

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

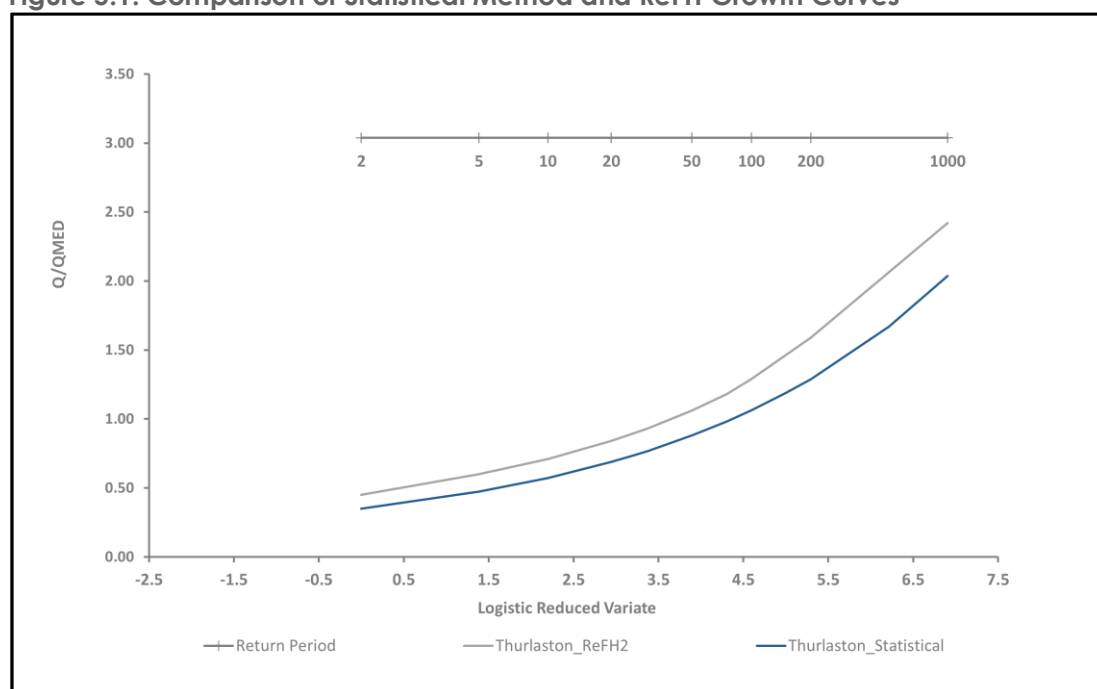
Comparison of method

- 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.
---	--

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

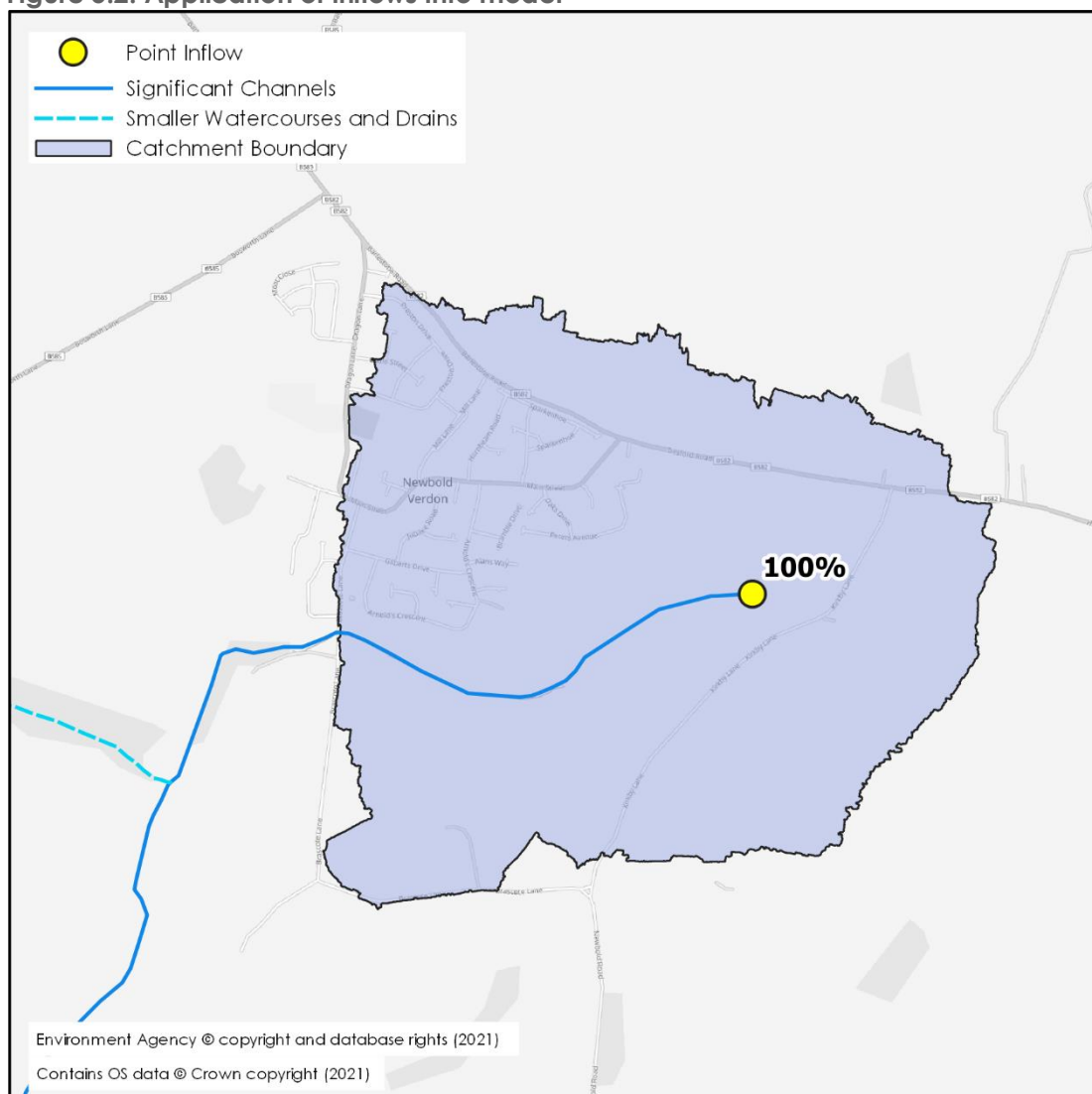
Are the results consistent?	Peak flows are consistent with the size and characteristics of the catchment.
What do the results imply regarding the return periods of floods during the period of record?	It is not possible to imply return periods of floods due to the lack of gauged data within the study 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		

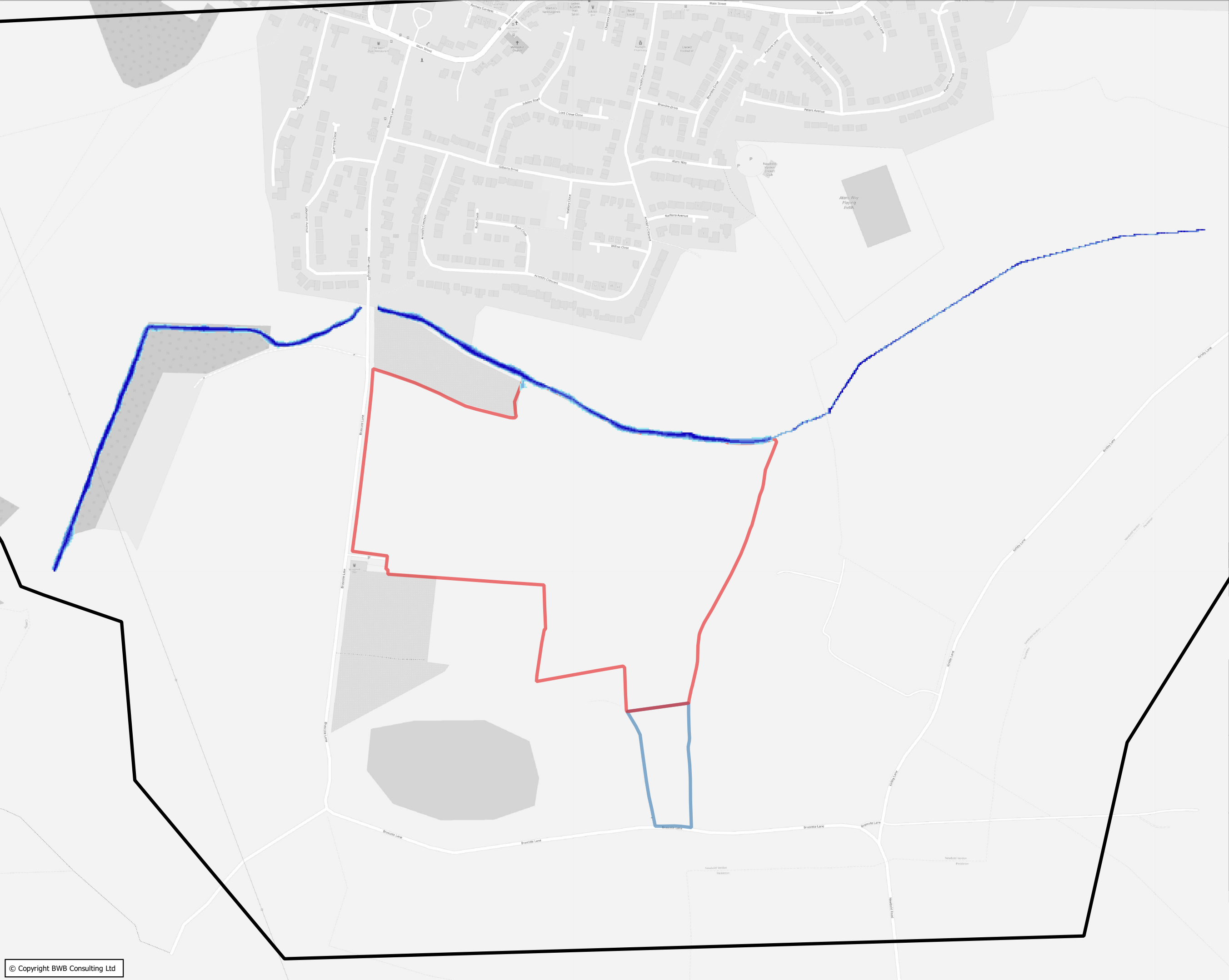
Table 6.2: Final pooling group: Thurlaston PG

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



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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	
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Project Title

Brascote Lane, Newbold Verdon

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

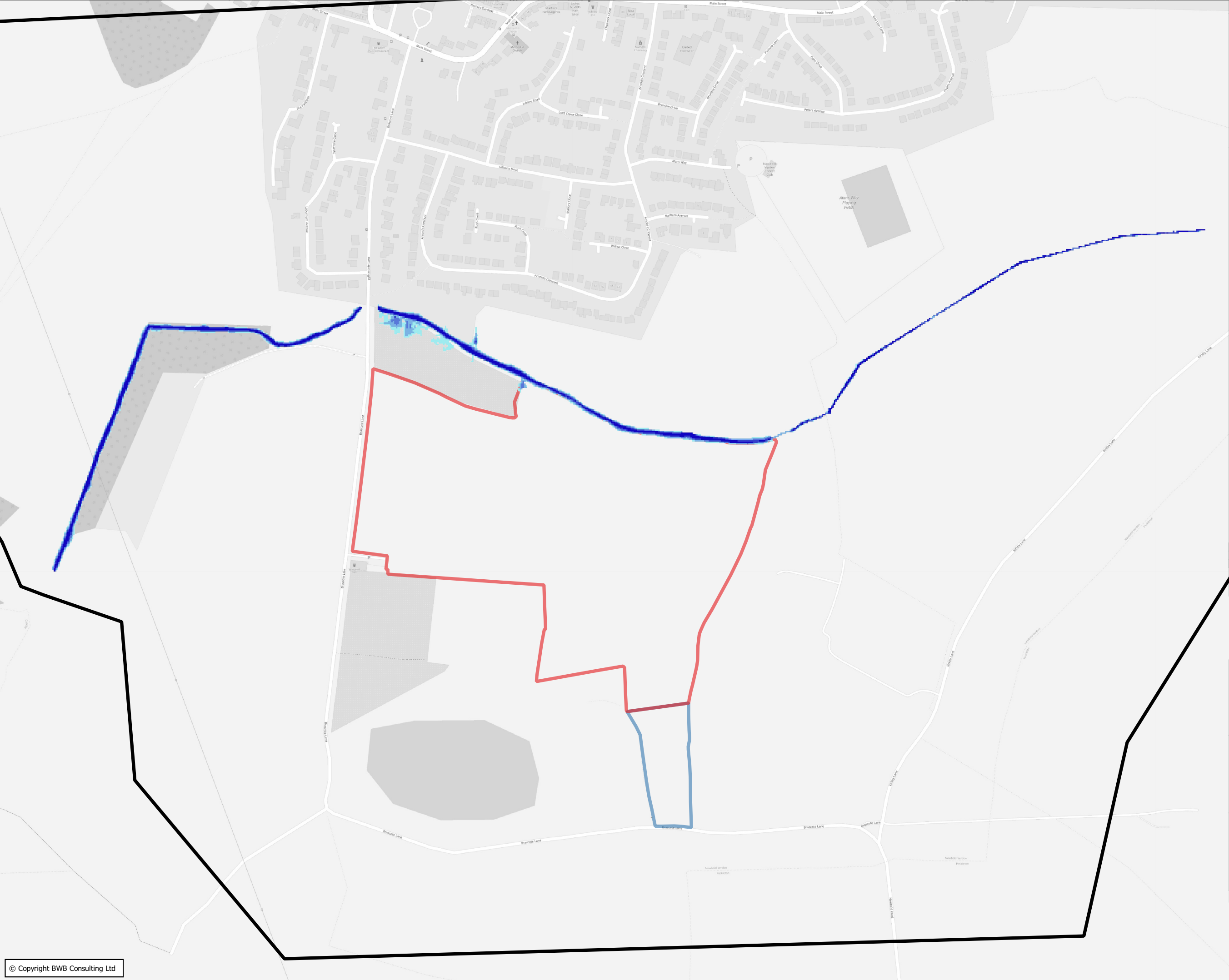
Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMV 3175	Date:	24/02/22
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Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
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0.1 - 0.2

0.2 - 0.3

0.3 - 0.4

> 0.4

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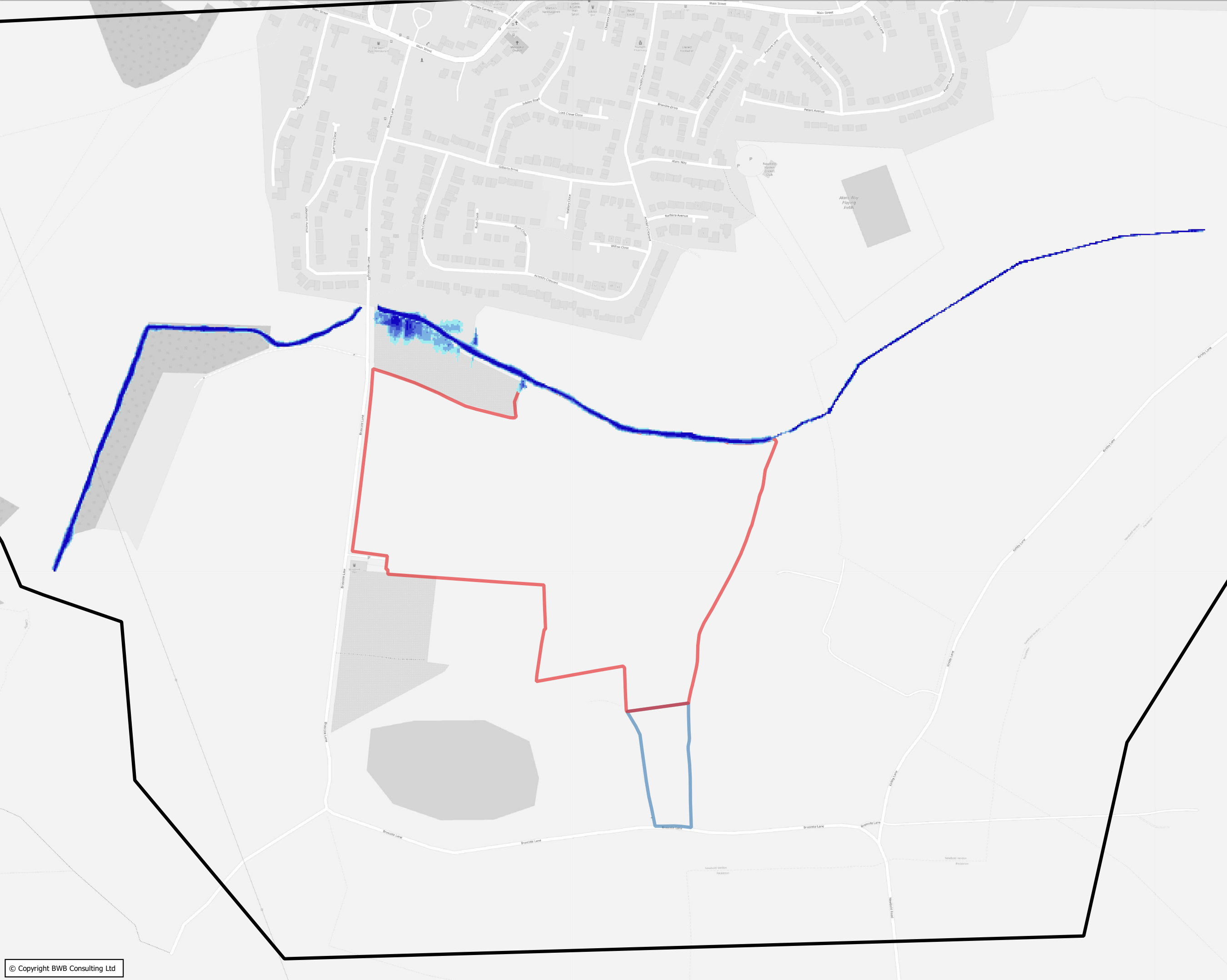
**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP)**

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

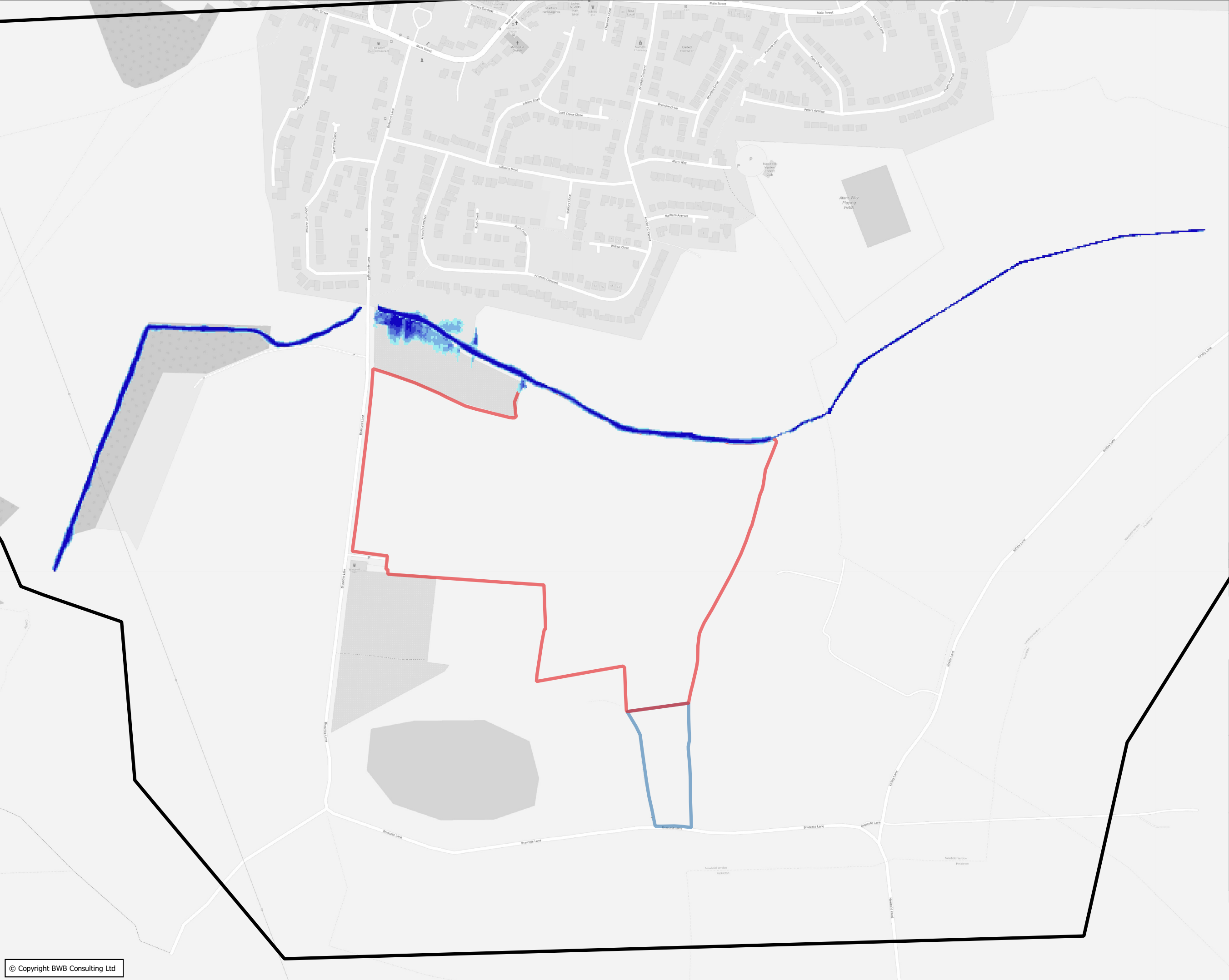
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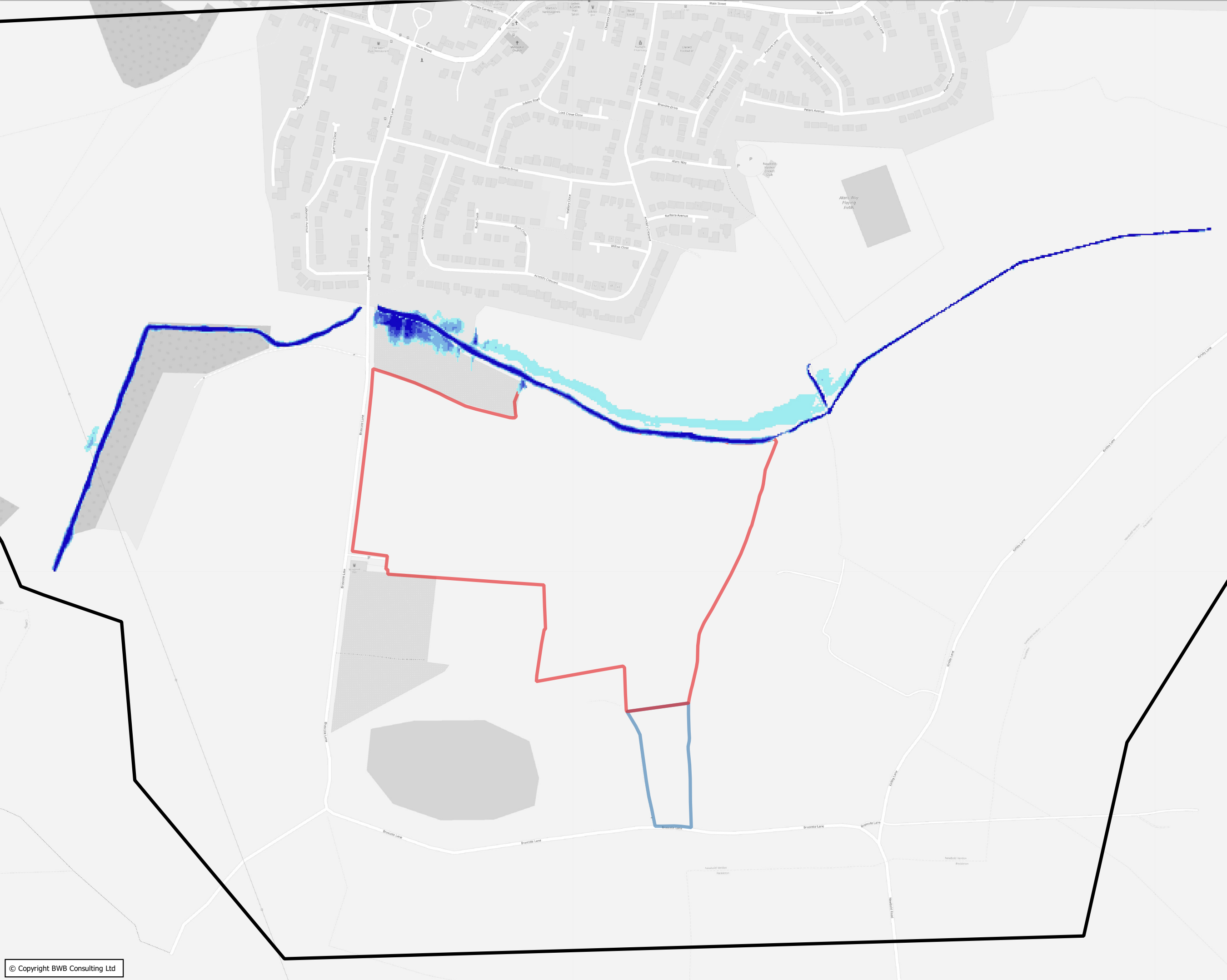
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**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP)
+60%CC**

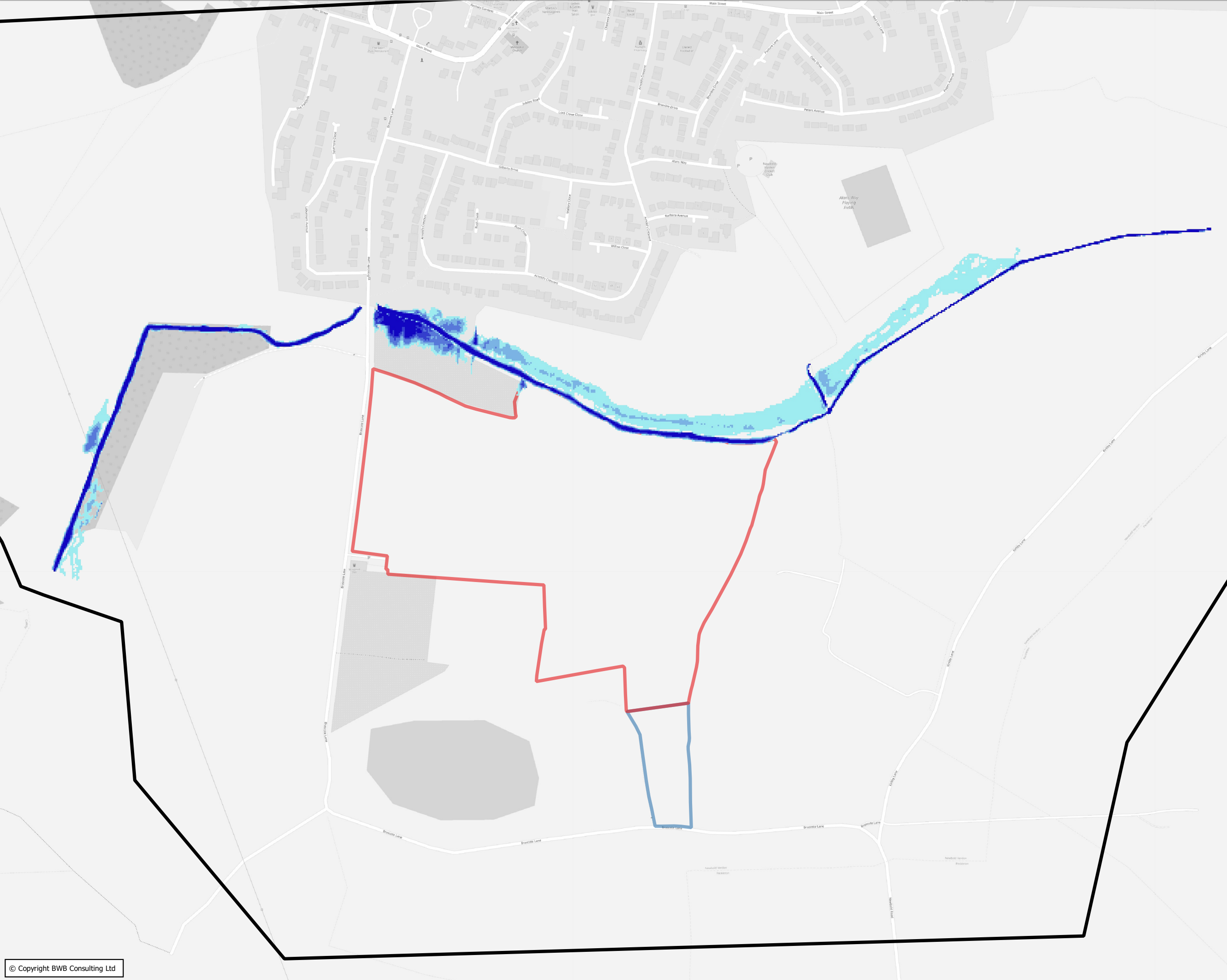
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- 0.2 - 0.3
- 0.3 - 0.4
- > 0.4

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	

Issues & Revisions

BWB

CONSULTANCY | ENVIRONMENT
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Nottingham | 0115 924 1100

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

**Thurlaston Brook Flood Depths:
1 in 1000-Year (0.1% 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-0007	S2	P02