PROPOSED CHANGE OF USE OF EXISTING BARNS AT THE FRING HALL ESTATE, DOCKING ROAD, FRING, NORFOLK

FLOOD MODELLING ASSESSMENT

MARCH 2022

REPORT REF: 2536/RE/07-20/02

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CONTRACT

Evans Rivers and Coastal Ltd has been commissioned by Oykel Farms Ltd to carry out a flood modelling assessment for a proposed change of use of existing barns at the Fring Hall Estate, Docking Road, Fring, Norfolk.

QUALITY ASSURANCE, ENVIRONMENT AND HEALTH AND SAFETY

Evans Rivers and Coastal Ltd operates a Quality Assurance, Environmental, and Health and Safety Policy.

This project comprises various stages including data collection; depth analysis; and reporting. Quality will be maintained throughout the project by producing specific methodologies for each work stage. Quality will also be maintained by providing specifications to third parties such as surveyors; initiating internal quality procedures including the validation of third party deliverables; creation of an audit trail to record any changes made; and document control using a database and correspondence log file system.

To adhere to the Environmental Policy, data will be obtained and issued in electronic format and alternatively by post. Paper use will also be minimised by communicating via email or telephone where possible. Documents and drawings will be transferred in electronic format where possible and all waste paper will be recycled. Meetings away from the office of Evans Rivers and Coastal Ltd will be minimised to prevent unnecessary travel, however for those meetings deemed essential, public transport will be used in preference to car journeys.

The project will follow the commitment and objectives outlined in the Health and Safety Policy operated by Evans Rivers and Coastal Ltd. All employees will be equipped with suitable personal protective equipment prior to any site visits and a risk assessment will be completed and checked before any site visit. Other factors which have been taken into consideration are the wider safety of the public whilst operating on site, and the importance of safety when working close to a water source and highway. Any designs resulting from this project and directly created by Evans Rivers and Coastal Ltd will also take into account safety measures within a "designers risk assessment".

Report carried out by:

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DISCLAIMER

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1. INTRODUCTION

1.1 Project Scope

1.1.1 Evans Rivers and Coastal Ltd has been commissioned by Oykel Farms Ltd to carry out a flood modelling assessment for a proposed change of use of existing barns at the Fring Hall Estate, Docking Road, Fring, Norfolk.

1.1.2 Specifically, this assessment intends to:

a) Estimate the fluvial flood flows within the watercourse using appropriate and up-to-date Flood Estimation Handbook methods for a range of return period events and updated UK climate change allowances.

b) Develop an InfoWorks flood model of the watercourse to determine the likely extent, depth and velocity of the floodwater.

c) Carry out a sensitivity analysis;

d) Report findings.

1.1.3 This assessment is carried out in accordance with the requirements of the National Planning Policy Framework (NPPF) dated 2021. Other documents which have been consulted include:

- DEFRA/EA document entitled *Framework and guidance for assessing and managing flood risk for new development Phase 2 (FD2320/TR2)*, 2005;

- Science Report (SC050050/SR) entitled *Improving the FEH statistical procedures for flood frequency estimation,* carried out by the Centre for Ecology and Hydrology and published in 2008 by DEFRA and the EA.

- EA guidance document entitled *Flood Estimation Guidelines Technical Guidelines (197_08)* dated June 2020.

- *The Revitalised Flood Hydrograph Model ReFH2 Technical Guidance.*

- DEFRA/EA document entitled *Estimating flood peaks and hydrographs for small catchments: Phase 1 (SC090031)* dated May 2012.

- Kjeldsen, T.R, Jones. D. A., and Morris, D. G. (2014). Using multiple donor sites for enhanced flood estimation in ungauged catchments, Water Resour. Res., 50, 6646–6657, doi:10.1002/ 2013WR015203.

- Stewart, L., Faulkner, D., Formetta. F., Griffin, A., Haxton, T., Prosdocimi, I., Vesuviano, G., Young. A. (2019). Estimating flood peaks and hydrograph for small catchments (Phase 2). Report SC090031/R0, Environment Agency.

- DEFRA/EA document entitled *The flood risks to people methodology (FD2321/TR1),* 2006;

- EA *Supplementary Note on Flood Hazard Ratings and Thresholds for Development Planning and Control Purpose*, 2008;

- Communities and Local Government 2007. *Improving the Flood Performance of New Buildings*. HMSO.

- National Planning Practice Guidance – Flood Risk and Coastal Change.

- UK Government's climate change allowances guidance.

- Kings Lynn and West Norfolk Strategic Flood Risk Assessment (SFRA) dated 2007/8.

- JBA Consulting *Level 1 King's Lynn and West Norfolk Strategic Flood Risk Assessment* (SFRA) dated 2018.

- JBA Consulting *Level 2 King's Lynn and West Norfolk Strategic Flood Risk Assessment* (SFRA) dated 2019.

- Kings Lynn and West Norfolk *Surface Water Management Plan (SWMP)* dated 2010 and 2012.

- Norfolk County Council *Flood Investigation Report* dated 2015.

- Norfolk County Council document entitled *Lead Local Flood Authority Statutory Consultee for Planning – Guidance Document* dated October 2021.

2. DATA COLLECTION

2.1 To assist with this report, the data collected included:

- Ordnance Survey 1:10,000 street view map (Evans Rivers and Coastal Ltd OS licence number 100049458).

- Filtered LIDAR data at 1m resolution covering the site and surrounding area (LIDAR-LIDAR-DTM-1m-2020-TF73nw and LIDAR-DTM-1m-2020-TF73sw downloaded from https://environment.data.gov.uk/DefraDataDownload/?Mode=survey on 3rd February 2022).

- Topographical survey of the site and watercourse carried out by BB Surveys (Drawing Numbers 2219-3284-SU00, 2219-3284-SU01, 2219-3284-SU02, 2219-3284-SU03, 2219-3284-SU04).

- 1:250,000 *Soil Map of Eastern England* (Sheet 4) published by Cranfield University and Soil Survey of England and Wales 1983.

- British Geological Survey, *Online Geology of Britain Viewer*.

- 1:625,000 *Hydrogeological Map of England and Wales*, published in 1977 by the Institute of Geological Sciences (now the British Geological Survey).

3. SITE CHARACTERISTICS

3.1 Existing Site Characteristics and Location

3.1.1 The site is located at Fring Hall Estate, Docking Road, Fring, Norfolk. The approximate Ordnance Survey (OS) grid reference for the site is 573630 334934 and the location of the site is shown on Figure 1.

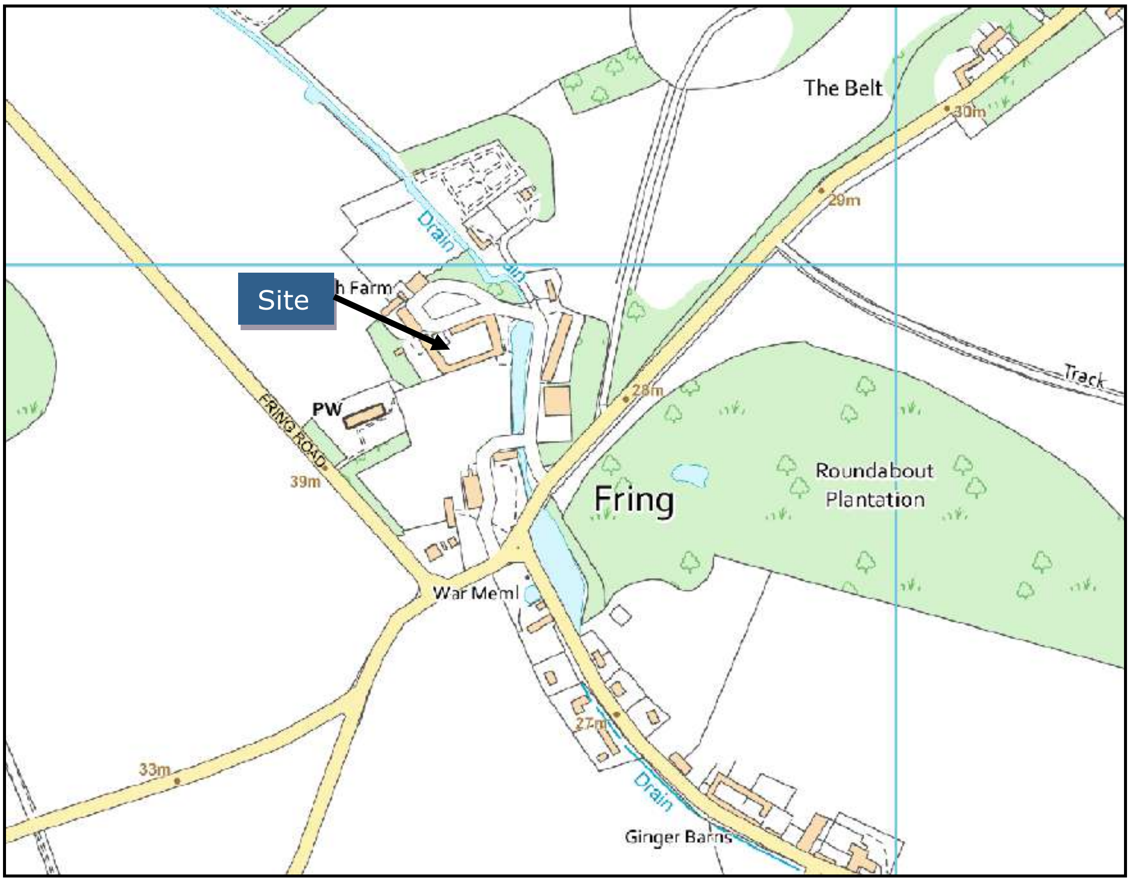

Figure 1: Site location plan (Source: Ordnance Survey)

3.1.2 The site comprises a collection of barns around a courtyard. The site is accessed from Docking Road via an access road.

3.1.3 The Heacham River flows in a north westerly direction through this area (Figure 3). However, the watercourse is not designated as 'Main River' at this location and Figure 6.1 of the SWMP together with 2017 SFRA map KL_16 shows that the watercourse is designated an Ordinary Watercourse.

3.1.4 A GPS topographical survey of the site and watercourse has been carried out by BB Surveys (Drawing Numbers 2219-3284-SU00, 2219-3284-SU01, 2219-3284-SU02, 2219-3284-SU03, 2219-3284-SU04).

3.1.5 Filtered LIDAR data at 1m resolution has also been obtained in order to illustrate the topography across the site and surrounding area (Figure 2).

3.1.6 By reviewing the survey it can be seen that the ground floor level of the barns is variable and set at 26.23m AOD, 25.99m AOD, 26.68m AOD, 27.14m AOD and 25.89m AOD.

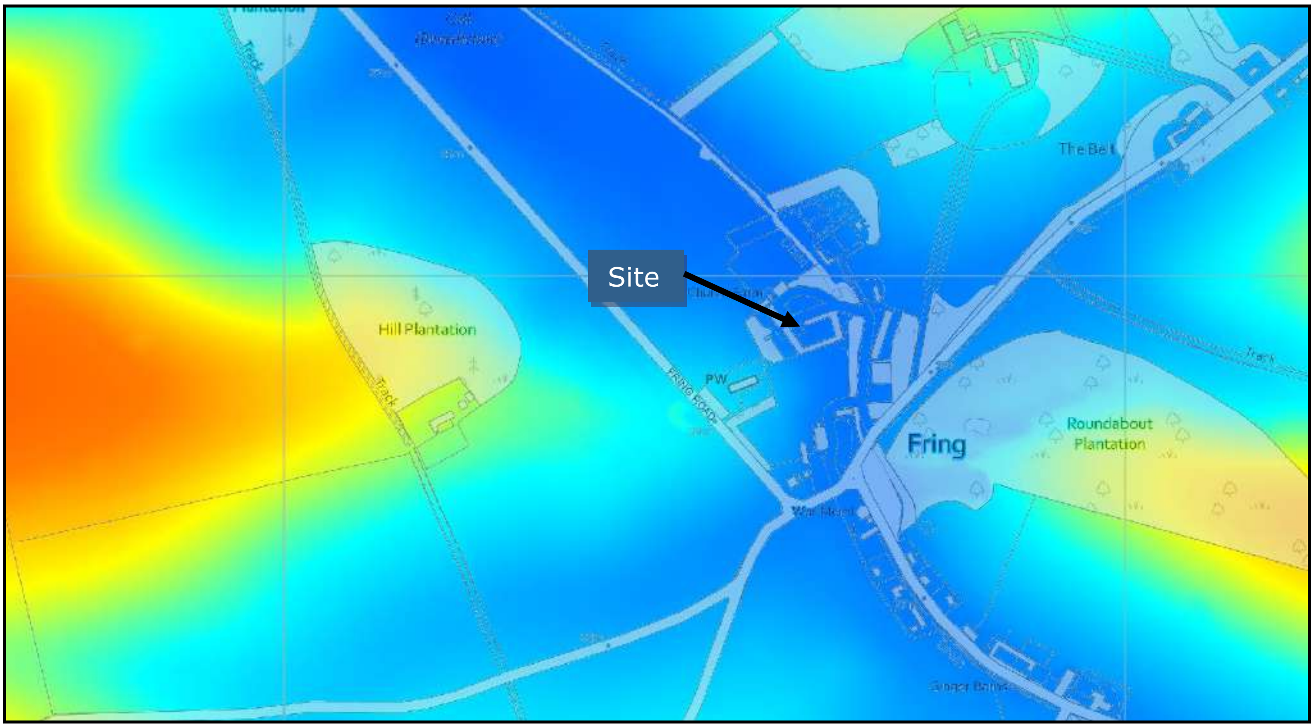

Figure 2: Filtered LIDAR survey of the site and surrounding area combined with OS

Figure 3: Aerial view of site and surrounding area looking north

3.2 Site Proposals

3.2.1 It is the Client's intention to use barns A-D as internal amenity space (including games room and kitchen) to be used in association with the holiday units proposed for the remainder of the barn complex (i.e. barns E – J).

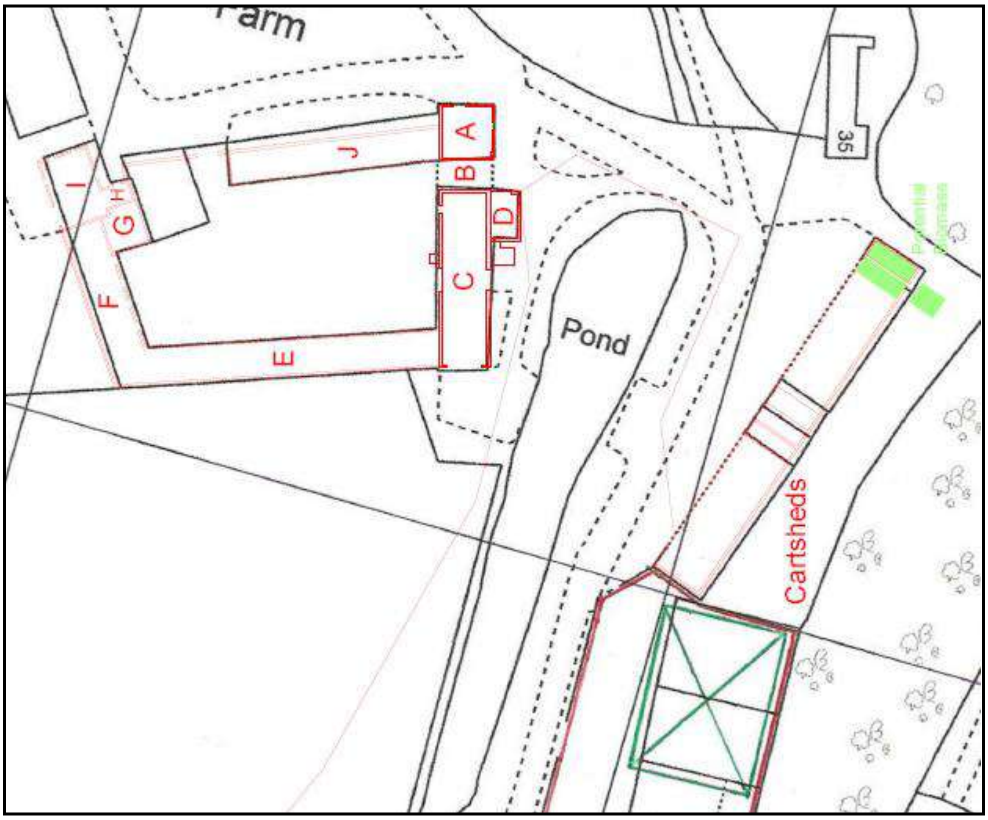

Figure 4: Barns to be converted

3.2.2 The proposed site layout can be seen on Drawing Numbers 20.024-002P and 20.024-003P.

3.2.3 The proposed ground floor level of the northern and eastern barns will be set at a minimum of 26.108m AOD so that they are above the climate change 1 in 1000 year flood level. The southern and western barns will be set at a minimum of 26.373m AOD.

3.2.4 Paragraph 33 (ID 7-033-20140306) of the NPPF Planning Practice Guidance (NPPG) states that the Sequential Test does not apply to change of use applications.

3.2.5 The proposals are classified as a "more-vulnerable" use according to Table 2 of the NPPF Planning Practice Guidance.

4. BASELINE INFORMATION

4.1 Environment Agency Flood Zone Map

4.1.1 The Environment Agency Flood Map (Figure 5) and 2017 SFRA map KL_16 show that the site is located within Flood Zone 3, 2 and 1 associated with the Heacham River.

4.1.2 The Flood Zone 3 is divided into two sub-categories, the Flood Zone 3a and Flood Zone 3b. The extent of the Flood Zone 3a 'High Probability' is defined as the 1 in 100 year return period fluvial event in this case.

4.1.3 Flood Zone 3b functional floodplain is defined in Table 1 of the NPPG as the area where water flows or is stored during flood events. The functional floodplain is generally defined by the limit of the 1 in 20 year flood envelope. The 2017 SFRA map KL_16 shows that the site is not located within the NPPF defined Flood Zone 3b but within the Indicative Flood Zone 3b which follows the extent of the Flood Zone 3a.

4.1.4 The Flood Zone 2 'Medium Probability' floodplain is defined as having between a 1 in 100 year annual probability and 1 in 1000 year annual probability of flooding. The threshold of the Flood Zone 2 floodplain is the 1 in 1000 year extreme event.

4.1.5 The NPPF Flood Zone 1, 'Low Probability' comprises land as having less than a 1 in 1000 year annual probability of fluvial or tidal flooding (i.e. an event more severe than the extreme 1 in 1000 year event). NPPF states that all uses of land are appropriate in this zone.

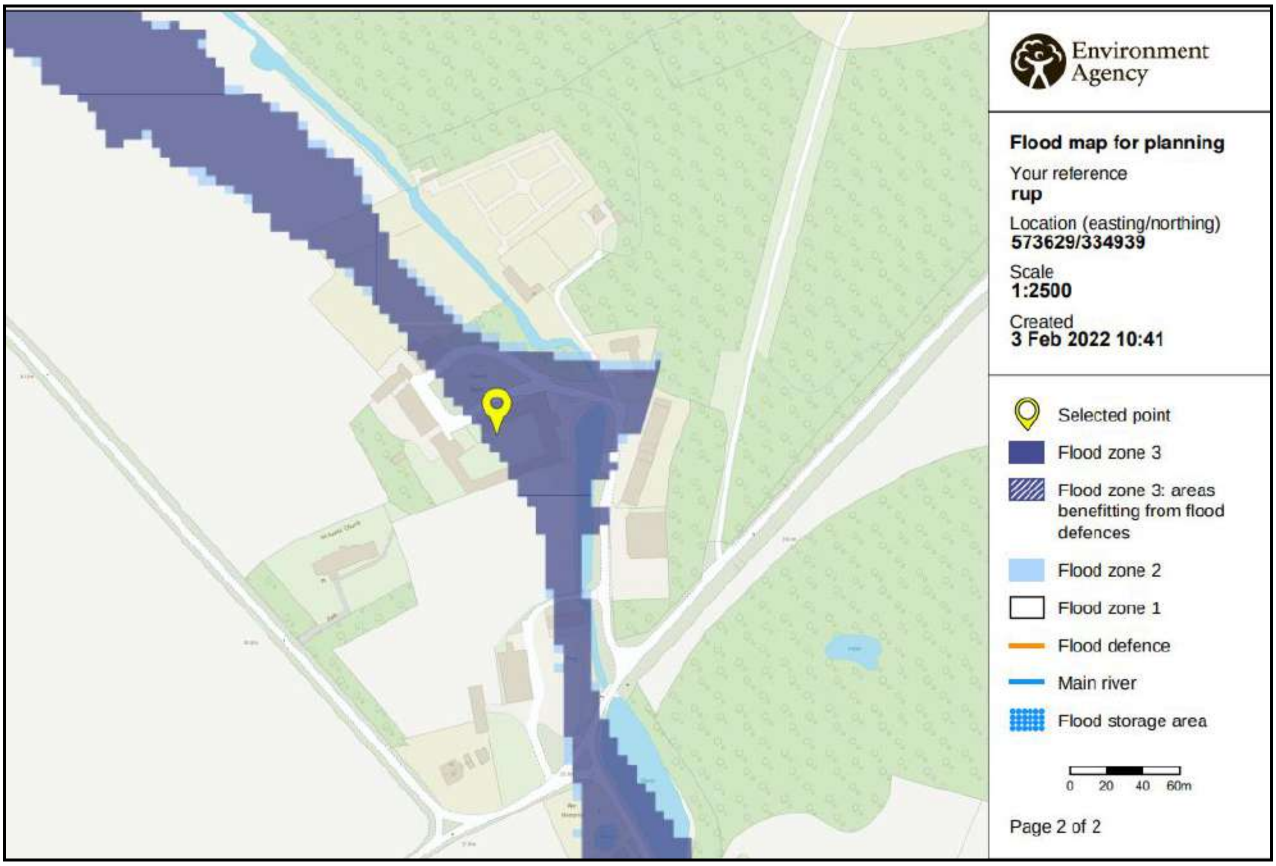

Figure 5: Environment Agency Flood Map (Source: Environment Agency, 2022)

4.1.6 There are no formal raised defences in this area and the Agency does not hold modelled flood level data at this location, hence the flood map is based on less accurate JFLOW data.

4.1.7 Therefore, the purpose of this modelling report is to more accurately define the flood extent across the site.

5. HYDROLOGICAL SETTING AND CATCHMENT DESCRIPTORS

5.1 The extent of the upstream catchment associated with the watercourse is shown on Figure 6. The catchment was also selected on the FEH Web Service at a point immediately downstream of the site (i.e. in order to include the site area in the calculations) as shown on Figure 7.

5.2 The catchment descriptors and catchment boundary at this point were exported from the FEH Web Service and were checked using the OS map and LIDAR survey data with no further changes made. A review of the OS mapping and aerial mapping indicates no unusual catchment features.

5.3 Reference to the catchment descriptors extracted from the FEH Web Service (Figure 8) shows that the catchment drains an upstream area of 41.53 sq km. The catchment receives a standard average annual rainfall (SAAR) of 697mm and there is little influence from lakes and reservoirs which is denoted by a FARL value of 0.987. The catchment has a moderate gradient (DPSBAR = 20.4m/km) and is of moderate elevation (ALTBAR = 63).

5.4 The new FEH catchment descriptor $URBEXT_{2000}$, the development of which is discussed in the DEFRA/EA report entitled *$URBEXT_{2000}$ – A New FEH Catchment Descriptor*, indicates that the catchment is essentially rural (i.e. an $URBEXT_{2000}$ value of 0.0074).

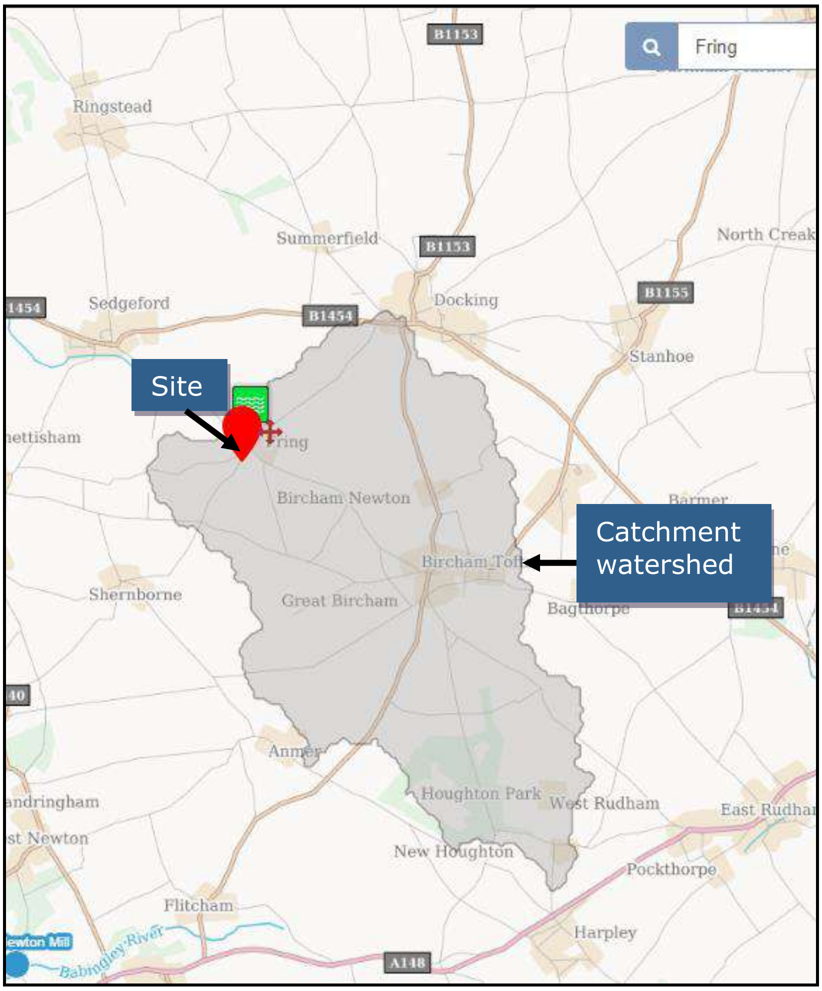

Figure 6: Location of site in relation to catchment watershed (Source: FEH Web Service)

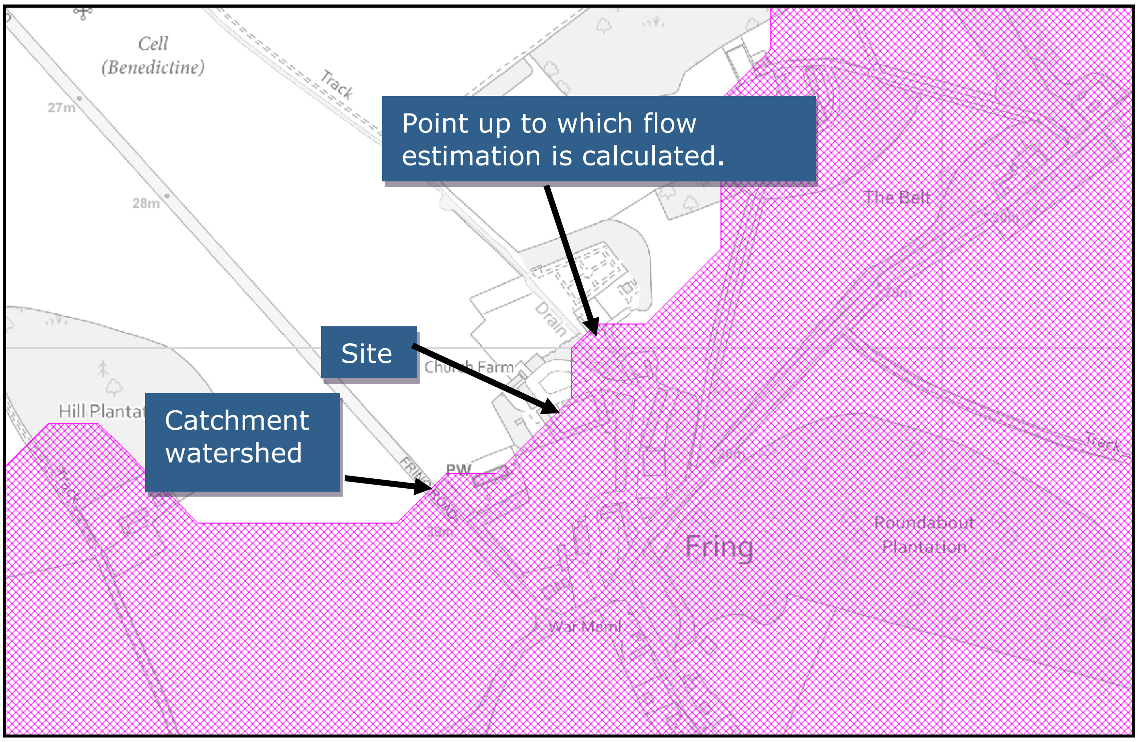

Figure 7: Site in relation to downstream catchment limit (Source: FEH Web Service)

VERSION	"FEH CD-ROM"	Version	4.0.0
CATCHMENT	GB	573650	335000
CENTROID	GB	576176	332341
AREA	41.53	exported at	
ALTBAR	63	TF 73650 35000	
ASPBAR	353	TF 76176 32341	
ASPVAR	0.16	09:19:48	GMT
BFIHOST	0.963	Thu	03-Feb-22
BFIHOST19	0.929		
DPLBAR	6.21		
DPSBAR	20.4		
FARL	0.987		
FPEXT	0.1314		
FPDBAR	0.56		
FPLOC	1.257		
LDP	14.49		
PROPWET	0.24		
RMED-1H	11		
RMED-1D	30.6		
RMED-2D	38.4		
SAAR	697		
SAAR4170	706		
SPRHOST	6.58		
URBCONC1990	0.538		
URBEXT1990	0.0168		
URBLOC1990	1.002		
URBCONC2000	0.618		
URBEXT2000	0.0074		
URBLOC2000	1.023		
C	-0.02116		
D1	0.31796		
D2	0.30238		
D3	0.28265		
E	0.307		
F	2.47891		
C(1 km)	-0.021		
D1(1 km)	0.308		
D2(1 km)	0.297		
D3(1 km)	0.27		
E(1 km)	0.309		
F(1 km)	2.479		

Figure 8: Catchment descriptors (Source: FEH Web Service)

URBEXT

5.5 $URBEXT_{2000}$ is based on a different methodology than $URBEXT_{1990}$ and therefore results in a separate set of FEH categories of urbanisation. For example, an essentially rural catchment will have an $URBEXT_{2000}$ value of up to 0.030 as opposed to 0.025 if using the former $URBEXT_{1990}$ value.

5.6 The WINFAP-FEH Version 5 software allows the user to consider any development in the catchment since the generation of the $URBEXT_{2000}$ value by using local information on urban extents and urban runoff characteristics. The software then updates the original $URBEXT_{2000}$ value extracted from the FEH Web Service.

5.7 A review of the relevant OS map and local observations indicates that the mapped urban area in the catchment is unlikely to have increased since 2000 and hence the catchment remains essentially rural.

SPRHOST/BFIHOST

5.8 The base flow index (BFIHOST) essentially proportions the flow within a watercourse which has been derived from the stored or slow release of groundwater. For example, high base flow values indicate that the flows are effectively groundwater fed. As the value drops, the catchment is likely to be dominated by surface water runoff.

5.9 The standard percentage runoff (SPRHOST) characterises the proportion of the surface water landing across the catchment that will infiltrate or runoff. Permeable catchments are defined by an SPRHOST value of <20 and/or BFIHOST value of >0.65.

5.10 BFIHOST has subsequently been revised in 2019 to address a number of issues such as an underestimation of BFI in clay-dominated catchments.

5.11 The SPRHOST and BFIHOST19 value is shown on Figure 8 to be 6.58 and 0.929 respectively, however it is generally recommended that such values are checked by the user.

5.12 Therefore, the 1:250,000 *Soil Map of Eastern England* (Sheet 4) published by Cranfield University and Soil Survey of England and Wales 1983, together with the guidance Volume 4 of the FEH Handbook has been consulted.

5.13 The soil map and British Geological Survey, *Online Geology of Britain Viewer/Local Borehole Data* indicates that across the catchment the soil types predominantly comprise comprise clay, silt, sand and gravel overlying Chalk.

5.14 Therefore the SPRHOST and BFIHOST values estimated by the FEH Web Service are considered to be reasonable and reflects an overall highly permeable catchment.

6. ESTIMATION OF FLUVIAL FLOWS

6.1 Choice of Method

6.1.1 In order to determine the most suitable flow estimation method, the guidance outlined in the FEH Handbook has been referred to, together with the EA guidance document entitled EA guidance document entitled *Flood Estimation Guidelines Technical Guidelines (197_08)* dated June 2020; *The Revitalised Flood Hydrograph Model ReFH2 Technical Guidance;* and DEFRA/EA document entitled *Estimating flood peaks and hydrographs for small catchments: Phase 1 (SC090031)* dated May 2012 and *Phase 2 (SC090031/R0)* dated 2019.

6.1.2 There are two main approaches for estimating flood flows for catchments of this size; the FEH Statistical Method (pooled analysis) and the Revitalised Flood Hydrograph Method (ReFH2). The FEH Statistical Method is based on a larger dataset of gauged flow records across the UK than the ReFH2 Method.

6.1.3 The FEH Statistical Method uses flow records from either a single reliable gauged site located within the catchment or several other gauged sites which are located in other hydrologically similar catchments. The method is based on a large flood event dataset in the UK and is more directly calibrated to reproduce flood frequency for UK catchments.

6.1.4 The ReFH2 Method is intended to update and address several constraints of the FEH Rainfall-Runoff method and ReFH1 Method. The key changes to the original FEH Rainfall-Runoff method are that in the ReFH Method baseflow varies throughout the event and the ReFH method uses a new (kinked) unit hydrograph shape. Furthermore, additional calibration data has been used within the ReFH which includes a larger number of flood events across the UK.

6.1.5 The catchment is highly permeable and the response to rainfall may be limited. Previous versions of the *Flood Estimation Guidelines Technical Guidelines (197_08)* recommend that an assessment of flood flows for such a catchment should be undertaken using the FEH Statistical Method, rather than the Revitalised Flood Hydrograph Method (ReFH1). Despite this, the current EA guidance states that the latest ReFH2 model is expected to perform better for permeable catchments and *The Revitalised Flood Hydrograph Model ReFH2 Technical Guidance* indicates that in comparison to the ReFH1 model, the ReFH2 permeable catchment performance is a considerable improvement especially when used with the FEH13 rainfall model, where performance is comparable to the current FEH statistical method.

6.1.6 Although both of the above methods are considered appropriate for flow estimation, the FEH Statistical Method is likely to be more appropriate in this instance as it is based on a larger dataset across the UK and uses good quality donor site data.

6.1.7 However, flow estimates have also been derived using the ReFH2 Method for comparison later in this Chapter.

6.2 Improved Statistical Method

6.2.1 The original FEH Statistical Method has been improved with the release of the Science Report (SC050050/SR) entitled *Improving the FEH statistical procedures for flood frequency estimation,* carried out by the Centre for Ecology and Hydrology and published in 2008 by DEFRA and the EA.

6.2.2 As stated by the research document, the improved features include a new QMED (median annual flood) equation; an improved procedure for the formation of pooled growth curves; and a revised procedure for the use of donor catchments in the data transfer process. A new catchment descriptor which describes the floodplain extent (FPEXT) was also developed as part of the study to assist in the derivation of pooling groups.

6.2.3 The WINFAP-FEH Version 5 software incorporates all of these changes to the FEH Statistical Method and has therefore been used to assist in the flood estimation process. A full hydrological report is generated by the software and is provided in Appendix A.

6.2.4 There is no observed flow or level records available as the watercourse is ungauged at this location. Therefore, FEH Statistical Method single-site analysis is not possible. Consequently, estimation of the flood flows has been carried out using the catchment descriptor method and pooled analysis.

6.3 Improved Statistical Method - Estimation of QMED

6.3.1 To estimate QMED for the catchment, the catchment descriptor method has been used. This method is described in Volume 3, Chapter 13, of the FEH and has been updated in the Science Report and Kjeldsen et al., 2008. The method produces the mean annual flood QMED, which is the flood flow along the river that is statistically exceeded on average every other year.

$$QMED = 8.3062 \times AREA^{0.8510} \times 0.1536^{\left(\frac{1000}{SAAR}\right)} \times FARL^{3.4451} \times 0.0460^{(BFIHOST19)^2}$$

6.3.2 The QMED equation only applies to rural catchments ($URBEXT_{2000}$ <0.030) and as the URBEXT value is 0.0074, an Urban Adjustment Factor (UAF) based on the urbanisation (URBEXT) and soil type (SPRHOST) of the catchment will not significantly influence the QMED (rural) value.

6.3.3 Using the WINFAP-FEH Version 5 software, the calculation using WINFAP-FEH based on catchment descriptors for the catchment gives a value for $QMED_{s,cds}$/QMED rural of 0.903 cu m/sec.

6.4 Improved Statistical Method - Revised Data Transfer Process

6.4.1 In order to make the ungauged rural estimate of $QMED_{s,cds}$ more accurate, it is necessary to use flow data from a similar (rural) donor site either within the catchment, or in another catchment with similar hydrological characteristics, and where gauged information does exist for an adequate number of years.

6.4.2 The suitability of the donor catchment will depend on how similar its catchment descriptors are to the subject catchment. For example, AREA should not differ by more than a factor of 5, SAAR a factor of 1.1 and BFIHOST by 0.18. It should be noted that this approach is acceptable as a rule of thumb but this is no longer included in the FEH Guidelines and is quite restrictive if looking at small catchments which are not well-represented in the dataset.

6.4.3 A local correction or adjustment factor to the estimate of $QMED_{s,cds}$ at the subject site can then be applied. The procedure involves deriving QMED from the observed annual maximum record at a gauged site ($QMED_{g,obs}$), and also from the catchment descriptors at a gauged site ($QMED_{g,cds}$) and using the ratio of these two estimates to adjust the catchment descriptor estimate of $QMED_{s,cds}$ at the subject site.

6.4.4 The Science Report and *Flood Estimation Guidelines Technical Guidelines (197_08)* also states that in addition to catchment similarity, the geographical proximity is important when considering the suitability of a donor site for the data transfer process, and the chosen donor should be the closest to the subject site.

6.4.5 The WINFAP-FEH Version 5 software user guide states that for small catchments with areas below 25 km^2 and up to/equal to 40 km^2, the 'use small catchments recommendations by default' can be selected when initiating a Pooled and QMED Analysis.

6.4.6 However, as the catchment is marginally above 40 km^2 in this case, the guidance states that for a standard estimate and where the small catchments option is not selected, the 6 closest stations are selected in the software for use in the estimation of rural QMED.

6.4.7 The subscript *s* refers to the ungauged subject site and *g* refers to the gauged donor site. The subscript *cds* refer to catchment descriptors and *obs* refers to the observed value at the donor site. The subscript d_{sg} refers to the geographical distance between the centroid of the subject site and donor site. The subscript *adj* refers to the adjusted value of QMED at the ungauged subject site.

6.4.8 A list of suitable donor sites (ranked by geographical proximity) for the data transfer process has been determined using the WINFAP-FEH Version 5 software by opening the *Pooled and QMED Analysis* dashboard and selecting *Donor Adjustment* as the method to calculate QMED. The software uses the latest NRFA Peak Flow Data (version 10) which is suitable for WINFAP-FEH (Note: HiFlows-UK data is now integrated with the National River Flow Archive on the CEH website).

6.4.9 Table 1 shows the list of suitable donor catchments as generated by the software.

Table 1: List of potential donor sites to be used in the data transfer process for the catchment

Station	Distance	URBEXT	QMED obs	QMED CD's	Centroid X	Centroid Y	AREA	SAAR	BFIHOST	FARL	Years of Data	Weight
Subject site		0.007			576176	332341	41.53	697	0.929	0.987		
33032 (Heacham @ Heacham)	1.73	0.006	0.442	1.091	574860	333465	56.163	688	0.932	0.983	52	0.68
33054 (Babingley @ Castle Rising)	6.76	0.005	1.132	1.026	574755	325733	48.53	686	0.895	0.944	44	0.423
34012 (Burn @ Burnham Overy)	9.97	0.005	1.03	1.5	584690	337532	83.868	668	0.93	0.997	54	0.381
33007 (Nar @ Marham)	17.79	0.006	3.62	3.355	582923	315881	147.39	683	0.835	0.926	38	0.322
33029 (Stringside @ Whitebridge)	26.63	0.007	2.722	1.823	573508	305842	95.412	628	0.879	0.991	54	0.27
34005 (Tud @ Costessey Park)	35.9	0.029	3.13	5.247	605696	311919	72.11	649	0.603	0.973	58	0.224
34003 (Bure @ Ingworth)	36.93	0.007	5.343	5.628	613103	333028	161.27	669	0.77	0.974	60	0.22
33049 (Stanford Water @ Buckenham	38.91	0.007	0.788	0.992	590027	295982	46.45	645	0.842	0.915	7	0.211
34001 (Yare @ Colney)	41.56	0.019	13.337	16.839	606922	304372	228.81	635	0.53	0.971	62	0.2
33048 (Larling Brook @ Stonebridge)	44.86	0.003	0.318	0.423	592750	290650	21.99	635	0.868	0.907	31	0.187

6.4.10 Reference to Table 1 shows that most potential donor sites have catchment areas which are higher than the subject site (some significantly higher) but typically lower than the recommended limit as discussed in paragraph 6.4.1.

6.4.11 SAAR values are all lower but within the acceptable limits apart from Station 33029. BFIHOST values are also higher and lower in some cases and within the acceptable limits.

6.4.12 The *Flood Estimation Guidelines Technical Guidelines (197_08)* states that in accordance with the FEH, several suitable donors at similar distances from the subject catchment may exist and that donor adjustment factors should be calculated for two to three potential donors rather than choosing the closest donor site ranked first in Table 1. The document continues to advise that a weighted average of multiple donor sites should then be considered. The WINFAP-FEH Version 5 includes the option to select multiple donor sites and calculates a weighted average for the user.

6.4.13 The Science Report suggests that influence of the donor site reduces when the geographical distance between the centroids increases (typically above 75km). Therefore, by using a geographically closer donor site, there will be more of an influence on QMED at the subject site.

6.4.14 Whilst the FEH Guidelines advocate the use of close donors, it is often the case that nearby catchments displaying such large differences in catchment descriptor values are discarded from the analysis. The Guidelines state "when considering an individual application [of donors] it makes hydrological sense to consider the physical similarity of catchments as well as their proximity", but also states that ungauged QMED should be used as a last resort.

6.4.15 In order to avoid simply choosing donor sites based on catchment descriptors, The FEH Guidelines also state that "If the various donor sites give similar adjustment factors, then this should strengthen confidence in the resulting estimate of QMED. If there is a wide variation in adjustment factors, then it is worth carrying out a more detailed review of the suitability of the potential donor catchments, in terms of both data quality and relevant to the subject site, before making a final choice".

6.4.16 An adjustment factor analysis in Table 2 shows that there is wide variation in adjustment factors, especially for the potential donor sites 33032, 33054 and 34012, and when the distance factor is applied and also when applied individually. Therefore, further scrutiny of the potential donors is required.

6.4.17 The WINFAP software and NRFA/CEH website indicates that these stations are suitable for QMED, with no major issues in terms of ratings and non-modular flow. These stations have a suitable record length.

6.4.18 the guidance states that preference should be given to donor sites on the same watercourse at the subject site (i.e. Station 33032 which is located at Heacham 6.56 km downstream of the site).

6.4.19 The WINFAP software indicates that the adjusted QMED value at the subject site, $QMED_{s,adj}$, using the three donor sites ranked first, second and third is 0.508 cu m/sec.

Table 2: Adjustment Factor Analysis

		Distance	QMED obs	QMED cds	Adjustment factor		Adjusted QMED if only this one	Scalar factor if only this one	Years of data
	Subject Site			0.903	Ratio (QMED Obs/QMED cds)	a (see below)	catchment is used.	catchment is used.	
1	**33032 (Heacham @ Heacham)**	**1.73**	**0.442**	**1.091**	**0.41**	**0.68**	**0.49**	**0.54**	**52**
2	**33054 (Babingley @ Castle Rising)**	**6.76**	**1.132**	**1.026**	**1.10**	**0.42**	**0.94**	**1.04**	**44**
3	**34012 (Burn @ Burnham Overy)**	**9.97**	**1.03**	**1.5**	**0.69**	**0.38**	**0.78**	**0.87**	**54**
4	33007 (Nar @ Marham)	17.79	3.62	3.355	1.08	0.32	0.93	1.02	38
5	33029 (Stringside @ Whitebridge)	26.63	2.722	1.823	1.49	0.27	1.01	1.11	54
6	34005 (Tud @ Costessey Park)	35.9	3.13	5.247	0.60	0.22	0.80	0.89	58
7	34003 (Bure @ Ingworth)	36.93	5.343	5.628	0.95	0.22	0.89	0.99	60
8	33049 (Stanford Water @ Buckenham	38.91	0.788	0.992	0.79	0.21	0.86	0.95	7
9	34001 (Yare @ Colney)	41.56	13.337	16.839	0.79	0.20	0.86	0.95	62
10	33048 (Larling Brook @ Stonebridge)	44.86	0.318	0.423	0.75	0.19	0.86	0.95	31

$$QMED_{s,adj} = QMED_{s,cds}\left(\frac{QMED_{g,obs}}{QMED_{g,cds}}\right)^{a_{sg}}$$

$$a_{sg} = 0.4598\exp\left(-0.0200d_{sg}\right) + \left(1-0.4598\right)\exp\left(-0.4785d_{sg}\right)$$

6.5 Improved Statistical Method - Pooled Analysis and Flood Growth Curve

6.5.1 In order to estimate a range of statistical flood return period events which will occur in the catchment, it is necessary to determine a flood growth curve and a flood frequency curve. This is done by forming a pooling group, which involves a group of gauged rural catchments across the UK which have very similar catchment characteristics such as AREA and SAAR.

6.5.2 The catchment output from the FEH Web Service is entered as a data file to the WINFAP-FEH software, which sorts a pooling group of similar catchments. The FEH states that the pooling group should contain 5 times as many station-years as the target return period (*5T*); however the *Flood Estimation Guidelines Technical Guidelines (197_08)* recommends that a fixed pooling group size of at least 500 AMAX events for all required return periods should be used.

6.5.3 The WINFAP-FEH Version 5 software incorporates the latest download of NRFA Peak Flow Data (version 10) and chooses sites suitable for pooling when generating the pooling group. By default, for stations with a catchment area above 25km^2 hydrological similarity is based on work completed by Kjeldsen et al., 2008 and is assessed with regards to the catchment descriptors: AREA, SAAR, FARL and FPEXT.

6.5.4 The generalised logistic (GL) technique has been applied in the statistical analysis, as the WINFAP guidance document states that in most situations this distribution is recommended for UK flood data. Kjeldsen et al., 2010 also showed that the GL distribution is the preferred distribution in the UK and Figure 9 overleaf shows that when producing the flood frequency curve the GL distribution results in higher flood flows typically during higher return period events.

Table 3: Pooling Group

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
33054 (Babingley @ Castle Rising)	0.379	44	1.132	0.204	0.205	0.069	0.068	0.672
33032 (Heacham @ Heacham)	0.457	52	0.442	0.298	0.299	0.139	0.138	0.065
26013 (Driffield Trout Stream @ Driffield)	0.554	10	2.685	0.292	0.293	0.281	0.28	2.648
26003 (Foston Beck @ Foston Mill)	0.578	59	1.76	0.249	0.249	-0.009	-0.01	1.183
36003 (Box @ Polstead)	0.727	60	3.875	0.314	0.317	0.088	0.086	0.462
41020 (Bevern Stream @ Clappers Bridge)	0.804	51	13.66	0.204	0.205	0.174	0.171	1.269
34005 (Tud @ Costessey Park)	0.842	58	3.13	0.287	0.292	0.225	0.22	0.576
36004 (Chad Brook @ Long Melford)	0.856	53	4.938	0.304	0.305	0.167	0.166	0.911
36007 (Belchamp Brook @ Bardfield Bridge)	0.863	55	4.63	0.378	0.378	0.112	0.111	1.457
30004 (Lymn @ Partney Mill)	0.948	58	7.184	0.224	0.225	0.03	0.029	0.757

6.5.5 The WINFAP-FEH software indicates that the pooling group is heterogeneous and a review of the pooling group is desirable. All of the sites which are ranked are satisfactory in terms of their hydrological similarity with the subject site and the pooling group distribution provides an acceptable statistical fit.

6.5.6 For example, the software indicates that station 26013 has a high discordancy, however, in many cases the discordancy is due to the presence of an extreme flood (e.g. for station 26013 an extreme flood could have occurred in 2012). The guidance continues to state that such sites should normally be left in the pooling group and therefore these stations have been kept in the group.

6.5.7 The FEH also states that a significant proportion of pooling group remains heterogeneous, even after a review and adapting a heterogeneous pooling group to make it homogeneous is not advised. Therefore, no manual adjustments were made to the pooling group.

Standardisation details

Standardised by median

Growth Curve L-moments

L-CV 0.275 L-skewness 0.116

Fitted parameters

	Location	Scale	Shape	H
GL	1.000	0.284	-0.116	
GEV	0.836	0.453	0.085	
KAP3	0.920	0.357	-0.025	-0.400

Return periods

	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.427	1.475	1.449
10	1.710	1.765	1.738
20	1.996	2.026	2.016
50	2.396	2.341	2.381
100	2.723	2.562	2.658
200	3.076	2.769	2.939
500	3.585	3.024	3.317
1000	4.008	3.204	3.608

Figure 9: 'As rural' Growth Curve Fittings for the watercourse catchment

6.6 Permeable Catchments and Revised Flood Growth Curve

6.6.1 The subject site catchment is classified by the guidance as highly permeable. Permeable catchments can exhibit some years during which no floods occur and the annual maximum flow is due to baseflow alone. This can result in the production of an unrealistic flood growth curve.

6.6.2 The WHS Permeable Adjustment Worksheet Beta v1.2 has been used to determine the permeable-adjusted growth curve.

6.6.3 Following the data entry as required by the spreadsheet (Figure 10), further guidance is offered in relation to the suitability of the pooling group stations (Figure 11) and after a review station 33032 was removed. Figure 12 shows the amended flood growth curve fittings.

WHS

Update NRFA PeakFlow Dataset

PeakFlow Dataset Location C:\NRFA Peak flows\NRFAPeakFlow_v10\suitable-for-pooling

Insert File Path to Peak Flow Dataset Suitable for Pooling in Cell I2

Pooling Group

Copy Pooling Group Here

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Station No	L-CVAdj	L-SKEWadj	k (Shape)	Beta (Scale)	Warnings
33054 (Babingley @ Castle Rising)	0.379	44	1.132	0.204	0.069	33054	0.190	0.113	-0.113	0.192	SPRHOST <=20.
33032 (Heacham @ Heacham)	0.457	52	0.442	0.298	0.139	33032	0.263	0.178	-0.178	0.270	SPRHOST <=20. Non-Flood Yrs over 15% of record, consider removing station
26013 (Driffield Trout Stream @ Driffield)	0.554	10	2.685	0.292	0.281	26013	0.292	0.281	-0.281	0.294	SPRHOST <=20. Zero non-flood yrs, permeable adjustment not applied.
26003 (Foston Beck @ Foston Mill)	0.578	59	1.76	0.249	-0.009	26003	0.219	0.027	-0.027	0.220	SPRHOST <=20.
36003 (Box @ Polstead)	0.727	60	3.875	0.314	0.088	36003	0.314	0.088	-0.088	0.325	
41020 (Bevern Stream @ Clappers Bridge)	0.804	51	13.66	0.204	0.174	41020	0.204	0.174	-0.174	0.206	
34005 (Tud @ Costessey Park)	0.842	58	3.13	0.287	0.225	34005	0.287	0.225	-0.225	0.294	
36004 (Chad Brook @ Long Melford)	0.856	53	4.938	0.304	0.167	36004	0.304	0.167	-0.167	0.316	
36007 (Belchamp Brook @ Bardfield Bridge)	0.863	55	4.63	0.378	0.112	36007	0.378	0.112	-0.112	0.398	
30004 (Lymn @ Partney Mill)	0.948	58	7.184	0.224	0.03	30004	0.224	0.030	-0.030	0.226	

URBAN	0.01
URBEXT2000	0.0074

Fill in **URBEXT2000** to calculate **URBAN** Parameter or manually overwrite cell C36 with **URBAN** (Listed in *Edit Urbanisation Method* in Pooled & QMED Dashboard within WINFAP). URBAN = 1.567 x URBEXT2000

SPECIFY TARGET RETURN PERIODS	2	5	10	20	25	50	100	200	500	1000
	1.000	1.412	1.691	1.976	2.071	2.380	2.714	3.079	3.613	4.062

Figure 10: Spreadsheet results without further amendments

Warning Message	Description	Action
SPRHOST <=20	SPRHOST is less than or equal to 20. If this message is shown in isolation permeable adjustment has been applied and no issues have been encountered.	No action required
Zero non-flood yrs, permeable adjustment not applied	SPRHOST is less than or equal to 20, however permeable adjustment has not been applied due to no non-flood years (Q<QMED/2) in the record.	No action required
Non-flood yrs over 15% of record, consider removing station	Permeable adjustment applied, but more than 15% of the record comprised of non-flood years.	This indicates that the catchment is permeable and potentially significantly different to your target catchment, consideration should be given to removing the station from the pooling group.
Adjusted L-skew is negative, consider removing station	Following permeable adjustment, the L-Skew value of the station's growth curve has become negative.	A negative L-Skew value reflects a bounded distribution. Standard practice is to remove these stations from the pooling group as a precautionary measure.

Figure 11: Guidance relating to pooling stations

PeakFlow Dataset Location C:\NRFA Peak flows\NRFAPeakFlow_v10\suitable-for-pooling

Update NRFA PeakFlow Dataset

Insert File Path to Peak Flow Dataset Suitable for Pooling in Cell I2

Pooling Group

Copy Pooling Group Here

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Station No	L-CVAdj	L-SKEWadj	k (Shape)	Beta (Scale)	Warnings
33054 (Babingley @ Castle Rising)	0.379	44	1.132	0.204	0.069	33054	0.190	0.113	-0.113	0.192	SPRHOST <=20.
											Not present in current NRFA dataset
26013 (Driffield Trout Stream @ Driffield)	0.554	10	2.685	0.292	0.281	26013	0.292	0.281	-0.281	0.294	SPRHOST <=20. Zero non-flood yrs, permeable adjustment not applied.
26003 (Foston Beck @ Foston Mill)	0.578	59	1.76	0.249	-0.009	26003	0.219	0.027	-0.027	0.220	SPRHOST <=20.
36003 (Box @ Polstead)	0.727	60	3.875	0.314	0.088	36003	0.314	0.088	-0.088	0.325	
41020 (Bevern Stream @ Clappers Bridge)	0.804	51	13.66	0.204	0.174	41020	0.204	0.174	-0.174	0.206	
34005 (Tud @ Costessey Park)	0.842	58	3.13	0.287	0.225	34005	0.287	0.225	-0.225	0.294	
36004 (Chad Brook @ Long Melford)	0.856	53	4.938	0.304	0.167	36004	0.304	0.167	-0.167	0.316	
36007 (Belchamp Brook @ Bardfield Bridge)	0.863	55	4.63	0.378	0.112	36007	0.378	0.112	-0.112	0.398	
30004 (Lymn @ Partney Mill)	0.948	58	7.184	0.224	0.03	30004	0.224	0.080	-0.080	0.226	
						-	-	-	-	-	
						-	-	-	-	-	
						-	-	-	-	-	
						-	-	-	-	-	
						-	-	-	-	-	
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						-	-	-	-	-	
						-	-	-	-	-	

URBAN	0.01
URBEXT2000	0.0074

Fill in **URBEXT2000** to calculate **URBAN** Parameter or manually overwrite cell C36 with **URBAN** (Listed in *Edit Urbanisation Method* in Pooled & QMED Dashboard within WINFAP). URBAN = 1.567 x URBEXT2000

SPECIFY TARGET RETURN PERIODS	2	5	10	20	25	50	100	200	500	1000
	1.000	1.411	1.687	1.968	2.061	2.364	2.691	3.045	3.562	3.994

Figure 12: Spreadsheet results with station 33032 removed

6.7 Improved Statistical Method - Flood Frequency Curve

6.7.1 The WINFAP-FEH Version 5 software allows the user to generate a flood frequency curve, however, it is not possible to update the fittings in the WINFAP software with the permeable-adjusted fittings derived by the spreadsheet.

6.7.2 Therefore, a manual calculation has been undertaken using the new permeable-adjusted growth curve fittings (i.e. by multiplying the QMED value of 0.508 cu m/sec by the growth factors estimated by the spreadsheet). The results can be seen on Table 4.

Table 4: Flood Frequency Curve Fittings (cu m/sec)

Flood Frequency	2yr	20yr	100yr	1000yr
Growth curve fitting	1.000	1.968	2.691	3.994
Flood Flow (cu m/sec)	0.508	0.999	1.367	2.028

6.8 Revitalised Flood Hydrograph Method (ReFH2)

6.8.1 The FEH Rainfall Runoff Method was largely superseded by the Revitalised Flood Hydrograph Method (ReFH1) in 2006. The ReFH Method is intended to update and address several constraints of the FEH Rainfall-Runoff method. The key changes are that in the ReFH Method baseflow varies throughout the event and the ReFH method uses a new (kinked) unit hydrograph shape. Furthermore, additional calibration data has been used within the ReFH which includes a larger number of flood events across the UK. The method uses a loss model, routing model and baseflow model to generate a flood hydrograph.

6.8.2 The ReFH1 has now been updated with ReFH2 which is discussed further within the document entitled *The Revitalised Flood Hydrograph Model ReFH2 Technical Guidance*. Whilst the base calibration dataset used is far smaller than the statistical method, in the final stages of development ReFH2 was calibrated to the NRFA Peak Flows Dataset.

6.8.3 It also uses the more up-to-date FEH13 rainfall data (which replaces the FEH99 data) which have been imported into the ReFH2.3 software from the FEH Web Service as well as the catchment descriptors (ReFH 2.3+ xml). The software automatically calculates the storm duration and data interval and allows the user to apply the $URBEXT_{2000}$ value. No sewer losses were included as the catchment has a minimal contributing sewer network.

6.8.4 The model parameters for the ReFH2 Method such as BFIHOST should ideally be based on actual flood event data comprising rainfall and flow records rather than catchment descriptors alone. However, due to the lack of available rainfall and flow data for the catchment, the catchment descriptor method and ReFH2 design standards has been adopted in this instance based on the relevant technical guidance.

6.8.5 When choosing either a winter or summer storm profile, the advice in Section 8.1 of the technical guide and Hydrosolutions support team suggests that winter profiles are used in all but the most heavily urbanised catchments (i.e. URBEXT greater than 0.3) in which a summer storm should be specified. The URBEXT value for the catchment equates to 0. Therefore, the URBEXT value for the catchment is lower than the URBEXT threshold of 0.3 and hence a winter storm should be used.

6.8.6 For the catchment the critical storm duration was calculated by software as 18 hours from the time-to-peak (T_p) and a data interval of 2 hours.

Table 5: Results from ReFH2 using catchment descriptors

Catchment	Data Interval (hours)	Design Storm Duration (hours)	2 year event (QMED) (cu m/sec)	20 year event (cu m/sec)	100 year event (cu m/sec)	1000 year event (cu m/sec)
Heacham River	2	18	0.81	1.82	3.12	5.95

6.8.7 A sensitivity analysis has been carried out whereby the storm duration has been modified to determine whether this has any impact on flow rates. The storm duration range which has been tested is between 14 and 30 hours so that the duration divided by the timestep is an odd integer. The results can be seen in Table 6.

6.8.8 The results indicate that the optimum storm duration which on balance gives a highest peak flow estimate for most return period events is 26 hours.

Table 6: Results from ReFH2 using catchment descriptors and adjusting storm duration

Data Interval (hours)	Design Storm Duration (hours)	2 year event (QMED) (cu m/sec)	20 year event (cu m/sec)	100 year event (cu m/sec)	1000 year event (cu m/sec)
2	14	0.77	1.77	3.00	5.72
2	18	0.81	1.82	3.12	5.95
2	22	0.84	1.87	3.18	6.06
2	**26**	**0.85**	**1.88**	**3.19**	**6.08**
2	30	0.86	1.88	3.19	6.06

6.9 Flow Method Comparison

6.9.1 Reference to Table 7 indicates that the results from the ReFH2 Method are significantly higher during all return period events.

6.9.2 It is difficult to conclude with any certainty given the lack of flow gauge or flood history why the ReFH2 Method produces higher results especially during higher return periods. The ReFH1 Method was known to overestimate flows especially for longer return periods which are outside of its calibration range of 150 years. However, the ReFH2 does not have the same limitation and can be used for events up to 1 in 1000 years.

6.9.3 Furthermore, the ReFH2 technical report suggests that when using FEH13 rainfall data the model performs comparably with the pooled statistical method whilst being completely independent of the statistical method in contrast to the ReFH1 Method and when using FEH99 data (i.e. due to the alpha scaling factor).

Table 7: Comparison of Flood Flows (cu m/sec)

Catchment	ReFH2 (26 hours SD)				FEH Statistical			
	2	20	100	1000	2	20	100	1000
Heacham River	0.85	1.88	3.19	6.08	0.508	0.999	1.367	2.028

6.10 Flood History

6.10.1 There is no observed flow or level records available as the watercourse is ungauged at this location. There is a lack of available rainfall and flow data for the catchment, hence the reason for the catchment descriptor method being adopted based on the relevant technical guidance.

6.11 Final Choice of Method

6.11.1 Although the FEH Statistical Method and ReFH2 Method are considered appropriate for flow estimation, the FEH Statistical Method is likely to be more appropriate in this instance as it is based on a larger dataset across the UK and uses good quality donor site data.

6.11.2 Furthermore, as the catchment is highly permeable and until the implications of the ReFH2 changes are understood to address this, it is considered that the well established procedure as part of the FEH Statistical Method should be taken forward.

6.12 Climate Change

6.12.1 It is understood from the recently updated UK Government's climate change allowances guidance, that for more-vulnerable development, the "Central" climate change allowance should be used in FRA's. Therefore, for the *North West Norfolk Management Catchment* the climate change allowance is 23% up to year 2080s.

Table 8: Final Flood Flows for the catchment (cu m/sec)

Flood Frequency	Q20	Q100	Q1000
Flood Flow	0.999	1.367	2.028
Flood Flow including (23%) climate change	1.230	1.681	2.494

6.13 Hybrid Method

6.13.1 Having determined that the FEH Statistical Method is preferred for estimating flood flows, a flow hydrograph is required for input into the hydraulic model, with a peak flow that matches the corresponding flood frequency estimate.

6.13.2 It is common to generate an inflow hydrograph in the InfoWorks RS modelling software using the ReFH boundary, then scaling it to match the FEH statistical estimates shown in Table 8 by using the 'fit to peak' option. This hydrograph then forms the inflow boundary condition.

6.13.3 It was also ensured that the hydrograph parameters derived from the ReFH2 Method above such as storm duration of 26 hours and data interval of 2 hour was entered into the model.

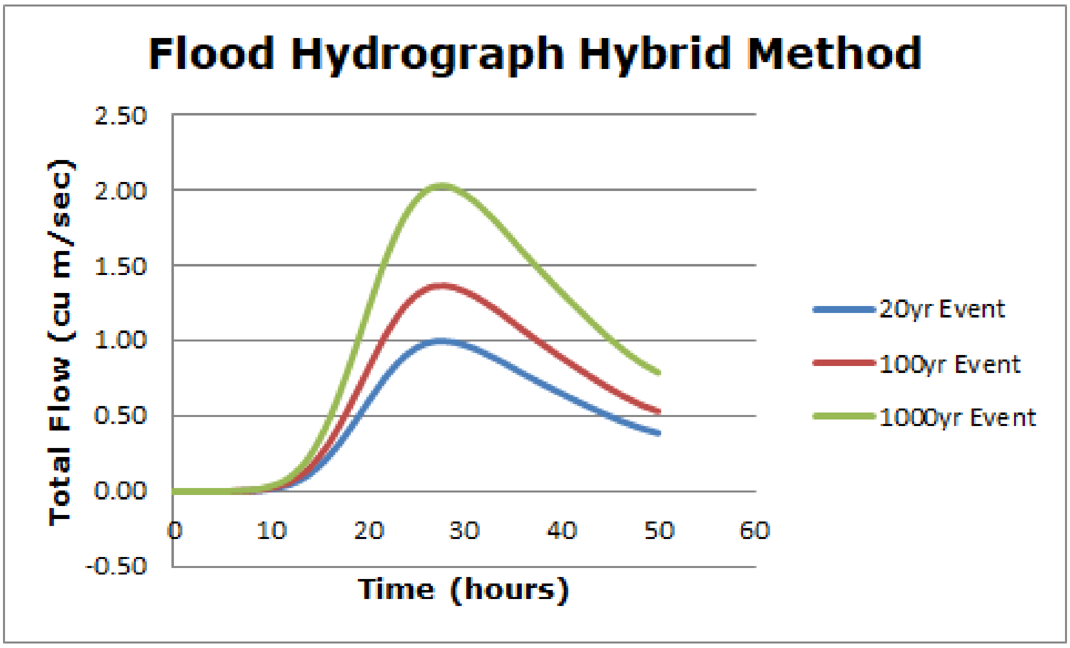

Figure 13: Flood hydrograph using the hybrid method without climate change

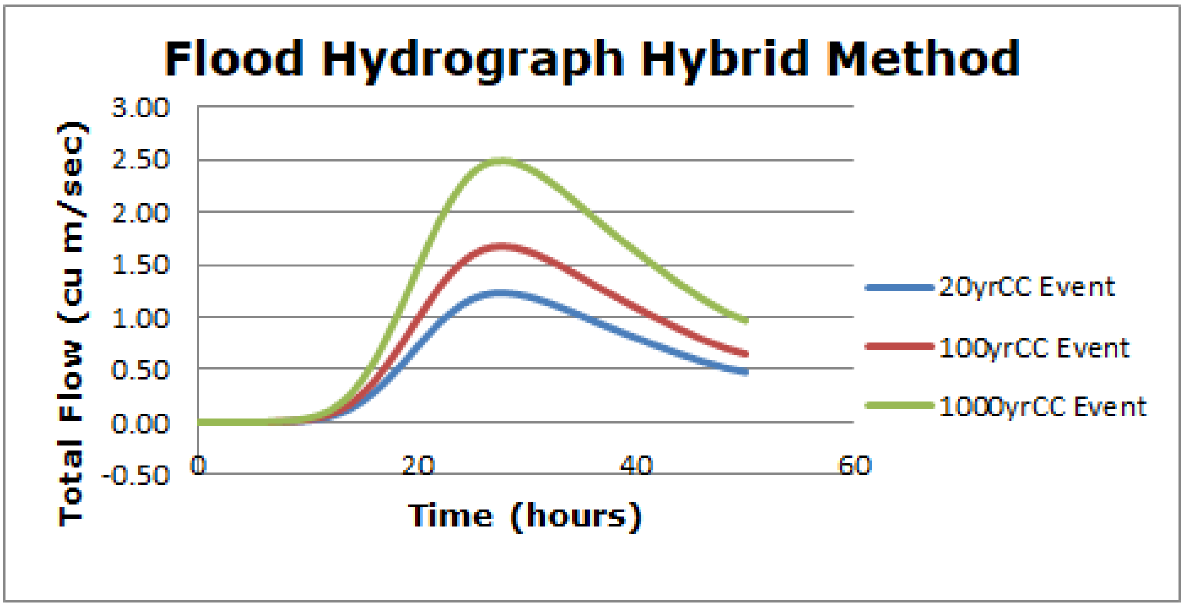

Figure 14: Flood hydrograph using the hybrid method with Central 23% climate change

7. HYDRAULIC ANALYSIS

7.1 Introduction

7.1.1 A site specific assessment of the probability and consequences of the site flooding from the watercourse has been undertaken using well established hydraulic modelling and flood mapping techniques. The Agency's guidance document entitled *Fluvial Design Guide (2009),* and Agency's Best Practice Guide dated 2006 entitled *Using Computer River Modelling as part of a flood risk assessment* have been consulted.

7.1.2 Figure 15 shows the file structure within the model (InfoWorks.iwm/.iwc) file which has been provided as a separate file for the Environment Agency (as well as ISIS files) to examine as part of their review (see file InfoWorks.iwc). It should be noted that the 'Network-Existing' is the relevant baseline network used and the branched networks below it are sensitivity runs. It should be noted that the 'Event – 1000yrCC' is the relevant event used and the branched events below it are other return period events.

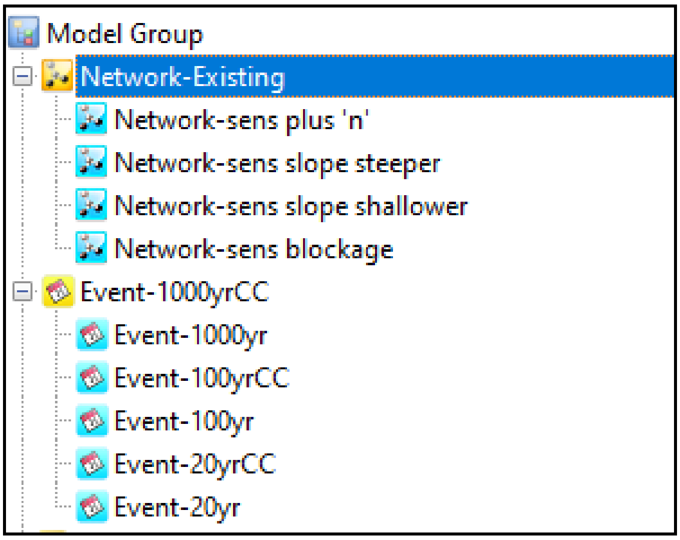

Figure 15: Model Setup

7.2 InfoWorks Model Development

7.2.1 One-dimensional (1D) unsteady hydrodynamic modelling of the watercourse and the study area was undertaken using the hydraulic modelling package InfoWorks RS Version 17.5. This software package combines the advanced ISIS Flow simulation engine and GIS functionality within a single environment. The software allows the representation of the river network as well as the floodplain area by extending cross sections. The software is fully supported by Innovyze technical support.

7.3 Topographic Information

Survey Data and Ground Model

7.3.1 A topographical survey (GPS and geo-referenced) of the watercourse and site was carried out. A topographical survey report has been carried out by BB Surveys and is provided in Appendix B.

7.3.2 Specific cross section locations were identified in order to gain accurate representation of the watercourse geometry. The cross section locations and elevations can be seen on Drawing Numbers 2219-3284-SU03 and 2219-3284-SU04 and are labelled 17-1.

7.3.3 The cross sections were also provided by BB Surveys as a series of *.csv* files containing xyz data. These cross section files were imported directly into the Infoworks software by right-clicking on the Network icon and selecting 'Import' and then 'From Section files...', and finally 'Bulk section import'. The locations of the imported cross sections can be seen on Figure 16.

7.3.4 To consider floodplain areas outside of the survey extents a composite ground model (DTM) was created using the topographical survey and filtered LIDAR data. The topographical survey was imported into the MapInfo GIS software and a ground model was generated which allowed the interpolation of ground levels between available elevation points. Filtered LIDAR survey data was used to supplement the ground model in areas outside of the site boundary and therefore not covered by the topographical survey due to access restrictions. The combined ground model was then exported in a suitable format which could be read by the InfoWorks software.

7.3.5 To include floodplain areas in the hydraulic model, the imported cross sections were extended across the DTM in the Infoworks software. Creating a DTM also provides flexibility when generating additional cross sections in the Infoworks software, particularly where there is a lack of survey points due to heavy vegetation and limited access rights.

Figure 16: Imported cross section within the Infoworks model

LIDAR Accuracy

7.3.6 By forming a ground model which includes the topographical survey information, a more accurate and representative ground model can be generated in contrast to LIDAR alone.

7.3.7 Where LIDAR data has been relied upon across areas not covered by the topographical survey (e.g. floodplain areas), it is important to consider its accuracy. This can be done by cross-referencing the LIDAR data with the topographical survey.

7.3.8 For example, the LIDAR compares well with the topographical survey across the site (typically ±0.1m) as shown on Figure 17 which is within the LIDAR accuracy range of ±0.15m.

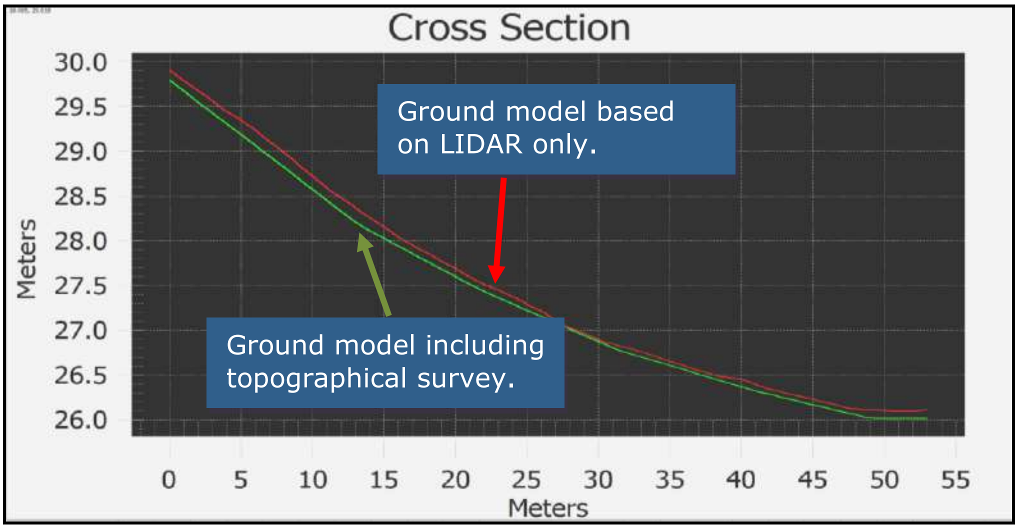

Figure 17: Comparison between LIDAR survey and topographical survey across site

7.3.9 When considering the watercourse channel, the LIDAR data can often be poorly defined in comparison to the topographical survey (i.e. as the laser reflects water surfaces rather than bed levels).

7.3.10 The LIDAR data does on balance compare well with the topographical survey along the surveyed part of the channel. For example, Figure 18 and the surveyed cross section plan shows that at cross section 11, the surveyed channel bed is approximately 0.170m lower than the LIDAR survey bed (although this is above the LIDAR accuracy range).

7.3.11 Despite this, as the model does not extend beyond the downstream topographical survey extents, there will not be a reliance on LIDAR to define the channel profile and hence no further changes are required.

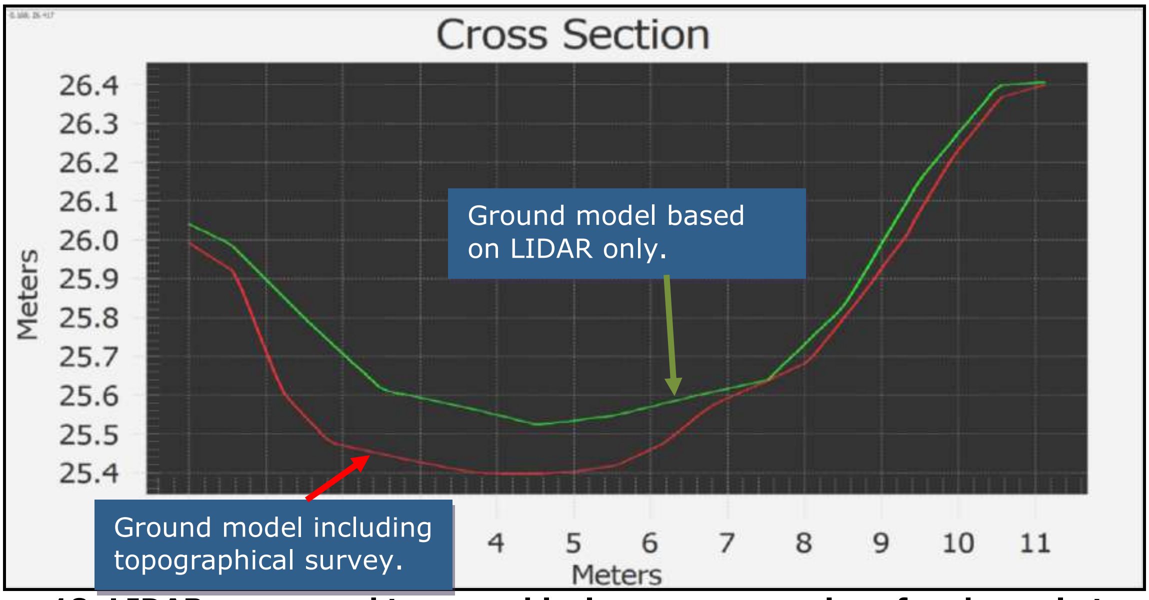

Figure 18: LIDAR survey and topographical survey comparison for channel at cross section 11

7.4 Surface Roughness

7.4.1 Surface roughness varies across the study area as a result of different land uses. To ensure an accurate representation of the impact of different surface roughness values on the flood flows, information from the OS map and site observations was used. The anticipated roughness values were checked with the CES Roughness Advisor created by Wallingford Software and resultant Manning's "n" values were entered for each cross section.

7.4.2 Figure 19 shows that the watercourse channel between cross sections 17 and 13 is generally free from vegetation and has recently been maintained. Figure 20 shows that the channel is less maintained between cross sections 3 and 1.

7.4.3 The channel is therefore represented by a roughness value of 0.046 as shown on Figure 21, as this considers the vegetation growth during the summer months and potential for fallen bank vegetation into the channel.

Figure 19: Photo of channel looking downstream between cross sections 17 and 13 (February 2022)

Figure 20: Photo of channel looking downstream between cross sections 3 and 1 (February 2022)

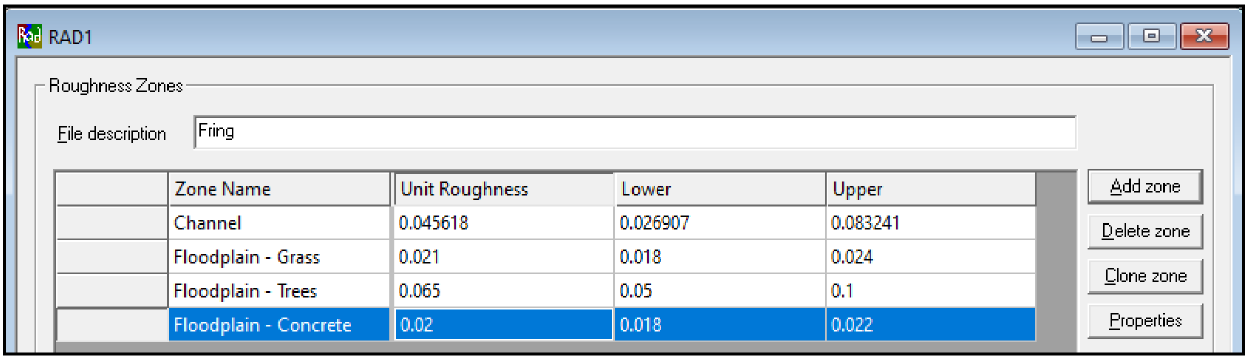

Figure 21: Manning's "n" roughness values derived from the CES Roughness Advisor

7.4.4 A paper by Syme (2008), entitled *Flooding in Urban Areas – 2D Modelling Approaches for Buildings and Fences*, suggests that representing buildings by a high surface roughness, rather than including the structures themselves in a model, is often a preferred and acceptable method. This is one of the reasons why the use of filtered LIDAR survey is often preferable in such cases.

7.4.5 To represent the various buildings across the site, in addition to including the floor level in the cross sectional profile, a Manning's roughness of 0.3 was applied across these areas as suggested by the aforementioned research paper. This allows floodwater to be obstructed somewhat by the structure whilst still allowing the potential for floodwater to propagate through them via doorways and other openings.

7.5 Structures

7.5.1 The topographical survey and survey sections drawing indicates that the watercourse flows through an arch bridge between sections 13 and 12 and upstream of the site which is 0.60m high and 2.20m wide.

7.5.2 The survey also shows that the watercourse flows through a second arch bridge between sections 4 and 3 and downstream of the site which is 0.55m high and 1.90m wide.

7.5.3 The bridges can be included using an Arch Bridge unit, however, in order to improve model stability and model convergence, particularly during events when the bridges are susceptible to surcharging, it is considered that the bridges are better represented in the model by an Orifice unit.

7.5.4 An alternative would be to model the bridge as a Conduit, however, friction losses are not considered to be significant (e.g. length to width ratio is 1:7 for the bridge between sections 4 and 3) and an Orifice unit will be more suitable in this instance where the length is not hydraulically significant.

7.5.5 The dimensions of the opening, including invert and soffit, were taken from the topographical survey and survey sections. The Bore Area has been calculated from the survey data as 0.633 sq m for the upstream bridge (taken as the downstream face which is smaller), and 0.453 sq m for the downstream bridge (taken as the upstream face which is smaller).

7.5.6 As the Orifice unit does not model the potential overtopping of floodwater across the deck/ground surface, a Spill unit was applied perpendicular to the bridge and ground/deck levels were derived from the topographical survey and LIDAR.

Figure 22: Bridge upstream of site with site in background

Figure 23: Bridge downstream of site

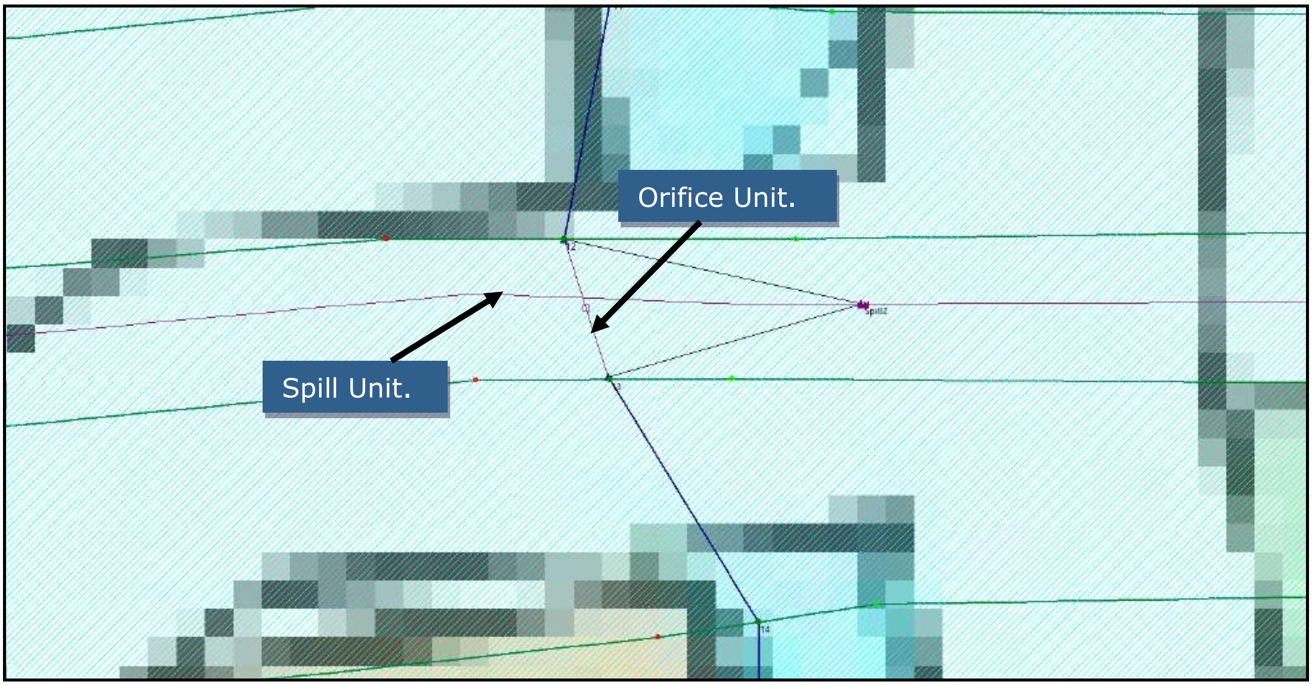

Figure 24: Example of orifice as it appears in the model

7.6 Model Boundary Conditions

Upstream Boundary

7.6.1 Having determined that the FEH Statistical Method is preferred for estimating flood flows, a flow hydrograph is required for input into the hydraulic model, with a peak flow that matches the corresponding flood frequency estimate.

7.6.2 It is common to generate a hydrograph using the ReFH Method, then scale it to match the statistical flow estimate as discussed in Section 6.13. This hydrograph then forms the upstream inflow boundary condition. It was ensured that the hydrograph parameters, shape, duration, data interval and results for each return period determined in Section 6.13 were reproduced in the InfoWorks RS software.

Downstream Boundary

7.6.3 For the downstream boundary, the InfoWorks software allows the user to define a Normal/Critical Depth downstream boundary which generates a flow-head relationship based on the channel slope.

7.6.4 Analysis of the topographical survey indicates that the bed slope is typically uniform and set at an approximate gradient of 1 in 1055. This slope gradient has been chosen which is more representative of the slope along the modelled channel length and not simply at the downstream end of the model where there could be localised steep/shallow reaches.

7.6.5 In accordance with the EA Best Practice Guide dated 2006 entitled *Using Computer River Modelling as part of a flood risk assessment*, the downstream boundary should be located sufficiently downstream of the site so that any errors in the boundary will not significantly affect predicted water levels at the site. This is proven by carrying out a sensitivity analysis in Section 7.8 which indicates that when making the downstream slope shallower there is negligible change in upstream water level at the site.

7.6.6 The aforementioned EA guidance states that for a typical fluvial river, a rule of thumb is that a backwater effect extends a length L = 0.7D/s, where D = bankfull depth and s = river slope (as a decimal). Hence, if the downstream boundary is greater than L from the site, it is likely that any errors in the rating curve at the boundary will not affect flood levels at the site.

7.6.7 It has been calculated that the "L" value is 700m based on a river slope of 1 in 1055 and bankfull depth of typically 0.90m. The downstream boundary is set 26m downstream of the site (due to access constraints) and therefore less than the required L value.

7.6.8 However, the downstream boundary has been positioned where the channel was accessible to the surveyors (i.e. land ownership) and where a good representation of the channel could be ascertained (i.e. rather than relying on less accurate LIDAR data further downstream to meet the required "L" value).

7.6.9 Moreover, the sensitivity analysis in Section 7.9 confirms that the downstream boundary is sufficiently positioned downstream of the site. The results indicate that when making the downstream slope 20% shallower and 20% steeper, there is negligible flood level difference within the channel adjacent to the site during the climate change 1 in 100 year event.

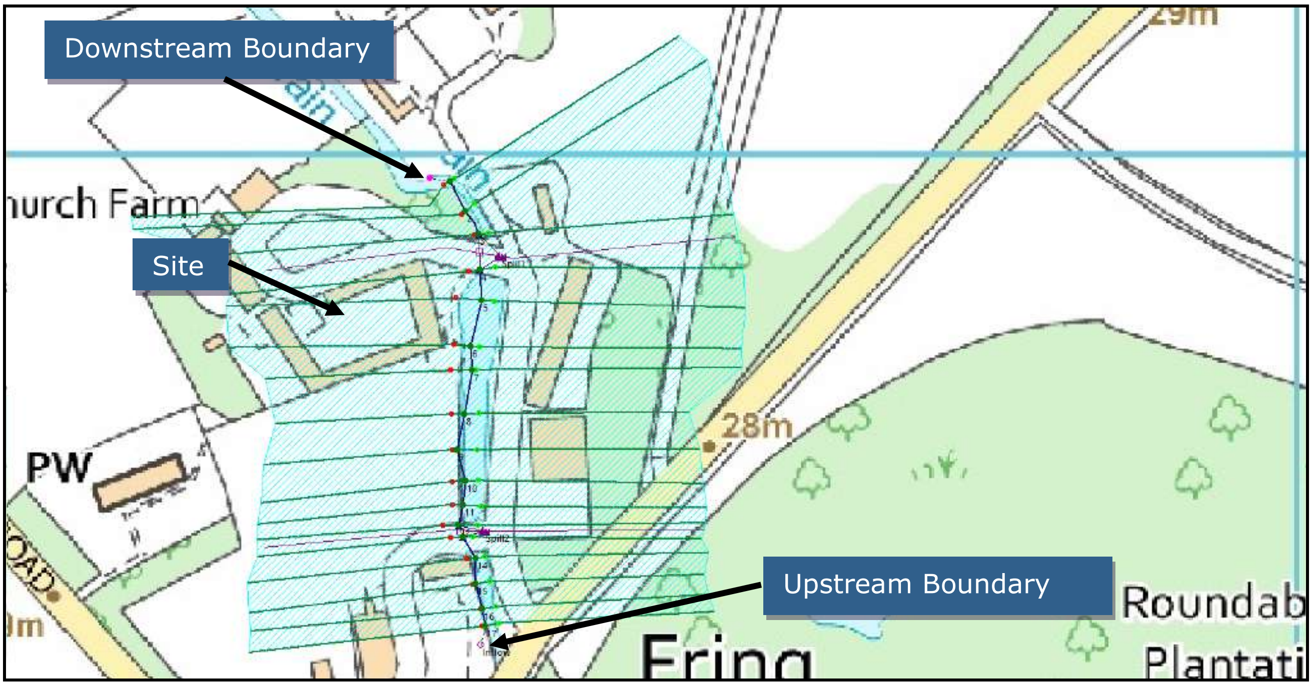

Figure 25: Model schematic as it appears in the InfoWorks software

7.7 Results

7.7.1 The model was initially run to consider the worst-case climate change 1 in 1000 year event, as this would allow the identification of any model instabilities and errors and the opportunity to correct them.

7.7.2 In order to prevent model convergence at the beginning of the event as a result of the channel running dry, the model was started at hour 8 during which flows in the channel were significant enough, and the *Automatically insert Preissmann slot for river sections* option was selected.

7.7.3 The results for each modelled return period are shown in the following tables.

7.7.4 The proposed ground floor level of the northern and eastern barns will be set at a minimum of 26.108m AOD so that they are above the climate change 1 in 1000 year flood level at cross section 7 (most relevant to the building location). The southern and western barns will be set at a minimum of 26.373m AOD.

Table 9: Results for climate change 1 in 1000 year event

	Results - 1000yrCC		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	2.494	26.439	0.462
16	2.494	26.44	0.351
15	2.494	26.433	0.368
14	2.494	26.426	0.387
13	2.494	26.415	0.474
12	2.494	26.126	0.844
11	2.494	26.124	0.426
10	2.494	26.12	0.335
9	2.495	26.114	0.33
8	2.494	26.11	0.269
7	2.495	26.108	0.209
6	2.495	26.106	0.217
5	2.496	26.106	0.105
4	2.496	26.101	0.175
3	2.496	26.012	0.823
2	2.496	25.958	0.638
1	2.496	25.938	0.399

Table 10: Results for 1 in 1000 year event

	Results - 1000yr		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	2.028	26.408	0.432
16	2.028	26.408	0.351
15	2.028	26.402	0.342
14	2.028	26.398	0.333
13	2.028	26.388	0.43
12	2.028	26.104	0.731
11	2.028	26.101	0.373
10	2.027	26.098	0.293
9	2.028	26.094	0.288
8	2.027	26.091	0.231
7	2.028	26.089	0.181
6	2.029	26.087	0.19
5	2.031	26.087	0.091
4	2.03	26.083	0.153
3	2.03	25.986	0.8
2	2.029	25.937	0.638
1	2.029	25.916	0.38

Table 11: Results for climate change 1 in 100 year event

	Results - 100yrCC		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	1.681	26.377	0.417
16	1.681	26.377	0.352
15	1.681	26.372	0.318
14	1.681	26.369	0.291
13	1.681	26.361	0.387
12	1.681	26.086	0.639
11	1.681	26.083	0.328
10	1.682	26.08	0.259
9	1.681	26.077	0.255
8	1.682	26.074	0.202
7	1.681	26.073	0.157
6	1.682	26.072	0.167
5	1.682	26.072	0.08
4	1.683	26.068	0.135
3	1.683	25.967	0.765
2	1.682	25.919	0.638
1	1.683	25.896	0.364

Table 12: Results for 1 in 100 year event

	Results - 100yr		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	1.367	26.34	0.416
16	1.367	26.34	0.351
15	1.366	26.335	0.295
14	1.366	26.332	0.253
13	1.366	26.326	0.338
12	1.366	26.066	0.547
11	1.367	26.063	0.283
10	1.366	26.061	0.226
9	1.366	26.059	0.221
8	1.366	26.057	0.173
7	1.367	26.056	0.135
6	1.366	26.055	0.144
5	1.367	26.055	0.069
4	1.367	26.052	0.118
3	1.367	25.947	0.716
2	1.367	25.901	0.638
1	1.367	25.876	0.347

Table 13: Results for climate change 1 in 20 year event

	Results - 20yrCC		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	1.23	26.318	0.416
16	1.23	26.318	0.35
15	1.23	26.313	0.287
14	1.23	26.311	0.237
13	1.23	26.305	0.315
12	1.23	26.056	0.506
11	1.23	26.054	0.262
10	1.231	26.052	0.211
9	1.23	26.05	0.205
8	1.231	26.049	0.16
7	1.231	26.048	0.124
6	1.231	26.047	0.134
5	1.231	26.047	0.065
4	1.231	26.044	0.115
3	1.231	25.938	0.685
2	1.231	25.892	0.638
1	1.23	25.866	0.341

Table 14: Results for 1 in 20 year event

	Results - 20yr		
Cross Section	Max Flow (m3/s)	Max Stage (m AD)	Max Velocity (m/s)
17	0.999	26.269	0.415
16	0.999	26.269	0.35
15	0.999	26.265	0.275
14	0.999	26.263	0.212
13	0.999	26.259	0.277
12	0.999	26.038	0.434
11	0.999	26.036	0.225
10	0.999	26.034	0.178
9	0.999	26.033	0.175
8	0.999	26.032	0.137
7	0.999	26.031	0.106
6	0.999	26.03	0.116
5	0.999	26.03	0.056
4	0.999	26.029	0.116
3	0.999	25.921	0.635
2	0.999	25.872	0.638
1	0.999	25.845	0.325

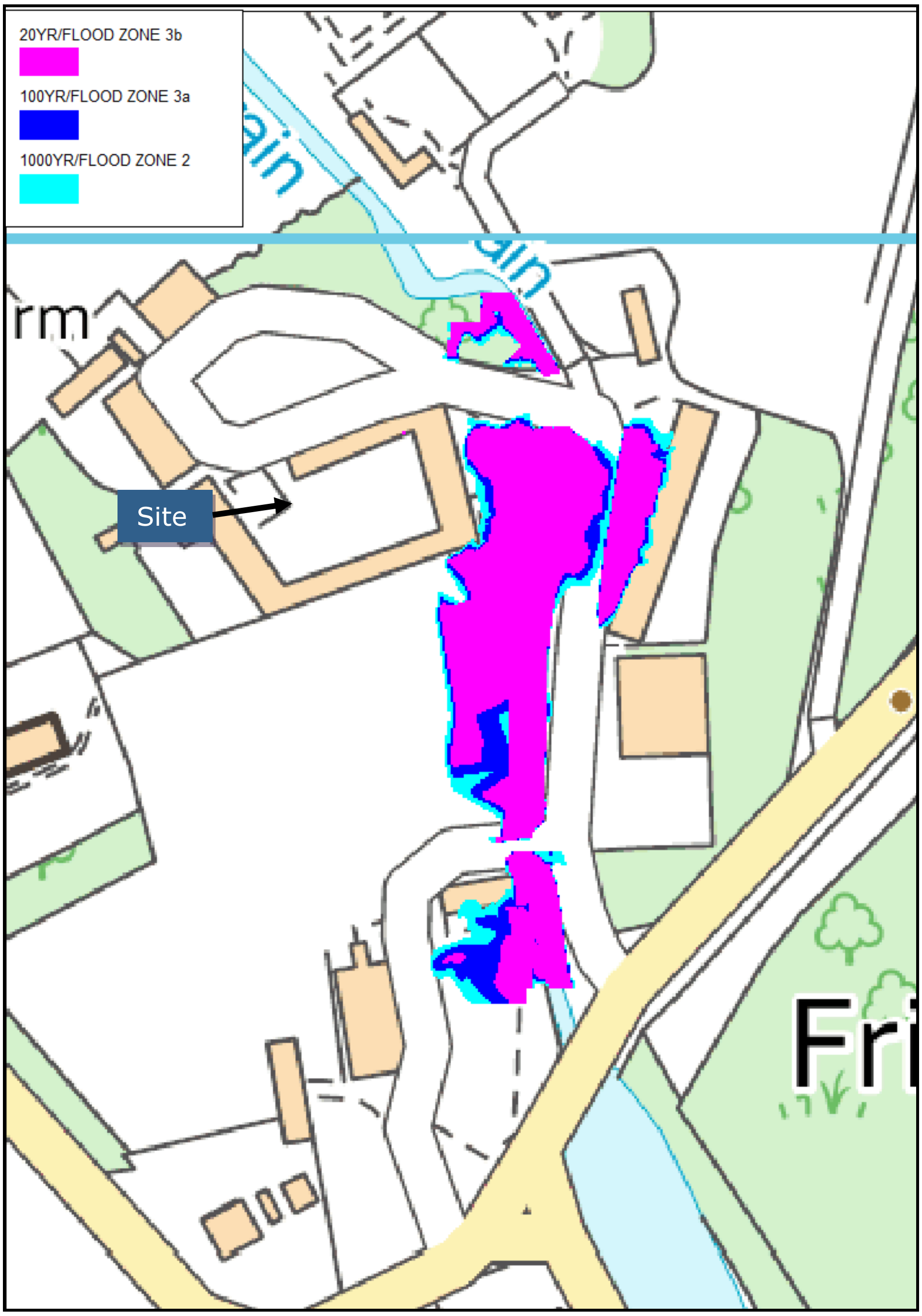

Figure 26: Present day flood extents and flood zones

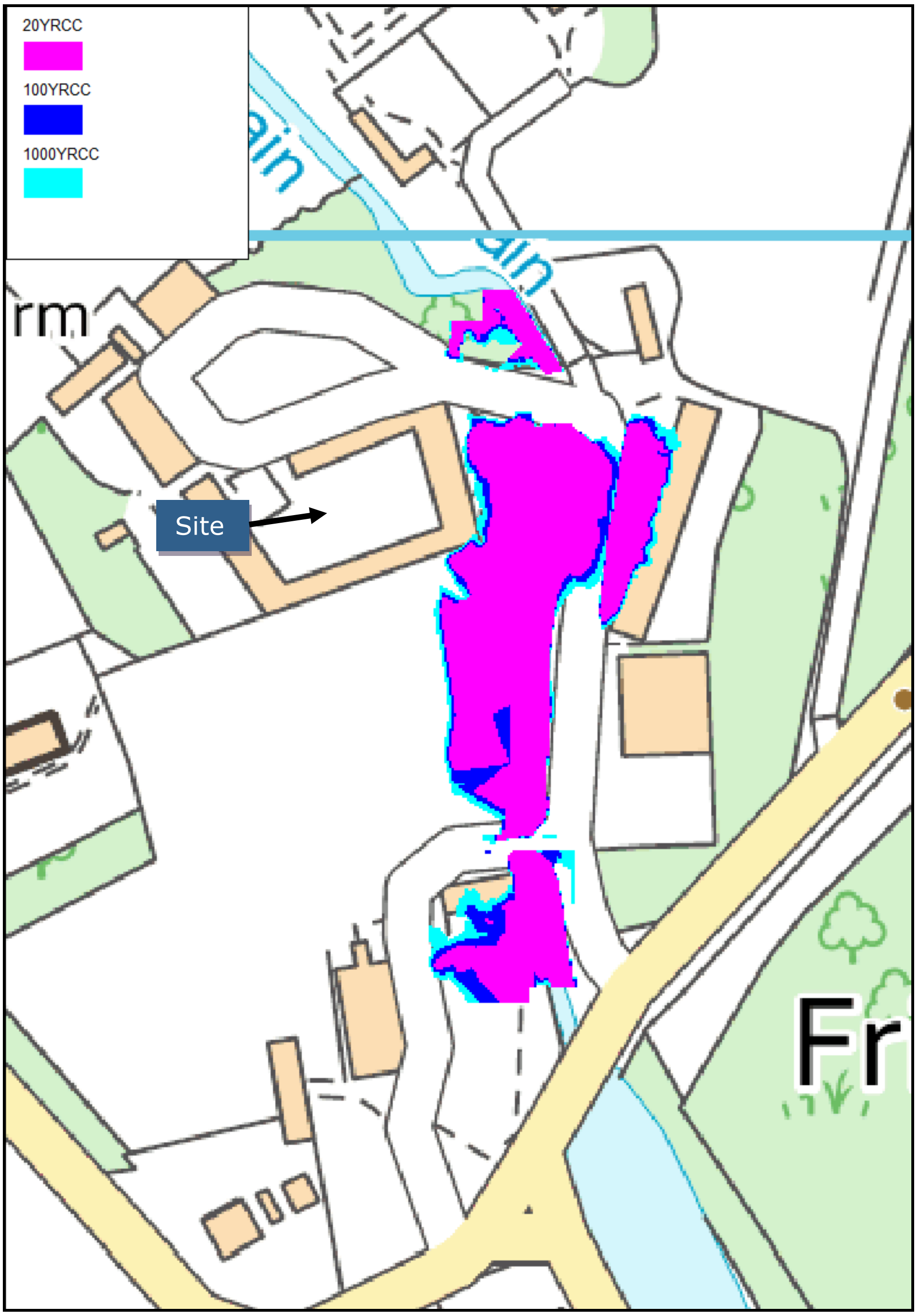

Figure 27: Climate change flood extents

7.8 Flood Zones

7.8.1 Reference to Figure 26 and inspection of the topographical survey indicates that the site is located within Flood Zone 1.

7.9 Sensitivity Analysis

7.9.1 Chapter 7 of the Agency's guidance document entitled *Fluvial Design Guide (2009)*, and Section 4.3 of the EA *Using Computer River Modelling as part of a flood risk assessment* guide, suggests that the model should be tested for sensitivity by adjusting key parameters such as the channel roughness values, downstream slope and flow rate.

7.9.2 In order to determine whether the model is sensitive when considering a particular parameter, each sensitivity test was carried out individually and as a separate model run. The sensitivity analysis has been carried out for the design climate change 1 in 100 year event.

7.9.3 The channel Manning's roughness has been increased by 20% (i.e. from 0.046 to 0.055 in order to consider an even higher density of channel vegetation). The floodplain roughness value has also been increased by 20% in the model.

7.9.4 The gradient of the downstream boundary slope has also been made shallower by 20% and steeper by 20%.

7.9.5 When considering changes to inflows, it is considered that modelling of the climate change 1 in 1000 year event in this assessment is sufficient.

7.9.6 To model a 50% blockage of the bridges caused by lack of maintenance, debris or vegetation growth, it is common to use a Blockage unit. However, it is understood that the Blockage unit performs better with arch bridge units or conduit units and not necessarily Orifice units. Therefore, instead of using a Blockage unit, the Bore Area within the Orifice data sheet was divided by 2 to represent a 50% reduction in flow area/blockage.

Results

7.9.7 The results in Table 15 show that when considering an increase in channel roughness, there is not a significant increase in flood level. It is considered that the previous conservative manning's value used in this assessment remains suitable.

7.9.8 Table 16 shows that there is no measurable increase in flood levels adjacent to the site when considering a shallower downstream slope, which is to be expected as discussed in Section 7.6. When making the slope steeper, the results in Table 17 show that there is also no major influence on water levels at the site.

7.9.9 Table 19 shows that when introducing a 50% blockage to the opening of the bridges there is negligible influence on water levels.

Table 15: Results comparison for increased "n" during climate change 1 in 100 year event

Manning's n					Original Results		
Node	Max Stage (m AD)	Max Velocity (m/s)		Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)
17	26.382	0.409		17	26.377	0.417	0.005
16	26.381	0.333		16	26.377	0.352	0.004
15	26.375	0.315		15	26.372	0.318	0.003
14	26.371	0.29		14	26.369	0.291	0.002
13	26.361	0.387		13	26.361	0.387	0
12	26.101	0.612		12	26.086	0.639	0.015
11	26.091	0.319		11	26.083	0.328	0.008
10	26.087	0.252		10	26.08	0.259	0.007
9	26.082	0.249		9	26.077	0.255	0.005
8	26.078	0.199		8	26.074	0.202	0.004
7	26.076	0.156		7	26.073	0.157	0.003
6	26.075	0.165		6	26.072	0.167	0.003
5	26.074	0.079		5	26.072	0.08	0.002
4	26.07	0.134		4	26.068	0.135	0.002
3	25.982	0.681		3	25.967	0.765	0.015
2	25.927	0.561		2	25.919	0.638	0.008
1	25.902	0.349		1	25.896	0.364	0.006

Table 16: Results comparison for shallower downstream slope during climate change 1 in 100 year event

Channel slope = Shallower				Original Results		
Node	Max Stage (m AD)	Max Velocity (m/s)	Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)
17	26.377	0.417	17	26.377	0.417	0
16	26.377	0.352	16	26.377	0.352	0
15	26.372	0.318	15	26.372	0.318	0
14	26.369	0.291	14	26.369	0.291	0
13	26.361	0.387	13	26.361	0.387	0
12	26.086	0.639	12	26.086	0.639	0
11	26.083	0.328	11	26.083	0.328	0
10	26.08	0.259	10	26.08	0.259	0
9	26.077	0.255	9	26.077	0.255	0
8	26.074	0.201	8	26.074	0.202	0
7	26.073	0.157	7	26.073	0.157	0
6	26.072	0.167	6	26.072	0.167	0
5	26.072	0.08	5	26.072	0.08	0
4	26.068	0.135	4	26.068	0.135	0
3	25.967	0.761	3	25.967	0.765	0
2	25.926	0.595	2	25.919	0.638	0.007
1	25.908	0.335	1	25.896	0.364	0.012

Table 17: Results comparison for steeper downstream slope during climate change 1 in 100 year event

Channel slope = Steeper				Original Results		
Node	Max Stage (m AD)	Max Velocity (m/s)	Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)
17	26.377	0.417	17	26.377	0.417	0
16	26.377	0.352	16	26.377	0.352	0
15	26.372	0.318	15	26.372	0.318	0
14	26.369	0.291	14	26.369	0.291	0
13	26.361	0.387	13	26.361	0.387	0
12	26.086	0.639	12	26.086	0.639	0
11	26.083	0.328	11	26.083	0.328	0
10	26.08	0.259	10	26.08	0.259	0
9	26.077	0.254	9	26.077	0.255	0
8	26.074	0.202	8	26.074	0.202	0
7	26.073	0.157	7	26.073	0.157	0
6	26.072	0.167	6	26.072	0.167	0
5	26.071	0.08	5	26.072	0.08	-0.001
4	26.068	0.135	4	26.068	0.135	0
3	25.967	0.764	3	25.967	0.765	0
2	25.915	0.673	2	25.919	0.638	-0.004
1	25.887	0.39	1	25.896	0.364	-0.009

Table 18: Results comparison for 50% blockage of bridges during climate change 1 in 100 year event

Blockage				Original Results		
Node	Max Stage (m AD)	Max Velocity (m/s)	Node	Max Stage (m AD)	Max Velocity (m/s)	Stage Difference (m)
17	26.416	0.345	17	26.377	0.417	0.039
16	26.416	0.224	16	26.377	0.352	0.039
15	26.412	0.271	15	26.372	0.318	0.04
14	26.409	0.27	14	26.369	0.291	0.04
13	26.403	0.335	13	26.361	0.387	0.042
12	26.094	0.624	12	26.086	0.639	0.008
11	26.092	0.319	11	26.083	0.328	0.009
10	26.089	0.25	10	26.08	0.259	0.009
9	26.086	0.246	9	26.077	0.255	0.009
8	26.084	0.196	8	26.074	0.202	0.01
7	26.082	0.153	7	26.073	0.157	0.009
6	26.081	0.161	6	26.072	0.167	0.009
5	26.081	0.077	5	26.072	0.08	0.009
4	26.079	0.129	4	26.068	0.135	0.011
3	25.967	0.764	3	25.967	0.765	0
2	25.919	0.638	2	25.919	0.638	0
1	25.896	0.364	1	25.896	0.364	0

8. CONCLUSIONS

- An InfoWorks RS model has been developed to determine the fluvial flood risk to the site from the adjacent watercourse.

- This assessment has determined that the site is located within Flood Zone 1.

- The proposed ground floor level of the northern and eastern barns will be set at a minimum of 26.108m AOD so that they are above the climate change 1 in 1000 year flood level at cross section 7 (most relevant to the building location). The southern and western barns will be set at a minimum of 26.373m AOD.

- A sensitivity analysis has been carried out in which the model was tested for a change in channel roughness, change in downstream slope and blockage of the bridges. The results indicate that the model is not significantly sensitive to a change in roughness, downstream slope or a blockage.

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APPENDIX A – WINFAP 5 HYDROLOGICAL REPORT

UK Design Flood Estimation

Summary of ESS/Pooled Estimation Analysis using the Flood Estimation Handbook Statistical Method

Date of creation:	07-03-2022 10:47:57
Software:	WINFAP Version: 5.0.7947 (29986)
Peak Flow dataset:	Peak Flow Dataset 10.0.0
Supplementary data used:	No

Site details

Site number:	4025755944
Site name:	FEH_Catchment_Descriptors_573650_335000
Site location:	TF 73650 35000
Easting:	573650
Northing:	335000
Catchment area:	41.53 km^2
SAAR:	697 mm
BFIHOST19:	0.929
FPEXT:	0.131
FARL:	0.987
URBEXT2000:	0.0074

Analysis settings

At-site data

At-site data present:	No

Urbanisation settings

User defined:	No
Urban area:	0.48 km^2
PRimp:	70.00%
Impervious Factor:	0.300
UAF:	1.03883

Growth curve settings

Distance Measure Method:	Standard
Pooling group URBEXT2000 Threshold:	0.030
Deurbanise Pooling Group L-moments:	Yes

QMED settings

Use at-site data:	No
Method:	Donor Station(s)

Growth curve data and results

Pooling Group

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised	Discordancy
33054 (Babingley @ Castle Rising)	0.379	44	1.132	0.204	**0.205**	0.069	**0.068**	0.672
33032 (Heacham @ Heacham)	0.457	52	0.442	0.298	**0.299**	0.139	**0.138**	0.065
26013 (Driffield Trout Stream @ Driffield)	0.554	10	2.685	0.292	**0.293**	0.281	**0.280**	2.648
26003 (Foston Beck @ Foston Mill)	0.578	59	1.760	0.249	**0.249**	-0.009	**-0.010**	1.183
36003 (Box @ Polstead)	0.727	60	3.875	0.314	**0.317**	0.088	**0.086**	0.462
41020 (Bevern Stream @ Clappers Bridge)	0.804	51	13.660	0.204	**0.205**	0.174	**0.171**	1.269
34005 (Tud @ Costessey Park)	0.842	58	3.130	0.287	**0.292**	0.225	**0.220**	0.576
36004 (Chad Brook @ Long Melford)	0.856	53	4.938	0.304	**0.305**	0.167	**0.166**	0.911
36007 (Belchamp Brook @ Bardfield Bridge)	0.863	55	4.630	0.378	**0.378**	0.112	**0.111**	1.457
30004 (Lymn @ Partney Mill)	0.948	58	7.184	0.224	**0.225**	0.030	**0.029**	0.757
Total		**500**						

Short records Discordant No Pooling No Pooling, no QMED

Pooling Group Rejected Stations

Station	Distance	Years of data	QMED AM	L-CV Observed	L-CV Deurbanised	L-SKEW Observed	L-SKEW Deurbanised

Growth curve L-moments

Rural L-CV:	0.275	Urban L-CV:	0.274
Rural L-Skewness:	0.116	Urban L-Skewness:	0.118

Rural fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.284	-0.116		-1.436
GEV	0.836	0.453	0.085		6.167
KAP3	0.920	0.357	-0.025	-0.400	-13.662

Urban fitted parameters

Distribution	Location	Scale	Shape	H	Bound
GL	1.000	0.282	-0.118		-1.400
GEV	0.837	0.451	0.083		6.262
KAP3	0.920	0.355	-0.026	-0.400	-12.734

Goodness of fit

GL:	2.5661
GEV:	-0.3815 *
P3:	-0.6235 *
GP:	-6.3658
KAP3:	1.4193 *

** Distribution gives an acceptable fit (absolute Z value < 1.645)*

Heterogeneity

Standardised test value H2: 2.2713

The pooling group is heterogeneous and a review of the pooling group is desirable.

Standardised growth curves

Rural

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.427	1.475	1.449
10	1.710	1.765	1.738
20	1.996	2.026	2.016
50	2.396	2.341	2.381
100	2.723	2.562	2.658
200	3.076	2.769	2.939
500	3.585	3.024	3.317
1000	4.008	3.204	3.608

Urban

Return period	GL	GEV	KAP3
2	1.000	1.000	1.000
5	1.425	1.473	1.447
10	1.708	1.762	1.736
20	1.993	2.024	2.014
50	2.394	2.339	2.378
100	2.721	2.560	2.656
200	3.074	2.768	2.938
500	3.584	3.025	3.317
1000	4.009	3.206	3.610

QMED data and results

Donor selection criteria

Only sites suitable for QMED: Yes
URBEXT2000: <0.030
Donor adjusted FSE: 1.289
No. of donors: 3

Donor stations

Station	Distance	URBEXT	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural	Centroid X	Centroid Y	Area	SAAR	BFIHOST19	FARL	Years of data	QMED suitability	Pooling suitability	Weight
FEH_Catchment_Descriptors_573650_335000 @ TF 73650 35000)		0.007						576176	332341	41.530	697	0.929	0.987				
33032 (Heacham @ Heacham)	1.73	0.006	Yes	0.442	**0.427**	1.091	1.091	574860	333465	56.163	688	0.932	0.983	52	Yes	Yes	0.680
33054 (Babingley @ Castle Rising)	6.76	0.005	Yes	1.132	**1.108**	1.026	1.026	574755	325733	48.530	686	0.895	0.944	44	Yes	Yes	0.423
34012 (Burn @ Burnham Overy)	9.97	0.005	Yes	1.030	**1.003**	1.500	1.500	584690	337532	83.868	668	0.930	0.997	54	Yes	Yes	0.381

Unused Donor stations

Station	Distance	URBEXT	Use QMED obs deurbanised	QMED obs	QMED deurbanised	QMED CDs urban	QMED CDs rural	Centroid X	Centroid Y	Area	SAAR	BFIHOST19	FARL	Years of data	QMED suitability	Pooling suitability	Weight
33007 (Nar @ Marham)	17.79	0.006	Yes	3.620	**3.557**	3.355	3.355	582923	315881	147.390	683	0.835	0.926	38	Yes	Yes	0.322
33029 (Stringside @ Whitebridge)	26.63	0.007	Yes	2.722	**2.656**	1.823	1.823	573508	305842	95.412	628	0.879	0.991	54	Yes	Yes	0.270
34005 (Tud @ Costessey Park)	35.90	0.029	Yes	3.130	**3.004**	5.247	5.247	605696	311919	72.110	649	0.603	0.973	58	Yes	Yes	0.224
34003 (Bure @ Ingworth)	36.93	0.007	Yes	5.343	**5.262**	5.628	5.628	613103	333028	161.270	669	0.770	0.974	60	Yes	No	0.220
33049 (Stanford Water @ Buckenham Tofts)	38.91	0.007	Yes	0.788	**0.770**	0.992	0.992	590027	295982	46.450	645	0.842	0.915	7	Yes	No	0.211
34001 (Yare @ Colney)	41.56	0.019	Yes	13.337	**13.034**	16.839	16.839	606922	304372	228.810	635	0.530	0.971	62	Yes	No	0.200
33048 (Larling Brook @ Stonebridge)	44.86	0.003	Yes	0.318	**0.314**	0.423	0.423	592750	290650	21.990	635	0.868	0.907	31	Yes	No	0.187

QMED

Rural: 0.508 m^3/s

Urban: 0.527 m^3/s

Flood Frequency Curve

Rural Flood Frequency Curve

Return period	GL (m^3/s)	GEV (m^3/s)	KAP3 (m^3/s)
2	0.508	0.508	0.508
5	0.724	0.749	0.736
10	0.868	0.896	0.882
20	1.014	1.029	1.024
50	1.217	1.189	1.209
100	1.383	1.301	1.350
200	1.562	1.406	1.492
500	1.820	1.535	1.684
1000	2.035	1.627	1.832

Urban Flood Frequency Curve

Return period	GL (m^3/s)	GEV (m^3/s)	KAP3 (m^3/s)
2	0.527	0.527	0.527
5	0.752	0.777	0.763
10	0.901	0.930	0.916
20	1.051	1.067	1.062
50	1.263	1.234	1.254
100	1.435	1.350	1.401
200	1.621	1.460	1.550
500	1.891	1.595	1.750
1000	2.114	1.691	1.904

APPENDIX B - SURVEY REPORT

1 CHESTNUT PLACE
CRINGLEFORD
NORWICH
NORFOLK
NR4 7BD

t: 01603 507917
m: 07786 388175
barry@bbsurveys.co.uk
www.bbsurveys.co.uk

COURTYARD BARNS

Fring, Norfolk

TOPOGRAPHIC SURVEY REPORT
2219-3284

Chapter

1. Introduction

In connection with Rupert Evans of Evans Rivers and Coastal, BB Surveys were instructed to carry out survey works at Courtyard Barns, Fring, Norfolk.

This required a topographic survey of the site and watercourse.

The extents of the survey were provided by the client.

Survey control points from a previous survey were observed for 30 mins using Trimble GPS surveying equipment which is fixed to Ordnance Survey, (OSTN15 and OSGM15).

2. Surveying Services

2.1 Scope

The survey scope was as per the clients requirements and it was agreed that cross section survey data would be recorded at approx. 10m – 20m intervals where possible, with sections taken at approx. 10m sections.

2.2 Programme

The survey took place 29th November 2021

2.3 Access and PPE

Access to site was agreed prior to the survey taking place with all relevant landowners.

Hi-vis vests, Safety boots & hard hats, life jackets and waders.

2.4 Personnel and Equipment Resources

All survey works was carried out by BB Surveys

Name	Role	Mobile Number
Barry Burrows	Director	07786 388175
Jennifer Burrows	Director / Secretary	07786 388125
Andrew Parish	Senior Land Surveyor	07446 865168
Jordan Burrows	Land Surveyor	07768 827147
Tyla Armstrong	Land Surveyor	07876 426585
Matthew Brook	Land Surveyor	07912 617730

Topographical survey equipment used consists of but not limited to, the following:

- Trimble S8 Total Stations
- Trimble R12 GNSS VRS - GPS/GLONASS receivers
- Trimble S Series Traverse Targets

Survey processing software used by BB Surveys, but not limited to, the following:

- Trimble Business Centre
- Applications in CADD, n4ce Professional
- MicroSurvey STAR*NET 8
- AutoCAD 2015
- Microsoft Office 2013

3. Methodology, Detail Survey & Processing

3.1 Survey Control

Survey Control was installed and observed using Trimble GPS

4no were logged with GPS to establish Ordnance Survey position and level.

Control Station No	Easting	Northing	Ele	Type
STNBBS1	573718.080	334836.039	28.201	MAG Nail
STNBBS2	573693.853	334800.498	27.458	MAG Nail
STNBBS3	573672.718	334762.011	26.778	MAG Nail
STNBBS4	573632.688	334731.836	27.205	MAG Nail

3.2 GNSS Computations

Control Survey Stations were observed for 30 minutes using the Trimble R8 and VRS NOW active station network to obtain OSGB36 co-ordinates and level.

These were then used to fix the raw data recorded with the Trimble S8 onto OS grid co-ordinates.

The National GPS Network, which contains over 90 active GPS reference stations of the OS Net network and about 900 passive reference stations. Using this reference network, precise ETRS89 positions are obtained from your GPS equipment.

National Grid Transformation OSTN15 – the definitive transformation between ETRS89 and OSGB36 National Grid. The National GPS Network in conjunction with OSTN15 provide the standard method of obtaining locally consistent National Grid coordinates for GPS surveyors. Occupying triangulation stations with GPS is no longer necessary.

National Geoid Model OSGM15 – the national standard precise geoid model, converting precise ETRS89 ellipsoid heights to heights above mean sea level (MSL)(ODN orthometric heights for the mainland UK). With high accuracy GPS positioning using the National GPS Network, surveyors can use OSGM15 to install their own bench marks relative to the MSL datum without levelling to Ordnance Survey bench marks.

3.3 Detail Survey

The survey was carried out using a Total Station and observations were taken where possible, the watercourse was overgrown with vegetation and we also tried to minimise any damage that may be caused to third party land. (See photos, Appendix B)

3.4 Office Processing

All GNSS Data will be processed through Trimble Business Centre.

Traverse Data to be processed through MicroSurvey STAR*NET 8

All survey observations will be processed in n4ce Pro.

Final drawings and table processed in AutoCAD and MS Excel.

4. Quality Control

All survey data has been collected in accordance with Environment Agency surveying standards.
(where possible)

Equipment Used	Type	Serial Number
Trimble S8	Total Station	98111406
Trimble TSC3	Survey Controller	RS13C19478
Trimble R12	GNSS	5948F00960
Leica Sprinter 100	Digital Level	333156

5. Deliverables

Topographic Survey data to be supplied in the following formats.

Full survey of watercourse in 2D and 3D AutoCAD .dwg

200mm & 500mm Gridded Survey Data in .csv

Cross Section Data in .csv

Full set of drawings in Adobe .pdf

Survey Report

Appendix A

Survey Drawings


BBS- BB- EGL- SU- 02
1:250
2219-3284
1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
Courtyard Barns
Fring
Existing Ground Level Survey
Sheet 2
BBS- BB- EGL- SU- 02


BBS- BB- EGL- SU- 03
1:100
2219-3284
1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
Courtyard Barns
Fring
Sections
BBS- BB- EGL- SU- 03


BBS- BB- EGL- SU- 04
1:100
2219-3284
BBS
1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
EVANS
Courtyard Barns
Fring
Sections
BBS- BB- EGL- SU- 04

Appendix B

Site Photos

Appendix C.

Instrumentation Documents

DATASHEET

TRIMBLE S8 TOTAL STATION

KEY FEATURES

Trimble's latest total station platform with flexibility for even more applications

Broader business opportunities with complete system support for specialized engineering tasks such as monitoring

MagDrive technology for maximum speed and efficiency

MultiTrack™ technology offers the choice between passive and active tracking

Trimble eProtect™ security feature locks total station from unauthorized users

The Trimble® S8 Total Station is Trimble's most advanced total station. Designed to deliver unsurpassed performance in both surveying and specialized engineering applications, the Trimble S8 offers 1" angular accuracy and EDM precision of 1 mm + 1 ppm, plus numerous features to enhance efficiency and productivity.

THE MOST ADVANCED TOTAL STATION PLATFORM

The Trimble S8 instrument is built on Trimble's latest total station platform. Whatever your application in surveying or specialized engineering, you can benefit from the latest optical technology to increase your productivity.

For instance, Trimble® MagDrive™ servo technology ensures the Trimble S8 is fast and silent, so you can survey or monitor (unobtrusively) targets up to 40% faster than conventional motorized total stations, detect movements faster, and initiate alarms earlier. Wear and tear is also greatly reduced due to the MagDrive frictionless motion, making worry-free 24/7 operation possible.

A COMPLETE SYSTEM FOR ENGINEERING APPLICATIONS

The Trimble S8 Total Station works in harmony with Trimble Survey Controller™ field software and the new Trimble® 4D Control software to provide a seamlessly connected, complete solution for specialized applications.

Trimble S8 Total Station

The Trimble S8 is equipped with unique features such as:

- Trimble® FineLock technology is a smart tracker sensor with a narrow field of view that enables the Trimble S8 to detect a target without interference from surrounding prisms. This feature makes the mounting of prisms more flexible, and offers outstanding and reliable accuracy.

- 10 Hz high-speed synchronized data output makes data collection in dynamic applications faster and more accurate. For example, for railway monitoring a trolley or ATV can move more quickly without compromising accuracy.

Trimble Survey Controller Field Software – Engineering Module

Trimble Survey Controller software now offers a separate Engineering module. Because this Trimble engineering solution uses the Trimble Survey Controller interface, it's easy for surveying businesses to broaden their offering to engineering applications—crews don't need to learn new software.

Trimble 4D Control Software

Trimble 4D Control is postprocessing software designed for engineering applications, including monitoring. It reads rounds from Trimble Survey Controller in the JobXML format as individual sessions, and indicates any movement of targets over time. Results in the highly visual interface are easy to analyze, and the software is customizable to provide features such as target movement warnings and alarms.

INTEGRATED SURVEYING

Whatever your application, the Trimble S8 Total Station offers the full Trimble® Integrated Surveying™ solution.

For engineering applications, data flow from the field to the Trimble 4D Control software is seamless, and the display of results fast as a result. When not in use for engineering applications, the Trimble S8 Total Station integrates into the Trimble solution for more typical surveying applications. For example, its optical data can be combined with GPS and 3D scanning data, or it can be used as a Trimble® I.S. Rover.

The flexibility of the Trimble S8 secures your investment and ensures a fast return on investment.

Trimble.

TRIMBLE S8 DR HIGH PRECISION

PERFORMANCE

- Angle measurement
- Accuracy (Standard deviation based on DIN 18723) ... 1" (0.3 mgon)
- Angle reading (least count)
  - Standard ... 1" (0.1 mgon)
  - Tracking ... 2" (0.5 mgon)
  - Averaged observations ... 0.1" (0.01 mgon)
- Automatic level compensator
  - Type ... Centered dual-axis
  - Accuracy ... 0.5" (0.15 mgon)
  - Range ... ±6' (±100 mgon)
- Distance measurement
- Accuracy (S. Dev.)
  - Prism mode
    - Standard ... ±(1 mm + 1 ppm) ±(0.003 ft + 1 ppm)
    - Tracking ... ±(5 mm + 2 ppm) ±(0.016 ft + 2 ppm)
  - DR mode
    - Standard measurement ... ±(3 mm + 2 ppm) ±(0.01 ft + 2 ppm)
    - Tracking ... ±(10 mm + 2 ppm) ±(0.032 ft + 2 ppm)
- Measuring time
  - Prism mode
    - Standard ... 2 s
    - Tracking ... 0.4 s
    - Averaged observations ... 2 s per measurement
  - DR mode
    - Standard ... 3–15 s
    - Tracking ... 0.4 s
    - Averaged observations[1] ... 3–15 s per measurement
- Range (under standard clear conditions[2,3])
  - Prism mode
    - 1 prism ... 3000 m (9,800 ft)
    - 1 prism Long Range mode ... 5000 m (16,400 ft)
    - 3 prism ... 5000 m (16,400 ft)
    - 3 prism Long Range mode ... 7000 m (23,000 ft)
    - Shortest possible range ... 1.5 m (4.9 ft)
  - DR mode (typically)
    - Kodak Gray Card (18% reflective)[4] ... >120 m (394 ft)
    - Kodak Gray Card (90% reflective)[4] ... >150 m (492 ft)
    - Shortest possible range ... 1.5 m (4.9 ft)

EDM SPECIFICATIONS

- Light source ... Laserdiode 660 nm; Laser class 1 in Prism mode; Laser class 2 in DR mode
- Laser pointer coaxial (standard) ... Laser class 2
- Beam divergence Prism mode
  - Horizontal ... 4 cm/100 m (0.13 ft/328 ft)
  - Vertical ... 4 cm/100 m (0.13 ft/328 ft)
- Beam divergence DR mode
  - Horizontal ... 2 cm/50 m (0.066 ft/164 ft)
  - Vertical ... 2 cm/50 m (0.066 ft/164 ft)
- Atmospheric correction ... –130 ppm to 160 ppm continuously

GENERAL SPECIFICATIONS

- Leveling
  - Circular level in tribrach ... 8'/2 mm (8'/0.007 ft)
  - Electronic 2-axis level in the LC-display with a resolution of ... 0.3" (0.1 mgon)
- Servo system ... MagDrive servo technology, Integrated servo/angle sensor; electromagnetic direct drive
- Rotation speed ... 115 degrees/sec (128 gon/sec)
- Rotation time Face 1 to Face 2 ... 3.2 sec
- Positioning speed180 degrees (200 gon) ... 3.2 sec
- Clamps and slow motions ... Servo-driven, endless fine adjustment

- Centering
  - Centering system ... Trimble 3-pin
  - Optical plummet ... Built-in optical plummet
- Magnification/shortest focusing distance ... 2.3x/0.5 m–infinity (1.6 ft–infinity)
- Telescope
- Magnification ... 30x
- Aperture ... 40 mm (1.57 in)
- Field of view at 100 m (328 ft) ... 2.6 m at 100 m (8.5 ft at 328 ft)
  - Shortest focusing distance ... 1.5 m (4.92 ft)–infinity
  - Illuminated crosshair ... Variable (10 steps)
- Tracklight built in ... Standard
- Operating temperature ... –20 °C to +50 °C (–4 °F to +122 °F)
- Dust and water proofing ... IP55
- Power supply
  - Internal battery ... Rechargeable Li-Ion battery 11.1 V, 4.4 Ah
  - Operating time[5]
    - One internal battery ... Approx. 6 hours
    - Three internal batteries in multi-battery adapter ... Approx. 18 hours
  - Robotic holder with one internal battery ... 12 hours
- Weight
  - Instrument (servo/Autolock) ... 5.15 kg (11.35 lb)
  - Instrument (Robotic) ... 5.25 kg (11.57 lb)
  - Trimble CU controller ... 0.4 kg (0.88 lb)
  - Tribrach ... 0.7 kg (1.54 lb)
  - Internal battery ... 0.35 kg (0.77 lb)
- Trunnion axis height ... 196 mm (7.71 in)
- Communication ... USB, Serial, Bluetooth®[7]
- Security ... Dual-layer password protection

ROBOTIC SURVEYING

- Autolock and Robotic range[3]
  - Passive prisms ... 500–700 m (1,640–2,297 ft)
  - Trimble MultiTrack Target ... 800 m (2,625 ft)
- Autolock pointing precision at 200 m (656 ft) (standard deviation)[3]
  - Passive prisms ... <2 mm (0.007 ft)
  - Trimble MultiTrack Target ... <2 mm (0.007 ft)
- Shortest search distance ... 0.2 m (.65 ft)
- Angle reading (least count)
  - Standard ... 1" (0.1 mgon)
  - Tracking ... 2" (0.5 mgon)
  - Averaged observations ... 0.1" (0.01 mgon)
- Type of radio internal/external ... 2.4 GHz frequency-hopping, spread-spectrum radios
- Search time (typical)[7] ... 2-10 s

FINELOCK

- Pointing precision at 300m (980 ft) (standard deviation)[4] ... <1 mm (0.003 ft)
- Range to passive prisms (min–max)[3] ... 20 m–700 m (64 ft–2,297 ft)
- Minimum spacing between prisms at 200 m (656 ft) ... < 0.8 m (2.625 ft)

GPS SEARCH/GEOLOCK WITH THE TRIMBLE MULTITRACK TARGET

- GPS Search/GeoLock ... 360 degrees (400 gon) or defined horizontal and vertical search window
- Solution acquisition time ... 15–30 seconds[8]
- Target re-acquisition time ... <3 seconds
- Range ... Autolock and Robotic range limits

1 Repeats for defined number of measurements up to 99.
2 Standard clear: No haze. Overcast or moderate sunlight with very light heat shimmer.
3 Range and accuracy depend on atmospheric conditions, size of prisms and background radiation.
4 Kodak Gray Card, Catalog number E1527795.
5 The capacity in –20 °C (–5 °F) is 75% of the capacity at +20 °C (68 °F).
6 Bluetooth type approvals are country specific. Contact your local Trimble Authorized Distribution Partner for more information.
7 Dependent on selected size of search window.
8 Solution acquisition time is dependent upon solution geometry and GPS position quality.

Specifications subject to change without notice.

TRIMBLE AUTHORIZED DISTRIBUTION PARTNER

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www.trimble.com

DATASHEET

Trimble R12

GNSS SYSTEM

KEY FEATURES

- Next generation Trimble® ProPoint™ GNSS positioning engine. Engineered for improved accuracy and productivity in challenging GNSS conditions.
- 672-channel solution with Trimble 360 satellite tracking technology
- Trimble SurePoint™ tilt compensation and precise position capture
- Trimble xFill® correction outage technology
- Support for RTK level precision Trimble CenterPoint® RTX corrections technology
- Optimized for Trimble Access™ field software
- Android™ and iOS platform support
- Cellular, Bluetooth®, Wi-Fi data connectivity
- Military-spec rugged design and IP-67 rating
- Ergonomic form factor
- All day battery with built-in status indicator
- 6 GB internal memory

Learn more:
geospatial.trimble.com/R12

PERFORMANCE SPECIFICATIONS		
GNSS MEASUREMENTS		
	Constellation agnostic, flexible signal tracking and improved positioning[1] in challenging environments with Trimble ProPoint GNSS technology	
	Increased measurement productivity and traceability with Trimble SurePoint eBubble tilt compensation	
	Advanced Trimble Custom Survey GNSS chips with 672 channels	
	Reduced downtime due to loss of radio signal or cellular connectivity with Trimble xFill technology	
	Signals tracked simultaneously	GPS: L1C, L1C/A, L2C, L2E, L5 GLONASS: L1C/A, L1P, L2C/A, L2P, L3 SBAS (WAAS, EGNOS, GAGAN, MSAS): L1C/A, L5 Galileo: E1, E5A, E5B, E5 AltBOC, E6[2] BeiDou: B1, B1C, B2, B2A, B3 QZSS: L1C/A, L1S, L1C, L2C, L5, L6 NavIC (IRNSS): L5 L-band: CenterPoint RTX
	Iridium filtering above 1616 MHz allows antenna to be used up to 20 m away from iridium transmitter	
	Japanese LTE filtering below 1510 MHz allows antenna to be used up to 100 m away from Japanese LTE cell tower	
	Digital Signal Processor (DSP) techniques to detect and recover from spoofed GNSS signals	
	Advanced Receiver Autonomous Integrity Monitoring (RAIM) algorithm to detect and reject problem satellite measurements to improve position quality	
	Improved protection from erroneous ephemeris data	
	Positioning Rates	1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz
POSITIONING PERFORMANCE[3]		
CODE DIFFERENTIAL GNSS POSITIONING		
	Horizontal	0.25 m + 1 ppm RMS
	Vertical	0.50 m + 1 ppm RMS
	SBAS[4]	typically <5 m 3DRMS
STATIC GNSS SURVEYING		
High-Precision Static		
	Horizontal	3 mm + 0.1 ppm RMS
	Vertical	3.5 mm + 0.4 ppm RMS
Static and Fast Static		
	Horizontal	3 mm + 0.5 ppm RMS
	Vertical	5 mm + 0.5 ppm RMS
REAL TIME KINEMATIC SURVEYING		
Single Baseline <30 km		
	Horizontal	8 mm + 1 ppm RMS
	Vertical	15 mm + 1 ppm RMS
Network RTK[5]		
	Horizontal	8 mm + 0.5 ppm RMS
	Vertical	15 mm + 0.5 ppm RMS
RTK start-up time for specified precisions[6]		2 to 8 seconds
TRIMBLE RTX™ TECHNOLOGY (SATELLITE AND CELLULAR/INTERNET (IP))		
CenterPoint RTX[7]		
	Horizontal	2 cm RMS
	Vertical	5 cm RMS
	RTX convergence time for specified precisions - Worldwide	< 15 min
	RTX QuickStart convergence time for specified precisions	< 1 min
	RTX convergence time for specified precisions in select regions (Trimble RTX Fast Regions)	< 1 min
TRIMBLE XFILL[8]		
	Horizontal	RTK[9] + 10 mm/minute RMS
	Vertical	RTK[9] + 20 mm/minute RMS

HARDWARE		
PHYSICAL		
Dimensions (W×H)	11.9 cm x 13.6 cm (4.6 in x 5.4 in)	
Weight	1.12 kg (2.49 lb) with internal battery, internal radio with UHF antenna, 3.95 kg (8.71 lb) items above plus range pole, Trimble TSC7 controller & bracket	
Temperature[10]		
	Operating	−40 °C to +65 °C (−40 °F to +149 °F)
	Storage	−40 °C to +75 °C (−40 °F to +167 °F)
Humidity		100%, condensing
Ingress protection		IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration (Tested and meets the following environmental standards)		
	Shock	Non-operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
	Vibration	MIL-STD-810F, FIG.514.5C-1
ELECTRICAL		
	Power 11 to 24 V DC external power input with over-voltage protection on Port 1 and Port 2 (7-pin Lemo)	
	Rechargeable, removable 7.4 V, 3.7 Ah Lithium-ion smart battery with LED status indicators	
	Power consumption is 4.2 W in RTK rover mode with internal radio[11]	
Operating times on internal battery[12]		
	450 MHz receive only option	6.5 hours
	450 MHz receive/transmit option (0.5 W)	6.0 hours
	450 MHz receive/transmit option (2.0 W)	5.5 hours
	Cellular receive option	6.5 hours
COMMUNICATIONS AND DATA STORAGE		
Serial	3-wire serial (7-pin Lemo)	
USB v2.0	Supports data download and high speed communications	
Radio modem	Fully Integrated, sealed 450 MHz wide band receiver/transmitter with frequency range of 403 MHz to 473 MHz, support of Trimble, Pacific Crest, and SATEL radio protocols:	
	Transmit power	2 W
	Range	3–5 km typical / 10 km optimal[13]
Cellular[14]	Integrated, 3.5 G modem, HSDPA 7.2 Mbps (download), GPRS multi-slot class 12, EDGE multi-slot class 12, Penta-band UMTS/HSDPA (WCDMA/FDD) 800/850/900/1900/2100 MHz, Quad-band EGSM 850/900/1800/1900 MHz, GSM CSD, 3GPP LTE	
Bluetooth	Fully integrated, fully sealed 2.4 GHz communications port (Bluetooth)[15]	
Wi-Fi	802.11 b,g, access point and client mode, WPA/WPA2/WEP64/WEP128 encryption	
I/O ports	Serial, USB, TCP/IP, IBSS/NTRIP, Bluetooth	
Data storage	6 GB internal memory	
Data format	CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1, RTCM 3.2 input and output	
	24 NMEA outputs, GSOF, RT17 and RT27 outputs, 1 PPS output	
WEBUI		
	Offers simple configuration, operation, status, and data transfer	
	Accessible via Wi-Fi, Serial, USB, and Bluetooth	
SUPPORTED CONTROLLERS & FIELD SOFTWARE		
	Trimble TSC7, Trimble T10, Trimble T7, Android and iOS devices running supported apps	
	Trimble Access 2019.10 or later	
CERTIFICATIONS		
	FCC Part 15 (Class B device), 24, 32; CE Mark; RCM; PTCRB; BT SIG	

Trimble.

DATASHEET

Trimble R12 GNSS SYSTEM

1. Challenging GNSS environments are locations where the receiver has sufficient satellite availability to achieve minimum accuracy requirements but where the signal may be partly obstructed by and/or reflected off of trees, buildings, and other objects. Actual results may vary based on user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability, and level of multipath and signal occlusion.
2. The current capability in the receivers is based on publicly available information. As such, Trimble cannot guarantee that these receivers will be fully compatible with a future generation of Galileo satellites or signals.
3. Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest-order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.
4. Depends on SBAS system performance.
5. Network RTK PPM values are referenced to the closest physical base station.
6. May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
7. RMS performance based on repeatable in field measurements. Achievable accuracy and initialization time may vary based on type and capability of receiver and antenna, user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability and level of multipath including obstructions such as large trees and buildings.
8. Accuracies are dependant on GNSS satellite availability. xFill positioning without a Trimble CenterPoint RTX subscription ends after 5 minutes of radio downtime. xFill positioning with a CenterPoint RTX subscription will continue beyond 5 minutes providing the Trimble RTX solution has converged, with typical precisions not exceeding 6 cm horizontal, 14 cm vertical or 3 cm horizontal, 7 cm vertical in Trimble RTX Fast regions. xFill is not available in all regions, check with your local sales representative for more information.
9. RTK refers to the last reported precision before the correction source was lost and xFill started.
10. Receiver will operate normally to −40 °C, internal batteries are rated to −20 °C.
11. Tracking GPS, GLONASS and SBAS satellites.
12. Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.
13. Varies with terrain and operating conditions.
14. Due to local regulations, the integrated cellular modem cannot be enabled in China, Taiwan, or Brazil. A Trimble controller integrated cellular modem or external cellular modem can be used to obtain GNSS corrections via an IP (Internet Protocol) connection.
15. Bluetooth type approvals are country specific.

Specifications subject to change without notice.

Contact your local Trimble Authorized Distribution Partner for more information

NORTH AMERICA
Trimble Inc.
10368 Westmoor Dr
Westminster CO 80021
USA

EUROPE
Trimble Germany GmbH
Am Prime Parc 11
65479 Raunheim
GERMANY

ASIA-PACIFIC
Trimble Navigation
Singapore PTE Limited
3 HarbourFront Place
#13-02 HarbourFront Tower Two
Singapore 099254
SINGAPORE

DRAWINGS

File Path E:\Workarea\Rupert Evans\2219-3284 ~ Courtyard Barns, Fring\Issued\2219-3284-SU00 ~ Courtyard Barns, Fring.dwg

BBS- BB- EGL- SU- 00 | -
Originator | Initials | Detail | Type | Number | Revision

STATION TABLE				
Station Name	Easting	Northing	Height (m)	Station Identifier
STNBBS1	573718.080	334836.039	28.201	Mag Nail & Washer
STNBBS2	573693.853	334800.498	27.458	Mag Nail & Washer
STNBBS3	573672.718	334762.011	26.778	Mag Nail & Washer
STNBBS4	573632.688	334731.836	27.205	Mag Nail & Washer

Control Stations have been forced to a Scale Factor of 1.

Scale 1:500 (0 10 20 30 40 50)

Notes:

AV	Air Valve	FH	Fire Hydrant	SP	Sign Post
BB	Bottom Bank	FP	Footpath	STAY	Stay
BH	Bore Hole	G	Gully Grate	SV	Sluice Valve
BL	Lit Bollard	GV	Gas Valve	TAC	Tactile Paving
BOL	Bollard	Hedge	Hedge	TB	Top Bank
BIN	Bin	IC	Inspection Cover	TBOX	Telephone Box
BS	Bus Stop	IL	Invert Level	TL	Traffic Light
Bushes	Bush	KO	Kerb Outlet	TOK	Top Of Kerb
BT	BT Box	LP	Lamp Post	TP	Telegraph Pole
CAB	Cabinet	MH	Manhole	TRK	Track
CHNL	Channel	MP	Marker Post	TS	Traffic Sign MH
CL	Centreline	NB	Name Board	VENT	Vent
CONC	Concrete	P/W	Partition Wall	W	Water Cover
COL	Column	PB	Post Box	WL	White Line
DB	Ditch Bottom	PM	Parking Meter	WO	Wash Out
DCHNL	Drainage Channel	PO	Post	YL	Yellow Line
Door	Door	RE	Rodding Eye		
EEB	Electric MH Cover	Ridge	Ridge Level		
EP	Electric Pole	RP	Reflector Post		
ER	Earth Rod	RS	Road Sign		
ET	EP+Transformer	SETTS	Granite Setts		
Feeder	Feeder Pillar	SF	Safety Fence		

FCB	Close Boarded
FCL	Chain Link
FHD	Hoarding
FHR	Heras Fence
FPL	Pallisade
FPR	Post & Rail
FPW	Post & Wire
RAIL	Railings

Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

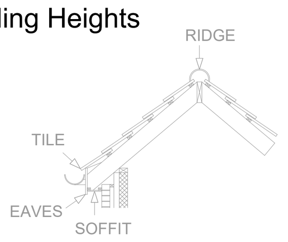
Features

Fences — FCB 1.6h
Walls — Wall 1.2h
Hedges — Hedge 1.3h — Average root line shown.
Overhead Line — OHL — Indicative position of cables.

Services

Foul Sewers — 0.225Ø FW MH
Storm Sewers — 0.375Ø SW MH
Pipe position and alignment is indicative only.

Building Heights



SURVEY CARRIED OUT USING TRIMBLE S6 TOTAL STATION & TRIMBLE R10 GPS.

THE SURVEY HAS BEEN ACCURATELY POSITIONED ON THE ORDNANCE SURVEY NATIONAL GRID SYSTEM USING GPS OBSERVATIONS TO THE OS ACTIVE NETWORK AND AND THE LATEST ORDNANCE SURVEY TRANSFORMATION (OSTN15/OSGM15)

LOCAL SCALE FACTOR HAS BEEN REMOVED TO TRANSFORM THE SURVEY TO A FLAT EARTH GRID (SCALE FACTOR 1.00000)

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REV	Date	Created By	Comments
-	02.03.22	BB	First Issue

Scale at A1	Project Number
1:500	2219-3284

Drawing Status

- [X] Existing Topographic Survey
- [ ] As Built Survey
- [ ] For Information

BBS BB SURVEYS LTD
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Norwich, Norfolk NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

Client
EVANS Rivers and Coastal

Project
Courtyard Barns
Fring

Title
Existing Ground Level Survey
Overview

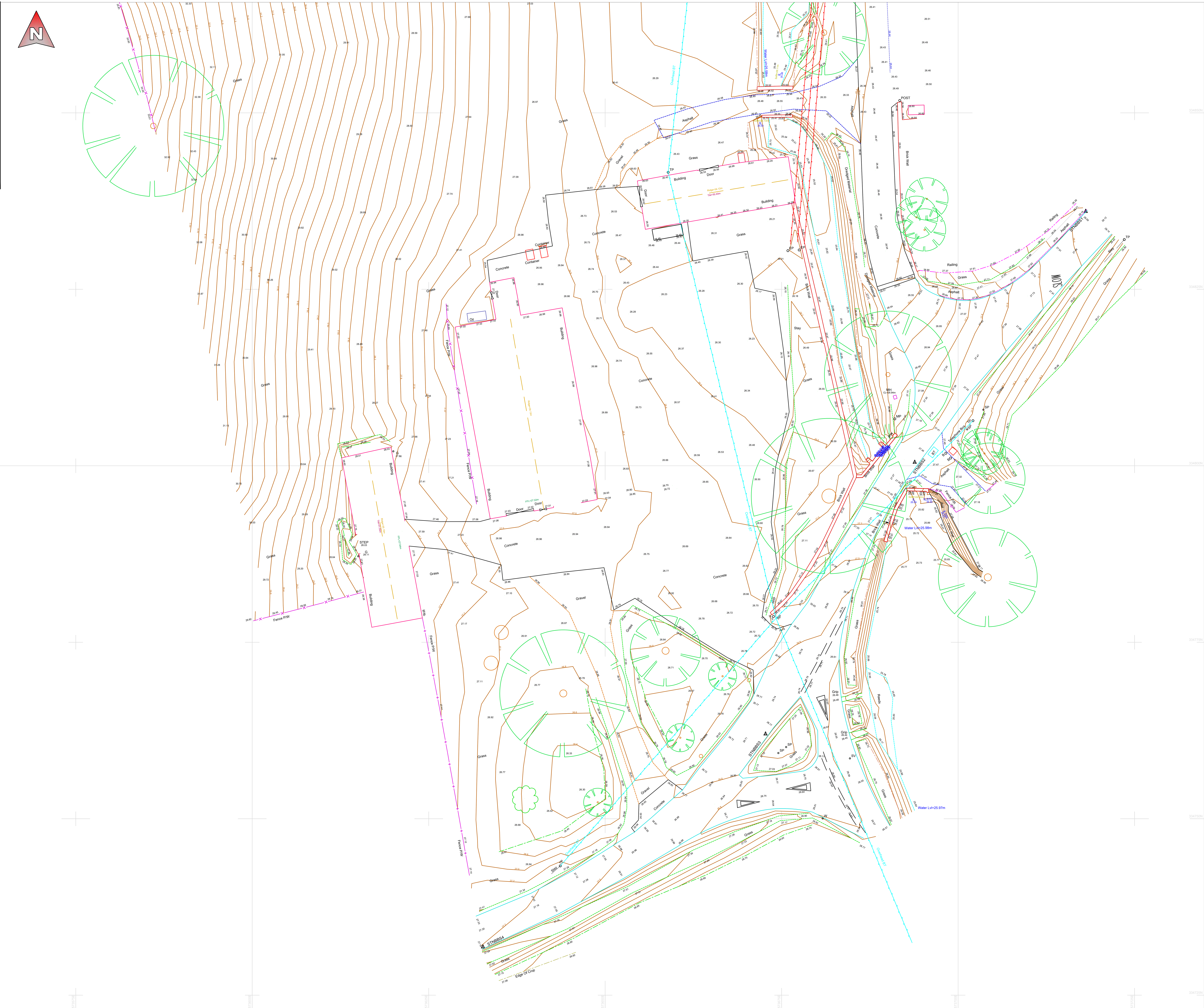
BBS- BB- EGL- SU- 00 | -
Originator | Initials | Detail | Type | Number | Revision

Sheet Size A1 841 x 594

Plot Date:03 March 2022 Plot Style: BB Surveys Std.ctb Saved By: Barry on 03 March 2022

Plot Scale Check 100mm

BBS- BB- EGL- SU- 01 | -
Originator | Initials | Detail | Type | Number | Revision



Scale 1:250 — 0, 5, 10, 15, 20, 25

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Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

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Fences — FCB 1.6h
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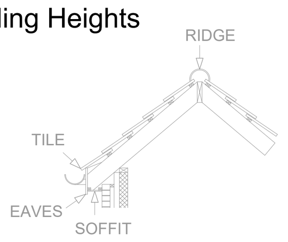

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REV	Date	Created By	Comments
-	02.03.22	BB	First Issue

Scale at A1	Project Number
1:250	2219-3284

Drawing Status
- X Existing Topographic Survey
- As Built Survey
- For Information

BBS BB SURVEYS LTD
1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

Client
EVANS Rivers and Coastal

Project
Courtyard Barns
Fring

Title
Existing Ground Level Survey
Sheet 1

BBS- BB- EGL- SU- 01 | -
Originator | Initials | Detail | Type | Number | Revision

Scale 1:250 (0, 5, 10, 15, 20, 25)

Notes:

AV	Air Valve	FH	Fire Hydrant	SP	Sign Post
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Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

Features

Fences — FCB 1.6h
Walls — Wall 1.2h
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Overhead Line — OHL — Indicative position of cables.

Services

Foul Sewers — FW MH
Storm Sewers — SW MH
Pipe position and alignment is indicative only.

Building Heights

RIDGE
TILE
EAVES
SOFFIT

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Scale at A1	Project Number
1:250	2219-3284

Drawing Status
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BBS BB SURVEYS LTD
1 Chestnut Place, Cringleford
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e: barry@bbsurveys.co.uk

Client
EVANS Rivers and Coastal

Project
Courtyard Barns
Fring

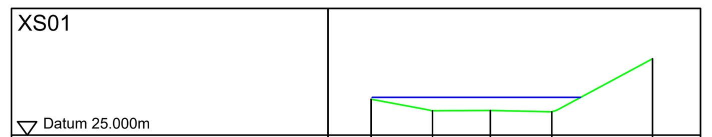
Title
Existing Ground Level Survey Sheet 2

BBS- BB- EGL- SU- 02 -
Originator | Initials | Detail | Type | Number | Revision

File Path:E:\Workarea\Rupert Evans\2219-3284 ~ Courtyard Barns, Fring\Issued\2219-3284-SU03 ~ Courtyard Barns, Fring.dwg

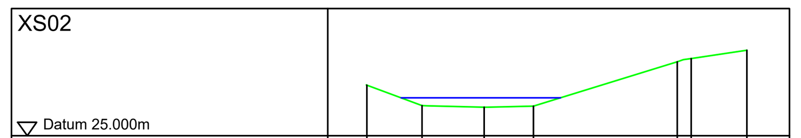
BBS- BB- EGL- SU- 03 | -
Originator | Initials | Detail | Type | Number | Revision

XS01



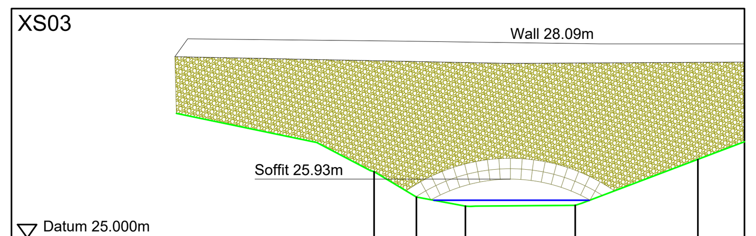
Chainage	0.18	1.15	2.06	3.04	4.63
Level : 220220 Courtyard Barns, Fring Model	25.566	25.385	25.390	25.369	26.207

XS02



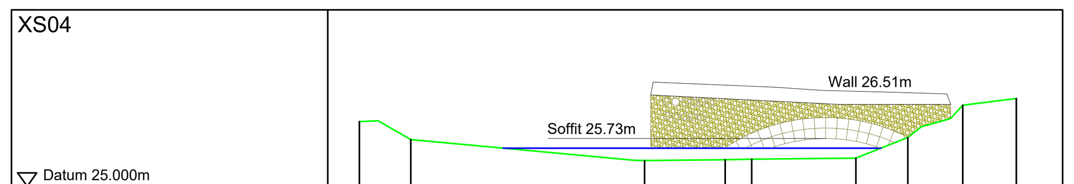
Chainage	0.12	0.99	1.97	2.75	5.02	5.25	6.12
Level : 220220 Courtyard Barns, Fring Model	25.796	25.473	25.446	25.463	26.161	26.212	26.345

XS03



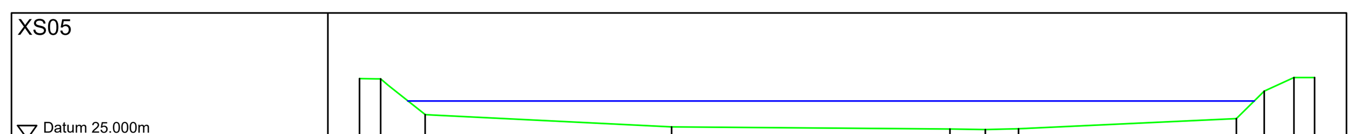
Chainage	0.23	0.90	1.67	3.41	5.35
Level : 220220 Courtyard Barns, Fring Model	26.048	25.645	25.503	25.516	26.245

XS04



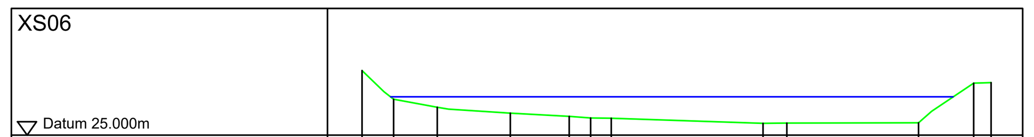
Chainage	0.00	0.81	4.51	5.78	6.20	7.85	8.67	9.54	10.38
Level : 220220 Courtyard Barns, Fring Model	26.021	25.738	25.408	25.422	25.428	25.448	25.770	26.281	26.386

XS05



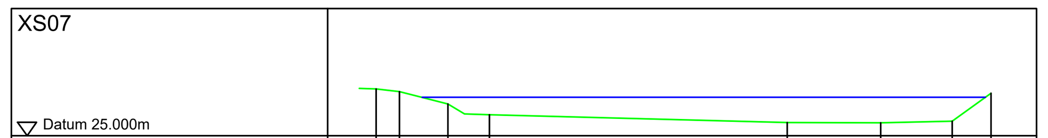
Chainage	0.00	0.33	1.04	4.93	9.33	9.89	10.41	13.85	14.29	14.76	15.09
Level : 220220 Courtyard Barns, Fring Model	25.955	25.952	25.386	25.193	25.158	25.149	25.160	25.321	25.759	25.975	25.974

XS06



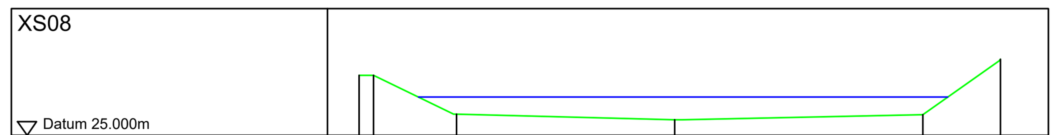
Chainage	0.05	0.55	1.24	2.39	3.32	3.66	3.99	6.39	6.77	8.85	9.72	9.99
Level : 220220 Courtyard Barns, Fring Model	26.017	25.567	25.439	25.347	25.294	25.272	25.266	25.184	25.190	25.193	25.820	25.828

XS07



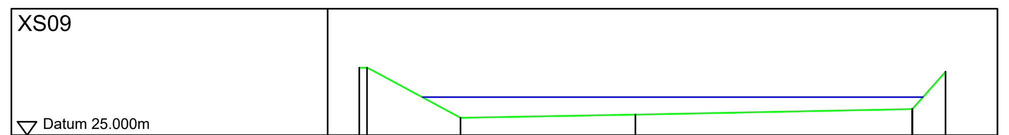
Chainage	0.27	0.64	1.40	2.06	6.76	8.24	9.37	9.99
Level : 220220 Courtyard Barns, Fring Model	25.735	25.692	25.499	25.329	25.205	25.203	25.227	25.668

XS08



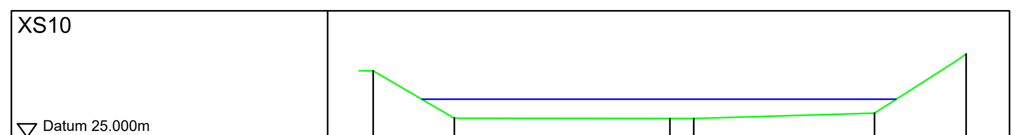
Chainage	0.00	0.23	1.54	4.99	8.91	10.14
Level : 220220 Courtyard Barns, Fring Model	25.946	25.947	25.334	25.242	25.324	26.200

XS09



Chainage	0.00	0.13	1.60	4.36	8.74	9.27
Level : 220220 Courtyard Barns, Fring Model	26.070	26.070	25.277	25.329	25.415	26.003

XS10



Chainage	0.22	1.50	4.91	5.29	8.15	9.59
Level : 220220 Courtyard Barns, Fring Model	26.052	25.305	25.297	25.297	25.384	26.320

Scale 1:100 — 0 2 4 6 8 10

Notes:

AV	Air Valve	FH	Fire Hydrant	SP	Sign Post
BB	Bottom Bank	FP	Footpath	STAY	Stay
BH	Bore Hole	G	Gully Grate	SV	Sluice Valve
BL	Lit Bollard	GV	Gas Valve	TAC	Tactile Paving
BOL	Bollard	Hedge	Hedge	TB	Top Bank
BIN	Bin	IC	Inspection Cover	TBOX	Telephone Box
BS	Bus Stop	IL	Invert Level	TL	Traffic Light
Bushes	Bush	KO	Kerb Outlet	TOK	Top Of Kerb
BT	BT Box	LP	Lamp Post	TP	Telegraph Pole
CAB	Cabinet	MH	Manhole	TRK	Track
CHNL	Channel	MP	Marker Post	TS	Traffic Sign MH
CL	Centreline	NB	Name Board	VENT	Vent
CONC	Concrete	P/W	Partition Wall	W	Water Cover
COL	Column	PB	Post Box	WL	White Line
DB	Ditch Bottom	PM	Parking Meter	WO	Wash Out
DCHNL	Drainage Channel	PO	Post	YL	Yellow Line
Door	Door	RE	Rodding Eye		
EEB	Electric MH Cover	Ridge	Ridge Level		
EP	Electric Pole	RP	Reflector Post		
ER	Earth Rod	RS	Road Sign		
ET	EP+Transformer	SETTS	Granite Setts		
Feeder	Feeder Pillar	SF	Safety Fence		

FCB	Close Boarded
FCL	Chain Link
FHD	Hoarding
FHR	Heras Fence
FPL	Pallisade
FPR	Post & Rail
FPW	Post & Wire
RAIL	Railings

Control Station
Column
X.XX Floor to Ceiling Height
X.XX F/C Floor to False Ceiling Height

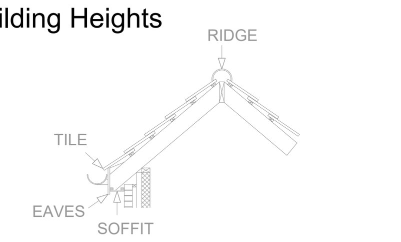
Features

Fences — FCB 1.6h
Walls — Wall 1.2h
Hedges — Hedge 1.3h — Average root line shown.
Overhead Line — OHL — Indicative position of cables.

Services

Foul Sewers — 0.225Ø FW MH
Storm Sewers — 0.375Ø SW MH
Pipe position and alignment is indicative only.

Building Heights



SURVEY CARRIED OUT USING TRIMBLE S6 TOTAL STATION & TRIMBLE R10 GPS.

THE SURVEY HAS BEEN ACCURATELY POSITIONED ON THE ORDNANCE SURVEY NATIONAL GRID SYSTEM USING GPS OBSERVATIONS TO THE OS ACTIVE NETWORK AND AND THE LATEST ORDNANCE SURVEY TRANSFORMATION (OSTN15/OSGM15)

LOCAL SCALE FACTOR HAS BEEN REMOVED TO TRANSFORM THE SURVEY TO A FLAT EARTH GRID (SCALE FACTOR 1.00000)

ALL LEVELS RELATE TO ORDNANCE SURVEY DATUM (NEWLYN). VERTICAL CONTROL HAS BEEN ESTABLISHED USING GPS OBSERVATIONS TO THE OS ACTIVE NETWORK AND AND THE LATEST ORDNANCE SURVEY TRANSFORMATION (OSTN15/OSGM15)

ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE STATED.

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ANY ERRORS SHOULD BE NOTIFIED TO BB SURVEYS LTD.

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DRAINAGE RUNS BETWEEN INSPECTION COVERS HAVE NOT BEEN INVESTIGATED. ANY SHOWN ARE ESTIMATED AND NOT CONFIRMED. ALL DRAINAGE RUNS SHOULD BE PROVED BY DYE TRACING AND IF NECESSARY BY RADIO DETECTION METHODS PRIOR TO ANY DESIGN WORK. ALL PIPE SIZES AND CONNECTIONS SHOULD ALSO BE CONFIRMED WITH YOUR LOCAL DRAINAGE AUTHORITY PRIOR TO ANY DESIGN WORK.

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REV	Date	Created By	Comments
-	02.03.22	BB	First Issue

Scale at A1	Project Number
1:100	2219-3284

Drawing Status

- X Existing Topographic Survey
- As Built Survey
- For Information

BBS
BB SURVEYS LTD
1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

Client

EVANS Rivers and Coastal

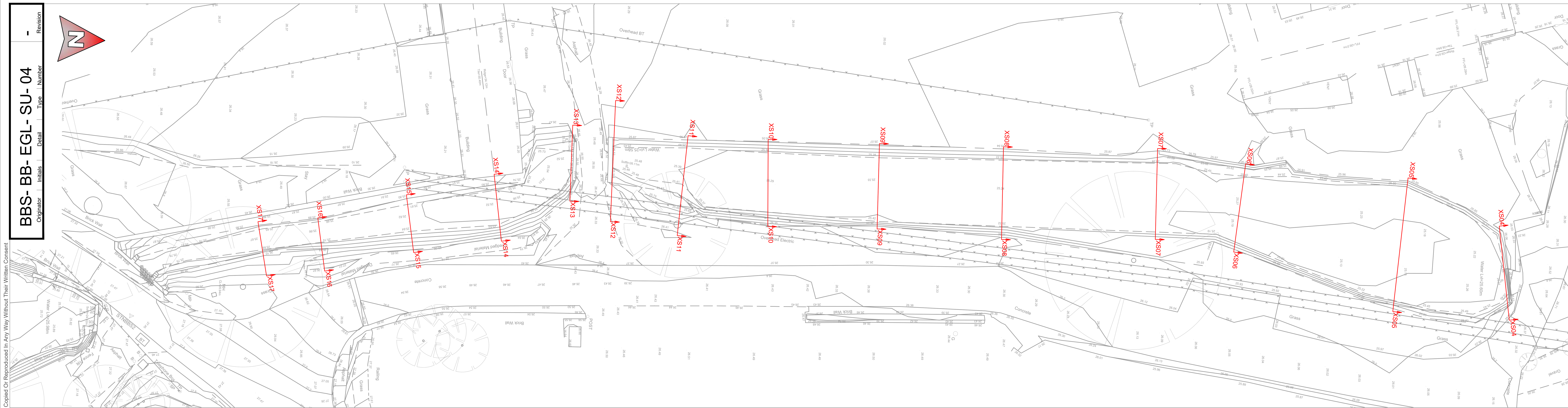
Project

Courtyard Barns
Fring

Title

Sections

BBS- BB- EGL- SU- 03 | -
Originator | Initials | Detail | Type | Number | Revision



Scale 1:100

0 2 4 6 8 10

Notes:

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BL	Lit Bollard	GV	Gas Valve	TAC	Tactile Paving
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Bushes	Bush	KO	Kerb Outlet	TOK	Top Of Kerb
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CAB	Cabinet	MH	Manhole	TRK	Track
CHNL	Channel	MP	Marker Post	TS	Traffic Sign MH
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FCL	Chain Link
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FPL	Palisade
FPR	Post & Rail
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Control Station
Column
Floor to Ceiling Height
Floor to False Ceiling Height

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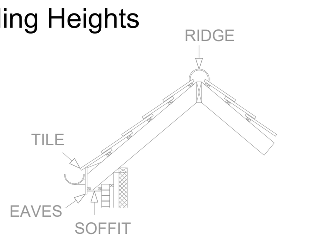

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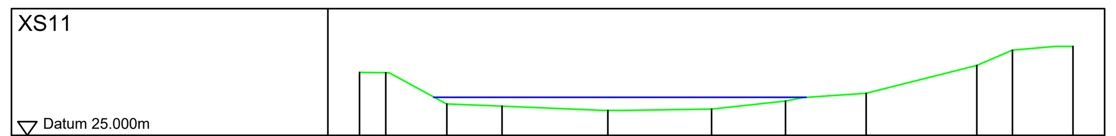
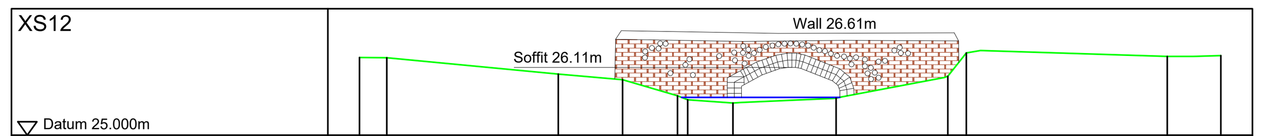
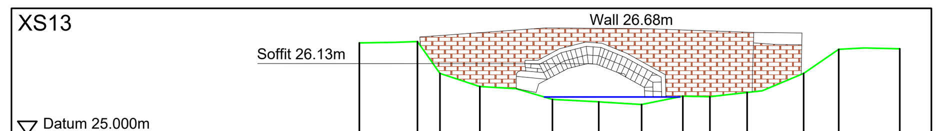


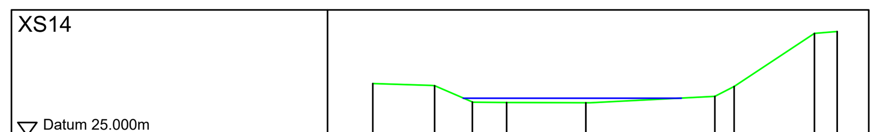
Chainage	0.00	0.41	1.38	2.25	3.92	5.56	6.73	8.00	9.75	10.31	11.27
Level : 220220 Courtyard Barns, Fring Model	25.993	25.988	25.494	25.460	25.392	25.413	25.541	25.664	26.102	26.344	26.402



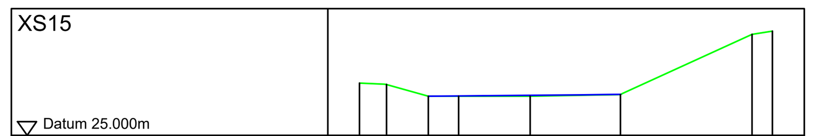
Chainage	0.00	0.43	3.14	4.16	5.02	5.19	5.90	7.53	9.30	9.59	12.76	13.61
Level : 220220 Courtyard Barns, Fring Model	26.230	26.224	25.968	25.879	25.626	25.560	25.512	25.584	25.932	26.302	26.245	26.259



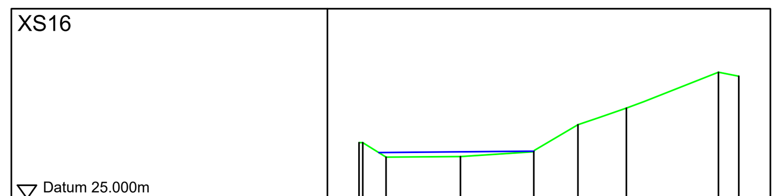
Chainage	0.00	0.92	1.27	1.90	3.05	3.78	4.46	5.11	5.54	6.13	7.02	7.57	8.54
Level : 220220 Courtyard Barns, Fring Model	26.452	26.474	25.969	25.763	25.562	25.522	25.478	25.610	25.604	25.669	25.970	26.351	26.359



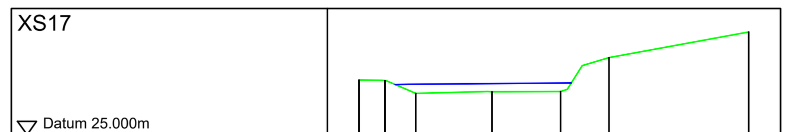
Chainage	0.22	1.19	1.79	2.33	3.58	5.62	5.93	7.20	7.56
Level : 220220 Courtyard Barns, Fring Model	25.832	25.797	25.537	25.531	25.524	25.628	25.782	26.627	26.654



Chainage	0.00	0.43	1.09	1.57	2.69	4.12	6.20	6.52
Level : 220220 Courtyard Barns, Fring Model	25.824	25.802	25.615	25.616	25.618	25.642	26.595	26.646



Chainage	0.00	0.06	0.43	1.61	2.76	3.46	4.23	5.68	6.01
Level : 220220 Courtyard Barns, Fring Model	25.885	25.881	25.655	25.665	25.739	26.168	26.431	26.997	26.933



Chainage	0.00	0.41	0.90	2.10	3.19	3.95	6.17
Level : 220220 Courtyard Barns, Fring Model	25.867	25.857	25.654	25.682	25.684	26.223	26.628

REV	Date	Created By	Comments
-	02.03.22	BB	First Issue

Scale at A1	Project Number
1:100	2219-3284

Drawing Status

X Existing Topographic Survey
As Built Survey
For Information

BBS BB SURVEYS LTD

1 Chestnut Place, Cringleford
Norwich, Norfolk NR4 7BD
t: 01603 507917
m: 07786 388175
e: barry@bbsurveys.co.uk

Client

EVANS Rivers and Coastal

Project

Courtyard Barns
Fring

Title

Sections

BBS- BB- EGL- SU- 04 | -

Originator | Initials | Detail | Type | Number | Revision

Sheet Size A1 841 x 594

BBS- BB- EGL- SU- 04 -
Originator Initials Detail Type Number Revision

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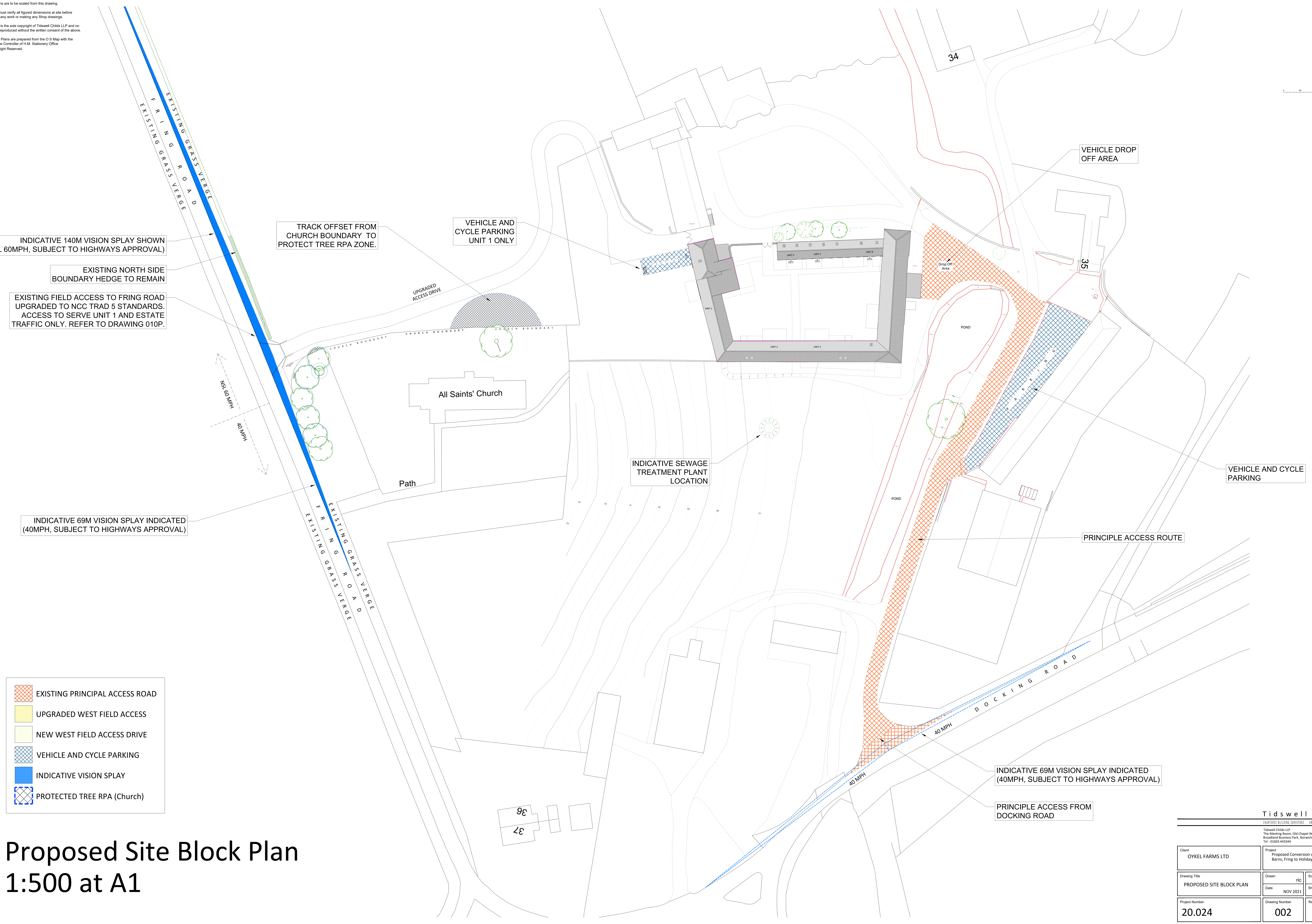
Plot Date:03 March 2022 Plot Style: BB Surveys Std.ctb Saved By: Barry on 03 March 2022

Plot Scale Check

100mm



Proposed Site Block Plan
1:500 at A1

Tidswell Childs
CHARTERED BUILDING SURVEYORS . ARCHITECTURAL CONSULTANCY

Tidswell Childs LLP
The Meeting Room, Old Chapel Way
Broadland Business Park, Norwich. NR7 0WG
Tel : 01603 443344

Client	OYKEL FARMS LTD
Project	Proposed Conversion of Church Farm Barns, Fring to Holiday Accommodation.
Drawing Title	PROPOSED SITE BLOCK PLAN
Drawn	ric
Date	NOV 2021
Scale	1:500 @ A1
Sheet	A1
Project Number	20.024
Drawing Number	002
Revision	P
Revision Date	22.11.21

Tidswell Childs

CHARTERED BUILDING SURVEYORS . ARCHITECTURAL CONSULTANCY

Tidswell Childs LLP
Tel : 01603 443344

Client: OYKEL FARMS LTD	Project: Proposed Conversion of Church Farm Barns, Fring to Holiday Accommodation.
Drawing Title: PROPOSED FLOOR PLANS	Drawn: ric; Scale: 1:100 @ A1; Date: NOV 2021; Sheet: A1
Project Number: 20.024	Drawing Number: 003; Revision: P; Revision Date: 24.11.21

EVANS
Rivers and Coastal