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A55 JUNCTION 16 AND 16A HYDROLOGICAL CALCULATIONS RECORD AND FLOOD RISK UPDATE

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A55 JUNCTION 16 AND 16A
HYDROLOGICAL CALCULATIONS RECORD AND FLOOD RISK UPDATE

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1. INTRODUCTION

1.1 Background

1.1.1 Following review of the Environment Statement for the A55 J16 and J16A Improvement Scheme, Natural Resources Wales (NRW) raised a number of points of concern / where they sought clarification. NRW's points were put in a letter dated 10 May 2021 (Ref CAS-142761-D5W2). The majority of responses were given in a letter from Welsh Government to NRW dated 19 July 2021 (reference qA1420023). For some of the items raised, more detailed clarification was to follow in a supplementary report. This report provides that detail for matters related hydrology and flood risk associated with the Afon Gyrach. Matters related to surface water quality and the Water Framework Directive (WFD) are covered in a separate report.

1.1.2 NRW's comments in relation to hydrology and flood risk associated with the Afon Gyrach were:

"The flood modelling is heavily influenced by the initial flood estimates used in any hydraulic modelling. If the hydrology used to obtain the flood estimates are incorrect then the model results will also be incorrect and may not give an accurate reflection of the flood risk associated with the proposal. We therefore offer the following comments which need to be addressed as part of an updated FCA (and agreed with NRW) prior to the Order being made.

With regards to Appendix 7.4 (Hydrological Calculations Record). The peak flow for the 1% Annual exceedance probability event appears reasonable, however, there are some points that need clarifying in the report for future reference and the response to them may change the final estimates slightly. The points which need addressing are as follows:

i. Software used. The latest version has not been used. We would expect the record to be updated to use the version released September 2020. We are unable to find in the report which version of ReFH2 has been used for this work. The report needs to confirm which version was used. ReFH 2.2 or 2.3 should be used with the FEH2013 rainfall model. The NRW guidance note GN008 (2017) states that we may not accept ReFH1 or ReFH2.1 estimates that use the FEH1999 model.

ii. Statistical. Urbanisation - the Environment Agency Flood Estimation Guidelines (June 2020) recommend that urbanisation adjustment of QMED is applied in all cases for consistency in WINFAP4. Section 4 should demonstrate that urban adjustment has been addressed adequately. It is accepted that this will only have limited changes in values.

iii. Revitalised Flood Hydrograph (ReFH). It is unclear if rural or urban results have been used in ReFH2 methodology. Table 5.2 appears to imply that rural have been used. The rural estimate is for information only and is as though the catchment is 100% rural. The urban results should always be used as that will include any urbanisation in the catchment, the differences are likely to be minimal in this case, but the calculation record should be updated, and revised estimates used in the modelling if necessary. A storm duration of 6.15 hours has been used. Further clarification as to how this duration was derived is required. Using ReFH2.3 may give a different duration and hydrograph used in the hydraulic model.

We would therefore suggest that the Flood Consequence Assessment (Appendix 7.2) and the Hydrological Calculations Record (Appendix 7.4) along with the Afon Gyrach Flood Modelling Report (Appendix 7.5) be revisited and the above comments be considered for any updates to ensure that all parties fully understand the flood risk associated with the proposal."

1.1.3 This technical report seeks to address NRW queries i, ii and iii with commentary on how these may have affected the Flood Consequence Assessment and Flood Modelling.

2. REVITALISED FLOOD HYDROGRAPH (REFH) METHOD

2.1 NRW Consultation

2.1.1 An original iteration of the flow calculations using the ReFH method was undertaken in June 2020 using the most up-to-date version of the software available at the time (ReFH 2.2). This now has been superseded by Version 2.3 of the software. Therefore the calculations have been repeated using Version 2.3 with the FEH2013 rainfall model.

2.1.2 Furthermore, following review of the original calculations, NRW has requested that Urban rather than Rural results derived from the ReFH software be calculated. In order to undertake a thorough comparison of results, peak flows have been derived using both the Rural and Urban models and with both the Winter and Summer seasonality rainfall events.

2.1.3 As set out in the ReFH Technical Guide[1], "*It is generally accepted that an increase in urban extent and hence impervious area should result in decreased infiltration capacity and surface storage, thereby increasing runoff volumes. At the same time the positive drainage of the impervious surfaces and green (pervious) spaces that drain to these impervious surfaces will reduce catchment response time. The combination of these two effects will both increases the peak flows experienced in urbanised catchments and the fraction of total runoff that is direct runoff*".

2.2 Parameters for ReFH Model

2.2.1 The parameters were estimated from catchment descriptors and are easily reproducible, so have not been listed in full below. It is noted that the URBEXT2000 value is 0.0072. In accordance with Table 4.1 of the Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme R&D Technical Report FD1919/TR (URBEXT2000 - A new FEH catchment descriptor Calculation, dissemination and application), such a value is considered to be 'Essentially Rural' and the original use of the Rural model would appear justified.

2.2.2 The BFIHOST Value is 0.488. Therefore, the Winter storm profile is used for these calculations. A Summer storm profile would only be selected where:

- URBEXT2000 is ≥ 0.30, or
- 0.15 ≤ URBEXT2000 < 0.30 and BFIHOST19 is ≥ 0.65.

[1] https://refhdocs.hydrosolutions.co.uk/The-ReFH2-Model/Rural-Model/

Table 2.1: Categories of Catchment Urbanisation (Table 4.1 of R&D Technical Report FD1919/TR)

Category	Urbext2000
Essentially rural	0.000 ≤ URBEXT2000 < 0.030
Slightly urbanised	0.030 ≤ URBEXT2000 < 0.060
Moderately urbanised	0.060 ≤ URBEXT2000 < 0.150
Heavily urbanised	0.150 ≤ URBEXT2000 < 0.300
Very heavily urbanised	0.300 ≤ URBEXT2000 < 0.600
Extremely heavily urbanised	0.600 ≤ URBEXT2000 < 1.000

2.3 Design Events for ReFH Method

Table 2.2: Original 2020 ReFH Design Events

Site Code	Urban or Rural	Season of Design Event (summer or winter)	Storm Duration (hours)	Storm Area for ARF (if not catchment area)
GYR01	Rural	Winter	6:15	Catchment Area Used

Table 2.3: Revised 2021 ReFH Design Events

Site Code	Urban or Rural	Season of Design Event (summer or winter)	Storm Duration (hours)	Storm Area for ARF (if not catchment area)
GYR01	Rural	Winter	6:15	Catchment Area Used
GYR01	Urban	Winter	6:15	Catchment Area Used

1.1.4 It is noted that the revised ReFH calculations using Version 2.3 also recommend a storm duration of 6 hours 15 minutes as per the previous modelling.

2.4 Flood Estimates from the ReFH Method

2.4.1 The previous peak flood flow estimates, as were derived in June 2020 are presented below.

Table 2.4: 2020 ReFH Flood Estimates at GYR01

AEP (%)	Return Period (years)	ReFH flood peak flow (m^3/s)
50	2	4.72
20	5	6.35
10	10	7.80
3.33	30	10.79
2	50	12.44
1.33	75	13.84
1	100	14.89
0.5	200	17.60
0.1	1000	24.70
1 + CC	100 +30% CC	19.36

2.4.2 The revised peak flood flow estimates are presented below.

Table 2.5: 2021 ReFH Flood Estimates at GYR01

AEP (%)	Return Period (years)	ReFH flood peak flow (m^3/s)		Comparison Against 2020 Flow Calculations	
		Rural Winter	Urban Winter	Rural Winter	Urban Winter
50	2	4.86	4.89	+0.14	+0.17
20	5	6.54	6.58	+0.19	+0.23
10	10	8.02	8.07	+0.22	+0.27
3.33	30	11.08	11.14	+0.29	+0.35
2	50	12.75	12.82	+0.31	+0.38
1.33	75	14.17	14.25	+0.33	+0.41
1	100	15.23	15.32	+0.34	+0.43
0.5	200	17.98	18.06	+0.38	+0.46
0.1	1000	25.16	25.26	+0.46	+0.56
1 + CC	100 +30% CC	19.80	19.92	+0.439	+0.556

The flood modelling upon which the Flood Consequences Assessment (FCA) for the site was based used design flood events with a range of return periods. The following table presents a comparison between the previously-modelled flows from 2020 with the 2021 flow calculations which use ReFH Version 2.3 and the Urban Winter profile showing the percentage difference in respect of the previously-modelled 2020 flows. The maximum increase occurs at low magnitude flows such as the 1 in 2 year flood. For higher flows including the 100 year and climate change-corrected 100 year, the difference is approximately 3%. For the 1,000 year flood, the difference is approximately 2%.

Table 2.6: 2020 ReFH Flood Estimates at GYR01

AEP (%)	Return Period (years)	ReFH flood peak flow (m^3/s) 2020 Calcs	ReFH flood peak flow (m^3/s) 2021 Calcs	Difference as a percentage (2020 to 2021)
50	2	4.72	4.89	4%
20	5	6.35	6.58	4%
10	10	7.80	8.07	3%
3.33	30	10.79	11.14	3%
2	50	12.44	12.82	3%
1.33	75	13.84	14.25	3%
1	100	14.89	15.32	3%
0.5	200	17.60	18.06	3%
0.1	1000	24.70	25.26	2%
1 + CC	100 +30% CC	19.36	19.92	3%

3. DISCUSSION AND SUMMARY OF RESULTS

3.1 Use of Updated Software

3.1.1 ReFH Version 2.3 incorporating the FEH2013 rainfall model was used for revised flow calculations to compare with those completed previously to inform the FCA. All of the following analyses are therefore based on using the most up-to-date software as requested by NRW. It is noted that ReFH Version 2.3 recommended a storm duration of 6 hours and 15 minutes as per the previous modelling.

3.2 Urban Adjustment for Statistical Method

3.2.1 It is noted that, with regard to the Statistical Method, NRW has suggested that the Environment Agency Flood Estimation Guidelines (June 2020) recommend an urbanisation adjustment of QMED is applied in *all cases* for consistency in WINFAP4. The June 2020 Flood Estimation Guidelines state that "*Although the FEH only mentions performing the urban adjustment for urban catchments, it makes sense to apply it on all catchments to avoid a discontinuity when URBEXT2000 exceeds the threshold value of 0.030*". The URBEXT2000 value for the catchment is 0.0072. As set out previously, in accordance with Technical Report FD1919/TR, such a value is considered to be 'Essentially Rural' and is significantly below the threshold of 0.03 above which discontinuities have been observed. Therefore, an urban adjustment is not considered necessary.

3.2.2 To adjust QMED for urbanisation, it would be necessary to multiply the rural estimate of QMED by an urban adjustment factor, UAF. The Wallingford Hydrosolutions report (WINFAP 4 Urban Adjustment Procedures) sets out that the UAF is calculated using:

$$UAF = (1 + URBEXT2000)^{0.37} PRUAF^{2.16}$$

3.2.3 The Percentage Runoff Urban Adjustment Factor PRUAF is an estimate of the increase in runoff volume that occurs as a consequence of urbanisation (a function of urban extent and catchment type) and is calculated using the equation:

$$PRUAF = (1 + 0.47URBEXT2000(\frac{BFIHOST}{1-BFIHOST})$$

3.2.4 Given the URBEXT2000 value of 0.0072 and the BFIHOST value of 0.488, the UAF value derived using this method is approximately 1.007. This is a low value which would be expected to have a negligible effect on the value of QMED. It is acknowledged by NRW that any urban adjustment would only result in limited changes in values. As the peak flows derived in 2020 using the Statistical Method were 7% lower than those derived from the ReFH method for the 1 in 100 AEP event and 9% lower for the 1 in 200 AEP event, an urban adjustment is extremely unlikely to change the conclusion that the flows derived using ReFH were most suitable for use in the hydraulic modelling study.

3.3 ReFH Urban

3.3.1 URBEXT2000 for the catchment is 0.0072 and therefore significantly below the threshold that is identified as 'Essentially Rural' (the catchment is over 99% rural). Nevertheless, a sensitivity check has been completed using an urban winter profile in ReFH. Peak flow rates derived using the method range between approximately 2% and 4% higher than those used in the hydraulic modelling.

3.3.2 The hydraulic modelling used conservative flow rates for setting design parameters. Impacts were assessed up to and including the 1,000 year flows and, as per the conclusions of the FCA,

the modelling concluded that while there is a minor afflux (increase) of flood water levels immediately upstream of the structure in extreme rainfall events (10 mm in a 1-in-100 year event including a 30% allowance for climate change and 130 mm in a 1-in-1,000 year event), this would impact land which is currently used for pasture only and would be owned and retained by Welsh Government as part of the Scheme. No residential receptors or other buildings would be affected and the afflux is therefore considered acceptable. The modelling also concluded that floating debris would be able to pass under and through the proposed new structure as the freeboard during a 1-in-1,000 year flood event would be more than 600 mm.

3.3.3 The flood modelling incorporated sensitivity tests (Section 7.4) to check on the potential for errors in the flow calculations to have a significant impact on the conclusions of the FCA. This included decreasing and increasing the rate of flow by ±20%. The effect of these changes resulted in a maximum increase in flood level anywhere in the model of 150 mm. The effect of using the urban winter profile is much less than 20%.

3.3.4 Potential impacts on flow velocities and scour would be subject to additional assessment at the detailed design stage to ensure that any changes would not adversely impact the bridge crossing nor the watercourse. This assessment will be added as a commitment within the updated REAC. The revised hydrological estimates based on urban winter ReFH calculations would be used for determining detailed designs.

3.4 Conclusions

3.4.1 The FCA and hydraulic modelling determined that a 600 mm freeboard between the peak flood level and soffit of the new structure would be possible even during a 1,000 year event. Likewise, impacts elsewhere would be limited to areas used for pasture only and would be owned and retained by Welsh Government as part of the Scheme.

3.4.2 Sensitivity checks undertaken during the hydraulic modelling exercise suggest that increasing flow rates by 20% would result in a maximum increase in flood level of 150 mm; well within the 600 mm freeboard. Flow calculations used previously assumed a rural catchment based on the recommendations of R&D Technical Report FD1919/TR for catchments with an URBEXT2000 of less than 0.03 (the catchment in question has an URBEXT2000 of 0.007). Nevertheless, Ramboll has undertaken additional hydrological modelling to determine the potential effect of using a winter urban profile in ReFH for calculating peak flows. This work suggests that, for higher magnitude floods, peak flows may be increased by 2-3%; significantly less than the percentages tested in Ramboll's sensitivity checks.

3.4.3 The structure will be subject to additional assessment at the detailed design stage to ensure that any changes would not adversely impact the bridge crossing nor the watercourse and will be a commitment within the updated REAC. The revised hydrological estimates based on urban winter ReFH calculations would be used for determining detailed designs. However, based on the above appraisal, changes to flow rates based on NRW recommendations do not exceed potential error thresholds already tested and would not therefore fundamentally alter the conclusions of the FCA.