Dwr Cymru Welsh Water

LLANISHEN AND LISVANE RESERVOIR VISITOR CENTRE

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1 INTRODUCTION

1.1 OVERVIEW

1.1.1. Dwr Cymru Welsh Water (DCWW) propose to undertake the redevelopment of the visitor centre and car park associated with the Llanishen Reservoir and Lisvane Reservoir. The Nant Fawr watercourse flows adjacent to the proposed visitor centre building site and the reservoirs. WSP were appointed to undertake the hydraulic modelling of the Nant Fawr watercourse to assess the impact of the proposed building on flood risk. The location of the proposed development is shown in Figure 1.1 below.

1.1.2. The site is located adjacent to the Llanishen and Lisvane reservoirs. The scheme will include a two-storey water sports building that includes facilities such as restaurant, educational area, showers and parking spaces within an approximate area of 0.7 ha. The site location plan and development red line area are shown in Appendix A of this report.

1.1.3. WSP has obtained the existing Natural Resources Wales (NRW) hydraulic model for Roath Brook and updated the Nant Fawr section of the model.

1.1.4. The objectives of this study are to:

- Review the NRW hydraulic model and update it as appropriate;
- Update the NRW hydraulic model of the Nant Fawr with the inclusion of new topographical data;
- Carry out hydrological analysis and update the model inflow;
- Develop the existing baseline model scenario (update the existing 1D model into 1D - 2D linked model using Flood Modeller Pro-TuFLOW);
- Build the proposed scenario hydraulic model;
- Assess the fluvial flood risk before and after the proposed development.

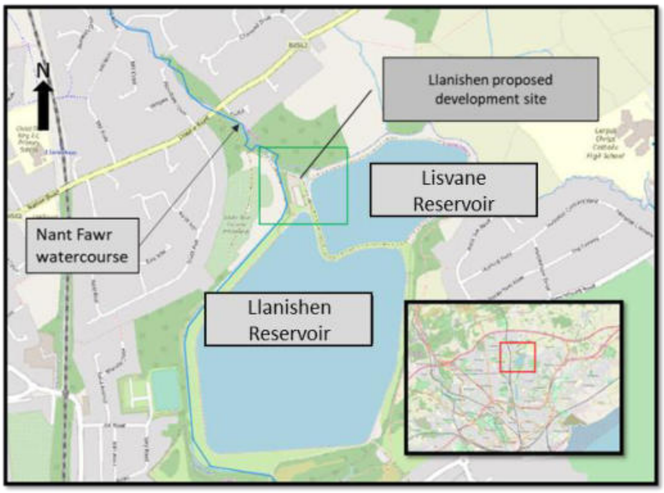


Figure 1.1: Location Plan

2 HYDROLOGY

2.1 WATERCOURSE CHARACTERISTICS

2.1.1. Nant Fawr is an ‘ordinary watercourse’ which flows in a southerly direction and drains an area of approximately 3.3km^2 upstream of the proposed development site. The watercourse flows to the south until Roath Park Lake where it joins with Llanishen Brook. Downstream of the lake, the watercourse is known as Roath Brook and is classified as “Main River”. Roath Brook discharges into Rhymney River in the area of Severn Estuary. Figure 2.1 below shows the alignment of the watercourses.

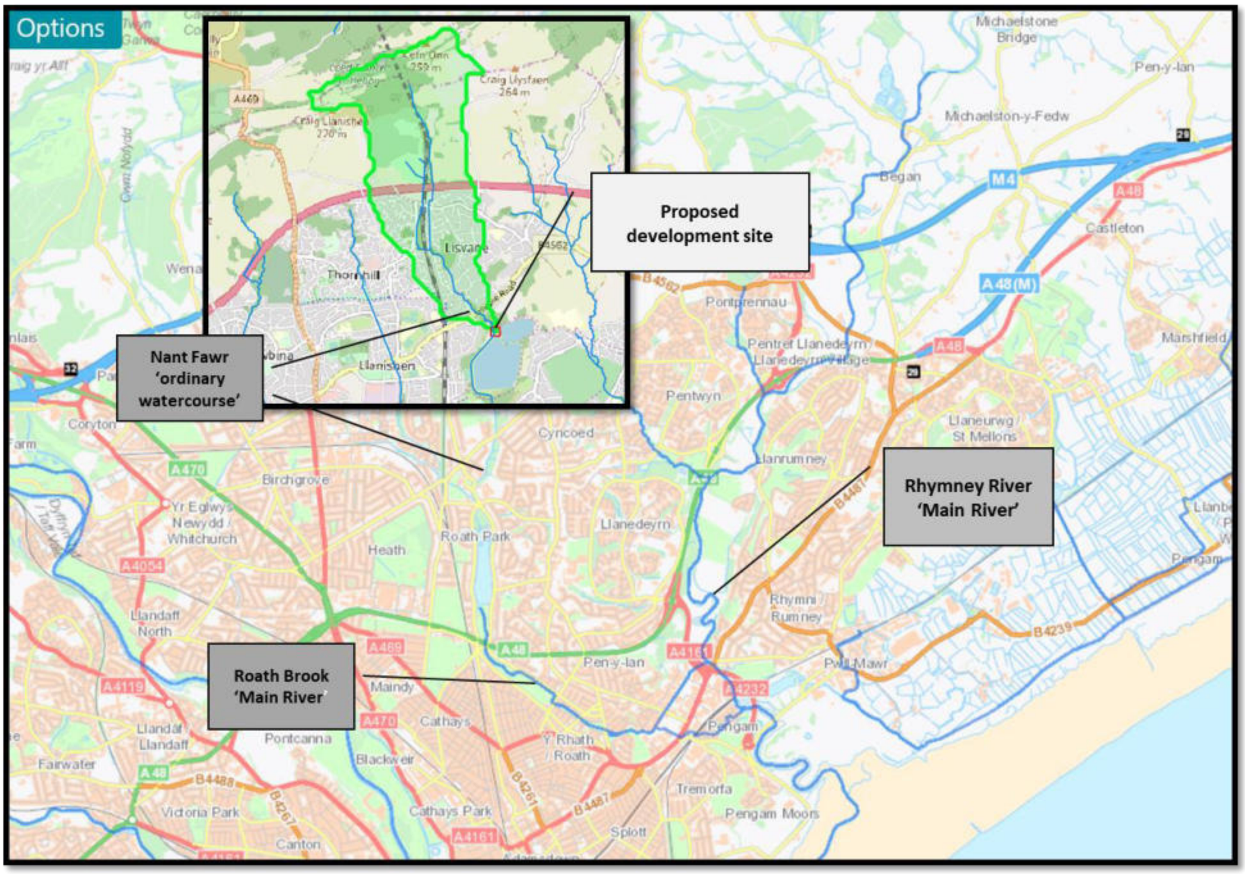


Figure 2.1: Natural Resources Wales Main River Map and FEH catchment

2.2 SUMMARY OF APPROACH

2.2.1. WSP have consulted with NRW to understand the local hydrology and the requirements for the hydraulic modelling in order to produce this hydraulic model. In particular, the hydrology and hydraulic modelling methodologies have been agreed prior to the completion of the modelling. The agreed methodology is included in Appendix B of this report and is summarised in this section.

2.2.2. For the selected section of watercourse to be modelled it was deemed necessary to update the hydrology with the latest database and software available. The existing model hydrology was carried out in 2007; therefore some of the techniques and databases used for their calculations have been superseded.

2.2.3. The hydrology of Nant Fawr catchment has been analysed at 3 Flood Estimation Points (FEPs) using the Flood Estimation Handbook (FEH) Statistical and Revitalised Flood Hydrograph ReFH2 methods. Hydrological calculations were required to derive peak flow estimates and design hydrographs for input into the new hydraulic model.

2.2.4. For the purpose of hydrological analysis, the entire catchment has been divided into 3 sub-catchments as shown in Figure 2.2.

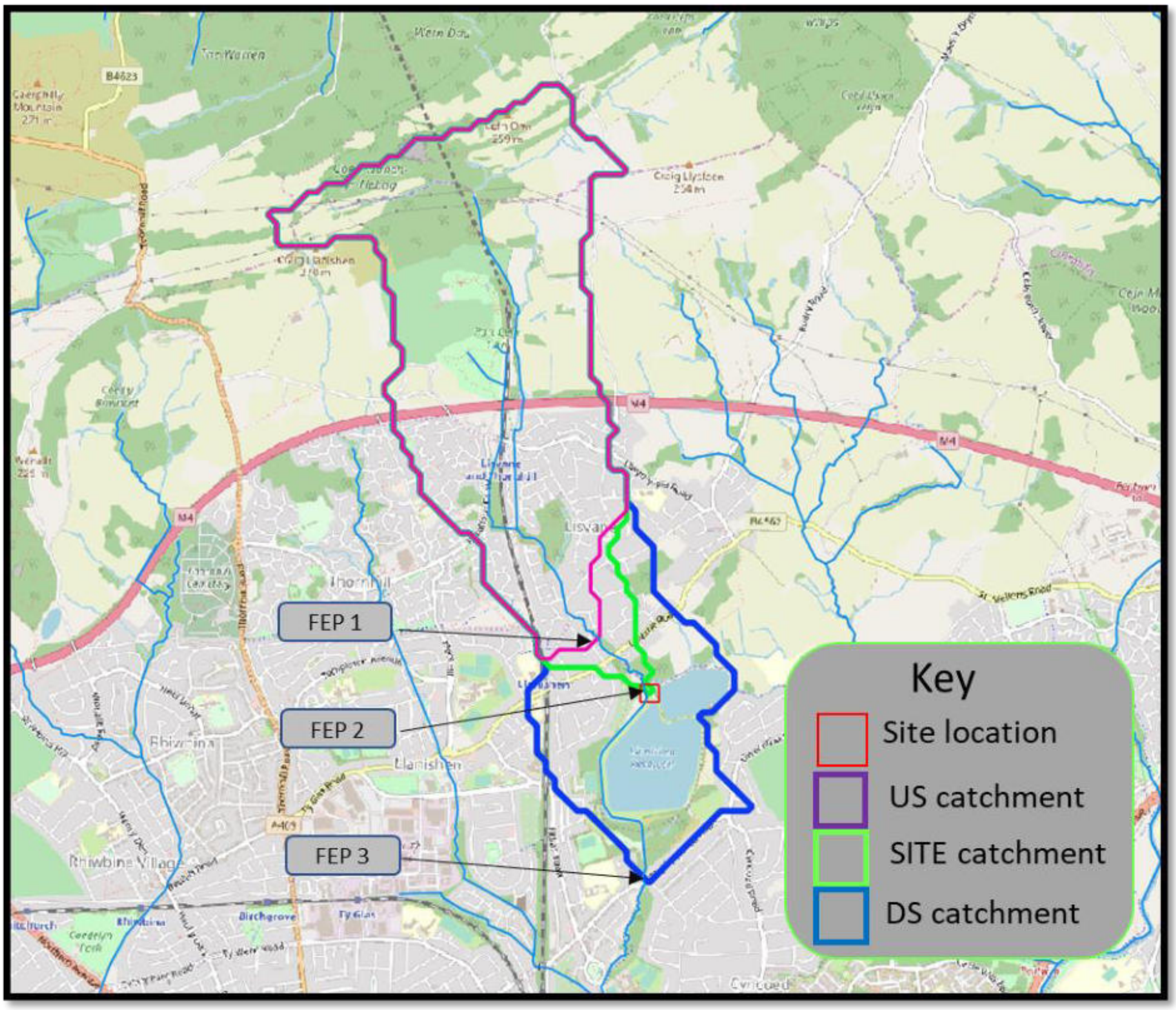


Figure 2.2 Map of Nant Fawr sub-catchments

2.3 CATCHMENT CHARACTERISTICS

2.3.1. Catchment descriptors for all three sub catchments were obtained directly from the FEH web services[1].

2.3.2. The key catchment descriptors at the three FEPs are presented in Table 2-1.

Table 2-1 - Key Catchment Descriptors

FEP	Key FEH Catchment Descriptors				
	URBEXT2000	**SPRHOST**	**BFIHOST**	**FARL**	**SAAR**
1	0.156	29.99	0.618	1	1247
2	0.167	30.48	0.617	1	1243
3	0.162	32.56	0.616	1(0.735)	1223

The FARL value of 1 at the FEPs 1 and 2 indicates no attenuation in the catchment upstream of these FEPs, whilst the FARL value of 0.735 at the FEP 3 indicates attenuation due to the presence of Llanishen reservoir. However, available information suggests that the reservoir is not connected with the Nant Fawr watercourse in terms of inflow and outflow. Therefore, the area occupied by the reservoir has been deducted from the total catchment area at FEP 3 and the FARL value of 1 has been taken forward for the purpose of this study.

The BFIHOST values for all three FEPs are less than 0.65[2] indicating that the catchment is moderately permeable. All three sub-catchments are heavily urbanised as the URBEXT value is more than 0.15.

2.4 FLOW ESTIMATION METHOD

FEH statistical Method

2.4.1. The FEH statistical method works with the catchment descriptors available on the FEH Web Service to estimate full flood frequency curves from catchment properties and gauged flow records. The FEH Statistical method consists of two main stages as follows;

- The estimation of the index flood or median annual flood (QMED); and

[1] *The FEH Web Service provides online access to the catchment descriptors and rainfall model outputs needed to carry out flood risk assessments.*

[2] *A catchment is considered as highly permeable if the BFIHOST > 0.65*

- The derivation of a growth curve. The latest software WINFAP – FEH v4.0 has been used to undertake the statistical analysis.

Estimation of QMED

2.4.2. The QMED for each sub-catchment was initially estimated using the catchment descriptors extracted from the FEH Web Service and the Environment Agency's QMED estimation guidance[3]. There is no gauging station within the Nant Fawr catchment.

Derivation of Growth Curves

2.4.3. Statistical analysis at all 3 FEPs was undertaken using FEH WINFAP v4.0 software to produce growth curves and calculate peak flow estimates for range of return periods. As the catchment is ungauged, pooled analysis were carried out.

Revitalized Flood Hydrograph Method

2.4.4. The ReFH (original) method provides an alternative approach to deriving peak flow estimates. This method uses catchment descriptors to generate a flood hydrograph based on a calculated design rainfall event profile. This method is generally believed to perform reasonably well on most catchments. Flood Modeller ReFH boundary unit has been used to derive flows from this method.

2.4.5. ReFH2 is an updated version of the original ReFH method and was released by Wallingford Hydro Solutions in 2015. The model draws on both the FEH 1999 and 2013 rainfall model data available from the FEH Web Service. The ReFH Flood Modelling software package, version 2.2.6589.25305 has been used to derive the flows from ReFH2 method.

2.4.6. The detailed calculations pertaining to each of these methods are presented in Appendix C – Flood Estimation Calculation Record.

2.5 CHOICE OF METHOD

The flow derived from FEH statistical analysis has been considered as the design flows at the three FEPs selected for this study. The statistical method is based on a much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments. Table 2.2 below shows the peak flows calculated from FEH statistical method for each sub-catchment (FEP). The results of this assessment are presented in the Flood Estimation Calculation Record in Appendix C.

[3] *Flood Estimation Guidelines: Technical guide*
Operational instruction 197_08, Environment Agency (2015)

Table 2.2 Peak flows

	Flood peak (m3/s) for the following return periods (in years)							
Site	2	10	25	50	100	100 +25%CC	100 +70%CC	1000
FEP 1	1.89	3.011	3.791	4.513	5.386	6.73	9.15	9.885
FEP 2	2.009	3.216	4.087	4.911	5.924	7.40	10.07	11.358
FEP 3	2.510	4.035	5.134	6.174	7.451	9.31	12.66	14.298

2.6 CLIMATE CHANGE

2.6.1. An allowance for climate change has been applied to the peak inflows in line with current guidelines provided by Natural Resources Wales (NRW). NRW require that a +25% allowance (central estimate) and a +70% allowance (upper end estimate) are allowed for within the assessment. This supersedes the precautionary contingency allowances provided in Table 1 of Technical Advice Note 15: Development and Flood Risk (TAN15) Guidance document. Table 2.3 below show the climate change allowance for Severn River basin district.

Table 2-3 - Climate Change Allowance for Wales. Source Welsh Government

	Total potential change anticipated for the 2020s (2015 to 2039)	**Total potential change anticipated for the 2050s** (2040 to 2069)	**Total potential change anticipated for the 2080s** (2070 to 2115)
Severn			
Upper (90th)	25%	40%	70%
Central (50th)	10%	20%	25%
West Wales			
Upper (90th)	25%	40%	75%
Central (50th)	15%	25%	30%
Dee			
Upper (90th)	20%	30%	45%
Central (50th)	10%	15%	20%

Table 2: Changes to river flood flows by river basin district (use 1961-90 baseline)

2.7 HYDROGRAPH DEVELOPMENT

2.7.1. Hydrographs have been generated within REFH software for a range of return periods up to the 0.1% AEP. The hydrographs have then been scaled to fit the peak flows derived from the FEH statistical method. Figure 2.3 shows the hydrographs for each return period and Table 2.2 summarises the peak design flows for the hydraulic model.

2.7.2. The difference of peak flow between FEP1 and FEP2 has been calculated and included into the model as lateral inflow in order to fit peak flow hydrograph at FEP2 (development site).

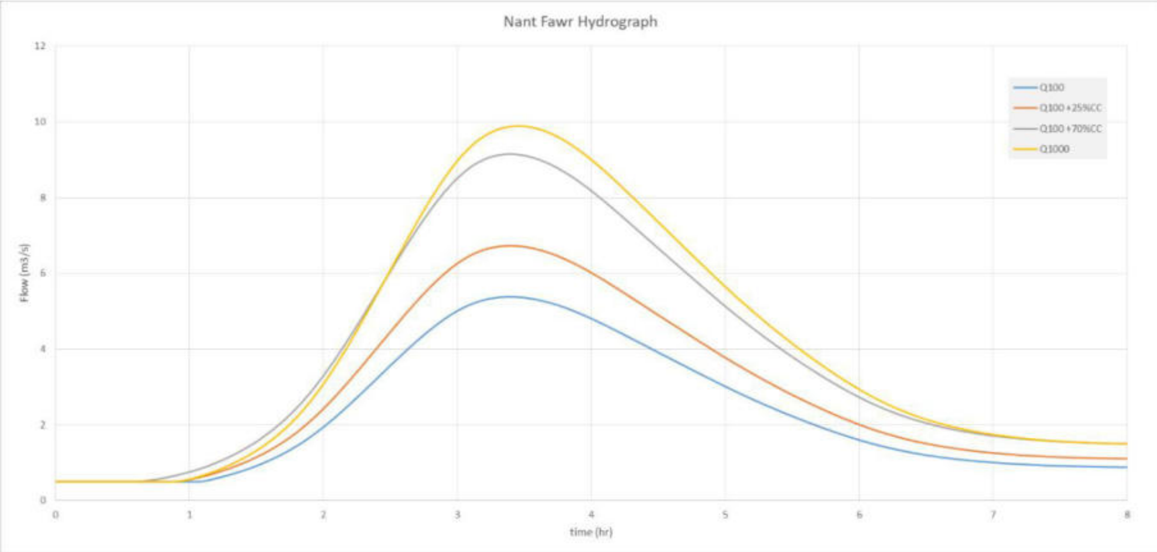


Figure 2.3 Nant Fawr hydrographs

2.7.3. The difference of peak flow between FEP2 and FEP3 has been calculated and included into the model as lateral inflow in order to fit peak flow hydrograph at FEP 3 (downstream boundary). More details of this calculations are located in Appendix C - Flood Estimation Calculation Record.

3 HYDRAULIC MODEL UPDATES

3.1.1. The existing hydraulic model of Roath Brook and associated reports were provided by NRW for use in this study. The following updates were applied to the original model for the purpose of this study:

- The model has been trimmed from both upstream (Mill Road) and downstream side (Rhyd-Penau Rd). The length of the trimmed model is 2.2km as opposed to the original length of 7.8 km. Figure 3-1 shows the original and updated extents of the model;
- The model inflows have been updated as described in Section 2;
- 26 model cross-sections were updated based on recent topographical survey;
- 14 structures were updated based on the recent topographical survey;
- Roughness values were updated as described in Section 3.4;
- The 1D flood modeller model has been linked with 2D (TUFLOW) to obtain more reliable flood; risk information at the development site. The extent of the 2D model is presented in Figure 3.1; and
- The structure spills in 1D model has been deactivated and included in the 2D model.

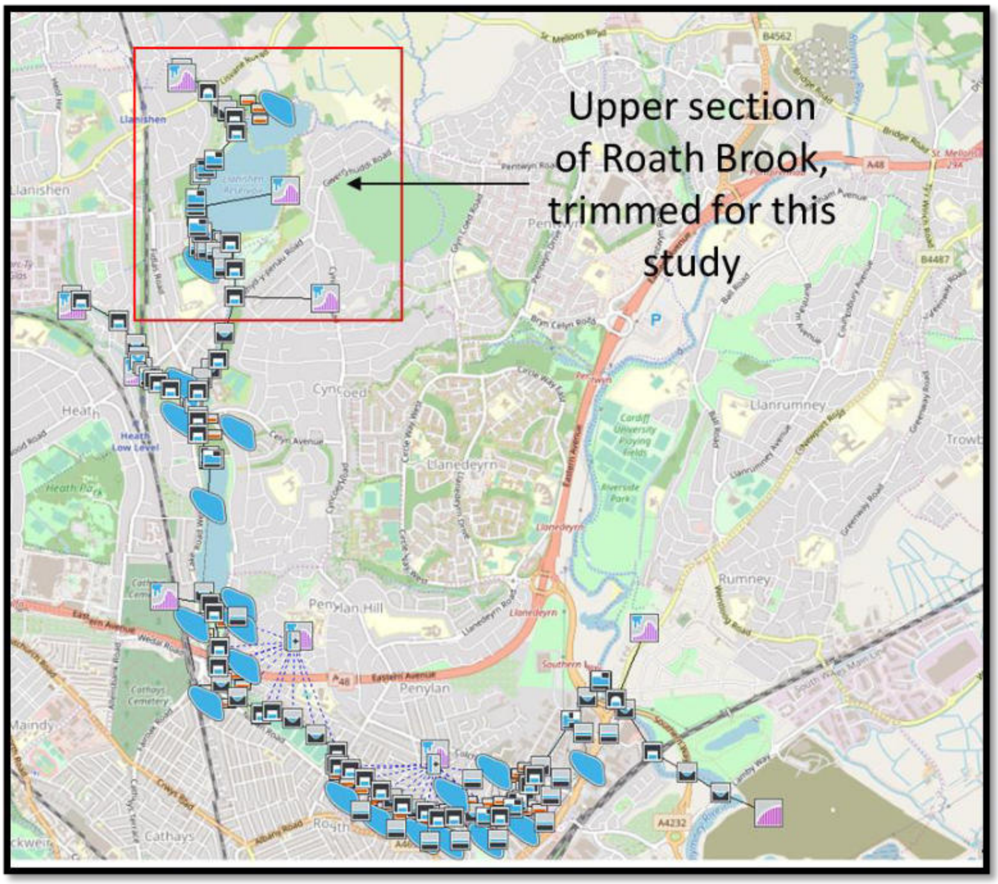


Figure 3.1 NRW 1D model extent for Roath Brook (Nant Fawr)

3.2 STRUCTURES

3.2.1. There are 14 structures within the reach of Nant Fawr model. All these 14 structures were included into the model, detailed information regarding the levels of the structures and how they have been represented in the model is located at Appendix D. Figure 3.2 below show the location of the structures within the model extent.

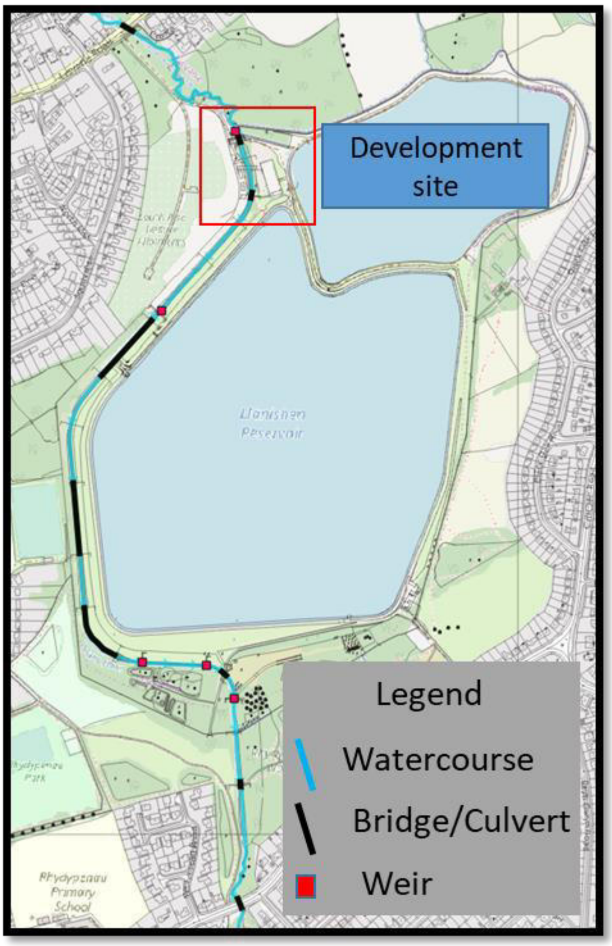


Figure 3.2 Location of structures updated

3.3 2D DOMAIN

3.3.1. The 1m composite Digital Terrain Model (DTM) resolution LiDAR has been used to define the ground model within the 2D domains. A cell size of 2m has been used in order to achieve sufficient accuracy in the floodplain representation. Bank-top elevations from the topographic survey at the cross sections have been applied to control the level at which water will start to overtop the banks and begin to flow out of the 1D channel into the 2D domain. The spill from the 1D channel into the floodplain over the left and right banks is defined by the HX lines. The HX lines are defined along the banks of the channel.

3.4 HYDRAULIC ROUGHNESS VALUES

3.4.1. Bank, bed and floodplain materials have been represented in the hydraulic model using Manning's roughness values. The Manning's roughness values are based on topographical survey data, photographic evidence and OS map. The dominant channel bed material within the model reach of the Nant Fawr is clean, straight but mixed with some stones and weeds. The watercourse flows through a man-made channel in the reach of the Llanishen reservoir. Table 3.1 below summarises the original and updated value of the Manning's "n" roughness in the channel. (Source: Ven Te Chow).

Table 3.1 - Updated Roughness values

Location		*Roughness*	
		Original	**Updated**
Reach 1	*From upstream boundary to Main entrance development*	*0.057*	*0.04*
Reach 2	*From main entrance to Rhydypenau Park Playground*	*0.051*	*0.035*
Reach 3	*From Rhydypenau Park Playground to Rhyd-Y-Penau Rd*	*0.052*	*0.035*

3.4.2. Within the 2D floodplain, the spatially varying hydraulic roughness values have been created using the OS Mastermap to distinguish between roads, buildings and open areas. Table 3-2 below highlights the Manning's values used for each land use classification.

Table 3.2 Manning's Roughness Values

MANNING'S VALUE	DESCRIPTION
0.050	General Surface/ Unclassified
1.000	Buildings
0.030	Inland Water
0.055	Grass
0.025	Roads, tracks and paths
0.065	Rail
0.070	Natural Environment/ woodland
0.065	Rough Grassland
0.065	Structure/ Landform
0.075	Glasshouse

3.4.3. The Manning's roughness coefficient was set at 0.050 for the general surface / unclassified areas. Within the 2D model, buildings are set with an elevated roughness value to slow the movement of water. Roads, tracks, paths and pavements were set with a lower roughness value to reflect the smoother surfaces that would act as preferential flow routes during an event.

3.5 BOUNDARY CONDITION DATA

3.5.1. The upstream inflow boundary along Nant Fawr is located at NGR: 318349, 182489. The location of this boundary is shown as yellow circle in Figure 3.3. The inflow at the upstream boundary is represented using ReFH hydrographs scaled to fit the statistical peak flow estimate at this location.

3.5.2. A Normal Depth boundary has been used to define the downstream boundary of the Nant Fawr; this is located approximately 2200m downstream of the proposed site (NGR: 318605, 180859). The location for the downstream cross section is shown by a green circle in Figure 3.3.

3.6 SCHEME MODEL (PROPOSED SCENARIO)

3.6.1. The location plan of the proposed development site and the extents of the model are shown in the Figure 3.3 below.

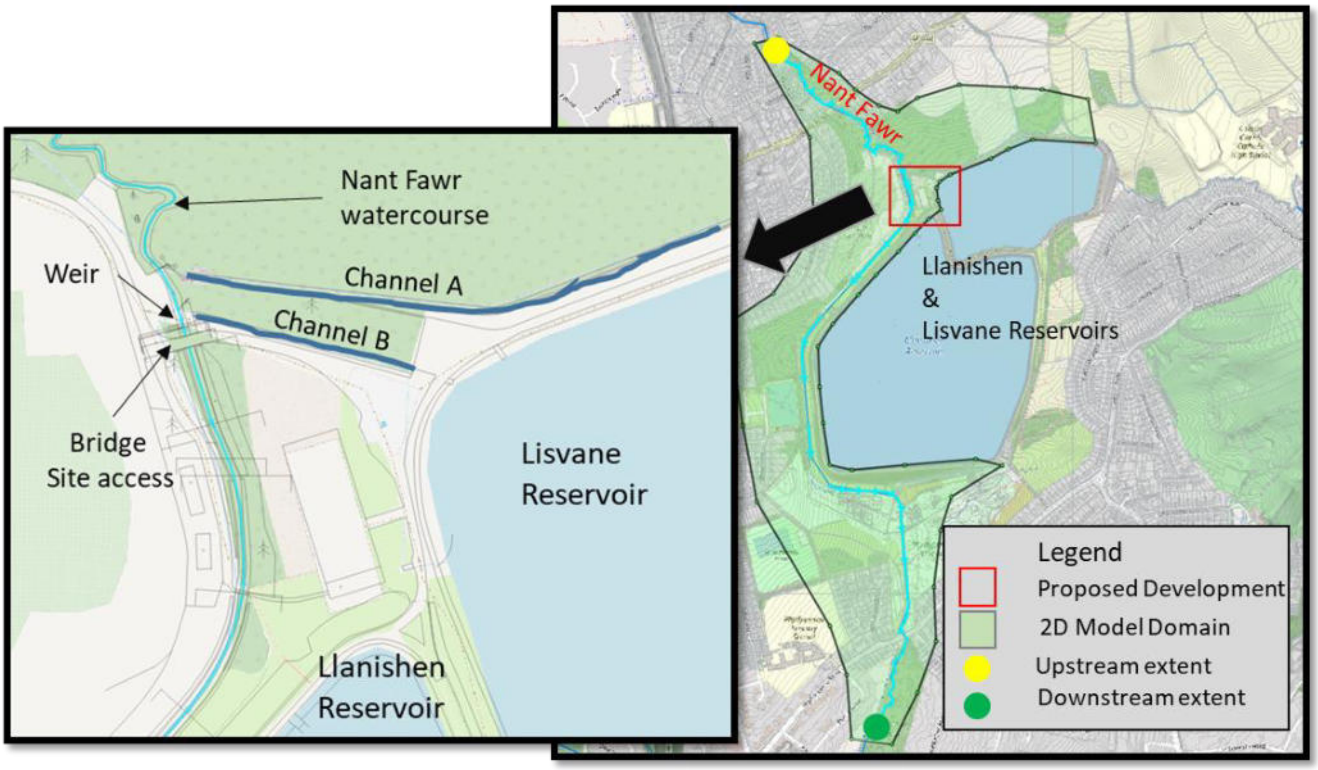


Figure 3.3 Site location and model extents

3.6.2. The scheme model comprises of following features:

- The development building has been included into the model with its initial proposed building finished floor level of 45.10m AOD; the results presented in this report are based on the 45.10mAOD Finished Floor Level (FFL) of the proposed building.
- Two small ditches are located to the north of the development site. These ditches are named as Channel A and B for the purposes of this report. The location of these channels are shown in Figure 3.4. Channel A runs parallel into the Lisvane reservoir and Channel B flows directly into the Lisvane reservoir. The Channel B (See Figure 3.2) is proposed to be replaced by a pipe below the parking area as is shown in Figure 3.4 below. Therefore, for the rest of the development site, the finished floor levels has been included into the model using the information provided by the Client.

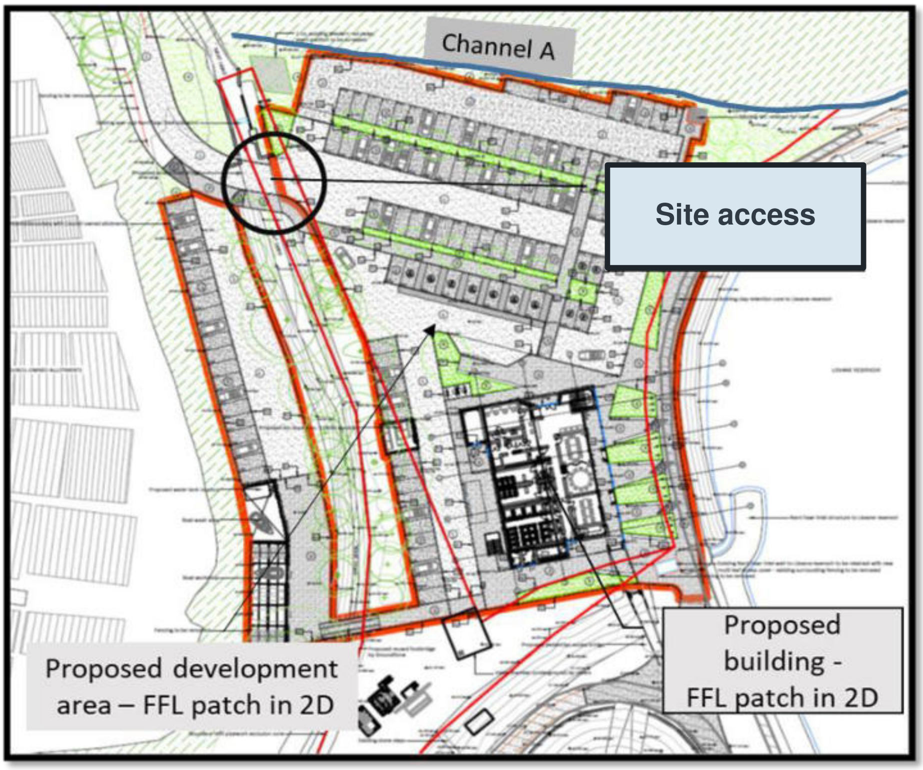


Figure 3.4 Changes in the 2D domain due to the proposed development FFL.

3.7 HYDRAULIC MODEL CALIBRATION

3.7.1. The Nant Fawr catchment is ungauged. Anecdotal records of flooding were also unavailable for this catchment. Therefore, calibration of the Nant Fawr model was not possible. However, a number of sensitivity tests were carried out and these are described in Section 5 of this report.

4 MODEL RESULTS

4.1 BASELINE MODEL RESULTS (EXISTING SCENARIO)

4.1.1. The baseline model development for this study has been used to run the 2, 20, 50, 100 and 1000 year return period events. Furthermore, the 100 year return period event model has also been run with 25, and 70% climate change allowances. The 1000 year return period has also been modelled with 25% climate change allowance.

4.1.2. Flood extent maps for each return period modelled are presented in Appendix E. Figure 4.1 below shows the 1 in 100 year return period event flood extent map in and adjacent to the development site.

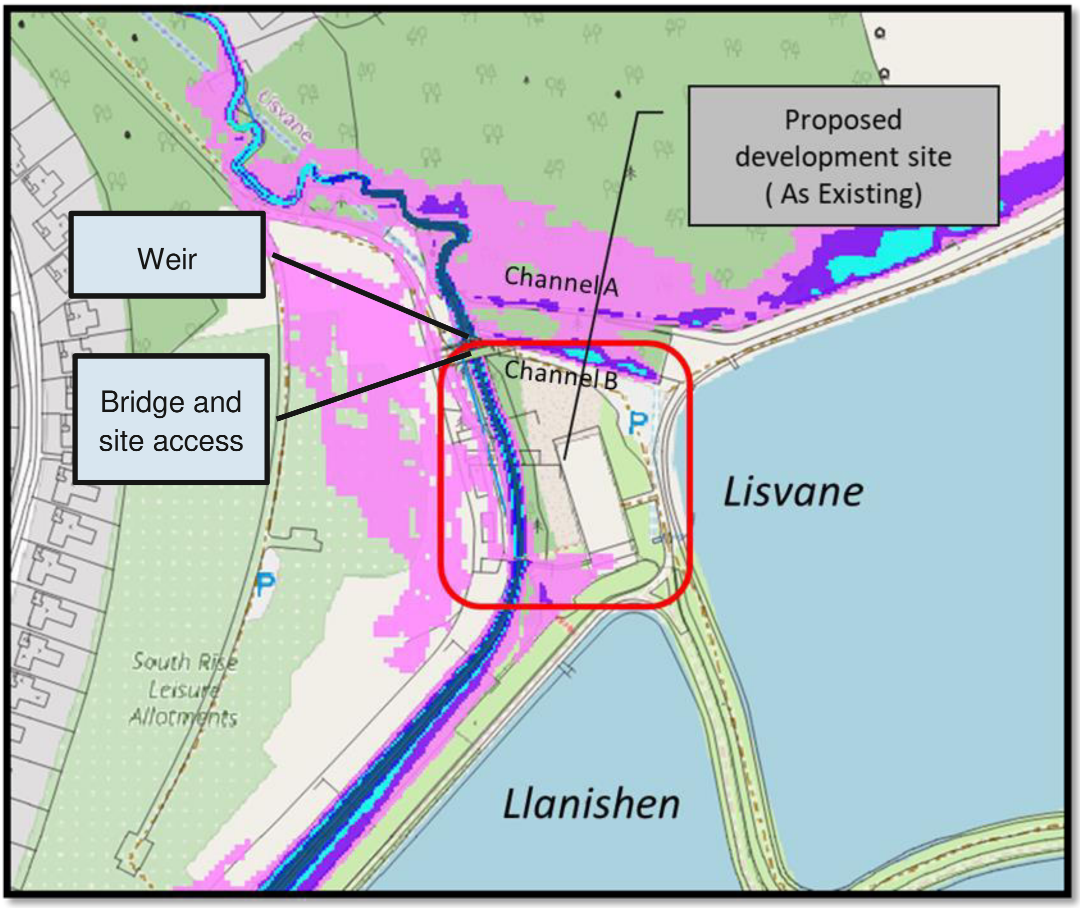


Figure 4.1 Baseline scenario maximum flood extent in 1% AEP (1 in 100) event.

4.1.3. The baseline model results show that the water levels increase within the channel upstream of the online weir located at the main entrance of the site as shown in Figure 4.1. Due to the increase in water level, the flow overtops the left banks. This overflow water then starts to flow through the Channels A and B located at the left bank of Nant Fawr watercourse. This flood mechanism occurs in events of 5% AEP (1 in 20 year return period) and greater. The model results also show that the flow overtops the right bank flooding the South Rise Leisure Allotments in the events of 1% AEP (1 in 100 year return period) and greater.

4.1.4. The model results show that, in the baseline scenario, the maximum flood depths at the location of the proposed building are 0.02m and 0.79m at 1%AEP +25%CC and 0.1%AEP events respectively.

4.1.5. The modelled flood extents for the existing baseline scenario are shown in Appendix E.

4.2 PROPOSED SCHEME SCENARIO

4.2.1. The proposed development model has been used to run the 2, 20, 50, 100 and 1000 year return period events. Similar to the baseline scenario, the 100 year return period event model has also been run with 25% and 70% climate change allowances.

4.2.2. Flood extent maps for each return period modelled are presented in Appendix E. Figure 4.2 below shows the 1 in 100 year return period event flood extent map in and adjacent to the development site.

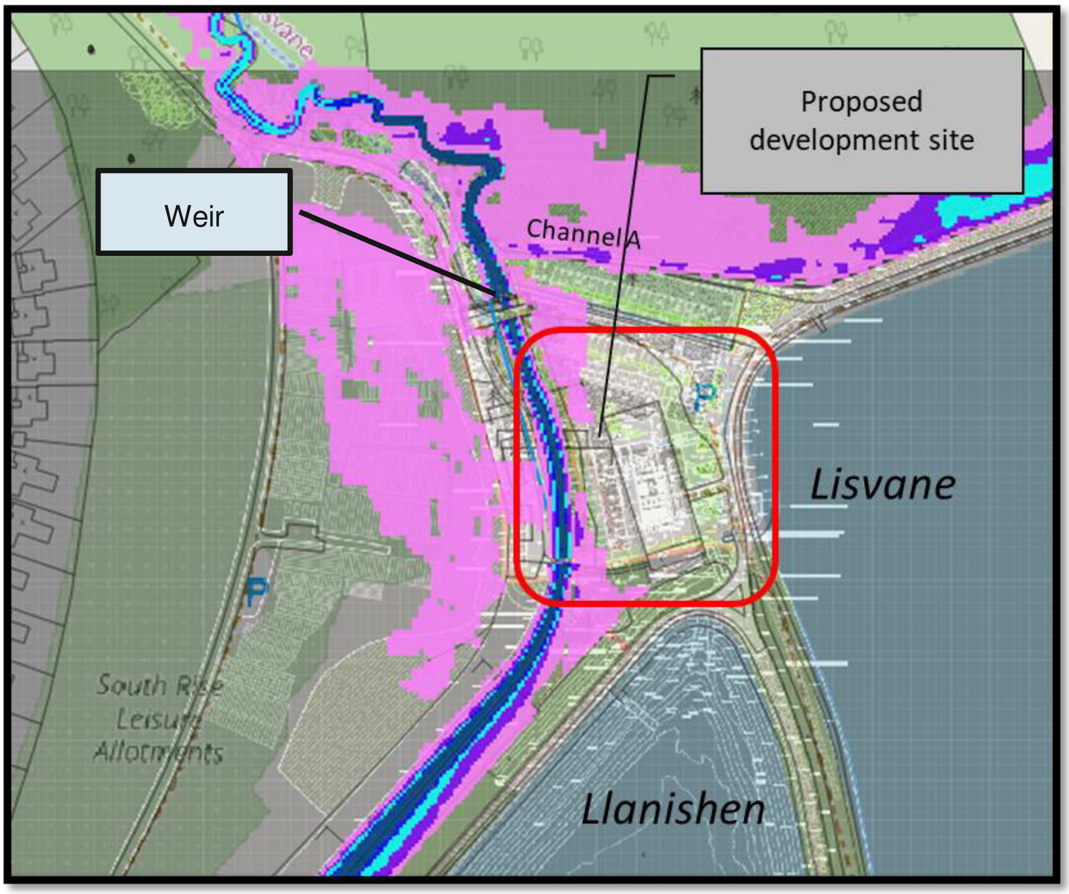


Figure 4.2 Proposed development scenario maximum flood extent 1% AEP (1 in 100) event.

4.2.3. The proposed development model results show the increase in water levels within the channel upstream of the online weir located at the main entrance of the proposed development site. The results also show that in the event of a 5% AEP (1 in 20 year return period) and greater, the water overtops the left banks, flowing along the Channel A located at the left bank of Nant Fawr watercourse. Similar to the baseline scenario, the flow also overtops the right bank flooding the South Rise Leisure Allotments in the event of 1% AEP (1 in 100 year return period) and greater.

4.2.4. The model results do not show any flooding to the proposed building up to the 1% AEP. However, a small part of the site within the red line boundary, located to the north of the proposed parking area will be flooded with water depths up to 20mm and lesser in the 1% AEP event.

4.2.5. The model results show that the proposed building remains flood free during the 1%AEP +25%CC event and have 0.19m depth during the 0.1%AEP event. The maximum flood depths within the remaining external areas within the red line boundary of the development site are 0.05m and 0.49m for the 1%AEP+25%CC and 0.1%AEP events respectively.

4.2.6. Water depths for the full range of events at different points of interest at the development site are presented in Appendix F.

4.2.7. Figure 4.3 below shows the flood extent and depths comparison for the baseline and proposed scheme scenarios during the 1%AEP+25%CC event.

Figure 4.3 Baseline vs proposed scheme 1%AEP +25%CC – flood depth

5 SENSITIVITY ANALYSIS

5.1.1. Sensitivity analyses have been undertaken using the baseline hydraulic model to assess the potential changes in water levels as a result of changing parameters within the model. The parameters altered in the model for the sensitivity test are those which are typically most influential on water levels, in particular:

- roughness for the river channels and floodplains,
- flows (climate change allowance) and
- downstream boundary model.

The sensitivity runs have been undertaken with the 1 in 100 year return period flood event. The changes in water levels have been assessed at the 8 cross sections shown in Figure 5.1. The results are presented in the following sub-sections.

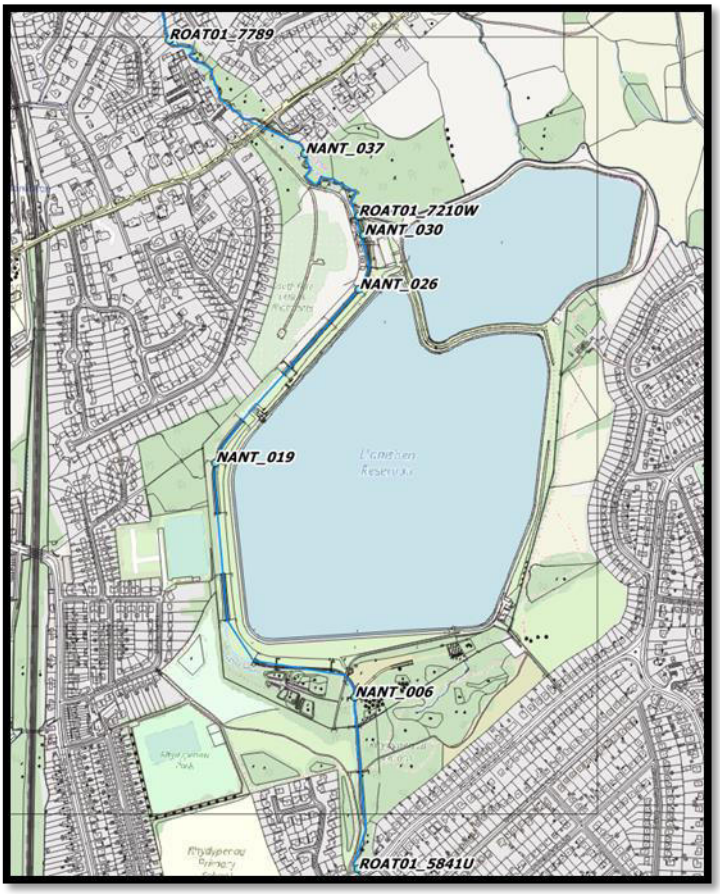


Figure 5.1 Location of water level point extraction (1D)

5.1.2. The proposed development site is located adjacent to cross section reference ROAT01_7210W and Nant_030 and Nant_026 as shown in Figure 5.1 above.

5.2 MANNING'S ROUGHNESS

5.2.1. A 20% increase and decrease in the Manning's "n" roughness values were applied to the 1% AEP model in both the river channel and floodplains for the baseline scenario. The changes in peak water levels are presented in Table 5.1 below; the closest cross-sections to the development site are highlighted in yellow.

Table 5.1 Manning's roughness sensitivity - water level comparison

Llanishen selected nodes	Model 1% AEP Baseline water level	100 year - 20% Manning's roughness		100 year + 20% Manning's roughness	
		Water level (m AOD)	Difference (m)	Water level (m AOD)	Difference (m)
ROAT01_7789	55.94	55.87	-0.07	56.00	0.06
NANT_037	48.69	48.62	-0.06	48.74	0.05
ROAT01_7210W	45.89	45.89	0.00	45.88	-0.01
NANT_030	44.59	44.55	-0.04	44.63	0.04
NANT_026	44.27	44.26	-0.01	44.29	0.02
NANT_019	42.65	42.55	-0.10	42.70	0.05
NANT_006	32.78	32.79	0.01	32.78	0.00
ROAT01_5841D	29.54	29.43	-0.10	29.64	0.11

5.2.2. The results in Table 5.1 show that the water levels increase in the range of 0.019 to 0.105m depending upon the location in the model reach when the roughness values are increased by 20%.

5.2.3. The water levels decrease in the range of 0.013 to 0.103m in the model reach with the 20% decrease in roughness values.

5.2.4. The model shows that at certain locations the model is comparatively more sensitive to both increase and decrease in the Manning's "n" roughness value.

5.2.5. Detailed flood maps for Manning's "n" sensitivity analysis are presented in Appendix G.

Figure 5.2 below compares the maximum flood extents between the baseline (blue) and the sensitivity scenario with 20% increase in roughness (grey). Figure 5.3 compares the maximum flood extent between the baseline (blue) and the sensitivity scenario with 20% decrease in roughness (red).

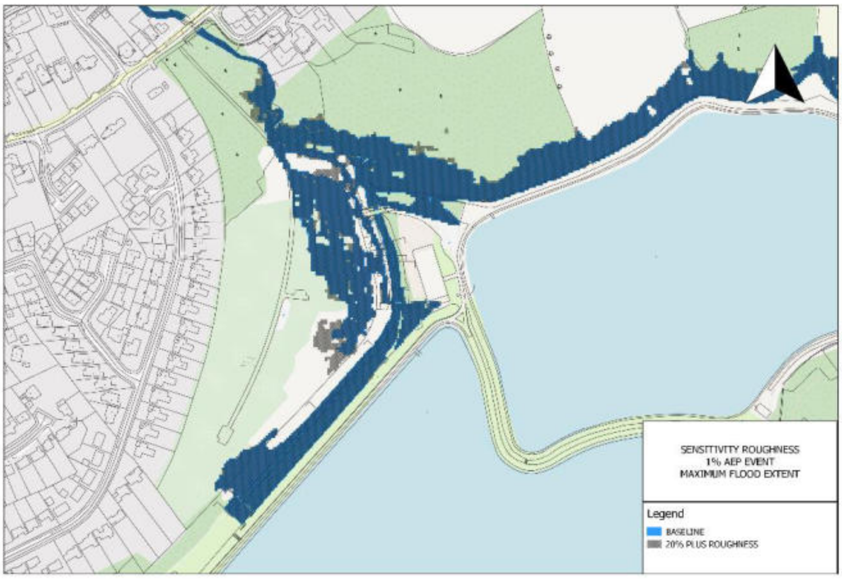


Figure 5.2 Baseline vs 20% increase in roughness. Maximum flood extent - Manning's sensitivity

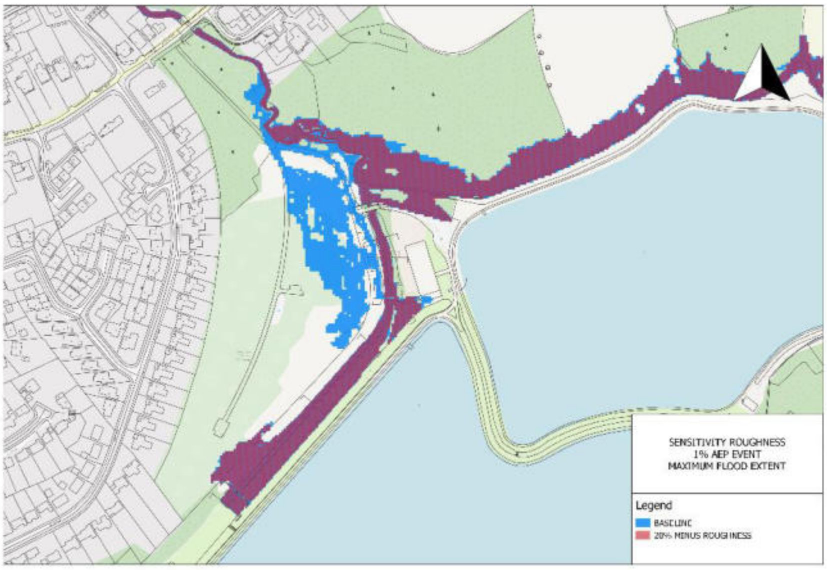


Figure 5.3 Baseline vs 20% decrease in roughness. Maximum flood extent - Manning's sensitivity

The comparison of the flood extents for roughness sensitivity shows that the model is susceptible to the changes within the watercourse as is shown in Figures 5.2, 5.3 and Table 5.1 above. The water level increase within the watercourse due to the increase in roughness and overspill both banks.

5.3 DOWNSTREAM BOUNDARY CONDITION

5.3.1. The downstream boundary of the model is located at Rhyd-Y-Penau Road. The downstream boundary depth has been both decreased and increased by 20% as a part of this sensitivity analysis. Table 5.2 shows the results of this sensitivity analysis. The closest cross-sections to the proposed development site are highlighted in yellow.

Table 5.2 Downstream boundary depth sensitivity - water level comparison

Llanishen selected nodes	Model 1% AEP Baseline water level	100 year - 20% Downstream Boundary condition		100 year + 20% Downstream Boundary condition	
		Water level (m AOD)	Difference (m)	Water level (m AOD)	Difference (m)
ROAT01_7789	55.94	55.94	0.00	55.94	0.00
NANT_037	48.69	48.69	0.00	48.69	0.00
ROAT01_7210W	45.89	45.89	0.00	45.89	0.00
NANT_030	44.59	44.59	0.00	44.59	0.00
NANT_026	44.27	44.27	0.00	44.27	0.00
NANT_019	42.65	42.65	0.00	42.65	0.00
NANT_006	32.78	32.78	0.00	32.78	0.00
ROAT01_5841D	29.54	29.49	-0.05	29.60	0.07

5.3.2. The results show that the water levels remain unaltered in the reach of proposed development when the downstream boundary depth is changed by +/- 20%.

5.3.3. Detailed flood maps for downstream boundary sensitivity analysis are presented in Appendix G.

Figure 5.4 below compares the maximum flood extents between the baseline (blue) and the sensitivity scenario with 20% increase in downstream boundary (grey). Figure 5.5 compares the maximum flood extents between the baseline (blue) and the sensitivity scenario with 20% decrease in roughness (red).

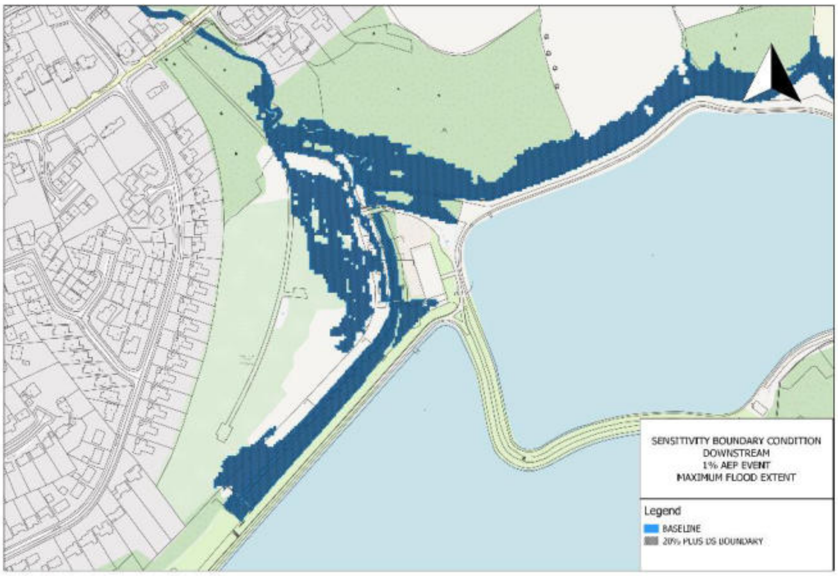


Figure 5.4 Baseline vs 20% increase in Downstream Boundary. Maximum flood extent - Boundary condition sensitivity

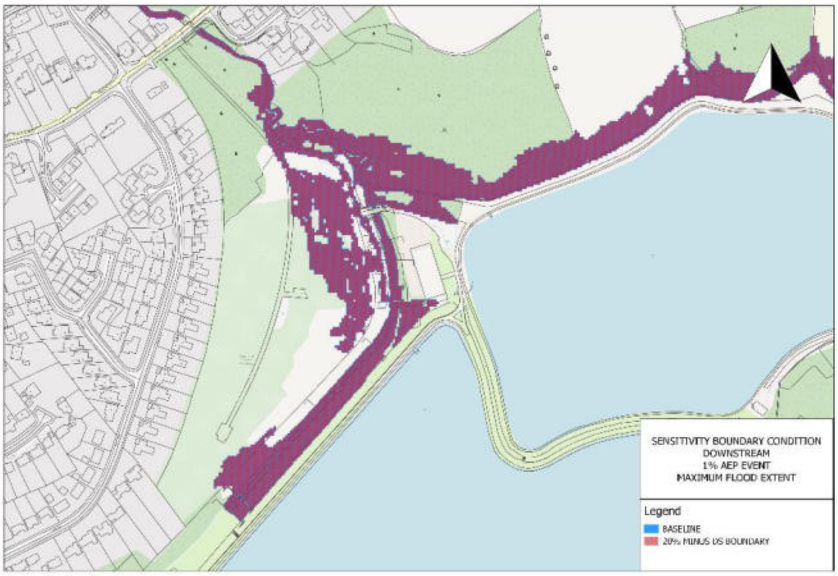


Figure 5.5 Baseline vs 20% decrease in Downstream Boundary. Maximum flood extent - Boundary condition sensitivity

Comparison of the flood extents of both increase and decrease downstream boundary conditions versus the baseline showed no changes at the proposed development site as shown in Figures 5.4 and 5.5 above.

5.4 SENSITIVITY WITH FLOW

5.4.1. The 1% AEP event inflows have been increased and decreased by 20%. The changes in peak water levels are presented in the Table 5.3 below; the closest cross-sections to the proposed development are highlighted in yellow.

Table 5.3 Flow sensitivity - water level comparison

Llanishen selected nodes	Model 1% AEP Baseline water level	100 year - 20% peak flow		100 year + 20% peak flow	
		Water level (m AOD)	Difference (m)	Water level (m AOD)	Difference (m)
ROAT01_7789	55.94	55.87	-0.07	56.00	0.06
NANT_037	48.69	48.62	-0.06	48.74	0.05
ROAT01_7210W	45.89	45.87	-0.02	45.90	0.02
NANT_030	44.59	44.37	-0.23	44.72	0.13
NANT_026	44.27	44.05	-0.22	44.46	0.19
NANT_019	42.65	42.51	-0.14	42.76	0.11
NANT_006	32.78	32.77	-0.01	32.79	0.01
ROAT01_5841D	29.54	29.50	-0.04	29.57	0.04

5.4.2. The results show that the maximum increase in water levels is 0.19m and the maximum decrease in water levels is 0.22m with 20% increase and decrease of flow respectively.

5.4.3. The results also show that the variation of water levels ranges from 0.02m (in model node - NANT_006) and 0.41m (in model node NANT_026) for the 20% increase and decrease in flow.

5.4.4. Detailed flood maps for Flow sensitivity analysis are presented in Appendix G.

Figure 5.6 below compares the maximum flood extents between the baseline scenario (blue) and the sensitivity scenario with 20% increase in peak flow (grey). Figure 5.7 compares the baseline scenario (blue) and the sensitivity scenario with 20% decrease in peak flow (red).

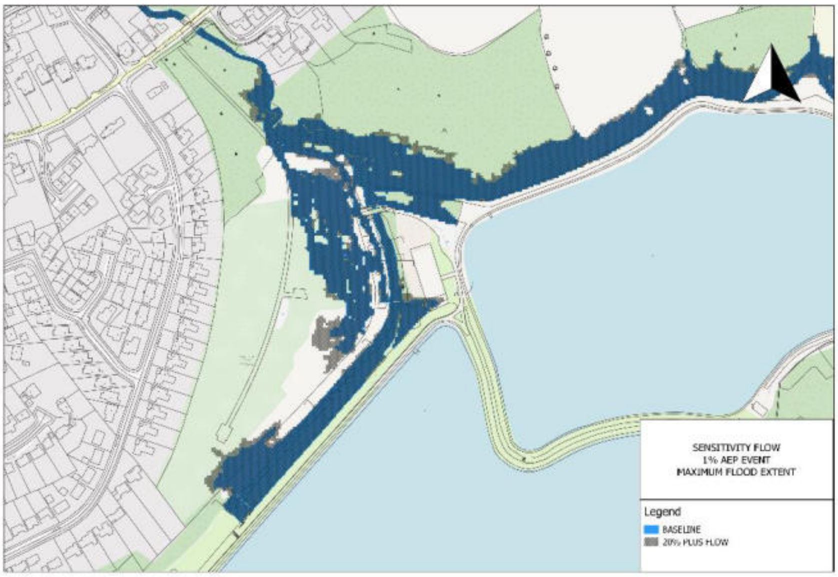


Figure 5.6 Baseline vs 20% plus flow. Maximum flood extent – Flow sensitivity

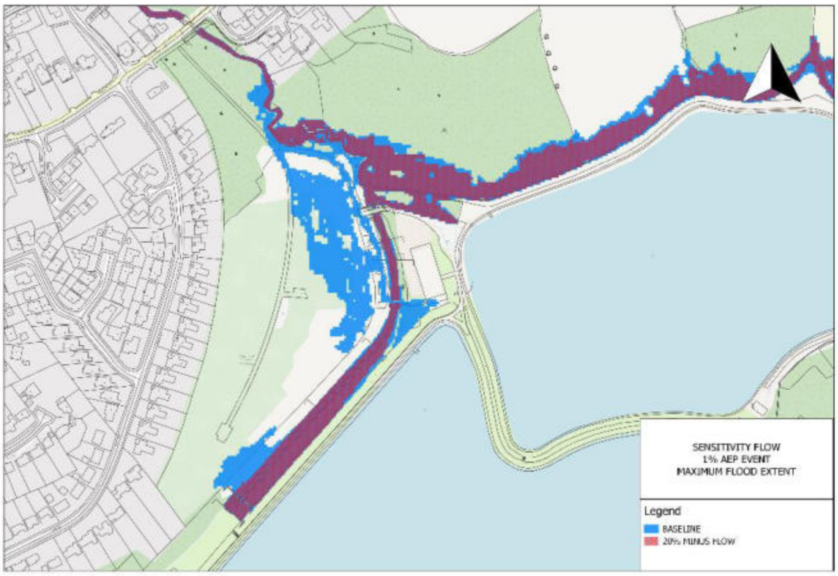


Figure 5.7 Baseline vs 20% minus flow. Maximum flood extent - Flow sensitivity

The results show that the flow will not overtop the right hand bank with the reduction of flow by 20%. Therefore, the South Rise Leisure Allotments will remain flood free as shown in Figure 5.7 above. The results show that the increase in the flow extent will increase from both banks as shown Figure 5.6.

5.5 BLOCKAGE SCENARIOS

5.5.1. Sensitivity analysis for blockage scenario have been undertaken in order to assess the possible impact in case of blockage of the bridge located at the main entrance of the scheme site. (Figure 5.8 below shows the structure location within the scheme site and the current shape of the bridge). This blockage sensitivity has been carried out with both the baseline and the proposed models. The event tested as part of this sensitivity is 1% AEP +70%CC (worst case scenario).

5.5.2. Three different blockage proportions have been applied at the bridge location in both the baseline and the proposed models: Low (30%), Medium (67%) and High (95%).

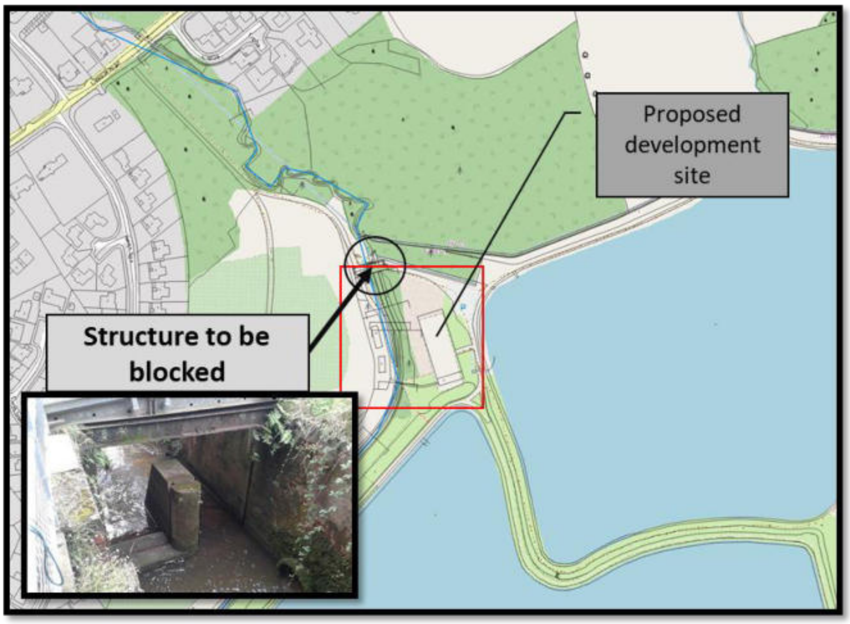


Figure 5.8 Location of structure to blockage scenario

Blockage in Baseline Scenario

5.5.3. The results show that the water levels within the watercourse do not change substantially with the low blockage scenario. The water levels decrease by approximately 25mm downstream of the bridge with the medium blockage. Table 5.4 below shows the reduction in water level along the watercourse due to the blockage and the increase in flood extent at the development area. The closest cross-sections to the proposed development site are highlighted in yellow.

5.5.4. Inclusion of the high blockage in the model decreases the water levels by approximately 1.45m downstream of the bridge (at model node NANT_026) due to the reduction of conveyance. The high blockage also increases the water levels upstream of the access bridge.

Table 5.4 Blockage scenarios - water level comparison (Blockage in Baseline Scenario)

BLOCKAGE SCENARIO							
Llanishen selected nodes	1 in 100 year +70%CC						
	Baseline (m AOD)	Low blockage	Difference	Medium blockage	Difference	High blockage	Difference
ROAT01_7789	56.13	56.13	0	56.13	0.00	56.13	0.00
NANT_037	48.87	48.87	0	48.87	0.00	48.87	0.00
ROAT01_7210W	45.93	45.93	0	45.93	0.00	45.99	0.06
NANT_030	44.92	44.92	0	44.90	-0.02	44.13	-0.80
NANT_026	44.90	44.90	0	44.88	-0.02	43.45	-1.45
NANT_019	42.99	42.99	0	42.98	-0.01	42.13	-0.87
NANT_006	32.81	32.81	0	32.81	0.00	32.73	-0.08
ROAT01_5841U	29.67	29.59	-0.09	29.59	-0.09	29.43	-0.24

5.5.5. The results show that the maximum flood depth at the location of the proposed site is approximately 0.35m for the low blockage scenario. Detailed flood extent maps for the blockage scenarios are presented in the Appendix G.

5.5.6. During the baseline scenario, the maximum flood depth on the proposed building area with the existing ground levels are as follows:

* Low (30%) blockage scenario, maximum water level 44.96 m AOD (0.35m depth),

* Medium (67%) blockage scenario, maximum water level 44.89 mAOD (0.28m depth), and

* High (95%) blockage scenario, maximum water level 44.63 mAOD (0.02m depth).

Blockage in the proposed model

5.5.7. The results show that with the low blockage scenario, the water levels do not change substantially (see Table 5.5 below) The medium blockage increases the flood extent considerably. The closest cross-sections to the proposed development site are highlighted in yellow in Table 5.5.

5.5.8. It was noted that, during the high blockage scenario, the water levels decreased downstream of the bridge by approximately 1.38m (at NANT_026) due to the reduction of conveyance.

Table 5.5 Blockage scenarios - water level comparison (Blockage in the proposed model)

BLOCKAGE SCENARIOS							
Llanishen selected nodes	1 in 100 year +70%CC						
	Proposed scheme (m AOD)	Low blockage	Difference	Medium blockage	Difference	High blockage	Difference
ROAT01_7789	56.13	56.13	0.00	56.13	0.00	56.13	0.00
NANT_037	48.87	48.87	0.00	48.87	0.00	48.87	0.00
ROAT01_7210W	45.94	45.94	0.00	45.94	0.00	46.00	0.07
NANT_030	45.03	45.03	0.00	45.03	0.00	44.17	-0.86
NANT_026	45.03	45.03	0.00	45.03	0.00	43.65	-1.38
NANT_019	43.06	43.06	0.00	43.06	0.00	42.26	-0.80
NANT_006	32.81	32.81	0.00	32.81	0.00	32.75	-0.07
ROAT01_5841U	29.68	29.59	-0.08	29.59	-0.08	29.51	-0.17

5.5.9. Using the proposed finished floor level of 45.10mAOD, the blockage scenario results show that the proposed visitor centre building is unlikely to be affected by fluvial flooding in the Low, Medium and Maximum blockage scenarios. Detailed flood maps for the blockage scenarios are presented at the Appendix G.

5.5.10. The maximum flood depth on other areas of the proposed development within the red line boundary are as follows:

* Low (30%) blockage scenario, maximum water level 45.04 m AOD (0.25m depth),

* Medium (67%) blockage scenario, maximum water level 45.02mAOD (0.23m depth), and

* High (95%) blockage scenario, maximum water level 44.94 mAOD (0.15m depth).

6 FLOW VELOCITY AND FLOOD HAZARD

6.1.1. Technical Advice Note 15 (TAN15), Section A1.14 provides advice for planning authorities and it suggests that development should be designed to be flood free during the 1% AEP fluvial flood.

6.1.2. The TAN15 - A1.15 also states “For instance it would not be sensible for developments to be built on areas where the velocity and depth of floodwaters was such that structural damage was possible on that people could be swept away by the flood”. The maximum velocity tolerable at the property access is 0.15m/sec.

6.1.3. The comparison between the baseline and the proposed scheme in flow velocities is shown in Figure 6.1 below. For the 1% AEP, the proposed building is not shown to be affected by fluvial flooding.

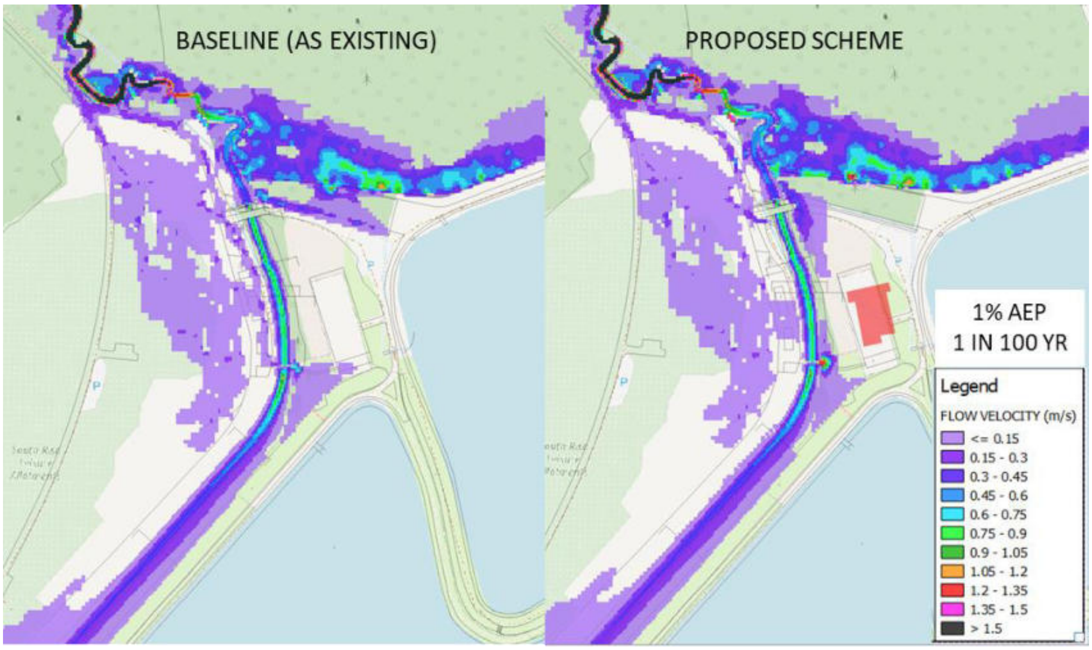


Figure 6.1 Baseline vs proposed scheme 1% AEP – flow velocity

6.1.4. The modelling outputs show that for the 1% AEP+25%CC, the flow velocities at the area of the proposed building is below 0.15m/s and the proposed building is unlikely to be affected by fluvial flooding as shown in Figure 6.2 below.

6.1.5. The hydraulic modelling for the 1% AEP +25%AEP shows that there is no increase in flood hazard rating at the proposed visitor centre site from the baseline to proposed scenario. The flood hazard rating remains “Low” in both scenarios. This can be seen in Figure 6.3 further below.

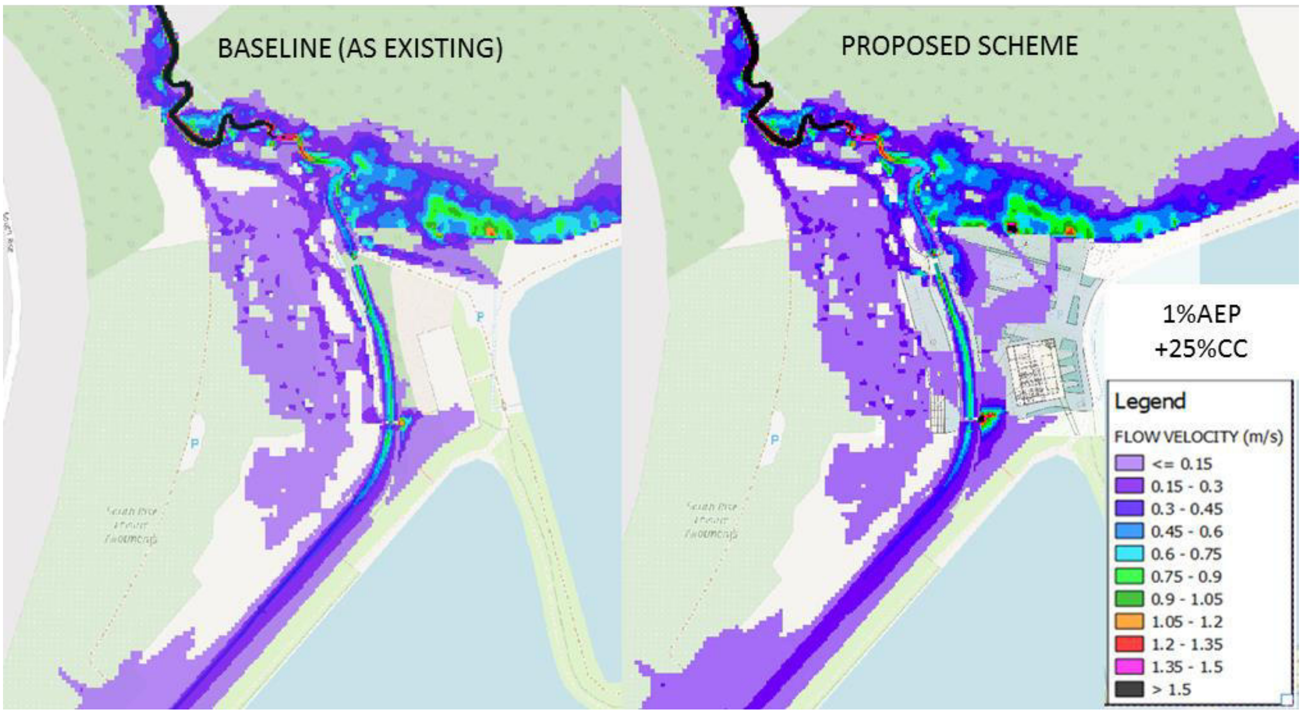


Figure 6.2 Baseline vs proposed scheme 1%AEP +25%CC – flow velocity

Figure 6.3 Baseline vs proposed scheme 1%AEP +25%CC – flood hazard

7 SUMMARY OF THE FINDINGS

7.1.1. Further to the hydraulic modelling of a wide range of scenarios (the baseline, proposed scheme, sensitivity and blockage scenarios) at different return periods, the findings are summarised as follows:

7.2 BASELINE SCENARIO

- The Baseline simulations show increases in water levels within the channel upstream of the online weir located at the main entrance of the proposed scheme site. Due to this, the flow overtops the left banks and starts to flow through the existing channels (Channel A and B) parallel to the Lisvane Reservoir. This flood mechanism is predicted to occur in events of 5% AEP (1 in 20 year return period) and greater.
- The flows overtop the right bank and flood the South Rise Leisure Allotments during the 1% AEP (1 in 100-year return period) and greater.
- The maximum baseline water level at the proposed scheme area (i.e. with existing ground levels) for a 1% AEP +25%CC and 0.1% event are 44.57m AOD (0.02m depth) and 45.21m AOD (0.79m depth) respectively.

7.3 PROPOSED SCHEME SCENARIO

- Similar to baseline scenario, the flow overtops the left banks as from the 5% AEP (1 in 20 year return period) and greater events, upstream of the online weir. This water then starts to flow along the Channel A.
- The flows overtop the right bank and flood the South Rise Leisure Allotments during the 1% AEP (1 in 100 year return period) and greater.
- The proposed building is unlikely to be affected by the 1% AEP event. However, a small area within the red line boundary will be flooded with a depth up the 20mm during the 1% AEP event.
- The proposed building is unlikely to be affected by the 1% AEP +25%CC.
- The maximum water levels within the proposed building area 0.1% AEP event is 45.28m AOD (0.19m depth).
- The following Table 7.1 summarizes the maximum water levels and flood depths at the proposed building area at different scenarios.

Table 7.1 Maximum water levels at the proposed building area.

				Proposed development		
	No blockage			*Low Blockage*	Medium Blockage	High blockage
Event	*Q100*	*Q100+25CC*	*Q1000*	*Q100+70CC*		
*Modelled Building level (mAOD)**	*45.100*	45.100	45.100	45.100	45.100	45.100
Maximum water level (mAOD)	-	45.039	45.287	45.040	45.040	45.028
Difference -Flood depth (m)	-	-	0.187	-	-	-

7.4 SENSITIVITY ANALYSIS

- The water levels remain unaltered in the reach of proposed development when the downstream boundary depth is increased or decreased by +/- 20%. Therefore, the model shows that the changes in downstream boundary does not affect the proposed building site.
- The maximum increase and decrease in water levels are between 0.19m and 0.27m with 20% increase and decrease in flow respectively. The South Rise Leisure Allotments will not be flooded with the 20% decrease in flow.
- Water levels will increase in the range of 0.019m to 0.105m depending upon the location in the model reach when the roughness values are increased by 20%. The water levels decrease in a range of 0.013m to 0.103m in the model reach with the 20% decrease in roughness value.
- The model shows that, at certain locations, the model is comparatively more sensitive to both increase and decrease in the Manning's "n" roughness value. However, the changes in roughness does not affect the proposed building site.

7.5 BLOCKAGE SCENARIOS

The blockage scenario results show the proposed building with a floor level of 45.10mAOD is unlikely to be affected by blockage scenarios at the access bridge.

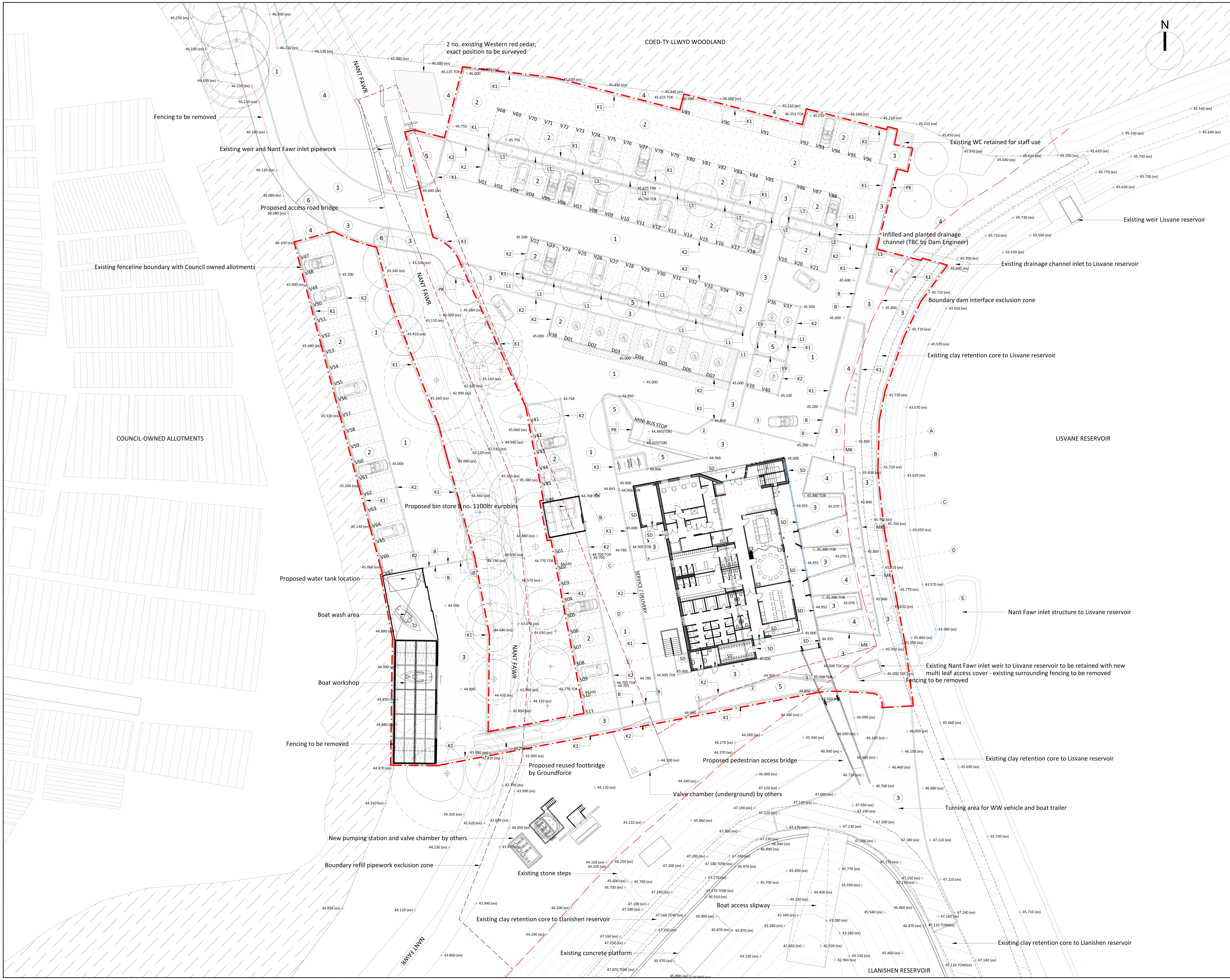
The maximum flood depth for the other areas of the development site within the proposed red line boundary are as follows:

* Low (30%) blockage scenario, maximum water level 45.04 m AOD (0.25m depth),

* Medium (67%) blockage scenario, maximum water level 45.02mAOD (0.23m depth), and

* High (95%) blockage scenario, maximum water level 44.94 mAOD (0.15m depth).

APPENDIX A
DEVELOPMENT SITE



GENERAL NOTES:

1. ALL DIMENSIONS AND LEVELS SHALL BE CHECKED ON SITE PRIOR TO CONSTRUCTION WORKS COMMENCING.
2. ALL LANDSCAPE DRAWINGS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS & ENGINEERS DRAWINGS AND SPECIFICATIONS.
3. ANY DISCREPANCY CONCERNING THE DRAWINGS SHOULD BE REFERRED TO LANDSCAPE ARCHITECT IMMEDIATELY.
4. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS NOTED OTHERWISE.
5. ALL LEVELS ARE IN METERS.
6. EXISTING SERVICE ALIGNMENTS SHALL BE CHECKED ON SITE BY THE CONTRACTOR PRIOR TO CONSTRUCTION WORK COMMENCING.

Key

- Site boundary
- Existing trees retained with root protection area as shown
- Proposed semi-mature trees
- 1 Tarmac road surface
- 2 Cell web-crate system with gravel infill
- 3 Resin-bound aggregate
- 4 Grass and wilflower meadow seeding
- 5 Proposed herbaceous planting areas
- 6 Tactile paving
- Proposed concrete benches
- Existing/proposed retaining walls
- Existing boundary fenceline/Existing fenceline to be removed
- Existing coniferous woodland to be retained
- Existing woodland and dense vegetation adjacent to Welsh water boundaries
- Gravel paths along reservoir edges
- Reservoir clay retention core outline
- Dam interface/Refill pipework exclusion zones
- S/V/D01 Proposed parking bays (S=Staff, V=Visitor, D=Disabled)
- K1 Concrete conservation kerb 915(l)x145(w)x255(d)mm - raised kerb laid upright - by Marshalls or similar & approved
- K2 Concrete conservation kerb 915(l)x145(w)x255(d)mm - kerb laid flush - by Marshalls or similar & approved
- PK Concrete pin kerb 914(l)x63(w)x150(d)mm laid upright by Marshalls or similar & approved
- MK Mild steel metal edging 10(w)x200(h)mm
- L1 Lighting columns
- EV Electric vehicle charging point
- B Removable vehicle bollard
- BT Bib tap locations
- SD Proposed slot drains
- +99.820 (ex) +99.800 Existing levels / Proposed levels

Rev	Date	Description	Drawn	Checked
A	21.06.19	Steps to Reservoir embankment removed	CG	MND

FOR PLANNING

LT STUDIO
Studio 3, Toll Bridge Studios
Toll Bridge Road
Bath, BA1 7DE
T +44 (0) 1225 852115
E contactus@ltstudio.co.uk

Client: DWR CYMRU WELSH WATER

Project: LISVANE & LLANISHEN VISITOR CENTRE

Title: LANDSCAPE GENERAL ARRANGEMENT

Designed: MND	Drawn: CG	Checked: NJR
Scale @ A1: 1:250	Date: MAR 2019	Approved: MND
Drawing No.: LTS_099(08)101		Revision: A

S.T. Job Code M5-0270

APPENDIX B

HYDRAULIC MODELLING METHODOLOGY

Request form for the Discretionary Advice Service

Please read the following notes before completing this form
You can use this form to request advice under our charged Discretionary Planning Advice Service (DPA service). We recommend that before you use this service, you make use of our free pre-application service and familiarise yourself with the guidance that is available on our website.

The "Guide to our pre-application service for development planning" explains in more detail what is covered by our DPA service. By submitting this form to NRW, you agree to the Terms & Conditions for the use of this service. These Terms & Conditions can be found on our website.

We will aim to provide you with a cost estimate for the work within 21 days of receiving this form. You will need to provide the information set out in section 5, as well as any other relevant information, before we can produce a cost estimate for you. Please allow at least 30 days for the work to start, from the date on which you return the form.

If you decide to make use of the service, you will need to return a signed copy of the quotation to NRW. You will not have entered into a contract for the provision of the service, until we have received this.

You should be advised that, in addition to planning permission, marine licence or consent, it is your responsibility to ensure that you secure all other permits and consents that are relevant to your development. NRW also offer a pre-application service for advice on certain types of permits and licenses. More information can be found on our website.

Section 1: Your details

Contact details	
Name	Alejandro Ortiz
Company name	WSP UK Limited
Address	Yale Business Village, LL137YL
Phone	01978368138
Email	Alejandro.ortiz@wsp.com

Invoicing details	
Contact name	Alejandro Ortiz
Company name	WSP UK Limited
Compay address	Yale Business Village, LL137YL
Phone	01978368138
Email	Alejandro.ortiz@wsp.com

Please note that if this section is left blank we will return the form to you for completion. We ask you to provide these details at this stage, but will not carry out any charged work, until we have agreed both the scope and the costs for the work.

Section 2: Advice received previously

Have you previously requested a preliminary opinion from NRW relating to this proposal?

Yes ☐ No ☒

If yes, please quote our reference number NRW reference number

We recommend that you make use of our free preliminary opinion service before you use the charged service. More information about the free preliminary opinion can be found on our website.

Have you, or are you planning to request pre-application advice from NRW on permits or licenses that are relevant to your development proposal?

Yes ☐ No ☒

If yes, please provide details about the advice you have requested, or intend to request. Include your reference number if applicable

Meeting NRW-DCWW-WSP attached
Reference number if applicable

Have you received any pre-application advice from the Local Planning Authority or consenting authority?

Yes ☒ No ☐

If yes, please provide a copy

Section 3: Project description.

Please note that you only need to fill out this section if you have not yet requested a preliminary opinion on your proposal. Please continue to section 4 if you have previously made use of NRW's free preliminary opinion for this development proposal.

Site address / location of site	
Address	**Nant Fawr, Llanishen, CARDIFF**
Postcode	DF14 0RH
National Grid map reference	318679, 182126

About the proposed development
Please provide a detailed description of your proposed development, including: • The current use of the site • The proposed new use • The size and type of the development, installation or activity • Any other relevant site history
The purpose is to develop a visitor and watersports centre at the Llanishen and Lisvane reservoirs.

You will also need to provide us with the following, in addition to the information set out in section 5:

☒ **A location plan** clearly showing the boundary of the proposed development. This should be at a scale between 1:100 and 1:2500 and should show any watercourses or water bodies within your development site. For marine developments, nearby protected sites should be clearly displayed

☒ **An indicative layout plan (detailed if available)** of the proposed works, including all proposed access roads, buildings, details of the method of disposing of foul sewage and any other proposed structures, together with any site formation and temporary works that you propose to carry out

☐ **Where relevant, a plan of any other development or works** that you may carry out, or request others to carry out, in order to construct and/or to operate your proposed development

Section 4: Request for advice

Please tell us what you would like advice on, by ticking each of the sections that apply and providing details.

Advice on Land Contamination, including voluntary remediation	☐
Please explain in the box below what advice you are requesting. *The following are examples of the services we can provide in relation to land contamination.* • *Evaluate preliminary risk assessment and/or interpretive site investigation report* • *Evaluate detailed quantitative risk assessment (DQRA)* • *Evalute piling risk assessment* • *Evaluate remediation options appraisal and/or remediation strategy* • *Evaluate remediation verification report* **Please also read the information set out in Annex 1 on land contamination.**	
Details of the advice you are requesting	

Advice on Groundwater Protection	☐
Please explain in the box below what advice you are requesting. *The following are examples of the services we can provide in relation to groundwater protection. If you require any other advice, please provide details.* • *Provide advice on requirements to meet our groundwater protection position statements* • *Evaluate a groundwater risk assessment* **Please also read the information set out in Annex 1 on ground water protection.**	
Details of the advice you are requesting	

Advice on Flood Consequence Assessments	☒
Please explain in the box below what advice you are requesting. *The following are examples of the services we can provide in relation to flood risk. If you require any other advice, please provide details.* • *Review of a Flood Consequence Assessment* • *Review of the hydrology report* • *Review of the hydraulic river/ tidal models*	
Hydrology and Hydraulic Modelling Methodology	

Advice on Nationally Significant Infrastructure Projects or Developments of National Significance	
Please explain in the box below what advice you are requesting. *The following are examples of the services we can provide in relation to NSIPs and DNSs. If you require any other advice, please provide details.* • *Advice on constraints and opportunities* • *Advice on the Environmental Impact Assessment* • *Advice on the Habitat Regulation Assessment* • *Advice on ecological assessments* • *Advice on mitigation measures* • *Advice on monitoring strategies* • *Advice on Landscape Impact Assessments*	
Details of the advice you are requesting	

Advice on Marine Developments	☐
Please explain in the box below what advice you are requesting. *The following are examples of the services we can provide in relation to marine developments. If you require any other advice, please provide details.* • *Advice on constraints and opportunities* • *Advice on the Environmental Impact Assessment* • *Advice on the Habitat Regulation Assessment* • *Advice on ecological assessments* • *Advice on mitigation measures* • *Advice on monitoring strategies* • *Advice on Landscape Impact Assessments*	
Details of the advice you are requesting	

If you have any additional information about the service you are requesting from NRW than please add this here. This could, for example, include specific queries that you are seeking our views on.	☐
Details of the advice you are requesting	

Section 5: Submitting your application

We ask you to provide the following information

☒ **A copy of this form**

☐ **A copy of advice received from the Local Planning Authority or consenting authority (if relevant)**

For advice on Flood Risk only, we ask you to provide a copy of the following (if applicable):

☐ A Flood Consequence Assessment, including a copy of any checklists we supplied as part of our free pre-application survey

☐ Hydraulic model/Hydrology Report

☐ A detailed location plan, if not previously supplied, showing both the existing and proposed development

For all other advice

If you are seeking our views on any other type of assessment, or report please list them below and provide copies. If your request is for a meeting, please also supply copies of any documents that are relevant to this meeting.

List of other asessments and/or reports
Insert details Nant Fawr, Llanishen. CARDIFF NRW- Natural Resources Wales CCC – Cardiff City Council Introduction Dwr Cymru Welsh Water (DCWW) proposes to develop a visitor and water sports centre adjacent to the Llanishen and Lisvane reservoirs in Cardiff. A review of the Natural Resources Wales (NRW) flood maps has identified that the proposed site lies partially in a C2 flood risk zone (risk of flooding equal of greater than 0.1% AEP without significant flood defence infrastructure) from Nant Fawr. Therefore, a hydraulic model of Nant Fawr is required to assess the existing flooding and impact of the proposed development at Llanishen area. DCWW has commissioned WSP to undertake the hydrology and updated the existing hydraulic model of Nant Fawr. This updated hydraulic model will be used to assess the existing flooding and impact of the proposed development. The hydraulic model will also be used to test proposed mitigation measures, if necessary. WSP are currently in the process to aquire the Product 7 “*model and licence for the RoathBrook_4_V2.0_2008 1D model*”. This existing model will be reviewed and updated as necessary. The results of the updataed modelling works will inform Flood Consequences Assessment (FCA) of the proposed development of a visitor and

watersports centre located at Llanishen and Lavisen reservoirs. Figure 1 below shows the location of the development area.

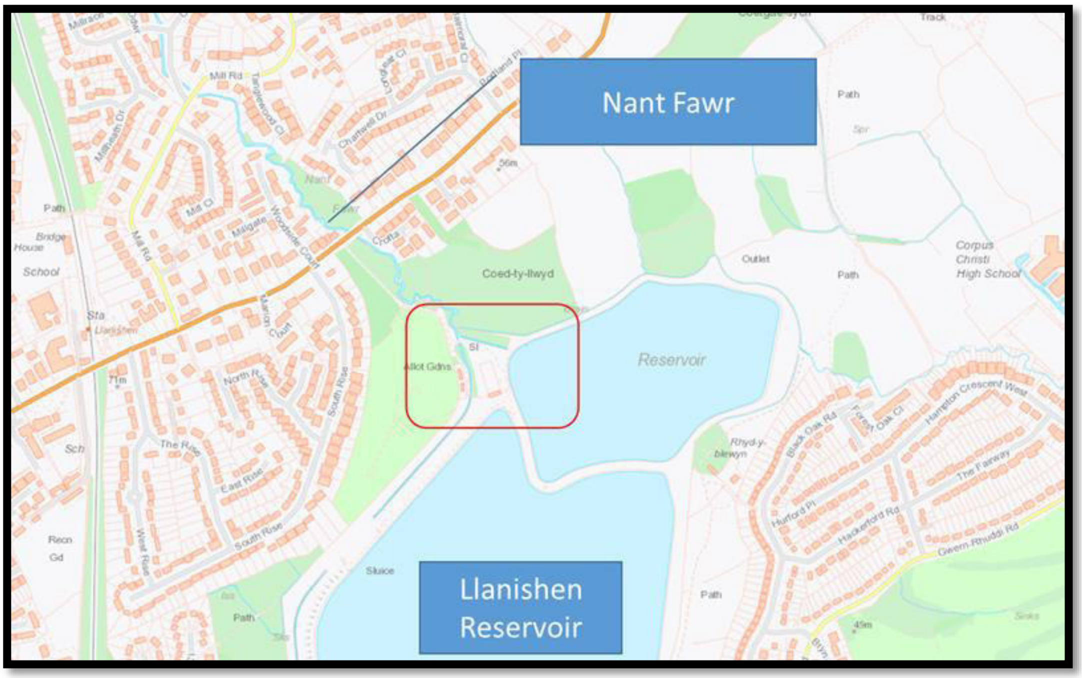


Figure 1 Development location. Source: Natural Resources Wales

WSP would like to seek advice from NRW on the hyrological and hydraulic modelling methodology, climate change allowance, blockage scenarios to be modelled and as well as on the scope of works that is required to achieve the objectives of this hydraulic modelling in line with the requirements of the NRW.

WSP Proposes following methodology for hydraulic modelling

- Review hydrological calculations used in the existing model and update them using ReFH2 (using 2013 rainfall) and FEH Statistical method (with WINFAP V4). We propose hydrological analysis for 50%AEP, 5%AEP, 2%AEP, 1%AEP, 1%AEP with climate change allwance; and 0.1%AEP. For the climate change allowance we will use the central and upper end estimate for Severn Basin as shown in Table 1.

  At the time of writing this methodlogy, WSP has already carried out hydrologicdal analysis to inform the modelling works. Details on hydrological assessment carried out by WSP is presented in separate note (GN008 Form 1 Flood estimation calculation record_LLANISHEN together with this document.

Table 1 Climate Change Allowance for Wales. Source Welsh Govrnment

	Total potential change anticipated for the 2020s (2015 to 2039)	**Total potential change anticipated for the 2050s** (2040 to 2069)	**Total potential change anticipated for the 2080s** (2070 to 2115)
Severn			
Upper (90th)	25%	40%	70%
Central (50th)	10%	20%	25%
West Wales			
Upper (90th)	25%	40%	75%
Central (50th)	15%	25%	30%
Dee			
Upper (90th)	20%	30%	45%
Central (50th)	10%	15%	20%

Table 2: Changes to river flood flows by river basin district (use 1961-90 baseline)

- Review existing hydraulic model in terms of model extent, roughness values boundary conditions; structures representations; model stability and results and update it as necessary.
- Update the hydraulic model with the new topographical survey data;
- Build 2d model to represent flood mechanism/extent more accurately in the area of ineterst. Enivronmetn Agency 1m LiDAR data will be used to represent ground model within the 2D domain.
- Run baseline hydraulic model for the 1%AEP both with and without climate change, and 0.1%AEP.
- Build proposed model with appropriate representation of the development area
- Run proposed hydraulic model for the 1%AEP both with and without climate change, and 0.1%AEP.
- Sensitivity model runs
- Run blockage scenario model with 30% (Low), 67% (Medium) & >90% (High) blockage at the culvert near Coed-ty-llwyd at the proposed development site, for 1%AEP . Figure 2 shows the location of the proposed culvert considered for the blockage scenario.

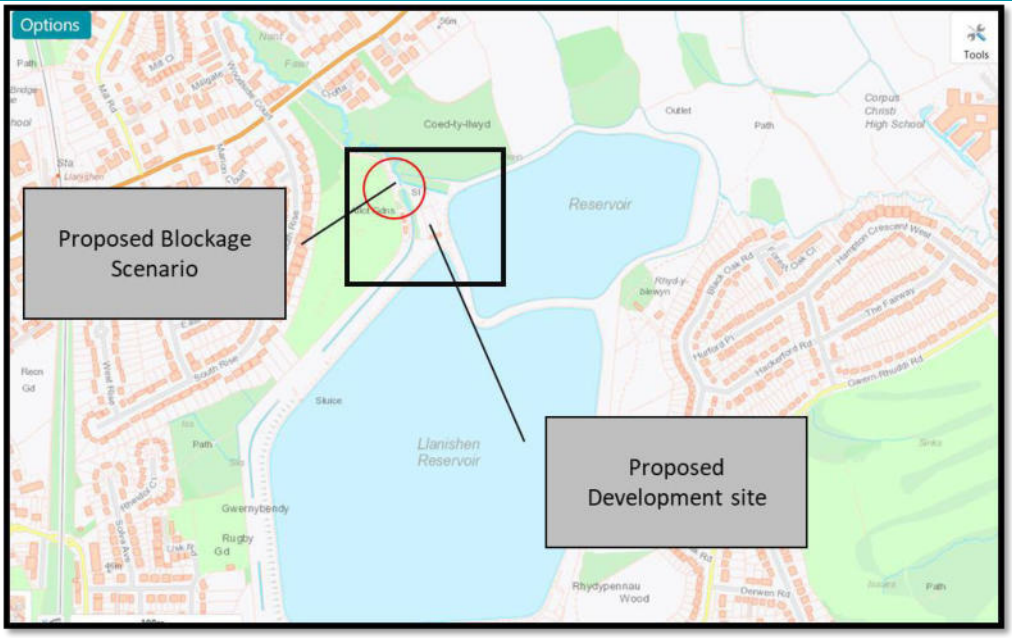


Figure 2 Proposed blockage location. Source: Natural Resources Wales

- Run hydraulic model with mitigation measures, if needed;
- Prepare a technical note with findings and comparison between scenarios.
- Prepare Flood Consequences Assessment (FCA), for approval by NRW/CCC.

We kindly request NRW's flood risk analysis team to review the above methodology and provide us feedbacks.

We would be very grateful if you could provide with the cost and timescale for assisting us on the above. If you have any queries please do not hesitate to contact myself

Section 6: Timescales

Please provide an indication of the timescale within which you would like to receive the advice. Please allow at least 30 days for the work to start, from the date on which you return the form Please note that, while we will try to meet your timescales, we cannot guarantee that we will be able to do so.
ASAP

Section 7: How to return this form

Please e-mail this form and all relevant information outlined in section 5 above to the relevant team in NRW. For marine developments, please send your form to the team that is dealing with the local planning authority that is nearest to your development. Contact details are set out in the table below.

Please note that we can only accept e-mail attachments up to 10MB via e-mail. If the combined size of your attachments is larger than this, please contact the relevant team below to request access to our file sharing system.

For projects in:	Email:
• Pembrokeshire • Pembrokeshire Coast National Park • Carmarthenshire • Swansea • Neath Port Talbot • Bridgend	swplanning@cyfoethnaturiolcymru.gov.uk
• Cardiff • Newport • Vale of Glamorgan • Rhondda Cynon Taf • Torfaen • Monmouthshire • Brecon Beacons National Park • Blaenau Gwent • Caerphilly • Merthyr Tydfil	southeastplanning@cyfoethnaturiolcymru.gov.uk
• Gwynedd • Anglesey • Conwy	northplanning@cyfoethnaturiolcymru.gov.uk

• Denbighshire • Powys • Ceredigion • Flintshire • Wrexham • Snowdonia National Park	

Section 8: How we will use your information

All of the information held by NRW, relating to your application for a licence will be processed and managed by us in accordance with our obligations and duties under the:

- Data Protection Act 1998;
- Freedom of Information Act 2000;
- The Environmental Information Regulations 2004; and
- All other laws relating to access to information.

With this in mind, your information, including your personal information, may be the subject of a request by another member of the public. When responding to such requests we may be required to release information, including your personal information. Our response to such requests will be in accordance with the guidelines provided by the Welsh Government Code of Practice on Access to Information which can be found at www.information.wales.gov.uk

For further information about the personal data collected and its use, if you have any concerns about the accuracy of personal data, or wish to exercise any of your rights under the above legislation you should contact:
Access to Information Officers, Natural Resources Wales, Ty Cambria, 29 Newport Road Cardiff CF24 0TP, or email accesstoinformationteam@naturalresourceswales.gov.uk or telephone 0300 065 3000

The Information Commissioners Office help line can be contacted on 029 2067 8400 or at www.ico.gov.uk

Section 9: Conditions under which the advice is offered

By requesting this service, you acknowledge that the content of any advice or assistance provided by NRW is advisory only and that it shall not be deemed to bind or in any other way restrict NRW in performing its statutory functions.

In particular you acknowledge that:

- any advice given or materials or documentation provided by NRW do not constrain or bind NRW in respect of its statutory functions or its role as a statutory consultee or any decision NRW may make in relation to any application for a licence or permit;
- any advice given by NRW does not bind NRW in respect of any future representations it may make as statutory consultee or any decision NRW may make in relation to any application for a licence or permit;
- any views or opinions expressed by NRW are without prejudice to the consideration NRW may be required to give to any application or any future representations as

statutory consultee or any decision NRW may make in relation to any application for a licence or permit;

- the final decision as to any representations made by NRW as statutory consultee will be based on all the relevant information available to NRW at the time it makes such representations;
- NRW cannot and does not give any guarantee as to the representations it may make as statutory consultee; and
- any advice given by NRW may be overtaken by changes in available information, law, policy and guidance relevant to the subject matter of the advice.

Annex 1: Additional information on land contamination and groundwater protection

For advice on land contamination

Land contamination management and groundwater risk assessments follow a tiered process. Therefore if you require us to evaluate work from a later stage in the process you must also provide all relevant preceding reports and documentation, if it hasn't previously been provided to us for evaluation. For example, if you require evaluation of your detailed quantitative risk assessment (DQRA) you will need to also provide us with your preliminary risk assessment and interpretive site investigation.

Guiding Principles for Land Contamination 3 (GPLC) contains several checklists which set out the level of information we require to evaluate your reports. It should also be clear that reports have been checked and signed off by an appropriately-qualified person. We may refuse to comment on reports if it becomes clear that important information is absent or has not been appropriately checked.

For advice on groundwater protection

If you wish to clarify a position statement or its applicability to your proposed activity or development we require you to provide all relevant documentation. For example, if you want to clarify our approach to underground storage of chemicals we would require you to provide details on the local ground conditions and the detailed design of your storage tanks and proposed pollution mitigation.

Cyfoeth Naturiol Cymru
Natural Resources Wales

Ein cyf/Our ref: CAS-102906-F6F1

Rivers House
St Mellons Business Park
St Mellons
Cardiff
CF3 0EY

F.A.O Alejandro Ortiz
WSP UK Limited
Yale Business Village
LL13 7YL

ebost/email:
southeastplanning@cyfoethnaturiolcymru.gov.uk
Ffôn/Phone: 03000 65 5161

20/11/2019

Annwyl Syr/Madam / Dear Sir/Madam,

DISCRETIONARY PLANNING ADVICE SERVICE

ADVICE : HYDROLOGY AND HYDRAULIC MODELLING METHODOLOGY
LOCATION: LLANISHEN & LISVANE RESERVOIR, CARDIFF

Thank you for your Discretionary Advice Service application, which we received on 07/10/2019. Please find our advice below.

Hydrology Review

We have reviewed the submitted document; GN008 Form 1 Flood Estimation Record – LLANISHEN – V2.

We are satisfied that the flows presented are suitable for modelling. However, we wish to note that the flows have been estimated using the FEH statistical method and this is not in line with current guidance. We usually recommend that flows are estimated using the FEH Statistical/ReFH 'Ratio' method using current software and data sets.

Please note, that whilst the flows presented are suitable for modelling, we have some additional queries regarding the hydrographs presented.

Firstly, the form states, in Section 5.2 ‘Final choice of method’ that 'The Hydrograph derived from the ReFH2 at the upstream boundary (FEP1) will be routed through the model and adjusted to match the statistical peak at the site of interest (FEP 2)'. Please note, we would expect the hydrographs to be scaled to the peak flows before being used in the model.

Secondly, Section 5.5 of the form, ‘Final Results’, states 'The ReFH2 hydrograph will be used to fit the peak of the statistical method adjusted to the design storm calculated.' From the information provided, it is unclear whether the hydrographs used in the model have all been derived using a storm duration of the most downstream point i.e. a storm duration of 4.5hrs; we advise this is the approach that should be followed.

Hydraulic Modelling Methodology Review

We have reviewed the proposed flood modelling methodology as described within the following document; Llanishen_Reservoir_y_FEH_&_hyd_Methodology.

The document states the following;

WSP proposes following methodology for hydraulic modelling

- Review hydrological calculations used in the existing model and update them using ReFH2 (using 2013 rainfall) and FEH Statistical method (with WINFAP V4). We propose hydrological analysis for 50%AEP, 5%AEP, 2%AEP, 1%AEP, 1%AEP with climate change allowance; and 0.1%AEP. For the climate change allowance, we will use the central and upper end estimate for Severn Basin as shown in Table 1.

We advise that instead of the 5%AEP, it would be beneficial to include analysis of the 0.33%AEP (Q30) return period, as it could input into the new Flood Risk Assessment Wales map, which will be coming out next year. Please also see the comment below regarding updating the Flood Map.

It may also be advisable to run the Q1000+CC (0.1%+CC) scenario, as the draft TAN15 (which is currently out for consultation from Welsh Government) includes consideration of this scenario. Therefore, including it now, may avoid having to re-run the model at a later date.

Page 9 of the report confirms that a 2d model will be built to represent flood mechanism/extent more accurately in the area of interest. From the information provded, it is unclear whether it is proposed to combine this new 2d model with NRW's FMP 1d model (to create a 1D/2D model) or whether a separate 2d model will be produced for a smaller area.

The document states that the hydraulic model will be run for the 1% AEP both with and without climate change, and 0.1%AEP. Please note as a minimum, to update the Flood Map, we would need the Q30, Q100 and Q1000.

We advise that the proposed sensitivity model will need to be run at +/-20% on flows, downstream boundary and mannings.

We recommend that you complete an internal Q&A before submitting the hydraulic model and FCA. We also recommend that you complete the 'GN028 Model Checklist' and submit it with your model and reports. Please see our website for further advice: https://naturalresources.wales/guidance-and-advice/business-sectors/planning-and-development/advice-for-developers/development-and-flood-risk/?lang=en

Please note that LiDAR data can be sourced from the Gov website here: https://lle.gov.wales/catalogue/item/LidarCompositeDataset/?lang=en

If you have any queries on the above, please do not hesitate to contact us.

Yn gywir / Yours faithfully

Alice Jewer
Cynghorydd - Cynllunio Datblygu / Advisor - Development Planning
Cyfoeth Naturiol Cymru / Natural Resources Wales

APPENDIX C
FLOOD CALCULATION RECORD FEH

Cyfoeth Naturiol Cymru
Natural Resources Wales

Flood estimation calculation record

Introduction

This document is a supporting document to the Natural Resources Wales (NRW) Flood Estimation Technical Guidance Note (GN008). It provides a record of the calculations and decisions made during flood estimation. It will often be complemented by more general hydrological information given in a project report. The information given here should enable the work to be reproduced in the future.

Contents

Approval

	Signature	Name and qualifications	For NRW staff: competence level
Calculations prepared by:	Alejandro Ortiz	Alejandro Ortiz Hydrologist and Hydraulic Modeller	Level 1
Calculations checked by:	Pravin Ghimire	Pravin Ghimire Senior Engineer	Level 2
Calculations approved by:			

Competence levels:
- level 1 – hydrologist with minimum approved experience in flood estimation
- level 2 – senior hydrologist
- level 3 – senior hydrologist with extensive experience of flood estimation

Abbreviations

AM	Annual maximum
AREA	Catchment area (km^2)
BFI	Base flow index
BFIHOST	Base flow index derived using the HOST soil classification
DPLBAR	Mean drainage path length (km)
DPSBAR	Mean drainage path slope (m/km)
FARL	FEH index of flood attenuation due to reservoirs and lakes
FEH	Flood Estimation Handbook
FPEXT	Floodplain extent
FSR	Flood Studies Report
HOST	Hydrology of soil types
NRFA	National River Flow Archive
NRW	Natural Resources Wales
POT	Peaks over a threshold
QMED	Median annual flood (with return period 2 years)
ReFH	Revitalised flood hydrograph method – used for rainfall run-off method
SAAR	Standard average annual rainfall (mm)
SPR	Standard percentage run-off
SPRHOST	Standard percentage run-off 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
URBEXT2000	Revised index of urban extent
WINFAP	Windows Frequency Analysis Package – used for FEH statistical method

1. Introduction

This calculation record document provides a record of the calculation and decisions made during flood estimation. It is complemented by more general hydrological information given in the Interim Hydrology Report. The information given here should enable the work produce in the future. This version of the record is for studies where flood estimates are needed at multiple location.

2. Method statement

1.1. Overview of requirements for flood estimates

Item	Comments
Give an overview which includes: • purpose of study • approximate number of flood estimates required • peak flows or hydrographs • range of return periods and locations • approximate time available	Dwr Cymru Wels Water (DCWW) proposed to develop a visitor and water sports centre at the Llanishen and Lisvane reservoirs in Cardiff. Nant Fawr crosses part of the proposed development area and is proposed to replace a bridge to cross the watercourse. Nant Fawr flows southerly direction and it parallel to the Llanishen reservoir. The watercourse is one of the tributaries of the Rhymney River. The purpose of this hydrological analysis is to: 1) derive peak flow from various methods at identified Flood Estimation Points (FEPS) whitin the reach of the hydraulic model; and 2) Select preferred method established design inflows for the hydraulic model.

1.2. Overview of catchment

Item	Comments

Brief description of catchment, or reference to section in accompanying report. Include maps where necessary.	The catchment has a geological composition (Sedimentary Bedrock), Llanishen conglomerate – conglomerate and sandstone. The superficial deposits consist in Till, Devensial-Diamicton. The British Geological Survey Hydrogeology classifies the catchment as Low productivity aquifer 2c. The catchment is located in a heavily urbanised area and that value is denoted in the catchment descriptors URBEXT2000 >0.15. The Average Annual Rainfall (SAAR) indicates that the catchment receives more than 1200mm. FARL factor for the catchments is 1.000 in the US and Site catchments for the DS catchment is >0.8 but in communication with NRW, Welsh Water I is commented that there is no direct flow from the Nant Fawr to the reservoirs therefore no reduction factor for flooding is caused by the reservoirs, the FARL factor was changed as 1.000 See section 1.8 for sub-catchment delineation.

1.3. Source of flood peak data

Item	Comments
Was the NRFA Peak Flows dataset used? If so, which version? If not, why not? Record any changes made.	Yes – Hi Flows v7 along with WINFAP-FEH v4 No modifications were made to the dataset

1.4. Gauging stations (flow or level)

At the sites of flood estimates or nearby at potential donor sites. Also state gauging authority number where it is different to the NRFA number.

Water course	Station name	NRFA number (used in FEH)	Grid reference	Catchment area (km2)	BFIHOST	FPEXT	URBEXT 2000
Rhymney	Llanedeyrn	57008	ST224821	178.7	0.52	0.0538	0.0767
Taff	Tongwynlais	57003	ST131818	486.9	0.42	0.0410	0.0639
Tynewydd	Rhondda Fawr	57017	SS932986	16.6	0.32	0.0117	0.0156

1.5. Data available at each flow gauging station

Station Name	Start and end date on NRFA	Update for this study?	Suitable for QMED?	Suitable for pooling?	Data quality check needed?	Other comments on station and flow quality e.g. information from NRFA Peak Flows, trends in flood peaks, outliers
Rhondda Fawr	2001 – N/A	N	Y	Y	N/A	Almost gauged to QMED within bank full.
Llanedeyrn	1973-N/A	N	Y	N	N/A	Rating does not fully account for bypassing and insufficient gaugings beyond QMED.
Tongwynlais	1961-1972	N	Y	N	N/A	Rating does not fully account for bypassing and insufficient gauging beyond QMED

1.6. Rating equations

Station name	Type of rating e.g. theoretical, empirical, degree of extrapolation	Rating review needed?	Reasons e.g. availability of recent flow gaugings, amount of scatter in the rating
Rhondda Fawr	Empirical	No	N/A
Llanedeyrn	Empirical	No	N/A
Tongwynlais	Empirical	No	N/A
Include a link or reference to any rating reviews carried out			

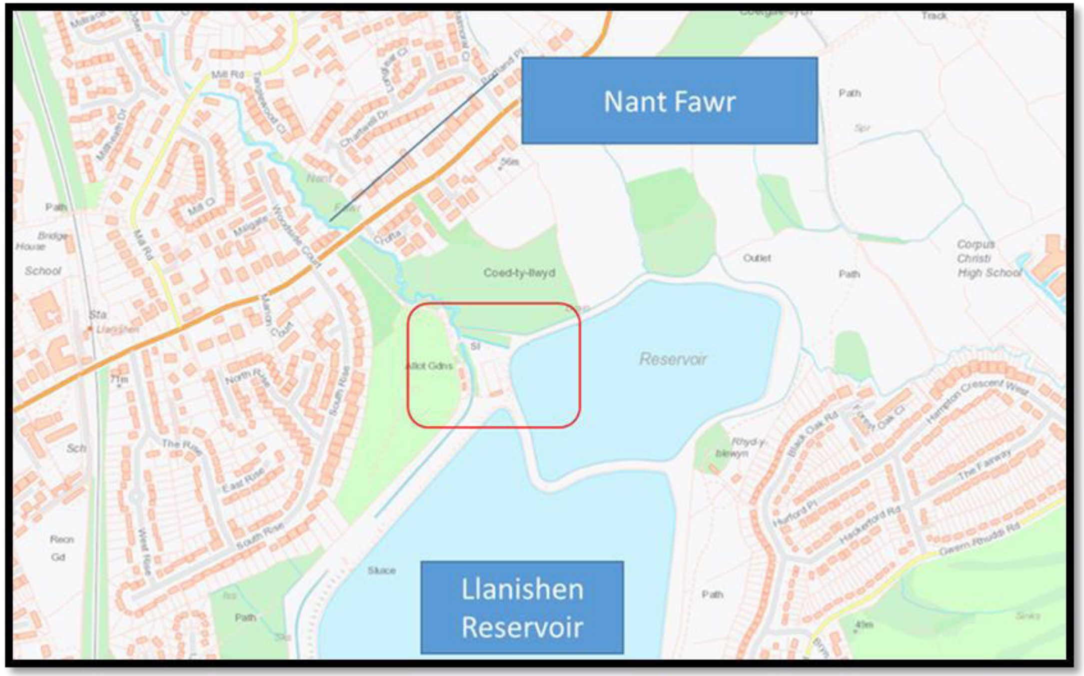
1.7. Other data available and how it has been obtained

Type of data	Data relevant to this study?	Data available?	Source of data and licence reference from NRW	Details
Check flow gaugings (if planned to review ratings)				
Historic flood data – give link to historic review if carried out				
Flow data for events				
Rainfall data for events				
Results from previous studies	Roath Brook	Roath Brook hydrology	ATI 18137A	Product 7
Other data or information e.g. groundwater, tides				

1.8. Initial choice of approach

Item	Comment
Is FEH appropriate? If not, describe why and give details of the other methods to be used.	FEH statistical method is appropriate for most of the sub-catchments. Flows have also been derived with ReFH2 method and compared.
Outline the conceptual model. Address questions such as:	

• Where are the main sites of interest? • What is likely to cause flooding at those locations? (E.g. peak flows, flood volumes, combination of peaks, groundwater, snowmelt) • Might those locations flood from run-off generated on part of the catchment only, e.g. downstream of a reservoir?	Dwr Cymru Welsh Water (DCWW) proposes to develop a visitor and water sports centre adjacent to the Llanishen and Lisvane reservoirs in Cardiff. A review of the Natural Resources Wales (NRW) flood maps has identified that the proposed site lies partially in a C2 flood risk zone (risk of flooding equal of greater than 0.1% AEP without significant flood defence infrastructure) from Nant Fawr. Therefore, a hydraulic model of Nant Fawr is required to assess the existing flooding and impact of the proposed development at Llanishen area. DCWW has commissioned WSP to undertake the hydrology and updated the existing hydraulic model of Nant Fawr. This updated hydraulic model will be used to assess the existing flooding and impact of the proposed development. The site of interest is the proposed development site located northwest of the Llanishen and Lavisen reservoirs. The Nant Fawr watercourse flows northwest to southeast upstream of the proposed site where it bends and flows in southwest direction, parallel to Llanishen reservoir. See Figure 1 below

	 *Figure 1 proposed development site* Is still unknown the cause of fluvial flooding in this area, but it is considered to be exceedance of channel capacity due to high peak flows or high volumes, the reduced capacity of the bridges including the location of online weirs that may obstruct the free flow within the watercourse can be a cause of flood risk at the area.
Any unusual catchment features to take into account? E.g.: • highly permeable (BFIHOST> 0.65). Consider permeable catchment adjustment for statistical method if SPRHOST<20% • highly urbanised – consider FEH Statistical or other alternatives;	The catchment is heavily urbanised with URBEXT2000 > 0.15. The BFIHOST of the catchment is around 0.61, and therefore, it doesn't fall on the highly permeable category. The SPRHOST of the catchment is more than 20%. Therefore, permeable catchment adjustment for statistical method is not deemed necessary. The catchment descriptors at the downstream extent of the model shows a FARL value of 0.735. This is potentially due to presence of the Lalnishen reservoir. However, according to NRW and Welsh Water, there is no link between the Llanishen reservoir and

consider method that can account for differing sewer and topographic catchments • pumped water course – consider low land catchment version of rainfall-run-off method • major reservoir influence (FARL<0.90) – consider flood routing • extensive floodplain storage – consider choice of method carefully	Nant Fawr. And therefore, the reservoir has no impact on the Nant Fawr flow. (*See NRW-DCWW-WSP Meeting Minutes*- ***Appendix A***). Based on this information, the FARL value at the d/s extent of the model (FEP 3 -see Figure 1) has been kept similar to upstream catchment (FEP 2).
Initial choice of method(s) and reasons will the catchment be split into sub-catchments? If so, how?	The catchment area of the Nant Fawr within the model domain ranges between 3.3 km2 at the upstream extent (FEP 1) and 4.3 at the downstream extent (FEP 3). The entire catchment area has been divided into 3 sub-catchments (FEP 1, 2 and 3) as shown in Figure 2.

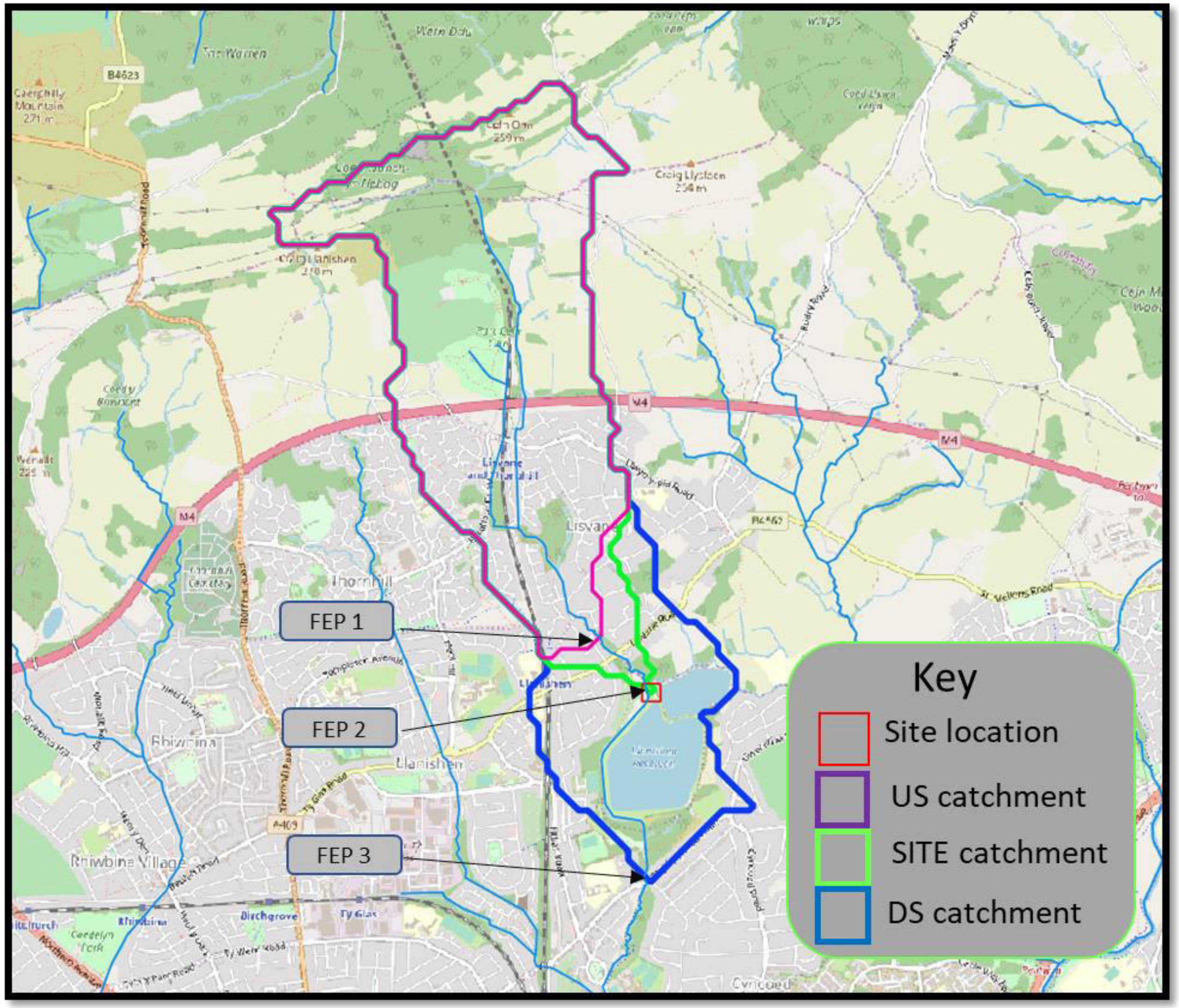


Figure 2 Map or Nant Fawr sub-catchments

FEP 1 – Upstream extent of the model
FEP 2 – At the development site

	FEP 3 – Downstream extent of the model The hydrology of these three sub-catchments has been analysed using the FEH Statistical and Revitalised Flood Hydrograph ReFH2 method
Software to be used (with version numbers) edit or delete as applicable, or add others	FEH WEB service WINFAP [v4] ReFH2.2]

2. Locations where flood estimates are required

2.1. Summary of subject sites

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

Site code	Watercourse	Site	Easting	Northing	AREA on FEH Web Service (km^2)	Revised AREA if altered
US	Nant Fawr	FEP 1	318400	182450	3.14	-
SITE	Nant Fawr	FEP 2	318700	182125	3.33	-
DS	Nant Fawr	FEP 3	318700	181100	4.47	-
Reasons for choosing above locations	These locations was selected carefully based on the potential extent of the updated hydraulic model. FEP 1 is the proposed upstream extent of the model. FEP 2 is the location of the proposed development site. FEP 3 is located 1.5 km downstream the proposed development site. It is considered that the selected downstream section (boundary sections) is located far enough from our area of interest and therefore it will not get impacted by any alterations in the downstream sections.					

2.2. Key catchment descriptors at each subject site

Site code	FARL	PROPWET	BFIHOST	DPLBAR (km)	DPSBAR (m/km)	SAAR (mm)	SPRHOST	URBEXT 2000	FPEXT
US	1.000	0.47	0.618	2.25	116.6	1247	29.99	0.156	0.0183

SITE	1.000	0.47	0.617	2.61	113.0	1243	30.48	0.167	0.0225
DS	1.000(0.735)	0.47	0.616	3.05	91.4	1223	32.56	0.162	0.0358

The catchment descriptors included in the table above are the original value from FEH web services except for the FARL value at the DS site (FEP3), which has been increased to 1 from the original value of 0.735. This adjustment has been done as the reservoir is disconnected from the Nant Fawr watercourse at present. The original URBEXT2000 value has been updated within WINFAP4.

2.3. Checking catchment descriptors

Item	Comment
Record how catchment boundary was checked • describe any changes • refer to maps if needed	The catchment areas as extracted from FEH Web service have been validated against OS mapping, LiDAR data and Terrain 50 contouring. All catchment boundaries were consistent with watercourse flow paths and no alterations were made to the extracted areas for the FEP 1 and 2. The original catchment descriptors extracted from FEH web service is presented in Figure 3. For the FEP 3 the area occupied by the reservoirs was removed as is considered to the precipitation fallen into the reservoir will be stored in the water body, therefore the area occupied by Llanishen and Lisvane reservoirs was removed for the downstream catchment area.
Record how other catchment descriptors were checked, especially soils • describe any changes • include a before and after table if necessary	The British Geological Survey Hydrogeology classifies the catchment as Low productivity aquifer 2c. FEH web service
Source of URBEXT / URBAN	FEH web service

Method for updating URBEXT / URBAN • Refer to WINFAP4 Urban Adjustment procedures/guidance	The URBEXT2000 values were updated for each sub-catchment within the WINFAP v4.

Catchment Descriptors	US upstream	SITE	DS downstream
Grid Ref	318400, 182450	318700, 182125	318700, 181100
AREA	3.145	3.3325	4.4725
ALTBAR	141	136	114
ASPBAR	160	158	160
ASPVAR	0.45	0.47	0.51
BFIHOST	0.618	0.617	0.616
DPLBAR	2.25	2.61	3.05
DPSBAR	116.5	113	91.4
FARL	1	1	0.735
FPEXT	0.0183	0.0225	0.0358
FPDBAR	0.116	0.17	0.289
FPLOC	0.63	0.573	0.527
LDP	4.3	4.78	5.92
PROPWET	0.47	0.47	0.47
RMED-1H	12	12	11.9
RMED-1D	44	43.9	43.7
RMED-2D	55.8	55.8	55.8
SAAR	1247	1243	1223
SAAR4170	1307	1304	1280
SPRHOST	29.99	30.48	32.56
URBCONC1990	0.694	0.719	0.693
URBEXT1990	0.0932	0.1054	0.1015
URBLOC1990	0.468	0.529	0.73
URBCONC2000	0.856	0.867	0.875
URBEXT2000	0.156	0.1669	0.1624
URBLOC2000	0.518	0.584	0.762
C	-0.02606	-0.02606	-0.026
D1	0.4179	0.41806	0.41828
D2	0.36709	0.36726	0.36749
D3	0.37897	0.37896	0.37867
E	0.29089	0.29079	0.29033
F	2.49612	2.49534	2.49123
C(1 km)	-0.025	-0.026	-0.026
D1(1 km)	0.42	0.42	0.411
D2(1 km)	0.367	0.369	0.365
D3(1 km)	0.38	0.377	0.376
E(1 km)	0.289	0.289	0.289
F(1 km)	2.484	2.474	2.482

Figure 3 Catchment descriptors for the three FEP's

3. Statistical method

The FEH statistical method constructs a flood frequency curve based on the estimation of the QMED, which is then used to calculate peak flow estimates for each return period. FEH methods should normally not be applied for heavily urbanised catchments (with an URBEXT value greater than 0.5) or catchments smaller than 0.5km2. All the sub-catchments extracted from the FEH Web service for the purpose of this study fall within these guidelines and can therefore be deemed well suited to the FEH Statistical method.

3.1. Search for donor sites for QMED (if applicable)

Note that donor catchments will usually be rural but may be urban provided the data is deurbanised prior to the adjustment process. Please include a map if necessary.

Comment on potential donor sites Mention: • number of potential donor sites available • distances from subject site • similarities in terms of AREA, BFIHOST, FARL and other catchment descriptors • quality of flood peak data	**Rhondda Fawr @ Tynewydd** was the best potential donor site for the upstream catchment, by distance and area (slightly above 5 times the size of US catchment) but due to the SAAR greater than 1.25 times and the BFIHOST smaller than 0.18. This donor was rejected. **Llanedeyrn@Rhymney**, for this donor the SAAR, FARL, BFIHOST are within the permitted parameters but the donor was rejected pecause the Area which is quite above the 5 times the studied catchments. **Tongwynlais@Taff** was another potential donor but due to the low BFIHOST, high SAAR and the AREA criteria. The decision has been taken to reject this donor

3.2. Donor sites chosen and QMED adjustment factors

If using WINFAP3 great caution should be taken in urban catchments that are also highly permeable (BFIHOST>0.65). Further details are provided in the EA Flood Estimation Guidelines

NRFA number	Reasons for choosing or rejecting	Method (AM or POT)	Adjusted for climatic variation?	QMED from flow data (gauged) (m^3/s)	QMED from flow data with urban influence removed (A) (m^3/s)	QMEDrural from catchment descriptors (B) (m^3/s)	Adjustment ratio (A/B)

57017 (Rhondda Awr @ Tynewydd)	High SAAR and low BFIHOST See **Annex 6**						
57008 (Llanrdeyrn @ Rhymney)	Area criteria much more than 5 times See **Annex 6**						
57003 (Taff @ Tongwynlais)	High SAAR, low BFIHOST and AREA parameters does not fulfil the criteria See **Annex 6**						
Has the WINFAP4 urban adjustment method (based on Kjeldsen, 2014) been applied? If not, why?				Yes			

3.3. Overview of estimation of QMED at each subject site

Notes for completing this table

- Methods
  - CD: catchment descriptors alone
  - DT: data transfer
  - BCW: catchment descriptors and bankfull channel width
  - FV: flow variability
- Urban adjustment procedures should be applied regardless of whether the subject site is rural or urban.
- If using WINFAP3, great caution should be taken in urban adjustment of QMED on catchments that are also highly permeable (BFIHOST>0.65).
- The data transfer procedure is from Science Report SC050050. 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 the initial estimate from catchment descriptors.

- If more than one donor has been used, use multiple rows for the site and give the weights used in the averaging. Record the weighted average adjustment factor in the table.

Site code	QMEDrural from CDs (m^3/s)	Method	Data transfer: NRFA numbers for donor site/s used (see 3.2)	Data transfer: Distance between centroids dij (km)	Data transfer: Moderated QMED adjustment factor (A/B)[a]	If more than one donor: Weight (if WINFAP 4 method not used)	If more than one donor: Weighted average QMED adjustment factor	Final estimate of QMEDrural (m^3/s)	Final estimate of QMEDurban (m^3/s)
FEP 1		CD	N/A	N/A	N/A			1.515	1.890
FEP 2		CD	N/A	N/A	N/A			1.587	2.009
FEP 2		CD	N/A	N/A	N/A			1.996	2.510
Has the Kjeldsen (2014) urban adjustment method (as used in WINFAP4) been applied? If not, why?					Yes				
How are the weights derived?									
Are the values of QMED consistent, for example at successive points along the watercourse and at conferences?					Yes, it is consistent				

The method used to adjust QMED for urbanisation is the Kjeldsen (2014) within WinFAP.

3.4. Derivation of pooling groups

The composition of pooling groups is given in the Annex. 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.** Include any sites that were investigated but retained in the group
The following stations are the station that were removed from the original pooling group and the reasons why, the selected polling stations are located at the **Annex 6.1**			
US Extent	FEP 1	No	49005 Bolingey Stream @Bolingey Low data 49006 Camel @ Camelford Low data 54022 Severn @ Plynlimon Flume Low BFI 57017 Rhondda Fawr @ Tynewydd negative L-skew
Proposed Site	FEP 2	No	49005 Bolingey Stream @Bolingey Low data 49006 Camel @ Camelford Low data 54022 Severn @ Plynlimon Flume Low BFI 57017 Rhondda Fawr @ Tynewydd negative L-skew, 206006 Annalong @Recorder Low BFI 25011 Langdon Beck @ Langdon Low BFI 44008 South Winterbourne at Winterbourne Steepleton High BFI
DS Extent	FEP 3	No	49005 Bolingey Stream @Bolingey Low data 49006 Camel @ Camelford Low data 54022 Severn @ Plynlimon Flume Low BFI 57017 Rhondda Fawr @ Tynewydd negative L-skew 206006 Annalong @Recorder Low BFI

			44008 South Winterbourne at Winterbourne Steepleton High BFI 25011 Langdon Beck @ Langdon Low BFI
URBEXT2000 threshold used to create pooling group(s)	We recommend that this is set to 0.03 to make maximum use of local data		

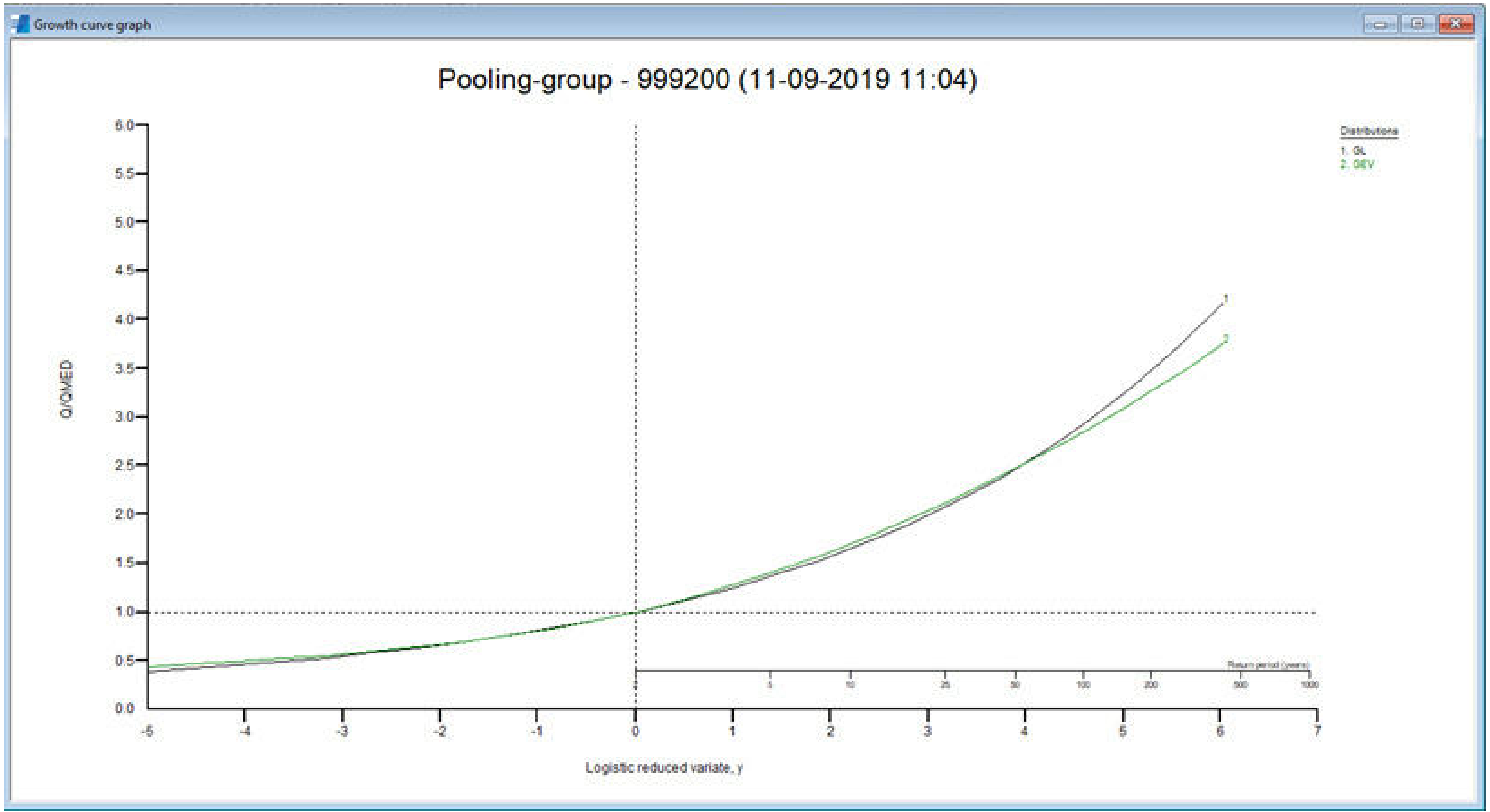
3.5. Derivation of flood growth curves at subject sites

Notes for completing this table

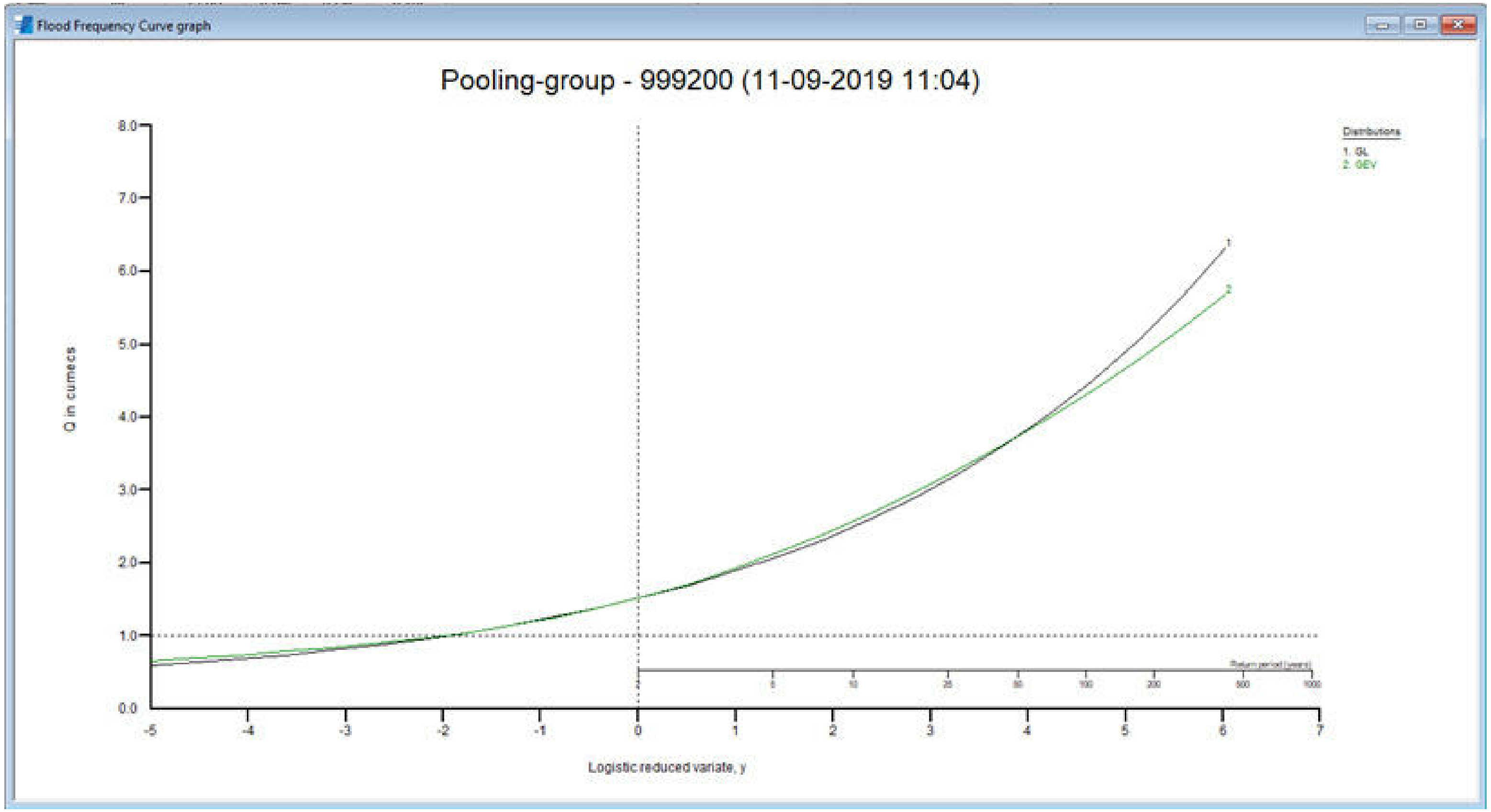
- Abbreviations for method types
  - SS: single site
  - P: pooled
  - ESS: enhanced single site
  - FH: single site with flood history
- A pooling group (or ESS analysis) derived at one gauge can be applied to estimate growth curves at a number of ungauged sites. Each site may have a different urban adjustment, and therefore different growth curve parameters.
- Urban adjustments to growth curves should use the latest methodologies in WINFAP
- Any relevant frequency plots from WINFAP, particularly showing any comparisons between single-site and pooled growth curves (including flood peak data on the plot) should be shown here or in a project report.

Site code	**Method** (SS, P, ESS, FH)	**If P, ESS, or FH, name of pooling group** (3.4)	**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**
FEP 1	P	NA	GL	V3 (Kjeldsen 2010) applied Growth curve	Loc 1.0 Scale 0.194 Shape -0.287	2.850
FEP 2	P	NA	GL	V3 (Kjeldsen 2010) applied Growth curve	Loc 1.0 Scale 0.190 Shape -0.312	2.949

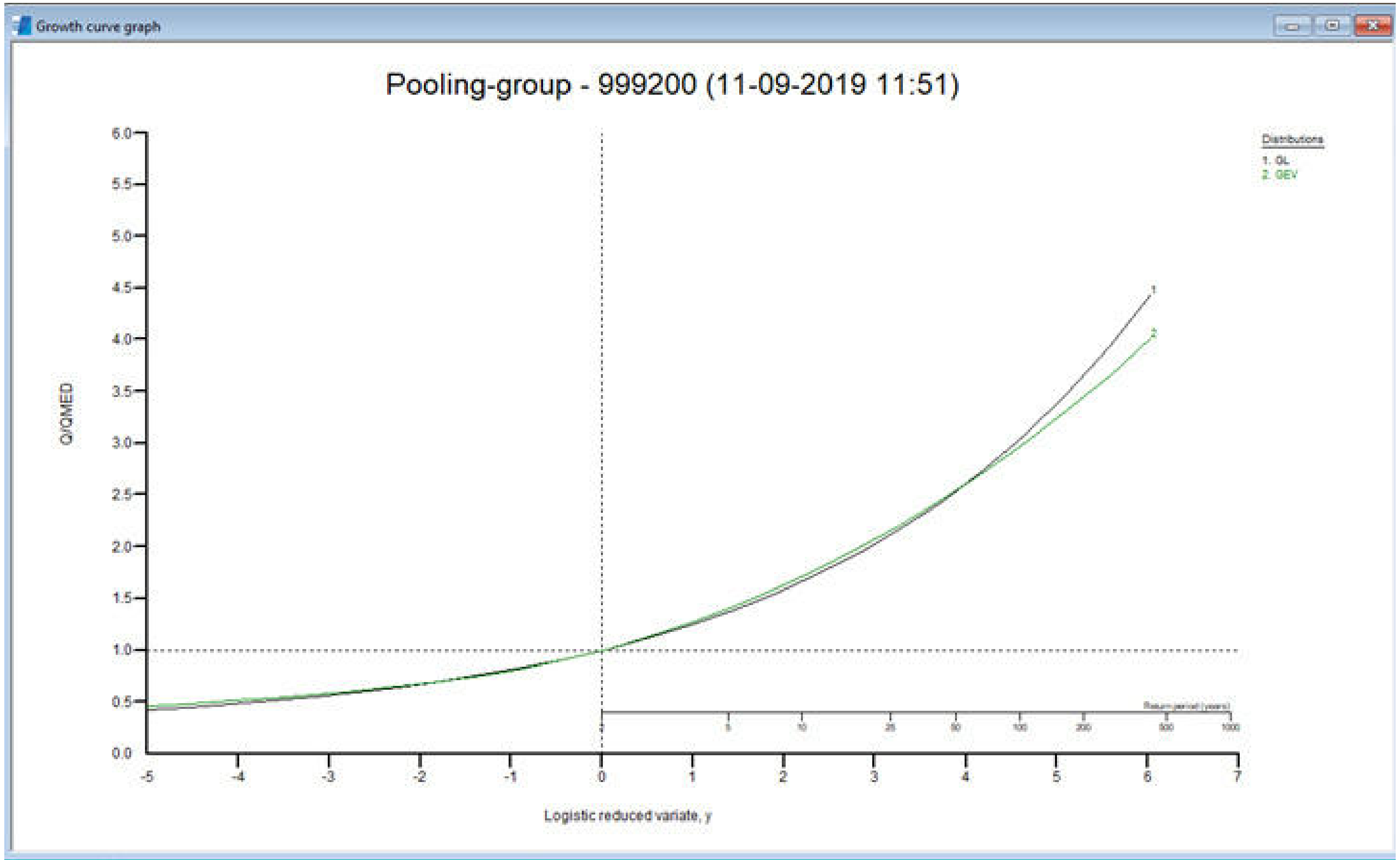
FEP 3	P	NA	GL	V3 (Kjeldsen 2010) applied Growth curve	Loc 1.0 Scale 0.219 Shape -0.281	2.969



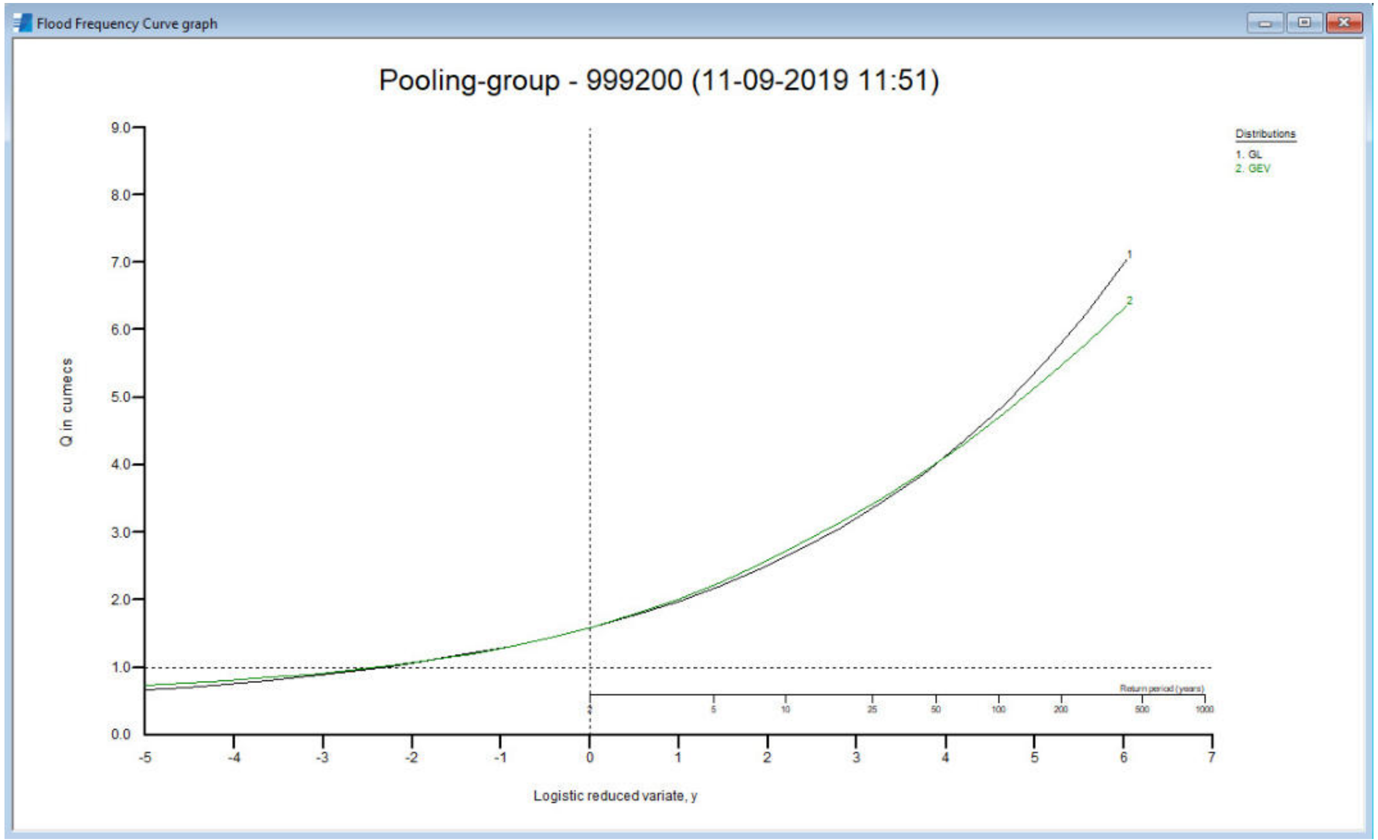
Growth Curve FEP 1 catchment



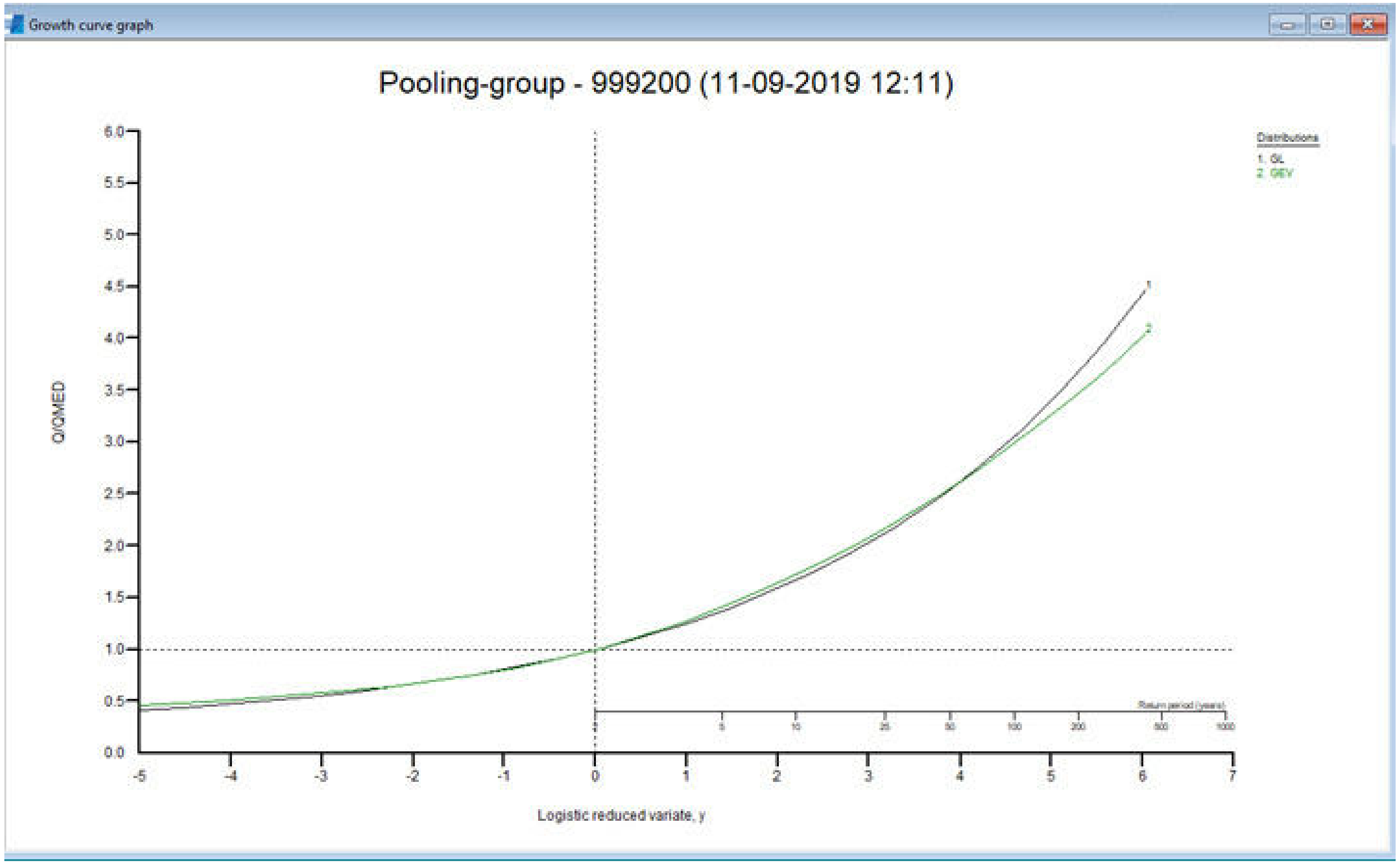
Frequency Flood Curve FEP 1 catchment



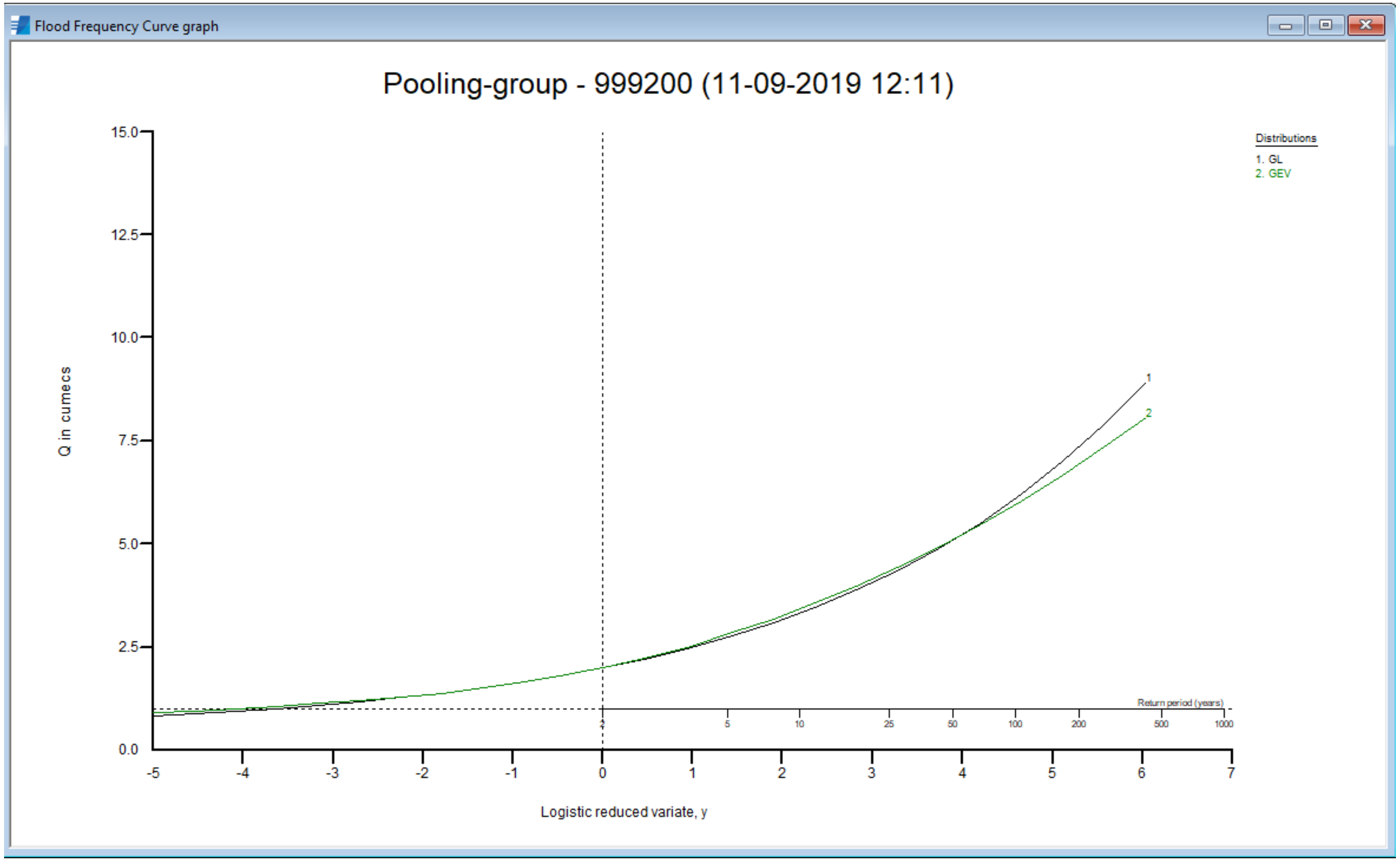
Growth Curve FEP 2 catchment



Frequency Flood Curve FEP 2 catchment



Growth Curve FEP 3 catchment



Frequency Flood Curve FEP 3 catchment

3.6. Flood estimate from the statistical method (Urban)

	Flood peak (m^3/s) for the following return periods (in years)								
Site code	2	5	10	25	50	100	200	500	1000
FEP 1	1.890	2.513	3.011	3.791	4.513	5.386	6.446	8.209	9.885
FEP 2	2.009	2.672	3.216	4.087	4.911	5.924	7.176	9.299	11.358
FEP 3	2.510	3.348	4.035	5.134	6.174	7.451	9.029	11.704	14.298

4. Revitalised flood hydrograph (ReFH) method

The Revitalised Flood Hydrographs (ReFH) method was developed by DEH to provide a more realistic representation of flood hydrology. This method is generally believed to perform reasonably well on most catchments. However, this method is not currently appropriate for either "heavily urbanised" or "very heavily urbanised" based on the values of URBEXT2000 extracted from FEH Web Service because its summer design event was only calibrated on seven urban catchments, and further research to improve the ReFH method has been recommended.

4.1. Parameters for ReFH model

If parameters are estimated from catchment descriptors, they are easily reproducible so it is not essential to enter them in the table.

Site code	**Details of method** OPT: optimisation BR: base flow recession fitting CD: catchment descriptors DT: data transfer	**Tp (hours)** Time to peak	**C_{max} (mm) maximum storage capacity**	**BL (hours)** base flow lag	**BR** base flow recharge
FEP 1	CD	1.59	518.38	39.07	1.79
FEP 2	CD	1.75	517.02	40.32	1.78
FEP 3	CD	2.05	515.68	41.67	1.78
Brief description of any flood event analysis carried out Provide further details either here or in a project report		N/A			

4.2. Design events for ReFH method

We recommend that the ReFH2 technical guidance should be referred to when completing this table

Site code	Season of design event (summer or winter)	Storm duration (hours)	Storm area for ARF (if not catchment area)	Source of design rainfall statistic (FEH13 or FEH99)
FEP 1	Winter	3.75	-	FEH13
FEP 2	Winter	3.75	-	FEH13
FEP 3	Winter	4.5	-	FEH13
Detail any changes to the default ReFH2 urbanisation model parameters		N		
Are storm durations likely to be changed in the next stage of the study For example by optimisation within a hydraulic model?		Yes , the storm durations may change following optimisation of the hydraulic model inflows		

4.3. Flood estimates from the ReFH method (urban/rural)

- Please indicate whether you have used urban or rural results
- We recommend that urban results are used regardless of the extent of urbanisation at the subject sites

	Flood peak (m^3/s) or volumes (m^3) for the following return periods (in years)									
Site code		2	5	10	25	50	100	200		1000
FEP 1	Urban	1.325	1.771	2.090	2.542	2.935	3.401	4.016		6.353
FEP 2	Urban	1.351	1.803	2.13	2.589	2.989	3.464	4.101		6.443
FEP 3	Urban	1.686	2.221	2.607	3.15	3.646	4.222	5.004		7.824

5. Discussion and summary of results

5.1. Comparison of results from different methods

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

	Return period 2 years (QMED)			Return period 100 years		
Site code	**Statistical**	**ReFH**	**Ratio (ReFH / statistical)**	**Statistical**	**ReFH**	**Ratio (ReFH / statistical)**
FEP 1	1.890	1.325	0.701	5.386	3.401	0.631
FEP 2	2.009	1.351	0.672	5.924	3.464	0.584
FEP 3	2.510	1.686	0.671	7.451	4.222	0.566

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 flow derived from FEH statistical analysis has been considered as the design flows at the three FEPs selected for this study. As the statistical method is based on much larger dataset of flood events and has been more directly calibrated to reproduce flood frequency on UK catchments. The Hydrograph derived from the ReFH2 at the upstream boundary (FEP1) will be routed through the model and adjusted to match the statistical peak at the site of interest (FEP 2)

5.3. Assumptions, limitations, and uncertainty

List the main assumptions made specific to the study	FARL was changed for the FEP3 as there is no impact of the reservoir (attenuation) on the Nant Fawr watercourse.

Discuss any particular limitations For example applying methods outside the range of catchment types or return periods for which they were developed	Peak discharges were calculated for each sub-catchment for the following events: 50%, 20%, 10%, 4%, 2%, 1%, 0.5% and 0.1%. The Climate Change allowance for the Severn Catchment is 25% for Central Estimate and 70% for Upper Estimate.
Give what information you can on uncertainty in the results For example using the methods detailed in 'Making better use of local and historic data, and estimating uncertainty in FEH design flood estimation (FEH Local) SC130009	For all the sub-catchments used in this study, the standard methods have been applied and appropriate guidance followed. There is more uncertainty in QMED where donor stations could not be found, as is the case of this study.
Comment on the suitability of the results for future studies For example at nearby locations or for different purposes	The results have made use for the most up-to-date data and methods and could be applied to future studies within the Nant Fawr upstream extend catchment.
Give any other comments on the study For example suggestions for additional work	None

5.4. Checks

Are the results consistent, for example at conferences?	Yes, the three sub-catchments are consistent the results, the estimates increase as the catchment area increase.
What do the results imply regarding the return periods of floods during the period of record?	The statistical peak flow estimates along Nant Fawr are consistent with the hydrological characteristics of the sub-catchments. The estimates increase as the catchment area increase.
What is the 100-year growth factor? Is this realistic? (The guidance suggests a typical range of 2.1 - 4.0)	The 100-year growth factor for the sub-catchments along Nant Fawr range from 2.85 to 2.9, and is within the typical range

If 1000-year flows have been derived, what is the range of ratios for the 1000-year flow over 100-year flow?	The ratios for the Q1000/Q100 are between 1.8 to 1.9
What is the range of specific run-offs (l/s/ha) do the results equate you? Are there any inconsistencies?	For the 1 in 100 event, the specific runoffs at the Nant Fawr are about 10.9 l/s/ha
How did the results compare with those of other studies? Explain any differences and conclude which results should be preferred	The results comparison could not be performed, as the existing hydraulic model and the associated hydrological assessment are not available at the time of the writing of this report.
Are the results compatible with the longer-term flood history?	Yes for the area of study.
Describe any other checks on the results	None

5.5. Final results

	Flood peak (m^3/s) or volumes (m^3) for the following return periods (in years)								
Site code	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
FEP 1	1.890	2.513	3.011	3.791	4.513	5.386	6.446	8.209	9.885
FEP 2	2.009	2.672	3.216	4.087	4.911	5.924	7.176	9.299	11.358
FEP 3	2.510	3.348	4.035	5.134	6.174	7.451	9.029	11.704	14.298

If flood hydrographs are needed for the next stage of the study, where are they provided? For example give a name of spreadsheet, name of hydraulic model, or reference to table below	The ReFH2 hydrograph will be used to fit the peak of the statistical method adjusted to the design storm calculated.

6. Annex – supporting information

Please include details of your pooling group(s)
Donor Catchment Criteria

Search criteria for HiFlows website to select Donor Catchments for data transfer								
Catchment descriptor	**General Search Criteria**				**Adopted Search Criteria**			
	Factor of	**Diff of**	**Lower Bound**	**Upper Bound**	**Factor of**	**Diff of**	**Lower Bound**	**Upper Bound**
AREA	5.00		**0.63**	**15.70**	5.00		**0.63**	**15.70**
SAAR	1.25		**998**	**1559**	1.25		**998**	**1559**
BFIHOST		0.18	**0.438**	**0.798**		0.18	**0.438**	**0.798**
FARL		0.05	**0.950**	**1.000**		0.05	**0.950**	**1.000**
SPRHOST		15	**14.99**	**44.99**	*SPRHOST is not available as a search term on the HiFlows Website*			

Proposed donors

Rhondda Fawr

Catchment Descriptors				
Area (km2)	**SAAR (mm)**	**FARL**	**BFIHOST**	**SPRHOST**
16.64	2458	0.999	0.317	27.71
Invalid	Invalid	Valid	Invalid	Valid

Llanedeyrn

Catchment Descriptors				
Area (km2)	**SAAR (mm)**	**FARL**	**BFIHOST**	**SPRHOST**
178.7	1409	0.981	0.521	33.17
Invalid	Valid	Valid	Valid	Valid

Tongwynlais

Catchment Descriptors				
Area (km2)	**SAAR (mm)**	**FARL**	**BFIHOST**	**SPRHOST**

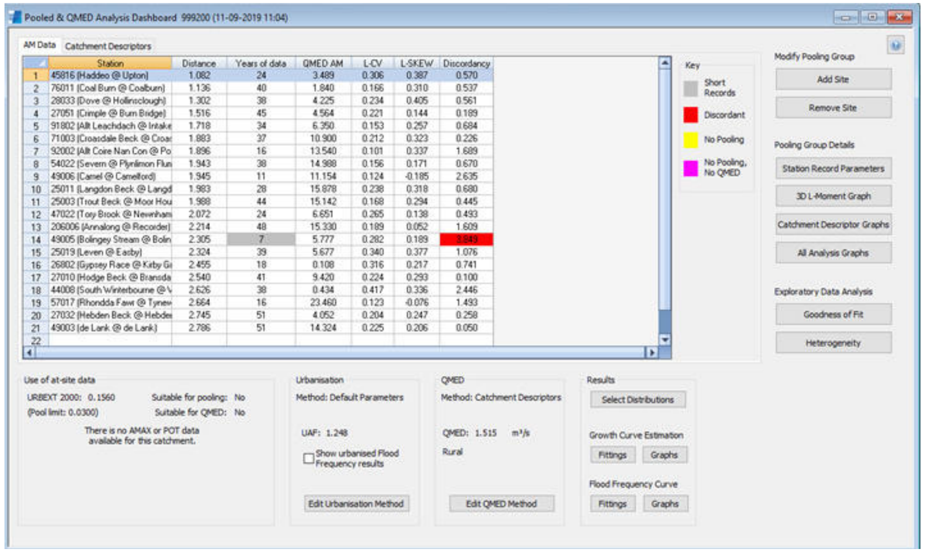
486.9	1801	0.950	0.42	-
Invalid	Invalid	Valid	Invalid	Invalid

6.1. Pooling group composition

FEP 1 -upstream sub-catchment

Original Pooling group

Edited Pooling group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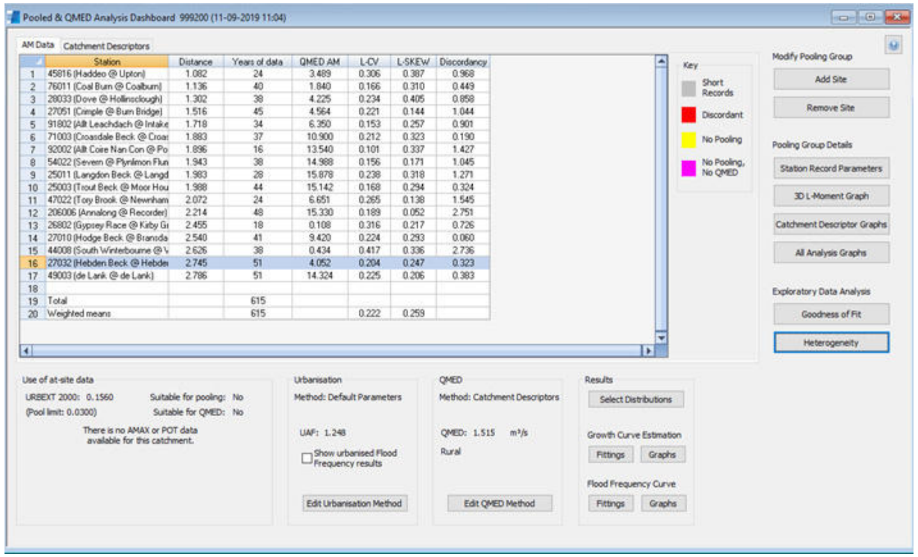
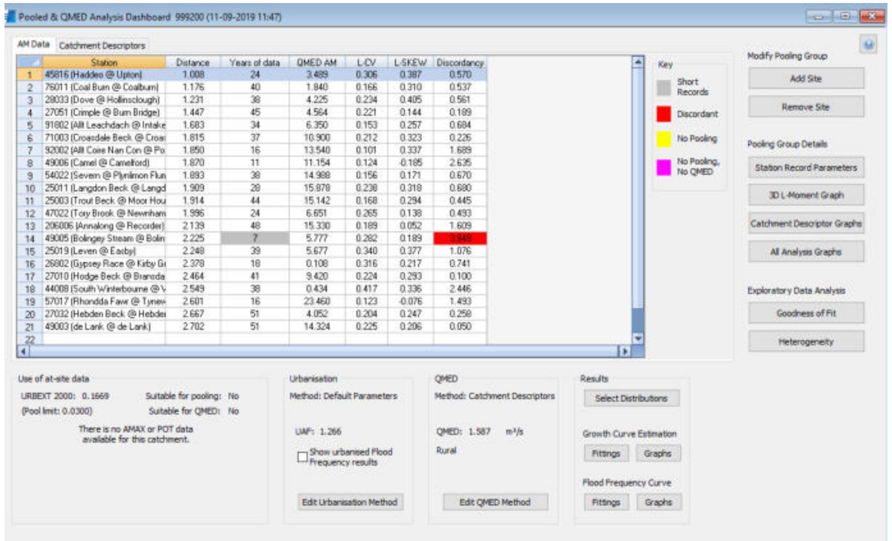
AM Data
Catchment Descriptors
Modify Pooling Group
Add Site
Remove Site
Pooling Group Details
Station Record Parameters
3D L-Moment Graph
Catchment Descriptor Graphs
All Analysis Graphs
Exploratory Data Analysis
Goodness of Fit
Heterogeneity

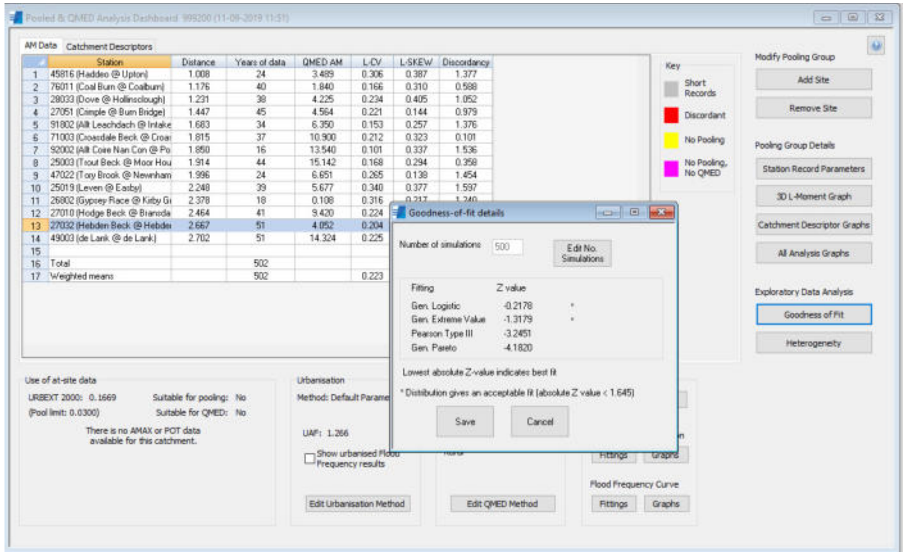

Pooled & QMED Analysis Dashboard 999200 (11-09-2019 11:04)
AM Data
Catchment Descriptors
Modify Pooling Group
Add Site
Remove Site
Pooling Group Details
Station Record Parameters
3D L-Moment Graph
Catchment Descriptor Graphs
All Analysis Graphs
Exploratory Data Analysis
Goodness of Fit
Heterogeneity

FEP 2 -SITE sub- catchment

Original Pooling group

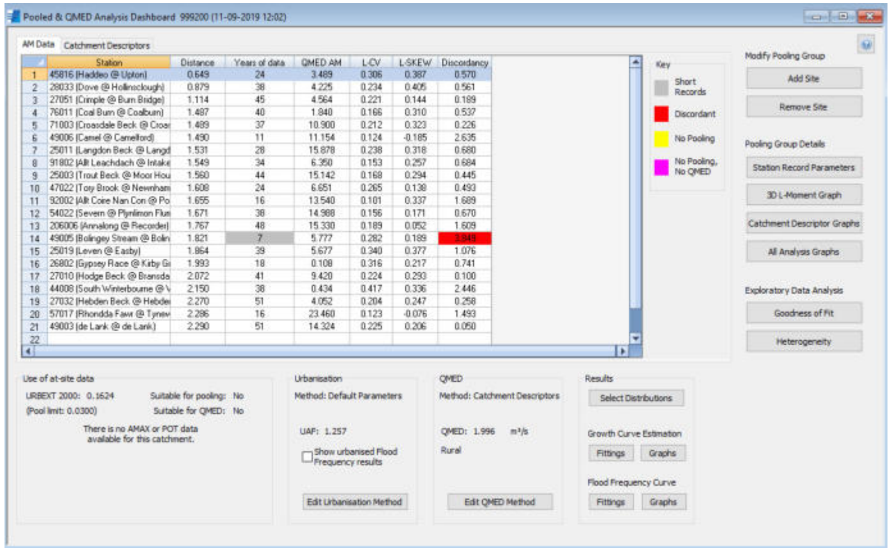
Edited Pooling group



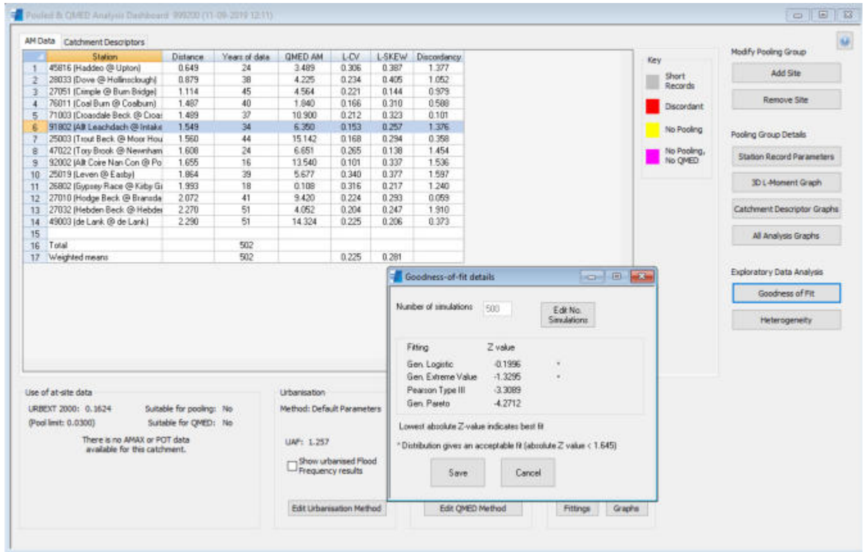


FEP 3 -downstream sub- catchment

Original Pooling group



Edited Pooling group



6.2. Additional supporting information

ReFH2 parameters

Parameters

Where the user has overriden a system-generated value, this original value is shown in square brackets after the value used.

** Indicates that the user locked the duration/timestep*

Rainfall parameters (Rainfall - FEH 2013 model)

Name	Value	User-defined?
Duration (hh:mm:ss)	04:30:00	No
Timestep (hh:mm:ss)	00:30:00	No
SCF (Seasonal correction factor)	0.8	No
ARF (Areal reduction factor)	0.96	No
Seasonality	Winter	n/a

Loss model parameters

Name	Value	User-defined?
Cini (mm)	84.93	No
Cmax (mm)	515.68	No
Use alpha correction factor	No	No
Alpha correction factor	n/a	No

Routing model parameters

Name	Value	User-defined?
Tp (hr)	2.05	No
Up	0.65	No
Uk	0.8	No

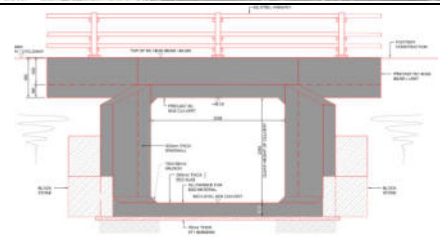
Baseflow model parameters

Name	Value	User-defined?
BF0 (m^3/s)	0.2	No
BL (hr)	41.67	No
BR	1.78	No

Urbanisation parameters

Name	Value	User-defined?
Urban area (km^2)	1.14	No
Urbext 2000	0.16	No
Impervious runoff factor	0.7	No
Imperviousness factor	0.3	No
Tp scaling factor	0.5	No
Sewered area (km^2)	0.00	Yes
Sewer capacity (m^3/s)	0.00	Yes

APPENDIX D
MODELLING STRUCTURES

Model Node	Structure	Dimensions (m)	Invert Level Upstream (m AOD)	Representation in the model	Survey year	Photograph
ROAT01_7525B	Lisvane Road Bridge	1 openings (WxH):3.02x 2.07;	49.38 US	Sprung arch bridge unit, overtopping is represented in 2D domain	2019	
ROAT01_7210W	Online weir	Elevation of crest: ~ 45.18 mAOD	44.13 US	Spill unit	2019	
ROAT01_7207B	(**Existing Structure**) Main proposed development site entrance, bridge unit	1 opening W 2.4 H 2.4	42.975 US	USBPR1978 Bridge unit, the central column is represented in the bridge cross section data, overtopping is represented in 2D domain	2019	
ROAT01_7207B	(**Proposed structure**) Main proposed development site entrance, bridge unit	1 opening W 3 H 2.36	43.06 US	USBPR1978 Bridge unit, the central column is represented in the bridge cross section data, overtopping is represented in 2D domain	PROPO SED	

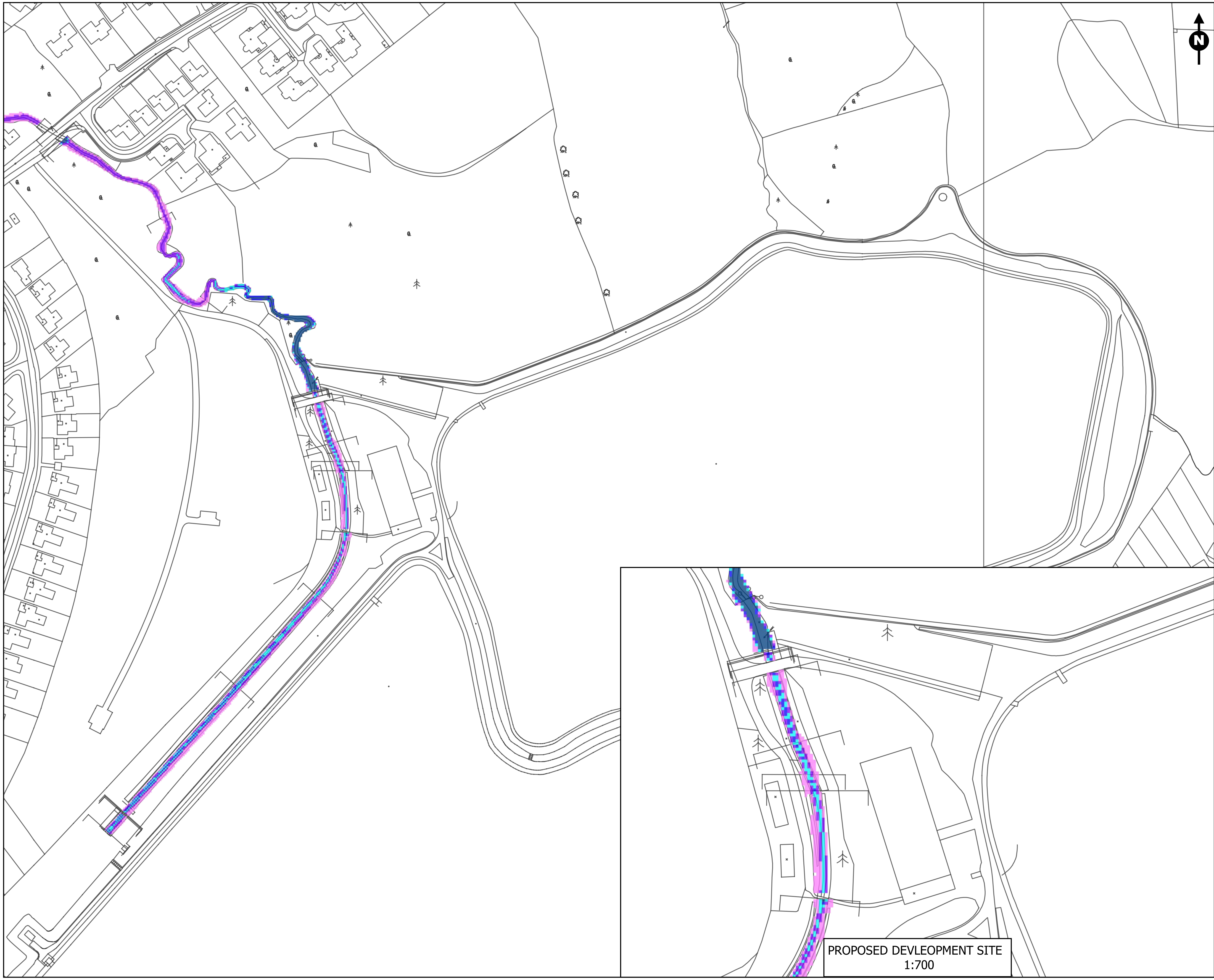
Model Node	Structure	Dimensions (m)	Invert Level Upstream (m AOD)	Representation in the model	Survey year	Photograph
ROAT01_7169B	Foot bridge,	1 openings soffit 45.33 H 2.45	42.79 US	USBPR1978 Bridge unit, overtopping is represented in 2D domain	2019	
NANT_024	Online weir	Elevation of crest: ~ 41.7 mAOD		Spill unit	2019	
ROAT01_6889C	South west arch culvert (1st upstream)	1x opening W 1.85 m H 1.22 m Length 106 m	41.33 US 40.93 DS	Sprung Arch culvert, overtopping represented in 2D domain	2019	

Model Node	Structure	Dimensions (m)	Invert Level Upstream (m AOD)	Representation in the model	Survey year	Photograph
ROAT01_6612C	Arch culvert (2nd upstream) parallel to Rugby field	1x opening W 1.76m H 1.24m Length 104m	40.41 US 40.08 DS	Sprung Arch culvert, overtopping represented in 2D domain	2019	
ROAT01_6431C	Arch culvert (3rd upstream) Rhydypenau park bend	1x opening W 1.75m H 1.24m Length 85m	39.76 US 38.64 DS	Sprung Arch culvert, overtopping represented in 2D domain	2019	
ROAT01_6305W	Online weir	Elevation of crest: ~ 38.03 mAOD	38.05 US 37.65 DS	Spill unit, change in channel shape	2019	

Model Node	Structure	Dimensions (m)	Invert Level Upstream (m AOD)	Representation in the model	Survey year	Photograph
ROAT01_6226W	Online weir	Elevation of crest: 33.43 mAOD	33.41 US 33.43 DS	Spill unit, change in channel shape	2019	
ROAT01_6186B	Foot bridge	1 openings soffit 33.99 H 1.06	32.72 US	USBPR Bridge unit in Flood Modeller. Overtopping of bridge deck is represented in 2D domain,	2019	
NANT_006	Online weir, step	Elevation of crest: 31.54 mAOD		Spill unit	2019	

Model Node	Structure	Dimensions (m)	Invert Level Upstream (m AOD)	Representation in the model	Survey year	Photograph
ROAT01_6019B	Rhydypenau foot bridge	1 openings soffit 31.96 H 1.04	30.42 US	USBPR Bridge unit in Flood Modeller. Overtopping of bridge deck is represented in 2D domain,	2019	
ROAT01_5841B	Rhyd-y-penau Road Bridge	1 openings soffit 29.55 H 0.95	28.60 US	USBPR Bridge unit in Flood Modeller. Overtopping of bridge deck was represented in 1D model.	2007 (JBA)	 Source JBA

APPENDIX E
FLOOD MAPS



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

wsp

Wrexham Office
+44 1978 368100

Opus House, Yale Business Village, Wrexham Tech. Park, Wrexham LL13 7YL

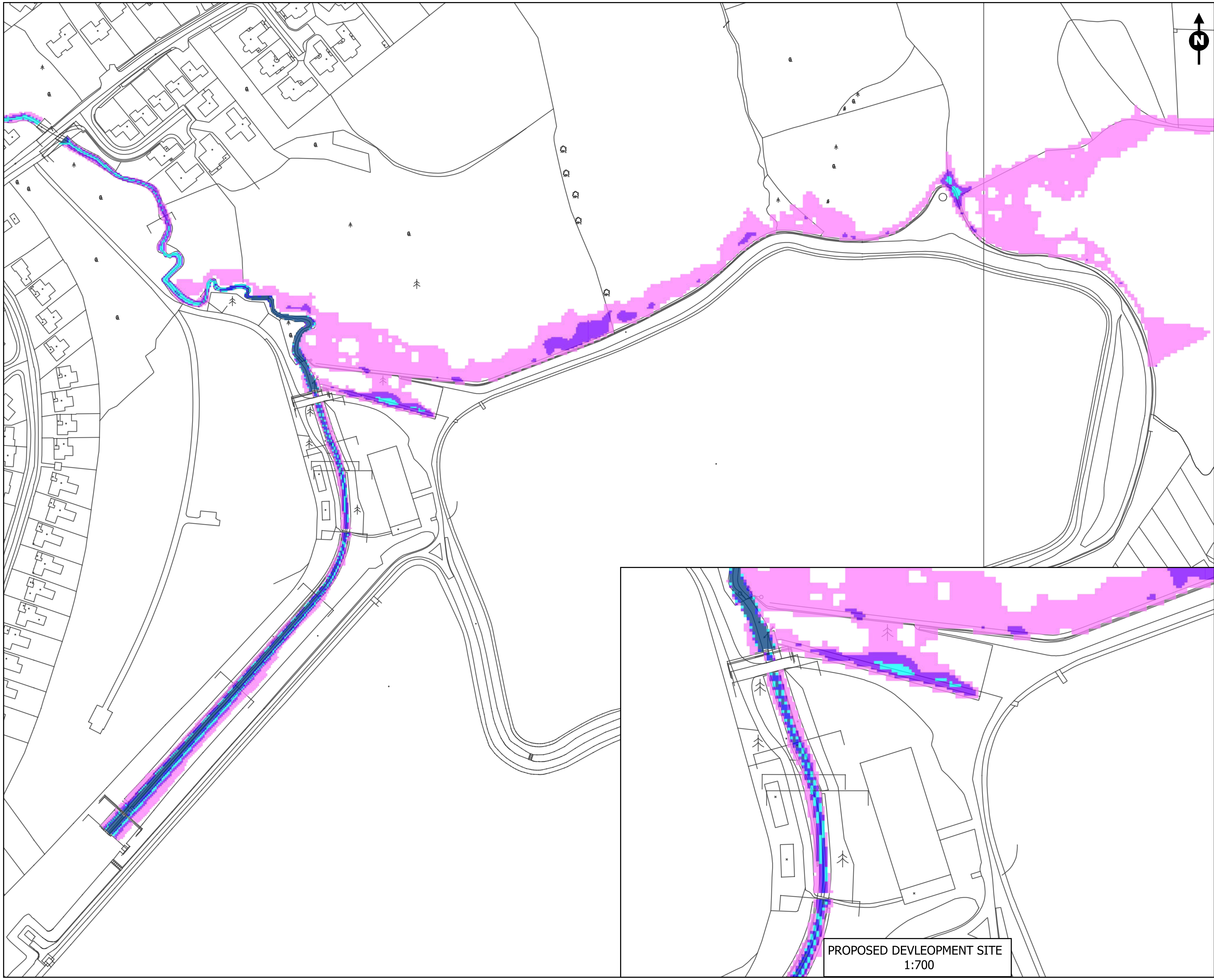
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 2 (50% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/001/G	001	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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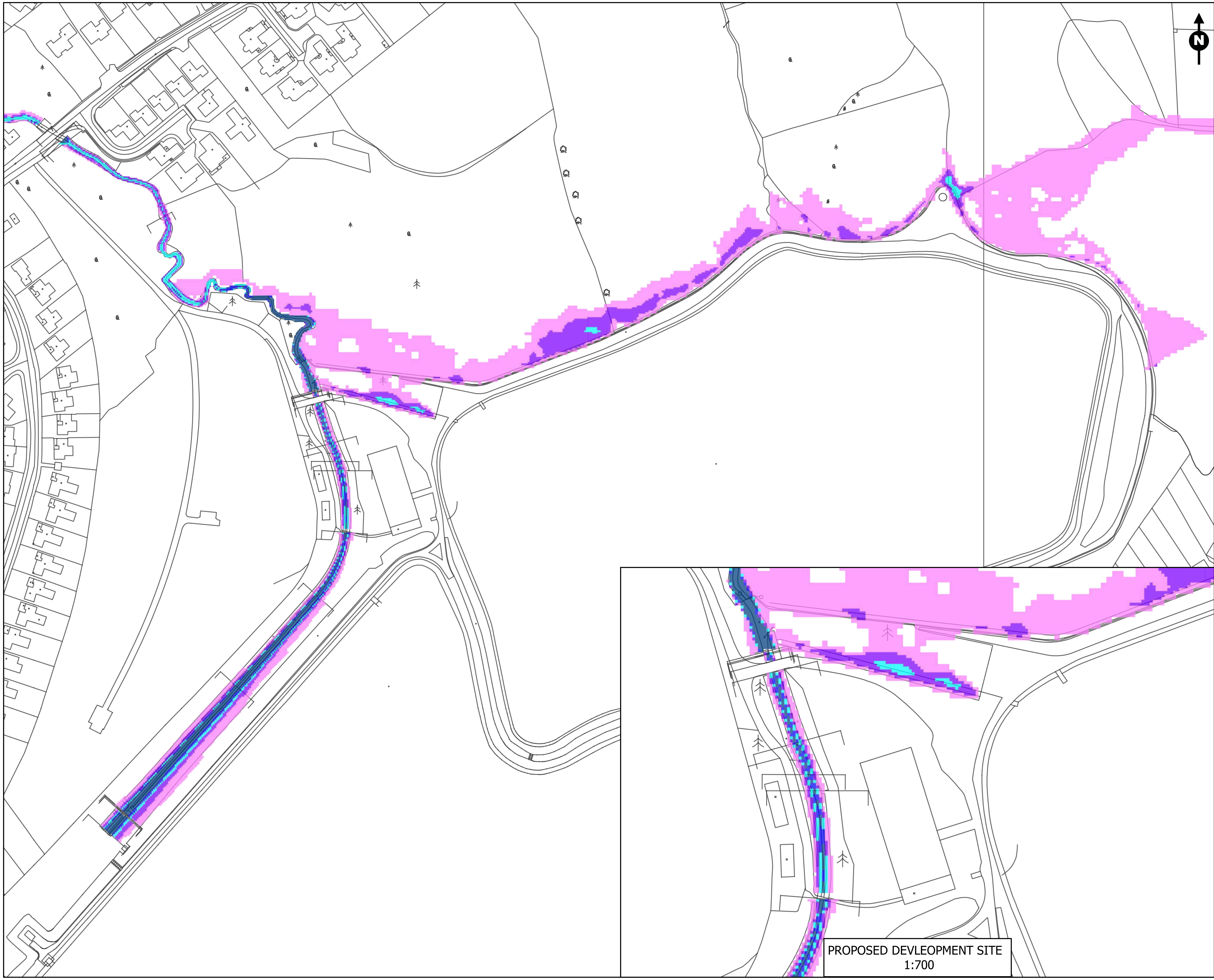
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 20 (5% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/004/G	004	P01

Original Sheet Size A3 [420x297] Plot Date 28.19.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

wsp

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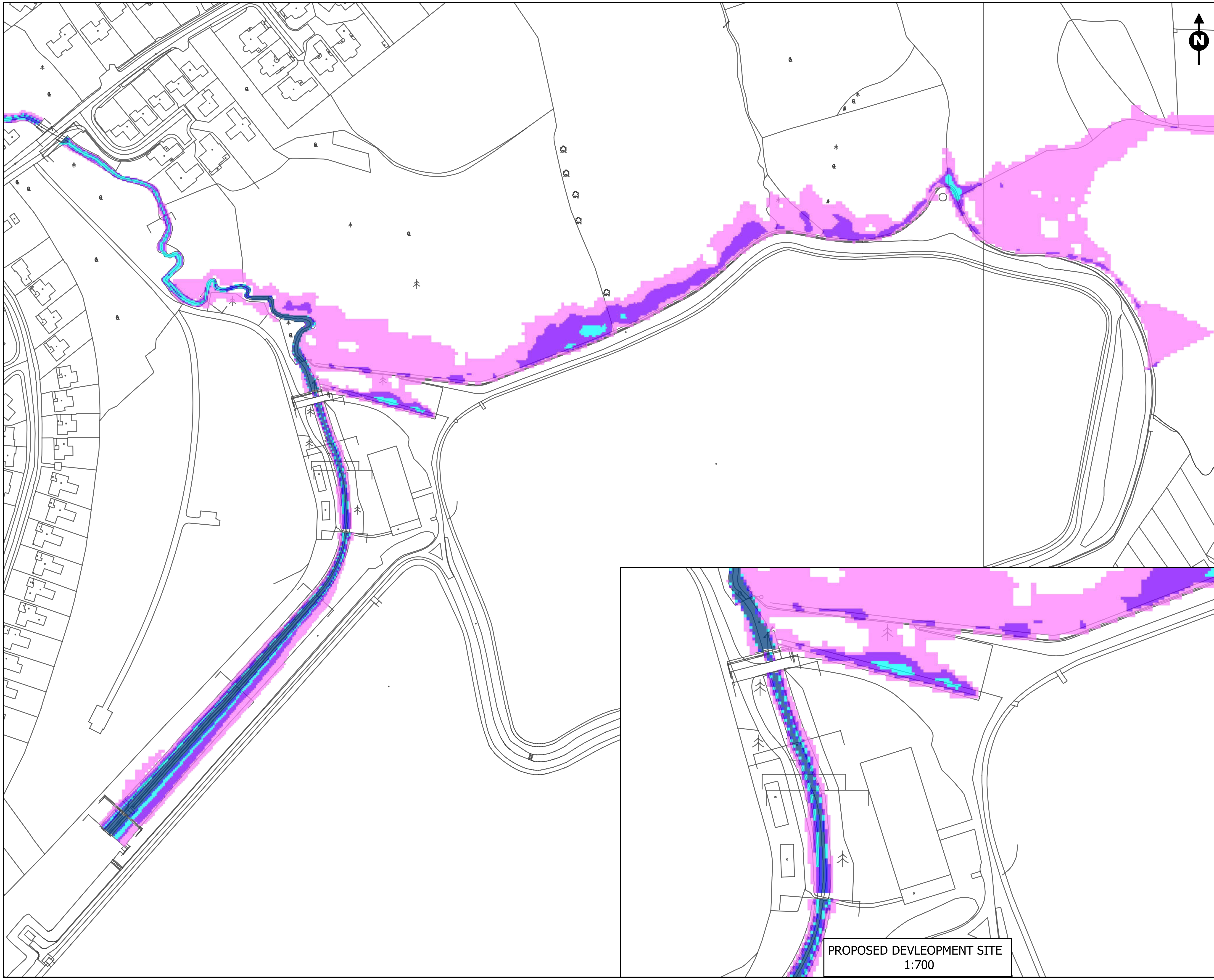
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 30 (3% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/007/G	007	P01

Original Sheet Size A3 [420x297] Plot Date 28.32.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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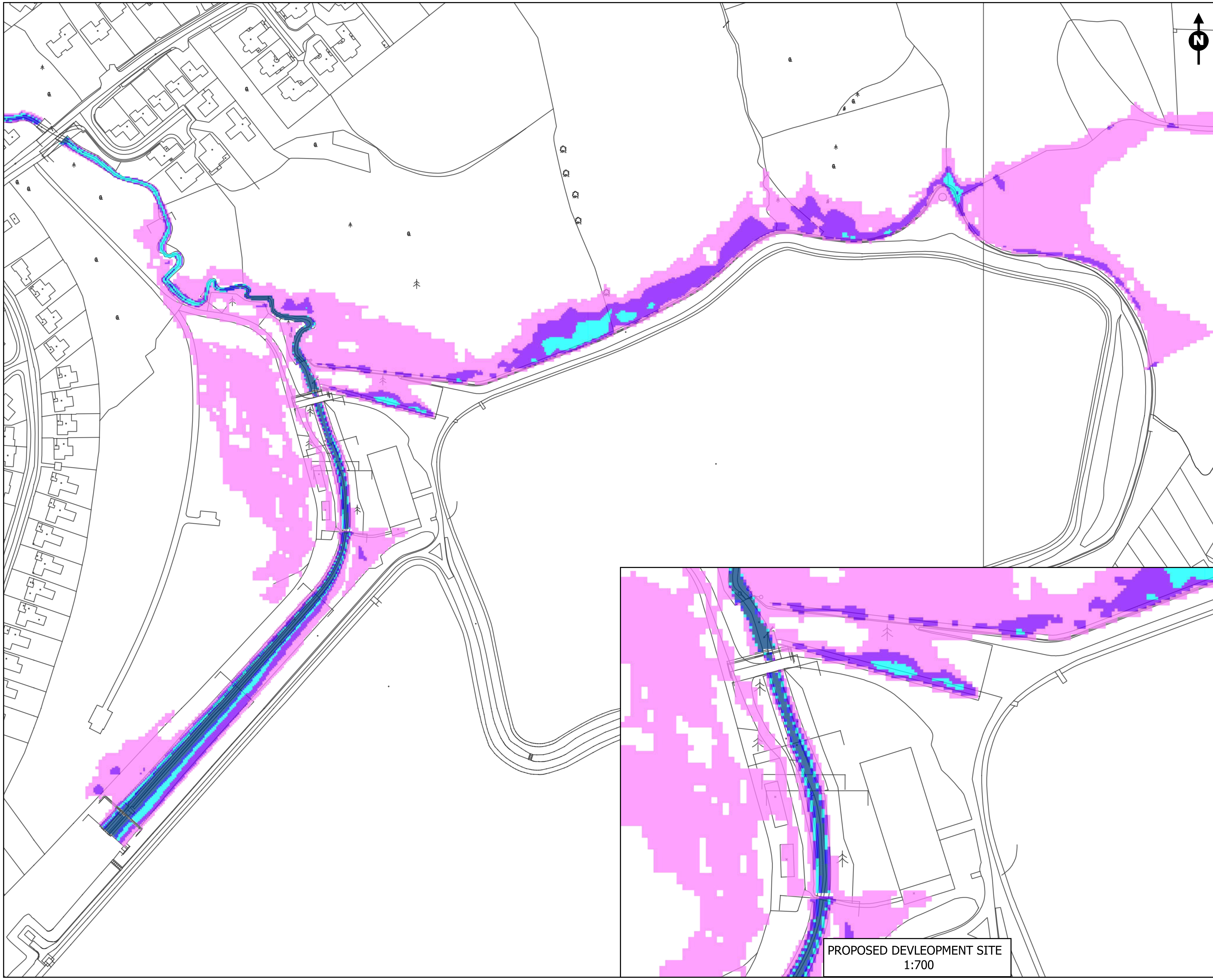
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 50 (2% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/010/G	010	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

wsp

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AJ	AO	VM	28th January 2020

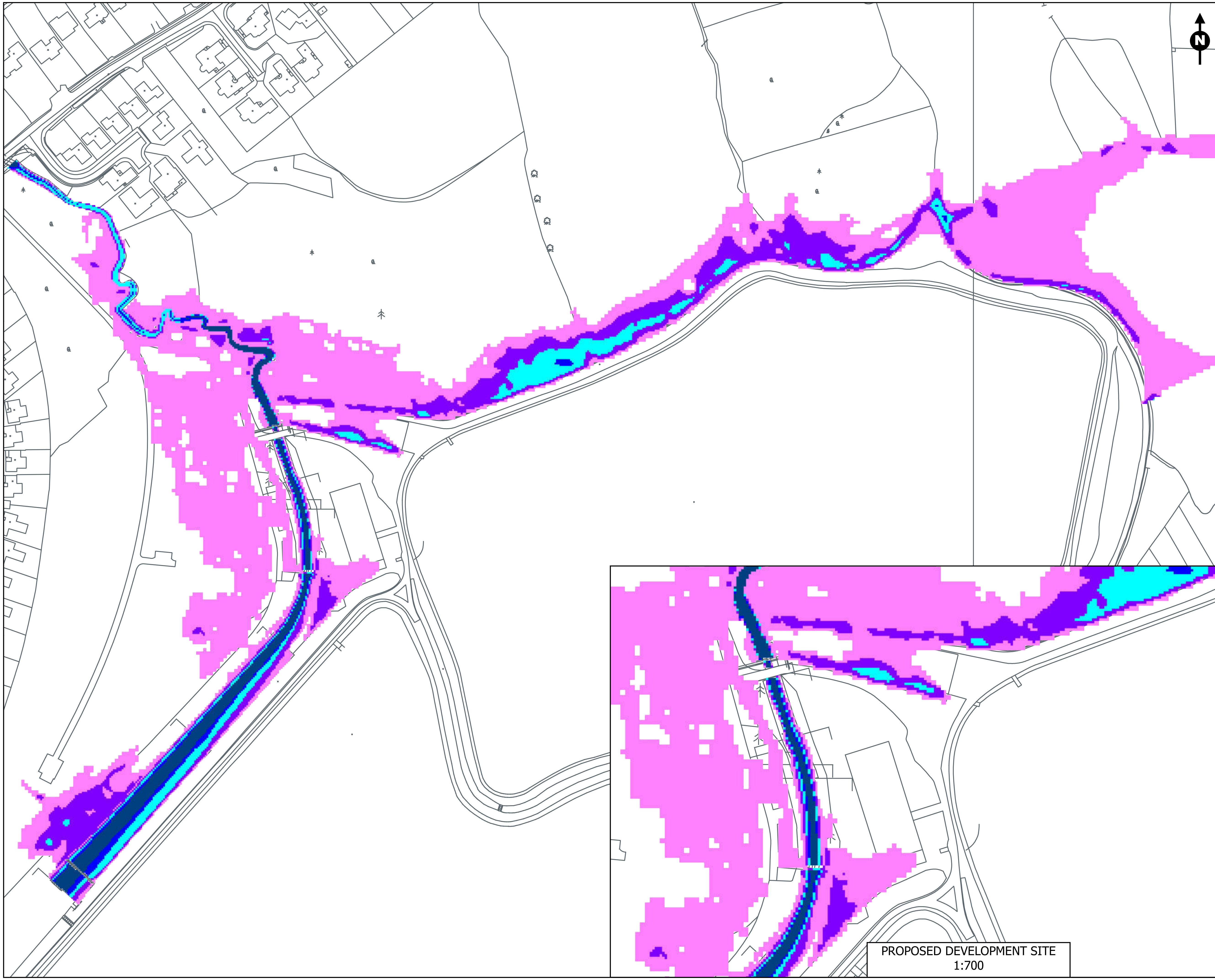
70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/013/G	013	P01

Original Sheet Size A3 [420x297] Plot Date 28.23.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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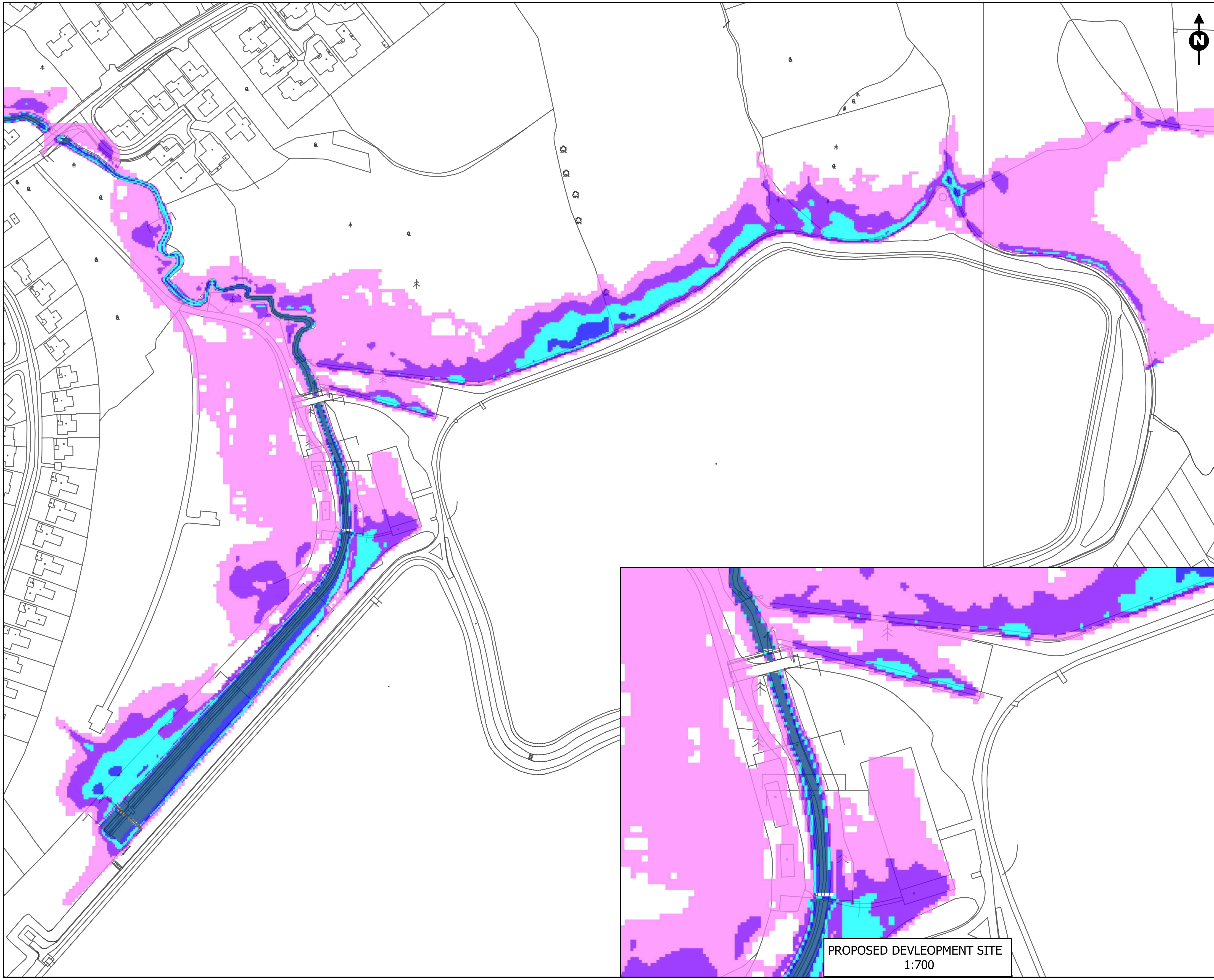
AJ	AO	VM	13th February 2020
70062284			1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/016/G	16	P01



wsp

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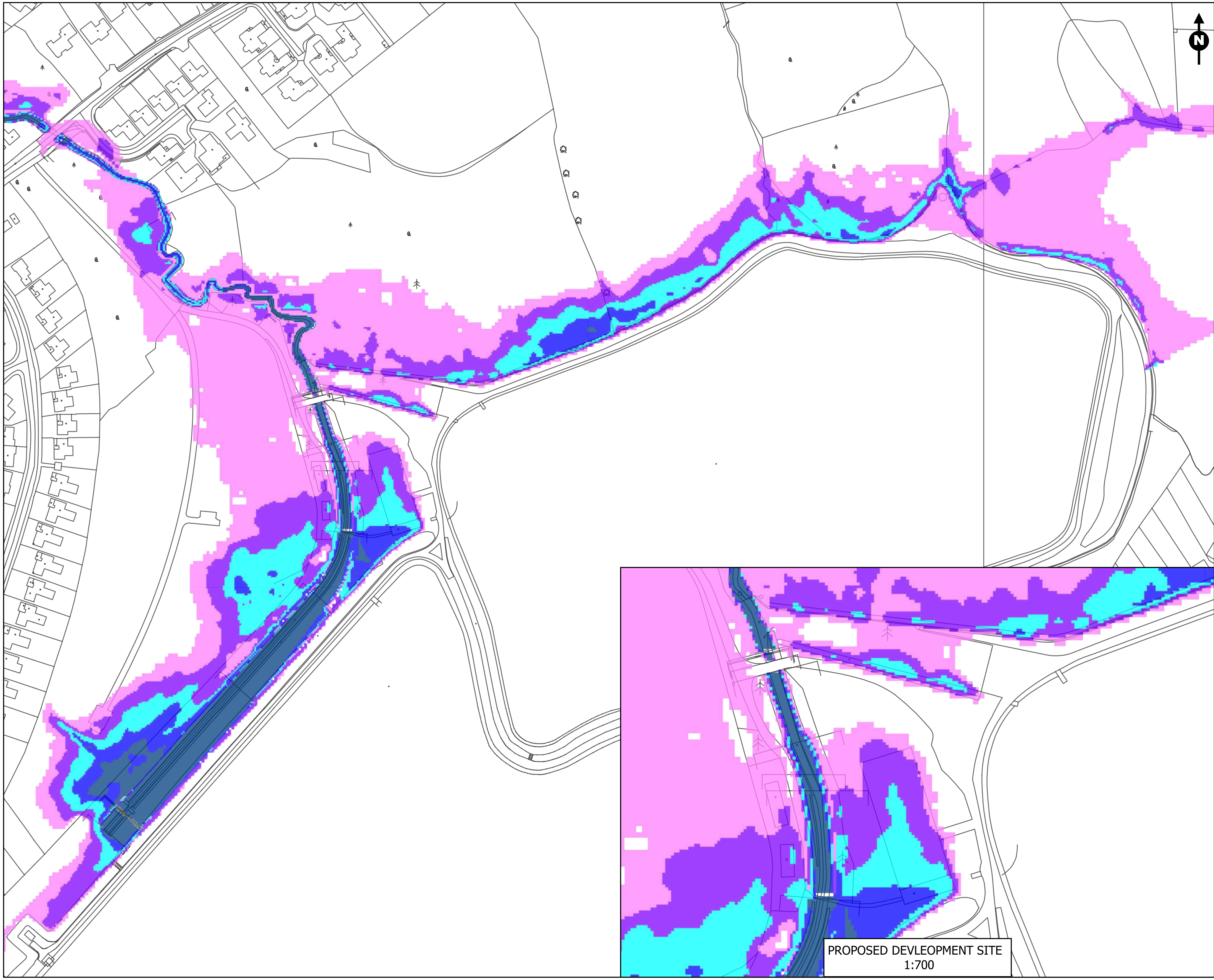
AJ	AO	VM	28th January 2020
70062284			1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/019/G	019	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

wsp

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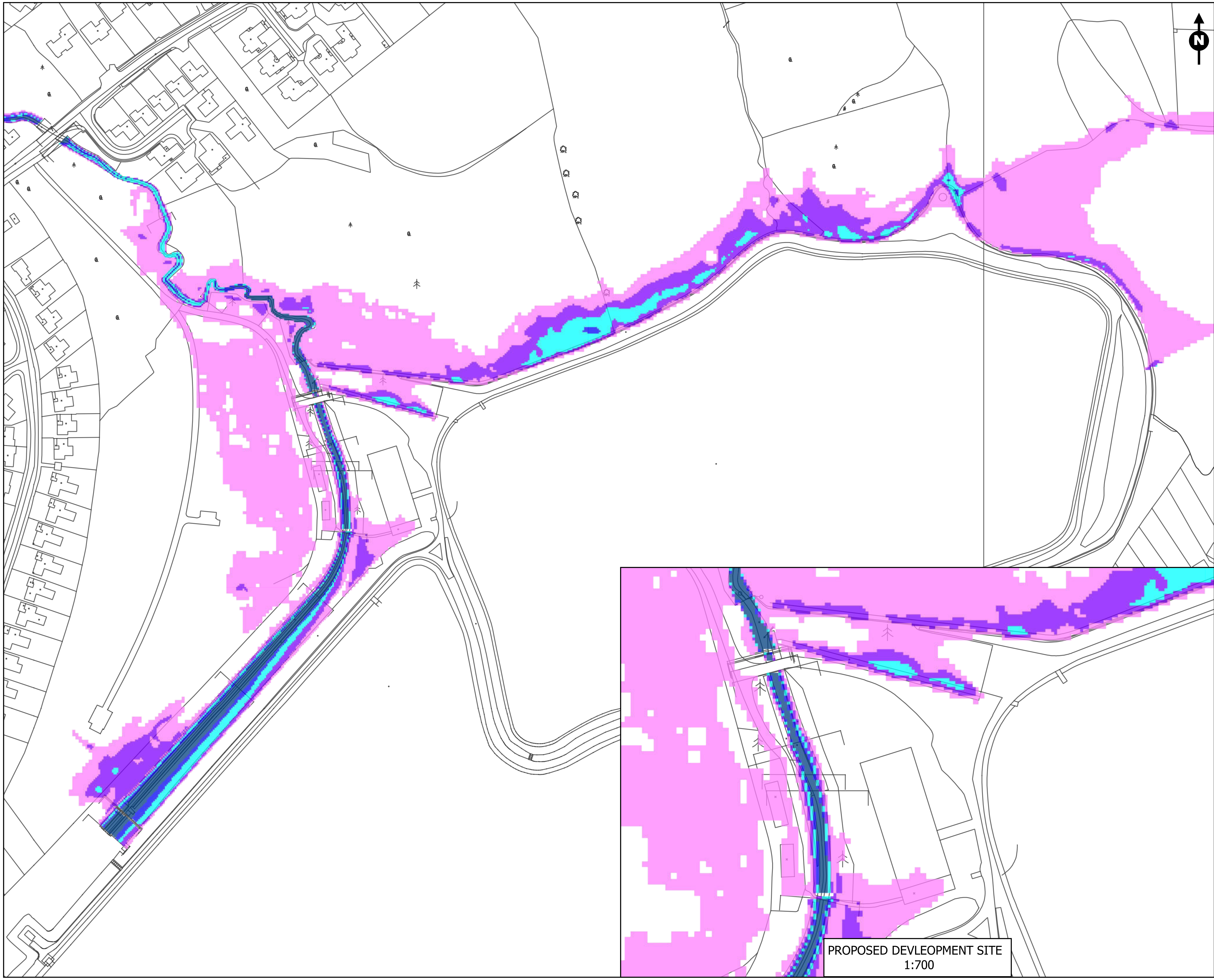
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/022/G	022	P01

Original Sheet Size A3 [420x297] Plot Date 28.9.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

wsp

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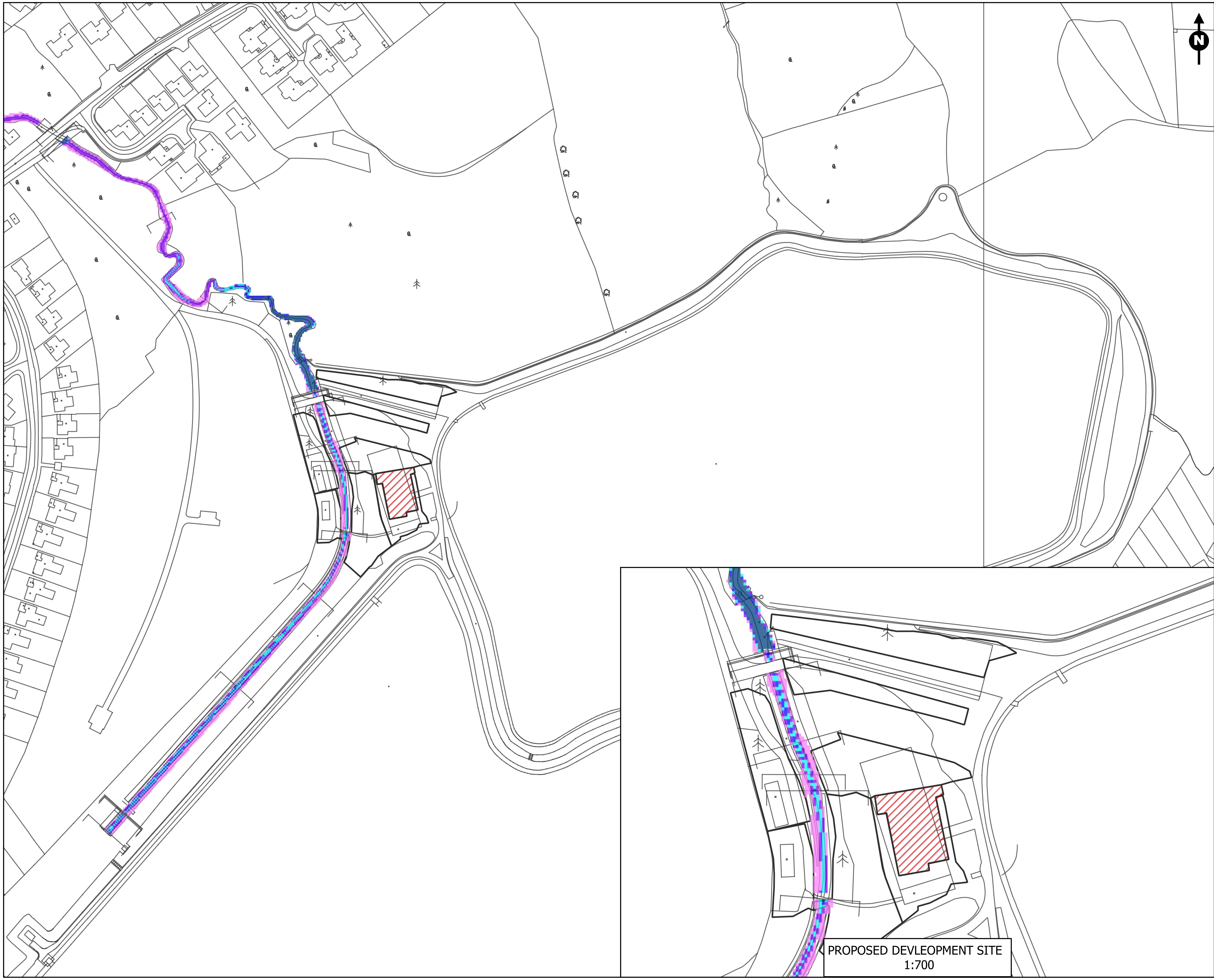
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/025/G	025	P01

Original Sheet Size A3 [420x297] Plot Date 05.38.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

wsp

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 2 (50% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/028/G	028	P01

Original Sheet Size A3 [420x297] Plot Date 05.25.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs

Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 20 (5% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/031/G	031	P01

Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 30 (4% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/034/G	034	P01

Original Sheet Size A3 [420x297] Plot Date 05.32.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs

Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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AJ	AO	VM	28th January 2020

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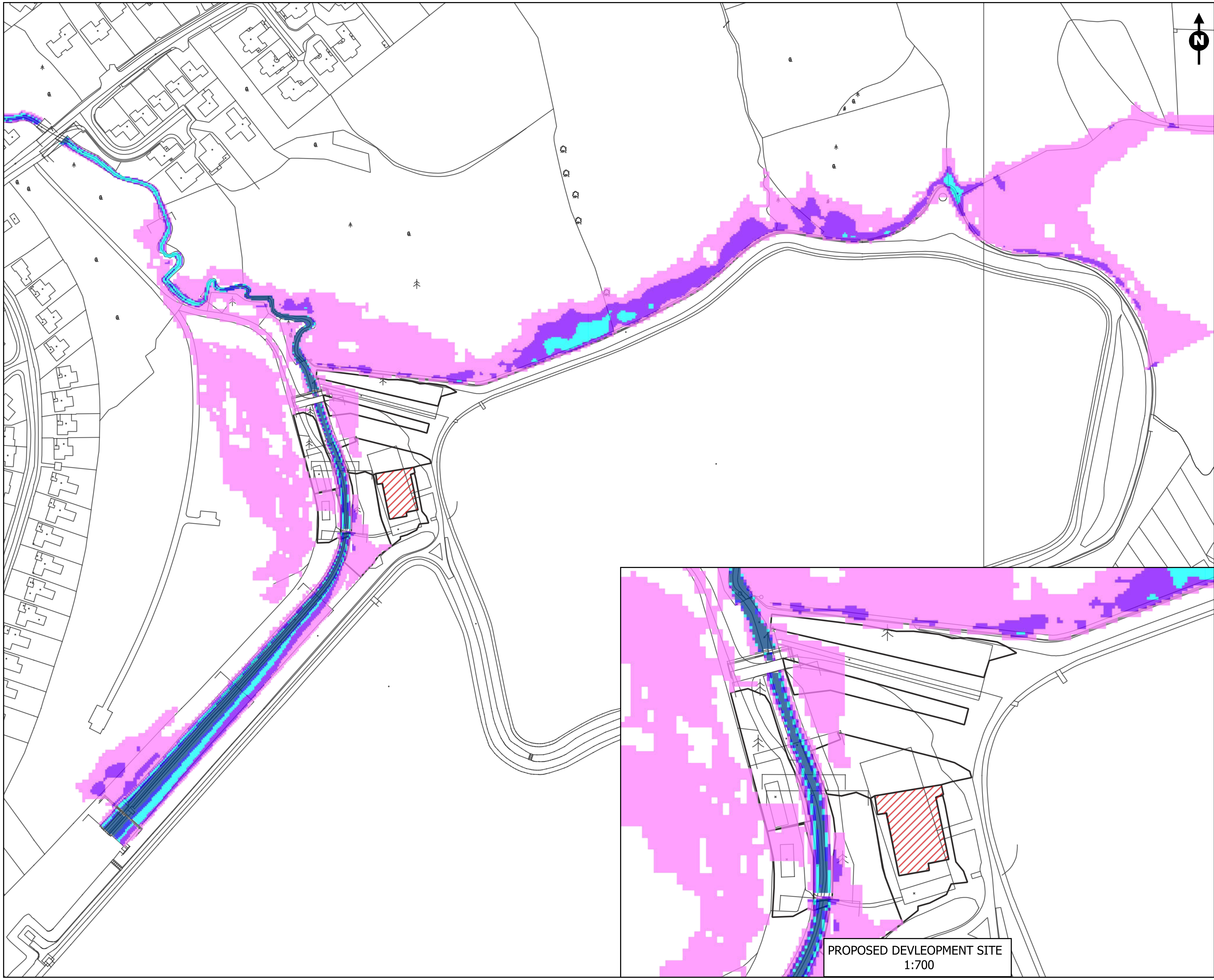
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 50 (2% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/037/G	037	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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AJ	AO	VM	28th January 2020

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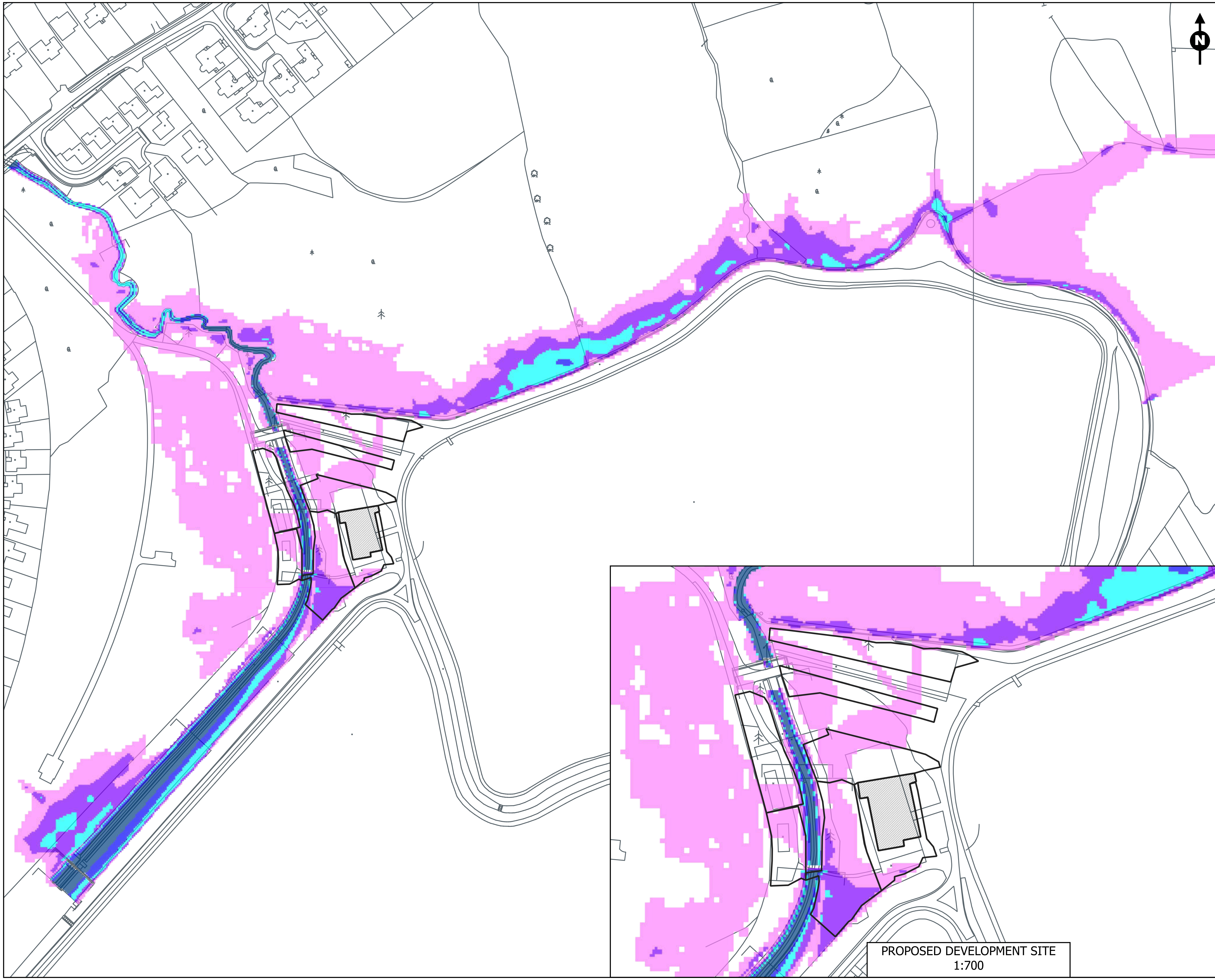
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/040/G	040	P01

Original Sheet Size A3 [420x297] Plot Date 05.58.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development Building
- Development Site

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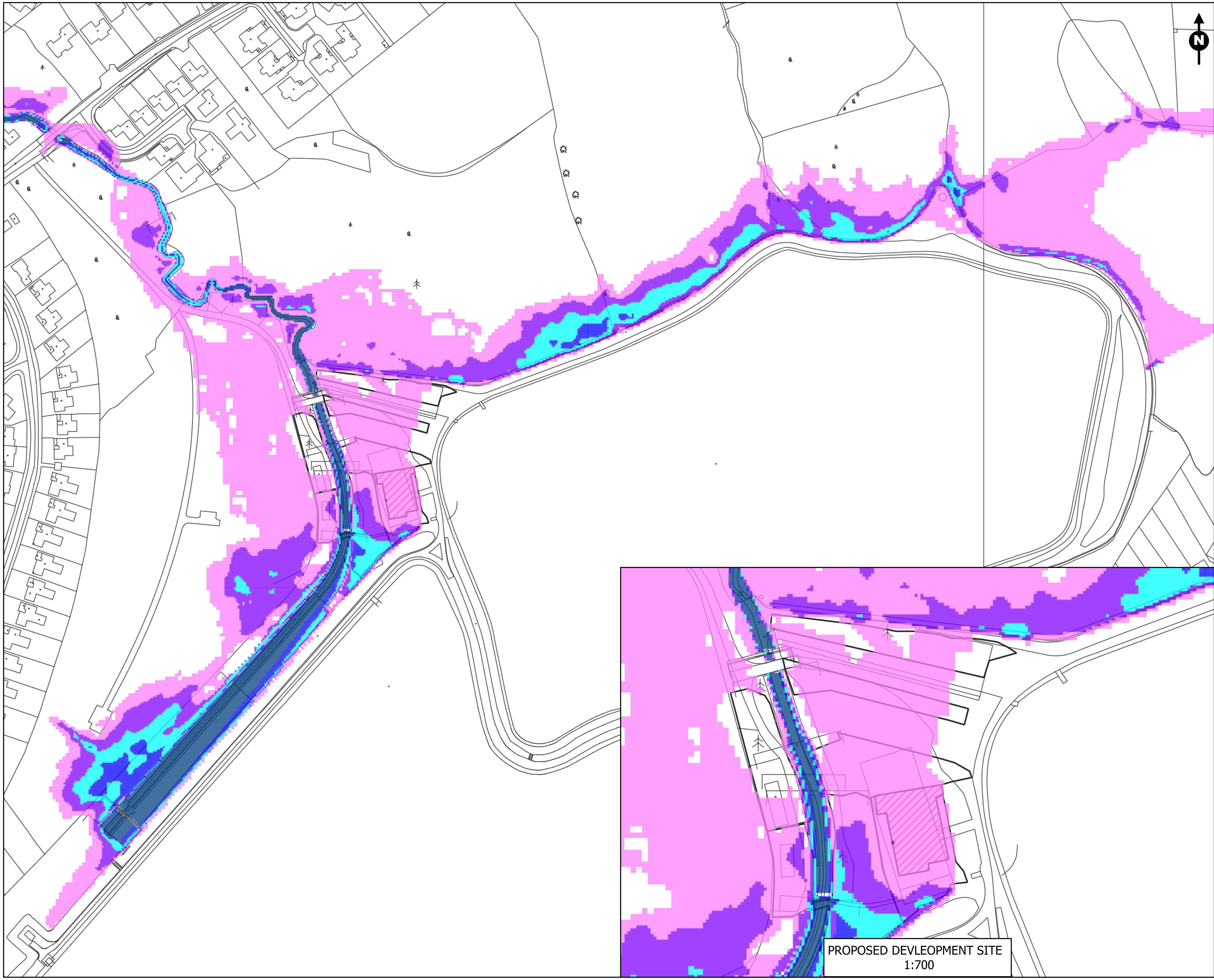
AJ	AO	VM	13th February 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/043/G	43	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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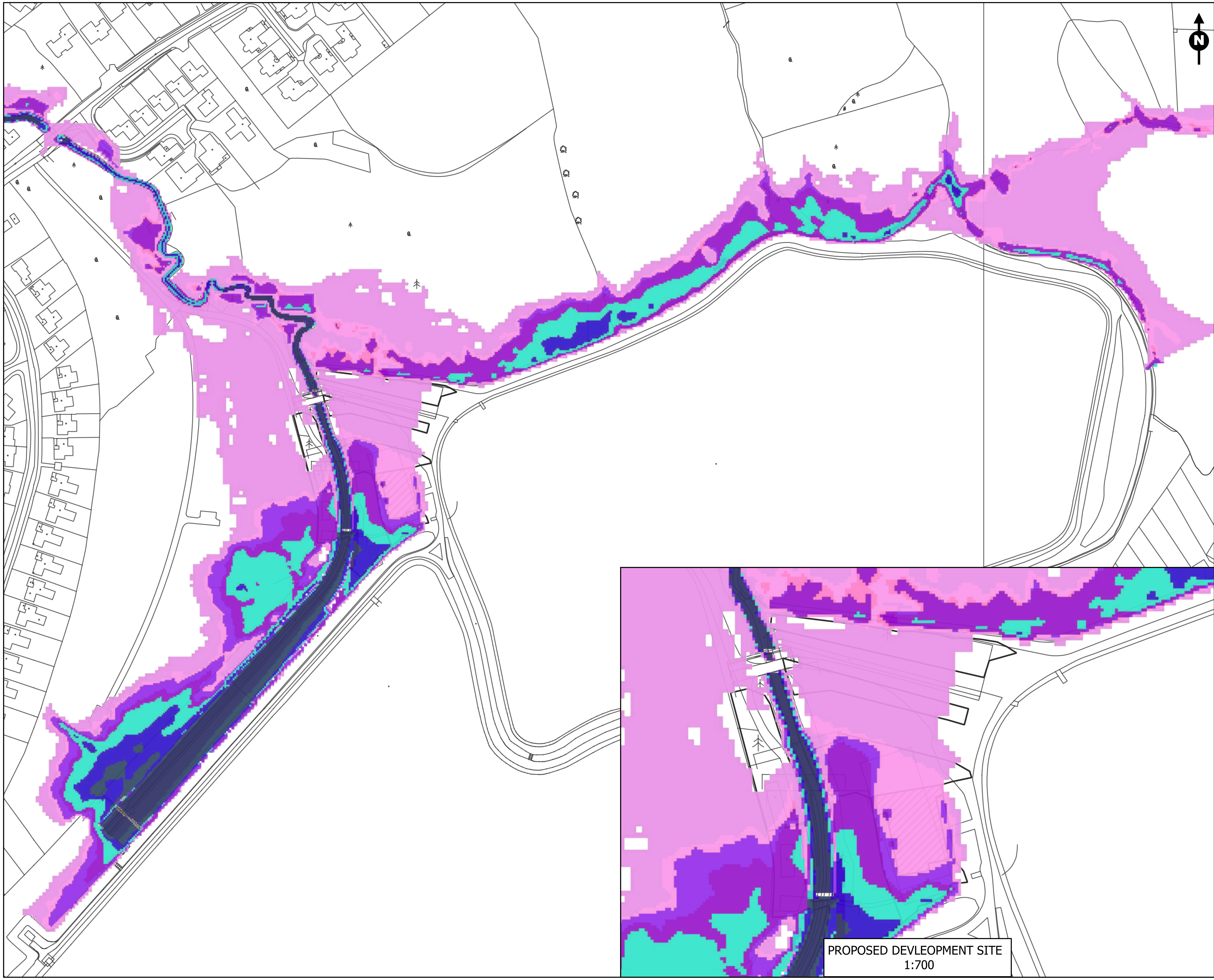
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/046/G	046	P01



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200
- Development
- Development Site

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AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 1000 (0.1% AEP)
AS PROPOSED - A - MAX FLOOD DEPTH

70062284/049/G	049	P01

APPENDIX F
FLOOD DEPTHS

Legend

- Depth Points
- Development_Building
- Development Site

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD DEPTH

70062284/025/G	025	P01

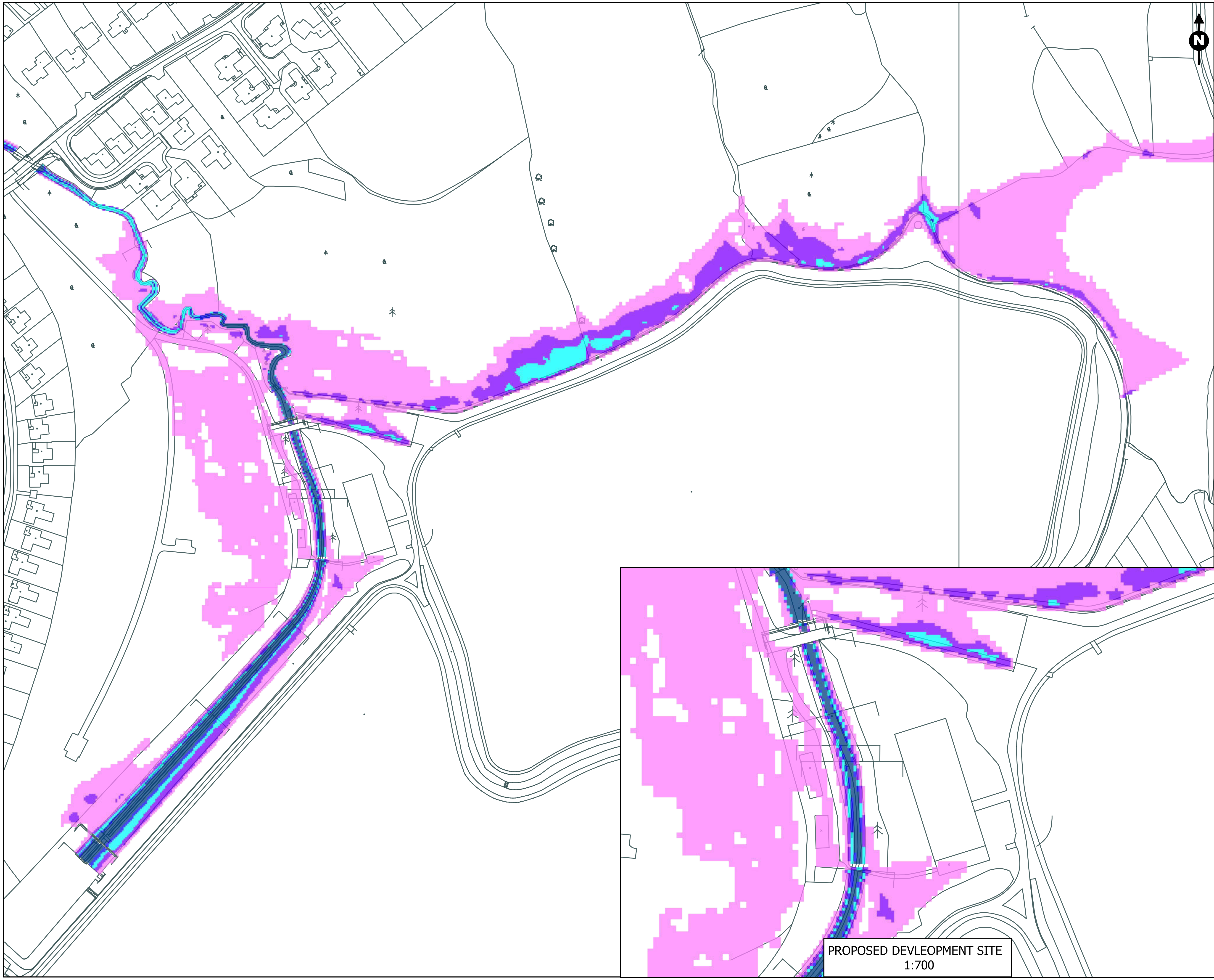
FLOOD DEPTH POINTS BASELINE

Point Depth Reference	Easting	Northing	Q_1000	Q_100 + 70% Climate Change	Q_100 + 25% Climate Change	Q_100	Q_50	Q_20	Q_2
1	318715.0001	182114.6923	0.7548	0.3234	0.0000	0.0000	0.0000	0.0000	0.0000
2	318725.6596	182116.1328	0.7603	0.329	0.0000	0.0000	0.0000	0.0000	0.0000
3	318710.3906	182135.147	0.5732	0.1425	0.0000	0.0000	0.0000	0.0000	0.0000
4	318724.3632	182119.1578	0.6236	0.1923	0.0000	0.0000	0.0000	0.0000	0.0000
5	318732.2858	182120.0221	0.2445	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6	318728.8286	182146.5267	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7	318726.5239	182141.197	0.0851	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	318730.5572	182141.7732	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	318614.0232	182142.9256	0.0112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	318706.9335	182134.1387	0.4931	0.0625	0.0000	0.0000	0.0000	0.0000	0.0000
11	318698.2907	182086.7472	1.1442	0.7105	0.3411	0.2053	0.0000	0.0000	0.0000
12	318709.3823	182097.5507	1.0209	0.5889	0.2177	0.0819	0.0000	0.0000	0.0000
13	318718.8894	182105.1852	1.0225	0.591	0.2194	0.0831	0.0000	0.0000	0.0000
14	318732.5739	182112.8197	0.6101	0.1839	0.0000	0.0000	0.0000	0.0000	0.0000
15	318694.8335	182096.2543	0.9968	0.5277	0.1506	0.0253	0.0000	0.0000	0.0000
16	318707.3656	182108.6424	0.9874	0.5558	0.1844	0.0485	0.0000	0.0000	0.0000
17	318617.9124	182094.0936	0.4354	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
18	318645.2814	182103.8888	0.4807	0.0404	0.0000	0.0000	0.0000	0.0000	0.0000
19	318666.7444	182113.54	0.5819	0.1434	0.0444	0.0000	0.0000	0.0000	0.0000
20	318681.4372	182117.8614	0.4728	0.0519	0.0000	0.0000	0.0000	0.0000	0.0000
21	318702.6121	182124.1994	0.5442	0.1182	0.0000	0.0000	0.0000	0.0000	0.0000
22	318616.0398	182114.5483	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	318641.8242	182120.5983	0.358	0.006	0.0041	0.0032	0.4643	0.4432	0.0000
24	318665.592	182127.3685	0.3401	0.0256	0.0101	0.0071	0.3962	0.3752	0.0000
25	318679.9967	182130.6816	0.2345	0.0143	0.0078	0.0031	0.0000	0.0000	0.0000
26	318697.1383	182139.1803	0.4493	0.0352	0.0000	0.0000	0.0000	0.0000	0.0000
27	318637.935	182144.6541	0.0295	0.0151	0.0118	0.0097	0.0000	0.0000	0.0000
28	318662.1349	182148.9755	0.0671	0.0385	0.0212	0.0188	0.0000	0.0000	0.0000
29	318675.3872	182150.7041	0.0677	0.0486	0.0348	0.024	0.0000	0.0000	0.0000
30	318696.7061	182158.9148	0.1448	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31	318719.6096	182160.7874	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
32	318634.3338	182173.6076	0.0168	0.0085	0.0052	0.0034	0.0000	0.0000	0.0000
33	318662.567	182177.3528	0.0621	0.0388	0.0157	0.0008	0.0000	0.0000	0.0000
34	318691.3764	182175.1921	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
35	318723.0668	182182.8266	0.5416	0.5172	0.5009	0.4878	0.0000	0.0000	0.0000
36	318632.3171	182199.1039	0.0225	0.0083	0.0041	0.0023	0.0000	0.0000	0.0000
37	318699.0109	182189.0206	0.4772	0.4509	0.4337	0.4201	0.3489	0.255	0.0000
38	318726.0917	182201.6967	0.6704	0.5851	0.485	0.4146	0.2628	0.1988	0.0000
39	318699.299	182206.3062	0.4755	0.4114	0.3456	0.3012	0.289	0.1965	0.0000
40	318673.0824	182207.4586	0.5853	0.5007	0.4102	0.3445	0.0000	0.0000	0.0000
41	318720.1448	182136.5558	0.4994	0.0707	0.0000	0.0000	0.0000	0.0000	0.0000
42	318722.2367	182124.6577	0.5926	0.1616	0.0000	0.0000	0.0000	0.0000	0.0000
43	318719.2193	182115.4725	0.7914	0.36	0.0000	0.0000	0.0000	0.0000	0.0000
44	318730.507	182123.9145	0.2841	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
45	318729.3687	182130.5544	0.08	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
46	318728.2305	182136.1508	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
47	318710.5875	182142.1267	0.5902	0.1595	0.0000	0.0000	0.0000	0.0000	0.0000
48	318708.8801	182135.9611	0.5612	0.1305	0.0000	0.0000	0.0000	0.0000	0.0000
49	318708.8801	182176.9385	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
50	318729.3687	182171.2472	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
51	318726.3334	182192.0204	0.0974	0.0754	0.0612	0.0495	0.0000	0.0000	0.0000
52	318695.9798	182197.522	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

FLOOD DEPTH POINTS DEVELOPMENT

Point Depth Reference	Easting	Northing	Q_1000	Q_100 + 70% Climate Change	Q_100 + 25% Climate Change	Q_100	Q_100	Q_100	Q_100
1	318715.0001	182114.6923	0.2935	0.046	0.0000	0.0000	0.0000	0.0000	0.0000
2	318725.6596	182116.1328	0.3019	0.0542	0.0000	0.0000	0.0000	0.0000	0.0000
3	318710.3906	182135.147	0.4162	0.1739	0.1365	0.0000	0.0000	0.0000	0.0000
4	318724.3632	182119.1578	0.2866	0.0391	0.0000	0.0000	0.0000	0.0000	0.0000
5	318732.2858	182120.0221	0.2996	0.0528	0.0000	0.0000	0.0000	0.0000	0.0000
6	318728.8286	182146.5267	0.2562	0.0242	0.0000	0.0000	0.0000	0.0000	0.0000
7	318726.5239	182141.197	0.2812	0.0391	0.0019	0.0000	0.0000	0.0000	0.0000
8	318730.5572	182141.7732	0.2365	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9	318614.0232	182142.9256	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	318706.9335	182134.1387	0.3475	0.1056	0.0000	0.0000	0.0731	0.0000	0.0000
11	318698.2907	182086.7472	1.0491	0.7988	0.455	0.1309	0.0000	0.0000	0.0000
12	318709.3823	182097.5507	0.9398	0.6917	0.3459	0.0239	0.0000	0.0000	0.0000
13	318718.8894	182105.1852	0.673	0.4253	0.08	0.0000	0.0000	0.0000	0.0000
14	318732.5739	182112.8197	0.3979	0.1549	0.0000	0.0000	0.0000	0.0000	0.0000
15	318694.8335	182096.2543	1.2782	0.9666	0.6222	0.2997	0.0000	0.0000	0.0000
16	318707.3656	182108.6424	0.6586	0.4109	0.0642	0.0000	0.0000	0.0000	0.0000
17	318617.9124	182094.0936	0.3785	0.1287	0.0000	0.0000	0.0000	0.0000	0.0000
18	318645.2814	182103.8888	0.4239	0.1698	0.0000	0.0000	0.0000	0.0000	0.0000
19	318666.7444	182113.54	0.5253	0.2719	0.0422	0.0000	0.0000	0.0000	0.0000
20	318681.4372	182117.8614	0.6855	0.42	0.1551	0.021	0.0000	0.0000	0.0000
21	318702.6121	182124.1994	0.5654	0.3221	0.0567	0.0000	0.0017	0.0016	0.0000
22	318616.0398	182114.5483	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23	318641.8242	182120.5983	0.3018	0.0481	0.0041	0.0032	0.0000	0.0000	0.0000
24	318665.592	182127.3685	0.283	0.0348	0.0092	0.0072	0.0000	0.0000	0.0000
25	318679.9967	182130.6816	0.4374	0.2012	0.0331	0.0229	0.0000	0.0000	0.0000
26	318697.1383	182139.1803	0.4685	0.2274	0.0053	0.0000	0.0000	0.0000	0.0000
27	318637.935	182144.6541	0.0184	0.0151	0.0118	0.0097	0.0000	0.0000	0.0000
28	318662.1349	182148.9755	0.0415	0.0309	0.0244	0.019	0.0000	0.0000	0.0000
29	318675.3872	182150.7041	0.0794	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30	318696.7061	182158.9148	0.388	0.1468	0.0031	0.0000	0.0000	0.0000	0.0000
31	318719.6096	182160.7874	0.0989	0.0043	0.0023	0.0000	0.0000	0.0000	0.0000
32	318634.3338	182173.6076	0.0099	0.0085	0.0052	0.0034	0.0000	0.0000	0.0000
33	318662.567	182177.3528	0.0033	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000
34	318691.3764	182175.1921	0.0144	0.0059	0.0034	0.0023	0.0000	0.0000	0.0000
35	318723.0668	182182.8266	0.0116	0.0069	0.0000	0.0000	0.0000	0.0000	0.0000
36	318632.3171	182199.1039	0.0099	0.0083	0.0041	0.0023	0.0000	0.0000	0.0000
37	318699.0109	182189.0206	0.0167	0.0000	0.0000	0.0000	0.3278	0.2222	0.0000
38	318726.0917	182201.6967	0.6365	0.5659	0.4686	0.3897	0.2668	0.2071	0.0000
39	318699.299	182206.3062	0.4461	0.4041	0.3455	0.3046	0.2881	0.2005	0.0000
40	318673.0824	182207.4586	0.557	0.493	0.4107	0.348	0.0000	0.0000	0.0000
41	318720.1448	182136.5558	0.2814	0.0387	0.002	0.0000	0.0000	0.0000	0.0000
42	318722.2367	182124.6577	0.2849	0.0391	0.0000	0.0000	0.0000	0.0000	0.0000
43	318719.2193	182115.4725	0.2868	0.0391	0.0000	0.0000	0.0000	0.0000	0.0000
44	318730.507	182123.9145	0.2881	0.0418	0.0000	0.0000	0.0000	0.0000	0.0000
45	318729.3687	182130.5544	0.2928	0.0481	0.0000	0.0000	0.0000	0.0000	0.0000
46	318728.2305	182136.1508	0.287	0.043	0.0000	0.0000	0.0000	0.0000	0.0000
47	318710.5875	182142.1267	0.2789	0.0381	0.0022	0.0000	0.0000	0.0000	0.0000
48	318708.8801	182135.9611	0.293	0.0513	0.0129	0.0000	0.0000	0.0000	0.0000
49	318708.8801	182176.9385	0.0193	0.0087	0.0000	0.0000	0.0000	0.0000	0.0000
50	318729.3687	182171.2472	0.0034	0.003	0.0021	0.0000	0.0000	0.0000	0.0000
51	318726.3334	182192.0204	0.0131	0.0082	0.0000	0.0000	0.0000	0.0000	0.0000
52	318695.9798	182197.522	0.0104	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

APPENDIX G
SENSITIVITY AND BLOCKAGE



Legend

Flood Depth(mm)

Flood Depth(mm)
0 to 300
300 to 600
600 to 900
900 to 1,200
> 1,200

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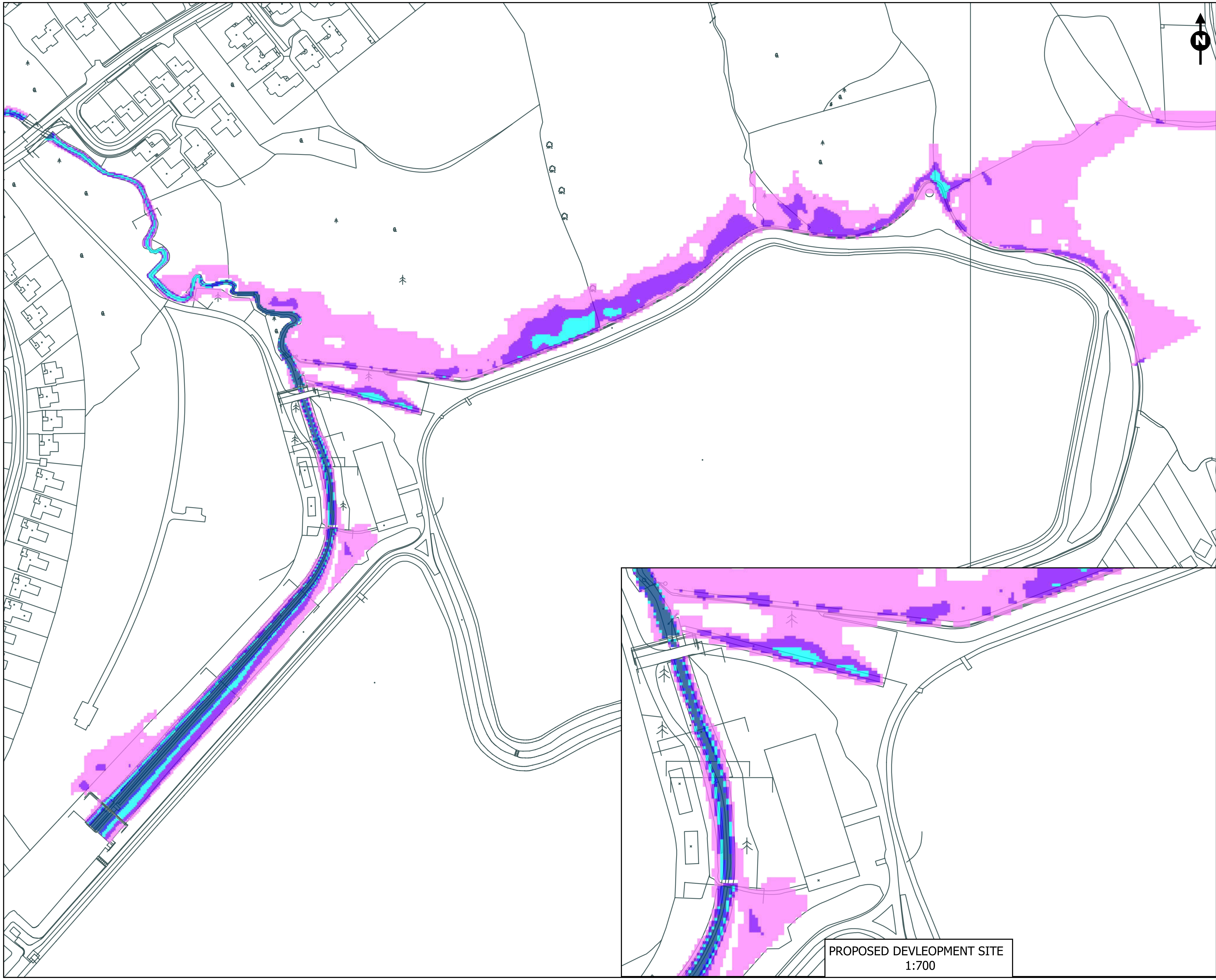
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20%
MANNING ROUGHNESS INCREASE

70062284/049/G	049	P01



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AJ	AO	VM	28th January 2020

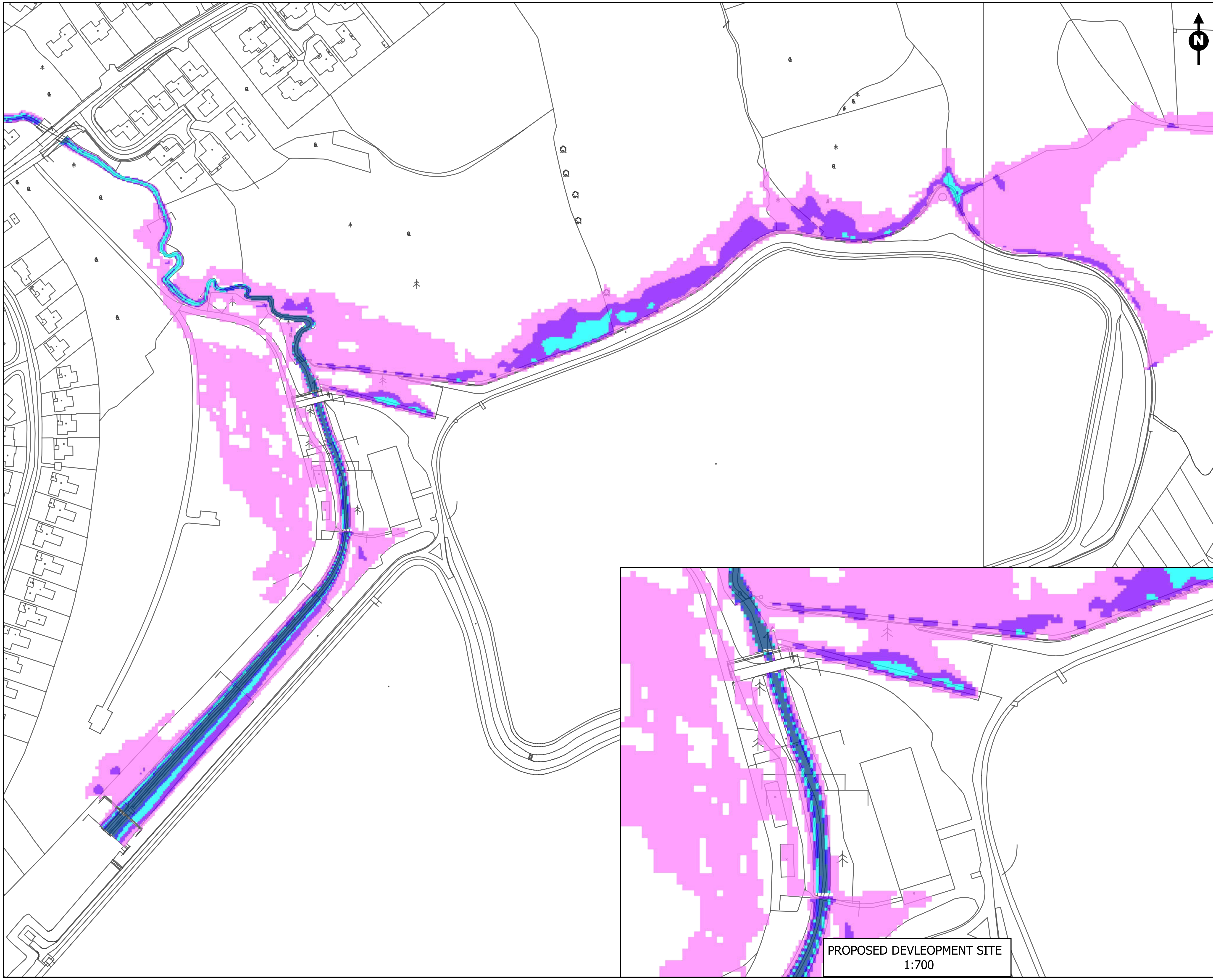
70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20%
MANNING ROUGHNESS DECREASE

70062284/050/G	050	P01

Original Sheet Size A3 [420x297] Plot Date 28.37.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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AJ	AO	VM	28th January 2020

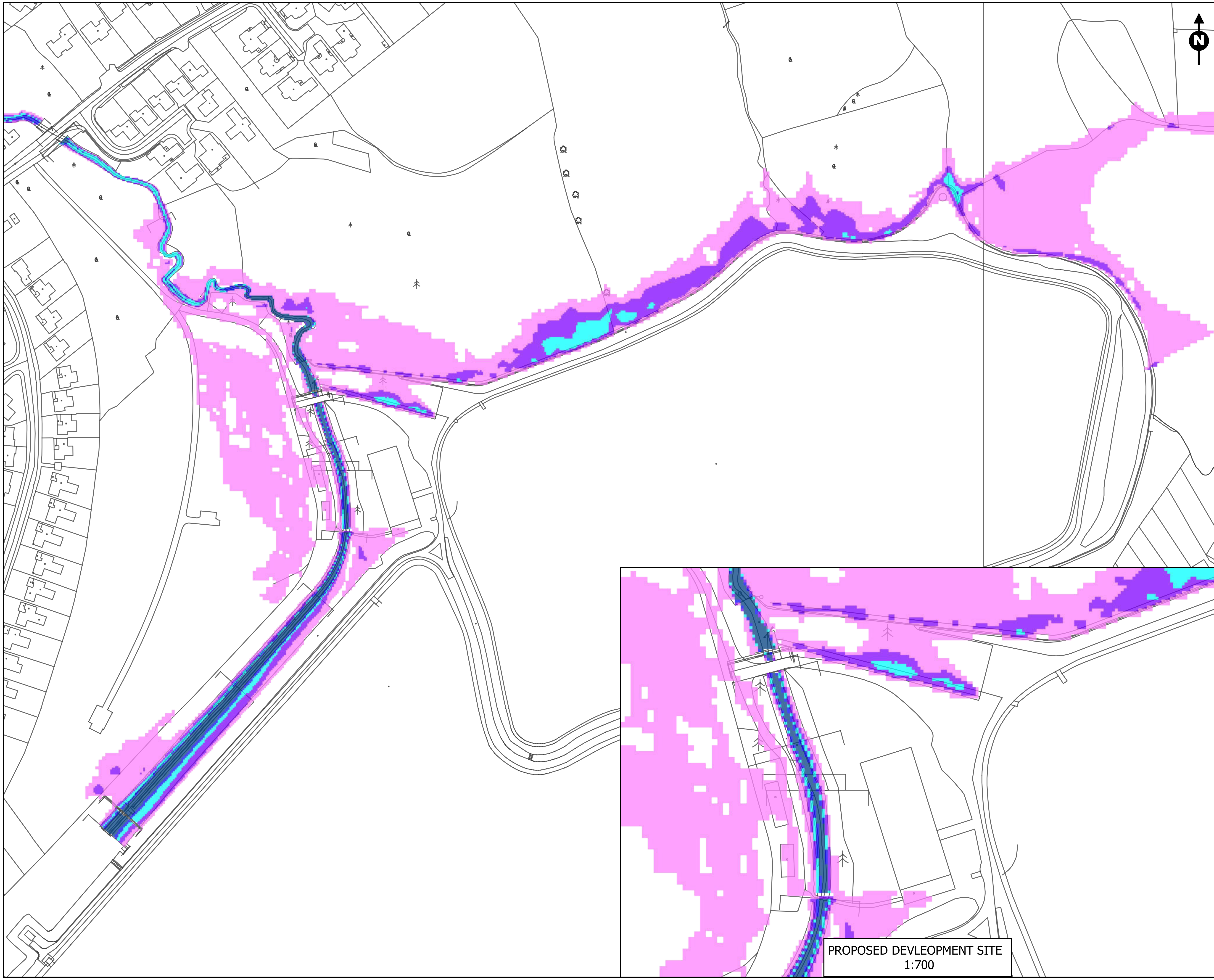
70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20% GRADIENT
DOWNSTREAM BOUNDARY CONDITION INCREASE

70062284/051/G	051	P01

Original Sheet Size A3 [420x297] Plot Date 05.7.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Flood depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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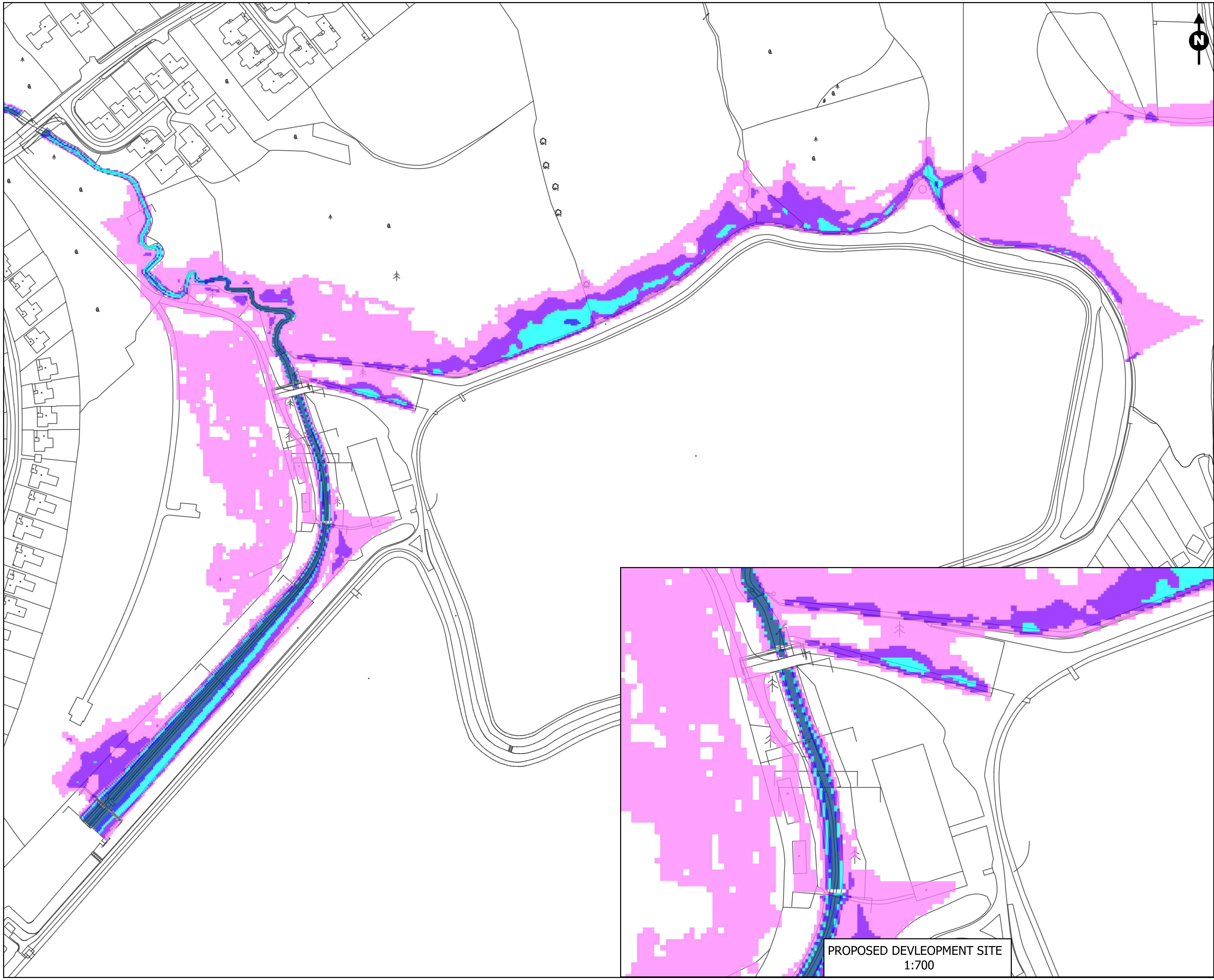
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20% GRADIENT
DOWNSTREAM BOUNDARY CONDITION DECREASE

70062284/052/G	052	P01



Legend

Flood Depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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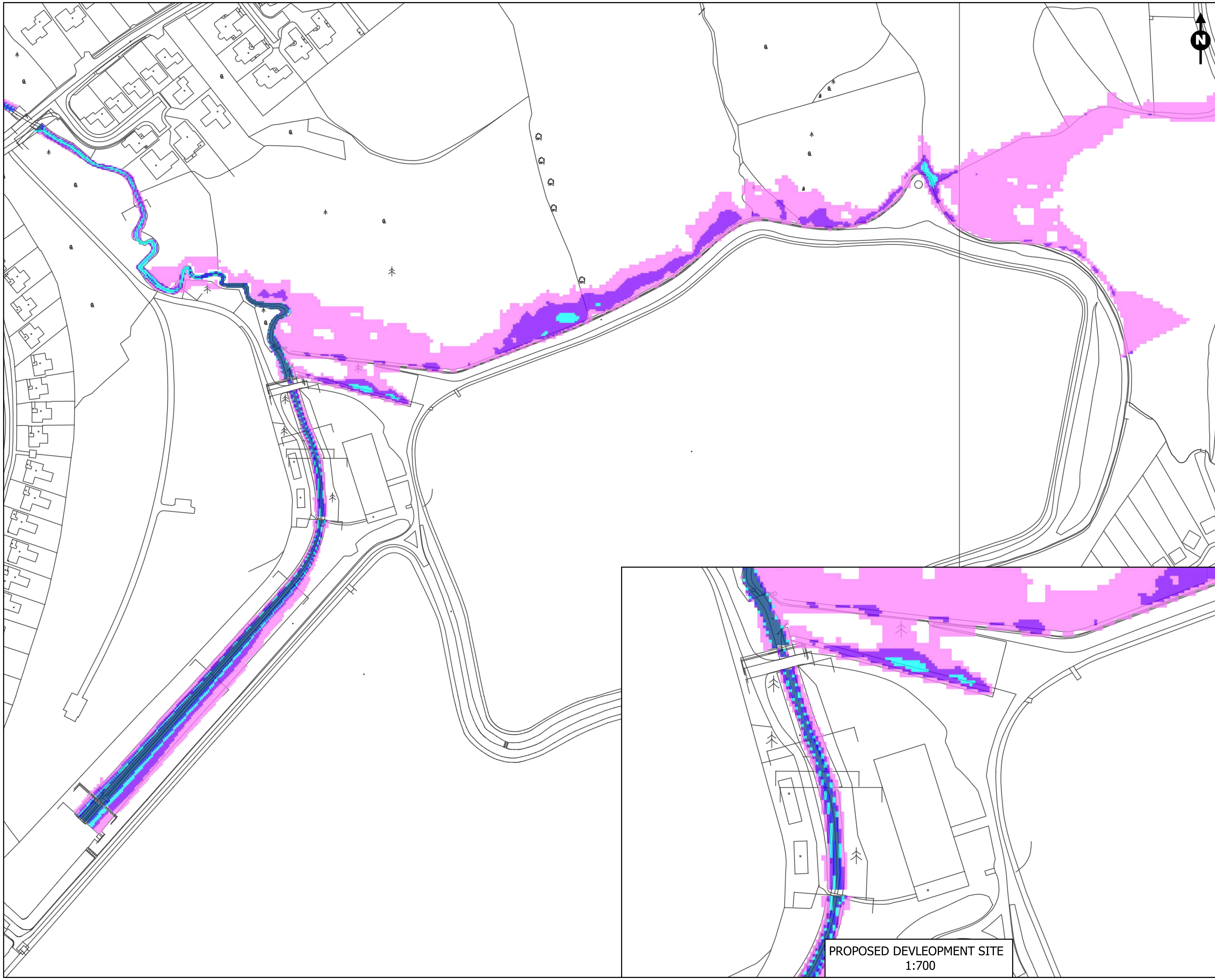
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20%
PEAK FLOW INCREASE

70062284/053/G	053	P01



Legend

Flood Depth(mm)

- 0 to 300
- 300 to 600
- 600 to 900
- 900 to 1,200
- > 1,200

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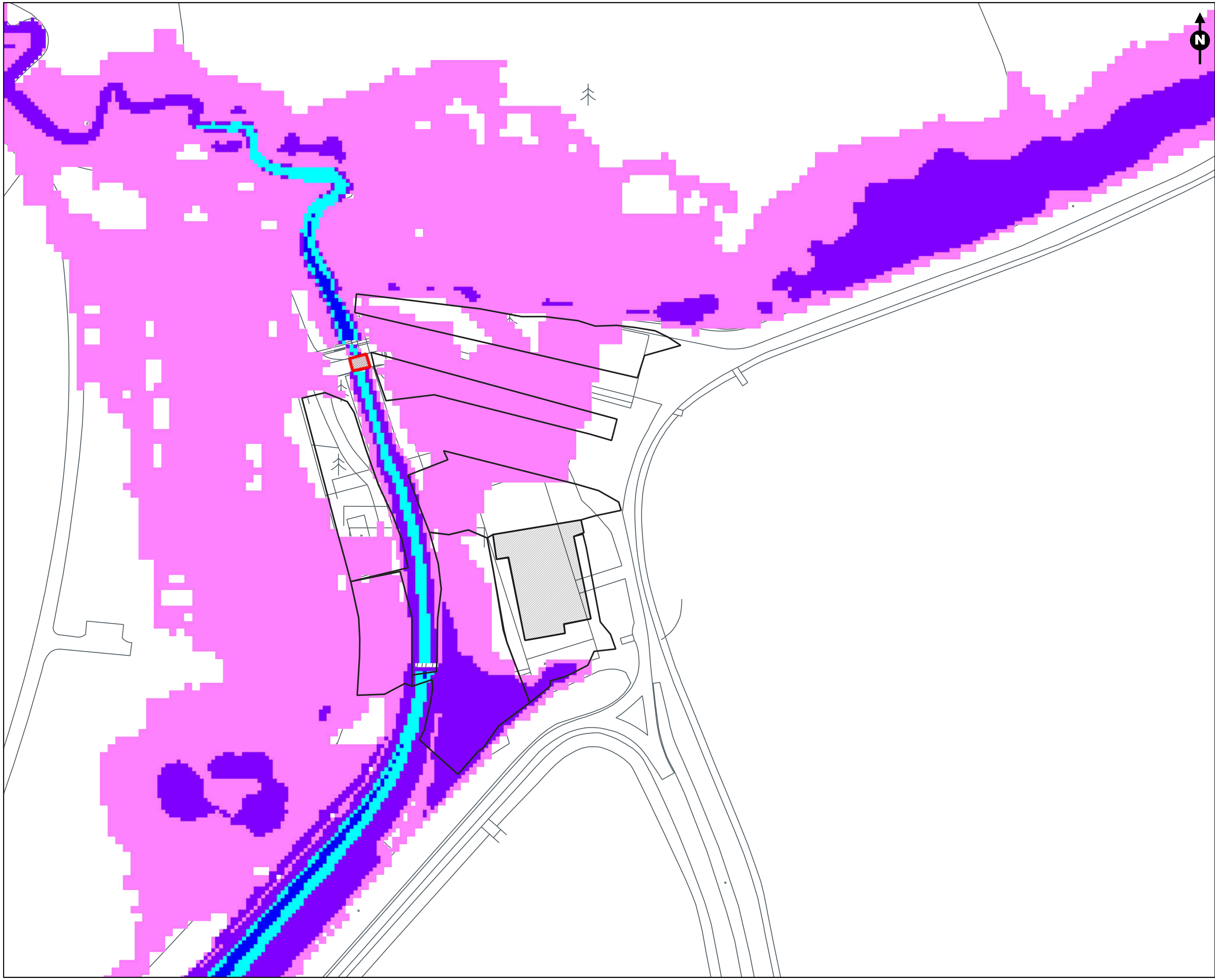
AJ	AO	VM	28th January 2020
70062284			1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

SENSITIVITY ANALYSIS - 1 IN 100 (1% AEP)
MAXIMUM FLOOD DEPTH MAP WITH 20%
PEAK FLOW DECREASE

70062284/054/G	054	P01

Original Sheet Size A3 [420x297] Plot Date 28.19.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



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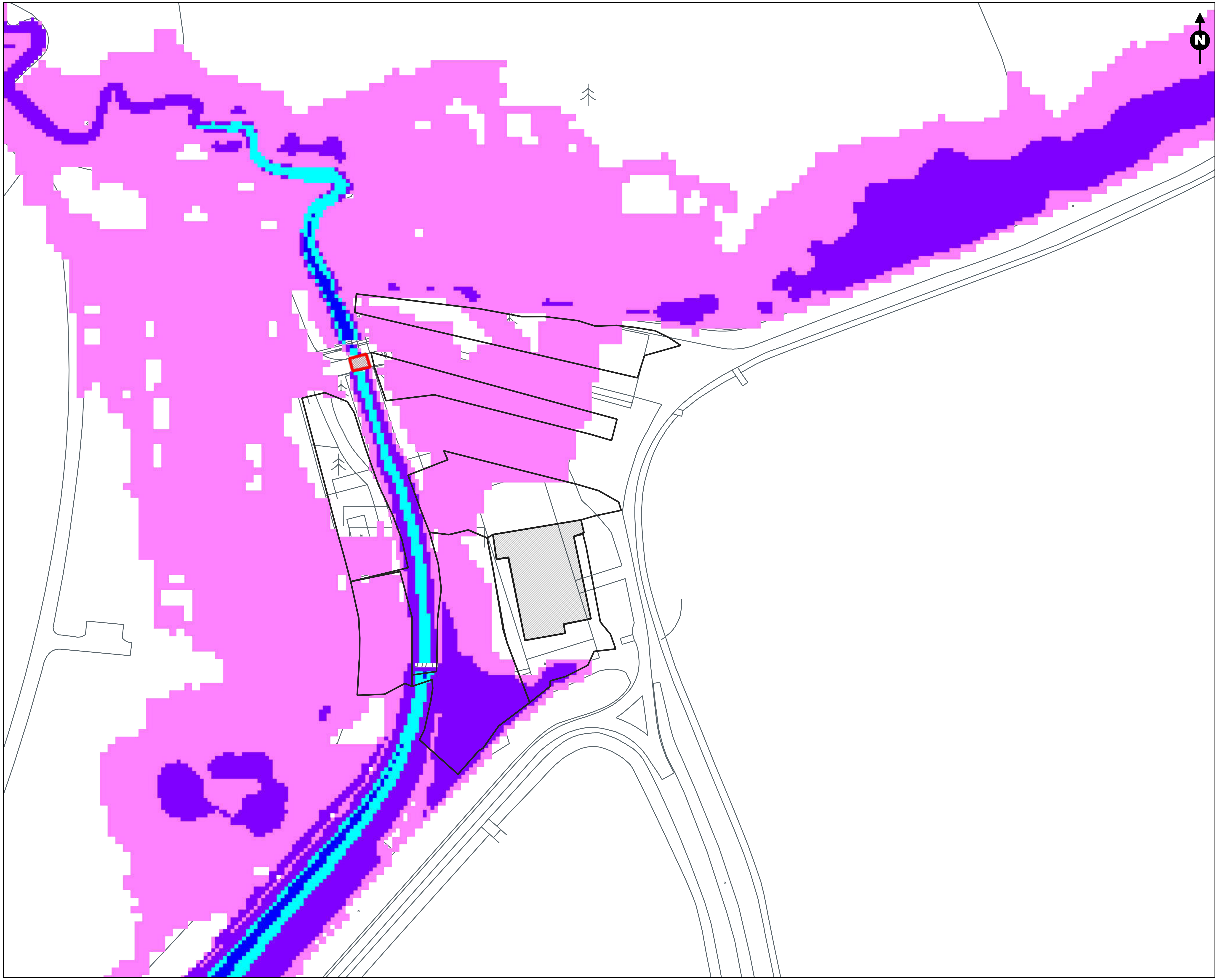
AJ	AO	VM	13th February 2020
70062284		1:900 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - 30% BLOCKAGE 1

70062284/055/G	55	P01

Original Sheet Size A3 [420x297] Plot Date 03.17.20 Path C:\Users\UKAOJ002\Documents\Projects\Llanishen\Templates



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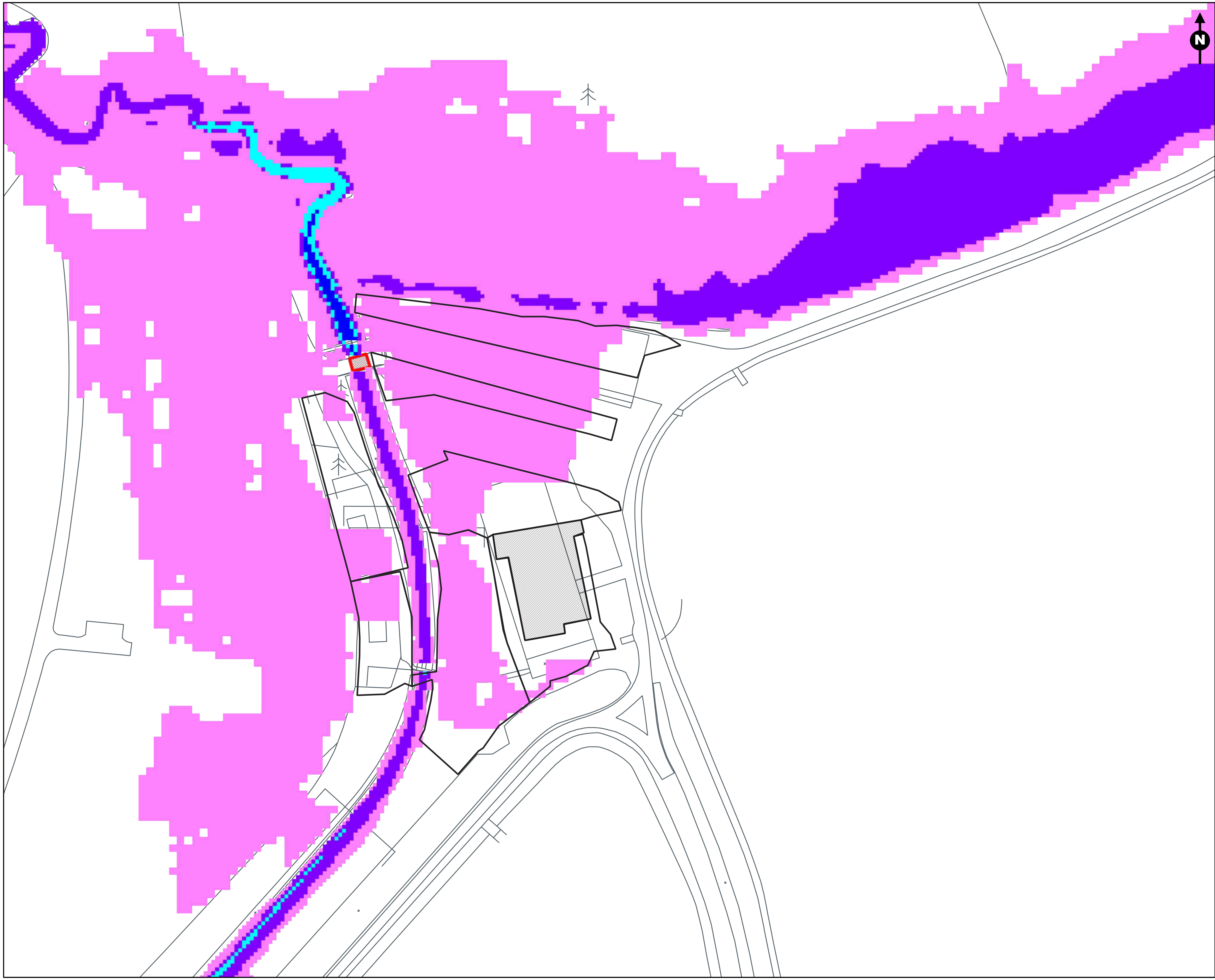
AJ	AO	VM	13th February 2020
70062284			1:900 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - 67% BLOCKAGE 1

70062284/056/G	56	P01



Legend

Flood depth(mm)

- 0 to 500
- 500 to 1,500
- 1,500 to 2,500
- 2,500 to 4,000
- > 4,000
- Development Building
- Development Site
- Blockage 1

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AJ	AO	VM	13th February 2020
70062284		1:900 @ A3	

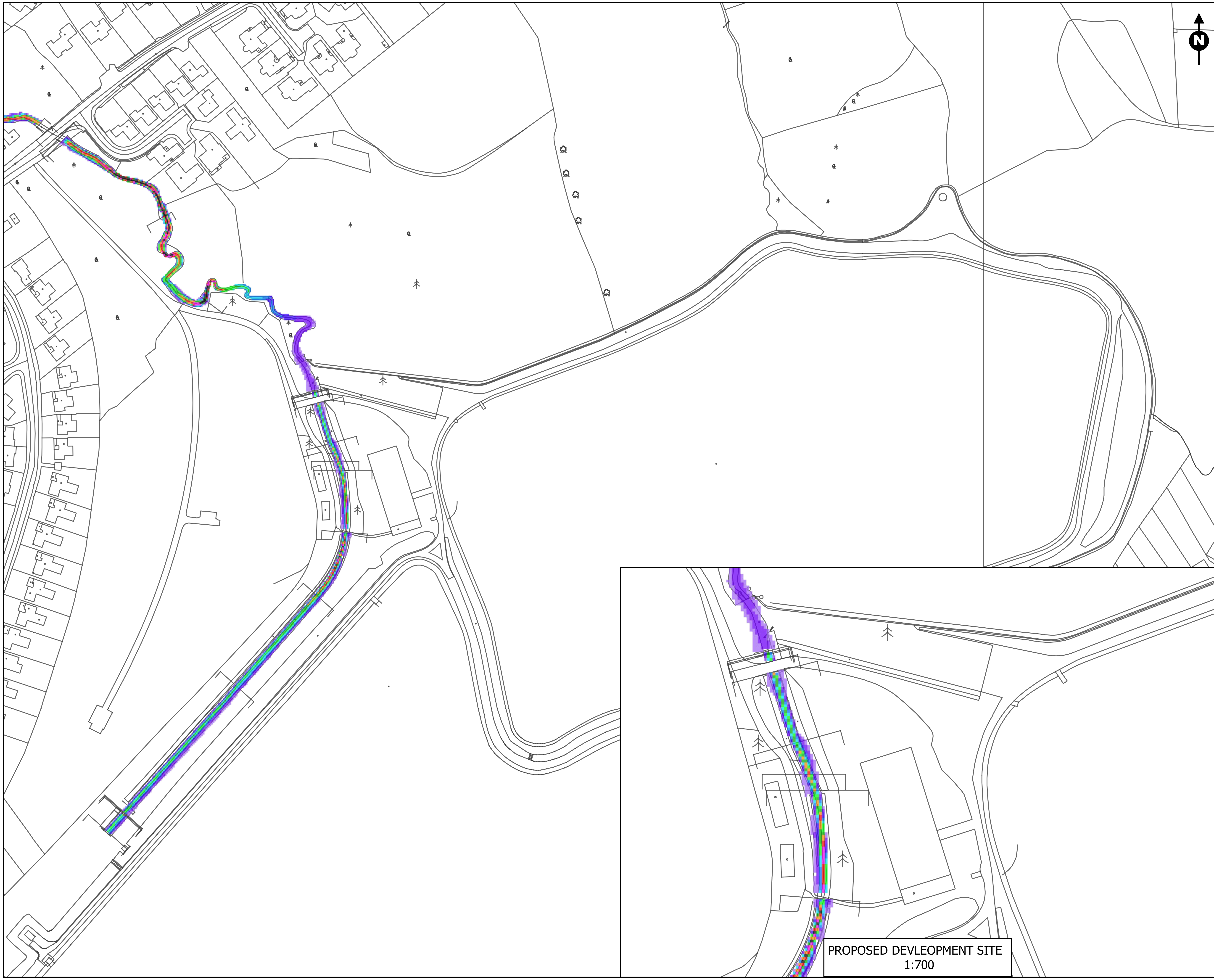
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - 95% BLOCKAGE 1

70062284/057/G	57	P01

Original Sheet Size A3 [420x297] Plot Date 03.31.20 Path C:\Users\UKAOJ002\Documents\Projects\Llanishen\Templates

APPENDIX H
FLOW VELOCITY AND FLOOD HAZARD



Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

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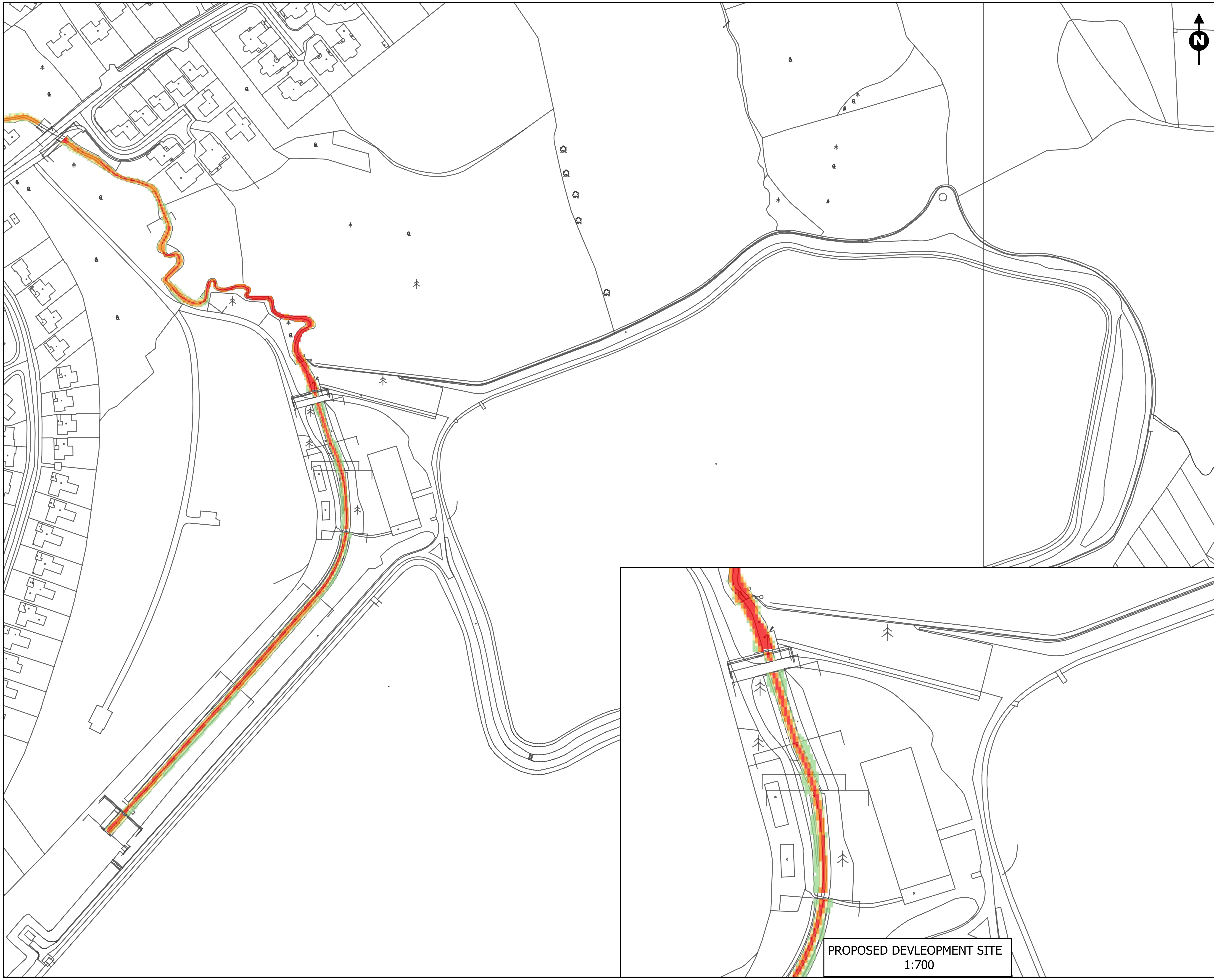
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 2 (50% AEP)
AS EXISTING - A - MAX VELOCITIES

70062284/002/G	002	P01



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 2 (50% AEP)
AS EXISTING - A - HAZARD

70062284/003/G	003	P01

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 20 (5% AEP)
AS EXISTING - A - MAX VELOCITY

70062284/005/G	005	P01

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 20 (5% AEP)
AS EXISTING - A - HAZARD

70062284/006/G	006	P01

Original Sheet Size A3 [420x297] Plot Date 28.37.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 30 (3% AEP)
AS EXISTING - A - HAZARD

70062284/009/G	009	P01

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

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Drawn	Designed	Approved	Revision Date
AJ	AO	VM	28th January 2020

Project No.	1:4500 @ A3
70062284	1:2500 @ A3

Project

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

Sheet

BASELINE ANALYSIS - 1 IN 50 (2% AEP)
AS EXISTING - A - MAX FLOOD VELOCITY

Drawing No.	Sheet. No.	Revision
70062284/011/G	011	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020

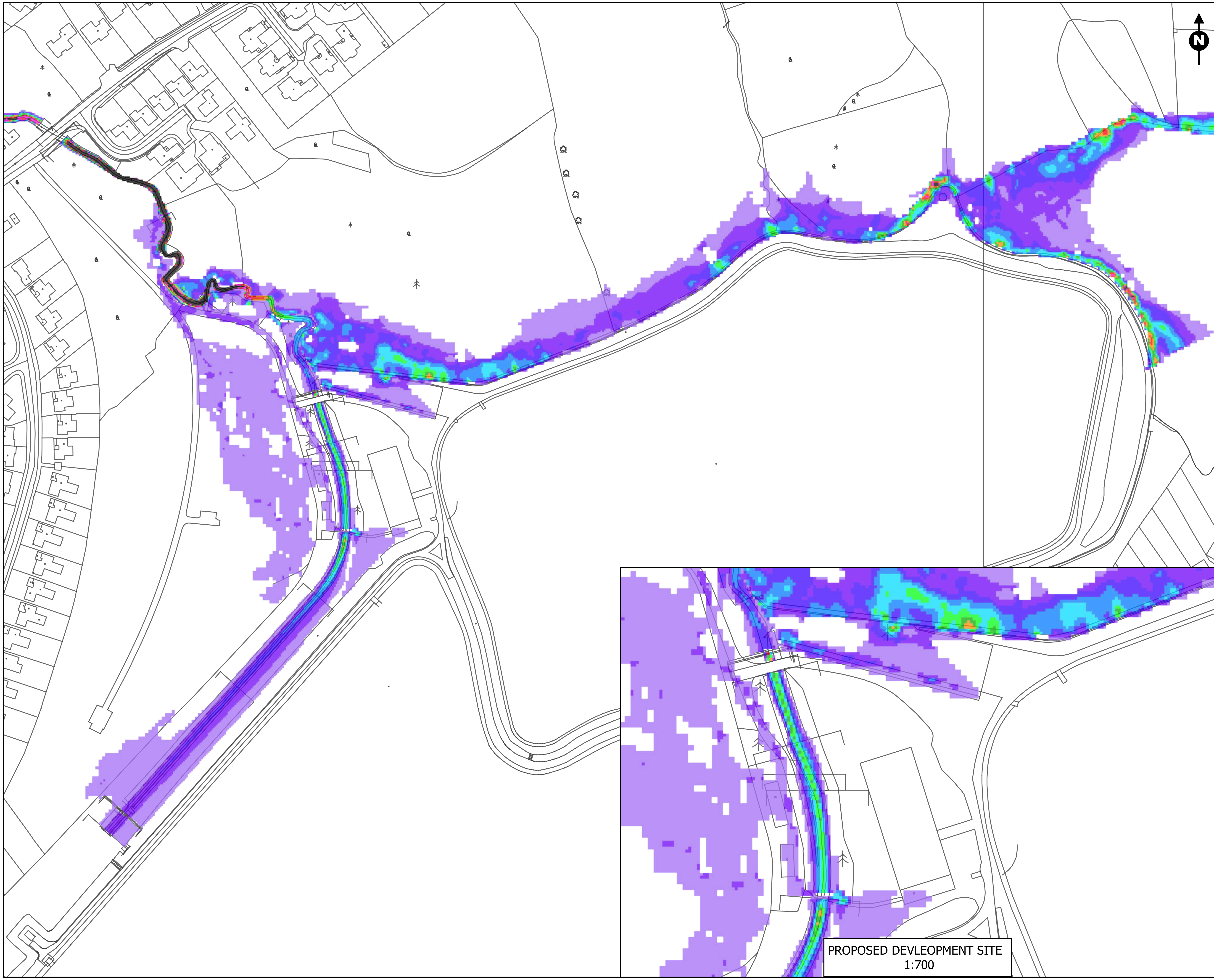
70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 50 (2% AEP)
AS EXISTING - A - HAZARD

70062284/012/G	012	P01

Original Sheet Size A3 [420x297] Plot Date 28.48.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

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AJ	AO	VM	28th January 2020

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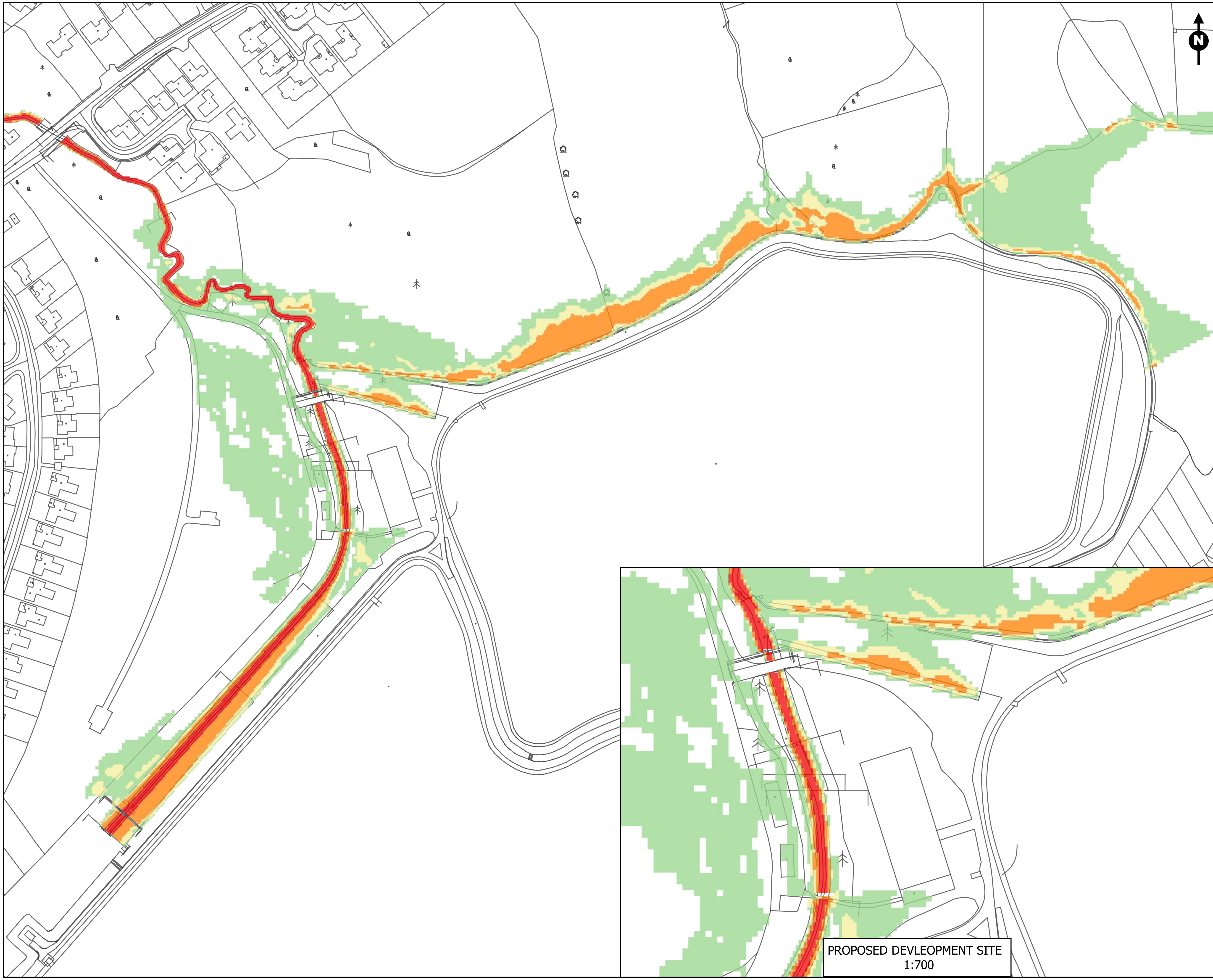
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP)
AS EXISTING - A - MAX FLOOD VELOCITY

70062284/014/G	014	P01



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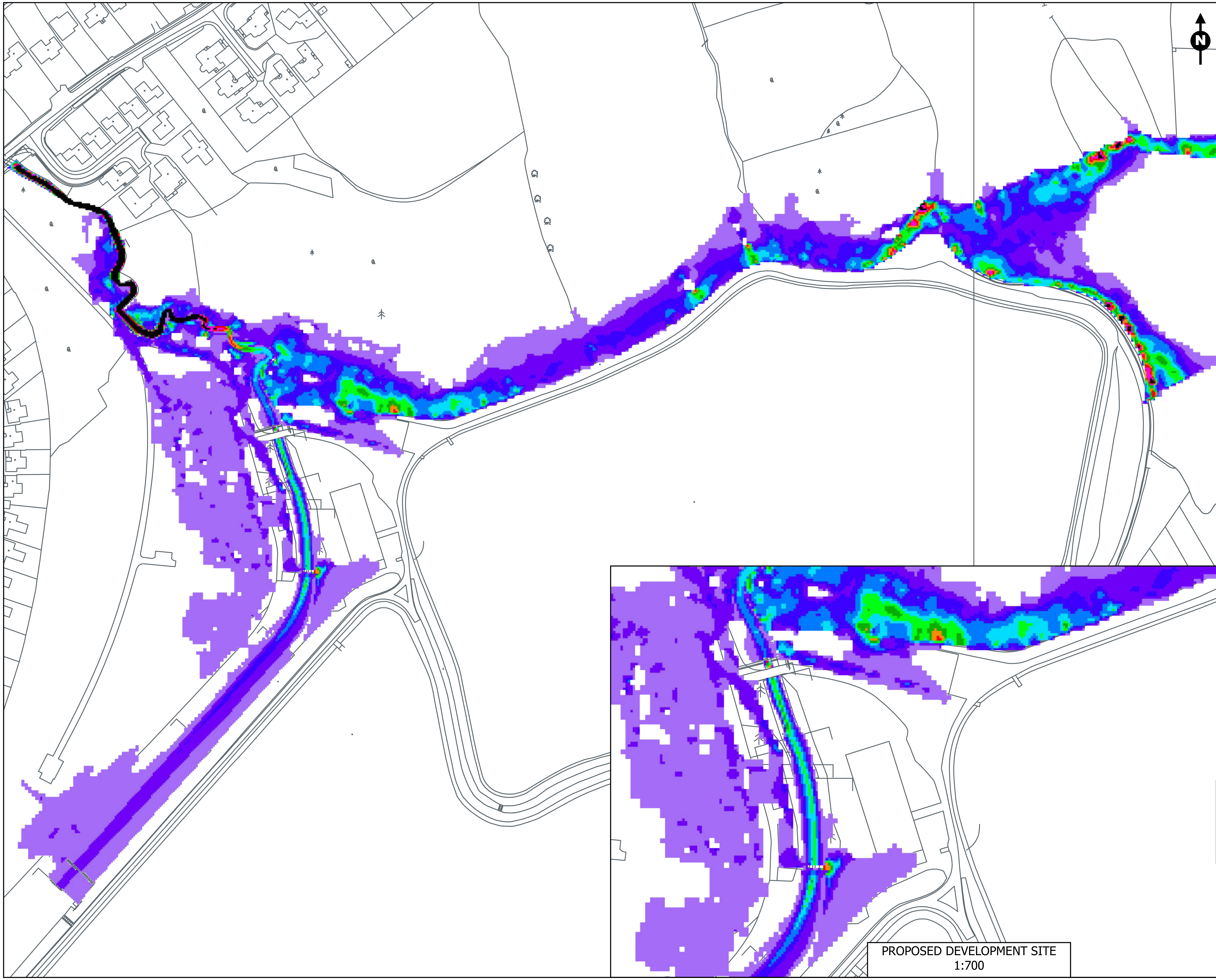
AJ	AO	VM	28th January 2020
70062284	1:2500 @ A3		
LLANISHEN RESERVOIR FLOOD CONSEQUENCE ASSESSMENT			
BASELINE ANALYSIS - 1 IN 100 (1% AEP) AS EXISTING - A - HAZARD			
70062284/015/G	015	P01	

Original Sheet Size A3 [420x297] Plot Date 28.14.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD VELOCITY

70062284/017/G	17	P01

Original Sheet Size A3 [420x297] Plot Date 03.17.20 Path C:\Users\UKAOJ002\Documents\Projects\Llanishen\Templates

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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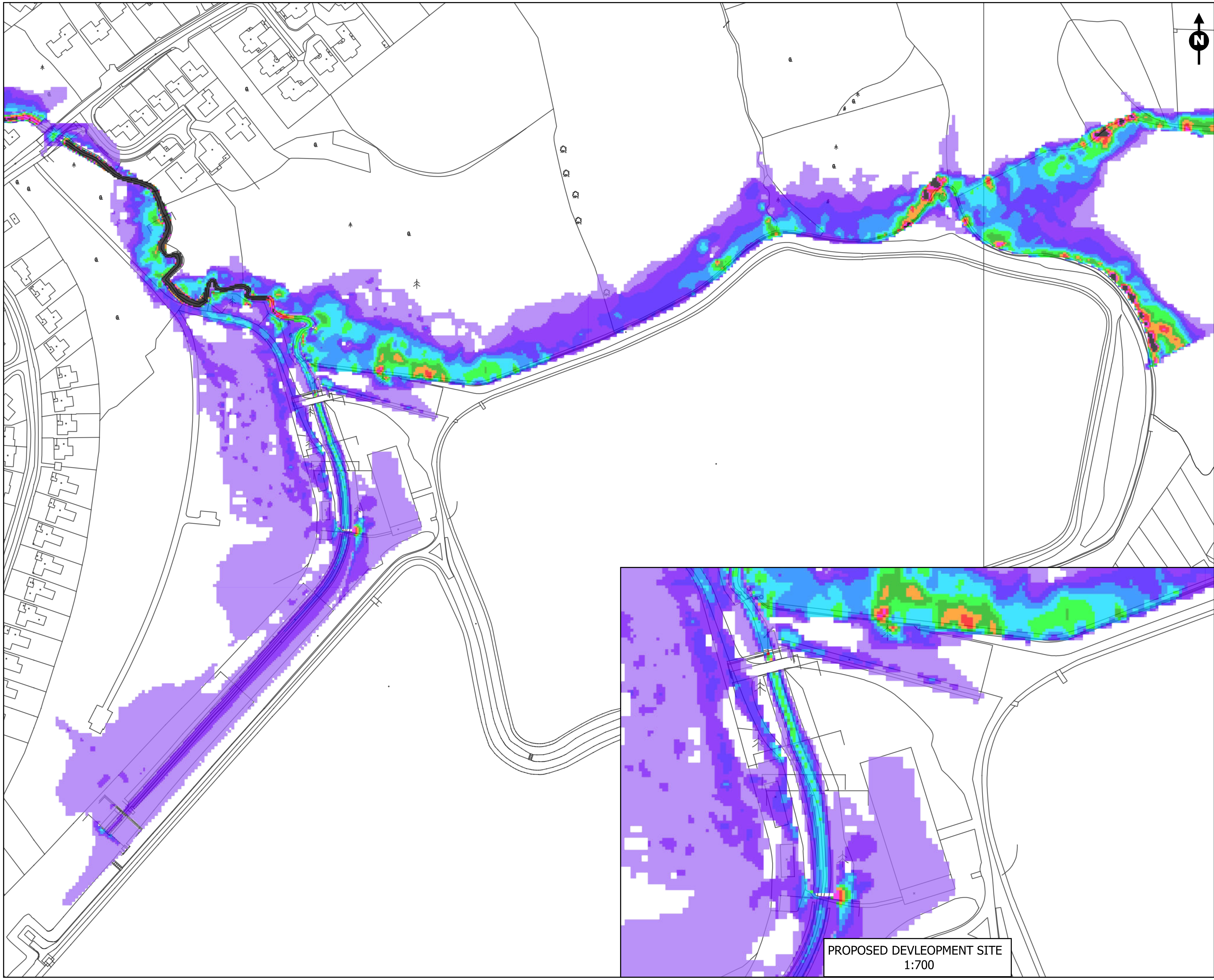
AJ	AO	VM	13th February 2020
70062284			1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - HAZARD

70062284/018/G	18	P01

Original Sheet Size A3 [420x297] Plot Date 03.20.20 Path C:\Users\UKAOJ002\Documents\Projects\Llanishen\Templates



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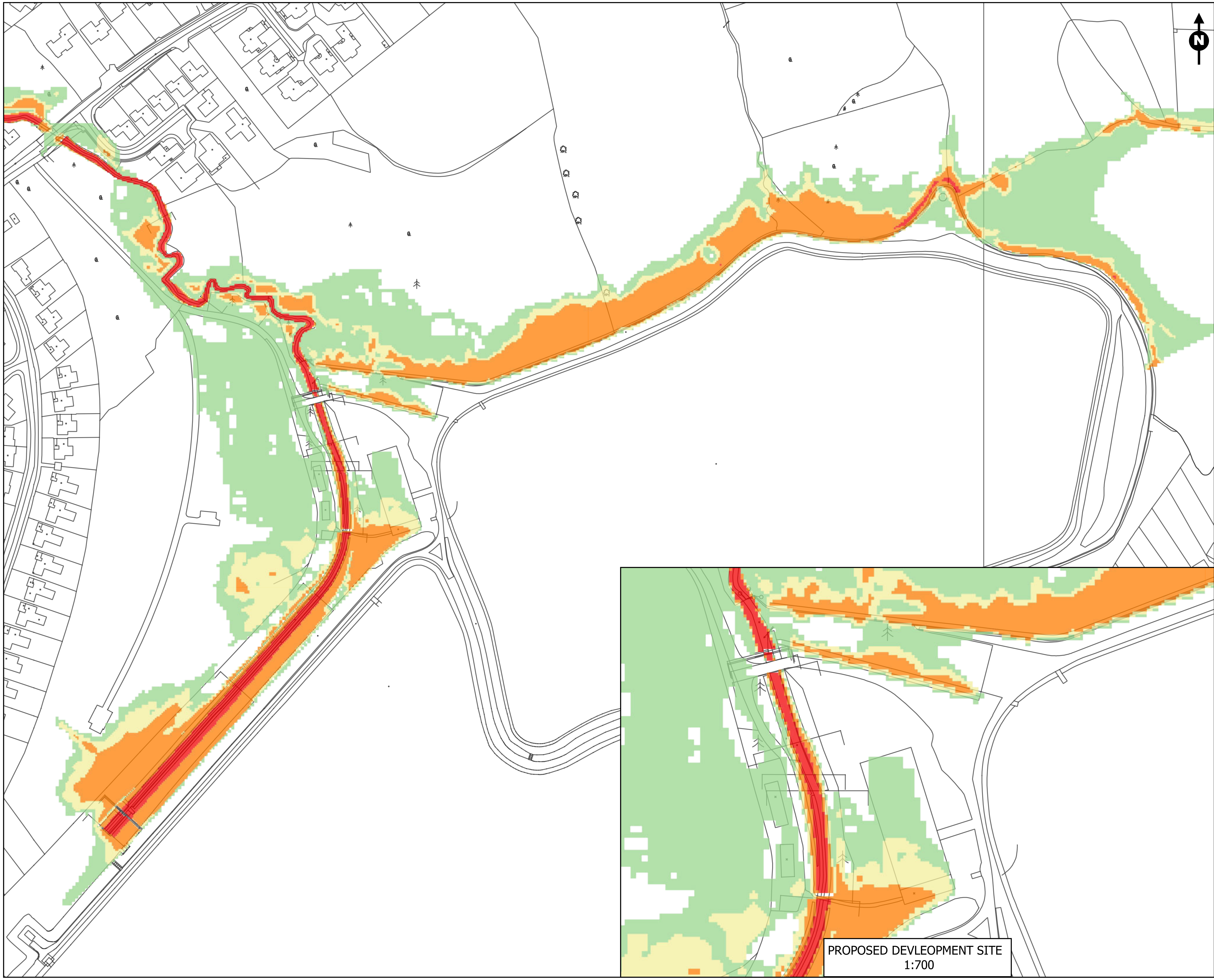
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	
LLANISHEN RESERVOIR FLOOD CONSEQUENCE ASSESSMENT			
BASELINE ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE) AS EXISTING - A - MAX FLOOD VELOCITY			
70062284/020/G		020	P01

Original Sheet Size A3 [420x297] Plot Date 28.59.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020
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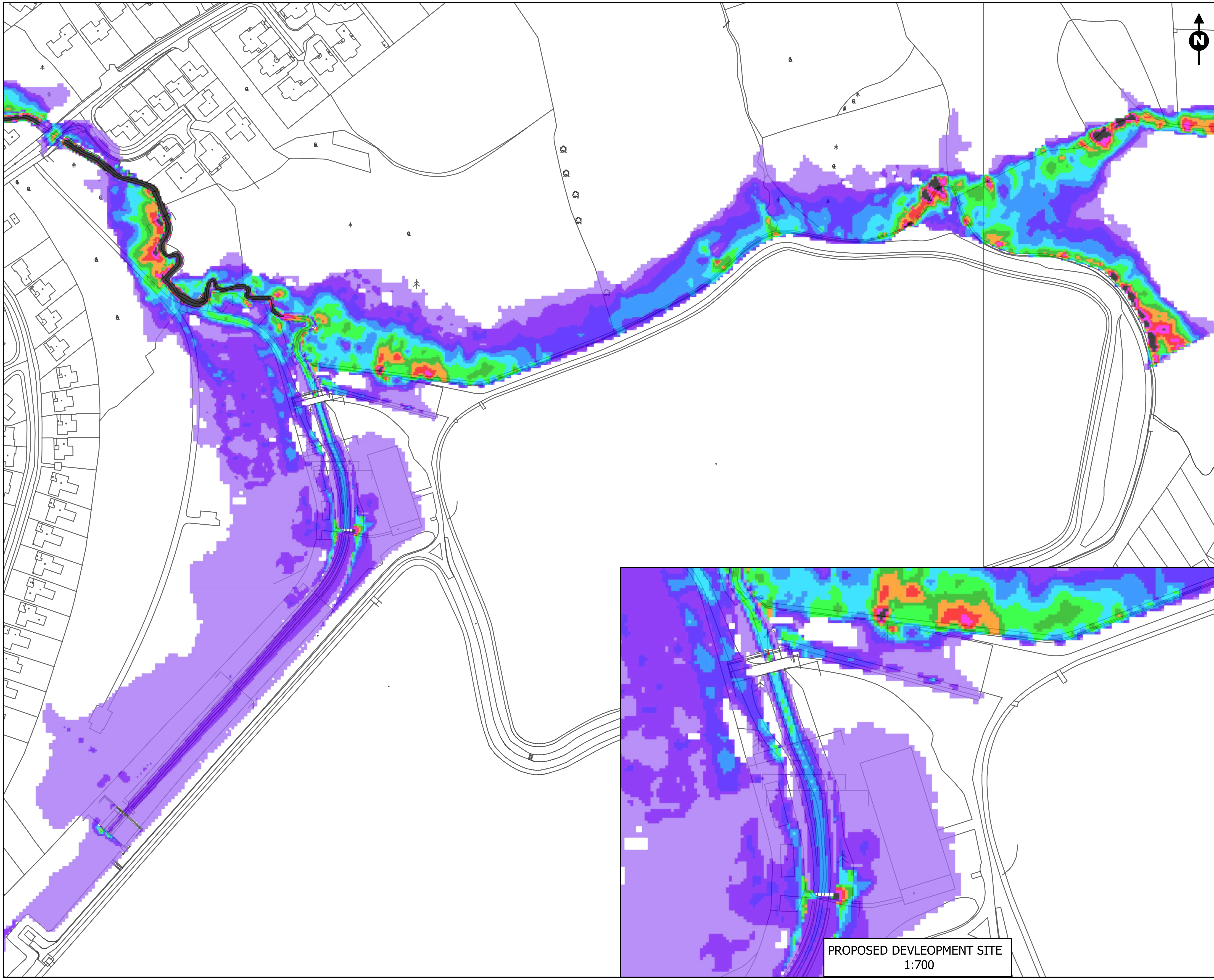
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE)
AS EXISTING - A - HAZARD

70062284/021/G	021	P01



Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

wsp
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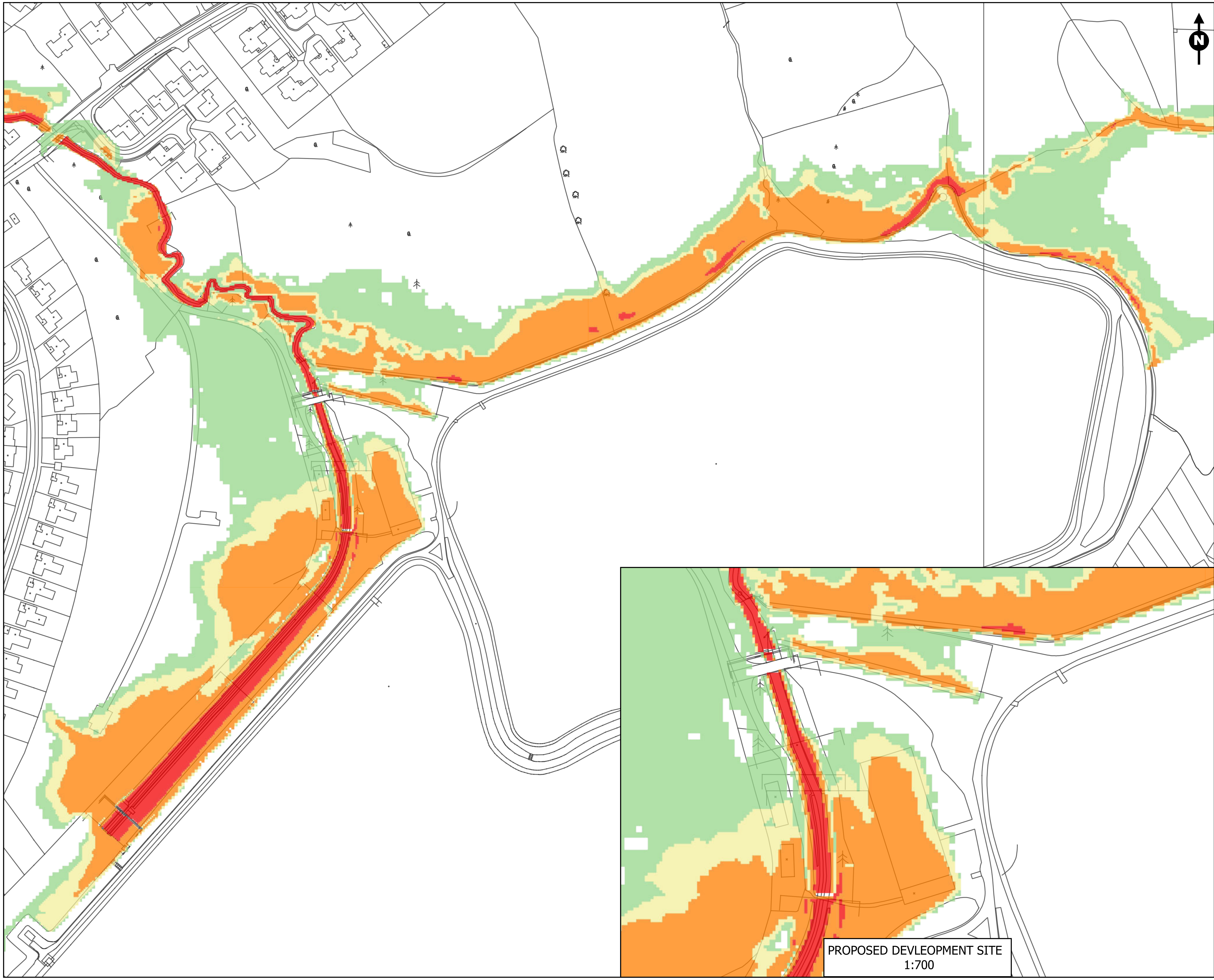
AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP)
AS EXISTING - A - MAX FLOOD VELOCITY

70062284/023/G	023	P01



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020
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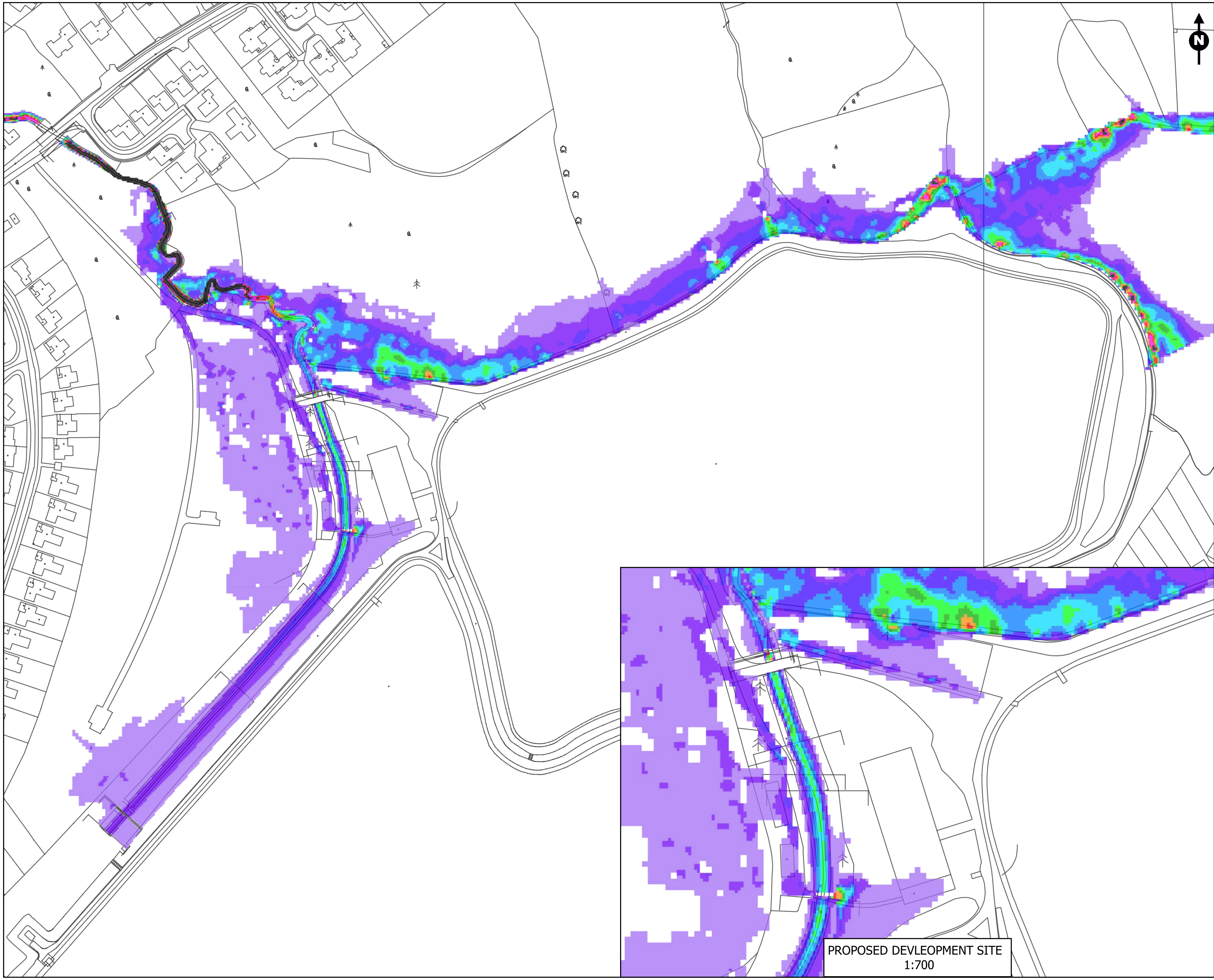
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP)
AS EXISTING - A - HAZARD

70062284/024/G	024	P01



Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5

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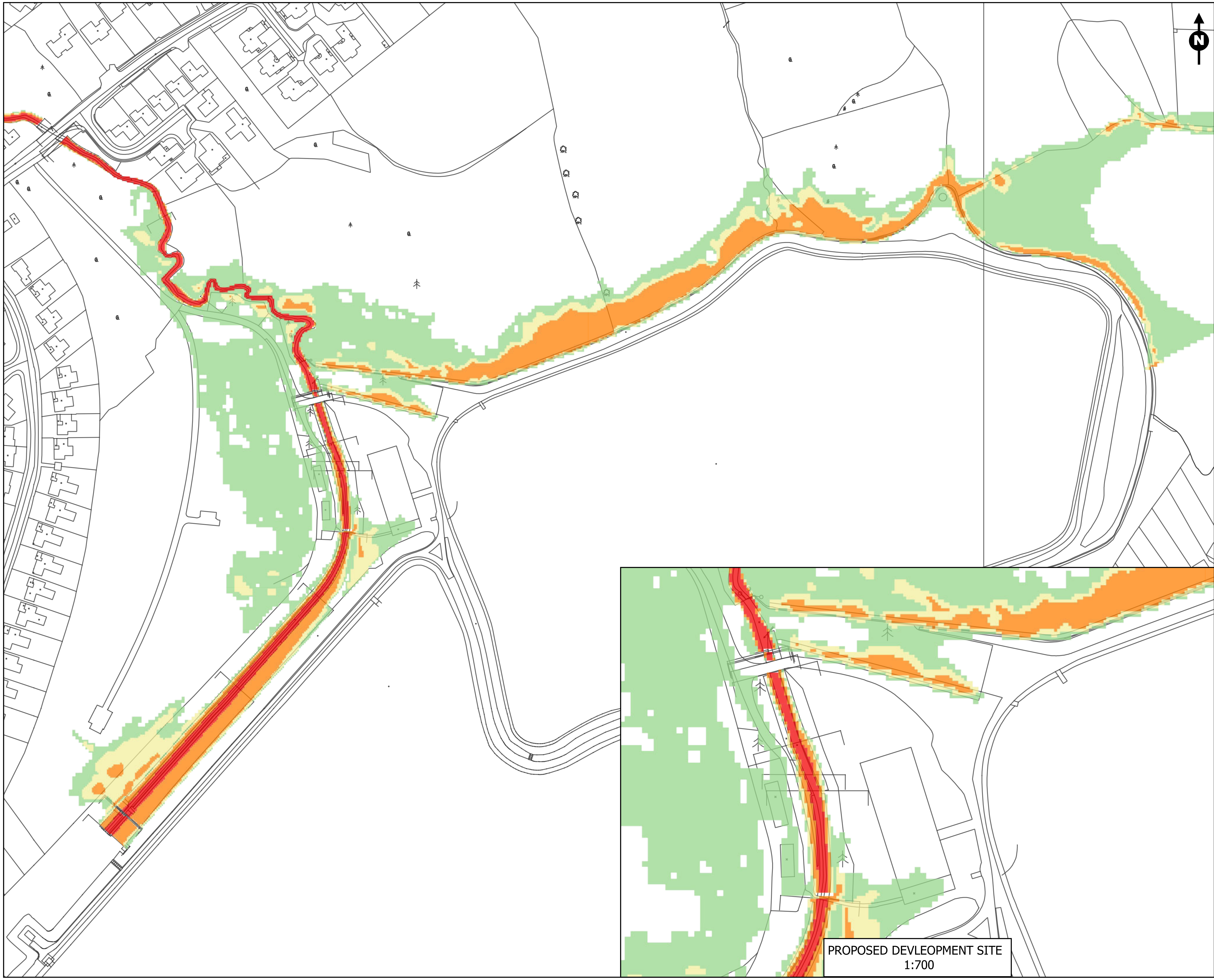
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - MAX FLOOD VELOCITY

70062284/026/G	026	P01



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme

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AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

BASELINE ANALYSIS - 1 IN 1000 (0.1% AEP + 25% CLIMATE CHANGE)
AS EXISTING - A - HAZARD

70062284/027/G	027	P01

Original Sheet Size A3 [420x297] Plot Date 29.48.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development
- Development Site

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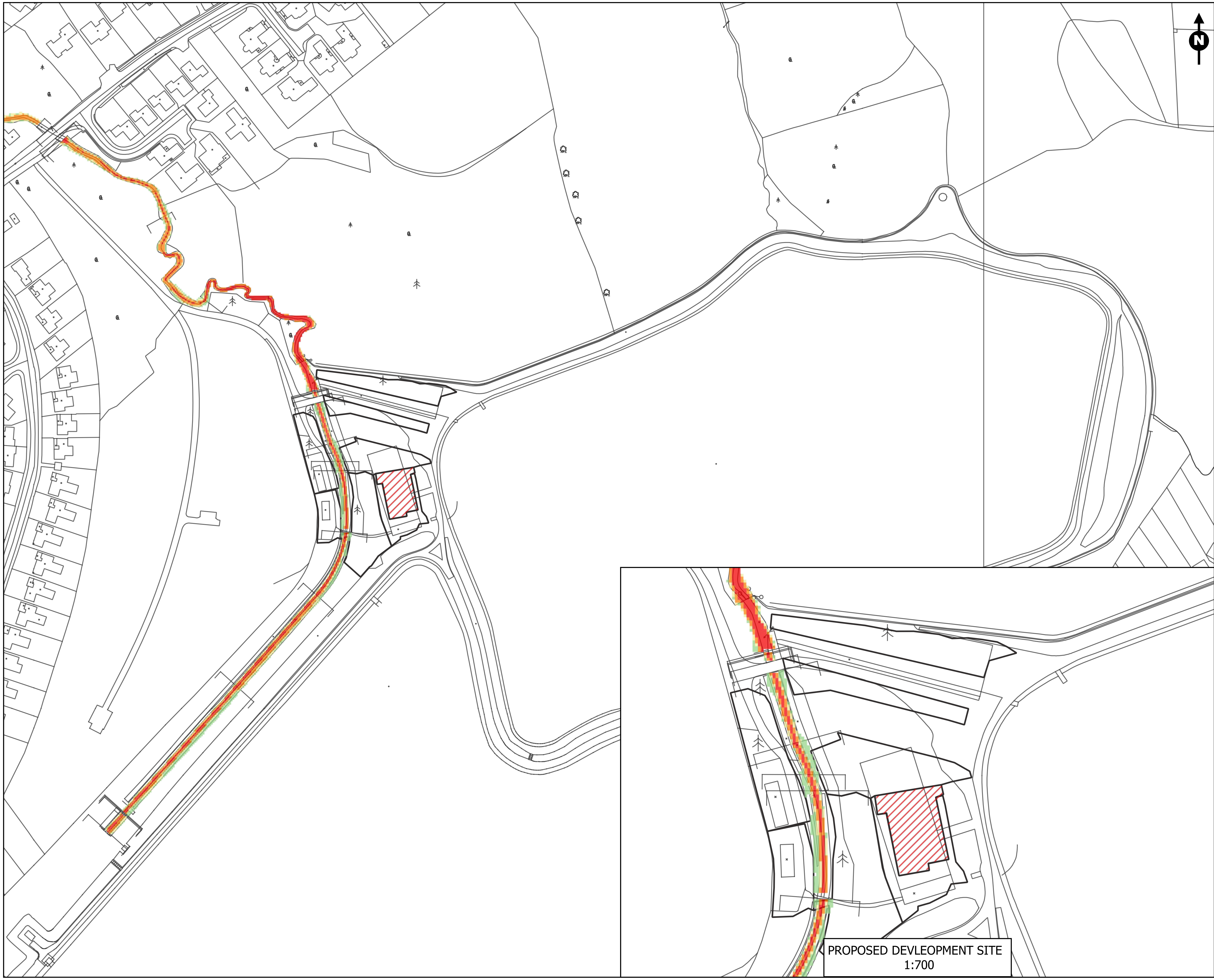
AJ	AO	VM	28th January 2020
70062284		1:2500 @ A3	

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 2 (50% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/029/G	029	P01



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

wsp

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AJ	AO	VM	28th January 2020
70062284			1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 2 (50% AEP)
AS PROPOSED - A - HAZARD

70062284/030/G	030	P01

Original Sheet Size A3 [420x297] Plot Date 05.31.20 Path C:\Users\UKAOJ002\Desktop\Llanishen Drawings Templates WSP Template.qgs

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development
- Development Site

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AJ	AO	VM	28th January 2020

70062284	1:2500 @ A3

LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 20 (5% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/032/G	032	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 20 (5% AEP)
AS PROPOSED - A - HAZARD

70062284/033/G	033	P01

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 30 (4% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/035/G	035	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 30 (4% AEP)
AS PROPOSED - A - HAZARD

70062284/036/G	036	P01

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 50 (2% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/038/G	038	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 50 (2% AEP)
AS PROPOSED - A - HAZARD

70062284/039/G	039	P01

Legend

Velocities(m/s)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/041/G	041	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP)
AS PROPOSED - A - HAZARD

70062284/042/G	042	P01

Legend

Velocities(mm)

- <= 0.15
- 0.15 - 0.3
- 0.3 - 0.45
- 0.45 - 0.6
- 0.6 - 0.75
- 0.75 - 0.9
- 0.9 - 1.05
- 1.05 - 1.2
- 1.2 - 1.35
- 1.35 - 1.5
- > 1.5
- Development Building
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/044/G	44	P01

Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development Building
- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 25% CLIMATE CHANGE)
AS PROPOSED - A - HAZARD

70062284/045/G	45	P01

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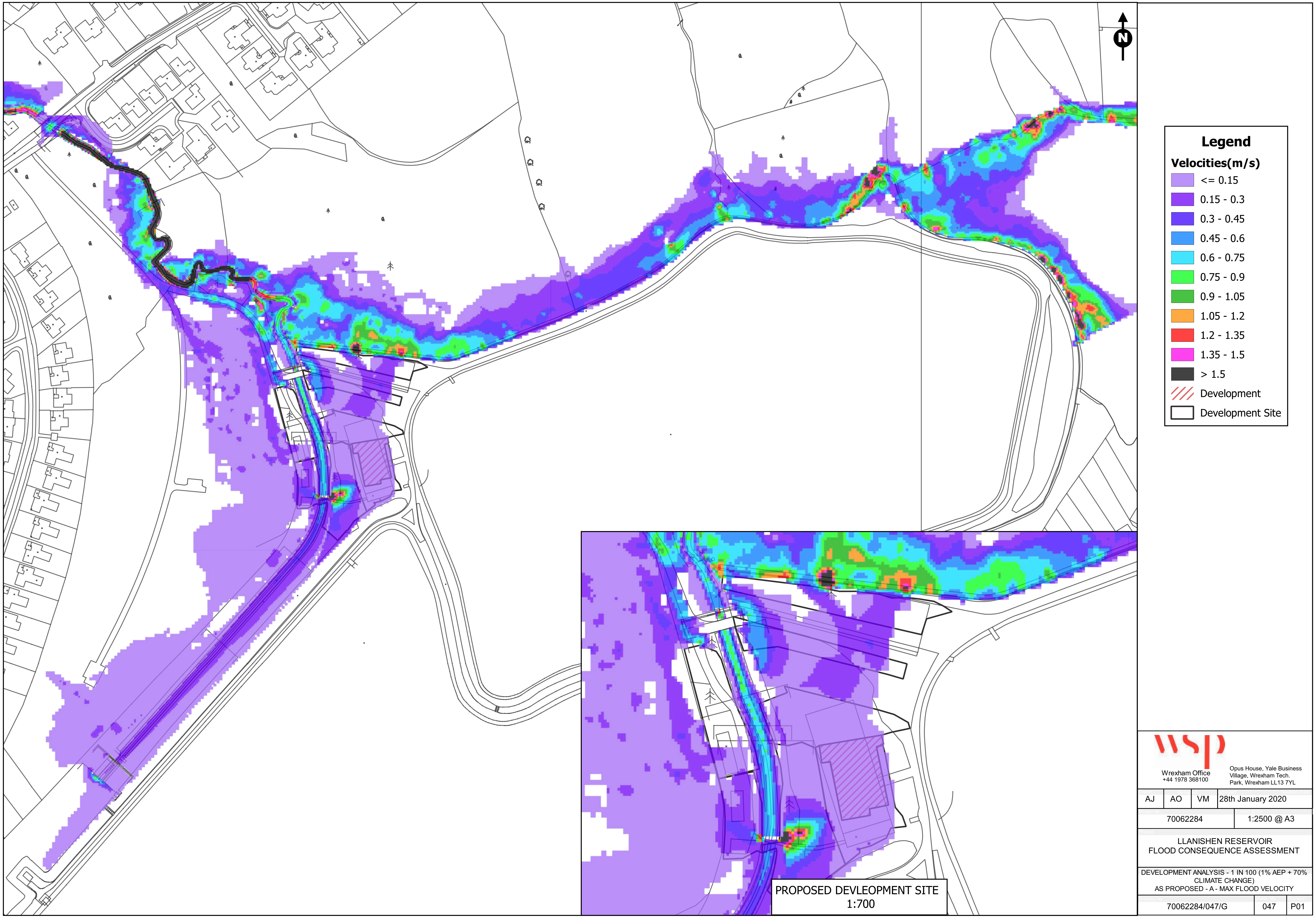

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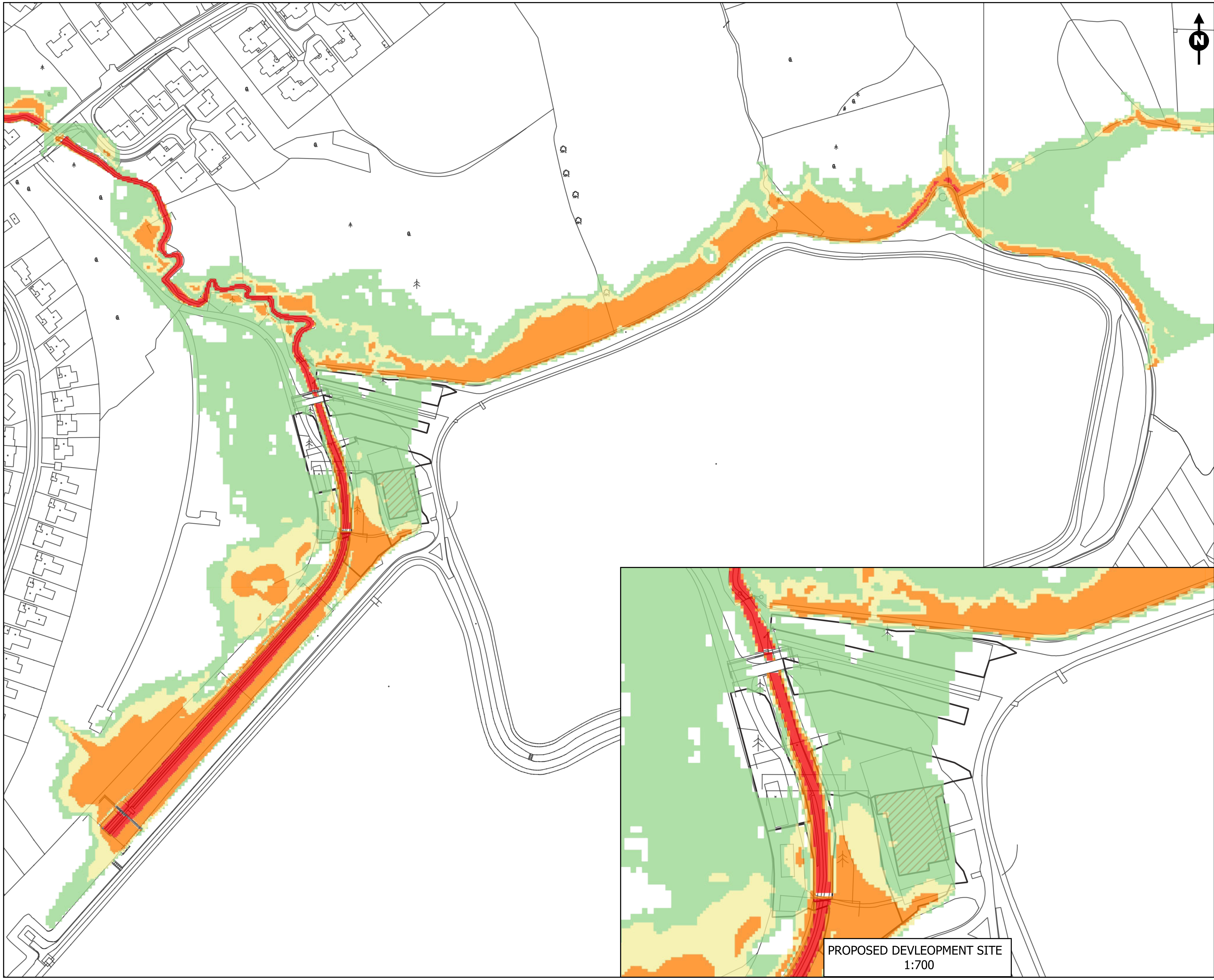
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/047/G	047	P01



Legend

Hazard

- Low
- Moderate
- Significant
- Extreme
- Development
- Development Site

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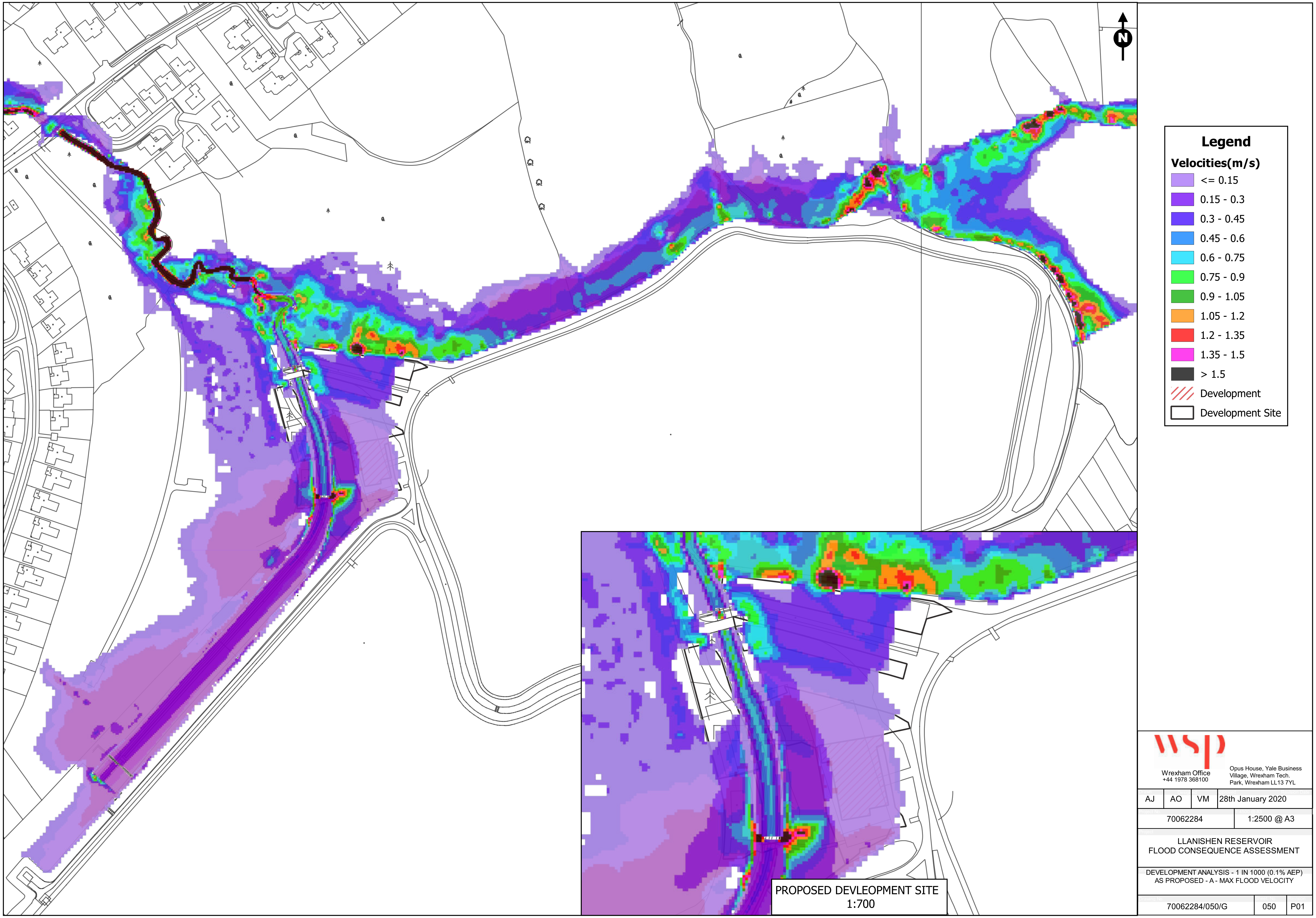
LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 100 (1% AEP + 70% CLIMATE CHANGE)
AS PROPOSED - A - HAZARD

70062284/048/G	048	P01



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AJ	AO	VM	28th January 2020
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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 1000 (0.1% AEP)
AS PROPOSED - A - MAX FLOOD VELOCITY

70062284/050/G	050	P01

Legend

Hazard

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- Significant
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- Development Site

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LLANISHEN RESERVOIR
FLOOD CONSEQUENCE ASSESSMENT

DEVELOPMENT ANALYSIS - 1 IN 1000 (0.1% AEP)
AS PROPOSED - A - HAZARD

70062284/051/G	051	P01

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