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Blaenau Gwent County Borough Council

Lower Plateau, Six Bells Colliery Site Stage 3 Strategic Flood Consequence Assessment

Final
February 2011

Prepared for

Cyngor Bwrdeisdref Sirol
Blaenau Gwent
County Borough Council

Revision Schedule

Lower Plateau, Six Bells Colliery Site Stage 3 SFCA
February 2011

Rev	Date	Details	Prepared by	Reviewed by	Approved by
01	February 2011	D129363 - Draft for comment	**Patrick Goodey** Flood Risk Consultant	**Jon Robinson** Technical Director	**Jon Robinson** Technical Director
01	February 2011	D129363 – Final incorporating comments	**Patrick Goodey** Flood Risk Consultant	**Jon Robinson** Technical Director	**Jon Robinson** Technical Director

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Table of Contents

1 Introduction

1.1 Commission

URS/Scott Wilson was commissioned by Blaenau Gwent County Borough Council (CBC) to undertake a Stage 3 Strategic Flood Consequences Assessment (SFCA) for the Lower Plateau site at Six Bells, Abertillery. The site reference within the emerging Local Development Plan (LDP) is D11.

1.2 Background

Following completion of the Stage 2 SFCA, discussion with the Environment Agency Wales (see Appendix A) has identified the potential requirement for a Stage 3 SFCA to be undertaken for site D11 at Six Bells, Abertillery. The site is proposed within the LDP to be allocated for non-resident education use.

The Environment Agency Flood Mapping indicates that the site is predominantly located within Flood Zone 3 (1% annual probability of flooding) and 2 (between a 1% and 0.1% annual probability of flooding), associated with the Ebbw Fach River. The Welsh Assembly Government (WAG) Development Advice Map (DAM) indicates that the site is predominantly located in Zone C2 (Undefended, with a 0.1% annual probability of flooding). However, the Ebbw Fach River flows within a large culvert beneath the western boundary of the site. Prior to undertaking hydraulic modelling, it was agreed that an assessment of the culvert capacity should be undertaken to identify the flow required to exceed the capacity and therefore provide an outline assessment of the potential flood risk posed to the site.

2 Site Location and Description

2.1 Location

The Lower Plateau, Six Bells site is located within the town of Abertillery, Blaenau Gwent on the site of the former Six Bells Colliery. The approximate NGR for the site is SO 220 029. The site is bordered to the north by Chapel Road and the Six Bells Baptist Church. To the east of the site are existing residential properties. The western boundary of the site is defined by sloping ground that rises up to Six Bells Road. To the south of the site is existing open space, also associated with the colliery. As site location map is provided in Figure 1 below.

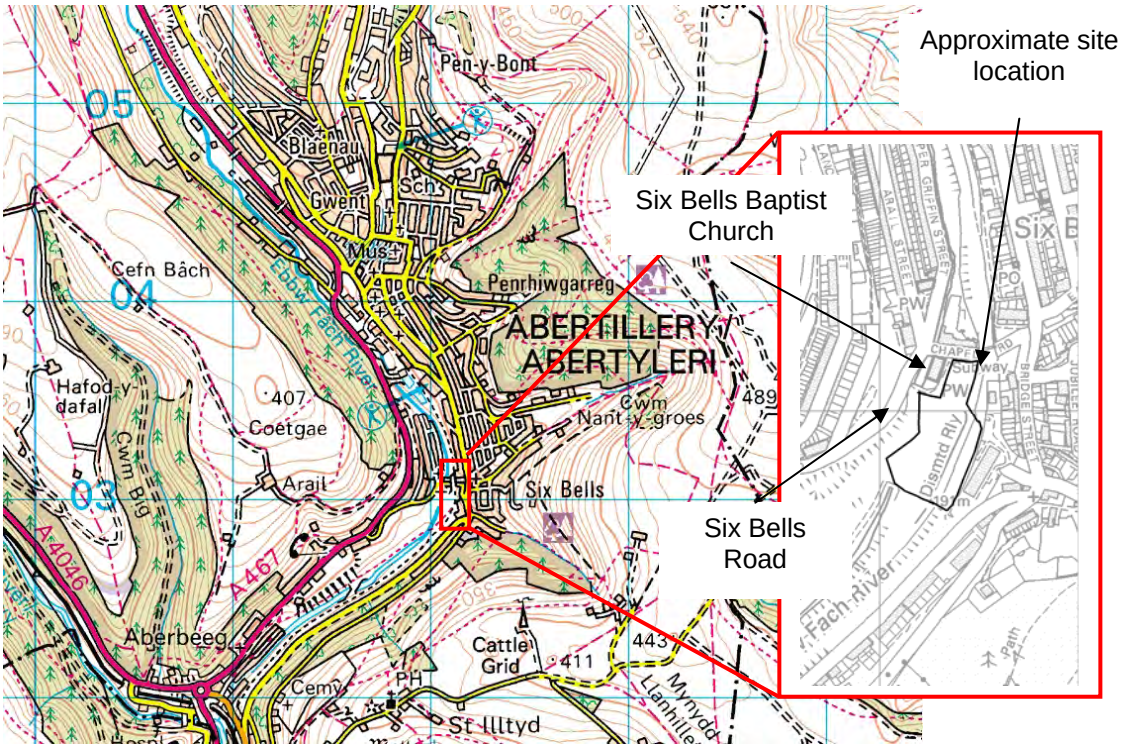

Figure 1 Lower Plateau, Six Bells, Abertillery site location. © Crown copyright, All rights reserved. 20. License number 0100031673.

2.2 Layout and Topography

The site itself is relatively flat and predominantly consists of greenfield land (see **Plate 1** and Plate 2 below). To the east and west of the site, the land rises relatively steeply. To the south of the site, the topography remains relatively uniform, with the slope generally following the gradient of the river. The land to the north of the site (e.g. Chapel Road and Upper Griffin Street) was observed as being at a lower topographical level than the site.

The Ebbw Fach River flows in southerly direction within a culvert along the western boundary of the site. To the north and south of the site, where the river flows as an open watercourse, it is relatively deeply incised with high banks (see Plate 3 and **Plate 4** below) and a high headwall (measured on-site as approximately 5m, see **Plate 3**). To the north (upstream) of the site, the river flows beneath another structure, the Chapel Road bridge, which was observed as having a deck soffit level lower than that of the top of bank (see Plate 5 and Plate 6).

Plate 1 Six Bells site looking south from northern boundary

Plate 2 Six Bells site looking north from southern boundary

Plate 3 Ebbw Fach River and culvert, looking downstream (south). The building on the left is the Six Bells Baptist Church

Plate 4 Ebbw Fach River at culvert outlet, to the south of the site, looking downstream (south)

Plate 5 Ebbw Fach River flowing beneath Chapel Road, looking upstream (north) from Chapel Road

Plate 6 Ebbw Fach River and Chapel Road bridge, looking upstream (north) from headwall of the culvert

3 Methodology and Data

In order to provide an outline assessment of the flood risk posed to the site from the Ebbw Fach River, a culvert capacity calculation was performed. Following the culvert assessment, an estimation of the likely flow expected within the Ebbw Fach was also undertaken. By comparing the culvert capacity with the likely flow in the river, an outline assessment of potential flood risk posed to the site has been provided, along with recommendations for further work, as necessary.

3.1 Culvert Capacity Estimation

In order to estimate the potential capacity of the culvert, the following information sources were used:

- Culvert Structural Inspection Report, undertaken by Kaymac Marine and Civil Engineering in December 2008;
- Information collated during a site visit undertaken in January 2011;
- Manning's formula for culvert capacity estimation.

The culvert Structural Inspection Report provided the following dimensions, structural make up and bed material of the culvert:

- Culvert vertical height at the entrance from invert to arch crown of 3.8m. This reduces to 3.0m at a chainage of 80m;
- Culvert entrance width at the entrance of 5.1m. This reduces to 3.1m at a chainage of 80m;
- The culvert is constructed of mostly masonry (bricks) with a natural bed material;
- The culvert has an overall length of 122m.

In order to estimate the approximate capacity of the culvert, the Manning's Equation has been utilised, as follows:

$$Q = \frac{A}{n} R^{2/3} \sqrt{s}$$

Where:

Q = Flow, in m^3/sec (cumecs)

A = Culvert area (m^2) – estimated using the above data

n = Manning's roughness 'n' value - estimated using the above data

R = Hydraulic radius - estimated using the above data

s = Channel slope (gradient) of the culvert, as a decimal – estimated using LiDAR data

An explanation of the derivation of the above values and parameters is provided within Appendix C of this report.

As described above, the culvert is wider at the entrance than at chainage 80m (i.e. 80m downstream from the entrance). Therefore, the Manning's Equation has been applied using the parameters provided by the Structural Inspection Report at various points along the culvert length to estimate the likely impact on the capacity of this culvert caused by such a constriction in the culvert area.

The results from the Manning's Equation are provided in Section 4 below.

3.1.1 Hydrological Flows

In order to estimate the likely flow range within the Ebbw Fach River at Six Bells, a hydrological estimation has been completed using the industry standard Flood Estimation Handbook (FEH) statistical analysis approach. Details of the methodology used to generate the flow estimates are provided in the Hydrological Analysis Report, included in Appendix B of this report. **Table 1** below provides a summary of the various flow estimations.

Table 1 Estimated flows within the Ebbw Fach River for various design return period events, obtained from the Hydrological Analysis Report, provided in Appendix B.

Annual Probability	Return Period (1 in *x* years)	Flow estimate (m3/s)
50%	2	17.2
4%	25	33.5
2%	50	39.2
1.33%	75	43.0
1%	100	45.9
1% inclusive of climate change[1]	100 inclusive of climate change	55.1
0.5%	200	53.8
0.1%	1000	77.9

Once the Manning's Equation has been applied to calculate the culvert capacity, this can be compared with the flow range within the Ebbw Fach to establish the likelihood that the culvert capacity could become exceeded.

[1] [1] In order to comply with TAN15, an addition of 20% has been added to the flows to account for the predicted impact of climate change, commensurate with the lifetime of a school development, assumed to be 60 years.

4 Results and Discussion

4.1 Culvert Capacity – Results of the Manning's Equation

The results of the Manning's Equation culvert capacity estimation are provided in Table 2 below. These represent the likely capacity at various points along the culvert.

Table 2 Estimated capacity of the culvert at various locations along the culvert length

Chainage (m)	Dimensions		Capacity estimate (m3/s)
	Height from Invert to Soffit (m)	Width (m)	
0	3.82	5.12	78.2
40	3.85	5.10	78.7
60	3.78	5.15	77.7
80	3.00	3.70	34.0

4.2 Discussion

The use of the Manning's equation to generate culvert capacity estimates is a simplistic method and has been used as a first pass at this stage to provide an indication of likely capacity only.

Comparing the results in Table 2 above indicates that for over 60m of the culvert (approximately half of the total length), it is able to convey flows generated from an event of between 0.5% and 0.1% annual probability (1 in 200 and 1 in 1000 year return period). However, the downstream extent of the culvert would only be able to convey flows generated during an event of between a 4% and 2% annual probability (1 in 25 and 1 in 50 year return period). As a result, it is likely that during an event which exceeds the magnitude of the 4% annual probability, the capacity of the downstream extent of the culvert would become exceeded. At the 1% annual probability (1 in 100 year return period), it is likely that significant constriction of flows could occur.

At this outline stage and without full hydraulic modelling, it is not possible to fully conclude whether or not such constriction of flows would cause flooding to the proposed site or surrounding area. However, the topography of the area results in a high headwall above the culvert entrance, meaning any water exceeding the culvert capacity would back up rather than spill over ground in a downstream direction. In addition, the site is located at a higher topographical level than the land to the north (e.g. Chapel Road and Upper Griffin Street). Therefore, this would provide a preferential flow route for any flooding resulting from culvert exceedance. However, during high flows (i.e. bankfull), it is likely that the Chapel Road bridge could present an obstruction to the flow of water, thus potentially reducing the flow of water entering the culvert beneath the site and hence lessening the risk of a capacity exceedance.

As a result of this outline assessment, whilst the flood risk posed to the proposed site remain relatively unknown, it is believed that the risk of flooding to the site following a culvert capacity exceedance may be relatively low. It is therefore very likely that the WAG DAMs and Environment Agency Flood Zone maps at the site are likely to be exaggerated on account of them not taking into consideration the culvert beneath the site.

4.3 Recommendations

As a result of the above it is recommended that a hydraulic modelling study should be undertaken to determine whether the current flood risk mapping available can be revised and the site can then be allocated within the LDP. The study undertaken to date suggests that such modelling will support allocation. This hydraulic modelling would investigate the likelihood of the culvert becoming exceeded, along with the likely flow routes of any flooding. The FCA arising from the work would also recommend any mitigation measures required to minimise the impact of flooding at the site, if necessary.

5 Conclusions

- The proposed Lower Plateau, Six Bells Colliery Site is included within the LDP as a potential education facility;
- The site is located within the WAG DAM flood zone C2 meaning it is potentially at risk during a 0.1% annual probability flood event;
- The site is located within the Environment Agency Flood Zone 3 (potentially at risk during a 1% annual probability event) and Flood Zone 2 (potentially at risk during a 0.1% annual probability event);
- The above flood zones however do not take into consideration the culvert that conveys the Ebbw Fach River beneath the western extent of the site;
- On account of the sites location within Flood Zone 3 and WAG DAM C2, the Stage 2 SFCA recommended the site be further investigated as part of a Stage 3 SFCA;
- This Stage 3 SFCA provides an outline investigation into the potential flood risks posed to the site by comparing the likely flows generated during a 1% and 0.1% annual probability event with the potential capacity of the culvert;
- Flows within the Ebbw Fach river were estimated using the FEH statistical approach and estimated the following flows:
    - 45.9m^3/sec during a 1% annual probability flow event;
    - 55.1m^3/sec during a 1% annual probability flow event, inclusive of climate change;
    - 77.9m^3/sec during a 0.1% annual probability flow event;
- The culvert capacity has been calculated using the Manning's Equation, a simplistic but indicative method at this stage;
- The culvert beneath the site has a capacity of approximately 78m^3/sec at its entrance and approximately 34m^3/sec from 80m along its length;
- As a result, the culvert has the potential to cause constriction of flows during very high flow events;
- The likelihood of flood water reaching the site in the event of a capacity exceedance is reduced due to the high headwall at the culvert entrance and local topography creating preferential flow routes to areas north (upstream) of the site;
- It is recommended that the site be continued through the LDP process but further hydraulic modelling be undertaken during a formal FCA for the site, which would be written to comply with TAN15.

Appendix A – Environment Agency Correspondence

Patrick Goodey
Scott Wilson
The Crescent Centre
Temple Back
Bristol
BS1 6EZ

Ein cyf/Our ref: SE/2007/102989/OR-03/AE1-L01
Eich cyf/Your ref:

Dyddiad/Date: 17 December 2010

Dear Mr Goodey

Blaenau Gwent County Borough Council Strategic Flood Consequences Assessment Stage 2

Thank you for sending us the following document for review, which we received on 15 November 2010:

- Blaenau Gwent County Borough Council. Strategic Flood Consequence Assessment Stage 2, Scott Wilson, September 2010 (DRAFT)

We have now reviewed the Stage 2 SFCA and we provide the following advice:

Section 1 Introduction

We note that following your Stage 1 SFCA, a screening exercise has now been undertaken of various candidate sites identified by Blaenau Gwent CBC as part of their emerging LDP for spatial planning purposes. This has resulted in you including nine candidate sites in this Stage 2 SFCA.

Section 2 Study area

We note that in paragraph 2.1.3 you state that the Castle Street, Abertillery has been removed from the LDP process and that the site will not be assessed as part of the Stage 2 report. However, we note that paragraph 5.1.1 in your Summary lists Castle Street, Abertillery as being a site that requires further investigation. Given that this site has been removed from the LDP process, we assume that its inclusion in paragraph 5.1.1 is in error. Furthermore, Roseheyworth Business Park is included in paragraph 2.1.1, but does not feature in paragraph 5.1.1. You may wish to clarify or amend this.

Assuming the above, we note the majority of candidate sites assessed are situated within Zone A/Flood Zone 1 apart from:

• Lower Plateau, Six Bells Colliery Site, Lower Ebbw Fach

This sites has been identified to require further study for the Stage 3 SFCA, with the 9 remaining sites, if allocated, requiring varying levels of site specific FCAs. This approach appears a reasonable way forward.

Section 3 Methodology

Section 3.2 You should amend this heading to state "Areas Susceptible to Surface Water Flooding " (not management).

We note that you have used our Areas Susceptible to Surface Water Flooding (AStSWF) maps to consider the risk of flooding from surface water (paragraph 3.2.1). Please be aware we recently sent all Local Authorities our Surface Water Flooding Maps, which supplement the AStSWF maps. You may wish to consider these Surface Water Flooding maps in any future SFCA stages.

We also seek clarification on whether you have sought information from Blaenau Gwent's drainage engineers. The Local Authority may have additional information on surface water flooding, which the SFCA should consider. You should explain whether you have done this (or why it has been omitted) in your Methodology.

Section 4 Candidate Site Assessment

We note the approach you have taken, and agree that it seems sensible for site specific FCAs to be undertaken for the sites you have suggested.

Section 4.8 North Rising Sun Industrial Estate: We note that the potential access to this site lies within Flood Zones 2 and 3. The SFCA may wish to flag up that any future FCA should consider whether operation access/ egress to the site can be achieved during a flood event.

Section 4.8 Lower Plateau, Six Bells Colliery : We agree that it is appropriate to undertake a Stage 3 SFCA for the Six Bells Colliery Site. We note how a culvert runs under this site. It appears likely that the culvert would convey much of the flow in the event of a flood event. Hence, mitigation for the flood risk appears likely to be possible.

We would be happy to discuss further with you the scope of the Stage 3 SFCA for this site. It may be possible to assess the flood risk without hydraulic modelling, as you may be able to do a coarse assessment of the flood risk, without the need for modelling. Whether this method is appropriate is partially dependent on the size of the culvert. We also advise that your Stage 3 SFCA assess whether mitigation in the form of opening up the culvert would be possible to create a more natural watercourse. It may be that this is not possible, due to the depth of the culvert underground, but we advise that the SFCA should explore the possibility. We would be pleased to provide further advice on the scope of the Stage 3 SFCA further with you; please contact us, should you wish to do so.

Section 5 Summary

We advise that you remove the reference to Castle Street, Abertillery to the list in paragraph 5.1.1 and include Roseheyworth Business Park, as discussed above.

Cont/d..

Additional issues: Compliance with tender brief

Your tender brief (dated December 2009) set out the points to be covered by the Stage 2 SFCA in paragraphs 3.1.2 and 3.2.5. It may be useful to ensure to state how the SFCA has addressed these points, and if it has not, give explanation for this. With reference to paragraph 3.1.2 of your Tender Brief, we seek clarity on how the SFCA has addressed the following points (in italics):

- *Assess the residual risk posed to potential sites following failure, breach or overtopping of flood management measures and identify areas within the relevant sites deemed to be at lowest residual risk of flooding:* The SFCA does not appear to have done this; we advise that you assess this, as it was included in your Tender Brief. If it is omitted because the certain sites are not defended, then the SFCA should explain this.

- *Provide appropriate outline guidance on flood risk management techniques, including the use of sustainable drainage methods and the indicative costs associated with the construction and maintenance of the proposed management technique:* While we note that the Key Information tables associated with each site includes a brief description of the mitigation measures required, which sometimes includes the appropriate use of surface water management techniques, the SFCA does not appear to have provided guidance on the indicative costs of these. We advise that you include this in your SFCA, or explain why it cannot be done.

- *Identify the need for and the type of policies required as part of the LDP (where appropriate):* While we note that the SFCA has given guidance on how future FCAs should be undertaken to inform developments, the SFCA does not appear to have included any advice on the policies required in the LDP. We advise that the SFCA should do this, or justify why it has not done so.

Should you have any queries on the above, please do not hesitate to get in contact.

Yours sincerely

Kayna Tregay
Planning Liaison Officer

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Appendix B – Hydrological Analysis Report

Blaenau Gwent County Borough Council

Lower Plateau, Six Bells Colliery Site Hydrological Analysis Report

Final
February 2011

Prepared for

Cyngor Bwrdeisdref Sirol
Blaenau Gwent
County Borough Council

Revision Schedule

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February 2011

Rev	Date	Details	Prepared by	Reviewed by	Approved by
01	February 2011	D129363 - Draft for comment	**Dr Rob Sweet** Senior Hydrologist	**Jon Robinson** Technical Director	**Jon Robinson** Technical Director
01	February 2011	D129363 – Final	**Dr Rob Sweet** Senior Hydrologist	**Jon Robinson** Technical Director	**Jon Robinson** Technical Director

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1 Introduction

1.1 Commission

URS/Scott Wilson was commissioned by Blaenau Gwent County Borough Council (CBC) to undertake a Stage 3 Strategic Flood Consequences Assessment (SFCA) for the Lower Plateau site at Six Bells, Abertillery. The site reference within the emerging Local Development Plan (LDP) is D11.

1.2 Background

Following completion of the Stage 2 SFCA, discussion with the Environment Agency Wales (see Appendix A) has identified the potential requirement for a Stage 3 SFCA to be undertaken for site D11 at Six Bells, Abertillery.

The Environment Agency Flood Mapping indicates that the site is predominantly located within Flood Zone 3 (greater than a 1% annual probability of flooding in any year) and the WAG DAM Mapping indicates that the site is predominantly located in Zone C2 (Undefended). However, the Ebbw Fach River within the site boundary flows within a significant culvert beneath the western boundary of the site. Prior to undertaking hydraulic modelling, it was agreed that an assessment of the culvert capacity should be undertaken to identify the flows required to exceed the capacity and therefore provide an outline assessment of the potential flood risks posed to the site.

This report provides the Stage 3 SFCA for the site by summarising the

2 FEH Statistical Method

2.1 Methodology

The following sources of data and software were used for the FEH statistical pooling group analysis:

- FEH CD-ROM v3
- WINFAP-FEH v3
- HiFlows-UK v 3.02

2.1.1 Estimation of Qmed

Catchment descriptors were exported from the FEH CD-ROM v3 for the catchment area to SO 22050 03050, these are provided in the calculation sheets in Appendix A. There are no flow records at the site and therefore the index flood (Qmed) has been derived using the updated catchment descriptor method described in Kjeldsen *et al* (2008).

Prior to deriving Qmed, the URBEXT2000 value was updated using the revised UEF equation described in Bayliss *et al* (2006) from 0.0759 to 0.0777.

The catchment is considered to be 'moderately urbanised' (URBEXT2000 > 0.03) and therefore an Urban Adjustment Factor (UAF) was applied to Qmed using the revised equation described in Kjeldsen (2010). It is noted that data transfer methods to improve the estimate of Qmed is not recommended in urbanised catchment (Section 9.1.4, WINFAP-FEH 3 User Guide).

The adjusted value for Qmed was calculated to be 17.23 $m^3 s^{-1}$, a calculation sheet is provided in Appendix A.

2.1.2 Statistical Pooling Group and Growth Curve Factors

An initial pooling group was created using WINFAP-FEH v3. Stations considered as 'Not suitable for pooling' and 'Not suitable for pooling or Qmed' were removed. Additional stations were added to provide a minimum of 500 years of data and form the revised pooling group (see Appendix A).

Exploratory data analysis was undertaken to assess the heterogeneity of the pooling group. The H2 Test value was -0.9420, therefore the pooling group was considered acceptably homogeneous and further review of the pooling group was not required.

The 'goodness-of-fit' test was also undertaken to identify distributions that provide an acceptable fit. The Generalised Logistic and Generalised Extreme Value distributions provided acceptable fits (z values of 0.9543 and -0.7582 respectively). The Generalised Logistic distribution was selected as this provides the best overall fit to data within the UK.

2.1.3 Flow estimates

Flow estimates were derived using the FEH statistical pooling group method based on the method provided above. Growth Curve Factors (GCF) were derived using the Generalised Logistic distribution and flow estimates calculated using the product of the GCF and adjusted Qmed value. These flow are provided in Table 2-1.

Table 2-1: Flows estimates derived using FEH Statistical Pooling Group method

Return Period	Growth Curve Factor	Flow estimate ($m^3 s^{-1}$)
2	1	17.232
5	1.326	22.847
10	1.574	27.116
20	1.849	31.861
25	1.946	33.528
50	2.278	39.247
75	2.497	43.027
100	2.665	45.932
200	3.121	53.79
500	3.852	66.376
1000	4.521	77.911

3 ReFH Method

3.1 Methodology

The following sources of data and software were used for the ReFH analysis:

- FEH CD-ROM v3
- ReFH v1.3 Spreadsheet
- ReFH Model Parameters (Appendix C, FEH Supplementary Report No. 1) for Station 56005.

3.1.1 Catchment Descriptors

Catchment descriptors were exported from the FEH CD-ROM v3 for the catchment area to SO 22050 03050, these were then imported into the ReFH Spreadsheet. The URBEXT1990 value was updated using the UEF equation (FEH Vol 5, Section 6.5.8) from 0.0604 to 0.0645.

3.1.2 Donor Adjustment

Due to the subject site being ungauged, the ReFH model parameters were enhanced through the transfer of information from Station 56005 (Lwyd@Ponthir) using the method described in Section 3.4 of the FEH Supplementary Report No.1. This station was deemed acceptable based on the following criteria:

- Catchment descriptors are considered comparable, in particular, the catchment are differs less than a factor of 5;
- The catchment centroids are separated by a distance of 8.39 km, therefore within the recommended value of 50 km;
- Both the subject site and donor site are considered as 'moderately urbanised'. The location and concentration of urbanisation are broadly comparable based on the catchment descriptors URBLOC and URBCONC. In addition, the underlying soil types are considered to be comparable with both underlain by soils considered to be 'well drained' from inspection of the '1:250000 Soil Map of England and Wales', this is also confirmed by similar BFIHOST and SPRHOST values.
- Whilst the site is not within the same catchment, it is within a neighbouring catchment with similar relief and catchment characteristics and therefore considered to be a suitable donor for transfer of information.

To provide consistency with the subject site, the URBEXT1990 value was updated using the UEF equation (FEH Vol 5, Section 6.5.8) from 0.0784 to 0.0844.

Donor correction factors were derived for the parameters C_{max} (Maximum Soil Moisture Capacity), T_p (Time to Peak), B_L (Baseflow Lag) and B_R (Baseflow Recharge), Table 3-1 provides the subject site, donor site values derived from catchment descriptors within ReFH and donor site observed values from Appendix C, FEH Supplementary Report No.1.

Table 3-1: ReFH Parameter values, donor correction factor and adjusted parameters values.

Parameter	Subject Site Parameter Value - Catchment Descriptors	Donor Site Parameter Value - Catchment Descriptors	Donor Site Parameter Values – Observed	Donor Correction Factor	Adjusted Parameter Value
C_{max}	379	384	459	1.195	453
T_p	1.7	3.44	3.61	1.049	1.78
B_L	32	39.3	65.64	1.693	54.2
B_R	1.52	1.45	1.84	1.269	1.92

3.1.3 Flow estimates

The ReFH model was run using the adjusted parameter values to derive a range of flow estimates, these are provided in Table 3-2. In addition, the growth curve factors have been derived by dividing the return period discharge (Q_T) by Qmed (1 in 2 year return period).

Table 3-2: Flows estimates derived using ReFH

Return Period	Growth Curve Factor	Flow estimate ($m^3 s^{-1}$)
2	1.000	22.6
5	1.301	29.4
10	1.540	34.8
20	1.770	40
25	1.850	41.8
50	2.137	48.3
75	2.327	52.6
100	2.478	56
200	2.898	65.5
500	3.615	81.7
1000	4.323	97.7

4 Summary and Recommendation

4.1 Summary of results and discussion

Table 4-1 provides a comparison of the GCFs and flow estimates derived using the methods described in Section 2 and 3. This comparison illustrates that flows estimated using the FEH statistical method are less than those from FEH. However, the GCFs using the FEH statistical method are greater, therefore creating a steeper growth curve based on pooled data.

Table 4-1: Comparison of Growth Curve Factors and Flow Estimates

	FEH Statistical Method		ReFH Method	
Return Period	Growth Curve Factor	Flow estimate ($m^3 s^{-1}$)	Growth Curve Factor	Flow estimate ($m^3 s^{-1}$)
2	1.000	17.232	1.000	22.6
5	1.326	22.847	1.301	29.4
10	1.574	27.116	1.540	34.8
20	1.849	31.861	1.770	40
25	1.946	33.528	1.850	41.8
50	2.278	39.247	2.137	48.3
75	2.497	43.027	2.327	52.6
100	2.665	45.932	2.478	56
200	3.121	53.79	2.898	65.5
500	3.852	66.376	3.615	81.7
1000	4.521	77.911	4.323	97.7

The donor adjustment used Station 56005 (Lwyd@Ponthir), a comparison of the Qmed derived using ReFH (54.2 $m^3 s^{-1}$) with Qmed from observed data (47.9 $m^3 s^{-1}$) provided on the HiFlows-UK website[1] indicates that ReFH estimates Qmed to be ~ 6.3 $m^3 s^{-1}$ greater. This difference is a similar magnitude to the difference between flow estimates for the subject site (~ 5.4 $m^3 s^{-1}$). It is noted that Station 56005 is used for flood warning and not considered suitable for Qmed or pooling. However, spot flow measurements indicate that at higher flows the rating curve is over-estimating flow estimates and suggests that ReFH flow estimates are likely to be an over-estimation of flow.

4.2 Recommendation

Based on the summary and discussion of results, it is recommended that the flow estimates derived using the FEH statistical pooling group method are in assessing the capacity of the culvert at the Six Bells Colliery site.

[1] http://www.environment-agency.gov.uk/hiflows/station.aspx?56005

5 References

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Kjeldsen, T.R., Jones, D.A. and Bayliss, A.C. 2008 '*Improving the FEH Statistical Method*', R & D Report SC050050/TR, Environment Agency, Bristol, UK.

Wallingford Hydrosolutions, 2009 'WINFAP-FEH 3 – User Guide', Wallingford, UK.

Appendix A – FEH Statistical Method Calculation Sheets

FEH Technical Review Sheets: Catchment Descriptors

Spreadsheet Version 1.0

Project Details	
Project Number	D129363
Project Name	Blaenau Gwent SFCA
Catchment Name	Ebbw Fach River @ Six Bells, Abertillery
User Name	Rob Sweet
Technical Reviewer Name	Peter Mansell

FEH CD-ROM Version	3		
Easting	322050	Northing	203050
Area	30.27		
Catchment Centroid			
Easting	320782	Northing	207693
FARL	0.958	RMED-1H	11.4
PROPWET	0.54	RMED-1D	52.2
ALTBAR	391	RMED-2D	68.1
ASPBAR	225	URBCONC1990	0.627
ASPVAR	0.2	URBEXT1990	0.0604
BFIHOST	0.531	URBLOC1990	0.998
DPLBAR	6.34	URBCONC2000	0.707
DPSBAR	212.4	**URBEXT2000**	0.0759
LDP	14.57	URBLOC2000	0.888
SAAR	1463	FPEXT	0.0395
SAAR4170	1543	FPDBAR	1.404
SPRHOST	31.08	FPLOC	1.249
C	-0.02615	C(1km)	-0.026
D1	0.46856	D1(1km)	0.482
D2	0.42887	D2(1km)	0.468
D3	0.36249	D3(1km)	0.337
E	0.28569	E(1km)	0.282
F	2.52452	F(1km)	2.525

Notes	
Is the catchment small (< 5 km^2)?	NO
Is the catchment permeable (SPRHOST < 20)?	NO
Is the catchment urbanised (URBEXT > 0.03)?	YES
Is the catchment flat (DPSBAR < 20)?	NO
Is the catchment low lying (ALTBAR < 20)?	NO
Is the catchment affected by lakes and reservoirs (FARL < 0.95)?	NO

FEH Technical Review Sheets:
Revised Pooling Group

Spreadsheet Version 1.0

Project Details	
Project Number	D129363
Project Name	Blaenau Gwent SFCA
Catchment Name	Ebbw Fach River @ Six Bells, Abertillery
User Name	Rob Sweet
Technical Reviewer Name	Peter Mansell

Station	Distance	Years of data	QMED AM	L-CV	L-SKEW	Discordancy
48004 (Warleggan @ Trengoffe)	0.288	39	9.565	0.244	0.207	0.86
72007 (Brock @ U/s a6)	0.343	30	29.438	0.194	0.273	2.033
48001 (Fowey @ Trekeivesteps)	0.372	39	16.858	0.22	0.3	0.276
48009 (st Neot @ Craigshill Wood)	0.464	12	8.469	0.246	0.372	1.5
25012 (Harwood Beck @ Harwood)	0.467	39	31.368	0.176	0.264	1.003
76811 (Dacre Beck @ Dacre Bridge)	0.48	9	34.576	0.25	0.345	2.245
48010 (Seaton @ Trebrownbridge)	0.496	36	6.47	0.236	0.254	0.783
47009 (Tiddy @ Tideford)	0.507	39	5.916	0.175	0.133	0.636
48803 (Carnon @ Bissoe)	0.534	14	5.307	0.247	0.161	1.645
27032 (Hebden Beck @ Hebden)	0.543	42	3.91	0.222	0.267	0.286
21017 (Ettrick Water @ Brockhoperig)	0.625	41	60.364	0.203	0.276	0.379
49003 (de Lank @ de Lank)	0.633	42	12.994	0.223	0.25	0.313
72014 (Conder @ Galgate)	0.639	41	16.957	0.189	0.054	1.708
24006 (Rookhope Burn @ Eastgate)	0.658	20	24.62	0.152	0.117	1.514
48007 (Kennal @ Ponsanooth)	0.667	40	3.958	0.182	0.186	0.374
47014 (Walkham @ Horrabridge)	0.67	35	37.518	0.219	0.251	0.445
Total		518				
Weighted means				0.211	0.228	

FEH Technical Review Sheets:
QMED CDs for Subject Site

Spreadsheet Version 1.0

Project Details	
Project Number	D129363
Project Name	Blaenau Gwent SFCA
Catchment Name	Ebbw Fach River @ Six Bells, Abertillery
User Name	Rob Sweet
Technical Reviewer Name	Peter Mansell

AREA	30.27
FARL	0.958
BFIHOST	0.531
SAAR	1463
SPRHOST	31.08
$URBEXT_{2000}$	0.0777

Calculation of rural QMED

QMED rural = 15.22

This is the revised Qmed Equation based on Science Report: SC050050 - Improving the FEH statistical procedures for flood frequency estimation. This can be accessed at:

http://publications.environment-agency.gov.uk/pdf/SCHO0608BOFF-e-e.pdf

Calculation of urban adjusted QMED applicable if catchment is urban (URBEXT2000 > 0.03).

QMED =UAF x QMED rural
where $UAF = (1+URBEXT)^{0.37}PRUAF^{2.16}$
and $PRUAF = 1 + 0.47URBEXT_{2000}((70/SPRHOST)-1)$

PRUAF =	1.046
UAF =	1.132
QMED =	**17.232**

To reflect $URBEXT_{2000}$ values, the UAF equation has been updated using guidance provided in report FD1919 - $URBEXT_{2000}$ A New FEH catchment descriptor and Kjeldsen, T.R. 2010 'Modelling the impact of urbanisation on flood frequency relationships in the UK', Hydrology Research, 41(5), 391-405.

As per WINFAP-FEH v3 User Guide, the use of Data Transfer methods to improve the estimate of QMED is not recommended where the catchment is urbanised (i.e. $URBEXT_{2000}$ > 0.03).

Appendix B – ReFH Calculation Sheets

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:22
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	5	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	1	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

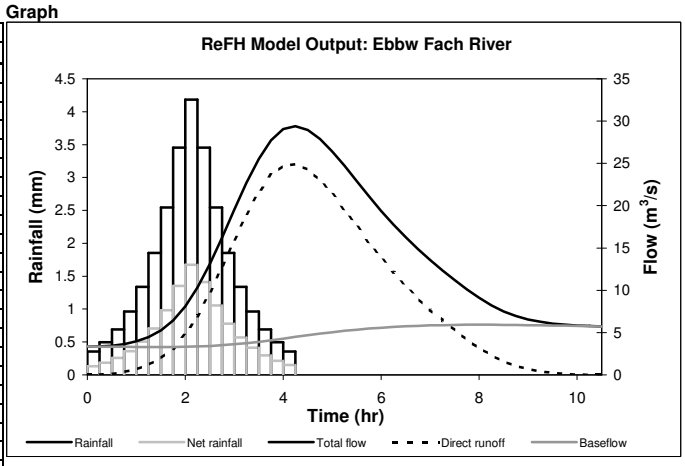
Summary of results

FEH DDF rainfall (mm)	35.7	**Peak rainfall (mm)**	4.2
Design rainfall (mm)	27.6	**Peak flow (m^3/s)**	29.4

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.4	0.1	0.0	3.4	3.4
0.25	0.5	0.2	0.0	3.3	3.4
0.50	0.7	0.3	0.1	3.3	3.5
0.75	1.0	0.4	0.3	3.3	3.6
1.00	1.3	0.5	0.7	3.3	4.0
1.25	1.9	0.7	1.2	3.3	4.5
1.50	2.5	1.0	2.0	3.3	5.3
1.75	3.5	1.4	3.1	3.3	6.4
2.00	4.2	1.7	4.8	3.3	8.1
2.25	3.5	1.4	7.0	3.4	10.3
2.50	2.5	1.1	9.7	3.4	13.1
2.75	1.9	0.8	12.7	3.5	16.2
3.00	1.3	0.6	15.9	3.6	19.5
3.25	1.0	0.4	18.9	3.8	22.7
3.50	0.7	0.3	21.6	3.9	25.5
3.75	0.5	0.2	23.6	4.1	27.7
4.00	0.4	0.2	24.8	4.3	29.1
4.25	0.0	0.0	24.9	4.5	29.4
4.50	0.0	0.0	24.2	4.7	28.9
4.75	0.0	0.0	23.0	4.9	27.9
5.00	0.0	0.0	21.4	5.1	26.4
5.25	0.0	0.0	19.5	5.2	24.7
5.50	0.0	0.0	17.5	5.3	22.9
5.75	0.0	0.0	15.6	5.5	21.1
6.00	0.0	0.0	13.8	5.6	19.4
6.25	0.0	0.0	12.1	5.7	17.8
6.50	0.0	0.0	10.5	5.7	16.3
6.75	0.0	0.0	9.1	5.8	14.9
7.00	0.0	0.0	7.7	5.8	13.6
7.25	0.0	0.0	6.5	5.9	12.3
7.50	0.0	0.0	5.3	5.9	11.2
7.75	0.0	0.0	4.2	5.9	10.1
8.00	0.0	0.0	3.2	5.9	9.1
8.25	0.0	0.0	2.3	5.9	8.2
8.50	0.0	0.0	1.6	5.9	7.5
8.75	0.0	0.0	1.1	5.9	7.0
9.00	0.0	0.0	0.7	5.9	6.6
9.25	0.0	0.0	0.4	5.9	6.3
9.50	0.0	0.0	0.2	5.8	6.1
9.75	0.0	0.0	0.1	5.8	5.9
10.00	0.0	0.0	0.1	5.8	5.8
10.25	0.0	0.0	0.0	5.8	5.8
10.50	0.0	0.0	0.0	5.7	5.7
Total (mm)	**27.6**	**11.0**	**11.0**	**6.1**	**17.2**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:22
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	10	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.98	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

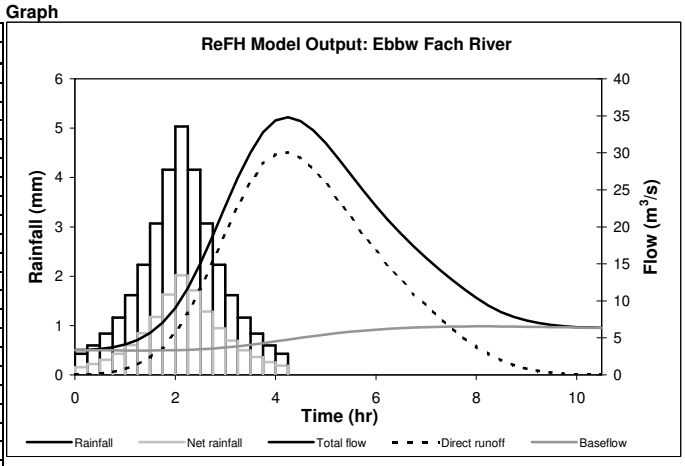
Summary of results

FEH DDF rainfall (mm)	43	**Peak rainfall (mm)**	5
Design rainfall (mm)	33.2	**Peak flow (m^3/s)**	34.8

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.4	0.2	0.0	3.4	3.4
0.25	0.6	0.2	0.0	3.3	3.4
0.50	0.8	0.3	0.2	3.3	3.5
0.75	1.2	0.4	0.4	3.3	3.7
1.00	1.6	0.6	0.8	3.3	4.1
1.25	2.2	0.8	1.4	3.3	4.7
1.50	3.1	1.2	2.3	3.3	5.6
1.75	4.2	1.6	3.7	3.3	7.0
2.00	5.0	2.0	5.7	3.3	9.0
2.25	4.2	1.7	8.3	3.4	11.7
2.50	3.1	1.3	11.6	3.5	15.0
2.75	2.2	0.9	15.3	3.6	18.8
3.00	1.6	0.7	19.1	3.7	22.8
3.25	1.2	0.5	22.8	3.9	26.6
3.50	0.8	0.4	26.0	4.1	30.1
3.75	0.6	0.3	28.5	4.3	32.8
4.00	0.4	0.2	29.9	4.5	34.4
4.25	0.0	0.0	30.1	4.8	34.8
4.50	0.0	0.0	29.3	5.0	34.3
4.75	0.0	0.0	27.8	5.2	33.0
5.00	0.0	0.0	25.8	5.5	31.3
5.25	0.0	0.0	23.6	5.6	29.2
5.50	0.0	0.0	21.2	5.8	27.1
5.75	0.0	0.0	18.9	6.0	24.9
6.00	0.0	0.0	16.7	6.1	22.8
6.25	0.0	0.0	14.6	6.2	20.9
6.50	0.0	0.0	12.8	6.3	19.1
6.75	0.0	0.0	11.0	6.4	17.4
7.00	0.0	0.0	9.4	6.4	15.8
7.25	0.0	0.0	7.8	6.5	14.3
7.50	0.0	0.0	6.4	6.5	12.9
7.75	0.0	0.0	5.1	6.5	11.6
8.00	0.0	0.0	3.9	6.6	10.4
8.25	0.0	0.0	2.8	6.6	9.4
8.50	0.0	0.0	1.9	6.5	8.5
8.75	0.0	0.0	1.3	6.5	7.8
9.00	0.0	0.0	0.8	6.5	7.3
9.25	0.0	0.0	0.5	6.5	7.0
9.50	0.0	0.0	0.3	6.5	6.7
9.75	0.0	0.0	0.2	6.4	6.6
10.00	0.0	0.0	0.1	6.4	6.5
10.25	0.0	0.0	0.0	6.4	6.4
10.50	0.0	0.0	0.0	6.3	6.3
Total (mm)	**33.2**	**13.3**	**13.3**	**6.6**	**19.9**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:22
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	20	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.94	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

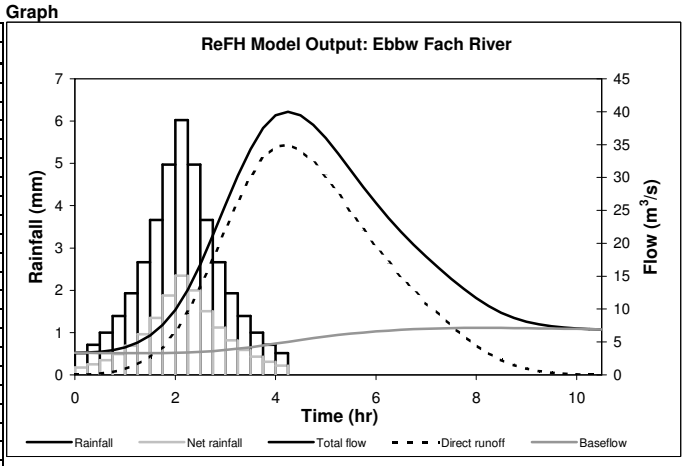
Summary of results

FEH DDF rainfall (mm)	51.3	**Peak rainfall (mm)**	6
Design rainfall (mm)	39.7	**Peak flow (m^3/s)**	40

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.5	0.2	0.0	3.4	3.4
0.25	0.7	0.2	0.0	3.3	3.4
0.50	1.0	0.3	0.2	3.3	3.5
0.75	1.4	0.5	0.4	3.3	3.8
1.00	1.9	0.7	0.9	3.3	4.2
1.25	2.7	1.0	1.6	3.3	4.9
1.50	3.7	1.4	2.7	3.3	6.0
1.75	5.0	1.9	4.3	3.3	7.6
2.00	6.0	2.3	6.5	3.4	9.9
2.25	5.0	2.0	9.5	3.4	12.9
2.50	3.7	1.5	13.3	3.5	16.8
2.75	2.7	1.1	17.6	3.6	21.2
3.00	1.9	0.8	22.0	3.8	25.8
3.25	1.4	0.6	26.3	4.0	30.3
3.50	1.0	0.4	30.1	4.2	34.3
3.75	0.7	0.3	33.0	4.5	37.5
4.00	0.5	0.2	34.7	4.7	39.4
4.25	0.0	0.0	35.0	5.0	40.0
4.50	0.0	0.0	34.1	5.3	39.4
4.75	0.0	0.0	32.4	5.6	38.0
5.00	0.0	0.0	30.2	5.8	36.0
5.25	0.0	0.0	27.5	6.1	33.6
5.50	0.0	0.0	24.8	6.3	31.1
5.75	0.0	0.0	22.1	6.4	28.5
6.00	0.0	0.0	19.5	6.6	26.1
6.25	0.0	0.0	17.1	6.7	23.9
6.50	0.0	0.0	14.9	6.8	21.8
6.75	0.0	0.0	12.9	6.9	19.8
7.00	0.0	0.0	11.0	7.0	18.0
7.25	0.0	0.0	9.2	7.1	16.2
7.50	0.0	0.0	7.5	7.1	14.6
7.75	0.0	0.0	6.0	7.1	13.1
8.00	0.0	0.0	4.5	7.1	11.7
8.25	0.0	0.0	3.3	7.1	10.5
8.50	0.0	0.0	2.3	7.1	9.4
8.75	0.0	0.0	1.5	7.1	8.6
9.00	0.0	0.0	1.0	7.1	8.1
9.25	0.0	0.0	0.6	7.1	7.7
9.50	0.0	0.0	0.3	7.0	7.4
9.75	0.0	0.0	0.2	7.0	7.2
10.00	0.0	0.0	0.1	7.0	7.1
10.25	0.0	0.0	0.0	7.0	7.0
10.50	0.0	0.0	0.0	6.9	6.9
Total (mm)	**39.7**	**15.5**	**15.5**	**7.0**	**22.5**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:23
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	25	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.92	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

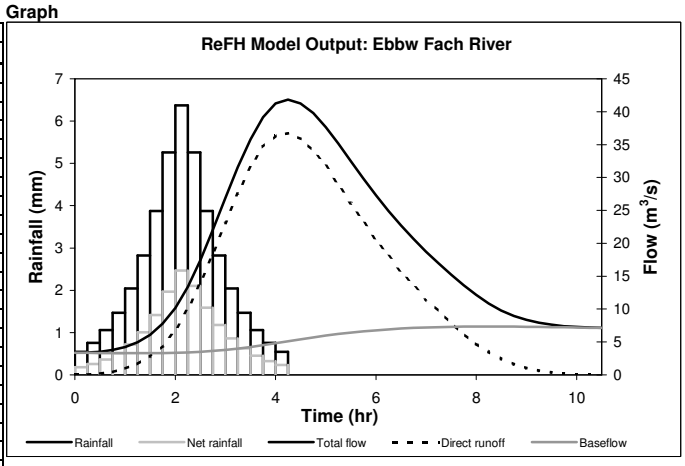
Summary of results

FEH DDF rainfall (mm)	54.3	**Peak rainfall (mm)**	6.4
Design rainfall (mm)	42	**Peak flow (m^3/s)**	41.8

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.5	0.2	0.0	3.4	3.4
0.25	0.8	0.3	0.0	3.3	3.4
0.50	1.1	0.4	0.2	3.3	3.5
0.75	1.5	0.5	0.5	3.3	3.8
1.00	2.0	0.7	0.9	3.3	4.2
1.25	2.8	1.0	1.7	3.3	5.0
1.50	3.9	1.4	2.8	3.3	6.1
1.75	5.3	2.0	4.4	3.3	7.8
2.00	6.4	2.5	6.8	3.4	10.1
2.25	5.3	2.1	10.0	3.4	13.4
2.50	3.9	1.6	13.9	3.5	17.4
2.75	2.8	1.2	18.4	3.6	22.0
3.00	2.0	0.9	23.0	3.8	26.8
3.25	1.5	0.6	27.6	4.0	31.6
3.50	1.1	0.5	31.6	4.3	35.8
3.75	0.8	0.3	34.7	4.5	39.2
4.00	0.5	0.2	36.4	4.8	41.2
4.25	0.0	0.0	36.7	5.1	41.8
4.50	0.0	0.0	35.8	5.4	41.3
4.75	0.0	0.0	34.1	5.7	39.8
5.00	0.0	0.0	31.7	6.0	37.7
5.25	0.0	0.0	29.0	6.2	35.2
5.50	0.0	0.0	26.1	6.4	32.5
5.75	0.0	0.0	23.2	6.6	29.9
6.00	0.0	0.0	20.5	6.8	27.3
6.25	0.0	0.0	18.0	6.9	24.9
6.50	0.0	0.0	15.7	7.0	22.7
6.75	0.0	0.0	13.5	7.1	20.7
7.00	0.0	0.0	11.5	7.2	18.8
7.25	0.0	0.0	9.7	7.3	16.9
7.50	0.0	0.0	7.9	7.3	15.2
7.75	0.0	0.0	6.3	7.3	13.6
8.00	0.0	0.0	4.8	7.4	12.2
8.25	0.0	0.0	3.5	7.4	10.8
8.50	0.0	0.0	2.4	7.4	9.8
8.75	0.0	0.0	1.6	7.3	8.9
9.00	0.0	0.0	1.0	7.3	8.3
9.25	0.0	0.0	0.6	7.3	7.9
9.50	0.0	0.0	0.4	7.3	7.6
9.75	0.0	0.0	0.2	7.2	7.4
10.00	0.0	0.0	0.1	7.2	7.3
10.25	0.0	0.0	0.0	7.2	7.2
10.50	0.0	0.0	0.0	7.1	7.1
Total (mm)	**42.0**	**16.3**	**16.3**	**7.1**	**23.4**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:24
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	50	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.88	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

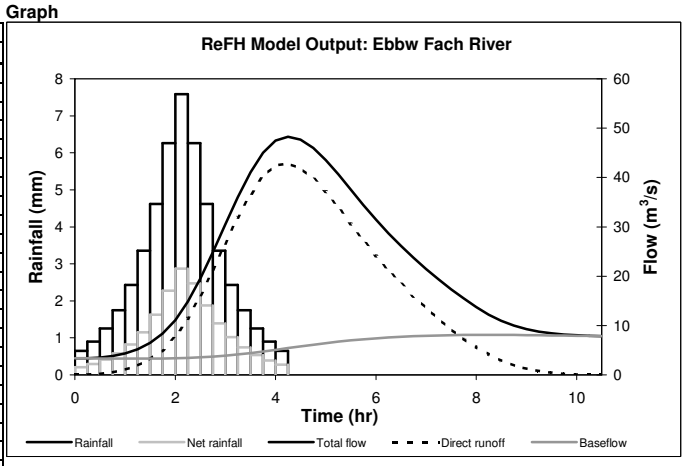
Summary of results

FEH DDF rainfall (mm)	64.7	**Peak rainfall (mm)**	7.6
Design rainfall (mm)	50	**Peak flow (m^3/s)**	48.3

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.6	0.2	0.0	3.4	3.4
0.25	0.9	0.3	0.0	3.3	3.4
0.50	1.3	0.4	0.2	3.3	3.5
0.75	1.7	0.6	0.5	3.3	3.8
1.00	2.4	0.8	1.0	3.3	4.4
1.25	3.4	1.2	1.9	3.3	5.2
1.50	4.6	1.6	3.2	3.3	6.5
1.75	6.3	2.3	5.1	3.3	8.4
2.00	7.6	2.9	7.7	3.4	11.1
2.25	6.3	2.5	11.4	3.4	14.8
2.50	4.6	1.9	16.0	3.6	19.5
2.75	3.4	1.4	21.2	3.7	24.9
3.00	2.4	1.0	26.6	3.9	30.5
3.25	1.7	0.7	31.9	4.1	36.0
3.50	1.3	0.5	36.6	4.4	41.0
3.75	0.9	0.4	40.3	4.7	45.0
4.00	0.6	0.3	42.4	5.1	47.5
4.25	0.0	0.0	42.8	5.4	48.3
4.50	0.0	0.0	41.9	5.8	47.7
4.75	0.0	0.0	39.9	6.1	46.0
5.00	0.0	0.0	37.1	6.4	43.5
5.25	0.0	0.0	33.9	6.7	40.7
5.50	0.0	0.0	30.6	7.0	37.6
5.75	0.0	0.0	27.3	7.2	34.5
6.00	0.0	0.0	24.1	7.4	31.5
6.25	0.0	0.0	21.1	7.6	28.7
6.50	0.0	0.0	18.4	7.7	26.1
6.75	0.0	0.0	15.9	7.8	23.7
7.00	0.0	0.0	13.6	7.9	21.5
7.25	0.0	0.0	11.4	8.0	19.3
7.50	0.0	0.0	9.3	8.0	17.3
7.75	0.0	0.0	7.4	8.1	15.5
8.00	0.0	0.0	5.7	8.1	13.8
8.25	0.0	0.0	4.1	8.1	12.2
8.50	0.0	0.0	2.9	8.1	11.0
8.75	0.0	0.0	1.9	8.1	10.0
9.00	0.0	0.0	1.2	8.1	9.3
9.25	0.0	0.0	0.8	8.0	8.8
9.50	0.0	0.0	0.4	8.0	8.4
9.75	0.0	0.0	0.2	8.0	8.2
10.00	0.0	0.0	0.1	7.9	8.0
10.25	0.0	0.0	0.0	7.9	7.9
10.50	0.0	0.0	0.0	7.9	7.9
Total (mm)	**50.0**	**19.0**	**19.0**	**7.7**	**26.6**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
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URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:24
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	75	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.85	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

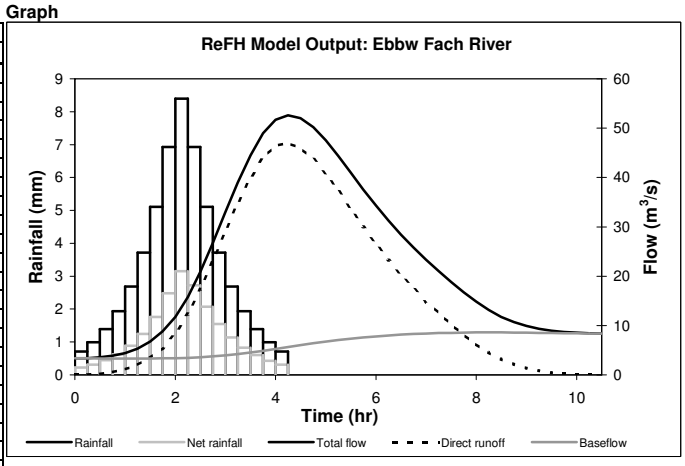
Summary of results

FEH DDF rainfall (mm)	71.6	**Peak rainfall (mm)**	8.4
Design rainfall (mm)	55.4	**Peak flow (m^3/s)**	52.6

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.7	0.2	0.0	3.4	3.4
0.25	1.0	0.3	0.0	3.3	3.4
0.50	1.4	0.4	0.2	3.3	3.5
0.75	1.9	0.6	0.6	3.3	3.9
1.00	2.7	0.9	1.1	3.3	4.4
1.25	3.7	1.2	2.0	3.3	5.3
1.50	5.1	1.8	3.4	3.3	6.7
1.75	6.9	2.5	5.5	3.3	8.8
2.00	8.4	3.2	8.4	3.4	11.7
2.25	6.9	2.7	12.3	3.5	15.8
2.50	5.1	2.1	17.3	3.6	20.9
2.75	3.7	1.5	23.0	3.7	26.7
3.00	2.7	1.1	29.0	4.0	32.9
3.25	1.9	0.8	34.8	4.2	39.0
3.50	1.4	0.6	40.0	4.5	44.5
3.75	1.0	0.4	44.1	4.9	48.9
4.00	0.7	0.3	46.4	5.3	51.7
4.25	0.0	0.0	47.0	5.6	52.6
4.50	0.0	0.0	46.0	6.0	52.0
4.75	0.0	0.0	43.8	6.4	50.2
5.00	0.0	0.0	40.8	6.7	47.5
5.25	0.0	0.0	37.3	7.1	44.4
5.50	0.0	0.0	33.6	7.3	41.0
5.75	0.0	0.0	30.0	7.6	37.6
6.00	0.0	0.0	26.5	7.8	34.3
6.25	0.0	0.0	23.3	8.0	31.2
6.50	0.0	0.0	20.3	8.1	28.4
6.75	0.0	0.0	17.5	8.3	25.8
7.00	0.0	0.0	14.9	8.4	23.3
7.25	0.0	0.0	12.5	8.5	21.0
7.50	0.0	0.0	10.3	8.5	18.8
7.75	0.0	0.0	8.2	8.6	16.7
8.00	0.0	0.0	6.3	8.6	14.9
8.25	0.0	0.0	4.6	8.6	13.2
8.50	0.0	0.0	3.2	8.6	11.8
8.75	0.0	0.0	2.1	8.6	10.7
9.00	0.0	0.0	1.4	8.6	9.9
9.25	0.0	0.0	0.8	8.5	9.4
9.50	0.0	0.0	0.5	8.5	9.0
9.75	0.0	0.0	0.3	8.5	8.7
10.00	0.0	0.0	0.1	8.4	8.5
10.25	0.0	0.0	0.0	8.4	8.4
10.50	0.0	0.0	0.0	8.3	8.3
Total (mm)	**55.4**	**20.8**	**20.8**	**8.0**	**28.8**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:24
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	100	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.83	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

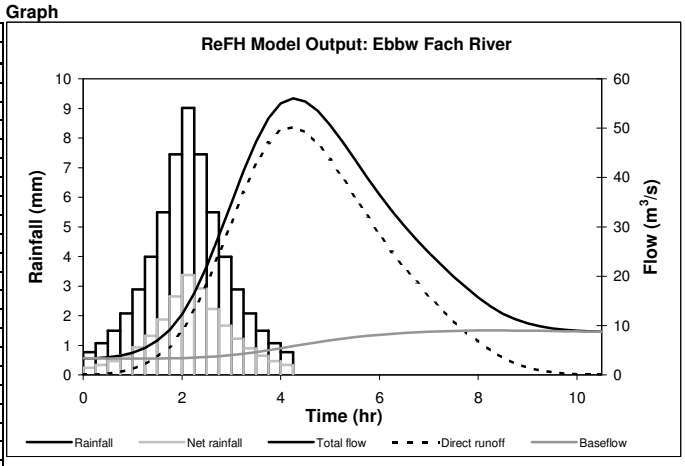
Summary of results

FEH DDF rainfall (mm)	76.9	**Peak rainfall (mm)**	9
Design rainfall (mm)	59.5	**Peak flow (m^3/s)**	56

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.8	0.2	0.0	3.4	3.4
0.25	1.1	0.3	0.1	3.3	3.4
0.50	1.5	0.5	0.2	3.3	3.6
0.75	2.1	0.7	0.6	3.3	3.9
1.00	2.9	0.9	1.2	3.3	4.5
1.25	4.0	1.3	2.1	3.3	5.5
1.50	5.5	1.9	3.6	3.3	6.9
1.75	7.4	2.6	5.8	3.3	9.1
2.00	9.0	3.4	8.8	3.4	12.2
2.25	7.4	2.9	13.0	3.5	16.5
2.50	5.5	2.2	18.4	3.6	22.0
2.75	4.0	1.7	24.4	3.8	28.2
3.00	2.9	1.2	30.8	4.0	34.8
3.25	2.1	0.9	37.0	4.3	41.3
3.50	1.5	0.6	42.6	4.6	47.2
3.75	1.1	0.5	47.0	5.0	52.0
4.00	0.8	0.3	49.6	5.4	55.0
4.25	0.0	0.0	50.2	5.8	56.0
4.50	0.0	0.0	49.2	6.2	55.4
4.75	0.0	0.0	46.9	6.6	53.5
5.00	0.0	0.0	43.7	7.0	50.7
5.25	0.0	0.0	40.0	7.3	47.3
5.50	0.0	0.0	36.0	7.6	43.7
5.75	0.0	0.0	32.1	7.9	40.0
6.00	0.0	0.0	28.4	8.1	36.5
6.25	0.0	0.0	24.9	8.3	33.3
6.50	0.0	0.0	21.7	8.5	30.2
6.75	0.0	0.0	18.8	8.6	27.4
7.00	0.0	0.0	16.0	8.8	24.8
7.25	0.0	0.0	13.4	8.8	22.3
7.50	0.0	0.0	11.0	8.9	19.9
7.75	0.0	0.0	8.8	9.0	17.7
8.00	0.0	0.0	6.7	9.0	15.7
8.25	0.0	0.0	4.9	9.0	13.9
8.50	0.0	0.0	3.4	9.0	12.4
8.75	0.0	0.0	2.3	9.0	11.3
9.00	0.0	0.0	1.5	9.0	10.4
9.25	0.0	0.0	0.9	8.9	9.8
9.50	0.0	0.0	0.5	8.9	9.4
9.75	0.0	0.0	0.3	8.8	9.1
10.00	0.0	0.0	0.1	8.8	8.9
10.25	0.0	0.0	0.0	8.8	8.8
10.50	0.0	0.0	0.0	8.7	8.7
Total (mm)	**59.5**	**22.2**	**22.2**	**8.3**	**30.5**

Graph



Audit comments

Catchment

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Catchment descriptor file = 'Six Bells.csv'
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DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:25
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	200	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.79	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

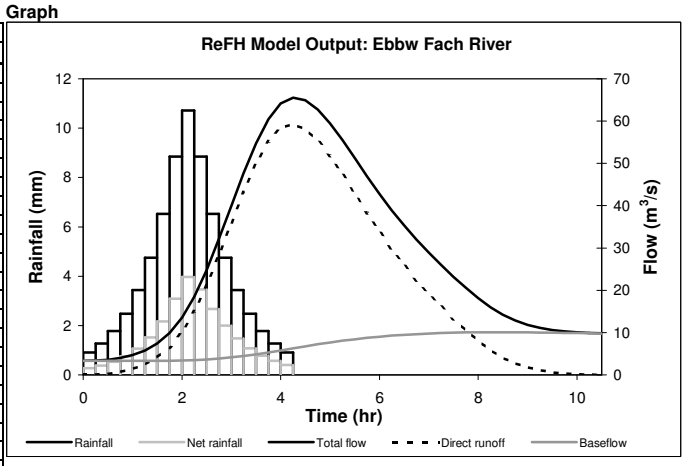
Summary of results

FEH DDF rainfall (mm)	91.4	**Peak rainfall (mm)**	10.7
Design rainfall (mm)	70.7	**Peak flow (m^3/s)**	65.5

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	0.9	0.3	0.0	3.4	3.4
0.25	1.3	0.4	0.1	3.3	3.4
0.50	1.8	0.5	0.3	3.3	3.6
0.75	2.5	0.8	0.7	3.3	4.0
1.00	3.4	1.1	1.3	3.3	4.7
1.25	4.7	1.5	2.4	3.3	5.7
1.50	6.5	2.2	4.1	3.3	7.4
1.75	8.8	3.1	6.6	3.4	9.9
2.00	10.7	4.0	10.1	3.4	13.5
2.25	8.8	3.5	15.0	3.5	18.5
2.50	6.5	2.7	21.2	3.7	24.8
2.75	4.7	2.0	28.3	3.9	32.2
3.00	3.4	1.5	35.8	4.1	39.9
3.25	2.5	1.1	43.2	4.5	47.7
3.50	1.8	0.8	49.9	4.8	54.7
3.75	1.3	0.6	55.2	5.3	60.5
4.00	0.9	0.4	58.4	5.8	64.2
4.25	0.0	0.0	59.3	6.3	65.5
4.50	0.0	0.0	58.1	6.8	64.9
4.75	0.0	0.0	55.5	7.2	62.7
5.00	0.0	0.0	51.8	7.7	59.5
5.25	0.0	0.0	47.5	8.1	55.5
5.50	0.0	0.0	42.8	8.4	51.2
5.75	0.0	0.0	38.2	8.8	46.9
6.00	0.0	0.0	33.8	9.0	42.8
6.25	0.0	0.0	29.6	9.3	38.9
6.50	0.0	0.0	25.8	9.5	35.3
6.75	0.0	0.0	22.4	9.6	32.0
7.00	0.0	0.0	19.1	9.8	28.9
7.25	0.0	0.0	16.0	9.9	25.9
7.50	0.0	0.0	13.2	10.0	23.1
7.75	0.0	0.0	10.5	10.0	20.5
8.00	0.0	0.0	8.1	10.1	18.1
8.25	0.0	0.0	5.9	10.1	16.0
8.50	0.0	0.0	4.1	10.1	14.2
8.75	0.0	0.0	2.8	10.1	12.8
9.00	0.0	0.0	1.8	10.0	11.8
9.25	0.0	0.0	1.1	10.0	11.1
9.50	0.0	0.0	0.6	10.0	10.6
9.75	0.0	0.0	0.3	9.9	10.3
10.00	0.0	0.0	0.1	9.9	10.0
10.25	0.0	0.0	0.0	9.8	9.9
10.50	0.0	0.0	0.0	9.8	9.8
Total (mm)	**70.7**	**26.2**	**26.2**	**9.1**	**35.3**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:25
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	500	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.74	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

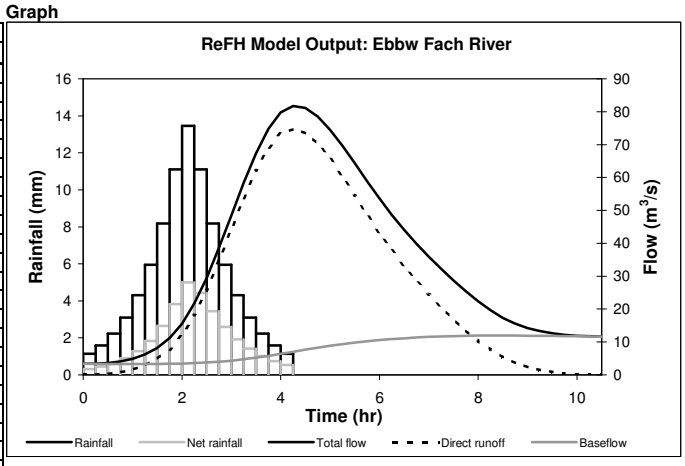
Summary of results

FEH DDF rainfall (mm)	114.7	**Peak rainfall (mm)**	13.5
Design rainfall (mm)	88.7	**Peak flow (m^3/s)**	81.7

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	1.1	0.3	0.0	3.4	3.4
0.25	1.6	0.4	0.1	3.3	3.4
0.50	2.2	0.6	0.3	3.3	3.6
0.75	3.1	0.9	0.8	3.3	4.1
1.00	4.3	1.3	1.6	3.3	4.9
1.25	6.0	1.8	2.9	3.3	6.2
1.50	8.2	2.6	4.9	3.3	8.2
1.75	11.1	3.8	7.8	3.4	11.2
2.00	13.5	5.0	12.1	3.5	15.6
2.25	11.1	4.4	18.1	3.6	21.6
2.50	8.2	3.4	25.8	3.7	29.5
2.75	6.0	2.6	34.7	4.0	38.7
3.00	4.3	1.9	44.1	4.3	48.5
3.25	3.1	1.4	53.5	4.7	58.3
3.50	2.2	1.0	62.1	5.2	67.4
3.75	1.6	0.7	69.0	5.8	74.8
4.00	1.1	0.5	73.3	6.4	79.7
4.25	0.0	0.0	74.7	7.0	81.7
4.50	0.0	0.0	73.5	7.6	81.1
4.75	0.0	0.0	70.3	8.2	78.6
5.00	0.0	0.0	65.8	8.8	74.6
5.25	0.0	0.0	60.3	9.3	69.6
5.50	0.0	0.0	54.5	9.8	64.3
5.75	0.0	0.0	48.6	10.2	58.8
6.00	0.0	0.0	43.0	10.6	53.6
6.25	0.0	0.0	37.8	10.9	48.6
6.50	0.0	0.0	33.0	11.1	44.1
6.75	0.0	0.0	28.5	11.4	39.9
7.00	0.0	0.0	24.4	11.5	35.9
7.25	0.0	0.0	20.5	11.7	32.2
7.50	0.0	0.0	16.9	11.8	28.7
7.75	0.0	0.0	13.5	11.9	25.4
8.00	0.0	0.0	10.4	11.9	22.4
8.25	0.0	0.0	7.7	12.0	19.6
8.50	0.0	0.0	5.4	12.0	17.3
8.75	0.0	0.0	3.6	11.9	15.5
9.00	0.0	0.0	2.3	11.9	14.2
9.25	0.0	0.0	1.4	11.9	13.3
9.50	0.0	0.0	0.8	11.8	12.7
9.75	0.0	0.0	0.4	11.8	12.2
10.00	0.0	0.0	0.2	11.7	11.9
10.25	0.0	0.0	0.1	11.7	11.7
10.50	0.0	0.0	0.0	11.6	11.6
Total (mm)	**88.7**	**33.0**	**33.0**	**10.4**	**43.4**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:26
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	1000	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	0.7	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

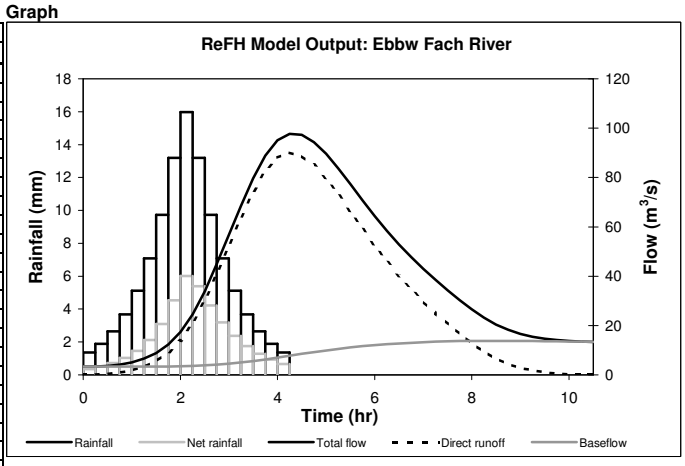
Summary of results

FEH DDF rainfall (mm)	136.2	**Peak rainfall (mm)**	16
Design rainfall (mm)	105.4	**Peak flow (m^3/s)**	97.7

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	mm	mm	m^3/s	m^3/s	m^3/s
0.00	1.4	0.4	0.0	3.4	3.4
0.25	1.9	0.5	0.1	3.3	3.4
0.50	2.6	0.7	0.3	3.3	3.7
0.75	3.7	1.0	0.9	3.3	4.2
1.00	5.1	1.5	1.8	3.3	5.1
1.25	7.1	2.1	3.3	3.3	6.6
1.50	9.7	3.1	5.5	3.3	8.9
1.75	13.2	4.5	9.0	3.4	12.3
2.00	16.0	6.0	13.9	3.5	17.4
2.25	13.2	5.4	21.0	3.6	24.6
2.50	9.7	4.2	30.1	3.8	33.9
2.75	7.1	3.2	40.7	4.1	44.8
3.00	5.1	2.4	52.1	4.5	56.6
3.25	3.7	1.8	63.5	5.0	68.5
3.50	2.6	1.3	74.0	5.6	79.6
3.75	1.9	0.9	82.6	6.3	88.9
4.00	1.4	0.7	88.1	7.0	95.1
4.25	0.0	0.0	90.0	7.7	97.7
4.50	0.0	0.0	88.8	8.5	97.3
4.75	0.0	0.0	85.1	9.2	94.3
5.00	0.0	0.0	79.7	9.9	89.6
5.25	0.0	0.0	73.2	10.6	83.7
5.50	0.0	0.0	66.1	11.1	77.3
5.75	0.0	0.0	59.1	11.6	70.7
6.00	0.0	0.0	52.3	12.1	64.3
6.25	0.0	0.0	45.9	12.4	58.3
6.50	0.0	0.0	40.1	12.8	52.9
6.75	0.0	0.0	34.7	13.0	47.8
7.00	0.0	0.0	29.7	13.3	43.0
7.25	0.0	0.0	25.1	13.4	38.5
7.50	0.0	0.0	20.7	13.6	34.3
7.75	0.0	0.0	16.6	13.7	30.3
8.00	0.0	0.0	12.8	13.8	26.6
8.25	0.0	0.0	9.4	13.8	23.2
8.50	0.0	0.0	6.6	13.8	20.4
8.75	0.0	0.0	4.5	13.8	18.2
9.00	0.0	0.0	2.9	13.8	16.6
9.25	0.0	0.0	1.8	13.7	15.5
9.50	0.0	0.0	1.0	13.7	14.7
9.75	0.0	0.0	0.5	13.6	14.1
10.00	0.0	0.0	0.2	13.5	13.8
10.25	0.0	0.0	0.1	13.5	13.5
10.50	0.0	0.0	0.0	13.4	13.4
Total (mm)	**105.4**	**39.7**	**39.7**	**11.7**	**51.4**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

User name	Dr Rob Sweet	**Catchment name**	Ebbw Fach River	**Date/time modelled**	28-Jan-2011 10:21
Company name	URS/Scott Wilson	**Catchment easting**	322050	**Version**	1.3
Project name	Blaenau Gwent - Six Bells	**Catchment northing**	203050		
		Catchment area	30.27		

Summary of model setup

Design rainfall parameters		Loss model parameters		Routing model parameters		Baseflow model parameters	
Return period (yr)	2	**C_{max} (mm)**	453	**T_p (hr)**	1.76	**BL (hr)**	54.2
Duration (hr)	4.25	**C_{ini} (mm)**	168	**U_p**	0.65	**BR**	1.92
Timestep (hr)	0.25	**α factor**	1	**U_k**	0.8	**BF_0 (m^3/s)**	3.4
Season	Winter						

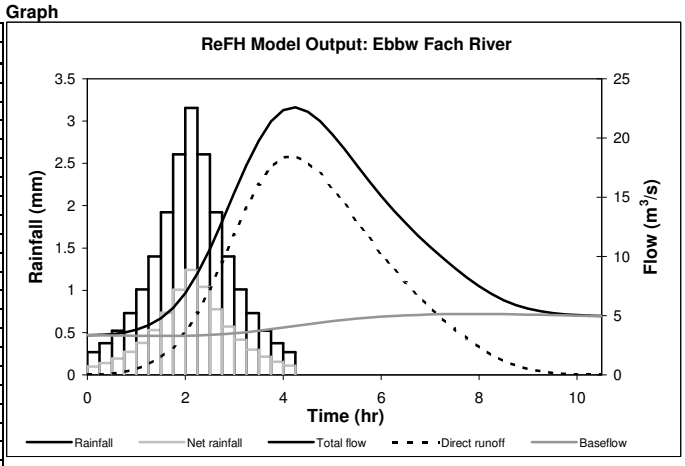
Summary of results

FEH DDF rainfall (mm)	26.9	**Peak rainfall (mm)**	3.2
Design rainfall (mm)	20.8	**Peak flow (m^3/s)**	22.6

Results

Series	Design Rainfall	Net rainfall	Direct runoff	Baseflow	Total flow
Unit	**mm**	**mm**	**m^3/s**	**m^3/s**	**m^3/s**
0.00	0.3	0.1	0.0	3.4	3.4
0.25	0.4	0.1	0.0	3.3	3.4
0.50	0.5	0.2	0.1	3.3	3.4
0.75	0.7	0.3	0.2	3.3	3.6
1.00	1.0	0.4	0.5	3.3	3.8
1.25	1.4	0.5	0.9	3.3	4.2
1.50	1.9	0.7	1.5	3.3	4.8
1.75	2.6	1.0	2.4	3.3	5.7
2.00	3.2	1.2	3.6	3.3	6.9
2.25	2.6	1.0	5.2	3.3	8.6
2.50	1.9	0.8	7.3	3.4	10.6
2.75	1.4	0.6	9.5	3.4	12.9
3.00	1.0	0.4	11.9	3.5	15.4
3.25	0.7	0.3	14.1	3.6	17.7
3.50	0.5	0.2	16.1	3.7	19.8
3.75	0.4	0.2	17.6	3.9	21.4
4.00	0.3	0.1	18.4	4.0	22.4
4.25	0.0	0.0	18.4	4.1	22.6
4.50	0.0	0.0	17.9	4.3	22.2
4.75	0.0	0.0	17.0	4.4	21.4
5.00	0.0	0.0	15.8	4.5	20.3
5.25	0.0	0.0	14.4	4.7	19.1
5.50	0.0	0.0	13.0	4.8	17.7
5.75	0.0	0.0	11.5	4.8	16.4
6.00	0.0	0.0	10.2	4.9	15.1
6.25	0.0	0.0	8.9	5.0	13.9
6.50	0.0	0.0	7.8	5.0	12.8
6.75	0.0	0.0	6.7	5.1	11.8
7.00	0.0	0.0	5.7	5.1	10.8
7.25	0.0	0.0	4.8	5.1	9.9
7.50	0.0	0.0	3.9	5.1	9.0
7.75	0.0	0.0	3.1	5.1	8.2
8.00	0.0	0.0	2.3	5.1	7.5
8.25	0.0	0.0	1.7	5.1	6.8
8.50	0.0	0.0	1.2	5.1	6.3
8.75	0.0	0.0	0.8	5.1	5.9
9.00	0.0	0.0	0.5	5.1	5.6
9.25	0.0	0.0	0.3	5.1	5.4
9.50	0.0	0.0	0.2	5.1	5.2
9.75	0.0	0.0	0.1	5.0	5.1
10.00	0.0	0.0	0.0	5.0	5.0
10.25	0.0	0.0	0.0	5.0	5.0
10.50	0.0	0.0	0.0	5.0	5.0
Total (mm)	**20.8**	**8.2**	**8.2**	**5.5**	**13.7**

Graph



Audit comments

Catchment

Catchment descriptors imported from file
Catchment descriptor file = 'Six Bells.csv'
Catchment decriptor file exported from CD ROM version 3
Catchment descriptor file exported on 24-Jan-2011 15:22
BFIHOST value of 0.531 used
PROPWET value of 0.54 used
SAAR value of 1463 used
DPLBAR value of 6.34 used
DPSBAR value of 212.4 used
URBEXT value of 0.0645 used
URBEXT changed from imported value of 0.0604 to 0.0645
C value of -0.02615 used
D1 value of 0.46856 used
D2 value of 0.42887 used
D3 value of 0.36249 used
E value of 0.28569 used
F value of 2.52452 used

Rainfall

Recommended season is Winter, as URBEXT < 0.125
ReFH design standard Seasonal Correction Factor of 0.84 applied
ReFH design standard Areal Reduction Factor of 0.93 applied

Loss Model

C_{Max} derived from catchment descriptors, with a user defined donor correction factor of 1.195 applied
ReFH design standard C_{ini} used
ReFH design standard α factor used

Routing Model

Revitalised FSR/FEH rainfall runoff method

Spreadsheet application report

T_p derived from catchment descriptors, with a user defined donor correction factor of 1.049 applied
ReFH design standard used for U_p
ReFH design standard used for U_k

Baseflow Model
BL derived from catchment descriptors, with a user defined donor correction factor of 1.693 applied
BR derived from catchment descriptors, with a user defined donor correction factor of 1.269 applied
ReFH design standard BF_0 used

Cmax, Tp, BL and BR adjusted using parameters for Station 56005 as per Supplementary Guidance

Appendix C – Derivation of Values used in the Manning's Equation

Estimation of Culvert Area

In order to estimate the culvert area, wetted perimeter and hydraulic radius, the culvert parameters as provided in the Structural Inspection Report were utilised. This represents the best available data to undertake such measurements. Only one dimension measurement was provided for both the height (from invert to soffit at the arch high point) and width of the culvert. Therefore, establishing accurate dimensions of the culvert arch is not possible. As a result, the culvert area was estimated by breaking the area down into solid shapes for simple area calculations, as shown in Figure 2 below

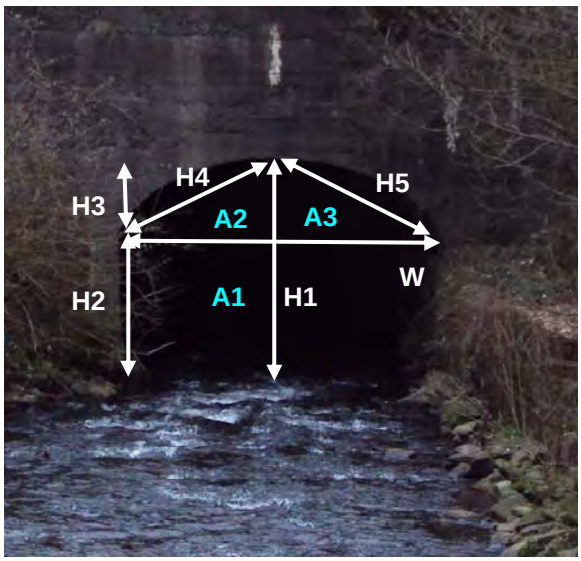


Figure 2 Culvert area breakdown used to aid estimation of the culvert area, wetted perimeter and hydraulic radius. H = Height W = Width and A = Area

By using Figure 2 and the information provided within the Structural Inspection Report, the following parameters were identified and corresponding areas calculated:

- H1 – obtained from the Structural Inspection Report;
- W - obtained from the Structural Inspection Report;
- H3 – estimated as being 40% of H1;
- H2 – estimated as being 60% of H1;
- A1 = H2 x (W / 2);
- A2 and A3 = (W / 2 x H3) x 0.5

The above calculation is believed to represent a conservative estimation of the culvert area, as derivation of the two triangles to represent the culvert arch has removed a small section of the arch.

Estimation of Manning's 'n' Value

The Manning's 'n' value represents the roughness and therefore friction forces acting upon water flowing through the culvert. The Manning's 'n' values have been derived using standard tables provided by Chow, 1959[2]. Using this reference, the bed material would have an approximate 'n' value of 0.04 with the culvert itself having a value of 0.015. Therefore, an average value of 0.02 has been used in the Manning's Equation.

Estimation of Hydraulic Radius

In order to calculate the hydraulic radius, the following formula has been used:

R = A / WP

Where R is the hydraulic radius, A is the culvert area (see above) and WP is the wetted perimeter. Using Figure 2 above, the wetted perimeter is calculated as follows:

(H2 x 2) + H4 + H5 + W

Estimation of Channel Slope

The culvert Structural Inspection Report did not provide the topographic levels of the river bed at either the upstream or downstream extent of the culvert. Therefore, in order to obtain the approximate bed levels and therefore determine the channel gradient, LiDAR Light Detection and Ranging) topographic data was utilised. This data was provided by the Environment Agency for use in the SFCA and deemed reasonably accurate enough to obtain the channel slope for use in the Manning's Equation. The approximated levels measured from the LiDAR data are:

- Upstream bed level at culvert inlet = 176.9mAOD
- Downstream bed level at culvert outlet = 175.2mAOD
- Length of culvert = 122m
- Resulting gradient = 0.01 (1 in 100)

[2] Chow, Ven Te, 1959,. *Open Channel Hydraulics*. McGraw Hill