A14.2 Surface Water Hydrology

1 Introduction

1.1.1 This document provides detailed information on the hydrology relevant to the Flood Risk Assessment (FRA) of the A9/A96 Inshes to Smithton Scheme. It is noted that almost all watercourse catchments crossed by this Scheme are also crossed by the A96 Dualling Scheme (Inverness to Nairn including Nairn Bypass) and so the previous work referenced in Section 2.2 has formed the basis of this assessment.

1.1.2 The A9/A96 Inshes to Smithton Scheme involves the construction of approximately 3km of carriageway and associated infrastructure which provides local access between Inshes to the south-east of Inverness and Smithton to the north east. For the DMRB Stage 2 assessment six route options have been considered. A preferred option will be selected for the DMRB Stage 3 assessment.

1.1.3 Hydrological estimates are required for the DMRB Stage 2 assessment. This report specifically provides information on the methods and approach used to derive design peak flow estimates for the culvert assessments of the smaller ungauged catchments. Design peak flows along with inflow hydrographs have also been derived for the Cairnlaw Burn (SWF 08) and Scretan Burn (SWF 04) which are identified for detailed hydraulic (numerical) modelling. This report also provides information on the methods used to derive low flow estimates at the road drainage outfall locations for dilution calculations of the receiving watercourses. The design peak flow estimates, inflow hydrographs and low flow estimates are presented within this report for the watercourses which have the potential to be impacted by the Scheme.

1.1.4 Within this Scheme, a total of 12 watercourses have been identified as having the potential to be impacted by the road and associated infrastructure. These watercourses are all relatively small in size (area<10km^2) consisting of small drainage ditches and small/moderate watercourses. The catchment areas of these watercourses are shown in Annex 14.2.1.

2 Approach and Methods

2.1 General Approach

2.1.1 Design peak flows, inflow flood hydrographs and low flow estimates are required to be produced for this DMRB Stage 2 Assessment for watercourses potentially impacted and/or crossed by the Scheme. Flood event peak flows with appropriate allowance for climate change are required for all watercourse crossing locations for the following annual exceedance probability (AEP) events: 50%, 20%, 10%, 3.33%, 2%, 1%, 0.5% and 0.1% (equivalent to the 2, 5, 10, 30, 50, 100, 200 and 1000-year return periods). For clarity, the notation used in this report, to describe for example the 0.5% AEP flood event, is '0.5% AEP (200-year) event[1]'. Inflow hydrographs are further required for the Cairnlaw and Scretan Burns and associated tributaries which have been identified for detailed hydraulic modelling. Low flow estimates such as Q95 and Qmean (average long-term flow) are also required for all road drainage outfall locations to assess the potential impacts of the outfalls on the receiving watercourses. The hydrological methods and approaches used to derive this required information are presented in the sections below.

[1] Annual Exceedence Probability (AEP) refers to the chance that a flood of a particular size is experienced or exceeded during any year. In this report we use a probability value expressed as a percentage to quantify this. For example a 50% AEP equates to a 1 in 2 chance of the flood being experienced or exceeded in a year. Similarly the 0.5% AEP equates to a 1 in 200 chance of the flood being experienced or exceeded in a year. It is important that the reader recognises that a low probability doesn't preclude the event happening in the following year – it's exactly analogous to rolling a dice such that having rolled one 6 the next throw would also be a 6.

2.2 Review of Previous Work

2.2.1 As part of the initial assessment for the A9/A96 Inshes to Smithton Scheme the following reports were reviewed and relevant information extracted:

- A96 Inshes to Nairn DMRB Stage 2 Assessment Scoping Study (Jacobs 2011);
- A96 Dualling Inverness to Nairn (including Nairn Bypass): DMRB Stage 2 Scheme Assessment Report (Jacobs 2014);
- A96 Dualling Inverness to Aberdeen Strategic Flood Risk Assessment (SFRA) (CH2M 2015a);
- A96 Dualling Inverness to Aberdeen Strategic Environmental Assessment, Tier 2 Environmental Report (CH2M, 2015b);
- A96 Dualling Inverness to Aberdeen Preliminary Engineering Assessment (Jacobs 2015);
- A9/A96 Connections Study Transport Appraisal Report (Jacobs 2016); and
- A96 Dualling Inverness to Nairn (Including Nairn Bypass) – DMRB Stage 3 Assessment Environmental Statement – Technical Appendices Flood Risk Assessment: Annex A13.2.G Hydrology Report (Jacobs, 2016).

2.2.2 A review of any Potential Vulnerable Areas[2] (PVA) within the project area and any historic flooding/culvert sizing issues/flood prone areas was also undertaken. SEPA Flood Maps were also reviewed to look for locations/properties at potential flood risk along the route.

2.3 Climate Change

2.3.1 Climate change considerations are required to be included as part of this assessment for the design flood events. At present the general approach to climate change is to increase design floods by 20%[3,4] in order to take into consideration the potential increase in flood flows that may occur in future as a result of a warming climate. This assessment follows standard practice and therefore an uplift factor of 20% has been applied to the design peak flow estimates.

2.3.2 No climate change adjustment factor has been applied to the low flows estimates.

2.4 Baseline Assessment

2.4.1 To undertake this assessment all watercourses that could potentially be impacted by the Scheme were identified and a list of these features compiled. This was undertaken using a GIS basemap and layers showing the Scheme options development footprint. The list of potentially impacted watercourses and waterbodies formed the basis of the hydrological assessment.

2.4.2 The FEH CD-ROM v3 was used to derive catchment descriptors for all identified watercourses and waterbodies potentially impacted by the Scheme. It should be noted that the FEH CD-ROM is not ideal at picking up small catchments and that a review of the derived catchment parameters was required. Catchment boundaries have been checked on Ordnance Survey maps supplemented with 2m LiDAR derived contour data. For a small number of catchments alterations to the FEH catchment were required and the catchment parameters have been adjusted using FEH methodologies. All catchments had their catchment boundaries reviewed, particularly when the catchments contained ambiguous flat areas or if a known artificial influence was present in the catchment. Some catchments within the route corridor were not picked up by the FEH CD-ROM due to the software imposing a minimum area of $0.5km^2$. Some catchment areas were also not picked

[2] A PVA is an area which has been identified by SEPA as requiring further assessment due to the potential impact from flooding being assessed as being great enough to warrant further assessment / appraisal of Flood Risk Management actions.

[3] The Highways Agency et al. (2009). HD45/09 DMRB, Volume 11, Section 3, Part 10, Road Drainage and the Water Environment, 2009. The Highways Agency, Scottish Executive, Welsh Assembly Government and The Department for Regional Development Northern Ireland.

[4] SEPA (2015). Technical Flood Risk Guidance for Stakeholders (Reference: SS-NFR-P-002)

up correctly by the FEH CD-ROM. Where this was the case catchment descriptors have been borrowed (and adjusted by area) from either an adjacent catchment considered to share similar features or by extending the selection point further downstream to pick up the nearest catchment from within the FEH dataset catchment (if judged suitable). Standard FEH methodologies were used for specific parameters that can't be scaled based upon areal adjustment (e.g. DPLBAR, URBEXT and FARL).

2.4.3 A desk based assessment of local flood histories was also undertaken using a combination of previous third party reports and local knowledge if readily available. A review of anthropogenic activity within the catchments was also undertaken and any notable impacts or activities highlighted.

2.4.4 All road drainage outfall locations were also identified based upon the route options since low flow estimates are required at these locations for dilution calculations. Additionally, interaction with the hydraulic modelling team helped identify those watercourses requiring hydrological simulation within the detailed hydraulic (numerical) modelling.

2.5 Design Flood Flows

2.5.1 Peak flows are required for all watercourse crossing locations for the following annual exceedance probability (AEP) events: 50%, 20%, 10%, 3.33%, 2%, 1%, 0.5% and 0.1% (equivalent to the 2, 5, 10, 30, 50, 100, 200 and 1000-year return periods). Watercourses identified for detailed modelling require not only the peak flow but also the full inflow hydrograph. All watercourses within the Scheme have relatively small and ungauged catchments. Flow estimation for small, ungauged catchments is challenging and open to greater uncertainty than for larger catchments, where more relevant gauged data is likely to be available to aid flow estimation.

2.5.2 For all the catchments within the Scheme the index flood (QMED) was initially derived from catchment descriptors for each target site. It should be noted that deriving QMED from catchments descriptors alone is subject to greater uncertainty than derivation using suitable local gauged data. Therefore, these initial QMED values were adjusted for all catchments using a regionally derived QMED adjustment factor similar to those derived for the A96 Dualling (Inverness to Nairn including Nairn Bypass) Scheme. From the analysis of the five suitable high flow rated gauges in the Hydrometric Area 7 the ratio of station QMED(observed)/ QMED (catchment descriptors) values were found to vary from 1.51 to 2.46 and the geometric mean of the ratios is found to be 1.74. This regional QMED adjustment factor was adopted for all catchments in the Scheme.

2.5.3 To derive the return period peak flows, the flood growth curves for each of the target watercourses in the Scheme was adopted from the growth curve derived during the detailed hydrological assessment for the A96 (including Nairn Bypass) Scheme.

2.5.4 The FEH statistical method was assessed as the most appropriate method to use for design peak flow estimation for all the small ungauged catchments potentially impacted by the Scheme. This was based on an assessment which was undertaken as part of the A96 (including Nairn Bypass) Scheme where a comparison of the FEH statistical method with the FEH rainfall-runoff and the Revitalised Flood Hydrograph (ReFH2) methods was undertaken for the small ungauged catchments. The ReFH2 model was applied using FEH13 rainfall. The results from this study favoured the FEH statistical method for design peak flow estimation for small ungauged watercourses within the Scheme.

2.5.5 The Scheme crosses over two watercourses (the Cairnlaw Burn and the Scretan Burn) which have been assessed as being a flood risk/having hydraulic complexity within the catchment and therefore have been subject to detailed hydraulic modelling. As there is no suitable donor gauging stations in the locality which could be used for hydrograph shape derivation, the FEH rainfall-runoff based hydrograph shapes were adopted to derive the design inflows to be used in the hydraulic models. The storm duration adopted for generating the hydrograph shapes for the Cairnlaw Burn and the Scretan Burn were the catchment specific FEH rainfall-runoff based durations calculated at the downstream extent of the models (developed during the DMRB Stage 3 assessment for the A96 Dualling (Inverness to Nairn including Nairn Bypass) Scheme). Accordingly, for the Cairnlaw Burn the theoretical storm duration was 5.4 hrs. For the Scretan Burn a theoretical storm duration of 6.2 hours was calculated at the downstream extent of the hydrology model.

2.5.6 The design hydrographs used in the model were then scaled to match the design peak flow estimates derived using the FEH statistical method for the Cairnlaw Burn. This follows the same approach that was adopted for the A96 Dualling Inverness to Nairn (including Nairn Bypass) Scheme.

2.5.7 A number of minor tributaries of the Scretan Burn were identified for hydraulic modelling, and this required model inflows to be derived for these minor tributaries. In order to avoid using multiple scaling factors required to match the FEH rainfall-runoff and statistical peak flows for each of the tributaries, the model inflows were derived using the FEH rainfall-runoff method alone, without using any scaling factor, but applying the storm duration near the downstream modelling extent (i.e., at the crossing of the A96 Dualling Scheme). The modelled peak flow at this location was then reconciled with the target peak flow (derived using the FEH statistical method for the A96 Dualling Scheme) through the iterations in the hydraulic modelling, using appropriate single scaling factor for all tributary inflows.

2.6 Low Flow Estimates

2.6.1 Low flow estimates [95-percentile flow (Q95), mean flow (Qmean)] are required for all the outfall locations for the DMRB Stage 2 assessment. These low flow estimates are required to support water quality, ecological and geomorphological assessments on the receiving watercourses. The following methodology has been used for deriving the low flow estimates.

2.6.2 For all the receiving watercourses potentially impacted by this Scheme, the Low Flows Enterprise (LFE) data purchased for the A96 Dualling Scheme is assessed as suitable to use for the A9/A96 Scheme (refer to Table 2 below which is reproduced from Table 3 of the A96 Dualling Scheme Surface Water Hydrology Report). Areal scaling was applied to what was judged to be the most hydrologically similar LFE site in order to transpose the estimate to the target site.

Table 2: LFE gauges (reproduced from Table 3 of A96 Dualling Scheme Surface Water Hydrology Report)

Site	Catchment Area (km^2)	Easting	Northing	Q95 (m^3/s)	Qmean (m^3/s)
1	3.08	292276	856494	0.003	0.023
2	4.39	276933	850754	0.008	0.041
3	5.85	285231	854279	0.009	0.045
4	1.45	288982	854525	0.002	0.010

3 Baseline Hydrology

3.1.1 Adopted catchment descriptors for each of the watercourses that could potentially be impacted by the A9/A96 Inches to Smithton Scheme are presented in Table 3. Manual adjustment of catchment descriptor values are discussed in further detail in Annex 14.2.2.

Table 3: Target site catchment descriptors

Watercourse	SWF Reference	Catchment Area (km^2)	SAAR 1961 -1990 (mm)	BFI-HOST	SPR-HOST (%)	FARL	URBEXT (2000)
Mill Burn (u/s confluence)	SWF01 A	6.04	826	0.679	28.9	0.99	0.009

Watercourse	SWF Reference	Catchment Area (km^2)	SAAR 1961 -1990 (mm)	BFI-HOST	SPR-HOST (%)	FARL	URBEXT (2000)
Mill Burn (d/s confluence)	SWF01 B	8.53	798	0.679	30.2	0.99	0.051
Inshes Burn	SWF02	1.90	742	0.763	25.5	0.994	0.031
Tributary of Scretan Burn	SWF03	1.20	760	0.712	29.6	1	0.027
Scretan Burn @ A96	SWF04	7.20	741	0.764	25.4	1	0.037
Tributary of Scretan Burn	SWF05	0.30	760	0.712	29.6	1	0.064
Tributary of Scretan Burn	SWF06	0.06	760	0.712	29.6	1	0.029
Unnamed Drains	SWF07	0.04	760	0.626	32.4	1	0.000
Cairnlaw Burn @ A96	SWF08 A	5.19	772	0.606	32.4	0.972	0.073
Cairnlaw Burn (d/s SWF10 trib)	SWF08 B	2.25	781	0.584	33.1	0.949	0.043
Tributary of SWF10	SWF09	0.44	727	0.786	23.5	1	0.168
Tributary of Cairnlaw Burn	SWF10	2.89	757	0.638	31.4	1	0.095
Hotel watercourse (tributary of Cairnlaw Burn)	SWF11	0.24	738	0.653	33.9	1	0.013
Kenneth's Black Well	SWF12	5.69	729	0.679	33.3	1	0.076

4 Peak Flow Estimates

4.1.1 The peak flow estimates based upon the statistical FEH method for the following Annual Exceedance Probability (AEP) events 50%, 20%, 10%, 3.33%, 2%, 1%, 0.5% and 0.1% (equivalent to the 2, 5, 10, 30, 50, 100, 200 and 1000-year return periods) are presented below in Table 4. The 0.5% AEP estimate is also given including a +20% allowance for climate change (+CC).

Table 4: Peak Flow Estimates – FEH Statistical method (m^3/s)

Watercourse / Structure Reference	AEP 50% (2-yr)	AEP 20% (5-yr)	AEP 10% (10-yr)	AEP 3.3% (30-yr)	AEP 2% (50-yr)	AEP 1% (100-yr)	AEP 0.5% (200-yr)	AEP 0.5% + CC	AEP 0.1% (1000-yr)
SWF01 A (u/s confluence)	1.65	2.32	2.83	3.76	4.26	5.06	5.98	7.18	8.84
SWF01 B (d/s	2.28	3.20	3.90	5.18	5.88	6.98	8.26	9.91	12.2

Watercourse / Structure Reference	AEP 50% (2-yr)	AEP 20% (5-yr)	AEP 10% (10-yr)	AEP 3.3% (30-yr)	AEP 2% (50-yr)	AEP 1% (100-yr)	AEP 0.5% (200-yr)	AEP 0.5% + CC	AEP 0.1% (1000-yr)
confluence)									
SWF02	0.37	0.51	0.63	0.83	0.94	1.12	1.33	1.59	1.96
SWF03	0.33	0.46	0.56	0.74	0.84	1.00	1.19	1.42	1.75
SWF04	1.18	1.65	2.02	2.68	3.04	3.60	4.27	5.12	6.30
SWF05	0.11	0.16	0.19	0.25	0.29	0.34	0.40	0.49	0.60
SWF06	0.03	0.04	0.04	0.06	0.07	0.08	0.09	0.11	0.14
SWF07	0.02	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.13
SWF08 A (A96)	1.75	2.46	3.00	3.98	4.52	5.36	6.35	7.62	9.37
SWF08 B (d/s SWF10 tributary)	0.83	1.17	1.42	1.89	2.14	2.54	3.01	3.61	4.44
SWF09	0.15	0.21	0.26	0.35	0.39	0.47	0.55	0.66	0.82
SWF10	1.05	1.48	1.80	2.39	2.71	3.22	3.81	4.57	5.63
SWF11	0.09	0.13	0.16	0.21	0.24	0.29	0.34	0.41	0.50
SWF12	1.42	2.00	2.43	3.24	3.67	4.35	5.15	6.19	7.61

5 Inflow Hydrographs – Modelled Catchments

5.1.1 The A9/A96 Inshes to Smithton Scheme will require two numerical hydraulic models one each for the Cairnlaw Burn and Scretan Burn. It is noted that the downstream reach of the Cairnlaw Burn was modelled during the DMRB Stage 3 assessment for the A96 Inverness – Nairn (including Nairn Bypass) Scheme. The flow estimation points and inflow locations of the two hydraulic model are shown in Figures 5-A. The road option presented in Figure 5-A is Option 1A.

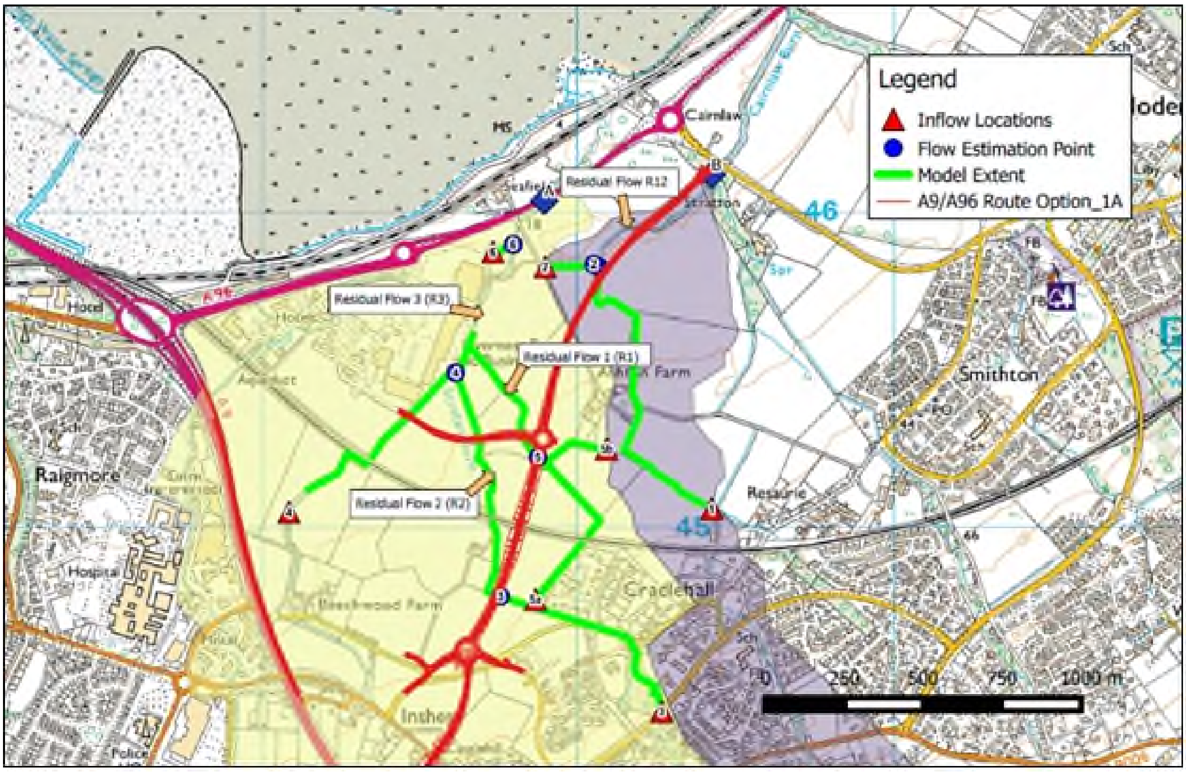


Figure 5-A Cairnlaw and Scretan Burn Flow Estimation Points and Inflow Locations

5.1.2 The design peak flow estimates described in Section 4 can be used in the two models, with some adjustment. The two models require design peak flow (target flow) at various locations as described below:

Cairnlaw Burn Model

5.1.3 Three inflows have been applied to the model at the boundaries of the 1D domain:

- Inflow 1 – at the upstream extent of Cairnlaw Burn (92.5% of the peak flow estimate at SWF08 B);
- Inflow 2 – at the left hand side (SWF07) minor tributary (1.2% of the peak flow estimated at SWF08 B); and
- R12 – one lateral inflow on Cairnlaw Burn between the confluence with the left hand side tributary and SWF08 B crossing of the A9/A96 Scheme (6.3% of the peak flow estimated at SWF08 B).

Scretan Burn Model

5.1.4 Eight inflows have been applied to the Scretan Burn model as follows:

- Inflow 3 – at the upstream extent of the Scretan Burn (SWF04);
- Inflow 4 – at the SWF03 tributary;
- Inflow 5a – at the upper reaches of SWF05 tributary;
- Inflow 5b – at the SWF06 tributary;
- Inflow 6 – at SWF02 (Inshes Burn);
- R1 - lateral flow;
- R2 - lateral flow; and
- R3 - lateral flow.

5.1.5 The peak flow estimates for the following AEP events 50%, 3.33%, and 0.5% (equivalent to the 2, 30 and 200-year design return periods) are presented in Table 5 for the two models. The 0.5% AEP (200-year) event estimate is also presented including a 20% allowance for climate change.

Table 5: Design peak flow estimates (m^3/s) for the two models at the inflow locations

Watercourse	AEP 50%	AEP 3.33%	AEP 0.5%	AEP 0.5% + CC
Cairnlaw Burn Model				
Inflow 1 (Cairnlaw Burn)	0.77	1.75	2.78	3.34
Inflow 2 (Cairnlaw Burn – tributary)	0.01	0.02	0.04	0.04
R12 (lateral flow)	0.05	0.12	0.19	0.23
Cumulative total	0.83	1.89	3.01	3.61
Target flow at SWF 08 B	0.83	1.89	3.01	3.61
Scretan Burn Model*				
Inflow 3	0.92	2.10	3.35	4.02
Inflow 4	0.43	0.97	1.53	1.84
Inflow 5a	0.08	0.18	0.28	0.33
Inflow 5b	0.02	0.04	0.06	0.07
Inflow 6	0.54	1.24	1.97	2.37
R1 (lateral flow)	0.04	0.10	0.15	0.18
R2 (lateral flow)	0.05	0.12	0.19	0.23
R3 (lateral flow)	0.09	0.20	0.31	0.37
Cumulative total	2.16	4.94	7.85	9.41
Target Flow (SWF04)	1.18	2.68	4.27	5..12

*scaling factors will be used to reconcile the modelled flows at the target location (SWF04) with the FEH statistical flows at that location.

5.1.6 Model inflows for the Cairnlaw Burn are based on the peak flow in Table 5 and the hydrograph shape is based on the FEH rainfall-runoff model hydrograph shape derived for the critical storm duration of 5.4-hours (theoretical critical storm duration calculated at the target location of the downstream model extent). The inflow hydrographs thus obtained are applied to the three inflow locations shown in Figure 5-A and Table 5. The typical inflow hydrographs for the 0.5% AEP (200-year) event are presented in Figure 5-B.

5.1.7 The model inflow hydrographs for the Scretan Burn model is based on the FEH rainfall-runoff method or the critical storm duration of 6.2-hours (theoretical critical storm duration calculated at the target location of the downstream model extent). The inflow hydrographs thus obtained are applied to the eight inflow locations shown in Figure 5-A. The typical inflow hydrographs for the 0.5% AEP (200-year) event are presented in Figure 5-C.

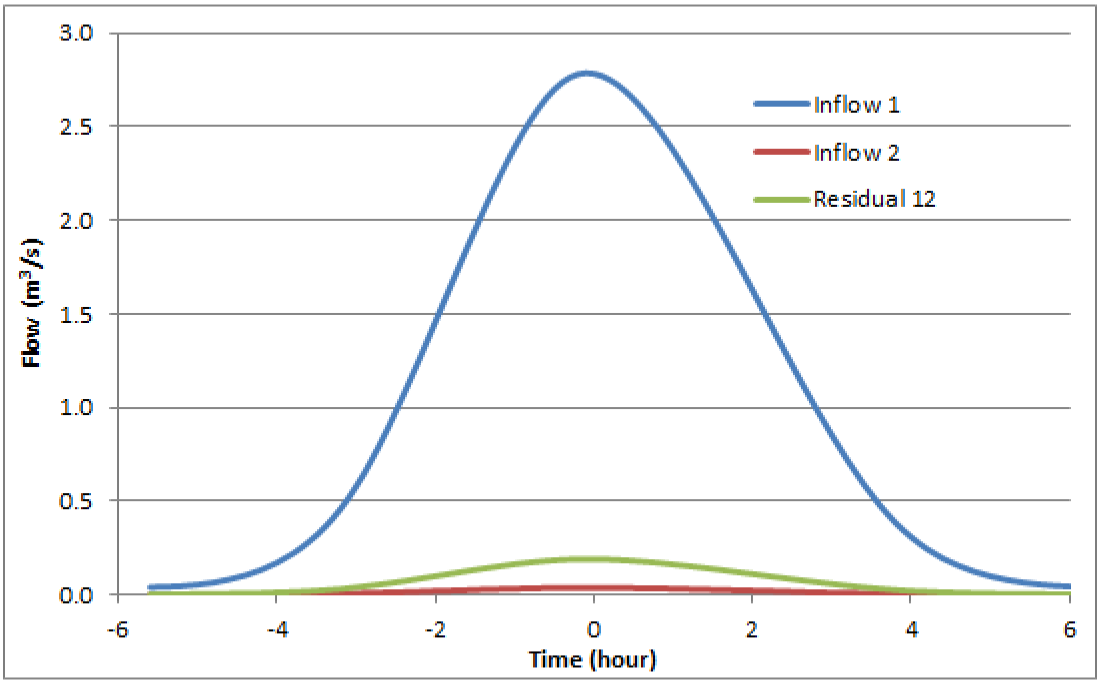


Figure 5 B: The 0.5% AEP (200-year) event inflow hydrographs for the Cairnlaw Burn Model

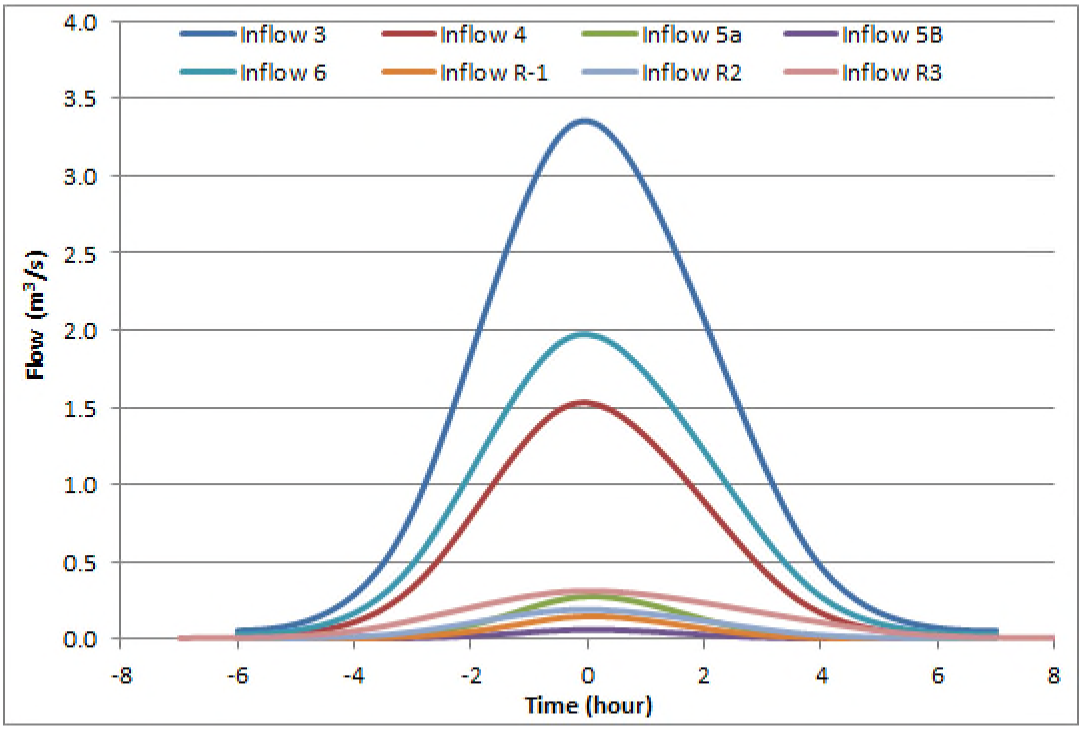


Figure 5 C: The 0.5% AEP (200-year) inflow hydrographs for the Scretan Burn Model

6 Low Flow Estimates

6.1.1 Low flow estimates are required for all the road drainage outfall locations. It is important that the low flow estimates (in particular Q_{95}) are reasonably accurate for dilution calculations. The low flow estimates for the outfall locations are presented in Figure 6 and Table 6.

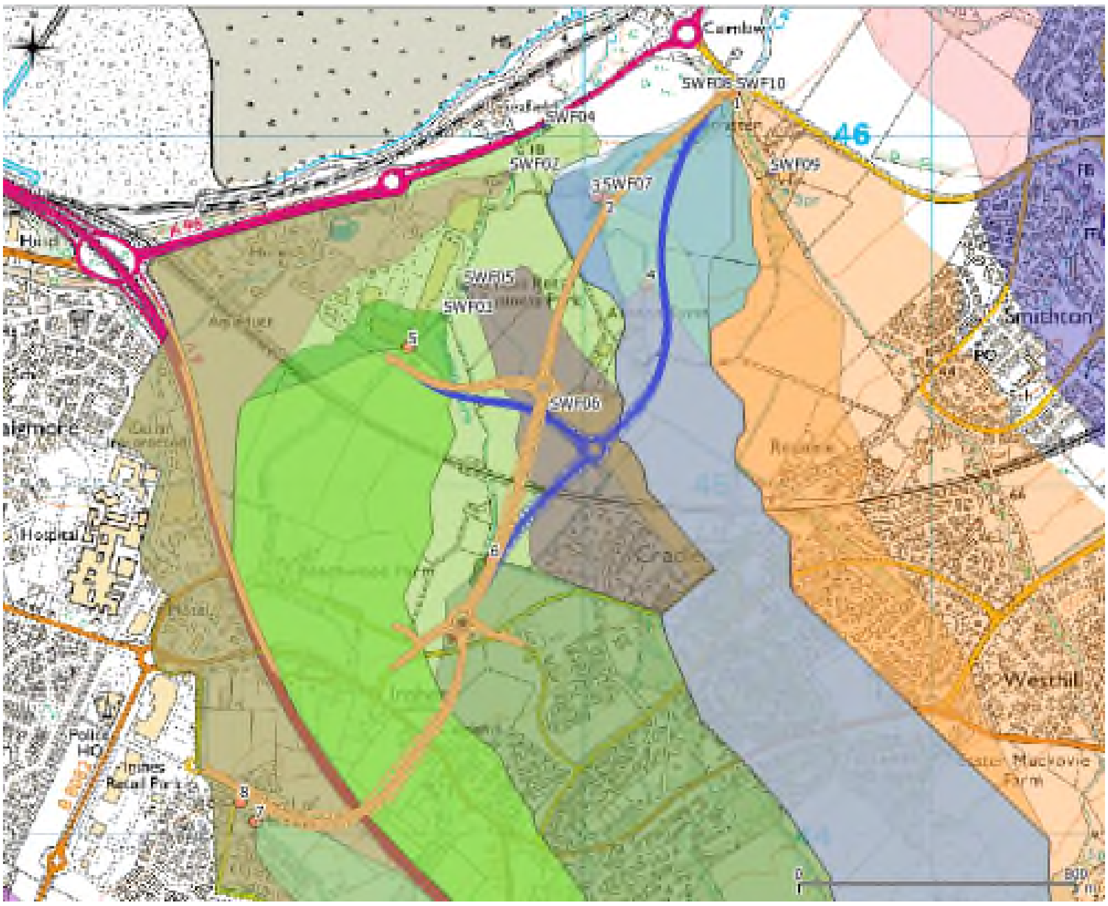


Figure 6: Outfall Locations

6.1.2 Figure 6 shows the A9/A96 Scheme options 1A and 1B. It should be noted that outfalls have been included in Figure 6-A and Table 6 for all of the proposed route options. The outfall locations will be revised when the Scheme option is finalised and taken forward for the DMRB Stage 3 assessment.

Table 6: Low Flow estimates for the outfall locations

Watercourse	Outfall	Grid Reference	Catchment Area (km^2)	Q_{95} (m^3/s)	Mean Flow (m^3/s)
SWF08	1	270426 846122	2.22	0.002	0.017
SWF08	2	270062 845822	2.06	0.002	0.015
SWF07	3	270032 845830	0.04	0.00004	0.0003
SWF08	4	270178 845575	1.99	0.002	0.015
SWF03	5	269494 845394	1.15	0.002	0.009
SWF04	6	269730 844784	3.24	0.005	0.025
SWF02	7	269054 844036	0.94	0.001	0.007
SWF02	8	269008 844133	0.95	0.001	0.007

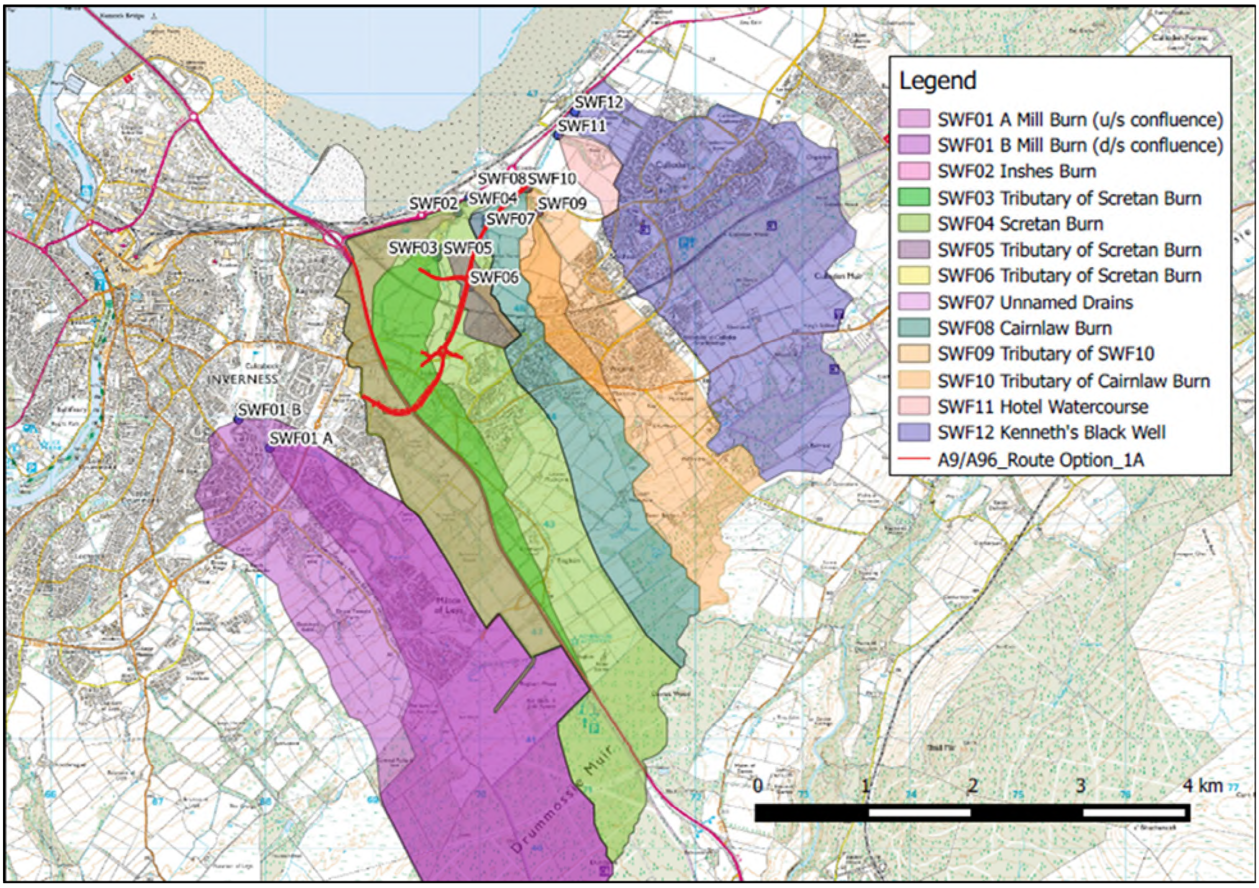
7 Conclusion

7.1.1 This report presents the assessment methods used to derive design peak flows, inflow flood hydrographs for watercourses within the A9/A96 Inshes to Smithton Scheme.

7.1.2 The following limitations should be noted when reviewing the findings from this report:

- Flow estimation is subject to some inevitable uncertainty. This is especially true of the flood estimates of the small catchments where appreciable differences among the three methods exist for those catchments with high permeability.
- A 20% climate change uplift factor has been applied to the design peak flow estimates based on current standard practice. It should be noted that climate change is an area of current research and therefore this uplift factor may be subject to change in the future based on the findings of evolving research.
- The Low Flow Enterprise (LFE) estimates provided by CEH Wallingford are assumed to be fit for purpose and have been used to derive low flow estimates for all watercourses impacted by the Scheme.
- The peak flood estimates (50% and 0.5% AEP) for the small watercourses for the A96 Inverness to Nairn (including Nairn Bypass) Scheme were undertaken using three methods: FEH statistical, FEH rainfall-runoff method, and the ReFH2 method - enabling a comparison of the estimates to be made. Although none of the methods is ideal the strengths and weaknesses of the three approaches in this hydro-climatic region were analysed and the statistical approach was favoured. This assessment has adopted the same approach as that for the A96 Inverness to Nairn (including Nairn Bypass) Scheme and therefore favoured the FEH statistical method for design peak flow estimation for this Scheme as well.

Annex 14.2.1: Catchment Boundary Map



The proposed scheme option 1A has been included in the above figure.

Annex 14.2.2: Amendments to Catchment Descriptors

In order to derive design peak flow estimates at each of the ungauged watercourses crossing the A9/A96 Inshes to Smithton Scheme, FEH catchment descriptors are required.

For watercourses draining an area >0.5km^2, catchment descriptors are extracted directly from the FEH CD-ROM and provide a starting point for the analysis. For each individual catchment lying within the Inshes to Smithton section of the study area, the following catchment descriptors have been checked and where necessary, have been manually adjusted following guidelines presented in the FEH Vol.5:

1) Catchment Area
2) DPLBAR
3) URBEXT
4) FARL

Catchment Area – the catchment boundary for each watercourse (if available) was extracted from the FEH CD-ROM and checked for accuracy within a GIS application by:

- Plotting and comparing the location of the FEH derived catchment outflow against the supplied structure grid reference; and
- Comparison of the FEH derived catchment area against the surface water drainage network as interpreted from a 1:25,000 scale OS map and as observed on site.

For watercourses too small (i.e. <0.5km^2) to be picked up by the FEH CD-ROM, catchment areas have been delineated manually using 1: 25,000 scale OS mapping together with 2m LiDAR derived contour data and the boundary confirmed by a site walk over, if necessary.

DPLBAR – where catchment boundaries required modification, the mean drainage path length was re-calculated using equation 7.1 presented in Volume 5 of the FEH[5].

URBEXT – The majority of catchments within the study area are rural in nature and as such have an URBEXT value of zero or very close to zero. Where a catchment is located within a particularly urban area and the catchment is too small to be included within the FEH software; catchment URBEXT was calculated manually from a 1:50,000 scale OS map and equation 6.2 presented in Volume 5 of the FEH and equation 5.4 presented in the Joint Defra/EA Technical Report 'URBEXT2000 – A new FEH catchment descriptor[6].

FARL – For the larger watercourses, catchment FARL values are derived directly from the FEH CD-ROM. However, for those catchments not included within the FEH CD-ROM (i.e. those having a catchment area <0.5km^2) or which have been picked up incorrectly by the FEH CD-ROM, FARL is calculated manually following the methodology described within section 4.3 of the FEH Vol. 5.

[5] Bayliss, A.C., 1999, Flood Estimation Handbook, Volume V, Catchment Descriptors, Institute of Hydrology.

[6] Bayliss, A.C., Black, K.B., Fava-Verde, A. and Kjeldsen, T.R. 2006. URBEXT2000 – A new FEH catchment descriptor - Calculation, dissemination and application. R&D Technical Report FD1919/TR

Annex 14.2.3: Abbreviations

ALTBAR – Mean catchment altitude (m above sea level)

AREA – catchment drainage area (km2)

AEP – Annual Exceedance Probability

BFIHOST – Base flow index derived using the hydrology of soil types classification

DPLBAR – Index describing catchment size and drainage path configuration (km)

DPSBAR – Index of catchment steepness (m/km)

FARL – Index of flood attenuation due to reservoirs and lakes

FEH – Flood Estimation Handbook

LDP – Longest drainage path (km)

LFE – Low Flows Enterprise

NRFA – National Rivers Flow Archive

PVA – Potential Vulnerable Area (in reference to flood risk)

SAAR – 1961 – 90 standard-period average annual rainfall (mm)

SFRA – Strategic Flood Risk Assessment

SPRHOST – Standard percentage runoff derived using the hydrology of soil types classification (%)

Q95 – The percentage of flow exceeded 95% of the time

Q50 – The percentage of flow exceeded 50% of the time

Qmean – Mean Flow

QMED – Median Annual Maximum Flood

URBEXT – FEH index of fractional urban extent