Land at Longbridge

Technical Note: Fluvial Flooding

30th September 2014

Executive Summary

This study assesses the River Avon watercourse hydrology, which includes computational hydrological assessment across the proposed development site to the south of warwick to understand the existing flooding regime and to develop flood alleviation proposals that can potentially provide serviceable development land.

The River Avon modelling assessment included: topographic surveys, photos, details of structures, Digital Terrain Models (DTMs), existing hydraulic models and modelling report, details of the Environment Agency's flood defences, historic flood information all of which combined give a reasonable level of confidence in the modelling undertaken.

Additionally, Brookbanks have more recently produced a detailed 2D model of the Gog Brook, including the now completed South West Warwick flood alleviation scheme and as such, the mapping in this area has been updated and the modelling is considered robust.

That said, the current flood modelling of the Southern part of the site around Old Horse Brook is based on historic data that does not account for several more recent interventions, including the construction of the elevated section of the M40 motorway. It is reasonable to assume the existing model is not accurate.

With the above in mind, further investigation is required which may result in the following outcomes:

- Confirmation that flood waters remain within the banks of the Old Horse Brook therefore confirming no flood extents across the site.
- Identification of flooding on the Old Horse Brook similar to that shown by the existing model.
- Out of bank flows on the Old Horse Brook within an area different to the existing model.

In the event of the modelling work confirming flooding along the Old House Brook, there are a number of strategies available which could be employed to control the extent of flooding, subject to the agreement of the EA:

- *Create a storage area to accommodate excess flow of water that would otherwise result in out-of-bank flooding*
- *Increase the capacity of Old Horse Brook to increased water flows to pass through the site.*

Based on the works undertaken on Gog Brook at the North of the site it is reasonable to conclude that the extent of 1 in 100 year and 1 in 1,000 year flood zones within the proposed area for development can be reduced subject to further detailed investigation and the full agreement of the Environment Agency in respect of the strategy employed.

1 Introduction

Brookbanks Consulting Limited is appointed by Severn Trent Property Ltd to complete a baseline review of the fluvial flood risk at the proposed site in Longbridge, to the south west of Warwick.

The objective of the study is to ascertain the robustness of the currently available data in order to identify what, if any, further work is required to ensure the risk to the development is accurately defined.

This study assesses the site watercourse hydrology, which includes computational hydrological assessment across the land to understand the existing flooding regime and to develop flood alleviation proposals that can potentially provide serviceable development land.

Further information about the wider catchment of the River Avon which lies to the east of the site was obtained from the "River Avon flood risk mapping report", produced by Halcrow Group Ltd and JBA Consulting on behalf of the Environment Agency in 2009.

2 Background Information

Location & Details

The proposed development lies to the south west of Warwick in an area known as Longbridge. To the east, the site is bound by the River Avon, beyond which lies undeveloped land and Lodge Woodland. The M40 forms the southern site boundary whilst the Stratford Road is identified as the western boundary. The Gog Brook and Leafield Farm are identified to the north.

The northern half of the site is currently occupied by the Longbridge Sewage Treatment Works and Depot, operated by Severn Trent Water whilst the land to the south, adjacent to the M40 comprises Longbridge farm and a number of small residential buildings. The site location and boundary is shown indicatively on Figure 2a, below.

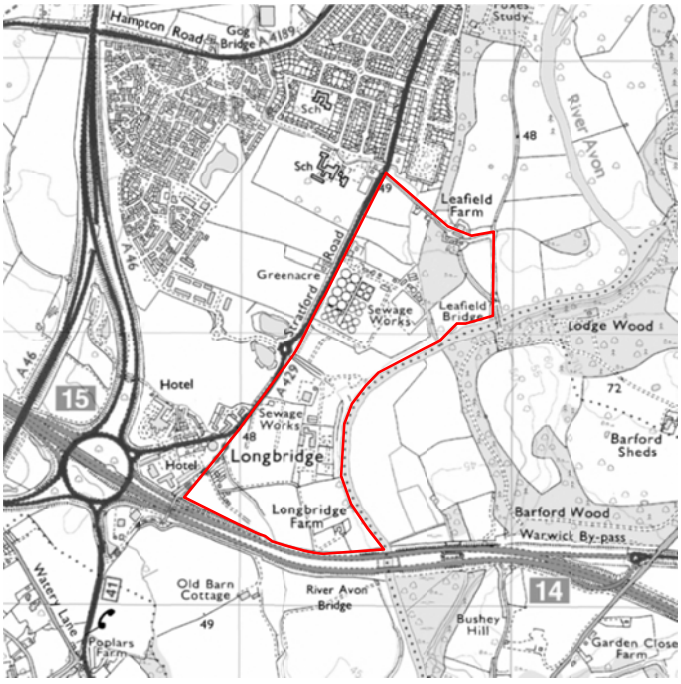

Figure 2a: Site Location

Watercourse Systems

Wider Scale

Reference to the Flood Estimation Handbook shows the site to lie within the wider catchment of the River Avon, on the eastern boundary of the site. Having an URBEXT2000 value of 0.0730 the catchment can be described as *"moderately urbanised"*. The FEH catchment is shown in Figure 2b, below.

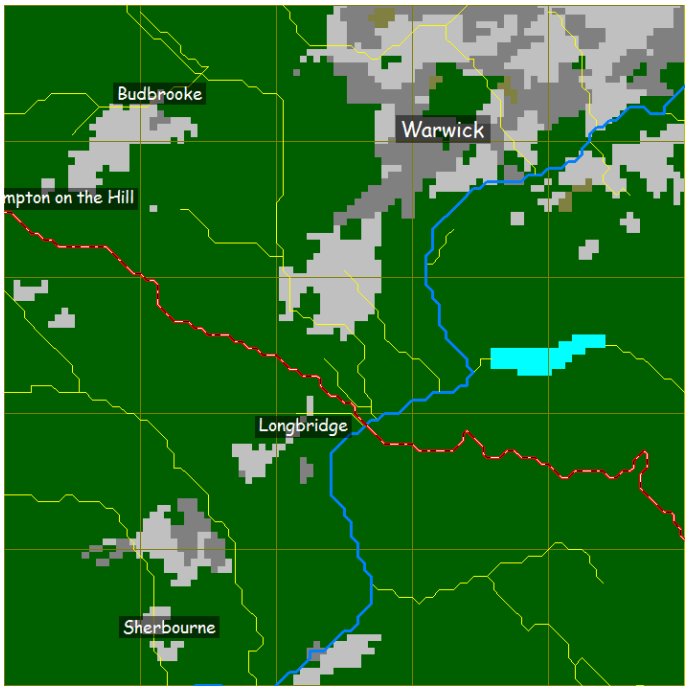

Figure 2b: FEH reported catchment

Local Scale

At a more local level, two watercourses are present within the site boundary; these are discussed in more detail below

Gog / Fishers Brook: The Gog Brook originates approximately 4km north west of the site near to Hatton Village. The watercourse flows in a south westerly direction through mostly undeveloped land before passing under the A46 and into Warwick Racecourse. Hereafter, the watercourse turns 90 degrees and flows due south along the western edge of the racecourse track. The Gog Brook passes through a culvert beneath the A4189 and enters the South West Warwick development land.

Over a period of approximately 18 months, various flood studies and option appraisals were completed to develop options to alleviate flooding along Gog Brook at this location and hence prevent out of bank flows across the South West Warwick and Tournament Fields land.

A scheme was ultimately development and implemented which involved:

- Removal of excessive vegetation along the existing Gog Brook, upstream of Stratford Road along the reach of watercourse fronting Shelley Avenue, to allow flood flows to be adequately conveyed.
- Localised channel cross sectional improvements along the Gog Brook reach fronting Shelley Avenue.
- Replacement of the A429 Stratford Road culvert with a 4 x 2m concrete box culvert.
- Minor channel vegetation clearance along the Fishers Brook reach between Stratford Road and Leafield Farm Cottages.
- Creation of a flood berm along Fishers Brook, downstream of Stratford Road and to the south of Lodge Crescent, extending to approximately 140m in length.
- Replacement of the Leafield Farm access culvert with a 3.6 x 1.5m concrete box culvert, plus localised bank re-profiling and additional bypass flood conveyance improvements.
- Implementation of landscape and ecology related enhancements and mitigation proposals into the scheme

Upon leaving the South West Warwick development land the Gog Brook flows in a southerly direction through the proposed development before making confluence with the River Avon on the eastern site boundary.

Old House Brook: Originating some 2km west of the site near Hampton Lodge, this watercourse flows easterly, being culverted beneath the A46 on multiple occasions before entering the existing South West Warwick development site. The Old House Brook forms the boundary between the South West Warwick site and the existing Hilton Hotel before being culverted beneath the A429 and into the proposed site. Within the development boundary the Old House Brook flows generally south easterly, along the reasr gardens of Home Farm and Manor Cottages before entering a culvert beneath the M40 on the southern site boundary.

Fluvial Flood Risk

The Environment Agency's (EA) National Generalised Modelling (NGM) Flood Zones Plan indicates predicted flood envelopes of Main Rivers across the UK. In many circumstances, the NGM is based on basic catchment characteristic data and modelling techniques. Where appropriate, more accurate Section 105 / SFRM models are produced using more robust analysis techniques.

The Flood Zone mapping identifies flooding on the River Avon, Gog Brook and Old House Brook within the site, with flows on all watercourses being seen to come out of bank during the 1 in 100 (1% AEP) and 1 in 1,000 year (0.1% AEP) events.

The EA Flood Zone plan is reprinted as Figure 2c below.

The mapping shows that much of the northern section of the site, currently occupied by the Longbridge Sewage Treatment Works, lies within Flood Zone 1 with the majority of Flood Zones 2 and 3 identified to the south of the site

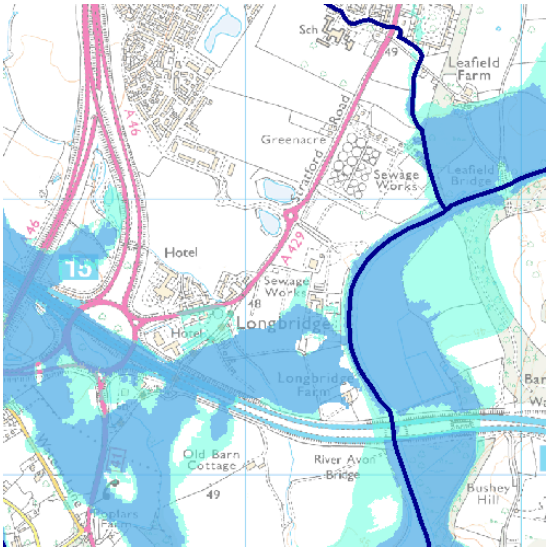

Figure 2c: EA Flood Zone Plan showing 1 in 100 & 1 in 1,000 year floodplains

Flooding from rivers without defences – 1 in 100 year (1%) event (Zone 3)

Extent of extreme flood – 1 in 1,000 year (0.1%) event (Zone 2)

Flood defences

Areas benefiting from flood defences

In order to determine the robustness of the Environment Agency Flood Zones for the area, the River Avon Flood Risk Mapping Study (2010) has been obtained. This report is discussed further in the following section

3 Environment Agency Modelling

The River Avon study covers the entire upstream catchment of the watercourse down to the M5 motorway, extending approximately 5.5km upstream of the confluence with the River Severn at Tewkesbury.

Although the report does not directly address the proposed site, information is included in relation to the wider area in the context of the River Avon catchment.

The computational hydraulic model of the River Avon and associated primary tributaries has been developed using ISIS Tuflow to integrate both urban and river catchments. A full integration of 1D and 2D hydrodynamic simulation techniques, both the above- and below- ground elements of catchments, can be modelled to accurately represent all flow paths. ISIS Tuflow enables the hydraulics and hydrology of natural and man-made environments to be incorporated into a single model.

The linking of 1D river channels and 2D floodplain is carried out by means of lateral banks. The flow can pass between these two components at any location along the river, allowing real conditions to be more accurately modelled.

The full 2D surface flood modelling can be employed across river components of the model, providing more precise modelling of flows through complex geometries.

ISIS Tuflow is an actively developed windows based product that is approved by the Environment Agency for watercourse modelling purposes.

As with all flood models, the main inputs required are flow hydrology, downstream control, channel roughness and geometric data. The following paragraphs outline the details used.

Hydrology

Hydrometric data are needed for flood estimation and for calibration of the hydraulic models. In instances when flood are estimated using local flood records, they offer a greater degree of reliability than when produced based on the FEH catchment descriptors alone. There are two main types of FEH descriptors, the FEH statistical method which uses flow peaks, whereas the revitalised Flood Hydrograph method (ReFH) requires rainfall and river level of flow event data to assess the time to peak during floods.

Calibration of hydraulic models is best archived using flow data for all reaches, together with water levels from known locations. In areas where his information is limited sensibility of the result is achieved, through ensuring flood extents tie in with flood histories for the specific location.

The River Avon catchment benefits from an extensive and reasonably comprehensive gauged flow and level history, along both the main river and its primary tributaries. This gives an opportunity to provide flood assessments in which a degree of assurance can be placed.

The data used for flood estimation of the River Avon includes:

- Level and flow data gauges on the River Avon and Tributaries, where available.
- Historical Outlines for the 2007 flood event
- HiFlows data set
- Past hydraulic model and hydraulic reports. Some hydrology of the catchment was taking from recent hydrological assessment.
- MORECS and rainfall Data
- Rating equations for rating reviews.

Roughness

Channel and floodplain roughness values are generally represented in hydraulic modelling software as a Manning's 'n' value.

The Manning's 'n' value were set to the values according to the hydraulic model produced by the EA. The calibration of the hydraulic and hydrological models involving refining the representation of features in the model (e.g. bank heights) and modifying parameters (e.g. Manning's n roughness coefficient) to ensure that the model reproduced the recorded water levels throughout the watercourse. Table 3a below confirms the Mannings roughness values used within the flood model.

Manning's 'n' Value	Land Use
0.030	Open Water
0.050	Roads/Paths/Tracks/Railways
0.500	Gardens/Glasshouses
0.050	Manmade surfaces/Embankments/Structures
0.050	Grass/Fields/Natural Lands
0.500	Trees
1.000	Buildings

Figure 3a: Roughness Values used in TUFLOW to represent the Floodplain

Geometry

The River Avon modelling work undertaken was completed in two stages.

1D Model Build: Originally, due to historic modelling limitations, the River Avon catchment modelling was split into four areas. These four original 1D models were combined as part of the revised modelling and subsequently divided into three models of equal length (the Upper, Middle and Lower Avon models).

For the reaches modelled in 1D only, the floodplain schematisation was represented as extended cross sections, with the geometry updated using the most up to date LIDAR data. This involved updating the geometry of the floodplain in the Upper and Middle models, and replacing the floodplains schematisation in the Lower Avon model, formerly represented by reservoirs. The in-bank geometry was retained from the original ISIS models since it is based on surveyed data.

Floodplain storage in the 1D models was represented by selecting appropriate roughness (Manning) values across the different reaches of the models. Initial roughness values were selected based on data available (photos) and experience; however, some of the values were later modified during calibration.

A comparison of the DTM data with topographic survey data from the Rugby area was undertaken. This analysis identified some discrepancies in the data. Further investigation suggested that the identified discrepancies were significantly influenced by the location of the in-bank channel within each cross section and were subsequently corrected. Interpolated sections were incorporated into the model to improve the numerical stability of the 1D-2D models.

2D Model Build: Five 2D domains were incorporated into the 1D models which coincided with the main urban areas. The floodplain area was modelled in TUFLOW. The 2D grid data was comprised of elevation data derived from the DTM which was created using filtered LIDAR data with 2m grid resolution. The grid resolution of the TUFLOW models was 8m in all cases.
The 1D and 2D elements of the model were then linked together within each of the three models. Flood defences were represented by modifying the 1D model terrain elevations. Where defences were located within the 2D domain, the geometry was updated accordingly.

Model Calibration and Details

Model calibration is completed to optimise the model unknowns; calibration was carried out to produce robust and conservative results.

Since the 1D model is considered shorter than the 1D-2D model run times, the River Avon model was only initially calibrated using the 1D model until the result was acceptable, A further calibration was also done using the 1D-2D combined model to refine the 1D results in urban areas where more details are sought.

Calibration of the 2D component of the hydraulic model consisted of refining the representation of the floodplain in the digital leaving and entering the river channel.

Bank heights are initially estimated from the LiDAR data using the standard algorithm for efficiency.

The refinement typically draws on information from the topography survey, but also uses LIDAR data to locate both low and high points that may be missed by the topography survey.

The Environment Agency have selected three events to calibrate the hydraulic models: April 1998, December 2000, and July 2007. These events were chosen as they were considered to be significant events which affected the whole catchments of the River Avon respectively. An additional fourth event (mid-June 2007) was selected for the model verification.

Discussion

The River Avon modelling assessment included: topographic surveys, photos, details of structures, Digital Terrain Models (DTMs), existing hydraulic models and modelling report, details of the Environment Agency's flood defences, historic flood information all of which combined give a reasonable level of confidence in the modelling undertaken.

Additionally, as previously discussed, Brookbanks have more recently produced a detailed 2D model of the Gog Brook, including the now completed South West Warwick flood alleviation scheme and as such, the mapping in this area has been updated and the modelling is considered robust.

That said, whilst the one of the 2D elements of the modelling covers the proposed site, the Old House Brook has not been included in the modelling exercise and thus, the subsequent floodplains associated with this watercourse, shown within the 2010 modelling report, is based on less accurate, historic modelling techniques.

This mapping also appears to show an interaction with the Horse Brook which lies further south of the site, beyond the M40. This watercourse has also been excluded from the 2010 Environment Agency model and therefore, whilst it is unlikely that an interaction at this location will be impacting upon the proposed site, the potential for same should be considered.

Based on our experience of the watercourses and hydrology of this area, there is potential for further work to gain back areas of land associated with the Old House Brook floodplain within the site. However, given the confidence in the modelling work completed for the River Avon and Gog Brook in this area it is unlikely that any amendments to same would result in significant changes.

Figure 3b below highlights the areas where it is believed that further refinement will result in the reclaiming of land from the floodplain.

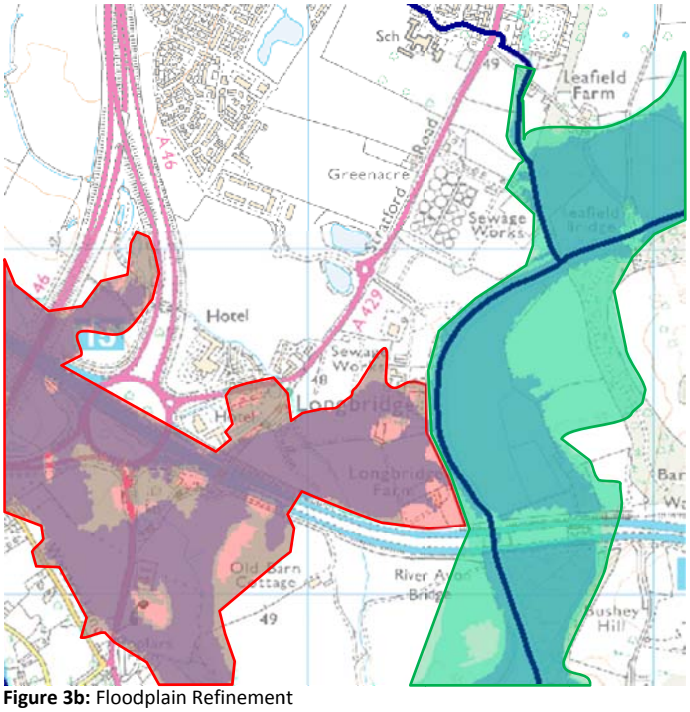

Figure 3b: Floodplain Refinement

Areas Deemed Robust

Areas of Potential Significant Refinement

The following chapter identifies the potential next steps in unlocking the definitive position within the site boundary along with some potential options for flood alleviation.

4 Next Steps

Whilst the River Avon and Gog Brook models are deemed suitably robust in this area, given that neither the Horse Brook nor Old House Brook are included within the modelling assessment, a detailed assessment of the fluvial flooding regime on these watercourses would offer the potential to further refine the 1 in 100 year and 1 in 1,000 year flood events shown on the Environment Agency mapping to be covering the southern half of the site.

Should the modelling work be undertaken, the following possible outcomes are envisaged:

- The Old House Brook is shown to retain the 100 and 1,000 year flood levels within bank and this removing the southern section of the site from Flood Zones 2 and 3.
- The Old House Brook is still shown to flood during the 100 and 1,000 year events however, when plotted against detailed topographical data, the extent of same is limited and can be accommodated within any future development of the site.
- Extensive flooding is still identified across the southern section of the site however the depths and extents are more accurately understood.

If, upon completion of the modelling work, the extent of the 1 in 100 and 1 in 1,000 year flood envelopes across the southern section of the site is deemed prohibitive, there may be potential for an alleviation scheme to be completed within the site to manage flood waters and release land more appropriate for development.

A number of potential options are discussed further below

Option 1 – Alleviation Storage

Similarly to the principles of a level for level compensation scheme, it may be possible to lower an area of land towards the south east of the proposed development to provide additional floodplain storage within the site, creating a flood storage berm.

At the downstream end of the site, near to the culvert beneath the M40 on the Old House Brook, a control structure could be put in place to limit the volume of water flowing downstream and retain peak discharges of water within the storage berm, thereby attenuating peak flows to a rate that may be safely conveyed along the downstream channel.

During critical storm events the control structure will be designed to permit the maximum volume of water into the Old house Brook without causing out of bank flows. All Additional flows will be redirected and into the storage area. Once the critical event has decreased the structure will release the retained water back to the Old house Brook at a controlled rate so as not to overload the watercourse. The control of peak flows through the Old house Brook provides valuable flood alleviation benefits as this will also provide alleviation for areas surrounding the watercourses.

The concept is shown on Figure 4a below.

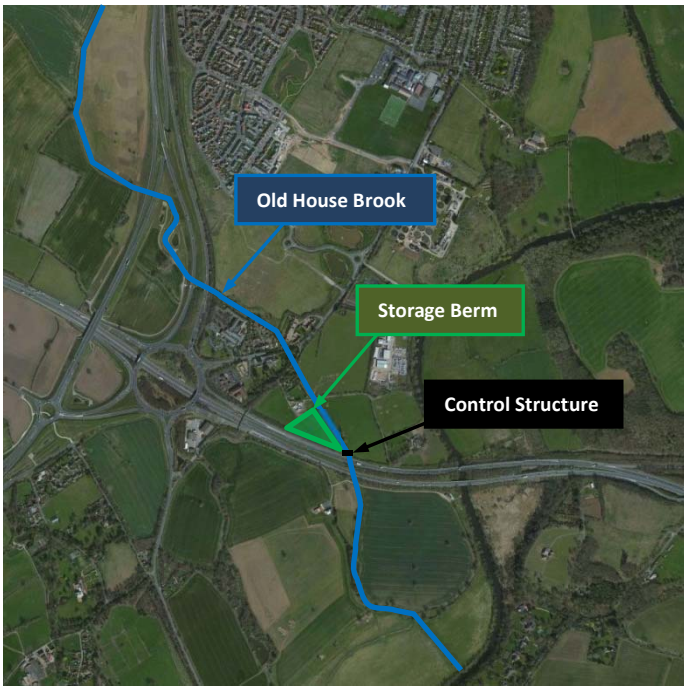

Figure 4a: Option 1 – Water storage within the site

Option 2 – Additional Capacity

To the north of the site, Brookbanks have completed an alleviation scheme on the Gog brook which involved increasing the capacity of the channel through earthwork scraping and the introduction of berms and bifurication channels along the reach.

The principles of a scheme of this type have previously been agreed and supported by the Environment Agency and has been proved to have significant flood alleviation benefits.

A plan view of the works completed for the Gog Brook are shown on Figure 4b below

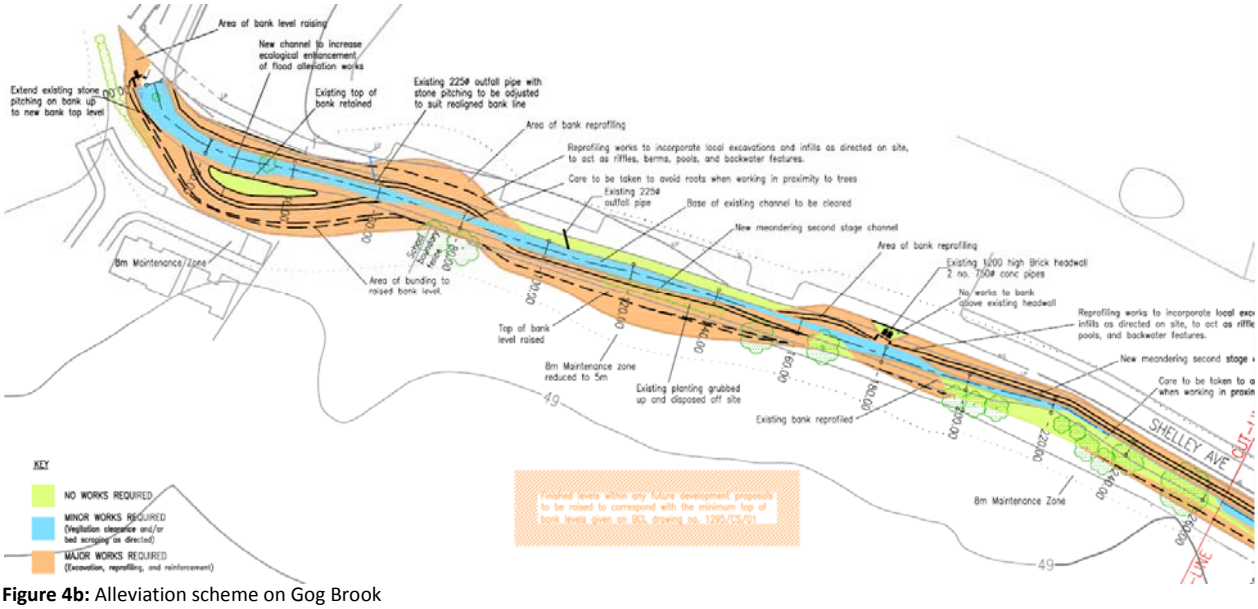

Figure 4b: Alleviation scheme on Gog Brook

5 Summary

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Additionally, as previously discussed, Brookbanks have more recently produced a detailed 2D model of the Gog Brook, including the now completed South West Warwick flood alleviation scheme and as such, the mapping in this area has been updated and the modelling is considered robust.

That said, whilst the one of the 2D elements of the modelling covers the proposed site, the Old House Brook has not been included in the modelling exercise and thus, the subsequent floodplains associated with this watercourse, shown within the 2010 modelling report, is based on less accurate, historic modelling techniques.

This mapping also appears to show an interaction with the Horse Brook which lies further south of the site, beyond the M40. This watercourse has also been excluded from the 2010 Environment Agency model and therefore, whilst it is unlikely that an interaction at this location will be impacting upon the proposed site, the potential for same should be considered.

Based on our experience of the watercourses and hydrology of this area, there is potential for further work to gain back areas of land associated with the Old House Brook floodplain within the site as the current mapping does not include for these features and the resulting volumes of out of bank flow should be manageable.

Despite of the current risk of fluvial flooding in the area, this report has outlined two potential options for providing alleviation to the proposed development and the surrounding area.

To ensure the most accurate and efficient outcome is achieved, it is recommended that a Stage 2 assessment is undertaken whereby both the Old House and Horse Brooks and surrounding areas undergo detailed modelling assessments to define the extend of flooding in more detail.

On the basis that the Stage 2 report provides positive results, Stage 3 alleviation assessments are considered viable to remove the site and some surrounding areas from the floodplain, thus reducing the risk of flooding and making the site a more preferable location for development.