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ENVIRONMENT

Richborough
Land Situated to the East of Brascote Lane and South of Arnold's Crescent
Newbold Verdon
Flood Risk Assessment

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Birmingham
Livery Place, 35 Livery Street, Colmore Business District, Birmingham, B3 2PB
T: 0121 233 3322

Leeds
Whitehall Waterfront, 2 Riverside Way, Leeds
LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street, Manchester, M1 3HU
0161 233 4260

Nottingham
Waterfront House, Station Street, Nottingham NG2 3DQ
T: 0115 924 1100

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Author:	Sian Renwick MSci (Hons)
Checked:	Claire Gardner BSc (Hons) MSc MCIWEM C.WEM ACMI fCMgr
Approved:	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env

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Notice

EXECUTIVE SUMMARY

This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance (PPG). It has been produced on behalf of Richborough in respect of a planning application for a proposed residential development at land situated to the east of Brascote Lane and south of Arnold's Crescent, Newbold Verdon (approximate grid reference: SK 4484 0329).

This report demonstrates that the proposed development is not at significant flood risk, subject to the recommended flood mitigation strategies being implemented.

The Phase 2 site is located entirely within Flood Zone 1 (Low Probability of Flooding from Rivers and Sea). The nearest Environment Agency (EA) Flood Zones located approximately 625m south-west of the site, associated with the Thurlaston Brook.

The Thurlaston Brook is present along the southern site boundary; however, there are no EA Flood Zones associated with the watercourse at this location. BWB Consulting previously completed a hydraulic modelling study in September 2021. The model was updated in April 2024 to be in line with updated hydrological guidance and to include a representation of an Unnamed Ordinary Watercourse and structure to the east of the Phase 2 site. The modelling confirmed that the proposed development is at low risk of flooding and is sequentially located outside of the 1 in 100-year +28% climate change design event floodplain.

The majority of the site is shown to be at very low risk of surface water flooding. Areas of surface water flood risk are present along the southern site boundary, associated with the Thurlaston Brook. There is also a low risk (1 in 1000-year) surface water flow route, which partially encroaches within the site along the western boundary.

The proposed development has been reviewed against other potential sources of flood risk, including groundwater, sewers, and reservoirs and large waterbodies. Based on the available data, these potential sources are considered to pose a low flood risk to the proposed development.

The proposed built development will be located outside of the 1 in 100-year + 28% climate change design event floodplain and there should be no topographical changes within the 1 in 100-year + 28% climate change design event to avoid displacement of the design event floodplain. It is recommended that finished floor levels are raised a minimum of 600mm above the nearest upstream modelled 1 in 100-year +28% climate change peak flood level.

It is also recommended that finished floor levels are raised a minimum of 150mm above immediate surrounding ground levels, where possible, to help mitigate the residual risk of flooding from groundwater and sewer sources. Ground levels should be profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.

It is recommended that groundwater levels are monitored during the construction phase, with appropriate dewatering techniques employed where necessary.

To mitigate the impact of the proposed development on the current runoff regime, it is proposed to incorporate surface water attenuation and storage as part of the development proposals. It is proposed to drain foul water from the proposed development separately to surface water.

In compliance with the requirements of the NPPF, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the proposed development will not increase flood risk to the wider catchment area, subject to suitable management of surface water runoff discharging from the site.

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APPENDICES

1. INTRODUCTION

1.1 This Flood Risk Assessment (FRA) has been prepared in accordance with the requirements set out in the National Planning Policy Framework (NPPF) and the associated Planning Practice Guidance (PPG). The FRA has been produced on behalf of Richborough in respect of a planning application for a proposed residential development at land situated to the east of Brascote Lane and south of Arnold's Crescent, Newbold Verdon.

1.2 This FRA is intended to support an outline planning application and, as such, the level of detail included is commensurate and subject to the nature of the proposals at the planning stage. Summary information is included as Table 1.1.

Table 1.1: Site Summary

Site Name	Land Situated to the East of Brascote Lane and South of Arnold's Crescent
Location	Newbold Verdon
NGR (approx.)	SK 4484 0329
Application Site Area (ha)	13.8 (approx.)
Development Type	Residential
Flood Zone Classification	Flood Zone 1
NPPF Vulnerability	More Vulnerable
Anticipated Development Lifetime	100+ years
Environment Agency Office	East Midlands
Lead Local Flood Authority	Leicestershire County Council
Local Planning Authority	Hinckley and Bosworth Borough Council

Sources of Data

i. Topographical Survey by BWB Consulting Limited, reference: NVP2-BWB-00-ZZ-M3-G-001
ii. Environment Agency (EA) consultation
iii. EA 1m spatial resolution Light Detection and Ranging (LiDAR) data, flown in 2022
iv. EA Risk of Flooding from Surface Water (RoFSW) data
v. Leicestershire County Council (LCC) consultation

vi. Hinckley and Bosworth Borough Council (HBBC) Level 1 Strategic Flood Risk Assessment
vii. HBBC Level 2 Strategic Flood Risk Assessment
viii. LCC Preliminary Flood Risk Assessment
ix. LCC Local Flood Risk Management Strategy
x. Humber River Basin District Flood Risk Management Plan
xi. LCC Section 19 Flood Investigation Reports
xii. HBBC Local Development Framework Core Strategy
xiii. Site visit undertaken by BWB Consulting Limited in February 2024
xiv. Hydraulic modelling of the Thurlaston Brook undertaken by BWB Consulting Limited, reference: 243693-BWB-ZZ-XX-TW-0001_HTMN
xv. Severn Trent Water (STW) Sewer Records
xvi. British Geological Survey (BGS) Drift and Geology Maps

Existing Site

1.3 The planning application boundary, as shown edged red in Figure 1.1, extends in total to 13.77ha hectares (hereinafter referred to as the "Combined Site"), which comprises the following:

- 6.91 hectares of land to the east of Brascote Lane and south of the Thurlaston Brook, as shown shaded grey on the plan below, which benefits from an extant planning permission under reference 22/00277/OUT, for the purpose only of providing access/egress to the public highway known as Brascote Lane (hereinafter referred to as "Phase 1"); and
- 6.86 hectares of land to the south of Arnold's Crescent and north of the Thurlaston Brook, as shown shaded pink on the plan below, for up to 135 dwellings with associated landscaping, open space, drainage infrastructure and associated works (hereinafter referred to as "Phase 2").

1.4 On the basis Phase 1 has the benefit of planning permission, the scope of this FRA focusses upon Phase 2 (hereinafter referred to as "the site").

1.5 The site is located south of Newbold Verdon, approximately 3.9km east of Market Bosworth, as illustrated within Figure 1.1. The site is bound by residential dwellings to the north and west, by recreational grounds and agricultural land to the east, and by the Thurlaston Brook to the south, beyond which lies agricultural land.

1.6 The existing condition of the site is greenfield, comprising agricultural land.

1.7 A topographical survey of the site is included as Appendix 1. The site is shown to generally fall in a south-easterly direction, with levels ranging from approximately 129.6metres Above Ordnance Datum (mAOD) in the north-east to approximately 122.9mAOD along the south-western boundary.

Proposed Development

1.8 The proposals comprise a residential development of up to 135 dwellings, with associated landscaping, open space, drainage infrastructure and associated works (all matters reserved except access from Brascote Lane). Access is proposed via Phase 1, located immediately south of the site on the left bank of the Thurlaston Brook. An Indicative Masterplan is included as Appendix 2.

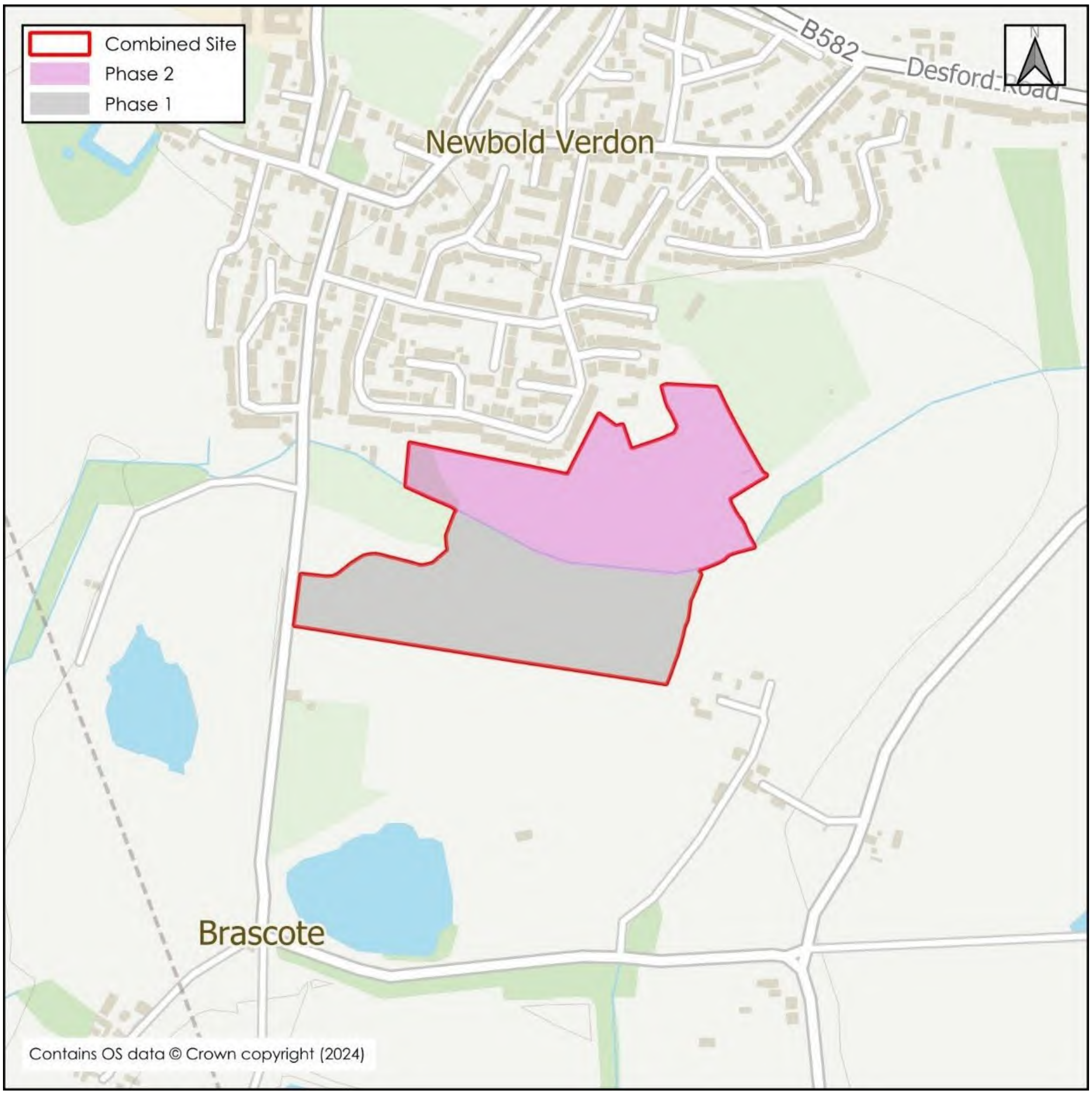


Figure 1.1: Site Location

2. FLOOD RISK PLANNING POLICY & GUIDANCE

National Planning Policy Framework

2.1 The NPPF[1] sets out the Government's national policies on different aspects of land use planning in England in relation to flood risk. The PPG is also available online[2].

2.2 The PPG sets out the vulnerability to flooding of different land uses. It encourages development to be located in areas of lower flood risk where possible and stresses the importance of preventing increases in flood risk off site to the wider catchment area.

2.3 The PPG also states that alternative sources of flooding, other than fluvial (river flooding), should be considered when preparing an FRA.

2.4 The PPG includes a series of tables that define Flood Zones (Table 1), the flood risk vulnerability classification of development land uses (Table 2) and 'compatibility' of development within the defined Flood Zones (Table 3). Table 2 and Table 3 are recreated within Appendix 3 of this report for reference.

2.5 This FRA is written in accordance with the NPPF and the PPG.

Flood Map for Planning

2.6 With particular reference to planning and development, the Flood Map for Planning identifies Flood Zones in accordance with Table 1 of the PPG. Further details on the Flood Zone classifications are outlined in Table 2.1.

Table 2.1: Flood Zone Classifications

Flood Zone	Description
Flood Zone 1 (Low Probability)	Land having less than a 1 in 1000 annual probability of river or sea flooding (<0.1% Annual Exceedance Probability). All land outside of Flood Zone 2 and 3.
Flood Zone 2 (Medium Probability)	Land having between a 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1% AEP); or between a 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1% AEP).
Flood Zone 3a (High Probability)	Land having a 1 in 100 or greater annual probability of river flooding (>1% AEP); or land having a 1 in 200 or greater annual probability of flooding from the sea (>0.5% AEP). This is represented by "Flood Zone 3" on the Flood Map for Planning.
Flood Zone 3b (The Functional Floodplain)	Flood Zone 3b (The Functional Floodplain) is defined as land where water must flow or be stored in times of flood. This is not identified or separately distinguished from Zone 3a on the Flood Map for Planning.

[1] Revised National Planning Policy Framework, Ministry of Housing, Communities & Local Government, amended 2021
[2] Planning Practice Guidance: https://www.gov.uk/government/collections/planning-practice-guidance

2.7 The Phase 2 site is shown to be located within Flood Zone 1, as shown in Figure 2.1. The nearest Flood Zone extents are located approximately 625m south-west of the site, associated with the Thurlaston Brook.

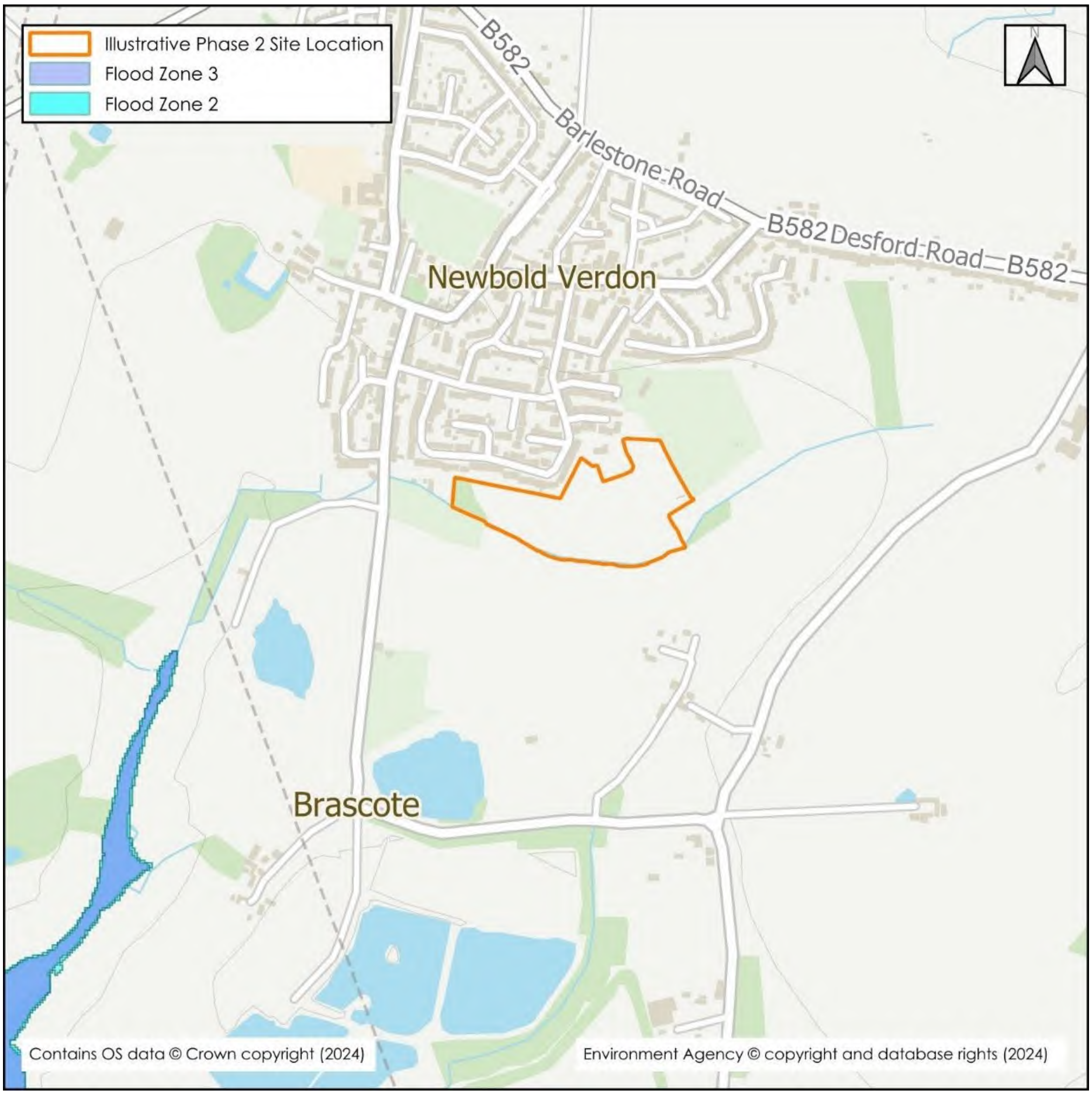


Figure 2.1: Flood Map for Planning

The Design Flood

2.8 The PPG identifies that new developments should be designed to provide adequate flood risk management, mitigation, and resilience against the 'design flood' for their lifetime.

2.9 This is a flood event of a given annual flood probability, which is generally taken as fluvial (river) and surface water (pluvial) flooding likely to occur with a 1% annual probability (a 1 in 100 chance each year), or tidal flooding with a 0.5% annual probability (1 in 200 chance each year), against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

Climate Change

2.10 Predicted future changes in peak river flows caused by climate change are provided by the EA[3], with a range of projections applied to regionalised 'River Basin Districts', which are further subdivided into Management Catchments.

2.11 The site falls within the Soar Management Catchment of the Humber River Basin District. Table 2.2 identifies the relevant peak river flow climate change allowances from this Management Catchment.

Table 2.2: Peak River Flow Climate Change Allowances for the Soar Management Catchment within the Humber River Basin District

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 21**25)
Upper End	28%	35%	60%
Higher Central	18%	21%	37%
Central	14%	16%	28%

2.12 When determining the appropriate allowance for use in an FRA, the Flood Zone classification, flood risk vulnerability and the anticipated lifespan of the development should be considered. Table 2.3 provides a matrix summarising the EA's guidance on determining the appropriate allowance(s).

Table 2.3: Application of Appropriate Peak River Flow Climate Change Allowances

<table>
<tr><th>Flood Zone</th><th>Essential Infrastructure</th><th>Highly Vulnerable</th><th>More Vulnerable</th><th>Less Vulnerable</th><th>Water Compatible</th></tr>
<tr><td>1</td><td colspan="5">Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.</td></tr>
<tr><td>2</td><td>Use the higher central allowance</td><td colspan="4">Use the central allowance</td></tr>
<tr><td>3a</td><td>Use the higher central allowance</td><td>Development should not be permitted</td><td colspan="3">Use the central allowance</td></tr>
<tr><td>3b</td><td>Use the higher central allowance</td><td colspan="3">Development should not be permitted</td><td>Use the central allowance</td></tr>
<tr><td colspan="6">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.</td></tr>
</table>

[3] Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances. Last accessed February 2024.

2.13 The site is located entirely within Flood Zone 1, the proposed development is classified as 'More Vulnerable', and it has an anticipated lifespan of 100+ years. Therefore, the Central allowance for the '2080s' epoch will be considered.

2.14 Therefore, to ensure the development is designed adequately for its lifetime, a climate change allowance of 28% will be applied to the design flood to identify minimum development levels.

2.15 When determining the potential off-site impacts of a proposed development, its vulnerability is not critical; instead, the land use in the wider floodplain needs to be considered. In their online guidance, the EA advise that generally it is appropriate to use the central allowance. Therefore, the 1 in 100-year + 28% climate change allowance will also be used to calculate any off-site impacts.

Strategic Flood Risk Assessment

2.16 A Strategic Flood Risk Assessment (SFRA) is 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.

2.17 The HBBC Level 1 SFRA[4] has been reviewed in the production of this FRA. The SFRA provides information specific to the site location in the form of fluvial, surface water and groundwater flood risk mapping, as well as records of historical flooding. It also includes flood risk policy and guidance for the area. Information from the Level 1 SFRA will be referenced within Section 3.

2.18 The HBBC Level 2 SFRA[5] was produced to facilitate the application of Sequential and Exception Tests to screen allocated development sites. The proposed application site is not referenced within the Level 2 SFRA. Upon review, no applicable information in relation to flood risk at the site was identified.

Preliminary Flood Risk Assessment

2.19 A Preliminary Flood Risk Assessment (PFRA) is 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 Authorities (LLFAs).

2.20 The LCC PFRA[6] considers flooding from surface water runoff, groundwater, ordinary watercourses and canals. It also references historical flooding which has occurred in the county; however, no historical instances of flooding at the site are referenced. Information from the PFRA will be referenced within Section 3, where applicable.

[4] Level 1 Strategic Flood Risk Assessment (JBA Consulting, July 2019)
[5] Level 2 Strategic Flood Risk Assessment (JBA Consulting, May 2020)
[6] Preliminary Flood Risk Assessment (URS/Scott Wilson, June 2011)

2.21 An addendum[7] was produced to update the Leicestershire PFRA. A review of past and future flood risk and flood risk areas was undertaken. Upon review, no applicable information relating to flood risk at the site was identified.

Local Flood Risk Management Strategy

2.22 A Local Flood Risk Management Strategy (LFRMS) is prepared by an LLFA to help understand and manage flood risk at a local level.

2.23 The LFRMS aims to ensure that the knowledge of local flood risk issues is communicated effectively so that they can be better managed. The LFRMS also aims to promote sustainable development and environmental protection.

2.24 The Leicestershire LFRMS[8] has been reviewed and no applicable information in relation to flood risk at the site was identified.

River Basin Flood Risk Management Plan

2.25 Flood Risk Management Plans (FRMPs) explain the risk of flooding from rivers, the sea, surface water, groundwater and reservoirs. FRMPs set out how risk management authorities will work with communities to manage flood and coastal risk. Risk management authorities include the EA, Natural Resources Wales, local councils, Internal Drainage Boards, Highways England and LLFAs.

2.26 The first FRMPs were published in March 2016 and updated versions were published in December 2022. The FRMPs describe actions to manage flood risk across England between 2021 to 2027.

2.27 The site is located within the Humber River Basin District and the relevant FRMP[9] has been reviewed. However, no relevant site-scale objectives were identified.

Section 19 Flood Investigation Reports

2.28 Under their duties of the Flood and Water Management Act 2010, LLFAs have a responsibility to publish reports of investigations of flood incidents. A Section 19 flood investigation report is a public statement of the circumstances of a historical flood event and what parties have a role in managing the risks. The investigation does not always give an in-depth analysis of the flood risk or mechanisms, but it can provide a valuable record of past events.

2.29 LCC have published 35 Section 19 reports on their website, which document flooding events that have occurred between 2014 and 2022. The reports have been reviewed in relation to the location of the site, but no evidence of flooding at the site was identified.

[7] Addendum to Preliminary Flood Risk Assessment (Leicestershire County Council, December 2017)
[8] Local Flood Risk Management Strategy (Leicestershire County Council, February 2024)
[9] Humber River Basin District Flood Risk Management Plan (Environment Agency, December 2022)

Local Plan

Hinckley and Bosworth Local Development Framework Core Strategy

2.30 The Local Development Framework Core Strategy[10] was adopted in December 2009 and sets out the spatial planning strategy for the area until 2026. This document was reviewed; however, there were no policies related to flood risk.

2.31 The Site Allocations and Development Management Policies Development Plan Document[11] was produced in support of the Local Plan and was adopted in July 2016. *Policy DM7 Preventing Pollution and Flooding* sets out the requirement that development should not "create or exacerbate flooding".

Hinckley and Bosworth Local Plan Review

2.32 HBBC is currently preparing a new Local Plan for the period 2020 to 2041. A draft plan[12], produced as part of the Regulation 19 consultation, has been reviewed for policies related to flood risk.

2.33 It is noted in *Draft Policy CC01 Mitigating and Adapting to Climate Change* that proposals should "demonstrate that flood risk from all sources has been mitigated".

2.34 *Draft Policy CC02 Flood Risk* provides detail on the requirements for new development with respect to flood risk. It is stated that development should "be safe and resilient to flooding for its lifetime, taking into account the relevant climate change allowances".

2.35 It should also be noted that *Draft Policy CC03 Sustainable Drainage Systems* requires development proposals to include Sustainable Drainage Systems (SuDS) to manage flood risk.

[10] Hinckley and Bosworth Local Development Framework Core Strategy (Hinckley and Bosworth Borough Council, December 2009)
[11] Hinckley and Bosworth Local Plan 2006 – 2026 Site Allocations and Development Management Policies DPD (Hinckley and Bosworth Borough Council, July 2016)
[12] Hinckley and Bosworth Local Plan 2020 – 2039 Regulation 19 Consultation (Hinckley and Bosworth Borough Council, February 2022)

3. POTENTIAL SOURCES OF FLOOD RISK

3.1 Flooding can occur from a variety of sources, or combination of sources, which may be natural or artificial. Table 3.1 below identifies the potential sources of flood risk to the site in its current condition, and the impacts which the development could have in the wider catchment, prior to mitigation. These are discussed in greater detail in the forthcoming section. The mitigation measures proposed to address flood risk issues and ensure the development is appropriate for its location are discussed within Section 4.

Table 3.1: Pre-Mitigation Sources of Flood Risk

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Fluvial			X		The site is located entirely in Flood Zone 1.
		X			The Thurlaston Brook is present along the southern site boundary. Bespoke hydraulic modelling has shown there is a risk of flooding from the Thurlaston Brook in the south of the site, adjacent to the watercourse.
Coastal				X	The site is removed from coastal influence.
Canals				X	There are no canals in the vicinity of the site.
Groundwater			X		Although the site is depicted on strategic mapping to fall in an area predicted to be at moderate susceptibility to groundwater flooding, a review of underlying geology and historical borehole logs indicates the risk at the site to be low.
Reservoirs and waterbodies			X		The site is shown to fall outside of the area at risk of inundation in the event of reservoir failure.
Pluvial runoff			X		The majority of the site is shown to be at very low risk of surface water flooding. Areas of surface water flood risk are present along the southern site boundary, associated with the Thurlaston Brook, and along the western boundary.

Flood Source	Potential Risk				Description
	High	Medium	Low	None	
Sewers			X		There are public sewers located within the site. In the event of exceedance, flows would be expected to flow south across the site.
Effect of Development on Wider Catchment			X		The proposed development has potential to impede a low risk surface water flow route prior to mitigation.
		X			The proposed development will increase the area of impermeable surfaces, leading to a potential increase in runoff prior to mitigation.

Fluvial Flood Risk

3.2 Flooding from watercourses occurs when flows exceed the capacity of the channel, or where a restrictive structure is encountered, which leads to water overtopping the banks into the floodplain. This process can be exacerbated when debris is mobilised by high flows and accumulates at structures.

3.3 The site is located within Flood Zone 1, as shown in Figure 2.1. This is defined as land which is at low probability of flooding from rivers or sea. The nearest EA Flood Zone extents are located approximately 625m south-west of the site, associated with the Thurlaston Brook. The site is elevated a minimum of approximately 5.4m above the nearest Flood Zone extents, as indicated by EA LiDAR data.

3.4 EA mapping shows the nearest recorded flood outline to be located approximately 5.8km east of the site, associated with the Rothley Brook in 1977 (no raised defences). Correspondence with the EA, included as Appendix 4, confirmed there are no records of historical fluvial flooding at the site.

Hydraulic Modelling of the Thurlaston Brook

3.5 The Thurlaston Brook runs in a westerly direction along the southern site boundary. There are no Flood Zones in the Flood Map for Planning associated with this watercourse in the vicinity of the site, due to it having a small catchment area at this point (<3km^2).

3.6 To provide an understanding of fluvial flooding from the Thurlaston Brook for Phase 1 of the proposed development, BWB Consulting completed a hydraulic modelling study in September 2021. The model was updated in April 2024 to be in line with updated hydrological guidance and to include a representation of a Unnamed Ordinary Watercourse (UOW) and structure which were identified during the site visit and which were previously omitted from the model. The details of the hydraulic modelling exercise, updates and detailed flood maps are available in the Hydraulic Modelling Technical Note (reference: 243693-BWB-ZZ-XX-T-W-0001_HMTN), included as Appendix 5.

3.7 The baseline floodplain extents at the site are shown in Figure 3.1 with modelled flood levels shown in Table 3.2.

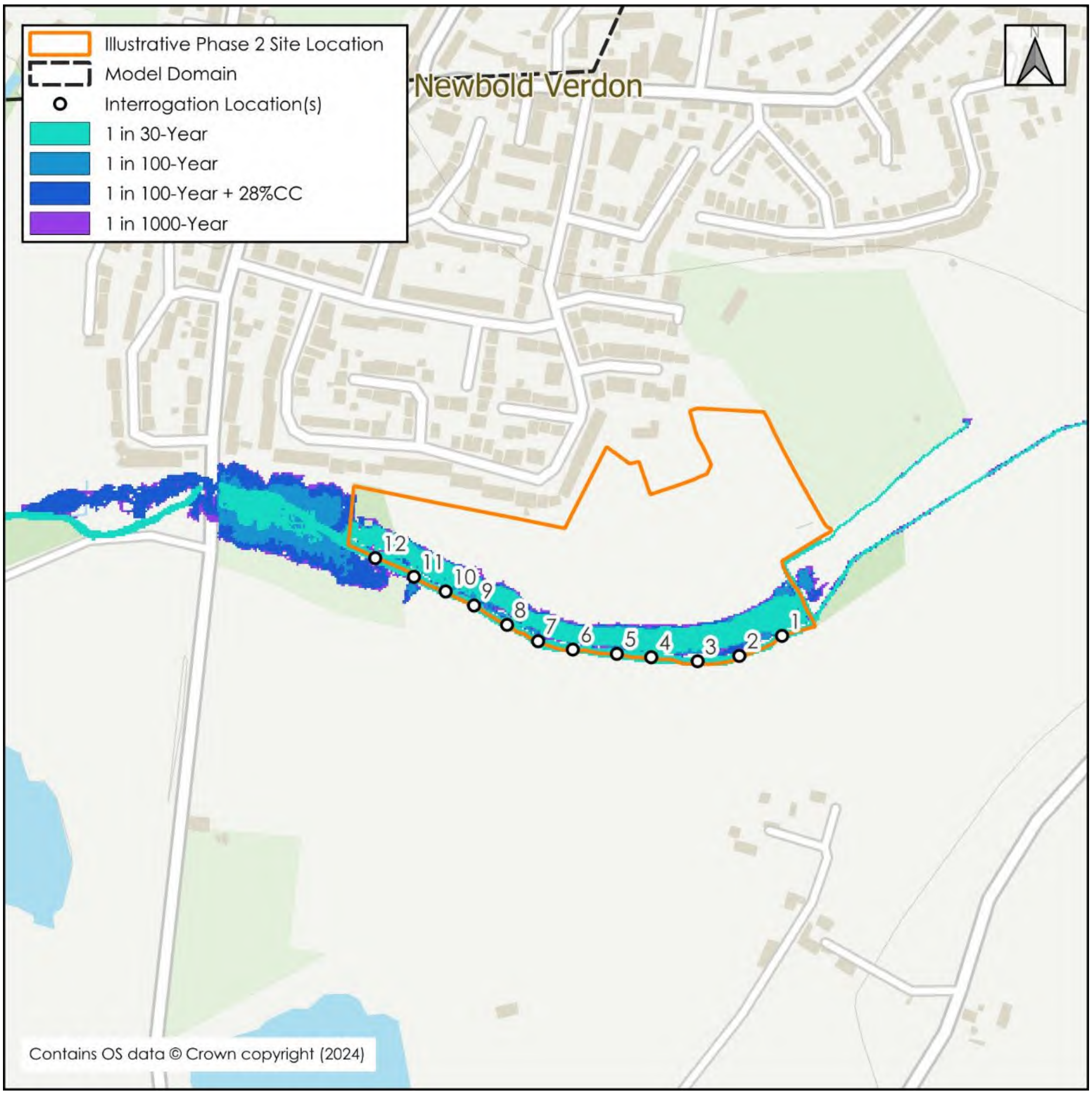


Figure 3.1: Modelled Fluvial Floodplain Extents

Table 3.2: Modelled Flood Levels (m AOD)

Node	1 in 30-Year	1 in 100-Year	1 in 100-Year + 22%CC	1 in 1000-Year
1	125.45	125.47	125.49	125.52
2	125.06	125.07	125.08	125.11
3	124.73	124.75	124.77	124.81
4	124.45	124.48	124.50	124.57

Node	1 in 30-Year	1 in 100-Year	1 in 100-Year + 22%CC	1 in 1000-Year
5	124.23	123.25	124.27	124.35
6	123.88	123.90	123.93	124.02
7	123.61	123.63	123.66	123.75
8	123.38	123.40	123.42	123.51
9	123.07	123.09	123.16	123.26
10	122.78	122.81	122.94	123.04
11	122.59	122.68	122.91	122.98
12	122.40	122.63	122.90	122.96

3.8 The floodplain extents are shown to encroach within the site due to the culvert immediately upstream of the site. This acts as a restrictive structure and results in water backing up into the UOW before overtopping the banks and flowing along the floodplain of the Thurlaston Brook within the Phase 2 site. These extents are considered to be representative of baseline conditions at the site.

3.9 Downstream of the site, the culverts beneath Brascote Lane are also considered to act as restrictive structures and result in water backing up and overtopping into the floodplain within the south-west of the site.

3.10 The risk of flooding from fluvial sources is therefore considered to be medium. Appropriate mitigation measures related to fluvial flood risk are set out in Section 4.

Pluvial Flood Risk

3.11 Pluvial flooding can occur during prolonged or intense storm events when the infiltration potential of soils, or the capacity of drainage infrastructure is overwhelmed, leading to the accumulation of surface water and the generation of overland flow routes.

3.12 RoFSW mapping has been collated and published by the EA; this shows the potential flooding which could occur when rainwater does not drain away through the normal drainage systems or soak into the ground, but lies on or flows over the ground instead. An extract from the mapping is included as Figure 3.2.

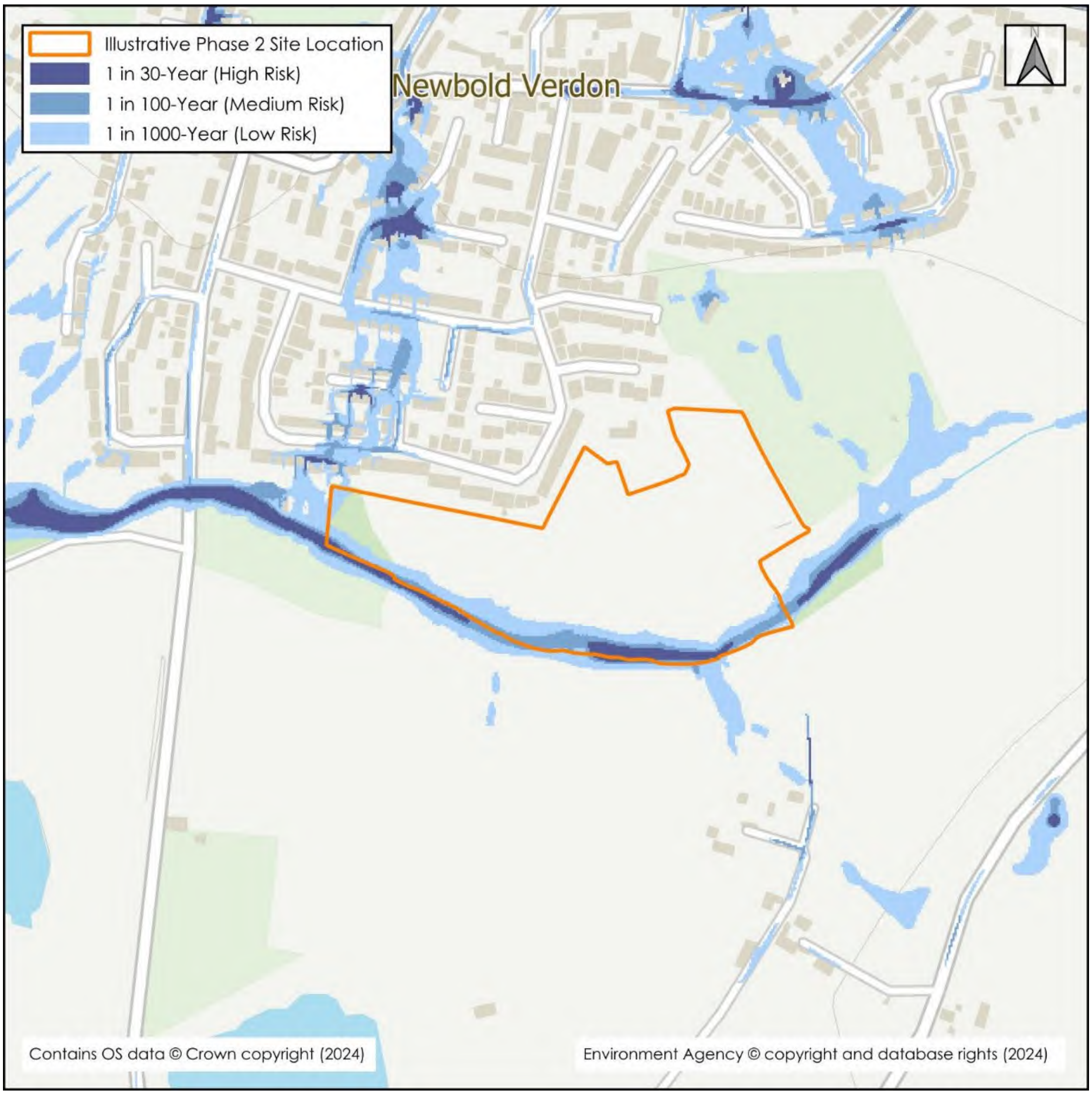


Figure 3.2: EA Risk of Flooding from Surface Water Mapping

3.13 The majority of the site is shown to be at a very low risk of surface water flooding.

3.14 A pluvial flow route is depicted along the southern site boundary, which is shown to present a low (1 in 1000-year) to high (1 in 30-year) surface water flood risk. This is associated with the Thurlaston Brook, which is discussed in the Fluvial Flood Risk section.

3.15 An overland flow route is depicted adjacent to the western site boundary. An area of low surface water flood risk associated with this route is shown to partially encroach within the site with depths of less than 150mm during a 1 in 1000-year event.

3.16 Mapping within the HBBC Level 1 SFRA[4] indicates that flooding occurred in the vicinity of the site in March 2016, within approximately 200m north-west of the site; however, this flooding is not attributed to a source.

3.17 The risk of flooding from pluvial sources is therefore considered to be low.

Groundwater Flood Risk

3.18 Groundwater flooding occurs when the water table rises above ground elevations, or it rises to depths containing basement level development. It is most likely to happen in low lying areas underlain by permeable geology. This is most common on regional scale chalk aquifers, but there may also be a risk on sandstone and limestone aquifers or on thick deposits of sands and gravels underlain by less permeable strata such as that in a river valley.

3.19 BGS mapping shows the site to be underlain by Gunthorpe Member (Mudstone), which is designated by the EA as a Secondary B Aquifer. Secondary B Aquifers are defined as predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

3.20 BGS mapping shows Glaciofluvial Deposits (Sand and Gravel) to be present across majority of the site. It also depicts Alluvium (Clay, Silt, Sand and Gravel) deposits in the south of the site, adjacent to the watercourse channel. Both these superficial deposits are designated as Secondary A Aquifers, which are defined as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

3.21 The Areas Susceptible to Groundwater Flooding map is presented in the Level 1 SFRA[4]. This indicates the site falls within an area at moderate (50% up to 75%) susceptibility of groundwater flooding. However, it should be noted that this susceptibility mapping is based on strategic scale mapping that uses a kilometre square grid. It identifies areas susceptible to flooding from groundwater at a broad scale on the basis of geological and hydrogeological conditions and as such, the classification could potentially be based on another area within the cell.

3.22 There are no historical groundwater flooding incidents in the HBBC administrative area referenced in the Leicestershire PFRA[6]. No information on historical groundwater flooding is provided in the HBBC SFRA[4].

3.23 There are no historical borehole records in the immediate vicinity of the site. BGS borehole logs, underlain by the same geology, within 750m of the site were reviewed. Groundwater was encountered at depths of between 2.6metres below ground level (m bgl) and 4.3m bgl (reference: SK40SE47 and SK40SE48), although no groundwater was encountered in some of the reviewed trial pits (reference: SK40SE39 and SK40SE49).

3.24 Overall, based on the available information, the risk of groundwater flooding is considered to be low. Mitigation measures for the residual risk are outlined in Section 4.

Flood Risk from Reservoirs & Large Waterbodies

3.25 Flooding can occur from large waterbodies or reservoirs if they are impounded above the surrounding ground levels or are used to retain water in times of flood. Although unlikely, reservoirs and large waterbodies could overtop or breach leading to rapid inundation of the downstream floodplain.

3.26 To help identify this risk, reservoir failure flood risk mapping has been prepared by the EA; this shows the largest area that might be flooded if a reservoir were to fail and release the water it holds. The map displays a worst-case scenario and is only intended as a guide.

3.27 There are two flooding scenarios shown on the reservoir flood maps: a 'dry-day' and a 'wet-day'. The 'dry-day' scenario predicts the flooding that would occur if the dam or reservoir failed when rivers are at normal levels. The 'wet-day' scenario predicts how much worse the flooding might be if a river is already experiencing an extreme flood.

3.28 The site is located outside of the flood extents of any reservoir failure. The nearest reservoir failure flood extents are located approximately 2.6km north-east of the site, attributed to the Thornton Reservoir during a 'wet-day' scenario.

3.29 There are noted to be large waterbodies in the vicinity of the site. A fishing lake is located approximately 415m south of the site. This waterbody is noted to have an embankment of a minimum height of approximately 1.3m. Should there be a breach in the embankment, flows would be expected to follow local topography towards the Thurlaston Brook, as indicated following a review of EA LiDAR data. It is expected that these flows would be directed towards the topographical low point of the site and would remain within the Thurlaston Brook corridor.

3.30 A waterbody is mapped approximately 390m south-west of the site. In the event of exceedance, flows would follow local topography and flow to the west, away from the site.

3.31 Overall, the risk of flooding at the site from reservoirs and large waterbodies is considered to be low.

Flood Risk from Sewers

3.32 Sewer flooding can occur when the capacity of the infrastructure is exceeded by excessive flows, or as a result of a reduction in capacity due to collapse or blockage, or if the downstream system becomes surcharged. This can lead to the sewers flooding onto the surrounding ground via manholes and gullies, which can generate overland flows.

3.33 The local sewerage undertaker is STW and a copy of their asset plans are included as Appendix 6.

3.34 The sewer records show that there is a public 225mm foul water sewer present in the north of the site. A manhole is indicated on the topographical survey (Appendix 1) which aligns with the sewer records, the depth to the invert of which is 3.13m. A second manhole is indicated in the sewer records, although this is not identified on the topographical survey. In the event of sewer exceedance, it is expected that flows would flow to the south across the site, to ultimately be conveyed within the Thurlaston Brook.

3.35 There is also depicted to be a public 100mm combined water sewer in the north-east of the site, which is indicated to outfall within the site. There is no infrastructure associated with this combined sewer shown on the topographical survey (Appendix 1). In the event of exceedance, it is expected that flows from this sewer would be expected to flow towards the Thurlaston Brook, as indicated by the topographical survey (Appendix 1). However, it is noted that this sewer is expected to have a small contributing catchment.

3.36 In addition, a public 225mm surface water sewer is adjacent to the western boundary, which may encroach within the site. In the event of exceedance, it is expected that flows from this sewer would be expected to flow south towards the Thurlaston Brook, as indicated by a pluvial flow route depicted in the RoFSW mapping (Figure 3.2).

3.37 Given the greenfield condition of the site, there is not anticipated to be private infrastructure within the site. No evidence of private drainage infrastructure is shown on the topographical survey (Appendix 1).

3.38 Overall, the site is considered to be at low risk of flooding from sewers. Mitigation measures for any residual risk is discussed in Section 4.

Effect of Development on Wider Catchment

Displacement of Floodplain

3.39 The proposed development has the potential to impede the fluvial floodplain prior to mitigation.

Impedance of Flood Flows

3.40 The proposed development has the potential to impede surface water flow routes prior to mitigation.

Development Land Use/Drainage Considerations

3.41 The proposed development will increase the impermeable area of the site, which will lead to an increase in surface water runoff. This could increase flood risk to downstream receptors prior to mitigation. The appropriate management of surface water is discussed in Section 4.

4. FLOOD RISK MITIGATION

4.1 Section 3 has identified the sources of flooding which could potentially pose a risk to the site and the proposed development. This section of the FRA sets out the mitigation measures which are to be incorporated within the proposed development to address and reduce the risk of flooding to within acceptable levels.

Development Modelling

4.2 Access to the Phase 2 site is proposed from the south via two watercourse crossings. These watercourse crossings are proposed to comprise rectangular culverts; the modelled dimensions of these are set out in Table 4.1. The proposed buried bed depths have been modelled in accordance with CIRIA c786 guidance.

Table 4.1: Summary of Modelled Culverts for Proposed Watercourse Crossings

Culvert Location	Width (m)	Height (m)	Buried Bed (m)	Freeboard* (m)
Eastern watercourse crossing	1.5	1.5	0.25	0.25
Western watercourse crossing	1.5	1.5	0.25	0.25

** Freeboard from the soffit level from peak flood level in the 1 in 100-year +28% climate change event.*

4.3 It is also proposed that a flood storage area is provided in order to capture and attenuate flood flows within the site. This has been incorporated into the eastern corner of the site. The concept flood storage area has been designed with 1:4 slopes and a depth of between 0.9m and 1.2m to allow for 300mm freeboard to be provided along the northern and western edge of the basin, adjacent to the proposed development. The proposed flood storage area is subject to detailed design.

4.4 In the proposed modelling scenario, the floodplain within the site is shown to be removed for the 1 in 100-year + 28% climate change event as a result of the proposed flood storage area. There is an increase in flood levels within the channel adjacent to the site; however, flood extents are shown to remain in channel. Downstream of the site, there are no changes to flood levels (within model tolerances). This is shown in Figure 4.1.

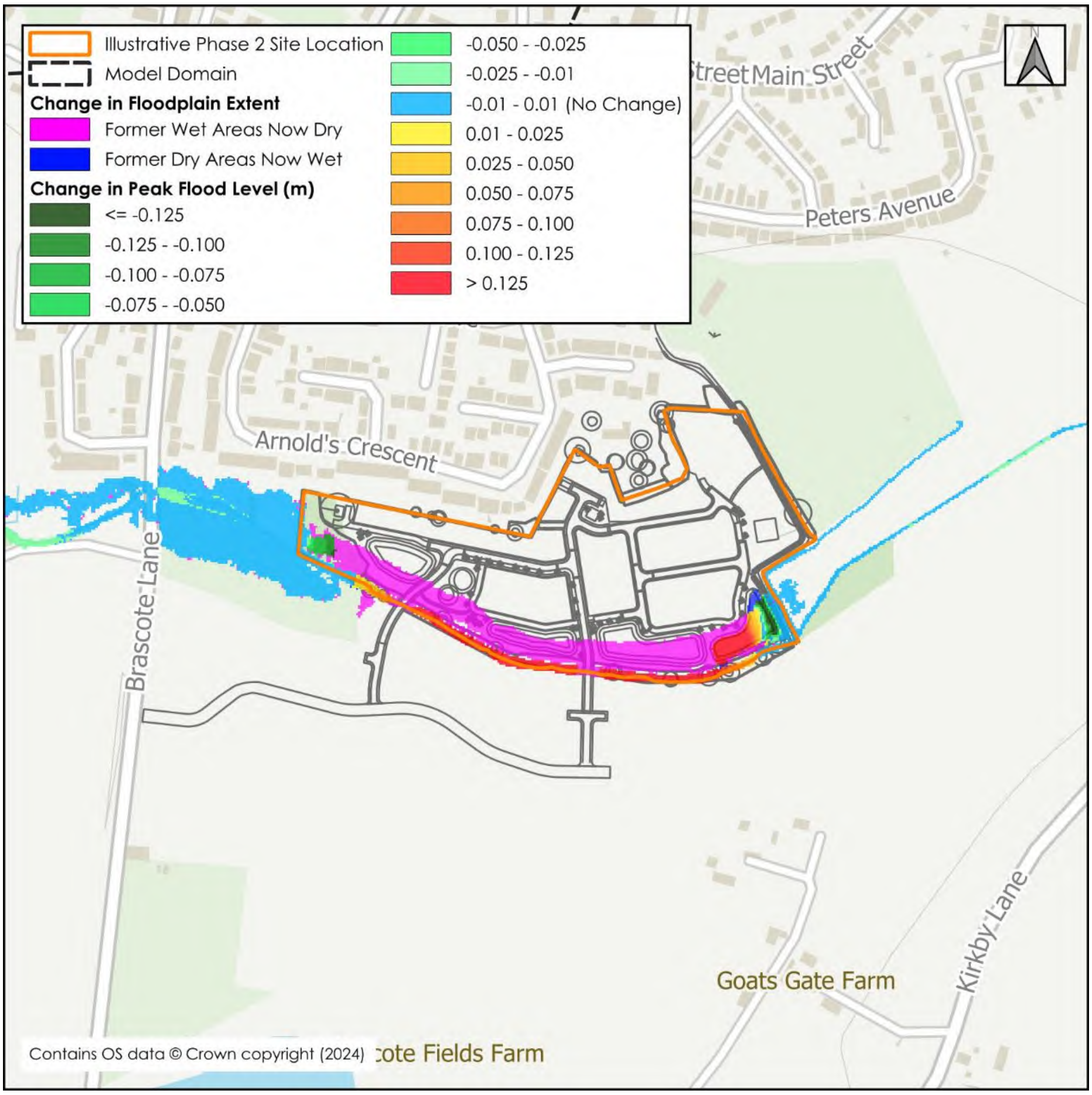


Figure 4.1: Baseline and Post-Development Comparative Analysis (1 in 100-Year + 28%CC)

4.5 The proposed development is shown to be located outside of the flood extents in all modelled return periods up to, and including, the 1 in 100-year + 28% climate change design event.

Sequential Arrangement

4.6 The proposed development is sequentially arranged in Flood Zone 1. The proposed development is sequentially located outside of the modelled flood extents for the Thurlaston Brook for the 1 in 100-year +28% climate change design event.

Floodplain Displacement

4.7 The proposed built development will be located outside of the 1 in 100-year + 28% climate change design event floodplain. There should also be no topographical changes within the 1 in 100-year + 28% climate change design event to avoid displacement of the design event floodplain.

Development Levels

4.8 It is recommended that finished floor levels are raised a minimum of 600mm above the modelled 1 in 100-year +28% climate change event peak flood level at the nearest upstream interrogation node, in line with the HBBC Level 1 SFRA[4].

4.9 It is also recommended that where possible, finished floor levels are raised a minimum of 150mm above immediate surrounding ground levels to help mitigate the residual risk of flooding from groundwater and sewer sources.

4.10 Ground levels should be profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.

Groundwater Considerations

4.11 It is recommended that groundwater levels are monitored during the construction phase, with appropriate dewatering techniques employed where necessary.

Safe Access and Egress

4.12 The proposed site access locations to the south of the site are located within Flood Zone 1. Safe access and egress via the proposed watercourse crossings was also shown to be achievable through the modelling exercise.

Watercourse Crossings

4.13 The proposed watercourse crossings will be designed in accordance with the relevant local and national guidance. This includes ensuring any proposed crossings include a suitable freeboard allowance above the peak design event flood level and retain an appropriate naturalised soft bed.

Surface Water Drainage

4.14 To mitigate the impact of the proposed development on the current runoff regime, it is proposed to incorporate surface water attenuation and storage as part of the development proposals.

4.15 Further information on the proposed surface water drainage approach is provided within the accompanying Sustainable Drainage Statement (SDS) (reference: 243693-BWB-ZZ-XX-T-W-0003_SDS).

4.16 In brief, the proposed development will continue to discharge surface water to the local watercourse at the equivalent greenfield QBAR rate. Attenuated surface water storage will be provided in the form of SuDS detention basins, with capacity for the 1 in 100-year storm with an allowance for climate change.

4.17 The attenuated storage should be designed to be outside of, and hydraulically isolated from, any fluvial floodplains that may be present in the site.

4.18 The low risk surface water flow route, in the north-west of the site, is localised. The proposed surface water drainage strategy and reprofiling of the site will provide mitigation.

4.19 The proposed development should be designed with exceedance in mind and the road network used to convey excess overland flows towards the attenuation points.

Foul Water Drainage

4.20 It is proposed to drain foul water from the proposed development separately to surface water.

4.21 Further information on the foul water drainage approach is provided within the accompanying SDS (reference: 243693-BWB-ZZ-XX-T-W-0003_SDS).

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 This FRA has been prepared in accordance with requirements set out in the NPPF and the associated PPG. The FRA has been produced on behalf of Richborough in respect of a planning application for a proposed residential development at land situated to the east of Brascote Lane and south of Arnold's Crescent, Newbold Verdon.

5.2 This FRA is intended to support an outline planning application and, as such, the level of detail included is commensurate and subject to the nature of the proposals at the planning stage.

5.3 This report demonstrates that the proposed development is not at significant flood risk, subject to the recommended flood mitigation strategies being implemented. The identified risks and mitigation measures are summarised within Table 5.1:

Table 5.1: Summary of Flood Risk Assessment

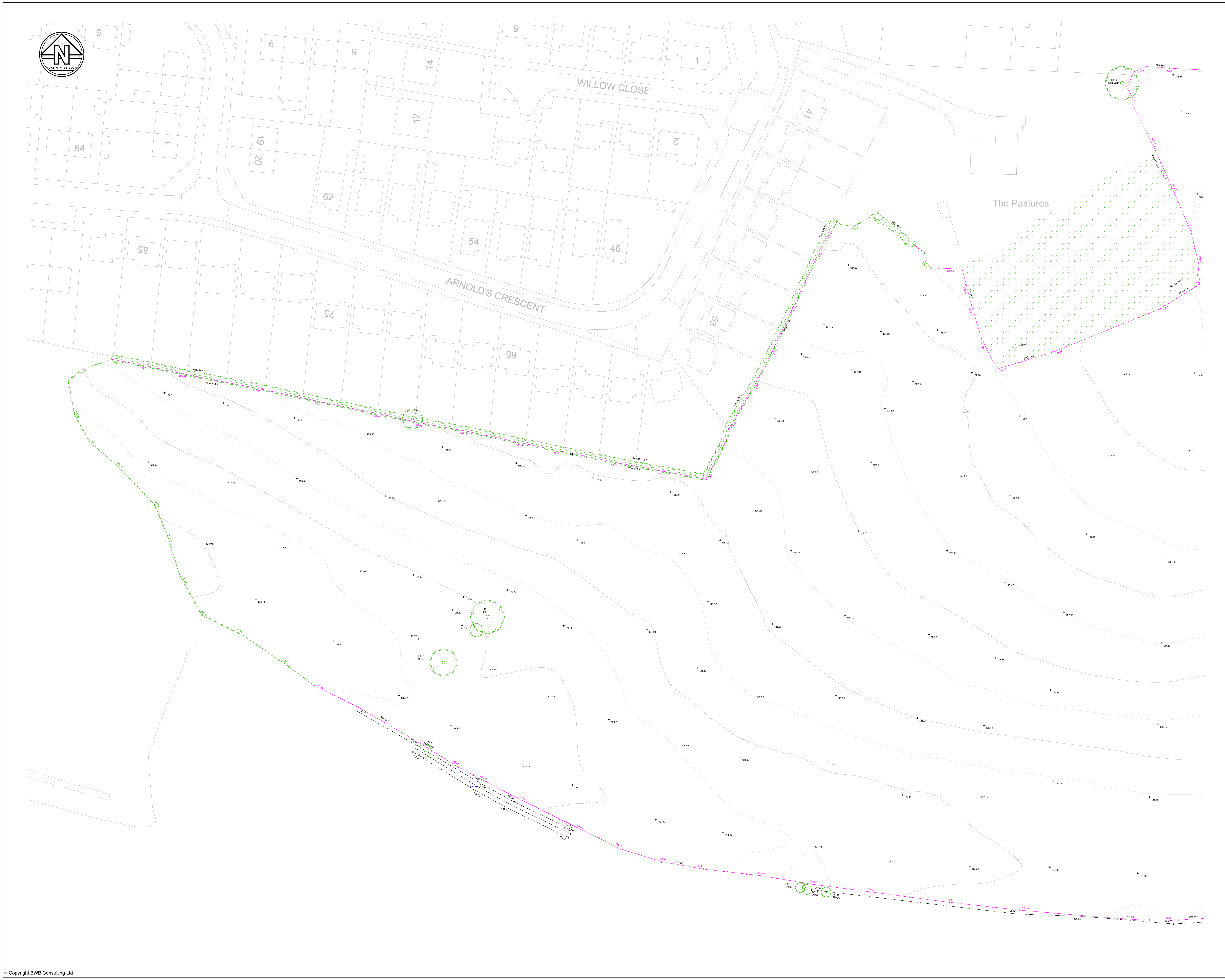
Flood Source	Risk & Proposed Mitigation Measures
Fluvial	The site is shown to be located entirely within Flood Zone 1. A hydraulic modelling exercise was updated to assess the risk of flooding to the site from the Thurlaston Brook on the southern boundary. The modelling has confirmed that the proposed development is at low risk of flooding and is sequentially located outside of the 1 in 100-year +28% climate change design event floodplain. It is recommended that finished floor levels are raised a minimum of 600mm above the nearest modelled 1 in 100-year +28% climate change peak flood level.
Groundwater	The site is considered to be at low risk of groundwater flooding, following a review of BGS mapping, SFRA and historical borehole records. It is recommended that finished floor levels are raised a minimum of 150mm above immediate surrounding ground levels, where possible, to help mitigate the residual risk of flooding including from groundwater. Groundwater levels should be monitored during the construction phase, with appropriate dewatering techniques employed where necessary.
Reservoirs and Waterbodies	The site is shown to fall outside of the area at risk of inundation in the event of reservoir failure and is also considered to not be at risk of flooding from nearby large waterbodies.
Pluvial Runoff	The majority of the site is shown to be at very low risk of surface water flooding. Areas of low to high surface water flood risk are present along the southern site boundary, associated with the Thurlaston Brook. A low risk pluvial flow route is also present along the western boundary. The above recommendation to raise finished floor levels a minimum of 150mm above immediate surrounding ground levels is also applicable to help mitigate the residual risk of flooding from pluvial sources.

Flood Source	Risk & Proposed Mitigation Measures
	Ground levels should be profiled to encourage pluvial runoff and overland flows away from the built development and towards the nearest drainage point.
Sewers	There are public sewers located within the site. Raising finished floor levels a minimum of 150mm above surrounding ground levels and profiling ground levels are expected to help mitigate the residual risk of flooding from sewer exceedance.
Other Sources	The site is considered to not be at risk of flooding from coastal/tidal and canal sources.
Impact of the Development	The site is not expected to encroach or displace any fluvial floodplain in the design event as the built development is located outside of the 1 in 100-year +28% climate change design event floodplain. There should also be no changes to levels within the 1 in 100-year +28% climate change design event floodplain. Surface water runoff from the proposed development will be controlled appropriately and discharged to the local watercourse at the equivalent greenfield QBAR rate. The foul water from the proposed development will be discharged separately to surface water.
This summary should be read in conjunction with BWB's full report. It reflects an assessment of the Site based on information received by BWB at the time of production.	

5.4 In compliance with the requirements of the NPPF, and subject to the mitigation measures proposed, the development could proceed without being subject to significant flood risk. Moreover, the proposed development will not increase flood risk to the wider catchment area, subject to suitable management of surface water runoff discharging from the site.

APPENDICES

Appendix 1: Topographical 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
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
Flow direction and pipe diameter (0.25)
Station and Name (1)
Monitoring Borehole (BH 1)
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
Spot Level (+50.00)
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	22.02.24	First Issue	IR	DS

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Client

Richborough Estates Ltd

Project Title

Newbold Verdon Phase 2

Drawing Title

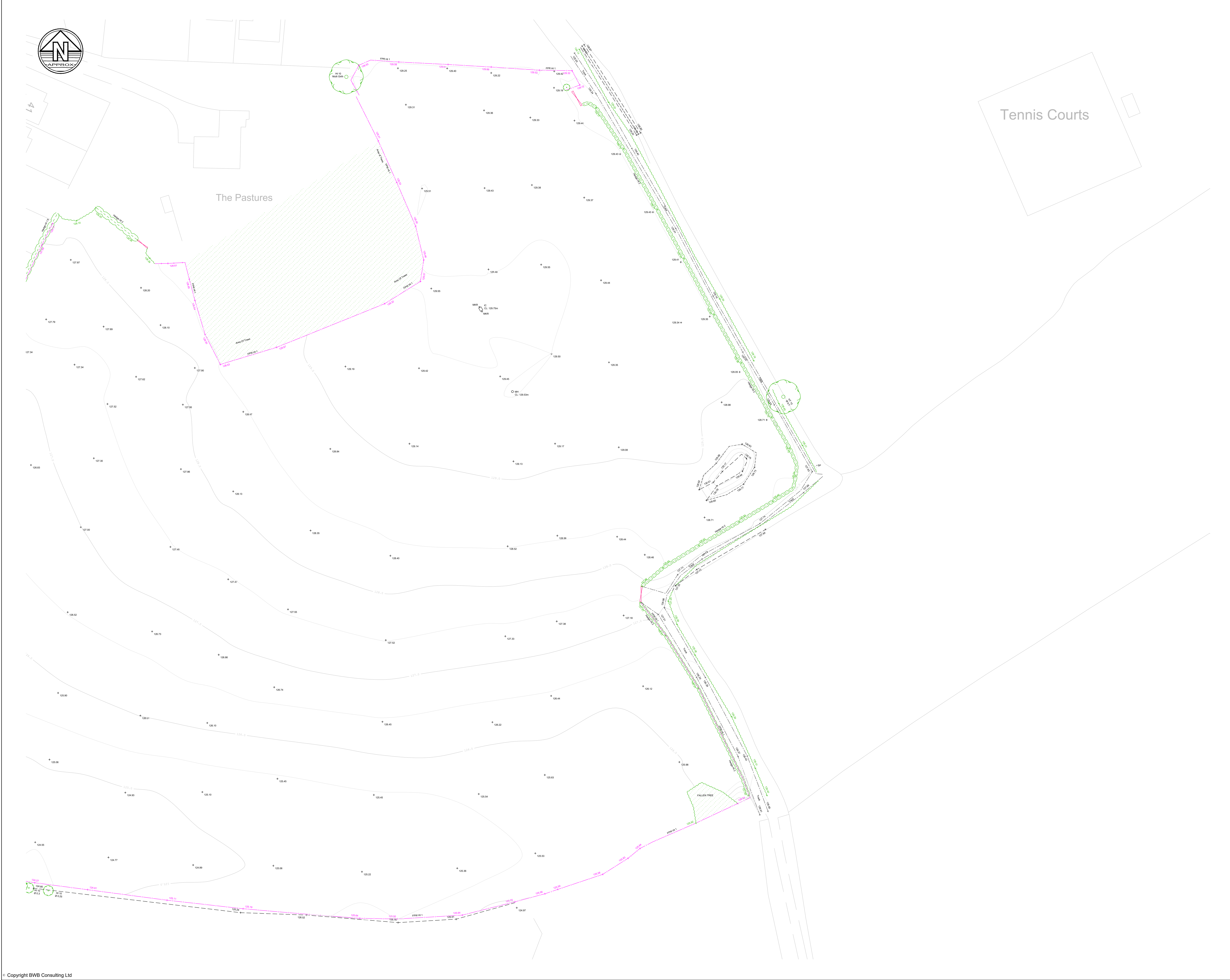
Existing Site 2D Plan Sheet 1 of 2

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref: 243693	Date:	22.02.24	Scale@A1: 1:500

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
NVP2-BWB-00-01-DR-G-001	S2	P1



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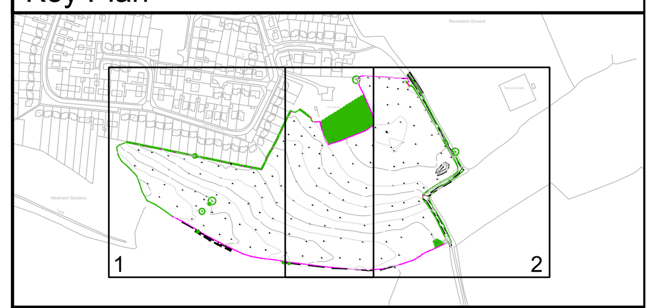
Key Plan



Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
0.25 Flow direction and pipe diameter
1 Station and Name
BH 1 Monitoring Borehole
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
+50.00 Spot Level
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole		
		Gas	Gas	THL	Threshold Level
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
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FL	Floodlight			WO	Wash Out

Rev	Date	Details of issue / revision	Drw	Rev
P1	22.02.24	First Issue	IR	DS

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Client

Richborough Estates Ltd

Project Title

Newbold Verdon Phase 2

Drawing Title

Existing Site 2D Plan Sheet 2 of 2

Drawn:	I.Riley	Reviewed:	D.Smith
BWB Ref:	243693	Date:	22.02.24
Scale@A1:	1:500		

Drawing Status

INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
NVP2-BWB-00-02-DR-G-001	S2	P1

Appendix 2: Indicative Masterplan

Status	PLANNING
Client:	Richborough
Project title:	Land South of Arnold's Crescent Newbold Verdon
Drawing title:	Development Framework Plan
Scale:	1:500@A0
Date:	June 2024
Drawn by:	JMP
Checked by:	LH
Drawing no.:	902832.36.03
Revision:	E

Notes:

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Appendix 3: NPPF Flood Risk Vulnerability and Flood Zone Compatibility

Flood Risk Vulnerability Classifications (recreated from the NPPF Planning Practice Guidance)

Vulnerability Classification	Description
Essential infrastructure	• Essential transport infrastructure (including mass evacuation routes) which has to cross the area at risk. • Essential utility infrastructure which has to be located in a flood risk area for operational reasons, including infrastructure for electricity supply including generation, storage and distribution systems; including electricity generating power stations, grid and primary substations storage; and water treatment works that need to remain operational in times of flood. • Wind turbines. • Solar farms.
Highly Vulnerable	• Police and ambulance stations; fire stations and command centres; telecommunications installations required to be operational during flooding. • Emergency dispersal points. • Basement dwellings. • Caravans, mobile homes and park homes intended for permanent residential use. • Installations requiring hazardous substances consent. (Where there is a demonstrable need to locate such installations for bulk storage of materials with port or other similar facilities, or such installations with energy infrastructure or carbon capture and storage installations, that require coastal or water-side locations, or need to be located in other high flood risk areas, in these instances the facilities should be classified as 'Essential Infrastructure'.)
More Vulnerable	• Hospitals • Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels. • Buildings used for dwelling houses, student halls of residence, drinking establishments, nightclubs and hotels. • Non–residential uses for health services, nurseries and educational establishments. • Landfill* and sites used for waste management facilities for hazardous waste. • Sites used for holiday or short-let caravans and camping, subject to a specific warning and evacuation plan.
Less Vulnerable	• Police, ambulance and fire stations which are not required to be operational during flooding. • Buildings used for shops; financial, professional and other services; restaurants, cafes and hot food takeaways; offices; general industry, storage and distribution; non-residential institutions not included in the 'more vulnerable' class; and assembly and leisure. • Land and buildings used for agriculture and forestry. • Waste treatment (except landfill* and hazardous waste facilities). • Minerals working and processing (except for sand and gravel working). • Water treatment works which do not need to remain operational during times of flood. • Sewage treatment works, if adequate measures to control pollution and manage sewage during flooding events are in place. • Car parks.
Water-Compatible Development	• Flood control infrastructure. • Water transmission infrastructure and pumping stations. • Sewage transmission infrastructure and pumping stations. • Sand and gravel working. • Docks, marinas and wharves. • Navigation facilities. • Ministry of Defence installations. • Ship building, repairing and dismantling, dockside fish processing and refrigeration and compatible activities requiring a waterside location. • Water-based recreation (excluding sleeping accommodation). • Lifeguard and coastguard stations. • Amenity open space, nature conservation and biodiversity, outdoor sports and recreation and essential facilities such as changing rooms. • Essential ancillary sleeping or residential accommodation for staff required by uses in this category, subject to a specific warning and evacuation plan.

Flood Zone Compatibility (recreated from the NPPF Planning Practice Guidance)

Flood Zone	Vulnerability Classification				
	Essential infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
Flood Zone 1 (Low Probability)	Development is appropriate	Development is appropriate	Development is appropriate	Development is appropriate	Development is appropriate
Flood Zone 2 (Medium Probability)	Development is appropriate	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk.	Development is appropriate	Development is appropriate	Development is appropriate
Flood Zone 3a (High Probability)	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk the sustainability benefits of the development to the community outweigh the flood risk. Additionally, essential infrastructure should be designed and constructed to remain operational and safe in times of flood.	Development should not be permitted	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk.	Development is appropriate	Development is appropriate

Flood Zone	Vulnerability Classification				
	Essential infrastructure	Highly Vulnerable	More Vulnerable	Less Vulnerable	Water Compatible
Flood Zone 3b (The Functional Floodplain)	To be deemed appropriate an exception test is required to demonstrate: • The development will be safe for its life time without increasing flood risk elsewhere, and where possible reduce overall flood risk • the sustainability benefits of the development to the community outweigh the flood risk. Additionally, development should be designed and constructed to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows and not increase flood risk elsewhere.	Development should not be permitted	Development should not be permitted	Development should not be permitted	Development is appropriate if designed and constructed to: • remain operational and safe for users in times of flood; • result in no net loss of floodplain storage; • not impede water flows and not increase flood risk elsewhere.

Appendix 4: Environment Agency Correspondence

Product 4 : Flood Risk Data Package for
Newbold Verdon, Leicestershire, LE9 9LD
SK4484203313

EMD 349665 **Date: 01/03/2024**

Flood Map for Planning: The Flood Map for Planning is now classed as Open Data. As such it can be downloaded free of charge under an open data licence from the following addresses:

- https://data.gov.uk/publisher/environment-agency
- https://flood-map-for-planning.service.gov.uk/

Your development is in **flood zone 1**

The flood zones on this map:

- refer to the land at risk of flooding and do not refer to individual properties refer to the probability of river and sea flooding.
- ignore the presence of defences,
- do not take into account potential impacts of climate change.
- This data is updated on a quarterly basis as better data becomes available.
- The NaFRA 2 will be completed Summer 2024 and the flood zones will then be updated NaFRA2 (As such we are not accepting any flood map challenges at this time).

Zone 1: Low Probability	Land having a less than 0.1% annual probability of river or sea flooding. (Shown as 'clear' on the Flood Map for Planning – all land outside Zones 2, 3a and 3b)
Zone2: Medium Probability	Land having between a 1% and 0.1% annual probability of river flooding; or land having between a 0.5% and 0.1% annual probability of sea flooding. (Land shown in light blue on the Flood Map)
Zone 3a: High Probability	Land having a 1% (1 in 100) or greater annual probability of river flooding; or Land having a 0.5% or greater annual probability of sea. (Land shown in dark blue on the Flood Map)
Zone 3b: Functional Floodplain	• land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively; or • land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding). • Local planning authorities should identify in their Strategic Flood Risk Assessments areas of functional floodplain and its boundaries accordingly, in agreement with the Environment Agency. • (Not separately distinguished from Zone 3a on the Flood Map)

Probability	Percentage chance of flooding each year
1 in 2 year	50%
1 in 5 year	20%
1 in 20 year	5%
1 in 50 year	2%
1 in 100 year	1%
1 in 1000 year	0.1%
Surface Water Flooding	
1 in 30	High Risk
1 in 100	Medium Risk
1 in 1000	Low Risk

Updated Climate Change Guidance: On 19th February 2016, the Flood risk assessments: climate change allowances' was published on www.gov.uk website. It has replaced previous guidance Climate Change Allowances for Planners. The climate change guidance can be found at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

The climate change allowances for this location are:

- **28% (central)**
- **37% (higher central),**
- **60% (upper)**

Modelled Information
This location is not close to main river.

Defence Information
There are no Environment Agency maintained raised defences in this area.

Historic Information
We have no records of historic fluvial flooding at this location. However, we would advise that this does not mean there has never been historic flooding in this location or that the area is automatically free from a risk of flooding. We do not claim that all flood events have been recorded.

Surface Water & Drainage: The Environment Agency (empowered under the Water Resources Act 1991) concentrates on the major elements of the drainage system, managing flood risk arising from designated "main rivers" and the sea. The Flood & Water Management Act (2010) has given Lead Local Flood Authorities (LLFAs) responsibility for the management of local flood risk, which includes surface runoff, groundwater and flooding from ordinary watercourses (smaller rivers and streams). The LLFA for this area is **Leicestershire County Council,** and we recommend that you contact them with concerns about any flooding issues for this area.

Further information and maps for surface water, ordinary watercourses, and reservoir flooding can be found here:
https://www.gov.uk/check-long-term-flood-risk ; Reservoir flood maps: when and how to use them - GOV.UK (www.gov.uk)

Open Data Information: Many datasets are now classed as Open Data and as such can be downloaded free of charge under an open data licence from the following address: https://data.gov.uk/publisher/environment-agency

Permitting Information: Under the Environmental Permitting (England and Wales) Regulations 2016, any permanent or temporary works in, over or under a designated main river will require an Environmental Permit for Flood Risk Activities from the Environment Agency. Any permanent or temporary works within 8 metres of the top of bank of a designated main river, or landward toe of a flood defence may require an Environmental Permit for Flood Risk Activities from the Environment Agency. In addition, any permanent or temporary works within the floodplain of a designated main river may also require an Environmental Permit for Flood Risk Activities. To find out whether your activity requires a permit or falls under a relevant exclusion, exemption or standard rule please follow this link: https://www.gov.uk/guidance/flood-risk-activities-environmental-permits. The Environment Agency require access to the watercourse and free movement up to 8m from the river bank/ defence for maintenance purposes.

Please note that a permit is separate to and in addition to any planning permission granted.

Strategic flood risk assessments: We recommend that you check the relevant local authority's strategic flood risk assessment (SFRA) as part of your work to prepare a site specific flood risk assessment. This should give you information about: the potential impacts of climate change in this catchment areas defined as functional floodplain flooding from other sources, such as surface water, ground water and reservoirs. This data has been generated by strategic scale flood models and is not intended for use at the individual property scale. If you're intending to use this data as part of a flood risk assessment, please include an appropriate modelling tolerance as part of your assessment. The Environment Agency regularly updates its modelling. We recommend that you check the data provided is the most recent, before submitting your flood risk assessment.

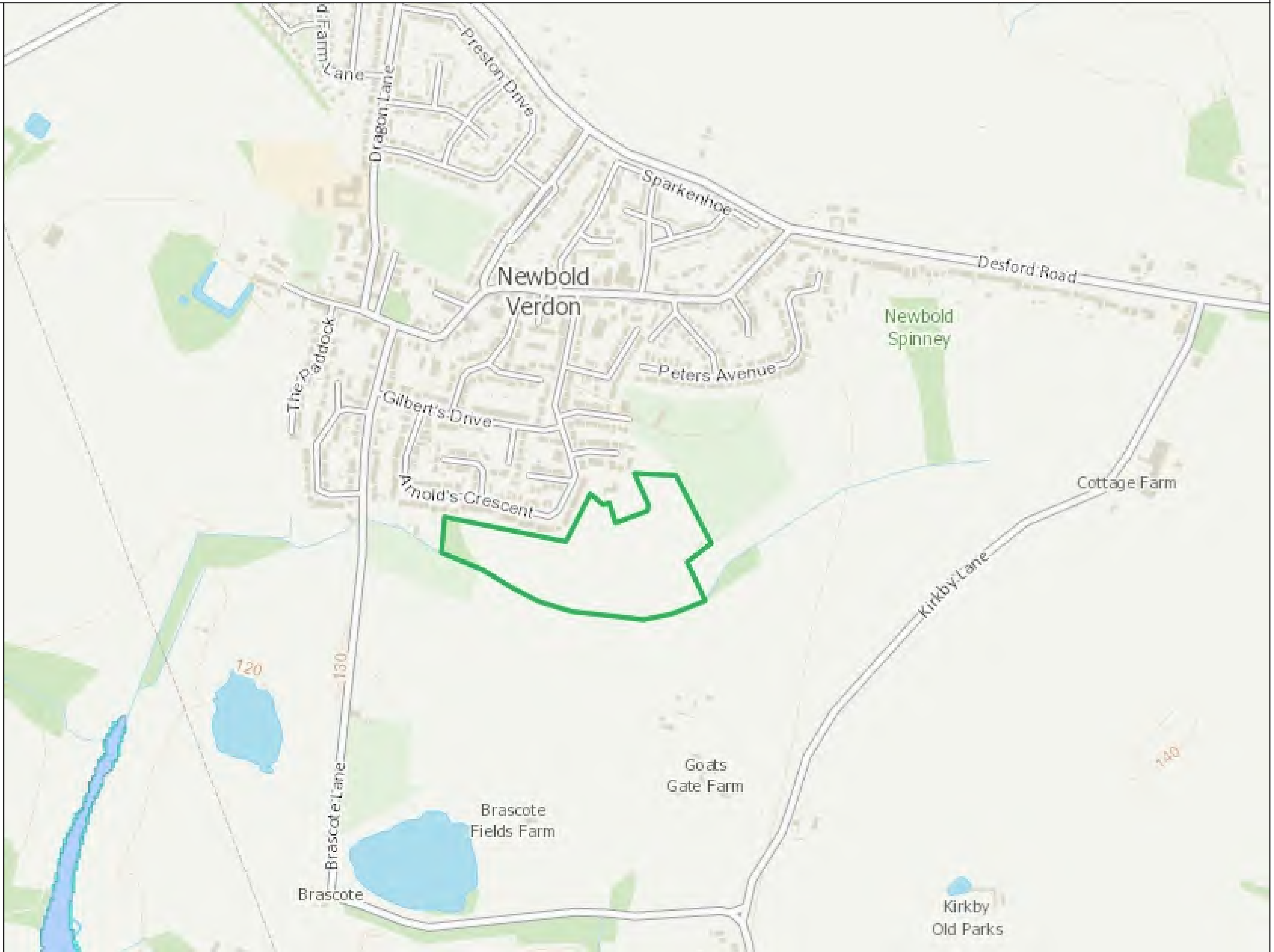
Flood Risk Assessment Advisory: All guidance on how to complete a full site specific Flood Risk Assessment (FRA) can be found here: Flood risk and coastal change - GOV.UK (www.gov.uk). Furthermore professional assistance can be provided by our planning officers, by contacting planning.trentside@environment-agency.gov.uk.

Detailed Flood Map, centred on Newbold Verdon, Leicestershire [EMD348086]

Environment Agency

Legend

- Statutory Main Rivers
- Defences
- Flood Storage Areas
- Flood Zone 3
- Flood Zone 2



1: 10,000

0 250

Metres

N W E S

Detailed River Network Map, centred on Newbold Verdon, Leicestershire

Environment Agency

Legend

Detailed River Network

- Primary River
- Secondary River
- Tertiary River
- Lake / Reservoir
- Canal
- Canal Tunnel
- Extended Culvert
- Multiple Channel Culvert
- Underground River (potential sewer)
- Underground River (inferred)
- Underground River (local knowledge)
- Undefined

Offline Drainage features

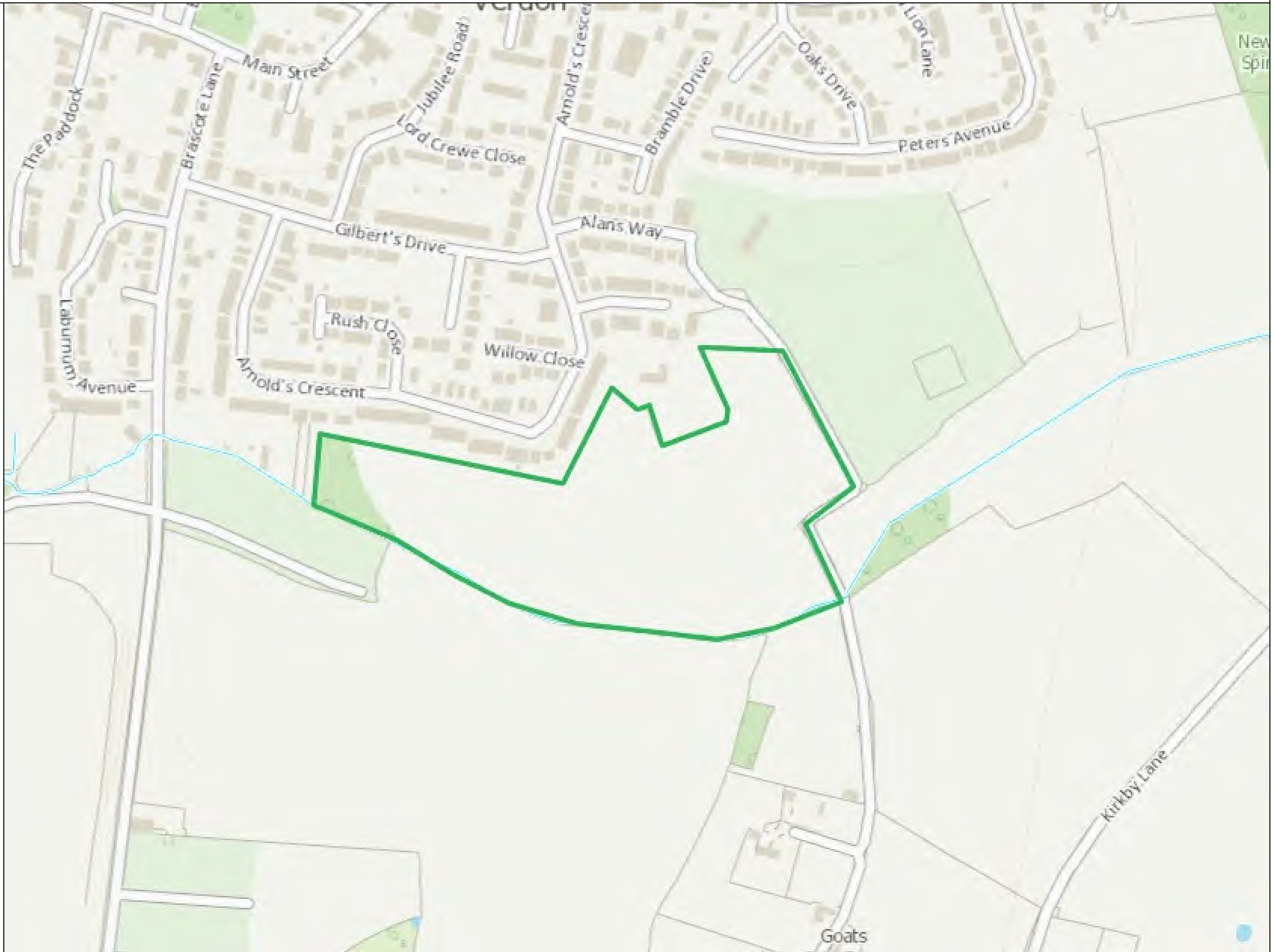
Detailed River Network

- Primary River
- Secondary River
- Tertiary River
- Lake / Reservoir
- Canal
- Canal Tunnel
- Extended Culvert
- Multiple Channel Culvert
- Underground River (potential sewer)
- Underground River (inferred)
- Underground River (local knowledge)
- Undefined

1: 5,000

0 125

Metres

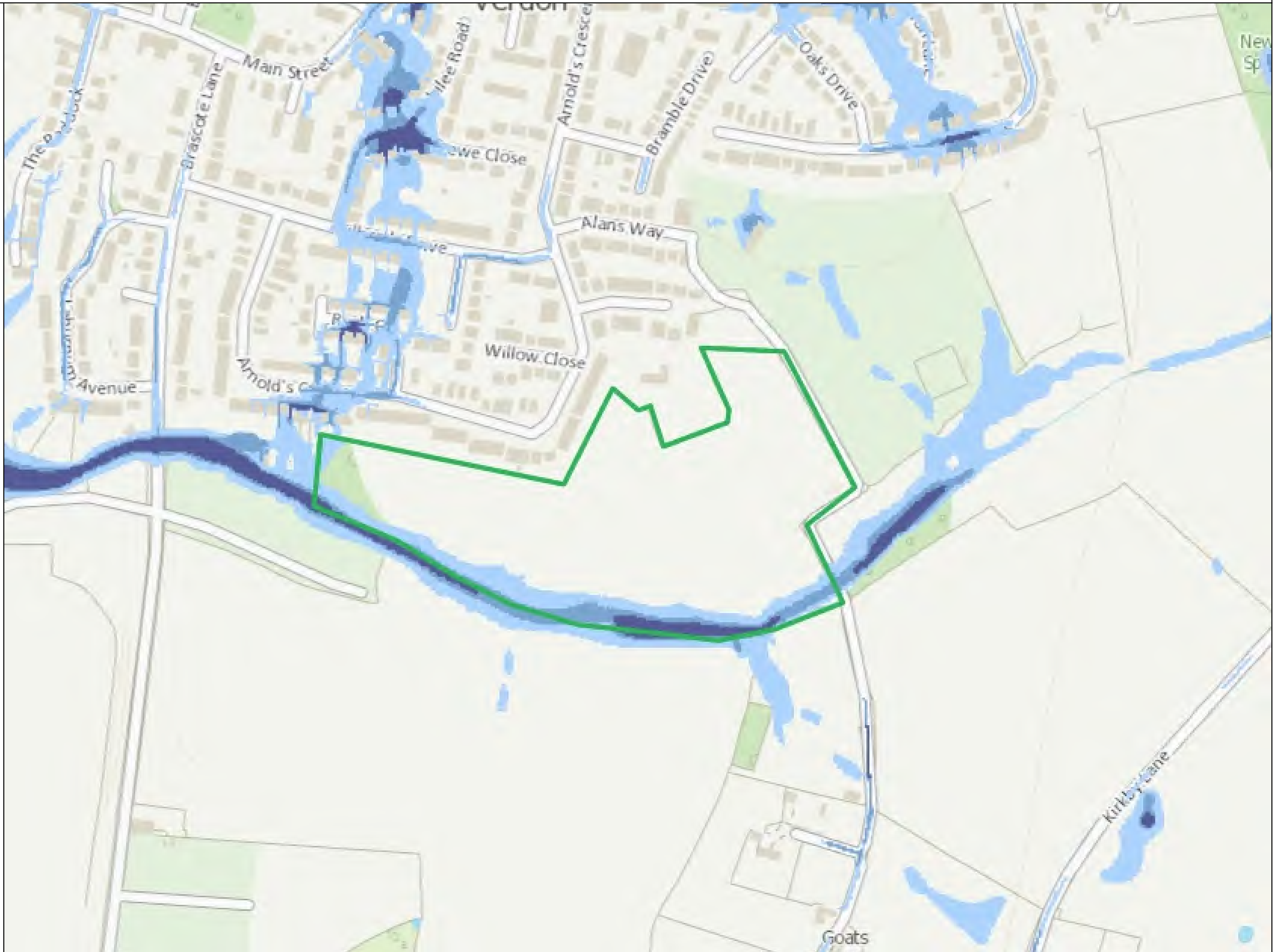


Surface Water Flood Map, centred on Newbold Verdon, Leicestershire

Environment Agency

Legend

- Flood Extent 1 in 30
- Flood Extent 1 in 100
- Flood Extent 1 in 1000



1: 5,000

0 125

Metres

N
W E
S

Appendix 5: Hydraulic Modelling Technical Note

ENVIRONMENT

Richborough
Land Situated to the East of Brascote Lane and South of Arnold's Crescent
Newbold Verdon
Hydraulic Model Technical Note

www.bwbconsulting.com

ENVIRONMENT

Richborough
Land Situated to the East of Brascote Lane and South of Arnold's Crescent
Newbold Verdon
Hydraulic Model Technical Note

Birmingham
Livery Place, 35 Livery Street, Colmore Business District, Birmingham, B3 2PB
T: 0121 233 3322

Cambridge
14-16 High Street, Histon, Cambridge
CB24 9JD
T: 01223 235 173

Leeds
Whitehall Waterfront, 2 Riverside Way, Leeds
LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street, Manchester, M1 3HU
0161 233 4260

Market Harborough
12a Woodcock House, Compass Point Market Harborough, Leicestershire, LE16 9HW
T: 01858 455020

Nottingham
Waterfront House, Station Street, Nottingham NG2 3DQ
T: 0115 924 1100

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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

m BGL – metres below ground level

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 LLFA.

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% 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 (the Client) to undertake updates to a hydraulic model of the Thurlaston Brook. The purpose of the updates is to include a representation of an Unnamed Ordinary Watercourse (UOW) and structure which were previously omitted from the model and ensure that the modelled flows are in accordance with current best practice methods.

1.2 The hydraulic model has also been updated to account for the proposed development, including watercourse crossings and a flood storage area.

1.3 The hydraulic model updates are intended to support a planning application for a proposed residential development at land situated to the east of Brascote Lane and south of Arnold's Crescent, Newbold Verdon (NGR: SK 4484 0329).

Site Description

1.4 The planning application boundary as shown edged red in Figure 1.1 extends to 13.77ha (hereinafter referred to as the 'Combined Site'), which comprises the following:

- 6.91ha of land to the east of Brascote Lane and south of the Thurlaston Brook, as shown shaded grey on the plan below, which benefits from an extant planning permission under reference 22/00277/OUT, for the purpose only of providing access/egress to the public highway known as Brascote Lane (hereinafter referred to as 'Phase 1'); and
- 6.86ha of land to the south of Arnold's Crescent and north of the Thurlaston Brook, as shown shaded pink on the plan below, for up to 135 dwellings with associated landscaping, open space, drainage infrastructure and associated works (hereinafter referred to as 'Phase 2').

1.5 On the basis that Phase 1 has the benefit of planning permission, the scope of this Hydraulic Model Technical Note focusses upon Phase 2.

1.6 The Phase 2 site is located immediately south of Newbold Verdon, approximately 14km west of Leicester City Centre, and is bound to the north by residential development, to the east by Newbold Verdon Cricket Club and agricultural land, to the south by the Thurlaston Brook and to the west by residential development. The site location is shown in Figure 1.1.

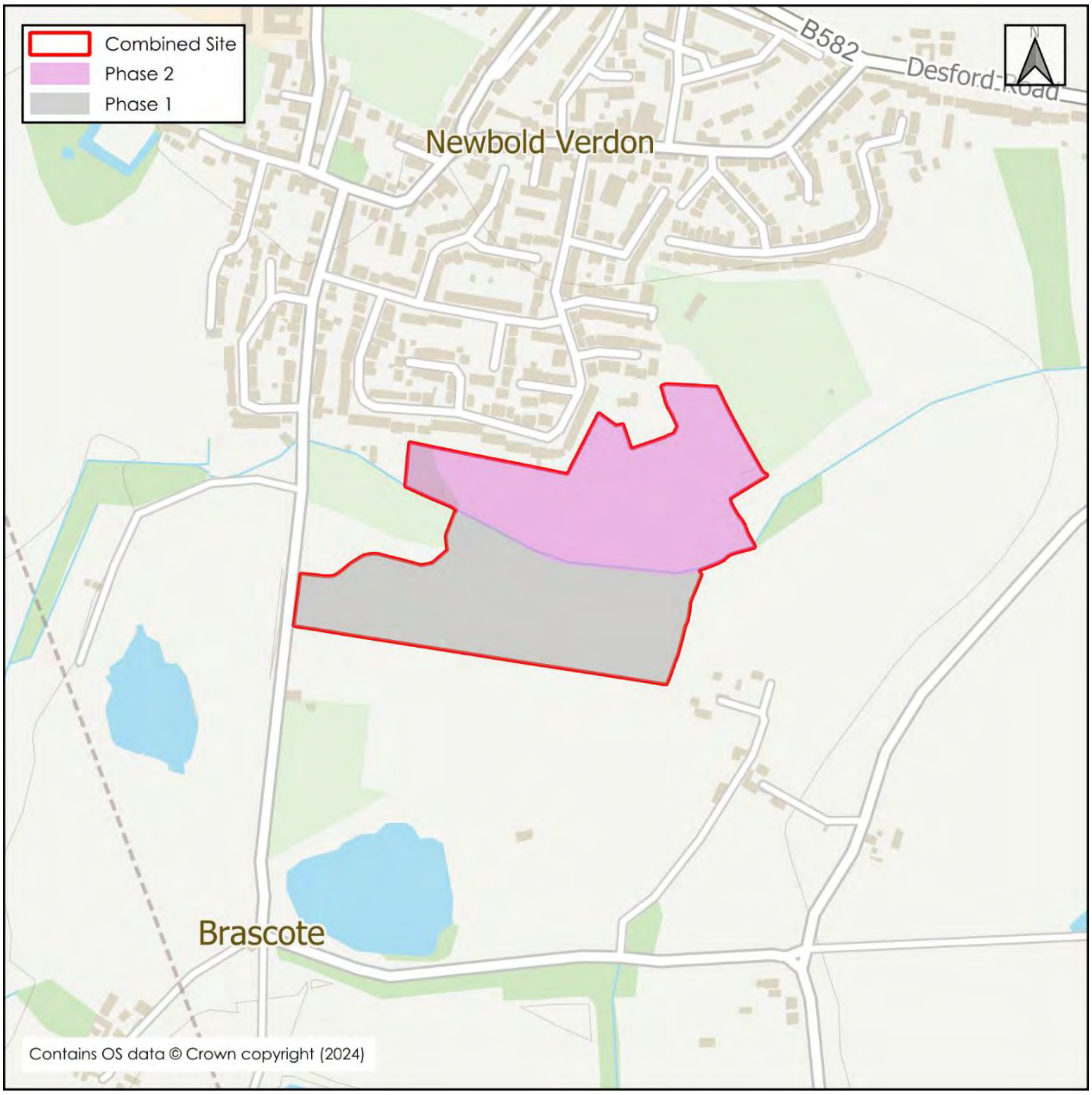

Figure 1.1: Site Location

1.7 The Thurlaston Brook, a tributary of the River Soar, flows along the Phase 2 southern site boundary in a westerly direction. The source of the watercourse is located approximately 600m upstream of the Phase 2 site. A UOW is located along the south eastern boundary of the Phase 2 site and flows in a westerly and then southerly direction before outfalling to the Thurlaston Brook adjacent to the south east of the Phase 2 site.

1.8 A second UOW flows into the Thurlaston Brook approximately 700m downstream of Brascote Lane. The watercourse network in the immediate vicinity of the Phase 2 site is shown in Figure 1.2.

Figure 1.2: Local Watercourse Network

Site History

1.9 Hydraulic modelling of the Thurlaston Brook was previously undertaken by BWB Consulting Ltd in 2021 to support the adjacent Phase 1 planning application (reference: 22/00277/OUT) located to the south of Phase 2, on the left bank of the Thurlaston Brook. The watercourse divides the Phase 1 and Phase 2 sites.

1.10 A planning application is now to be submitted for the Phase 2 development on the right bank of the Thurlaston Brook and the hydraulic model needs to be updated to account for changes in hydrology guidance and the definition of functional floodplain which have been released since the 2021 modelling.

1.11 A site visit, undertaken in February 2024, also identified a structure along the Thurlaston Brook and a UOW located along the south eastern boundary of the Phase 2 development which had not previously been included within the model. Therefore, these will be added to the model.

1.12 Access to the Phase 2 development is proposed from the Phase 1 development via two watercourse crossings. Following the baseline modelling, the model will be updated to include an appropriate representation of the proposed watercourse crossings along with a proposed flood storage area.

Aims and Objectives

1.13 To update the model, the following objectives have been identified:

i. Undertake a review of the hydrology assessment previously completed.
ii. Undertake an updated hydrological assessment of the Thurlaston Brook and UOW using latest methodologies.
iii. Update the inflows into the model following the hydrological review.
iv. Update the 2D hydraulic model domain with up-to-date topographical information, where available.
v. Update the 1D hydraulic model domain to include the structure and UOW.
vi. Undertake simulations of key flood return period events to understand the floodplain extents and peak flood levels within and adjacent to the site.
vii. Undertake simulations to account for climate change flows within the model.
viii. Undertake simulations of post-development conditions for key flood return period events to include for the proposed watercourse crossings and flood storage area and compare to baseline conditions.
ix. Undertake sensitivity analysis of post-development conditions.

Approach

1.14 To achieve the objectives identified above, the existing 1D/2D ESTRY- TUFLOW model was simulated with the updated hydrology and inclusion of the additional structure and UOW.

1.15 The model has been simulated for a series of design storm events. These modelled events include the 1 in 30-year, 1 in 100-year and 1 in 1000-year events that are typically equivalent to Flood Zones 3b (Functional Floodplain), 3a and 2 respectively, used by the EA for planning purposes.

Previous Studies & Available Data

Hydraulic Modelling

1.16 In 2021, BWB Consulting Ltd constructed a 1D/2D ESTRY-TUFLOW model of the Thurlaston Brook, based on a watercourse survey completed in July 2021.

1.17 The final choice of methodology for deriving peak flows was the ReFH2 method as this produced the more conservative flow estimates. The flow estimates were made at the downstream extent of the site, downstream of Brascote Lane.

1.18 The 1D domain for the Thurlaston Brook was modelled from the upstream extent of the Phase 1 site boundary. The majority of the channel was represented within the 1D domain, however the first 650m of the watercourse, at the upstream limit of the model, was modelled in the 2D domain.

1.19 Further information on the hydraulic modelling approach can be found within the Hydraulic Modelling Report (reference: BLN-BWB-ZZ-XX-RP-YE-0004) included as Appendix 1.

Historical Flooding

1.20 EA recorded flood outline mapping shows that there are no historical flood outlines recorded at the site. However, it is possible that flooding may have taken place that has not been recorded by the EA.

1.21 A flood history review of the catchment has been undertaken using EA recorded flood outlines, Hinckley and Bosworth Council Level 1 SFRA[1], Hinckley and Bosworth Council Level 2 SFRA[2], Leicestershire County Council PFRA[3], Leicestershire County Council Local Flood Risk Management Strategy (LFRMS)[4] Leicestershire County Council Flood Investigation Reports, the British Chronology of Hydrological Events and online newspaper records.

1.22 Mapping within the Level 1 SFRA shows historical flooding from March 2016 to be located approximately 200m north west of the site, however, the flooding is not attributed to a source. No further record of flooding to the catchment has been found during the search of the above sources.

BWB Site Visit (February 2024)

1.23 A site visit was undertaken by BWB during February 2024 to walk the local watercourse and observe whether the watercourse survey undertaken in 2021 is representative of existing conditions on site. A UOW, a tributary of the Thurlaston Brook, was observed to flow along the south east of the Phase 2 site boundary, as shown in Figure 1.3.

[1] Level 1 Strategic Flood Risk Assessment (JBA Consulting, July 2019)
[2] Level 2 Strategic Flood Risk Assessment (JBA Consulting, May 2020)
[3] Preliminary Flood Risk Assessment (Leicestershire County Council, June 2011)
[4] Local Flood Risk Management Strategy (Leicestershire County Council, February 2024)

Figure 1.3: UOW, a Tributary of the Thurlaston Brook, Located along the South Eastern Boundary of the Phase 2 Site

1.24 A culvert was also noted to be present along the Thurlaston Brook, to the south east of the Phase 2 site, as shown in Figure 1.4.

Figure 1.4: Culvert Along the Thurlaston Brook Located to the South East of the Phase 2 Site

1.25 Both the UOW and the culvert were not previously represented within the hydraulic model. It is therefore proposed to update the hydraulic model to include the UOW and culvert along the Thurlaston Brook.

<u>EA Flood Maps</u>

1.26 The EA Flood Map for Planning shows the Phase 2 site to be located entirely within Flood Zone 1. This is due to the small catchment associated with the Thurlaston Brook meaning it is not included in the national scale mapping. The nearest Flood Zone extents are located approximately 600m south west of the Phase 2 site. The mapping is included as Figure 1.5.

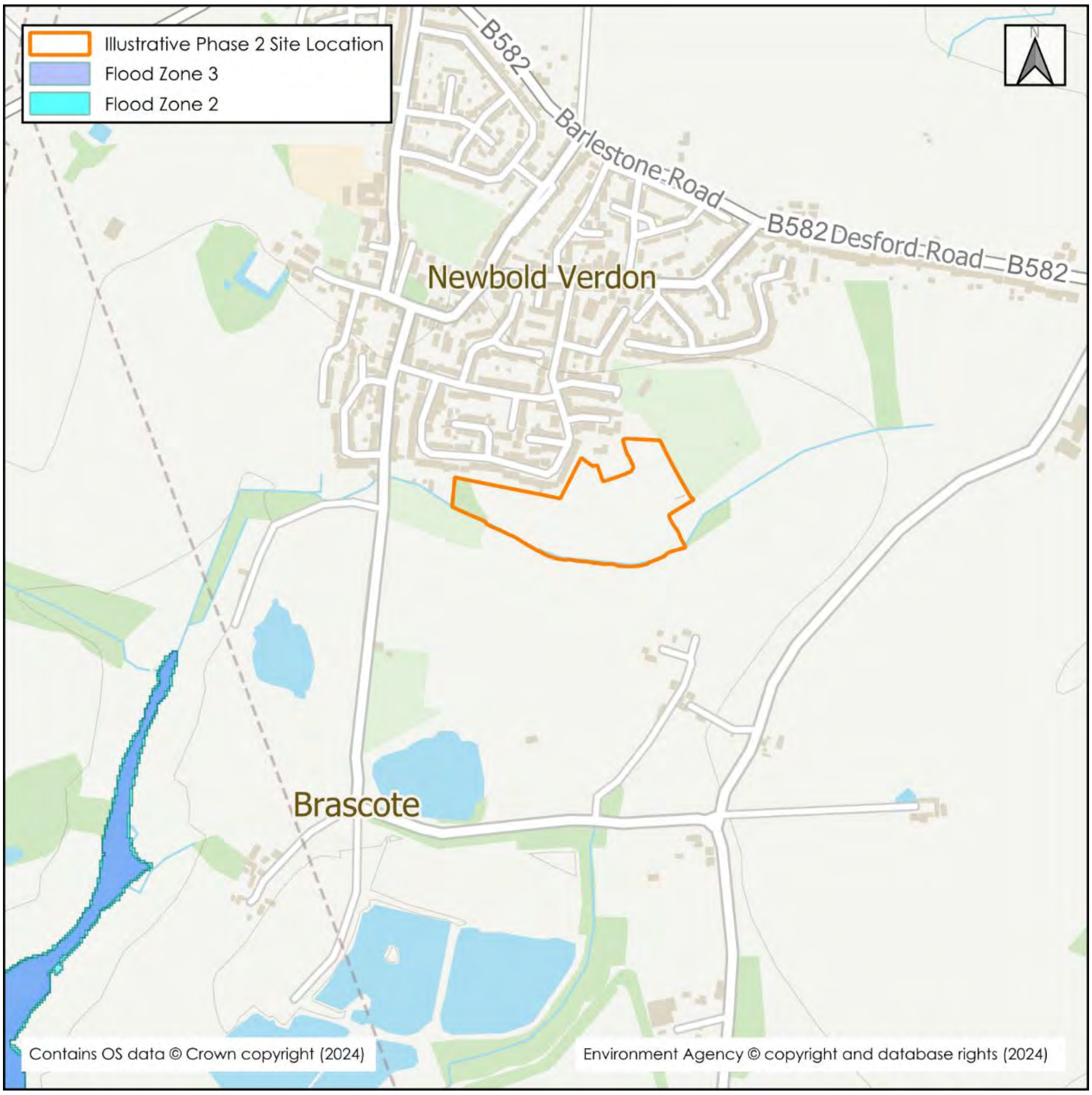

Figure 1.5: EA Flood Map for Planning

1.27 The EA Risk of Flooding from Surface Water (RoFSW) mapping provides an indication of the floodplain associated with ordinary watercourses that are not included within the Flood Map for Planning. The mapping is included within Figure 1.6.

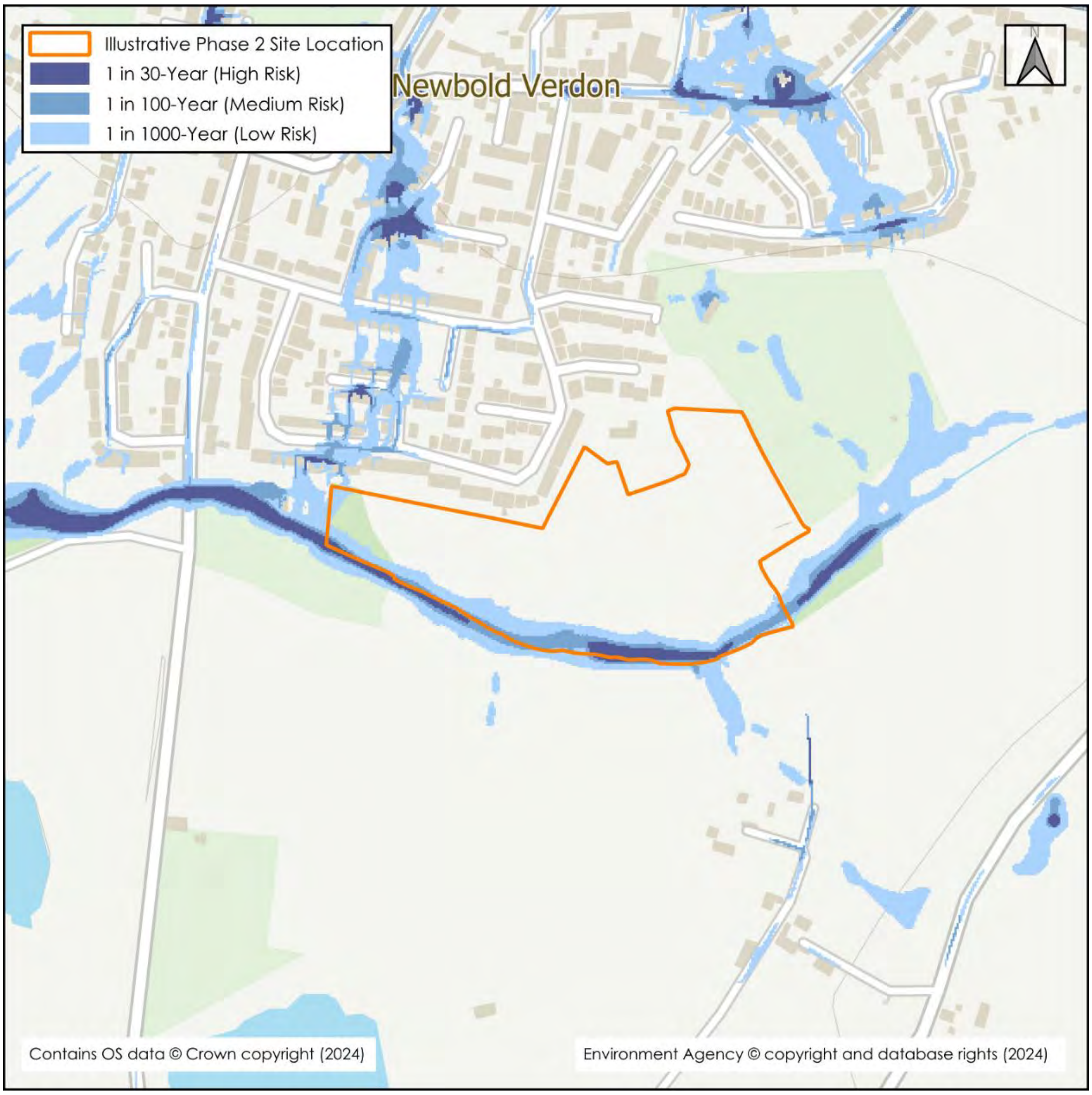

Figure 1.6: EA Risk of Flooding from Surface Water Mapping

1.28 The mapping shows a pluvial flow route, associated with the Thurlaston Brook, to be present adjacent to the southern Phase 2 site boundary. The extents are generally confined to the channel. However, there is some encroachment into the Phase 2 site, most notably during the 1 in 1000-year.

1.29 A pluvial flow route is also shown to be present within the residential development to the north west of the Phase 2 site. The flow route marginally encroaches into the Phase 2 site as it flows towards the Thurlaston Brook.

<u>Other Sources of Data</u>

1.30 The BWB 2021 hydraulic model was updated using the following additional datasets as part of this exercise:

- EA LiDAR data (2022) 1m resolution composite DTM.
- An updated hydrological assessment of flood flows undertaken by BWB Consulting Ltd (Section 2).

- Cross-sectional watercourse survey, undertaken in March 2023 (included as Appendix 2).
- Development Framework Plan undertaken by Marrons (included as Appendix 3).

Assumptions and Limitations

1.31 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:

- Any assumptions and limitations inherited from the 2021 hydraulic model will be carried forward into this study.
- The catchment boundary amended as part of the previous assessment is representative of the catchment.
- The flow estimate derived at the downstream extent of the Thurlaston Brook is applicable to the upstream catchment and the UOW.
- The URBAN50k method used to calculate $URBEXT_{2000}$ for the revised catchment boundary has been retained as no significant changes to urban area have been identified.
- Due to access limitations, it was not possible to survey the upstream face of the culvert located to the south east of the Phase 2 site. Therefore, the downstream section (NBVR1_01303) has also been duplicated and used as the upstream section and therefore channel geometry and invert levels remain the same for both the upstream and downstream sections of the structure.
- 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 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.

2. HYDROLOGY

2.1 There have been changes in guidance relating to the calculation of flood flows since the hydraulic modelling was initially undertaken in 2021. The hydrology was updated in February 2024 to ensure that the modelled flows are in accordance with current best practice, using industry standard methodologies and guidance, as detailed below.

Method Statement

2.2 The NRFA Peak Flow Dataset Version 21.1 (released November 2023) will be utilised in this assessment for the purpose of identifying any potential donor stations and for the development of pooling groups.

2.3 Flows will be estimated using both Statistical and ReFH2 methods. Both methods are suitable for the catchment and using both will enable comparison before choosing the final method.

2.4 The flow estimation location, taken at the downstream extent of the hydraulic model, was retained. The catchment boundary was also reviewed using EA LiDAR, and the adjustments made as part of the previous assessment were retained.

2.5 Catchment descriptors remained as per the previous assessment and URBEXT was not updated as there has been no significant urban development in this area since the previous assessment.

Statistical Method

2.6 WINFAP (v5) was utilised to undertake a statistical analysis of the catchment using a hydrometric record of gauged catchments with similar characteristics.

QMED Development

2.7 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.

2.8 Phase 2 of Science Report SC090031[5] recommends using a single donor, chosen on the basis of proximity, to adjust QMED for 'small catchments' (defined as catchments with an area of less than 25km^2). This method can also be applied to catchments less than 40km^2 and is implemented in WINFAP5.

[5] Science Report SC090031/R0: Estimating flood peaks and hydrographs for small catchments (Phase 2), Environment Agency (2019)

2.9 With this guidance in mind, a search was undertaken within WINFAP to identify the closest station to the flow estimation point(s). The data quality of potential donor(s) was also reviewed.

2.10 Whilst FEH recommends avoiding urbanised donors, the Littlethorpe gauge (NRFA reference: 28082) is approximately 10km from the site and only just over the 0.03 threshold for $URBEXT_{2000}$. 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 also extended to donors with URBEXT > 0.046 to allow WINFAP to include Littlethorpe as a donor.

2.11 It was decided to use Littlethorpe as a donor as this station was used as one of the donors for the initial hydrology assessment (reference: BLN-BWB-ZZ-XX-RP-YE-0003).

2.12 Details for the donor station used to adjust QMED, and the flow estimation point it has been applied to, are provided in Table 2.1. Details of the donor adjustment and final QMED estimation are provided in Table 2.2.

Table 2.1: Donor Station Details

Station Number	**QMED from 'as rural' Observed** Data (A)* (m^3/s)	**'As rural' QMED** from Catchment Descriptors (b)** (m^3/s)	Adjustment Ratio (A/B)	Flow estimation point(s) donor is applied to
28082	15.58	18.59	0.84	THB001

Table 2.2: 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)	Power term, a	Moderated QMED adjustment factor $(A/B)^a$	
THB001	Donor transfer	0.30	28082	10.23	0.379	0.94	0.26

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 WINFAP.

Derivation of Pooling Groups

2.13 A pooled group of hydrologically similar gauged sites was generated by the WINFAP software for the subject sites using the 'OK for Pooling' dataset. WINFAP uses the deurbanised pooling group L-moments as default.

2.14 The 'small catchment' pooling procedure implemented within WINFAP has been used. This procedure selects the pooling group using a similarity measure that only considered AREA and SAAR, as recommended by SC090031.

Pooling Group Review

2.15 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.

Highly Permeable Stations

2.16 There are only a small number of small, gauged catchments within the peak flow dataset, and a number of these are located on highly permeable catchments.

2.17 The EA FEH guidelines do not provide explicit guidance on what to do with highly permeable stations in a pooling group when the subject site is not classed as highly permeable. However, it does set out two options.

i. Retain the permeable stations within the pooling group and adjust for non-flood years (previously known as 'permeable adjustment'). However, limitations with this approach include:
    a. It only applied the Generalised Logistic (GL) distribution.
    b. It does not offer Enhanced Single Site analysis.
    c. It cannot be applied in WINFAP.
ii. Remove highly permeable stations from the pooling group. The disadvantage of this approach is that any replacement stations will be less similar to the subject site in terms of AREA and SAAR, than those removed. However, EA guidelines suggest an alternative which is the acceptance of a group smaller than the default size of 500-year. This is based on SC050050 which showed the uncertainty associated with pooling does not increase much until the number of years drops below 300.

2.18 Given the various uncertainties and limitations around the different approaches, both will be applied for this study and the results compared before deciding on the final method.

Urban Adjustment

2.19 Growth curves were also adjusted for to reflect the urban influence, using the methods adopted in WINFAP[6] which is based on those proposed by Kjeldsen 2010[7].

Choice of Distribution

2.20 In accordance with the EA FEH Guidelines, the distribution has been chosen based on which gives the best fit from GL, Generalised Extreme Value (GEV) and Kappa 3.

2.21 The only exception to this is when a pooling group has been adjusted for non-flood years as the procedure for the adjustment uses the GL distribution.

2.22 GL provided the best fit for both approaches.

Growth Curve Comparison

2.23 Further detail on pooling group composition is provided in Appendix 4.

Table 2.3: Derivation of Pooling Groups: THB001_PG

Name of group	Subject site treated as gauged? (enhanced single site analysis)	Distribution used	Change made to default pooling group with reasons, including any sites investigated but retained in the group	Weighted average L-moments L-CV and L-skew (before any urban and non-flood year adjustment)
Adjusted for non-flood years	No	GL	Stations Removed: 26014 - a review of the station on the NRFA suggests catchment response differs to that of the site 44008 – non-flood years over 15% of record and a review of the station on the NRFA suggests catchment response differs to that of the site. Stations Added: 39033 – added to get pooling group record above 500 years Comments: Station 36010 was reviewed for suitability as it was identified as having non-flood years over 15% of record. The catchment response was not considered to be significantly different to the study catchment and	L-CV: 0.275 L-Skew: 0.267

[6] Wallingford HydroSolutions (2016), WINFAP 4 Urban adjustment procedures, Wallingford HydroSolutions Ltd 2016.
[7] Kjeldsen, T.K., 2010. Modelling the impact of urbanisation on flood frequency relationships in the UK. Hydrology Research, volume 41, issue 5, pp391-405

Name of group	Subject site treated as gauged? (enhanced single site analysis)	Distribution used	Change made to default pooling group with reasons, including any sites investigated but retained in the group	Weighted average L-moments L-CV and L-skew (before any urban and non-flood year adjustment)
			therefore the station was retained. Station 7011 was investigated due to a steep growth curve; however, the station was not removed as there is no obvious reason for the steep growth curve. The pooling group is heterogeneous and a review of the pooling group is desirable. However, it is not considered possible to improve the pooling group any further.	
Highly permeable stations removed	No	GL	Stations Removed: 27073, 26016, 26014, 44008 and 7011 – BFIHOST > 0.66 Stations Added: None Comments: The pooling group is possibly heterogeneous and a review of the pooling group is optional.	L-CV: 0.254 L-Skew: 0.267

2.24 A comparison of the growth curves for the different methods is provided in Figure 2.1.

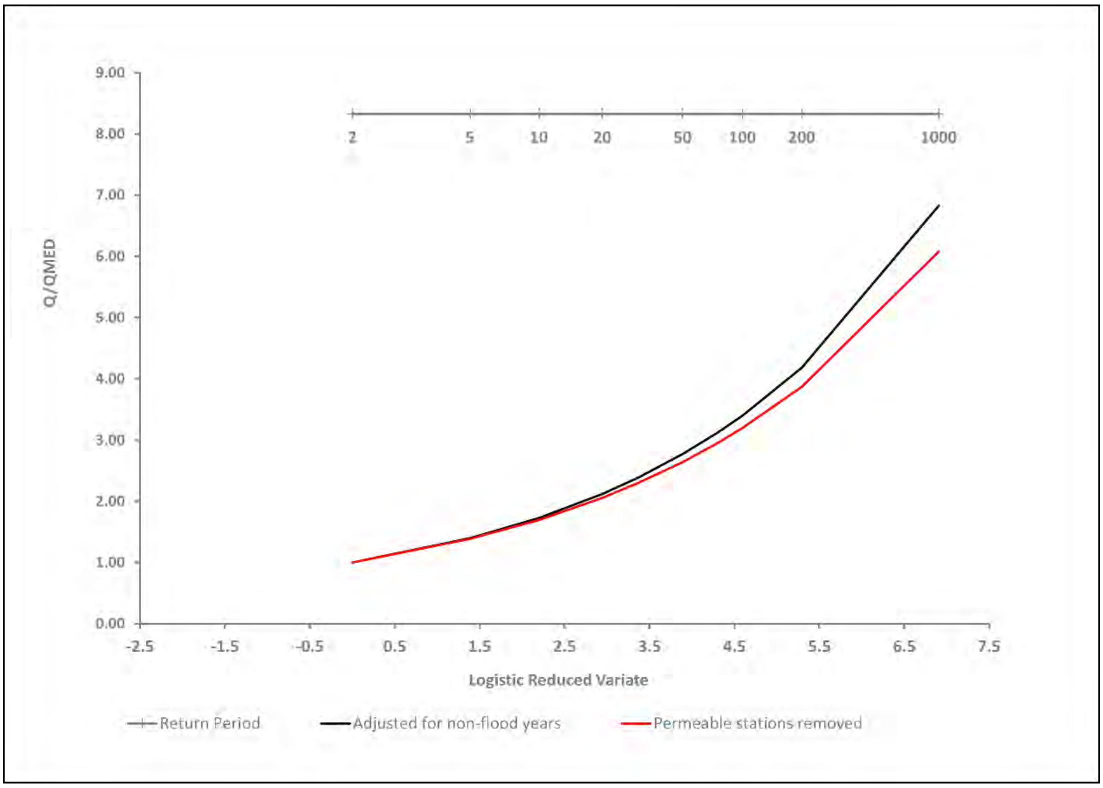

Figure 2.1: Comparison of Pooled Growth Curves

2.25 The growth curves are similar at the lower return periods. At around the 20-year event, the growth curve for the pooling group which has been 'adjusted for non-flood years' shows a steepening in comparison to the 'permeable stations removed' pooling group. The 'adjusted for non-flood years' pooling group provides higher flows when compared to the pooling group with 'permeable stations removed', particularly during the higher return periods.

2.26 The final choice of growth curve has been based on the 'adjusted for non-flood years' pooling group as this provides the highest peak flows.

Table 2.4: Final Choice of Flood Growth Curves at Subject Site

Site code	Method (SS, P, ESS)	Name of pooling group	Distribution used and reason for choice	Urban adjustment and/or non-flood years adjustment applied?	Growth factor for 1% AEP event
THB001	P	Adjusted for non-flood years	GL distribution was chosen because it is the default distribution used for the adjustment for non-flood years.	Urban adjustment and adjustment for non-flood years applied	3.40

Table 2.5: Flood Estimates from the Statistical Method

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
THB001	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.5	2.5

Revitalised Flood Hydrograph (ReFH) Method

2.27 The ReFH2 Revitalised Flood Hydrograph Modelling Tool (Model 2.3, Version 4.0) was used to undertake an estimation of the peak flows for the subject site.

Table 2.6: Overview of Parameters for ReFH2 Method

Site code	Method OPT: Optimisation BR: Baseflow recession fitting CD: Catchment descriptors DT: Data transfer	Tp (hours) Time to peak	C_{max} (mm) Maximum storage capacity	BL (hours) Baseflow lag	BR Baseflow recharge
All	Parameters calculated using catchment descriptors.				
Description of flood event analysis carried out			Flood event analysis is not possible as catchment is ungauged.		

Table 2.7: Design Events

Site code	Rainfall DDF model	Season of design event	Storm duration	Selected interval	Initial soil moisture (Cini)	Initial baseflow (BFO)
THB001	FEH22	Winter	6.5hr	0.5hr	Default value	Default value
Comments	A uniform 6.5hr winter storm will be applied at the modelling stage.					

Table 2.8: Flood Estimates from the ReFH Method

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
THB001	0.4	0.6	0.7	0.8	0.9	1.0	1.1	1.1	1.3	2.0

Discussion and Summary of Results

2.28 A comparison of the peak flows for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in Table 2.9. Comparisons of the growth curves for both methods are shown in Figure 2.2.

2.29 The Statistical method provides a steeper growth curve when compared to the ReFH2 method. The ReFH2 method provides greater flows up to the 50-year event and the Statistical method provides greater flows for events greater than the 1 in 50-year event.

Table 2.9: Comparison of Results

Site code	1 in 2-year peak flows			1 in 100-year peak flows		
	Statistical	ReFH	Ratio	Statistical	ReFH	Ratio
THB001	0.4	0.4	1.0	1.2	1.1	0.9

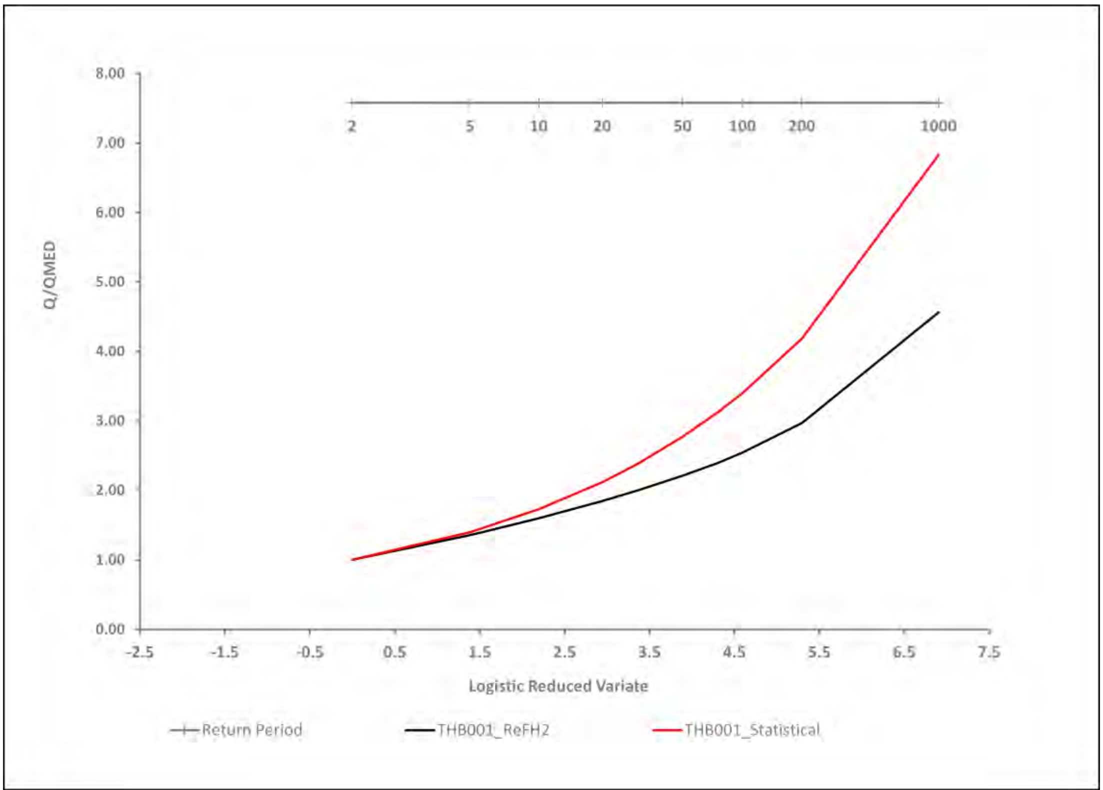

Figure 2.2: Comparison of Statistical Method and ReFH2 Growth Curves

2.30 The final choice of peak flows for input into the modelling study is the FEH Statistical method, this updates the approach utilised within the previous hydrology assessment where the ReFH2 method was chosen for peak flows. The FEH Statistical method benefits from up-to-date flood peak data using growth curves from hydrologically similar catchments to derive a growth curve. ReFH2 will be used to provide a hydrograph shape.

Table 2.10: Flood Estimates from Chosen Method (Statistical)

Site Code	Flood peak (m^3/s) for the following return periods									
	2	5	10	20	30	50	75	100	200	1000
THB001	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.2	1.5	2.5

2.31 The final peak flows have shown to marginally decrease when compared to the previous hydrological assessment, as shown in Table 2.11. These changes are thought to be due to updates to the methodology associated with the pooling groups, in particular the adjustment for non-flood years which now provides deurbanised values.

Table 2.11: Comparison of Previous Hydrology Results

Site code	1 in 2-year peak flows		1 in 100-year peak flows	
	Previous Hydrological Assessment	Updated Hydrological Assessment	Previous Hydrological Assessment	Updated Hydrological Assessment
THB001	0.5	0.4	1.3	1.2

Application of Flows

2.32 In the previous assessment, the flows were applied to the model as a lumped point inflow at the upstream extent of the hydraulic model. The updated model includes a small reach of UOW and therefore, the application of inflows has been updated and is summarised below:

- To derive hydrographs, the ReFH2 hydrographs were scaled to meet the FEH Statistical method peak flows.
- The catchment was divided into sub catchments and the flows were pro-rated to cover the area of the sub-catchments that would drain to the modelled extents of the UOW and the Thurlaston Brook.
- The catchment was split to provide an inflow at the upstream extent of the Thurlaston Brook and an inflow at the upstream extent of the UOW.

2.33 The proportion of the hydrograph applied at each inflow, as well as the type of inflow, is shown in Table 2.12. Figure 2.3 demonstrates how the flows will be applied to the model.

Table 2.12: Hydrograph Proportions

Sub Catchment	Type of Inflow	Proportion of Hydrograph
Thurlaston Brook	Point	76%
UOW	Point	24%

Figure 2.3: Application of Inflows into Model

Climate Change

2.34 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance[8], with a range of projections applied to regionalised 'River Basin Districts'. These districts are further split into 'Management Catchments'. The Thurlaston Brook and UOW fall within the Soar Management Catchment. Table 2.13 identifies the relevant peak river flow allowances.

[8] Environment Agency, Flood risk assessments: climate change allowances: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-1, last accessed June 2024

Table 2.13: 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 21**25)
Upper End	28%	35%	60%
Higher Central	18%	21%	37%
Central	14%	16%	28%

2.35 To estimate the potential future design floodplain under a range of scenarios, the central climate change (CC) allowance for the 2080s will be applied to the 1 in 100-year flood flows. Therefore, the 1 in 100-year + 28%CC event will be simulated.

3. THE HYDRAULIC MODEL UPDATES

Software and Solver

3.1 The TUFLOW version was updated to 2023-03-AC-iDP for all model runs. TUFLOW's Classic solver was retained.

The 1D Domain

3.2 The 1D model extent was extended upstream to include the UOW and the culvert along the Thurlaston Brook. The updated to the 1D extent can be seen in Figure 3.1.

Figure 3.1: 1D Domain

3.3 The majority of the river channel geometry is based on the previous watercourse survey carried out by BWB Consulting in July 2021. The extended 1D model extent, including a small upstream reach of the Thurlaston Brook, culvert and UOW is based on a new watercourse survey carried out by BWB Consulting in March 2024. The survey also captured hydraulic structures that were present such as bridges and culverts. The river channel survey is available as Appendix 2.

3.4 The channel sections were truncated at the top-of-bank from survey data, at what would be the interface with the 2D domain.

3.5 Roughness values for new channel sections and structures have been reviewed and are largely similar to previous values used.

3.6 One hydraulic structure was added to the 1D domain, the data for which was collected during the watercourse survey. The hydraulic structure is summarised in Table 3.1.

Table 3.1: Additional Hydraulic Structures

Network ID, Cross Section ID	Model Details	Photograph/Survey Section
THURL_01307	Description: Farm Track Culvert NGR: 303217, 445025 Domain: 1D Unit Type: Circular Culvert Dimensions: 0.5m Upstream Invert Level: Not surveyed, therefore downstream invert of 125.53m AOD applied Downstream Invert Level: 125.53m AOD Length: 4m **Manning's N:** 0.02 Blockage: 0% Spill/Bypass: Modelled in 2D domain.	

3.7 A review of the previous survey was undertaken and the twin culverts beneath Brascote Lane were updated to reflect the survey.

3.8 Model inflows were applied to the 2D domain, in accordance with the previous modelling approach and are discussed later in Section 3.

3.9 No further changes were made to the 1D domain.

1D/2D Links

3.10 The 1D channel was linked to the floodplain using "HX" links. These transfer the calculated water level from the 1D cross sections into the 2D floodplain, providing that the water level is above the level of the cell that the HX link is located in. Therefore, HX links should be digitised along the top of bank of the watercourse visible in LiDAR data or along the crest of any embankments if present.

3.11 For the upstream limit of both the Thurlaston Brook and UOW, the 1D domain has been linked to the 2D domain through a "HX" link. This transfers the calculated water level from between the 2D domain and 1D cross sections. The approach to 1D/2D links elsewhere was retained as per the previous model.

3.12 The river channel previously deactivated to ensure that it was modelled in the 1D domain was extended upstream to include the culvert and the UOW. 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.

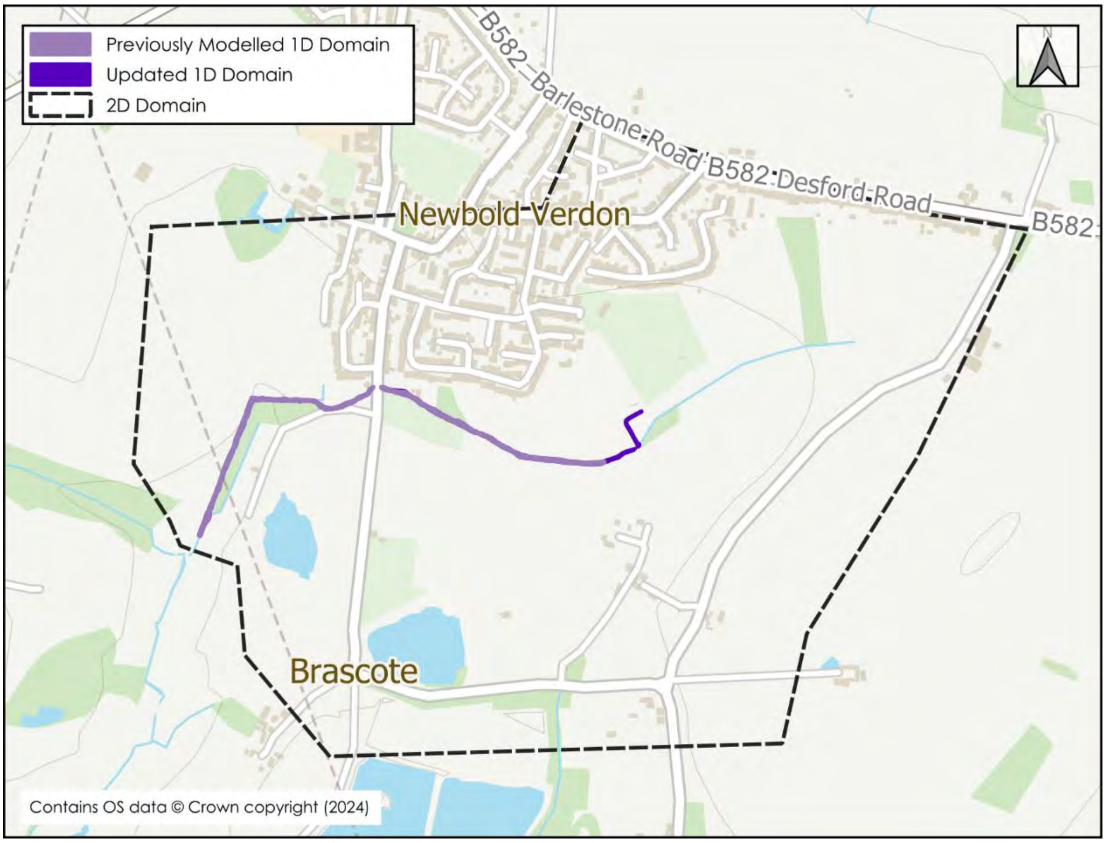

Figure 3.2: 2D Active Area

The 2D Domain

3.13 The general floodplain topography is based on the latest available LiDAR data and topographical survey (where appropriate).

3.14 The LiDAR was updated to the 2022 version and subsequently bank points and 2D elements of the watercourse were reviewed and updated where relevant.

3.15 The 2D z-shape representing the upstream channel of the Thurlaston Brook was retained and a further 2D z-shape was added to extend the UOW further upstream than the watercourse survey.

3.16 The QT (flow vs time) boundary, used to represent the fluvial inflows, was updated to include a second point inflow at the upstream extent of the UOW. Figure 2.3 shows where the boundary units were applied.

3.17 Floodplain roughness values for 'Water' were amended to include the UOW.

3.18 No further changes were made to the 2D domain.

Stability, Warnings and Messages

3.19 TUFLOW has a number of indicators available to assess the stability of a model. These differ slightly between the Classic and HPC solver, the Classic solver was used for this study. 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 +/-2% is considered acceptable.
- Velocities – Unusually high velocities or circulating vectors are usually a sign of instabilities.

3.20 The time series graphs were reviewed along the modelled reaches and no significant issues were present that could compromise results at the site. The river channel stages were shown to peak approximately 7.5 hours into the event.

3.21 No 1D or 2D negative depths were reported.

3.22 The baseline simulations reported a peak cumulative mass error within +/- 2% except for in the 1 in 1000-year event. The maximum peak mass error for the 1 in 1000-year event was -3.38%. The mass error has been reviewed spatially and is largely shown to occur downstream of the Phase 2 site, upstream of Brascote Lane where water overtops the banks. The mass balance is not considered to have an impact on the model results at the Phase 2 site or the flood mechanisms informing these.

Model Runs

3.23 In order to achieve the study objectives, the simulations summarised in Table 3.2 were completed.

Table 3.2: Model Runs

Model Geometry	Return Periods	Comments
Baseline	1 in 30-Year 1 in 100-Year 1 in 1000-Year 1 in 100-Year+28%CC	Representative of existing conditions.
Post-Development	1 in 30-Year 1 in 100-Year 1 in 100-Year+28%CC	Baseline conditions with updates for Proposed Development, including 2x watercourse crossings and proposed flood storage area.
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%.
Downstream Boundary +	1 in 100-Year	1D HT downstream boundary unit was decreased by 150mm. The 2D HQ slope value was increased by 20%.
Downstream Boundary -	1 in 100-Year	1D HT downstream boundary unit was increased by 150mm. The 2D HQ slope value was decreased by 20%.
Blockage 1 (THURL_1113_P)	1 in 100-Year	50% blockage of 1.5m x 1.5m proposed culvert beneath the eastern watercourse crossing.
Blockage 2 (THURL_0924_P)	1 in 100-Year	50% blockage of 1.5m x 1.5m proposed culvert beneath the western watercourse crossing.
Blockage 3 (THURL_0660a & THURL_0660b)	1 in 100-Year	75% blockage of each of the two 600mm diameter pipes that are culverted beneath Brascote Lane.

4. BASELINE RESULTS

4.1 The results from the existing conditions model are mapped within Appendix 5 and are summarised below.

4.2 The floodplain extents at the Phase 2 site are shown in Figure 4.1 with modelled flood levels shown in Table 4.1.

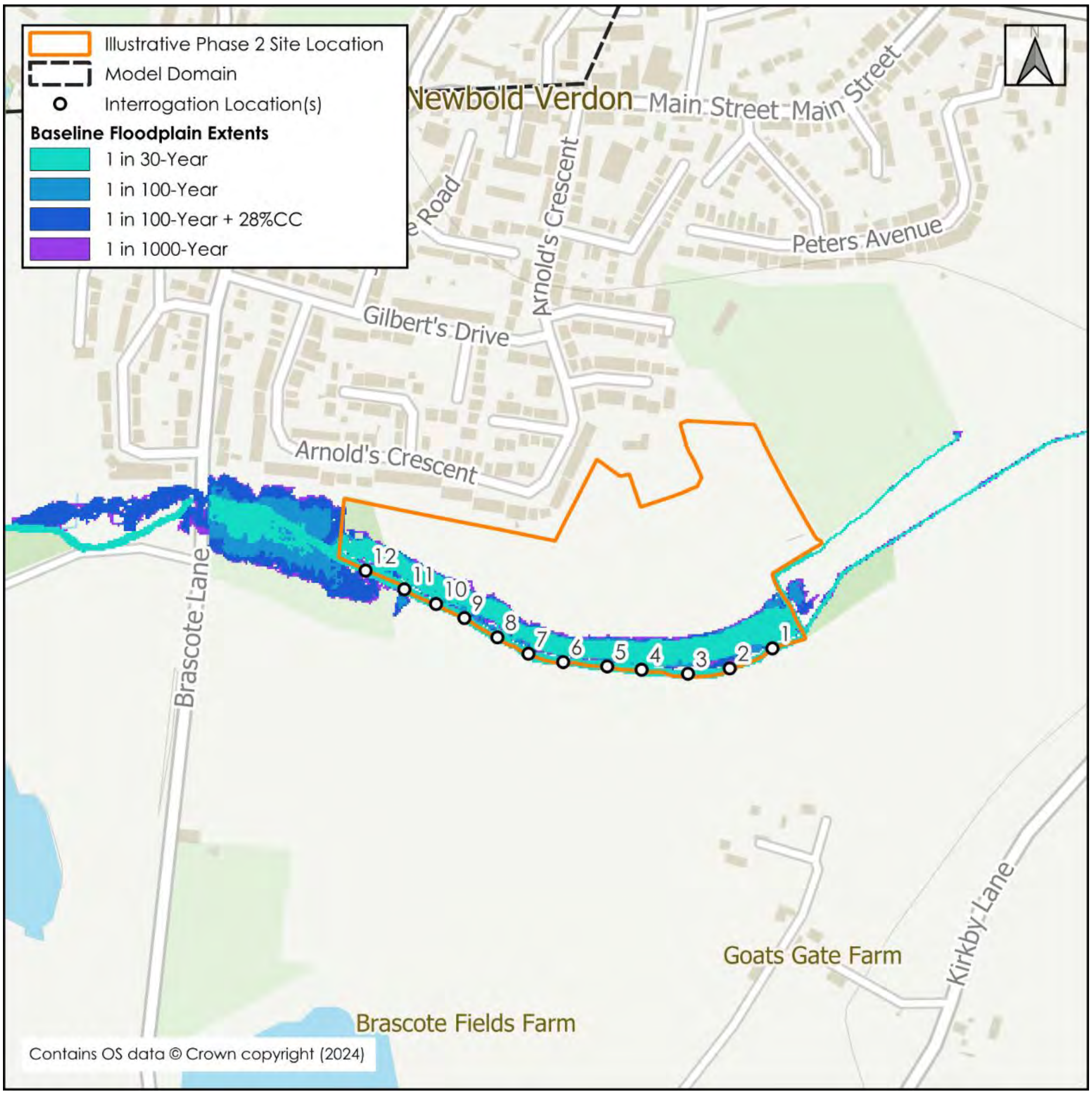

Figure 4.1: Baseline Fluvial Floodplain Extents

Table 4.1: Modelled Peak Flood Levels (m AOD)

Node	1 in 30-Year	1 in 100-Year	1 in 100-Year + 22%CC	1 in 1000-Year
1	125.45	125.47	125.49	125.52
2	125.06	125.07	125.08	125.11
3	124.73	124.75	124.77	124.81
4	124.45	124.48	124.50	124.57
5	124.23	123.25	124.27	124.35
6	123.88	123.90	123.93	124.02
7	123.61	123.63	123.66	123.75
8	123.38	123.40	123.42	123.51
9	123.07	123.09	123.16	123.26
10	122.78	122.81	122.94	123.04
11	122.59	122.68	122.91	122.98
12	122.40	122.63	122.90	122.96

4.3 The floodplain extents within the Phase 2 site are shown to increase when compared to the previous modelling, as shown in Figure 4.2. This is due to the addition of the culvert which acts as a restrictive structure and results in water backing up into the UOW before overtopping the banks and flowing along the floodplain within the Phase 2 site. This structure was omitted from the previous model, however, a blockage scenario was previously undertaken to represent the channel as 100% blocked at this location and the modelled blockage scenario results are broadly similar to the updated baseline extents. Therefore, the updated extents are considered to be representative of baseline conditions at the site.

Figure 4.2: Comparison Between Previous and Updated Hydraulic Model Extents

4.4 The flooding mechanisms around the culverts beneath Brascote Lane are broadly similar to those outlined as part of the previous assessment. The increase in floodplain extents around Brascote Lane is due to the changes to the modelled structures beneath Brascote Lane to represent a more restrictive structure than was previously modelled.

5. POST-DEVELOPMENT MODELLING

Philosophy

5.1 The proposals comprise a residential development located to the north of the Thurlaston Brook. Access to the Phase 2 site is proposed from the south via two proposed watercourse crossings, to the east and the west.

5.2 It is proposed that the culverts beneath the eastern and western watercourse crossings are 1.5m in height with a width of 1.5m. 250mm of the culvert bed will be buried in line with CIRIA sedimentation allowance guidance[9] and a minimum 250mm freeboard will be provided from the soffit level to the peak flood level in the 1 in 100-year + 28%CC event.

5.3 It is also proposed that a flood storage area is provided in order to capture and attenuate flood flows within the Phase 2 site. The concept flood storage area has been designed with 1:4 slopes and a depth of between 0.9m – 1.2m to allow a 300mm freeboard to be provided along the northern and western edge of the basin, adjacent to the proposed development. The proposed flood storage area is subject to detailed design.

5.4 Minor bank re-profiling has been undertaken on the left bank of the Thurlaston Brook, downstream of the western watercourse crossing to help resolve a small area of out of bank flooding.

Representation in Hydraulic Model

5.5 The baseline model was updated to include:

- The proposed 1.5m x 1.5m box culverts were represented within the 1D model domain, including the sedimentation allowance described above in line with CIRIA guidance.
- The deck levels of the proposed crossings were represented using 2D z-shapes with the elevations set 1m above the soffit level of the proposed culverts to allow for any proposed services which may need to be accommodated within the crossings.
- The proposed flood storage area, and associated overflow, was represented within the 2D model domain using a z-shape. A piped outfall from the flood storage area to the watercourse was represented within the 1D domain. A 2D z-shape has also been used to reinforce ground levels surrounding the basin.
- The 2d z-line layer representing the banks was updated downstream of the western watercourse crossing.
- The hydrology was adjusted to include the proposed runoff rates from the Phase 2 site.

5.6 No further changes were made to the existing model. A proposed model schematic is shown in Figure 5.1.

[9] Culvert, screen and outfall manual C786 (CIRIA, 2019)

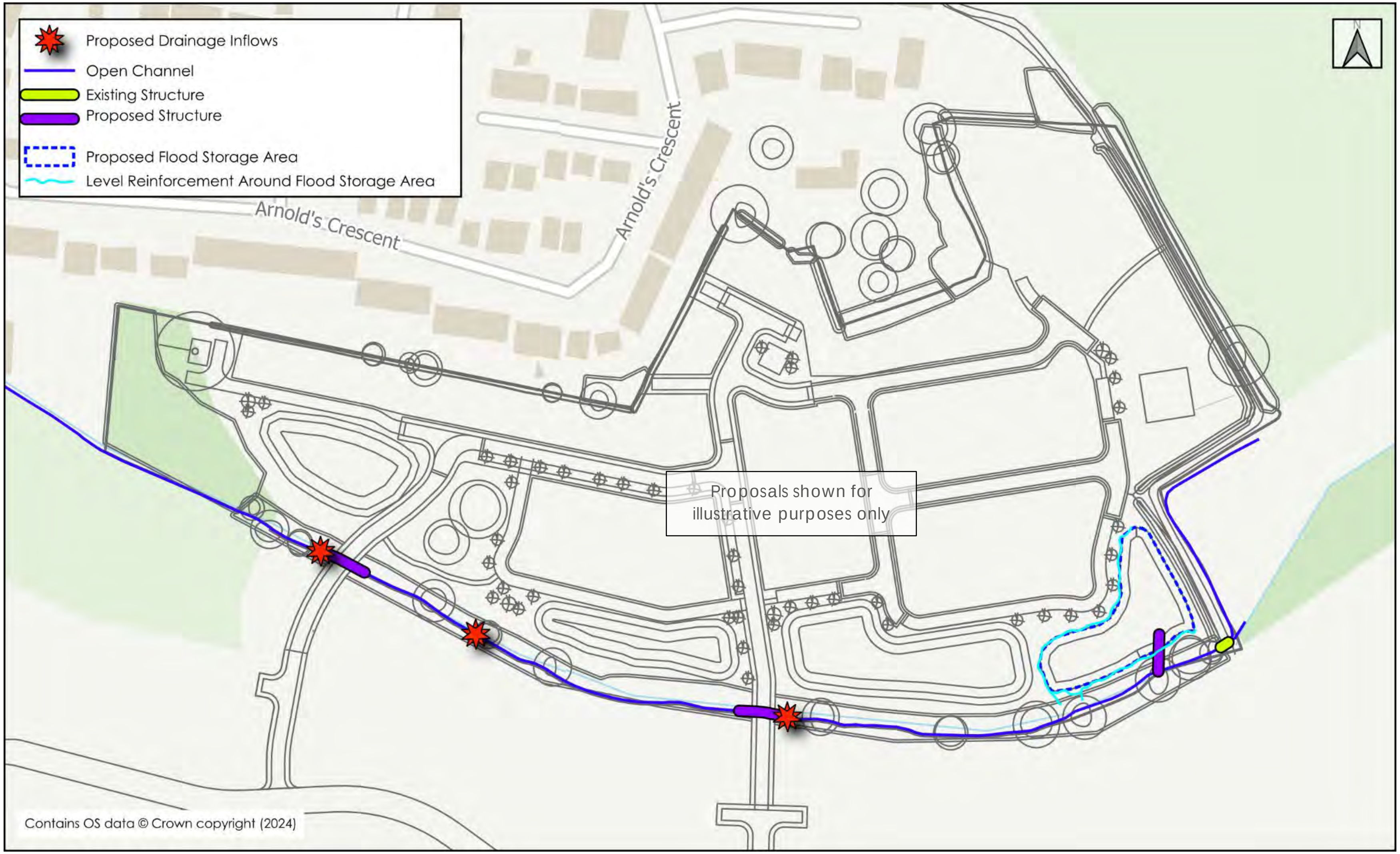

Figure 5.1: Proposed Model Schematic

Model Results

5.7 The post-development model results are included in Figure 5.2 and Appendix 6.

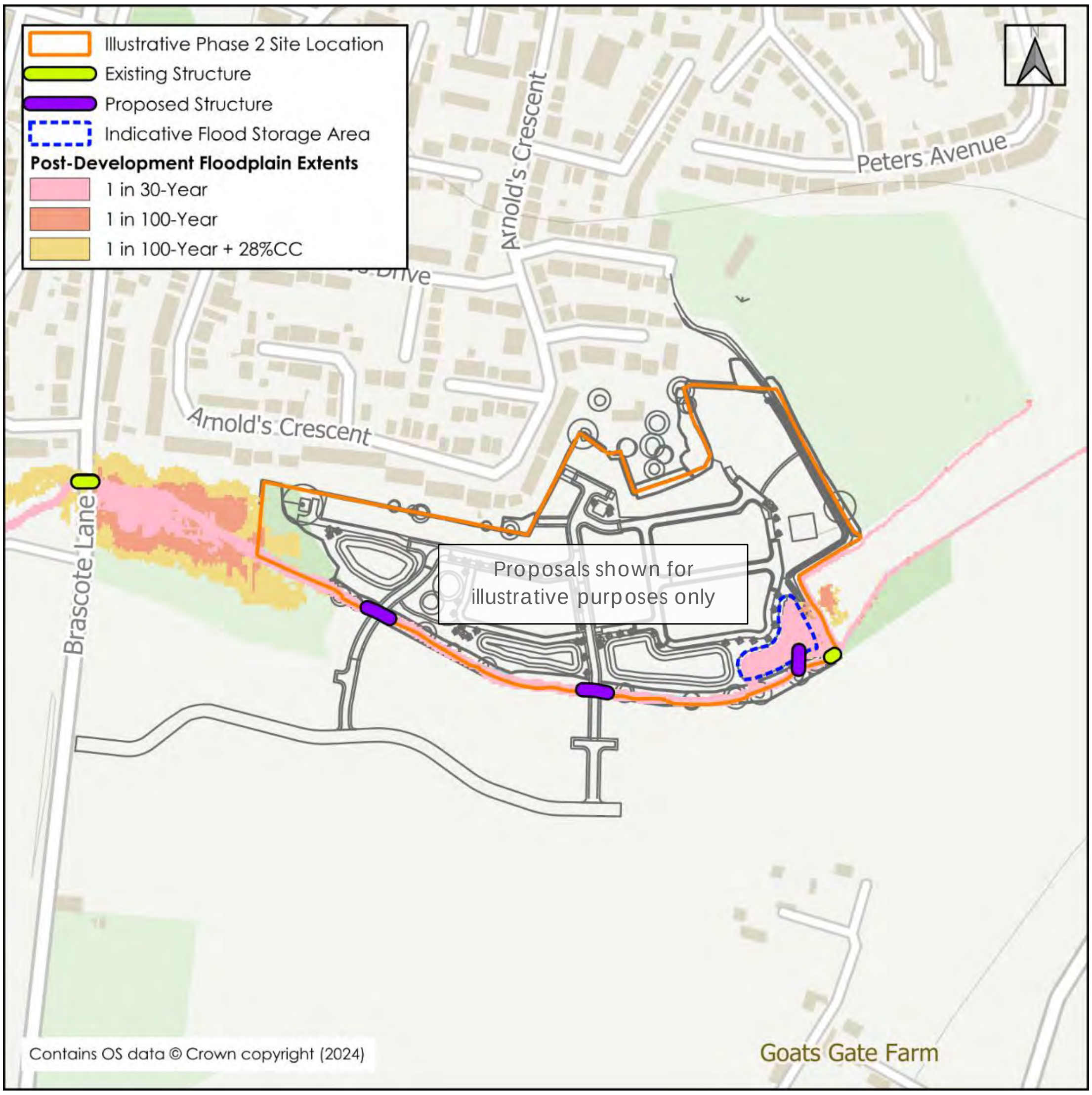

Figure 5.2: Post-Development Floodplain Extents

5.8 The results show the proposed development is located outside of the flood extents in all modelled return periods up to, and including, the 1 in 100-year + 28%CC design event.

5.9 A minimum of 250mm freeboard from the soffit level to the peak flood level is achieved within both the proposed eastern and western culverts during the 1 in 100-year + 28%CC event. The freeboard provided is in line with the CIRIA C786 guidance[9]. Cross sections of the proposed culverts and peak flood level during the 1 in 100-year + 28%CC event are shown in Figure 5.3 and Figure 5.4.

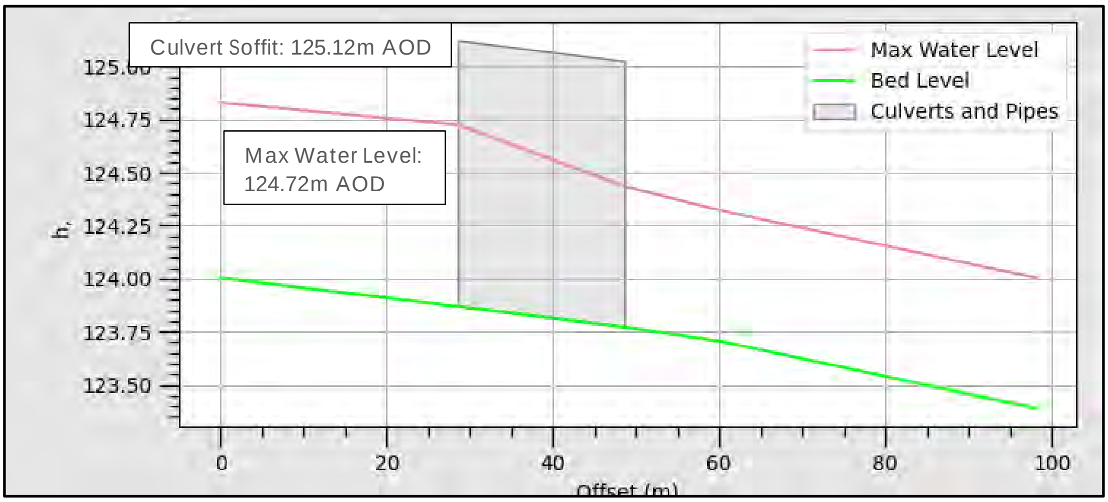

Figure 5.3: Eastern Proposed Watercourse Crossing Culvert

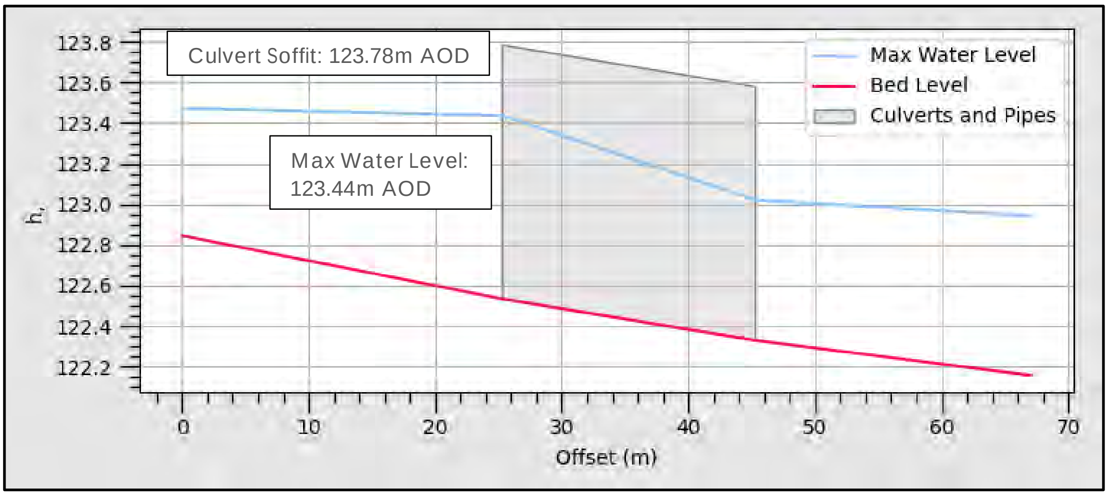

Figure 5.4: Western Proposed Watercourse Crossing Culvert

Impact Analysis

5.10 The post-development modelled peak flood levels have been compared to the equivalent baseline peak flood levels to establish off site impacts as shown in Figure 5.5 and included as Appendix 6.

5.11 Based on the latest EA guidance, this has been assessed for the 1 in 100-year + 28% (central) climate change allowance.

5.12 There is an increase in flood depths and extents within the proposed flood storage area by design, however, the flood storage area largely removes the floodplain on the right bank of the Thurlaston Brook. There is an increase in flood levels within the channel adjacent to the Phase 2 site, however, modelled flood levels are shown to remain within the channel.

5.13 Peak flood levels downstream of the site are shown to have no change (within model tolerances) or decrease during the 1 in 100-year + 28%CC design event.

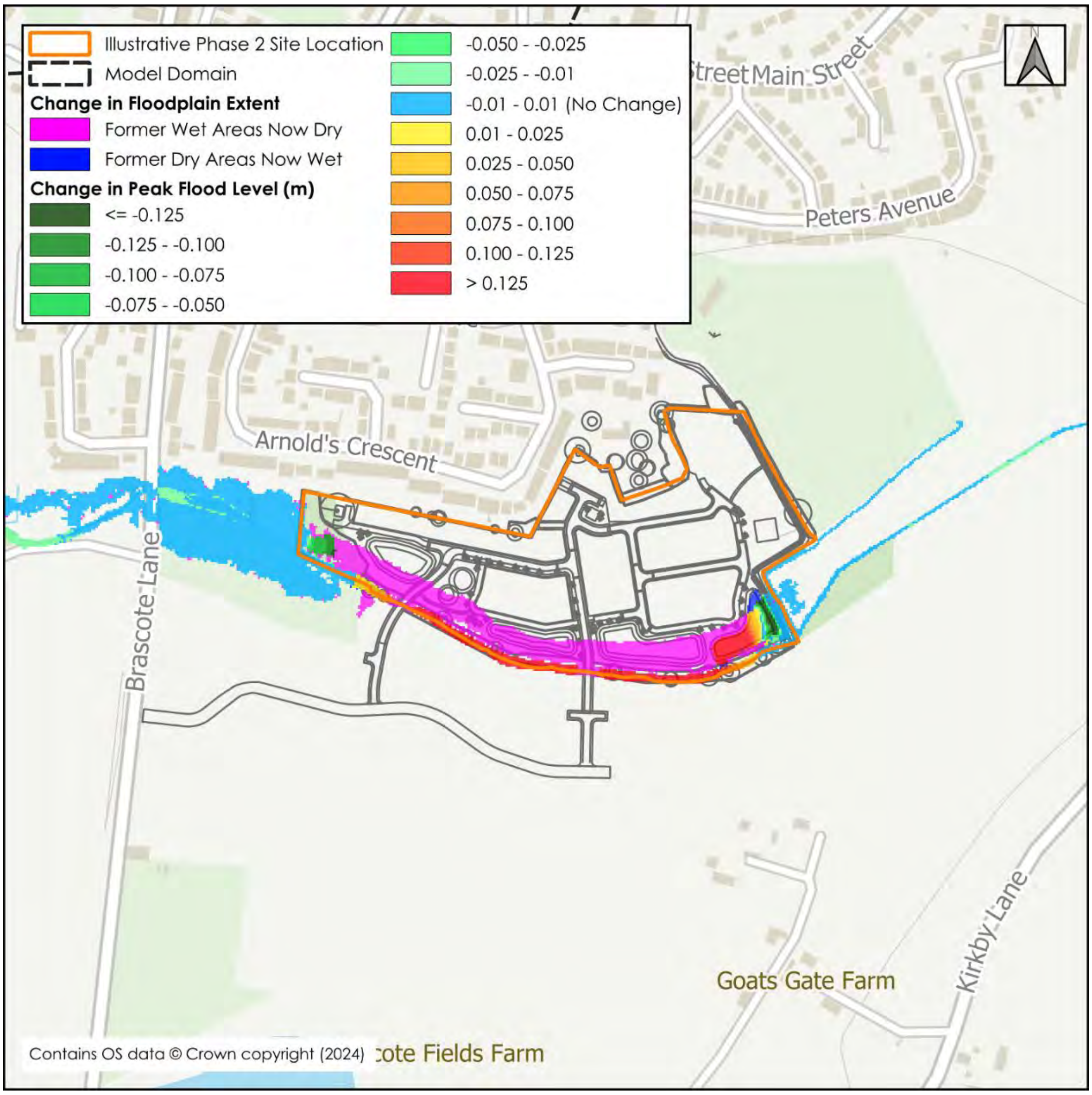

Figure 5.5: Baseline and Post-Development Comparative Analysis (1 in 100-Year + 28%CC)

6. SENSITIVITY TESTING

6.1 Sensitivity tests have been carried out for the proposed scenario 1 in 100-year event. Tests were undertaken on the downstream boundary, Manning's n roughness coefficients and blockage of structures.

6.2 The difference in peak water level and floodplain extent between the sensitivity test scenarios and the 1 in 100-year post-development event are mapped in Appendix 7.

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

Roughness

6.4 Increasing and decreasing the roughness values in the channel and at structures as well as in the floodplain tests how seasonal variation and maintenance regimes may affect the flood risk posed to the site.

6.5 A 20% increase in Manning's n roughness coefficient, representative of a period without maintenance, leads to increased peak flood levels and floodplain extents across the model domain. Within the Phase 2 site, peak flood levels are expected to increase by up to 70mm compared to baseline conditions.

6.6 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. Subsequently, more flood water would likely be retained on the floodplain during these conditions, therefore resulting in a general increase in flood levels. Similarly, greater in-channel Manning's values would be expected to increase water levels as a rougher channel would detrimentally impact flow conveyance.

6.7 A 20% decrease in Manning's n roughness coefficient, representative of a period with maintenance, largely leads to decreases in peak flood levels and floodplain extents across the model domain. Peak flood levels and extents are shown to increase upstream of the culvert beneath Brascote Lane. Within the Phase 2 site, peak flood levels are expected to decrease by up to 130mm within the south of the site, however, peak flood levels are expected to increase by up to 200mm in the south west of the site.

6.8 It is expected that the reduced roughness will increase the conveyance of the floodplain and culverts, allowing water to flow more freely through the system. However, this means water is backing up within the Brascote Lane culvert more quickly, resulting in an increase in flood depths and extents upstream of Brascote Lane.

6.9 Whilst an increase and decrease in roughness would increase flood levels in the site, the increases do not impact the built development which is shown to remain outside of the modelled flood extents.

Downstream Boundary

6.10 The downstream boundary is located approximately 700m downstream of the Brascote Lane. The downstream boundary consists of a 1D head-time (HT) boundary and a 2D head-flow (HQ) boundary. 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 350mm of floodplain.

6.11 An increase in slope (+20% applied to the 2D HQ boundary in combination with a 150mm decrease in the 1D HT boundary water level) leads to predominately no change across the model domain within the model tolerances. There is shown to be a small increase and decrease in peak flood levels up to +/- 150mm within the channel immediately upstream of the downstream boundary. Upstream of Brascote Lane, there is shown to be an increase in peak flood levels, this is due to some instabilities within the model as a result of the culvert.

6.12 A reduction in slope (-20% applied to the 2D HQ boundary in combination with a 150mm increase in the 1D HT boundary water level) leads to predominantly no change across the model domain within the model tolerances. There is shown to be a small increase in peak flood levels by up to 150mm within the channel immediately upstream of the downstream boundary. Upstream of Brascote Lane, there is shown to be an increase in peak flood levels, this is due to some instabilities within the model as a result of the culvert.

6.13 The peak flood level at the site is slightly altered during the increase and decrease in gradient at the downstream boundary, however, the changes in flood level are minimal (50mm) and are not thought to have an impact on the flooding mechanisms and therefore does not affect the aim of the exercise. The proposed built development is not impacted and is shown to remain outside of the modelled flood extents.

Blockage Scenarios

6.14 Blockage testing was undertaken at four individual locations over three blockage scenarios to understand the impacts of blocking key structures. The locations of the blockages are annotated on the respective mapping, included as Appendix 7. Smaller culverts are more at risk of a significant blockage due to their limited capacity. Therefore, the magnitude of the blockage was determined by the size of the culvert, as shown in Table 6.1.

Table 6.1: Sensitivity Test Blockage Percentages

Culvert Diameter (m)	Blockage Applied
< 0.5	100%
0.5 – 1.0	75%
1.0 – 1.5	50%
> 1.5	25%

Blockage 1

6.15 A 50% blockage of the proposed 1.5m height x 1.5m width box culvert beneath the eastern watercourse crossing was tested within the hydraulic model.

6.16 The blockage scenario leads to an increase in flood levels and extents within the Phase 2 site. Flows are shown to overtop the right bank of the Thurlaston Brook upstream of the proposed crossing and flow along the floodplain within the site. Flood levels immediately upstream of the culvert are predicted to increase by up to 440mm. Flood levels immediately downstream of the culvert are shown to decrease, however, they slightly increase where the floodplain flows are routed over the right bank and re-enter the channel.

6.17 While the blockage scenario is shown to result in increases in flood extents in the Phase 2 site, the proposed residential development extent is largely located outside of the modelled flood extent. In addition, it is recommended that finished floor levels are raised a minimum of 600mm above the modelled 1 in 100-year + 28%CC event, which will provide resilience against the blockage scenario.

Blockage 2

6.18 A 50% blockage of the proposed 1.5m height x 1.5m width box culvert beneath the western watercourse crossing was tested within the hydraulic model.

6.19 The blockage scenario leads to an increase in flood levels and extents within the site. Flows are shown to overtop the left and right banks of the Thurlaston Brook upstream of the proposed crossing and flow along the floodplain within the site. Flood levels immediately upstream of the culvert are predicted to increase by up to 240mm.

6.20 While the blockage scenario is shown to result in increases in flood extents in the Phase 2 site, the proposed residential development extent is located outside of the modelled flood extent. In addition, it is recommended that finished floor levels are raised a minimum of 600mm above the modelled 1 in 100-year + 28%CC event, which will provide resilience against the blockage scenario.

Blockage 3

6.21 Two 600mm diameter circular culverts are located beneath Brascote Lane. A 75% blockage was applied to each opening.

6.22 The blockage scenario leads to an increase in flood levels and extents within the site. Flows are shown to back up upstream of the culvert. Flood levels immediately upstream of the culvert are predicted to increase by up to 350mm. Flood levels downstream of the culvert are shown to decrease.

6.23 While the blockage scenario is shown to result in increases in flood extents in the Phase 2 site, the proposed development extent is located outside of the modelled flood extent. In addition, it is recommended that finished floor levels are raised a minimum of 600mm above the modelled 1 in 100-year + 28%CC event, which will provide resilience against the blockage scenario.

7. SUMMARY & RECOMMENDATIONS

7.1 Please note that this conclusion should be read in conjunction with the study limitations and assumptions in Section 1.

7.2 BWB Consulting Ltd has been commissioned by Richborough (the Client) to undertake updates to a hydraulic model of the Thurlaston Brook. The purpose of the updates is to include a representation of a UOW and structure which were previously omitted from the model and ensure that the modelled flows are in accordance with current best practice methods.

7.3 The modelled flood flows have been informed by a hydrological review of the catchment associated with the Thurlaston Brook. The latest climate change allowances have been incorporated into the hydrological assessment. The final peak flows have shown to marginally decrease when compared to the previous hydrological assessment. These changes are thought to be due to updates to the methodology associated with the pooling groups, in particular the adjustment for non-flood years which now provides deurbanised values.

7.4 The baseline model has also been updated to include for revised watercourse survey, the latest LiDAR data and run in the latest software. The floodplain extents within the Phase 2 site are shown to increase when compared to the previous modelling. This is due to the addition of the culvert which acts as a restrictive structure and results in water backing up into the UOW before overtopping the banks and flowing along the floodplain within the Phase 2 site.

7.5 The hydraulic model has been updated to include for a post-development scenario which includes for consideration of the proposed development (including proposed watercourse crossings and flood storage area). The results show that the flood storage area captures and attenuates flows which removes the floodplain along the right bank of the Thurlaston Brook. The watercourse crossings will be buried in line with CIRIA sedimentation allowance guidance and provide the recommended freeboard from the soffit level to the peak flood level in the 1 in 100-year + 28%CC event.

7.6 The modelling has shown that a 20% increase and decrease in Manning's n roughness coefficient leads to an increased and decreased peak flood level and floodplain extents. However, the increased peak flood levels do not impact the built development which is shown to remain outside of the modelled flood extents.

7.7 Blockages of culverts result in increased flood levels and extents within the Phase 2 site. However, the proposed residential development extent is located outside of the modelled flood extents associated with all blockage scenarios and it is recommended that finished floor levels are raised a minimum of 600mm above the modelled 1 in 100-year + 28%CC event, which will provide resilience against the potential risk of blockage.

7.8 Additional testing shows the model results are predominantly not sensitive to changes in downstream boundary.

7.9 The sensitivity tests do not have implications for flood risk to the development.

APPENDICES

Appendix 1: 2021 Hydraulic Model Report

A CAF GROUP COMPANY

ENVIRONMENT

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

BWB

ENVIRONMENT

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

Birmingham
Livery Place, 35 Livery Street, Colmore Business District, Birmingham, B3 2PB
T: 0121 233 3322

Cambridge
14-16 High Street, Histon, Cambridge
CB24 9JD
T: 01223 235 173

Leeds
Whitehall Waterfront, 2 Riverside Way, Leeds
LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street, Manchester, M1 3HU
0161 233 4260

Market Harborough
12a Woodcock House, Compass Point Market Harborough, Leicestershire, LE16 9HW
T: 01858 455020

Nottingham
Waterfront House, Station Street, Nottingham NG2 3DQ
T: 0115 924 1100

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2	24/02/22	Finalised Site Layout	Max Brambani BSc (Hons) PgCert MCIWEM	Robin Green BSc (Hons)	Matthew Day BA (Hons) MSc FRGS MCIWEM C.WEM C.Sci C.Env

Notice

All comments and proposals contained in this report, including any conclusions, are based on information available to BWB Consulting during investigations. The conclusions drawn by BWB Consulting could therefore differ if the information is found to be inaccurate or misleading. BWB Consulting accepts no liability should this be the case, nor if additional information exists or becomes available with respect to this scheme.

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(i) The date on which this assessment was undertaken, and
(ii) The date on which the final report is delivered

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All Environment Agency mapping data used under special license. Data is current as of September 2021 and is subject to change.

The information presented, and conclusions drawn, are based on statistical data and are for guidance purposes only. The study provides no guarantee against flooding of the study site or elsewhere, nor of the absolute accuracy of water levels, flow rates and associated probabilities.

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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.

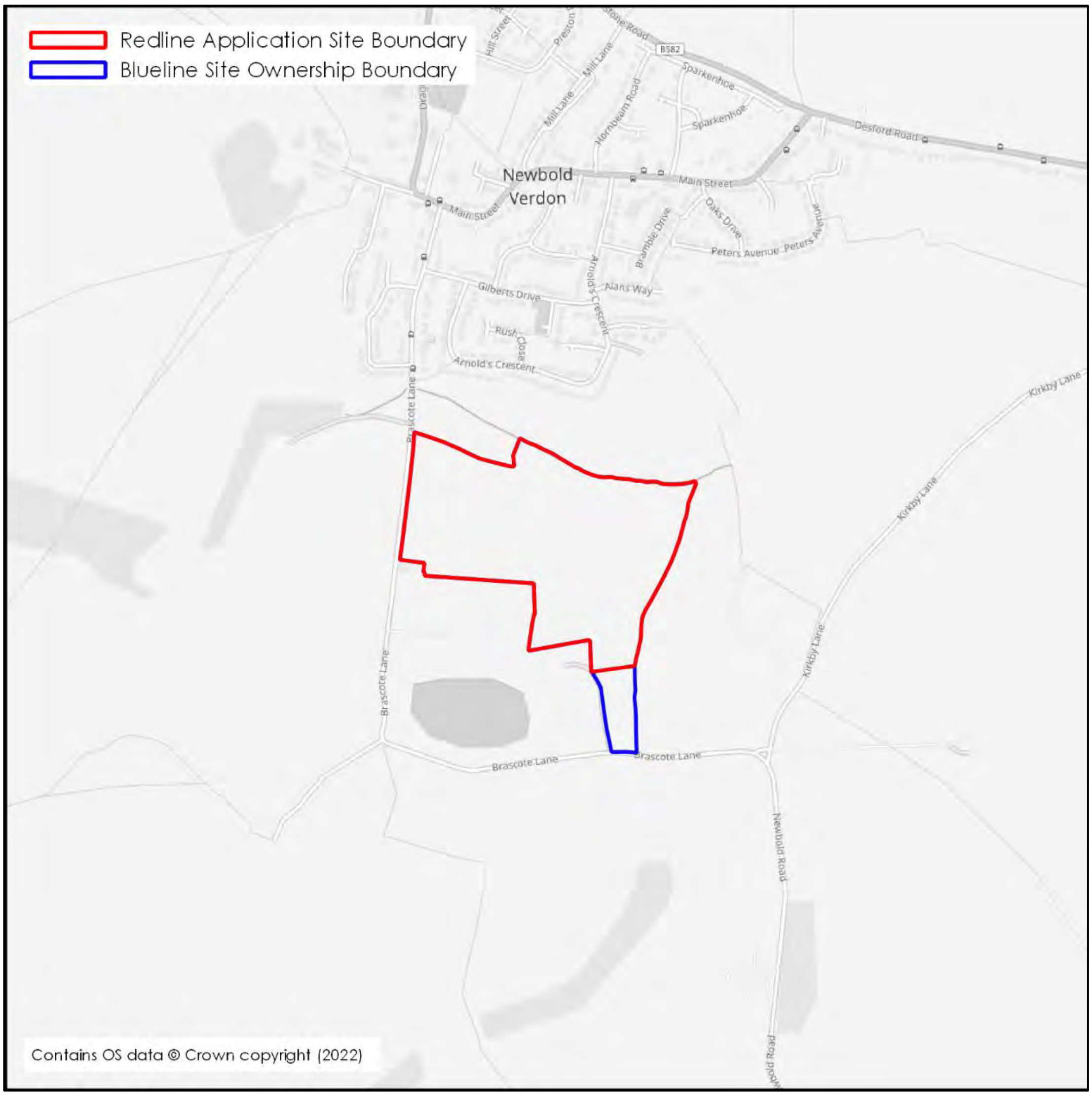


Figure 1.1: Site Location Plan

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.

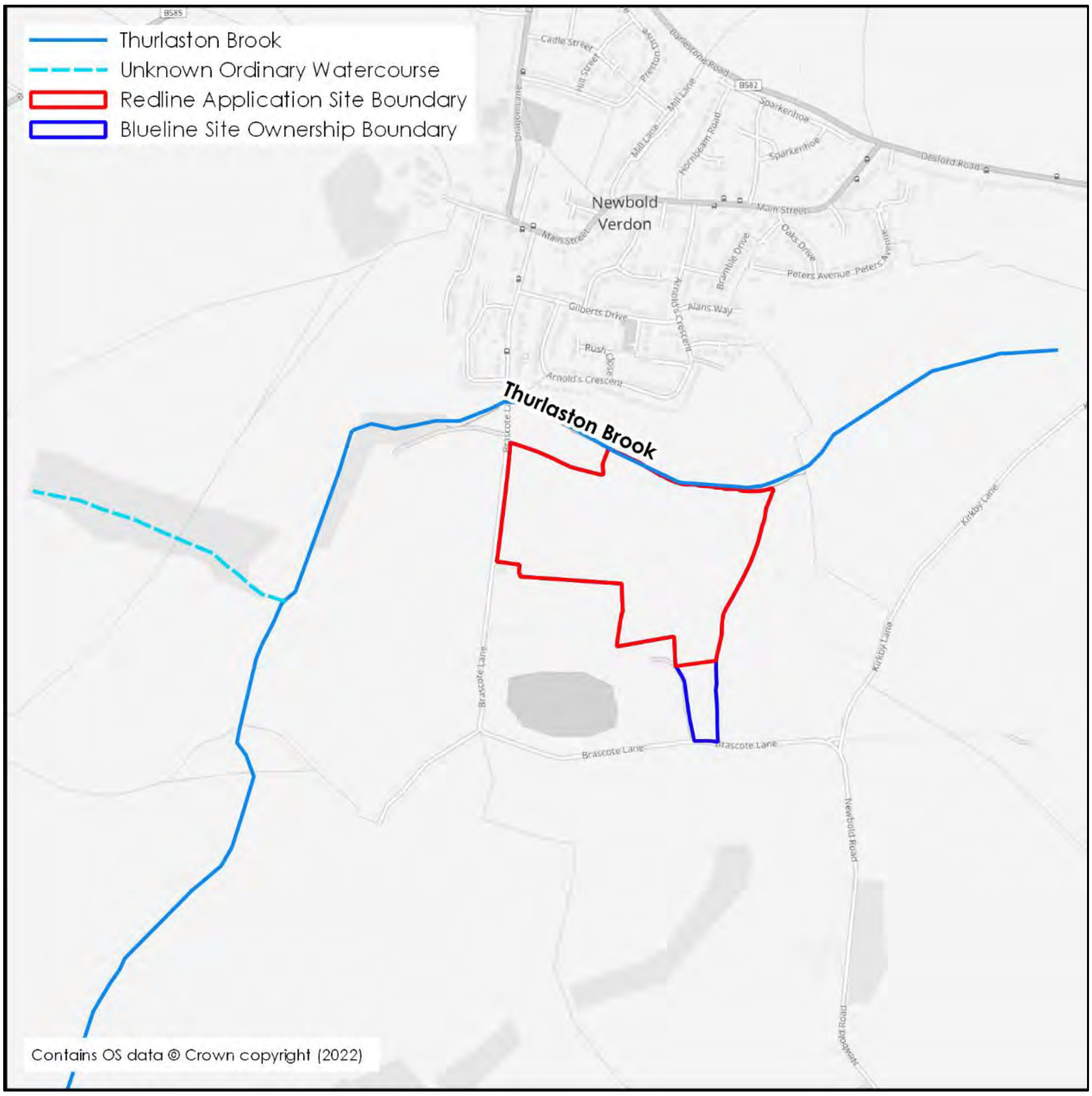


Figure 1.2: Watercourse Network

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.

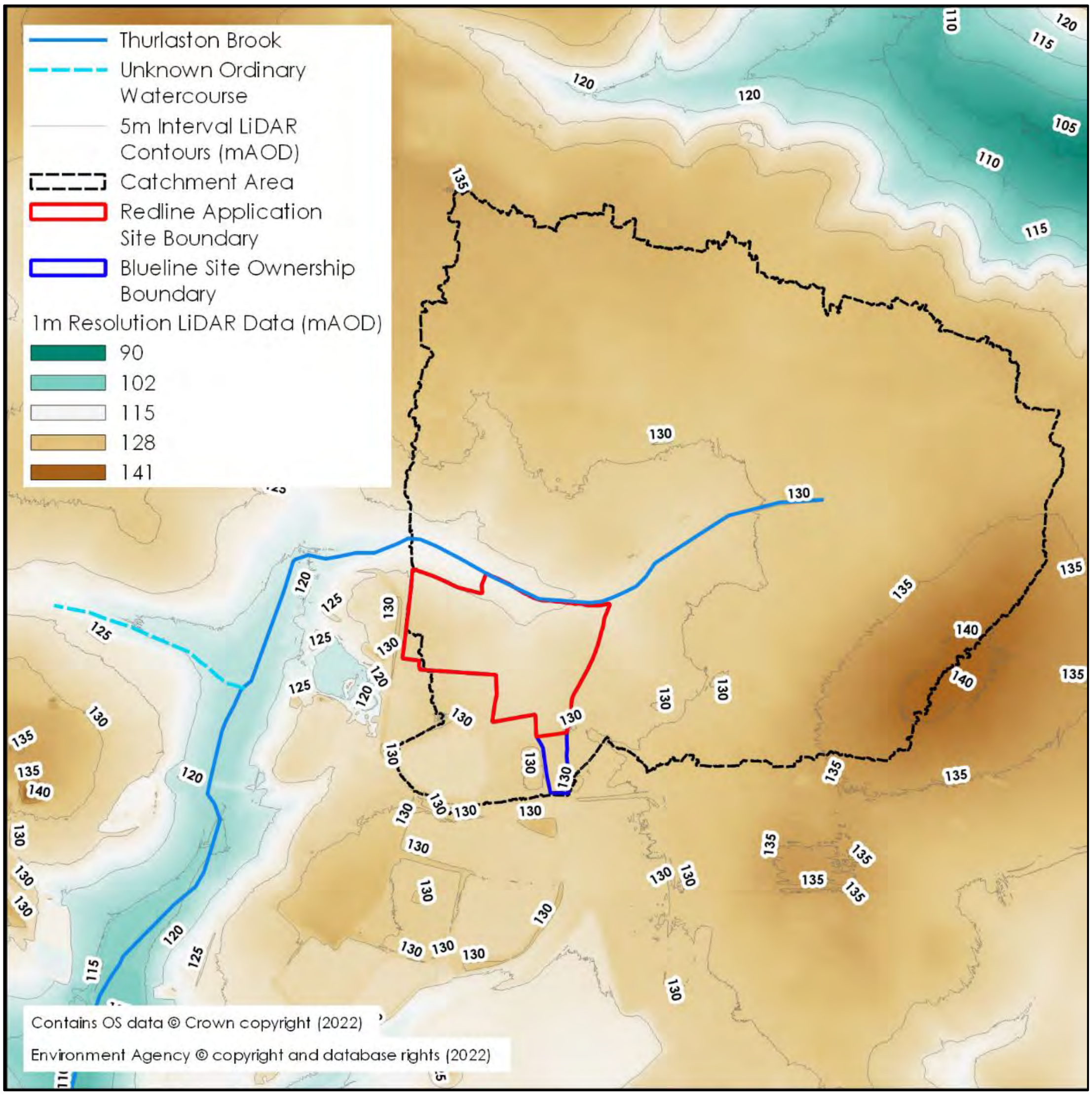


Figure 1.3: Site Topography

Previous Studies & Available Data

<u>EA Recorded Flood Outlines</u>

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.

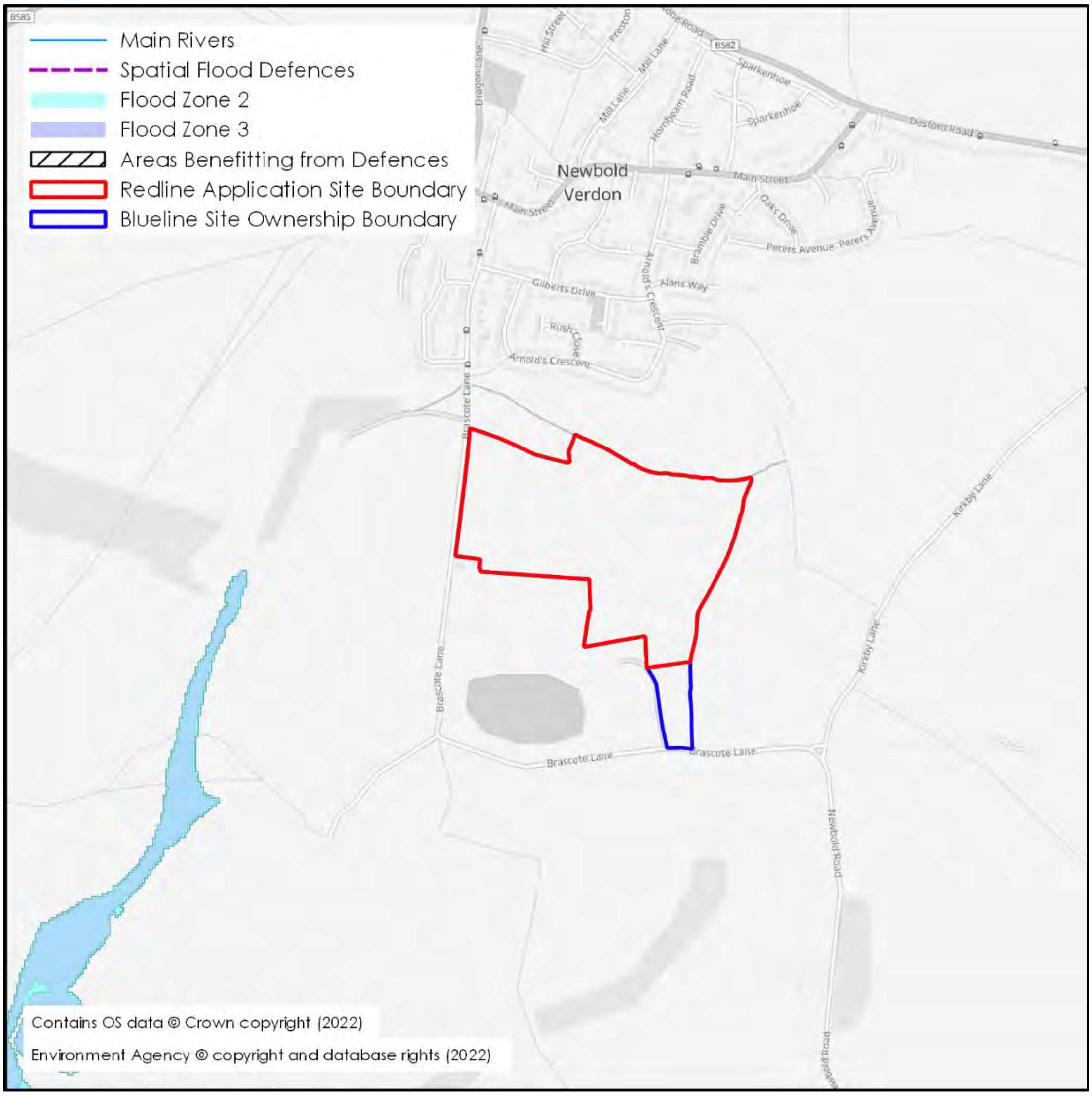


Figure 1.4: EA Flood Map for Planning

<u>Risk of Flooding from Surface Water</u>

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.

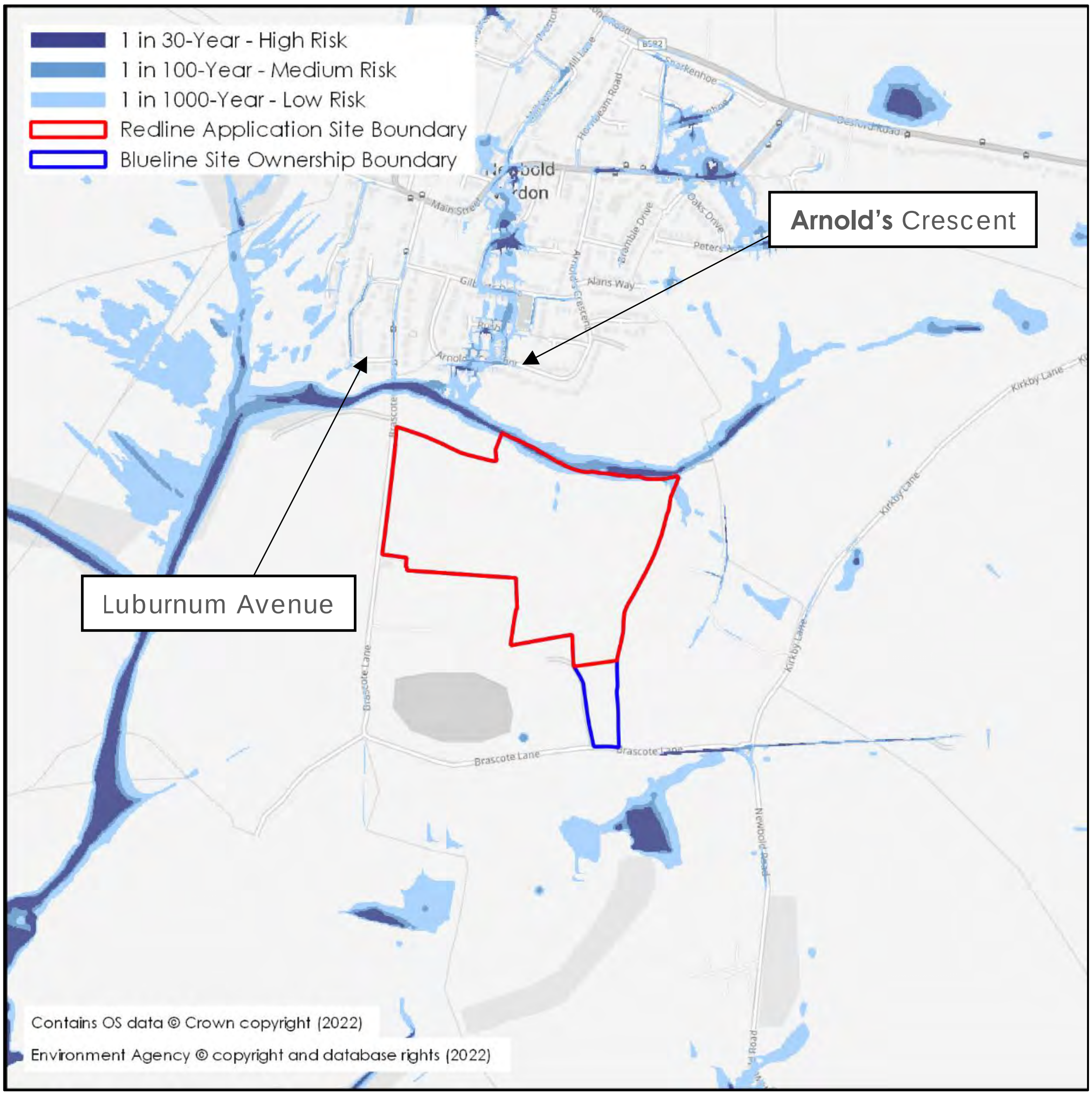


Figure 1.5: Risk of Flooding from Surface Water Map

<u>Other Sources of Data</u>

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 (2.14km^2), 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 guidance[1]. 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 (2.14km^2) 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.

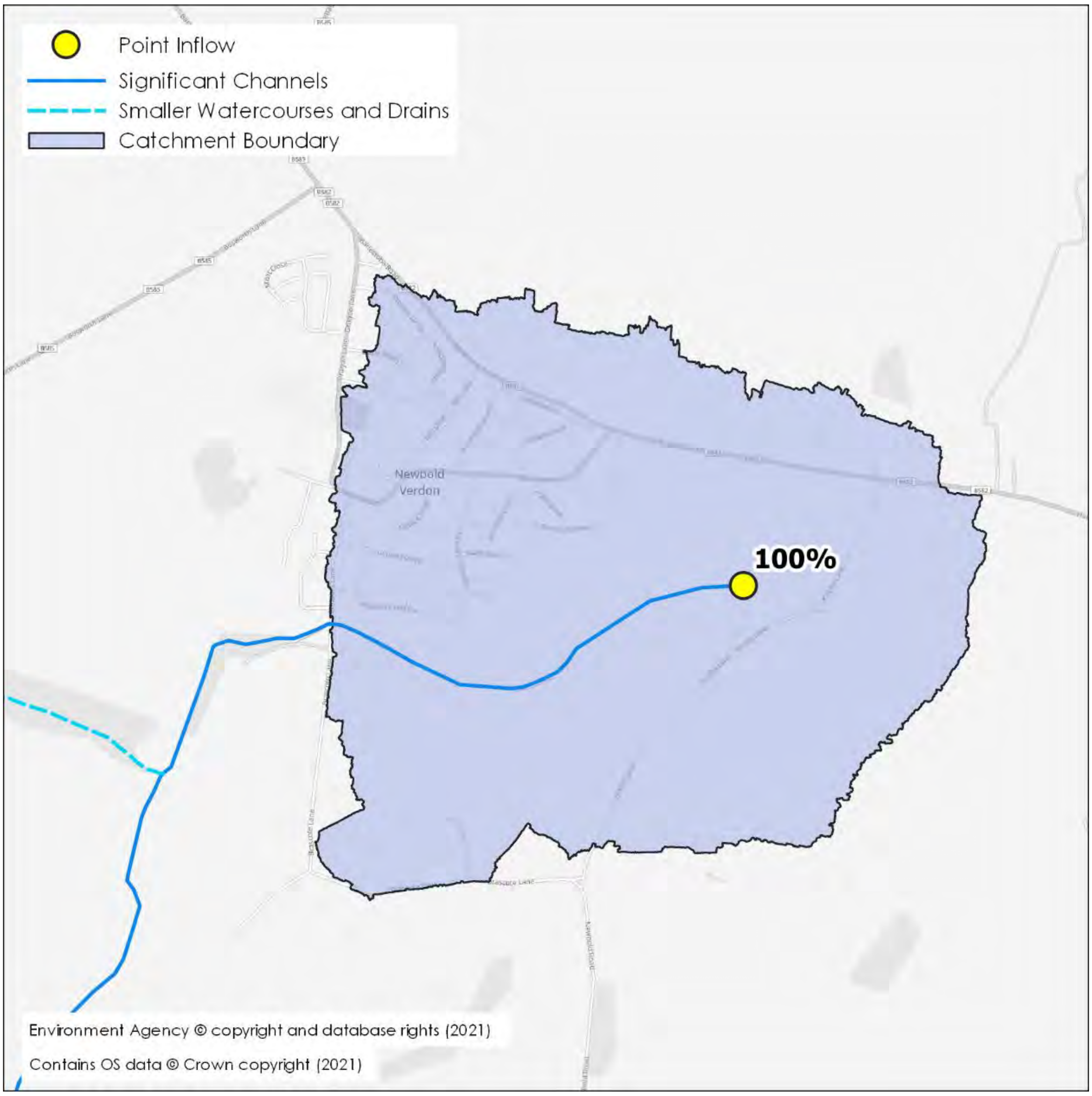


Figure 2.1: Distribution of Model Inflows

Climate Change

2.10 Predicted future change in peak river flows caused by climate change are provided by the EA within their online guidance[2], 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 21**25)
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.

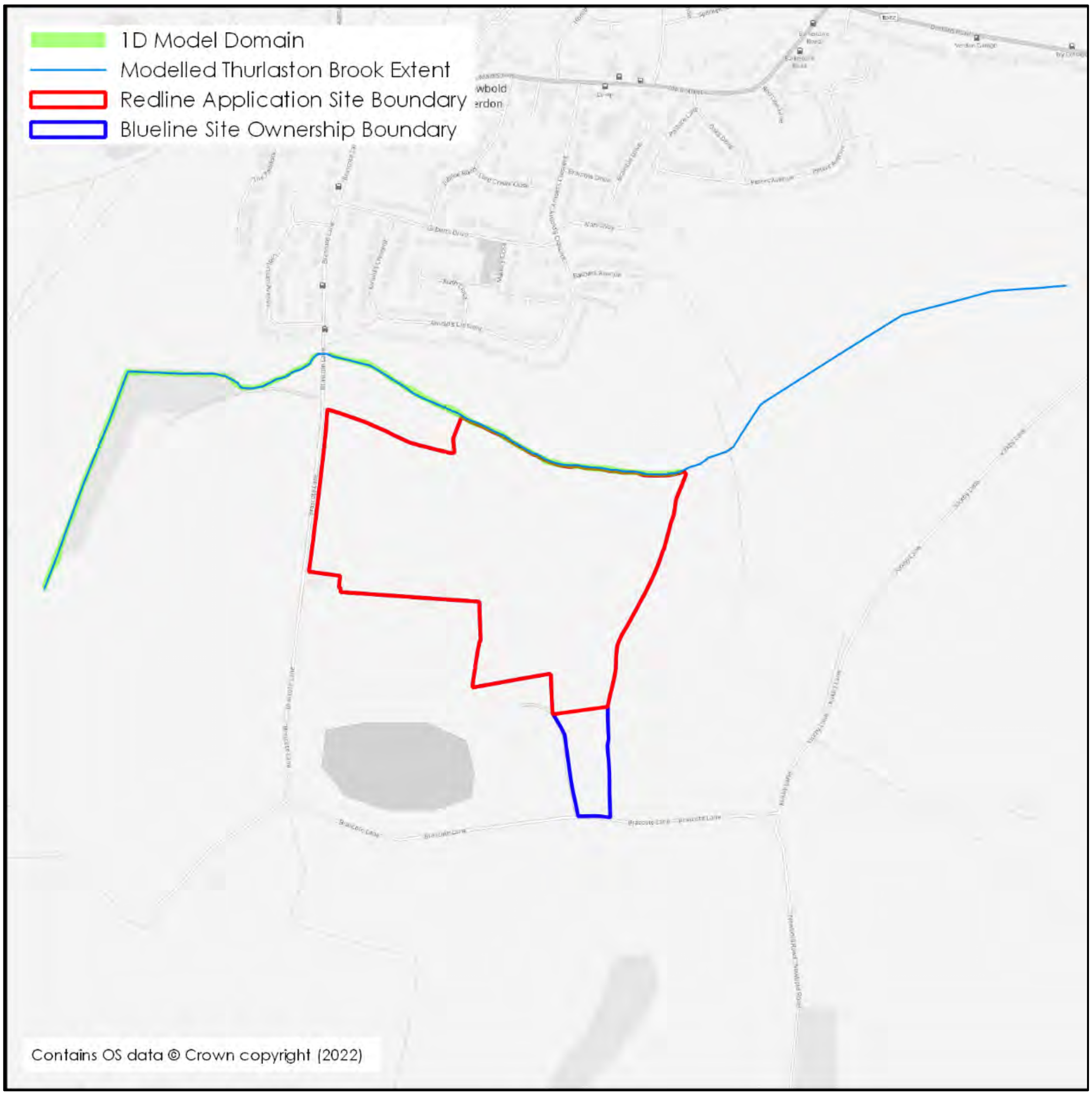


Figure 3.1: Modelled Thurlaston Brook and 1D Domain Extents

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

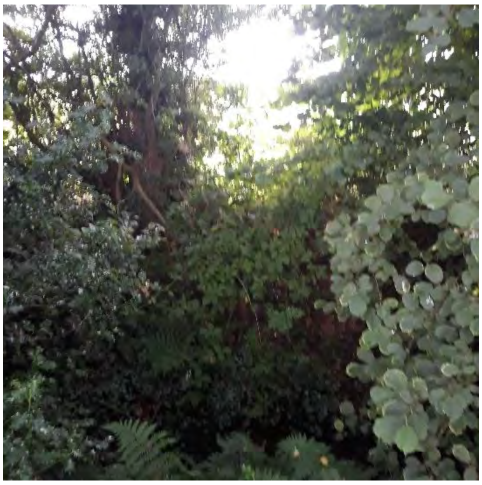
3.7 Hydraulic roughness has been represented using the Manning's n coefficient. The values applied are based on those stipulated in the literature, using Chow (1959)[3]. This study documents appropriate values based on channel bed material, sinuosity and presence of vegetation.

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.

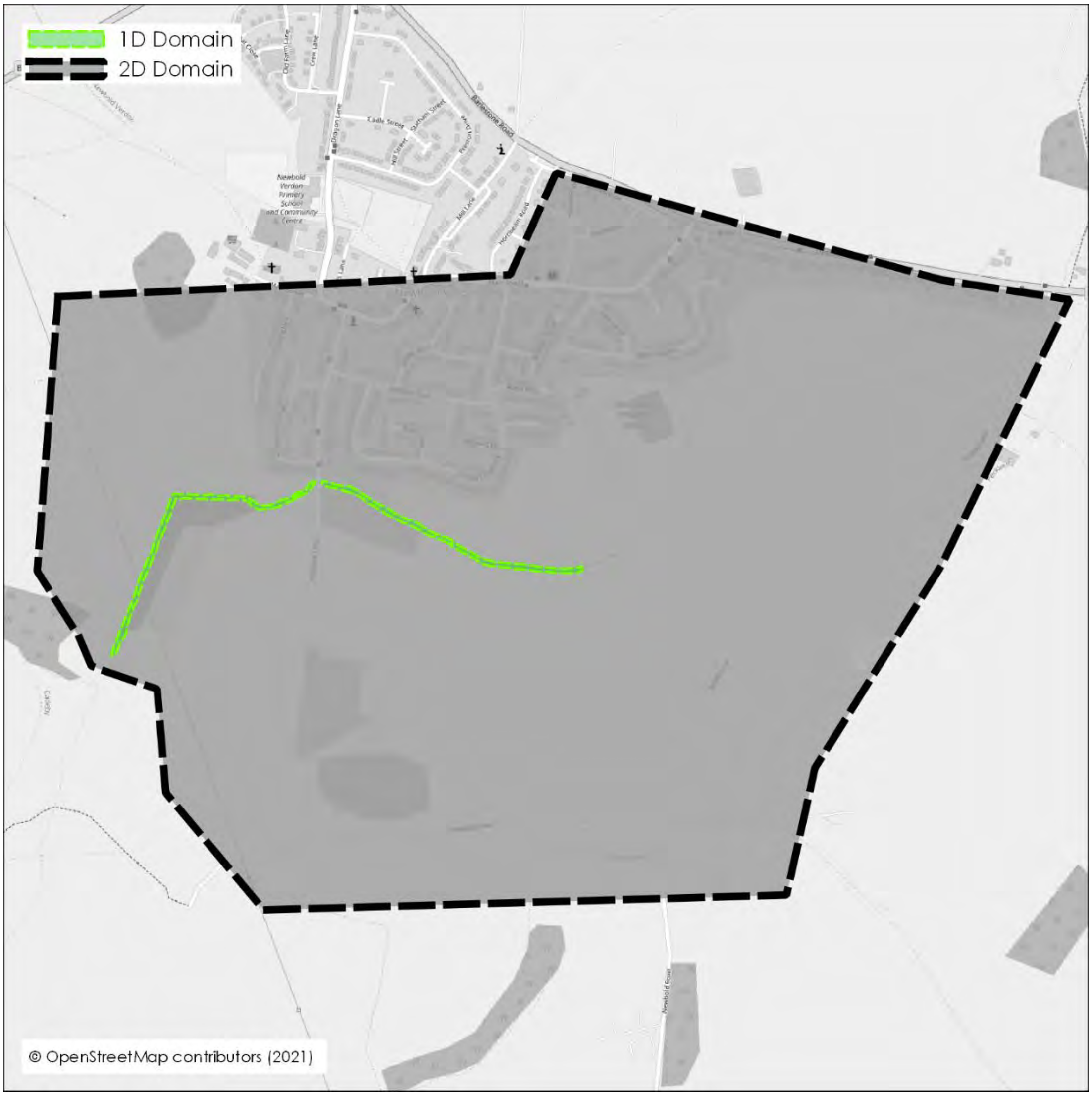


Figure 3.2: 2D Active Area

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.

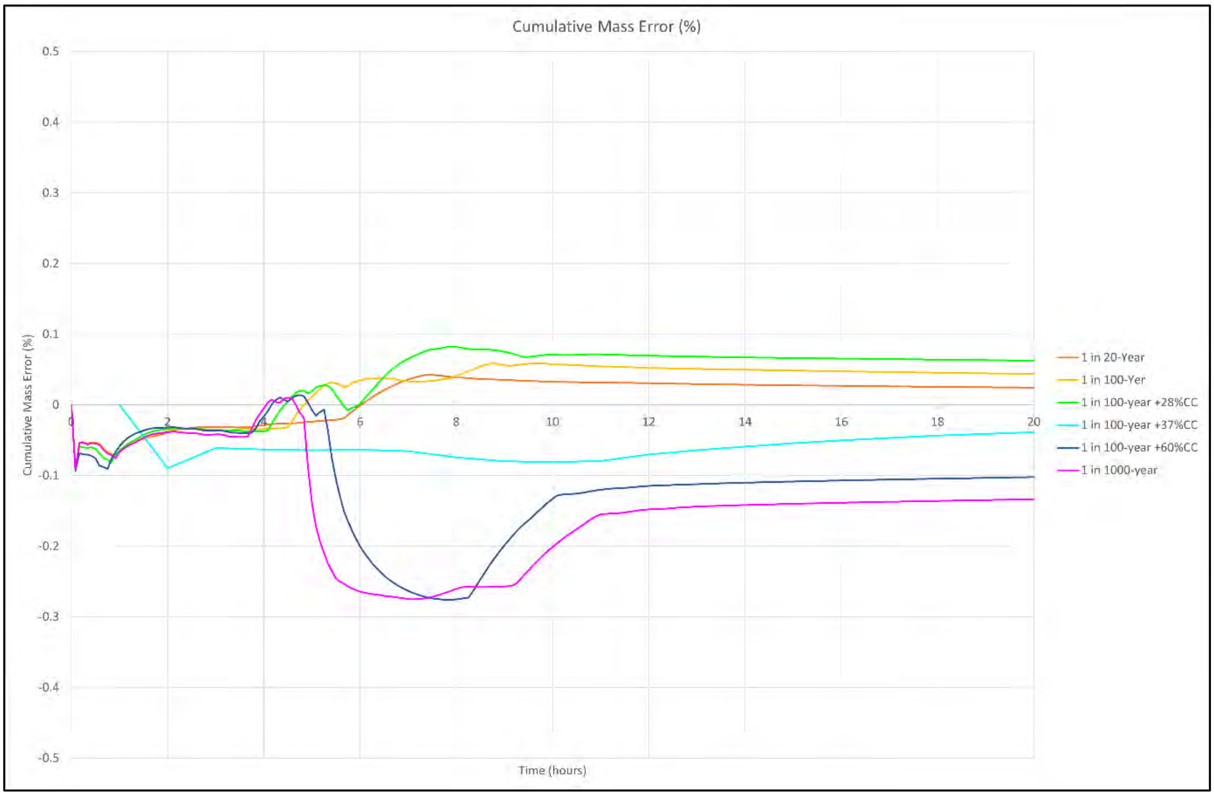


Figure 3.3: Cumulative Mass Error Time Series Plots

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.

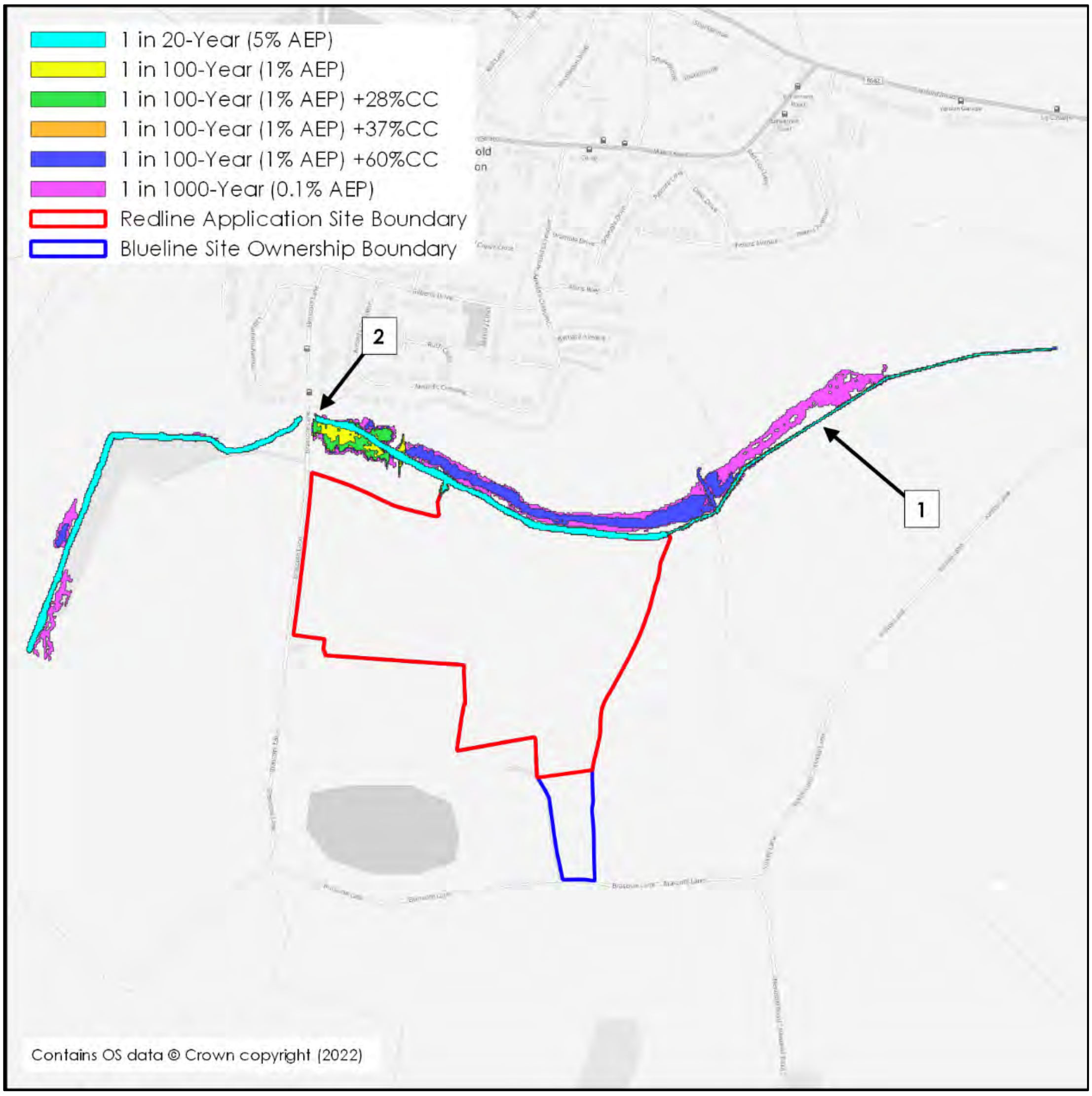


Figure 4.1: Fluvial Floodplain Extents

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.

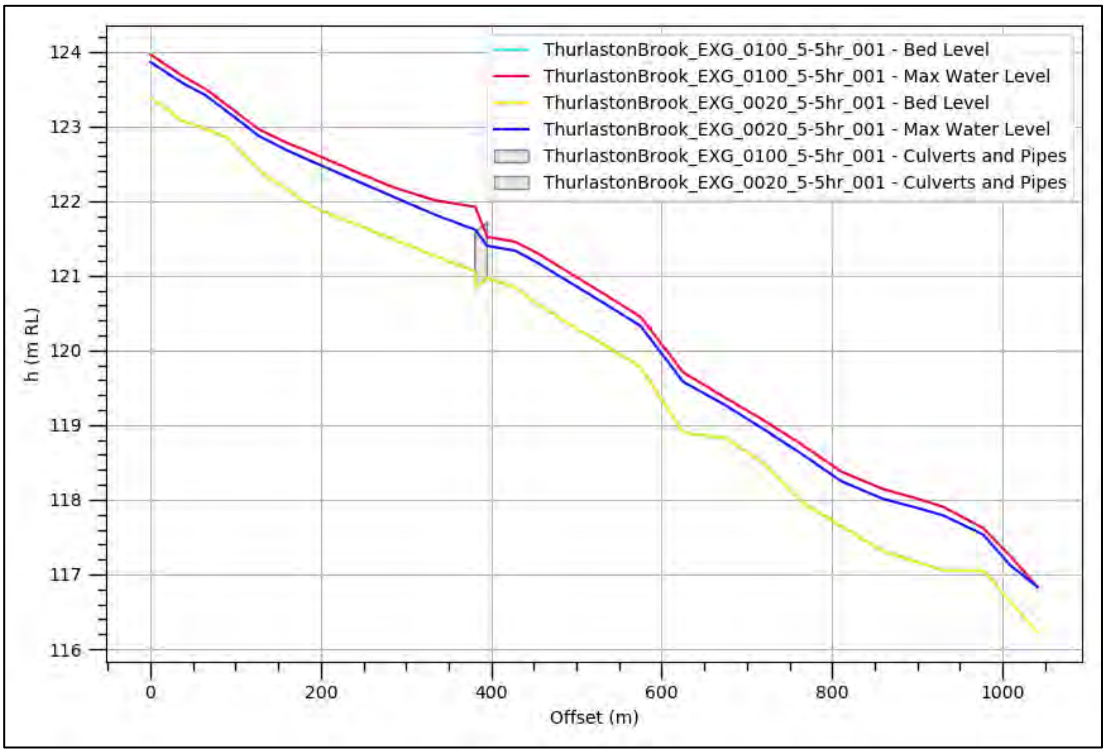


Figure 4.2: Long Section Plot Demonstrating Maximum Water Levels for 5% and 1% AEP Events

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 ESTRY 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.

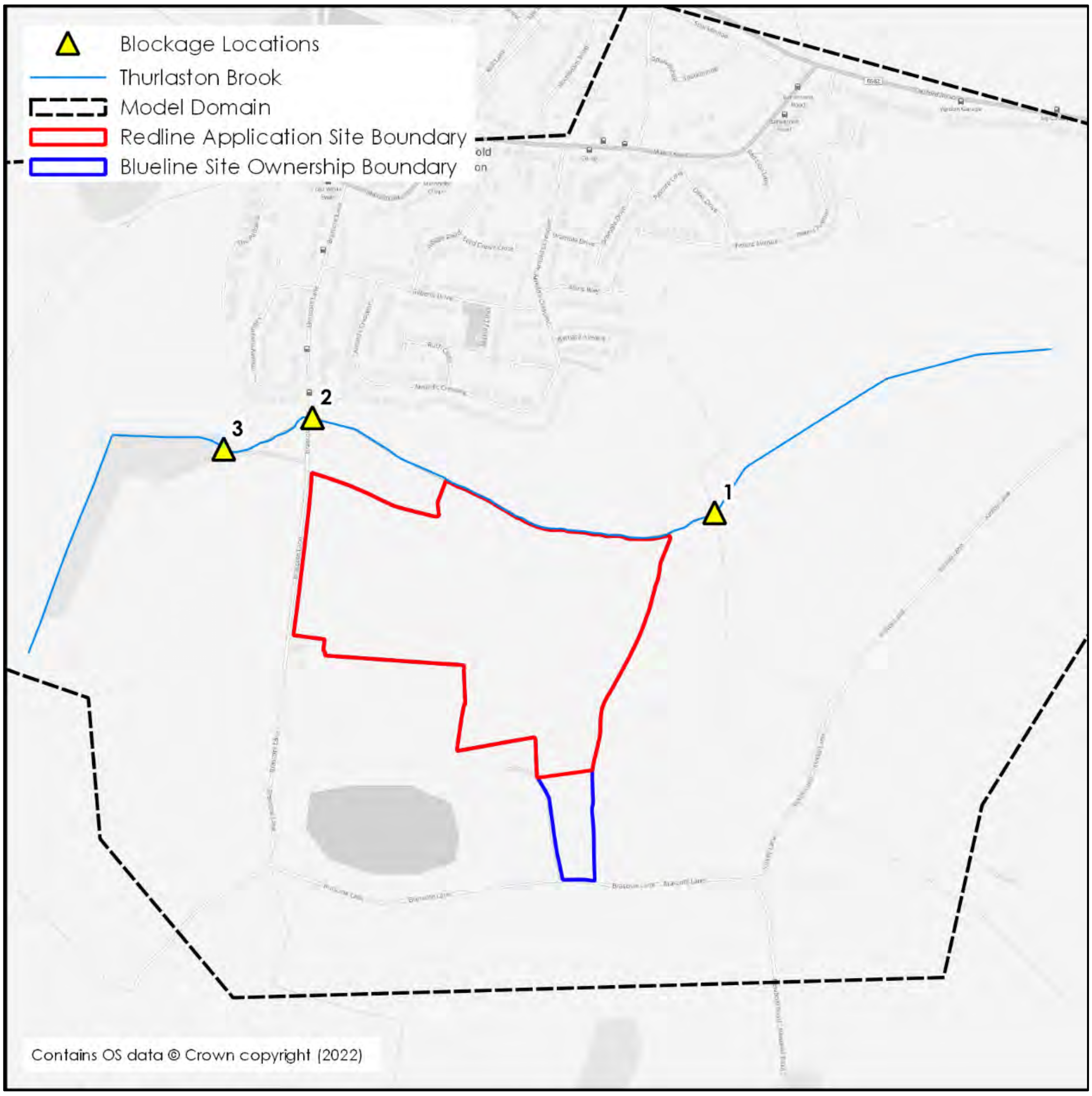


Figure 5.1: Blockage Locations

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.

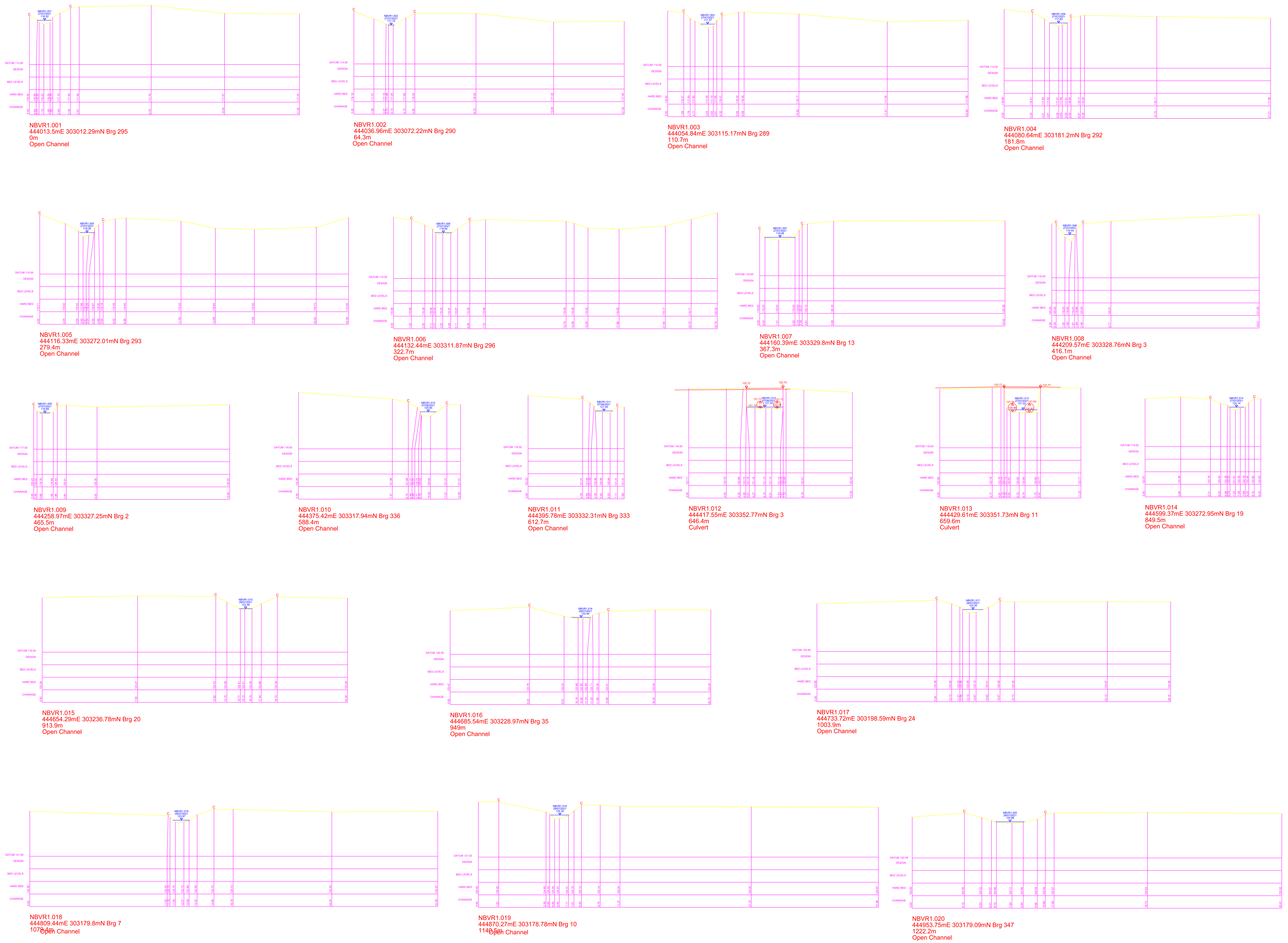
6.4 The baseline modelling has shown that the site boundary remains largely unaffected during all modelled flood events. Fluvial flood extents are shown adjacent to the north of the site due to the Thurlaston Brook forming the northern border of the site.

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

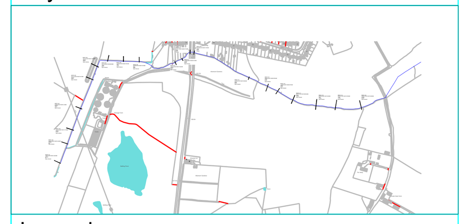
Appendix 1: River Channel Survey



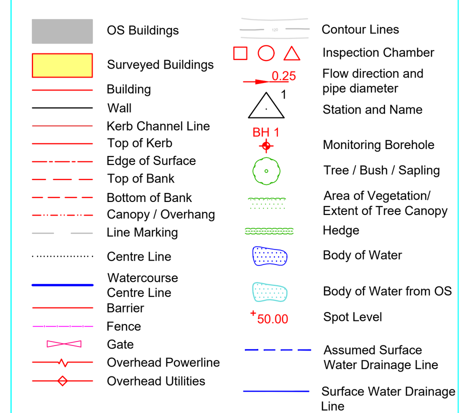
Notes

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



AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
CCTV	Security Camera	FSP	Fence Steel Palisade	ST	Stop Tap
CTV	Cable TV	FWM	Fence Wire Mesh	SV	Stop Valve
DC	Drainage Channel	FFL	Finished Floor Level	TCB	Telephone Call Box
DK	Drop Kerb	FP	Flagpole	THL	Threshold Level
DP	Down Pipe	Gas	Gas	TL	Traffic Light
Elec	Electric	GV	Gas Valve	TP	Telegraph Post
EP	Electricity Post	GY	Gully	TS	Traffic Signal
ER	Earth Rod	Ht	Height	UTS	Unable to Survey
FH	Fire Hydrant	IC	Inspection Chamber	WL	Water Level
FL	Floodlight	IFL	Internal Floor Level	WM	Water Meter
		IL	Invert Level (as a reduced level)	WO	Wash Out

Issues & Revisions

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

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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:	I.Riley	Reviewed:	D.Smith
BWB Ref:	BMW 3175	Date: 29.07.21	Scale@A0: 1:100

Drawing Status
INFORMATION

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

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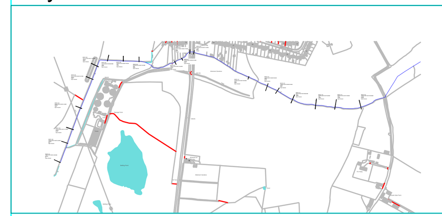
Key Plan



Legend

OS Buildings
Surveyed Buildings
Building
Wall
Kerb Channel Line
Top of Kerb
Edge of Surface
Top of Bank
Bottom of Bank
Canopy / Overhang
Line Marking
Centre Line
Watercourse Centre Line
Barrier
Fence
Gate
Overhead Powerline
Overhead Utilities
Contour Lines
Inspection Chamber
Flow direction and pipe diameter (0.25)
Station and Name (1)
Monitoring Borehole (BH 1)
Tree / Bush / Sapling
Area of Vegetation/ Extent of Tree Canopy
Hedge
Body of Water
Body of Water from OS
Spot Level (+50.00)
Assumed Surface Water Drainage Line
Surface Water Drainage Line

AP	Anchor Point	FBW	Fence Barbed Wire	LB	Litter Bin
BG	Back Gully	FCB	Fence Closed Board	LP	Lamp Post
BO	Bollard	FCL	Fence Chain Link	MH	Manhole
BS	Bus Stop	FEL	Fence Electric	Mkr	Service Marker
BT	British Telecom	FMP	Fence Metal Panel	PB	Post Box
C	Crest	FMR	Fence Metal Railing	PT	Post
CL	Cover Level	FOB	Fence Open Board	RE	Rodding Eye
CMP	Cable Marker Post	FPW	Fence Post & Wire	SP	Sign Post
		FSP	Fence Steel Palisade	ST	Stop Tap
CCTV	Security Camera	FWM	Fence Wire Mesh	SV	Stop Valve
CTV	Cable TV	FFL	Finished Floor Level	TCB	Telephone Call Box
DC	Drainage Channel	FP	Flagpole	THL	Threshold Level
		Gas	Gas		
DK	Drop Kerb	GV	Gas Valve	TL	Traffic Light
DP	Down Pipe	GY	Gully	TP	Telegraph Post
Elec	Electric	Ht	Height	TS	Traffic Signal
EP	Electricity Post	IC	Inspection Chamber	UTS	Unable to Survey
ER	Earth Rod	IFL	Internal Floor Level	WL	Water Level
FH	Fire Hydrant	IL	Invert Level (as a reduced level)	WM	Water Meter
FL	Floodlight			WO	Wash Out

Issues & Revisions

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

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Project Title
Brascote Lane Newbold Verdon

Drawing Title
Existing Watercourse Layout Sheet 2 Of 2

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

Drawing Status
INFORMATION

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

Appendix 2: Hydrological Assessment

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Brascote Lane, Newbold Verdon

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Flow Estimation Record

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Leicestershire
Flow Estimation Record

Birmingham
Livery Place, 35 Livery Street, Colmore Business District
Birmingham, B3 2PB
T: 0121 233 3322

Leeds
Whitehall Waterfront, 2 Riverside Way
Leeds, LS1 4EH
T: 0113 233 8000

London
11 Borough High Street
London, SE1 9SE
T: 0207 407 3879

Manchester
11 Portland Street
Manchester, M1 3HU
T: 0161 233 4260

Nottingham
5th Floor, Waterfront House, Station Street
Nottingham, NG2 3DQ
T: 0115 924 1100

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1	17/08/21	Draft	Max Brambani BSc (Hons) PgCert MCIWEM	Claire Gardner BSc (Hons) MSc MCIWEM C.WEM	Robin Green BSc (Hons)

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CONTENTS

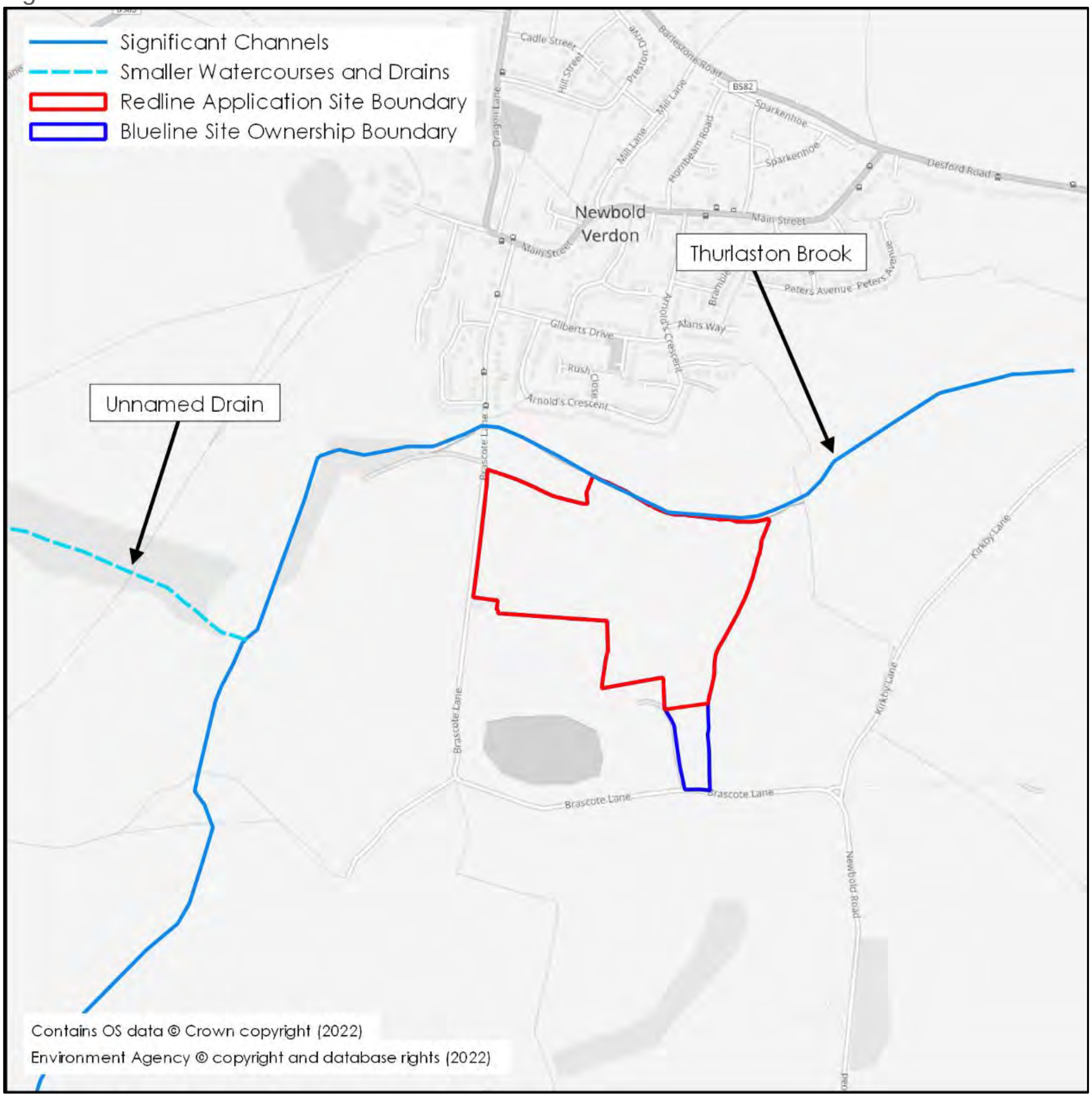
1. METHOD STATEMENT

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 fo 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

<table>
<tr><th>Flood Zone</th><th>Essential Infrastructure</th><th>Highly Vulnerable</th><th>More Vulnerable</th><th>Less Vulnerable</th><th>Water Compatible</th></tr>
<tr><td>1</td><td colspan="5">Use the central allowance where a location may fall within Flood Zone 2 or 3 in the future.</td></tr>
<tr><td>2</td><td>Use the higher central allowance</td><td colspan="4">Use the central allowance</td></tr>
<tr><td>3a</td><td>Use the higher central allowance</td><td>Development should not be permitted</td><td colspan="3">Use the central allowance</td></tr>
<tr><td>3b</td><td>Use the higher central allowance</td><td colspan="3">Development should not be permitted</td><td>Use the central allowance</td></tr>
</table>

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

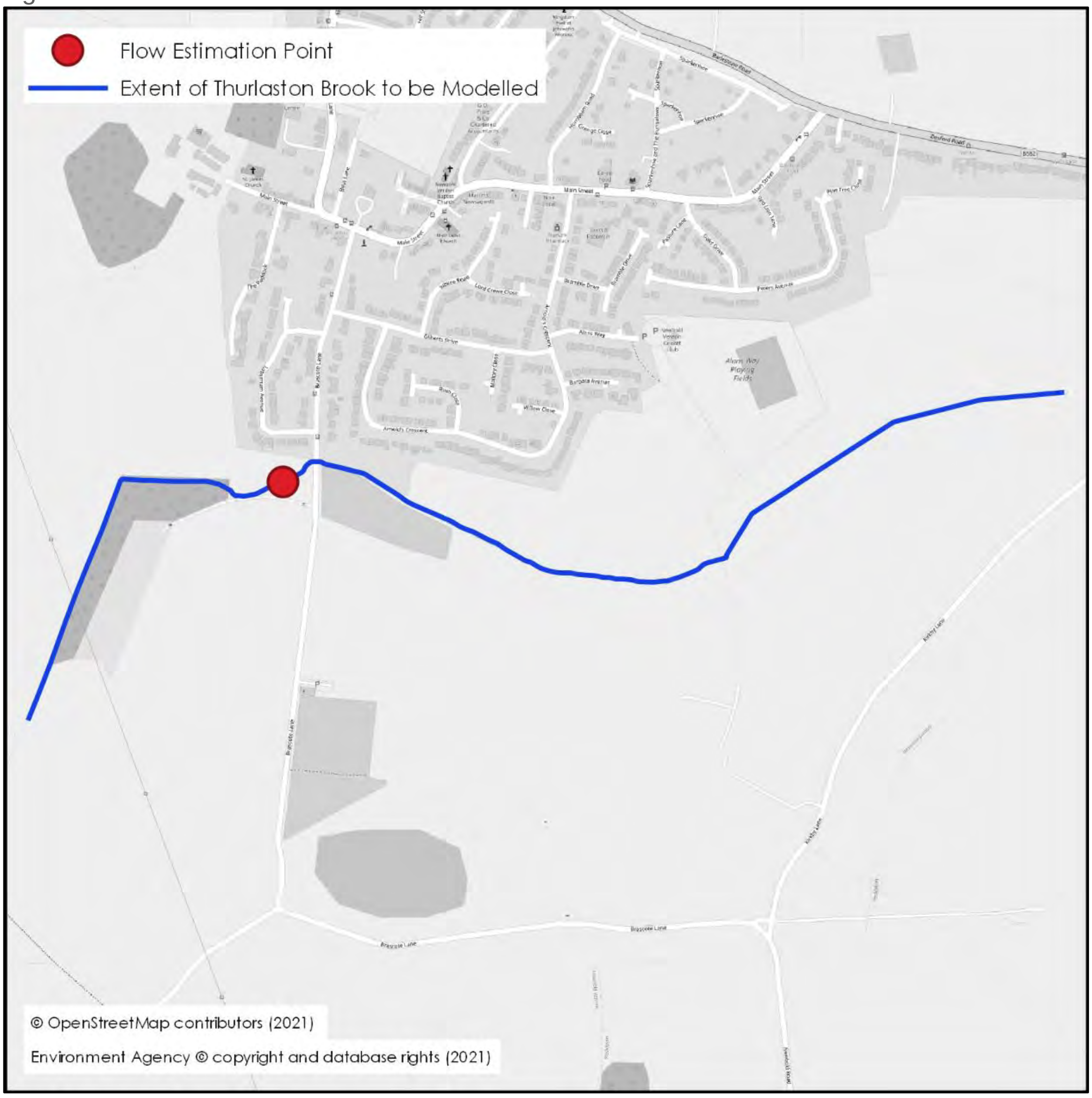
2. LOCATIONS WHERE FLOOD ESTIMATES ARE REQUIRED

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 boundariy 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) mapping[1] 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 Soilscapes website[2], 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. $URBEXT_{2000}$ 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 $URBEXT_{2000}$ were recalculated following the amendments to the catchment boundary using formula 5.4 from 2006 CEH report on $URBEXT_{2000}$, which allows $URBEXT_{2000}$ to be calculated from the present day urban area of the catchment.

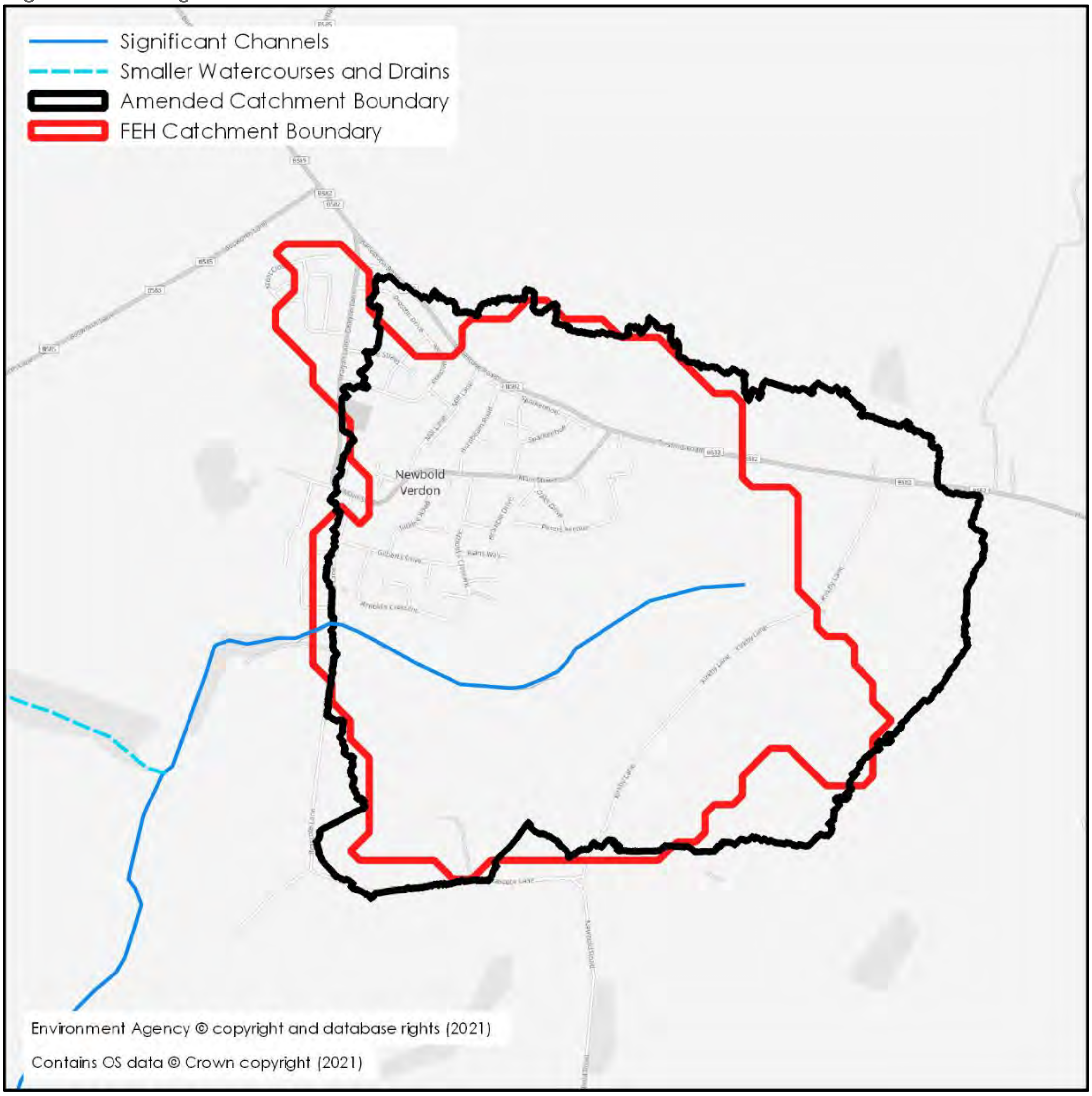
[1] https://mapapps.bgs.ac.uk/geologyofbritain/home.html

[2] http://www.landis.org.uk/soilscapes/

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 $URBEXT_{2000}$. 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 2010[4].

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 meterological 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	Tp (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, sensitvitiy 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 (m3/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

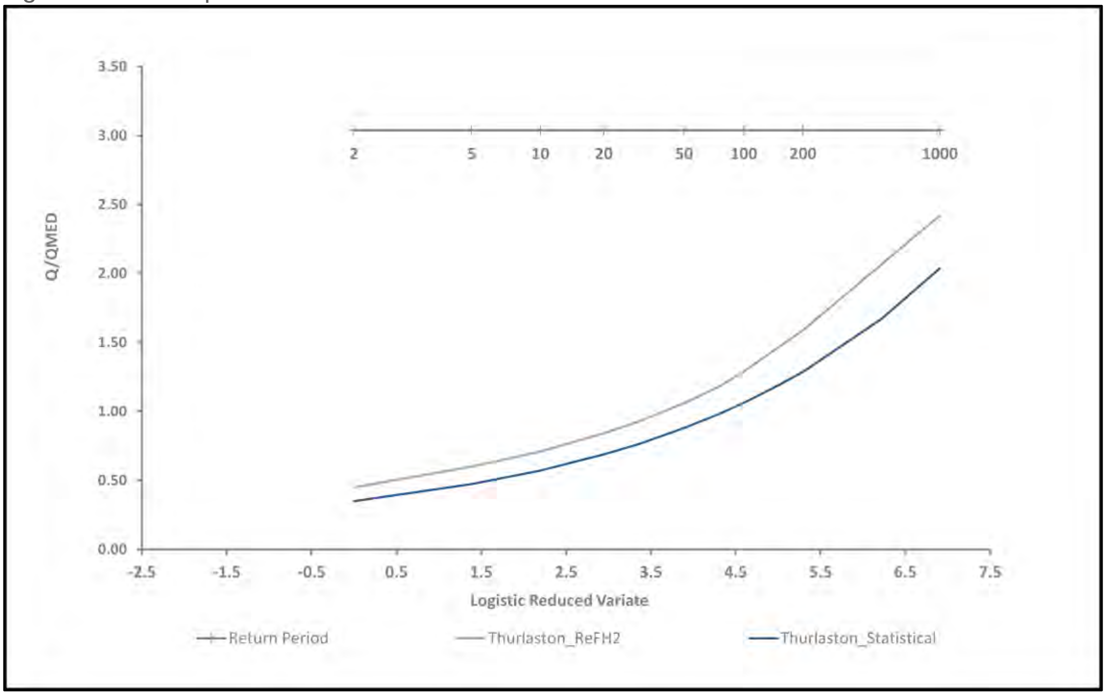
5.1 A comparison of the peak flow results for the different estimation methods for the 1 in 2-year and 1 in 100-year events is provided in Table 5.1. Comparisons of the growth curves for both methods are shown in Figure 5.1.

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 quantity 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	Sensibility 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.

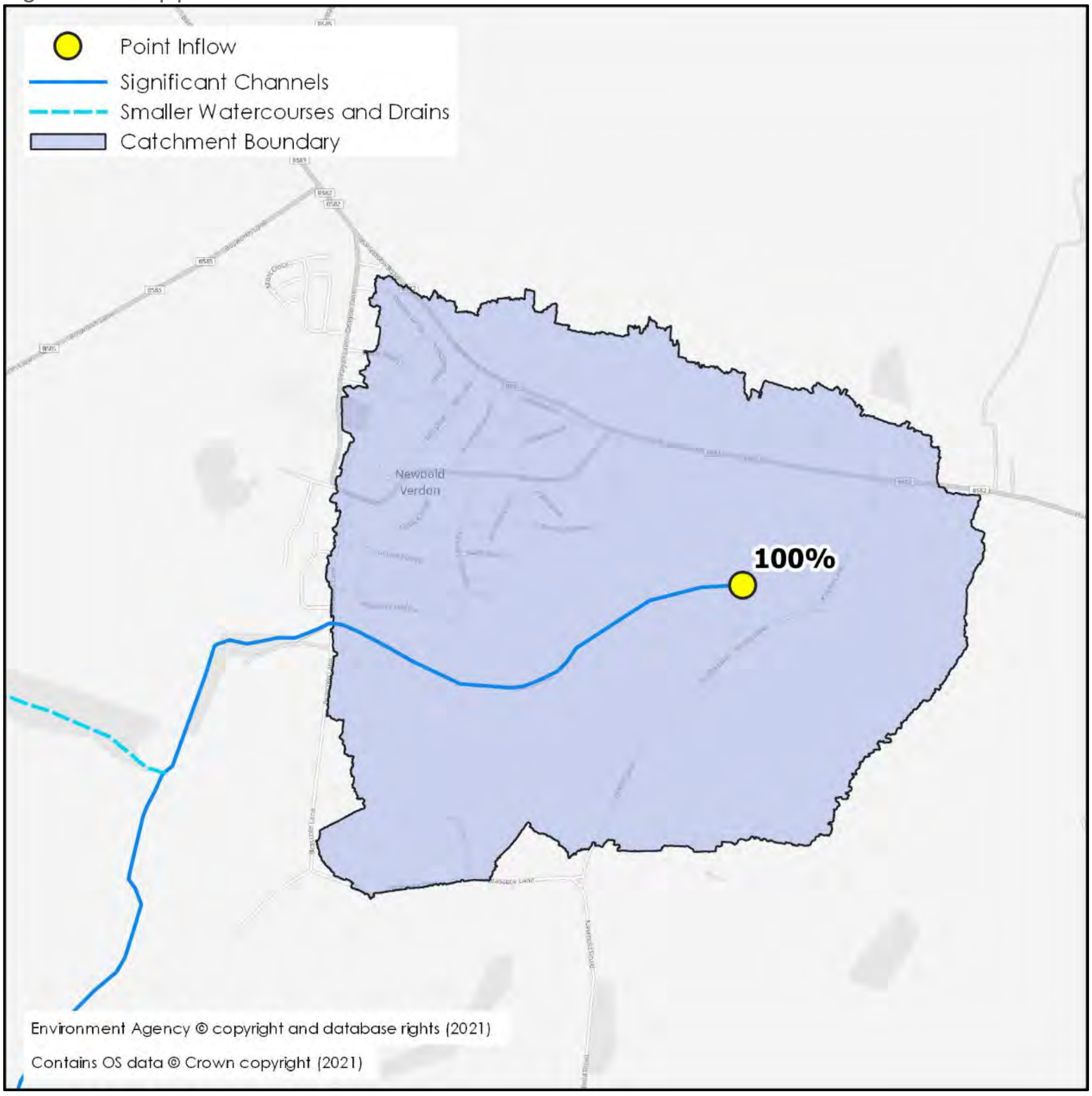
Application of flows to model

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 (2.14km^2) 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 Assessments[6], 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 (Gypsey 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		

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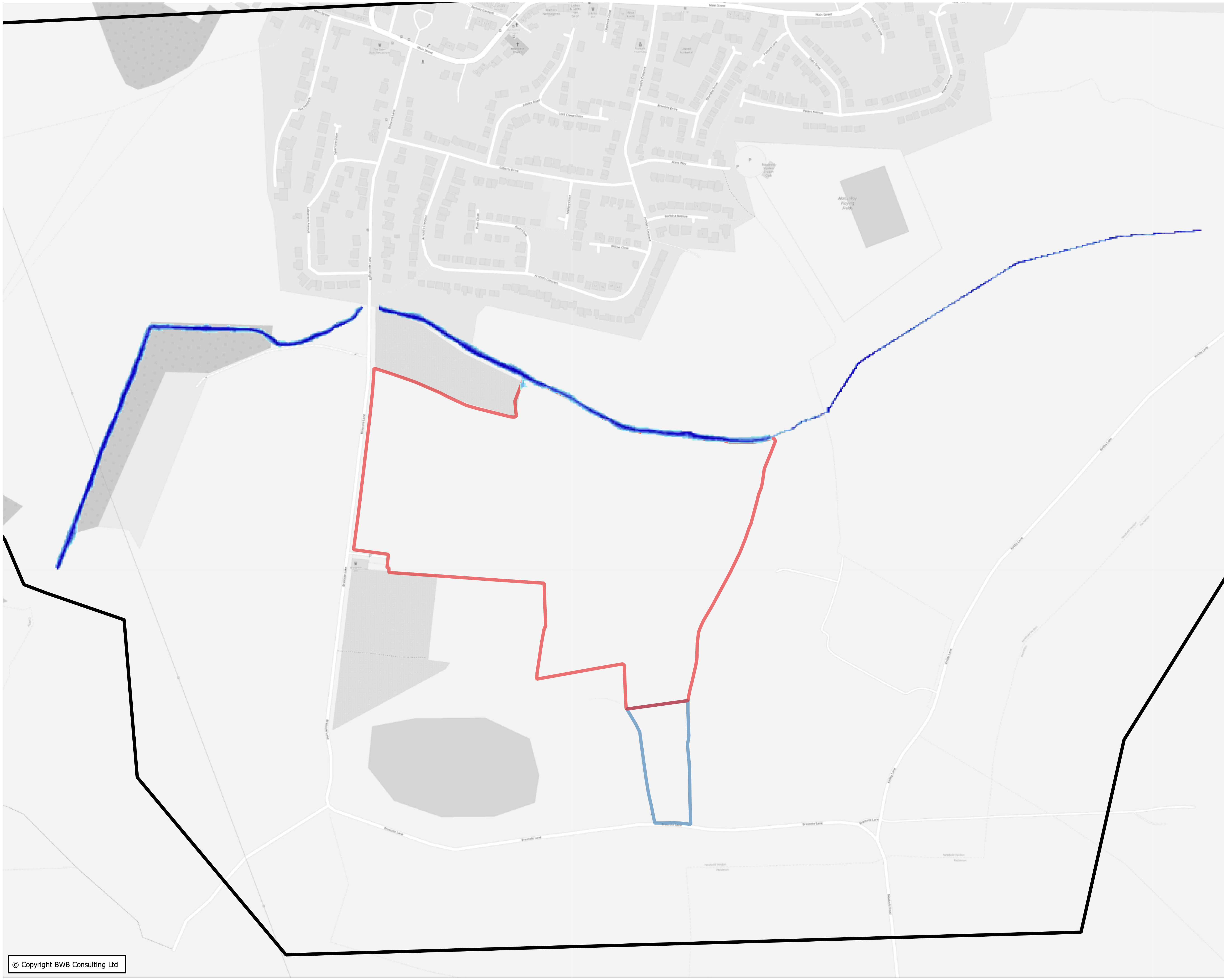
Appendix 3: Table of Hydraulic Structures

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

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4. Any discrepancies noted on site are to be reported to the engineer immediately.
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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

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

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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)

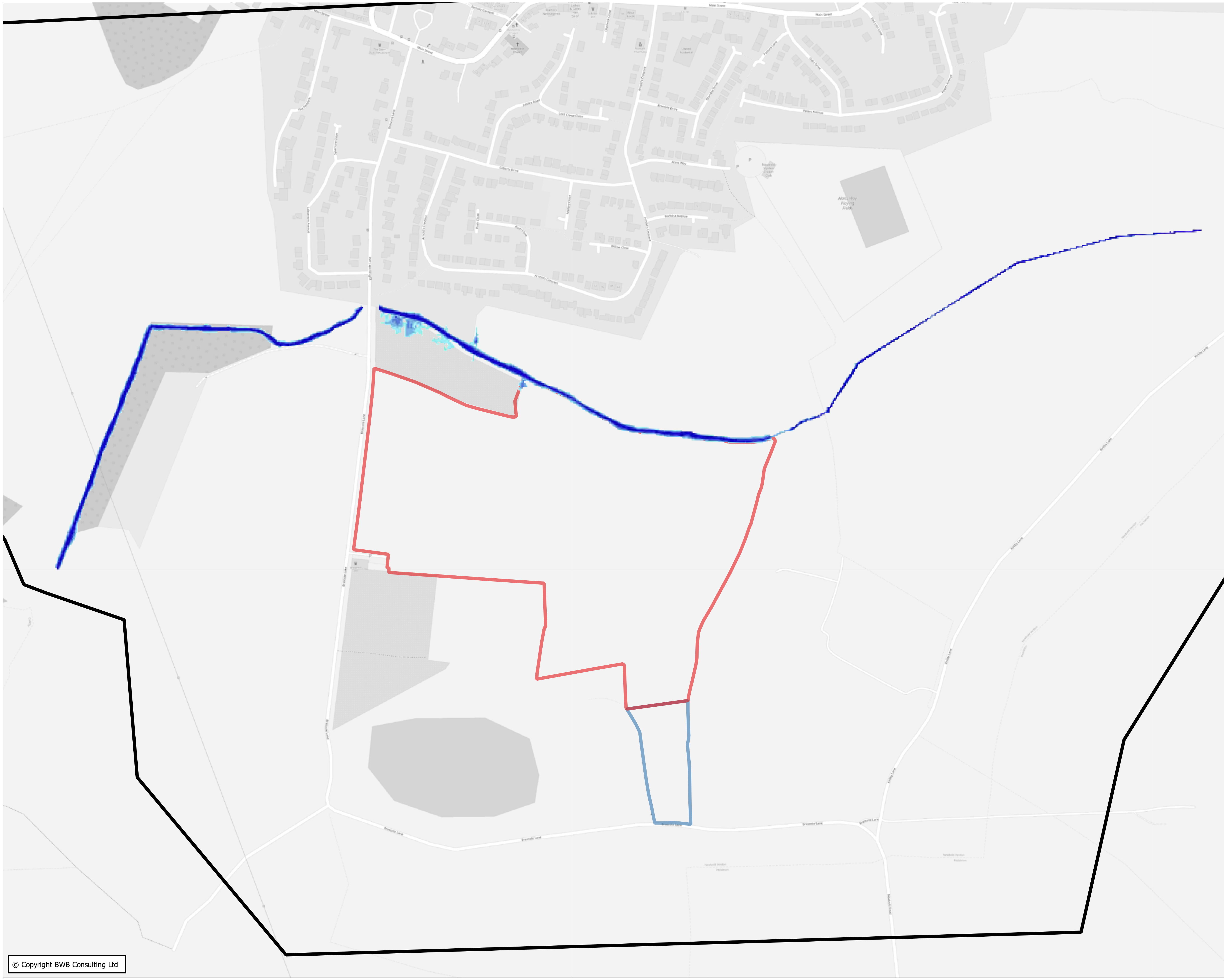
Drawn:	M. Brambani	Reviewed:	R. Green

BWB Ref:	BMW 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



Notes

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Key

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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

Rev	Date	Details of issues/ revision	Drw	Rev
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Client

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

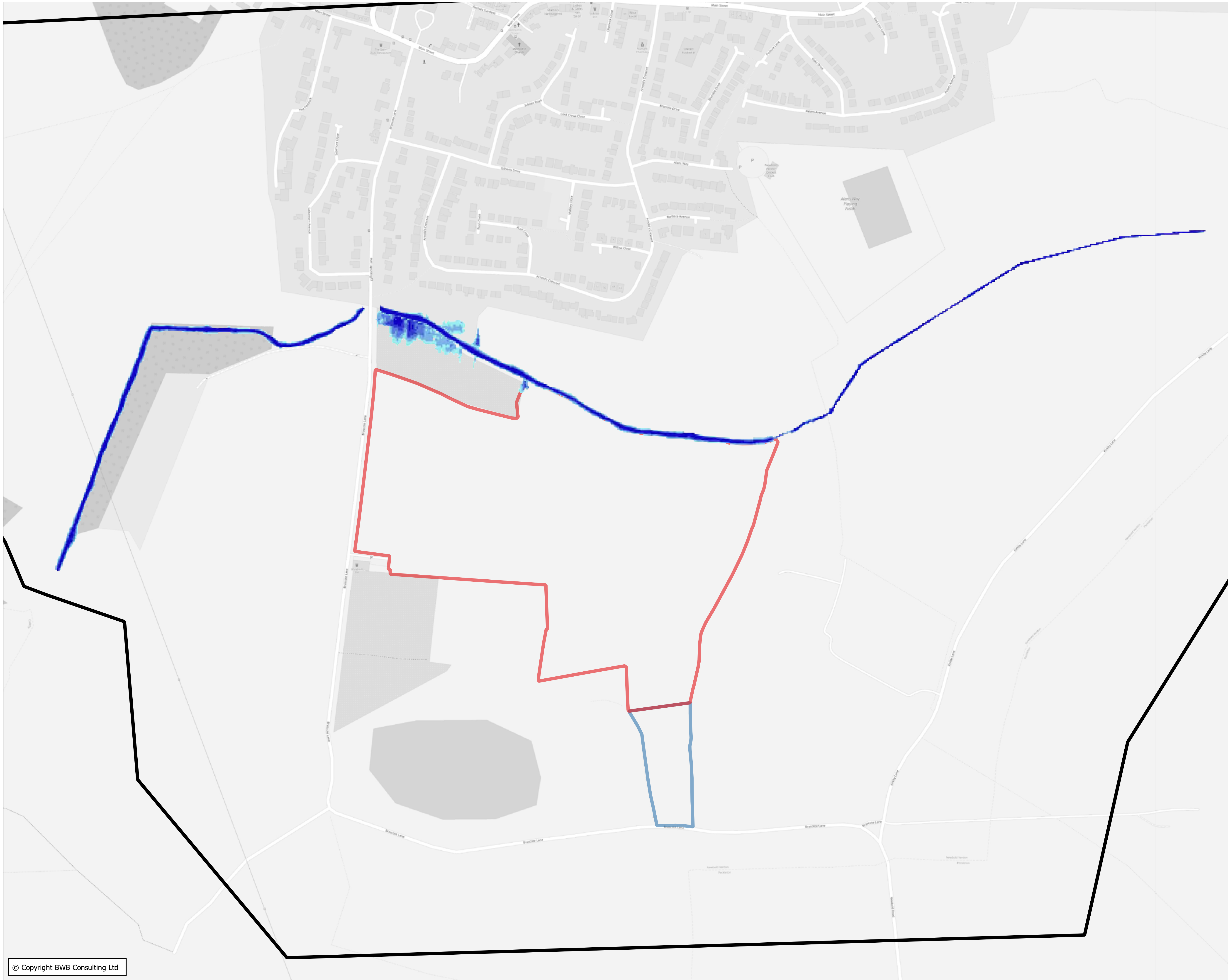
Thurlaston Brook Flood Depths: 1 in 100-Year (1% AEP)

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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



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Key

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- 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

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

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Client

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

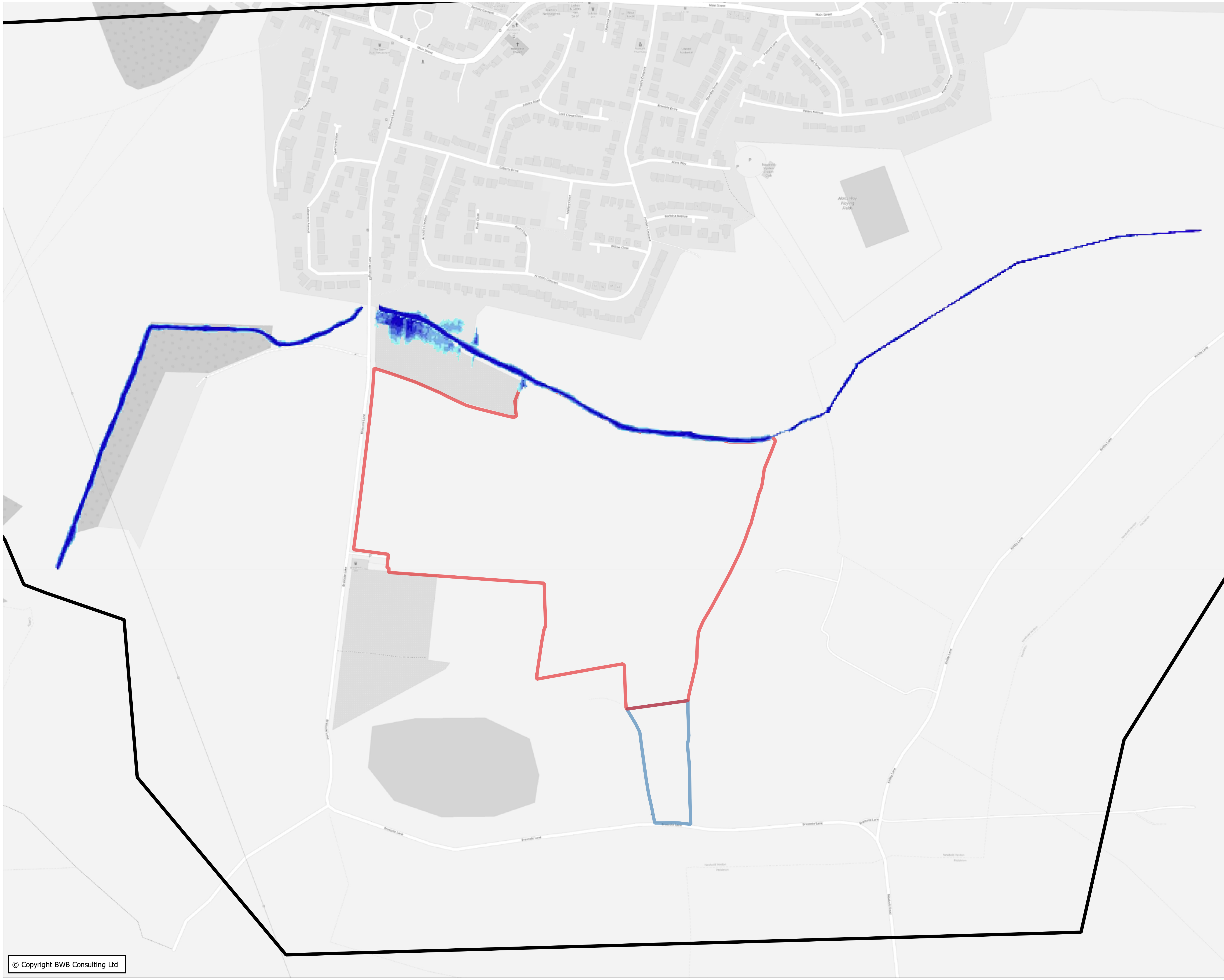
**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP) +28%CC**

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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



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- 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

Rev	Date	Details of issues/ revision	Drw	Rev
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P01	08.09.2021	PRELIMINARY ISSUE	MB	RG

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

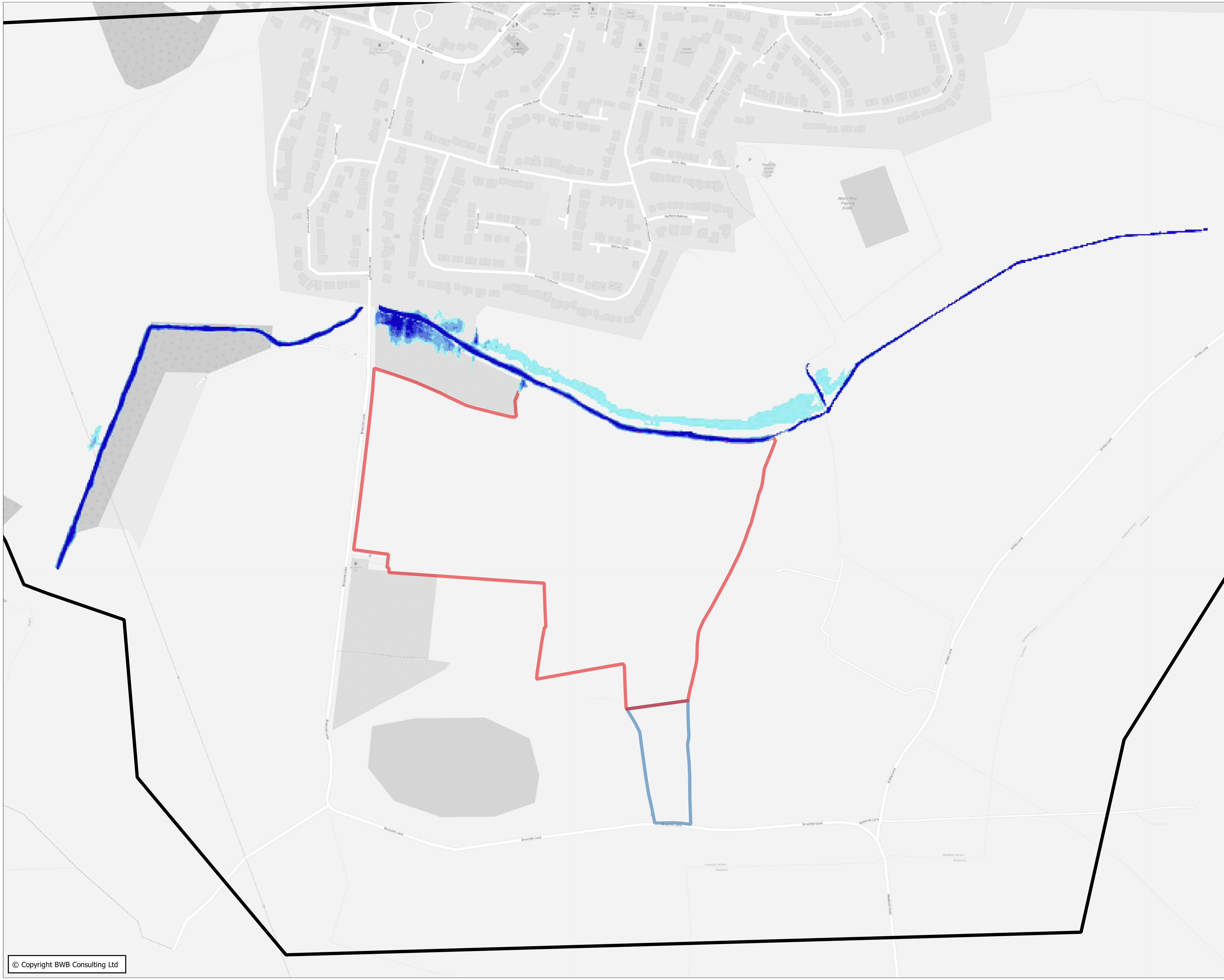
Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP) +37%CC

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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-0005	S2	P02



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Key

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- 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

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

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

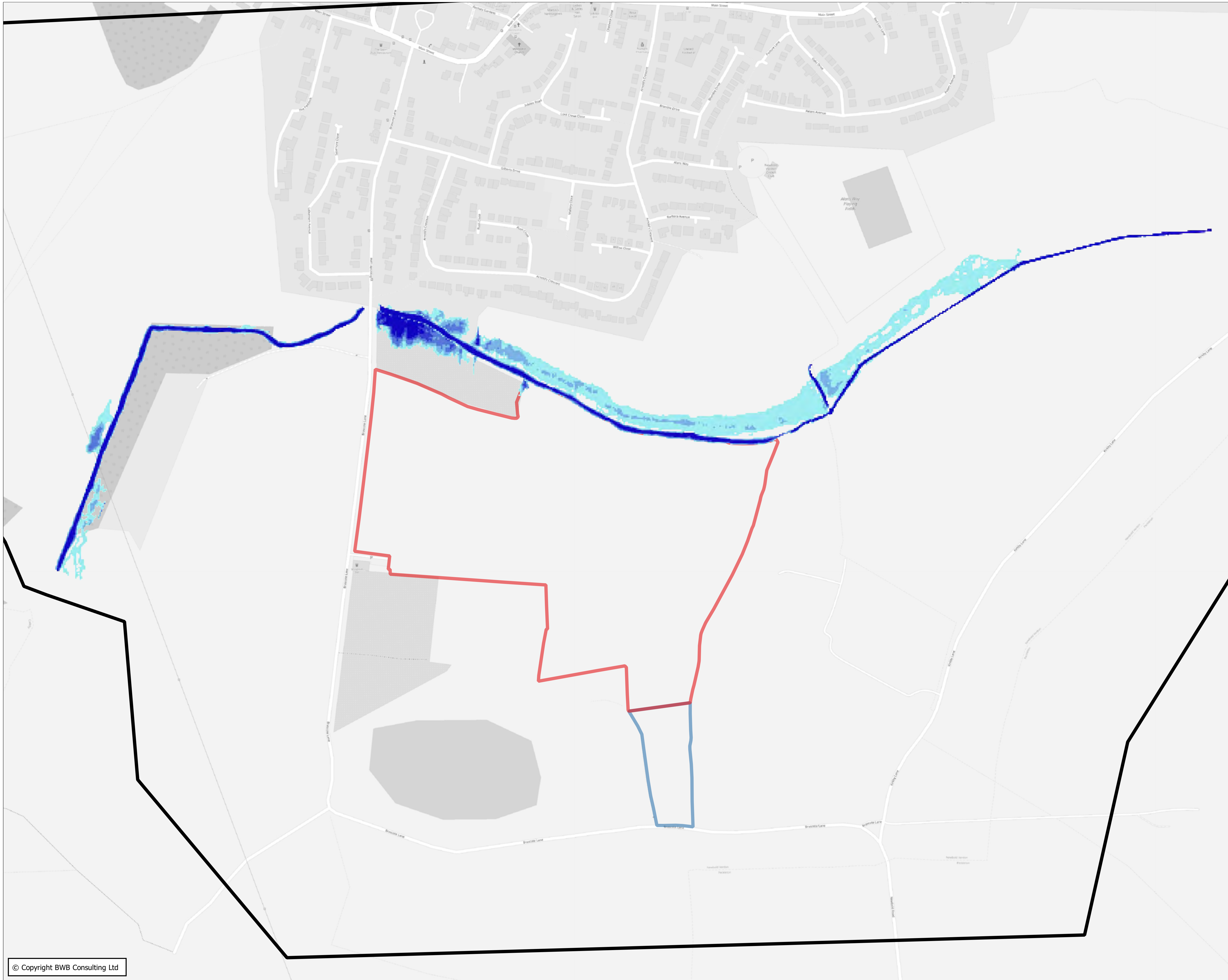
**Thurlaston Brook Flood Depths:
1 in 100-Year (1% AEP) +60%CC**

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0006	S2	P02



Notes

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Key

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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

Rev	Date	Details of issues/ revision	Drw	Rev
P02	24.02.2022	FINALISED SITE LAYOUT	MB	RG
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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

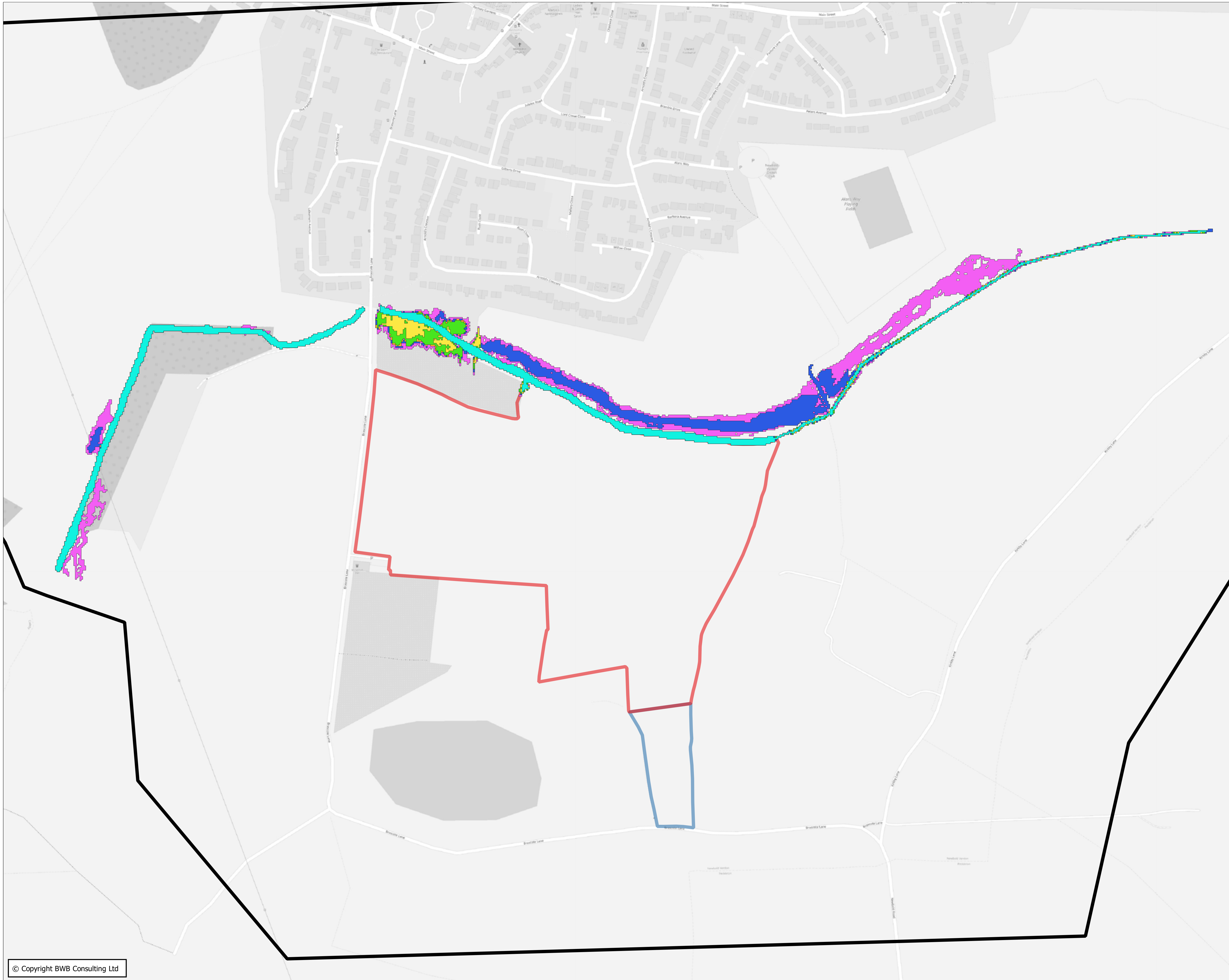
**Thurlaston Brook Flood Depths:
1 in 1000-Year (0.1% AEP)**

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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



Notes

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Key

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- Blueline Site Ownership Boundary
- Model Domain
- 1 in 20-Year (5% AEP)
- 1 in 100-Year (1% AEP)
- 1 in 100-Year (1% AEP) +28%CC
- 1 in 100-Year (1% AEP) +37%CC
- 1 in 100-Year (1% AEP) +60%CC
- 1 in 1000-Year (0.1% AEP)

Rev	Date	Details of issues/ revision	Drw	Rev
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Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

Thurlaston Brook Floodplain Extents

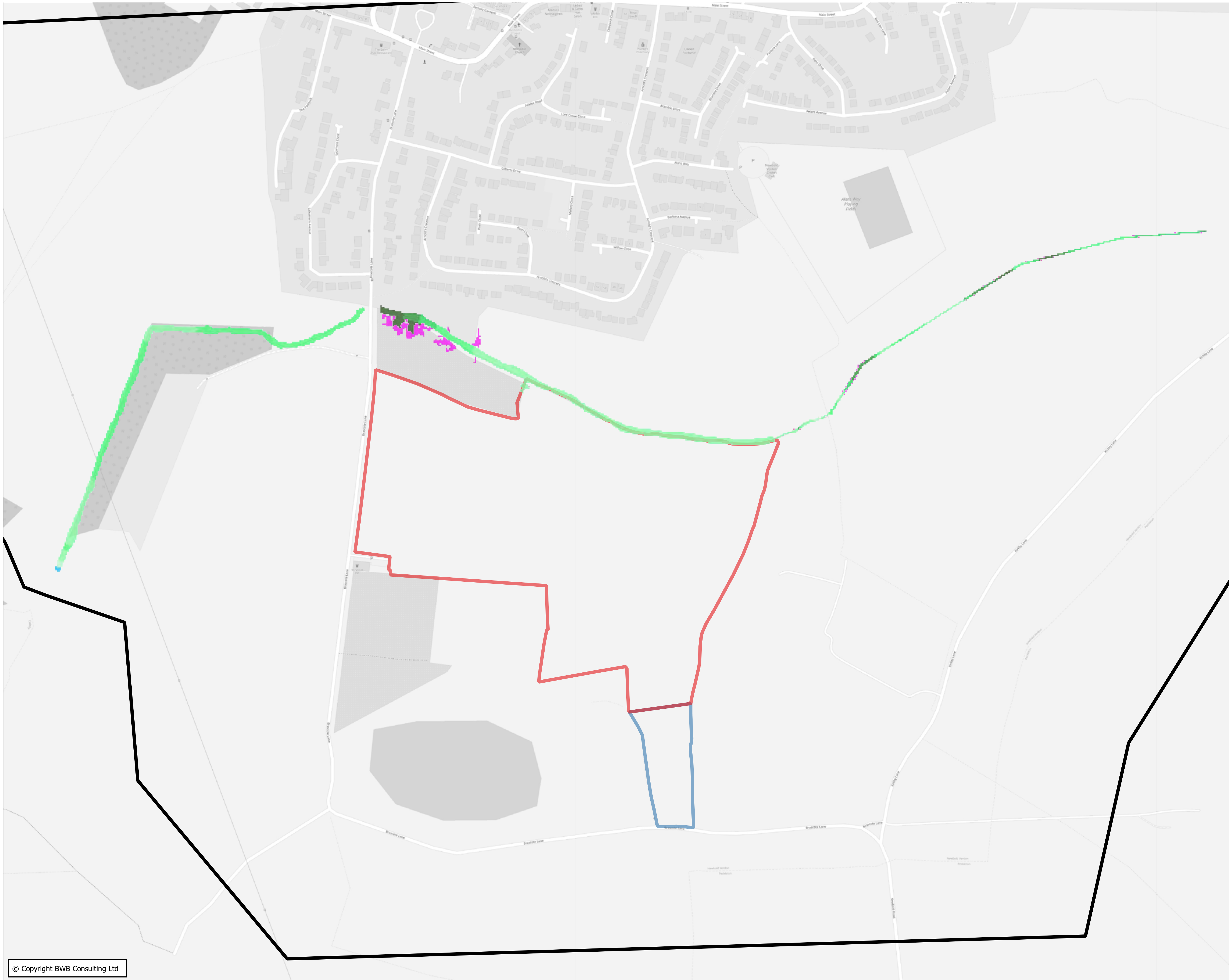
Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 3175	Date: 24/02/22	Scale@A3: 1:4,500

Drawing Status

FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0008	S2	P02

Appendix 5 – Sensitivity Maps



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

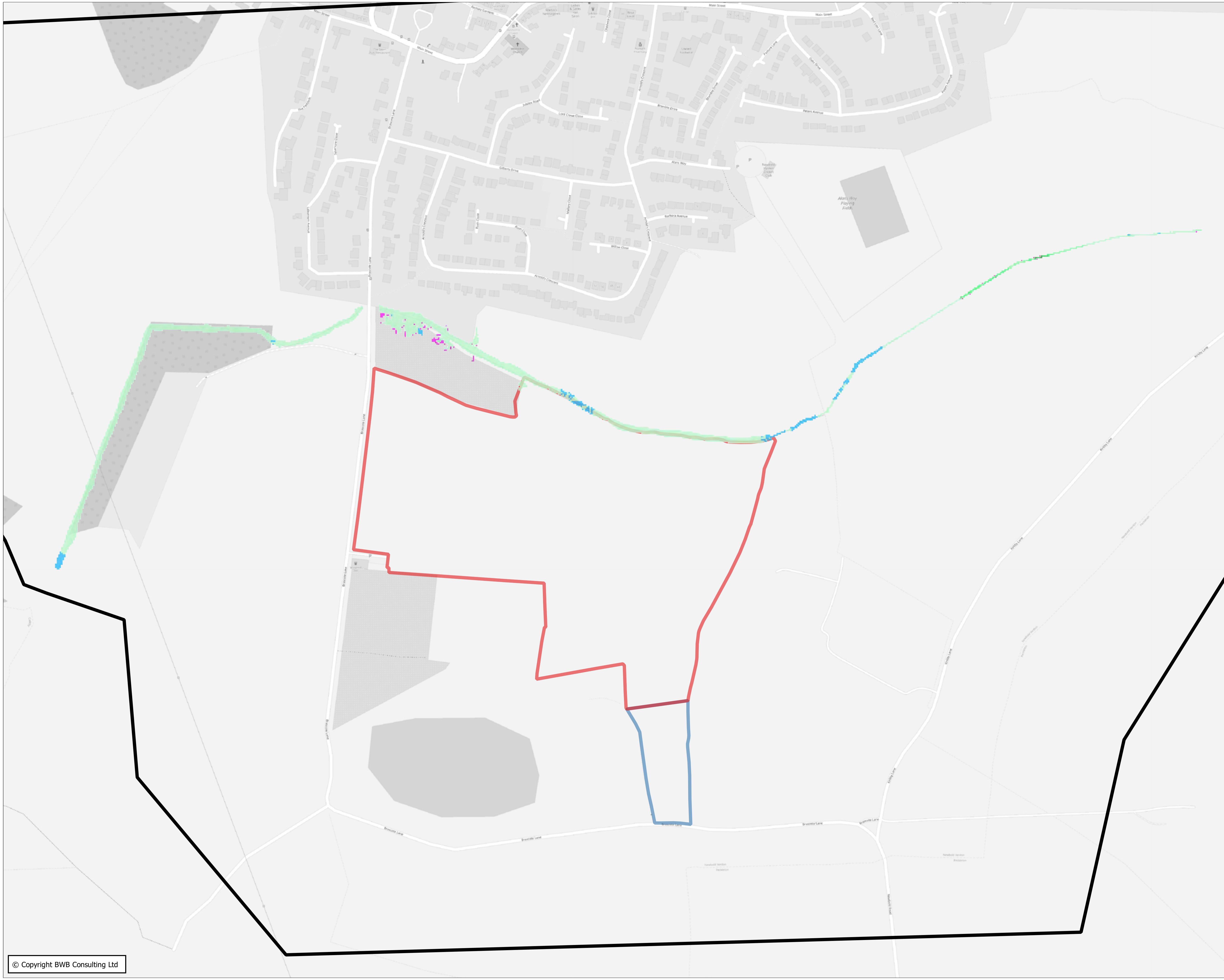
Sensitivity Tests: 1 in 100-Year (1% AEP) 5.5hr Storm Compared to 3hr Storm

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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-0009	S2	P02



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

Rev	Date	Details of issues/ revision	Drw	Rev
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P01	08.09.2021	PRELIMINARY ISSUE	MB	RG

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

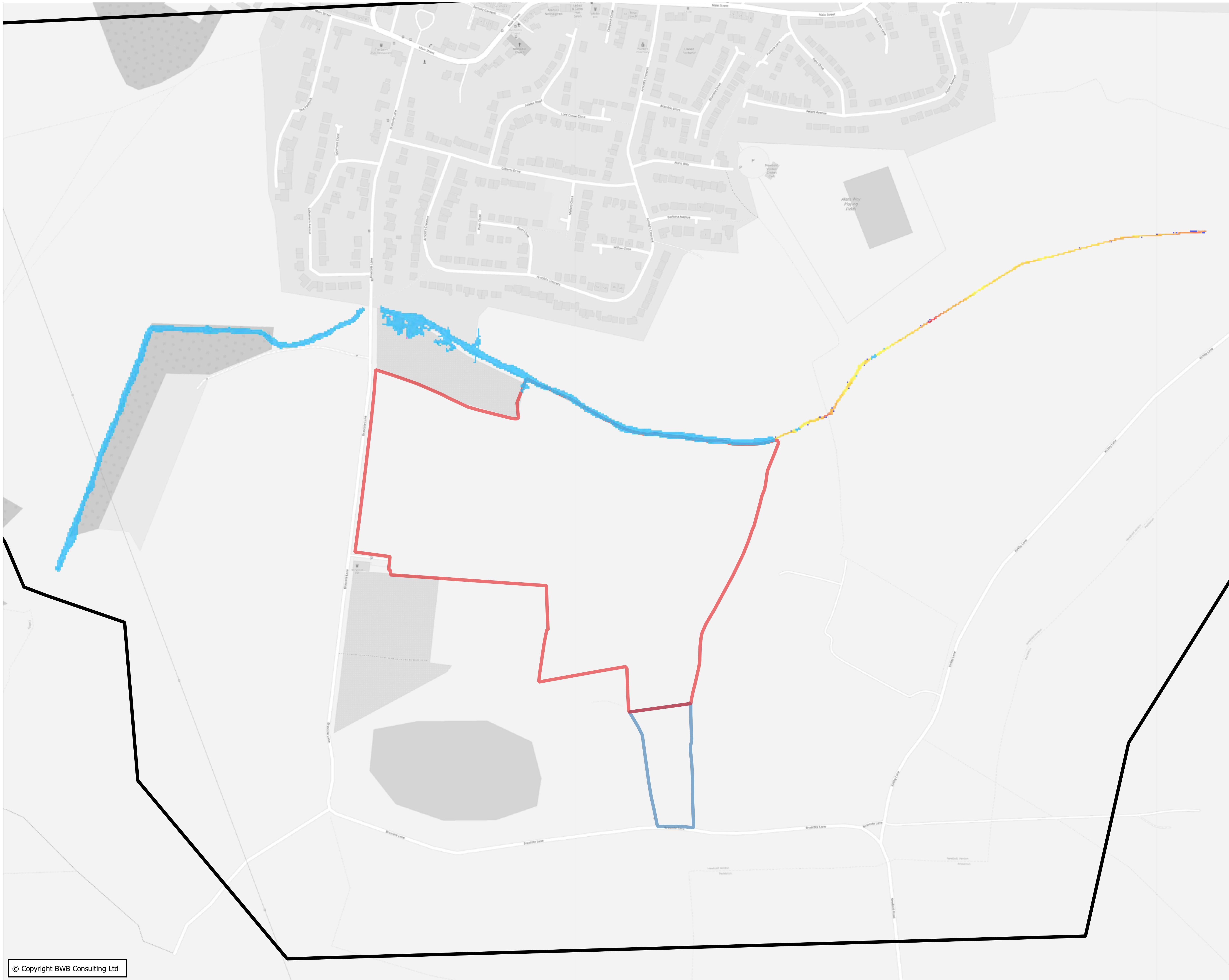
Sensitivity Tests: 1 in 100-Year (1% AEP) 5.5hr Storm Compared to 11hr Storm

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0010	S2	P02



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

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Client

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Project Title

Brascote Lane, Newbold Verdon

Drawing Title

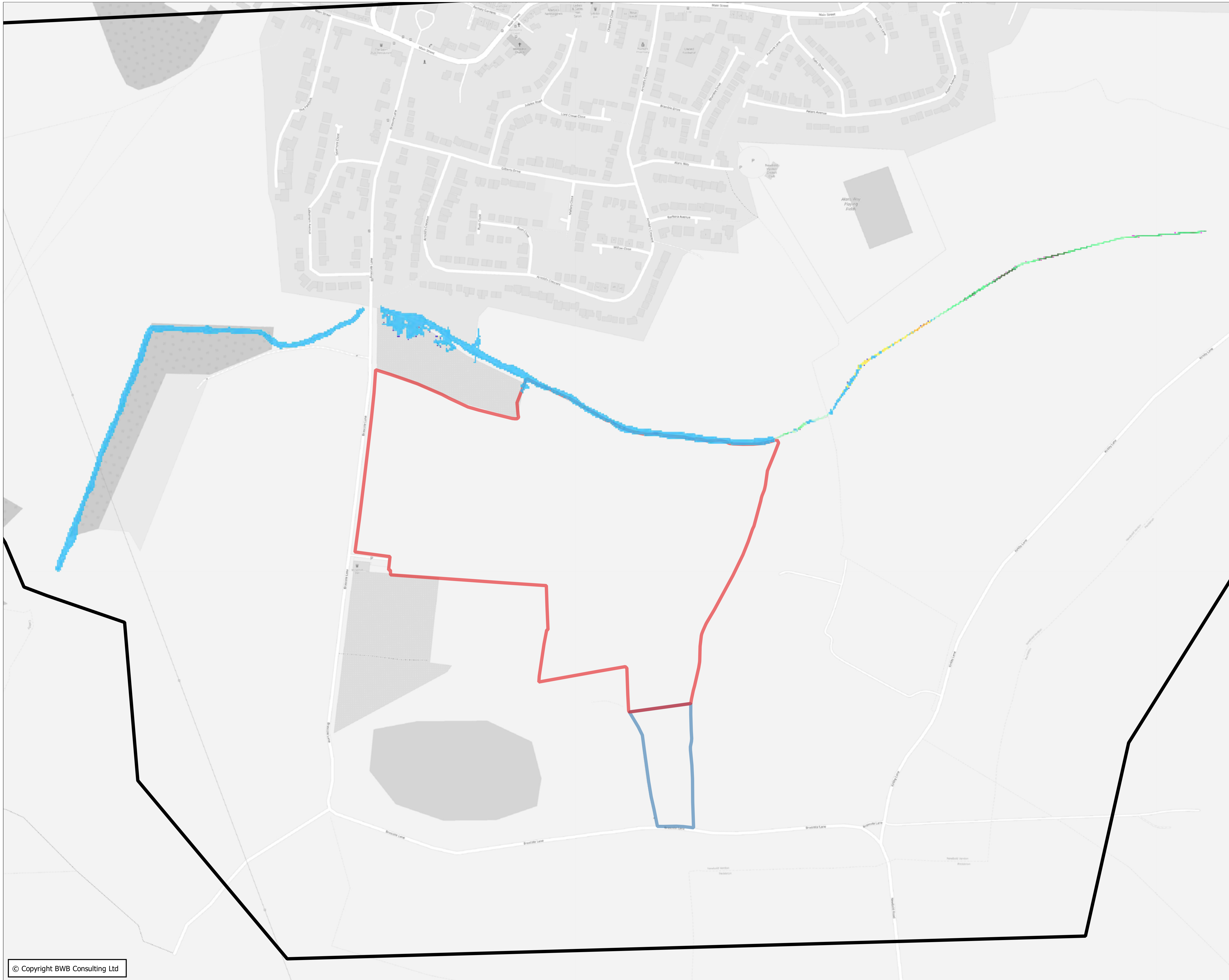
Sensitivity Tests: 1 in 100-Year (1% AEP) Increased Roughness (+20%)

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0011	S2	P02



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

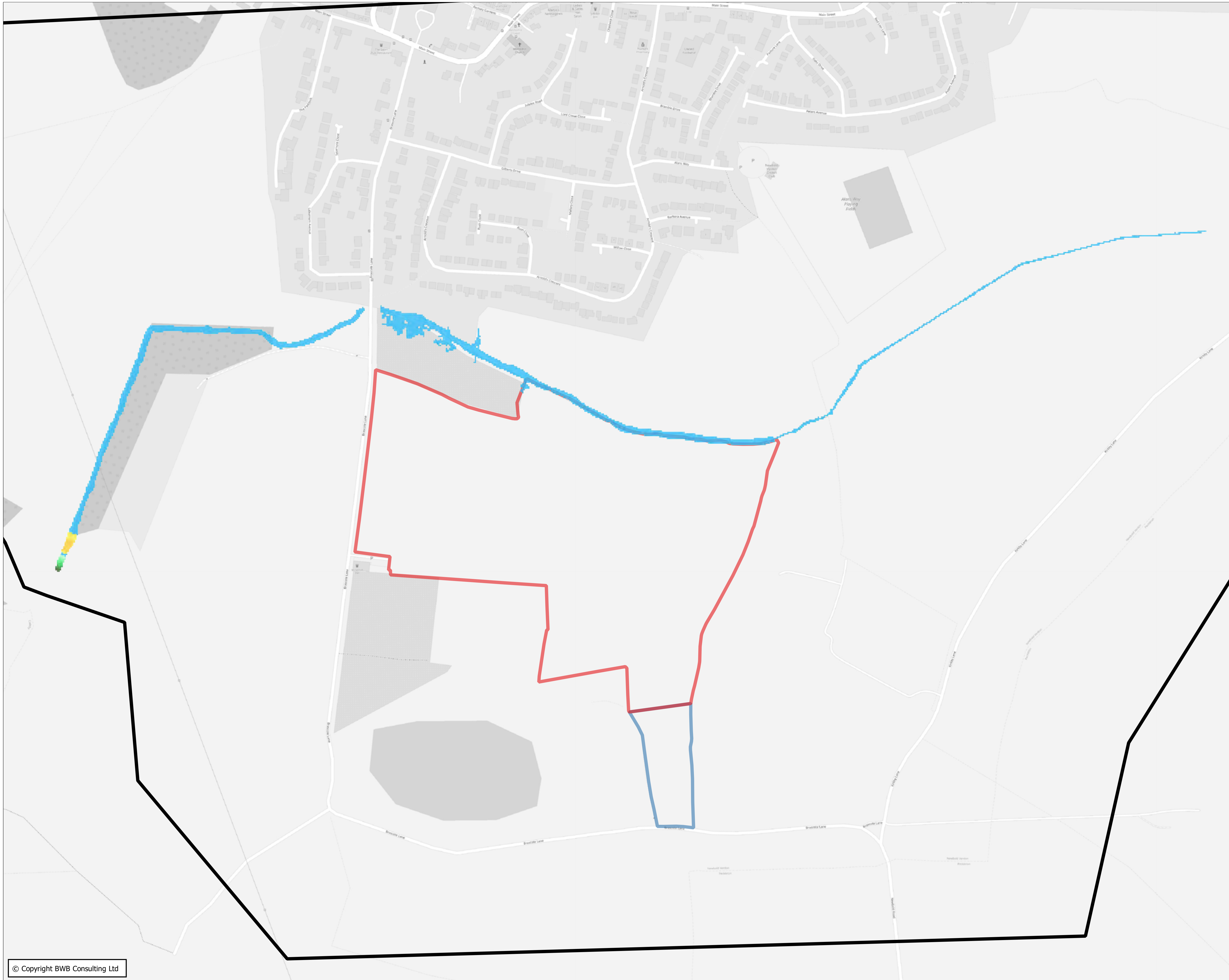
Sensitivity Tests:
1 in 100-Year (1% AEP)
Decreased Roughness
(-20%)

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0012	S2	P02



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

Issues & Revisions

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

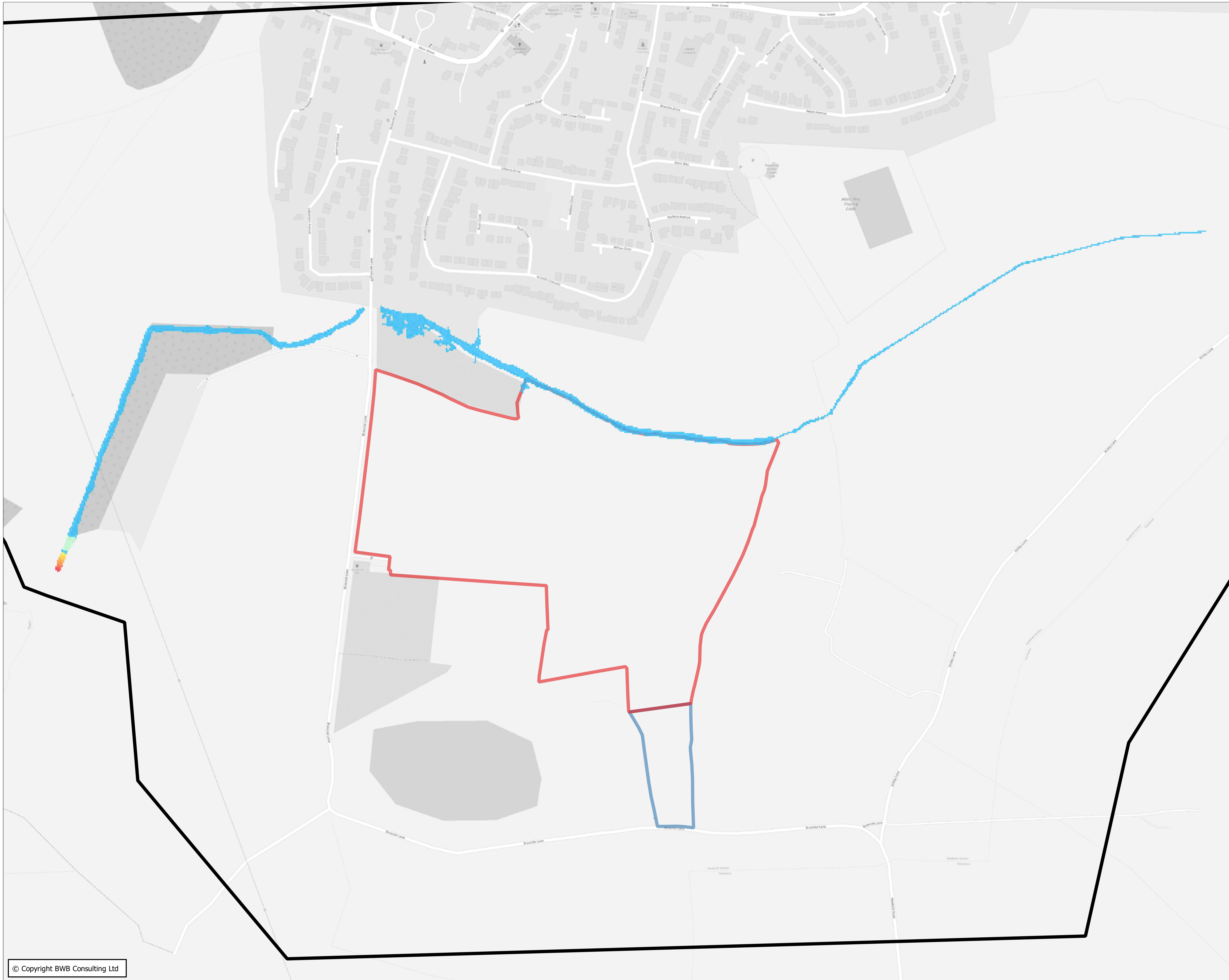
Sensitivity Tests: 1 in 100-Year (1% AEP) Downstream Boundary Gradient (+20%)

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0013	S2	P02



Notes

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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.

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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

Issues & Revisions

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

Sensitivity Tests: 1 in 100-Year (1% AEP) Downstream Boundary Gradient (-20%)

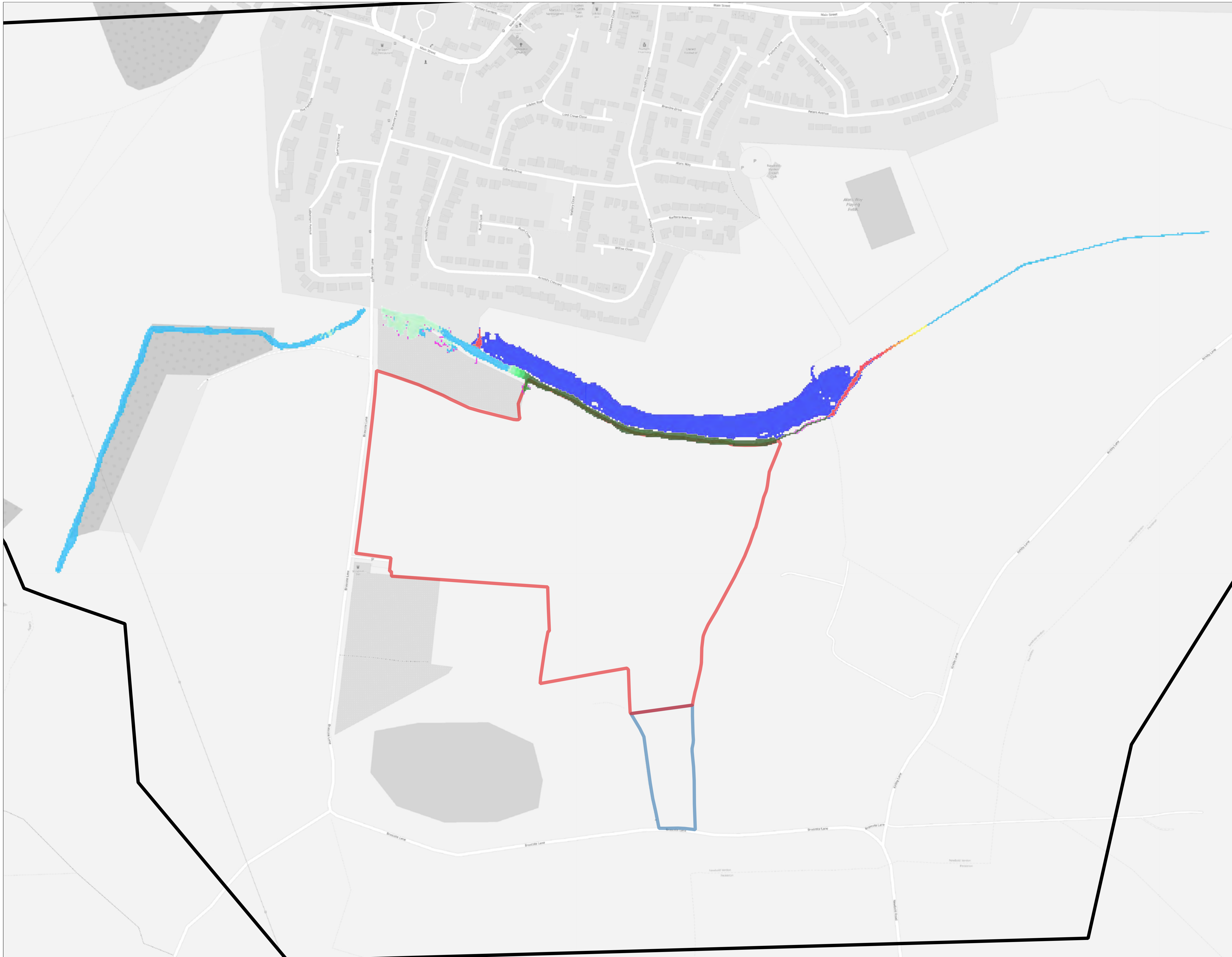
Drawn:	M. Brambani	Reviewed:	R. Green

BWB Ref:	BMW 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-0014	S2	P02



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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

Issues & Revisions

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Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

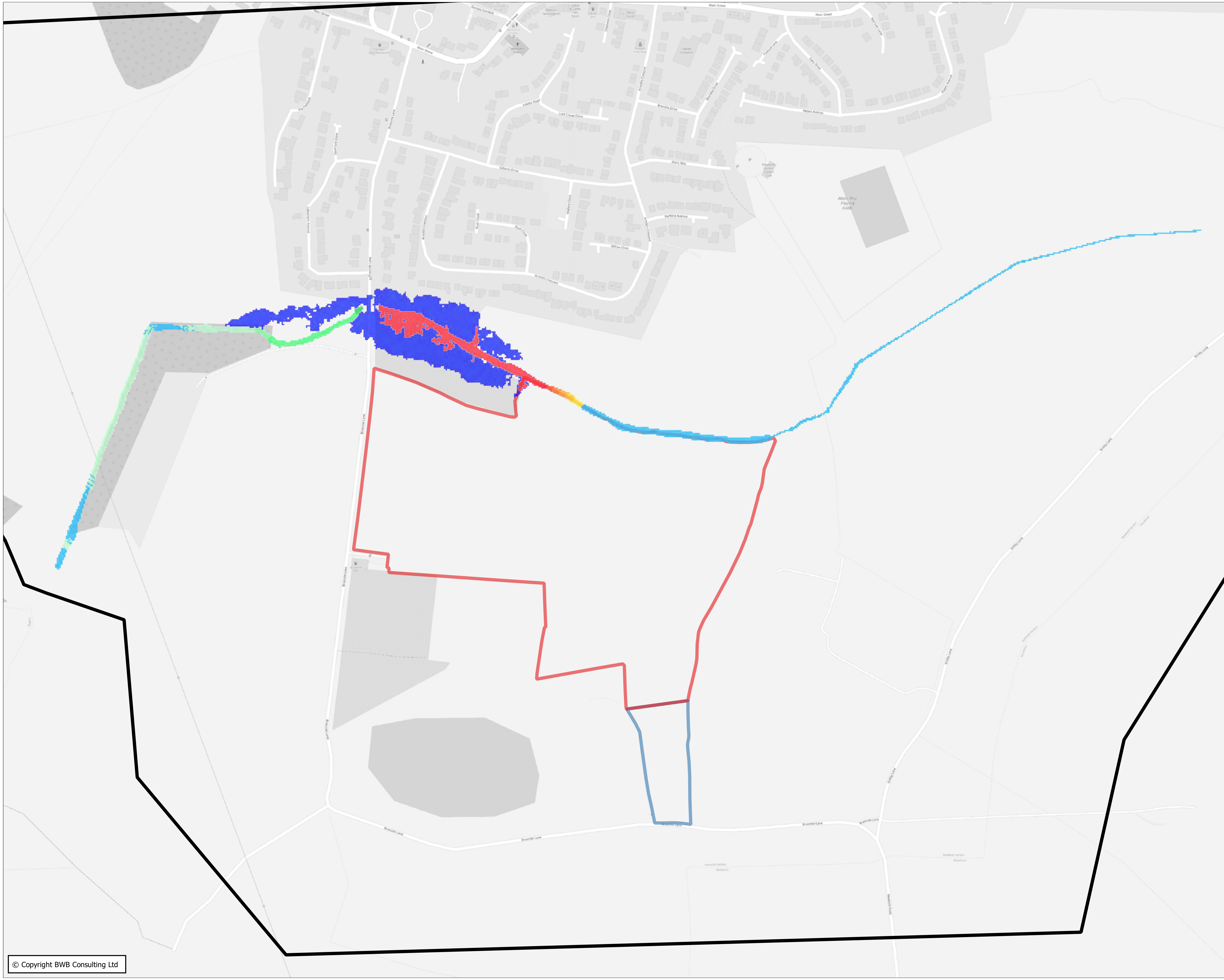
**Sensitivity Tests:
1 in 100-Year (1% AEP)
Blockage Test Location 1
(100%)**

Drawn:	M. Brambani		Reviewed:	R. Green	
BWB Ref:	BMW 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-0015	S2	P02



Notes

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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

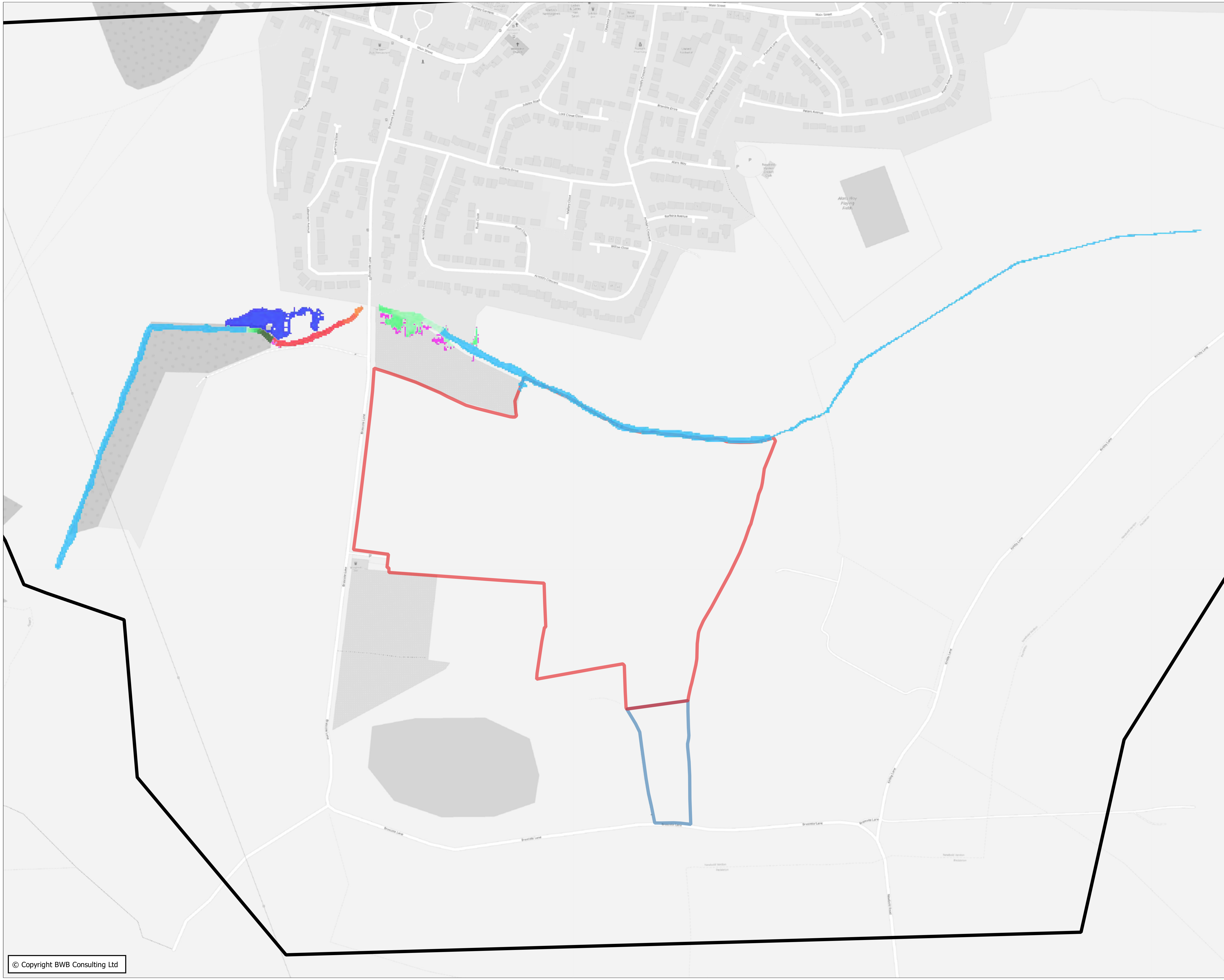
**Sensitivity Tests:
1 in 100-Year (1% AEP)
Blockage Test Location 2
(100%)**

Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref:	BMW 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-0016	S2	P02



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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.

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Key

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

Change in Flood Level (m)

- <= -0.125
- -0.125 - -0.100
- -0.100 - -0.075
- -0.075 - -0.050
- -0.050 - -0.025
- -0.025 - -0.01
- -0.01 - 0.01 (No Change)
- 0.01 - 0.025
- 0.025 - 0.050
- 0.050 - 0.075
- 0.075 - 0.100
- 0.100 - 0.125
- > 0.125

Change in Floodplain Extent

- Former Wet Areas Now Dry
- Former Dry Areas Now Wet

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

Issues & Revisions

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Client

Richborough Estates Ltd

Project Title

Brascote Lane, Newbold Verdon

Drawing Title

Sensitivity Tests: 1 in 100-Year (1% AEP) Blockage Test Location 3 (100%)

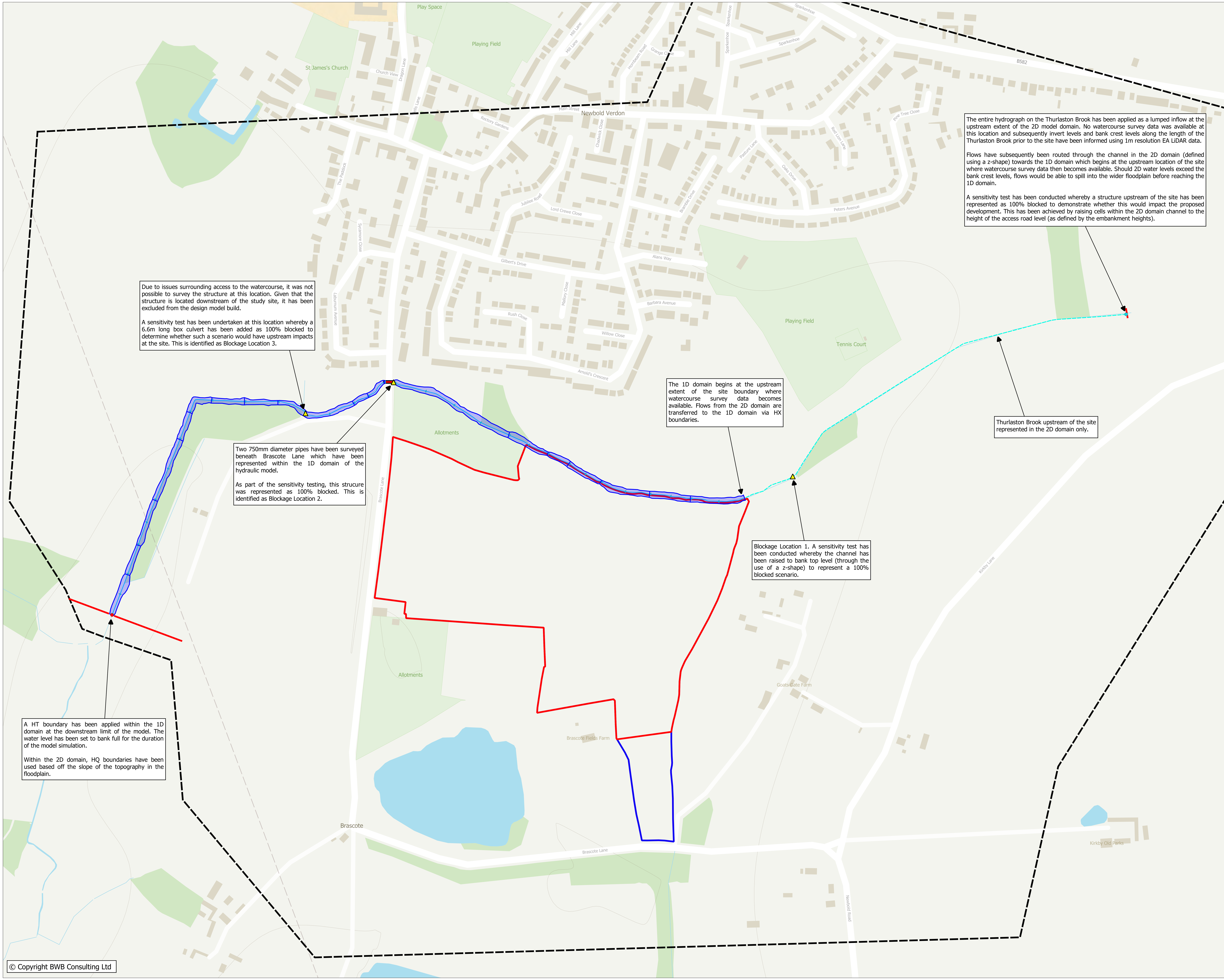
Drawn:	M. Brambani	Reviewed:	R. Green
BWB Ref: BMW 3175	Date: 24/02/22	Scale@A3:	1:4,500

Drawing Status

FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0017	S2	P02

Appendix 6 – Model Schematic



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Key

- 2D Inflow Location (QT)
- 1D Downstream Boundary (HT)
- 2D Downstream Boundary (HQ)
- 2D Thurlaston Brook Channel
- 1D Thurlaston Brook Channel
- 1D Hydraulic Structures
- Blockage Locations
- 1D-2D Boundary (HX)
- 1D Domain
- 2D Domain
- Blueline Site Ownership Boundai
- Redline Application Site Boundar

Rev	Date	Details of issue / revision	Drw	Rev
P02	22.02.22	Updated Redline Application Boundary	MB	RG
P01	08.09.21	Preliminary Issue	MB	RG

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Client
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Project Title
Brascote Lane, Newbold Verdon

Drawing Title
Hydraulic Model Schematic

Drawn:	M. Brambani	Reviewed:	R. Green

BWB Ref:	BMW 3175	Date:	22/02/22	Scale@A1:	1:2,500

Drawing Status
FINAL

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-ZZ-XX-SK-YE-0001	S2	P02

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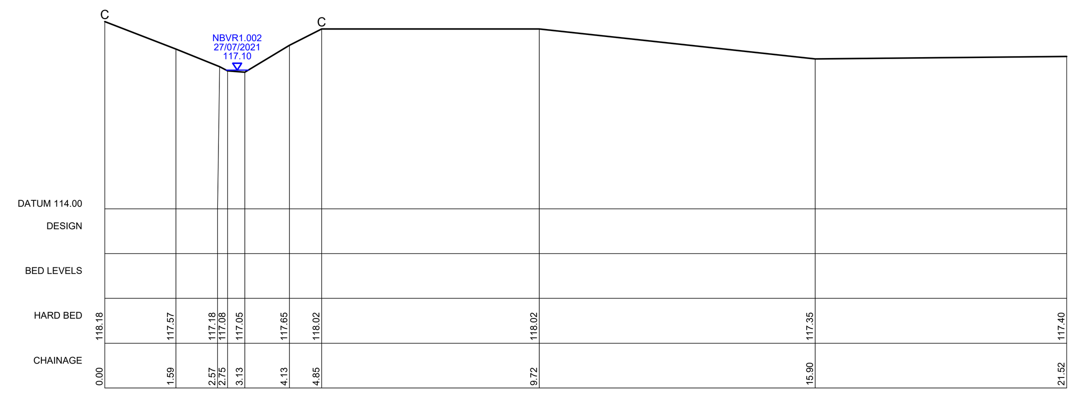
Appendix 2: Watercourse Survey

NBVR1.001
444013.5mE 303012.29mN Brg 295
0m
Open Channel



NBVR1.002
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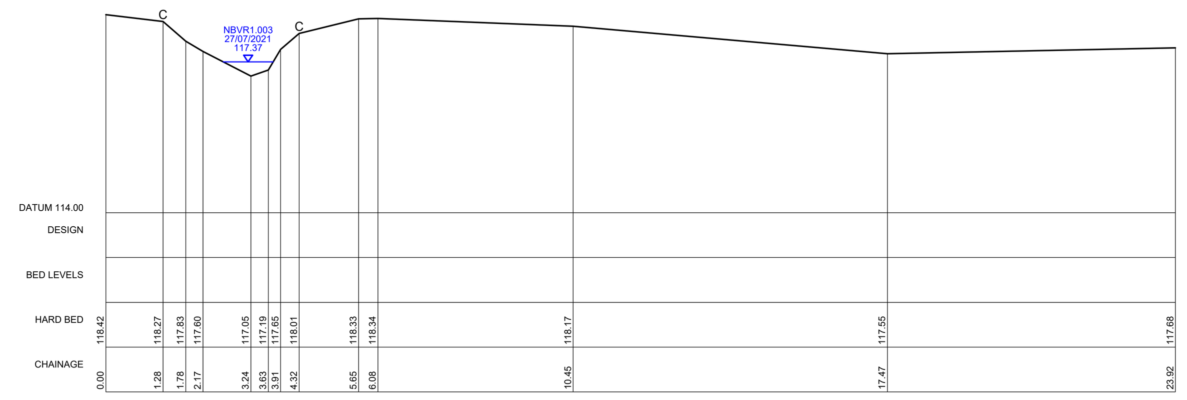
64.3m
Open Channel



NBVR1.003
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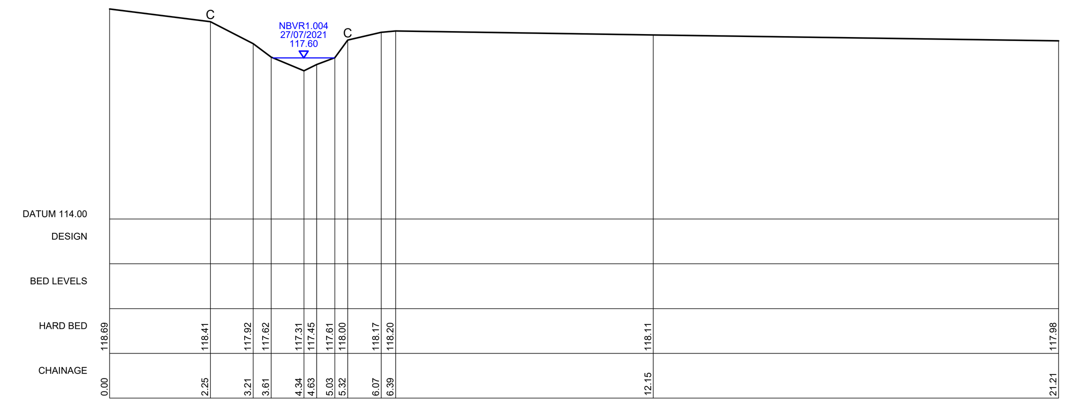
110.7m
Open Channel



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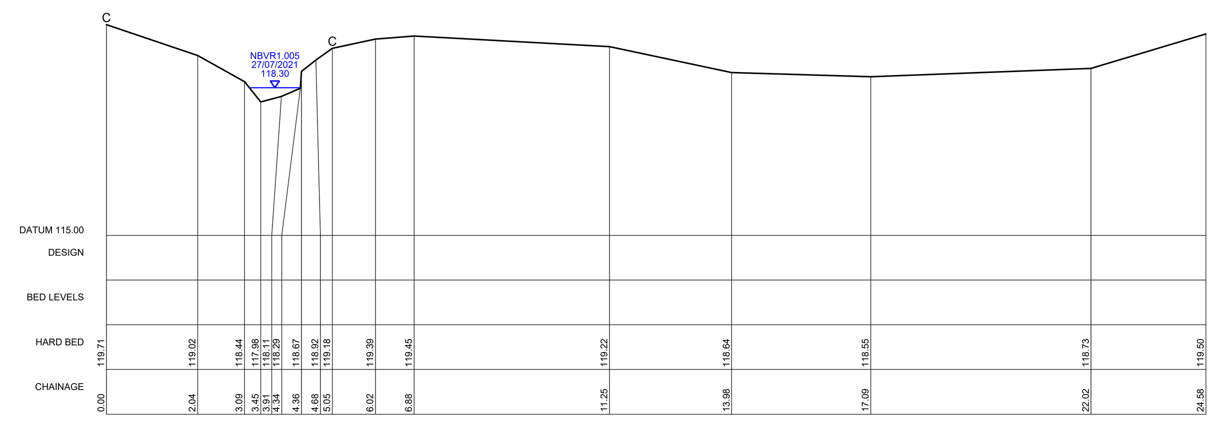
181.8m
Open Channel



NBVR1.005
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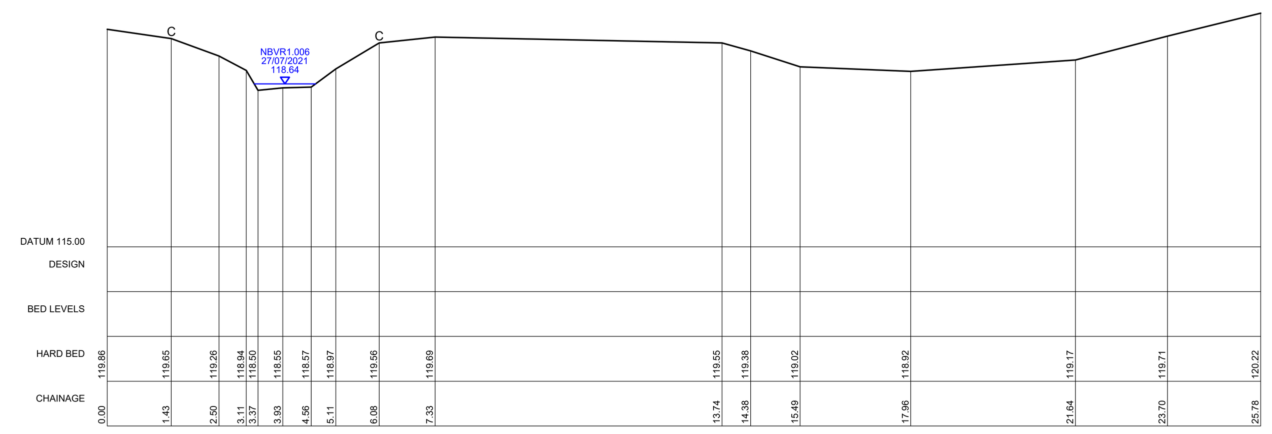
279.4m
Open Channel



NBVR1.006
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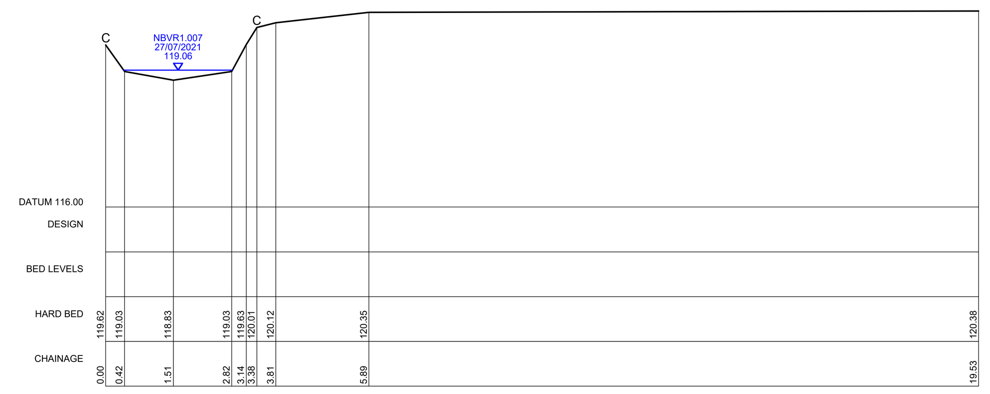
322.7m
Open Channel



NBVR1.007
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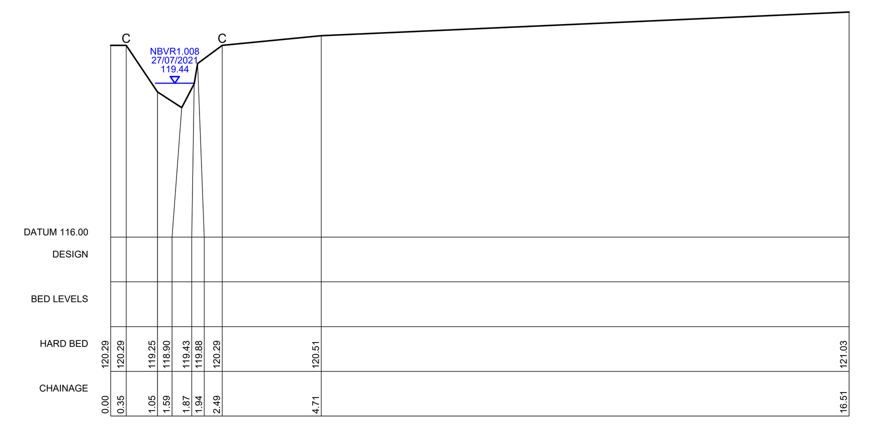
367.3m
Open Channel



NBVR1.008
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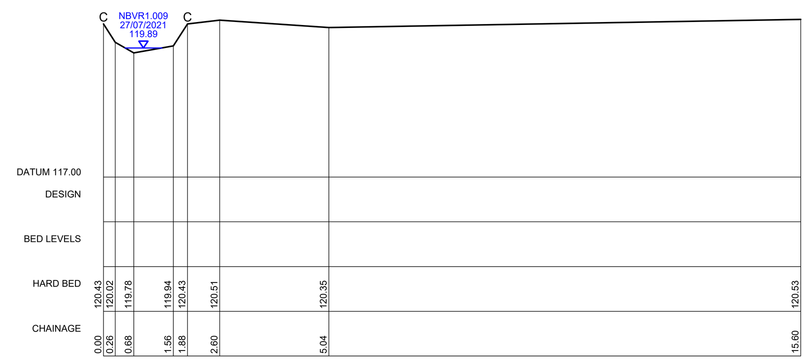
416.1m
Open Channel



NBVR1.009
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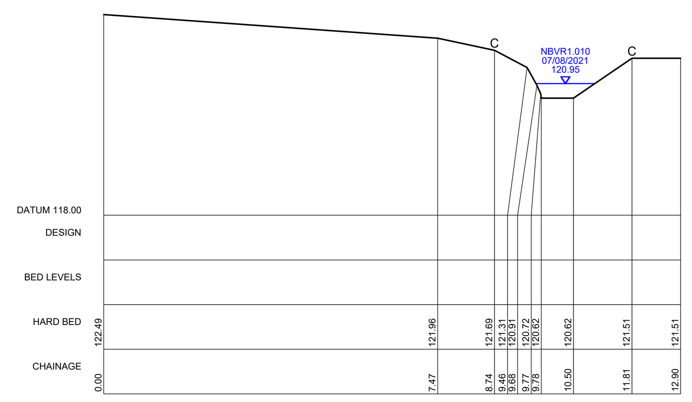
465.5m
Open Channel



NBVR1.010
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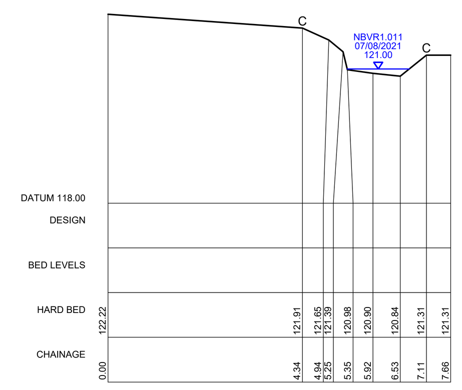
588.4m
Open Channel



NBVR1.011
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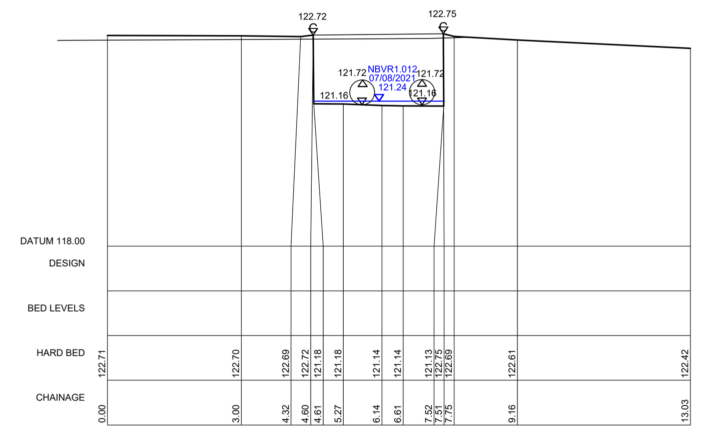
612.7m
Open Channel



NBVR1.012
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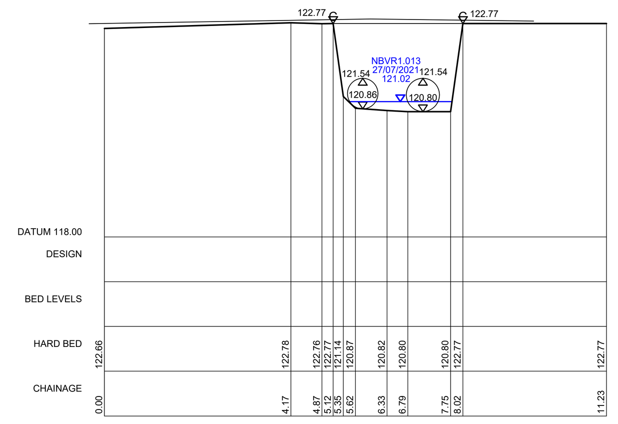
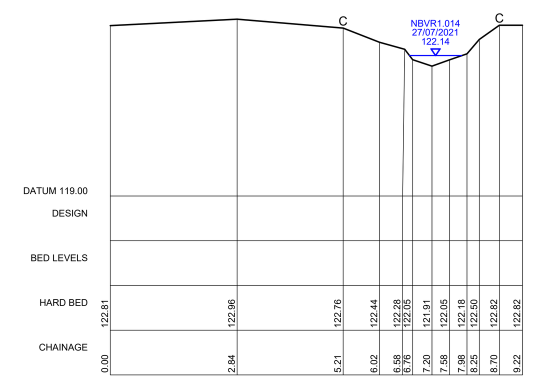
646.4m
Culvert



NBVR1.013
444429.61mE 303351.73mN Brg 11
659.6m
Culvert



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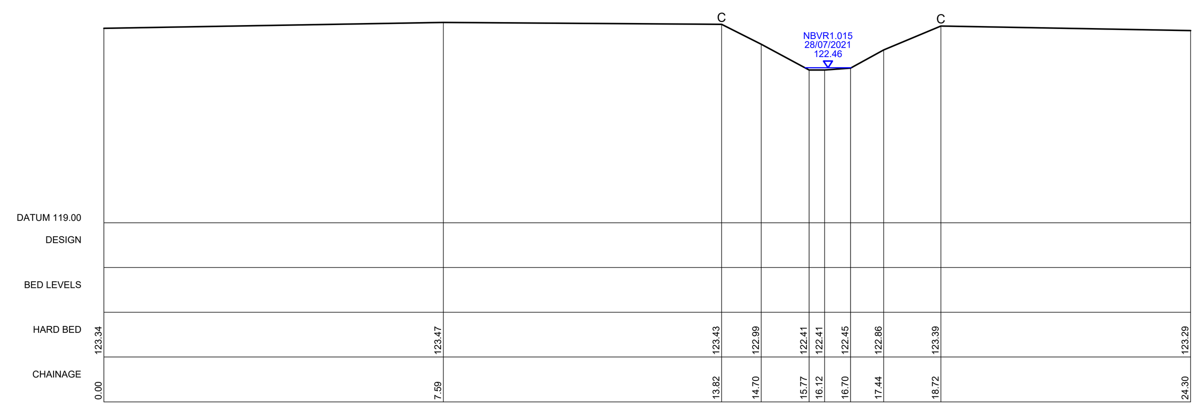
849.5m
Open Channel



NBVR1.015
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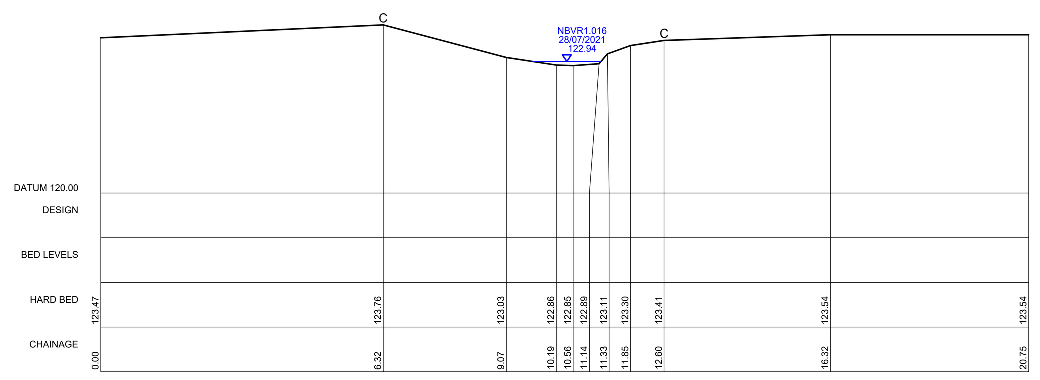
913.9m
Open Channel



NBVR1.016
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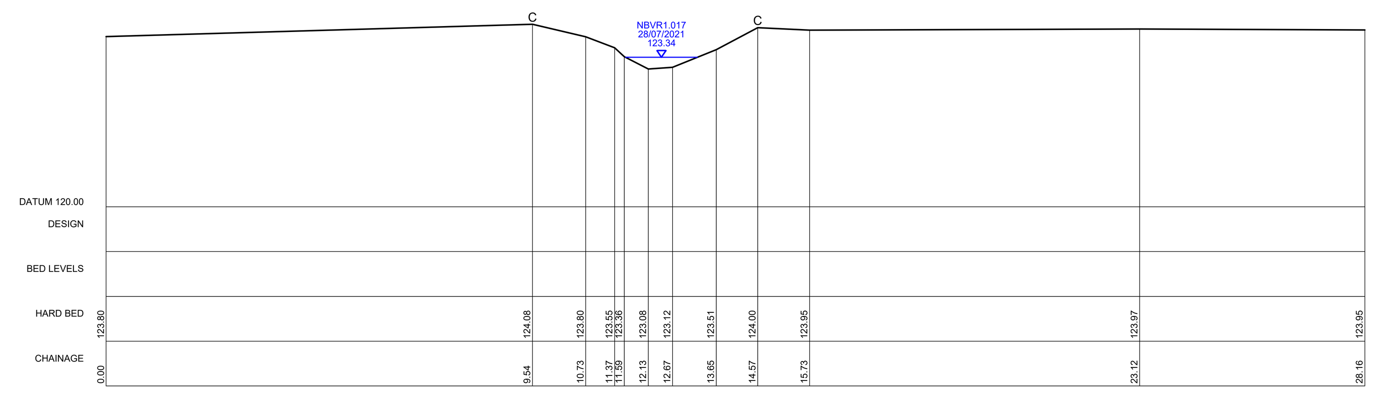
949m
Open Channel



NBVR1.017
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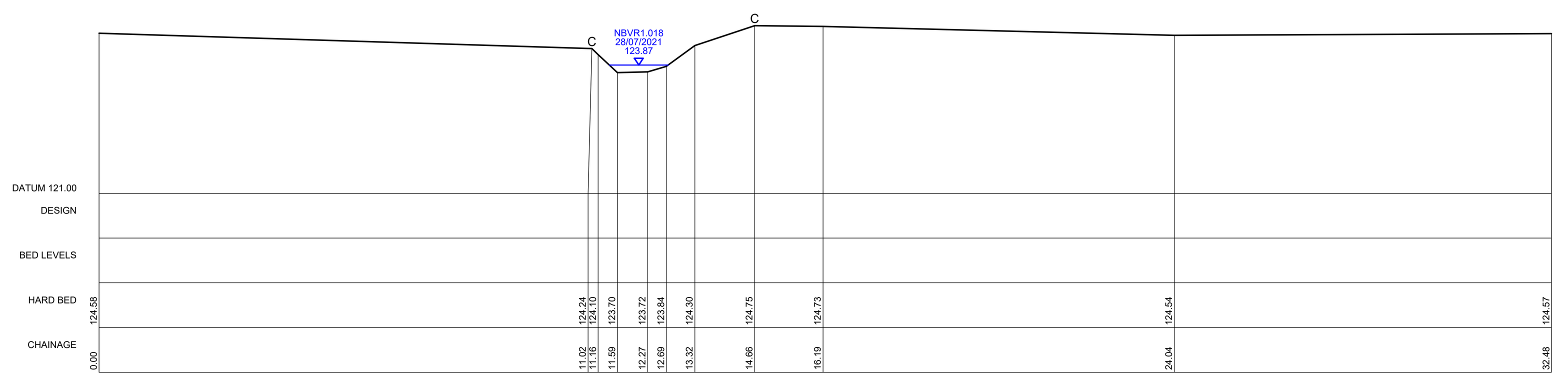
1003.9m
Open Channel



NBVR1.018
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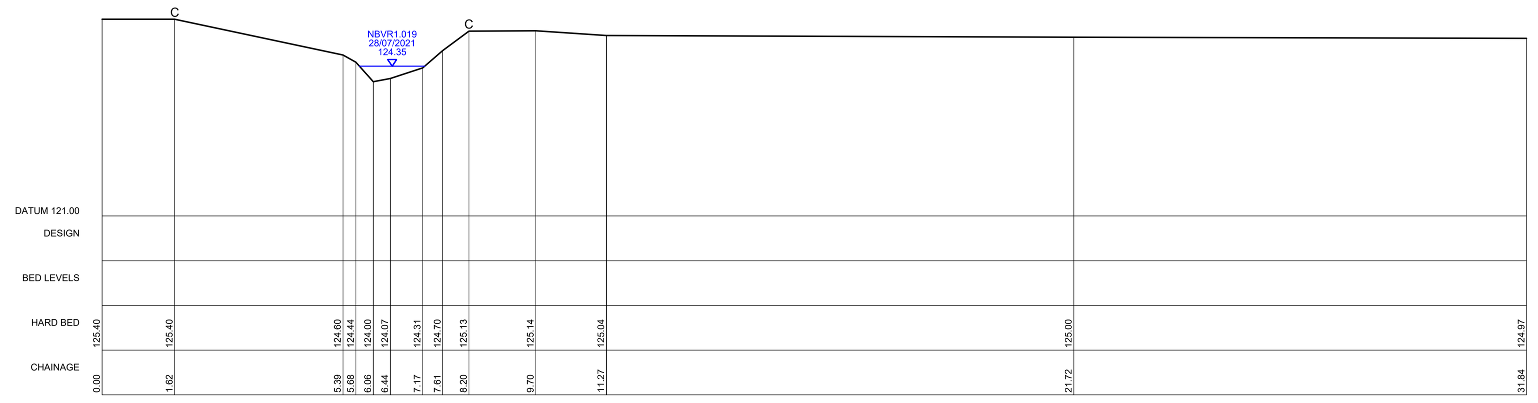
1079.4m
Open Channel



NBVR1.019
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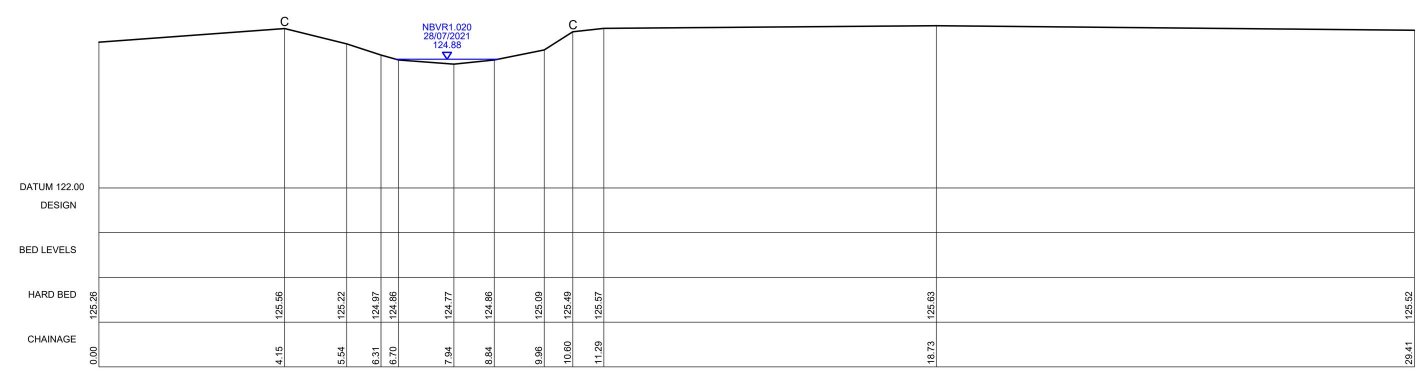
1140.5m
Open Channel



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

Notes

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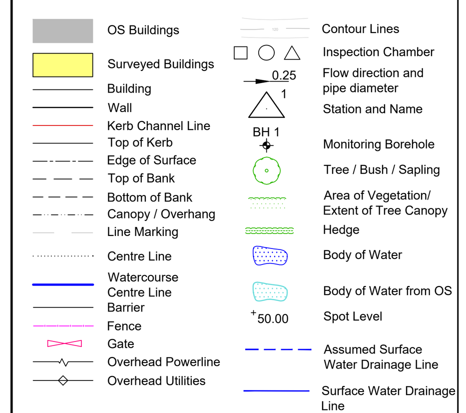
4. Any discrepancies noted on site are to be reported to the engineer immediately.
5. No scale factor has been applied to this survey, therefore the os coordinates are to be treated as arbitrary. Please refer to survey station information below for on site control establishment.
6. All coordinates and 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



AP Anchor Point
BG Back Gully
BO Bollard
BS Bus Stop
BT British Telecom
C Crest
CL Cover Level
CMP Cable Marker Post
CCTV Security Camera
CTV Cable TV
DC Drainage Channel
DK Drop Kerb
DP Down Pipe
Elec Electric
EP Electricity Post
ER Earth Rod
FH Fire Hydrant
FL Floodlight
FBW Fence Barbed Wire
FCB Fence Closed Board
FCL Fence Chain Link
FEL Fence Electric
FMP Fence Metal Panel
FMR Fence Metal Railing
FOB Fence Open Board
FPW Fence Post & Wire
FSP Fence Steel Palisade
FWM Fence Wire Mesh
FFL Finished Floor Level
FP Flagpole
Gas Gas
GV Gas Valve
GY Gully
Ht Height
IC Inspection Chamber
IFL Internal Floor Level
IL Invert Level (as a reduced level)
LB Litter Bin
LP Lamp Post
MH Manhole
Mkr Service Marker
PB Post Box
PT Post
RE Rodding Eye
SP Sign Post
ST Stop Tap
SV Stop Valve
TCB Telephone Call Box
THL Threshold Level
TL Traffic Light
TP Telegraph Post
TS Traffic Signal
UTS Unable to Survey
WL Water Level
WM Water Meter
WO Wash Out

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

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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 3

Drawn:	I.Riley		Reviewed:	D.Smith	
BWB Ref:	BMW 3175	Date:	29.07.21	Scale@A0:	1:100

Drawing Status
INFORMATION

Project - Originator - Zone - Level - Type - Role - Number	Status	Rev
BLN-BWB-00-ZZ-M2-G-0060	S2	P2

C:\Users\Iain.Riley\Documents\LSS FILES\JOBS\2024 JOBS\Newbold Verdon WC Extension\Watercourse Extension Data\BLN-BWB-00-ZZ-M2-G-0060_Existing_Watercourse_Survey-S2-P2.dwg