Appendix A13.7: Hydraulic Modelling Report

1 Introduction

Purpose of the Hydraulic Modelling

1.1.1 This Hydraulic Modelling Report provides detailed information on the hydraulic model build process undertaken to assess the risk of fluvial flooding from the Cairnlaw Burn and Scretan Burn to the proposed scheme between Inshes and Smithton.

1.1.2 The report supports the hydraulic modelling results presented in Appendix A13.1 (Flood Risk Assessment) in Chapter 13 Road Drainage and the Water Environment (RDWE) of the Environmental Impact Assessment Report (EIAR).

1.1.3 In accordance with the Design Manual for Roads and Bridges (DMRB), the proposed scheme development is currently at DMRB Stage 3 'Detailed Assessment'. This report documents the modelling undertaken on the DMRB Stage 3 only.

Modelling Approach

1.1.4 The hydraulic model was built using a linked One-Dimensional/Two-Dimensional (1D/2D) technique, where the river channel is represented as a 1D component using Flood Modeller Pro (FM) version 4.4 software and the floodplain is represented using TUFLOW 2018 software version AC. The linked 1D/2D modelling approach means that the model dynamically transfers the water between the watercourses and the floodplain. The flow exchange at the link in this approach is controlled by the bank crest levels, which were informed by Digital Terrain Model (DTM) data along the channel banks (with some detailed survey along a portion of the Cairnlaw Burn).

1.1.5 The hydraulic modelling aimed to predict the peak water level within the modelled river reach and the floodplain for the 3.33% Annual Exceedance Probability (AEP) (30-year), 0.5% AEP (200-year) and 0.5% AEP plus an allowance for Climate Change (plus CC) flood events for both the baseline and proposed scheme scenarios. These were then used to understand the existing fluvial flood risk and assess the potential impacts of the proposed scheme on flooding. Subsequently, the hydraulic model was used to test options to mitigate these impacts.

Modelled Area

1.1.6 Figure 1 illustrates the extent of the modelling work undertaken for the proposed scheme.

1.1.7 A hydraulic model was constructed to understand the flood risk from both the Cairnlaw Burn and Scretan Burn to the proposed Inshes to Smithton link road. The model covers a 2,542m long reach of the Scretan Burn and a 2,068m long reach of the Cairnlaw Burn approximately. The upstream extent of the Scretan Burn represented in the model is at Caulfield Road, whilst the upstream extent of the Cairnlaw Burn reach is at Caulfield Road North. The downstream extent of the Cairnlaw Burn is at the Smithton Junction whilst the downstream extent of the Scretan Burn reach is 54m downstream of the Highland Main Line Railway.

1.1.8 In addition to the Cairnlaw and Scretan Burns a number of tributaries have also been represented within the hydraulic model. The full list of watercourses represented in the model are:

- SB1 (853m long) – Scretan Burn downstream of confluence with SB4 and SB2 to coastal boundary.
- SB2 (1,652m long) – Main Scretan Burn channel.
- SB3 (78m long) – Small tributary of Scretan Burn at outlet of culvert passing under supermarket car park.
- SB4 (1,049m long) – Tributary of Scretan Burn flowing from Cradlehall Meadow.

- SB5 (193m long) – Tributary of Scretan Burn flowing from Ashton Farm.
- SB6 (576m long) – Tributary of Scretan Burn flowing from Beechwood Farm.
- CBLN (694m) – Cairnlaw Burn Reach downstream of confluence of CB2 and CB3 reaches.
- CB2 (1,374m long) – Upper reach of Cairnlaw Burn passing through Ashton Farm.
- CB3 (156m long) – Field Drain running west to east to confluence with CB2 reach.
- CLT1 (1,358m long) – Tributary of Cairnlaw Burn.

1.1.9 The model extents were chosen based on the key locations where the Cairnlaw and Scretan Burns are close to the proposed route of the Inshes to Smithton link road, which could potentially influence the flood risk to and from the road in both baseline and proposed scheme scenarios.

Figure 1: Modelled area

2 Input Data

2.1.1 The data used to construct the hydraulic model are summarised in Table 1.

Table 1: Data used to build the hydraulic model

Data	Description	Source
Topographic Data	1m LiDAR (Light Detection and Ranging) Digital Terrain Model	Scottish Remote Sensing Portal
OS Maps	Mastermap data	Transport Scotland
Channel Survey	In-channel cross sections and hydraulic structures	Jacobs Site Survey 2017/18
Site Visit observations	Site visit – in-channel watercourse photographs	Jacobs Site Survey 2018
Hydrological analysis	Hydrological analysis was carried out for both the Cairnlaw and Scretan Burn (and associated tributaries)	Jacobs 2017/2018
Scottish Environment Protection Agency (SEPA) Flood Maps	Flood maps (SEPA 2018) showing the fluvial flood extent for medium likelihood of flooding. See Section 7.2.2	SEPA
Proposed Scheme Topography – Road vertical and horizontal alignments	MXROAD (software) ASCII grids of the road alignment that also include road accesses and drainage ponds across the floodplain.	Jacobs 2019
Proposed Scheme Structure Details	Design drawings for proposed structure modifications: watercourse crossings, drainage ponds and other structures.	Jacobs 2019
NMU Bridge Survey	Spot level survey of NMU at culvert C05	Jacobs Site Survey 2019

3 Hydrology

3.1.1 The details of the analysis carried out to produce design inflows for the hydraulic model are provided in Appendix A13.2 (Surface Water Hydrology). Inflows have been provided for the 3.33% AEP (30-year), 0.5% AEP (200-year) and 0.5% AEP (200-year) plus CC flood events.

3.1.2 The inflows for the Cairnlaw Burn and Scretan Burn tributaries were derived for each individual inflow location using the Flood Estimation Handbook (FEH) statistical, FEH rainfall-runoff and the Revitalised Flood Hydrograph Model version 2 (ReFH2) methodologies (Centre for Ecology & Hydrology 1999). The FEH statistical methodology was favoured for all but two of the inflows as it generally produced higher peaks in comparison to the other two methods.

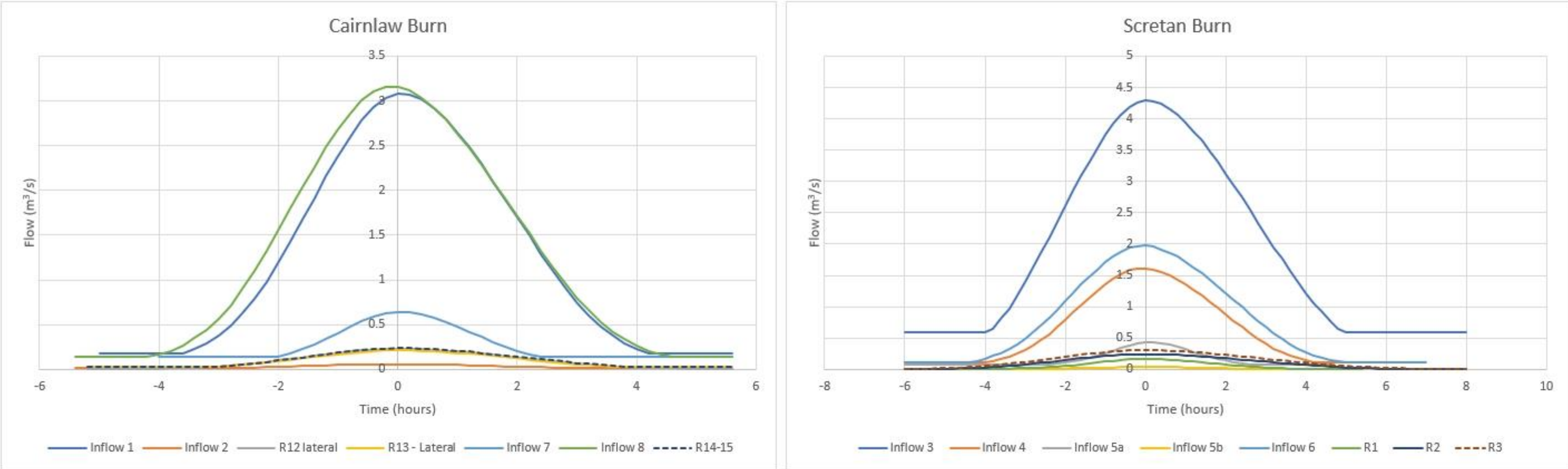
3.1.3 Two runs were required for the hydraulic modelling to ensure the design peak flows were reconciled at both the downstream model extents (Run 1) but also to ensure the critical design peak flows at the proposed scheme watercourse crossing locations (Run 2) were used to assess fluvial flood risk at these locations. Hydrological analysis was undertaken to determine the critical storm duration for each of the proposed scheme watercourse crossing locations. The analysis concluded that three different storm durations would be required for Run 2 (5.7 hours – as critical for Culverts 1,4 and 8, 3.9-hours – as critical for Culverts 5, 6 and 7 and 1.5-hours – as critical for Culverts 2 and 3).

3.1.4 The peak flows for the modelled catchments are shown in Table 2 for the 0.5% AEP Run 1 scenario along with the locations where they were estimated (as illustrated in Figure 6). The flow hydrographs are shown in Figure 2.

Table 2: Run 1 Hydrological peak inflow estimates and locations for Model

Inflow	Model Inflow	Peak Flow (m³/s)		
		AEP 3.33% (30-year)	AEP 0.5% (200-year)	AEP 0.5% (200-year) + CC
Cairnlaw Burn (SWF08) and modelled tributaries				
Inflow 1 (Cairnlaw Burn)	CB2_1505u	1.98	3.08	3.70
Inflow 2 (Cairnlaw Burn – tributary SWF07)	CB3_0155	0.04	0.06	0.07
Inflow 7 (Cairnlaw Burn – indirect tributary – SWF09)	CLT1_1373	0.40	0.64	0.77
Inflow 8 (Cairnlaw Burn – tributary SWF10 (Tower Burn))	CLT1_0340F	2.01	3.16	3.79
R12 (lateral flow)	R12	0.15	0.23	0.28
R13 (lateral flow)	R13	0.14	0.21	0.26
R14/R15 (lateral flows)	R14-15	0.15	0.24	0.28
Target flow at SWF08-1 (Location A)		**3.99**	**6.35**	**7.62**
Modelled Flows SWF08-1		**4.39**	**6.35**	**7.31**
Scretan Burn (SWF04) and modelled tributaries				
Inflow 3 (Scretan Burn (SWF04))	SB2_1646	2.80	4.29	5.15
Inflow 4 (Beechwood Burn (SWF03))	SB6_0576	1.03	1.61	1.94
Inflow 5a (Tributary of Scretan Burn (SWF05))	SB4_1049In	0.29	0.44	0.53
Inflow 5b (Indirect Tributary of Scretan Burn (SWF06))	SB5_0192	0.02	0.04	0.05
Inflow 6 (Inshes Burn (SWF02))	SB3_0057	1.24	1.97	2.37
R1 (lateral flow)	R1	0.11	0.17	0.20
R2 (lateral flow)	R1	0.16	0.25	0.30
R3 (lateral flow)	R1	0.19	0.31	0.37
Target Flow from Statistical method (@SWF04-3)		**4.61**	**7.35**	**8.82**
Modelled Flows SWF04-3		**5.56**	**8.44**	**10.50**

Figure 2: 0.5% AEP (200-year) Inflow hydrographs for Scretan Burn and Cairnlaw Burn



4 Baseline Modelling

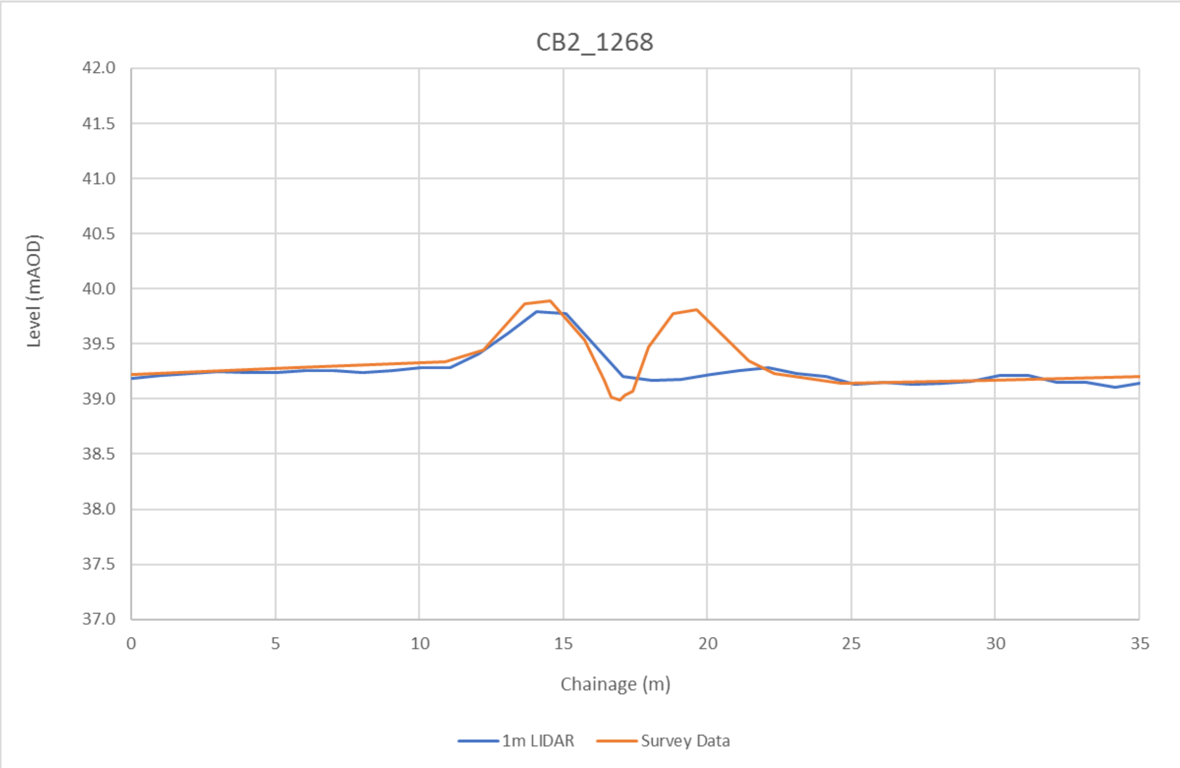
4.1 Watercourse Schematisation – 1D Domain

In-Channel Geometry

4.1.1 Surveyed river cross section data has been used to inform the in-channel geometry of the modelled watercourses. The locations of the surveyed river cross sections are shown in Figure 6. To aid model performance interpolated cross sections were added between the surveyed cross sections where required.

4.1.2 A comparison between the channel survey and the 1m LiDAR DTM was undertaken. Figure 3 shows an example of this comparison. Generally, it was found that the LiDAR data does not pick up very well the in-channel geometry including bank tops. However, across the floodplain, there is good correlation between the two data sets.

Figure 3: Comparison of cross-section survey data with 1m LiDAR DTM at Cairnlaw Burn



In-Channel Hydraulic Friction

4.1.3 Hydraulic roughness (Manning's 'n' coefficient) values were determined primarily using the photographs taken during the survey (see Figure 4 and Figure 5 for examples). Roughness values adopted were taken from standard guidance (Chow 1959). The in-channel coefficients used are shown in Table 3.

4.1.4 In some locations the 1D cross sections extend into the floodplain and roughness coefficients have been used as discussed in the section on floodplain hydraulic friction (Section 4.2.4).

Table 3: In-channel Manning's 'n' coefficients

Watercourse	Flood Modeller Nodes	Bed Manning's 'n'	Bed Material	Banks Manning's 'n'	Banks Material
Scretan Burn	SB2_1646to SB2_0204d	0.05	Larger pebbles and vegetation	0.07	Medium vegetation
Scretan Burn	SB2_0190 to SB2_0000	0.05	Larger pebbles and vegetation	0.10 0.07	Trees on right bank Medium vegetation
Scretan Burn	SB1_0852u to SB1_0765	0.05	Larger pebbles and vegetation	0.10	Trees
Scretan Burn	SB1_0762 to SB1_0000	0.05	Larger pebbles and vegetation	0.07	Medium vegetation
Tributary SB3	SB3_0057 to SB3_000d	0.03	Short Vegetation	0.03	Short vegetation
Tributary SB4	CB3_0155 to CB3_0000	0.06	Medium Vegetation	0.07	Medium vegetation
Tributary SB5	SB5_0192 to SB5_0000	0.07	Medium Vegetation	0.07	Medium vegetation
Tributary SB6	SB6_0576 to SB6_0000	0.07	Medium Vegetation	0.07	Medium vegetation
Cairnlaw Burn	CB2_1505 to CB2_0000	0.04	Pebbles and vegetation	0.05	Medium vegetation
Cairnlaw Burn	CLBN_1715 to CLBN_1516	0.06	Vegetation	0.055	Medium vegetation
Cairnlaw Burn	CLBNa_1393u to CLBN_1041	0.05	Pebbles and vegetation	0.055	Medium vegetation
Cairnlaw Burn	CLBNR_0475	0.04	Pebbles and vegetation	0.04	Medium vegetation
Tributary CB3	CB3_0155 to CB3_0000	0.04	Vegetation	0.05	Medium vegetation
Tributary CLT1	CLT1_1373 to CLT1_0277	0.05	Pebbles	0.07	Medium vegetation
Tributary CLT1	CLT1_0255 to CLT1_0115d	0.05	Pebbles	0.10	Trees
Tributary CLT1	CLT1_0010	0.05	Pebbles	0.055	Medium vegetation

Figure 4: Channel material for the Cairnlaw Burn (CB2), Tributary of Cairnlaw Burn (CLT1) and downstream reach of Cairnlaw Burn (CLBN) respectively

Figure 5: Channel material for the Scretan Burn (SB2), Tributary of Scretan Burn (SB6) and downstream reach of Scretan Burn (SB1) respectively

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In-Channel Hydraulic Structures

4.1.5 The in-channel hydraulic structures included in the 1D model extent are specified in Table 4, and locations are shown in Figure 6.

Table 4: In-channel hydraulic structures (represented in Flood Modeller)

Watercourse	Structure	Flood Modeller Node	Specification	
Cairnlaw Burn	Culvert under an access track	CB2_1432c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 43.670 mAOD 43.670 mAOD 6.400 m 0.900m
Cairnlaw Burn	Culvert under path	CB2_1371o	**Type:** **Invert level:** **Throat soffit level:**	Circular Orifice 43.117 mAOD 43.117 mAOD
Cairnlaw Burn	Railway Bridge	CB2_1354b	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge (Double Span) 41.576 mAOD 2.378 m 43.727 mAOD 44.327 mAOD
Cairnlaw Burn	Footbridge	CB2_1335b	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 40.559 mAOD 2.702 m 41.845 mAOD 41.845 mAOD
Cairnlaw Burn	Culvert under an access track	CB2_0962c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 33.196 mAOD 33.166 mAOD 8.870 m 1.000m
Cairnlaw Burn	Culvert under Ashton Farm Road	CB2_0597c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular conduit 30.063 mAOD 30.023 mAOD 6.042 m 1.410 m 0.970 m
Cairnlaw Burn	Culvert under an access track	CB2_0000c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 17.930 mAOD 17.930 mAOD 5.000 m 0.750 m
Cairnlaw Burn	Bridge under Barn Church Road	CLBN_1201d	**Type:** **Upstream bed level:**	Symmetrical conduit 13.271 mAOD

Watercourse	Structure	Flood Modeller Node	Specification	
			Downstream bed level: **Length:** **Width:** **Crown height:**	12.956 mAOD 47.570 m 3.93m 2.52m
Cairnlaw Burn	Bridge under an access track	CLBN_1045B	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 11.395 mAOD 11.621 m 12.981 m 12.981 m
Tributary of Cairnlaw Burn CLT1	Footbridge for field access	CLT1_1136bru	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 34.387 mAOD 4.450 m 35.340 mAOD 35.340 mAOD
Tributary of Cairnlaw Burn CLT1	Culvert under field boundary	CLT1_0992c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 32.650 mAOD 32.780 mAOD 2.400 m 0.400 m
Tributary of Cairnlaw Burn CLT1	Bridge under an access track	CLT1_0854c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular conduit 31.200 mAOD 31.075 mAOD 5.900 m 0.525 m 0.271 m
Cairnlaw Burn CLT1	Bridge under an access track	CLT1_849cd	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 31.075 mAOD 30.950 mAOD 5.900 m 0.600 m
Tributary of Cairnlaw Burn CLT1	Culvert for field access	CLT1_0560c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 25.660 mAOD 25.600 mAOD 1.600 m 1.000 m
Tributary of Cairnlaw Burn CLT1	Bridge under an access track	CLT1_0115Ou	**Type:** **Invert level:** **Bore Area:**	Rectangular orifice 15.900 mAOD 0.032 m^2
Scretan Burn	Culvert under Caufield Road North	SB2_1417c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:**	Circular conduit 45.295 mAOD 45.028 mAOD 12.591 m

Watercourse	Structure	Flood Modeller Node	Specification	
			Diameter:	1.217m
Scretan Burn	Bridge under an access track	SB2_1396bu	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 44.655 mAOD 3.929 m 45.815 mAOD 45.815 mAOD
Scretan Burn	Bridge under an access track	SB2_1331bu	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 42.815 mAOD 2.318 m 43.620 mAOD 43.620 mAOD
Scretan Burn	Culvert under Cradlehall Farm Drive	SB2_1320c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Spring height:** **Total height:**	Conduit sprung arch 41.554 mAOD 41.867 mAOD 15.140 m 1.970 m 0.696 m 1.499 m
Scretan Burn	Bridge under an access track	SB2_0758bu	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 32.573 mAOD 2.140 m 33.190 mAOD 33.190 mAOD
Scretan Burn	Bridge under railway	SB2_0712b	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 32.070 mAOD 2.271 m 32.870 mAOD 32.870 mAOD
Scretan Burn	Bridge under an access track	SB2_0683b	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	USBPR bridge 31.354 mAOD 4.280 m 32.717 mAOD 32.717 mAOD
Scretan Burn	Culvert	SB1_0796c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 19.385 mAOD 19.400 mAOD 31.048 m 1.960 m
Scretan Burn	A96 bridge	SB1_0421	**Type:** **Bed level:** **Width:** **Springing level:**	Arch bridge 12.465 mAOD 3.455 m 14.430 mAOD

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Watercourse	Structure	Flood Modeller Node	Specification	
			Crown level:	14.430 mAOD
Scretan Burn	Scretan bridge	SB1_0053	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 3.816 mAOD 2.597 m 5.120 mAOD 6.126 mAOD
Tributary SB6	Culvert under railway track	SB6_0398	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 23.897 mAOD 2.770 m 26.050 mAOD 26.050 mAOD
Tributary SB6	NMU	SB6_0190b	**Type:** **Bed level:** **Width:** **Springing level:** **Crown level:**	Arch bridge 22.992 mAOD 2.97 m 23.510 mAOD 23.510 mAOD
Tributary SB4	Culvert under railway track	SB4_0818c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Springing height:** **Total height:**	Symmetrical conduit 34.330 mAOD 33.935 mAOD 28.368 m 1.20 m 1.00 m 1.48 m
Tributary SB4	Culvert under an access track	SB4_0514cu	**Type:** **Invert level:** **Diameter:** **Bore area:**	Circular orifice 31.370 mAOD 0.260 m 0.053 m^2
Tributary SB4	Culvert under an access track	SB4_0456c	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Diameter:**	Circular conduit 30.430 mAOD 30.180 mAOD 12.516 m 0.390 m
Tributary SB4	Culvert under an access track	SB4_0189cu	**Type:** **Invert level:** **Diameter:** **Bore area:**	Circular orifice 24.740 mAOD 0.430 m 0.145 m^2
Tributary SB4	Culvert under an access track	SB4_0000cu	**Type:** **Invert level:** **Diameter:** **Bore area:**	Circular orifice 21.27 mAOD 0.490 m 0.189 m^2

Boundary Conditions – 1D Domain

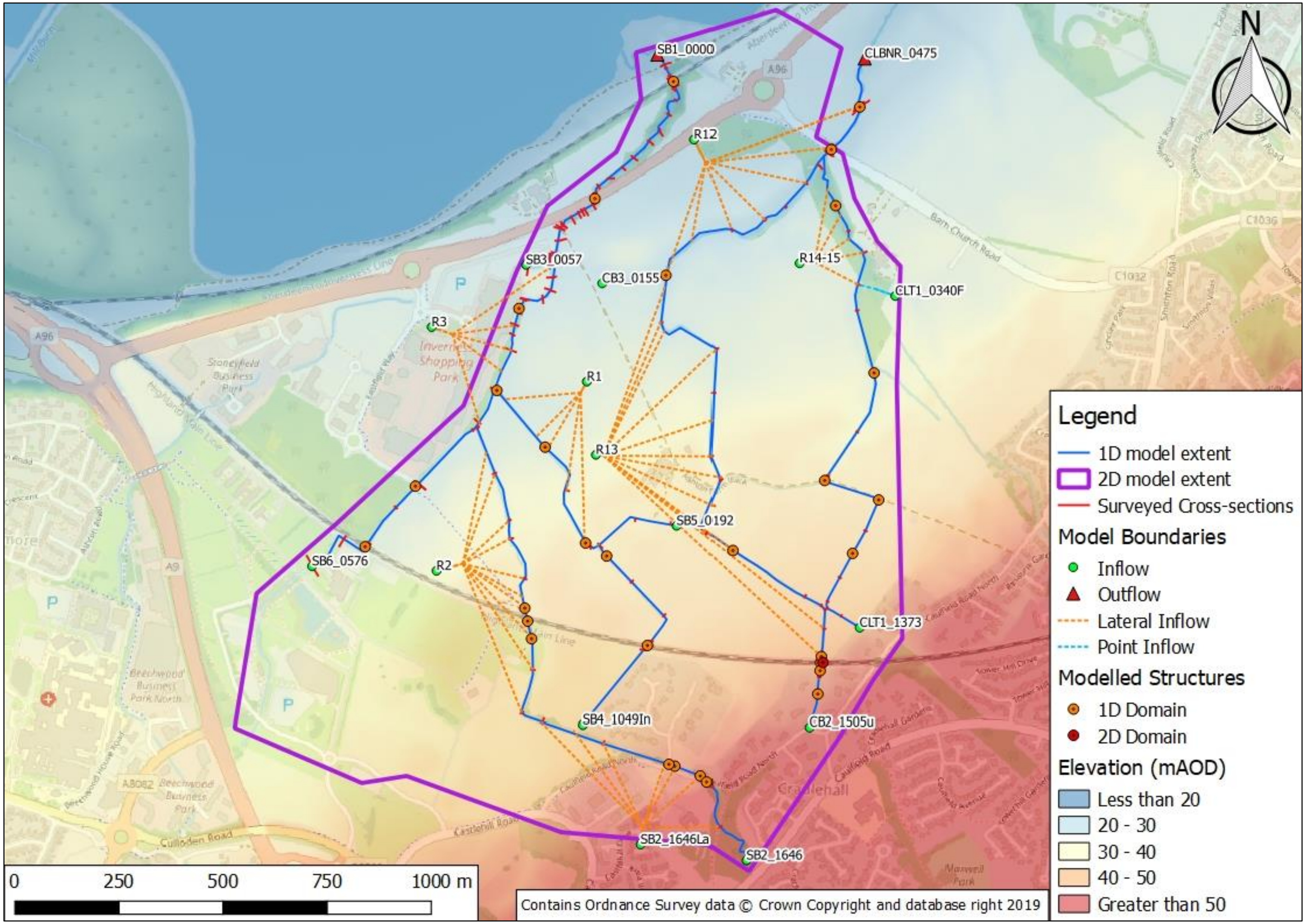
4.1.6 Figure 6 below illustrates the combined Cairnlaw and Scretan Burn 1D model schematic, including the boundary conditions. The model contains nine direct inflows represented by flow-time FEH boundaries and seven lateral inflows which allow flow from a flow-time FEH boundary to be distributed evenly along a user defined river reach. There are two downstream boundaries within the model. The Cairnlaw Burn downstream boundary is represented using a stage discharge relationship derived from the existing A96 Inverness to Nairn Stage 3 model (located downstream of this model) (Jacobs, 2016), whilst the Scretan Burn downstream boundary is represented using a Normal Depth boundary. A Normal Depth boundary is appropriate at the downstream extent of the Scretan Burn because the bed level of the watercourse at this location (3.58mAOD) is sufficiently higher than the Mean High-Water Springs (2.21mAOD) and the predicted 0.5% AEP tidal level (3.35mAOD). A description of all boundaries in the model are shown in Table 5.

4.1.7

Table 5: 1D boundary conditions

Type of Boundary	Flood Modeller Node	Description
Flow-Time FEH Boundary	CB2_1505u	Hydrological inflow applied at the upstream end of the Cairnlaw Burn
Flow-Time FEH Boundary	CB3_0155	Hydrological inflow applied at the upstream end of the one of the tributaries of Cairnlaw Burn
Flow-Time FEH Boundary	CLT1_1373	Hydrological inflow applied at the upstream end of the tributary of Cairnlaw Burn at Resaurie
Flow-Time FEH Boundary	CLT1_0340F	Hydrological applied at node CLT1_0340, representing flow from minor tributary
Flow-Time FEH Boundary	SB2_1646	Hydrological inflow applied at the upstream end of the Scretan Burn
Flow-Time FEH Boundary	SB3_0057	Hydrological inflow applied at the upstream end of minor tributary of the Scretan Burn (at the Inverness shopping park
Flow-Time FEH Boundary	SB4_1049In	Hydrological inflow applied at the upstream end of a minor tributary of Scretan Burn (upstream of the Highland Main Line Railway at Cradlehall)
Flow-Time FEH Boundary	SB5_0192	Hydrological inflow applied at the upstream end of a minor tributary of Scretan Burn (at Ashdon Farm)
Flow-Time FEH Boundary	SB6_0576	Hydrological inflow applied at the upstream end of the Tributary of Scretan Burn
Flow-Time FEH Boundary	R1	Hydrological inflow distributed laterally between nodes SB4_0444I and SB4_0173In5I
Flow-Time FEH Boundary	R2	Hydrological inflow distributed laterally between nodes SB2_0970I and SB2_0321In1I
Flow-Time FEH Boundary	R3	Hydrological inflow distributed laterally between nodes SB2_0204dI and SB2_0626I
Flow-Time FEH Boundary	R12	Hydrological inflow distributed laterally between nodes CLBN_1715I and CLBN_1496L
Flow-Time FEH Boundary	R13	Hydrological inflow distributed laterally between nodes CB2_1335dL and CB2_0923L
Flow-Time FEH Boundary	R14-15	Hydrological inflow distributed laterally between nodes CLT1_0340L2 and CLT1_0115n2L
Flow-Time FEH Boundary	SB2_1646Lat	Hydrological inflow distributed laterally between nodes SB2_1646In1 and SB2_0985
Flow-Head Boundary	CLBNR_0475	Flow-Head boundary condition applied at the downstream end of the model on Cairnlaw Burn
Normal Depth Boundary	SB1_0000	Normal Depth boundary condition applied at the downstream end of the model on Scretan Burn

Figure 6: Baseline schematisation



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4.2 Floodplain Schematisation – 2D Domain

Floodplain Topography

4.2.1 The 2D domain covers an area of 1.99km². The topography is represented using a 2m resolution square grid. The levels for the grid cells are based on a 1m resolution Digital Terrain Model (DTM) derived from LiDAR survey.

4.2.2 Appropriate use has been made of 2D breaklines to accurately represent the watercourse top of bank using a combination of surveyed bank top levels and LiDAR where no cross-section survey was undertaken.

4.2.3 The dual span railway bridge crossing the Cairnlaw Burn (1D model node: CB2_1354b) at the top end of the model has been represented so that one of the openings is represented within the 1D model. The second opening (which is for an access track located on the watercourse right bank) has been represented using a 2D z-shape layer within the TUFLOW software. The 2D z-shape allows the user to modify ground levels within a DTM. In this instance, the 2D z-shape layer was used to represent the railway bridge deck over the left hand bridge opening, whilst allowing flow within the right bank floodplain to flow through the right hand railway bridge opening (which was not elevated).

Floodplain Hydraulic Friction

4.2.4 Hydraulic roughness coefficients are applied across each cell of the 2D domain as shown in Table 6, depending on land use taken from OS Mastermap data. Roughness patches were added to certain locations for the scheme scenario (with and without mitigation) at locations where flood water interacts with the proposed scheme. This was to ensure a more appropiate roughness value was used for embankments, roads and short grass depicting swales. Roughness values adopted were taken from standard guidance (Chow 1959).

Table 6: Manning's 'n' coefficients - 2D domain

Land Use	Manning's 'n'
Water bodies	0.02
Roads, tracks and paths	0.025
Short grass	0.035
Gardens	0.05
Railway	0.05
Embankments	0.05
General green areas	0.055
Trees/Thick Vegetation	0.1
Buildings and glasshouses	1

Floodplain Hydraulic Structures

4.2.5 As detailed in 4.2.3 the second opening of the dual span bridge under the railway line has been represented within the 2D domain using a 2D z-shape layer which enables the user to modify DTM ground levels.

Boundary Conditions – 2D Domain

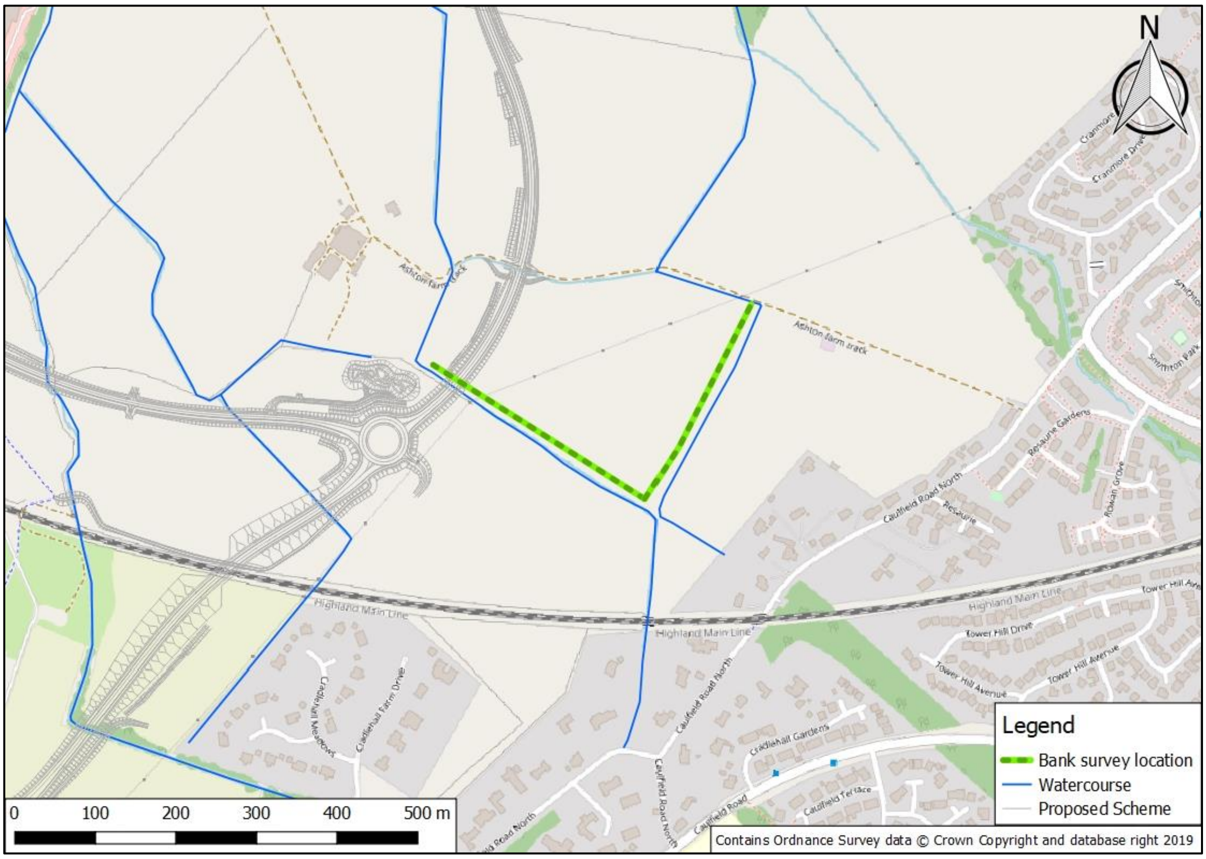
4.2.6 There was no requirement to represent direct inflows in the 2D domain. All flows across the 2D domain are a result of the 1D channel being overtopped.

4.2.7 As with the inflows, there was no requirement to apply free discharge (HQ) boundaries at the downstream end of the model aligned to the edge of 2D domain. This is because the flood extents predicted by the hydraulic model do not reach the 2D model boundary.

1D/2D Linking

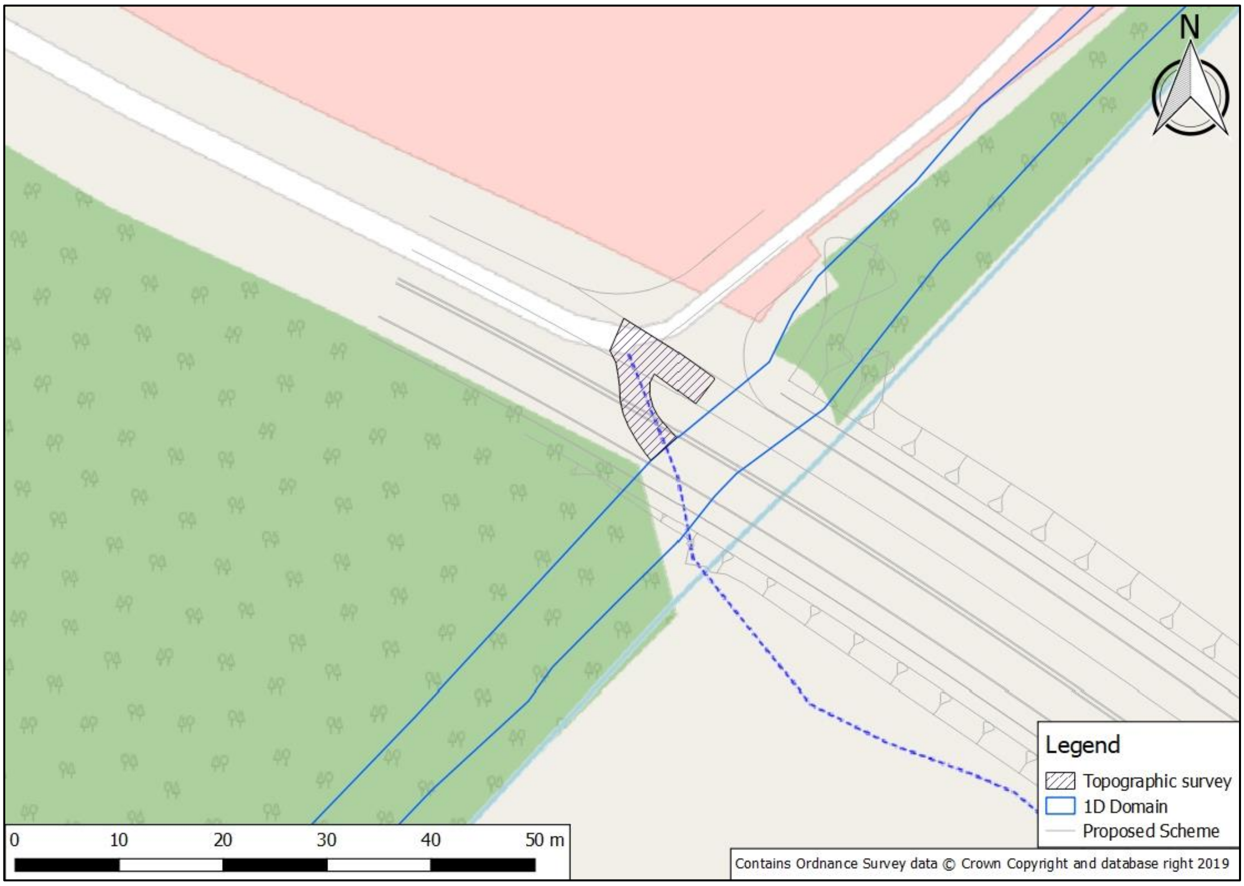
4.2.8 The link between the 1D and the 2D domains was defined along the banks of all watercourses using bank crest levels informed by both the DTM data and bank top levels recorded at each channel cross-section. In one location along the Cairnlaw Burn bank top survey was undertaken and used instead of the levels informed by the DTM data. Additional bank top survey was commissioned for this location since the SEPA Flood Maps (SEPA 2018) show overtopping of the Cairnlaw Burn in this location for the medium scenario (i.e. 0.5% AEP). However, site visit inspections indicate that the bank tops along this reach have been raised by the landowner. The survey has been used to update the bank top levels within the model (replacing those from DTM data). The location of the additional banktop survey along the Cairnlaw Burn is illustrated in Figure 7.

Figure 7: Bank top survey location



4.2.9 Additional topographical survey was also used to update the 2D domain ground profile at the existing NMU route at culvert C05 (located on the left bank of SB6). This modification was implemented using a z-shape with levels coming from the survey. The location of the additional topographical survey is shown in Figure 8.

Figure 8: SB6 NMU route additional topographical survey



5 Proposed Scheme Modelling

5.1 Initial Scheme Model Testing

5.1.1 Model simulations were run initially with the proposed highway layout (with no mitigation measures). The proposed scheme crosses the Cairnlaw Burn, Scretan Burn and their tributaries in multiple locations. As such, there was a requirement to represent eight new culverts in the scheme model as listed in Table 7. The initial scheme with no mitigation simulations indicated that there were a number of locations in which the proposed scheme negatively impacted the peak flood levels. A range of mitigation options were then tested to determine the final, proposed scheme arrangement (see section 5.3).

Table 7: Scheme Hydraulic Structures

Watercourse	Structure	Flood Modeller Node	Specification	
Scretan Burn (SB2)	Culvert C01 under proposed highway	SB2_0995	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 36.136 mAOD 34.749 mAOD 47.75 m 4.5 m 2.1 m
Scretan Burn (SB4)	Culvert C02 under proposed highway	SB4_0700	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 33.163 mAOD 32.667 mAOD 54.15 m 3.00 m 1.70 m
Tributary of Scretan Burn (SB4)	Culvert C03 under access road	SB4_0535	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 31.476 mAOD 30.893 mAOD 35.155 m 2.50 m 1.55 m
Scretan Burn (SB2)	Culvert C04 under access road	SB2_0490	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 28.066 mAOD 27.479 mAOD 28.401 m 5.50 m 1.80 m
Beechwood Burn (SB6)	Culvert C05 under NMU	SB6_0190	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Double Barrel Rectangular Culvert 22.992 mAOD 22.921 mAOD 16.40 m 4.00 m x 2 barrels 1.25 m x 2 barrels

Watercourse	Structure	Flood Modeller Node	Specification	
Cairnlaw Burn (CB2)	Culvert C06 under proposed highway	CB2_0934	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 32.910 mAOD 32.551 mAOD 26.63 m 3.50 m 1.70 m
Cairnlaw Burn (CLBN)	Culvert C07 under proposed highway	CLBN_1495	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 15.686 mAOD 15.303 mAOD 38.98 m 3.00 m 1.70 m
Scretan Burn	Culvert C08 under access road	SB2_0658	**Type:** **Upstream bed level:** **Downstream bed level:** **Length:** **Width:** **Height:**	Rectangular Culvert 31.261 mAOD 31.165 mAOD 6.00 m 4.00 m **5.20** m

5.1.2 The proposed scheme was found to increase flood risk upstream of Culverts C01, C02, C05, and C06 as presented in Appendix A13.1 (Flood Risk Assessment) during a 0.5% AEP flood event. For further details refer to Appendix A13.1 (Flood Risk Assessment).

5.1.3 Excluding the proposed carriageway, the only other receptor which sees an increase in flood risk as a result of the scheme is the Highland Main Line Railway. The railway sees an increase in flood risk approximately 91m south of the proposed culvert C02. A range of mitigation options were then tested to determine the final, proposed scheme arrangement, as reported in Section 5.2. For more information please refer to Appendix A13.1 (Flood Risk Assessment).

5.2 Proposed Scheme Arrangement

5.2.1 Figure 9 shows the layout of the proposed scheme as per Design Fix 3B of the DMRB Stage 3 process.

1D Model Updates

5.2.2 As discussed in section 5.1, eight new culverts were incorporated into the proposed scheme model at each location where the carriageway crosses the Cairnlaw Burn, Scretan Burn and their tributaries. The culverts were designed to adhere to DMRB requirements (600mm freeboard for 0.5% AEP + CC scenario). Specific details of the proposed culverts are illustrated in Table 7.

5.2.3 The proposed scheme retains all existing hydraulic structures crossing the watercourses with the exception of Culvert C05 which replaces an existing bridge structure crossing the Scretan Burn with a double barrel culvert as specified in Table 7. It should be noted that Culvert C05 does not adhere to the DMRB requirements due to restrictions in possible NMU deck levels.

Figure 9: Proposed scheme layout

5.3 2D Model Updates

5.3.1 The proposed scheme elevations were exported from the 3D design drawings (MXROAD software) as raster grids (GeoTIFF), for inclusion in the hydraulic model. Within the footprint of the proposed scheme these raster grids were stamped onto the existing ground elevations.

5.3.2 Four wetlands and a number of swales are included in the proposed scheme. These have been included in the model by updating the ground elevations using the raster grids exported from the 3D design drawings (MXROAD software).

5.3.3 As part of the proposed scheme additional structures will be constructed to help mitigate additional flooding caused as a result of the proposed scheme blocking existing flood pathways (see Figure 10). Upstream of Culvert C01, two 2m wide by 1.5m height Flood Relief Culverts will be constructed on the left bank floodplain of the Scretan Burn to allow flood water to pass under the proposed carriageway. The right bank of the Cairnlaw Burn will also be raised by approximately 100mm upstream of the proposed culvert C06 for approximately 20m. Downstream of the Highland Main Line Railway line and upstream of Culvert C02, the Scretan Burn left bank top will be raised by approximately 200mm for 25m to prevent additional water spilling into the left bank floodplain as a result of the proposed watercourse crossing. Upstream and downstream of Culvert C08 the left bank top will be raised. The bank raising will cover approximately 17m downstream of the proposed culvert and 18m upstream. Table 8 summarises these changes.

Table 8: Floodplain hydraulic structure modifications

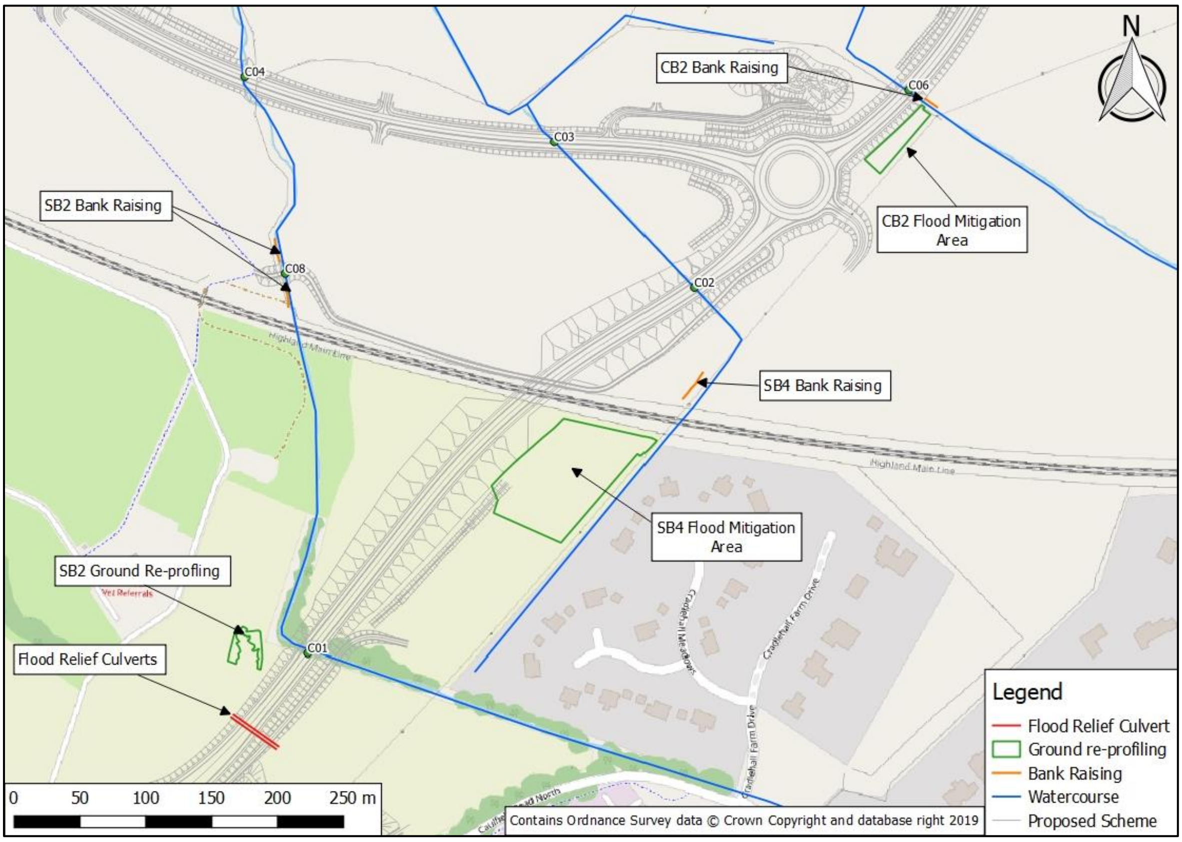
Structure	Type	Watercourse	Dimensions/ height (m)	Length (m)	Upstream Invert Level (mAOD)	Downstream Invert Level (mAOD)
New Relief Culvert (North)	Rectangular Culvert	SB2	2 x 1.5	42	35.32	34.96
New Relief Culvert (South)	Rectangular Culvert	SB2	2 x 1.5	42	35.32	34.94
Right bank U/S C06	Bank Raising	CB2	0.1	20	N/A	N/A
Left bank D/S railway on SB4	Bank Raising	SB4	0.1 – 0.27	25	N/A	N/A
C08 – D/S left bank	Bank Raising	SB2	0.24	17	N/A	N/A
C08 – U/S left bank	Bank Raising	SB2	0.23 – 0.52	18	N/A	N/A
SB2 Ground re-profiling	Ground lowering	Left floodplain of SB2	0.01 – 0.2 lowering	N/A	N/A	N/A
CB2 ground modification	Ground lowering	Left floodplain of CB2	0.3 – 0.6	N/A	N/A	N/A

5.3.4 In addition to the mitigation options as described in Table 8, one area of ground re-profiling was required to mitigate additional flood water caused as a result of the proposed scheme. Details of these flood storage basins are shown in Table 9 and illustrated in Figure 10.

Table 9: Proposed Flood Mitigation Basins

Structure	Proposed Crossing	Surface Area of Basin (m^2)	Average depth of excavation (m)	Volume of available storage (m^3)
Flood Mitigation Basin (SB4)	C01	6,196	0.59	3,656

Figure 10: Proposed Mitigation Measures



6 Modelled Events

6.1.1 Table 10 shows the AEP flood events and model scenarios that were simulated with the hydraulic model.

Table 10: Modelled events

Scenario	AEP Event		
	3.33% (30-year)	0.5% (200-year)	0.5% (200-year) + CC
Baseline – Run 1 Hydrology	✓	✓	✓
Baseline – Run 2A Hydrology	✓	✓	✓
Baseline – Run 2B Hydrology	✓	✓	✓
Baseline – Run 2C Hydrology	✓	✓	✓
Roughness Sensitivity – Run 1 Hydrology		✓	
Hydrological Inflow Sensitivity – Run 1 Hydrology		✓	
Downstream Boundary Sensitivity – Run 1 Hydrology		✓	
Proposed Scheme no mitigation – Run 1 Hydrology	✓		✓
Proposed Scheme no mitigation – Run 2A Hydrology	✓		✓
Proposed Scheme no mitigation – Run 2B Hydrology	✓		✓
Proposed Scheme no mitigation – Run 2C Hydrology	✓		✓
Proposed Scheme with flood mitigation – Run 1 Hydrology	✓	✓	✓
Proposed Scheme with flood mitigation – Run 2A Hydrology	✓	✓	✓
Proposed Scheme with flood mitigation – Run 2B Hydrology	✓	✓	✓
Proposed Scheme with flood mitigation – Run 2C Hydrology	✓	✓	✓

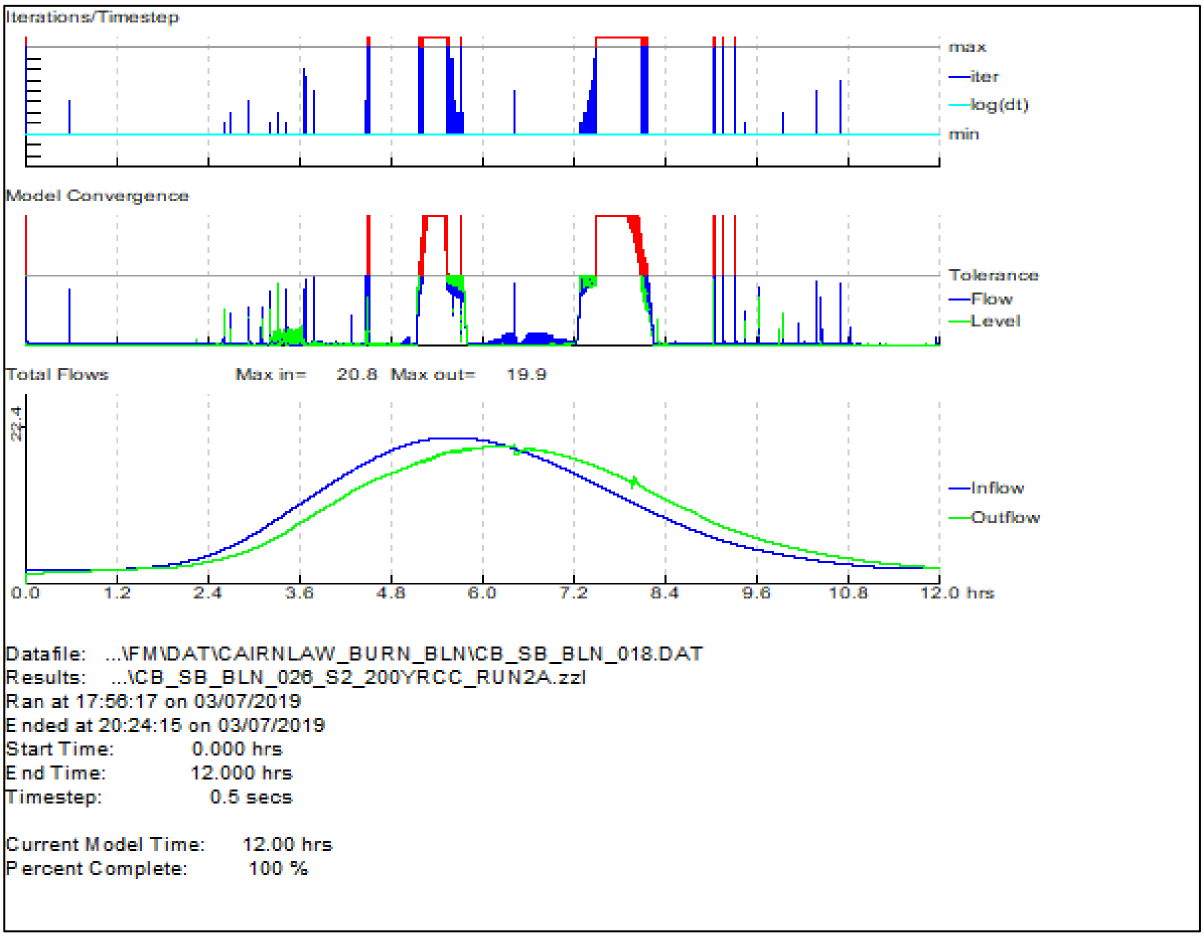
7 Model Proving

7.1 Model Performance

7.1.1 Run performance has been monitored throughout the model build process and then during each simulation carried out, to ensure a suitable model convergence was achieved. Convergence is calculated for each modelled time step and shows the consistency of the modelled water level and flow within the iterations that are computed for each model time step.

7.1.2 As shown in Figure 11, there are four 1D non-convergence issues diagnosed by Flood Modeller Pro software. The non-convergence occurs in both the baseline and scheme (with mitigation) models at approximate simulation times: 4.5hrs, 5.1hrs, 7.5hrs and 9.0hrs. All non-convergence issues were investigated and the cause of the non-convergence was identified. Modelling diagnostics indicate that the instability occurs along a 112m reach of the Scretan Burn (between model nodes SB2_1417 and SB2_1305) near the Cradlehall housing development and Caulfield North Road. The instability has a negligible impact on peak water level (variation of approximately +/-1-3mm) and flow (variation of approximately +/-0.042m^3/s) for the 0.5% AEP plus CC scenario (for Run 2A which depicts the worst hydrological scenario for this location). The uncertainty associated with this instability does not affect the flood risk prediction at the location of the scheme which is located approximately 310m downstream of the area of instability.

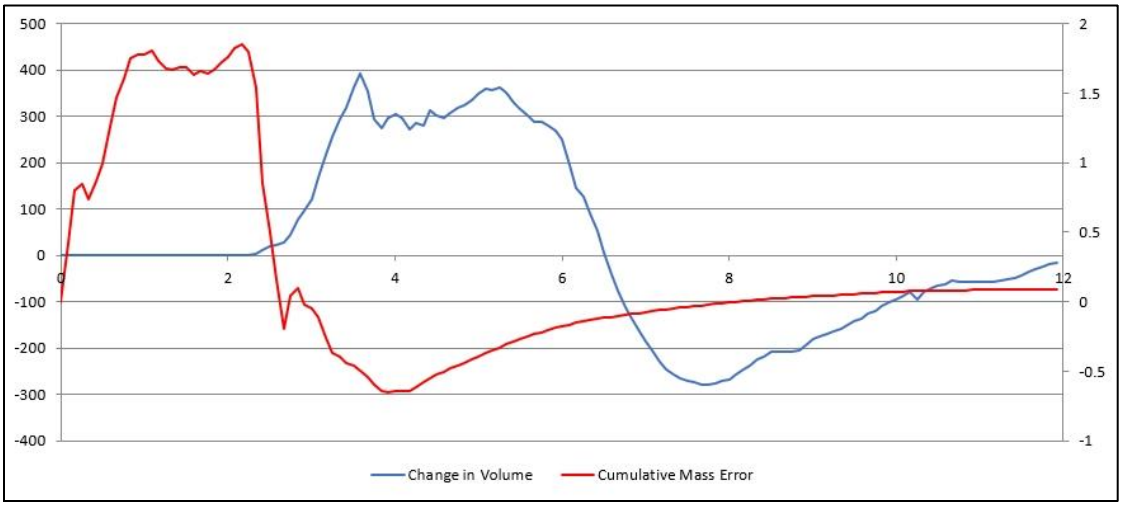
Figure 11: Model convergence plot



7.1.3 For the proposed scheme (with mitigation) scenarios, an additional instability occurs along the Scretan Burn between proposed Culvert C01 (model node: SB2_0947) and the Highland Main Line Railway (SB2_0712). Within this model reach, results indicate that directly downstream of Culvert C01 at the right-hand bend, the Scretan Burn overtops on both banks resulting in overland flow that runs in parallel to the watercourse before re-entering Scretan Burn upstream of the Highland Main Line Railway. Due to this overtopping the flow within the watercourse along this reach reduces to approximately 1m^3/s for the 0.5% AEP plus CC flood event. Unfortunately, this causes instability within the in-bank channel. Water levels at peak fluctuate by approximately +/-20mm and peak flows by approximately 0.21m^3/s. However, the peak water levels within the watercourse remain below the bank top levels and as such are likely to have minimal effects on the flooding within the 2D domain.

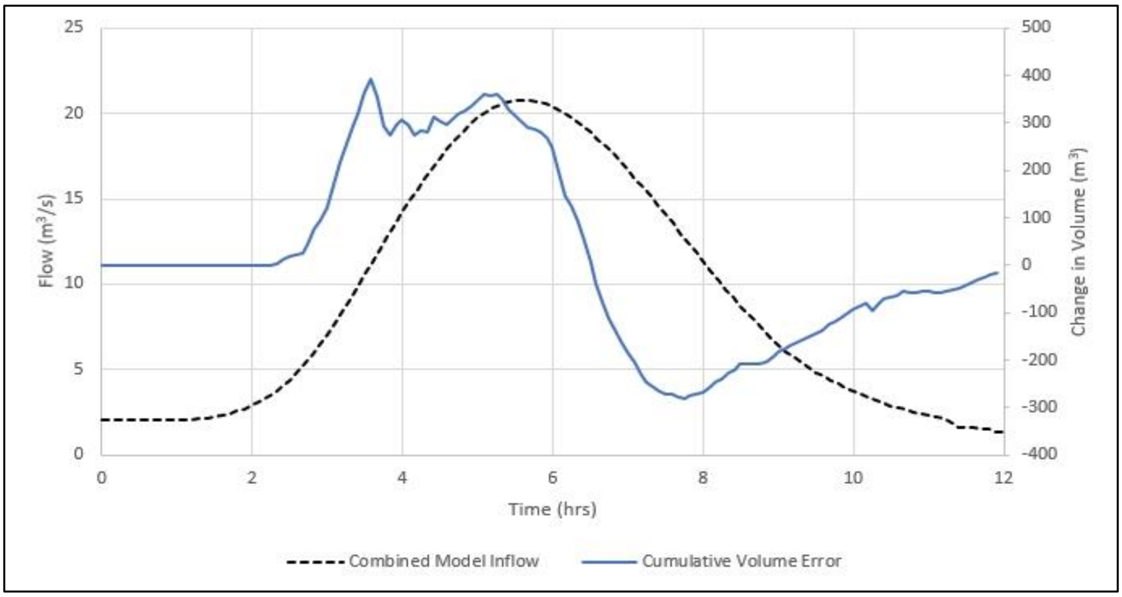
7.1.4 The cumulative mass error diagnostics output from the TUFLOW 2D model have been checked. The accepted tolerance range recommended by the software manual is +/- 1% mass balance error. Figure 12 shows that for the 0.5% AEP plus CC flood event (Run 1) the cumulative mass error tolerance is exceeded somewhat at the onset of the simulation until approximately 2.5hrs into the simulation. Then, the cumulative mass error stabilises to less than 1% error before there is any significant volume in the floodplain (approximately 1300 wet cells compared to a maximum of 45000 wet cells). This mass error diagnostic is typical for all events simulated and is considered satisfactory as the out of tolerance cumulative mass error is happening outwith the peak of volume.

Figure 12: 2D Cumulative mass error and change in volume - 0.5% AEP plus CC event (Baseline – Run 1)



7.1.5 The change in volume has also been checked and shows that the volume error starts to decrease just before the peak of the combined hydrograph. At the end of the simulation the change in volume is negligible as it approaches zero. The change in cumulative volume error compared to the combined model inflows is shown in Figure 13.

Figure 13: Inflow hydrograph profile and 2D change in volume - 0.5% AEP plus CC event



7.2 Calibration and Verification

Calibration

7.2.1 Unfortunately, calibration of the model was not possible due to lack of local gauging stations on the Cairnlaw and Scretan Burns.

Verification

7.2.2 As stated in section 7.2.1, the Cairnlaw Burn and Scretan Burn are both ungauged watercourses, making theverification of the model particularly difficult. As such the 0.5% AEP baseline flood event extent (Run 1) predicted by the model was compared with the corresponding medium likelihood flood extent (0.5% AEP event) on the SEPA Flood Maps (SEPA 2018).

7.2.3 Figure 14 shows the comparison between the two flood extents. The modelled flood extent is broadly similar to that of the SEPA Flood Maps (SEPA 2018) which provides confidence to the present model analysis. However, there are some differences between the two extents of inundation. Along a reach of the Cairnlaw Burn (west of Resaurie) the SEPA Flood Maps (SEPA 2018) shows the burn overtopping its right bank into the floodplain flowing overland and re-entering approximately 250m downstream. The model uses bank top survey along this reach of the Cairnlaw Burn as there is a bund running along the watercourse which increases the capacity of the watercourse and hence prevents the flooding to occur during the 0.5% AEP flood event. During the 0.5% AEP plus CC flood event flooding due to overtopping of the right bank does occurs. Another difference is the flooding which occurs in the Cradlehall housing development along Scretan Burn. These differences can be attributed to the more detailed representation of the watercourses and their adjacent floodplain considered in the present study.

Figure 14: Modelled 0.5% AEP (200-year) flood event extent vs. SEPA medium likelihood fluvial extent

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7.3 Sensitivity Analysis

7.3.1 In order to test the model sensitivity to key hydraulic parameters, simulations were undertaken using the baseline 0.5% AEP event. The assessed hydraulic parameters were: Manning's 'n' roughness coefficients, hydrological inflows and downstream boundary conditions.

Roughness Sensitivity

7.3.2 In-channel and floodplain roughness coefficients (Manning's 'n') were changed by +20% and -20%. Table 11 shows the impact of changing the model roughness on the 1D in-channel water levels at the locations of the proposed crossings. The impact on the 2D maximum flood extents is illustrated in Figure 15. The results show that the in-channel water levels are not greatly sensitive to changes in roughness coefficients at the locations of the scheme crossings. There is limited response for the 2D modelled flood extents of the Scretan Burn, but along the upper reach of the Cairnlaw Burn the 2D modelled flood extents seem to be slightly more sensitive to channel roughness.

Table 11: Model roughness sensitivity results

Sensitivity	Water Level Difference Compared with Baseline Results (mm)							
	SB2_0995 (C01)	SB4_0712 (C02)	SB4_0508 (C03)	SB2_0483 (C04)	SB6_0184 (C05)	CB2_0934 (C06)	CLBN_1495 (C07)	SB2_0678 (C08)
+20% Roughness	13	88	78	49	45	18	30	81
-20% Roughness	-39	-43	-41	-69	-90	0	-36	-83

Hydrological Inflow Sensitivity

7.3.3 The flows into the model were adjusted by +20% and -20%. Table 12 shows the impact of changing model inflows on the 1D in-channel water levels at the locations of the proposed crossings; the 2D maximum flood extents are shown in Figure 16. The model responses are found to be slightly more sensitive to changes in flow than to roughness, and there is slightly more noticeable change in the extents of flooding within the modelled 2D flood extents.

Table 12: Model flow sensitivity results

Sensitivity	Water Level Difference (mm)							
	SB2_0995 (C01)	SB4_0712 (C02)	SB4_0508 (C03)	SB2_0483 (C04)	SB6_0184 (C05)	CB2_0934 (C06)	CLBN_1495 (C07)	SB2_0678 (C08)
+20% Flow	16	211	171	45	42	4	9	53
-20% Flow	-18	-203	-182	-39	-93	-4	-13	-44

Downstream Boundary Sensitivity

7.3.4 To test the model sensitivity to the downstream boundary condition, the hydraulic gradient assumed at the Normal Depth boundary on Scretan Burn was slackened to increase the modelled water level at the boundary, as follows:

- Baseline:
  - Scretan Burn (Normal Depth boundary) = 1:87
- Uplift:
  - Scretan Burn (Normal Depth boundary) = 1:73

7.3.5 Similarly, the stage discharge relationship at the downstream end of Cairnlaw Burn was modified by increasing each stage value across the stage discharge relationship by 200mm, an example of this change (for a flow of 9m3/s) is shown below:

- Baseline:
  - Cairnlaw Burn (Flow-Head boundary) = 12.301

- Uplift:
    - Cairnlaw Burn (Flow-Head boundary) = 12.501 (200mm increase)

7.3.6 Table 13 shows the impact of changing boundary conditions on the 1D in-channel water levels at the locations of the proposed crossings; the 2D maximum flood extents are shown in Figure 17. The model responses are found to be insensitive to changes in downstream boundary conditions at the locations of the scheme crossings, there is very limited response in the modelled 2D flood extents as well.

Table 13: Downstream Boundary sensitivity results

Sensitivity	Water Level Difference (m)							
	SB2_0995 (C01)	SB4_0712 (C02)	SB4_0508 (C03)	SB2_0483 (C04)	SB6_0184 (C05)	CB2_0934 (C06)	CLBN_1516 (C07)	SB2_0678 (C08)
Uplift	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

7.3.7 The sensitivity analysis indicates that the model is slightly sensitive to both flow and roughness. Increasing the flow by 20% sees an increase of peak water level ranging between 4mm to 211mm, whilst an increasing the roughness by 20% has a lesser impact on the peak water levels with a peak increase ranging between 13mm to 88mm. Modelling results show that the model is not sensitive to changes in the downstream boundary conditions. As can be seen from Figure 15 to Figure 17 increasing /decreasing flow and roughness by 20% increases /decreases the flood extents. However, the changes are relatively minor. The results do show that the model is behaving as expected.

Figure 15: Roughness sensitivity 2D flood modelled flood extents

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Figure 16: Inflow sensitivity 2D flood modelled flood extents

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Figure 17: Downstream Boundary sensitivity 2D flood modelled flood extents

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8 Model Assumptions and Limitations

8.1 Introduction

8.1.1 The accuracy and validity of the hydraulic model results is heavily dependent on the accuracy of the hydrological and topographic data included in the model. While the most appropriate available information has been used to construct the model to represent fluvial flooding mechanisms, there are uncertainties and limitations associated with the model.

8.1.2 Efforts have been made to assess and reduce levels of uncertainty in each aspect of the modelling process. The assumptions made are considered to be generally conservative for modelled water levels at the proposed scheme location and are therefore appropriate for the flood risk assessment. Additionally, the sensitivity analysis has quantified the magnitude of potential uncertainty, and the verification process indicates that the modelling outputs are sensible.

8.1.3 The following sections summarise the key sources of uncertainty in addition to the limitations associated with the modelling.

8.2 1D Domain

Channel Roughness

8.2.1 Channel roughness has been assigned using the best available information (site visit, survey data and aerial photographs). The roughness values are based on standard industry guidance (Chow 1959). The channel roughness values may vary over the year and sensitivity tests have been carried out to quantify the impact.

Representation of Structures

8.2.2 Hydraulic coefficients for structures have been applied using available guidance within the Flood Modeller Pro software. The dimensions for structures have been based on detailed survey measurements for baseline scenario and using the detailed structural drawing for the proposed scheme.

Downstream Boundary

8.2.3 The 1D downstream boundary for the Scretan Burn assumes a Normal Depth condition based on the local channel bed gradient of 1:87, whilst the 1D downstream boundary for the Cairnlaw Burn is based on a Flow-Head boundary. Sensitivity testing has shown that the boundaries are suitably distant from the areas of interest, and as such adjustment of the boundary assumptions have negligible impact upon the flood risk at the scheme.

8.3 2D Domain

Floodplain Topography

8.3.1 The floodplain topography has been represented using 1m resolution LiDAR data, which is acceptable for the DMRB Stage 3 assessment.

8.3.2 The connectivity of the river channel and the floodplain at the banks for modelled watercourses is based on a combination of detailed topographical survey and LiDAR data.

Floodplain Structures

8.3.3 Floodplain structures have only been included where they were considered to have an impact on flow mechanism. Levels and dimensions local to the scheme have been taken from the detailed topographic survey. Only one floodplain structure is represented in the scheme model (the right hand opening of the Highland Main Line Railway bridge on the Cairnlaw Burn). Survey data has been used to incorporate this structure into the model.

Grid Size

8.3.4 A 2m grid has been used. This is suitable to represent most of the floodplain features across the model to an appropriate level of detail.

DTM Modifications

8.3.5 Breaklines and elevation polygons have been used as required to better represent topographic features. Elevations for these features have been informed by the detailed topographic survey as well as the 1m Lidar DTM data.

8.3.6 For the proposed scheme, the existing ground levels were modified within the proposed scheme footprint from the MXROAD software.

8.3.7 A polygon has been added to depict topographic survey levels where needed. At the same time z-shape polygons were added to apply the proposed mitigations modifying the ground levels accordingly.

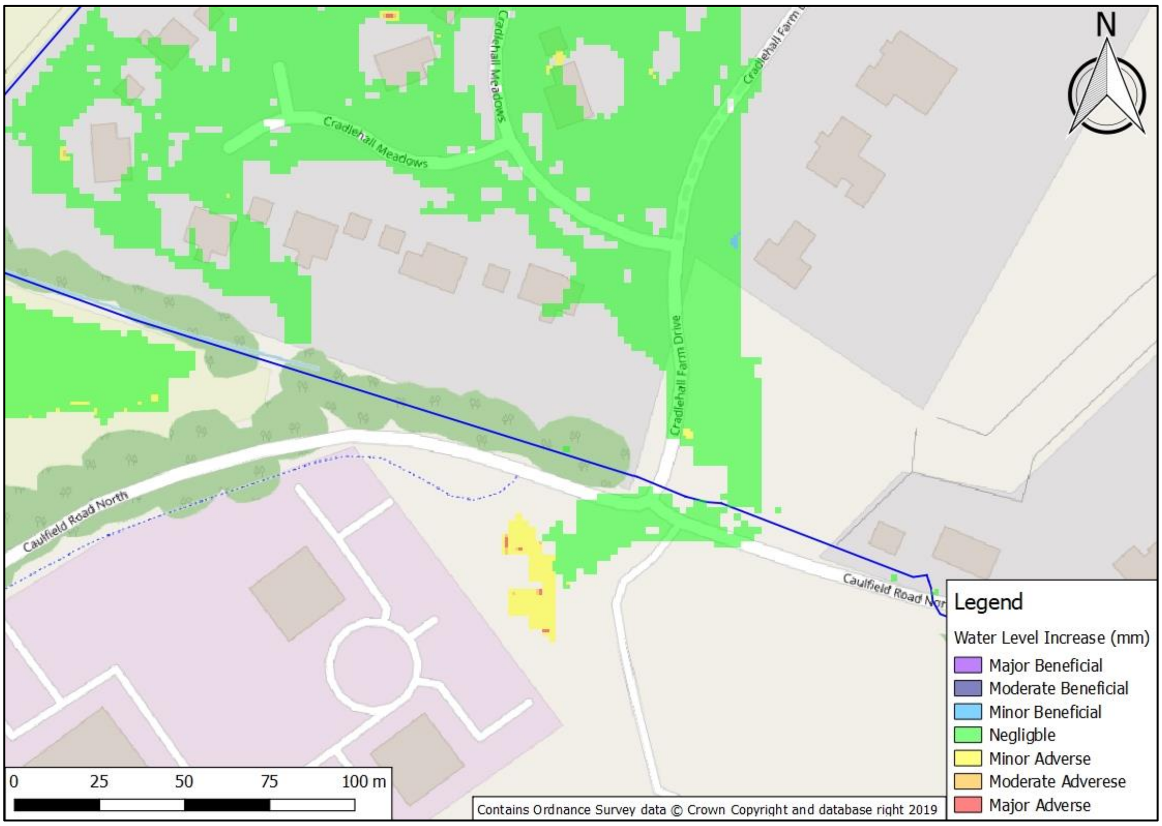
Blockage Scenario

8.3.8 Considering the large size of the eight proposed culverts openings, it is considered unrealistic that these structures would become blocked during flood event conditions. As such no blockage sensitivity scenarios were considered.

8.4 Model Tolerance

8.4.1 As discussed in section 7.1.2 and section 7.1.3 there are two areas of instability within the 1D model. The instability that occurs within the 1D model along the Scretan Burn adjacent to the Cradlehall housing development, Cradlehall Business Park and Caulfield Road North results in small pockets of areas within the 2D predicted flood extents that indicate minor adverse impacts as illustrated in Figure 18. These areas of increased water depth can be attributed to model artefacts and should not be considered an impact of the proposed scheme (this is also described in Appendix A13.1: Flood Risk Assessment section 3.1.74).

Figure 18: Inconsistency in flood extents due to model instability (Run 2C for 0.5% AEP event)



9 Conclusion

9.1.1 This report has detailed the modelling carried out to assess the baseline flood risk along the Cairnlaw Burn, Scretan Burn and their tributaries for a combined reach of approximately 8000m, in the vicinity of the proposed A96 Inshes to Smithton scheme. The 3.33%, 0.5% and 0.5% AEP plus CC flood events were simulated.

9.1.2 The proposed scheme was then incorporated into the model for the design scenarios in order to assess the impact of the proposed scheme on the baseline flood risk. Where increases to flood risk were identified, mitigation measures were developed and incorporated into the proposed scheme and tested with hydraulic model simulations.

9.1.3 Model results have been used to inform the Flood Risk Assessment and are presented in Appendix A13.1 (Flood Risk Assessment) of the EIAR.

9.1.4 The assumptions and limitations associated with the hydraulic modelling are discussed in Section 8 of this report, which should be considered for any future application of the hydraulic model.

10 References

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