D Topography

D.1 Topographic survey

TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

AH	Arch Head Height	ER	Earth Rod	RSD	Roller Shutter Door
A/B	Air Brick	ET	EP+Transformer	RSJ	Rolled Steel Joist
AR	Assumed Route	FB	Flower Bed	SI	Sign Post
AV	Air Valve	FBD	Floor Board Direction	SP	Arch Spring Point Height
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BO	Bollard	FW	Foul Water	Tac	Tactile Paving
BrP	Brace Post	GG	Gully Grate	TC	Telecom Cover
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BU	Bush	HH	Head Height	THL	Threshold Level
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C/B	Close Board Fence	I/R	Iron Railings	TP	Telegraph Pole
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C/P	Chestnut Paling Fence	OHL	Overhead Line (approx)	UMG	Unmade Ground
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SURVEY CONTROL CO-ORDINATES

STATIONS	EASTINGS	NORTHINGS	LEVEL	DESCRIPTION
ST01	624558.853	306904.258	3.457	PK Nail
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REV	DESCRIPTION	DRAWN	APPR	DATE

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LAND SURVEYING
BUILDING SURVEYING
UNDERGROUND SURVEYING
SITE ENGINEERING
MONITORING

0845 040 5969
survey-solutions.co.uk

IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 1 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-01			REVISION	ISSUE DATE 29.07.22

ISO 9001 REGISTERED FIRM · RICS · chartered ices · THE SURVEY ASSOCIATION

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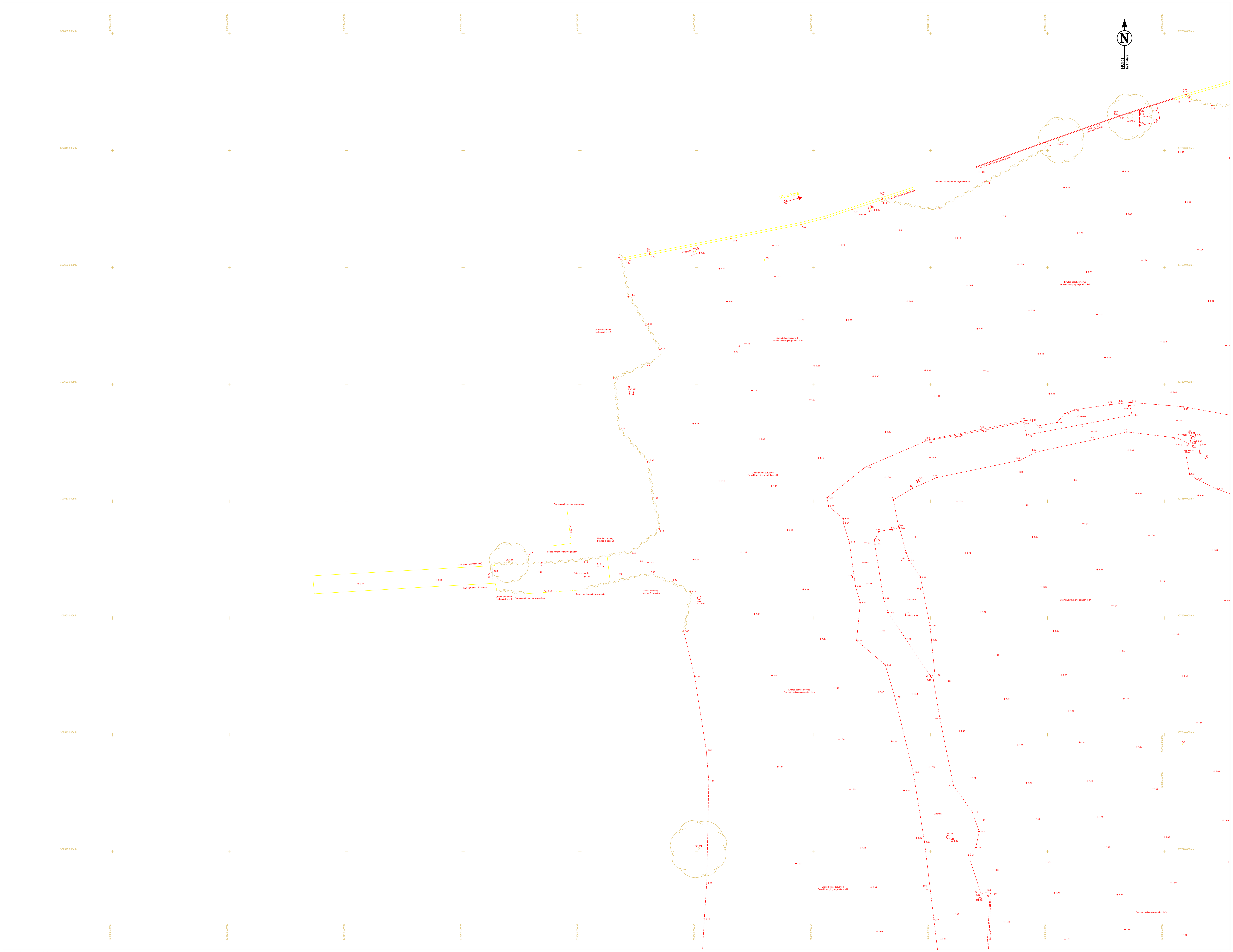
Original Sheet Size A0H



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PROJECT TITLE
LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 2 of 11

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HOPKINS HOMES				1:200
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JHS/AK/AH	18.07.2022	DWB	JLH	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
42887IPLS-02				29.07.22

ISO 9001 REGISTERED FIRM
RICS
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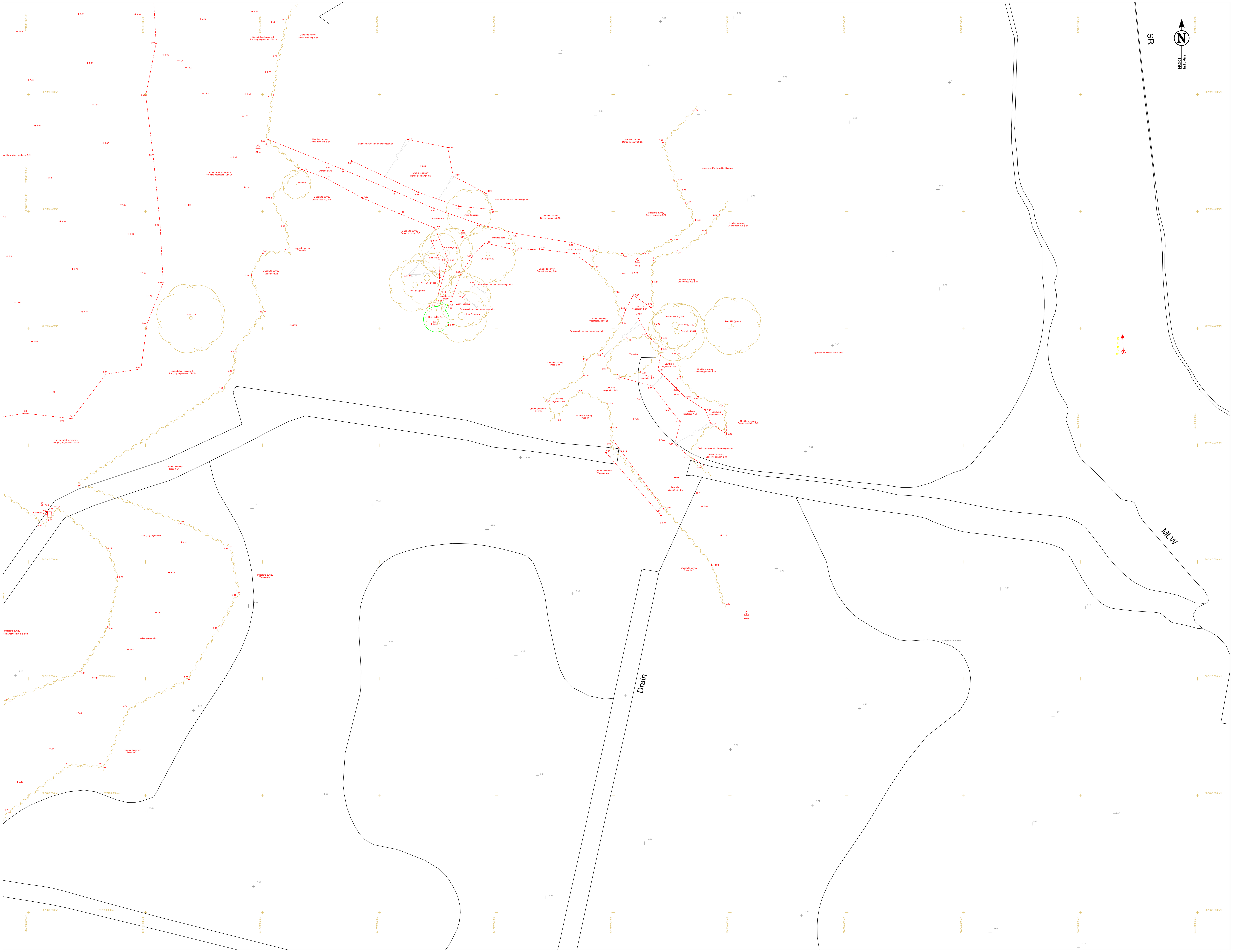

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Sheet 3 of 11

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ST15	624616.048	307391.549	2.127	PK Nail
ST16	624719.249	307511.018	1.951	Peg & Nail
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EABM	624422.625	306963.273	4.474	

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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 4 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-04			REVISION	ISSUE DATE 29.07.22

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TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

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A/B	Air Brick	ET	EP+Transformer	RSJ	Rolled Steel Joist
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BrP	Brace Post	GG	Gully Grate	TC	Telecom Cover
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BU	Bush	HH	Head Height	THL	Threshold Level
B/W	Barbed Wire Fence	IC	Inspection Cover	TL	Traffic Light
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CL	Cover Level	LP	Lamp Post	TV	Cable TV Cover
C/L	Chain Link Fence	MH	Manhole	UB	Universal Beam
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Col	Column	NB	Name Board	UK	Unknown Tree
C/P	Chestnut Paling Fence	OHL	Overhead Line (approx)	UMG	Unmade Ground
CR	Cable Riser	Pan	Panel Fence	USB	Under Side Beam
C/W	Chicken Wire	PB	Post Box	UTL	Unable To Lift
DC	Drainage Channel	PM	Parking Meter	UTS	Unable To Survey
DH	Door Head Height	PO	Post	VP	Vent Pipe
Dil.	Dilapidated	P/R	Post & Rail Fence	WB	Waste Bin
DP	Down Pipe	P/W	Post & Wire Fence	WH	Weep Hole
DR	Drain	P/Wall	Partition Wall	WL	Water Level
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DRAWING NOTES

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REV	DESCRIPTION	DRAWN	APPR	DATE

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LAND SURVEYING
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SITE ENGINEERING
MONITORING

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 5 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-05			REVISION	ISSUE DATE 29.07.22

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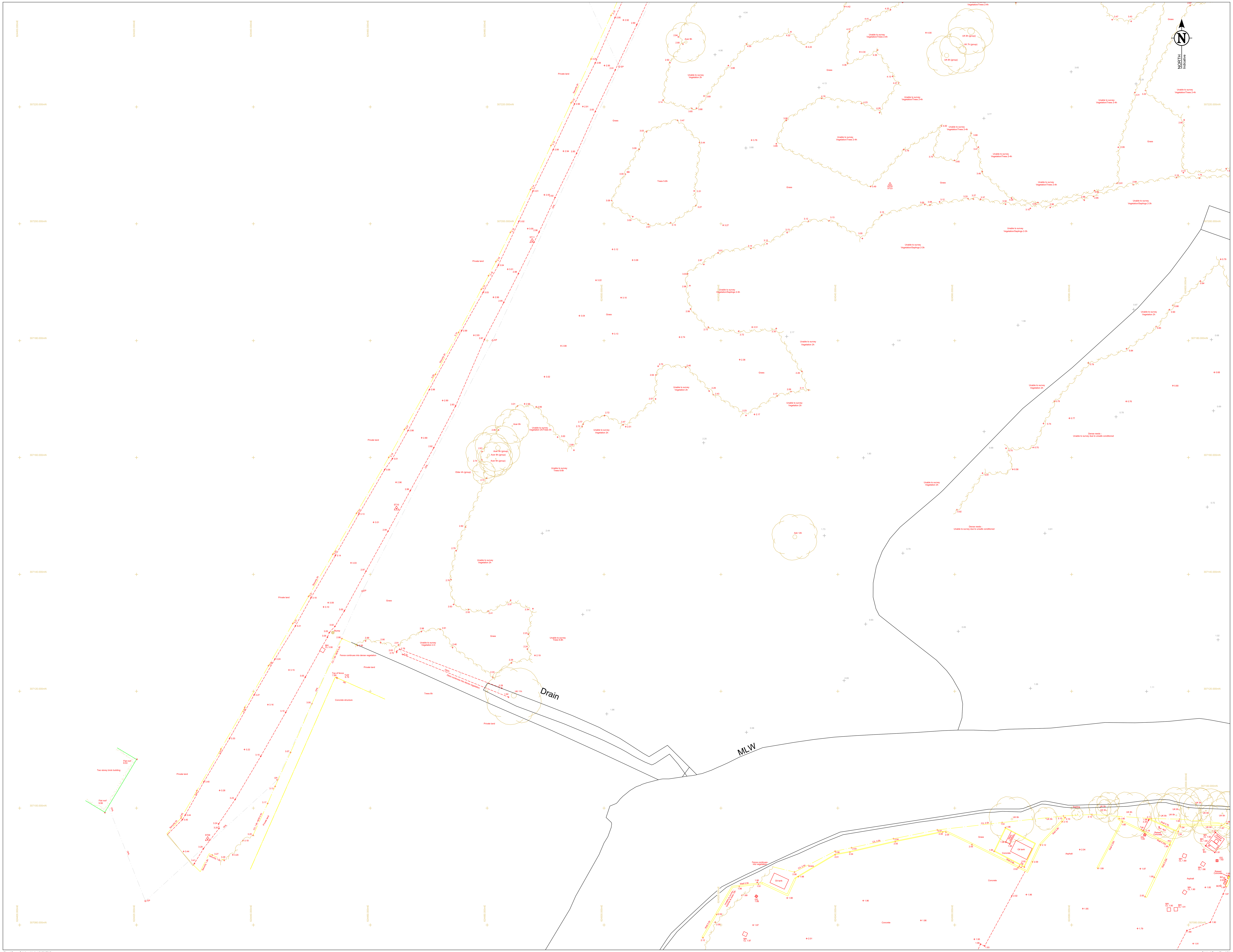

TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE				
LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL: TOPOGRAPHICAL SURVEY Sheet 6 of 11				
CLIENT: HOPKINS HOMES				SCALE: 1:200
SURVEYOR: JHS/AK/AH	SURVEY DATE: 18.07.2022	CHECKED BY: DWB	APPROVED BY: JLH	DWG STATUS: FINAL
DRAWING NUMBER: 42887IPLS-06			REVISION:	ISSUE DATE: 29.07.22

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TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

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A/B	Air Brick	ET	EP+Transformer	RSJ	Rolled Steel Joist
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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 7 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-07			REVISION	ISSUE DATE 29.07.22

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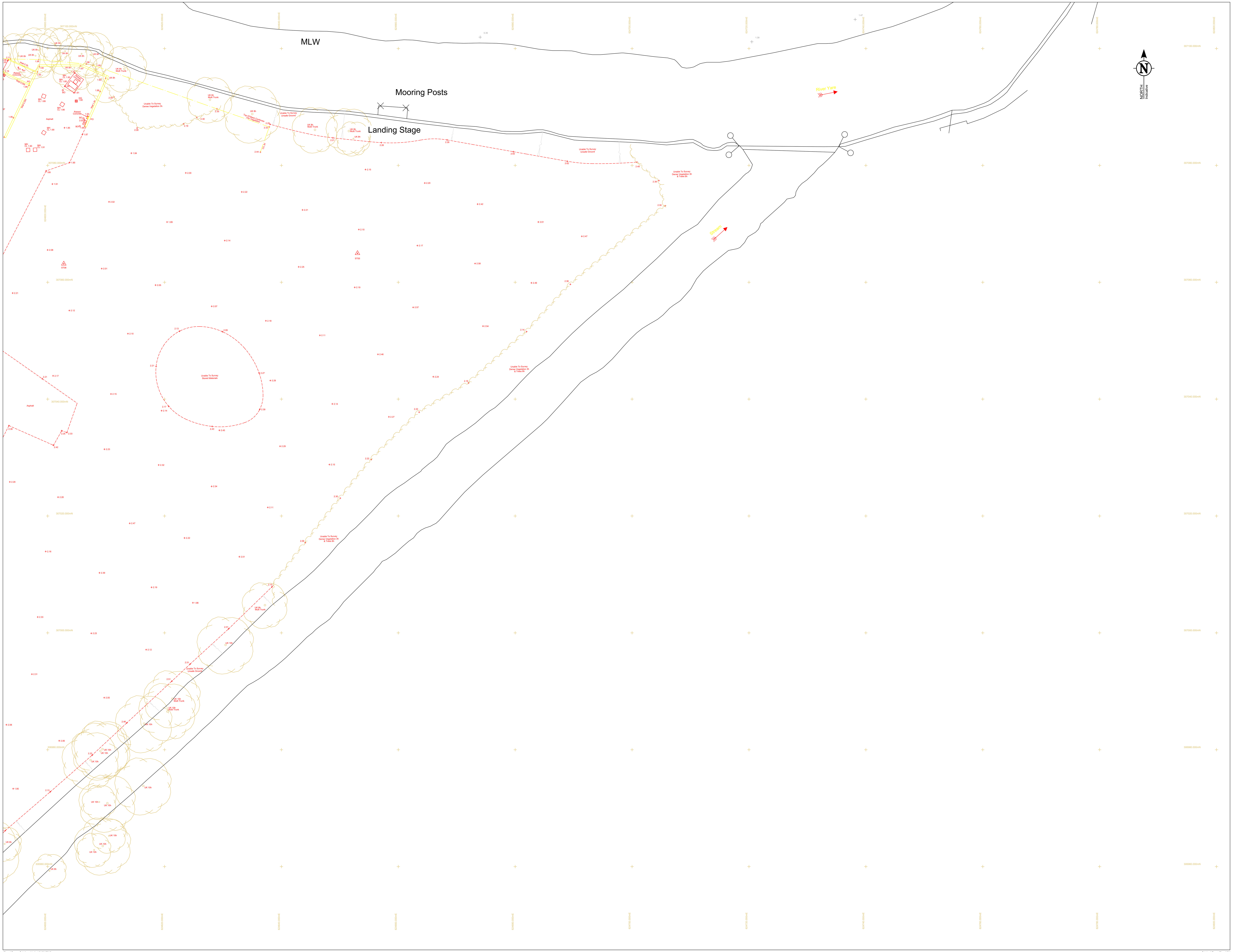

TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

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SURVEY CONTROL CO-ORDINATES

STATIONS	EASTINGS	NORTHINGS	LEVEL	DESCRIPTION
ST01	624558.853	306904.258	3.457	PK Nail
ST02	624517.568	306926.067	3.037	PK Nail
ST03	624430.360	306959.194	4.026	PK Nail
ST04	624553.819	307029.937	2.242	PK Nail
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ST26	624810.413	307621.133	2.116	PK Nail
EABM	624422.625	306963.273	4.474	

SURVEY GRID AND LEVEL DATUM

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REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

LAND SURVEYING
BUILDING SURVEYING
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SITE ENGINEERING
MONITORING

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 8 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-08			REVISION	ISSUE DATE 29.07.22

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Original Sheet Size A0H

TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

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SURVEY SOLUTIONS

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE
LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 9 of 11

CLIENT				SCALE
HOPKINS HOMES				1:200
SURVEYOR	SURVEY DATE	CHECKED BY	APPROVED BY	DWG STATUS
JHS/AK/AH	18.07.2022	DWB	JLH	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
42887IPLS-09				29.07.22

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Original Sheet Size A0H

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BUILDING SURVEYING
UNDERGROUND SURVEYING
SITE ENGINEERING
MONITORING

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE
LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 10 of 11

CLIENT				SCALE
HOPKINS HOMES				1:200
SURVEYOR	SURVEY DATE	CHECKED BY	APPROVED BY	DWG STATUS
JHS/AK/AH	18.07.2022	DWB	JLH	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
42887IPLS-10				29.07.22

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Original Sheet Size A0H

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IPSWICH BRENTWOOD COVENTRY GLASGOW NORWICH NOTTINGHAM YEOVIL

PROJECT TITLE LAND AT DEAL GROUND, A147, NORWICH, NORFOLK, NR1 2BF.				
DRAWING DETAIL TOPOGRAPHICAL SURVEY Sheet 11 of 11				
CLIENT HOPKINS HOMES				SCALE 1:200
SURVEYOR JHS/AK/AH	SURVEY DATE 18.07.2022	CHECKED BY DWB	APPROVED BY JLH	DWG STATUS FINAL
DRAWING NUMBER 42887IPLS-11			REVISION	ISSUE DATE 29.07.22

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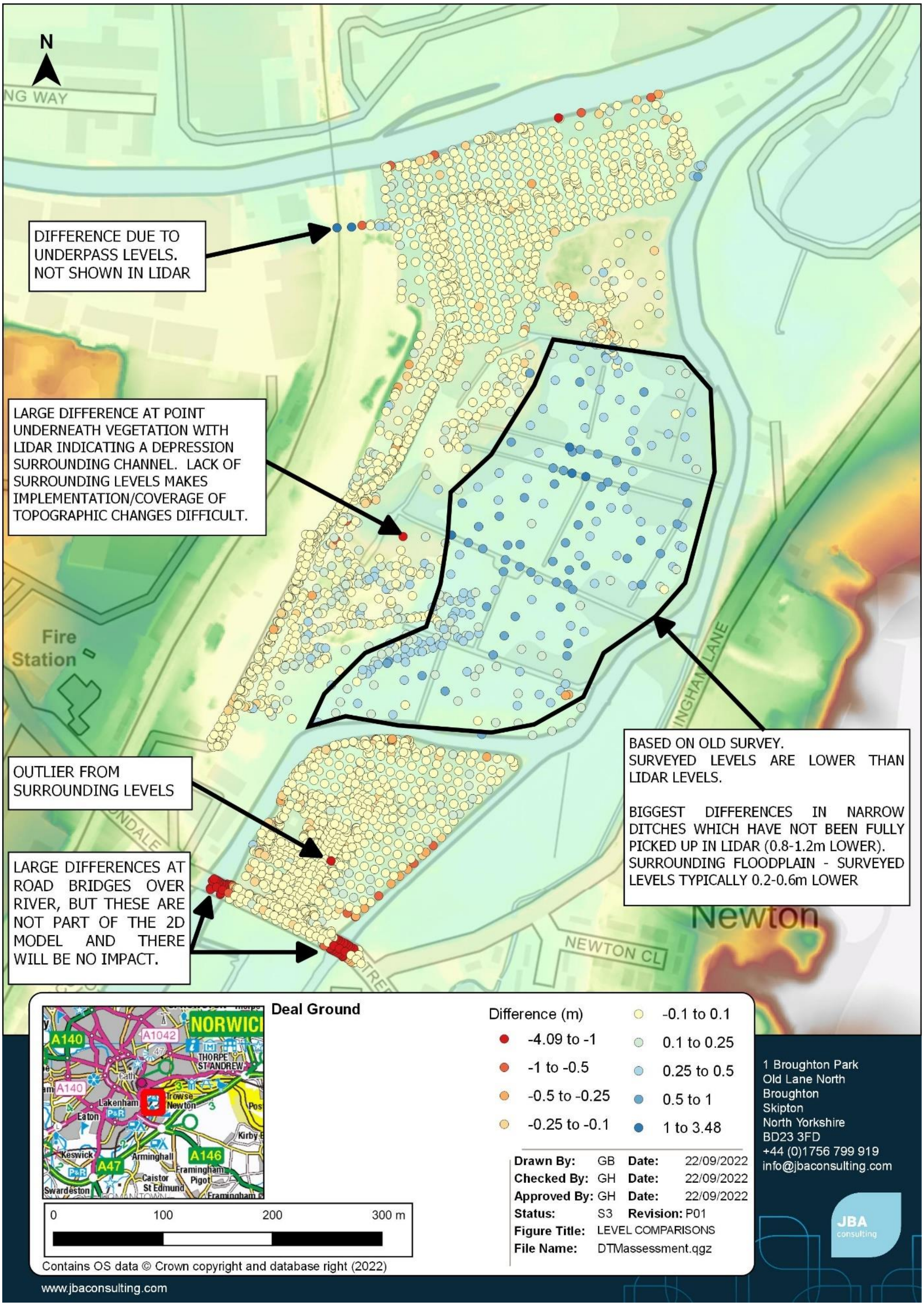
THE SURVEY ASSOCIATION

D.2 LiDAR Comparison



E Consultation Response

E.1 LLFA

Norfolk County Council

Community and Environmental Services
County Hall
Martineau Lane
Norwich
NR1 2SG

via e-mail
Blanaid Skipper
Planning Section
South Norfolk Council
Thorpe Lodge
1 Yarmouth Road
Norwich
NR7 0DU

NCC contact number: 0344 800 8020
Textphone: 0344 800 8011

CC: Cllr Vic Thomson

Your Ref:	23/0517	My Ref:	FW2023_0221
Date:	30 March 2023	Tel No.:	0344 800 8020
NCC Member: Cllr Vic Thomson		Email:	llfa@norfolk.gov.uk

Dear Ms Skipper,

Town and Country Planning (Development Management Procedure) (England) Order 2015

Details of Condition 10: design code of previous permission 2011/0152/O at The Deal Ground And Former May Gurney Site The Street Trowse Norfolk

Thank you for your consultation on the above site, received on 9 March 2023. We have reviewed the request as submitted and wish to make the following comments:

This is a discharge of conditions application. The applicant is requesting to discharge condition 10 of planning application 2011/0152/O. Condition 10 is worded as follows:

> *"Prior to the submission of any reserved matters application relating to Wensum Riverside character area, a detailed design code for that area shall be submitted to the local planning authority and approved in writing. The design code shall include the following information:*
>
> a) *frontage principles, including the set back of properties from the road, division of public and private space and boundary treatments;*
>
> b) *building heights and built form including approach to roofscape;*
>
> c) *approach to parking location and layout;*
>
> d) *landscaping strategy for external areas (private / communal gardens; streets; parking areas; public realm and riverside) including palette of materials to be used in the external surfaces;*
>
> e) *approach to the multi-functional use of the Wensum riverside frontage, including the provision of 2m wide (minimum width) pedestrian access for uninhibited public use;*

f) palette of materials for buildings;

g) architectural treatment (including details of openings and materials) of building elevations at street-level;

h) approach to the integration of sustainability measures within the building design.

The design code shall conform with the parameters approved at outline stage. All reserved matters applications relating to Wensum Riverside shall comply with the approved design code.

Reason for condition
To ensure a consistent approach to the design of the river frontage in the interests of the visual appearance of the site and to accord with the NPPF and Policy 2 of the adopted Joint Core Strategy for Broadland, Norwich and South Norfolk."

This assessment of flood risk has only focused on fluvial flood risk. There is no consideration of Surface water flood risk or groundwater flood risk. The LLFA notes the applicant intends on building up the ground levels for constructing the development. Therefore, it is likely the development platform will be compacted and could result in landscaped areas being sited in a heavily compacted base. This would alter the existing permeable nature of the site in these areas. Therefore, the LLFA would expect the development platform area to treated as a wholly impermeable area for the development of SuDS design for the proposed development.

At present, the current design code is inconsistent as to in where SuDS (including viable attenuation features) would be positioned or how they would be included in the proposed design. This inconsistency is shown throughout the document, however examples of it are discussed in the following sections to illustrate our concerns. In section 4 on Movement, SuDS are not mentioned in the first five sub-sections including in the active travel section and yet, throughout the remains of the document, there are indications that potentially SuDS would be integrated with the active travel and highways provisions. Once into section 4.6, there is an indication of surface level SuDS being included in the proposed highway and footpath network under the boundary treatment section in the sketches. However, there is no indication of where these features will drain to.

The LLFA note that a swale / verge is identified in Boundary 2, while in Boundary 3 tree pits and permeable paving is indicated and Boundaries 1, and 4 to 8 there are no SuDS features indicated. Furthermore, planting is only indicated rarely and is shown to be used as a road separators rather than rain gardens or tree pits.

While in section 8, there are a number of sketches that indicate the inclusion of swales on secondary streets (including the main spine road), however the proposals offering for streetside SuDS on local streets is much more limited. In all the typical street scenes the commitment to SuDS is inconsistent and lacks supporting information that is consistent with other sections of the design code.

In section 5, the applicant indicates the use of blue green infrastructure is to be located in areas already identified as being at flood risk. The LLFA reminds the applicant that additional surface water attenuation for the surface water runoff will need to be provided outside of the existing flood extents and without loss of storage due to existing flood risk from all sources (including surface water and groundwater). As the LLFA previously mentioned, the Design Code has not presented any consideration of other sources of flood risk, which is not in accordance with NPPF requirements.

The LLFA notes on pages 51-52, we were unable to observe any obvious inclusions of roadside SuDS that were previously indicated in section 4. While on page 54, there is a sustainable drainage street scene photograph included along with the generic reference to sustainable drainage in the Ecology and recreation paragraphs. Rain gardens are mentions for the first time to be added to the street scene, however these were not included in the boundary treatments and typical road layout sections. The LLFA would expect a design code to contain consistent information pertaining to the design approach, which, at the moment, we believe it does not.

In section 5.7, the applicant presents their Water Strategy as one that includes SuDS features and identifies possible locations within the northern area of the proposed development. This is welcomed, although it remains unclear if there is a viable sustainable drainage design at this time as there is no overall plan presented in the Design Code unlike the many other topics.

In section 5.8 on Flood Risk, the LLFA has considers that the applicant's approach to parking as inappropriate. The LLFA is aware of the Table 3 definition of "Car Parks" as "less vulnerable". The LLFA considers "car parks" to mean large public car parks. However, in the context of the proposed car parking for the proposed development, the parking is associated with the residential properties as there are no public car parks and only some on street parking. This is supported by the information provided in section 4.9. Therefore, classification of the plot should be on the most vulnerable use. The LLFA considers the proposed car parking as part of the residential development, which would classify the car parking in the **more vulnerable** development class, resulting in the requirement for the car parking to be set above a 1% AEP plus climate change level. The areas of communal car parking are also associated with residential development. There are a few areas where onsite parking is provided, however as the streets are part of the safe access and egress routes these areas are also required to be above the 1% AEP plus climate change level.

In Section 5.9 the applicant considers the inclusion of sustainable drainage into the proposed development. The information provided is just an explanation of the high level principle of SuDS. There is an indication that SuDS are to be included, however there is no plan that specifically indicates where different SuDS features are proposed to be included in this section. The LLFA notes that when reviewing other sections of the design code, there are some mentions of SuDS, but again, not firm commitment or indication of where the SuDS will be placed and where space has been provided for SuDS within the proposed design. The LLFA considers there to be a **significant lack of information** associated with sustainable surface water management. Later in section 11.4 there is an indication of including roadside swales and the swale design require, yet there continues to be no confirmation about where the swales will be included.

The LLFA notes that in sections 4 and 5 there were indications that green roofs have been considered for inclusion. However, there is no clear commitment to where these green roofs will be located or that they are to be included in section 7.10 on the future roofscapes. There are no examples of green roofs included. There is an acknowledgement that the roofs will be generally pitched for the houses (Section 7.11). While in section 11.4, the applicant has indicated that "Flat roof areas should incorporate planting where possible" but again, no further commitment or detail is provided.

The LLFA notes that in section 11.2 there is mention of water reuse opportunities although the commitment is limited. The applicant is indicating the inclusion of water butts on all houses to irrigate gardens and that rainwater harvesting may be considered for larger buildings, but may not be considered acceptable by management companies. This lack of commitment to sustainable water management for a water sensitive development is concerning. The LLFA notes the applicant is keen to have large public / communal garden spaces and also acknowledges the benefit of possibly including water butts for householders to irrigate their gardens. However, the LLFA note that the applicant considers rainwater harvesting for the irrigation of the public, communal gardens and newly planted trees should be down to the convenience of the management company and most likely using a potable water supply. The LLFA would expect full consideration of the water reuse opportunities in accordance with the LLFA's Developer Guidance.

It is not clear at this time whether any flood storage compensation is required and if so where it is proposed to be provided. This information would be helpful to inform the LLFA's and others understanding of the proposed development's water sensitive approach.

The LLFA was unable to find any information on the applicant's proposed strategy or provision for the nutrient neutrality requirements within the design code. Therefore, it is not possible at this time to determine whether a suitable amount of space remains available for the management of surface water in addition to the nutrient neutrality requirements.

We are therefore **unable to recommend that the condition is discharged** at this time as the design code is unable to provide suitable information to demonstrate

"h) *approach to the integration of sustainability measures within the building design*."

The LLFA requires the Design Code to have suitable amendments applied to address our concerns raised before we are able to support the discharge of this condition.

Further guidance on the information required by the LLFA from applicants can be found at https://www.norfolk.gov.uk/rubbish-recycling-and-planning/flood-and-water-management/information-for-developers.

If you, the Local Planning Authority review and determine this application you should notify us, the Lead Local Flood Authority, by email at llfa@norfolk.gov.uk. Alternatively, if further information is submitted, we request we are re-consulted and we will aim to provide bespoke comments within 21 days of the formal consultation date.

We would like to highlight that Flood Re insurance is not available for houses built after 1 January 2009. This is to ensure that the risks of flooding are appropriately considered and mitigated at the planning stage. Thus, new developments are subject to risk reflective pricing, meaning those built without due consideration of flood risk may struggle to access affordable insurance. We advise the applicant that they fully consider the potential available finance and insurance for the future owners and / or tenants of the proposed dwellings.

Yours sincerely,

Sarah

Sarah Luff
Strategic Flood Risk Planning Officer
Lead Local Flood Authority

Disclaimer
We have relied on the accuracy and completeness of the information supplied to us in providing the above advice and can take no responsibility for incorrect data or interpretation, or omissions, in such information. If we have not referred to a particular issue in our response, it should not be assumed that there is no impact associated with that issue.

Norfolk County Council
Community and Environmental Services
County Hall
Martineau Lane
Norwich
NR1 2SG

via e-mail
Sarah Hinchcliffe
Planning Services
Norwich City Council
City Hall
Norwich
NR2 1NH

NCC contact number: 0344 800 8020
Textphone: 0344 800 8011

CC: Cllr Vic Thomson

Your Ref: 23/00261
Date: 30 March 2023
NCC Member: Cllr Ben Price

My Ref: FW2023_0224
Tel No.: 0344 800 8020
Email: llfa@norfolk.gov.uk

Dear Ms Hinchcliffe,

Town and Country Planning (Development Management Procedure) (England) Order 2015

Details of Condition 13: design code of previous permission 12/00875/O at The Deal Ground And Former May Gurney Site The Street Trowse Norfolk

Thank you for your consultation on the above site, received on 9 March 2023. We have reviewed the request as submitted and wish to make the following comments:

This is a discharge of conditions application. The applicant is requesting to discharge condition 13 of planning application 12/00875/O. Condition 13 is worded as follows:

> *“Prior to the submission of any reserved matters application relating to Wensum Riverside character area, a detailed design code for that area shall be submitted to the local planning authority and approved in writing. The design code shall include the following information:*
>
> *a) frontage principles, including the set back of properties from the road, division of public and private space and boundary treatments;*
>
> *b) building heights and built form including approach to roofscape;*
>
> *c) approach to parking location and layout;*
>
> *d) landscaping strategy for external areas (private / communal gardens; streets; parking areas; public realm and riverside) including palette of materials to be used in the external surfaces;*
>
> *e) approach to the multi-functional use of the Wensum riverside frontage, including the provision of 2m wide (minimum width) pedestrian access for uninhibited public use;*
>
> *f) palette of materials for buildings;*

g) architectural treatment (including details of openings and materials) of building elevations at street-level;

h) approach to the integration of sustainability measures within the building design.

The design code shall conform with the parameters approved at outline stage. All reserved matters applications relating to Wensum Riverside shall comply with the approved design code".

This assessment of flood risk has only focused on fluvial flood risk. There is no consideration of Surface water flood risk or groundwater flood risk. The LLFA notes the applicant intends on building up the ground levels for constructing the development. Therefore, it is likely the development platform will be compacted and could result in landscaped areas being sited in a heavily compacted base. This would alter the existing permeable nature of the site in these areas. Therefore, the LLFA would expect the development platform area to treated as a wholly impermeable area for the development of SuDS design for the proposed development.

At present, the current design code is inconsistent as to in where SuDS (including viable attenuation features) would be positioned or how they would be included in the proposed design. This inconsistency is shown throughout the document, however examples of it are discussed in the following sections to illustrate our concerns. In section 4 on Movement, SuDS are not mentioned in the first five sub-sections including in the active travel section and yet, throughout the remains of the document, there are indications that potentially SuDS would be integrated with the active travel and highways provisions. Once into section 4.6, there is an indication of surface level SuDS being included in the proposed highway and footpath network under the boundary treatment section in the sketches. However, there is no indication of where these features will drain to.

The LLFA note that a swale / verge is identified in Boundary 2, while in Boundary 3 tree pits and permeable paving is indicated and Boundaries 1, and 4 to 8 there are no SuDS features indicated. Furthermore, planting is only indicated rarely and is shown to be used as a road separators rather than rain gardens or tree pits.

While in section 8, there are a number of sketches that indicate the inclusion of swales on secondary streets (including the main spine road), however the proposals offering for streetside SuDS on local streets is much more limited. In all the typical street scenes the commitment to SuDS is inconsistent and lacks supporting information that is consistent with other sections of the design code.

In section 5, the applicant indicates the use of blue green infrastructure is to be located in areas already identified as being at flood risk. The LLFA reminds the applicant that additional surface water attenuation for the surface water runoff will need to be provided outside of the existing flood extents and without loss of storage due to existing flood risk from all sources (including surface water and groundwater). As the LLFA previously mentioned, the Design Code has not presented any consideration of other sources of flood risk, which is not in accordance with NPPF requirements.

The LLFA notes on pages 51-52, we were unable to observe any obvious inclusions of roadside SuDS that were previously indicated in section 4. While on page 54, there is a sustainable drainage street scene photograph included along with the generic reference to sustainable drainage in the Ecology and recreation paragraphs. Rain gardens are mentions for the first time to be added to the street scene, however these were not included in the boundary treatments and typical road layout sections. The LLFA would expect a design code to contain consistent information pertaining to the design approach, which, at the moment, we believe it does not.

In section 5.7, the applicant presents their Water Strategy as one that includes SuDS features and identifies possible locations within the northern area of the proposed development. This is welcomed, although it remains unclear if there is a viable sustainable drainage design at this time as there is no overall plan presented in the Design Code unlike the many other topics.

In section 5.8 on Flood Risk, the LLFA has considers that the applicant's approach to parking as inappropriate. The LLFA is aware of the Table 3 definition of "Car Parks" as "less vulnerable". The LLFA considers "car parks" to mean large public car parks. However, in the context of the proposed car parking for the proposed development, the parking is associated with the residential properties as there are no public car parks and only some on street parking. This is supported by the information provided in section 4.9. Therefore, classification of the plot should be on the most vulnerable use. The LLFA considers the proposed car parking as part of the residential development, which would classify the car parking in the **more vulnerable** development class, resulting in the requirement for the car parking to be set above a 1% AEP plus climate change level. The areas of communal car parking are also associated with residential development. There are a few areas where onsite parking is provided, however as the streets are part of the safe access and egress routes these areas are also required to be above the 1% AEP plus climate change level.

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Yours sincerely,

Sarah

Sarah Luff

Strategic Flood Risk Planning Officer
Lead Local Flood Authority

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RECORD OF MEETING

JBA Project Code	2023s0187
Contract	Deal Ground
Client	Serruys Property Company Limited
Day, Date and Time	11 April 2023 at 13:00
Meeting	Surface water drainage strategy
Venue	MSTeams

ATTENDING	Akis Chrisovelides (Serruys Property Limited)	AC
	Rob Barker (Stolon Studio - Architect)	RB
	Matt Hill (Maddox - Planning)	MH
	Reagan Laidlaw (Stolon Studio - Architect)	RL
	Dylan Kerni (Maddox - Planning)	DK
	Sarah Luff (NCC as LLFA)	SL
	Dean Shelton (NCC as LLFA)	DS
	Gavin Hodson (JBA)	GH
	Stuart Harwood (JBA)	SH

1 Background and Context

GH explained that the purpose of the meeting was to present details of the surface water drainage strategy ‘concept’ and agree the design principles and parameters to be adopted for the purposes of developing the strategy in further detail (i.e. as required to support reserved matters applications).

RB provided an overview of the redevelopment proposals, confirming that Outline planning permission was secured in 2013 for up to 670 residential units and commercial/retail uses, including food outlets.

SL queried whether the proposals comprised a departure from the wider ENSRA strategy/plan. AC explained that the intention was to ‘lock-in’ the scheme as per the current masterplan, but a developer may of course elect to revise the current proposals in accordance with the ENSRA SPD.

RB confirmed that development/design principles were set out pre-ENSRA, but the intention is to embrace and embed ENSRA principles as part of reserved matters applications.

RB and AC noted that the current masterplan is ‘landscape-led’ and centred upon protecting and enhancing the marsh environment, ‘making space’ for water and providing north-south and east-west connectivity for future planned development.

GH provided an overview of the flood modelling used to inform scheme design, resulting in a development platform at a level of 2.7mAOD (600mm above the 100yr plus climate change flood level). GH noted that the modelling analysis was based upon a revised and updated version of the EA’s latest Norwich 1D-2D hydraulic model and that JBA was in discussion with the EA regarding review/approval of the modelling analysis.

It was noted that the surface water drainage strategy that supported the consented 2013 scheme did not meet current standards/requirements (i.e. in terms of SuDS, integrated blue-green space, water treatment, etc). The 2013 strategy was based entirely upon below ground storage, a pumped solution and brownfield run-off rates minus 30%. The 2023 solution proposes gravity drainage, that surface water outflows will be limited to greenfield rates and the use of ‘green’ space SuDS, supplemented by permeable paving and geo-cellular storage.

2 Highway Drainage (adoptable)

GH explained that the spine road and Wensum 'loop' are to be adopted by NCC, thereby necessitating a surface water drainage system that is separate from the system serving any unadopted/private areas. Based upon NCC Design Standards (requiring that surface water outfalls are set above the 1 in 10yr flood level) and a development platform set at 2.7mAOD, the vertical 'envelope' for incorporating the surface water drainage solution is rather limited at c.1.1m. The preferred solution for drainage of the 'loop' road and length of spine road extending south adjacent to Fen Village comprises a linear SuDS feature within the landscape buffer located immediately to the west of the spine road. This would provide surface water storage (i.e. such that outflows could be limited to greenfield rates) and could also incorporate a number of broader wetland/marsh features to provide enhanced water treatment. The 'loop' road would discharge surface water run-off to the head of the linear SuDS feature via a Beany Block combined kerb and drainage system (an industry-standard solution for flat areas characterised by limited fall to the point of outfall). Street-scene SuDS features, such as tree pits and raingardens, could be incorporated to supplement the storage and treatment provided by the linear feature.

The access/spine road passing through the Yare Newton area would also drain, via a Beany Block combined kerb and drainage system, to a linear SuDS feature aligned along the northern edge of the development and outfalling to the River Yare at greenfield rates.

SL requested that information regarding groundwater levels was provided. SL also highlighted that design of the drainage solution should consider potential interaction with groundwater and also demonstrate how the capacity of drainage/surface water storage measures would be secured (i.e. so that it is available when needed).

GH explained that the majority of surface water storage would be provided above the 100yr plus climate change flood level.

3 Wensum Edge

GH highlighted the landscape components of the masterplan, comprising a riverside path and a central (north-south) green corridor that 'makes space' for the existing flood flow mechanism between the Wensum and Yare and also incorporates play areas.

GH explained that surface water run-off would be limited to greenfield rates using a combination of green roofs, permeable paving and geo-cellular storage, alongside street-scene SuDS (tree-pits and raingarden features). Water treatment would be provided by the source control measures, supplemented by routing run-off through the landscaped, central green corridor, comprising marsh habitat.

GH noted that the drainage strategy would aim to provide two levels of water treatment. SL welcomed the aspiration and suggested that the design team used the CIRIA Simple Index Approach to determine the 'pollution hazard index' for the area being drained and the 'pollution mitigation index' of the proposed SuDS measures (i.e. to determine whether sufficient pollution mitigation is provided). SL commented that in general (i.e. residential areas), one level of water treatment would suffice.

SL noted that JBA's 'Wensum Edge SuDS appraisal' tables appeared to exclude education opportunities and suggested that engagement on water management themes should be embedded within the scheme (i.e. by raising awareness of the SuDS measures and the role they play in flood risk management). SL also noted that on the theme of water re-use, the tables only noted water butts. SL encouraged wider use of rainwater harvesting for the purposes of irrigating the landscaped areas and for 'wash down' in bin store areas.

4 Fen Village

GH explained that the drainage solution for Fen Village places an emphasis on multi-functional, blue-green spaces and creating a strong but sympathetic interface between the development and the marshland environment (development blocks being framed around 'green fingers' that bring the marsh into the fabric of the development). Surface water outflows to the River Yare will be limited to greenfield rates.

GH explained that surface water management would comprise (i) roof water being drained into the landscaped, multi-functional 'green fingers' and (ii) permeable paving serving areas of car-parking and unadopted highway. Where possible, outflows from permeable paving would be routed through 'green' areas to provide secondary treatment prior to surface water entering the marsh and river environment.

SL welcomed the approach comprising multi-functional spaces but noted that a community orchard was unlikely to thrive in a marshy/waterlogged setting. RB noted that there was flexibility to re-locate the orchard and that this would be reviewed.

5 Yare Newton

GH highlighted the brownfield nature of the site, currently comprising significant areas of impermeable surfacing, with run-off collected and discharged to the River Yare via a pipe system. Following redevelopment, surface water outflows will be limited to greenfield rates, thereby contributing to a significant betterment compared to the current situation.

GH explained that surface water management would be provided primarily via permeable paving serving areas of car-parking and unadopted highway, alongside street-scene SuDS (tree-pits and raingarden features). Where possible, outflows from permeable paving would be routed through 'green' areas to provide secondary treatment prior to surface water entering the River Yare.

6 General Discussion

SL commented that areas/pockets of surface water flooding should be identified and consideration given to the volume of surface water that may be displaced by the development proposals. SL also asked whether the surface water flood model was being revised and updated in a similar way to the fluvial model. GH advised that the flood risk from surface water map at https://check-long-term-flood-risk.service.gov.uk identifies very few, localised areas at risk of flooding within the site and that the site is unaffected by overland surface water flow routing entering the site from adjacent areas. On this basis, detailed assessment of surface water flood risk is not considered necessary – the principal issue being the management and control of surface water run-off arising from within the development so that flood risk beyond the development boundary is not increased (this being addressed by the surface water management/SuDS strategy).

SL suggested that the FRA was supported by fluvial flood risk 'change mapping', with particular attention paid to off-site areas. GH noted that the FRA will include pre- and post-development flood map outputs.

SL referred to the Broadlands Futures Initiative and the hydraulic modelling being undertaken in support of this flood risk management strategy, noting that the Deal Ground site is located at the upstream end of the Broadlands study area. SL suggested that JBA engage with the relevant EA team and check for consistency in terms of the modelling evidence base being used. GH confirmed that JBA has been engaging with the EA regarding the hydraulic modelling undertaken for the Deal Ground scheme.

JBA Project Code	2023s0187
Contract	Deal Ground
Client	Serruys Property Company Limited
Day, Date and Time	11 April 2023 at 13:00
Meeting	Surface water drainage strategy
Venue	MSTeams

SL asked whether a joint probability analysis (fluvial – tidal) had been completed as part of the flood modelling. GH explained that CC has been applied to the downstream boundary and previous modelling determined that fluvial and tidal flooding in Norwich act independently. Therefore, it is a valid approach to use MHSW as the downstream boundary. As a sensitivity test the model has been run with an extreme tide occurring at the same time as a fluvial flood. Also the timing of the Wensum and Yare have been tested to determine the worst case scenario for each river.

SL queried to what extent residential gardens would be 'permeable' on account of compaction due to construction activities. Whilst the topsoil may be free-draining, a compacted layer may be present beneath this. SL advised that this should be considered when designing the surface water drainage/SuDS strategy.

> POST-MEETING NOTE: use of a subsoiler is an established method for dealing with soil compaction and 'hardpan'. Such methods could be included within the Construction Management Plan and used to improve drainage within 'green' areas following construction activities.

SL advised that a 10% urban creep allowance should be applied.

> POST-MEETING NOTE: an allowance for urban creep would ordinarily only apply to residential elements of a development. SL to confirm NCC's policy position and requirements

SL referred to the 'exception rule' that applies across the Broadlands river basin area. This requires that a 45% uplift is applied to peak rainfall intensity when designing SuDS measures, etc. FEH rainfall data (as opposed to FSR) must also be used.

SL queried where the floodplain storage compensation (i.e. for ground raising within the floodplain) would be located and whether/how this would be clearly identified. GH confirmed that details will be presented on mapped outputs and in tabulated form in the FRA.

SL advised that car-parking areas serving residential units should be set at the 100yr design flood level. SL commented that it is not considered appropriate to work on the basis that residents could move cars to flood-free areas during flood conditions, thereby allowing residential parking areas to flood.

> POST-MEETING NOTE: Noting that the NPPF Annex 3 classifies car-parks as 'less vulnerable', it would be helpful if NCC could confirm (i) its formal policy position on the design and siting of car-parking areas (for both residential and commercial uses) within flood risk areas and (ii) the policy/guidance/standards that underpin NCC's advice/requirements.

SL highlighted the importance of identifying a mechanism to protect/safeguard the proposed 'voids' beneath buildings in the Wensum Edge area (i.e. so that they are not 'developed', used for storage, etc). Options include covenants on property title and ownership of the void space being retained within the freehold as opposed to forming part of the leasehold.

SL asked whether the project team had received NCC's latest comments on the Design Code. MH indicated that the team had yet to receive comments. SL advised that the Code requires updating and that its scope should extend to include wider water management/flood risk/SuDS considerations.

On the matter of water shortage and 'drying out' within the marsh and any proposals for 're-wetting' the marsh, SL requested that evidence off the issue was included with any submission.

SL and DS commented that the proposals are 'heading in the right direction' and constitute a significant improvement when compared to the (consented) 2013 scheme.

F Ground Investigation

G Hydraulic Modelling

Technical note summarising hydraulic model information for EA review.

JBA consulting

Hydraulic Modelling Technical Report

Draft (S3-P01)

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Serruys Property Company Ltd

www.jbaconsulting.com

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Prepared by	Peter Barber MEng Analyst
Reviewed by	Gavin Hodson BSc FdSc Chartered Analyst
Authorised by	Gavin Hodson BSc FdSc Chartered Analyst

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1 Model Build

1.1 Overview

The model developed as part of this study is a combination of two Environment Agency (EA) models that have been truncated and merged to form one site specific model. These two models are:

- The Wensum (Norwich) Model (CH2M, 2017)
- The Broadlands Environmental Services Limited (BESL) model (Jacobs & CH2M, 2019)

This report documents decisions made in regard to model set up and assumptions made in the modelling process.

1.2 Wensum Model - CH2M 2017

The Wensum model starts is Drayton (617759,313244) and ends at downstream of Norwich (628663,307535). The start of the Wensum model is 1D only which and includes the River Tud. The model becomes a 1D | 2D model from Mile Cross Bridge (621737, 309873) until the downstream boundary of the model located immediately downstream of the A47.

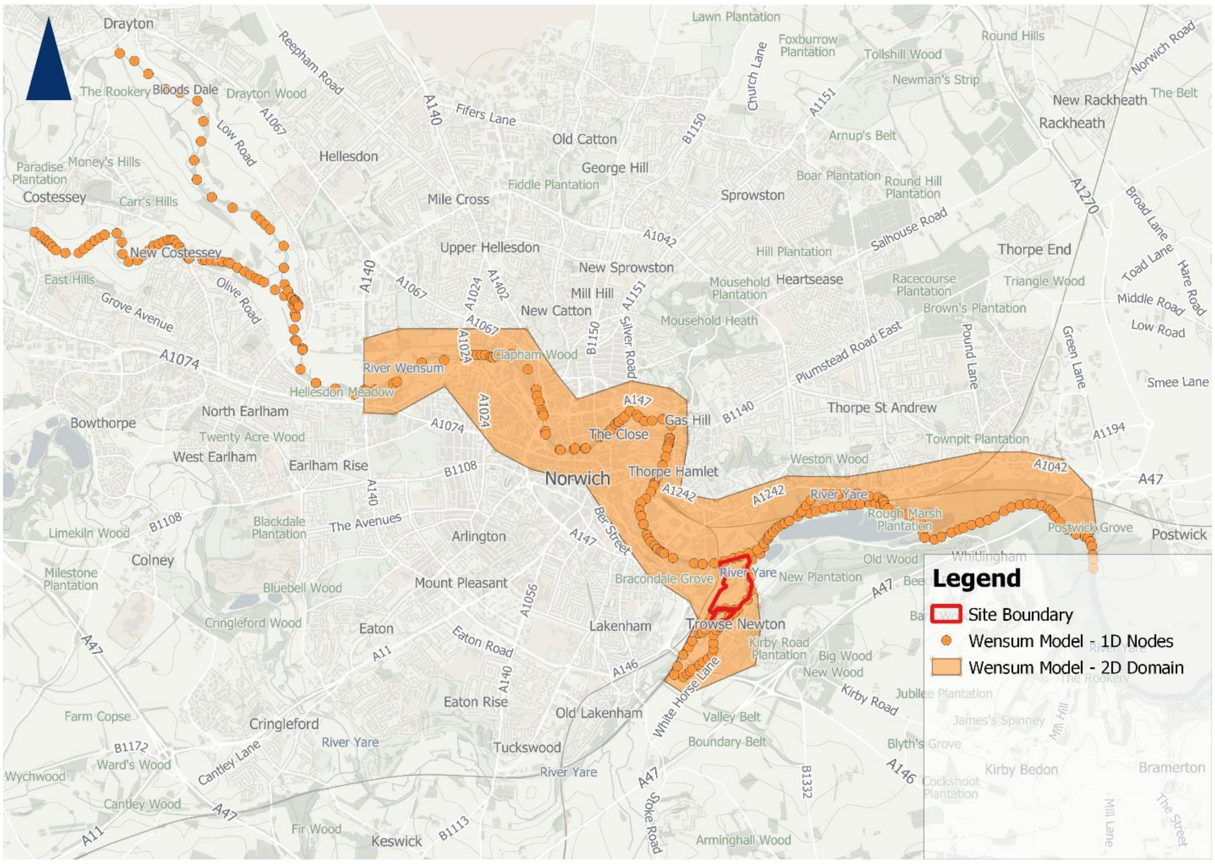

Figure 1-1: Wensum Model - CH2M, 2017 - Extent

1.2.1 Model Review - Wensum 2017

A detailed model review has been conducted and is provided in the supporting documentation named "2022s0896-Norwich_Techincal_Review_V1.0". The key model issues have been highlighted below:

- Model instability in the upper reaches of River Wensum – located well away from the subject site.
- Out-of-date LIDAR – 2009/11 LIDAR in existing model.
- The positioning of 1D-2D connections is not necessarily along channel bank tops.
- Incorrect schematisation of some bridge decks in model which have been included in both the 1D and 2D domains.
- Widespread use of 0.03 roughness across the 2D floodplain which is not necessarily realistic.
- Missing flow route connection between Whittingham Little and Great Broad.

1.2.2 Model Updates - Wensum 2017

The model extends much further upstream along the Wensum than is required for this site-specific study. Therefore, model truncation is desirable to reduce run times (originally 40 hours for the entire model) and the removal of model instability associated with the 1D model build in the upper reaches of the River Wensum. A review of the existing model outputs has found that high ground at Carrow Road (to the west of the development site) acts a barrier to flow. With flow confined to the Carrow Road bridge, this provides a suitable location to truncate the model where flows can easily be extracted.

As stated in the model review, the existing model uses out-of-date LIDAR (2009/11). This will be updated to use the newer 2015 LIDAR.

1.3 Broadlands Environmental Services Limited - Jacobs & CH2M 2019

The BESL model represents much of the north-east coast of east Anglia. Much of the Broadlands system is below sea level, the model included many man-made defences, drainage structures as well as the main watercourses: Ant, Bure, Chet, Thurne, Waveney and Yare. The Broadland water levels are tidally dominated and features large storage areas.

The BESL model was incorporated into this study to accurately represent the tidal downstream boundary. The Wensum 2017 downstream boundary did not account for the large amount of tidal storage. By using the BESL model in conjunction with the Wensum model the tidal impact at the site can be better represented and allow for comparison with gauge data at Reedham.

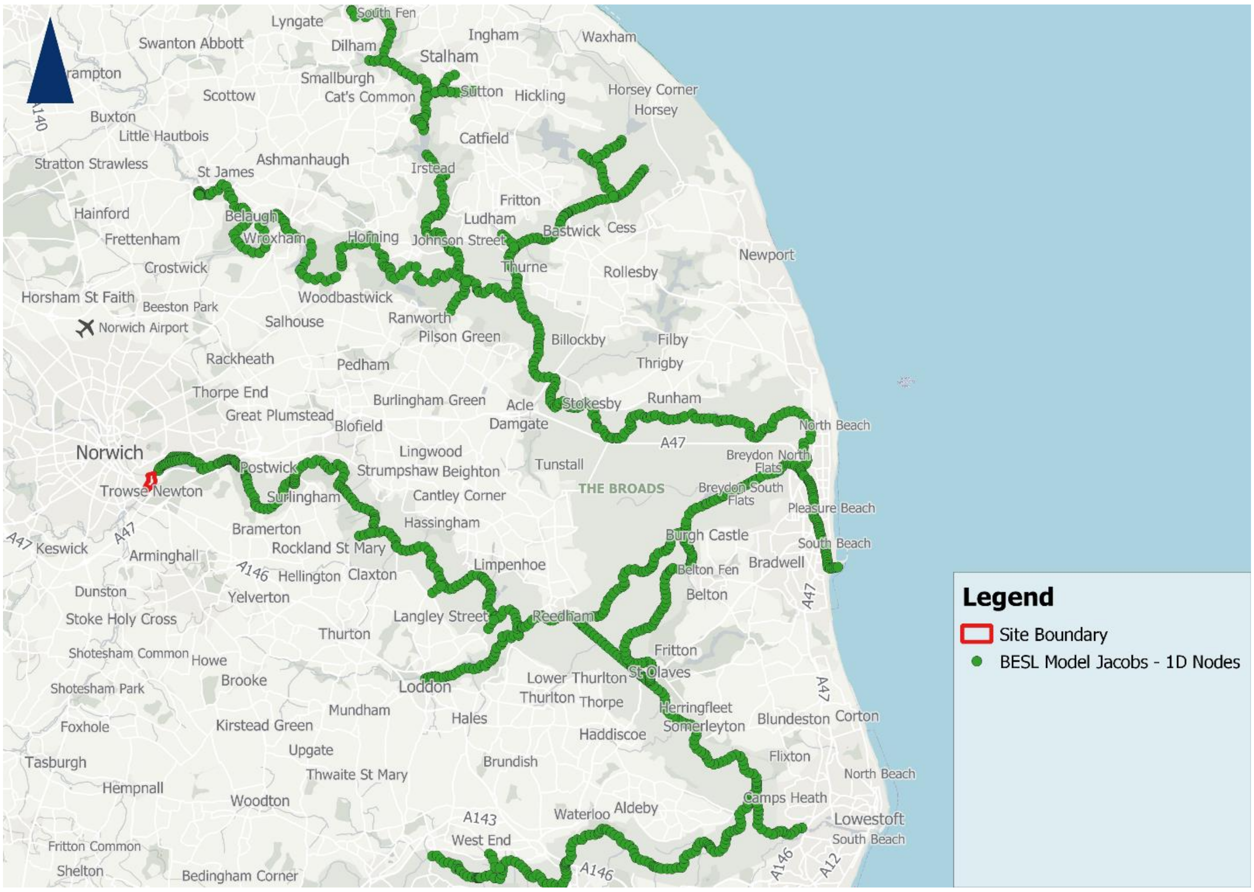

Figure 1-2: BESL Model - Jacobs & CH2m, 2019 - Extent

1.3.1 Model Review - BESL 2019

A brief model review was performed. Model updates were conducted recently by Jacobs and CH2M in 2019. The key review findings are highlighted below:

- Bank top levels compare well with latest topographical survey.
- Model stability is within tolerance.

- Implementation of hydrology climate change allowances is unconventional, and the methods used are not detailed in the supplied report.

1.3.2 Model Updates - BESL 2019

The BESL model covers a large portion of the Broadlands system that is not required for this modelling study. The model was truncated at the upstream node Y30200D and the downstream node Y10000d. The upstream node was truncated here to provide continuance from the Wensum model. The downstream node was terminated at Y10000d as it provides comparison with gauge data at Reedham level gauge.

1.4 Site Specific Model - JBA 2023

The site-specific model is a merger of the Wensum model and BESL model. Figure 1-3 shows the 1D model data sources and extent of the Norwich model. The model also contains the model updates that have been previously discussed in section 1.2.2 and 1.3.2.

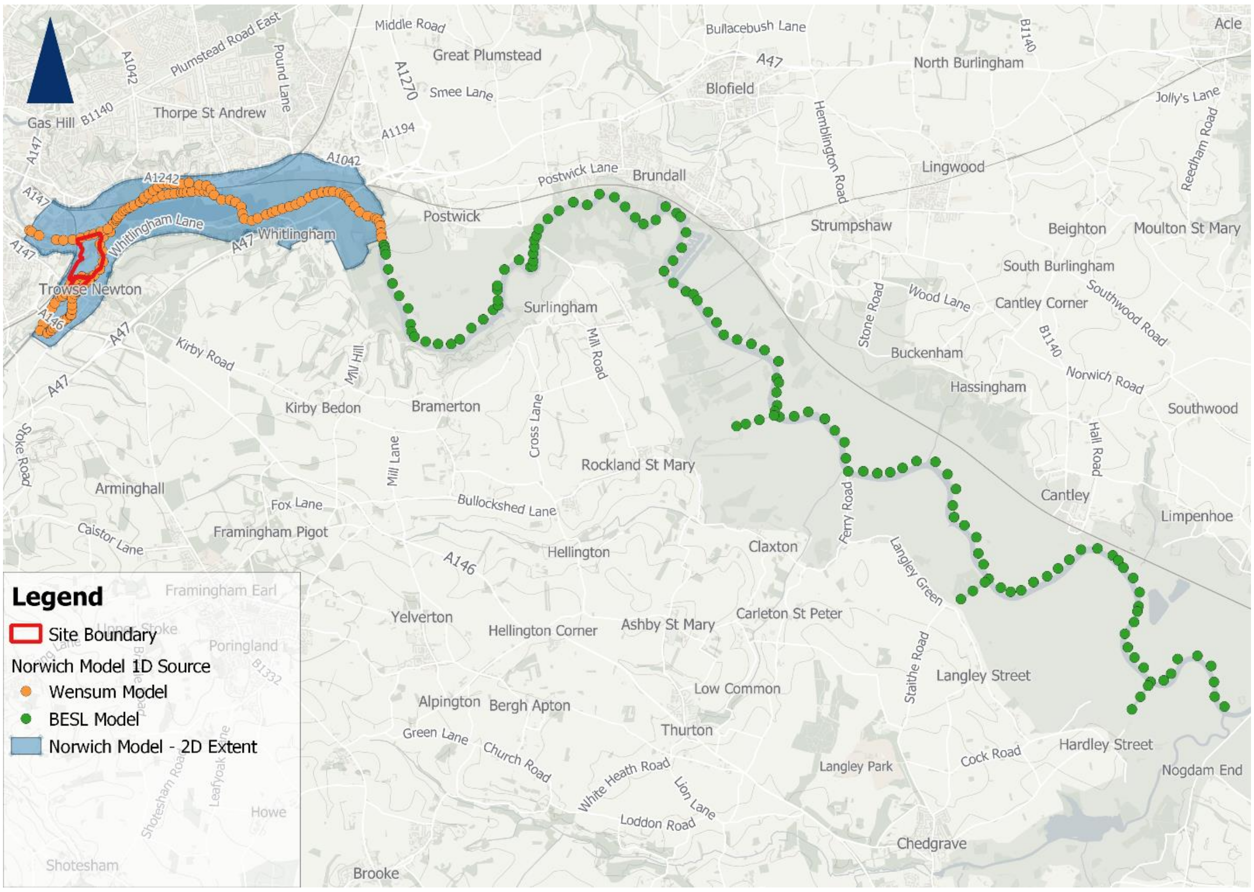

Figure 1-3: Norwich Model - JBA 2023 - 1D Model Node Source

1.5 Proposed Development

The proposed development is shown in Figure 1-4. The development will involve ground raising for development areas, the inclusion flood compensatory storage, and the addition of a road bridge across the River Yare.

The development will require the addition of four culverts, Figure 1-4 shows the location and a summary is shown in Table 1-1. There will be two at the north of the site, to maintain the flow route from the Bottle kiln to the Wensum. And two culverts either side of the proposed bridge that connects Deal Ground and May Gurney. The culverts at the bridge maintain conveyance through the bridge.

Table 1-1: Norwich Model - JBA 2023 - Proposed Culverts

Culvert Location	Upstream Invert level (mAOD)	Downstream Invert level (mAOD)	Size (width x height) (m)
Bridge (Left Bank)	1.22	1.21	7.50 x 2.70
Bridge (Right Bank)	1.82	1.81	7.50 x 0.97
DG Culvert North	1.21	1.20	0.6 (diameter)
DG culvert South	1.22	1.21	0.6 (diameter)

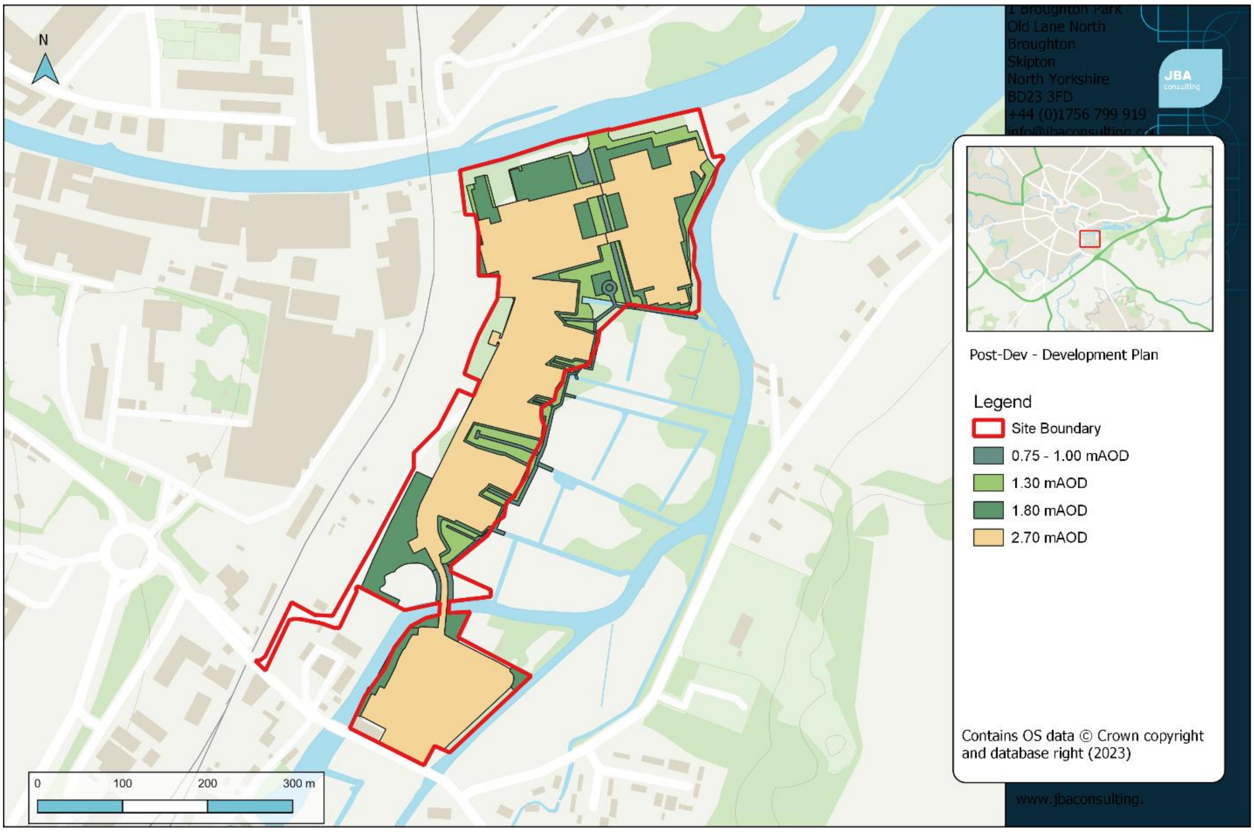

Figure 1-4: Norwich Model - JBA, 2023 - Deal Ground Proposed development

The baseline LiDAR and development plan LiDAR are compared in Figure 1-5. It can be seen where the land raising activities have occurred, as well as the storage space gained.

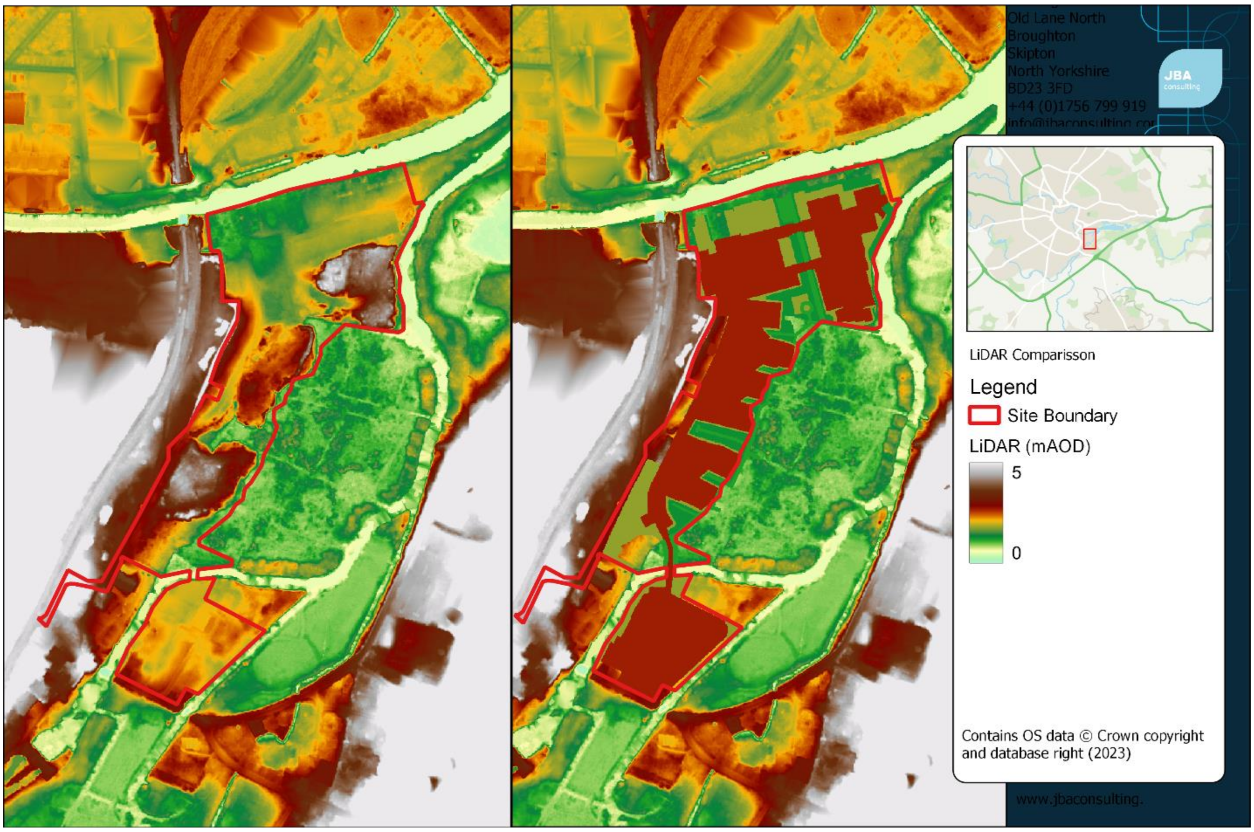

Figure 1-5: Norwich Model - JBA, 2023 - Deal Ground LiDAR Comparison

1.6 Model Run Record

Table 1-2 shows a complete model run list for the Norwich Model. The fluvial AEP indicates the input event for all the fluvial model inflows. The DSBDY has been calculated by using the Norfolk Broads model (BESL). The fluvial and tidal AEP listed in Table 1-2 show the input values for the downstream boundary.

Table 1-2: Model Simulation Record

Primary Scenario	Fluvial AEP	DSBDY Event (Fluvial AEP | Tidal event)
Baseline	3.3%	5%	MHWS
	3.3% + 11% CC	5% + 11%CC	MHWS + CC
	1.0%	1.0%	MHWS
	1.0% + 11% CC	1.0% +11%CC	MHWS + CC
	0.1%	0.1%	MHWS
	0.1% + 11% CC	0.1% + 11%CC	MHWS + CC
MP_F_001	3.3%	5%	MHWS
	3.3% + 11% CC	5% + 11%CC	MHWS + CC
	1.0%	1.0%	MHWS
	1.0% + 11% CC	1.0% +11%CC	MHWS + CC
	0.1%	0.1%	MHWS
	0.1% + 11%CC	0.1% + 11%CC	MHWS + CC

2 Model Boundary Conditions

2.1 Overview

The 1D model has ten boundary conditions in total, which can be divided into four categories:

Wensum Model inflows - There are six inflows along the truncated Wensum model. The inflows at WE1227d and YARF1_550d are the upstream inflows of the Wensum and Yare rivers, respectively, where the upstream of the original model was truncated. The remaining four inflows are lateral inflows, representing incoming water from other sources.

Wensum BESL Model Border - Due to the combination of a 1D|2D model into a 1D only model, an additional boundary condition was required to transfer the mass of water in the 2D floodplain into the downstream 1D model boundary.

BESL Model Inflows - These are the two remaining Yare inflows present in the original BESL model between the point of upstream truncation (Y30200U) and downstream truncation (Y10000).

BESL Downstream Boundary - This is the downstream model boundary located upstream of Reedham, just before the confluence with the River Chet.

Table 2-1 summarises the inflows, and Figure 2-1 shows the location of the model nodes.

Table 2-1: Model Boundary Conditions - Summary

Category	Boundary Name	Boundary Type	Location (NGR Reference)
Wensum Model Inflows	WE1227d	QT	Carrow Road Bridge (623903, 307741)
Wensum Model Inflows	YARF1_550d	QT	Loddon Road Bridge (A146) (624007, 306386)
Wensum Model Inflows	Y5int	Lateral ReFH QT	YAN6913 (624238, 306752) YAN5955 (624889, 307314)
Wensum Model Inflows	N4	Lateral ReFH QT	YAN5134 (625166, 308010) YAN4200 (625989, 308270)
Wensum Model Inflows	N6	Lateral ReFH QT	YAN2894 (626988, 307924) YAN1803 (628034, 308282)

Category	Boundary Name	Boundary Type	Location (NGR Reference)
Wensum Model Inflows	N7	Lateral ReFH QT	YAN1607 (628222, 308206) YAN0817 (628724, 307707)
Wensum Model / BESL	YAN0726ND	HT BDY	Wensum model / BESL model border (628446, 307336)
BESL Inflows	YARE1	FEH QT	Y22400U (632822, 307088)
BESL Inflows	YARE2	FEH QT	SD6LD (634064, 305542)
BESL Downstream Boundary	Y10000d	HTBDY	Upstream of Reedham (640046, 301255)

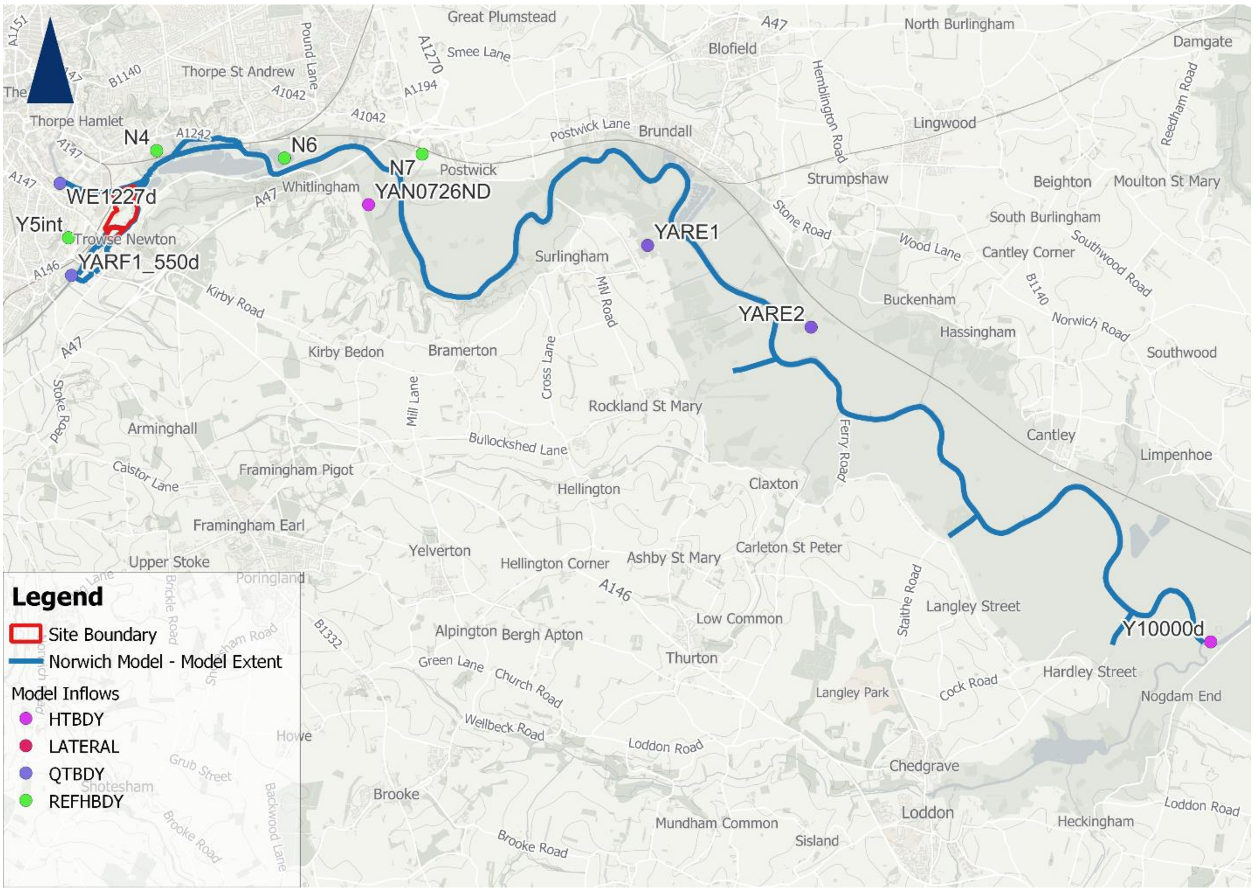

Figure 2-1: Model Boundary Conditions Location Plan

2.2 Climate Change Allowances

The River Wensum and River Yare are located within the Broadlands River Management Catchment. To estimate the fluvial model inflows for the catchment's lifetime, the central value from the 2080s epoch was used. The climate change allowances are shown in Table 2-2.

Table 2-2: Climate Change Allowances

Epoch	Central	Higher	Upper
2020s	8%	14%	27%
2050s	3%	10%	27%
2080s	11%	20%	44%

The tidal climate change allowances have remained unchanged from the Jacobs BESL model.

2.3 Model Inflows - Norwich

The lateral inflows (Y5int, N4, N6, and N7) have been configured with a ReFH flow-time boundary, which is applied to lateral inflow across multiple nodes. This approach has remained unchanged from the original Wensum model.

As for the inflows at WE1227d and YARF1_550d, they are flow time boundaries (QT) and represent the upstream inflows of the Wensum and Yare rivers, respectively. Two approaches have been taken to find the upstream model inflow values. One approach involves extracting the model flow-time series results from the node at the point of truncation in the full Wensum model, while the other approach uses the ReFH2 method.

2.3.1 Wensum Model 2017 Model Inflows

This approach involves extracting the flow-time series data from the WE1227d and YARF1_550d nodes from the original model, which utilizes the existing hydrology. These flows were updated as part of the 2017 assessment.

2.3.2 ReFH2 Approach

2.3.2.1 Catchment Descriptors

The hydrology has been calculated using an Urban ReFH2 approach. The catchment descriptors were captured from the FEH web application at the inflow node locations. A summary of key catchment descriptors is shown in Table 2-3.

The two catchments exhibit many similarities; both have high BFIHOST values, which are indicative of chalk catchments. At this stage in the rivers' reach, the Wensum catchment covers a much larger area than the Yare catchment.

Table 2-3: ReFH2 Approach - Key Catchment Descriptors

Catchment Descriptors	WE1227d	YARF1_550d
Area (km2)	673	278
URBEXT	0.032	0.032
SAAR (mm)	666	632
BFIHOST	0.689	0.547
DPLBAR (km)	47.61	30
DPSBAR (m/km)	20.6	19.5

2.3.2.2 Storm Duration Analysis

The critical storm duration can be defined as ‘The duration of rainfall event likely to cause the highest peak flows or levels at a particular location, for a specified return period event’ (CIRIA, 2015).

The storm duration of 1% AEP rainfall events have been compared for each catchment in Figure 2-2 and Figure 2-3. The storm durations that yield the peak flow are 62 hours for the Wensum catchment and 42 hours for the Yare catchment. However, the storm duration with the greatest peak flows may not necessarily cause the greatest flooding impact. This is because some catchments are more sensitive to volume, such as those with large floodplain storage, and therefore a longer storm duration would result in more water in the catchment.

The chosen model storm duration is the 62-hour storm duration for both catchments. Both catchments will be modelled with the same storm duration due to the equidistant location of the confluence from both inflow locations. This means that both watercourses will peak together at the confluence near the site, providing a conservative estimated of flooding.

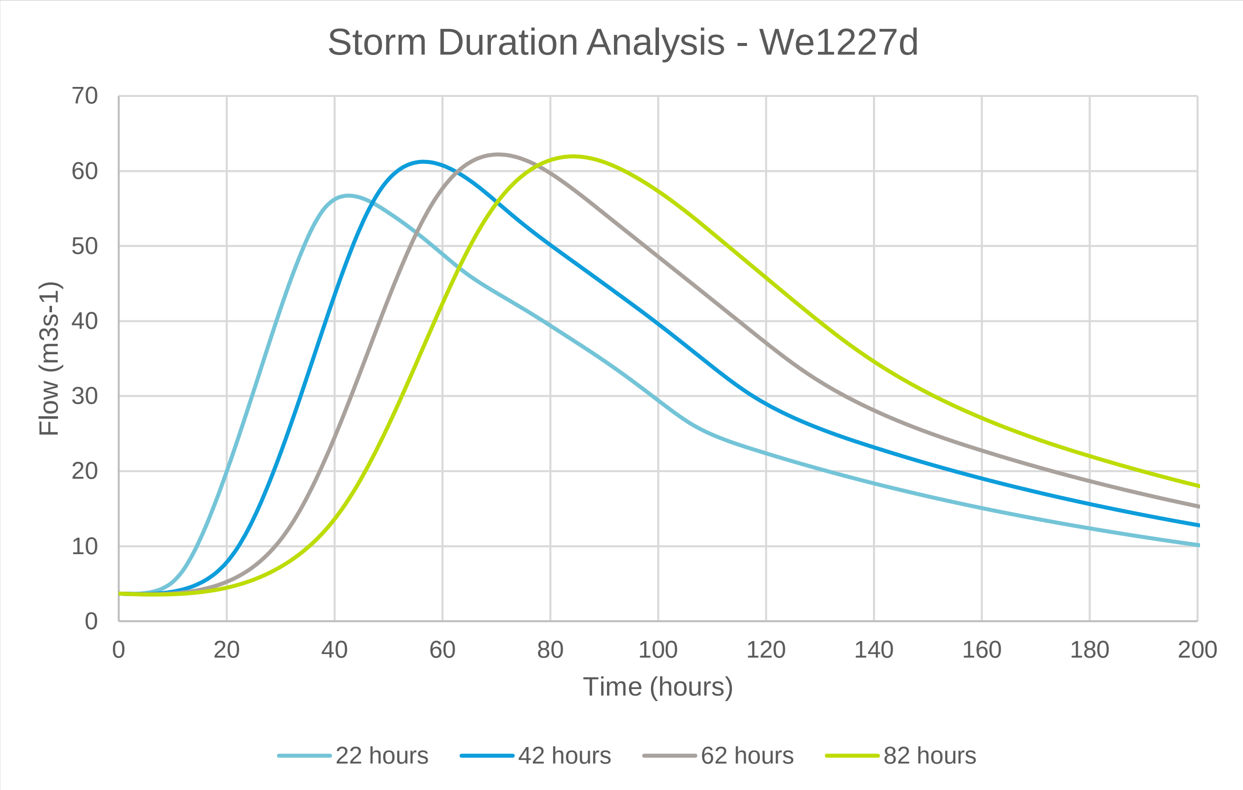

Figure 2-2: Storm Duration Analysis - WE1227d - 1% AEP

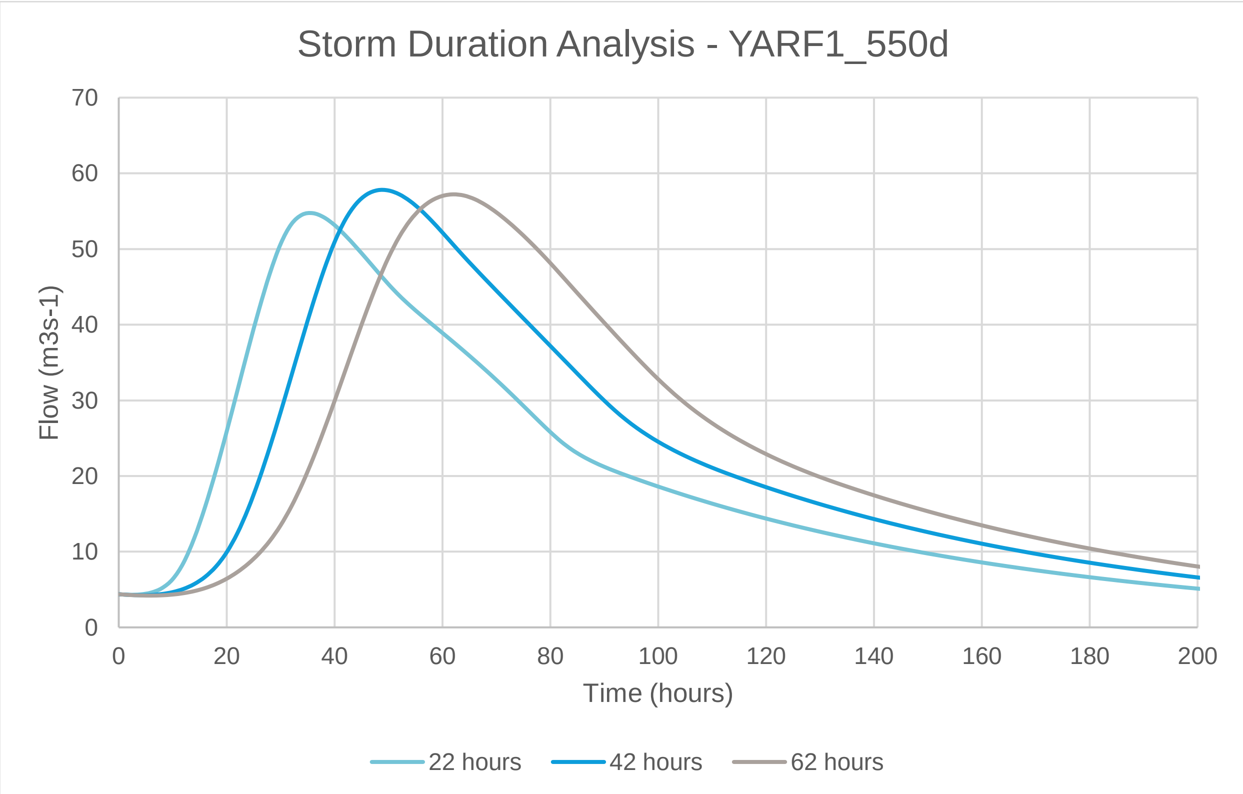

Figure 2-3: Storm Duration Analysis - YARF1_550d - 1% AEP

2.3.2.3 ReFH2 Model Inflows

The ReFH2 Model inflows are shown in Figure 2-4 and Figure 2-5. The Wensum shows the higher peaks, which is expected given the higher catchment area.

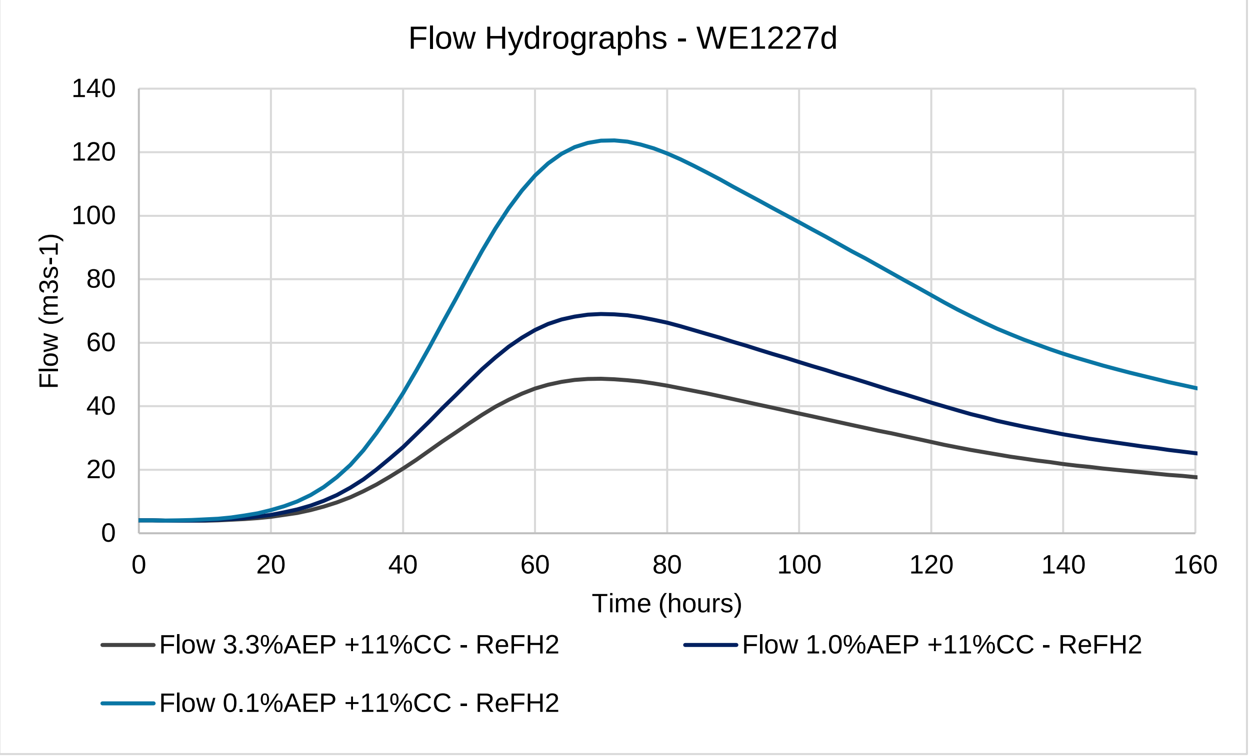

Figure 2-4: ReFH2 62-Hour Model Inflows - WE1227d

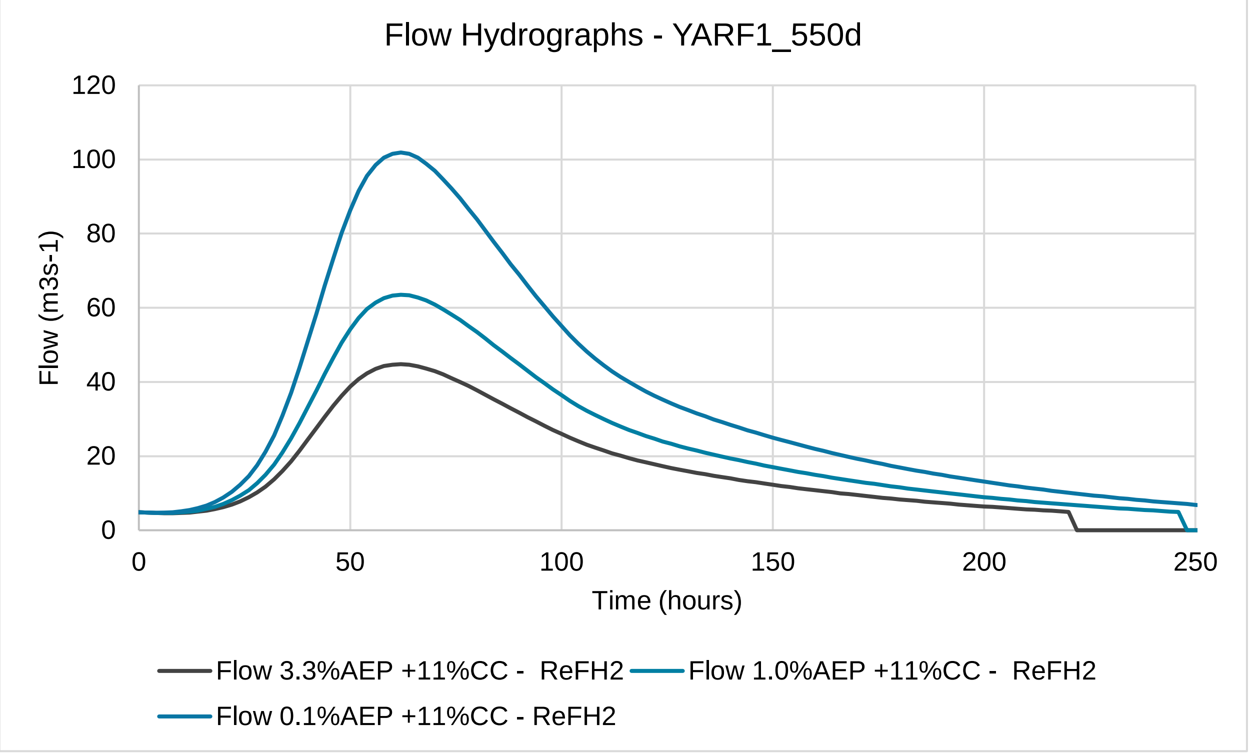

Figure 2-5: ReFH2 62-Hour Model Inflows - YARF1_550d

2.3.3 Method Comparison

The two methods have been plotted together in Figure 2-6 and Figure 2-7, as well as a comparison of peak flows in Table 2-4.

The two approaches to the Wensum inflow, yield similar peak values in low % AEP events but the ReFH2 produces lower peak flows in higher % AEP events. This shows that the growth curves used to create both flows are different but converge near the 1.0% and 0.1% AEP events. The two approaches show very different shapes, the ReFH2 approach shows a very smooth rising and falling limb. Whereas the other method shows a much flatter flow peak and longer period. This due to the hydrographs being extracted from the model and the influence of the downstream boundary is felt. Hence the oscillations at the start and end of the hydrograph.

The two approaches to the Yare inflow, show the opposite peak flow relationship to the Wensum. The Yare shows similar peak values in High % AEP events, and very different peak flows in low % AEP events. Both methods show similar shapes, except for the initial small "hump" in the model extracted flow curves.

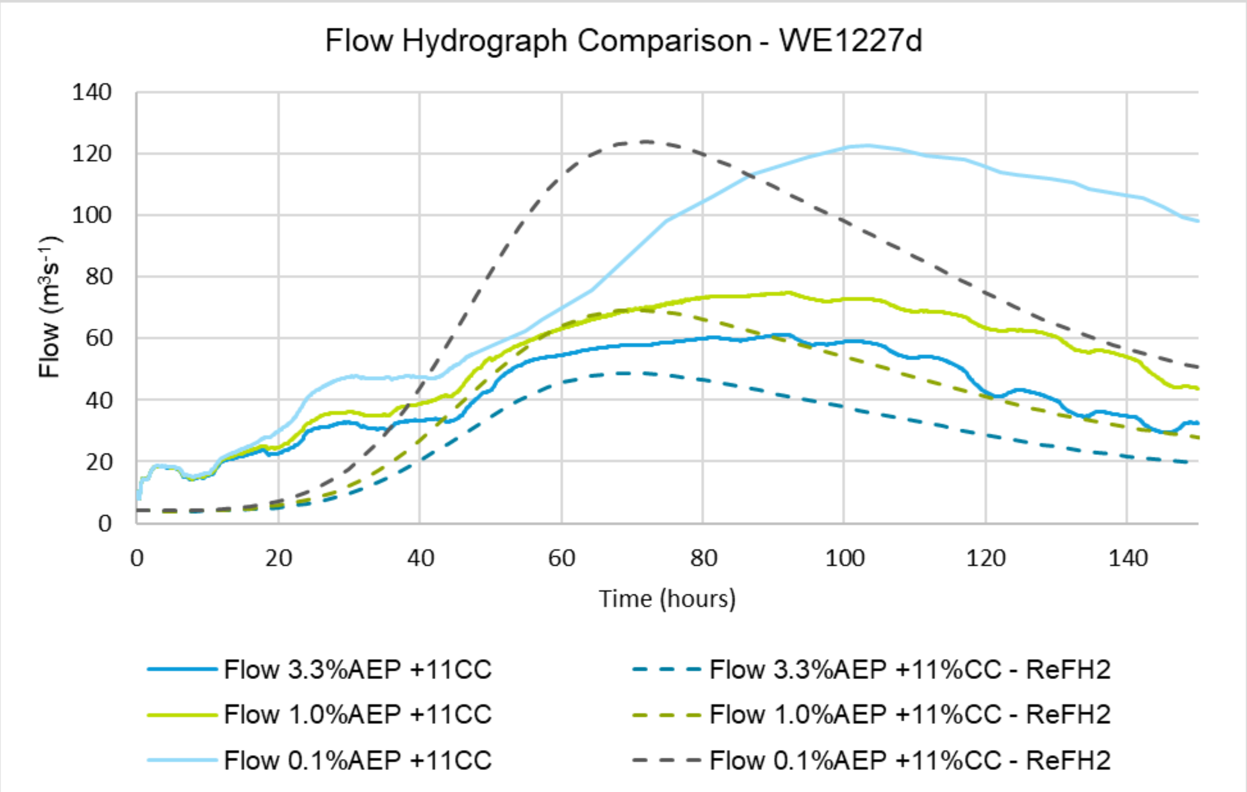

Figure 2-6: Model Flow Method Comparison - WE1227d

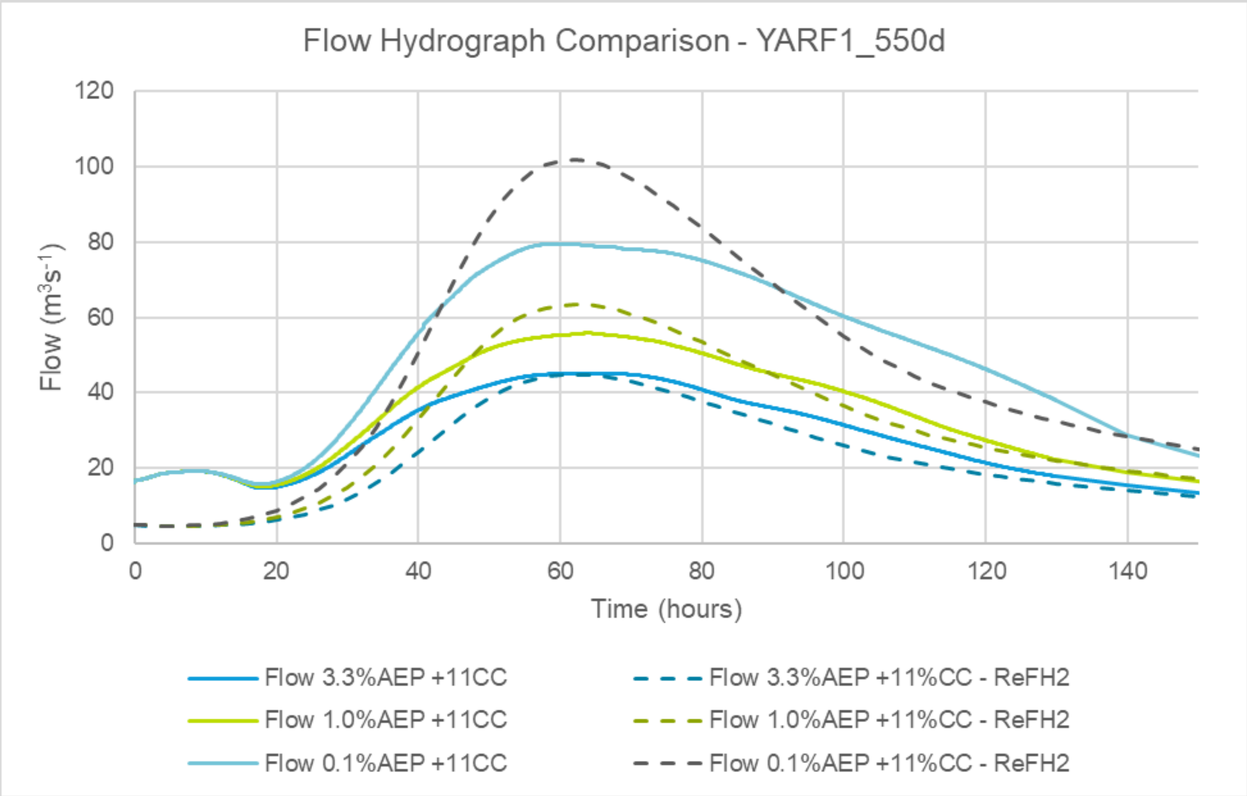

Figure 2-7: Model Flow Method Comparison - YARF1_550d

Table 2-4: Peak Flow comparison

% AEP	WE1227d Flows (m3s-1)		YARF1_550d Flows (m3s-1)	
	Model 2017	ReFH2 62h	Model 2017	ReFH2 62h
3.30	55.04	43.83	40.70	40.36
3.3 + 11%CC	61.09	48.66	45.18	44.80
1.00	67.28	62.19	50.52	57.22
1.0 + 11%CC	74.68	69.03	56.08	63.51
0.10	110.33	111.44	71.72	91.79
0.1 + 115CC	122.46	123.70	79.61	101.89

2.4 Wensum Model - BESL Model

The truncated Wensum model is a 1D|2D model. Where the Wensum model blends into the BESL model there is water in the 2D Floodplain. The BESL model is 1D only, the water in the 2D floodplain must be inputted into the 1D model.

This has been achieved by using a TUFLOW Type SX 2d boundary condition on the border between the two models. The SX boundary intakes the water into the 2D floodplain and connects it to a 1D node, called YAN0726ND. YAN0726ND is represented as a 1D Head Time (HT) Boundary that inputs the 2D flow into the 1D BESL model. This ensure the mass balance is conserved. YAN0726ND is not rated to AEPs, as it is dependent on the movement of water in the 2D floodplain.

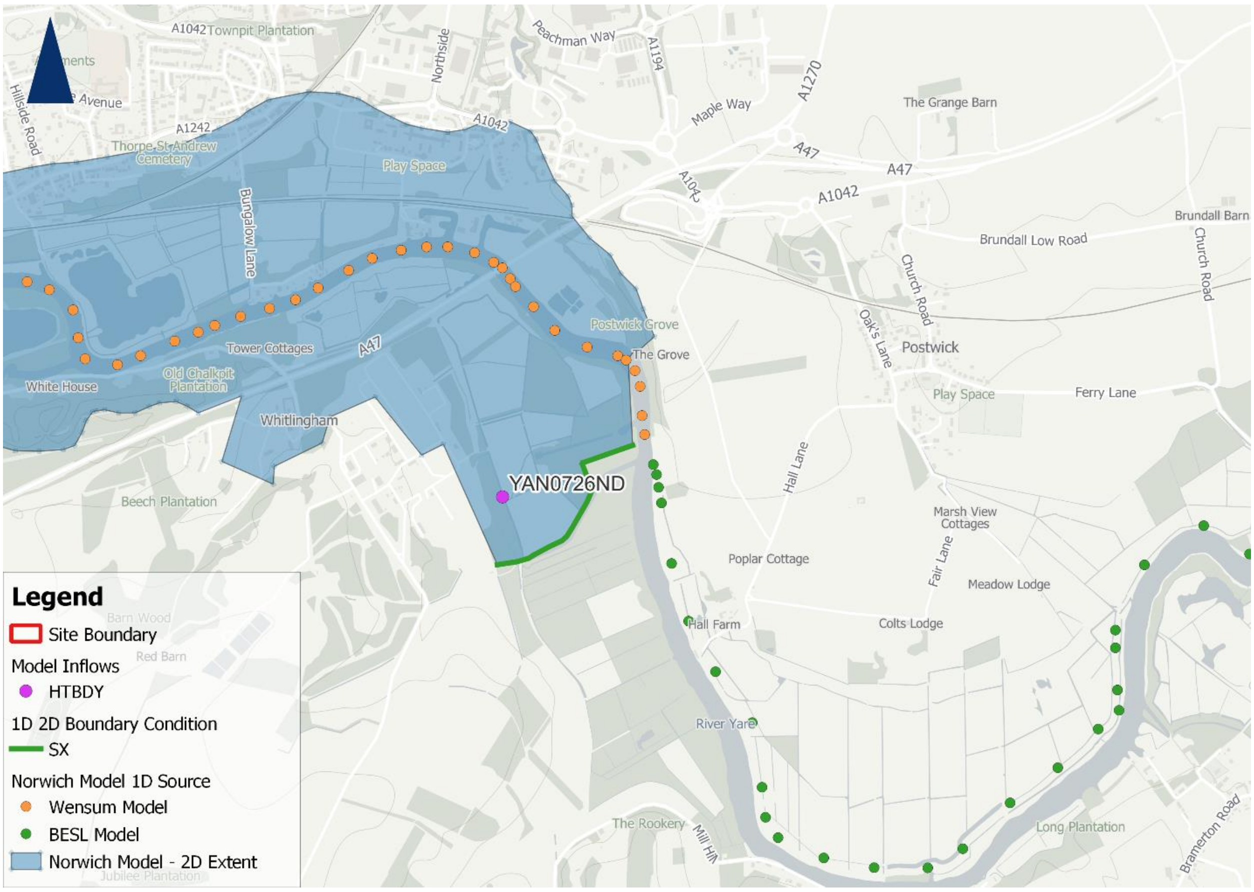

Figure 2-8: Wensum / BESL Model Border - SX Boundary Condition

2.5 BESL Inflows - Yare

The original BESL model covers a large area and contains many inflows. When the model was truncated the only inflows that remained are Yare_1 and Yare_2. These inflows are FEH QT boundaries and are identical because they contain the same FEH catchment descriptors. The model inflow peak values are shown in Table 2-5.

Table 2-5: BESL Inflows - Peak Flows (m3s-1)

Event	Yare 1 Peak Flow (m3s-1)	Yare 2 Peak Flow (m3s-1)
3.3% AEP	11.99	11.99
3.3% AEP +11%CC	13.30	13.30
1.0% AEP	16.85	16.85
1.0% AEP +11%CC	18.70	18.70
0.1% AEP	32.52	32.52
0.1%AEP +11%CC	36.10	36.10

2.6 BESL Downstream Boundary - Reedham

The downstream boundary is located 2.1km upstream of the village of Reedham, where the Yare meets the River Chet. The downstream boundary is a normal depth boundary to represent the tidal influence of the catchment.

The downstream boundary was calculated by running the original Jacobs and CH2M (2020) BESL model and extracting the stage-time series data at the Y10000d node. Inflows in the Jacobs and CH2M BESL model were updated to represent current climate change adjustments in the Broadlands River Management catchment. Table 2-6 shows the peak stage and Figure 2-9 show the stage-time data Y10000d for each event.

The events are detailed as "Fluvial %AEP | Tidal event ".

A fluvial 5% AEP event was run in place of a 3.3%AEP event. This is because the original model was not run for a 3.3% AEP event and due to the complex nature of the model hydrology it was not possible to create one.

Table 2-6: Peak Stage

Event	Peak Stage (mAOD)
5.0% AEP | MHWS	1.06
5.0% AEP + 11%CC | MHWS CC	1.60
1.0% AEP | MHWS	1.12
1.0% AEP + 11%CC | MHWS CC	1.63
0.1% AEP | MHWS	1.36
0.1% AEP + 11%CC | MHWS CC	1.84

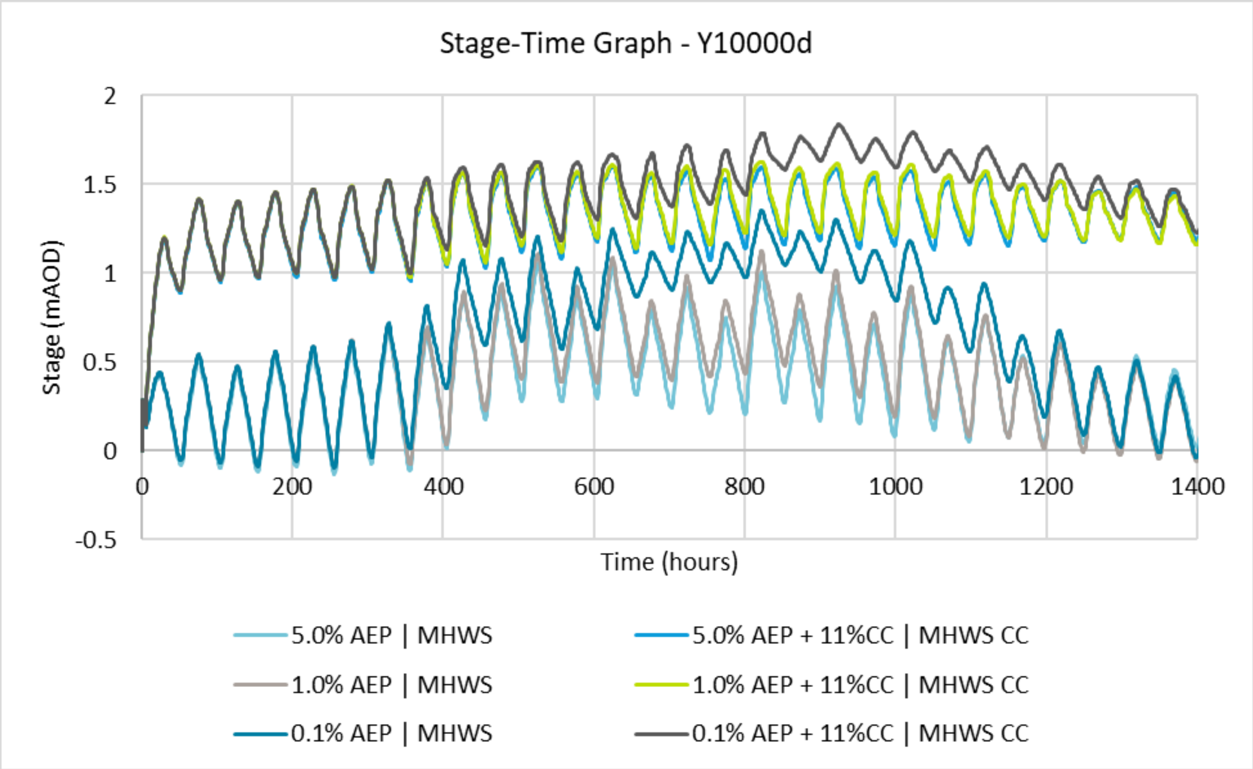

Figure 2-9: Stage-Time Graph - Y10000d

3 Model Performance

3.1 Overview

Sensitivity Testing is an essential part of the model build process. Sensitivity testing determines the impact of key model parameters on the model results and stability. The model parameters tested in this study are Manning's roughness and Downstream boundary level.

3.2 Model Sensitivity Analysis

Sensitivity to flow and downstream boundary undertaken as part of the modelling process. Further tests to be agreed as part of EA review process.

3.3 Model Stability

3.3.1 1D Model Convergence

Figure 3-1 and Figure 3-2 show the Flood Modeller iteration and convergence plots for both the 3.3% AEP + 11%CC and the 1% AEP +11%CC events. The 1D model shows poor convergence, requiring high numbers of iterations of to reach a solution.

The stabilities issues are caused by the tidal downstream boundary and the large 2D storage areas. The downstream boundary controls the model level and causes fluctuations in the model flow series. The large amount of water in the 2D floodplain is due to the vast low lying storage areas in the catchment. This water is slow moving and "sits" on the 1D/2D boundary creating small oscillations between the two domains.

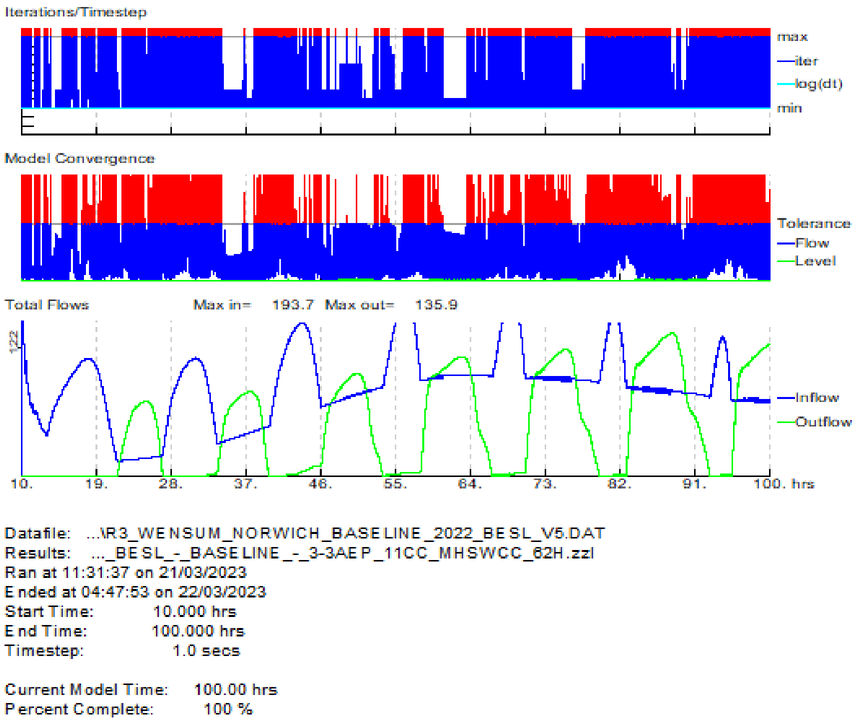

Figure 3-1: Model Stability Analysis - 3.3% AEP + 11%CC 1D Summary

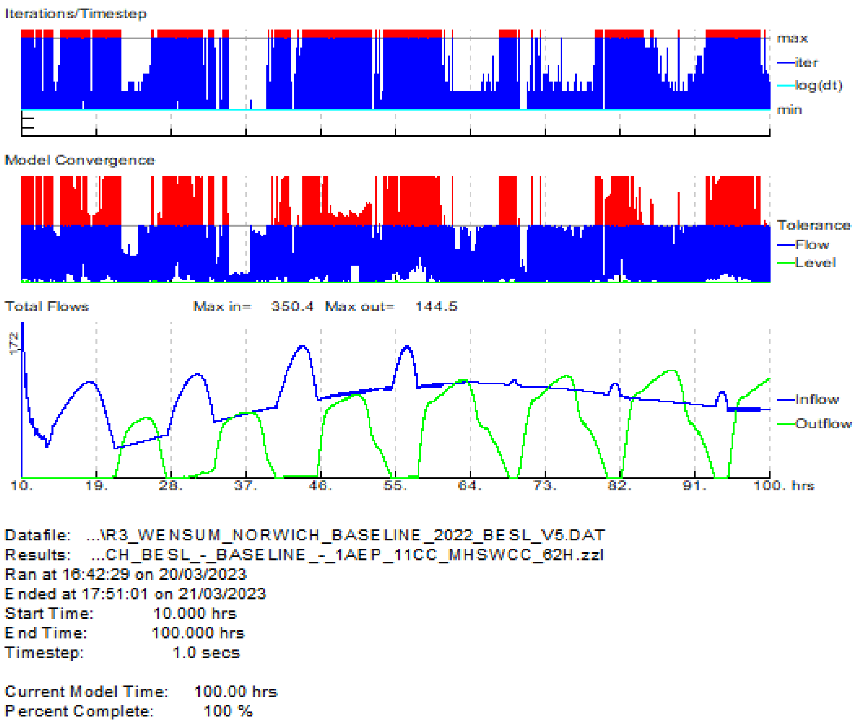

Figure 3-2: Model Stability Analysis - 1.0% AEP + 11%CC 1D Summary

3.3.2 Model Stability Parameter Adjustments

In order improve model stability several 1D and 2D parameters have been adjusted. The parameters that have been changed from default are listed in Table 3-1. These values have been used in selective runs where model instability led to no solution being found.

Table 3-1: Model Stability Parameter Adjustments

Parameter	Default	Adjusted	Comment
Alpha (1D)	0.7	0.5	Alpha is an under-relaxation parameter. It determines the weighting of the result towards the previous iteration, therefore increasing its value towards 1 will improve mass conservation.
Theta (1D)	0.9	0.5	Theta is a Preissmann box weighting factor. A value of 1.0 gives a fully implicit numerical scheme. Allowed range 0.5-1.0
Pivotal Choice (1D)	0.1	0.5	Specifies the degree of matrix pivoting away from non-zero values. A value of zero would result in no solution being found. In "noisy" models this value may need adjusting where the matrix values are oscillating near zero.
Min/Max Iterations (1D)	3/11	6/18	The minimum and maximum number of iterations impacts the number of iterations in which the model will process to find a solution. It is recommended to change these values in conjunction with Alpha and Theta.
HX - A (Form Loss Coefficient) (2D)	0.0	0.5	Applies a form loss coefficient to the HX line at the specified location. This can be useful for 1D/2D models where additional energy losses are needed to model the flow between a river (1D) and the floodplain (2D).

3.3.3 Cumulative Mass Error

Another indication of model stability is cumulative mass error. Typically, during a stable model run the cumulative mass error will have a value of ±1%. Figure 3-3 shows the mass balance recorded during the model run for the 3.3% AEP +11%CC and 1% AEP + 11%CC events. Both events are within the EA recommended tolerance. The 1% AEP + 11%CC event shows a high initial spike in mass error due to high stage initial conditions; this causes water to immediately enter the 2D floodplain. Because this occurs at the start of the model, where there is little water present in the entire model, this represents a significant percentage causing a large spike.

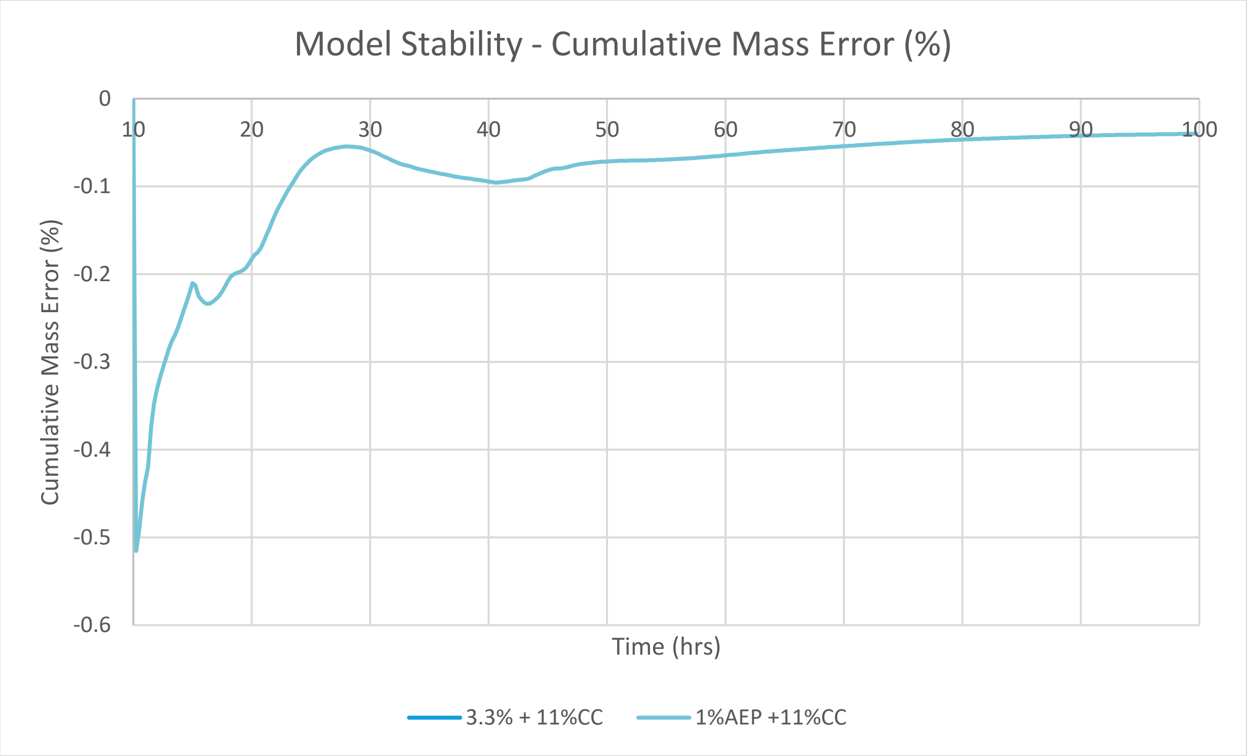

Figure 3-3: Model Stability Analysis - Cumulative Mass Error (%)

3.3.4 2D Volume

The output dVol measures the change in volume present in the 2D domain. Figure 3-4 shows the 2d volume recorded during the model run for the 3.3% AEP +11%CC and 1% AEP + 11%CC events. The volume mimics the time series of the tidal downstream boundary. The curves are gradual due to the slow movement of water between the 1D and 2D boundary.

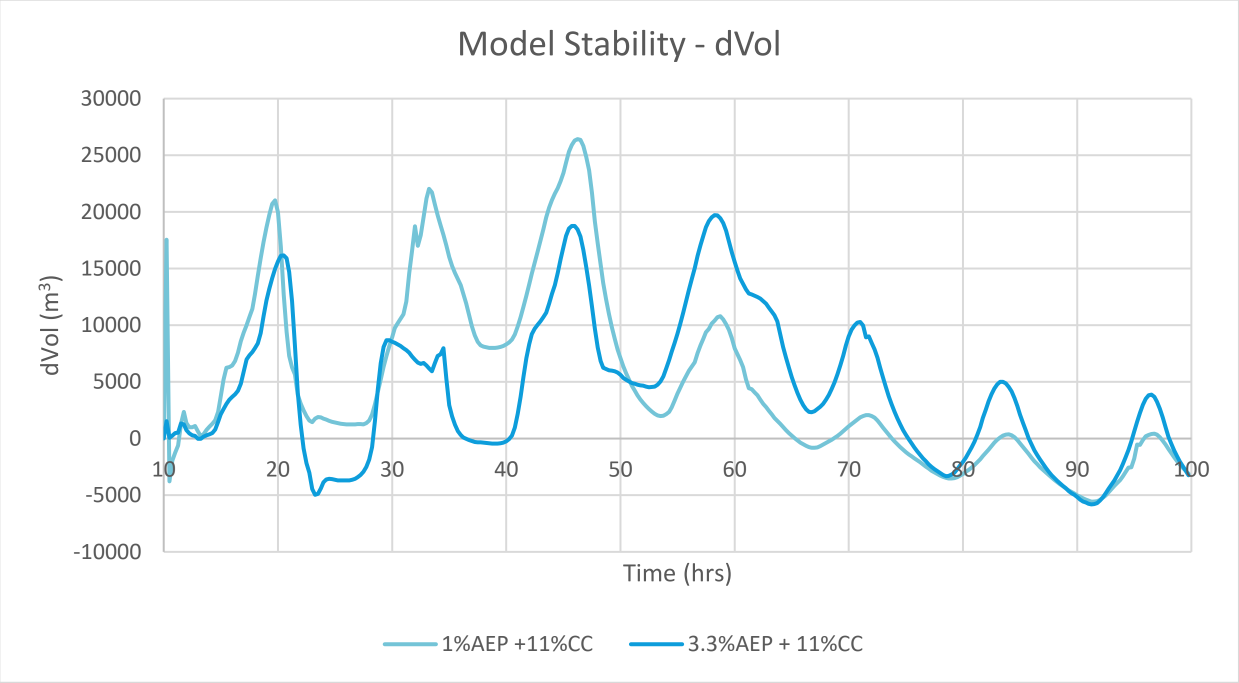

Figure 3-4: Model Stability Analysis - dVol

4 Model Files

4.1 1D Model Files

The core 1D Model files are shown in Table 4-1. The return period or AEP is represented by a place holder "X".

Table 4-1: 1D Model Files

File type		File Name
Data File (.DAT)	Baseline	R4_Wensum_Norwich_BESL_ 2023_Baseline-001.dat
	Post-Development	R4_Wensum_Norwich_BESL_ 2023_MP_F_001-001.dat
Event file (.IED)	Wensum & Norwich Inflows	R3_"X"%AEP_NORWICH-62hSD
	BESL Inflows	Yare_"X"yr_47hr_PH0
	Downstream Boundary - Present Day	R3-Y10000d- "X"AEP_11CC_MHWSCC.ied
	Downstream Boundary - Climate Change	R3-Y10000d-"X"AEP_MHWS.ied
Initial conditions (.IIC)		R3_N_BESL_-_MP_F_001_3- 3AEPCC-H-P-T-3h.iic
Results (.ZZL)	Baseline	R4_001_NORWICH_BESL_- _BASELINE_"X"AEP_MHSW(CC).zzl
	Post-Development	R4_001_NORWICH_BESL_- _MP_F_002_"X"AEP_MHSW(CC).zzl

4.2 2D Model Files

The core 2D model files are shown in Table 4-2.

Table 4-2: 2D Model Files

File Type	File Name
Tuflow Control file (.tcf)	R4_NORWICH_~s1~_~e1~_001.tcf
Tuflow Boundary Controller (.tbc)	R4_Wensum_Norwich_2023.tbc
Tuflow Geometry Controller (.tbc)	R4_Wensum_Norwich_2023.tgc
Tuflow Material File (.tmf)	R4_Wensum_Norwich_2023.tmf
Digital terrain Model (DTM)	Norwich_DTM-2021_Merge.asc