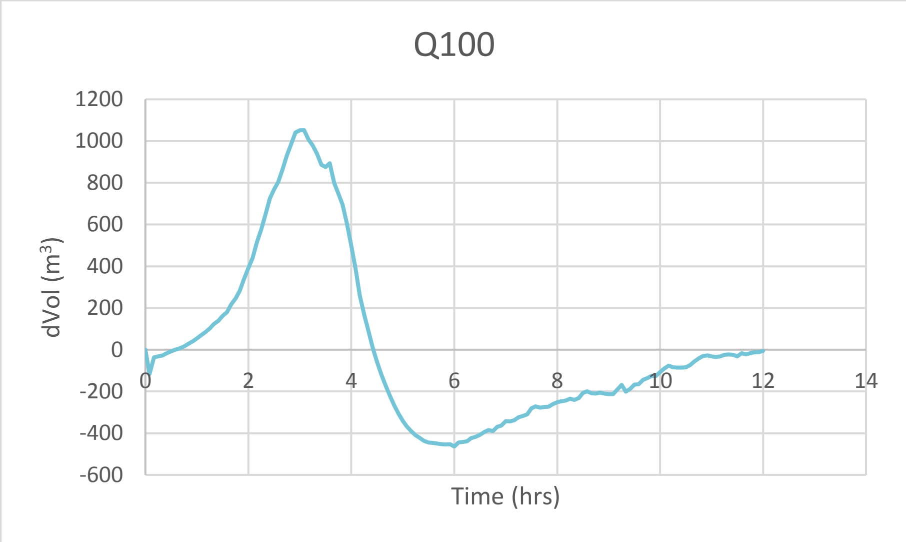
A.1 Horton Heath Stream model

Table 4-1: Horton Heath 2D model overview

Area of 2D domain	0.41 km^2	**DTM data source**	LIDAR
Resolution of grid	2m	**DTM resolution**	1m
Modifications to topography and reasons	2d_zsh_HH_L_002.shp 2d_zsh_HH_P_002.shp	Used to define elevations in channel where the LIDAR is poorly filtered (e.g. dense trees or footbridges), by defining elevations upstream and downstream of the obstruction.	
	2d_zsh_HH_stream_L_001.shp	Used to lower elevations and define a channel where no obvious flow route is visible in the LIDAR; elevations lowered by 0.3m.	

Table 4-2: Horton Heath model stability

<table>
<tr><td>Cumulative Mass Error</td><td>At the peak of the event (between 2 and 4 hours), the cumulative mass error is within acceptable model tolerances (±1%).

</td></tr>
<tr><td>dVol</td><td>The dVol plot for the Horton Heath model, which presents the change in volume between each timestep, shows a relatively smooth profile that suggests generally the model is stable.</td></tr>
</table>



A.2 Stoke Park Stream model

Table 4-3: Stoke Park Stream 2D model overview

Area of 2D domain	0.19 km^2	**DTM data source**	LIDAR
Resolution of grid	2m	**DTM resolution**	1m
Modifications to topography and reasons	2d_zsh_SPS_L_002.shp 2d_zsh_SPS_P_002.shp	Used to define elevations in channel where the LIDAR is poorly filtered (e.g. dense trees or footbridges), by defining elevations upstream and downstream of the obstruction.	

Table 4-4: Stoke Park Stream model stability

Cumulative Mass Error	The cumulative mass error extends just beyond acceptable model tolerances (±1%) at the peak of the simulation; however, the cause of the mass error is understood to be the poor filtering of the channel through a densely forested land. Whilst efforts have been made to define a channel by removing obstructions in the DTM, some remain and cause ponding of water in some locations resulting in a slightly greater mass error than expected. Given the uncertainties inherent to 2D modelling techniques, the results are considered acceptable for use.

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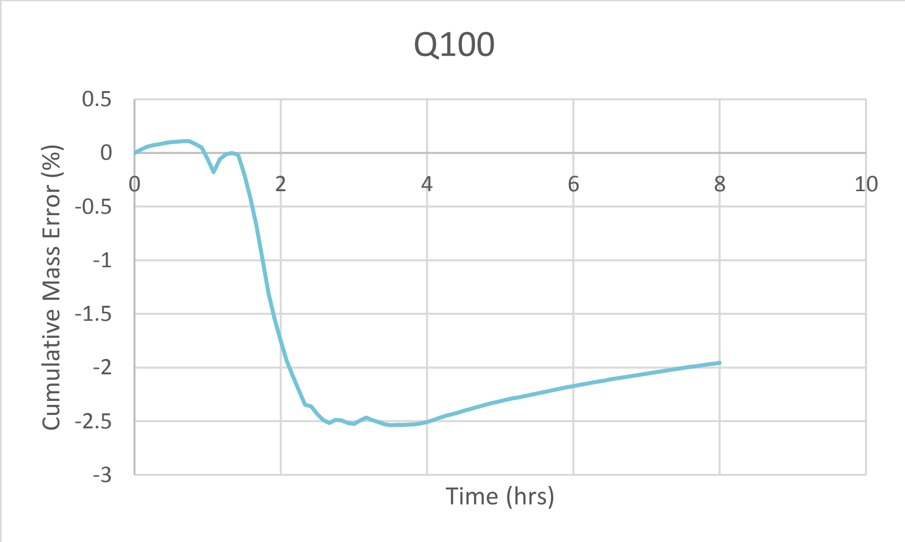
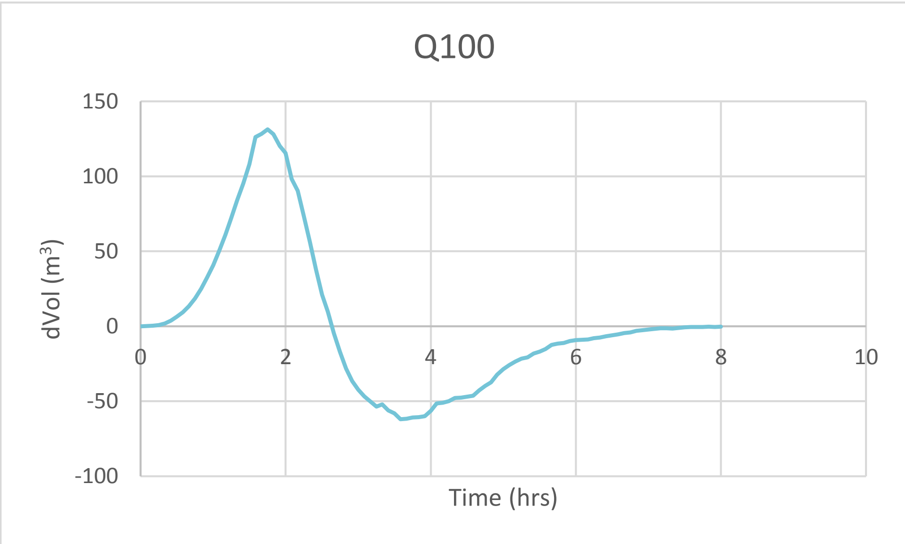
	
dVol	The dVol plot for the Stoke Park Stream model, which presents the change in volume between each timestep, shows a relatively smooth profile that suggests generally the model is stable. 

Given the confined floodplain and similarity in flood extents produced by the Stoke Park Stream model, the resulting flow was checked against the model inflows using TUFLOW PO lines. Comparing the plots below, the resulting flow estimates correspond well to the estimated inflows for each of the small headwater catchments. Flow estimates also increase as the severity of the flood event increases. The limited size of the flood extents is therefore considered to be due to the confined floodplain of each of the streams, and also due to the very small flow estimates produced by the small catchment areas.

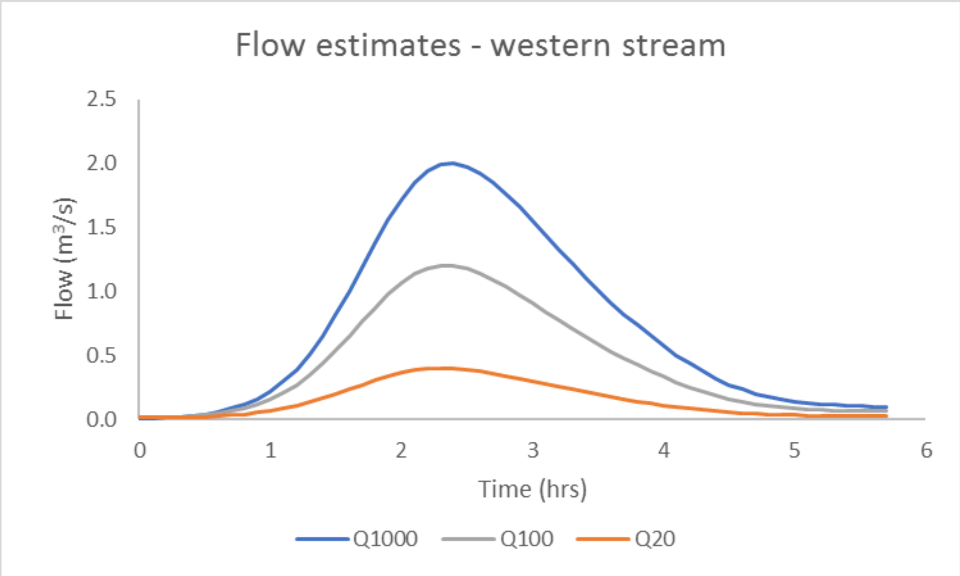


Figure 4-1: Inflows for the Stoke Park western stream

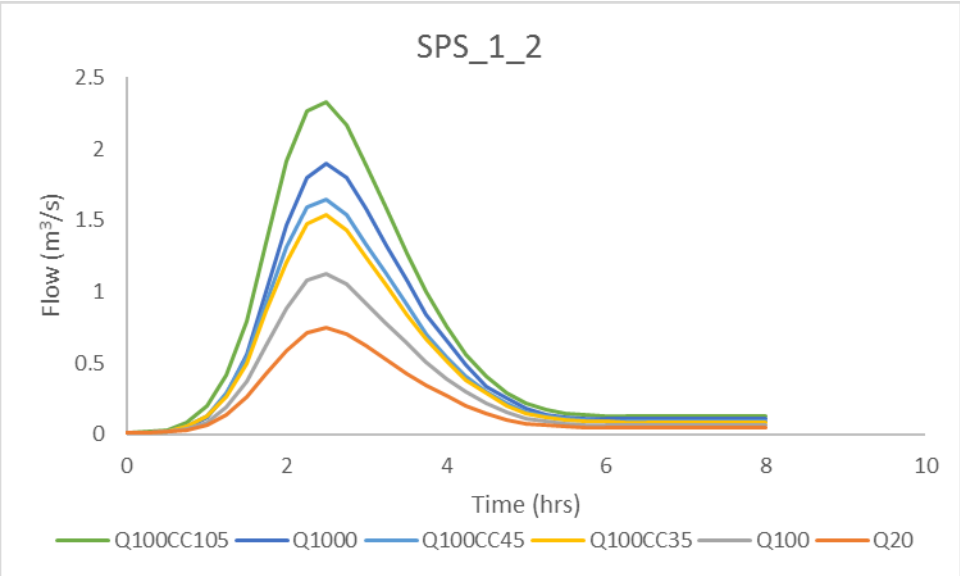


Figure 4-2: Modelled flow results for the Stoke Park western stream

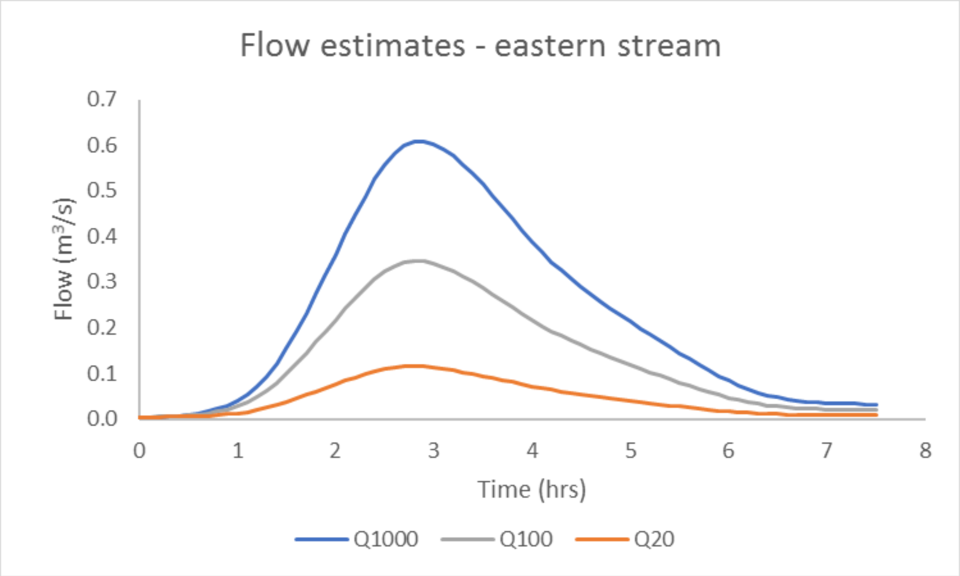


Figure 4-3: Inflows for the Stoke Park eastern stream

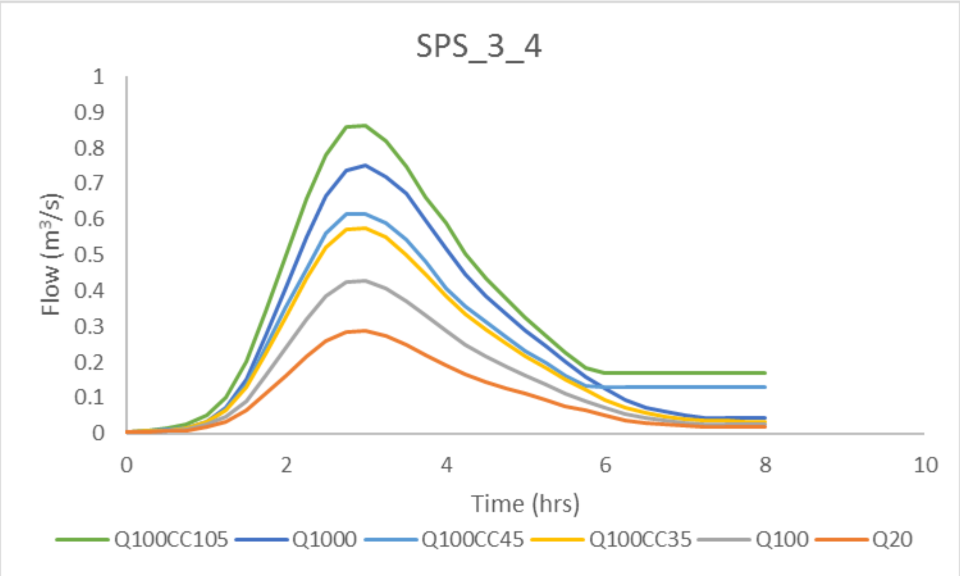


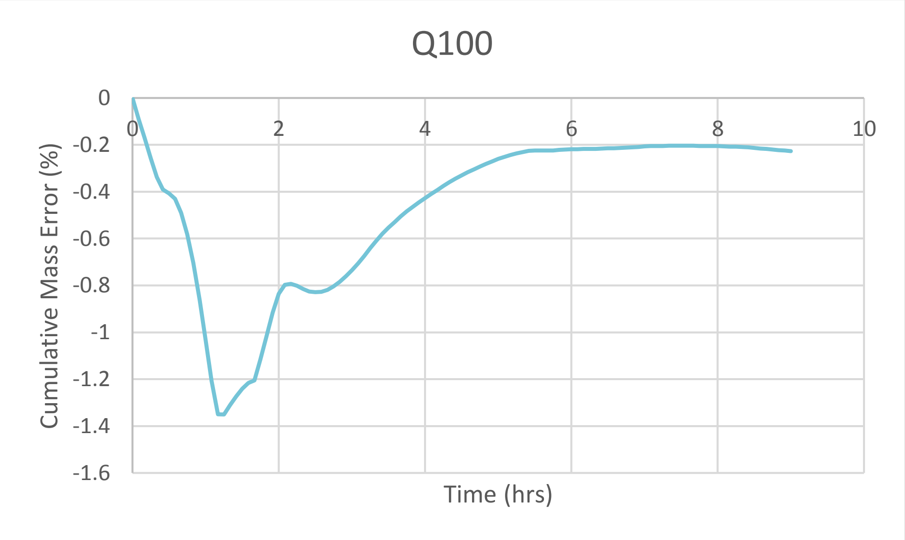
Figure 4-4: Modelled flow results for the Stoke Park eastern stream

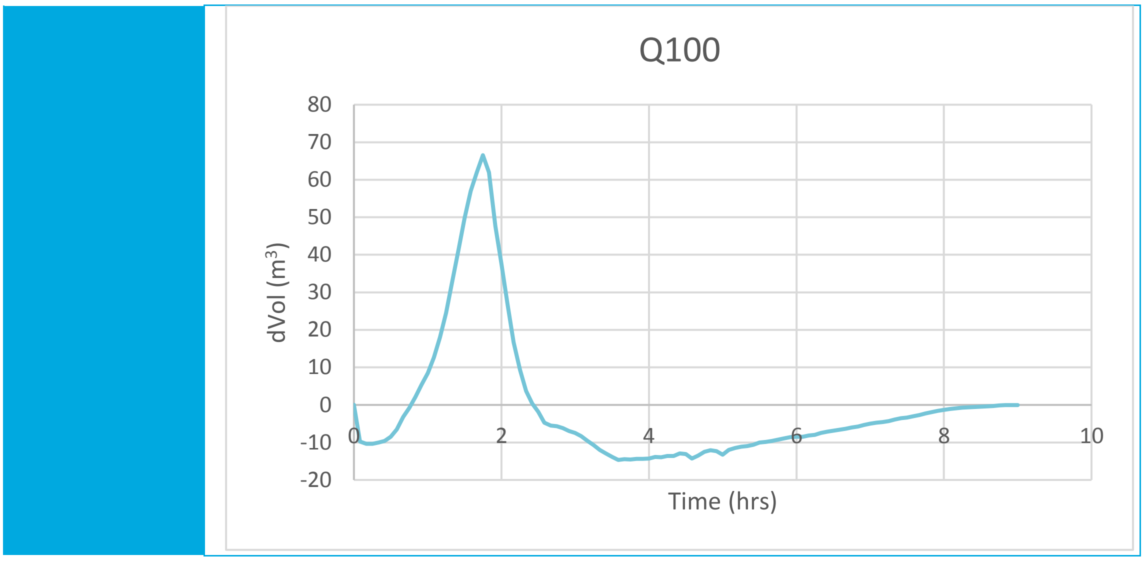
A.3 Fair Oak Stream model

Table 4-5: Fair Oak Stream 2D model overview

Area of 2D domain	0.28 km^2	**DTM data source**	LIDAR
Resolution of grid	2m	**DTM resolution**	1m
Modifications to topography and reasons	2d_zsh_filter_FOS_L_004.shp 2d_zsh_filter_FOS_P_004.shp	Used to define elevations in channel where the LIDAR is poorly filtered (e.g dense trees, footbridges or culverts), by defining elevations upstream and downstream of the obstruction.	
	2d_zsh_FOS_L_005.shp	Used to lower elevations and define a channel where no obvious flow route is visible in the LIDAR; elevations lowered by between 0.2m and 0.35m.	

Table 4-6: Fair Oak Stream model stability

Cumulative Mass Error	Cumulative mass error extends slightly beyond acceptable model tolerances (±1%) just before the peak of the simulation. Similar to the Stoke Park Stream model, the Fair Oak streams flow through woodland areas and through urban areas; 2D techniques mean that a well-defined flow route is not always achievable, and water may be ponding in some areas resulting in a slightly higher mass error. The results are considered acceptable for use. 
dVol	The dVol plot shows a smooth profile that suggests the model is stable.



Similar to the Stoke Park Stream model, the resulting flow was checked against the Fair Oak Stream model inflows. Comparing the plots below, the resulting flow estimates correspond well to the estimated inflows for each of the small headwater catchments. Flow estimates also increase as the severity of the flood event increases. The limited size of the flood extents is therefore considered to be due to the very small flow estimates produced by the small catchment areas, and to some extent, the confined floodplain of each of the streams.

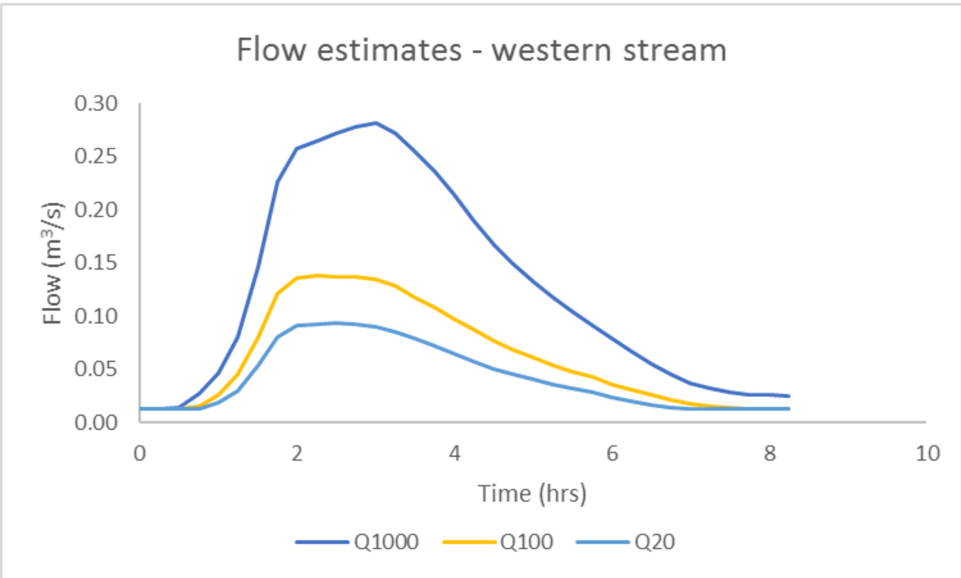


Figure 4-5: Inflows for the Fair Oak Stream western stream

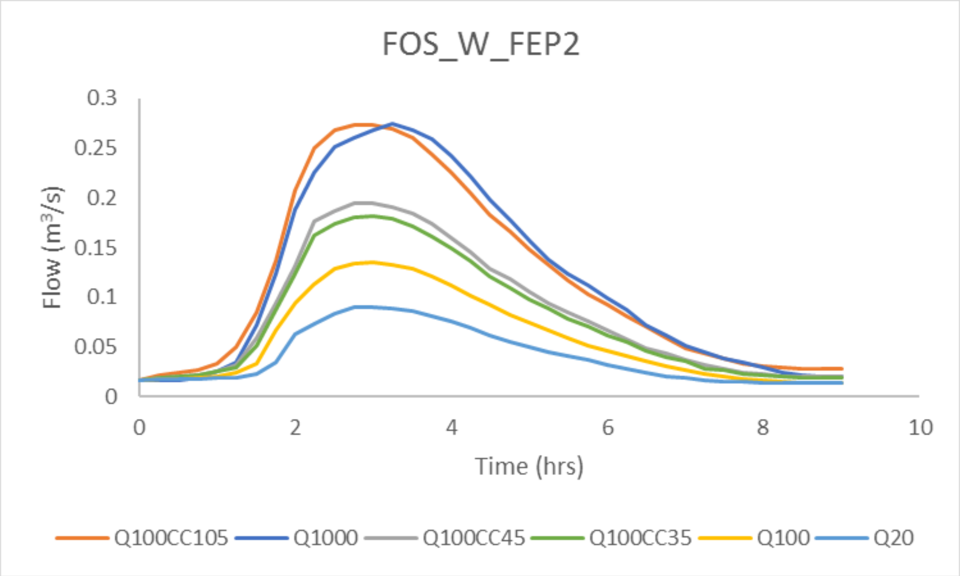


Figure 4-6: Modelled flow results for the Fair Oak Stream western stream

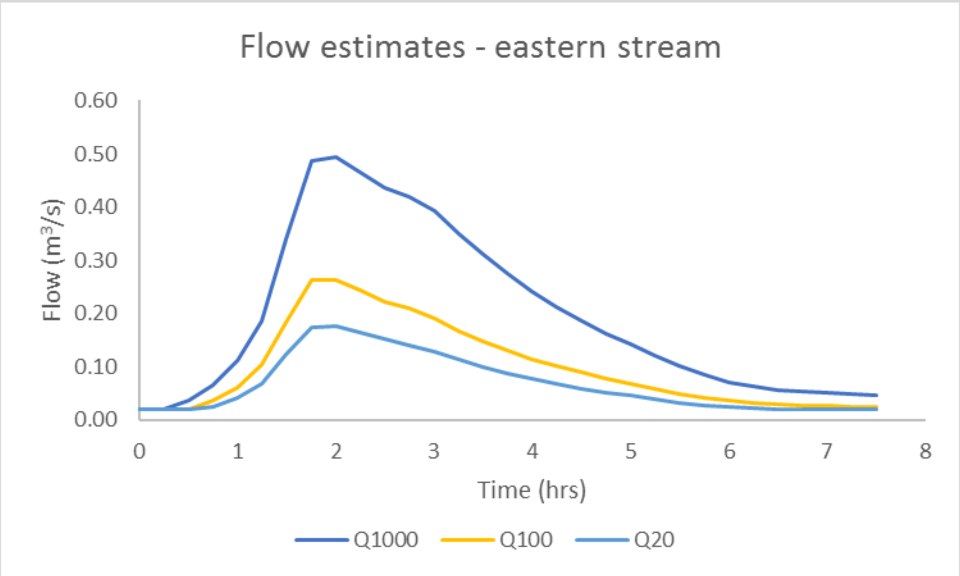


Figure 4-7: Inflows for the Fair Oak Stream eastern stream

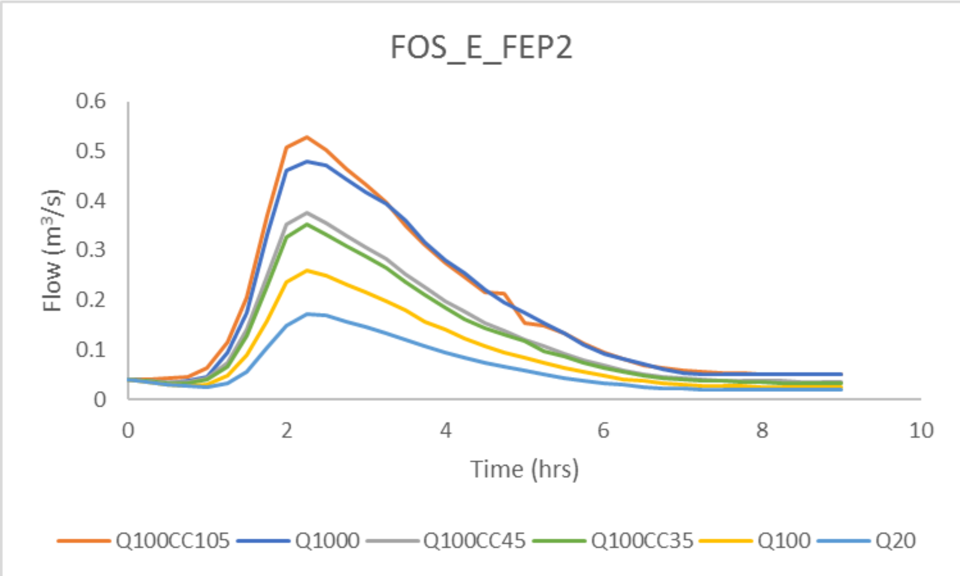


Figure 4-8: Modelled flow results for the Fair Oak Stream eastern stream

A.4 Bow Lake model

Given that this study has only modified the 2D part of the draft Bow Lake model, an overview of the 2D model is given below. For details on the development and operation of the 1D/2D model, refer to the 2016s5115 Bow Lake Model Operation Manual.

Table 4-7: Bow Lake 2D model overview

Area of 2D domain	1.94 km^2	**DTM data source**	LIDAR
Resolution of grid	3m	**DTM resolution**	1m
Modifications to topography and reasons	2d_zsh_2017s6220_BowLake_003_L.shp 2d_zsh_2017s6220_BowLake_003_P.shp	Used to define elevations in the streams where the LIDAR is poorly filtered (e.g dense trees, footbridges or culverts), by defining elevations upstream and downstream of the obstruction.	
	2d_zln_banks_2016s5115_BowLake_001_L.shp *2d_zln_banks_2016s5115_BowLake_001_P.shp*	*A Z-line was used to represent bank levels throughout the model. This used bank elevations extracted from the 1m LIDAR DTM. Refer to section 1.3.2 of the Model Operation Manual for Bow Lake (2016s5115) for further information.*	
	2d_zsh_roads_embankments_2016s5115_BowLake_001_L.shp *2d_zsh_roads_embankments_2016s5115_BowLake_001_P.shp*	*A Z-shape was used to represent the road and track embankments across the floodplain including for the Portsmouth Road (B2177), Marwell Manor Farm, Simba Business Park, Winchester Road (B3354) and Stoke Park Farm. Refer to the Model Operation Manual for Bow Lake (2016s5115) for further information.*	

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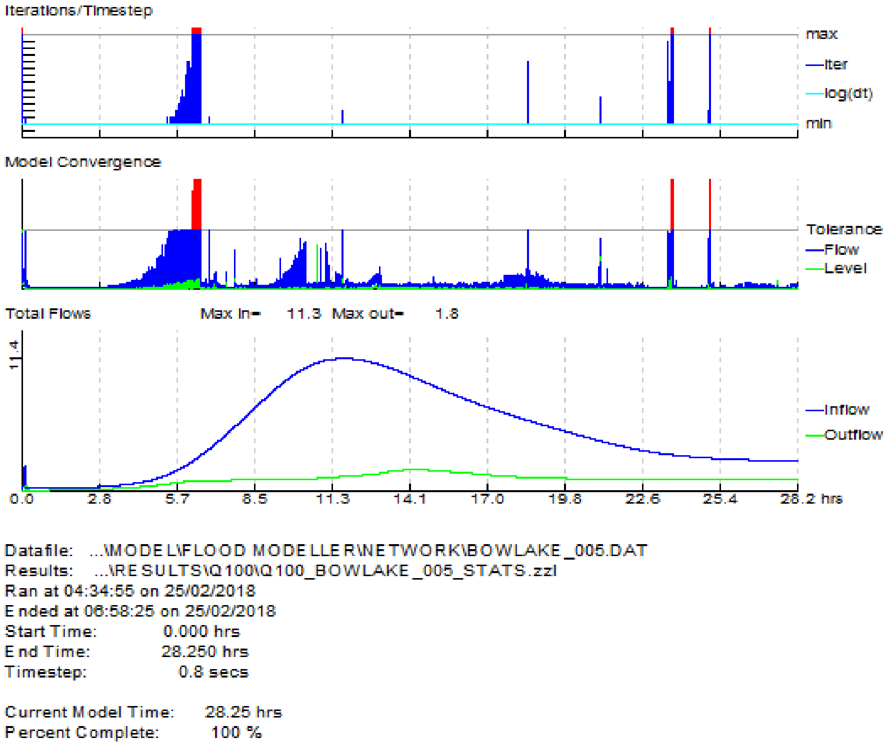
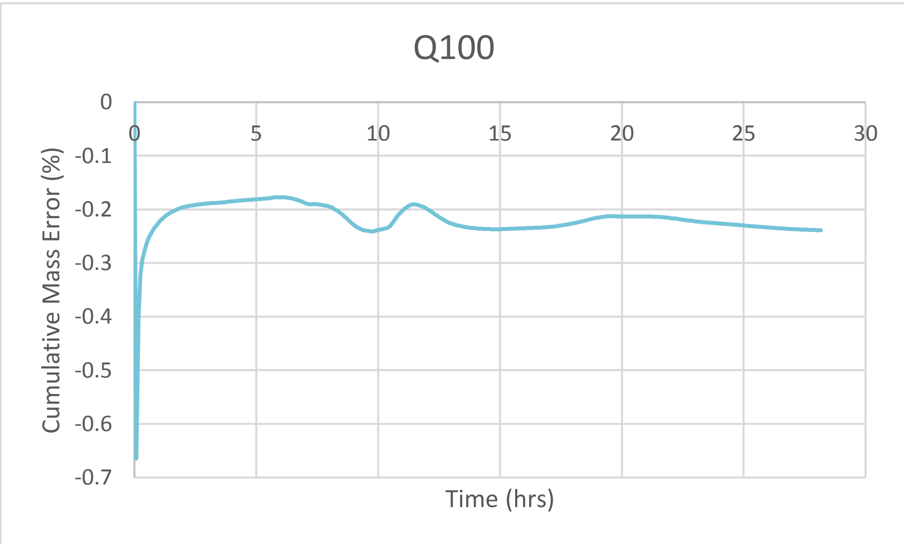
Table 4-8: Bow Lake model stability

<table>
<tr><td>1D diagnostic / convergence plot</td><td>The Flood Modeller Convergence plots for the design events are in line with the existing Bow Lake model. They do not show any significant non-convergence, except for a brief period on the rising limb, and indicate the model is generally stable especially at the peak of the event.

</td></tr>
<tr><td>2D Cumulative Mass Error</td><td>Cumulative mass error is within acceptable model tolerances (±1%) for the whole simulation, despite a spike at the onset resulting from the downstream boundary conditions.

</td></tr>
</table>

2D dVol	The dVol plots suggests some instability at the peak of the event; however, the profile is similar to the existing draft Bow Lake model dVol plot and was considered acceptable for use. The plot below shows a spike at the start of the simulation, which can be attributed to the downstream boundary conditions which have been modified in this study to improve the mass balance error, as discussed in section 2.2.2. As a sensitivity test, the results have been compared to a version of the model with the downstream boundary conditions set to existing. The results demonstrate some change in flood extent, but which is confined to the vicinity of the downstream boundary. The mass balance error produced by the lower downstream boundary extends to -12%, making the results unacceptable for use. The amendments made to the downstream boundary are therefore considered an improvement and the initial spike shown in the dVol plot is not considered to impact the peak results.