

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Hydraulic Model Report

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GLOSSARY & NOTATION

1D – one-dimensional hydraulic model, good for representing the hydraulics of a definitive channel or flow pathway and hydraulic structure.

2D – two-dimensional hydraulic model, good for representing complex flow routing present within the floodplain.

Annual Exceedance Probability (AEP) - the probability (%) of a flood event occurring in any year.

Catchment - the land area that drains (normally naturally) to a given point on a river, drainage system or body of water.

Design flood event - magnitude of the flood adopted for the design of the whole or part of a development, usually defined in relation to the severity of the flood in terms of its return period. Typically, the 1 in 100-year return period event including an allowance for future climate change for fluvial flood events.

DTM – Digital Terrain Model

EA – Environment Agency

ESTRY - a 1D hydraulic modelling software package published by BMT.

Flood Estimation Handbook (FEH) – industry standard guidance on rainfall and river flood frequency estimation across the UK.

Floodplain - any area of land over which water flows or is stored during a flood event.

FRA – Flood Risk Assessment

Freeboard - the height of the top of a bank, floodwall or other flood defence structure, above the design water level. Freeboard can be seen as a safety margin that makes allowance for uncertainty associated with the potentially damaging effects of flood rise or wave action.

Hydraulic model - a mathematical (generally computer based) model of a water/sewer/storm system which is used to analyse the system's hydraulic behaviour.

LiDAR – Light Detection and Ranging aerial survey data

LLFA – Lead Local Flood Authority

mAOD – metres above Ordnance Datum

mBGL – metres below ground level

Main River - a statutory type of watercourse in England and Wales, usually larger streams and rivers. The EA can carry out maintenance, improvement or construction work on main rivers to manage flood risk as part of its duties and powers.

NRFA – National River Flow Archive

OS – Ordnance Survey

Preliminary Flood Risk Assessment (PFRA) - an assessment of floods that have taken place in the past and floods that could take place in the future. It generally considers flooding from surface water runoff, groundwater and ordinary watercourses, and is prepared by the Lead Local Flood Authority.

ReFH – Revitalised Flood Hydrograph rainfall-runoff hydrological model

Return period - a statistical term defining the probability of occurrence of a flood event. Thus a 1 in 50-year flood is one likely to be equalled or exceeded on average only once in a 50-year period: a flood with a 2.0% annual probability exceedance (AEP).

Strategic Flood Risk Assessment (SFRA) - a study carried out by one or more local planning authorities to assess the risk to an area from flooding from all sources, now and in the future.

TUFLOW – a 2D fixed grid hydraulic modelling software package published by BMT.

UOW – Unnamed Ordinary Watercourse

Watercourse – a natural or man-made open channel for the conveyance of water.

Z-line – a break line layer in TUFLOW which can be used to reinforce linear features in the 2D model domain such as a riverbank, flood defence, or channel bed.

Z-shape – a layer in TUFLOW which can be used to manipulate the 2D model geometry.

1. INTRODUCTION

- 1.1 BWB Consulting Ltd has been commissioned by Richborough Estates Limited (the client) to undertake a site-specific hydraulic modelling exercise of the Thurlaston Brook to provide a detailed understanding of potential flood risk to the proposed development site at land off Brascote Lane, Newbold Verdon (NGR: SK 4468 0320).

Aims and Objectives.

- 1.2 The aim of the modelling exercise is to identify peak flood levels and floodplain extents within the vicinity of the site to help inform the flood risk management strategy of a proposed development. The model will be used to assess the potential impact of climate change on the floodplain, as well as assess residual risks associated with the watercourse, such as a blockage of the downstream bridge.
- 1.3 This modelling exercise will be used to inform a FRA in support of the proposed development.

Approach

- 1.4 In order to achieve the aim, a new 1D/2D ESTRY-TUFLOW model was constructed, based on a watercourse survey completed by BWB Consulting in July 2021 (see **Appendix 1**).
- 1.5 The model has been simulated for a series of design storm events. These modelled events include the 1 in 20-year, 1 in 100-year and 1 in 1000-year events that are typically used by the Environment Agency (EA) to define Flood Zones 3b, 3a and 2 respectively for planning purposes.
- 1.6 Furthermore, simulations have been run to account for the impacts of climate change in accordance with the recent allowances that were released by the EA in July 2021. This is necessary to demonstrate within the FRA that the proposed development can be deemed safe for its lifetime.
- 1.7 Sensitivity testing has also been undertaken to understand what impacts changes to roughness, downstream boundary and storm duration has upon the model outputs. Blockage testing has also been conducted at 3 locations to understand the potential impacts to the site, should such a scenario occur.
- 1.8 The modelled flood extents and levels from this study have been assessed in the associated FRA (REF: **BLN-BWB-ZZ-XX-RP-YE-0002_FRA**). Following an assessment of how the development proposals correspond to the model outputs, appropriate development levels and mitigation measures have been recommended as part of the FRA.

Site Description

- 1.9 The site is located off Brascote Lane, immediately south of the residential setting of Newbold Verdon. Leicester city centre is located approximately 1.5km east of the site and the village of Newbold Verdon.
- 1.10 Brascote Lane forms the western and southern boundaries of the site. The northern limit of the redline site boundary is bordered by the Thurlaston Brook which flows from east to west. The east of the site is surrounded by farmland.
- 1.11 The site itself is wholly comprised of farmland, bordered by hedgerows and tree lines. A site location plan is shown in **Figure 1.1**.

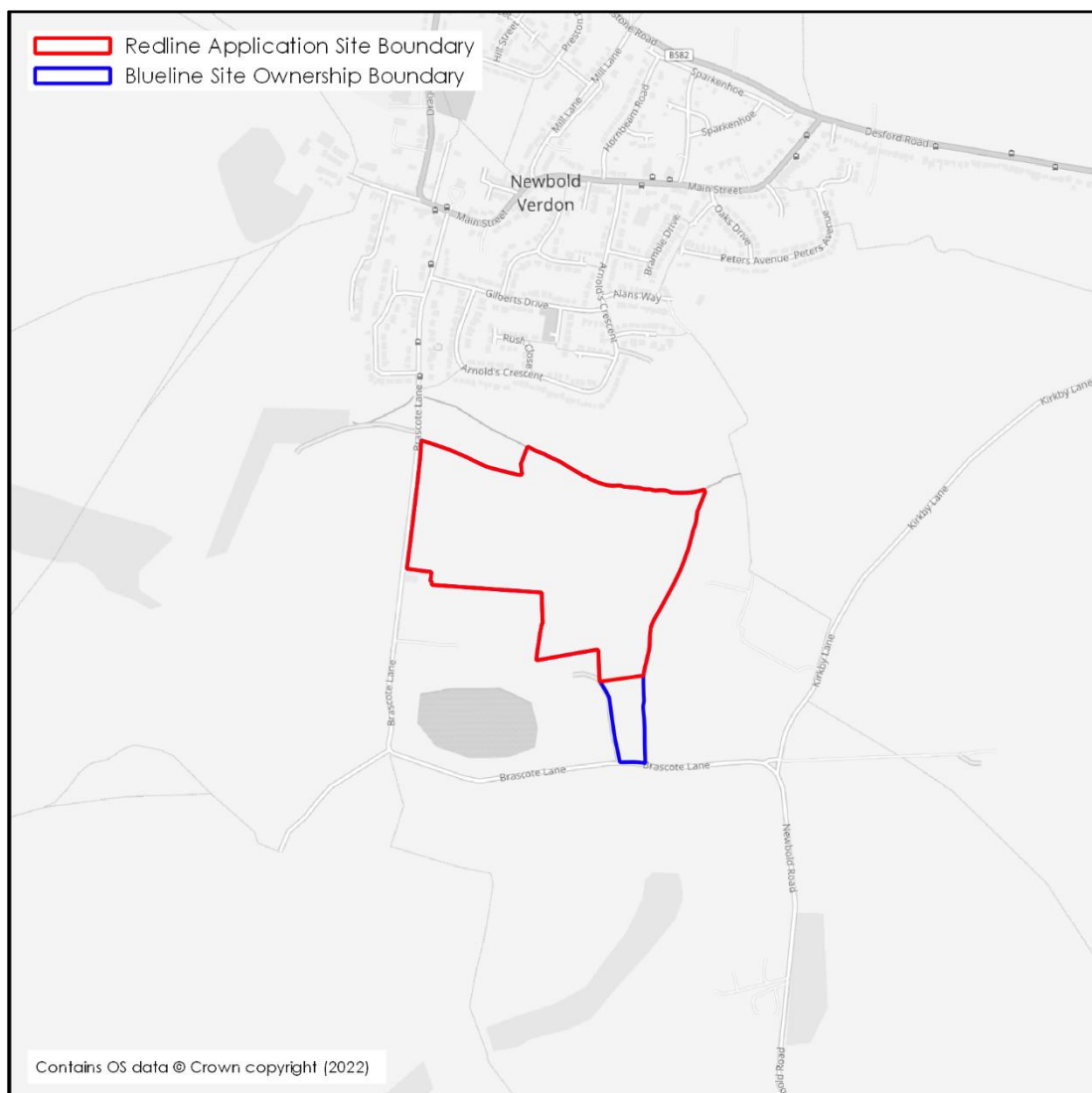


Figure 1.1: Site Location Plan

Local Watercourse Network and Catchment

- 1.12 The Thurlaston Brook flows alongside the northern boundary of the site in a westerly direction. The source of this watercourse is located approximately 700m upstream of

the site. An UOW flows into the Thurlaston Brook approximately 700m downstream of the Brascote Lane road crossing. The Thurlaston Brook later becomes a tributary to the River Soar, approximately 17km downstream of the site.

- 1.13 **Figure 1.2** shows the local watercourse network. The watercourse labels shown will be used throughout this report.

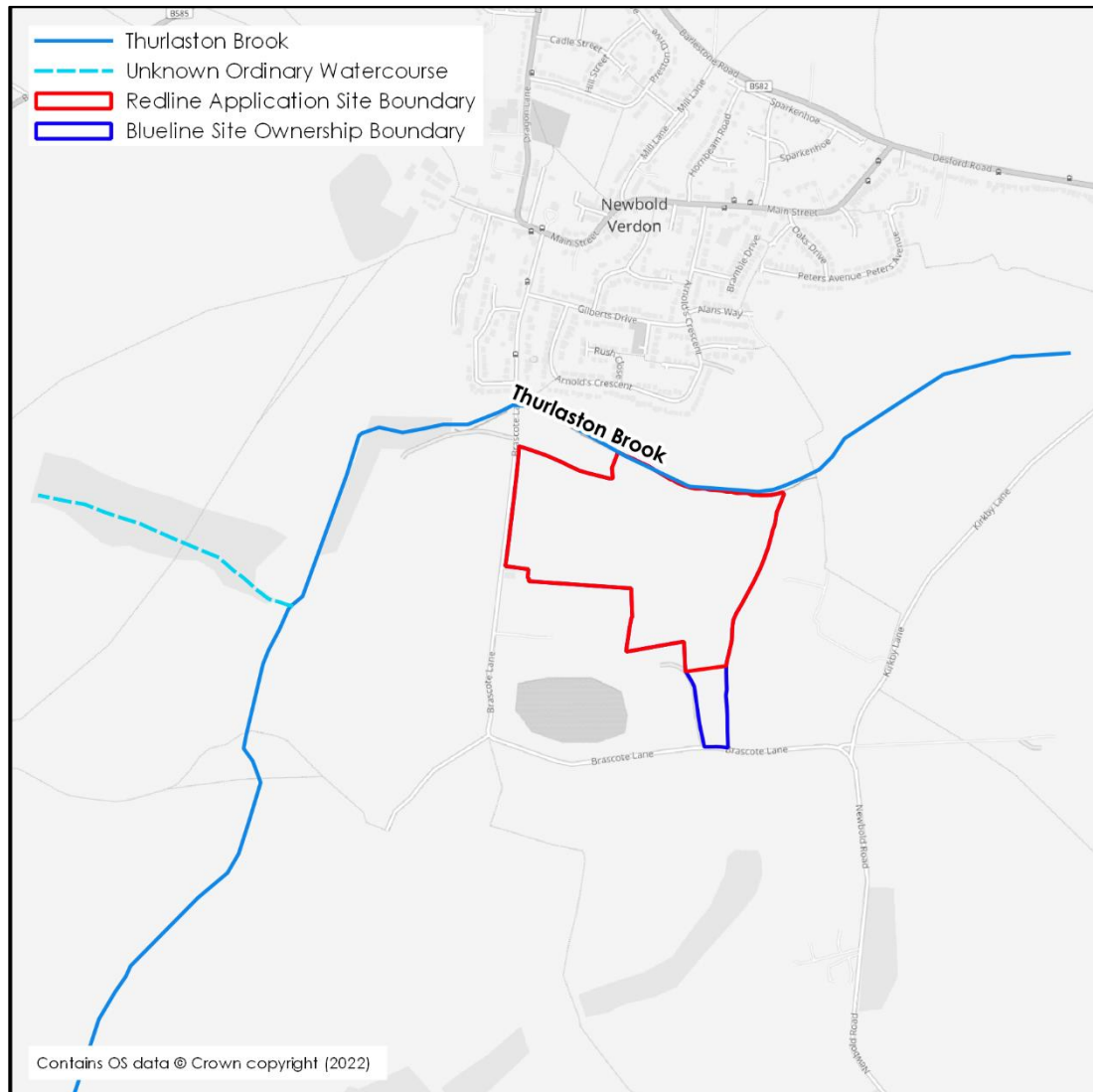


Figure 1.2: Watercourse Network

- 1.14 The Thurlaston Brook is a tributary of the River Soar with a total catchment area of approximately 37.52km². The proposed development site is located at the very upstream limit of the catchment. The watercourse has a catchment area of 1.74km² upstream of the Brascote Lane road crossing.
- 1.15 The catchment area associated with this study is illustrated within **Figure 1.3**. Also displayed is EA 1m LiDAR data which provides a general illustration of the topography in the area.

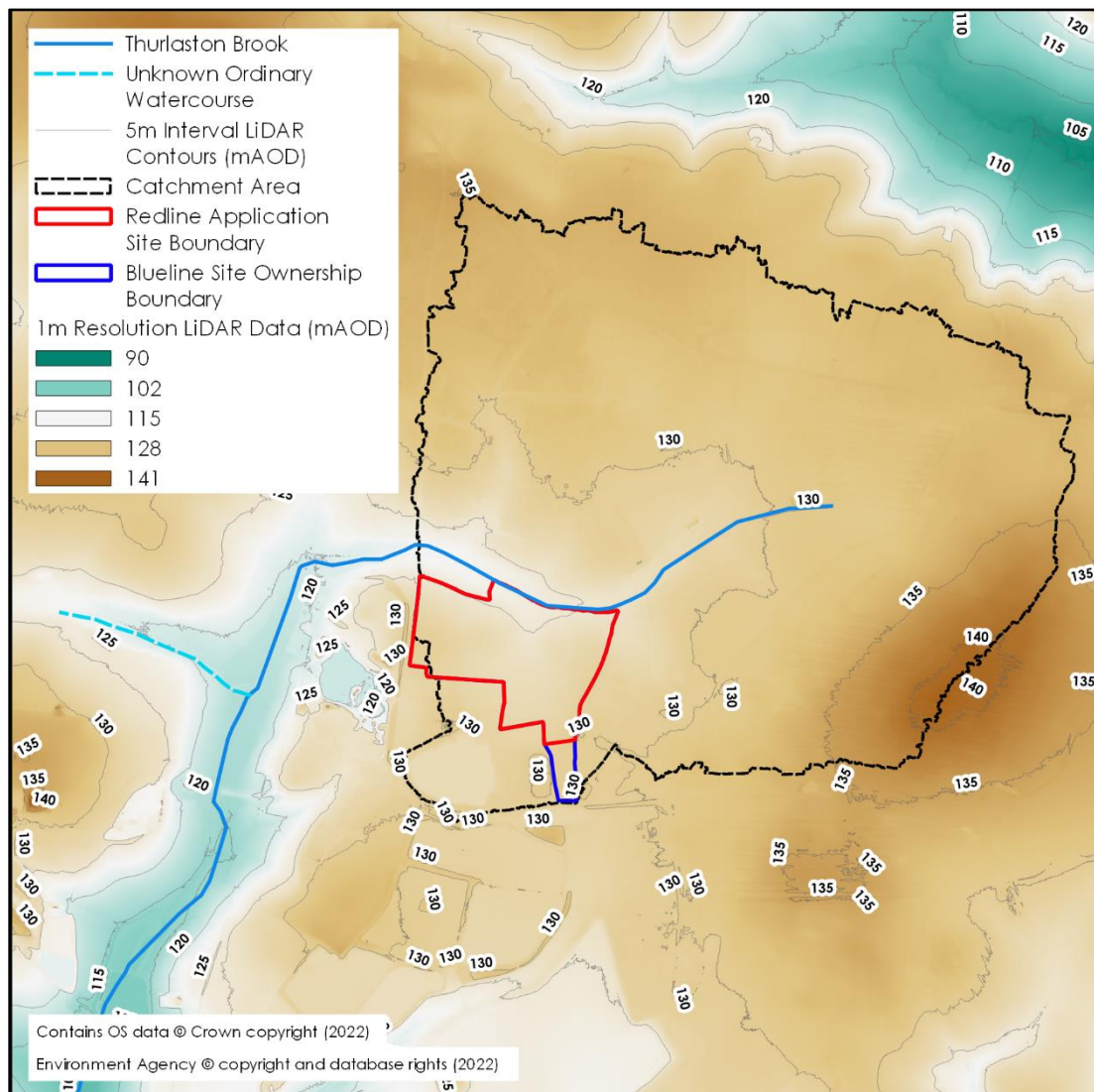


Figure 1.3: Site Topography

Previous Studies & Available Data

EA Recorded Flood Outlines

- 1.16 A review of the 2019 Hinckley and Bosworth Strategic Flood Risk Assessment (SFRA), the 2011 Leicestershire County Council Preliminary Flood Risk Assessment (PFRA), EA recorded flood data, and local news outlets did not return any reports of flooding within the site or further upstream.
- 1.17 Following liaison with Leicestershire County Council, acting as the Lead Local Flood Authority (LLFA), it has been reported that there are two records of flooding incidents within close proximity to the site. Specifically, these are referred to as:
 - March 2016 = Arnolds Crescent. Here, driveways were flooded from the highway. The source was not identified, but as this location is removed from the watercourse it is most likely associated with surface water flooding. The pluvial mapping displayed in **Figure 1.5** estimates flooding at this location.

- September 2019 = The corner of Brascote Lane and Luburnum Avenue. This incident was limited to the highway and was believed to be caused by localised surface water ponding due to the highway topography.

1.18 There have subsequently been no records of historic flooding provided at the site specifically.

Hydraulic Model(s)

1.19 BWB Consulting contacted the EA and Leicestershire County Council (LLFA) to request for any hydraulic model data/ files that were held at the site. Both authorities confirmed that they held no such information at this location. The EA specifically stated that:

"This location is within flood zone 1. As such we do not hold any modelled information (no heights, or products 5, 6 & 7) for this site."

1.20 Leicestershire County Council commented stating:

"The County Council has [not] commissioned flood modelling studies in Newbold Verdon at this time. As such, no sensitive receptors or critical areas have been identified."

Environment Agency Flood Maps

1.21 The EA Flood Map for Planning confirms that the site lies wholly in Flood Zone 1. The EA have confirmed that there is not any modelled data available for this location as existing. This is because no detailed modelling exercise has been completed to date.

1.22 The JFLOW national mapping programme does recognise the Thurlaston Brook catchment and, accordingly, flood extents have been produced for this watercourse. However, these extents do not include the stretch of the Thurlaston Brook immediately adjacent to the site (or upstream) and are only available further downstream. This confirms the need for explicit hydraulic modelling to inform the associated Flood Risk Assessment.

1.23 The Flood Map for Planning is displayed in **Figure 1.4**.

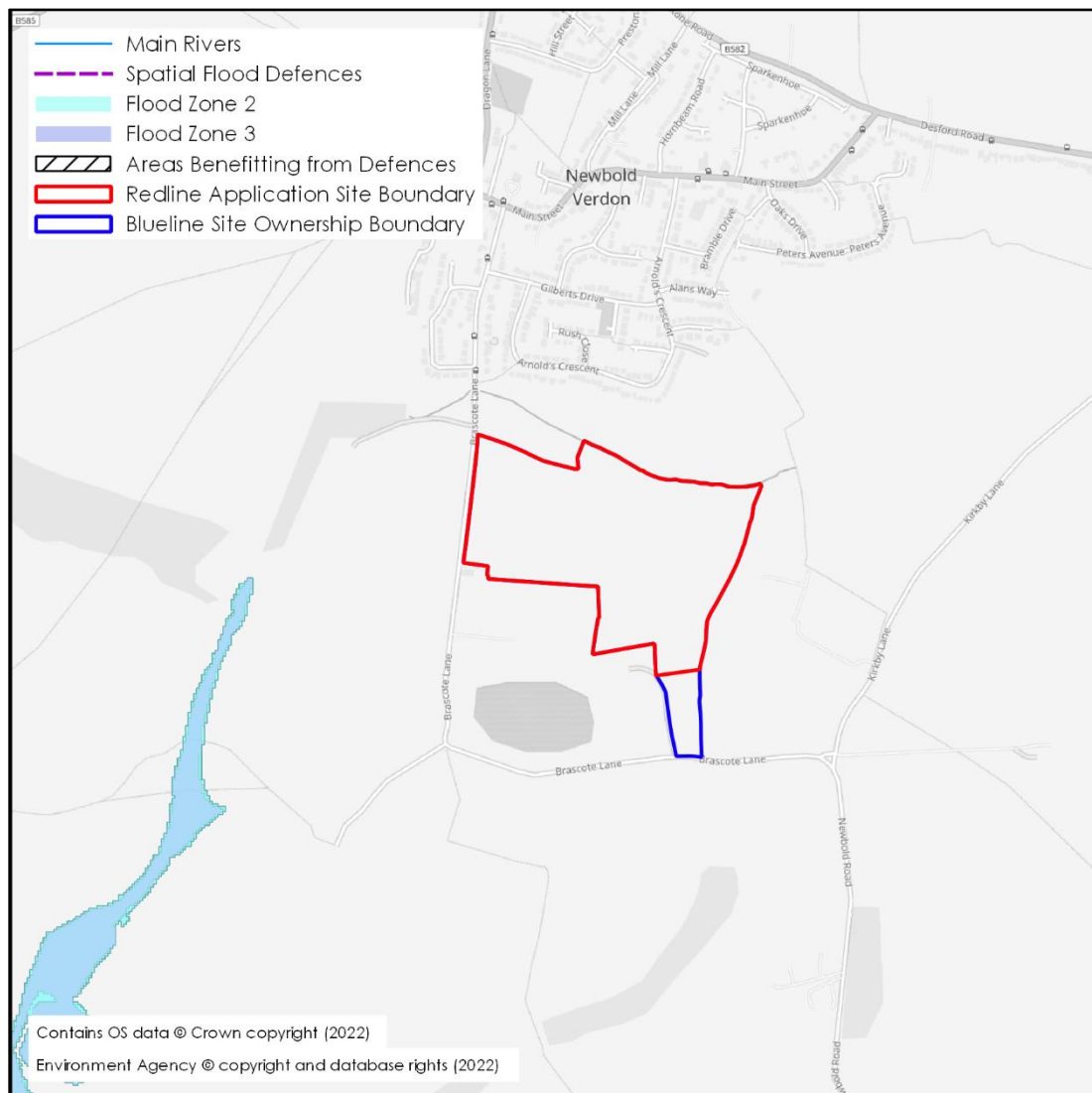


Figure 1.4: EA Flood Map for Planning

Risk of Flooding from Surface Water

- 1.24 EA surface water flood risk maps identify the potential areas at risk of flooding if rainwater does not enter the drainage system or infiltrate into the ground. While not strictly a fluvial source, this mapping can provide an indication of the potential flood risk associated with minor watercourses excluded from the Flood Maps for Planning.
- 1.25 The surface water maps suggest that the potential floodplain associated within the watercourses is relatively constrained and remains close to the channels. The site boundary is shown to remain largely unaffected.
- 1.26 An extract of the Surface Water Flood Risk maps is illustrated within **Figure 1.5**.

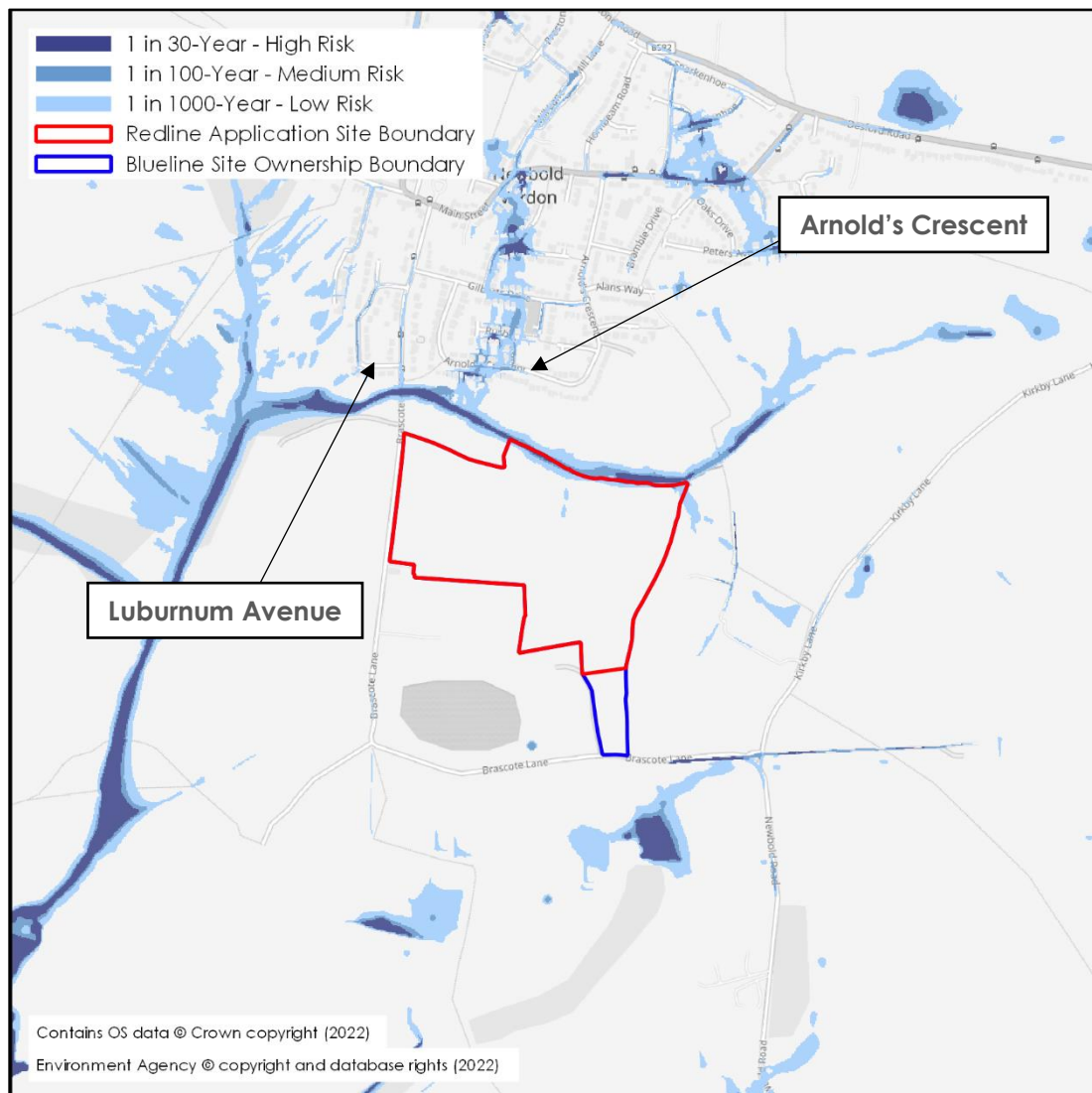


Figure 1.5: Risk of Flooding from Surface Water Map

Other Sources of Data

1.27 The following additional datasets were used within the hydraulic modelling exercise:

- EA LiDAR aerial survey. 1m resolution composite Digital Terrain Model (DTM).
- Topographic survey of the study site, undertaken in July 2021.
- Cross-sectional Watercourse Survey, undertaken in July 2021 (included as **Appendix 1**).
- Photographs and observations from site visit undertaken in July 2021 by BWB Consulting.
- A hydrological assessment of Flood Flows undertaken by BWB Consulting (included as **Appendix 2**).

Assumptions and Limitations

1.28 Several assumptions were made during the study which may lead to implications on the modelled results. However, the study has been based on the data available at the time of writing. The key assumptions and limitations are as follows:

- The modelling exercise has made use of the available data at the time of construction and simulation. The model represents the floodplain and channel conditions at the time of survey.
- The modelling exercise has made use of the latest hydrological and hydraulic modelling software versions at the time of analysis and completion (the hydrological assessment was completed in August 2021 with the hydraulic modelling completed between August and September 2021).
- The model contains no formal representation of the conveyance within minor watercourses or ditches other than that captured by the model grid and within the 1D model domain.
- The 2m resolution of the model may negate any small-scale topographic features, although all the significant features are believed to have been captured.
- Outside of the site boundary (where topographic survey is available), floodplain levels are derived from LiDAR which has limited accuracy (+/- 0.15m). however, this is considered to be sufficient for the purpose of this study.
- The bare earth DTM does not include for the presence of walls, buildings or other structures. Buildings have been modelled at ground level with an elevated roughness in line with best practice.
- The modelling exercise has been undertaken to produce a good representation of flood risk mechanisms in and around the study site. It has not been designed to accurately map flooding in the wider catchment.
- Due to the size of the catchment area modelled (2.14km²), flows have been applied to the model as a lumped inflow at the upstream limit of modelled watercourse. This is considered to be a conservative approach as 100% of the calculated flows for each event are being conveyed through the model at the upstream limit of the site.
- Due to access limitations, it was not possible to survey an informal farm access track that crosses the Thurlaston Brook immediately upstream of the site as well as an additional structure downstream of Brascote Lane road crossing. Subsequently, these hydraulic structures were excluded from the baseline model. Sensitivity testing was undertaken whereby the channel was represented as 100% blocked at these locations to understand a worst-case scenario.

2. HYDROLOGY

Flood Flow Estimation

- 2.1 A hydrological review of the catchment was undertaken using Flood Estimation Handbook (FEH) methodologies to estimate peak flood flows and derive an appropriate hydrograph shape. This was undertaken in relation to the EA's latest guidance¹. This assessment is documented within **Appendix 2**.
- 2.2 In summary, there were no hydrometric data available in the area to inform the hydrological analysis. Therefore, the industry standard FEH statistical method and Revitalised Flood Hydrograph (ReFH2.3) rainfall-runoff model were both reviewed, and a comparative analysis undertaken.
- 2.3 The industry standard FEH statistical method and ReFH2.3 rainfall-runoff model were both reviewed, and the ReFH2 method was determined to be the most suitable for a site-specific hydraulic model as it produced the more conservative flow estimates.
- 2.4 While conservative estimates are not necessarily the 'correct' estimates, given the exercise will be supporting an assessment of flood risk, and given the lack of site-specific flow information, a precautionary approach was considered appropriate.
- 2.5 The flow estimates were made at the downstream extent of the site, and therefore represent runoff generated upstream and from within the site.
- 2.6 The catchment area was updated using a watershed analysis to improve its accuracy. The catchment was compared against public sewer records which showed that no cross-catchment transfers are present – the sewer networks generally follow the topographical catchment.
- 2.7 Flood flow estimates were derived for a range of return period events, the adopted peak flow estimates are provided within **Table 2.1**.

Table 2.1: Adopted Peak Flood Flows

Return Period Event (Yrs)	Annual Exceedance Probability	Catchment Peak Flow (m ³ /s)
1 in 2	50%	0.45
1 in 5	20%	0.60
1 in 10	10%	0.71
1 in 30	3.3%	0.84
1 in 50	2.0%	1.06
1 in 75	1.3%	1.18

¹ Flood Estimation Guidelines 197_08 (Environment Agency, June 2020)

Return Period Event (Yrs)	Annual Exceedance Probability	Catchment Peak Flow (m ³ /s)
1 in 100	1.0%	1.29
1 in 200	0.5%	1.59
1 in 1000	0.1%	2.42

- 2.8 Flows have been applied to the model as a lumped point inflow at the upstream extent of the hydraulic model.
- 2.9 Given the size of the catchment area (2.14km²) and the length of watercourse modelled (approximately 1.8km), this approach was considered to be appropriate. Using a lumped inflow at the upstream extent of the catchment subsequently allows for a conservative volume of flow being conveyed through the model at the upstream limit of the site. **Figure 2.1** demonstrates how the flows were applied to the model.

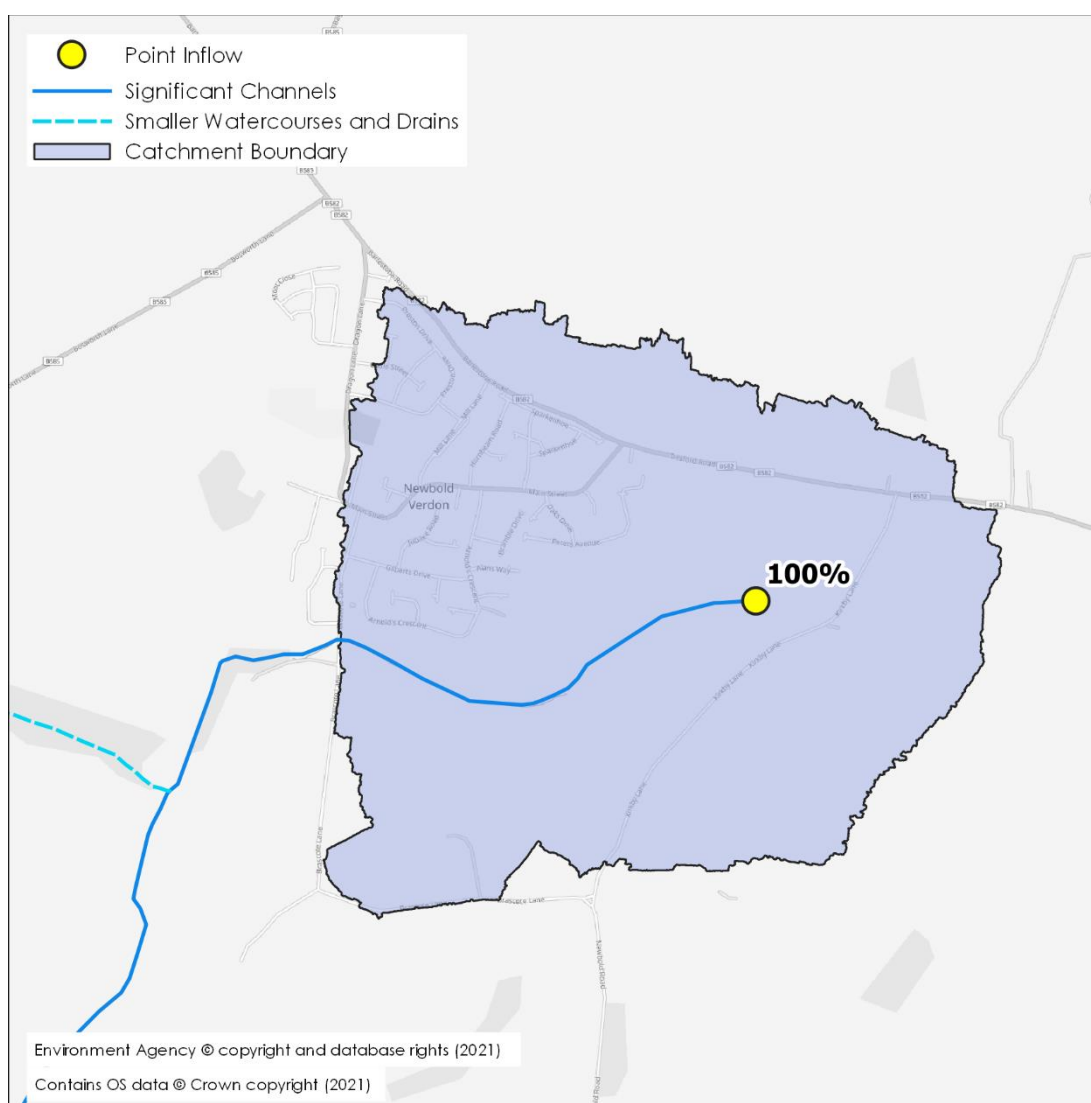


Figure 2.1: Distribution of Model Inflows

Climate Change

- 2.10 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance², with a range of projections applied to regionalised 'River Basin Districts'. These districts are further split into 'Management Catchments'. The Thurlaston Brook falls within the Soar Management Catchment. **Table 2.2** identifies the relevant peak river flow allowances.

Table 2.2: Peak River Flow Allowance for the Soar Management Catchment

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Upper End	28%	35%	60%
Higher Central	18%	21%	35%
Central	14%	16%	28%

- 2.11 To estimate the potential future design floodplain under a range of scenarios, the Central, Higher Central and Upper End climate change allowance for the 2080s will be applied to the 1.0% AEP flood flows.
- 2.12 The proposed development is for residential use which would be classified as a 'More Vulnerable' development with reference to the Planning Practice Guidance (PPG). EA climate change guidance states that the central allowance should be used to assess whether a 'More Vulnerable' proposed development can be deemed safe for its lifetime in Flood Zones 2 and 3a. Given that the site borders the Thurlaston Brook and will be in close proximity to the fluvial flood extents (even if they remain in-channel), the central allowance has subsequently been simulated and will be assessed in detail as part of the FRA.
- 2.13 The higher central and upper end allowances have also been simulated to provide additional information on floodplain extents and depths, although they are not specifically required under the EA climate change guidance.

² Environment Agency, Flood risk assessments: climate change allowances: <https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1>

3. THE HYDRAULIC MODEL

Software and Solver

- 3.1 TUFLOW version 2020-10-AA was used for all model runs. TUFLOW's Classic solver was used.
- 3.2 TUFLOW's built in 1D component, ESTRY, was used to model the 1D domain/channel.

The 1D Domain

Extent

- 3.3 The 1D domain begins at the upstream extent of the illustrative site boundary. The remainder of the modelled Thurlaston Brook channel is represented within the 1D domain until the downstream boundary. The extent can be seen in **Figure 3.1**.

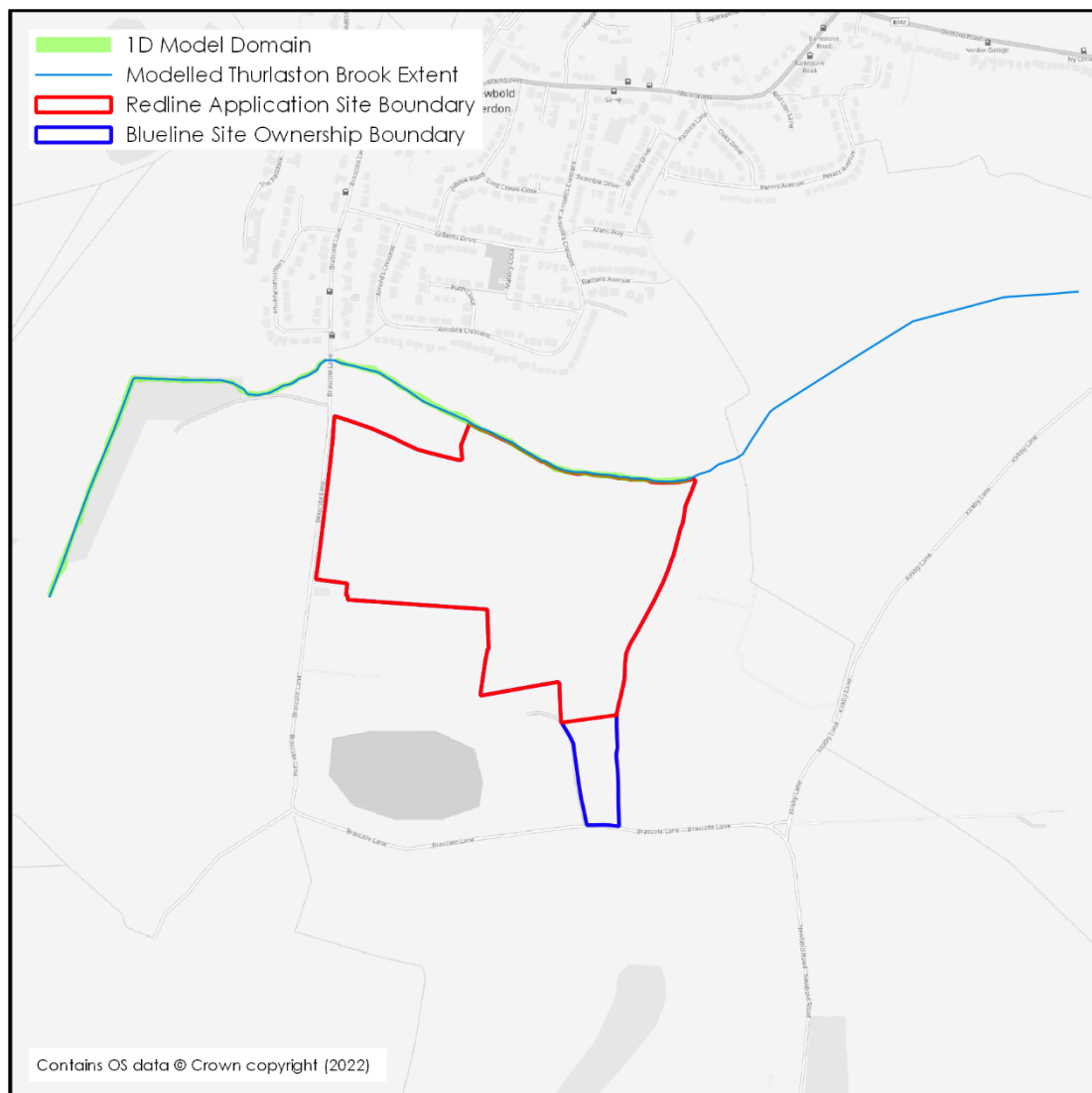


Figure 3.1: Modelled Thurlaston Brook and 1D Domain Extents

Channel Geometry

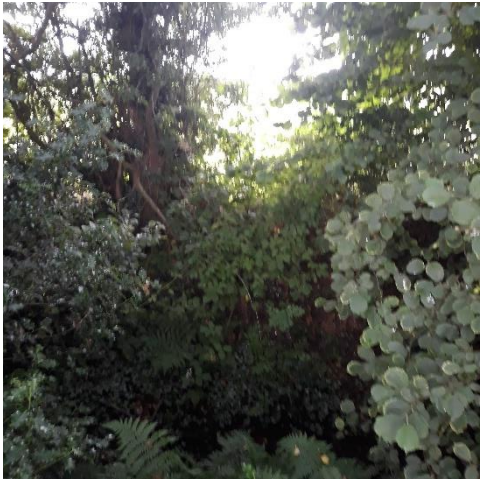
- 3.4 The river channel geometry is based on a new watercourse survey carried out by BWB Consulting in July 2021. The survey also captured the culvert at Brascote Lane road crossing. This hydraulic structure is of significant interest given its location at the downstream boundary of the site boundary.
- 3.5 Due to access constraints, the maximum distance between surveyed cross sections is 189m. However, sections are more generally spaced approximately 50m apart. The river channel survey is available as **Appendix 1**.
- 3.6 The channel sections were truncated at top-of-bank from survey data, at what would be the interface with the 2D domain.

Hydraulic Roughness

- 3.7 Hydraulic roughness has been represented using the Manning's n coefficient. The values applied are based on those stipulated in the literature, using Chow (1959)³. This study documents appropriate values based on channel bed material, sinuosity and presence of vegetation.
- 3.8 The guideline values are chosen using engineering judgement, based on photographs of the channel condition taken at the time of survey. Each cross section has a Manning's roughness value applied in the same way as the channel geometry and is read into TUFLOW within a CSV file.
- 3.9 The Thurlaston Brook was observed to be free flowing. The channel was considered to be relatively straight with few rifts or deep pools. Some stones and weeds could be seen within the channel. As such, a Manning's n coefficient of 0.035 was deemed suitable to represent in-channel roughness. The banks and top of bank were in some instances lined with long grass and in other instances bordered by woodland. Values of 0.035 and 0.080 was used to represent the long grass and woodland conditions respectively. Some examples are highlighted in **Table 3.1**.

³ http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

Table 3.1: Manning's n Examples

Model ID	Values chosen and description	Photograph
THURL_0279	0.035 1. Main Channels b. clean, straight, full stage, no rifts or deep pools, some stones and weeds.	
THURL_1004	0.035 3. Floodplains a. Pasture, no brush 2. high grass.	
THURL_1079	0.080 3. Floodplains d. Trees 4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches.	

Hydraulic Structures

- 3.10 A single hydraulic structure at the Brascote Lane road crossing was represented in the 1D domain, the data for which was collected during the watercourse survey.
- 3.11 The structure was represented as a culvert with two 750mm diameter pipes. Please view **Appendix 3** for details on the modelled structure.
- 3.12 Due to access constraints, it was not possible to survey two additional structures in the study area. The first of which is an access track crossing located approximately 100m upstream of the site boundary (NGR: SK 4502 0321). The second missing structure is believed to be a culvert located approximately 150m downstream of the Brascote Lane road crossing (NGR: SK 4429 0332).
- 3.13 The baseline model has subsequently been built without consideration of these structures, adopting an open channel approach at these locations. Sensitivity testing was later undertaken whereby the channel was represented as 100% blocked at these locations to understand a worst-case scenario and what implications this could have at the site. Of these two structures, the missing culvert downstream of the site (NGR: SK 4429 0332) was added to the model in the 1D domain as a 100% blocked 0.8m x 0.8m box culvert. This scenario was 'Blockage Location 3'.

Boundary Conditions

- 3.14 Boundary conditions were applied to the 1D domain to allow flow in and out of the model.
- 3.15 A HT (water level vs time) boundary was applied at the downstream limit of the 1D domain. This was set to 116.83mAOD which is the top of bank surveyed level at the downstream cross-section (THURL_0000).
- 3.16 Model inflows were applied to the 2D domain further upstream and are discussed later in **Section 3**. The upstream limit of the Thurlaston Brook 1D domain has been linked to the Thurlaston Brook represented in the 2D domain through a "HX" link. This transfers the calculated water level from between the 2D domain and the 1D cross sections.

Initial Conditions

- 3.17 Initial conditions were applied by defining each cross-section with the surveyed water level. At interpolated cross-sections, the surveyed water level was also interpolated between upstream and downstream cross-sections accordingly. This provides a baseflow throughout the model.

1D/2D Links

- 3.18 The 1D channel was linked to the floodplain and the upstream extent of the Thurlaston Brook (represented within the 2D domain) using "HX" links. These transfer the calculated water level from the 1D cross sections into the 2D floodplain, and vice versa. Water levels will be transferred from the 1D domain to the 2D domain, providing that

the in-channel water level is above the level of the cell that the HX link is located in. Therefore, HX links are typically found to be digitised along the top of bank of the watercourse visible in LiDAR data or along the crest of any embankments if present.

- 3.19 The average modelled width of the channel was approximately 6-8m.

The 2D Model Domain

Extent and Active Area

- 3.20 The main influence on the 2D domain extent is generally the expected width of the floodplain, meaning that it should be large enough to allow for flows to be routed through the floodplain where necessary and so that no “glass walling” occurs.
- 3.21 The river channel was deactivated to ensure that it was only represented in the 1D domain. This deactivated area may appear fragmented in places where the deck of a structure is modelled in the 2D domain. The active area is displayed in **Figure 3.2**.

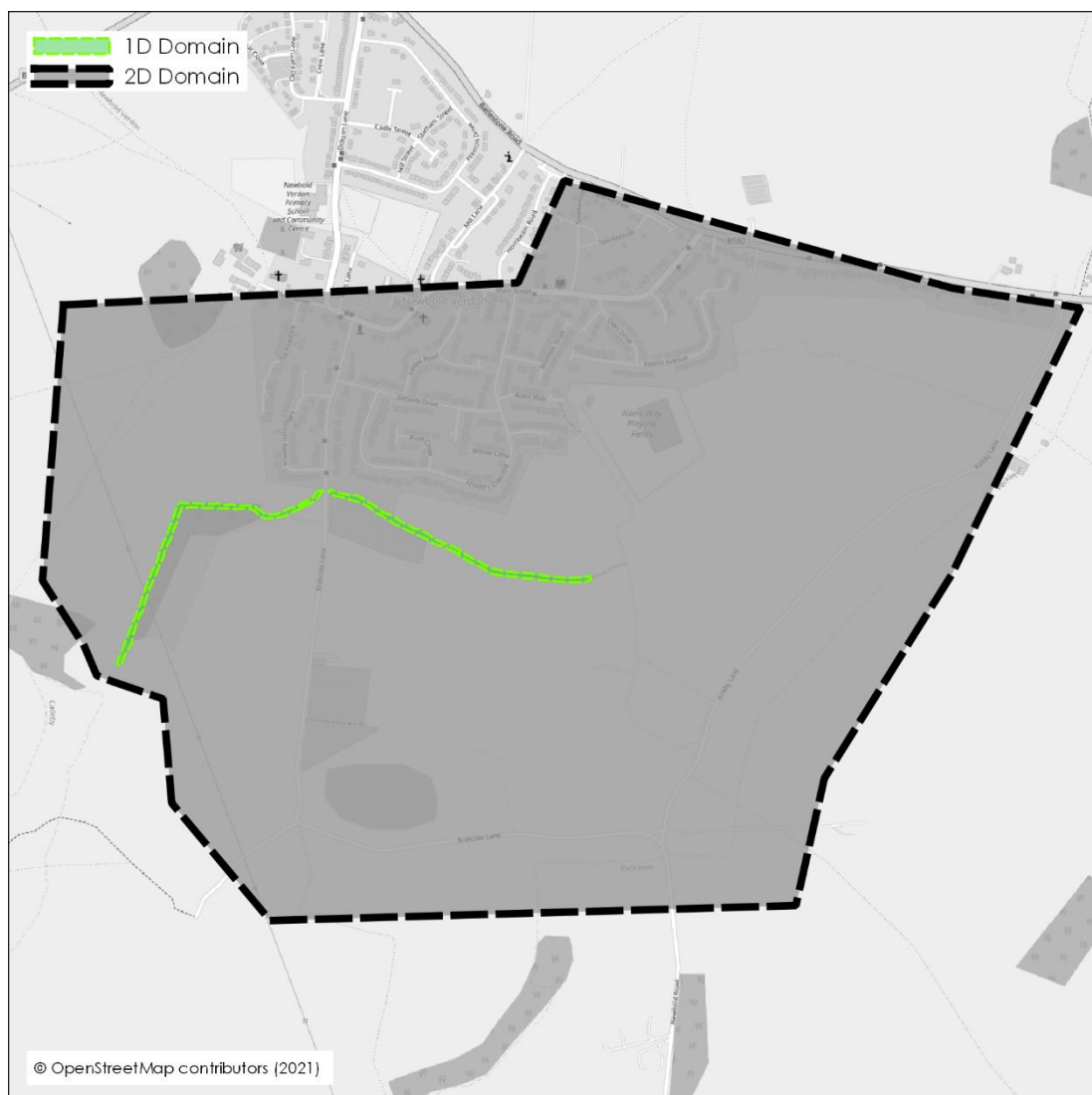


Figure 3.2: 2D Active Area

Grid Size and Orientation

- 3.22 The grid cell size should be chosen in order to sufficiently represent the average width of the modelled channel and its ability to capture key floodplain topographic features.
- 3.23 The selected grid size of 2m provides a high enough resolution to capture the capacity of the channel where it needs to be represented in the 2D domain (6m width = 3 number of 2m cells) as well as provide appropriate representation of key floodplain features.
- 3.24 The orientation of the grid is important for flow routing as flow cannot pass to the neighbouring cell via its corner, only via the cell sides. Therefore, the location line (2d_loc) was drawn to orientate the grid in the predominant direction of flow adjacent to the site (east to west).

Simulation Parameters

- 3.25 A timestep of 0.5 seconds was adopted for the 2D TUFLOW domain, this is representative of 1/4 of the adopted grid size and is therefore within the typical range.
- 3.26 A timestep of 0.25 second was adopted for the 1D ESTRY domain, this is an equal interval of the 2D timestep and is therefore in line with best practise.
- 3.27 All TUFLOW and ESTRY parameters were retained as default.
- 3.28 Flood events were simulated for 20 hours, to allow the flood flows generated by the 5.5-hour storm duration events to flow through the site and start to recede.

Floodplain Roughness

- 3.29 Floodplain roughness is defined by the Manning's n coefficient, as per the 1D domain. However, the method in which it is applied differs.
- 3.30 A global roughness value is set based on the predominant land use (long grass) in the catchment. This is then supplemented by a series of polygons, based on spatial variation in land use, which applies values where appropriate from a variety of sources such as OS MasterMap data (where available), OS Zoomstack and aerial imagery. These are linked to a coefficient listed in a TUFLOW Materials File (TMF).
- 3.31 The values applied for different land use types are listed in **Table 3.2**.

Table 3.2: Floodplain Roughness Values

Land Use Type	Manning's n Coefficient
Long grass	0.035
Urban areas	0.025
Roads	0.015

Land Use Type	Manning's n Coefficient
Water	0.035
Woodland	0.080
Buildings	0.500

Floodplain Topography and Amendments

- 3.32 The general floodplain topography is based on the latest available LiDAR data, which was downloaded from the DEFRA Open Survey website at a 1m resolution.
- 3.33 The following amendments to the base topography were made:
- The July 2021 topographic survey was exported as a Digital Elevation Model (DEM). This surface was stamped atop of the LiDAR data to provide more accurate levels across the site boundary.
 - River bank levels were reinforced through the use of a 'THICK' Z-line. Bank elevations were provided at 5m intervals along the Z-line. These are informed by surveyed cross-section data where available. Bank levels on the left bank immediately north of the site have been informed by the topographic survey. LiDAR data has been used to inform elevations elsewhere, where survey data is unavailable.
 - The representation of the Thurlaston Brook in the 2D domain was reinforced through the use of a 2m wide Z-shape which was assigned the 'GULLY' command. This therefore only changes a Zpt elevation if the Z-shape elevation at the specified Zpt is lower.

Floodplain Structures

- 3.34 There were no floodplain structures within the baseline model. The Brascote Lane road crossing was hence represented in the 1D domain.
- 3.35 As previously mentioned, a hydraulic structure located approximately 100m upstream of the site boundary could not be surveyed due to access constraints. Subsequently, this was excluded from the baseline model. A sensitivity test was conducted, referred to as Blockage Location 1, whereby the access track crossing was added to the model as a floodplain structure (100% blocked). This was achieved by using a Z-shape to raise Zpts in the 2D channel to a consistent level. The level was determined by reviewing 1m LiDAR data along the access road at bank top level.

Boundary Conditions

- 3.36 A QT (flow vs time) boundary was used to represent the fluvial inflows (**Section 2**) as hydrographs. This consisted of a point inflow which was added to the upstream extent of the 2D Thurlaston Brook channel. **Figure 2.1: Distribution** shows where this boundary unit was applied.
- 3.37 Boundary conditions within the 2D domain are often used to prevent "glass walling" at the downstream end of the model through use of a "HQ" boundary. This is a flow vs

stage relationship automatically defined in TUFLOW when the user inputs a slope value, to allow water to flow out of the model.

- 3.38 Slope in the “HQ” boundary was calculated by assessing the fall in floodplain levels on both banks over the distance of approximately 350m. The fall in levels was divided by the distance measured over to determine a slope value.

Calibration

- 3.39 A lack of hydrometric flow or level gauge data for the catchment meant that there was limited opportunity to calibrate the model.
- 3.40 Due to the lack of documentation on previous historical instances of flooding, the model cannot be verified against historic events. A conservative approach adopted to the model build mitigates this.

Stability, Warnings and Messages

- 3.41 TUFLOW has a number of indicators available to assess the stability of a model. These differ slightly between the Classic and HPC solver. The following indicators were checked to ensure the model was performing as expected:
- **Stage and flow time series** – A number of spot checks should be completed to ensure that conveyance through the channel is as expected and that both the stage and flow time series are reasonably smooth, particularly around the study area.
 - **1D negative depths** – Significant negative depths indicate that instabilities are present.
 - **Cumulative Mass Error** – A value of +/-1% is considered acceptable.
 - **Velocities** – Unusually high velocities or circulating vectors are usually a sign of instabilities.
- 3.42 No 1D or 2D negative depths were reported.
- 3.43 The remaining values highlighted above were considered acceptable.
- 3.44 Following review of all baseline model runs, the cumulative mass error stayed below +/- 0.5% for all simulations, and so was within the accepted tolerance levels. This is illustrated for within **Figure 3.3** as an example.

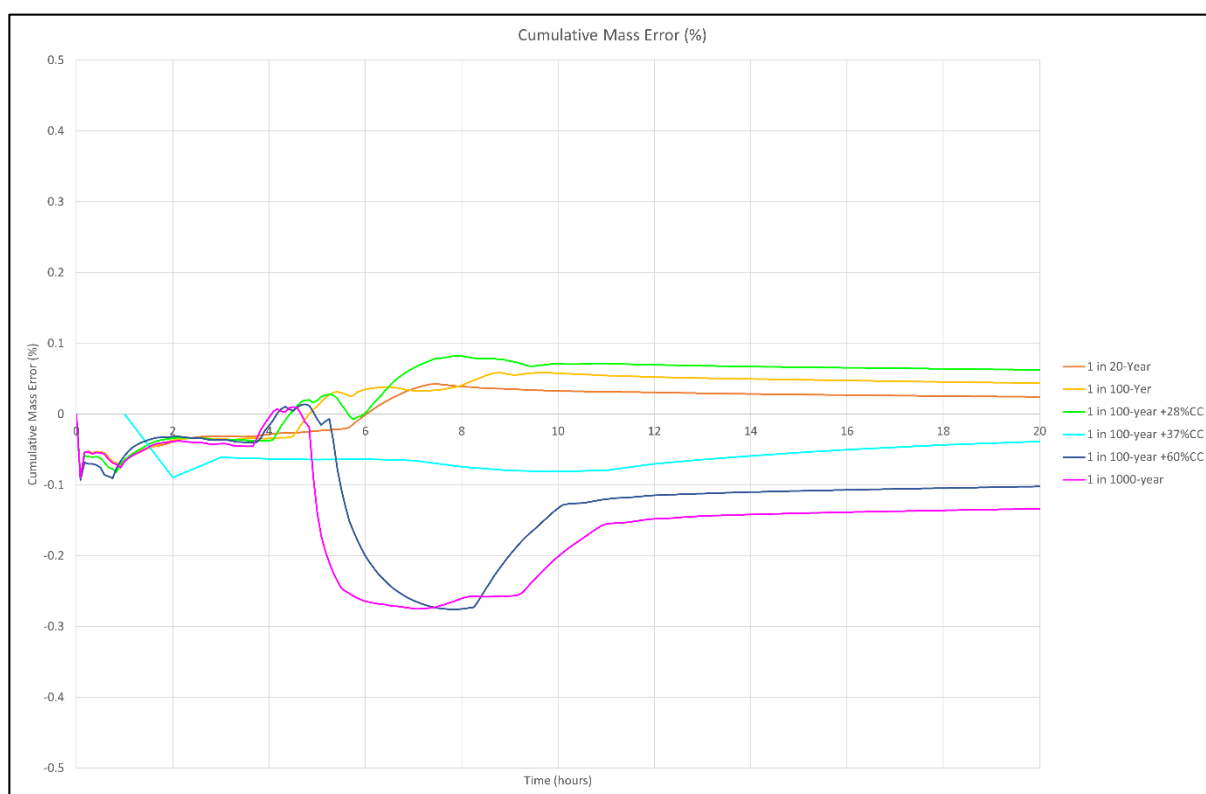


Figure 3.3: Cumulative Mass Error Time Series Plots

Model Runs

3.45 In order to achieve the study objectives, the simulations summarised in **Table 3.3** were completed.

Table 3.3: Model Runs

Model Geometry	Return Periods	Comments
Baseline	1 in 20-Year 1 in 100-Year 1 in 1000-Year 1 in 100-Year +28%CC 1 in 100-Year +37%CC 1 in 100-Year +60%CC	Representative of "as surveyed" conditions.
Roughness +20%	1 in 100-Year	Floodplain, channel and structure roughness increased by 20%
Roughness -20%	1 in 100-Year	Floodplain, channel and structure roughness decreased by 20%
DSBDY +20%	1 in 100-Year	1D HT downstream boundary unit was decreased by 150mm. The 2D HQ slope value was increased by 20%.

Model Geometry	Return Periods	Comments
DSBDY -20%	1 in 100-Year	1D HT downstream boundary unit was increased by 150mm. The 2D HQ slope value was decreased by 20%.
3-hour Storm Duration	1 in 100-Year	The 1 in 100-year was simulated for the 3-hour storm duration using a 20-minute time interval over a duration of 15 hours.
11-hour Storm Duration	1 in 100-Year	The 1 in 100-year was simulated for the 3-hour storm duration using a 1-hour time interval over a duration of 25 hours.
Blockage Location 1	1 in 100-Year	The missing access track crossing upstream of the site boundary was represented as 100% blocked in the 2D domain through using a Z-shape.
Blockage Location 2	1 in 100-Year	The two 750mm diameter pipes that are culverted beneath Brascote Lane were represented as 100% blocked in the 1D domain.
Blockage Location 3	1 in 100-Year	The missing structure downstream of Brascote Lane was added to the 1D domain as a 100% blocked 0.8m x 0.8m box culvert for this scenario.

4. BASELINE RESULTS

- 4.1 The results from the existing conditions model are mapped within **Appendix 4** and are summarised below. The flood mechanisms are discussed further within the forthcoming section.
- 4.2 The floodplain extents at the site have been summarised and are in **Figure 4.1**.

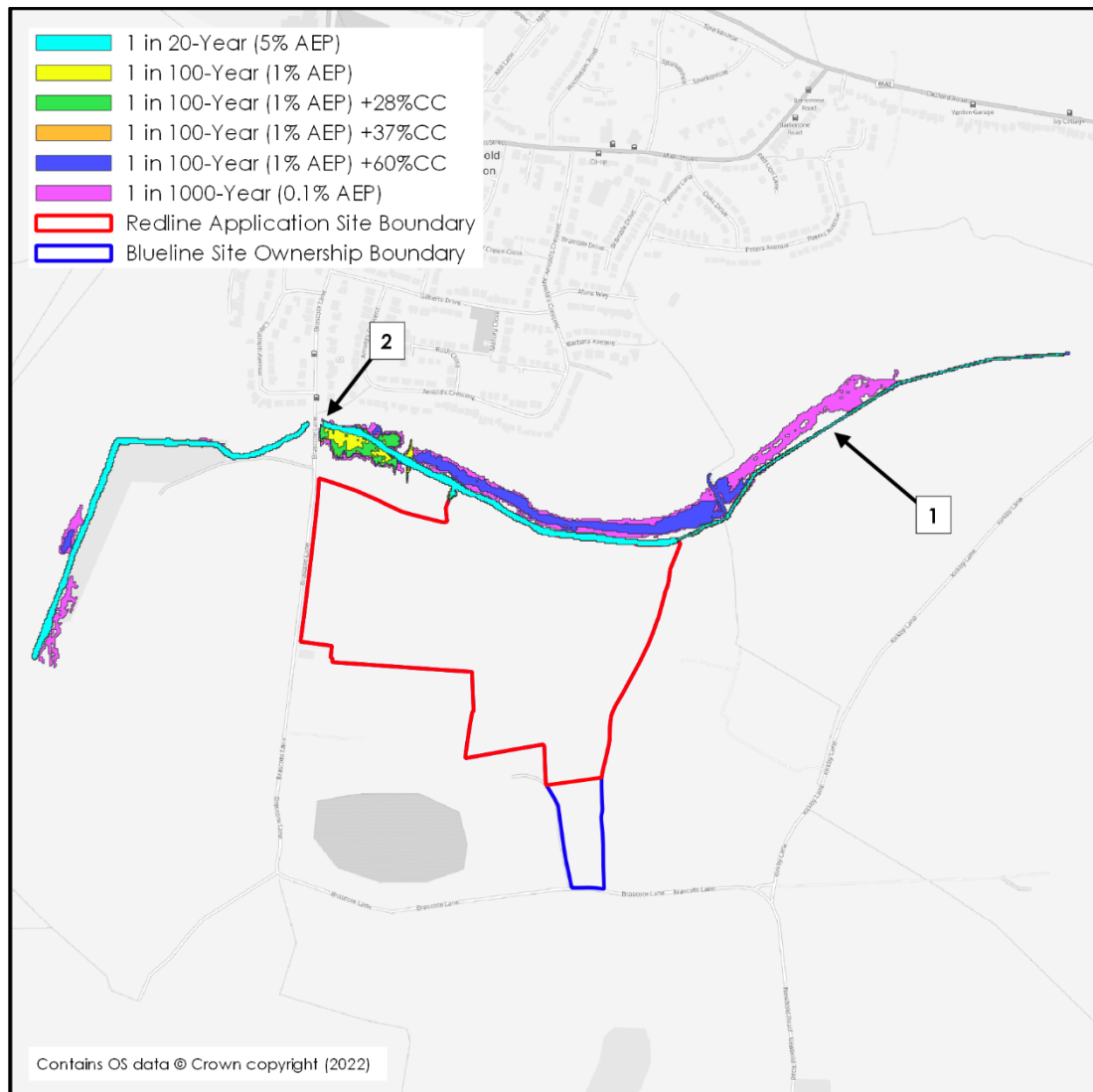


Figure 4.1: Fluvial Floodplain Extents

1. Thurlaston Brook 2D Channel

- 4.3 The floodplain extents are shown to be contained to the 2D Thurlaston Brook channel for all events excluding the 1 in 100-year +60%CC and 1 in 1000-year events.
- 4.4 During the 1 in 100-year +60%CC event, in-channel levels exceed the channel capacity approximately 150m upstream of the site boundary. Bank levels are lower on the right back of the watercourse at this location and subsequently, flood waters spill

into the floodplain north of the channel. These are shown to be conveyed in the floodplain for approximately 550m before entering back into the floodplain upstream of Brascote Lane road crossing.

- 4.5 Similar flow patterns are displayed in **Figure 4.1** for the 1 in 1000-year event. However, during this event, in-channel water levels exceed the channel capacity further upstream, again overtopping the right bank crest level and, in turn, spilling into the floodplain. This is displayed by the pink flood extent.

2. Brascote Lane Road Crossing

- 4.6 The smallest modelled return period was the 1 in 20-year event. The flood extent is shown to remain largely in-channel for the duration of the simulation. There is a small corner of the site boundary immediately upstream of the allotments which is shown to be partly affected by the 1 in 20-year floodplain extent. Water levels during the 1 in 20-year event remain in-channel immediately upstream and downstream of the Brascote Lane road crossing.
- 4.7 Similar flood patterns can be seen during the 1 in 100-year event, with the same area immediately upstream of the allotments being shown to be affected with a marginally larger area. The key difference between the 1 in 20-year and 1 in 100-year extent is that the 1 in 100-year extent is shown to spill into both sides of the floodplain immediately upstream of the Brascote Lane road crossing. This therefore suggests that the hydraulic structure has an insufficient capacity to convey flows for the 1 in 100-year event, which is confirmed by the long-section plot displayed in **Figure 4.2**. Downstream of this structure, the flood extent is shown to be contained within the Thurlaston Brook channel.

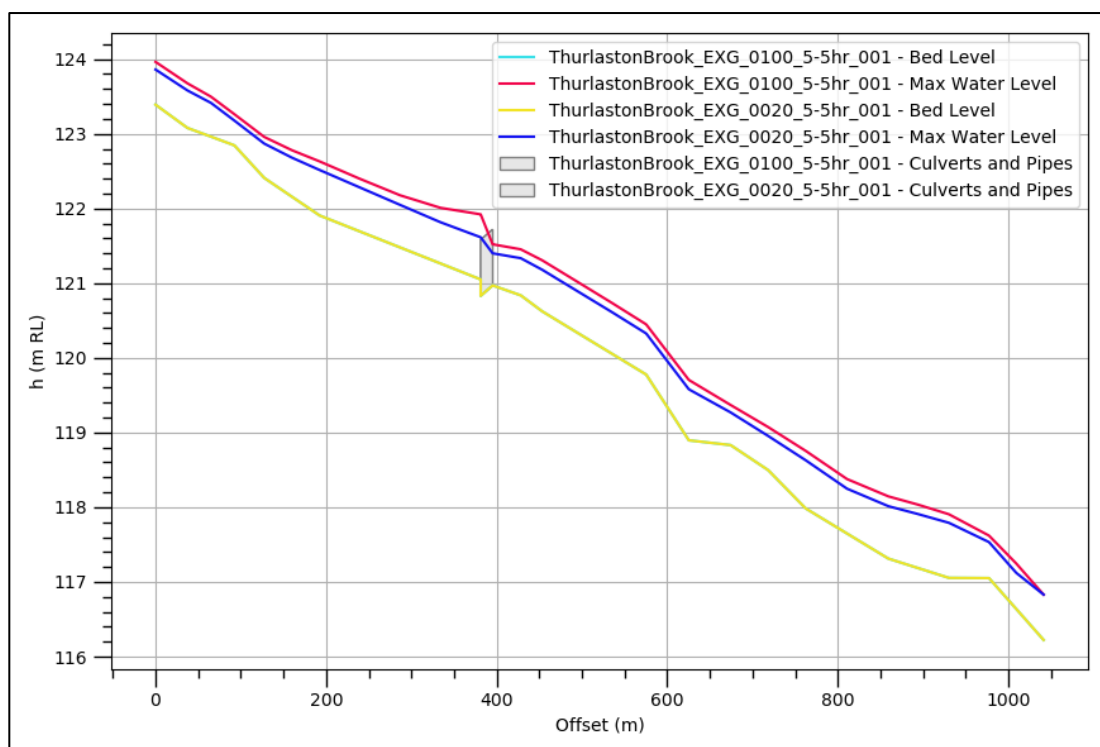


Figure 4.2: Long Section Plot Demonstrating Maximum Water Levels for 5% and 1% AEP Events

- 4.8 The 1 in 100-year +28%CC and 1 in 100 year +37%CC extents are similar to that of the 1 in 100-year extent except that they are associated with larger flood extents on the floodplain immediately upstream of the Brascote Lane road crossing. This is to be expected given the larger flows that are associated with these events.
- 4.9 As expected, the 1 in 100-year +60%CC and 1 in 1000-year flood extents are also associated with larger floodplain extents immediately upstream of the road crossing. The 1 in 1000-year extent also affects a small area of floodplain immediately downstream of Brascote Lane. Closer to the downstream boundary, both the 1 in 100-year +60%CC and 1 in 1000-year flood extents spill into the right bank, resulting in a small localised area of ponding. At the very downstream limit of the model, the 1 in 1000-year extent is also shown to be out-of-bank after exceeding the left bank crest level.

5. SENSITIVITY TESTING

5.1 To account for seasonal variations in vegetation and to ensure the robustness of boundary conditions, a series of sensitivity tests were conducted using the 1 in 100-year flood return period event. The difference in peak water level and floodplain extent between the sensitivity test scenarios and the 1 in 100-year baseline event are mapped in **Appendix 5**.

5.2 Robust sensitivity analysis also provides improved confidence in the model outputs, particularly in absence of calibration data.

Flow Estimates

5.3 As a climate change allowance has been assessed, it was not considered necessary to test variations on the predicted flood flows.

Storm Duration

5.4 The adopted recommended storm duration (5.5-hours) was derived in ReFH2.3 from the total study catchment area.

5.5 To assess how sensitive the model is to changes in storm duration, 3-hour and 11-hour storm durations were also simulated for the 1 in 100-year event. The results were compared against the 5.5-hour 1 in 100-year flood event to identify the extent of changes in water levels.

5.6 The comparison identified that for both the 3-hour and 11-hour storm durations, in-channel peak water levels were lower than for the 5.5-hour storm. The difference between flood levels for the 11-hour storm and the 5.5-hour storm were fairly minor and were generally shown to be no greater than 0.05m.

5.7 A much greater difference in model outputs can be seen between the 5.5-hour 1 in 100-year event and the 3-hour 1 in 100-year event. The flood extent can be seen to be notably smaller for the 3-hour storm duration with a relatively large area of floodplain immediately upstream of the Brascote Lane road crossing in the allotments identified as a "Former wet area now dry". More specifically, the peak difference in 1D water levels is reported as 0.167m. On the floodplain, the maximum difference is 0.157m.

Roughness

5.8 Sensitivity testing has shown that a 20% reduction in channel and floodplain roughness (representative of winter seasonal conditions or channel conditions following maintenance) results in a general decrease of in-channel flood levels.

5.9 There was a notable difference to how in-channel levels differed between the reach of the Thurlaston Brook modelled in the 1D domain, and the reach represented in the 2D domain. Within the 1D ETRY component, the 20% reduction scenario resulted in a negligible increase in water levels of <0.01m. This is contrary to expectations as a

reduction to the frictional drag effects imposed by rougher surfaces would typically increase the conveyance of the channels and culverts.

- 5.10 The increase within the 1D domain can be explained by the larger differences that can be seen between maximum water levels across the upper stretch of the Thurlaston Brook, that is represented in the 2D domain only. More considerable differences of between +0.082m to -0.213m are noted in the 2D domain. There is generally a reduction in levels in the watercourse (where represented in the 2D domain), which would be as a result of the improved channel conveyance in this reach. This perhaps subsequently explains why levels marginally increase in the 1D channel further downstream, although the differences could be described as insignificant (< 0.01m).
- 5.11 The impact on floodplain extents was shown to be negligible, with a small reduction in floodplain extent visible at the allotments, immediately upstream of Brascote Lane.
- 5.12 In contrast, a sensitivity test was also conducted whereby a 20% increase in Manning's 'n' (representative of summer seasonal conditions or a period without maintenance) was applied to the 1D and 2D domains of the hydraulic model. The model outputs are shown to result in a general increase of in-channel flood levels.
- 5.13 Again, there was a negligible difference in peak water levels shown in the 1D domain with levels increasing by <0.01m. Levels in the 2D reach of the Thurlaston Brook were shown to be up to 0.164m greater.
- 5.14 The impact on floodplain extents on the site are shown to be negligible with a very minor increase in extent (of 2 cells) in the allotments immediately upstream of Brascote Lane. This is to be expected given that an increase in roughness values across the floodplain would be associated with greater frictional forces against the flow of water as it looks to drain back into the channel. Subsequently, more flood water would likely be retained on the floodplain during these conditions.

Downstream Boundary

- 5.15 The downstream boundary is located approximately 700m downstream of the Brascote Land road crossing. It consists of a 1D head-time (HT) unit and a 2D head-flow (HQ) unit. The HT boundary has a set water level for the length of the simulation, whilst the HQ unit has an applied gradient derived from a terrain profile measured over the downstream 350m of floodplain.
- 5.16 As per the roughness tests, two sensitivity tests were conducted with the downstream boundary. Firstly, a decrease in gradient of 20% was applied to the 2D HQ boundary unit to represent a shallower slope. In combination with this, the 1D HT level was increased by 150mm. This therefore represented a scenario where in-channel levels were higher at the end of the system and there was a reduced impact of gravity on conveying flows out of the system.
- 5.17 In contrast, the alternative test increased the 2D HQ gradient by +20% to represent a steeper topography in the floodplain. The 1D HT boundary unit was decreased by 150mm. This scenario represented in an increase in gravity-driven conveyance of flow out of the model domain.

- 5.18 The model outputs reported localised impacts at the downstream limit of the model. The impacts on flood levels downstream of Brascote Lane road crossing were shown to be minimal and no differences are reported within the channel adjacent to the site.

Blockage Scenarios

- 5.19 Blockage scenarios were undertaken at locations of all surveyed hydraulic structures and known missed structures. These are identified within **Figure 5.1**.
- 5.20 A conservative worst-case scenario approach has been adopted whereby each hydraulic structure has been represented as 100% blocked. This is largely due to a lack of information on the structure opening areas at two of the blockage locations where surveyors were unable to access the watercourse.

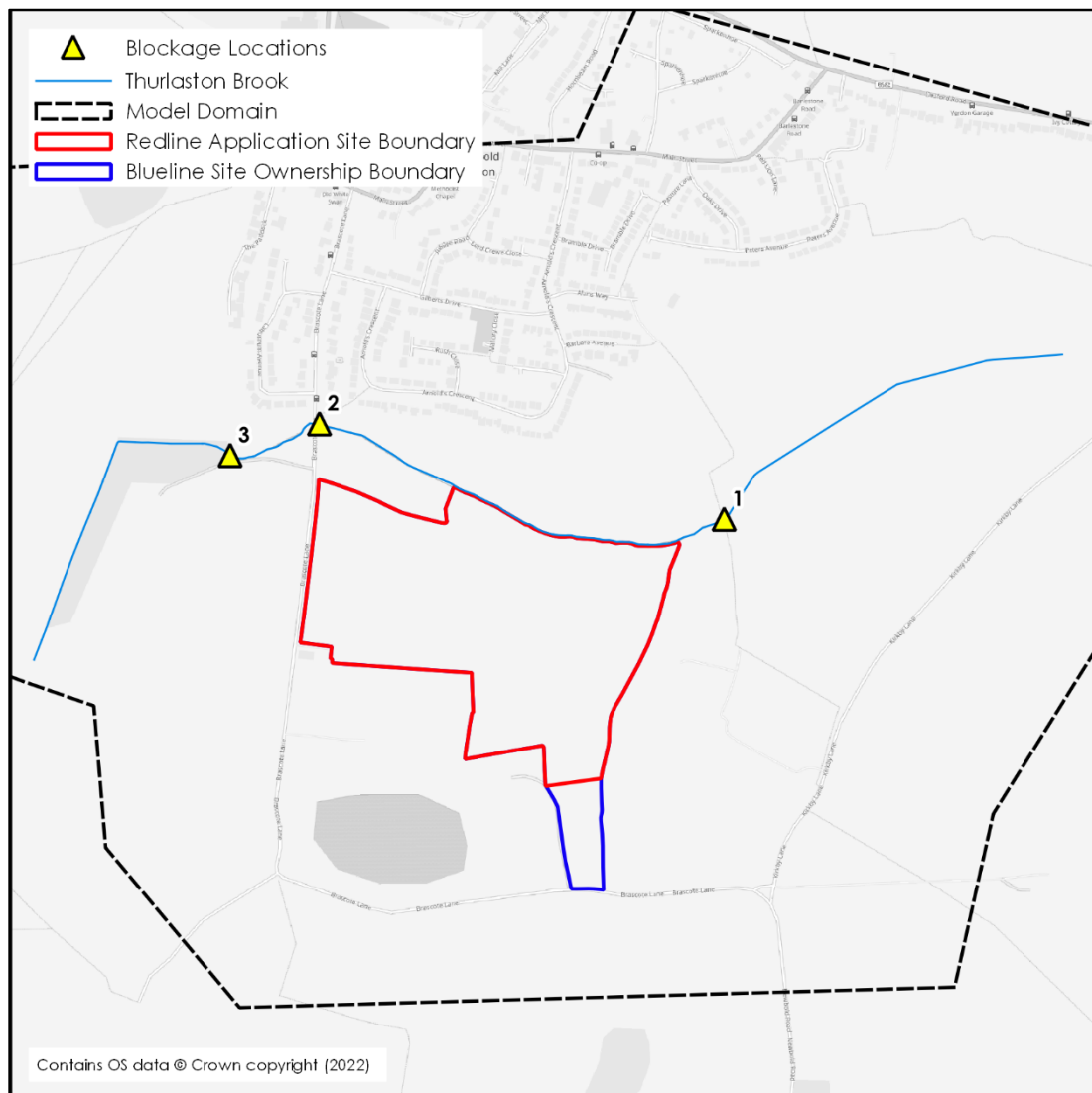


Figure 5.1: Blockage Locations

- 5.21 Blockage Location 1 (BLK1) was undertaken at an access track crossing that can be seen via satellite imagery. It was not possible for the surveyors to access this structure due to the watercourse being completely overgrown. At this location, the Thurlaston

Brook is represented in the baseline model as part of the 2D domain. Subsequently, a Z-shape was used to raise the cells over the deck of the road to the height of the access road. This was therefore considered as representing the channel as 100% blocked.

- 5.22 The BLK1 test has significant impacts on floodplain extents and flood levels in the channel. The blockage results in an increase in water levels in-channel immediately upstream which is to be expected as the obstruction prevents the conveyance of flows downstream of this location within the channel. As a result, levels continue to rise in-channel upstream of the blockage location until the right bank crest level is exceeded. Flows subsequently are shown to spill into the floodplain, resulting in a large area of floodplain north of the channel being shown as wet in a former dry area. Due to the volume of flow that has been directed to the floodplain, in-channel water levels immediately downstream of BLK1 are up to 0.496m lower than in the 1 in 100-year baseline scenario.
- 5.23 Blockage Location 2 (BLK2) was undertaken to the two surveyed 0.75m diameter circular culverts beneath the Brascote Lane road crossing. A 100% blockage percentage was applied to the ESTRY 1d_nwk unit.
- 5.24 In-channel water levels immediately upstream of the culvert increased by up to 1.083m. As a result of in-channel levels rising so dramatically, the capacity of the Thurlaston Brook becomes exceeded and water levels exceed the embankment and spill over the road crossing, returning back into the watercourse. Due to the slower conveyance of flows caused by the blockage, downstream levels in-channel are reported as being approximately -0.050m to -0.09m lower than the baseline 1 in 100-year levels.
- 5.25 Finally, Blockage Location 3 (BLK3) was modelled downstream of Brascote Lane at a location identified by OS Master Mapping as being crossed by a structure. The watercourse surveyors were also unable to access the river at this location due to thick vegetation. Given that the Thurlaston Brook at this location is represented within the 1D domain, a different approach was adopted to BLK1. For the purpose of the sensitivity test, a 'dummy' 0.8m x 0.8m box culvert was added to the model, and a 100% blockage was applied to it. Flow was allowed to leave the blocked channel through HX links following a break in the 1D domain.
- 5.26 The model outputs show in-channel flood levels increase immediately upstream of the blocked structure by up to 0.695m. Subsequently, the channel capacity is shown to become exceeded with floodwater spilling out the right bank and into the floodplain to the north. Flood waters return to the channel further downstream after bypassing the structure. Flood levels are reported as up to 0.238m lower immediately downstream of the blocked structure. The higher water level downstream of the Brascote Lane road crossing also results in a reduction in flood levels immediately upstream of this culvert. This is likely to be due to the downstream invert level of the circular culverts being surveyed and modelled as 0.14m higher than the upstream invert levels.
- 5.27 None of the three blockage scenarios are subsequently shown to result in an increased flood risk to the site and the proposed development.

6. SUMMARY & RECOMMENDATIONS

- 6.1 The conclusion should be read in conjunction with the study limitations and assumptions in **Section 1**.
- 6.2 The primary aim of this exercise was to establish a provide a detailed understanding of potential flood risk to the proposed development site at land off Brascote Lane, Newbold Verdon (NGR: SK 4468 0320). This was achieved through the creation of a site specific 1D-2D hydraulic model to better understand flood risk associated with the Thurlaston Brook.
- 6.3 The hydraulic assessment was informed by a hydrology assessment of the likely flood flows. This was undertaken using the industry standard FEH methodologies, as there was no gauged data available within the study area.
- 6.4 The baseline modelling has shown that the site boundary remains largely unaffected during all modelled flood events. Fluvial flood extents are shown adjacent to the north of the site due to the Thurlaston Brook forming the northern border of the site.
- 6.5 A number of sensitivity tests have been undertaken within the model on key assumptions. These tests have identified that the model results for the watercourses are sensitive to changes in roughness, flow, and blockages of key structures. The sensitivity tests confirmed that the most conservative storm duration has been adopted.
- 6.6 Whilst the model is shown to be appropriately sensitive to the tested parameter changes and blocked structures, the assessed differences are not shown to result in an increase in flood risk to the proposed development site.

APPENDICES

Appendix 1: River Channel Survey

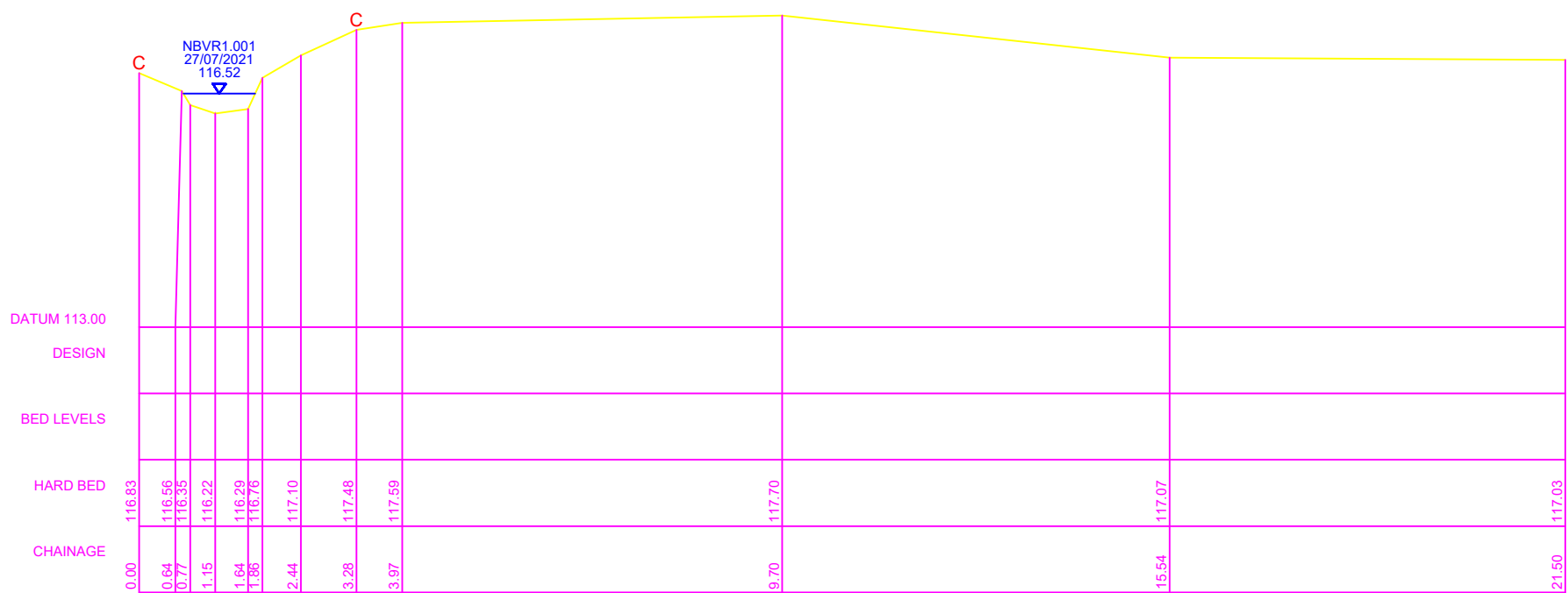
- Notes**
1. Do not scale this drawing. All dimensions must be checked/verified on site. If in doubt ask.
 2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
 3. All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
 4. Any discrepancies noted on site are to be reported to the engineer immediately.
 5. No scale factor has been applied to this survey, therefore the OS coordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
 6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
 7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
 8. OS license number: 100022432

Key Plan

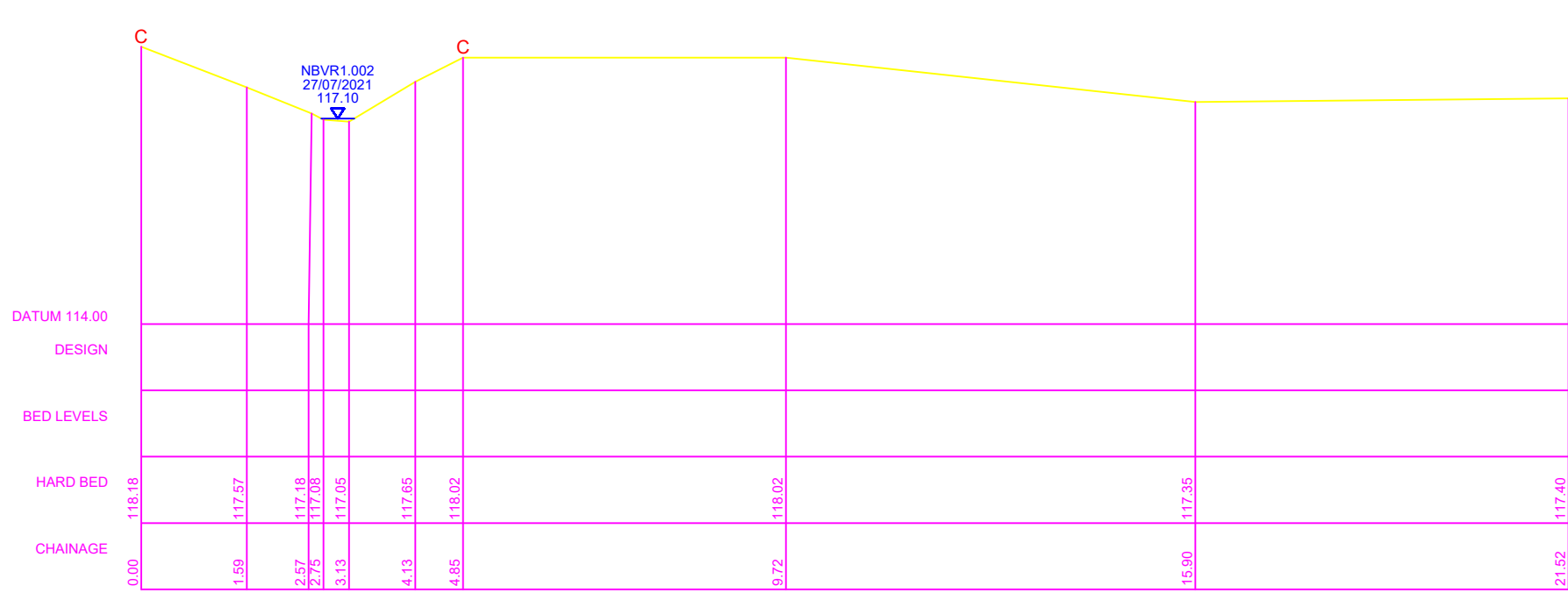


Legend

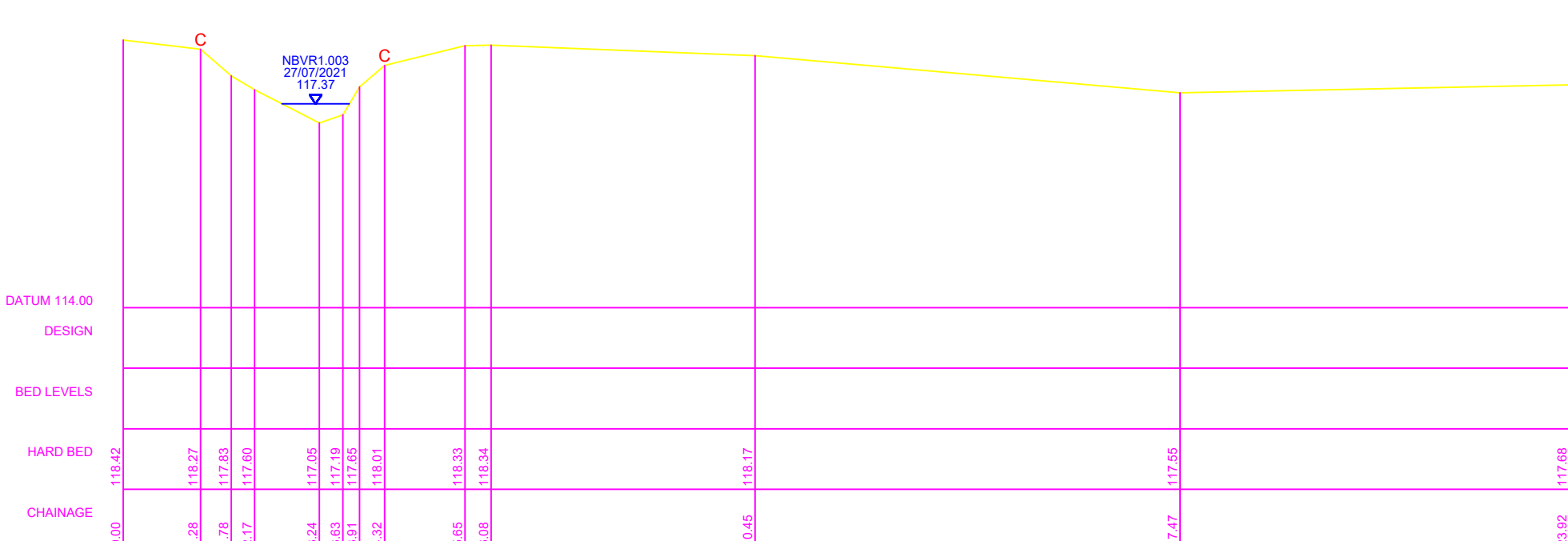
- | | |
|--------------------|---|
| OS Buildings | Contour Lines |
| Surveyed Buildings | Inspection Chamber |
| Building | Flow direction and pipe diameter |
| Wall | Station and Name |
| Kerb Channel Line | Monitoring Borehole |
| Top of Kerb | Tree / Bush / Sapling |
| Edge of Surface | Area of Vegetation/ Extent of Tree Canopy |
| Top of Bank | Hedge |
| Bottom of Bank | Body of Water |
| Canopy / Overhang | Body of Water from OS |
| Line Marking | Spot Level |
| Centre Line | Assumed Surface |
| Watercourse | Water Drainage Line |
| Centre Line | Surface Water Drainage Line |
| Barrier | |
| Fence | |
| Gate | |
| Overhead Powerline | |
| Overhead Utilities | |
-
- | | | |
|----------------------|--------------------------|----------------------|
| AP Anchor Point | FBW Fence Barbed Wire | LB Litter Bin |
| BO Back Gully | FOB Fence Closed Board | LP Lamp Post |
| BOB Bollard | FCL Fence Chain Link | MH Manhole |
| BS Bus Stop | FEL Fence Electric | MV Service Marker |
| BT British Telecom | FMP Fence Metal Panel | PS Post Box |
| C Crest | FMF Fence Metal Rolling | PT Post |
| CL Cover Level | FOB Fence Open Board | RE Roadside Eye |
| CMP Cable Marker | FPW Fence Post & Wire | SP Sign Post |
| Post | FSP Fence Steel Pipeline | ST Stop Sign |
| CCTV/Security Camera | FVM Fence Wire Mesh | SV Stop Valve |
| Cable TV | FPL Finished Floor Level | TGS Telephone |
| DK Drainage | FP Flagpole | THL Threshold Level |
| Channel | Gas Gas | TL Traffic Light |
| DK Drain Kerb | GV Gas Valve | TS Telegraph Post |
| DP Down Pipe | GY Gully | TS Traffic Signal |
| Elec Electric | HS Height | UTS Unable to Survey |
| EP Electricity Post | IC Inspection Chamber | VL Water Level |
| ER Earth Road | IFL Internal Floor Level | WM Water Meter |
| FI Fire Hydrant | IL Invert Level | WO Wash Out |
| FL Floodlight | (as a reduced level) | |



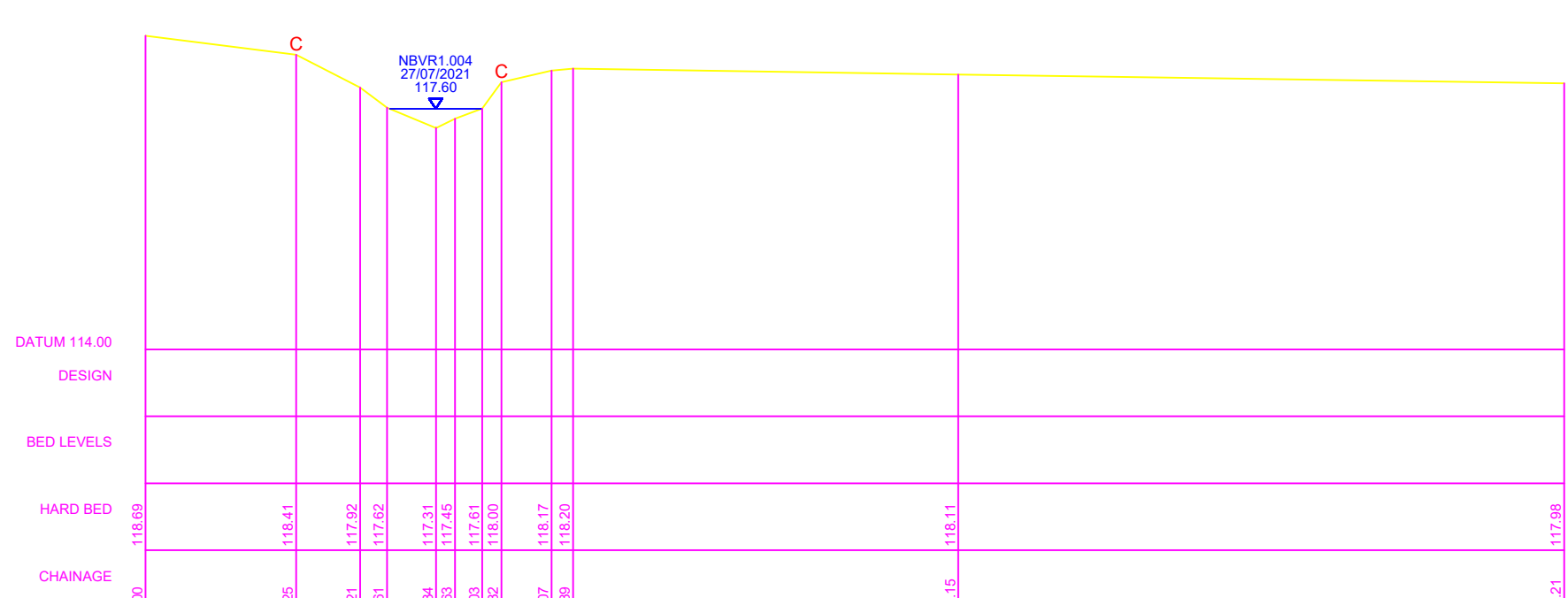
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0m
Open Channel



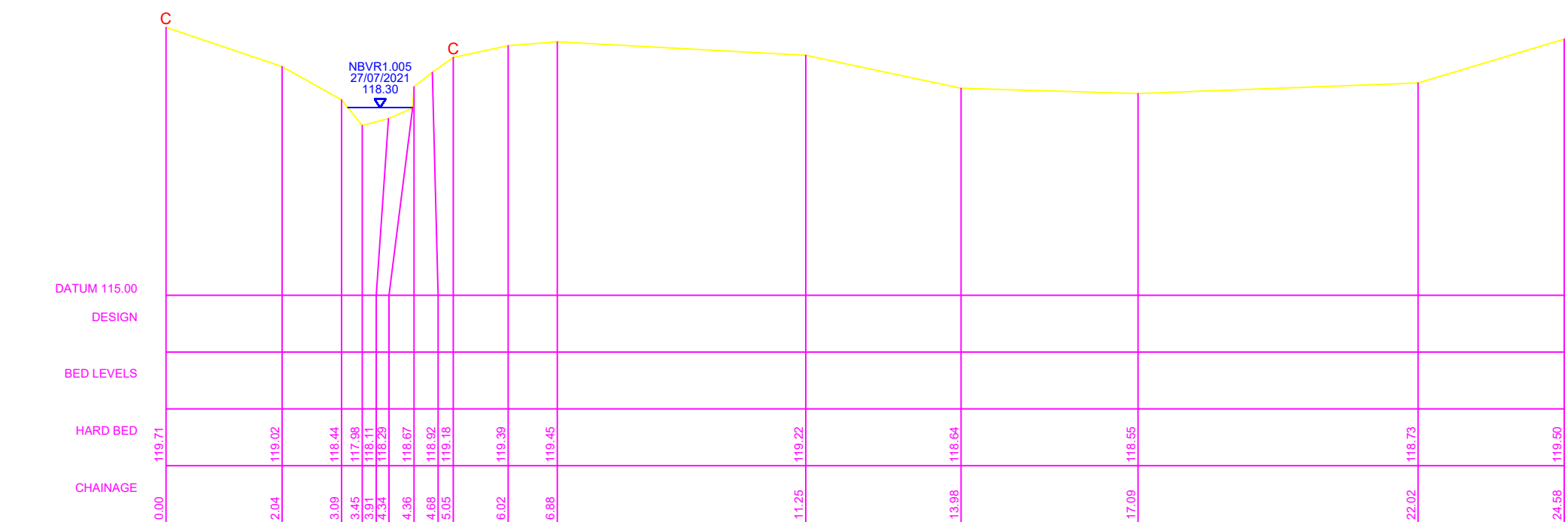
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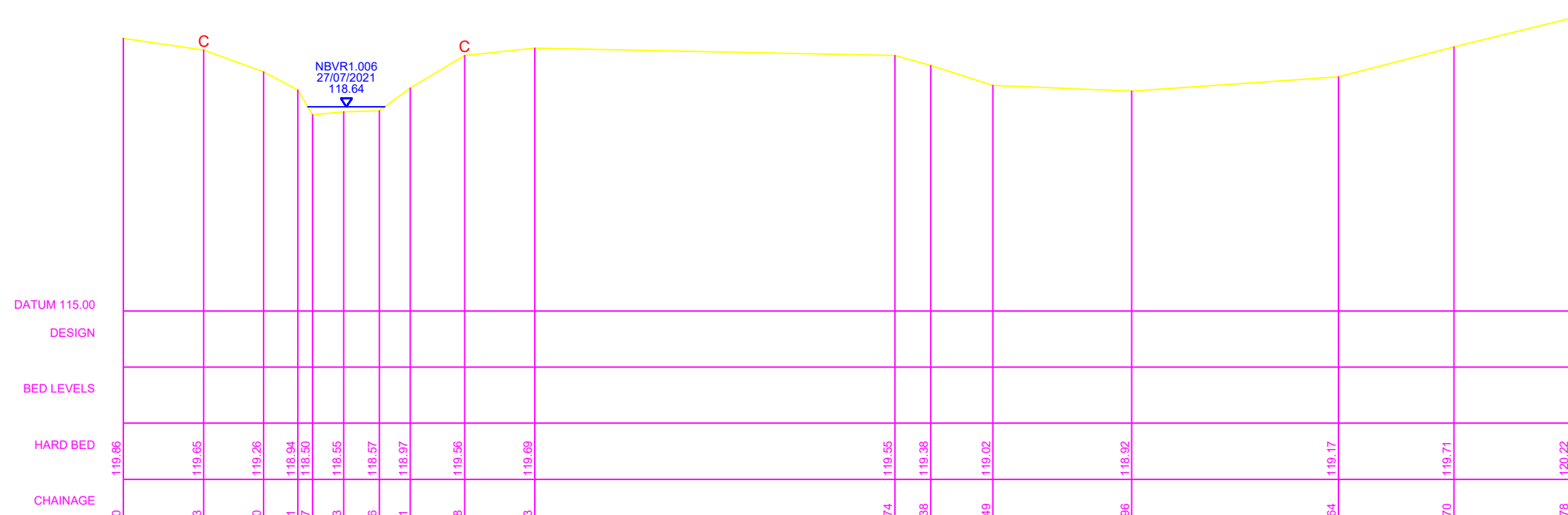
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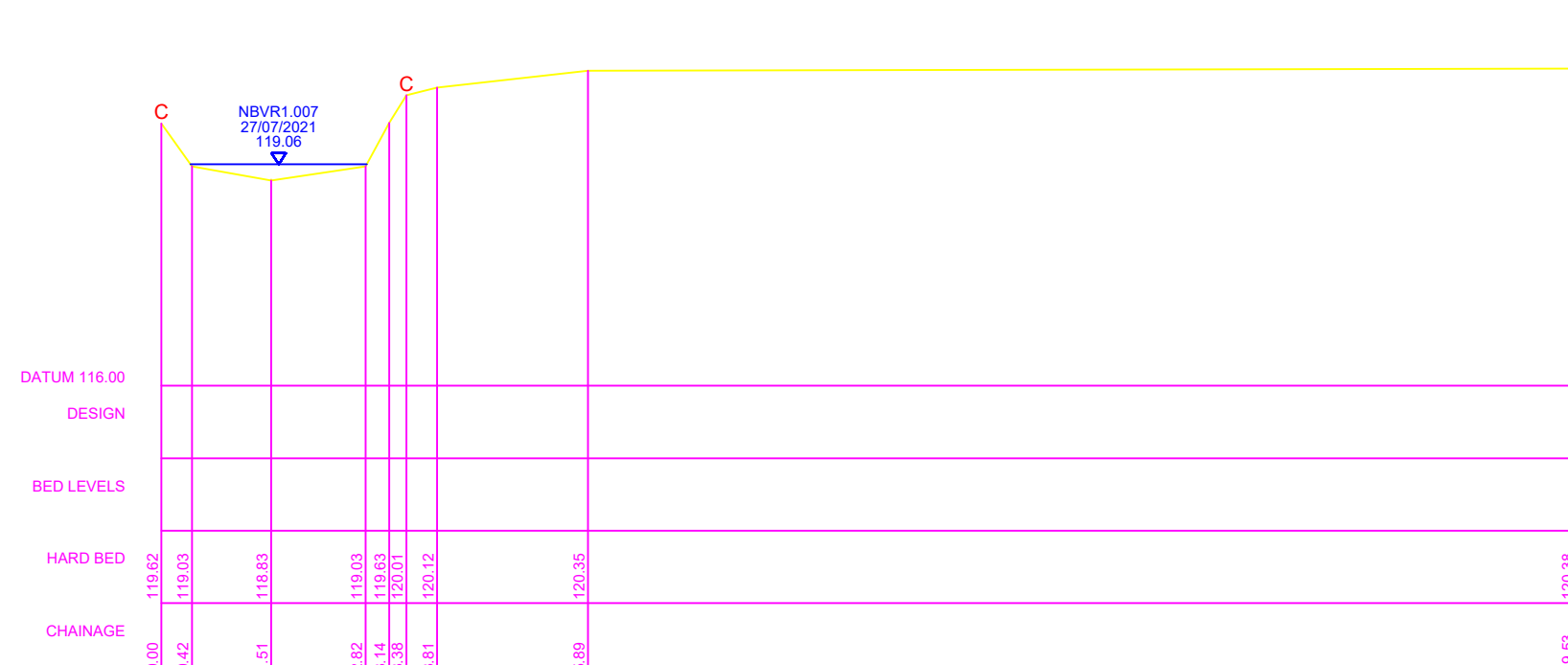
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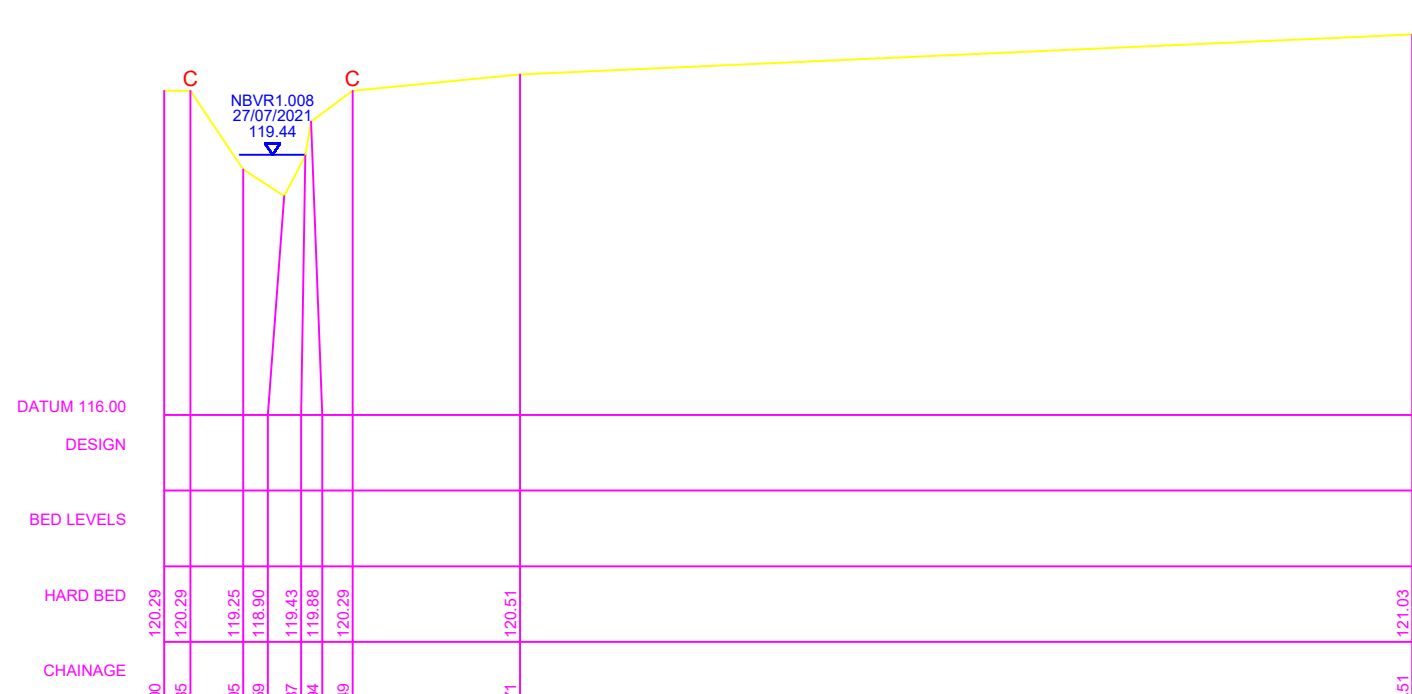
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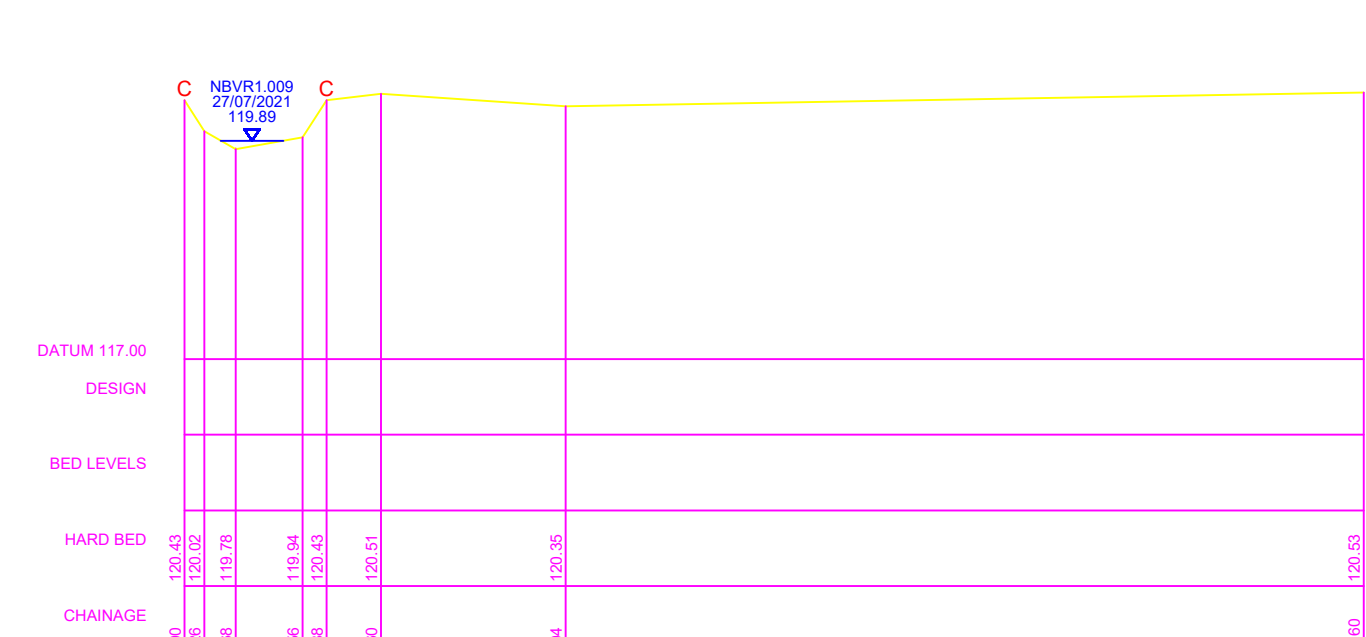
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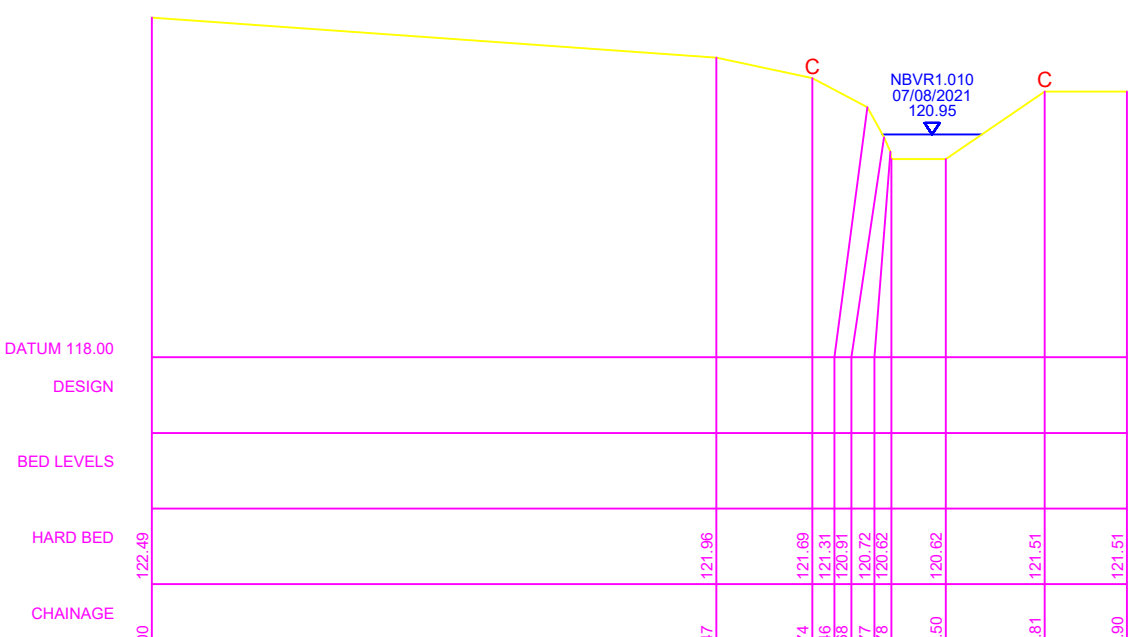
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Open Channel



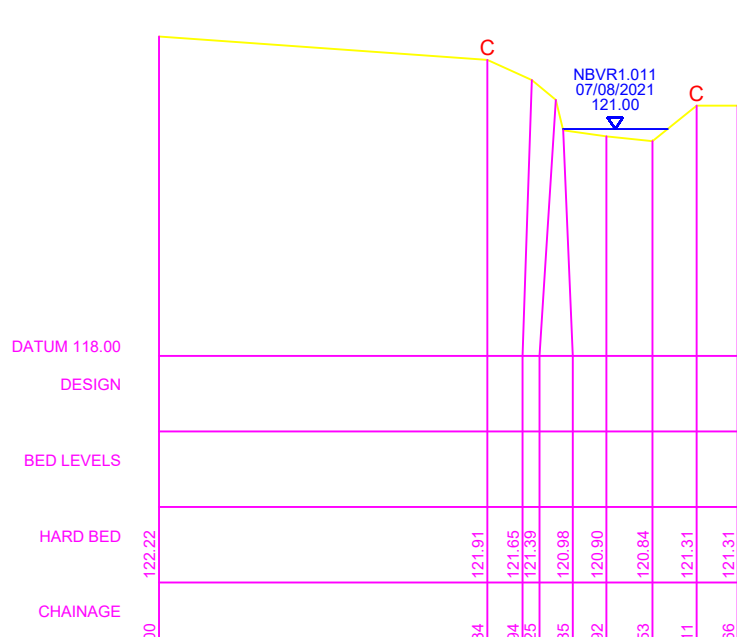
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Open Channel



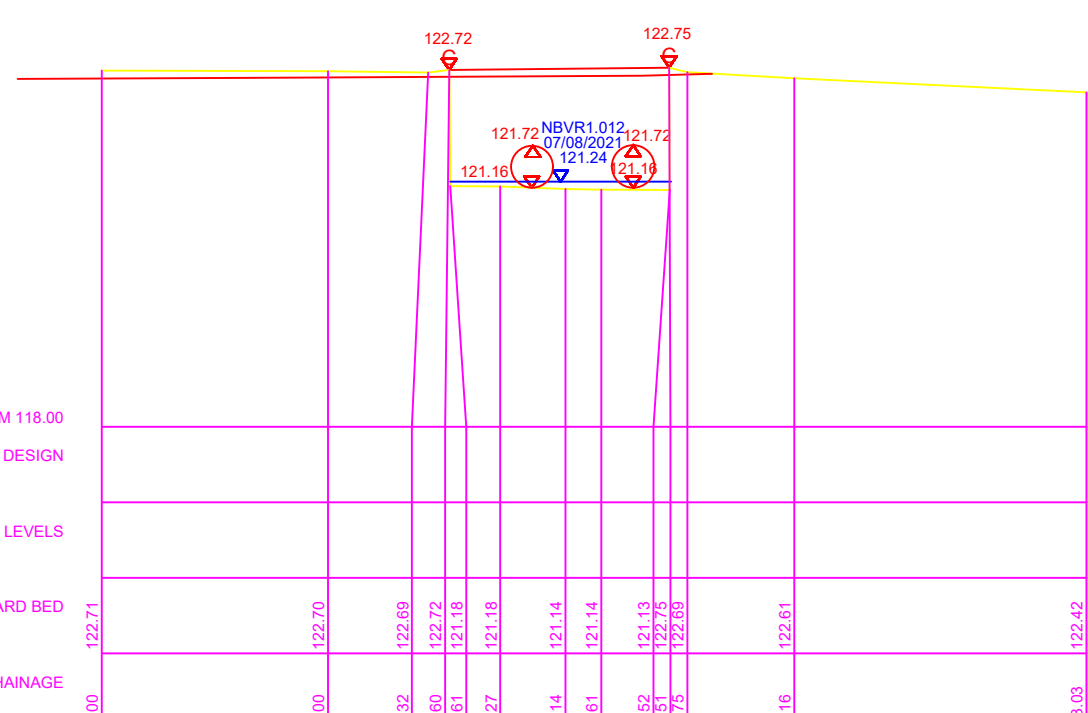
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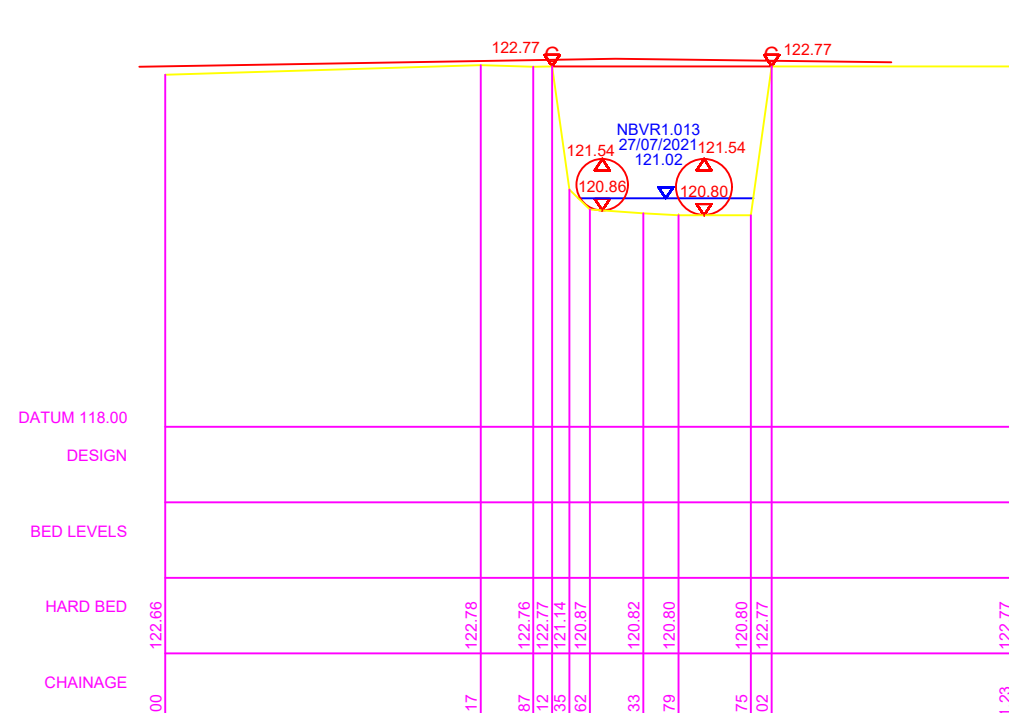
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Open Channel



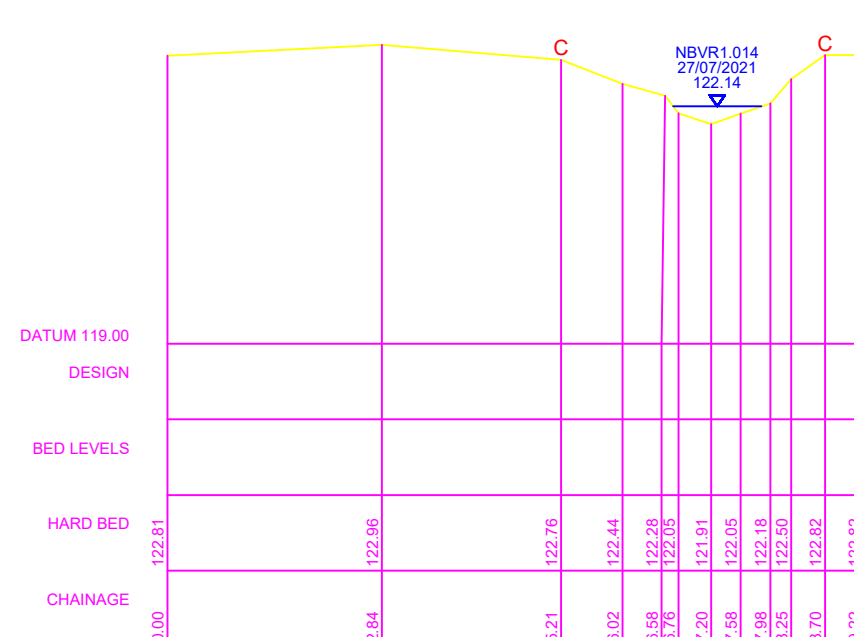
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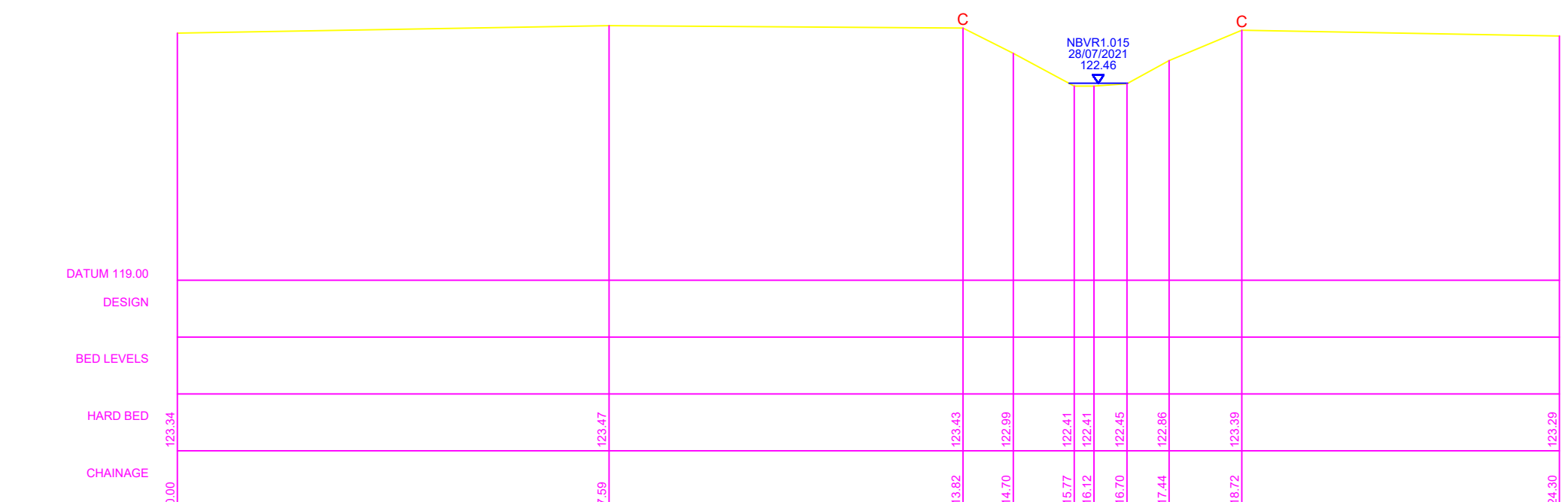
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Culvert



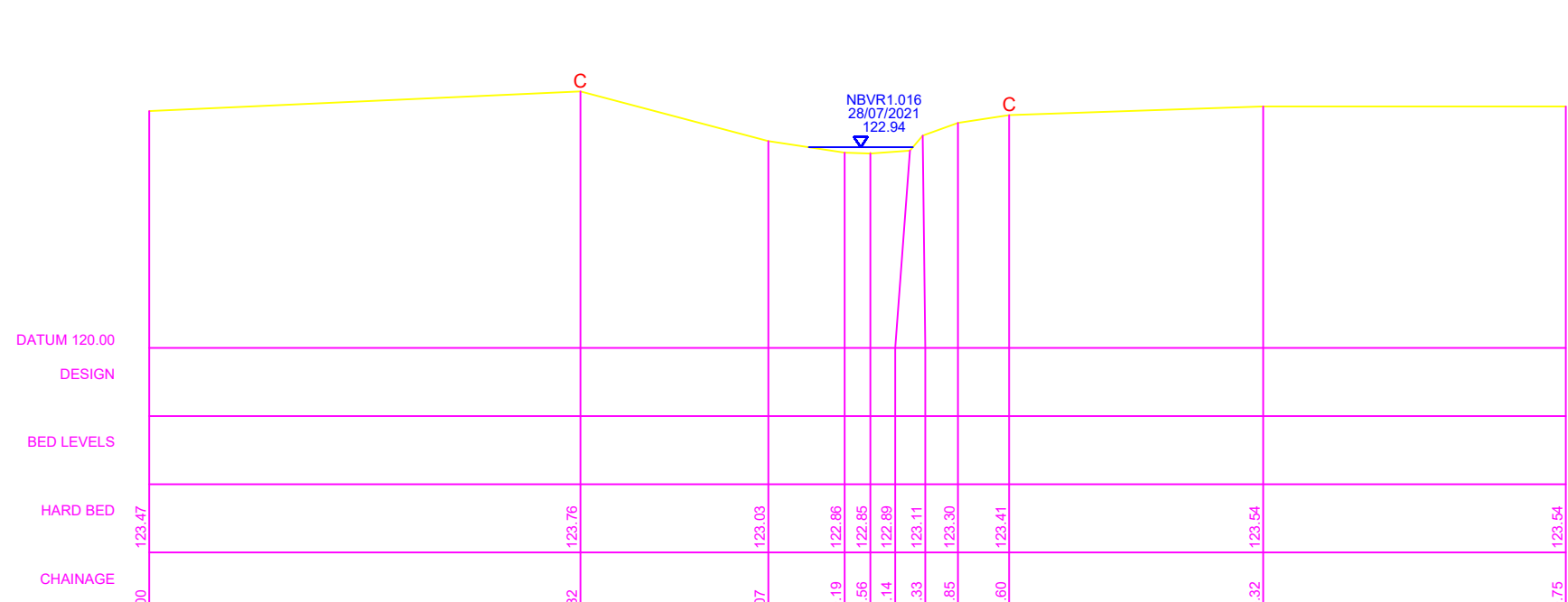
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659.6m
Culvert



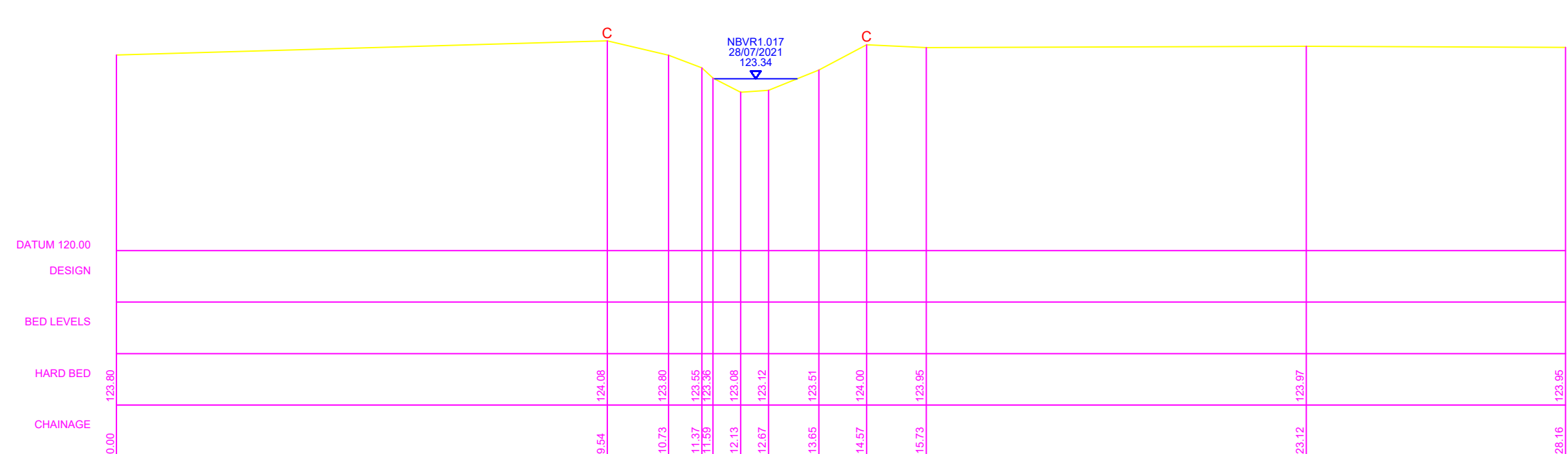
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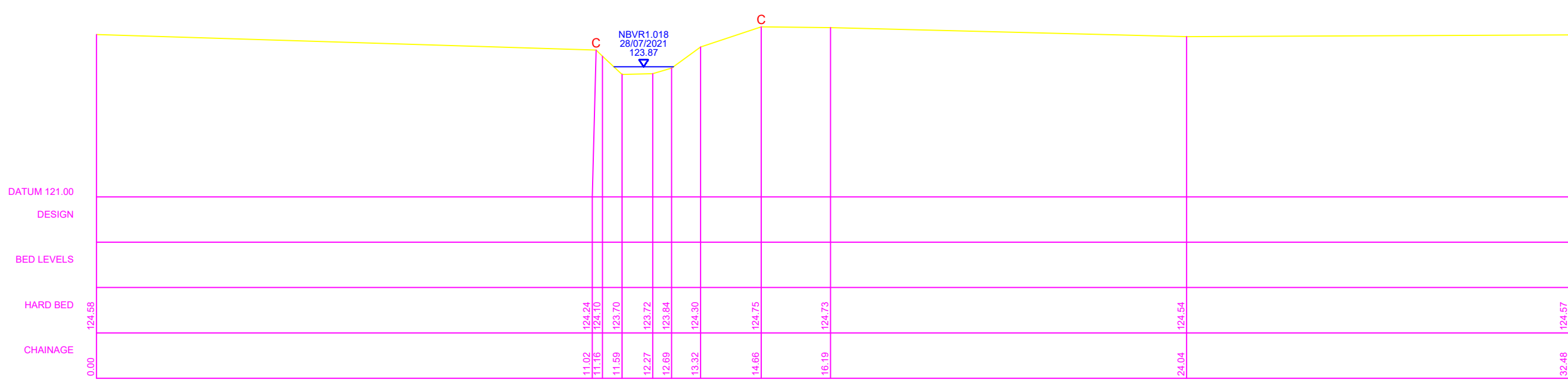
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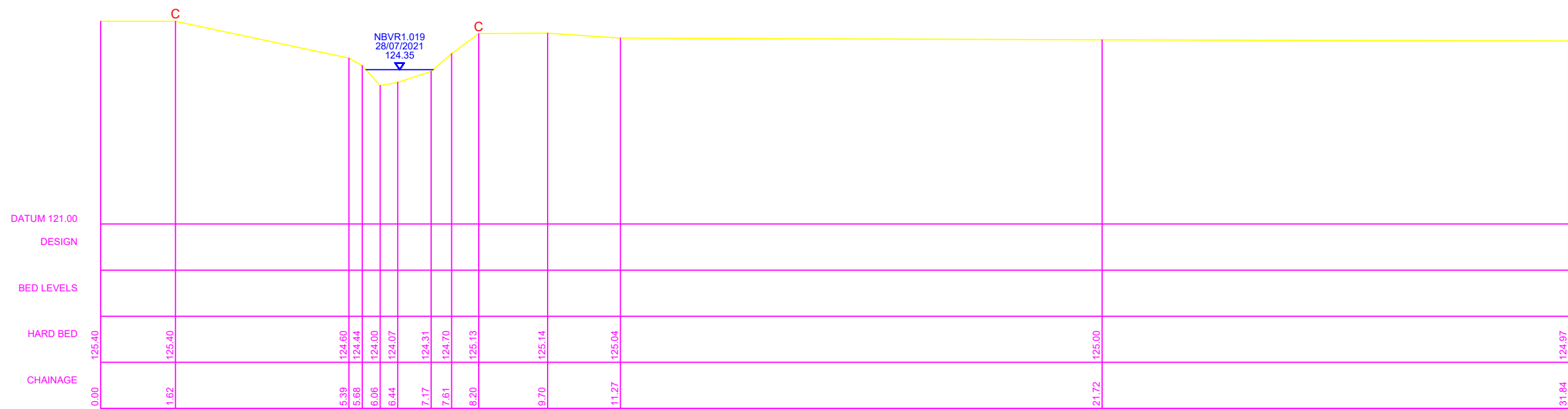
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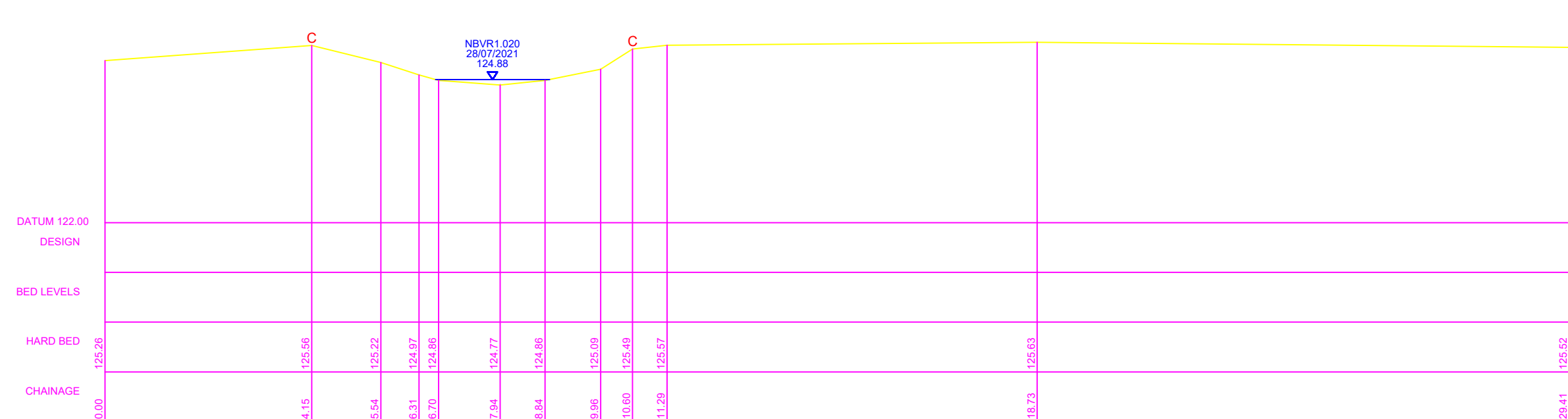
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1003.9m
Open Channel



NBVR1.018
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1076.9m
Open Channel



NBVR1.019
444870.27mE 303178.78mN Brg 10
1140.6m
Open Channel



NBVR1.020
444953.75mE 303179.09mN Brg 347
1222.2m
Open Channel

P1	29.07.21	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

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Client

Richborough Estates Ltd

Project Title

**Brascote Lane
Newbold Verdon**

Drawing Title

**Watercourse Survey
Reach 1 Sections 1 - 20
Sheet 1 Of 2**

Drawn:	L.Riley	Reviewed:	D.Smith
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BWB Ref:	BMW 3175	Date:	29.07.21	Scale/No:	1:100
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Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-00-ZZ-M2-G-0060	S2	P1

- Notes
1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
 2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
 3. All dimensions in metres unless noted otherwise. All levels in metres unless noted otherwise.
 4. Any discrepancies noted on site are to be reported to the engineer immediately.
 5. No scale factor has been applied to this survey, therefore the OS coordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
 6. All coordinates and height data relate to OSGB36(15). Control stations are coordinated by means of GPS receiving real time corrections via OS smart net.
 7. All manhole data is collected from ground level therefore discrepancies may occur. More accurate data is only achievable via confined space entry.
 8. OS license number: 10002422

Key Plan



Legend

OS Buildings	Contour Lines	Inspection Chamber
Surveyed Buildings	Flow direction and pie-diameter	Station and Name
Building	Monitoring Borehole	Tree / Bush / Sapling
Wall	Edge of Surface	Area of Vegetation/ Extent of Tree Canopy
Kerb Channel Line	Top of Bank	Hedge
Top of Surface	Bottom of Bank	Body of Water
Top of Bank	Canopy / Overhang	Body of Water from OS
Line Marking	Centre Line	Spot Level
Watercourse	Centre Line	*50.00
Barrier	Fence	Assumed Surface
Gate	Overhead Powerline	Water Drainage Line
Overhead Powerline	Overhead Utilities	Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BO	Back Gully	FOB	Fence Chain Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	MV	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PS	Post Box
C	Crest	FMR	Fence Metal Rolling	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Roadside Eye
CMP	Cable Marker	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Cable TV	FSP	Fence Steel Pile/sole	ST	Stop Sign
CCTV	Cable TV	FVM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FVL	Fence Floor Level	TGB	Telephone
DC	Drainage	FP	Flagpole	TL	Threshold Level
DK	Drop Kerb	OV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
ELC	Electric	HS	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Road	IFL	Internal Floor Level	VL	Water Level
FH	Fire Hydrant	IL	Invert Level	WM	Water Meter
FL	Floodlight			WO	Wash Out

P1	29.07.21	First Issue	IR	DS
Rev	Date	Details of issue / revision	Dw	Rev

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Client

Richborough Estates Ltd

Project Title

Brascote Lane

Newbold Verdon

Drawing Title

Existing Watercourse

Layout

Sheet 2 Of 2

Drawn:	I.Riley	Reviewed:	D.Smith
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BWB Ref:	BMW 3175	Date:	29.07.21	Scale@A0:	1:1000
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Information

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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BLN-BWB-00-ZZ-M2-G-0060

S2 P1

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Appendix 2: Hydrological Assessment

ENVIRONMENT

Richborough Estates Limited
Brascote Lane, Newbold Verdon
Leicestershire
Flow Estimation Record

ENVIRONMENT

Richborough Estates Limited
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Leicestershire
Flow Estimation Record

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August 2021

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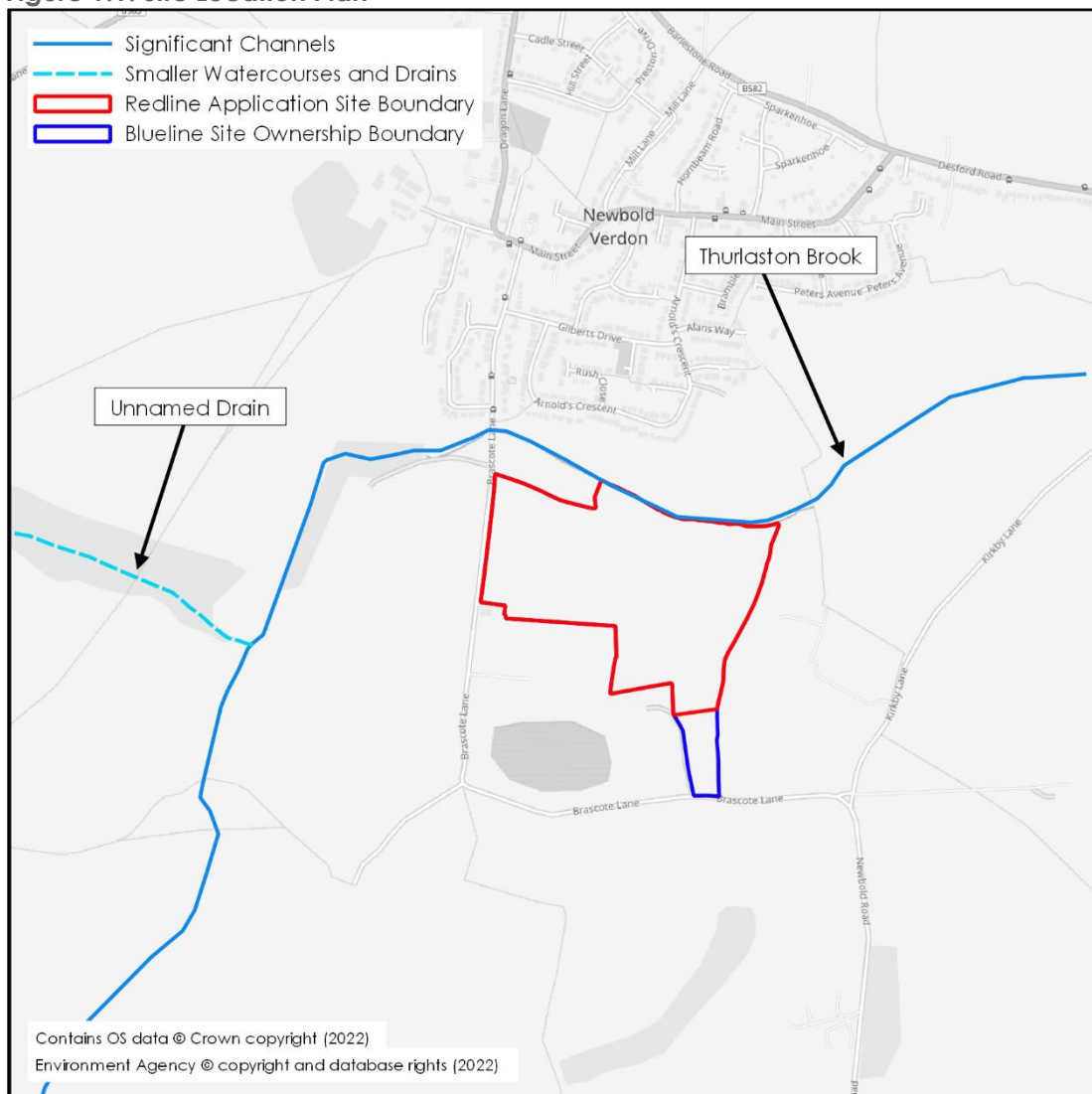
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1. METHOD STATEMENT

Overview of requirements

- 1.1 Flow estimates are required for input into a hydraulic model of the Thurlaston Brook, to support the planning application for a residential development at the land off Brascote Lane, Newbold Verdon, Leicestershire.
- 1.2 The location of the site of interest and the watercourses to be modelled are provided in **Figure 1.1**. The site is located immediately downstream of the source of the Thurlaston Brook, which is a tributary to the River Soar.

Figure 1.1: Site Location Plan



- 1.3 Return periods to be assessed include: 2, 5, 10, 20, 50, 75, 100, 200 and 1000-years. To inform the design event and potential future floodplain, the 1 in 100-year event with a range of climate change allowances applied will also be simulated. Hydrographs are required as well as peak flows.

- 1.4 The hydrological assessment was undertaken in August 2021.

Climate change

- 1.5 Predicted future change in peak river flows caused by climate change are provided by the Environment Agency (EA), with a range of projections applied to 'Management Catchments', which are sub-catchments of regionalised 'River Basin Districts'.
- 1.6 The site falls within the 'Soar' Management Catchment which is located within the 'Humber' River Basin District. **Table 1.1** identifies the relevant peak river flow allowances for the Soar Management Catchment.

Table 1.1: Peak River Flow Allowance for the Soar Management Catchment

Allowance Category	Total potential change anticipated for the '2020s' (2015 to 2039)	Total potential change anticipated for the '2050s' (2040 to 2069)	Total potential change anticipated for the '2080s' (2070 to 2125)
Soar Management Catchment			
Upper End	28%	35%	60%
Higher Central	18%	21%	37%
Central	14%	16%	28%

- 1.7 When determining the appropriate allowance, the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of a future development should be considered.
- 1.8 **Table 1.2** provides a matrix summarising the EA's guidance on determining the appropriate allowances.

Table 1.2: Application of the Appropriate Climate Change Allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
1	Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.				
2	Use the higher central allowance	Use the central allowance			
3a	Use the higher central allowance	Development should not be permitted	Use the central allowance		
3b	Use the higher central allowance	Development should not be permitted			Use the central allowance

Flood Zone	Essential Infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
If development is considered appropriate by the local authority when not in accordance with Flood Zone vulnerability categories, then it would be appropriate to use the higher central allowance.					

Available hydrometric data

- 1.9 There are no hydrometric gauges within the study catchment. Therefore, there are no current hydrometric records of river flows or levels for the watercourse on which a hydrological assessment of flood flows can be made.
- 1.10 Following review of the National River Flow Archive (NRFA), the closest gauging station to the site is located on the River Soar at Littlethorpe. This is located approximately 20km downstream of the site.
- 1.11 The Littlethorpe gauge is located on a different watercourse to the study watercourse. As such, whilst the gauge can be used as part of the Statistical analysis for donor adjustment of QMED, its use for calibration and verification is limited.
- 1.12 **Table 1.3** and **Table 1.4** provide details on the Littlethorpe gauge. A detailed review of the data quality at the Littlethorpe gauge, beyond a review of the information on the NRFA website, was outside the scope of this assessment.

Table 1.3: Hydrometric gauges within the Study Catchment

Watercourse	Station Name	NRFA number	Grid Reference	Catchment Area (km ²)	Type	Period of Record
River Soar	Littlethorpe	28082	SP542973	183.9	Cross-correlation	08/1971 - present

Table 1.4: Gauging Station Data Availability and Quality

Station Name	Period of data in Peak Flow dataset	Suitable for QMED?	Suitable for Pooling?	Comments on station and data quality
Littlethorpe	1981 - 2019	Yes	Yes	Flood relief channel joins on the right bank just upstream. Bypassed at high flows above 2.4 mASD. During electromagnetic data, a rating was used to derive flows above 2.3m when instrumentation underestimated. Prone to weed growth.

- 1.13 The NRFA Peak Flow Dataset Version 9 (most up to date version available at the time of this assessment) will also be utilised in this assessment for the purposes of identifying any potential donor stations and for the development of pooling groups.

Initial choice of approach

Table 1.5: Method statement

Is FEH appropriate?	Yes. The study catchment is greater than 0.5km ² , is not considered to be highly permeable (BFIHOST is less than 0.75), and there is no significant reservoir attenuation (FARL>0.9). Catchment is considered to be moderately urbanised (URBEXT2000>0.060).
Initial choice of method(s) and reason	Both the FEH Statistical and the ReFH2 methods will be used. Both methods are suitable for the catchments and using both will enable comparison between the two flow estimation methods before choosing the final method.
Software to be used	WINFAP v4 and ReFH2 version 2.3

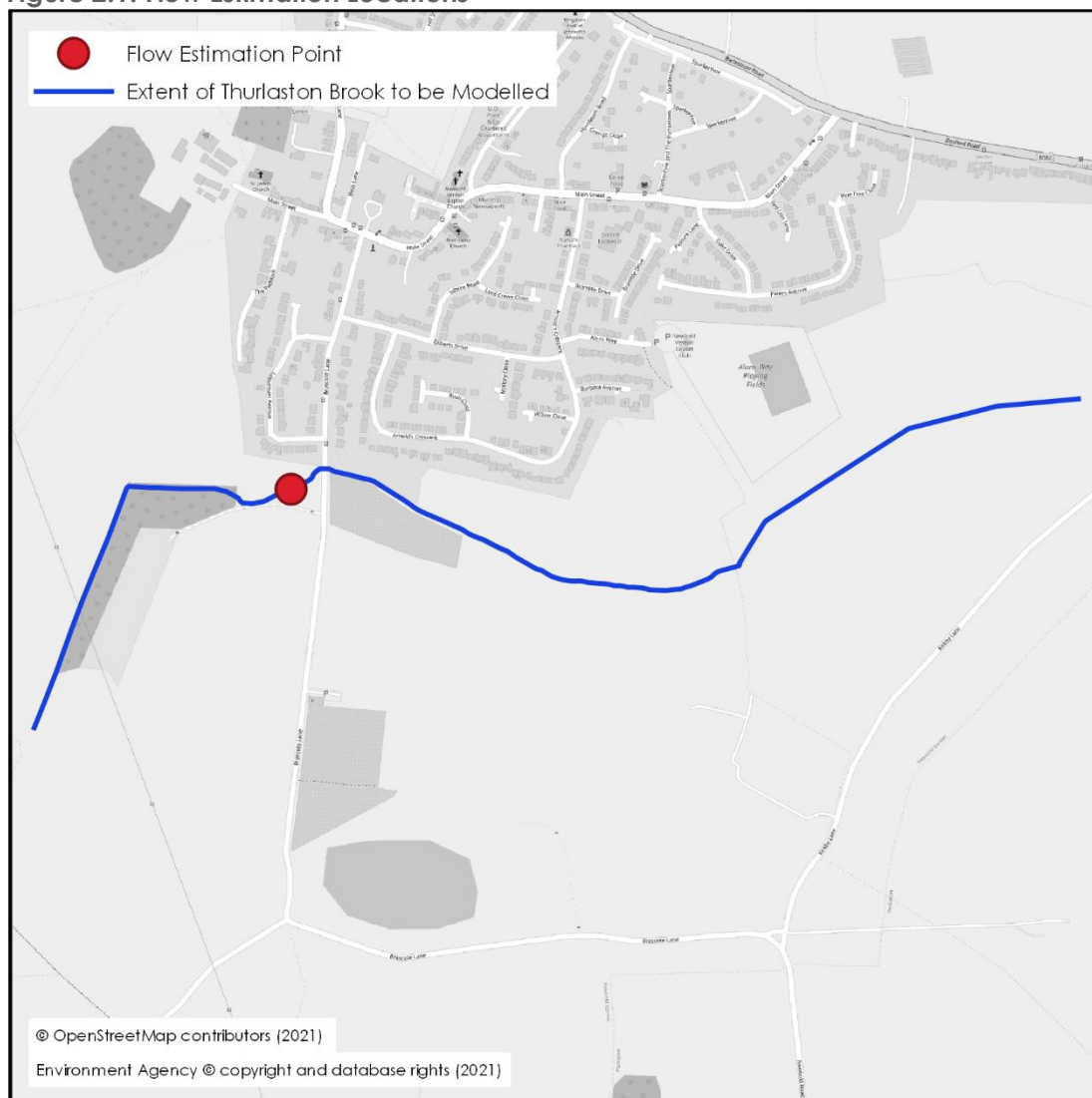
2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

Location of Flow Estimates

Table 2.1: Summary of subject sites

Site code	Watercourse	Site	Easting	Northing	Area on FEH Webservice	Revised area (if altered)
Thurlaston	Thurlaston Brook	Brascote Lane	444400	303300	1.74	2.14
Reasons for choosing locations		A single flow estimation point was extracted immediately downstream of the structure at Brascote Lane. This was considered suitable to capture all flows draining to the Thurlaston Brook, whilst also being located downstream of the study site.				

Figure 2.1: Flow Estimation Locations



Checking Catchment Descriptors

Table 2.2: Catchment Descriptor Checks

Record how catchment boundary was checked and describe any changes.	The catchment boundary for the flow estimation point was identified by the FEH Web Service. The boundary was reviewed using EA LIDAR. A watershed analysis was undertaken using the LIDAR and the results compared to the FEH boundary. Results were also compared to sewers records; the sewer catchment follows the topographical catchment as expected. Following a review of the watershed analysis, the catchment boundary was updated to reflect the results. The original and amended catchment boundary is shown in Figure 2.2.
Record how other catchment descriptors (especially soils) were checked and describe any changes. Include before/after table if necessary.	British Geological Survey (BGS) mapping¹ indicates that the catchment is predominately underlain by the Gunthorpe Member (mudstone), with superficial deposits largely consisting of Glaciofluvial Deposits (sand and gravel, Oadby Member (diamicton) and Alluvium (clay, silt, sand and gravel). According to the Soilscales website², the catchment is predominantly underlain by loamy soils with naturally high groundwater. The underlying geology and soils suggest the BFIHOST and SPRHOST values of the FEH catchment descriptors are appropriate for the catchments. DPLBAR has been updated using the standard equation for DPLBAR, given in the FEH Volume 5. Following the change in AREA, a review of the urban coverage of the amended catchment boundary was undertaken against satellite imagery. URBEXT₂₀₀₀ was subsequently determined using the URBAN50k method. The FARL value was also reviewed following updates made to the AREA value. This value was retained as no online storage areas have been identified within the amended catchment boundary.
Source of URBEXT	URBEXT ₂₀₀₀
Method for updating of URBEXT to present day.	Values of URBEXT₂₀₀₀ were recalculated following the amendments to the catchment boundary using formula 5.4 from 2006 CEH report on URBEXT₂₀₀₀, which allows URBEXT₂₀₀₀ to be calculated from the present day urban area of the catchment.

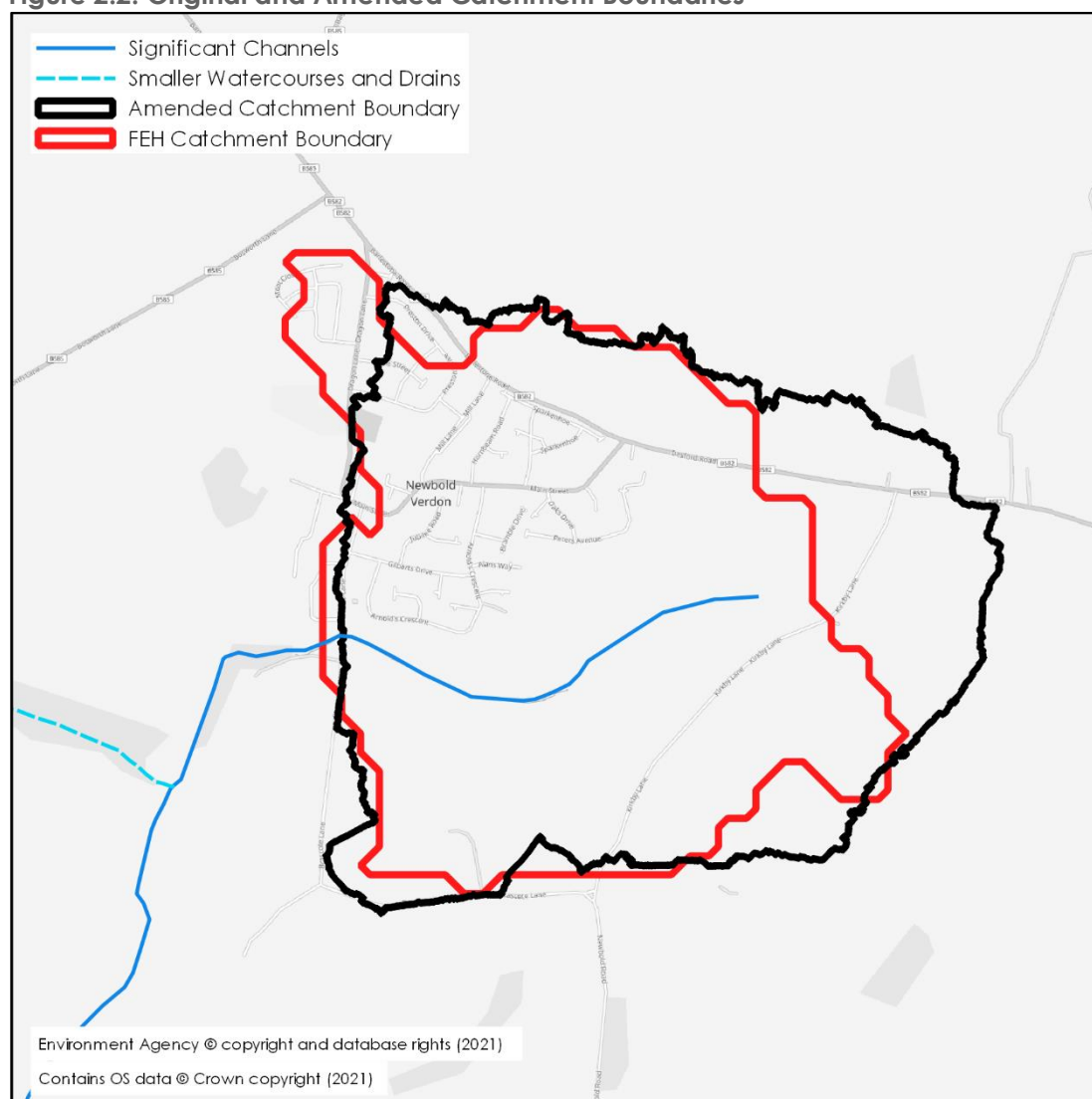
¹ <https://mapapps.bgs.ac.uk/geologyofbritain/home.html>

² <http://www.landis.org.uk/soilscales/>

Table 2.3: Important catchment descriptors at each subject (changes made are highlighted in red)

Site Code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR	SPRHOST	URBEXT 2000	FPEXT
Thurlaston	1.00	0.30	0.589	1.17	17.8	650	40.16	0.1474	0.1191

Figure 2.2: Original and Amended Catchment Boundaries



3. STATISTICAL METHOD

- 3.1 WINFAP version 4 was utilised to undertake a statistical analysis of the catchment using a hydrometric record of gauged catchments with similar characteristics. The latest version of the NRFA Peak Flow dataset (v9) was used to provide an up-to-date hydrometric record.

QMED Development

- 3.2 Catchment descriptors were originally used to estimate the rural QMED of the study site using the revised equation from Science Report (SC050050). The FEH states that flood frequency is best estimated by gauged data and estimation of key variables from catchment descriptors alone should be a method of last resort. As such, a search was undertaken to identify any potential donor sites that could be used to adjust QMED.
- 3.3 The research underlying the revised data transfer method (SC050050) found that identification of potential donor catchments should be based on geographical closeness rather than on hydrological similarity, as defined by catchment descriptors. More recent research on small catchments (SC090031) has supported the findings of SC050050, again recommending that donors are selected purely based on proximity. The EA FEH Guidelines advises similarity in catchment descriptors is not essential for donors. However, in view of the sometimes-uncertain relationship between BFIHOST and runoff, similarity in geology or soil type may be relevant. The guidelines also advise considering more than one donor.
- 3.4 With the guidance in mind, a search was undertaken within WINFAP 4 for suitable donor stations for QMED data transfer. Whilst the FEH recommends avoiding urbanised donors, the Littlethorpe gauge is approximately 20km downstream of the site and only just over the 0.03 threshold for URBEXT₂₀₀₀. WINFAP allows the use of urban donors, applying the urban adjustment factor in reverse to attempt to remove the urban influence. As such, the search for donors was extended to donors with URBEXT > 0.046 to allow WINFAP to include Littlethorpe as a donor.
- 3.5 The six nearest donors were reviewed based on similarity in BFIHOST to the subject site and data quality. Of the recommended donors, station 54111, was rejected due to concerns over data quality, particularly with early flow estimates.
- 3.6 Details for the donor stations are provided in **Table 3.1**.

Table 3.1: Donor Station Details

Station Number	QMED from Observed Data (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio (A/B)
28082	15.472*	19.528	0.792
28086	21.807*	18.886	1.155
54019	27.319*	34.588	0.790
54102	12.313	13.242	0.930

Station Number	QMED from Observed Data (A)	QMED from Catchment Descriptors (B)	Adjustment Ratio (A/B)
28024	34.45	37.726	0.913

* As URBEXT2000 is greater than 0.03, QMED from observed data has been deurbanised.

Table 3.2: Overview of estimation of QMED at each subject site

Site Code	Method	Initial Estimate of QMED (m ³ /s) (Rural)	Data Transfer				Final estimate of QMED (m ³ /s) (URBAN)
			Donor site NRFA no	Distance between centroids d _j (km)	Weight	Final Adjustment Factor	
Thurlaston	Data Transfer	0.31	28082	10.23	0.379	0.944	0.35
			28086	20.99	0.302		
			54019	26.45	0.271		
			54102	29.94	0.253		
			280024	34.15	0.232		
Are the values of QMED consistent, for example at successive points along the watercourse and at confluences?			QMED is consistent with the size and characteristics of the catchment.				
Which version of the urban adjustment was used for QMED?			Urban adjustment was applied using Kjeldsen (2010), as applied in WINFAP4.				

Derivation of Pooling Groups

- 3.7 A pooled group of hydrologically similar gauged sites was generated by the WINFAP software for the subject sites using the 'OK for Pooling' dataset.
- 3.8 The pooling group was reviewed to identify sites which may be inappropriate due to being significantly hydrologically dissimilar to the study site, or if they have any inaccuracies, uncertainties, or limitations in their data record.
- 3.9 The growth curve derived from the pooling group was also adjusted to reflect the urban influence using the methods adopted in WINFAP3 which is based on those published by Kjeldsen 2010⁴.
- 3.10 Further detail on pooling group composition is provided in **Section 6**.

³ Wallingford HydroSolutions (2016), WINFAP 4 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2016.

⁴ Kjeldsen, T.K., 2010. Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

Table 3.3: Derivation of pooling groups

Name of group	Site code from whose descriptors the group was derived	Subject site treated as gauged? (enhanced single site analysis)	Change made to default pooling group with reasons, including any sites investigated but retaining in the group	Weighted average L-moments L-CV and L-skew (before urban adjustment)
Thurlaston_PG	Thurlaston	No	Stations Removed: 27073 and 26016 – highly permeable compared to subject site. 49005 – high discordancy caused by negative and comparatively low L-kurtosis compared to rest of the sites. The station is also an outlier with regards to seasonality and has a relatively short record of 9 years of data. 106002 and 206006 – removed due to being located in geographically dissimilar locations that are subject to different rainfall patterns and meteorological conditions. 106002 in particular was an outlier with regards to seasonality. Stations Added: 54022 and 36010 – added to ensure the pooling group exceeded the recommended minimum record length of 500 years. Comments: Final pooling group is acceptably homogeneous and a review of the pooling group is not required.	L-CV: 0.231 L-Skew: 0.280

Table 3.4: Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS)	If P, ESS or J, name of pooling group	Distribution used and reason for choice	Note any urban or permeable adjustment	Parameters of distribution (location, scale and shape) after urban adjustment	Growth factor for 1% AEP event
Thurlaston	Pooled	Thurlaston_PG	Generalised logistic provided an acceptable fit and is regarded as the best fit for	Urban adjustment using methods adopted in WINFAP which is	Location: 1.000 Scale: 0.201 Shape: -0.307	3.034

Site code	Method (SS, P, ESS)	If P, ESS or J, name of pooling group)	Distribution used and reason for choice	Note any urban or permeable adjustment	Parameters of distribution (location, scale and shape) after urban adjustment	Growth factor for 1% AEP event
			most UK catchments	based on those published by Kjeldsen 2010		

Table 3.5: Flood estimates from the Statistical method

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
Thurlaston	0.35	0.47	0.57	0.69	0.88	0.98	1.06	1.29	2.04

4. REVITALISED FLOOD HYDROGRAPH (REFH) METHOD

- 4.1 The ReFH2 Revitalised Flood Hydrograph Modelling Tool (Version 2.3) was used to undertake an estimation of the peak flows for the subject sites.

Table 4.1: Overview of parameters for ReFH2 method

Site code	Method OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer	T _p (hours) Time to peak	C _{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
Thurlaston	CD	3.313	508.274	39.729	2.41*
Description of flood event analysis carried out			No flood event analysis was undertaken due to a lack of gauging station in the study catchment.		

* Baseflow recharge reported for the 1 in 100 year return period.

Table 4.2: Critical storm durations

Site code	Season of design event	Storm duration	Selected interval
Thurlaston	Winter	5hrs 30 mins	30 mins
Comments	The recommended storm duration for the upper catchment of the Thurlaston Brook is 5.5 hours. As such the model will be run with a 5.5 hour storm duration using a winter storm profile. However, sensitivity analysis will also be undertaken using 3 hr and 11 hr storm durations to assess the sensitivity of the model to differing storm durations.		

Table 4.3: Flood estimates from the ReFH method (based on critical duration for individual catchments)

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
Thurlaston	0.45	0.60	0.71	0.84	1.06	1.18	1.29	1.59	2.42

5. DISCUSSION AND SUMMARY OF RESULTS

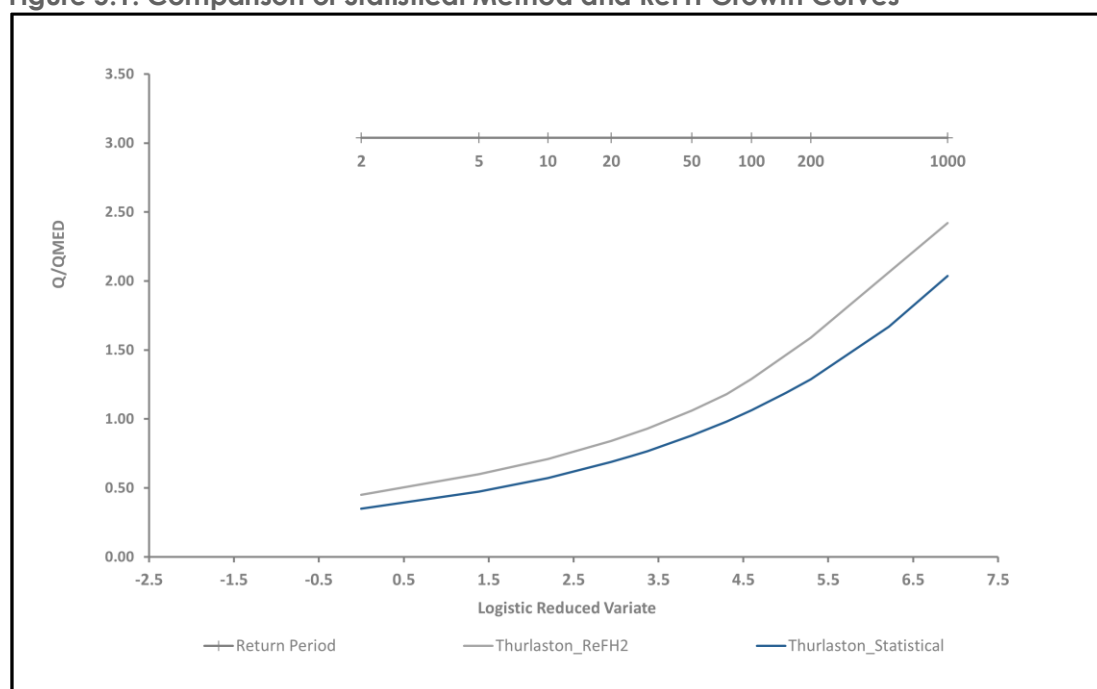
Comparison of method

- 5.1 A comparison of the peak flow results for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in **Table 5.1**. Comparisons of the growth curves for both methods are shown in **Figure 5.1**.
- 5.2 The ReFH method gave the highest peak flows for the Thurlaston Brook flow estimation point. Both the Statistical and ReFH methods share a fairly similar steepness to their growth curves.

Table 5.1: Comparison of results

Site code	1 in 2-year peak flows			1 in 100-year peak flows		
	Statistical	ReFH	Ratio	Statistical	ReFH	Ratio
Thurlaston	0.35	0.45	1.29	1.06	1.29	1.22

Figure 5.1: Comparison of Statistical Method and ReFH Growth Curves



Final method and flows

Table 5.2: Final choice of method

Choice of method and justification	Whilst, both Statistical and ReFH2 methods are considered suitable for the catchments, the final choice of peak flows for input into the model is the ReFH2 method. Although the Statistical method incorporates local data from the Littlethorpe gauge, the Littlethorpe gauge is located on the River Soar not the Thurlaston Brook. As such, due to the lack of gauged data on the Thurlaston Brook itself, with which to verify flows, the more conservative ReFH2 flows will be applied to the hydraulic model.
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Table 5.3: Final Peak Flows from Chosen Method (ReFH)

Site Code	Flood peak (m ³ /s) for the following return periods								
	2	5	10	20	50	75	100	200	1000
Thurlaston	0.45	0.60	0.71	0.84	1.06	1.18	1.29	1.59	2.42

Table 5.4: Assumptions, limitations and uncertainty

List the main assumptions made	- The pooling group is representative of the catchment. - The River Soar at Littlethorpe gauge is suitable for use as a donor for QMED. - The ReFH2 hydrograph shape is representative of catchment response. - Tp and storm duration is representative of the catchment response. - The characteristics of the catchment do not change significantly between the up and downstream extents of the model.
Discuss any limitations e.g. applying methods outside the range of catchment types or return periods for which they were developed	- The FEH Statistical and ReFH2 methods are believed to be suitable up to the 1 in 200-year event. Estimates of flow beyond these events are extrapolations and, therefore, have a higher level of uncertainty. - There are only a small number of small gauged sites in the UK. As such the representation in the pooling is not ideal given the relatively small size of the study catchment. - There is no observed flow data within the catchment with which to calibrate or verify the flow estimates.
Give what information you can on uncertainty in the results	According to Table 4 of the EA FEH Guidelines, confidence intervals for the 1 in 100 year for a rural site when calculated from catchment descriptors are quoted as 0.45-2.23 (for the 95% confidence interval). Confidence is considered to be improved when using observed data from a donor site.

	It is more difficult to quantify uncertainty in design flows estimated from the ReFH rainfall-runoff model. However, evidence ⁵ suggests the factorial standard errors from ReFH2 are comparable to those observed for the FEH pooled Statistical method when the catchment is treated as ungauged.
Comment on the suitability of the results for future studies	The design flow estimates have been derived for the purpose of providing flow hydrographs into a hydraulic model to support planning decisions for a site near Newbold Verdon. Users for different studies should, as a minimum, review results to assess suitability for the purpose of the study.
Give any other comments on the study	While the installation of temporary flow gauges would provide local data with which to better inform the design peak flows, this would not align with the timescales of this project.

Table 5.5: Checks

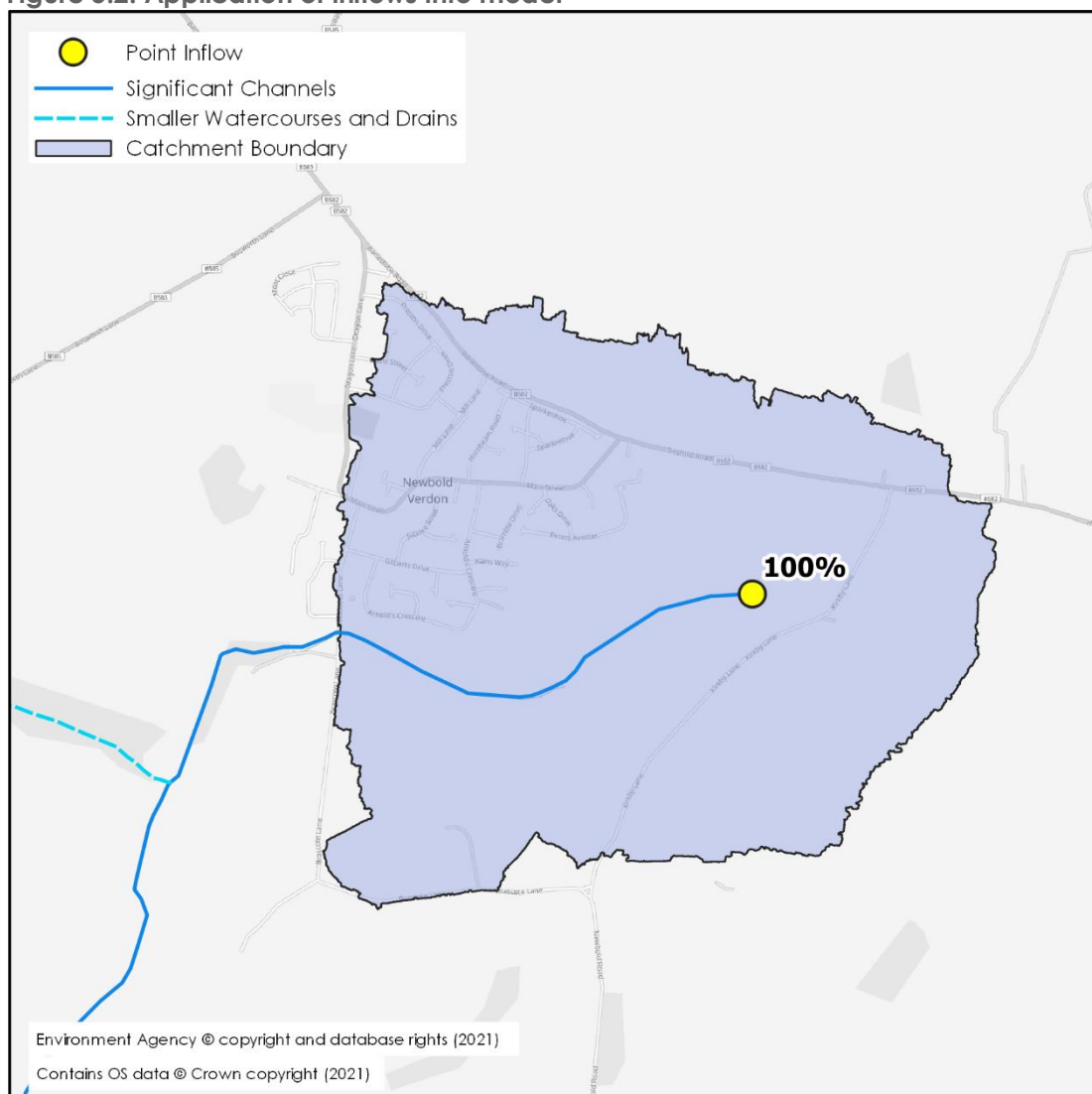
Are the results consistent?	Peak flows are consistent with the size and characteristics of the catchment.
What do the results imply regarding the return periods of floods during the period of record?	It is not possible to imply return periods of floods due to the lack of gauged data within the study catchment.
What is the 1 in 100-year growth factor? (the guidance suggests a typical range or 2.1 to 4.0)	- Statistical Method: 3.03 - ReFH2 Method: 2.87 These all fall within the typical range.
If 1 in 1000-year flows have been derived, what is the range of ratios for 1 in 1000-year flow over 1 in 100-year flow?	- Statistical Method: 1.92 - ReFH2 Method: 1.88
How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred	There are no previous detailed studies on the Thurlaston Brook with which to make a comparison.
Are the results consistent with the longer-term flood history?	It is not possible to compare the results with the longer-term flood history due to the lack of gauged data within the study catchment.
Describe any other checks on the results	Sensitivity checks of modelled outlines will be undertaken at the modelling stage.

⁵ Wallingford Hydrosolutions (2019) ReFH2 Science Report: Evaluation of the Rural Design Event Model.

Application of flows to model

- 5.3 Flows will be applied to the model as a lumped point inflow at the upstream extent of the hydraulic model.
- 5.4 Given the size of the catchment area (2.14km²) and the length of watercourse modelled (approximately 1.8km), this approach was considered to be appropriate. Using a lumped inflow at the upstream extent of the catchment subsequently allows for a conservative volume of flow being conveyed through the model at the upstream limit of the site.
- 5.5 **Figure 5.2** demonstrates how the flows will be applied to the model.

Figure 5.2: Application of inflows into model



6. SUPPORTING INFORMATION

Flood history

- 6.1 A flood history review for the area has been undertaken using Environment Agency recorded flood outlines, Strategic Flood Risk Assessments⁶, Leicestershire County Council Flood Investigation Reports, the British Chronology of Hydrological Events and online newspaper reports. No record of flooding to the proposed development site has been found during the search of the sources.
- 6.2 Leicestershire County Council have reported two records of flooding incidents within close proximity:
- March 2016: Driveways were flooded from the highway along Arnolds Crescent
 - September 2019: Surface water ponding as a result of the highway topography occurred at the corner of Brascote Lane and Luburnum Avenue.
- 6.3 Nether of the above reports have affected the redline application site.

Detailed pooling group information

- 6.4 The default pooling group generated by WINFAP is provided in **Table 6.1** and the final pooling group following review is provided in **Table 6.2**.

Table 6.1: Default pooling group: Thurlaston_PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
76011 (Coal Burn @ Coalburn)	1.183	42	1.84	0.163	0.301	0.646
27051 (Crimple @ Burn Bridge)	2.277	47	4.524	0.218	0.156	0.209
27073 (Brompton Beck @ Snainton Ings)	2.286	39	0.812	0.215	0.035	1.267
45816 (Haddeo @ Upton)	2.342	26	3.456	0.3	0.406	0.868
28033 (Dove @ Hollinsclough)	2.616	44	4.177	0.228	0.371	0.599
26016 (Gypsy Race @ Kirby Grindalythe)	2.985	22	0.1	0.321	0.266	1.116
25019 (Leven @ Easby)	2.987	41	5.09	0.342	0.386	1.469
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	3.152	9	5.777	0.271	0.151	2.793
47022 (Tory Brook @ Newnham Park)	3.169	25	6.176	0.257	0.191	0.507
25011 (Langdon Beck @ Langdon)	3.175	33	15.647	0.232	0.328	0.647
25003 (Trout Beck @ Moor House)	3.234	46	15.142	0.168	0.29	0.513
71003 (Croasdale Beck @ Croasdale Flume)	3.244	37	10.9	0.212	0.323	0.266
91802 (Allt Leachdach @ Intake)	3.312	34	6.35	0.153	0.257	0.645
106002 (Laxdale @ Laxdale)	3.356	12	17.449	0.103	0.132	1.258
206006 (Annalong @ Recorder)	3.419	48	15.33	0.189	0.052	2.196

⁶ Strategic Flood Risk Assessment for Hinckley and Bosworth Borough Council: Final Report, Hinckley and Bosworth Council (July 2019)

Total	505			
Weighted Means			0.224	0.248
H2 value	2.2481			
Goodness of Fit	Generalised Logistic		General Extreme Value	
	0.3807		-1.0599	

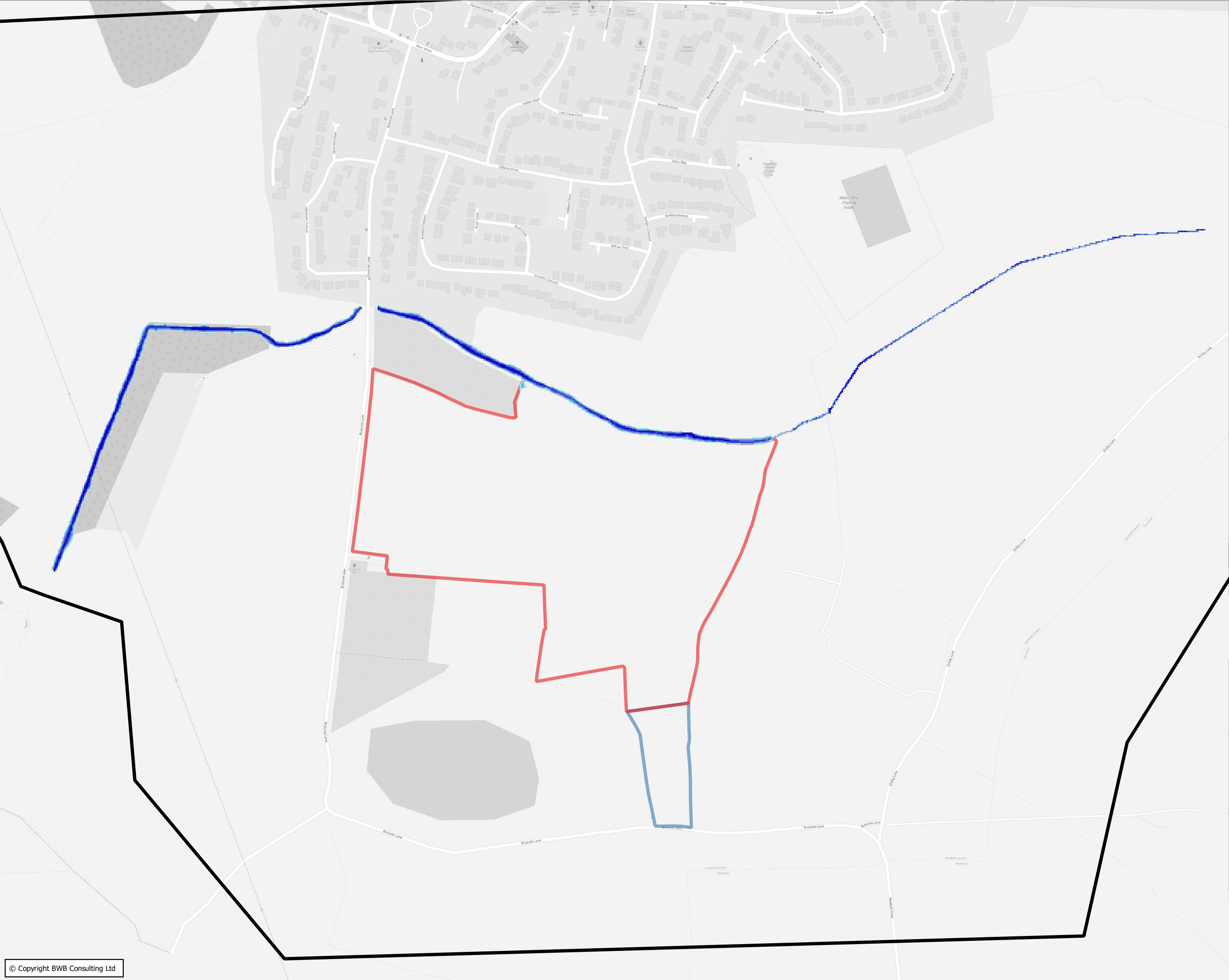
Table 6.2: Final pooling group: Thurlaston PG

Station	Distance	Years of Data	QMED AM	L-CV	L-Skew	Discordancy
76011 (Coal Burn @ Coalburn)	1.183	42	1.84	0.163	0.301	0.57
27051 (Crimple @ Burn Bridge)	2.277	47	4.524	0.218	0.156	0.892
45816 (Haddeo @ Upton)	2.342	26	3.456	0.3	0.406	0.978
28033 (Dove @ Hollinsclough)	2.616	44	4.177	0.228	0.371	0.66
25019 (Leven @ Easby)	2.987	41	5.09	0.342	0.386	1.237
47022 (Tory Brook @ Newnham Park)	3.169	25	6.176	0.257	0.191	1.71
25011 (Langdon Beck @ Langdon)	3.175	33	15.647	0.232	0.328	1.21
25003 (Trout Beck @ Moor House)	3.234	46	15.142	0.168	0.29	0.339
71003 (Croasdale Beck @ Croasdale Flume)	3.244	37	10.9	0.212	0.323	0.17
91802 (Allt Leachdach @ Intake)	3.312	34	6.35	0.153	0.257	0.564
27010 (Hodge Beck @ Bransdale Weir)	3.374	41	9.42	0.224	0.293	0.047
54022 (Severn @ Plynlimon Flume)	3.453	38	14.988	0.156	0.171	1.895
36010 (Bumpstead Brook @ Broad Green)	3.675	52	7.395	0.382	0.181	2.728
Total		506				
Weighted Means				0.231	0.280	
H2 value	0.7046					
Goodness of Fit	Generalised Logistic		General Extreme Value			
	0.1133		-1.1292			

Appendix 3: Table of Hydraulic Structures

Network ID, Cross Section ID	Model Details	Photograph/Survey Section
THURL_0660	Description: Brascote Lane road culvert NGR: 444424, 303358 Domain: 1D ESTRY Unit Type: Circular conduit Dimensions: 2 x 0.75m diameter Upstream Invert Level: 120.83mAOD Downstream Invert Level: 120.97mAOD (downstream and upstream faces surveyed) Length: 14m Manning's N: 0.025 Blockage: Represented as 100% blocked in BLK2 sensitivity test Spill/Bypass: Modelled in 2D domain	

Appendix 4: Floodplain Maps



- Notes**
1. Do not scale this drawing. All dimensions must be checked/ verified on site. If in doubt ask.
 2. This drawing is to be read in conjunction with all relevant architects, engineers and specialists drawings and specifications.
 3. All dimensions in millimetres unless noted otherwise. All levels in metres unless noted otherwise.
 4. Any discrepancies noted on site are to be reported to the engineer immediately.
 5. OpenStreetMap data have been reproduced under the terms of the Open Data Commons Open Database License. © OpenStreetMap contributors.

Key

- Redline Application Site Boundary
- Blueline Site Ownership Boundary
- Model Domain

Peak Flood Depth (m)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- > 0.4

P02	24.02.2022	FINALISED SITE LAYOUT	MB	RG	
P01	08.09.2021	PRELIMINARY ISSUE	MB	RG	
Rev	Date	Details of issues/ revision	Drw	Rev	

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

**Thurlaston Brook Flood Depths:
1 in 20-Year (5% AEP)**

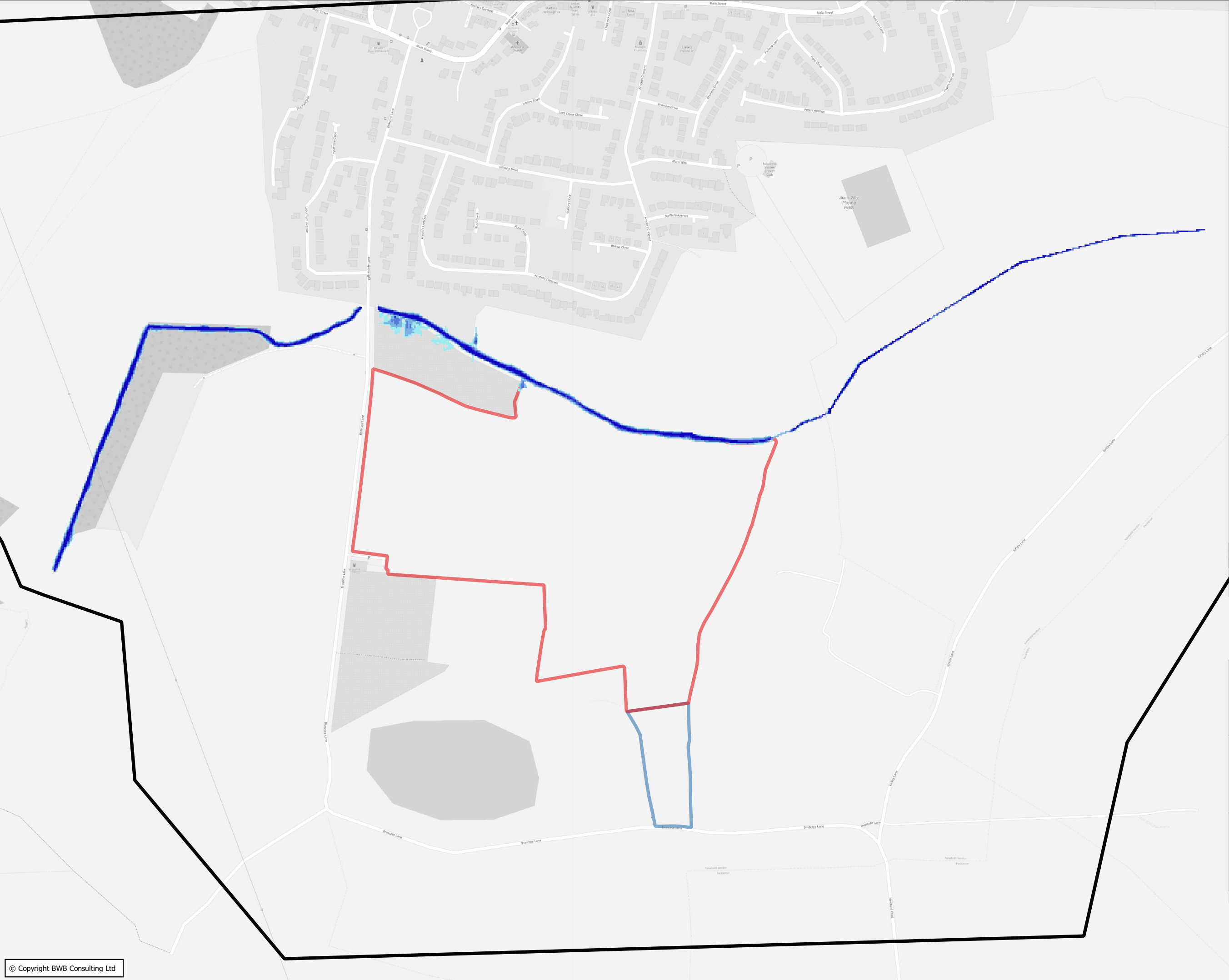
Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMV 3175	Date:	24/02/22
		Scale@A3:	1:4,500

Drawing Status

FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0002	S2	P02

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Key

Redline Application Site Boundary

Blueline Site Ownership Boundary

Model Domain

Peak Flood Depth (m)

<= 0.1

0.1 - 0.2

0.2 - 0.3

0.3 - 0.4

> 0.4

P02	24.02.2022	FINALISED SITE LAYOUT	MB	RG	
P01	08.09.2021	PRELIMINARY ISSUE	MB	RG	
Rev	Date	Details of issues/ revision	Drw	Rev	

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

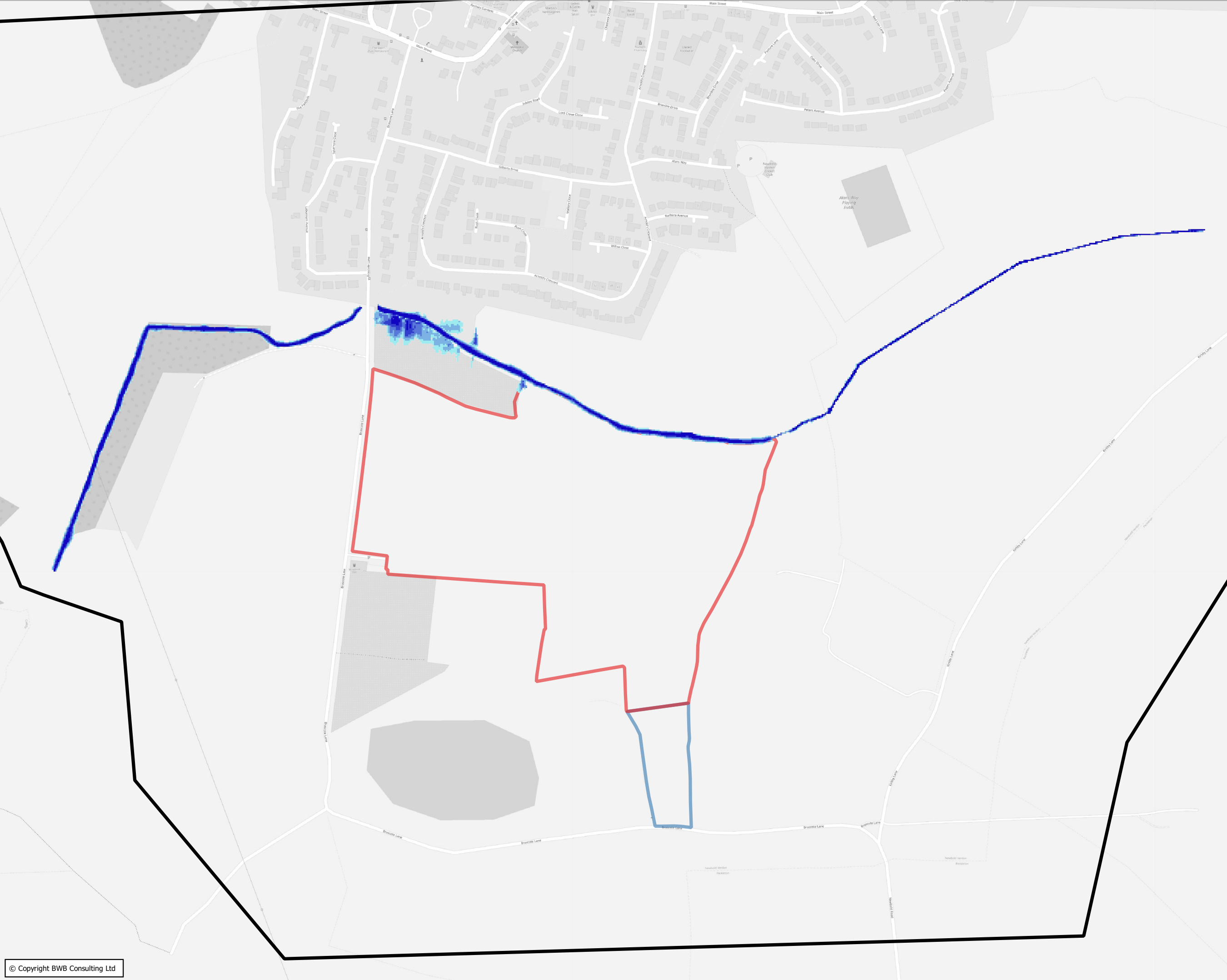
**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP)**

Drawn:	M. Brambani	Reviewed:	R. Green		
BWB Ref:	BMV 3175	Date:	24/02/22	Scale@A3:	1:4,500

Drawing Status

FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0003	S2	P02



- Notes**
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Key

- Redline Application Site Boundary
- Blueline Site Ownership Boundary
- Model Domain

Peak Flood Depth (m)

- <= 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- > 0.4

P02	24.02.2022	FINALISED SITE LAYOUT	MB	RG	
P01	08.09.2021	PRELIMINARY ISSUE	MB	RG	
Rev	Date	Details of issues/ revision	Drw	Rev	

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP)
+28%CC**

Drawn:	M. Brambani	Reviewed:	R. Green		
BWB Ref:	BMV 3175	Date:	24/02/22	Scale@A3:	1:4,500

Drawing Status

FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0004	S2	P02