Figure 3-3: Baseline 100-year plus 35% Climate Change flood levels

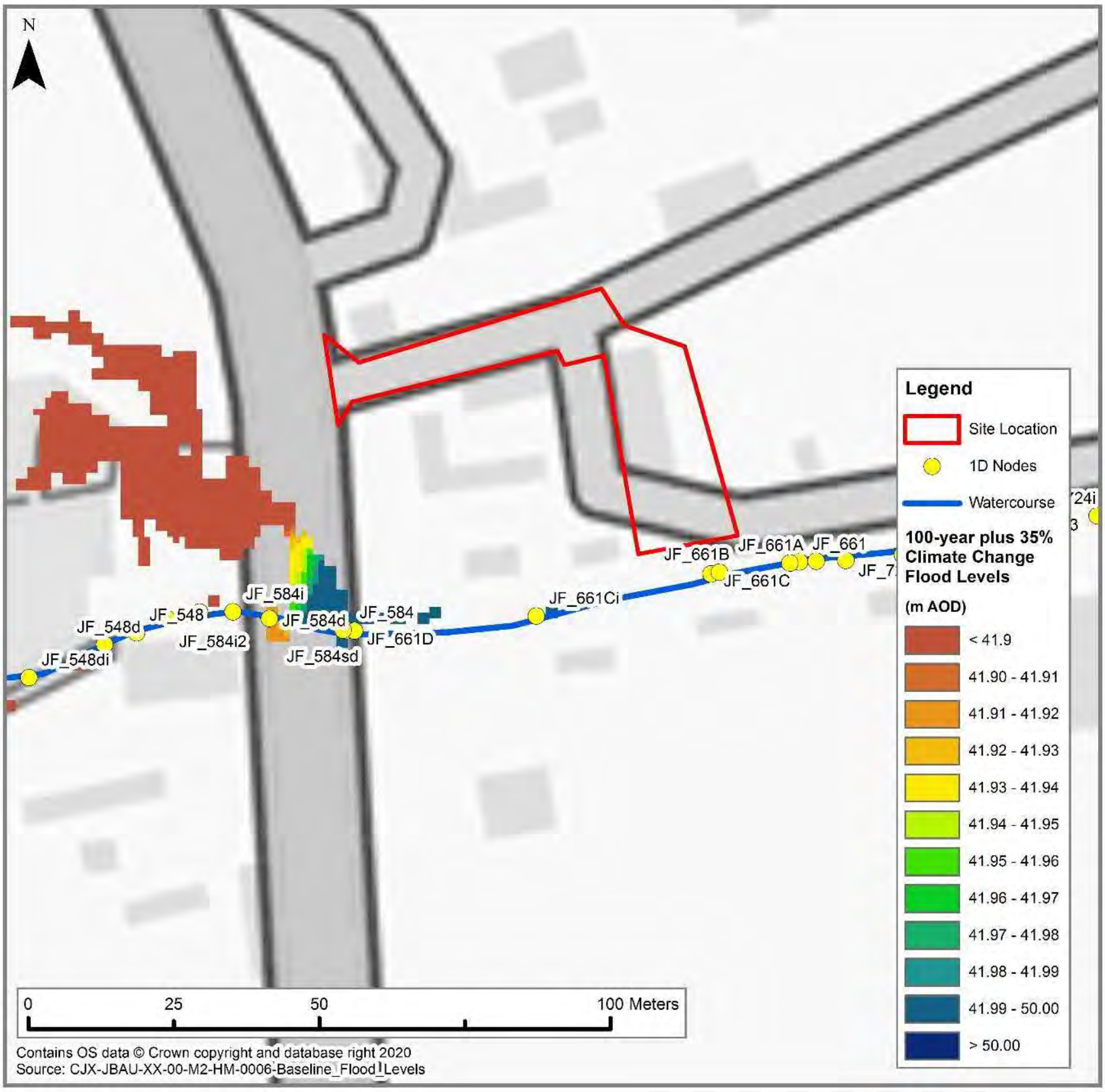


Figure 3-3 shows:

- No flooding occurs within the site boundary, this is due to the steep terrain surrounding the proposed development.
- Flood levels up to 50.00m AOD are seen downstream of the site boundary.

1D model results adjacent to the site are summarised in

Table 3-3: 1D model results

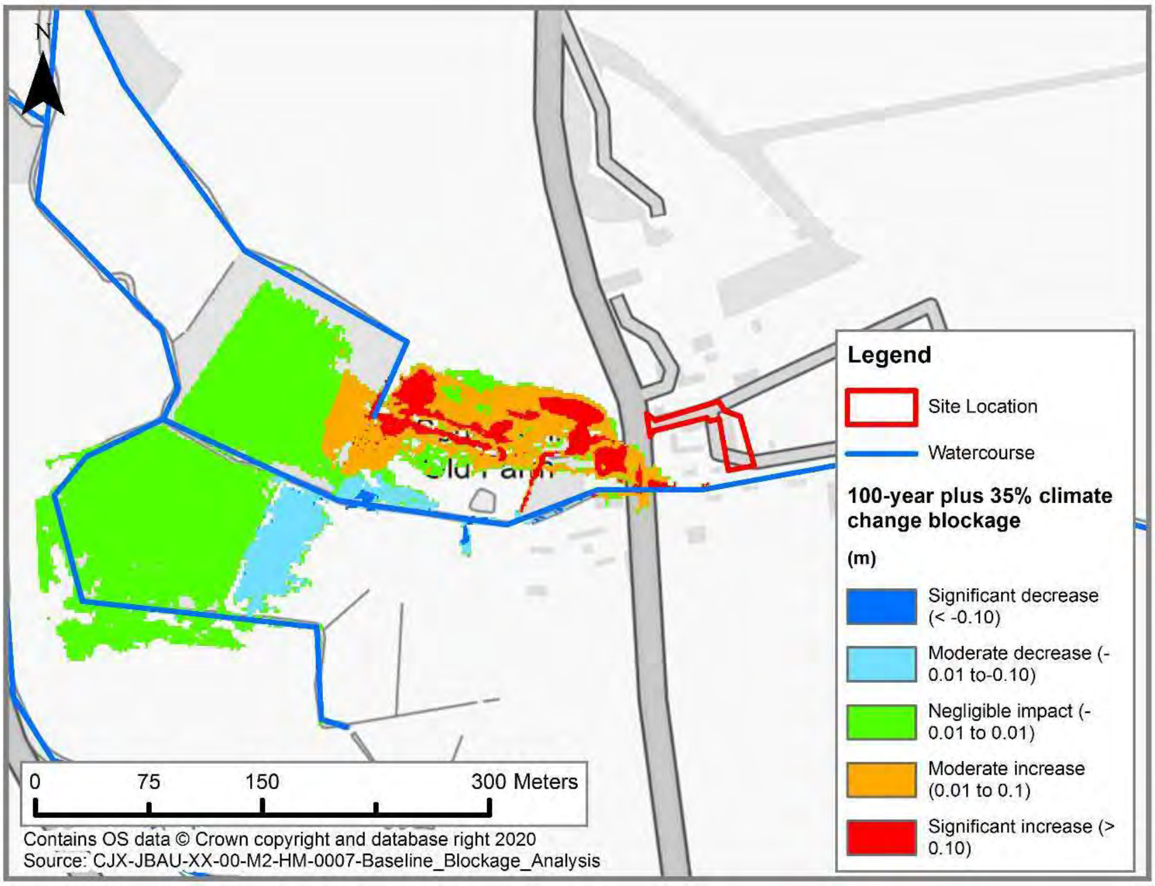
Flood Modeller 1D Nodes	Peak Water level (m AOD)					
	JF_661	JF_661A	JF_661B	JF_661C	JF_661Ci	JF_661D
20-year	42.8	42.7	42.4	42.4	41.8	41.3

100-year	42.9	42.9	42.5	42.5	41.9	41.7
100-year 35% cc	43.1	43.1	42.6	42.6	42.2	42.1
100-year 65%cc	43.2	43.2	42.7	42.7	42.3	42.2
1,000-year	43.3	43.3	42.8	42.8	42.42	42.2

3.4 Blockage Risk Analysis

The impact of a 90% blockage at the B184 culvert was modelled during the 100-year plus 35% climate change baseline scenario. Results indicate an increase in flood depths downstream of the site boundary (when compared to the 100-year plus 35% climate change baseline scenario), as shown in Figure 3-4.

Figure 3-4: Baseline Blockage Analysis (100-year plus 35% climate change)



Due to the nature of the surrounding environment (i.e. branches hanging over the channel), a 90% blockage was put on the culvert running underneath the B184. The results from this analysis show that flood water would bypass the culvert headwall without causing flooding on site. To the east of the B184, a moderate to significant increase in fluvial depths is seen during the blockage scenario.

3.5 Hazard-to-people

The baseline 100-year plus 35% climate change hazard-to-people is represented in Figure 3-5 respectively.

Figure 3-5: Baseline Hazard-to-people (100-year plus 35% climate change)

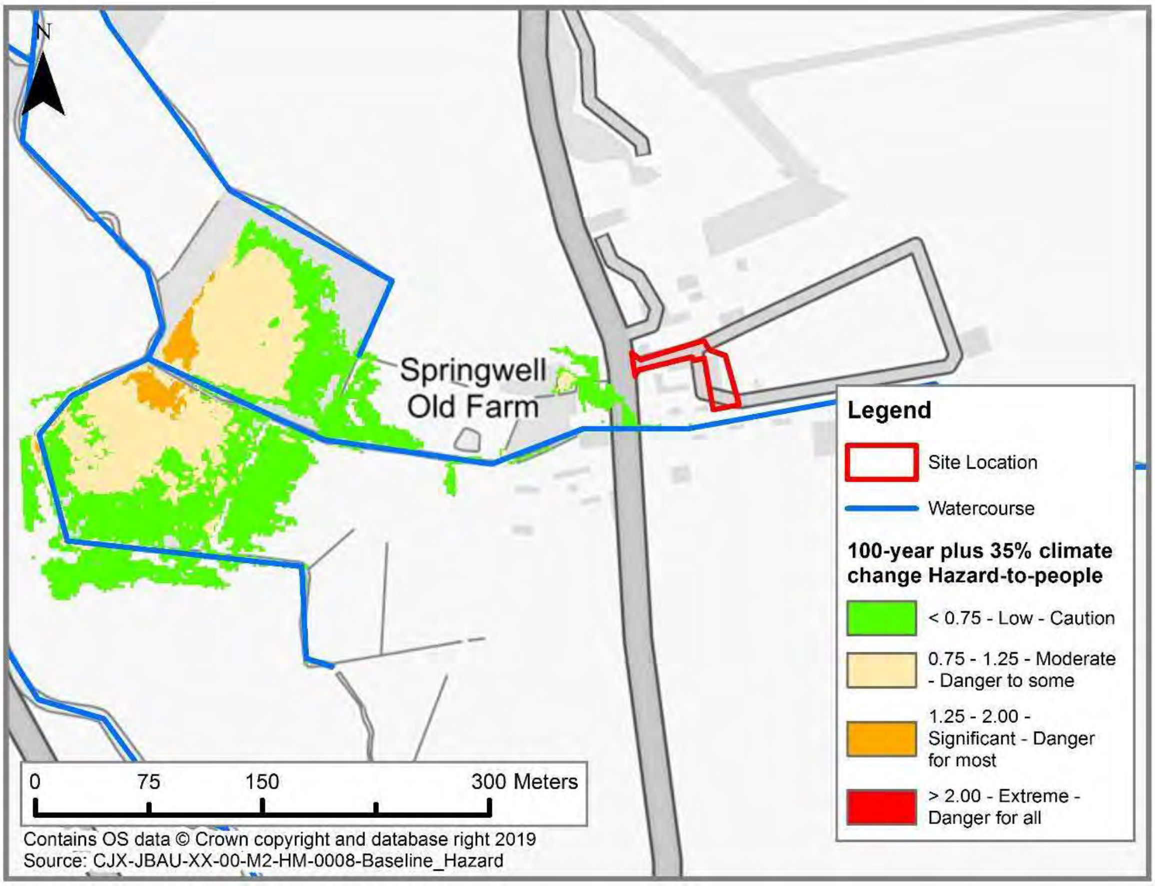


Figure 3-5 shows:

- There is no fluvial flood risk within the site boundary.
- The B184 has a 'Low' hazard to people rating to the west of the development site during the 100-year plus 35% climate change event.
- Safe access and egress to/from the site is available at all time during the 100-year plus 35% climate change event.

3.6 Sensitivity Analysis

The model's sensitivity to changes in flow, roughness and downstream boundary parameters was checked (see Appendix E).

Appendix E shows that, at the proposed development site, the model results are sensitive in the channel to changes in flow values, roughness and downstream boundary conditions whereas the site is insensitive to these changes.

4 Conclusions

JBA Consulting was contacted on 05/07/2019 by Jack Dudmish from Stomor, on behalf of Caroline Richardson, to undertake a hydraulic modelling study in relation to a proposed residential dwelling at Joseph Farm.

The site is located within the vicinity of an unnamed watercourse which is a tributary of the River Cam. To represent the watercourse, a 1D – 2D detailed hydraulic model was built using version 4.3.6458.29637 of FLOOD MODELLER and version 2018-03-AE-ISP-W64 of TUFLOW. LiDAR data was used to provide ground levels throughout the floodplain.

The baseline model results indicate that:

- The site is located outside of the 20-year, 100-year, 100-year plus 35% climate change, 100-year plus 65% climate change and 1,000-year fluvial flood extent.
- No flooding occurs within the site boundary, this is due to the steep terrain surrounding the proposed development.
- Flood depths along the BB184 will not exceed 0.2m during the 100-year plus 35% climate change fluvial flood event. This will not affect the site entrance.
- The B184 has a 'Low' hazard to people rating to the west of the development site during the 100-year plus 35% climate change event.
- Safe access and egress to/from the proposed site is available at all time during the 100-year plus 35% climate change event.

A blockage analysis was carried out at the closest structure to the proposed site at Joseph Farm. Due to the nature of the surrounding environment (i.e. branches hanging over the channel), a 90% blockage was put on the culvert running underneath the B184. The results from this analysis show that flood water would bypass the culvert headwall without causing flooding on site.

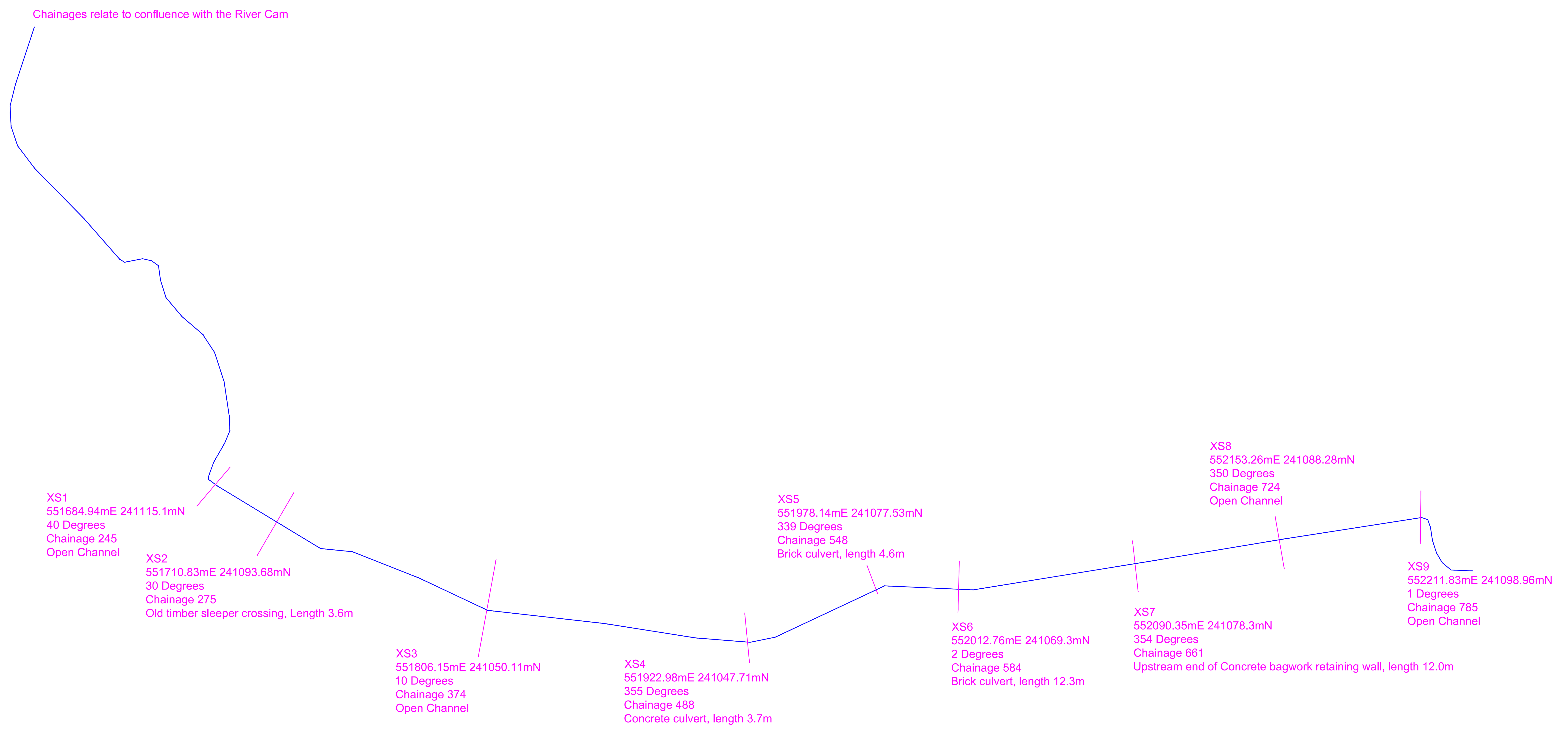
The sensitivity of the model results for changes in roughness, flow values and downstream boundary conditions were also tested. Results indicate that the model is sensitive to change in the channel whereas the site is deemed insensitive.

4.1 Recommendations

It is recommended that the results from this modelling study are taken into consideration in the Flood Risk Assessment when confirming safe access and egress routes and recommending minimum Finished Floor Levels for the proposal.

Appendices

A Channel Survey



N

Notes

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Whilst every effort has been made to identify all above ground details, it should be noted that some items may have been obscured at time of survey.

Below ground drainage information as been visually inspected from the surface and should therefore be treated as approximate only.

Where this survey has been carried out for the purpose of enabling trackside drainage design. The position of any running rail has been surveyed in line with a general topographic survey and should not be used for the purpose of track design.

All dimensions to be checked on site prior to design and construction.

Legend

AIR VALVE	AV	WATER TAP	TAP
BOLLARD	BD	TEMPORARY BENCH MARK	TBM
BORE HOLE	BHL	TELEPHONE CALL BOX	TCB
BUS STOP	BS	TELEPHONE POST	TEL
BT INSPECTION COVER	BT	THRESHOLD LEVEL	THL
BT BOX	BTB	TRAFFIC LIGHT	TL
CABLE TV INSPECTION COVER	CTV	TOP OF WALL	TOW
COVER LEVEL	CL	TELEGRAPH POLE	TP
DOWN PIPE	DP	UNABLE TO LIFT	UTL
DROPPED KERB	DK	VENT PIPE	VP
ELECTRICITY CONTROL BOX	ECB	RAIL WELD	WE
EAVES HEIGHT	EH	WATER METER	WM
ELECTRICITY MANHOLE	EM	WASHOUT	WO
ELECTRICITY POLE	EP		
EARTH ROD	ER		
FINISHED FLOOR LEVEL	FFL		
FIRE HYDRANT	FH	SURVEY STATION	GCS1
FOUL WATER	FW		
GULLY	GY		
GATE POST	GP	BUSHES	BH
GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES	Height Species (Spread to scale)
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x x
STUMP	SP	FENCE	/ /
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH OH
SIGNAL POST	SIG	FOUL WATER	FW FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL TEL
SIGN POST	SN	WATER MAIN	WM WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

Control Table

Station	Description	Eastings	Northings	Height

Grid and Datum

Grid: ***OS National Grid*** **Datum:** ***Ordnance Datum Newlyn***
Survey related to Ordnance Survey National Grid (OSGB36) via GPS and the OS Active Network.
A National Grid (OSGB36) coordinate has been established on site via Transformation OSTN15 and Geoid Model OSGM15, a further OS coordinate was used to orientate the survey to Ordnance Grid.
No scale factor has been applied to the survey

Title:

WATERCOURSE SURVEY AT Walden Road, Saffron Walden (Key Plan)

Client:

JBA CONSULTING
The Library
St. Philip's Courtyard
Coleshill
Warwickshire B46 3AD

Grantham Coates Surveys Ltd

Land - Engineering - Building Surveyors

2 Arden Court, Arden Road, Alcester
Warwickshire, B49 6HN

Tel: 01789 764420

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Web Site: www.gcsurveys.co.uk

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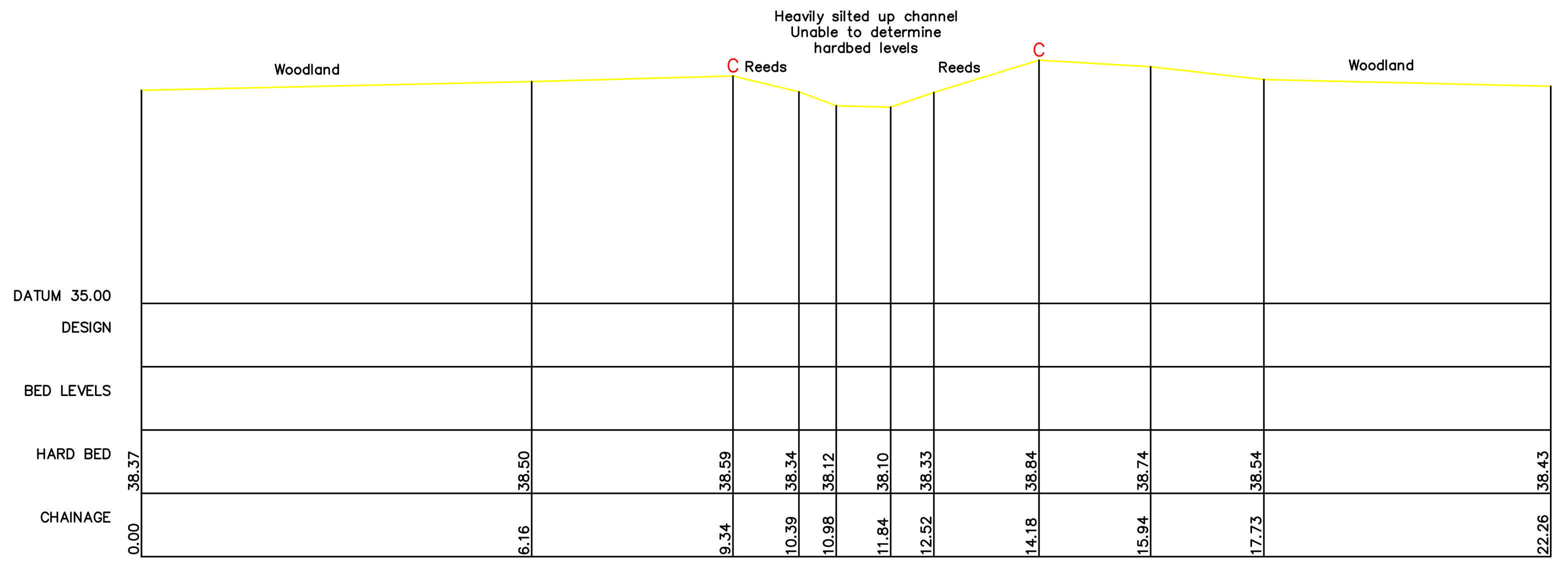

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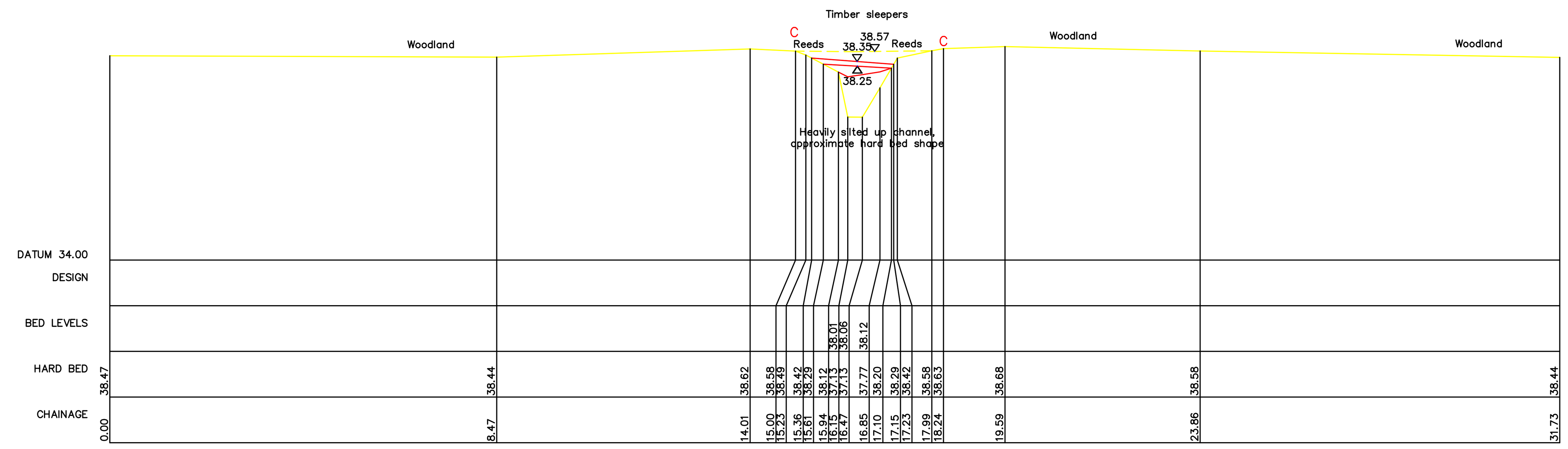
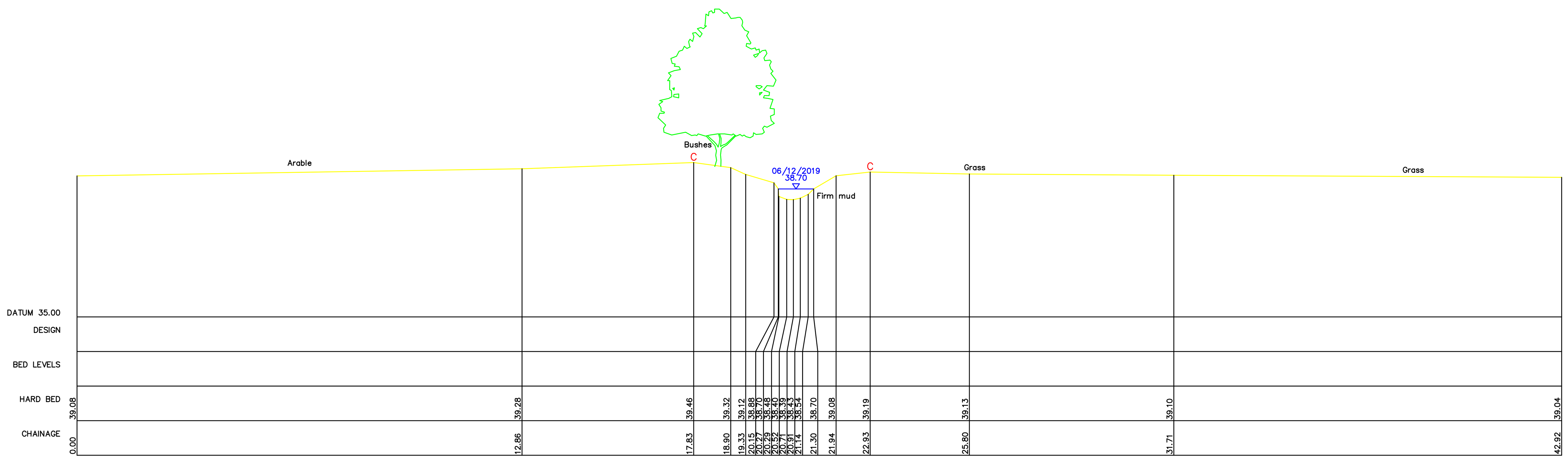
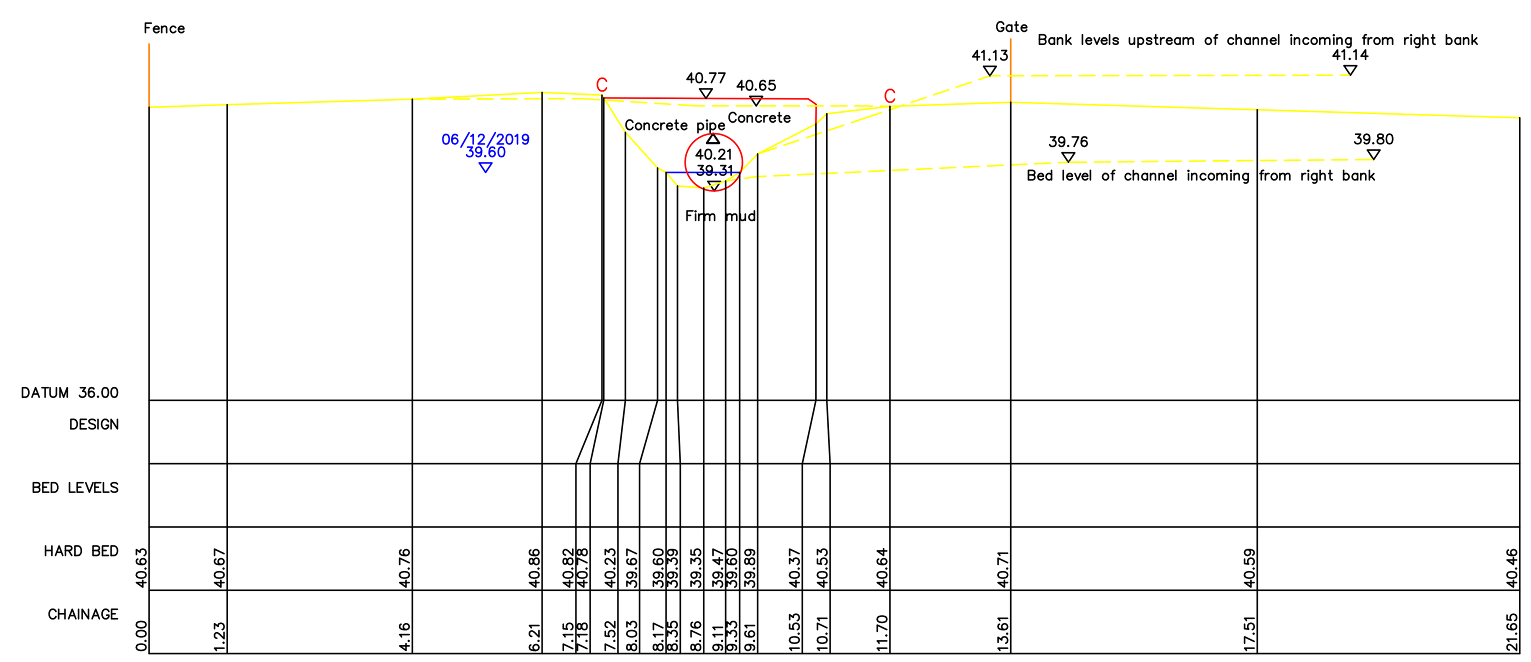
Chainage 244.5
Open Channel



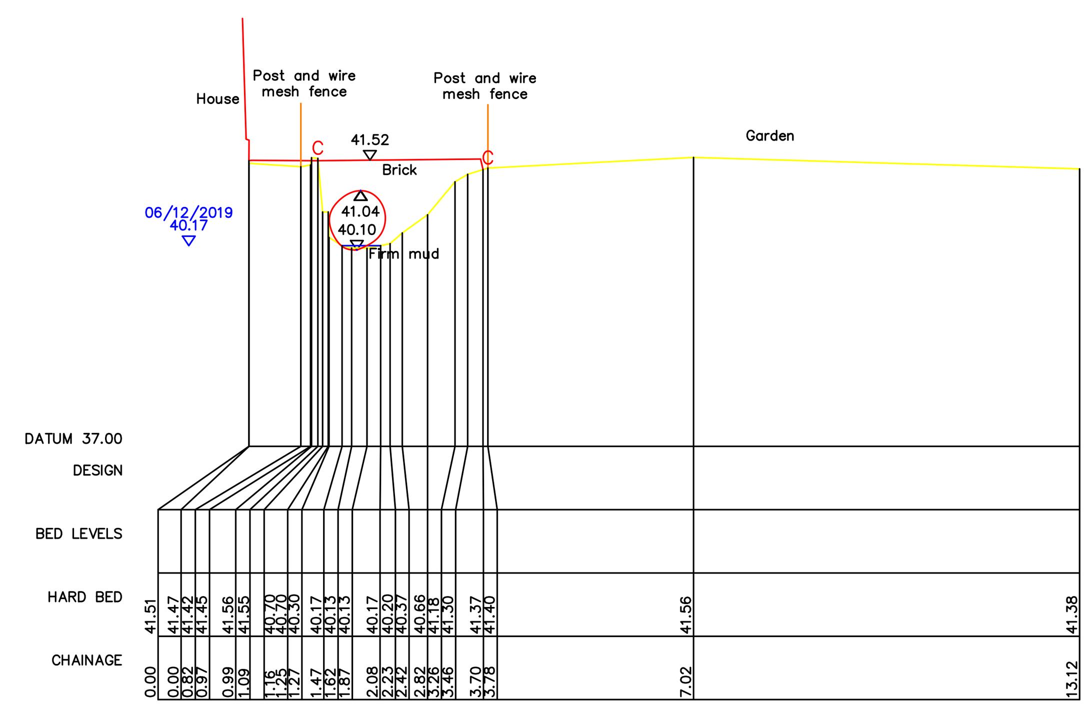
XS2
551710.83mE 241093.68mN Brg 30
Chainage 275.5
Old timber sleeper crossing, Length 3.6m



XS3
551806.15mE 241050.11mN Brg 10
Chainage 374.5
Open Channel



XS4
551922.98mE 241047.71mN Brg 355
Chainage 487.6
Concrete culvert, length 3.7m



XS5
551978.14mE 241077.53mN Brg 339
Chainage 547.8
Brick culvert, length 4.6m

Notes

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GAS VALVE	GV		
INSULATED BLOCK JOINT	IBJ		
INSPECTION COVER	IC	HEDGES	
INVERT LEVEL	IL		
KERB OUTLET	KO		
LAMPPOST	LP	TREES (Height, Species, Spread to scale)	
LITTER BIN	LB		
MARKER POST	MK		
MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	
STUMP	SP	FENCE	
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
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SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
SIGNALS AND TELECOMS CABLE	STC	STORM WATER	SW
SIGNALS AND TELECOMS POST	STP	U/G TELEPHONE	TEL
SIGN POST	SN	WATER MAIN	WM
STOP TAP	ST		
STOP VALVE	SV		
STAY	SY		
STORM WATER	SW		

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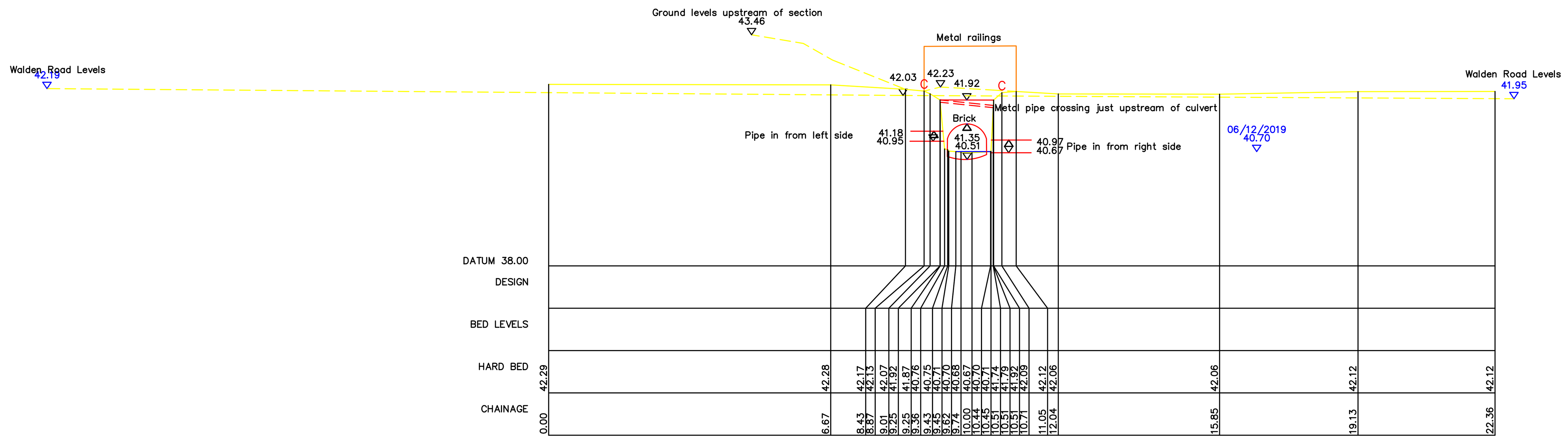
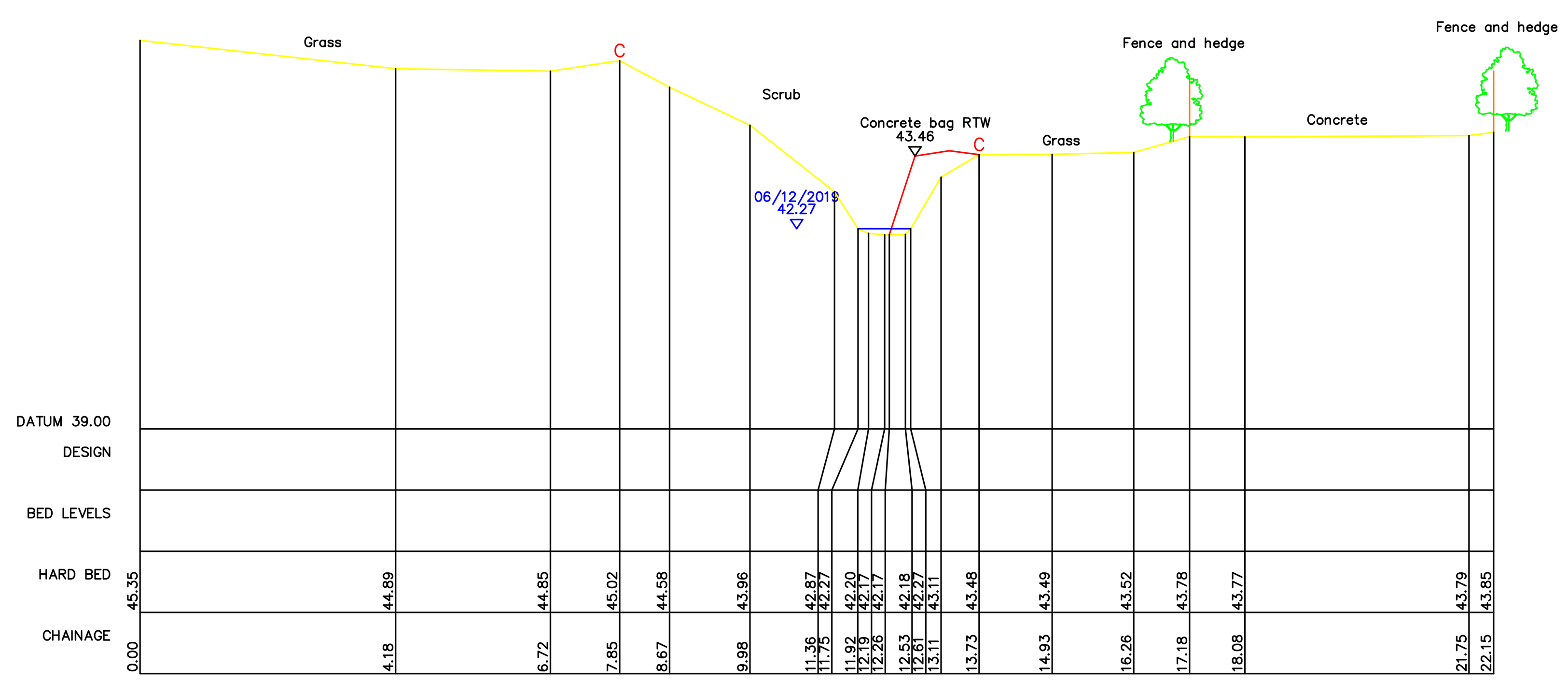
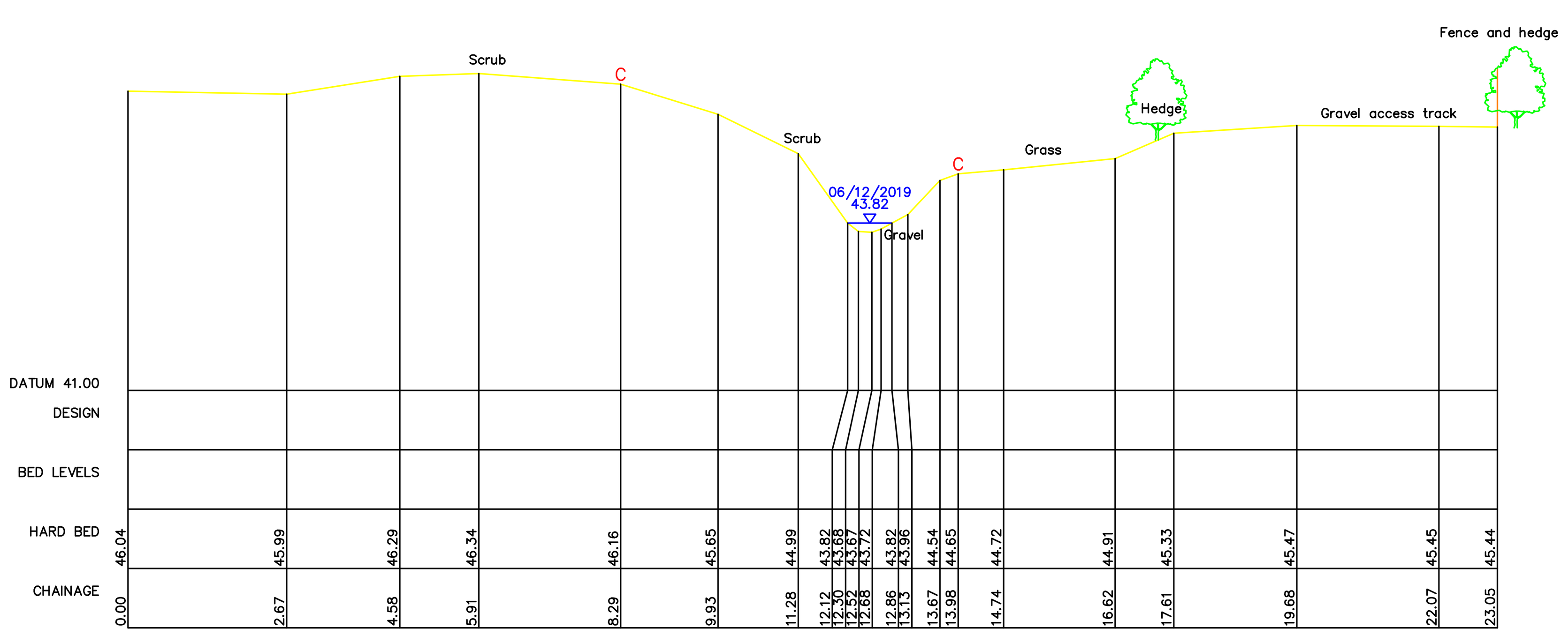


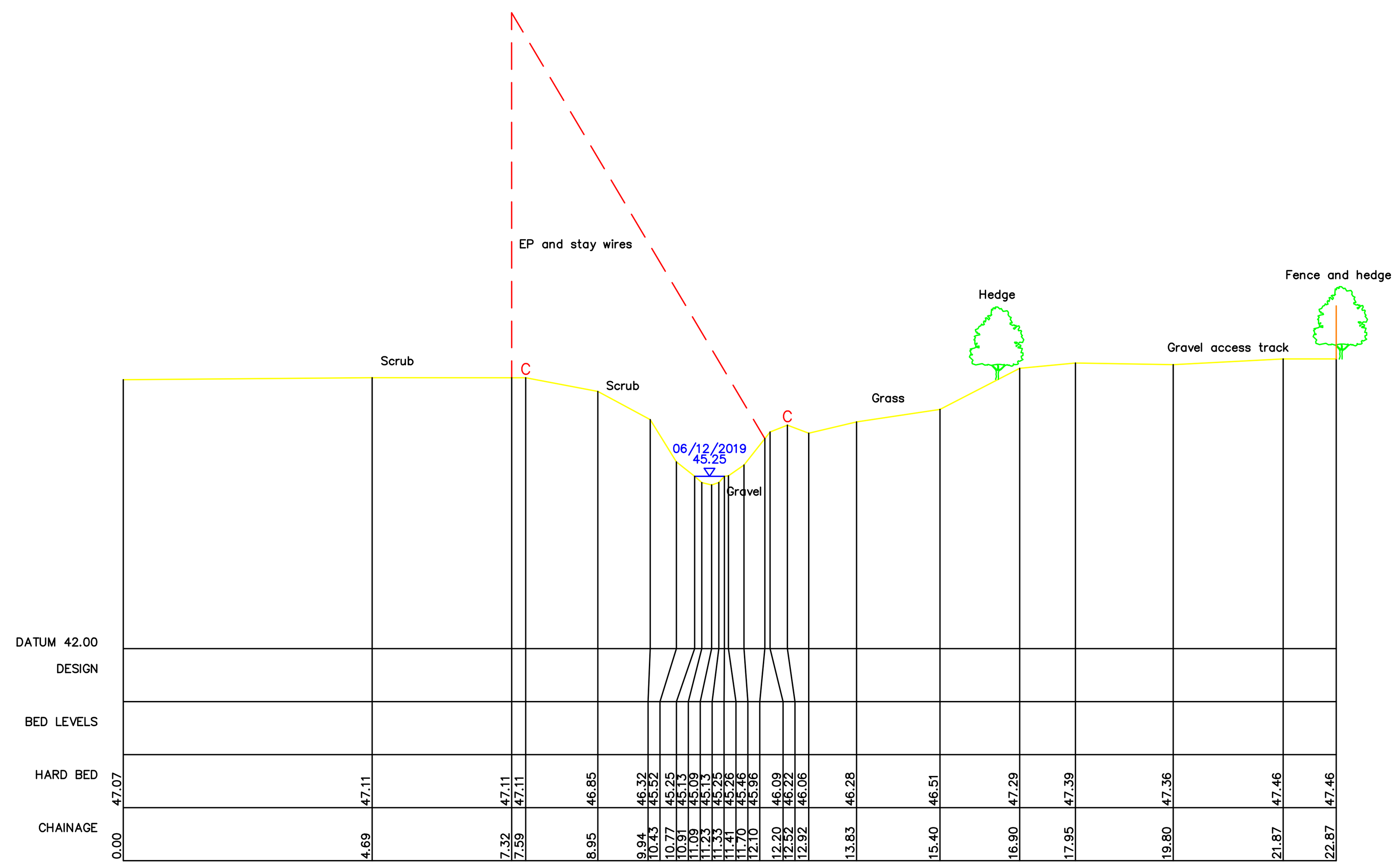
XS6
552012.76mE 241069.3mN Brg 2
Chainage 583.7
Brick culvert, length 12.3m



XS7
552090.35mE 241078.3mN Brg 354
Chainage 660.6
Upstream end of Concrete bagwork retaining wall, length 12.0m



XS8
552153.26mE 241088.28mN Brg 350
Chainage 723.6
Open Channel



XS9
552211.83mE 241098.96mN Brg 1
Chainage 785.2
Open Channel

N

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FOUL WATER	FW		
GULLY	GY	BUSHES	BH
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INSPECTION COVER	IC		
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KERB OUTLET	KO		
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MILE POST	MP		
POST	PO		
RODDING EYE	RE	GATE	
RIDGE HEIGHT	RH		
ROAD NAMEPLATE	RN		
ROAD SIGN	RS	SECURITY FENCE	x
STUMP	SP	FENCE	/
SOFFIT LEVEL	SF	OVERHEAD CABLES	OH
SIGNAL POST	SIG	FOUL WATER	FW
RAIL SLEEPER LEVEL	SLP	GAS MAIN	GM
SIGNALS AND TELECOMS BOX	STB	U/G POWER LINE	PL
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SIGN POST	SN	WATER MAIN	WM
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STORM WATER	SW		

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GCS-JBA-0444-1	A1	3 of 3

B Topographic Survey

SURVEY STATION CO-ORDINATE LIST

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S1	552120.066	241167.747	46.267	HILTI
S2	552182.107	241194.900	50.464	HILTI
S3	552130.545	241170.370	46.816	HILTI
S4	552069.393	241137.196	43.337	PEG
S5	552199.581	241201.950	52.065	HILTI
S6	552229.190	241122.460	48.212	PEG
S7	552087.333	241098.936	43.751	HILTI
S8	552074.376	241089.395	43.125	PEG
S9	552013.270	241082.057	42.038	HILTI
S10	552010.058	241116.315	42.120	HILTI
S11	552002.996	241065.278	42.079	HILTI
S12	552079.083	241093.401	43.290	PEG
S13	552108.080	241102.893	44.511	HILTI
S14	552231.254	241124.295	48.253	PEG
S15	552198.269	241204.515	52.105	PEG
S16	552185.994	241194.967	50.820	PEG
S17	552156.637	241182.836	48.577	PEG
S18	552187.218	241162.941	48.189	HILTI
S19	552140.967	241146.801	45.771	HILTI
S20	552109.478	241163.411	45.581	HILTI
S21	552092.207	241150.098	44.328	HILTI
S22	552081.905	241198.500	46.881	PEG
S23	552152.359	241115.370	45.373	PEG
S24	552066.863	241137.340	43.273	PEG
S25	552086.712	241121.251	43.475	HILTI
S26	552086.776	241108.685	43.680	HILTI
S27	552100.215	241105.123	44.088	PEG
S28	552010.103	241115.357	42.201	HILTI

ALL EASTINGS AND NORTHINGS SHOWN ON THIS DRAWING ARE RELATED TO OS BRITISH NATIONAL GRID (OSTN02) USING GNSS EQUIPMENT.
ALL HEIGHTS ARE RELATED TO OS DATUM NEWLYN (OSGM02).
A LOCAL SCALE FACTOR OF 1.00000 HAS BEEN USED.

EAST ANGLIAN LAND SURVEYS LTD
Unit 10 Charles Industrial Estate
Stowupland Road
Stowmarket
Suffolk IP14 5AH

t: 01449 770289
e: eals@btconnect.com

AMENDMENTS

REV	DATE	DETAILS

ABBREVIATIONS AND NOTES

AV	AIR VALVE	IL	INVERT LEVEL	UTL	UNABLE TO LIFT		
B	BOLLARD	LP	LAMP POST	VP	VENT PIPE		
BH	BOREHOLE	MP	MARKER POST	VRC	VAPOUR RECOVERY CHAMBER		
BT	BRITISH TELECOM	OMW	OBSERVATION WELL	WL	WATER LEVEL		
CH	CILL HEIGHT	PI	PETROL INTERCEPTOR	WM	WATER METER		
CL	COVER LEVEL	RE	RODDING EYE	WO	WASH OUT VALVE		
COL	COLUMN	RS	ROAD SIGN	WSV	WATER STOP VALVE		
CTV	CABLE TV	RWP	RAINWATER PIPE				
DH	DOOR HEIGHT	SA	SOAKAWAY				
EP	ELECTRICITY POLE	SV	STOP VALVE				
ER	EARTH ROD	SVP	SOIL AND VENT PIPE				
FB	FLOOR TO BEAM SOFFIT	SW	SURFACE WATER				
FC	FLOOR TO CEILING HEIGHT	TCB	TELEPHONE CALL BOX	BL	BLOCK	PA	PANEL
FFC	FLOOR TO FALSE CEILING	TH	TRIAL HOLE	BR	BRICK	PK	PICKET
FFL	FINISHED FLOOR LEVEL	THL	THRESHOLD UNDERSIDE	BW	BARBED WIRE	PL	PLASTIC
FH	FIRE HYDRANT	TL	TRAFFIC LIGHT	CB	CLOSE BOARDED	PR	POST AND RAIL
FW	FOUL WATER	TOF	TOP OF FENCE	CL	CHAINLINK	PW	POST AND WIRE
G	GULLY	TOP	TOP OF PIPE	CP	CHESTNUT PALING	RA	RAILINGS
GSV	GAS STOP VALVE	TOW	TOP OF WALL	CW	CHICKEN WIRE	ST	STONE
HH	HEAD HEIGHT	TP	TELEGRAPH POLE				
IC	INSPECTION COVER	USB	UNDERSIDE OF BEAM				

NO ATTEMPT HAS BEEN MADE TO ENTER ANY CONFINED SPACES ON THIS SITE. WE HAVE MEASURED INVERT DEPTHS, ESTIMATED PIPE SIZES AND SHOWN THE DIRECTION OF FLOW ONLY WHERE DRAIN RUNS ARE ACTIVE AT THE TIME OF SURVEY. INSPECTION COVERS WHICH WE WERE UNABLE TO LIFT BY MANUAL METHODS ARE DENOTED AS UTL. WE DID NOT QUOTE FOR THE USE OF HYDRAULIC LIFTING EQUIPMENT.

DRAINAGE RUNS BETWEEN INSPECTION COVERS HAVE NOT BEEN INVESTIGATED OR SHOWN. 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 UTILITY PRIOR TO ANY DESIGN WORK.

THERE MAY BE INSPECTION COVERS ON SITE WHICH WERE NOT VISIBLE AT THE TIME OF SURVEY. THEY MAY HAVE BEEN BURIED OR COVERED BY VEGETATION OR SNOW. YOU SHOULD CONSULT YOUR LOCAL DRAINAGE UTILITY OR COMMISSION A CCTV DRAINAGE SURVEY TO ENSURE THAT YOU LOCATE ANY MISSING COVERS OR DRAINAGE RUNS.

KERB 32.41 — ALL LEVELS SHOWN THUS ARE TAKEN IN THE CHANNEL AND NOT ON TOP OF THE KERB.

KERB 32.56 — ALL LEVELS SHOWN THUS ARE TAKEN ON THE TOP OF THE KERB.

BUILDING 33.17 — ALL SHORT BUILDING RETURNS SHOWN THUS HAVE BEEN DRAWN AT 90° AND SHOULD NOT BE USED FOR DESIGN PURPOSES.

RIDGE, TILE, EAVES, SOFFIT

CLIENT	BRIAN CHRISTIAN BUILDING SURVEYOR
PROJECT	SPRINGWELL NURSERY WALDEN ROAD LITTLE CHESTERFORD ESSEX CB10 1UE
DRAWING TITLE	TOPOGRAPHIC SURVEY
JOB NO.	9153
DATE	16.10.15
SCALES	1:200
DRAWN BY	J CLARK
CHECKED BY	D BEATTY
DWG NO.	9153–1
SHEET NO.	1 OF 4

C Hydrological Assessment

Flood estimation report: Joseph Farm, Little Chesterford

Introduction

This report template is based on a supporting document to the Environment Agency's flood estimation guidelines. It provides a record of the hydrological context, the method statement, the calculations and decisions made during flood estimation and the results.

Contents

Approval

	Name and qualifications	Date
Method statement prepared by:	James Axton MSci	12/12/19
Method statement reviewed by:	Joanne Chillingworth BSc MSc MCIWEM C.WEM	17/12/19
Calculations prepared by:	James Axton MSci	12/12/19
Calculations reviewed by:	Joanne Chillingworth BSc MSc MCIWEM C.WEM	17/12/19

Abbreviations

AEP ....Annual Exceedance Probability

AM...........................Annual Maximum

AREA ....Catchment area (km^2)

BFI ....Base Flow Index

BFIHOST ....Base Flow Index derived using the HOST soil classification

CFMP ....Catchment Flood Management Plan

CPRE ....Council for the Protection of Rural England

FARL.........................FEH index of flood attenuation due to reservoirs and lakes

FEH ....Flood Estimation Handbook

FRA ....Flood Risk Assessment

FSR ....Flood Studies Report

HOST ....Hydrology of Soil Types

NRFA ....National River Flow Archive

POT ....Peaks Over a Threshold

QMED ....Median Annual Flood (with return period 2 years)

ReFH.........................Revitalised Flood Hydrograph method

SAAR ....Standard Average Annual Rainfall (mm)

SPR ....Standard percentage runoff

SPRHOST ....Standard percentage runoff derived using the HOST soil classification

Tp(0) ....Time to peak of the instantaneous unit hydrograph

URBAN ....Flood Studies Report index of fractional urban extent

URBEXT1990 ....FEH index of fractional urban extent

URBEXT2000 ....Revised index of urban extent, measured differently from URBEXT1990

WINFAP-FEH ....Windows Frequency Analysis Package – used for FEH statistical method

1 Method statement

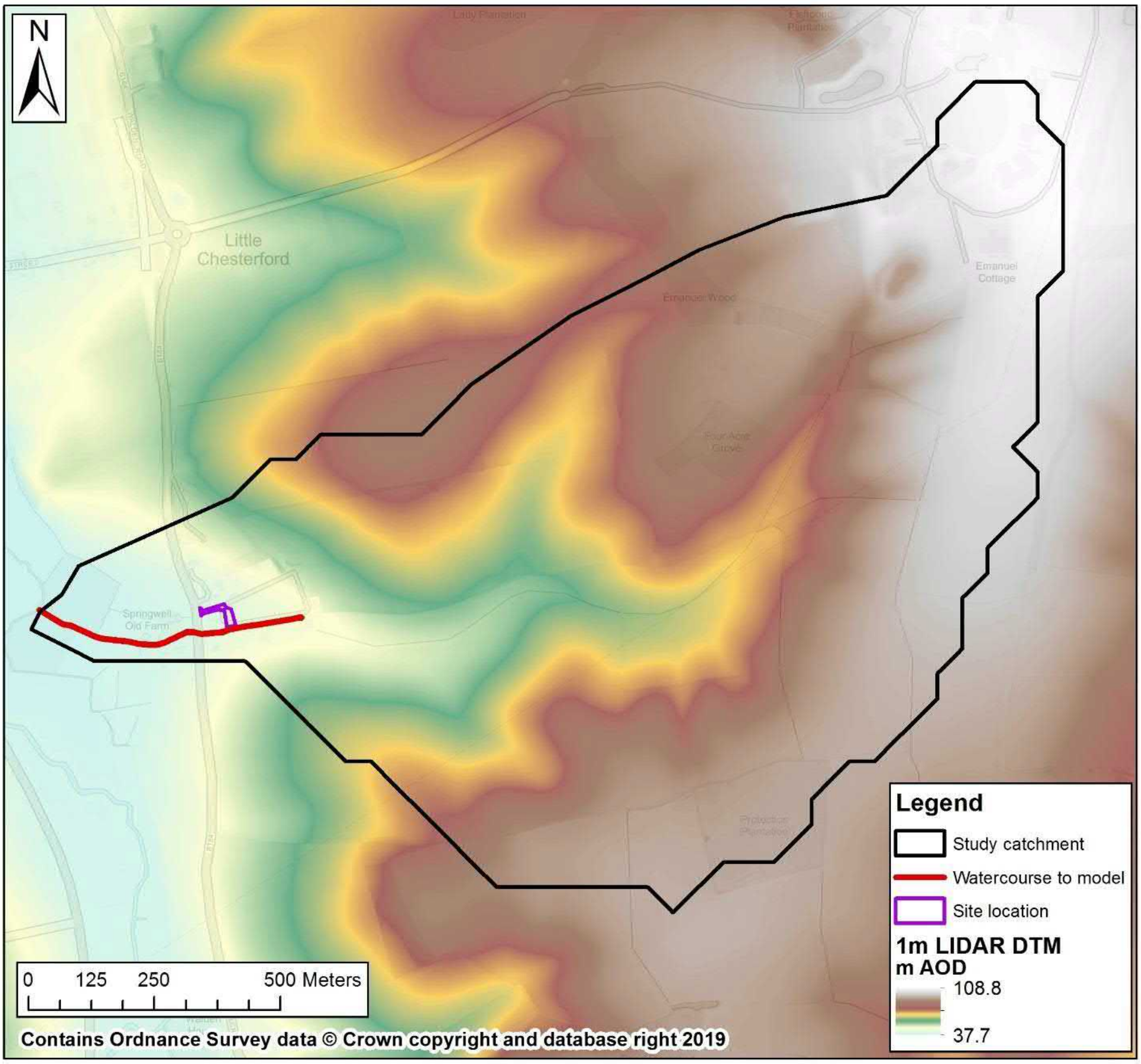
1.1 Requirements for flood estimates

Overview • Purpose of study • Peak flows or hydrographs? • Range of return periods and locations	JBA Consulting were commissioned by Stomor Civil Engineering Consultants to prepare hydraulic modelling with appropriate hydrology to determine the flood risk from an unnamed ordinary watercourse. This study will support a Flood Risk Assessment (FRA) for a change of use development at Joseph Farm, Little Chesterford, Essex. The site is bounded by the ordinary watercourse to the south, with no flood level information related to the watercourse currently available. The Environment Agency's flood maps for planning show the site to be within Flood Zone 3, though this relates to flood risk from the River Cam, which is located roughly 500m west of the site[1]. This study seeks to prepare a hydrological assessment for the ordinary watercourse, in order to derive inflows for the hydraulic model developed as part of this commission. The assessment will utilise the latest methods and software to provide the best estimate of design peak flows and hydrograph shapes. There is no available hydrometric data for the catchment to assist with the preparation of flood hydrology. A Flow Estimation Point (FEP) is required at the downstream extent of the model. Given the relatively short distance from the downstream model extent to the upstream extent (c. 550m) and the narrow catchment in the area of the proposed model, it is assumed any lateral flows are likely to be negligible, with no additional watercourses known to join the study watercourse along its modelled length. Therefore, it is proposed that the flow estimates for the downstream extent will be applied to the upstream extent of the model, providing a conservative estimate of flood levels at the development site. Estimates are required for the 5%, 1%, and 0.1% Annual Exceedance Probability (AEP) events (20-year, 100-year, 1,000-year return periods). In addition, the effects of climate change will be considered for the 1% AEP event, with flows uplifted by 35% and 65% in line with the Environment Agency Climate Change allowances for the Anglian River Basin District.

[1] Environment Agency Flood Map for Planning. Available: https://flood-map-for-planning.service.gov.uk/confirm-location?easting=552033&northing=241150&placeOrPostcode=CB10%201UE

1.2 The catchment

Map (Include river network, catchment boundary and gauging stations)



Description Include topography, climate, geology, soils, land use and any unusual features that may affect the flood hydrology.	The upstream model extent (NGR 552217 241119) is located approximately 130m upstream of the proposed development site and the model extends to approximately 400m downstream of the site (NGR 551685 241128). The modelled watercourse drains an area of approximately 1.67km^2. The modelled extent is primarily open channel apart from a bridge at Walden Road, approximately 50m downstream of the site. The catchment is fairly steep, with an average DPSBAR of 59.1 m/km across the whole catchment. Therefore, it is expected that the catchment would be quite responsive to rainfall. The catchment is rural, consisting largely of arable land with some areas of woodland. There are only a small number of buildings in the study catchment, located in the upper extent of the catchment and in the area around the development site around Walden Road (URBEXT1990 and URBEXT2000 = 0). The underlying catchment bedrock consists of a combination of chalk formations (See Annex). The catchment has a relatively high BFIHOST

	value of 0.552 but is not considered to be permeable (BFIHOST <0.65; this is the recommended limit for the application of the ReFH method). Parts of the upper catchment are overlain by superficial deposits of diamicton, while the area downstream of Walden Road is covered by alluvium (clay, silt, sand and gravel)[2]. The Groundwater Vulnerability Map for England defines the area as having intermediate to high vulnerability and is considered to be a principal aquifer[3]. Catchment soil is primarily composed of freely draining loamy soils, though with loamy and clayey soils with impeded drainage in the areas of higher elevation[4]. There is no gauged data available for the catchment. Mapping of the catchment geology is provided within the annex.

1.3 Source of flood peak data

Source	NRFA peak flows dataset, Version 7, released October 2018. This contains data up to water year 2016-17.

1.4 Gauging stations (flow or level)

(at or very near to the sites of flood estimates)

Water-course	Station name	Gauging authority number	NRFA number	Catchment area (km²)	Type (rated / ultrasonic / level...)	Start of record and end if station closed
N/A – The study watercourse is ungauged						

1.5 Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data	Details
Check flow gaugings (if planned to review ratings)	No	No	N/A	Ungauged catchment
Historic flood data Include chronology and interpretation of flood history in Annex or separate report.	No	No	N/A	
Flow or river level data for events	No	No	N/A	Ungauged catchment
Rainfall data for events	No	No	N/A	No flood event analysis is included within the scope
Potential evaporation data	No	No	N/A	No flood event analysis is included within the scope

[2] British Geological Survey Geology Viewer. Available: http://mapapps.bgs.ac.uk/geologyofbritain/home.html
[3] Defra Magic Map viewer – Groundwater vulnerability. Available: https://magic.defra.gov.uk/MagicMap.aspx
[4] Landis Soilscapes. Available: http://www.landis.org.uk/soilscapes/

Results from previous studies	Yes	Yes	EA	Existing hydraulic model of River Cam used to inform downstream boundary condition in model
Other data or information (e.g. groundwater, tides, channel widths, low flow statistics)	No	No	N/A	

1.6 Hydrological understanding of catchment

Outline the conceptual model, addressing questions such as: • Where are the main sites of interest? • What is likely to cause flooding at those locations? (peak flows, flood volumes, combinations of peaks, groundwater, snowmelt, tides…) • Might those locations flood from runoff generated on part of the catchment only, e.g. downstream of a reservoir? • Is there a need to consider temporary debris dams that could collapse?	The main site of interest is at Joseph Farm, located on Walden Road South, Little Chesterford. The site is bounded by an unmade watercourse to the south, as well as a garden centre and residential properties to the north, east and west. Flood risk is most likely to originate from the River Cam, with the site located within Flood Zone 3. However, there is also potential flood risk from runoff from the topography upstream, with a relatively small catchment draining to the watercourse that flows past the site. There is also the possibility of flooding from blockages where the watercourse flows under Walden Road to the west of the site.
Any unusual catchment features to take into account? e.g. • highly permeable – avoid ReFH if BFIHOST>0.65, consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – seek local flow data; consider method that can account for differing sewer and topographic catchments • pumped watercourse – consider lowland catchment version of rainfall-runoff method • major reservoir influence (FARL<0.90) – consider flood routing, extensive floodplain storage – consider choice of method carefully	No – Catchment is rural, not considered to be permeable and there is no attenuation in the catchment (FARL = 1).

1.7 Initial choice of approach

Is FEH appropriate? (it may not be for extremely heavily urbanised or complex catchments) If not, describe other methods to be used.	Yes.
Initial choice of method(s) and reasons How will hydrograph shapes be derived if needed? Will the catchment be split into sub-catchments? If so, how?	FEH Statistical and ReFH2 methods will be tested and compared. Flow estimates derived for JF01 at the downstream extent of the model will be used to as the primary inflow for the upstream extent of the model. It is not deemed necessary to generate flow estimates for the upstream extent due to the short modelled

	length of watercourse and the likelihood that any lateral catchment inflows will be negligible. This approach will provide conservative inflows for the upstream of the model. The model will use ReFH boundaries to obtain hydrograph shapes.
Software to be used (with version numbers)	FEH Web Service[5] / WINFAP-FEH v3.0.003[6] / ReFH2.2

[5] CEH 2015. The Flood Estimation Handbook (FEH) Online Service, Centre for Ecology & Hydrology, Wallingford, Oxon, UK.

[6] WINFAP-FEH v3 © Wallingford HydroSolutions Limited and NERC (CEH) 2009.

2 Locations where flood estimates required

The table below lists the locations of subject sites. The site codes listed below are used in all subsequent tables to save space.

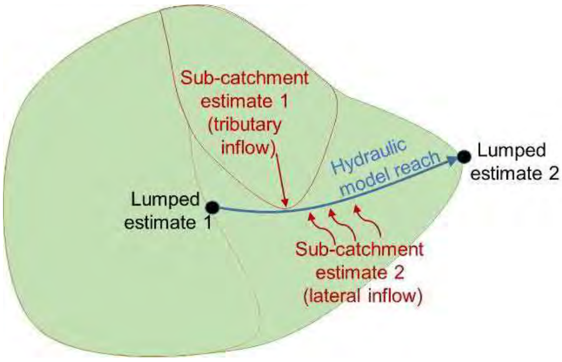
2.1 Summary of subject sites

Site code	Type of estimate L: lumped catchment S: Sub-catchment	Watercourse	Name or description of site	Easting	Northing	AREA on FEH CD-ROM (km^2)	Revised AREA if altered
JF01	L	Unnamed ordinary watercourse	Downstream lumped catchment	551695	551695	1.47	1.66

Note: Lumped catchments (L) are complete catchments draining to points at which design flows are required.

Sub-catchments (S) are catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system. There is no need to report any design flows for sub-catchments, as they are not relevant: the relevant result is the hydrograph that the sub-catchment is expected to contribute to a design flood event at a point further downstream in the river system. This will be recorded within the hydraulic model output files. However, catchment descriptors and ReFH model parameters should be recorded for sub-catchments so that the results can be reproduced.

The schematic diagram illustrates the distinction between lumped and sub-catchment estimates.



2.2 Important catchment descriptors at each subject site (incorporating any changes made)

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	URBEXT 1990	URBEXT 2000	FPEXT
JF01	1.00	0.26	0.552	1.46	59.1	579	0.00	0.00	0.017

2.3 Checking catchment descriptors

Record how catchment boundary was checked and describe any changes (add maps if needed)	The catchment boundary was checked using a combination of available LIDAR DTM and OS OpenMap Local mapping. Based on this comparison, the catchment generally seemed reasonable. However, the OSOpenMapLocal mapping suggests the catchment drains slightly differently to the catchment shown on the FEH boundary downstream of Walden Road. The study watercourse is shown to flow west before turning northwest and joining the River Cam, instead of flowing southeast as suggested by the FEH boundary. The boundary was therefore adjusted following topographically high points and avoiding any drainage ditches draining away from the catchment (see Annex A.1). The boundary was also adjusted in the north of the catchment, where LIDAR data showed the FEH boundary does not follow the topographical high points. The change in catchment area is +0.18km^2 / +12%. Therefore, given the relatively minor change in area it was not considered necessary to adjust the other catchment descriptors.
Record how other catchment descriptors were checked and describe any changes. Include before/after table if necessary.	URBEXT A visual check was undertaken of the urban areas shown on the FEH WEB service compared to current OS mapping. The URBEXT1990 and URBEXT2000 values of 0 were deemed to be appropriate given the low level of development in the catchment, with only a small number of buildings located around the study site and in the upper extent of the catchment. FARL The FARL value was visually compared against the current OS mapping. As no surface water features were identified within the mapping, a FARL value of 1.0 was deemed to be representative of the catchment and no changes were made. SPRHOST and BFIHOST The SPRHOST and BFIHOST values were deemed representative of the of the underlying soil types and geology, and therefore the FEH values have been retained.
Source of URBEXT	URBEXT2000 for FEH Statistical and ReFH2 methods
Method for updating of URBEXT	URBEXT values of 0 did not need updating.

3 Statistical method

3.1 Overview of estimation of QMED at each subject site

Site code	Initial QMED rural (m^3/s) (from catchment descriptors)	Final method	Data transfer					Urban adjust-ment factor (UAF)	Final QMED estimate (m^3/s)
			NRFA numbers for donor sites used (see 3.3)	Distance between centroids d_{ij} (km)	Moderated QMED adjustment factor, $(A/B)^a$	If more than one donor			
						Weight	Weighted ave. adjustment		
JF01	0.2	CD	N/A	N/A	N/A	N/A	N/A	N/A	0.2

Are the values of QMED spatially consistent?	N/A
Method used for urban adjustment for subject and donor sites	N/A

Notes

Methods: AM – Annual maxima; POT – Peaks over threshold; DT – Data transfer (with urban adjustment); CD – Catchment descriptors alone (with urban adjustment); BCW – Catchment descriptors and bankfull channel width (add details); LF – Low flow statistics (add details).

The QMED adjustment factor A/B for each donor site is given in Table 3.2. This is moderated using the power term, a, which is a function of the distance between the centroids of the subject catchment and the donor catchment. The final estimate of QMED is: $(A/B)^a \times QMED_{initial} \times UAF$

Important note on urban adjustment

The method used to adjust QMED for urbanisation published in Kjeldsen (2010)[7] in which PRUAF is calculated from BFIHOST is not correctly applied in WINFAP-FEH v3.0.003. Significant differences occur only on urban catchments that are highly permeable.

[7] Kjeldsen, T. R. (2010). Modelling the impact of urbanization on flood frequency relationships in the UK. Hydrol. Res. **41**. 391-405.

3.2 Search for donor sites for QMED (if applicable)

Comment on potential donor sites Include a map if necessary. Note that donor catchments should usually be rural.	Given that there is no observed flow data within the study catchment, a brief assessment of donor stations was carried out for this study using WINFAP-FEH to assess stations that are classified as suitable for QMED within the NRFA peak flows dataset. A total of ten potential donor sites were identified within the NFRA peak flows dataset (see Annex). Potential donor sites were consequently assessed to identify the most suitable donor (if any) based on distance to the study site and similarity of catchment characteristics. The three most hydrologically similar characteristics (in terms of SAAR, BFIHOST, FARL and URBEXT) were: • 33055 (Granta @ Babraham) • 33027 (Rhee @ Wimpole) • 33023 (Lea Brook @ Beck Bridge) Station 33055 was also the closest station to the study catchment, though has an area of 101.97km^2, over 60 times greater than the study site. The other most similar stations, 33027 and 33023, have catchments even larger than this. As a result, the three stations have been deemed unsuitable for donor adjustment. The study catchment has a very small area (1.66km^2 at the downstream extent) and the donor site with the most similar area value was still around 20 times larger (33052 – Swaffham Lode @ Swaffham Bulbeck). Additionally, station 33052 has a BFIHOST value of 0.841, over 65% higher than the value of the study catchment so was also excluded. The final flow estimates for the study catchment have consequently been made using catchment descriptors alone.

3.3 Donor sites chosen and QMED adjustment factors

NRFA no.	Reasons for choosing	Method (AM or POT)	Adjust-ment for climatic variation ?	QMED from flow data (A)	QMED from catchment descriptors (B)	Adjust-ment ratio (A/B)
No donor sites were chosen, therefore the FEH Statistical estimates derived for the study catchment have been based on catchment descriptors.						

3.4 Derivation of pooling groups

Several subject sites may use the same pooling group.

Name of group	Site code from whose descriptors group was derived	Subject site treated as gauged? (enhanced single site analysis)	Changes made to default pooling group, with reasons	Weighted average L-moments, L-CV and L-skew, (before urban adjustment)
JF01_PG	JF01	No, pooled.	A total of 15 stations were identified within the pooling group for JF01. These stations were reviewed, with one station subsequently removed (49005 – Bollingey Stream @ Bollingey Cocks Bridge). The Bollingey Stream gauging station ercord is very short, with only 8 years of data. This could mean that there is little variation in the AMAX series (as fewer large events have been recorded) and therefore would produce a shallower growth curve. Alternatively, if the short records were captured during a storm rich period, the storm duration curve produced may be steeper than expected. As a result, the gauge was deemed to be unrepresentative of the study catchment. The final pooling group has a total of 503 years of data and can be found in the Annex.	L-CV = 0.227 L-skew = 0.263
Note: Pooling groups were derived using the procedures from Science Report SC050050 (2008).				

3.5 Derivation of flood growth curves at subject sites

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
JF01	P	JF01_PG	GL has been deemed most suitable as the z-value was closest to zero when using the GL distribution.	No adjustment made as URBEXT1990 and URBEXT2000 values are 0.	Location = 1.00 Scale = 0.223 Shape = -0.263	2.99

Site code	Method (SS, P, ESS, J)	If P, ESS or J, name of pooling group (Error! Reference source not found.)	Distribution used and reason for choice	Note any urban adjustment or permeable adjustment	Parameters of distribution (location, scale and shape after adjustments)	Growth factor for 100-year return period
Notes Methods: SS – Single site; P – Pooled; ESS – Enhanced single site; J – Joint analysis A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters. Urban adjustments are all carried out using the method of Kjeldsen (2010). Growth curves were derived using the procedures from Science Report SC050050 (2008).						

3.6 Flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the following return periods (in years)		
	20yr	100yr	1,000yr
JF01	0.4	0.6	1.1

3.6.1 Climate change flood estimates from the statistical method

Site code	Flood peak (m^3/s) for the 1% AEP event (plus climate change)	
	+35%	+65%
JF01	0.8	1.0

4 Revitalised flood hydrograph 2 (ReFH2) method

4.1 Parameters for ReFH2 model (rural catchment)

Site code	Method	Tp (hours)	C_{max} (mm)	BL (hours)	BR
JF01	CD	3.02	494.74	43.45	1.25
Brief description of any flood event analysis carried out (further details should be given in the annex)			N/A		
Methods: OPT: Optimisation, BR: Baseflow recession fitting, CD: Catchment descriptors, DT: Data transfer (give details)					

4.2 Design events for ReFH2 method: Lumped catchments

Site code	Urban or rural	Season of design event (summer or winter)	Storm duration (hours)
JF01	Rural	Winter	4.5

4.3 Flood estimates from the ReFH2 method

Note: This table is for recording results for lumped catchments. There is no need to record peak flows from sub-catchments or intervening areas that are being used as inputs to a semi-distributed model of the river system.

Site code	Flood peak (m^3/s) for the following return periods (in years)		
	20yr	100yr	1,000yr
JF01	0.6	0.9	1.8

4.3.1 Climate change flood estimates from the ReFH2 method

Site code	Flood peak (m^3/s) for the 1% AEP event (plus climate change)	
	+35%	+65%
JF01	1.2	1.5

5 Discussion and summary of results

5.1 Comparison of results from different methods

This table compares peak flows from the ReFH2 method with those from the FEH Statistical method at the study catchment site for two key return periods.

Site code	Ratio of peak flow to FEH Statistical peak	
	Return period 2 years	Return period 100 years
	ReFH	ReFH
JF01	1.54	1.51

5.2 Final choice of method

Choice of method and reasons Include reference to type of study, nature of catchment and type of data available.	The ReFH2 estimates are more conservative at all return points for the flow estimation point at the downstream extent of the model and produce a steeper growth curve. Either method could be considered suitable for this catchment, especially in the absence of any gauge data to verify the peak flow estimates. The FEH Statistical method benefits from being calibrated with a large dataset of flood events, sourcing flow estimates and growth curves from hydrologically similar catchments (pooled analysis) and making fewer assumptions. In comparison, as the study catchment is particularly small, the catchment-wide design storm assumed by the ReFH2 method is likely to be more realistic. Additionally, at higher return periods the ReFH2 method can be justified due to rainfall records tending to be longer than flow records, potentially providing better estimates of flow at higher return periods. In the absence of gauged data, it is recommended that the peak flows derived using the ReFH2 method are initially adopted and tested within the hydraulic model. This is because the ReFH2 flows will provide a more conservative estimate of flood risk to the site once modelled, giving a 'worst-case' scenario to support the Flood Risk Assessment. The EA typically recommend the use of the most conservative method unless there are clear reasons for preferring one method over another. Therefore, the use of the ReFH2 flows is considered to be appropriate given there is no flow data available to verify the estimates produced.
How will the flows be applied to a hydraulic model? If relevant. Will model inflows be adjusted to achieve a match with lumped flow estimates, or will the model be allowed to route inflows?	Flows will be applied to the hydraulic model using ReFH Boundary units (REFHBDYs) in Flood Modeller modelling software. These will apply a uniform storm duration across the entire catchment (see Section 4.2). The inflows to the upstream extent of the model will be applied using the flow estimates derived for JF01 at the downstream extent of the model.

5.3 Assumptions, limitations and uncertainty

List the main assumptions made (specific to this study)	The main assumptions are: • The FEH Statistical and ReFH2 methods provide suitable flow estimates using derived catchment

	descriptors in the absence of observed flow data. • The adjustments to the FEH Web Service catchment boundaries noted in Section 2 using the LIDAR DTM accurately reflect the drainage of the area. • The JF01 pooling group is representative of all flow estimation points. • It is assumed that the ReFH2 hydrograph shape is representative of the catchment response.
Discuss any particular limitations, e.g. applying methods outside the range of catchment types or return periods for which they were developed.	The main limitations are: • The FEH Statistical method is not recommended for predicting flow estimates for long return periods (e.g. 1,000-year return period) and is generally believed to only be suitable for return periods up to 200 years. Estimates of flow beyond this return period are extrapolations and have a higher degree of uncertainty. • The limited amount of quantitative flood history information or flow gauge data limits the ability to verify design peak flow estimates, hydrographs, and model results based on these estimates. • The study catchment is small, which adds uncertainty to the FEH Statistical method as there is a shortage of small catchments in the national peak flow dataset from which to form robust pooling groups or identify suitable donor sites.
Give what information you can on uncertainty in the results, e.g. confidence limits from Kjeldsen (2014).	It is important to consider the implications of the uncertainty in hydrological estimates on the outputs from a study. However, methods to try and quantify the uncertainty in design flows from ReFH models have not yet been developed and therefore it is not possible to directly quantify the uncertainty for the ReFH2 method results. It is possible to try and quantify the uncertainty in the results of the FEH Statistical method in some more standard situations. The uncertainty will depend on a variety of factors, for example how unusual the catchment is relative to the pooling group and donor catchment, and the uncertainty in flow measurement at other gauges. A UK average measure of uncertainty is presented in a technical guidance report generated by a R&D project into the FEH, local data and uncertainty (Environment Agency funded consortium of JBA, CEH and others). The report presents results for rural catchments (URBEXT2000 <0.03) and moderately urbanised catchments (0.03 ≤ URBEXT2000 < 0.15). The 95% confidence limits for flood estimates for a moderately urbanised catchment are: • Without donor adjustment of QMED: 0.39 – 2.54 times the best estimate for the 50% AEP event and 0.33 - 3.01 for the 1% AEP event
Comment on the suitability of the results for future studies, e.g. at nearby locations or for different purposes.	It is emphasised that the results of the analysis should be considered in the context of the needs of this study. The results of this assessment should be revisited for use on future studies. The results in this study have been produced using the most up-to-date flow estimation methods and the Environment Agency's Flood Estimation Guidelines. However, given that

	there is no gauge data available to adjust the design peak flow estimates and hydrographs derived from this study, there is a level of uncertainty associated with these estimates. Therefore, it may be worth reviewing both QMED and peak flow estimates for the study catchment in future studies, particularly if better quality observed flow and level data is made available in the future.
Give any other comments on the study, e.g. suggestions for additional work.	N/A

5.4 Checks

Are the results consistent, for example at confluences?	Yes, the flood peaks increase with return period at the FEP for both the FEH Statistical method and ReFH2 method.
What do the results imply regarding the return periods of floods during the period of record?	N/A - The study catchment is ungauged.

What is the range of 100-year growth factors? Is this realistic?	The 1% AEP growth factors for the JF01 flow estimation point are as follows:
	• FEH Statistical method
	  o 2.99
	• ReFH2
	  o 2.87
	These values are all within the expected range for small catchments (<20km2), which is between 2 - 5.

If 1000-year flows have been derived, what is the range of ratios for 1000-year flow over 100-year flow?	The 0.1% / 1% AEP event ratios for the JF01 flow estimation point are as follows:
	• FEH Statistical method
	  o 1.78
	• ReFH2
	  o 2.07

How do the results compare with those of other studies? Explain any differences and conclude which results should be preferred.	No other studies were available to compare flow estimates against.
Are the results compatible with the longer-term flood history?	There is no information on peak flows for historical flooding events.
Describe any other checks on the results	Sensibility checks will be applied to the flood outlines once the flows have been routed through the model to ensure the flow inputs result in realistic outputs.

5.5 Final results

Site code	Flood peak (m^3/s) for the following return periods (in years)		
	20yr	100yr	1,000yr
JF01	0.6	0.9	1.8

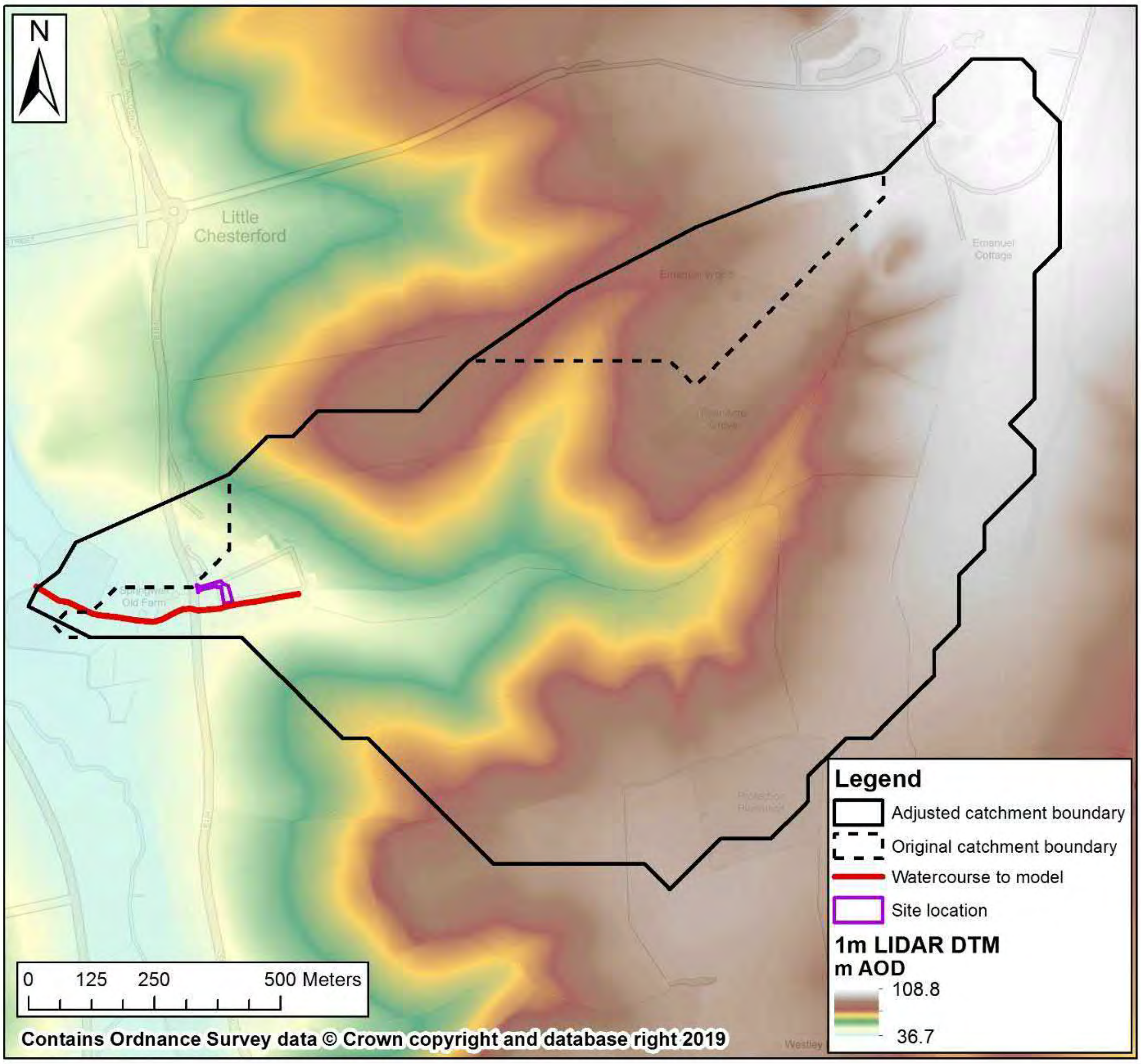
5.5.1 Climate change flood estimates

Site code	Flood peak (m^3/s) for the 1% AEP event (plus climate change)	
	+35%	+65%
JF01	1.2	1.5

If flood hydrographs are needed for the next stage of the study, where are they provided? (e.g. give filename of spreadsheet, hydraulic model, or reference to table below)	Flood hydrographs will be required for the hydraulic modelling and will be provided in the Flood Modeller data (.DAT) files. Using this file, individual Flood Modeller Event Data (.IED) files can be produced for the hydraulic model boundary units. The ReFH2 design hydrographs are to be taken forward for this study. A common design storm of 4.5 hours based on the JF01 catchment is to be applied within the model (in terms of storm area and storm duration).

6 Annex

A.1 Modifications to FEH catchment



A.2 Catchment geology

Geology map taken from the British Geological Survey Geology of Britain Viewer[8]

[8] Geology of Britain Viewer. Available: http://mapapps.bgs.ac.uk/geologyofbritain/home.html

A.3 Pooling groups (FEH Statistical method)

A.3.1 Default pooling group

Original pooling group for the JF01 catchment

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.375	41	1.84	0.165	0.315	0.657
27051 (Crimple @ Burn Bridge)	2.353	46	4.539	0.219	0.148	0.291
45816 (Haddeo @ Upton)	2.428	25	3.456	0.306	0.399	1.064
28033 (Dove @ Hollinsclough)	2.72	43	4.205	0.231	0.369	0.466
25019 (Leven @ Easby)	3.165	40	5.384	0.343	0.378	1.781
26802 (Gypsey Race @ Kirby Grindalythe)	3.202	19	0.109	0.309	0.183	1.193
27073 (Brompton Beck @ Snainton Ings)	3.338	37	0.82	0.2	0.047	1.166
25011 (Langdon Beck @ Langdon)	3.363	32	15.533	0.235	0.334	1.645
49005 (Bolingey Stream @ Bolingey Cocks Bridge)	3.373	8	6.511	0.262	0.049	2.528
47022 (Tory Brook @ Newnham Park)	3.4	25	6.18	0.273	0.149	0.52
91802 (Allt Leachdach @ Intake)	3.429	34	6.35	0.153	0.257	0.881
71003 (Croasdale Beck @ Croasdale Flume)	3.448	37	10.9	0.212	0.323	0.213
25003 (Trout Beck @ Moor House)	3.539	45	15.12	0.167	0.302	0.616
27010 (Hodge Beck @ Bransdale Weir)	3.548	41	9.42	0.224	0.293	0.102
54022 (Severn @ Plynlimon Flume)	3.627	38	14.988	0.156	0.171	1.878
Total		511				
Weighted means				0.229	0.257	

A.3.2 Modified pooling group

Pooling group for JF01. This has been adjusted to remove station 49005 (Bolingey Stream @ Bolingey Cocks Bridge).

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
76011 (Coal Burn @ Coalburn)	1.375	41	1.84	0.165	0.315	0.657
27051 (Crimple @ Burn Bridge)	2.353	46	4.539	0.219	0.148	0.291
45816 (Haddeo @ Upton)	2.428	25	3.456	0.306	0.399	1.064
28033 (Dove @ Hollinsclough)	2.72	43	4.205	0.231	0.369	0.466
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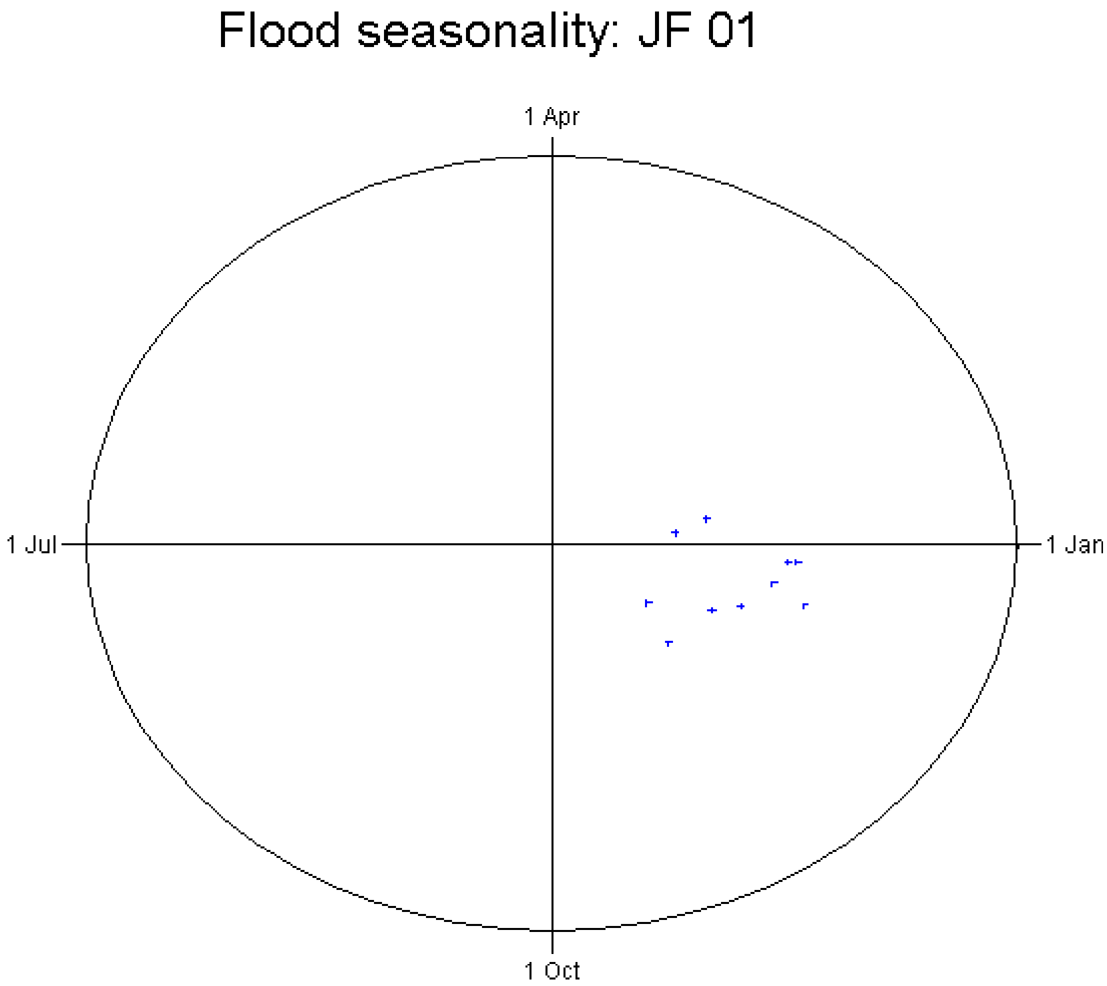
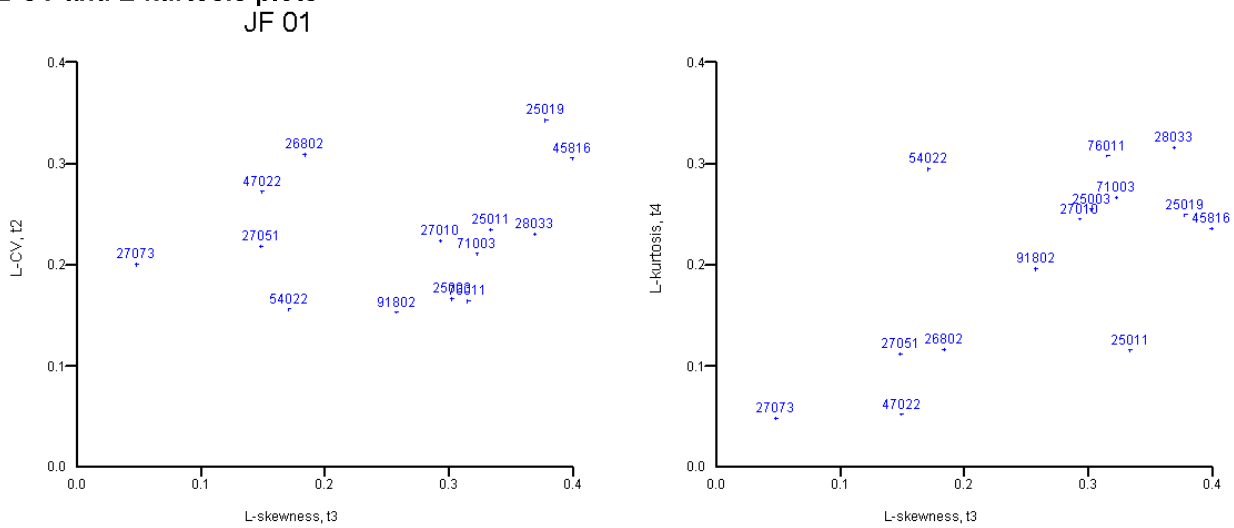
25003 (Trout Beck @ Moor House)	3.539	45	15.12	0.167	0.302	0.616
27010 (Hodge Beck @ Bransdale Weir)	3.548	41	9.42	0.224	0.293	0.102
54022 (Severn @ Plynlimon Flume)	3.627	38	14.988	0.156	0.171	1.878
Total		503				
Weighted means				0.227	0.263	

A.3.3 Modified pooling group details

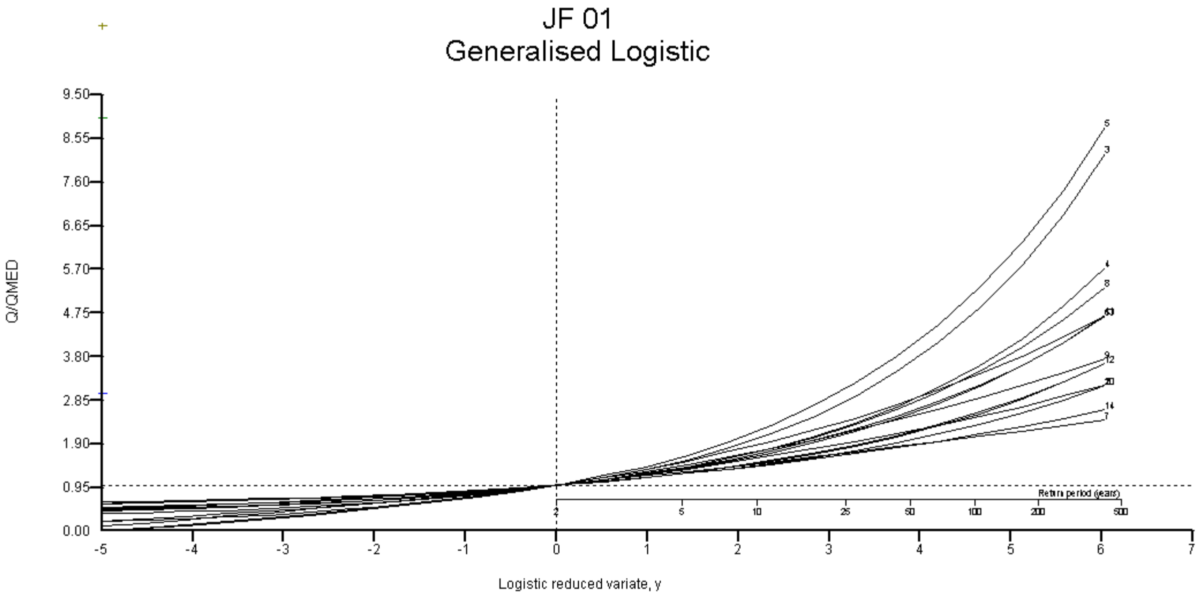
Flood seasonality plots



L-CV and L-kurtosis plots



Flood growth curves



A.4 Potential donor sites (FEH Statistical method)

Station	Centroid distance (km)	AREA	SAAR	BFIHOST	FARL	URBEXT	Years of data
JF01 – Study catchment		1.655	579	0.552	1	0	
33055 (Granta @ Babraham)	6.83	101.97	579	0.638	0.999	0.012	42
37011 (Chelmer @ Churchend)	14.36	72.78	591	0.448	0.992	0.012	52
37017 (Blackwater @ Stisted)	17.28	140.38	579	0.493	0.994	0.025	49
36012 (Stour @ Kedington)	17.64	76.64	599	0.396	0.99	0.01	51
33021 (Rhee @ Burnt Mill)	18.43	308.05	559	0.713	0.994	0.021	55
37012 (Colne @ Poolstreet)	20.15	64.49	574	0.403	0.992	0.009	54
33052 (Swaffham Lode @ Swaffham Bulbeck)	21.74	33.13	567	0.841	0.998	0.012	49
33027 (Rhee @ Wimpole)	24.22	128.49	558	0.613	1	0.013	53
36015 (Stour @ Lamarsh)	24.64	481.29	583	0.474	0.987	0.021	47

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D Key Modelled Structures

D.1 Culvert

<table>
<tr><td>Included in model?
(state reason if not):</td><td>Yes</td></tr>
<tr><td>Model label:</td><td>JF_584 (B184 Culvert)</td></tr>
<tr><td>Type:</td><td>Circular Brick Culvert</td></tr>
<tr><td>How has structure been modelled?</td><td>The structure was modelled as a circular conduit unit using FLOOD MODELLER. The following modelling parameters were used:
<table>
<tr><td>JF_584</td><td>RIVER</td><td>SECTION</td></tr>
<tr><td>JF_584su</td><td>SPILL</td><td></td></tr>
<tr><td>JF_584</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_584ucu1</td><td>CULVERT</td><td>INLET</td></tr>
<tr><td>JF_584ucu</td><td>CONDUIT</td><td>CIRCULAR</td></tr>
<tr><td>JF_584ucd</td><td>CONDUIT</td><td>CIRCULAR</td></tr>
<tr><td>JF_584ucd</td><td>CULVERT</td><td>OUTLET</td></tr>
<tr><td>JF_584dcu1</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_584d</td><td>RIVER</td><td>SECTION</td></tr>
</table>
Geometry
<table>
<tr><td>Distance to Next Conduit:</td><td>Elevation Of Invert:</td><td>Diameter:</td></tr>
<tr><td>12.300</td><td>40.510</td><td>0.840</td></tr>
</table>
Friction
<table>
<tr><td>Equation:</td><td>Value Below Axis:</td><td>Value Above Axis:</td></tr>
<tr><td>MANNING</td><td>0.02500</td><td>0.02500</td></tr>
</table>
Overtopping of the structure was represented within the 1D domain using an in-line spill unit.</td></tr>
<tr><td>Downstream Face, looking Upstream

</td><td>Upstream Face, looking Downstream

</td></tr>
</table>

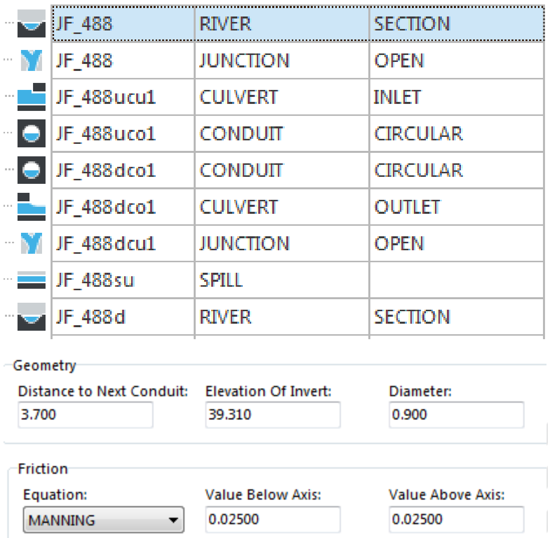
D.2 Culvert

<table>
<tr><td>Included in model?
(state reason if not):</td><td>Yes</td></tr>
<tr><td>Model label:</td><td>JF_548</td></tr>
<tr><td>Type:</td><td>Circular Brick Culvert</td></tr>
<tr><td>How has structure been modelled?</td><td>The structure was modelled as a circular conduit unit using FLOOD MODELLER. The following modelling parameters were used:
<table>
<tr><td>JF_548</td><td>RIVER</td><td>SECTION</td></tr>
<tr><td>JF_548</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_548su</td><td>SPILL</td><td></td></tr>
<tr><td>JF_548ucu1</td><td>CULVERT</td><td>INLET</td></tr>
<tr><td>JF_548uco1</td><td>CONDUIT</td><td>CIRCULAR</td></tr>
<tr><td>JF_548dco1</td><td>CONDUIT</td><td>CIRCULAR</td></tr>
<tr><td>JF_548dco1</td><td>CULVERT</td><td>OUTLET</td></tr>
<tr><td>JF_548dcu1</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_548d</td><td>RIVER</td><td>SECTION</td></tr>
</table>
Geometry
<table>
<tr><td>Distance to Next Conduit:</td><td>Elevation Of Invert:</td><td>Diameter:</td></tr>
<tr><td>4.600</td><td>40.100</td><td>0.940</td></tr>
</table>
Friction
<table>
<tr><td>Equation:</td><td>Value Below Axis:</td><td>Value Above Axis:</td></tr>
<tr><td>MANNING</td><td>0.02500</td><td>0.02500</td></tr>
</table>
Overtopping of the structure was represented within the 1D domain using an in-line spill unit.</td></tr>
<tr><td>Downstream Face, looking Upstream

</td><td>Upstream Face, looking Downstream
</td></tr>
</table>

D.3 Culvert

<table>
<tr><td>Included in model?

(state reason if not):</td><td>Yes</td></tr>
<tr><td>Model label:</td><td>JF_488</td></tr>
<tr><td>Type:</td><td>Circular Concrete Culvert</td></tr>
<tr><td>How has structure been modelled?</td><td>The structure was modelled as a circular conduit unit using FLOOD MODELLER. The following modelling parameters were used:


JF_488	RIVER	SECTION
JF_488	JUNCTION	OPEN
JF_488ucu1	CULVERT	INLET
JF_488uco1	CONDUIT	CIRCULAR
JF_488dco1	CONDUIT	CIRCULAR
JF_488dco1	CULVERT	OUTLET
JF_488dcu1	JUNCTION	OPEN
JF_488su	SPILL	
JF_488d	RIVER	SECTION

Geometry
Distance to Next Conduit: 3.700
Elevation Of Invert: 39.310
Diameter: 0.900
Friction
Equation: MANNING
Value Below Axis: 0.02500
Value Above Axis: 0.02500

Overtopping of the structure was represented within the 1D domain using an in-line spill unit.</td></tr>
<tr><td>Downstream Face, looking Upstream

</td><td>Upstream Face, looking Downstream

</td></tr>
</table>

D.4 Old timber sleeper crossing

<table>
<tr><td>Included in model?

(state reason if not):</td><td>Yes</td></tr>
<tr><td>Model label:</td><td>JF_275</td></tr>
<tr><td>Type:</td><td>Timber sleeper crossing</td></tr>
<tr><td>How has structure been modelled?</td><td>The structure was modelled as a USBPR Bridge unit using FLOOD MODELLER. The following modelling parameters were used:
<table>
<tr><td>JF_275</td><td>RIVER</td><td>SECTION</td></tr>
<tr><td>JF_275su</td><td>SPILL</td><td></td></tr>
<tr><td>JF_275bru</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_275bru</td><td>BRIDGE</td><td>USBPR1978</td></tr>
<tr><td>JF_275brd</td><td>JUNCTION</td><td>OPEN</td></tr>
<tr><td>JF_275d</td><td>RIVER</td><td>SECTION</td></tr>
</table>
Openings:
<table>
<tr><th>Start (m)</th><th>Finish (m)</th><th>Springing Level (m AD)</th><th>Soffit Level (m AD)</th></tr>
<tr><td>15.612</td><td>17.103</td><td>38.250</td><td>38.250</td></tr>
</table>
Overtopping of the structure was represented within the 1D domain using an in-line spill unit.</td></tr>
<tr><td>Downstream Face, looking Upstream

</td><td>Upstream Face, looking Downstream

</td></tr>
</table>

E Sensitivity Analysis

The hydraulic model was tested for sensitivity to key model parameters which might impact flood risk at the proposed development site. This included the following scenarios:

- Increasing flows by 20% (i.e. the 100-year plus climate change event)
- Increasing the Manning's n values by +20%. This was both in the FLOOD MODELLER 1D channel and in the 2D TUFLOW domain.
- Increasing the downstream boundary by 250mm in the 1D

The following sections discuss the impacts of these sensitivity scenarios.

E.1 Sensitivity to flow

Figure E 1.1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to all inflows.

Figure E 1.1: Sensitivity analysis for +20% inflows

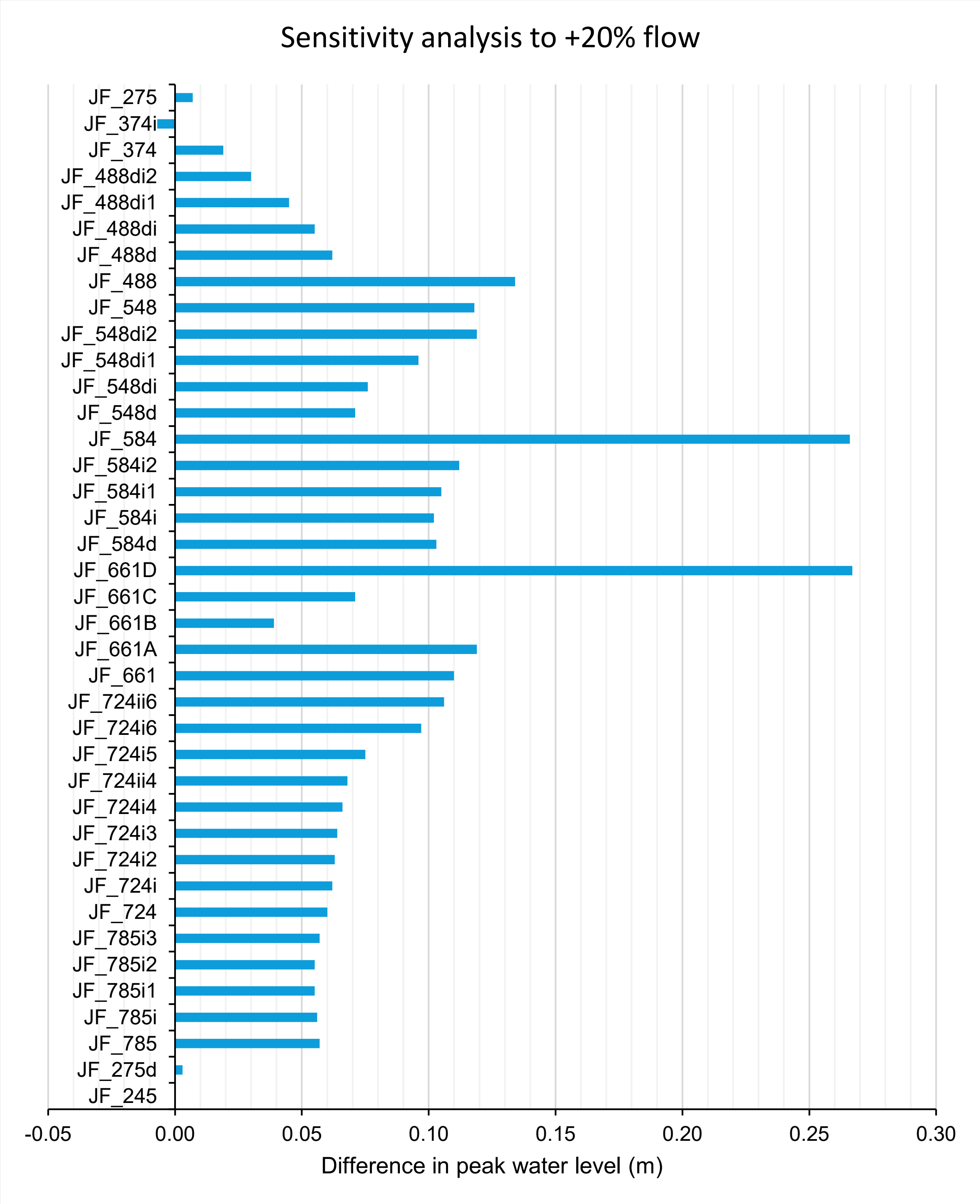


Figure E 1.1 indicates there is a maximum increase in peak water level of 270mm around node JF_661D and JF_584. Near the site boundary (JF_661), an increase in peak water level can be seen. The site does not flood from the 0.11m increase and it is deemed that the channel is sensitive whereas the site is insensitive to change.

E.2 Sensitivity to roughness

Figure E 2.1 shows the changes in peak water level compared to the baseline 100-year event when an increase of 20% is applied to Manning's 'n' in both the 1D and 2D domains.

Figure E 2.1: Sensitivity analysis for +20% roughness

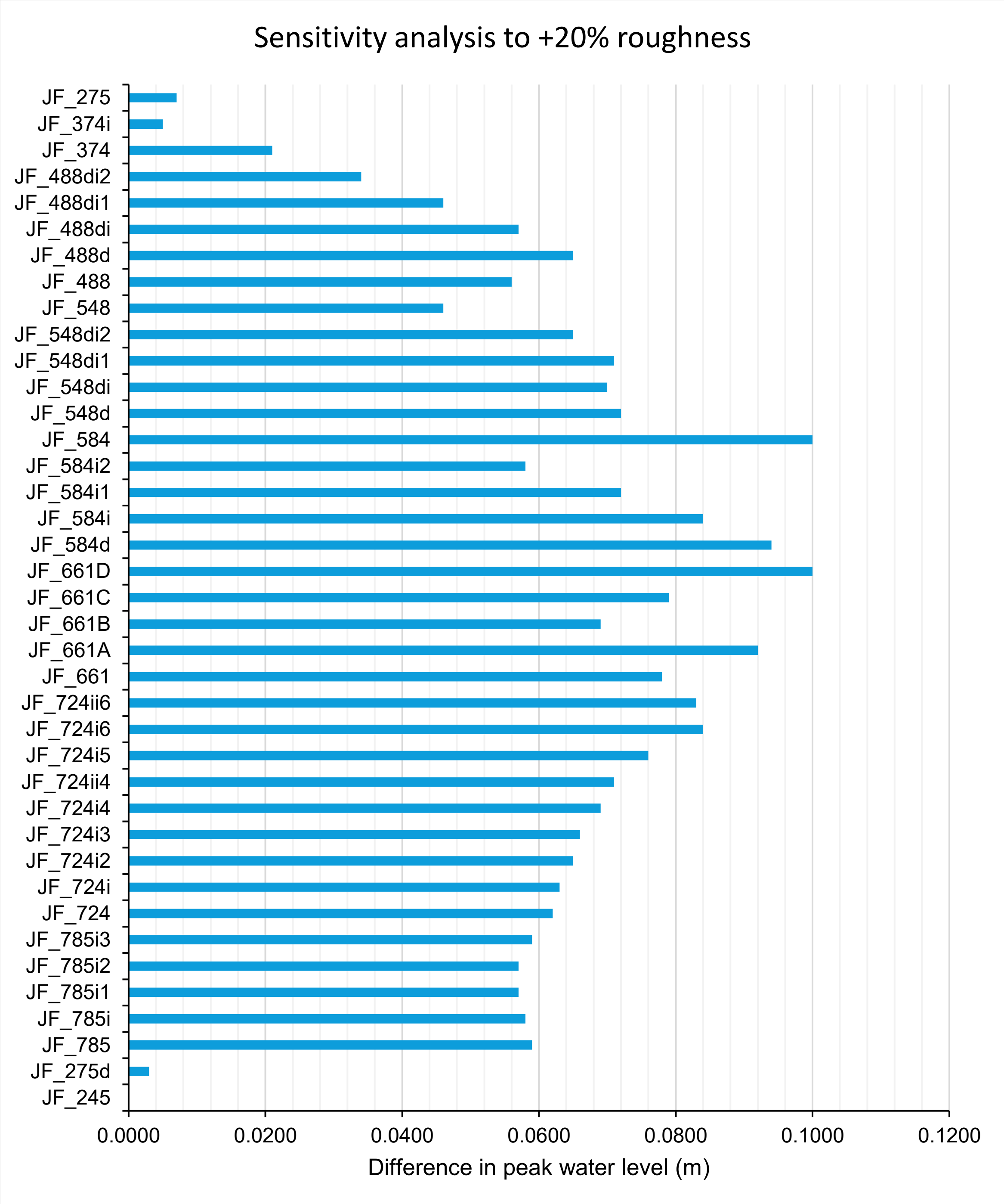


Figure 2.1 indicates there is a maximum increase in peak water level of 100mm, linking to node JF_661D and JF_584. Near the site boundary (JF_661), an increase in peak water level can be seen. The site does not flood from the 0.07m increase and it is deemed that the channel is sensitive whereas the site is insensitive to change.

E.3 Sensitivity to downstream boundary conditions

Figure 3.1 shows the changes in peak water levels compared to the baseline 100-year event when an increase of 250mm is applied to the downstream 'stage-time' model boundary condition.

Figure E 3.1: Sensitivity analysis for +250mm at the downstream boundary

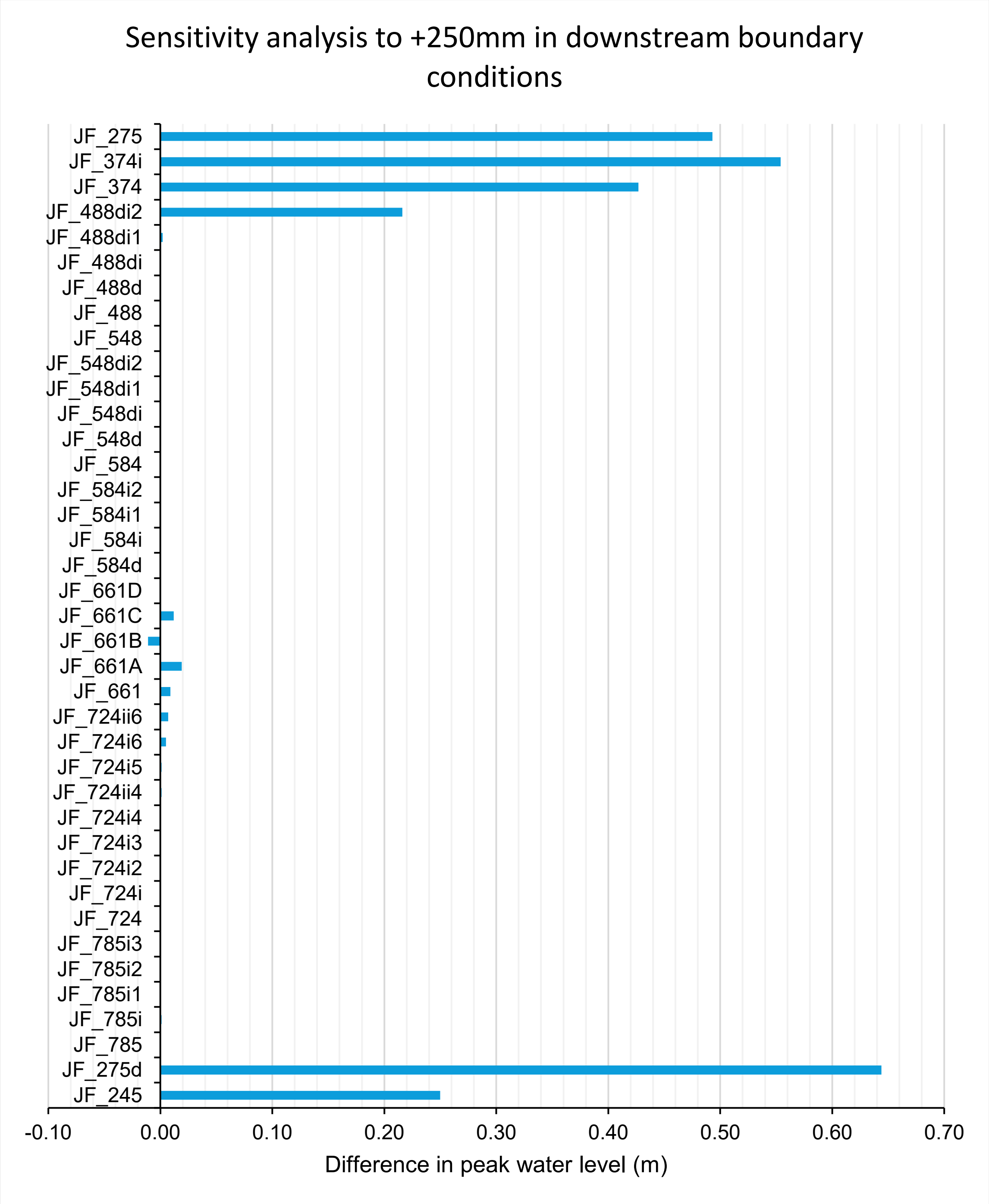


Figure E 3.1 indicates that the maximum increase in peak water level at the downstream boundary is 640mm, linking to node JF_275d. Near the site boundary (JF_661), minimum change has been seen due to the increase in the downstream boundary. The site does not flood from the 250mm increase and it is deemed that the channel is sensitive whereas the site is insensitive to change.

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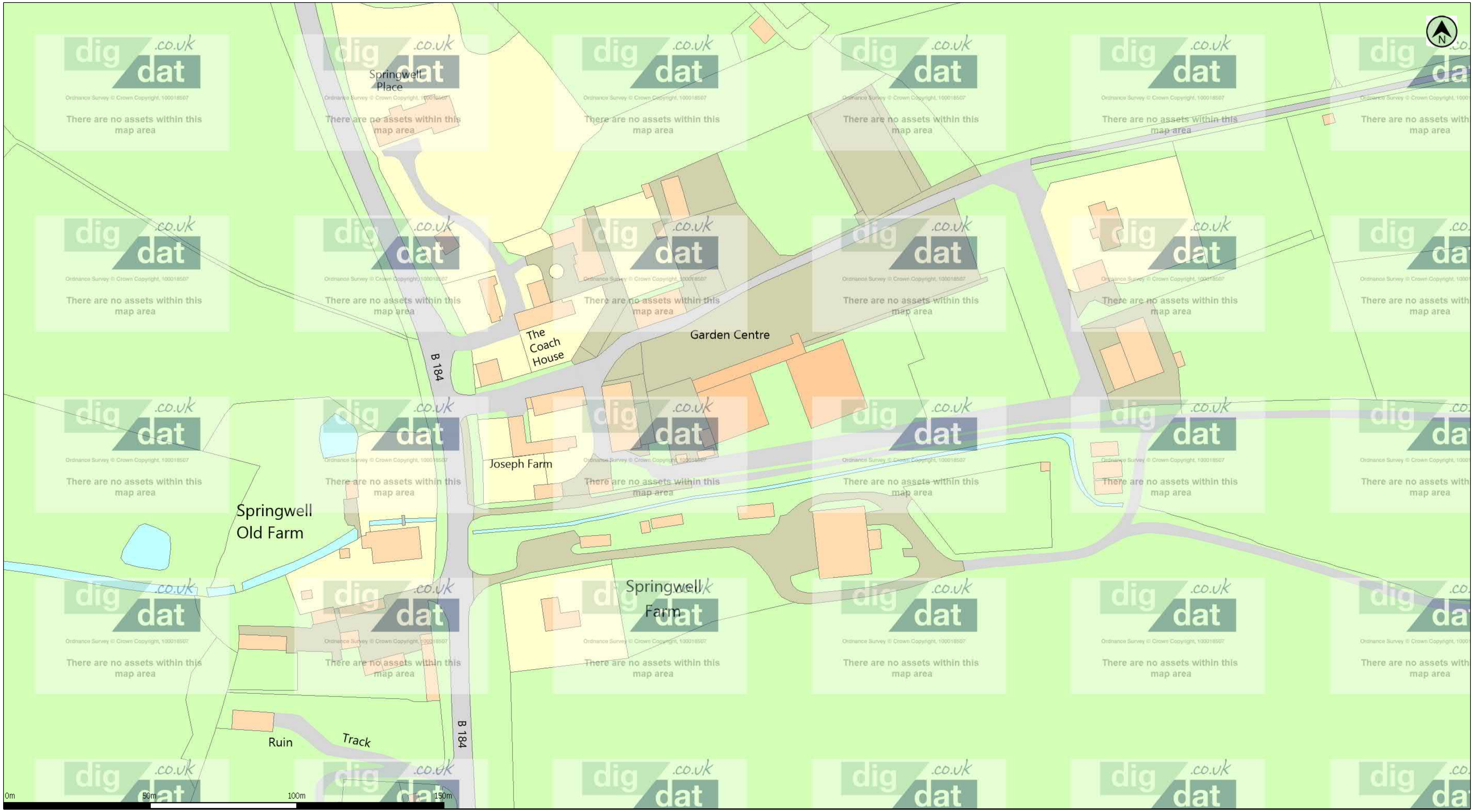
Appendix C – Anglian Water

Wastewater Plan A3 ref: 573813 – 1



(c) Crown copyright and database rights 2021 Ordnance Survey 100022432 | Date: 08/06/21 | Scale: 1:1250 | Map Centre: 552103,241120 | Data updated: 31/05/21 | Our Ref: 573813 - 1 | Wastewater Plan A3

Foul Sewer
Surface Sewer
Combined Sewer
Final Effluent
Rising Main*
Private Sewer*
Decommissioned Sewer*

Outfall*
Inlet*
Manhole*

Sewage Treatment Works
Public Pumping Station
Decommissioned Pumping Station

*(Colour denotes effluent type)

beverley.hunter@mlm.uk.com

65202774

love every drop
anglianwater

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Manhole Reference	Liquid Type	Cover Level	Invert Level	Depth to Invert

Appendix D – Drainage Strategy

Brownfield calculations

Greenfield calculations

Sweco drawing 65202774-SWE-ZZ-XX-DR-C-0110 – Surface & Foul Water Drainage Strategy

MicroDrainage calculations

Klargester AquaTreat SWT030 Design Data Sheet

Ref.	Calculation	Output

1. Brownfield Run-off Calculation

Based on the Modified Rational Method the current discharge rate from the site for the 100%, 3.3% and 1% annual exceedance probability (AEP) events (1, 30 & 100 year) can be calculated as:

Q = 3.61 CiA

C = Volumetric run-off co-efficient	0.9	
i = Rainfall intensity	see below	mm / hr
A = Contributing Area	0.257	ha

Rainfall intensity taken from MicroDrainage Rainfall Generator

100%	32.084	mm / hr
3.3%	78.760	mm / hr
1%	102.344	mm / hr

Discharge rate

100%	26.790	l / s
3.3%	65.764	l / s
1%	85.457	l / s

ICP SUDS Mean Annual Flood

Input

Return Period (years)	100	Soil	0.150
Area (ha)	0.267	Urban	0.000
SAAR (mm)	600	Region Number	Region 5

Results	**l/s**
QBAR Rural	0.1
QBAR Urban	0.1
Q100 years	0.3
Q1 year	0.1
Q30 years	0.2
Q100 years	0.3