JACOBS

Appendix A13.1: Flood Risk Assessment

1 Introduction

Purpose

1.1.1 This Flood Risk Assessment (FRA) provides detailed information on the assessment of all sources of flood risk relevant to the A9/A96 Inshes to Smithton scheme, hereafter referred to as the 'proposed scheme'. The assessment informs Chapter 13 (Road Drainage and the Water Environment), of the Environmental Impact Assessment Report (EIAR).

1.1.2 The purpose of this FRA is to:

- investigate existing (baseline) flood risks;
- identify potential flood risk impacts associated with the proposed scheme; and where necessary; and
- provide details of appropriate flood mitigation / flood management measures.

1.1.3 As a result, this FRA demonstrates that the proposed scheme has adequately addressed local flood risk issues, ensuring that the proposed scheme would remain safe and operational during times of flood and that it would have a neutral or better effect on overall flood risk, taking cognisance of environmental, engineering and economic constraints.

1.1.4 This report is to be read in conjunction with the following sections of the EIAR:

- Chapter 13 (Road Drainage and the Water Environment);
- Appendix A13.2: Surface Water Hydrology;
- Appendix A13.3: Sustainable Drainage Systems (SuDS) and Water Quality;
- Appendix A13.4: Fluvial Geomorphology;
- Appendix A13.5: Watercourse Crossing Report;
- Appendix A13.6: Water Framework Directive (WFD) and River Basin Management Planning; and
- Appendix A13.7: Hydraulic Modelling.

Context

1.1.5 The proposed scheme commences to the west of the A9 Perth – Inverness Trunk Road (hereafter referred to as the A9) with a new overbridge running parallel and to the south of the existing Inshes Overbridge. To the east of the A9, and at the existing junction between the U1058 Caulfield Road North and B9006 Culloden Road, the proposed scheme continues north-east to connect to the proposed Smithton Junction, which will form part of the A96 Dualling Inverness to Nairn (including Nairn Bypass) scheme at Stratton. The proposed scheme will provide local access to different development areas within the existing corridor. Two at-grade roundabouts and a lane gain/lane drop arrangement on the A9 southbound carriageway between Raigmore and Inshes junctions would also be included as part of the proposed scheme. This FRA pertains to the proposed scheme and any land potentially impacted by the proposed scheme.

1.1.6 The land within the vicinity of the proposed scheme is sloped varying between approximately 50 metres above ordnance datum (mAOD) in the vicinity of Inshes to approximately 10mAOD at the existing A96. The land use within the study area is principally agricultural and comprises open fields used for both livestock grazing and crops. There are also several communities and settlements located within the study area. In addition to the existing developments within the proposed scheme corridor, there are a number of proposed or ongoing developments (The Highland Council 2018) which the proposed scheme may also cross in close proximity to including:

- Inverness Campus;
- a new prison;
- upgrade to Inverness Retail and Business Park;
- a care home at Cradlehall; and
- several areas of housing (including the Stratton development to the north east of the study area).

1.1.7 Parts of the proposed route corridor have been identified as being at risk of flooding according to the SEPA Flood Map (SEPA 2018). This has been confirmed through baseline hydraulic modelling which indicate flooding occurs within the vicinity of the proposed scheme during the 'high' likelihood (10% Annual Exceedance Probability (AEP) (10-year)) as well as during the 'medium' likelihood (0.5% AEP (200-year)), and 'low' likelihood (0.1% AEP (1000-year)) events.

1.1.8 The proposed scheme has the potential to alter existing hydrological regimes and flood mechanisms, which may result in undesirable ecological, social and economic impacts. Any adverse effects will be mitigated against where practical and appropriate.

Flood Risk Policy and Guidance

1.1.9 This FRA has been developed with reference to the following legislation, policy and guidance:

Flood Risk Management (Scotland) Act 2009

1.1.10 The Flood Risk Management (Scotland) Act 2009 sets in place a statutory framework for delivering a sustainable and risk-based approach to the management of flooding, including the preparation of assessments of the likelihood and impacts of flooding and associated catchment focussed plans.

1.1.11 The Act places a duty on responsible authorities (Scottish Ministers, Scottish Environment Protection Agency (SEPA), Scottish Water and local authorities) to manage and reduce flood risk and promote sustainable flood risk management. The main elements of the Act, which are relevant to the planning system, are the assessment of flood risks and undertaking structural and non-structural flood management measures.

1.1.12 With reference to the proposed scheme, local authorities are required to consider flood risk management plans that are produced under Section 41 of the Act. For proposed developments, applicants must assess flood risk in respect of the development (Section 42 of the Act). This amends the Town and Country Planning (Development Management Procedure) (Scotland) Regulations 2008 so that local planning authorities require applicants to provide an assessment of flood risk where a development is likely to result in the material increase in the number of properties at risk of flooding.

Scottish Planning Policy

1.1.13 Through the Flood Risk Management Act, Scottish Planning Policy (Scottish Government 2014) requires planning authorities to consider all sources of flooding (coastal, fluvial, pluvial, groundwater, sewers and blocked culverts) and their associated risks when preparing development plans and reviewing planning applications. One of the key principles of Scottish Planning Policy (SPP) is to avoid development in areas at risk of flooding, where practicable.

1.1.14 SPP proposes a flood risk framework to guide development away from flood risk areas. The guidance acknowledges that planning for developments cannot always be solely based on flood risk. The proposed scheme involves the construction of a new local road within a constrained space and therefore avoidance of all flood risk areas is not always practicable. For further details of some of the alternative route options considered refer to Part 1 of Transport Scotland (2017) A9/A96 Inshes to Smithton DMRB Stage 2 Scheme Assessment Report.

1.1.15 SPP recognises that built-up areas considered to be at 'medium' to 'high' risk of flooding (an annual probability of coastal or watercourse flooding greater than 0.5% AEP (200-year) flood event), may be suitable for "Essential Infrastructure", such as the proposed scheme. This is under the provision that they are designed and constructed to remain operational during times of flood and should not impede or adversely impact flood flow.

SEPA Technical Flood Risk Guidance for Stakeholders

1.1.16 The Technical Flood Risk Guidance for Stakeholders document (SEPA 2019) provides an overview of the risk assessment process; primarily appropriate methodologies and techniques to be adopted to ensure flood risk matters have been addressed in a manner consistent with SPP and the Flood Risk Management Act. This guidance recommends that the 0.5% AEP (200-year) peak flow estimates should be increased by a minimum of 20% to account for the impacts of climate change. This should be over and above any separate allowance for freeboard, which is recommended to be a minimum of 600mm.

Design Manual for Roads and Bridges (DMRB)

1.1.17 The Design Manual for Roads and Bridges (DMRB) provides a comprehensive system, which accommodates current design standards, advice notes and other published documents, for the design, assessment, operation, maintenance and improvement of trunk roads and motorways. DMRB Volume 11, Section 3, Part 10, HD45/09: Road Drainage and the Water Environment (Highways Agency, Transport Scotland, Welsh Assembly Government, The Department for Regional Development Northern Ireland 2009) provides guidance on the assessment and management of the impacts that road projects may have on the water environment, including flooding.

1.1.18 In line with SPP, DMRB states that route alignments should avoid the functional floodplain where possible. The functional floodplain is the flood extent up to and including the area covered by a 0.5% AEP (200-year) flood event as defined by the SEPA Flood Map (SEPA 2018). Where this is not possible, and a route alignment encroaches into the functional floodplain, it must be designed and constructed to:

- remain operational and safe for users during times of flood;
- result in no loss of floodplain storage;
- not impede water flows; and
- not increase flood risk elsewhere.

The Highland and Argyll Council Local Flood Risk Management Plan (2016-2022)

1.1.19 The Highland and Argyll Local Flood Risk Management Plan (LPD01) (The Highland Council 2016) identifies a list of constraints to development in the Highlands, one of which is proposed development in areas at 'medium' to 'high' risk of flooding. Flood risk and drainage impacts are highlighted as material considerations for any new application and new developments are required to follow guidance on flood risk and drainage presented in The Flood Risk and Drainage Impact Assessment Supplementary Guidance (The Highland Council 2013).

The Highland and Argyll Council Flood Risk and Drainage Impact Supplementary Guidance

1.1.20 The Highland and Argyll Council Flood Risk and Drainage Impact Supplementary Guidance allows The Highland Council's general planning policy to be effectively implemented through design and construction of developments. The document stipulates additional regional FRA requirements including consultation with organisations such as SEPA, The Highland Councils Technical Environmental and Community Services (TECS) and Scottish Water to establish the flood history of the site.

1.1.21 The supplementary guidance also highlights that The Highland Council are committed to ensuring developments are free from unacceptable flood risk and are not likely to exacerbate flood risk elsewhere. The guidance further emphasises that developments proposed within or bordering 'medium' to 'high' flood risk areas will need to demonstrate compliance with SPP. This includes the criteria in SPP that all new developments should be free from unacceptable flood risk for all flood events up to and including the 0.5% AEP (200-year), plus an allowance for climate change. For potentially vulnerable developments such as schools, hospitals and critical infrastructure, this becomes the 0.1% AEP (1000-year) event.

1.1.22 Where flood management measures are required, natural techniques (e.g. restoration of floodplains, wetlands and water bodies) should be incorporated into the design or sufficient justification provided as to why they are not included. All proposed new developments are also required to be drained by Sustainable Drainage Systems (SuDS) to attenuate flows and reduce pollution to receiving watercourses.

Flood Risk Assessment Approach

1.1.23 Throughout this report flood events are presented as AEP events such as 50%, 20%, 10%, 3.33%, 2%, 1%, 0.5% and 0.1%, which are equivalent to the 2, 5, 10, 30, 50, 100, 200 and 1000-year return period respectively. AEP refers to the chance that a flood of a particular magnitude is experienced or exceeded during any one year. For clarity, the notation used in this report, to describe for example the 0.5% AEP flood event, is '0.5% AEP (200-year) flood event'.

1.1.24 In order to ensure that the proposed scheme has considered flood risk at all stages of the design process, DMRB guidance advocates a staged approach to the evidence-based assessment. Table 1 presents the adopted process of assessing flood risk within the context of DMRB and how this relates to SEPA's technical requirements as a statutory consultee.

1.1.25 In accordance with the DMRB process, the development of the proposed scheme has been assessed at DMRB Stage 3 'Detailed Assessment', as indicated in Table 1 below. This FRA documents the findings of the assessment undertaken on the latest design only.

Table 1: DMRB Assessment Stages

Stage	Assessment Detail	Purpose	Alignment with the requirements of SEPA Technical Guidance
DMRB Stage 1 Scoping Assessment	The 'Scoping Assessment' uses readily available information to: • highlight potential sources of flood risk; and • identify and establish areas and flood sources that require further detailed assessment. Assessment including rivers, small to medium watercourses, ditches and existing water-crossings.	To scope the DMRB 2 'Simple Assessment'.	Identification of sources and types of flooding.
DMRB Stage 2 Simple Assessment	The 'Simple Assessment' aims to assess and compare flood risks between alternative alignment route options by: • providing a description of the baseline conditions; • identifying receptors sensitive to flooding; • assessing the impacts of the proposed scheme route options; and • assessing the importance of the impact i.e. magnitude of the impact against the sensitivity of the receptor.	To inform the selection of a preferred route option and the Stage 2 assessment Environmental Report.	Assessment of design flows. Identification of the plan extents of flooding. Describe the proposed structure/changes and impacts on predicted water level. Assessment of climate change impacts.

Stage	Assessment Detail	Purpose	Alignment with the requirements of SEPA Technical Guidance
DMRB Stage 3 Detailed Assessment	The 'Detailed Assessment' focuses on the potential effects of the preferred alignment route option and where necessary considers appropriate flood mitigation measures to achieve a neutral flood risk.	To inform the proposed scheme design and the EIAR.	Provide details of proposed flood mitigation measures. Provide an assessment of any displaced floodwater on sensitive receptors. Provide reference to any other impact on the river environment.

1.1.26 This FRA has adopted a range of assessment techniques, ranging from preliminary hydraulic calculations to detailed one-dimensional (1D) / two-dimensional (2D) hydraulic modelling, to quantify the existing risk of flooding and potential impact of the proposed scheme on flood risk. Where necessary to aid discussion, the FRA includes a brief overview of the adopted techniques. Further detail of the hydrology and hydraulic modelling techniques adopted are contained within:

- Appendix A13.2 (Surface Water Hydrology); and
- Appendix A13.7 (Hydraulic Modelling).

1.1.27 As the proposed scheme has progressed from the DMRB Stage 2 assessment through to DMRB Stage 3 assessment, so has the level of supporting flood risk evidence, as outlined in Table 1. As a result, the detailed assessment of flood risk has focused on existing areas of 'medium' to 'high' flood risk or where the proposed scheme is likely to have a potential impact on flood sensitive receptors in line with the impact assessment criteria (Annex A: Impact Assessment Criteria).

1.1.28 Where the FRA has identified potential flood risk impacts, flood mitigation measures (either embedded in design or standalone) have been considered to minimise the overall impact on flood risk. At locations where the proposed scheme may have an impact; a range of measures have been explored with the aim of achieving a neutral effect on overall flood risk.

Sources of Flooding

1.1.29 The assessment of flood risk has considered all sources of flooding, specifically:

- Fluvial Flood Risk: Flooding originating from major watercourses in the study area has been analysed through numerical hydraulic modelling. Watercourses selected for hydraulic modelling are based on the perceived sensitivity to flood risk, the impact of the proposed scheme on the watercourse and the potential for the watercourse to pose significant flood risks within the study area. In addition, flooding originating from minor watercourses or drainage channels, with localised or less significant flood risk issues or watercourses not likely to be significantly impacted by the proposed scheme has been analysed through the review of SEPA Flood Map (SEPA 2018) (see Section 3: Fluvial Flooding).
- Surface Water (Pluvial) Flooding: Urban or rural flooding resulting from high intensity rainfall saturating the drainage system (either natural or man-made), with excess water travelling overland and ponding in local topographic depressions before the runoff enters any watercourse, drainage systems or sewer (see Section 4: Surface Water Flooding).
- Groundwater Flooding: Flooding due to a significant rise in the water table, normally as a result of prolonged and heavy rainfall over a sustained period of time (see Section 5: Groundwater Flooding).
- Flooding from Sewers and Water Mains: Flooding due to exceedance of the capacity of man-made drainage systems. A review undertaken as part of the FRA indicated that the majority of the proposed scheme is within a relatively rural area (consistent of predominantly farmland) and that the extent and coverage of the existing sewer network in this area is likely to be relatively limited. The proposed scheme would not result in additional flow being discharged into the existing sewer, or affect the

water supply networks, therefore it is anticipated that the risk of flooding is unlikely to change and consequently the FRA has not considered this source of flooding further.

- Flooding from Land Drainage and Artificial Drainage: Failure of land drainage infrastructure such as drains, channels and outflow pipes, which is most commonly the result of obstructions, poor maintenance and / or blockages. For the proposed scheme, a like for like replacement would be undertaken where this infrastructure is affected. Therefore, the risk of flooding is unlikely to change and consequently the FRA has not considered this source of flooding further.
- Flooding from the Failure of Water Retaining Infrastructure: Flooding due to the collapse and/or failure of man-made water retaining features such hydropower-dams, water supply reservoirs, canals, flood defences structures, underground conduits, and water treatment tanks or pumping stations. The project area is not located downstream of any reservoirs, which could result in inundation of the proposed scheme corridor in the event of failure. The two closest reservoirs to the proposed scheme are Loch Dochfour and Loch Duntelchaig, which are not hydraulically connected to the Inshes to Smithton area and are located more than 10km from the proposed scheme. Therefore, this source of flooding is not considered further in this FRA.
- Coastal/Tidal Flooding: Flooding originating from the sea where water levels exceed the normal tidal range and flood onto the low-lying areas that define the coastline. The proposed scheme is at an elevation of between 20 to 50mAOD and consequently does not traverse areas considered to be at risk of coastal flooding (as indicated by the SEPA Flood Map (SEPA 2018)). Therefore, this source of flooding is not considered further in this FRA.
- Construction Risks: Risk associated with all sources of flooding, which could influence the construction phase (see Section 6: Construction Phase Flood Risk).

1.1.30 This FRA uses the SEPA Flood Maps (SEPA 2018) to assess the risk of fluvial flooding for the un-modelled watercourses and to assess surface water (pluvial) flooding. For each source of flooding, the maps illustrate flood extents for a Low, Medium and High probability of flooding, which refer to the 0.1% AEP (1,000-year), 0.5% AEP (200-year) and 10% AEP (10-year) flood events respectively. The functional floodplain is defined by the SEPA 0.5% AEP (200-year) flood extent. It should be noted that the SEPA Flood Map (SEPA 2018) can be indicative in nature and does not include an allowance for climate change (CC). Consequently, the 0.5% AEP (200-year) flood extent outline indicates the areas considered to be at flood risk for this flood event at the present time. It should also be noted that the SEPA Flood Maps (SEPA 2018) do not indicate flood risk for watercourses with catchment areas less than 3km^2. For watercourses/drainage ditches with catchment areas less than 3km^2, a desk-based flood risk assessment has been undertaken using OS maps.

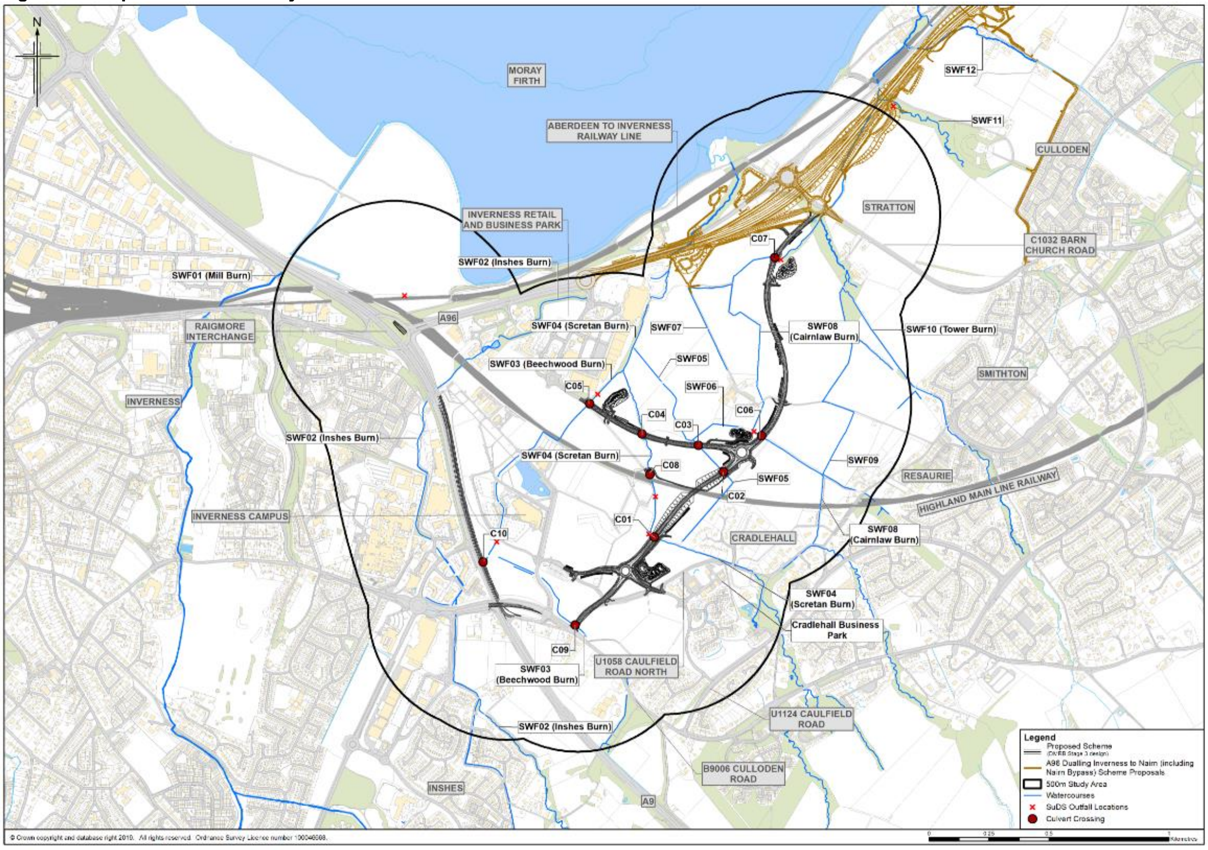
1.1.31 Detailed hydraulic analysis has been undertaken on Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) (and their significant tributaries) using industry standard modelling software. The flood extents produced from these models will supersede the published SEPA Flood Map (SEPA 2018) as the assessment of baseline (existing) flood risk. The hydraulic model developed for this FRA includes survey information obtained for the proposed scheme, including river cross sections, and is more detailed and up to date than the version used to produce the SEPA Flood Map (SEPA 2018). For example, the FRA has considered the potential impact of climate change on fluvial flood depths and extents. In line with current fluvial guidance as published by the Department for Environment, Food and Rural Affairs (Defra) and quoted in SEPA's Technical Flood Risk Guidance for Stakeholders (SEPA 2019), peak flow estimates for the 0.5% AEP (200-year) flood event have been increased by 20% as an allowance for climate change. This is denoted by 0.5% AEP (200-year) plus CC and has been adopted as the 'design flood event'.

2 A9/A96 Inshes to Smithton Scheme Corridor

Scheme Corridor

2.1.1 The FRA for the proposed scheme covers the corridor between Inshes (Inverness) and Stratton as shown in Figure 1.

Figure 1: Proposed Scheme Layout



2.1.2 The proposed scheme corridor extends between Inshes (Inverness) and Stratton and slopes from the south towards the coast. The land largely consists of agricultural land (arable/grazing), with small urban settlements, relatively small areas of retail / business development and Inverness Campus. The A9 runs south-east/north-west at the western edge of the proposed scheme and the A96 Aberdeen – Inverness Trunk Road (hereafter referred to as the A96) runs east/west to the north of the corridor. Several areas within the corridor are planned development locations as part of the Inverness East masterplan as outlined in the Inverness East Development Brief (The Highland Council 2018).

2.1.3 Most residential properties within the project area are located within the communities of Inshes and Cradlehall, as well as a new housing development at Stratton (refer to PA18 to PA21 (Phase 1A) as shown on Figure 15.4: Planning Applications and Development Land Allocations which accompanies Chapter 15: People and Communities – Community and Private Assets). The remainder of residential properties are made up of scattered rural dwellings across the site including a number of farmhouses, associated cottages and agricultural buildings. To the west of the site, east of the Raigmore Interchange is Inverness Retail and Business Park. Inverness Campus (part of Inverness College University of Highlands and Islands (UHI)) is located further south, with the construction of consented expansions to Inverness Campus, in particular a life sciences building (PA13) and a pedestrian bridge (PA12) (under LA03 and LA06) (as shown on Figure 15.4: Planning Applications and Development Land Allocations) currently underway.

2.1.4 The Highland Main Line Railway bisects the site north of Cradlehall between Raigmore and Smithton. The railway is on an embankment through parts of the floodplain with a number of culverts and bridges through the embankment maintaining hydraulic connectivity between the north and south sections of the floodplain. The proposed scheme would cross the Highland Main Line Railway to the north-west of Cradlehall.

2.1.5 There are 12 watercourses within the proposed scheme corridor, seven of which are of 'moderate' catchment area (greater than $0.5km^2$). There are also five minor tributaries and ditches (typically with catchment areas of less than $0.5km^2$). The watercourses drain lateral catchments and generally flow under access tracks/roads/the Highland Main Line Railway. Although watercourse SWF01 (Mill Burn) flows through more heavily urbanised areas of Inverness, it is not crossed by the proposed scheme alignment and no surface runoff from the proposed scheme will be discharged to this watercourse. The watercourses in the vicinity of the proposed scheme are listed in Table 2.

The Proposed Scheme

2.1.6 The proposed scheme would commence to the west of the A9, with a new overbridge running parallel and to the south of the existing Inshes Overbridge, which would be provided to accommodate two lanes in each direction of travel. The proposed scheme would connect to The Highland Council's Inshes Junction Improvements – Phase 2 to the west of the new overbridge. An A9 southbound lane gain/drop arrangement between the Raigmore and Inshes junctions would be included as part of the proposed scheme.

2.1.7 The single carriageway element of the proposed scheme commences where the existing U1058 Caulfield Road North meets the B9006 Culloden Road. The U1058 Caulfield Road North approach to the B9006 Culloden Road would be widened and a new single lane carriageway of approximately 2.2km in length provided, travelling in a north-east direction across land predominantly in agricultural use.

2.1.8 The subsequent subsections provide an overview of the key features of the proposed scheme pertaining to flood risk. Chapter 4 (The Proposed Scheme) of the EIAR contains a full description of the proposed scheme, while Figure A13.1.1 in Annex B of this Appendix illustrates the horizontal alignment of the proposed scheme features.

<u>A9/A96 Inshes to Smithton Scheme**,** Junctions, Access Roads and Tracks</u>

2.1.9 Overall, the proposed scheme includes the following:

- an overbridge crossing the A9 parallel with the existing A9 overbridge (Inshes Overbridge (PS02));
- a four-arm roundabout at Cradlehall that ties into the existing U1058 Caulfield Road North (Cradlehall Roundabout);
- widening of the U1058 Caulfield Road North approach to the B9006 Culloden Road;
- a four-arm roundabout North of Cradlehall that ties into Inverness Retail and Business Park Access (Eastfield Way Roundabout);
- an underbridge crossing the Highland Main Line (Cradlehall Railway Bridge (PS03)); and
- lane gain/drop arrangement along the A9 on the southbound side of the carriageway.

2.1.10 The proposed scheme requires the construction of the road primarily on an embankment as well as limited areas of cutting into the natural topography.

2.1.11 The proposed scheme would include the provision of modified or new local surfaced access roads to Inverness Retail and Business Park, Inverness Campus and Cradlehall, and maintains existing accesses to Ashton Farm.

2.1.12 Other surfaced access roads or unsurfaced access tracks which would be modified or provided by the proposed scheme include new access roads for Sustainable Drainage System (SuDS) features and access tracks serving a small number of properties.

Watercourse Crossings

2.1.13 Twelve watercourses have been identified within the area/in close proximity to the proposed scheme as shown in Table 2. Three watercourses (SWF01/SWF11/SWF12) are located at a distance greater than 500m from the proposed scheme and therefore there are no associated watercourse crossings. Of the remaining nine, five watercourses (SWF02 / SWF03 / SWF04 / SWF08 / SWF10) have a catchment size greater than 0.5m^2 and four watercourses have catchment areas of less than 0.5km^2 and are considered to be minor tributaries/ditches (SWF05 / SWF06 / SWF07 / SWF09). The proposed scheme will result in new crossings for a number of these watercourses (typically by culvert) and a small number of culvert extension / replacements and / or enlargement of existing culverts.

Table 2: Watercourses Within the Area / Near the Proposed Scheme

Watercourse	Modelled (Y/N)	Crossing	0.5% AEP + CC Design Peak Flow (m^3/s)
SWF01 – Mill Burn	N	n/a	n/a
SWF02 – Inshes / Dell Burn	N	n/a	n/a
SWF03 - Beechwood Burn	**Y***	C05	2.28
		C09	1.42
		C10	n/a
SWF04 - Scretan Burn	**Y**	C01	7.39
		C04	7.66
		C08	7.63
SWF05 - Tributary of Scretan Burn	**Y**	C02	0.61
		C03	0.68
SWF06 - Indirect tributary of Scretan Burn	**Y**	n/a	n/a
SWF07 - Un-named Drain	**Y**	n/a	n/a
SWF08 - Cairnlaw Burn	**Y**	C06	4.05
		C07	4.17
SWF09 - Indirect Tributary of Cairnlaw Burn	**Y**	n/a	n/a
SWF10 - Tower Burn	**Y**	n/a	n/a
SWF11 - Tributary of Cairnlaw Burn	N	n/a	n/a
SWF12 - Kenneth's Black Well	N	n/a	n/a
**The lower reaches of SWF03 are included as part of the main 1D/2D model and a section of the upper reach was modelled separately using a 1D model.*			

2.1.14 This FRA is supported by a combined numerical hydraulic model (See Appendix A13.7: Hydraulic Modelling) that was developed for the hydraulic assessment of SWF08 (Cairnlaw Burn) and SWF04 (Scretan Burn) and their associated tributaries (SWF03 to SWF10). Hydraulic simulations were undertaken for the 50% AEP (2-year), 3.33% AEP (30-year), the 0.5% AEP (200-year), and the 0.5% AEP (200-year) plus CC events. The modelled watercourses are described in further detail in Section 3 (Fluvial Flooding).

2.1.15 The design process for the watercourse and minor tributary / ditch crossings is complex, taking account of a range of design criteria and constraints to develop the most appropriate crossing for each watercourse. The factors that influence the culvert design include:

- horizontal and vertical alignment of the proposed scheme;
- maintenance requirements to meet DMRB standards;
- ecological considerations, such as the need to provide adequate mammal passage through culverts;
- geomorphological considerations related to potential erosion and sedimentation issues upstream and downstream of the watercourse crossings; and
- existing flood risk and the potential impact on upstream and downstream flood sensitive receptors in the event that a culvert / bridge is built, or an existing culvert is extended (based on current geometry) or enlarged.

2.1.16 For all areas, these influencing factors need to be considered collectively on a case-by-case basis to develop the most appropriate culvert design for each crossing. During the design process, the decision-making hierarchy adopted was to decide whether a new crossing was required (typically the case for the proposed scheme) or if an existing culvert is present whether to retain the culvert or to extend the culvert on a ‘like-for-like’ basis to accommodate the proposed scheme.

2.1.17 Appendix A13.5 (Watercourse Crossing Report) contains further detail and justification for the design of each structure.

Surface Water Drainage

2.1.18 The proposed scheme will include the construction of new surface water drainage features to treat and attenuate surface water runoff to ensure no detrimental impact upon flood risk and water quality of receiving watercourses. This will include Pre-Earthwork Drainage (PED) and road drainage networks which will include SuDS features (Swales, Wetlands, Filter Drains, and Retention Ponds) with associated outfall structures and access tracks. As part of the proposed scheme, eight surface water drainage catchments and associated drainage networks have been designed to collect, treat and attenuate runoff from the proposed scheme road surface drainage system prior to its discharge into the nearest appropriate receiving watercourse via an outfall. Further details of these SuDS features can be found in Section 4, Table 16 of this report and within Appendix A13.3 (SuDS and Water Quality).

Proposed Scheme Design Principles and Standards

2.1.19 The design of the proposed scheme has developed over the three DMRB assessment stages and has considered a range of design principles and standards and locational and environmental issues. Table 3 provides a list of flood risk design principles and standards considered during the development of the proposed scheme to minimise potential flood risk impacts.

Table 3: Proposed Scheme Flood Risk Design Principles and Standards

Proposed scheme	Design Principles and Standards	Description
A9/A96 Inshes to Smithton scheme carriageway, Junctions, Access Roads and Tracks	The functional floodplain is defined by the 0.5% AEP (200-year) flood envelope. The design flood event is the 0.5% AEP (200-year) plus CC flood event. Flood freeboard is 600mm.	Avoid locating the proposed scheme and any associated works within the functional floodplain where possible. Set the carriageway, junctions and surfaced access roads above the design flood event level plus appropriate flood freeboard. Any unsurfaced access tracks will remain unchanged from existing elevations and as a result may have lower flood design standard.

Proposed scheme	Design Principles and Standards	Description
Watercourse Crossings	The functional floodplain is defined by the 0.5% AEP (200-year) flood envelope. The design flood event is the 0.5% AEP (200-year) plus CC flood event. Flood freeboard is 600mm. Freeboard to bridge and culvert soffits shall meet the requirements of DMRB HA 107/04 (The Highways Agency, Scottish Executive, Welsh Assembly Government, The Department for Regional Development Northern Ireland 2004): • Culverts or bridges up to or equal to 2.4m in diameter or height shall provide a minimum freeboard above the design event peak water level of D/4 where D is the diameter for a circular culvert, or the height for non-circular. • For culverts or bridges with a diameter or height greater than 2.4m, the minimum freeboard shall be 600mm	Avoid locating the proposed scheme and any associated works including bridge piers and abutments within the functional floodplain where possible. Where the proposed scheme intends to replace existing structures, soffit levels are set above the design flood event level plus appropriate freeboard. In line with DMRB, all new (or replaced) mainline and access road culverts and bridges are designed to freely pass the 0.5% AEP (200-year) design flood event (with appropriate freeboard within the culvert barrel). The impact of the proposed scheme on flood risk has been assessed against the design flood event.
Pre-earthwork Drainage (PED)	1.3% AEP (75-year) rainfall runoff flood event	In line with DMRB, PED are designed to capture and convey surface water runoff from the catchment they would be intercepting and discharge into the nearest watercourse.
Road drainage system	100% AEP (1-year) rainfall flood event, without surcharging 20% AEP (5-year) rainfall flood event, plus a 20% allowance for climate change, without exceeding the chamber cover	As per DMRB HD 33/16 (Highways England, Transport Scotland, Welsh Government and Department for Infrastructure 2016), the design of the road drainage system would accommodate a short duration, high intensity rainfall event, without surcharging.
SuDS Features	0.5% AEP (200-year) Functional Floodplain	Avoid developing SuDS in the functional floodplain (where possible) and provide mitigation for increase in flood risk caused by any loss of floodplain capacity where practicable.
	3.33% AEP (30-year) flood event	SuDS features not to be inundated with floodwater during the fluvial event
	0.5% AEP (200-year) rainfall flood event, plus an allowance for climate change and appropriate freeboard.	SuDS features to treat and attenuate the peak flow from the proposed road drainage system.
	50% AEP (2-year) 'greenfield' runoff rate where practicable and no greater than existing 50% AEP (2-year) runoff where not.	SuDS features to discharge into the nearest watercourse at a controlled rate.
Compensatory Flood Storage	Same volume to be provided at the same level relative to the design flood event, which is the 0.5% AEP (200-year) flood event.	Compensatory flood storage should be provided close to the point of lost floodplain and provide the same volume at the same level relative to the design flood level as that lost. In designing compensatory flood storage, the impacts of the measure will be tested against a range of flood events up to the design flood event. Where appropriate, the feasibility of providing storage will also be tested up to the 200-year event plus climate change to take account of criteria associated with long-term sustainability detailed in Scottish Planning Policy (2014), although noting that SEPA Technical Flood Risk

Proposed scheme	Design Principles and Standards	Description
		Guidance for Stakeholders (SEPA 2019) only explicitly requires Compensatory Flood Storage to be provided up to the 0.5% AEP (200-year) flood event.

Flood History

2.1.20 Historical flood records provided by SEPA and The Highland Council have been reviewed for details of recorded flood events that have occurred within or close to the study area. The source of the flooding has generally been attributed to fluvial and / or pluvial events. Anecdotal flood information has also been included from tenants/landowners where available / relevant.

2.1.21 Significant flooding from watercourses and from surface water runoff within the project area have been recorded as recently as October 2014. Recent examples are presented in Table 4.

Table 4: Historic Flood Events

Data Source	Date	Location	Source	Cause and further details
SEPA	November 1997	Cradlehall Park	Fluvial	Scretan Burn 'burst its banks' and water entered property.
SEPA	November 1998	Cradlehall Court	Fluvial	Scretan Burn 'burst its banks' and water entered property.
The Highland Council / SEPA	November 1999	Inshes	Pluvial/Fluvial	Water from the Caulfield Road area flooded the B9006 (Inshes) and multiple properties. A report was also received of the burn overflowing at Caulfield Road North.
SEPA	April 2000	Between Inshes and Westhill	Pluvial	B9006 Culloden Road at Inshes/Westhill – Road badly flooded with flood water up to three feet deep. Road reported as flooding due to water coming from fields.
SEPA	September 2002	Inshes (west) Milton of Culloden Smallholdings Inverness	Fluvial/Pluvial	Extensive floods in and around the Moray firth area. Heavy rainfall, causing Dell Burn to 'burst its banks' flooding large area in Inshes, Old Perth Road and caused damage to slip road on A9 and flooded Thistle Hotel Inverness. Extreme localised rainfall caused flooding of roads, gardens, houses, commercial premises. Multiple road closures. Road washed away between A9 slip and Raigmore interchange.
SEPA	July 2011	Inverness	Pluvial/Other	Flooding issues on roads caused by heavy and localised rainfall.
The Highland Council	January 2012	Barn Church Road	Fluvial/Pluvial	Water flowing down embankment and damaged the roadside drainage at the manhole and damaged the road gully.
SEPA / The Highland Council	October 2014	Cradlehall (Caulfield Road North)	Fluvial	Culvert/trash screen on Scretan Burn block and flood water overflowed onto road. Flood water flowed down road before returning to burn. Some agricultural land likely affected.
SEPA / The Highland Council	October 2014	Inshes (west)	Fluvial/ Groundwater	At the top end, properties were affected by flow overtopping the Beechwood Burn at Simpsons Nursery and running down fields into properties. At lower end there are issues with ground water flooding.
SEPA / The Highland Council	October 2014	Inshes (west)	Fluvial (Blockage)	Trash screen and culvert surcharged and burn backed up and flooded petrol station. Sandbags protected Tesco store from flooding.
The Highland Council	Ongoing	Inshes	Pluvial	Water running down the Culloden Road east of the A9 has been an issue in the past and getting worse over the past 4 to 5 years.

Data Source	Date	Location	Source	Cause and further details
Landowner	Ongoing	Cradlehall/Highland Main Line	Fluvial (Blockage)	Annual flooding of SWF05 (Tributary of Scretan Burn) just south of Highland Main Line Railway caused by heavy rainfall and blockage of drain. No properties affected.

3 Fluvial Flooding

Introduction

3.1.1 Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) will be crossed by the proposed scheme. Both watercourses, together with their tributaries in the vicinity of the proposed scheme, have therefore been selected for hydraulic modelling for this DMRB Stage 3 assessment. A combined numerical hydraulic model for Cairnlaw Burn and Scretan Burn has been developed by extending the existing numerical hydraulic model of the Cairnlaw Burn developed for the A96 Dualling Inverness to Nairn (including Nairn bypass) scheme. The model was expanded to include additional tributaries that may have a hydraulic impact on the proposed scheme. Further details on the combined model is provided in Appendix A13.7 (Hydraulic Modelling). The upstream model extents are from the Cradlehall area on both Cairnlaw Burn and Scretan Burn, the downstream extent of the Scretan Burn (SWF04) model is to the Inner Moray Firth. The Cairnlaw Burn (SWF08) model extent ends at Stratton where the downstream boundary is based upon a stage/discharge relationship extracted from the Cairnlaw Burn (SWF08) model for the A96 Inverness to Nairn (including Nairn Bypass) scheme (the downstream boundary of which extends to the Inner Moray Firth). Within the model extent, sections of the watercourses' main stem and some of their tributaries are in close proximity or cross the proposed scheme.

3.1.2 The study area includes areas of floodplain identified on the SEPA Flood Map (SEPA 2018) for the 'medium' likelihood 0.5% AEP (200-year) flood event. Scretan Burn (SWF04) has notable areas of flooding for the 0.5% AEP (200-year) flood event from the Highland Main Line railway to its confluence with the Inner Moray Firth. Cairnlaw Burn (SWF08) also has notable areas of flooding for the 0.5% AEP (200-year) flood event from just south of the Highland Main Line railway to its confluence with the Inner Moray Firth and along the southern edge of the Highland Main Line railway to Scretan Burn (SWF04). Flooding is also shown along Cairnlaw Burn's tributaries; indirect tributary of Cairnlaw Burn (SWF09) and Tower Burn (SWF10).

3.1.3 Given the location of the proposed scheme within areas of the floodplain, an assessment has been undertaken to consider the risk of flooding to the road and potential impact on flood risk within the catchments examined.

Assessment Approach

3.1.4 For the purposes of this FRA, a numerical hydraulic model has been developed for the proposed scheme area. The model adopts 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 flood water between the watercourses and the floodplain.

3.1.5 It should be noted that hydraulic modelling is subject to a degree of uncertainty regarding predicted water levels. The source of this uncertainty arises from the accuracy of survey data, hydrology, peak flow estimates and other information used to construct the model such as channel bed and bank roughness. Sensitivity testing is used to explore these uncertainties and further details are provided in Appendix A13.2 (Surface Water Hydrology) and Appendix A13.7 (Hydraulic Modelling). As these uncertainties are applicable to both the baseline and proposed scheme modelling they are not considered to have an impact on the assessment of flood risk to the proposed scheme. This inherent uncertainty is addressed via the incorporation of freeboard within the proposed scheme design.

Throughout this FRA, modelling results are reported to the nearest millimetre (mm) to provide as detailed an indication of the difference between the baseline and proposed scheme scenarios.

3.1.6 The baseline hydraulic model was developed to reflect the existing situation (prior to the proposed scheme) and included representation of:

- SWF08 (Cairnlaw Burn) and its tributaries SWF07, SWF09 and SWF10; and
- SWF04 (Scretan Burn) and its tributaries SWF03, SWF05, and SWF06.

3.1.7 In addition, a 1D model has been used to represent the upper reach of SWF03 (Beechwood Burn) and where it is crossed by the proposed scheme at culvert C09. This model is discussed below in 'Beechwood Burn Model (SWF03)'.

3.1.8 To assess existing flood risk and the potential impact of the proposed scheme, the modelling considers two scenarios: the 'baseline (existing corridor) scenario' and the 'proposed scheme (without mitigation) scenario'. A third modelling scenario, the 'proposed scheme (with mitigation) scenario' was developed to identify methods of mitigating any adverse impacts. Appendix A13.7 (Hydraulic Modelling), provides further details of the hydraulic model build process, but in summary, modifications to the baseline model to represent the proposed scheme included:

- the new carriageway, which includes embedded mitigation to prevent the carriageway from flooding;
- modifications to existing structures (if required) and inclusion of new hydraulic structures (culverts) in the river channel or flood relief culverts; and
- inclusion of proposed scheme features within the floodplain, including junctions, access roads and tracks, and road drainage features, such as SuDS features (e.g. wetlands/swales).

3.1.9 Following consultation with SEPA (2018 and 2019), two sets of hydraulic simulation runs (namely, Run 1 and Run 2) have been undertaken in the hydraulic model for all scenarios in order to assess a range of flooding conditions for different storm durations at different target locations. Run 1 adopts the longer storm duration for the entire catchment / sub-catchments to the downstream model extent (target location at the A96 crossing). Run 2 considers the design flows specific to each of the proposed culvert crossing locations (target locations) associated with the proposed scheme (which changes the focus to upstream locations within the catchments). Accordingly, in Run 2 the design storm duration appropriate for each of the proposed culvert locations was adopted, which resulted in three model runs being required (namely, Run 2a, 2b and 2c). Further details on the model runs is provided in Appendix A13.2 (Surface Water Hydrology) and Appendix A13.7 (Hydraulic Modelling).

3.1.10 All model scenarios were then simulated for a range of flood events including the design flood event in accordance with SEPA recommendations (SEPA 2019). Appendix A13.2 (Surface Water Hydrology) provides further detail of the flood hydrology. The model inflows for both Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) and their modelled tributaries were applied to the hydraulic model in the form of full hydrographs (point flow or lateral flow as appropriate), and the peak model inflows in Run 1 are shown in Table 5.

Table 5: Run 1 Peak Inflows (m^3/s) Applied to Modelled Watercourses

Watercourse	50% AEP (2-year) (m^3/s)	3.33% AEP (30-year) (m^3/s)	0.5% AEP (200-year) (m^3/s)	0.5% AEP (200-year) plus CC (m^3/s)
Cairnlaw Burn (SWF08) and its modelled tributaries				
Inflow 1 (Cairnlaw Burn)	0.88	1.98	3.08	3.70
Inflow 2 (Cairnlaw Burn – tributary)	0.02	0.04	0.06	0.07
Inflow 7 (SWF09)	0.17	0.40	0.64	0.77
Inflow 8 (Tower Burn)	0.89	2.01	3.16	3.79

Watercourse	50% AEP (2-year) (m^3/s)	3.33% AEP (30-year) (m^3/s)	0.5% AEP (200-year) (m^3/s)	0.5% AEP (200-year) plus CC (m^3/s)
R12 (lateral flow)	0.07	0.15	0.23	0.28
R13 (lateral flow)	0.06	0.14	0.21	0.26
R14/15 (lateral flow)	0.07	0.15	0.24	0.28
Cumulative total	*2.14*	*4.85*	*7.61*	*9.14*
Scretan Burn (SWF04) and its modelled tributaries				
Inflow 3 (Scretan Burn)	1.25	2.80	4.29	5.15
Inflow 4 (Beechwood Burn)	0.45	1.03	1.61	1.94
Inflow 5a (Tributary of Scretan Burn)	0.13	0.29	0.44	0.53
Inflow 5b (Tributary of Scretan Burn)	0.01	0.02	0.04	0.04
Inflow 6 (Indirect tributary of Scretan Burn)	0.54	1.24	1.97	2.37
R1 (lateral flow)	0.05	0.11	0.17	0.20
R2 (lateral flow)	0.07	0.16	0.25	0.30
R3 (lateral flow)	0.09	0.19	0.31	0.37
Cumulative total	**2.58**	**5.84**	**9.07**	**10.89**

3.1.11 Similarly, the peak flows of the model inflow hydrographs for the two main stem watercourses and their tributaries applied as point inflow and lateral inflow (as appropriate) for Run 2a, 2b and 2c are presented in Annex C.

3.1.12 Once hydraulic simulation for the Run 1 and Run 2 scenario was completed, the 1D and 2D model outputs were extracted and mapped as a composite flood extent, with comparison made to:

- peak flood flow and peak water level within the channel;
- peak flood water depth within the floodplain;
- spatial flood extent;
- peak water velocity;
- flood inundation volume; and
- historic flood records for verification purposes.

3.1.13 Annex B contains mapping illustrating the baseline scenario, the proposed scheme (no mitigation) scenario flood depths across the modelled floodplain, and the proposed scheme (with mitigation). The flood mapping also illustrates the impacts on maximum flood level difference, categorised using Table 6, during the design flood event. It is important to note that all figures contained within this Appendix and Annex B are the 'worst-case' composite maps of Runs 1, 2a, 2b and 2c which means that the maps are conservative. Additionally, some impact maps depict areas of 'minor adverse' impact which are often the result of computational differences and are not due to impacts from the proposed scheme. More details can be found in Appendix 13.7 (Hydraulic Modelling), which also presents the peak water levels for each model cross-section.

Table 6: Fluvial Flood Risk Impacts

Potential flood impact		Change in Peak Flood Level for the Design Flood Event
(red)	Major Adverse	Increase in peak flood level >100mm
(amber)	Moderate Adverse	Increase in peak flood level >50mm
(yellow)	Minor Adverse	Increase in peak flood level >10mm
(green)	Negligible	Negligible change in peak flood level <+/- 10mm

Potential flood impact		Change in Peak Flood Level for the Design Flood Event
	Minor Beneficial	Reduction in peak flood level >10 mm
	Moderate Beneficial	Reduction in peak flood level >50mm
	Major Beneficial	Reduction in peak flood level >100mm

Baseline Fluvial Flood Risk

3.1.14 This section provides an overview of baseline fluvial flood risk along the existing corridor identified using the hydraulic model.

3.1.15 Figures 2 and 3 show the baseline flood risk during the 3.33% AEP (30-year) and 0.5% AEP (200-year) plus CC events respectively. The flood extents and flow paths are discussed within the context of three different areas:

- Cradlehall to the Ashton Farm (Cairnlaw Burn (SWF08) and Scretan Burn (SWF04));
- Ashton Farm to Smithton Junction (Cairnlaw Burn (SWF08)); and
- Inverness Retail and Business Park to the Inner Moray Firth (Scretan Burn (SWF04)).

Figure 2: Proposed Scheme Corridor 3.33% AEP (30-year) Modelled Baseline Composite Flood Risk Map.

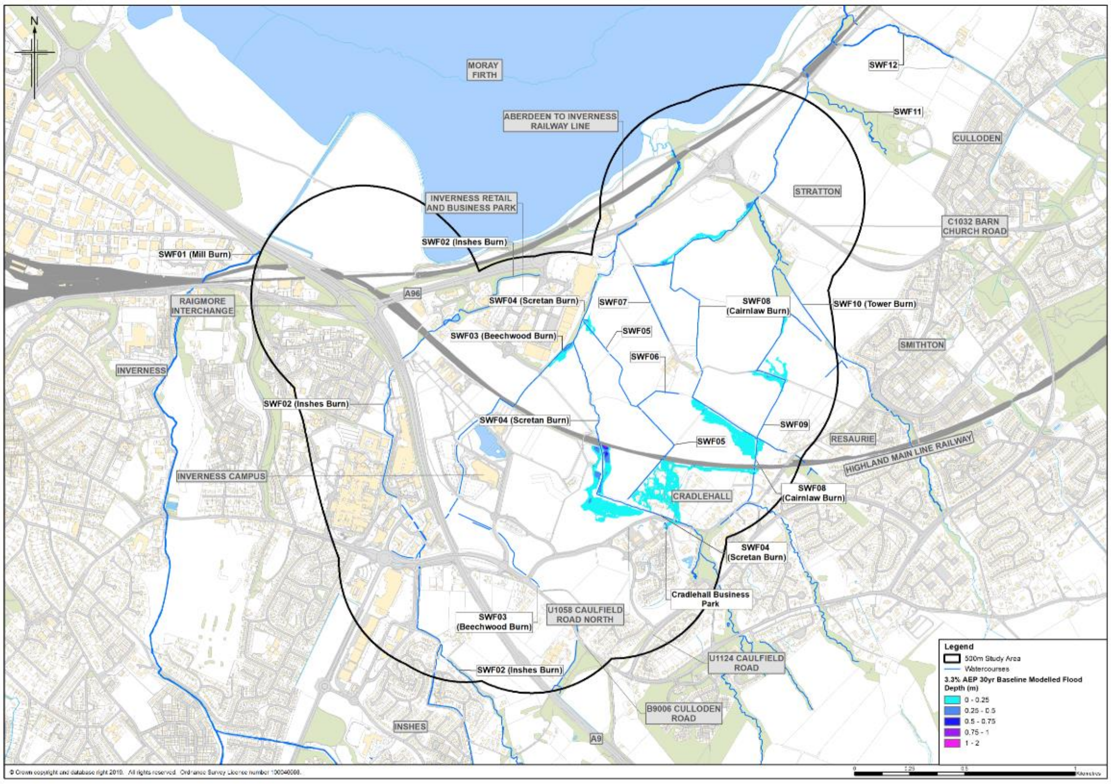
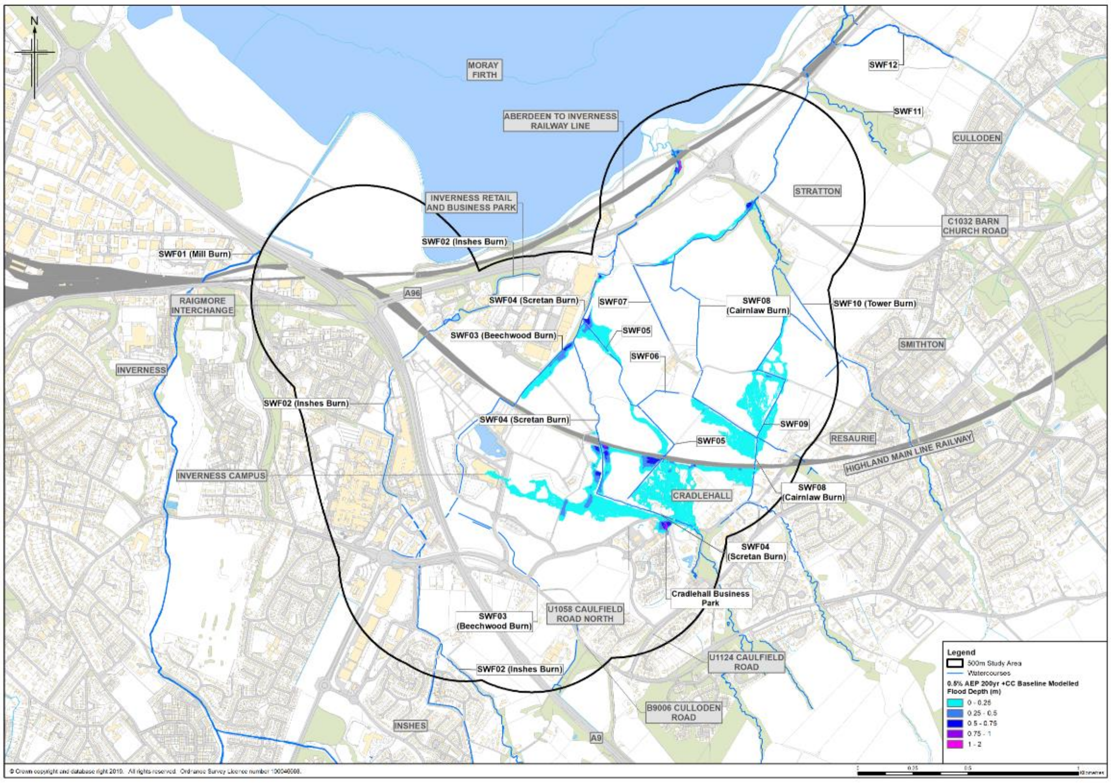


Figure 3: Proposed Scheme Corridor 0.5% AEP (200-year) plus CC Modelled Baseline Composite Flood Risk Map.

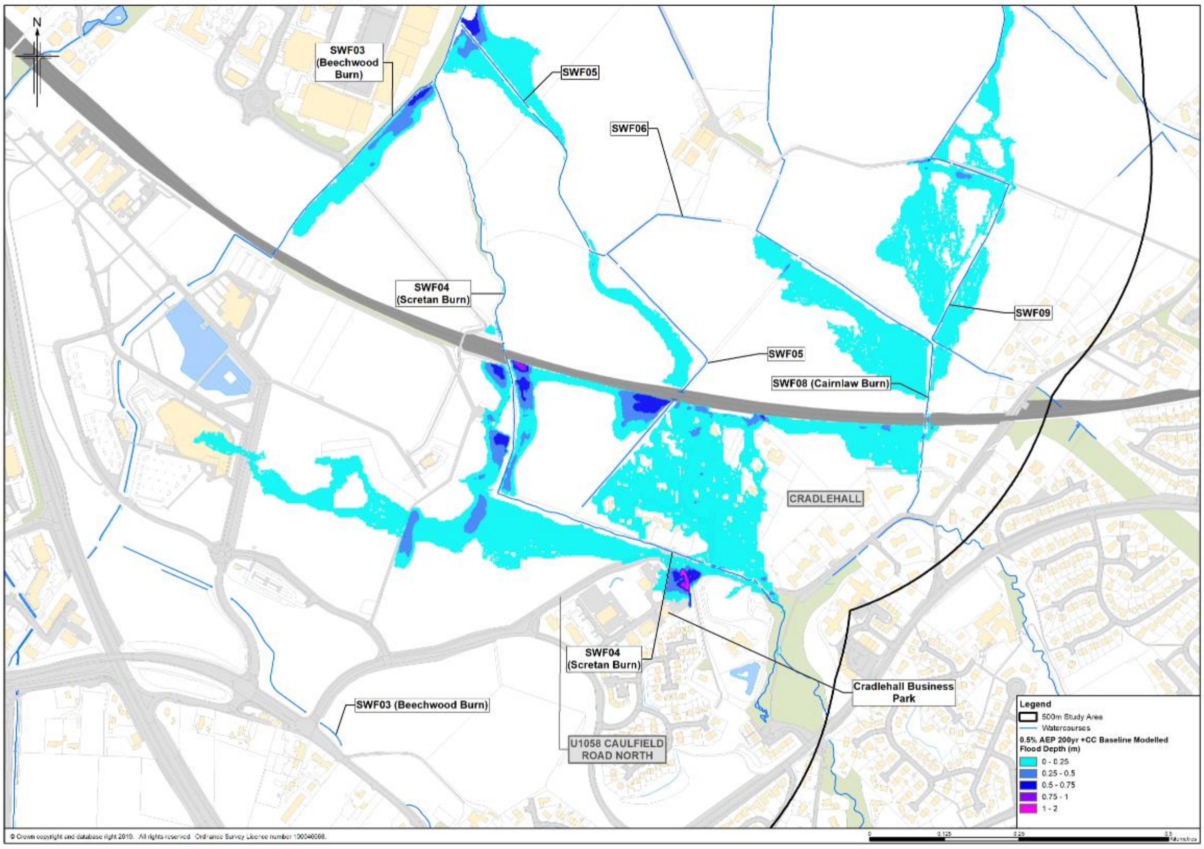


Cradlehall to Ashton Farm

3.1.16 Flood Mapping for the Cradlehall to Ashton Farm area is shown on Figure 4 for the 0.5% AEP (200-year) plus CC flood event.

3.1.17 East of Cradlehall, the hydraulic modelling predicts that during the 3.33% AEP (30-year) event, flows from Cairnlaw Burn (SWF08) will overtop the left bank upstream of the railway culvert, inundating an area just south of the Highland Main Line Railway (refer to Figure 2). The model predicts transfer of flow from Cairnlaw Burn to the tributary of Scretan Burn (SWF05) at this location for the 3.33% AEP (30-year) event. The extent of flood water inundation on the left bank floodplain of Cairnlaw Burn is increased slightly during the 0.5% AEP (200-year) plus CC event with greater volumes of flood water being transferred from Cairnlaw Burn to SWF05 (refer to Figure 4).

Figure 4: Cradlehall to Ashton Farm 0.5% AEP (200-year) plus CC Modelled Baseline Composite Flood Risk Map.



3.1.18 North of the Highland Main Line Railway the hydraulic model predicts that during the 3.33% AEP (30-year) event, the left bank of Cairnlaw Burn (SWF08) is overtopped and an area of the agricultural land adjacent to the Cairnlaw Burn is inundated (refer to Figure 2). An area to the east of the Cairnlaw Burn is also inundated by water spilling from the Cairnlaw Burn/SWF09 (indirect tributary of the Cairnlaw Burn). Flood water further spills from SWF09 to the north of this location flooding the access track between Ashton Farm and Resaurie. During the design flood event these areas of land are predicted to have greater flood extents especially along the left and right banks of SWF09. During the 0.5% AEP (200-year) plus CC event (refer to Figure 4), the right bank of SWF09 overtops, causing flooding along approximately 250m of the river corridor. The left bank is also overtopped, and a significant volume of water flows north across agricultural land before re-joining the watercourse south of the eastern Ashton Farm access track culvert. The access track between Ashton Farm and Resaurie on the left bank of SWF09 is predicted to be flooded along approximately 160m of its length, inundating a similar extent to the 3.33% AEP (30-year) event.

3.1.19 South of Cradlehall, Scretan Burn (SWF04) is simulated to overtop its right bank during the 3.33% AEP (30-year) event (see Figure 2), inundating properties in Cradlehall (the average flood depth in this area is 0.024m). The model also predicts that an area is inundated on the left bank of the watercourse in close proximity to a business premises in the Cradlehall Business Park (the average flood depth in this area is approximately 0.130m). During the 0.5% AEP (200-year) plus CC event (refer to Figure 4) the model predicts that the inundation at this area is significantly increased in the Cradlehall Meadows and Cradlehall Farm Drive area. Approximately 20 properties are predicted to be within the potential inundation extents; however, the average flood depth in this area is only 0.051m which is likely to be below the floor level of these properties. Some areas of the Cradlehall Business Park are predicted to become inundated during the design event 0.5% AEP (200-year) plus CC event with an average flood depth of 0.305m and a localised maximum depth of 1.315m.

3.1.20 South-west of Cradlehall, Scretan Burn (SWF04) is simulated to flood the left bank floodplain from the 3.33% AEP (30-year) event (see Figure 2). Flood extents are simulated to increase during the 0.5% AEP (200-year) plus CC event (refer to Figure 4) with overland flow towards the Inverness Campus, inundating sections of two local access roads and extending to Inverness College (UHI).

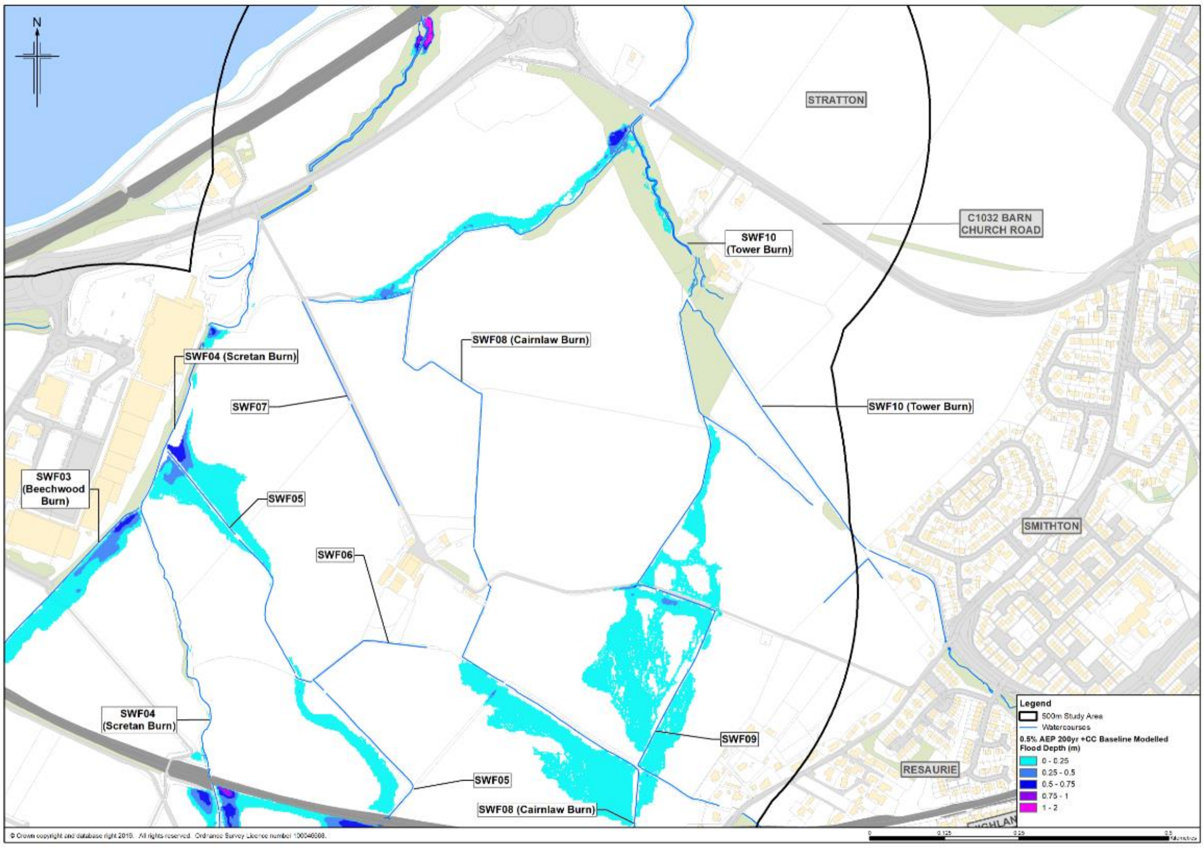
3.1.21 During a 3.33% AEP (30-year) event (see Figure 2), the hydraulic modelling simulates that Scretan Burn (SWF04), west of Cradlehall, overtops both its banks flowing parallel to the watercourse and re-entering Scretan Burn immediately upstream of the culvert under the Highland Main Line Railway. During the 0.5% AEP (200-year) plus CC event (refer to Figure 4) the flood depths in the floodplain on the east side of Scretan Burn would be slightly increased, particularly at the entrance of the Highland Main Line Railway culvert. During the design event the left bank of Tributary of Scretan Burn (SWF05) is simulated to overtop due to lateral overland inflow from Cairnlaw Burn (SWF08). Flood water then flows adjacent to the Highland Main Line Railway before joining Scretan Burn.

3.1.22 During the design event the Tributary of Scretan Burn (SWF05) is also simulated to overtop its left bank downstream of the Highland Main Line Railway culvert, however this overtopping is not predicted at the 3.33% AEP (30-year) event (refer to Figure 2 and 4). The flood water flows over agricultural land before re-joining the watercourse.

Ashton Farm to Smithton Junction

3.1.23 The Flood Mapping for the Ashton Farm to Smithton Junction is provided in Figure 5 for the 0.5% AEP (200-year) plus CC flood event.

Figure 5: Ashton Farm to Smithton Junction 0.5% AEP (200-year) plus CC Modelled Baseline Composite Flood Risk Map



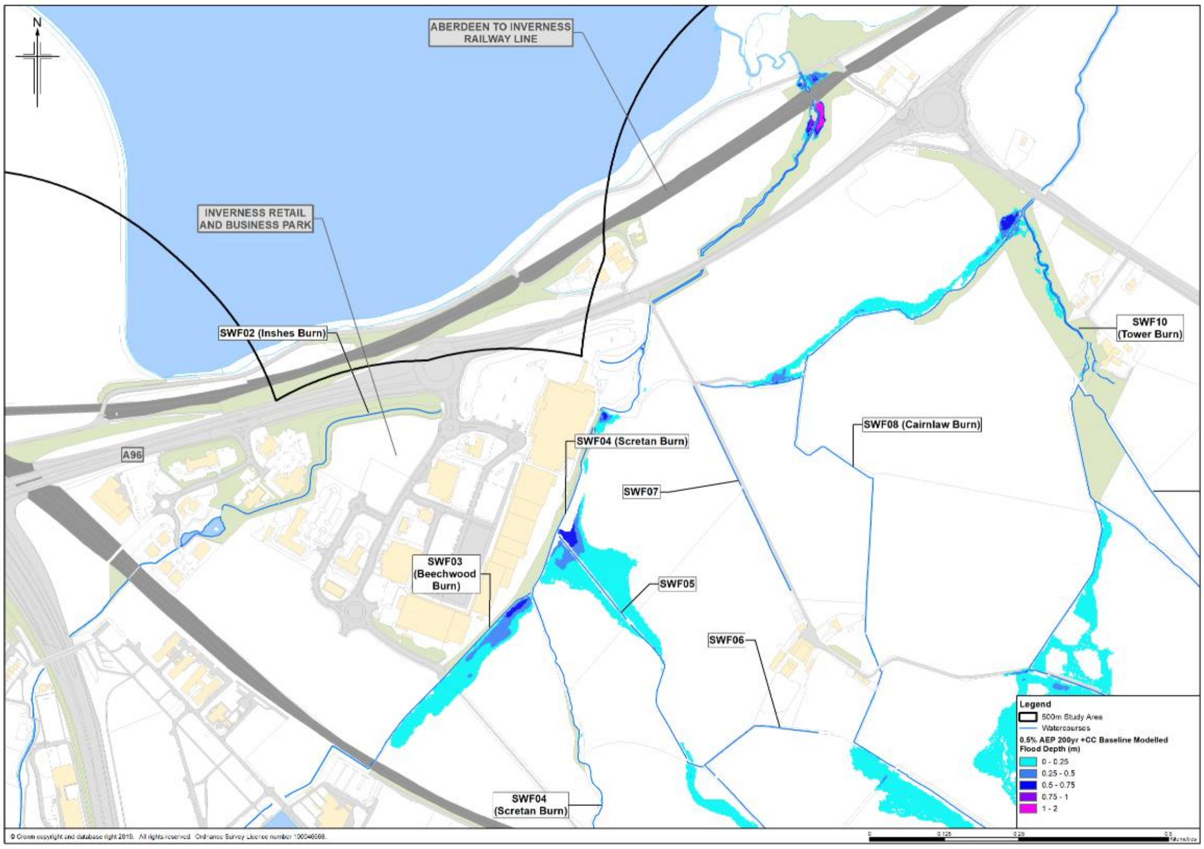
3.1.24 Immediately north of the eastern Ashton farm access track, hydraulic modelling simulates overtopping of the right bank of Indirect tributary of Cairnlaw Burn (SWF09) during a 3.33% AEP (30-year) event (see Figure 2) resulting in floodplain inundation which becomes more extensive during the 0.5% AEP (200-year) plus CC flood event (refer to Figure 5), with water flowing overland before re-joining the watercourse approximately 290m downstream.

3.1.25 Between the confluence of Cairnlaw Burn (SWF08) with Un-named drain (SWF07) and the confluence between Cairnlaw Burn and Tower Burn (SWF10), hydraulic modelling simulates that an area of Cairnlaw Burn floodplain is inundated during the 3.33% AEP (30-year) event (see Figure 2), and the inundation is widespread at the 0.5% AEP (200-year) plus CC event (with an increase in water depths) (refer to Figure 5). Flooding is also simulated on the left bank of SWF07 (Un-named drain). South of the confluence of Tower Burn with Cairnlaw Burn the modelling also simulates that the Tower Burn floodplain is inundated during the 0.5% AEP (200-year) plus CC design flood event. However, this area of Tower Burn floodplain is not simulated to become inundated during the 3.33% AEP (30-year) event (see Figure 2).

Inverness Retail and Business Park to Inner Moray Firth

3.1.26 The Flood Mapping for the Inverness Retail and Business Park to Inner Moray Firth is provided in Figure 6 for the 0.5% AEP (200-year) plus CC flood event.

Figure 6: Inverness Retail and Business Park to Inner Moray Firth 0.5% AEP (200-year) plus CC Modelled Baseline Composite Flood Risk Map



3.1.27 Upstream of the confluence with Scretan Burn (SWF04), Beechwood Burn (SWF03) overtops its right bank, partially inundating the agricultural land adjacent to the watercourse. This area becomes completely inundated during the 0.5% AEP (200-year) plus CC flood event with a maximum floodwater depths in this area of approximately 0.641m (refer to Figure 6).

3.1.28 At the confluence between Scretan Burn (SWF04) and Tributary of Scretan Burn (SWF05), localised flooding is simulated by the hydraulic model to occur south-east of Inverness Retail and Business Park during the 3.33% AEP (30-year) event (refer to Figure 2). During the 0.5% AEP (200-year) plus CC event (refer to Figure 6), the inundation area becomes more widespread, with the out of bank flow predicted on both sides of the Tributary of Scretan Burn (SWF05) approximately 250m upstream of the confluence.

3.1.29 Immediately upstream and downstream of the Aberdeen to Inverness Railway culvert there are areas of flooding either side of Scretan Burn (SWF04) during the 3.33% AEP (30-year) event. During the 0.5% AEP (200-year) plus CC event the flood extent is greater with significantly greater depths (>1m).

Summary

3.1.30 The predicted baseline flood risk within the project area is summarised below in Table 7.

Table 7: Summary of Baseline Flood Risk

Location	Baseline Flood Risk in 0.5% AEP (200-year) plus CC event
Cradlehall to Ashton Farm	Flooding to properties in Cradlehall, Inverness College (UHI), various local roads, some parts of the Cradlehall Business Park and extensive flooding to agricultural land.
Ashton Farm to Smithton Junction	Extensive flooding to agricultural land and to sections of Ashton Farm access track.
Inverness Retail and Business Park to Inner Moray Firth	Flooding to agricultural land east of Inverness Retail and Business Park. Areas of flooding immediately upstream and downstream of Aberdeen to Inverness Railway Line culvert.

Potential Impacts

3.1.31 This section provides an overview of the impact of the proposed scheme upon fluvial flood risk without mitigation for the 0.5% AEP (200-year) plus CC event.

3.1.32 Culverts have been included in the model simulation at watercourse crossings and have been designed to replicate baseline channel flow conditions and are considered as embedded mitigation within the 'pre-mitigation' scenario.

3.1.33 The proposed scheme includes raising the main alignment above the 0.5% AEP (200-year) plus CC peak water level to reduce the risk of flooding to the proposed scheme. A minimum freeboard of 600mm to the proposed scheme has been provided above this level as per SEPA guidance (SEPA 2019).

3.1.34 As per previous sections, the impact of the proposed scheme on flood extents and depths is discussed in terms of three areas:

- Cradlehall to the Ashton Farm;
- Ashton Farm to Smithton Junction; and
- Inverness Retail and Business Park to Moray Firth.

3.1.35 The 0.5% AEP (200-year) plus CC flood depth impact map (pre-mitigation) for the proposed scheme corridor is shown in Figure 7.

Figure 7: Proposed Scheme Corridor 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Pre-mitigation)

Cradlehall to Ashton Farm

3.1.36 Flood Mapping for the Cradlehall to Ashton Farm area is shown on Figure 8 for the 0.5% AEP (200-year) plus CC flood event.

3.1.37 East of Cradlehall, immediately upstream and downstream of the Highland Main Line Railway, no changes to flood extents/depths are simulated by the hydraulic model from SWF08 (Cairnlaw Burn) due to the proposed scheme. However, the depths and extents of flooding on the access to between Ashton Farm and Resaurie upstream of culvert C06 are predicted to increase due to the proposed scheme. The hydraulic model simulates ponding upstream of culvert C06, causing a major adverse increase in flood depths during the design event. Impoundment due to the proposed road embankment results in an increase in peak flood depth by 0.808m in comparison with the baseline flood depth at this location.

3.1.38 The proposed scheme is likely to have a ‘negligible’ impact on the flood extents/depths caused by the overtopping and overland flow associated with SWF09 (indirect tributary of Cairnlaw Burn), as predicted by the hydraulic model.

3.1.39 The proposed scheme is predicted to have a ‘negligible’ impact on the overtopping of SWF04 (Scretan Burn) in the vicinity of Cradlehall and the flooding of properties in north Cradlehall (including Cradlehall Meadows and the Cradlehall Farm Drive area). There are areas (individual cells or groups of cells) in which there is minor adverse increase in depth, but these can be discounted as being the result of numerical variability/instabilities within the modelling software (for further details refer to Section 7 of Appendix A13.7 (Hydraulic Modelling Report)). This is discussed further in section 3.1.74 and has been highlighted in consultation with SEPA during discussions on the site hydrology and model schematisation.

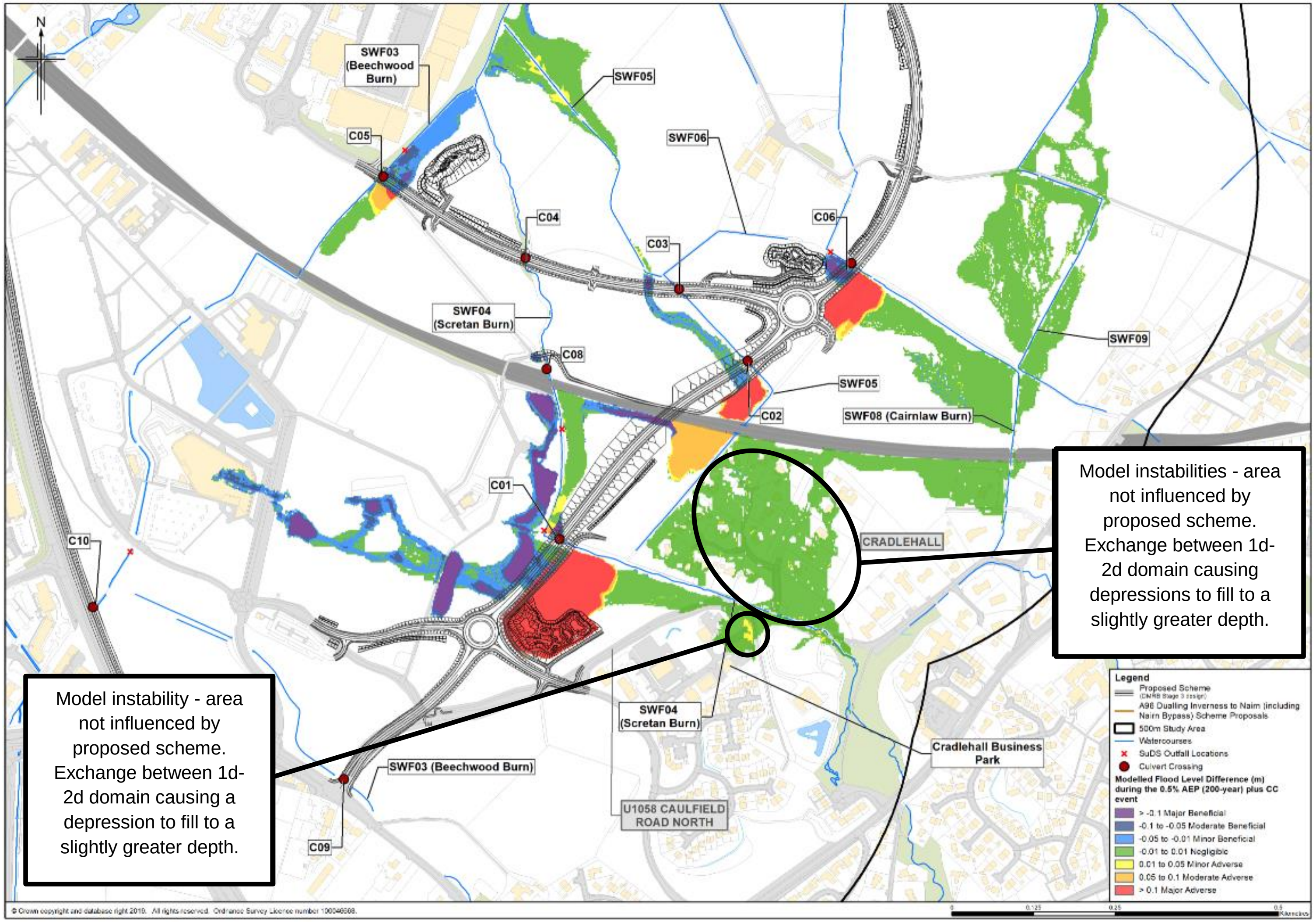
3.1.40 The results of hydraulic modelling indicate that the proposed scheme will result in a significant increase in flood depths upstream of culvert C01 on SWF04 (Scretan Burn), causing a ‘major adverse’ increase in flood depths, especially in the depression south-west of SWF04 (Scretan Burn) with an increase in peak depth of 1.916m. Impoundment on the upstream side of the proposed scheme prevents the flow pathway westward towards Inverness Campus, thus resulting in a ‘negligible’ to ‘major beneficial’ impact in this area for the design event. As such the risk to the local access roads and Inverness Campus would be reduced but this would leave a significant impounded volume on the upstream side of the road embankment. Therefore, suitable mitigation measures are required to mitigate the impact of flooding at this location.

3.1.41 Between culvert C01 and C08, the model predicts that the right bank of SWF04 (Scretan Burn) has a ‘minor to moderate adverse’ increase in flood depths for approximately 70m downstream of culvert C01 in comparison with the baseline.

3.1.42 The proposed scheme has a ‘moderate adverse’ impact on the flooding associated with the overtopping of the left bank of SWF05 (tributary of Scretan Burn) upstream of the railway culvert. This leads to an increase in depth of 0.075m in the floodplain adjacent to the watercourse. Immediately downstream of the SWF05 (tributary of Scretan Burn) railway culvert, the out of bank flow is constrained by the proposed scheme road embankment, resulting in a ‘major adverse’ impact with ponding in this area with an increase in depth of 0.578m. This impounding effect prevents the north westerly overland flow mechanism across agricultural land, resulting in a ‘negligible; to ‘major beneficial’ impact in this area.

3.1.43 The ‘Mitigation Appraisal and Selection’ details methods applied to mitigate increased flood risk caused by the proposed scheme.

Figure 8: Cradlehall to Ashton Farm 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Pre-mitigation)



Ashton Farm to Smithton Junction

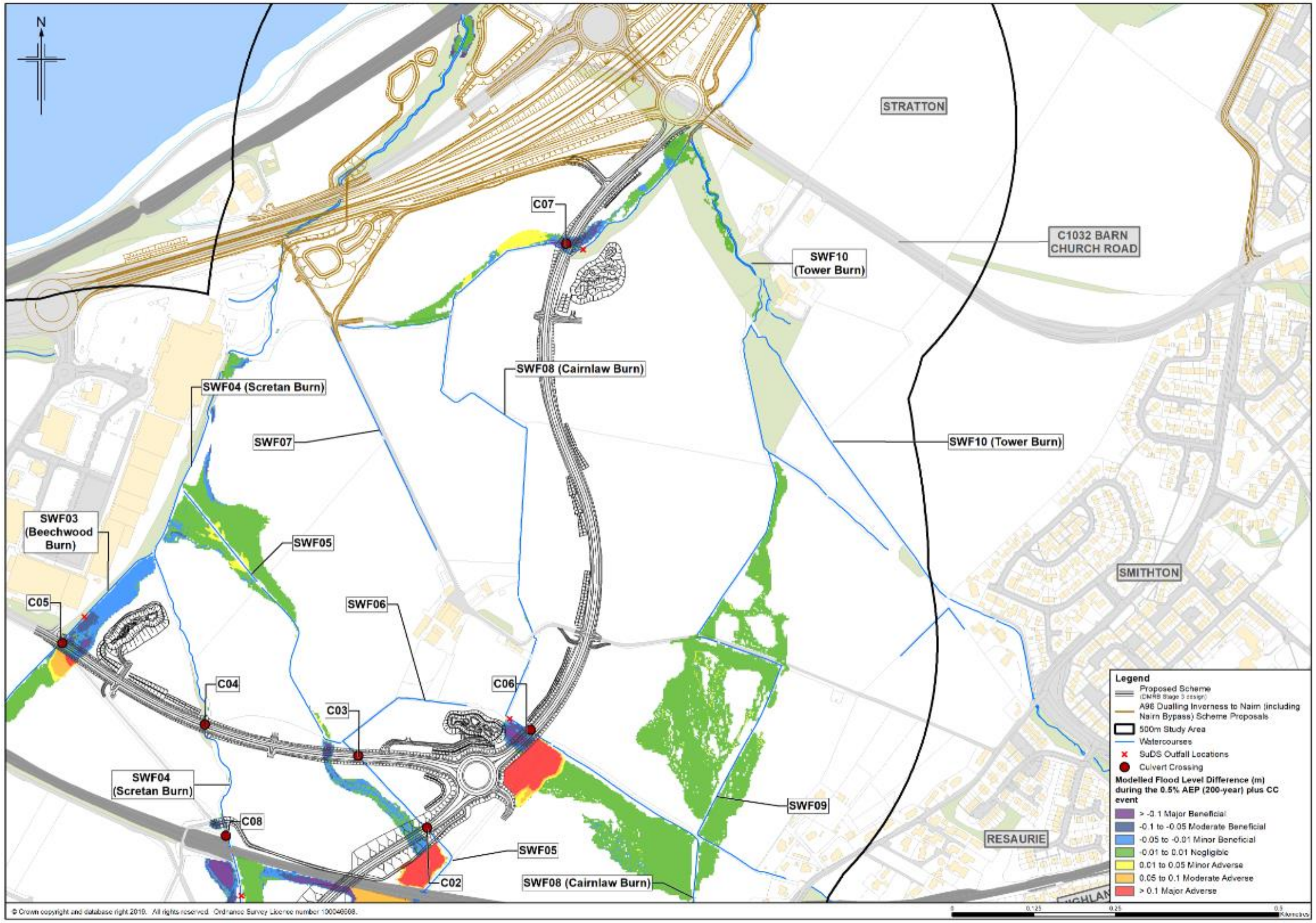
3.1.44 Flood Mapping for the Ashton Farm to Smithton Junction area is shown on Figure 9 for the 0.5% AEP (200-year) plus CC flood event.

3.1.45 The flood extents and depths in the vicinity of the east Ashton Farm access track are simulated to be unaffected by the proposed scheme for the design event as the model predicts 'negligible' changes to overland flow from upstream sections of SWF09 (Indirect tributary of Cairnlaw Burn). The section of SWF09 further downstream near its confluence with SWF10 (Tower Burn), is also predicted to remain unaffected by the proposed scheme.

3.1.46 The hydraulic model predicts that immediately upstream of culvert C07, out of bank flooding from SWF08 (Cairnlaw Burn) increases due to the proposed scheme resulting in a 'moderate adverse' impact with peak depth increase of 0.091m. Flood depths are also simulated by the model to reduce in some areas. Downstream of culvert C07 the flow constriction results in a 'negligible' to 'major beneficial' impact between culvert C07 and the C1032 Barn Church Road Culvert (part of the A96 Dualling Inverness to Nairn (including Nairn Bypass) scheme).

3.1.47 The proposed scheme is simulated to have a 'negligible' impact on flooding from SWF10 (Tower Burn) immediately upstream of its confluence with SWF08 (Cairnlaw Burn).

Figure 9: Ashton Farm to Smithton Junction 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Pre-mitigation)



Inverness Retail and Business Park to Inner Moray Firth

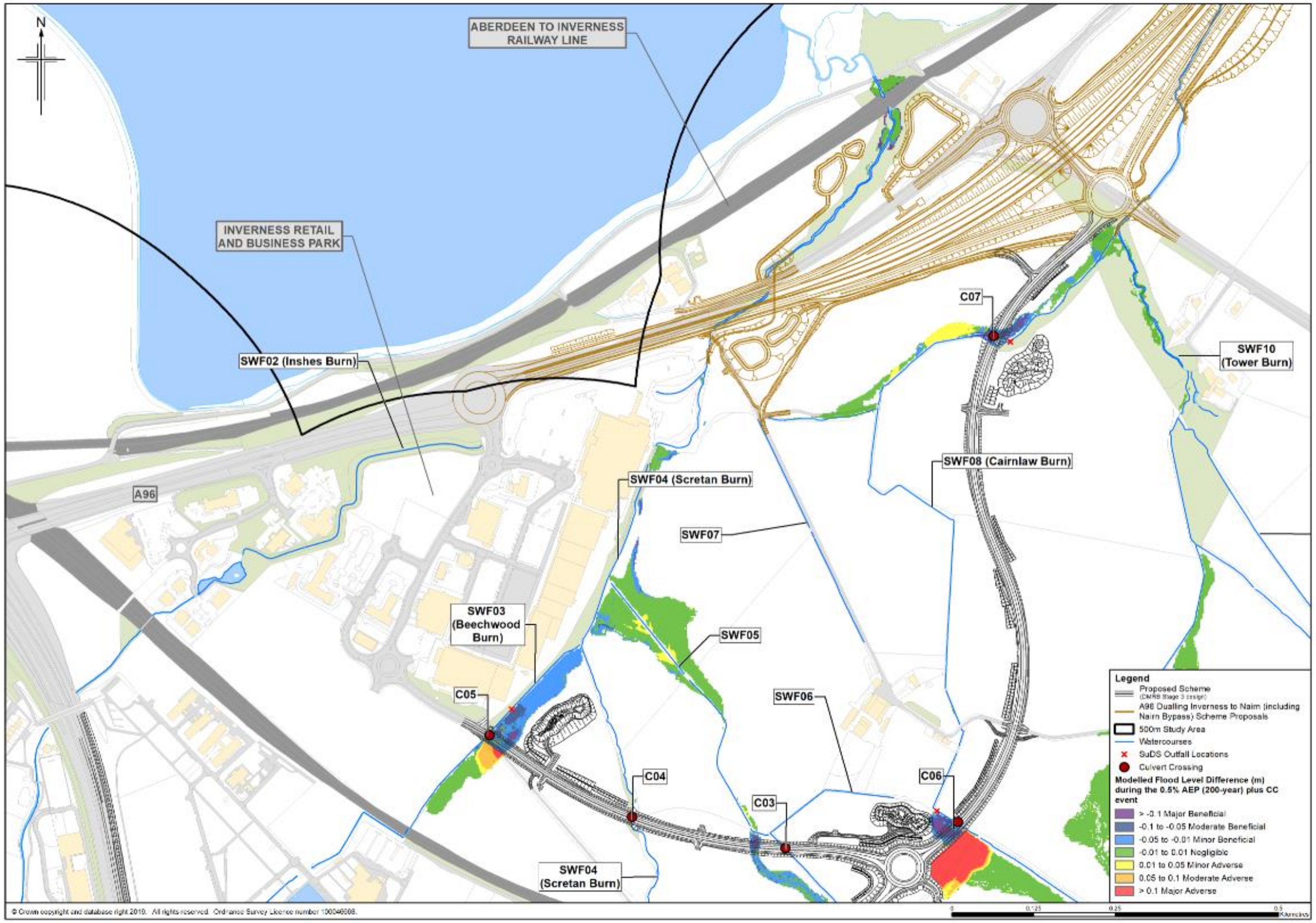
3.1.48 Flood Mapping for the Inverness Retail and Business Park to Inner Moray Firth area is shown on Figure 10 for the 0.5% AEP (200-year) plus CC flood event.

3.1.49 Upstream of the confluence with SWF04 (Scretan Burn), the addition of the culvert C05 on SWF03 (Beechwood Burn) and the road embankment (associated with the proposed scheme) is simulated to result in impoundment upstream of the culvert with a peak depth increase of 0.128m (major adverse). Downstream of the culvert a minor to major beneficial impact on flood depths is simulated on the right bank of SWF03.

3.1.50 At the confluence between SWF04 (Scretan Burn) and SWF05 (tributary of Scretan Burn), 'minor to moderate beneficial' impacts are predicted in the vicinity of Inverness Retail and Business park. The proposed scheme also results in areas of 'minor beneficial' and 'minor adverse' changes to flood depths upstream on SWF05 (tributary of Scretan Burn).

3.1.51 The hydraulic model also simulates 'negligible' to 'major beneficial' impacts to flood depths immediately upstream and downstream of SWF04 (Scretan Burn) Aberdeen to Inverness Railway culvert due to the proposed scheme.

Figure 10: Inverness Retail and Business Park 0.5% AEP (200-year) plus CC modelled flood depth impact map (pre-mitigation)



Summary

3.1.52 The impact of the unmitigated scheme on flood risk within the project area is summarised in Table 8.

Table 8: Impact of Proposed Scheme Upon 0.5% AEP+CC (200-year+CC) Fluvial Flood Risk (unmitigated)

Location	Approximate Volume of Floodplain Lost (m^3)	Impact [1]
Cradlehall to Ashton Farm	573	Increased peak flood depth in floodplain upstream of culvert C01 (SWF04) of 1.916m Increased peak flood depth in floodplain of 0.075m upstream of the Highland Main Line Railway (SWF05). Increased peak flood depth of 0.578m (worst case model run) in the floodplain downstream of the Highland Main Line Railway (SWF05) but upstream of Culvert C02. Negligible to major beneficial change to peak flood depth in floodplain downstream of culvert C02. Negligible to major beneficial changes to peak flood depth in the floodplain on the left hand bank of SWF04 downstream of culvert C01. This results in negligible to major beneficial changes to peak flood depths to areas of land including part of the Inverness Campus. No change to peak flood depth in floodplain upstream of culvert C04. Increased peak flood depth in floodplain upstream of culvert C06 (SWF08) of 0.808m No change to peak flood depth in floodplain downstream of culvert C08. No change to peak flood depth in floodplain upstream of culvert C09.
Ashton Farm to Smithton Junction	58	Increased peak flood depth in floodplain upstream of culvert C07 (SWF08) of 0.097m Downstream of culvert C07 (SWF08) the flow constriction results in a 'negligible' to 'major beneficial' impact between culvert C07 and the C1032 Barn Church Road culvert (part of the A96 Dualling Inverness to Nairn (including Nairn Bypass) scheme.
Inverness Retail and Business Park to Inner Moray Firth	94	Increased peak flood depth in floodplain upstream of culvert C05 (SWF03) of 0.128m Downstream of culvert C05 (SWF03) a 'minor' to 'major beneficial' impact on flood depths is simulated on the right-hand bank of SWF03.
Total	**725**	

1: For the 0.5% AEP+CC (200-year+CC) event, unless stated otherwise

Mitigation Measures

Embedded Mitigation

3.1.53 Initially, potential changes in the proposed scheme design to reduce the impact on flood risk were considered. The embedded mitigation options considered and whether they have been incorporated are included in Table 9. It should be noted that the volumes of floodplain lost due to the proposed scheme are included in Table 8.

Table 9: Embedded Mitigation Measures Considered

Measure	Flood Risk Benefit	Incorporation in Proposed scheme
Relocate scheme outside floodplain	Would prevent loss of floodplain storage.	• A multi-disciplinary technical study looking at potential alternative routes was undertaken at DMRB Stage 2. Routes that completely avoided the floodplain were considered impracticable.

Measure	Flood Risk Benefit	Incorporation in Proposed scheme
Reduce extent of scheme within floodplain	Would reduce loss of floodplain storage.	• A multi-disciplinary technical study considering potential scheme layouts was undertaken at DMRB Stage 2. A desire to reduce impact on the floodplain was one of the factors influencing the proposed scheme design. • Where possible, side roads have been relocated to be outwith the functional floodplain. • When considering options for the location of the Cradlehall Railway Bridge (PS03), areas of lower flood risk have been considered in preference to areas of higher flood risk. • Where practicable, embankment slopes within the floodplain, have been steepened to minimise encroachment.
Remove raised elements of SuDS ponds within the floodplain	Would reduce loss of floodplain storage.	• Where practicable wetlands, retention ponds and/or swales have been removed from functional floodplain.

Flood Risk Mitigation

3.1.54 Where it has not been possible to prevent the proposed scheme from impacting on the functional floodplain by embedding mitigation within the design, the initial measure considered for standalone mitigation has been the provision of compensatory storage. In accordance with SEPA guidance, compensatory flood storage should '*be provided close to the point of lost floodplain, provide the same volume and be at the same level relative to the design flood level as that lost'* (SEPA, 2018). The same SEPA guidance also states that '*the preferred method of like-for-like replacement storage should be followed as standard although there may be exceptions. For example, large-scale, brownfield, development-plan led proposals for which it has been clearly demonstrated that like-for-like compensatory storage cannot be fully achieved may be progressed with information based on the detailed and robust application of acceptable modelling practices in consultation with SEPA'*.

3.1.55 There are significant topographical, ecological, environmental and land constraints to the provision of compensatory storage within the proposed scheme area. These have all been considered as part of the assessment of mitigation measures and appropriate levels of mitigation have been proposed that reflect these constraints. In the two locations where flood storage has been investigated the road embankment prevents the downstream movement of flood flows and to prevent this, large span bridges would be required in these locations, thus making this option impractical due to significant cost implications. It is also considered impractical to provide compensatory storage close to the point of storage loss as it would require an engineered solution to achieve this aim. Because of this, providing an attenuation storage area is considered the most practical and appropriate flood mitigation measure (see paragraph 3.1.66).

3.1.56 The primary aim in mitigation design and assessment has been to achieve a neutral impact on flood risk resulting from the proposed scheme. Where this has been identified as impractical due to local constraints, prevention of increase in flood risk to sensitive receptors such as buildings and local infrastructure has been prioritised over increases to agricultural and other undeveloped land within the existing floodplain.

3.1.57 The process for identifying required mitigation has generally been as follows:

- identify areas of floodplain loss as a result of the proposed scheme;
- develop a long-list of potential mitigation options, including areas of potential level for level compensation;
- undertake multi-criteria analysis of long-list to create short-list for more detailed consideration; and
- detailed analysis of shortlisted options, generally including hydraulic modelling.

3.1.58 The following sections set out the mitigation that has been short listed for consideration within the proposed scheme extents. The mitigation options considered have been assessed for their effectiveness both to mitigate changes in flood risk locally and as part of a wider range of measures to consider the wider floodplain. For ease of discussion, the proposed scheme extents have been split into three separate areas and are discussed in turn, however the hydrology of the proposed scheme area is such that there are clear links between the flooding in different sections and mitigation proposed in one section may provide benefits in another. Where this is the case it has been included within the discussion in the section where the mitigation is first cited.

Shortlisted Measures

3.1.59 Shortlisted mitigation options located within the proposed scheme area are included in Table 10. It should be noted that the mitigation options within an area are not necessarily required to mitigate an increase in flood risk within the same area. A detailed discussion of the assessment undertaken and the rationale for the selected options can then be found in the following sections.

Table 10: Shortlisted Mitigation Measures

Location	Mitigation measures shortlisted
Cradlehall to Ashton Farm	• Do-nothing • Flood Relief Culverts • Ground re-profiling • Bank Raising Upstream of culvert C02 (SB4) • Bank Raising Upstream of culvert C06 (CB2) • Bank Raising Downstream of culvert C08 (SB2) • Flood Storage Area (SB4) • Flood Mitigation Area (CB2)
Ashton Farm to Smithton Junction	• Do-nothing
Inverness Retail and Business Park to Moray Firth	• Do-nothing

Mitigation Appraisal and Selection

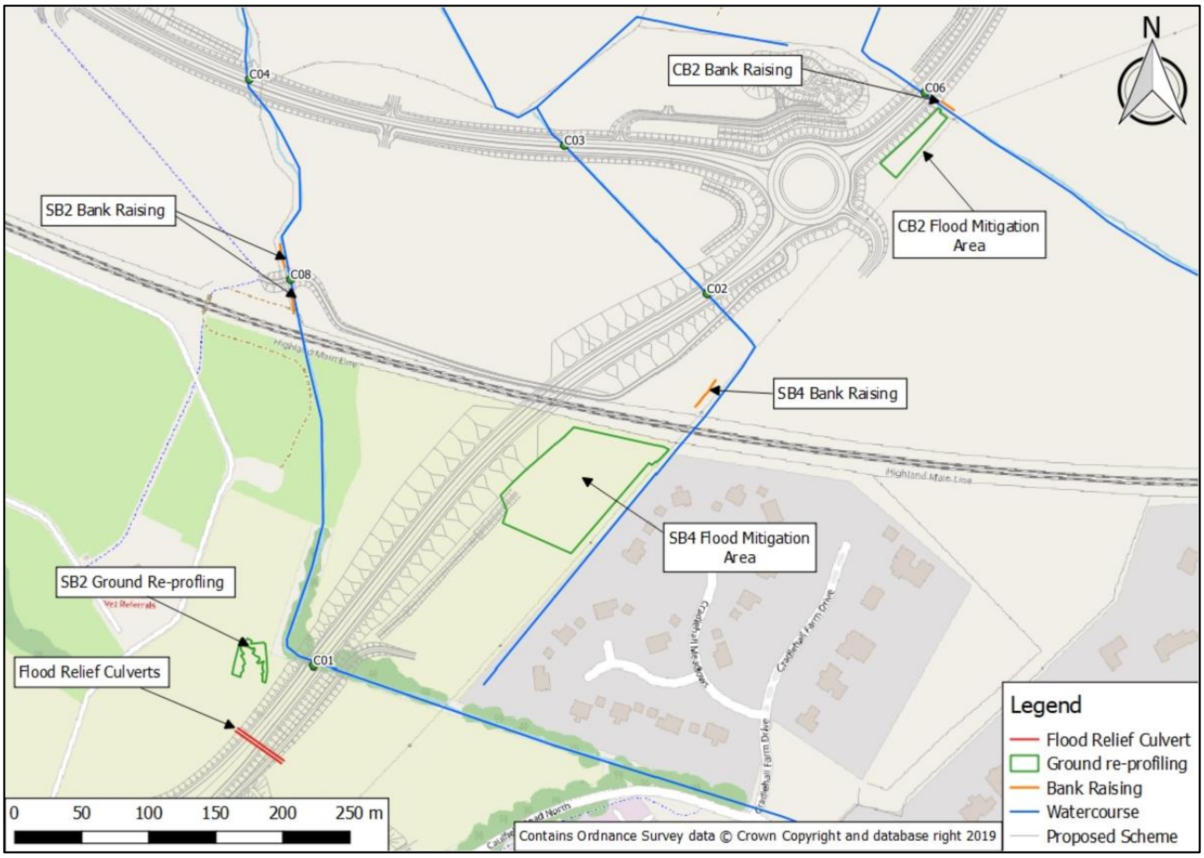
Cradlehall to Ashton Farm

3.1.60 Eight potential measures were shortlisted for consideration in this area as shown in Figure 11. Approximately 573m^3 of flood storage would be lost as a result of the proposed scheme in this section, predominantly due to the construction of the new road alignment in areas within the floodplain extent. This results in an increase in flood depth upstream of the proposed scheme but no increased flood risk to sensitive receptors.

3.1.61 'Do-nothing' was one of the options considered for this section. This would minimise cost, and environmental impact; however, it would result in a larger land-take required upstream of culvert C01. Additionally, the peak flood depths upstream of culvert C01 would be 1.54m larger than with provided mitigation as discussed below. This would require higher bunds to be constructed to provide the required 600mm to SuDS pond (ch25 Cradlehall Roundabout to Eastfield Way Roundabout). Un-mitigated there would be an increase in flood depths upstream of culverts C02 and C06 resulting from the proposed scheme. This option would also fail to address a flood risk posed to the proposed scheme upstream of culvert C06. This option would not be in accordance with SPP or the proposed scheme design principles and therefore this option has been rejected.

3.1.62 Flood relief culverts were considered south-west of culvert C01 to reconnect the floodplain on either side of the proposed scheme embankment. The use of different numbers and sizes of flood relief culverts in this location were investigated. The optimal configuration of flood relief culverts was two 2m wide by 1.5m high rectangular culverts constructed on the left floodplain of Scretan Burn (SWF04). This arrangement along with ground re-profiling downstream of the flood relief culverts (to the south of the bend in SWF04 (Scretan Burn)), so the crest of the embankment is lowered to a uniform 35mAOD over an approximate 76m arc, allows for a reduction of the flood risk to the existing Inverness Campus west of the proposed scheme. The maximum depth excavated would be approximately 0.103m. This option also leads to a reduction in the depth of water in the floodplain upstream of culvert C01 of 1.597m, as stated above. As such, these options were adopted.

Figure 11: Cradlehall to Ashton Farm Mitigation Options



3.1.63 The implementation of a 25m stretch of raised bank on the left side of SWF05 (SB4) between the existing Highland Main Line Railway (HML) culvert and culvert C02 was considered in order to prevent water ponding against the proposed scheme in this location. By ensuring the top of the left bank is raised by 0.08m to 0.27m (to an average level of 34.89mAOD) and used in conjunction with the SB4 flood storage area described below, flood risk to this area due to the proposed scheme would be mitigated. Given that there are 'major adverse' impacts on flood risk downstream of the existing HML culvert as a result of the proposed scheme and this option mitigates that increased risk, this option was adopted.

3.1.64 The implementation of a 20m stretch of raised bank (CB2) upstream of culvert C06 was considered to prevent any water spilling into the right floodplain as a result of the proposed watercourse crossing. By ensuring the top of the right bank is raised by 0.1 to 0.3m flood risk to the right floodplain would be reduced. Flood mitigation area CB2 is further located on the left bank of Cairnlaw Burn (SWF08) at this location (see Figure 11 and text below) and has been designed to lead flood water in the left floodplain into SWF08 (through its sloping towards the channel design). Given that there are 'major adverse' impacts on flood risk upstream of culvert C06, resulting from the proposed scheme and this option mitigates that increased risk, these options were adopted.

3.1.65 The implementation of a 18m stretch of raised bank upstream of culvert C08 on the left bank of SWF04 (Scretan Burn) and a 17m stretch of raised bank downstream of this culvert on the left bank of SWF04 (SB2) was considered to prevent the water spilling into the left floodplain in the vicinity of culvert C08. By raising the top of the left bank by 0.23 to 0.52m upstream of the culvert and by a maximum of 0.24m downstream of the culvert, flood risk to the Non-Motorised Users (NMU) access associated with the proposed scheme in this location would be reduced. Given that there are 'minor adverse' impacts on flood risk in the vicinity of the culvert and this option mitigates that risk, this option was adopted.

3.1.66 A flood storage area (SB4) was considered north-east of culvert C01 in an area of the left floodplain of SWF05 (tributary of Scretan Burn). This area currently floods during the design event. Downstream of the existing HML culvert the left floodplain would have a depth increase of 0.578m during the design event resulting from the proposed road embankment severing an existing flow path. The proposed mitigation considered would involve adjusting ground levels in the existing area of depression shown on Figure 11 to 35mAOD. This would provide an additional storage volume of 4,826m^3 during the design event. Because of this storage area, the pass-forward flow through the existing HML culvert would be reduced, assisting in the prevention of out of bank flow downstream of the culvert. This storage also reduces the depth of ponding next to the HML. Given that there are 'major adverse' impacts on flood risk downstream of the existing HML culvert resulting from the proposed scheme and this option mitigates that increased risk, this option was adopted.

3.1.67 A flood mitigation area (CB2) was considered immediately upstream of culvert C06 in an area of the left floodplain of Cairnlaw Burn (SWF08). This area does not currently flood during the design event, but the proposed scheme would cause some area of inundation (refer to Figure 9) in the area upstream of culvert C06 (maximum depth 0.808m) which would cause flood risk to part of the proposed scheme. The proposed mitigation measure considered would involve ground re-profiling in the area shown on Figure 11 above to an average of 33.15mAOD, providing a flood mitigation area during the design event. This area would be sloped towards the watercourse to guide out of bank flows back towards the watercourse. As a result of this flood mitigation area, the flood risk to the proposed scheme would be mitigated and the area of floodplain inundation significantly reduced. Given that there are 'major adverse' impacts on flood risk at this location, including inundation of part of the proposed scheme, and that this option mitigates the increased risk, this option was adopted.

Ashton Farm to Smithton Junction

3.1.68 No additional mitigation was proposed in this area and as such a 'do-nothing' approach was adopted.

Inverness Retail and Business Park to Inner Moray Firth

3.1.69 The existing structure located on SWF03 (Beechwood Burn) at the south of the Inverness Retail and Business Park breaks the flood embankment located on the left bank of the watercourse. A double box culvert (C05) will be adopted as part of the proposed scheme to convey out-of-bank flood flows underneath the proposed scheme, which minimises the increases in flood depths associated with the proposed scheme being located within the 0.5% AEP (200-year) plus CC flood extent. The proposed C05 culvert will need to incorporate a closed abutment which ties into the existing flood embankment located upstream of the structure. This is to prevent overtopping of the left bank which will mitigate the flooding into this area. The details of these elements of mitigation will be finalised at the specimen design stage.

Recommended Mitigation

3.1.70 The proposed mitigation measures adopted are:

- Two Flood Relief Culverts in the floodplain south-west of culvert C01.
- Ground re-profiling of land to the west of the proposed scheme in the floodplain of the SWF04 (Scretan Burn).
- Raised Bank SB4 adjacent to tributary of Scretan Burn (SWF05) downstream of existing HML culvert.
- Raised Bank CB2 upstream of culvert C06.
- Raised Bank SB4 downstream of culvert C08.

- Flood Storage Area SB4 adjacent to tributary of Scretan Burn (SWF05) upstream of existing HML culvert.
- Flood Mitigation Area CB2 adjacent to Cairnlaw Burn (SWF08) upstream of culvert C06.

3.1.71 The volume of storage provided by the proposed mitigation is summarised in Table 11.

Table 11: Volume of Storage Proposed

Storage Area	Storage Volume (m^3)
Total Additional Storage Provided (SB4)	4,826
Total Storage Lost with scheme unmitigated	725
Total Storage Loss with scheme with mitigation	687*
Change in Storage with scheme with mitigation	+4,139

*the proposed scheme mitigation results in less loss of floodplain storage.

Impact of Scheme with Proposed Mitigation

3.1.72 The proposed scheme has been modelled with all the proposed mitigation included to identify any residual impact of the proposed scheme. The impact of the proposed scheme has been investigated for the following AEP events: 3.33% AEP (30-year), 0.5% AEP (200-year) and 0.5% AEP (200-year) plus CC and the impact of the proposed scheme on peak depths has also been investigated.

Peak Flood Depth at Receptors

3.1.73 The change in peak flood depth at a range of receptors is presented in Table 12. The receptors included are commercial and residential properties, as well as areas of critical infrastructure within the flood extents modelled for the design event.

3.1.74 There are small areas of flooding where adverse impacts are shown in the flood mapping at sensitive receptors. These model artefacts result from minor instabilities and model performance issues in the hydraulic model, resulting in adverse impacts displayed in locations at the Cradlehall Business Park and the Cradlehall Residential Area (including Cradlehall Farm Drive and Cradlehall Meadows area) for both the 3.33% AEP and 0.5% AEP plus CC flood events. These small areas of adverse impact have been investigated and are not considered to be due to the proposed scheme as discussed in further detail in Appendix A13.7 Section 7.1 Model Performance. The areas are a distance upstream and at a higher elevation than the proposed scheme and therefore no impact on flood risk is anticipated due to the proposed scheme influencing flood risk at these locations.

Table 12: Maximum Depths at Receptors

Receptor Name	Indicative Location	3.33% AEP (30-year)			0.5% AEP (200-year) + CC		
		Baseline Depth	With-Scheme Depth	Change (mm)	Baseline Depth	With-Scheme Depth	Change (mm)
Cradlehall Farm Drive/ Cradlehall Meadows Residential Area	NH 7004 4482	0.327	0.327	0	0.487	0.488	+1*
Cradlehall Business Park	NH 7001 4464	0.654	0.694	+40*	1.315	1.315	0
Inverness Campus	NH 6921 4489	N/A	N/A	N/A	0.112	0	-112
Highland Main Line (SB2)	NH 7002 4496	0.989	0.989	0	1.037	1.028	-9
Highland Main Line (SB4)	NH 6972 4503	0.327	0.327	0	0.730	0.713	-17

*Note: the increase in modelled flood depths at the Cradlehall Business Park and the Cradlehall Residential Area (including Cradelhall Farm Drive and Cradlehall Meadows area) for both the 3.33% AEP and 0.5% AEP plus CC flood events have been assessed as due to model instability and not due to the proposed scheme. As such no impact on flood risk is anticipated due to the proposed scheme at these locations.

Cradlehall to Ashton Farm

3.1.75 Flood Mapping for the Cradlehall to Ashton Farm area is shown on Figure 12 for the 0.5% AEP (200-year) plus CC flood event.

3.1.76 The results presented in Table 12 and Figure 12 show that any change to flood risk, resulting from the proposed scheme is 'negligible' in impact, with the exception of a beneficial impact to Inverness Campus and adverse impacts within areas of floodplain compensation or areas to be included in the Compulsory Purchase Orders (CPO) for the proposed scheme. Land purchased for the proposed scheme and returned to the landowner would include appropriate conditions reflecting the increased flood risk. Four areas outside of the proposed scheme footprint have been identified as having 'major adverse' increased flood risk during the design event, all of which will be purchased to allow the construction of the proposed scheme. The four areas are described in the subsequent paragraphs.

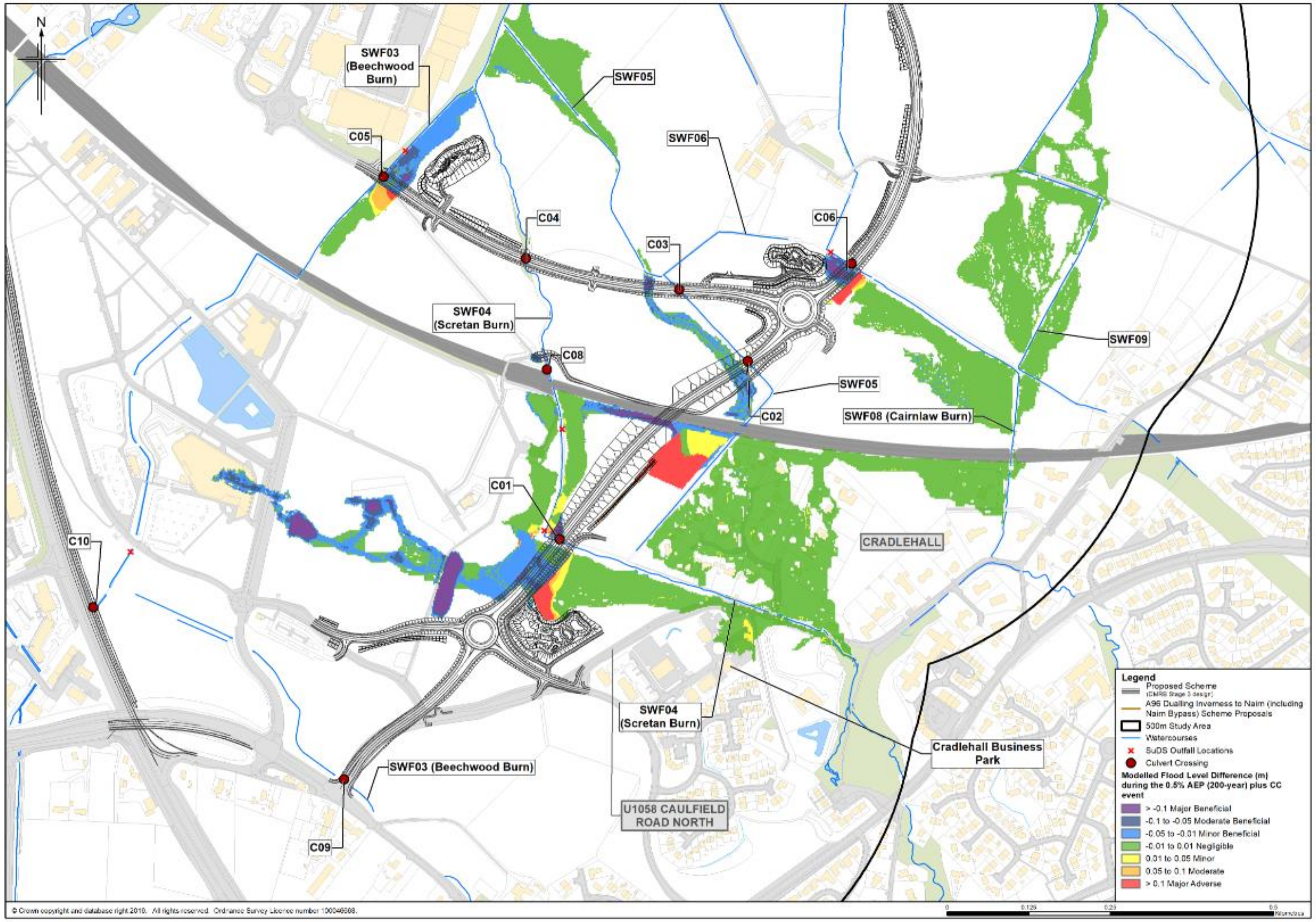
3.1.77 The first area is the left floodplain upstream of culvert C01 (in the vicinity of the proposed flood relief culverts). Shallow ponding occurs in this area on the upstream side of the proposed scheme with a peak increase in flood depth simulated as 0.319m during the design event. The flood relief culverts have been sized and positioned at an elevation that mimics the hydraulics of the existing flood mechanism but due to the concentration of flow at the flood relief culvert inlets, (as opposed to the shallow and wide floodplain extent in the baseline) there is some ponding to a greater depth than in the baseline. Allowing this area to flood to a shallow depth is part of the flood mitigation strategy and given that the freeboard to the lowest lying receptor, the proposed scheme, remains greater than 0.6m, no further mitigation is proposed.

3.1.78 The second area is an area of floodplain downstream of culvert C01. The peak increase in flood depth here is 0.127m during the design event due to reductions in the topographic level as part of the mitigation measures. This reduction in level improves conveyance back to the channel to the north and prevents preferential flow (due to the concentration of flow at the outlet of the culverts) developing to the west. The freeboard to the lowest lying receptor, the proposed scheme, remains greater than 0.6m, no further mitigation is proposed.

3.1.79 The third area is the area of floodplain upstream of the existing HML culvert on Tributary of Scretan Burn (SWF05). The peak increase in flood depth here is 0.701m during the design event. Allowing this area to flood is part of the flood mitigation strategy. Given that the freeboard to the lowest lying receptor, the proposed scheme, remains greater than 0.6m, no further mitigation is proposed.

3.1.80 The fourth area is the area of floodplain upstream of culvert C06. The peak increase in flood depth here is 0.527m during the design event. Allowing this area to flood is part of the flood mitigation strategy and given that the freeboard to the lowest lying receptor, the proposed scheme, remains greater than 0.6m, no further mitigation is proposed.

Figure 12: Cradlehall to Ashton Farm 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Post-Mitigation)



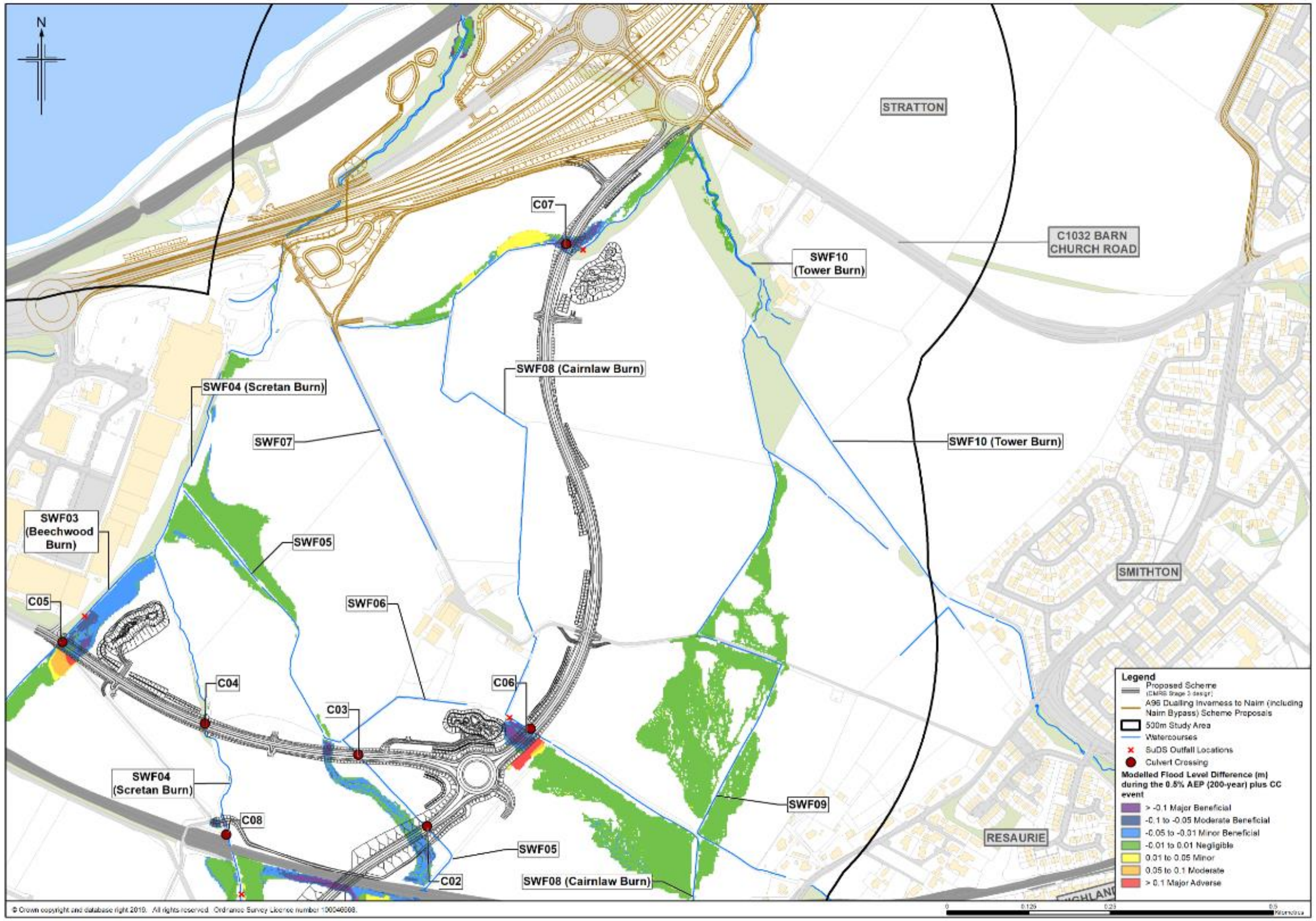
Ashton Farm to Smithton Junction

3.1.81 Flood Mapping for the Ashton Farm to Smithton Junction area is shown on Figure 13 for the 0.5% AEP (200-year) plus CC flood event.

3.1.82 There are no sensitive receptors within this area of the proposed scheme impacted by flooding. Any change resulting from the proposed scheme is ‘negligible’ in impact, with the exception of some areas of improvement within the floodplain and one area which is simulated to be adversely impacted during the design event. The area of land simulated to be adversely impacted by the proposed scheme will be purchased to allow construction of the proposed scheme. Land purchased for the proposed scheme and returned to the landowner would include appropriate conditions reflecting the increased flood risk.

3.1.83 The area of the floodplain with increased flood risk is upstream of culvert C07. The increase in peak flood depth at this location is 0.098m during the design event. This ‘minor to moderate adverse’ increase is the result of floodplain lost due to the proposed scheme embankment and flow throttling by culvert C07; however, the inundation extents remain the same, maintaining the existing flood mechanisms. This area will be purchased to allow the construction of the proposed scheme. Given that the freeboard to the lowest lying receptor, i.e., the proposed scheme, remains greater than 0.6m, no further mitigation is proposed.

Figure 13: Ashton Farm to Smithton Junction 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Post-Mitigation)



Inverness Retail and Business Park to Inner Moray Firth

3.1.84 Flood Mapping for the Inverness Retail and Business Park area is shown on Figure 14 for the 0.5% AEP (200-year) plus CC flood event.

3.1.85 There are no receptors in this area of the proposed scheme. Any change in flood risk as a result of the proposed scheme are negligible in impact, with the exception of some areas of improvement within the floodplain and one area which is simulated to be adversely impacted during the design event. The area of land which is simulated to be adversely impacted by the proposed scheme will be purchased to allow construction of the proposed scheme. Land purchased for the proposed scheme and returned to the landowner would include appropriate conditions reflecting the increased flood risk.

3.1.86 The area of the floodplain with increased flood risk is located upstream of culvert C05. The increase in peak flood depth here is 0.128m during the design event. This 'major adverse' increase is the result of floodplain lost due to the proposed scheme embankment and flow throttling by culvert C05; however, the inundation extents remain the same, maintaining the existing flood mechanisms. This area will be purchased to allow the construction of the proposed scheme. The freeboard to the lowest lying receptor, i.e., the proposed scheme, remains greater than 0.6m. It should be noted, as discussed previously, a closed abutment would need to be adopted and tied into the existing flood embankment to minimise flood risk to the road.

Figure 14: Inverness Retail and Business Park to Moray Firth 0.5% AEP (200-year) plus CC Modelled Flood Depth Impact Map (Post-Mitigation)

Downstream Impact

3.1.87 Flood risk downstream of the proposed scheme and potential impacts on downstream receptors is also an important consideration. To examine this further and demonstrate a negligible impact on downstream receptors the 0.5% AEP (200-year) plus CC event hydrographs are presented in Figure 15 for Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) with flow and stage depth presented in Table 13.

Table 13: Downstream Extent of Model – Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) Peak Flow Rates (m^3/s)

Model	Flow (m^3/s)	Stage (mAOD)
Cairnlaw Burn		
Baseline (Existing)	7.543	12.778
With-Scheme (mitigated)	7.509	12.777
Change	-0.034	-0.001
Scretan Burn		
Baseline (Existing)	10.589	4.619
With-Scheme (mitigated)	10.442	4.612
Change	-0.147	-0.007

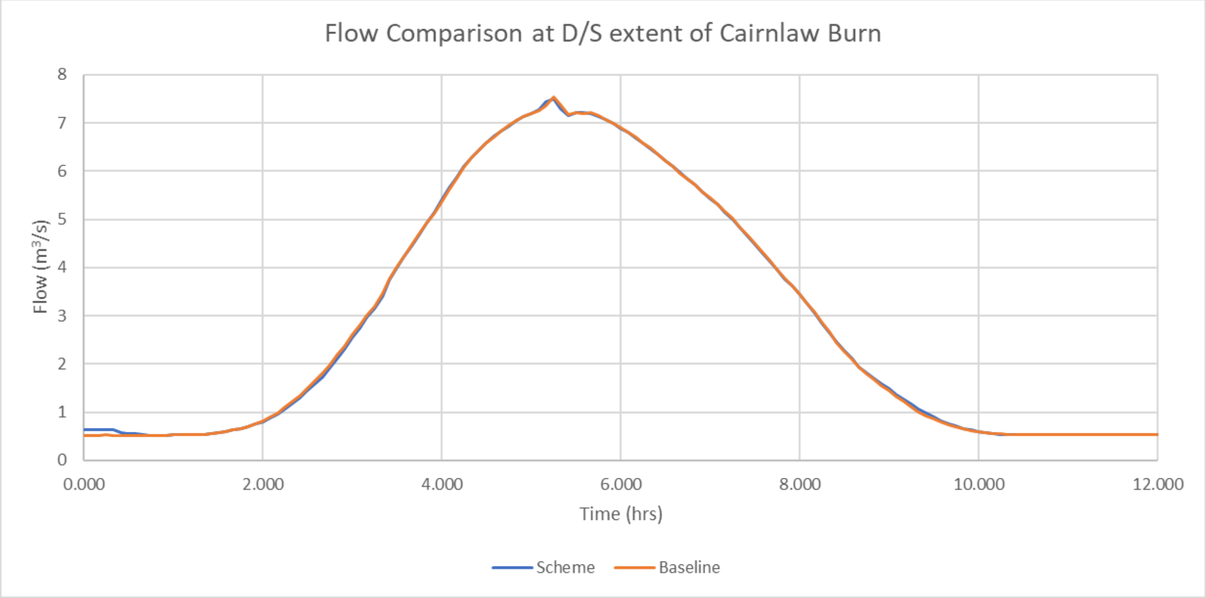
3.1.88 These downstream locations are towards the boundary of the proposed scheme This demonstrates that:

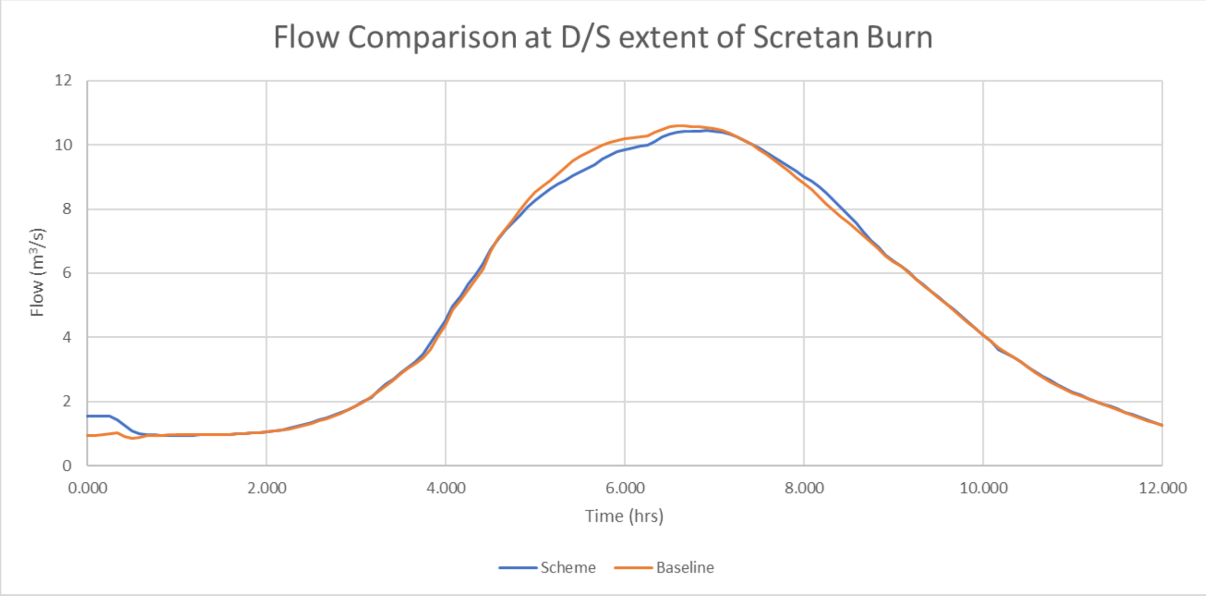
- For Cairnlaw Burn (SWF08) the hydrograph is very similar for the baseline and proposed scheme scenario. There is a slight reduction in peak flow of $0.034m^3/s$, (0.5% lower than the baseline) and small decrease in stage level of 1mm; and
- For Scretan Burn (SWF04) there is a reduction in peak flow of $0.147m^3/s$ (1.4% lower) and lower stage level of 7mm in comparison with the baseline. The recession limb of the hydrograph occurs very slightly later as a result of the measures provided for mitigation at culvert C01.

3.1.89 This demonstrates that for the design event there is a 'negligible' impact on the downstream flood risk on Cairnlaw Burn and Scretan Burn.

3.1.90 In the flow comparison shown within Figure 15 it can be seen, that at the downstream extent of Scretan Burn (SWF04), there is a higher flow at the start of the model run for the 'scheme' scenario. This is explained by the fact that a higher baseflow was required to initiate the model run. Further details of the hydraulic modelling can be found in Appendix A13.7 (Hydraulic Modelling).

Figure 15: Flow Comparison at D/S extent of Cairnlaw Burn (SWF08) and Scretan Burn (SWF04)





Beechwood Burn Model (SWF 03)

3.1.91 A 1D model has been constructed for a 761m stretch of Beechwood Burn (SWF03) between the A9 and the Inverness Campus access road. The downstream limit of the model is almost 1.1km upstream of the upstream limit of Beechwood Burn within the main hydraulic model. As such, it is unlikely any alterations in this area will affect the other model.

3.1.92 The existing culvert C09 is composed of 20m section with 0.791m diameter, tied into a 15.27m section with a 0.516m diameter pipe culvert. Hydraulic modelling indicates that the current 0.516m diameter culvert section does not meet DMRB freeboard requirements. As such the 0.791m diameter culvert will be extended/partially replacing the 0.516m diameter section.

3.1.93 The proposed culvert C09 will be approximately 40m long with a 0.791m diameter along its full length. The freeboard provision of the culvert during the 0.5% AEP (200-year) plus CC is presented in Table 14.

Table 14: Culvert C09 Freeboard Provision During Design Event (m)

	Inlet	Outlet
Baseline		
Required Freeboard	0.198	0.129
Available Freeboard	-0.076	-0.213
With Scheme		
Required Freeboard	0.198	0.198
Available Freeboard	0.302	0.522

3.1.94 The top of channel banks, both upstream and downstream of the culvert, are significantly above the 0.5% AEP (200-year) plus CC flood level and as such the risk of flooding at this location is low.

Un-modelled Watercourses

3.1.95 There are 12 watercourses, tributaries and drainage channels within 1km of the proposed scheme. Three of these watercourses (SWF01, SWF11 and SWF12) have been excluded from this assessment as they have been assessed as unlikely to be impacted by the proposed scheme. Scretan Burn (SWF04) and Cairnlaw Burn (SWF08) along with their tributaries (within the modelled reaches) have been selected for hydraulic modelling.

3.1.96 The remaining unmodelled watercourses are Inshes Burn (SWF02) and the middle reaches of Beechwood Burn (SWF03) between the main 1D/2D model and the 1D model of culvert C09.

3.1.97 The proposed scheme will not cross Inshes Burn, and this watercourse has a propensity for flooding in the vicinity of the existing B9006 Culloden Road culvert. Therefore, any construction within the floodplain of Inshes Burn has the potential to significantly increase flood risk. It should be noted that only works up to and including the western abutment of the Inshes Overbridge are included in the proposed scheme. As such no loss of floodplain storage is anticipated for Inshes Burn. Works to the west of the western abutment of the Inshes Overbridge (PS01) will be assessed separately by The Highland Council as part of the Inshes Junction Improvements Phase 2 scheme. Further assessment of the flood risk at the Inshes Burn is therefore not considered as required as part of the proposed scheme.

3.1.98 The un-modelled section of Beechwood Burn (SWF03) has one culvert (C10) under the existing A9. This culvert does not convey any watercourse flow and is believed to only convey road drainage into Beechwood Burn and will have negligible impact on flood risk. As such, further assessment of this section of Beechwood Burn is not considered to be required.

Impact of Other Development on the Assessment

3.1.99 This assessment has been undertaken based on existing land use/infrastructure in the project area. There is therefore a risk that any significant development upstream/in the vicinity of the proposed scheme could have future impacts on the hydrology in this area. Future developments should, however, be subject to planning regulations which should ensure the developments do not have any significant impacts on hydrology or flood risk. Key developments planned/currently being built in the area of the proposed scheme (shown by reference on Figure 15.4: Planning Applications and Development Land Allocations) taken into consideration in this assessment include:

- A96 Dualling Inverness to Nairn (including Nairn Bypass): The hydraulic modelling has been undertaken with the cumulative impact of the proposed scheme and the A96 Dualling Inverness to Nairn (including Nairn Bypass) development included within the with scheme hydraulic model. The results of modelling state demonstrate that impacts to pass-forward flow and stage at the downstream end of the proposed scheme are 'negligible'.
- Stratton Development Phase 1A (PA18 to PA21 (Phase 1A)) (currently being built): The proposed 400 residential units, associated with Phase 1A of the Stratton Development will be located at the downstream extent of the proposed scheme and are largely outwith the functional floodplain. The proposed Stratton Development surface water drainage should be designed to meet greenfield discharge rates. Because of this, the proposed development is unlikely to have any effect on flooding in the vicinity of the proposed scheme.
- Construction of public transport, cyclist and pedestrian bridge (PA12) and Construction of 2 no storey life sciences building (PA13) (both of which are consented expansions to Inverness Campus, which are currently under construction). Given these developments have been consented, they are required to satisfy relevant attenuation standards for runoff. Because of this the proposed developments are unlikely to have an effect on flooding in the vicinity of the proposed scheme.
- Demolition of Steading and Erection of Dwelling at Inshes (PA07), Erection of Care Home at Cradlehall (PA10) and Erection of Dwelling and Garage at Resaurie (PA25) have been considered, however, no impacts to these developments due to the proposed scheme or from these developments on the proposed scheme are anticipated.

Erosion Risk

3.1.100 The proposed scheme also has the potential to impact on velocities within the affected watercourses and the floodplain. Any increase in velocity has the potential to increase the risk of erosion whilst any decrease could potentially lead to an increase in sediment deposition. The geomorphology of the area is covered in more detail in Appendix A13.4 (Fluvial Geomorphology).

Residual Risks

3.1.101 The residual flood risks from the discussed watercourses will include:

- Blockages of culverts by large debris that reduce the conveyance capacity of the culverts. The results of the analyses undertaken as part of this FRA confirm that the proposed scheme is robust to partially reduced conveyance capacity, but flooding of sensitive receptors including the proposed scheme could occur if a blockage is excessive; and
- Severe flood events which exceed the design capacity of the culverts. It has been confirmed that all culverts in the proposed scheme will not cause flooding of the main alignment for floods up to the 0.5% AEP (200-year) plus CC design event, but some flooding could occur for events rarer than the design flood event.

3.1.102 It will be important that the relevant management company carry out routine inspection and ongoing maintenance of the culverts. The information contained in this FRA could be used to identify the sensitive locations and prioritise any inspection schedule within the proposed scheme operation and maintenance plan.

4 Surface Water Flooding

Introduction

4.1.1 Surface water (pluvial) flooding results from rainfall-generated overland flow before the runoff enters any watercourse, drainage system or sewer or when the infiltration capacity of the ground surface is exceeded during extreme rainfall events. Excessive surface water runoff itself may pose a flood risk especially if flowing at high velocity. Localised depressions in the ground topography may result in the ponding of water, sometimes to a significant depth.

4.1.2 The antecedent conditions, permeability of the soil type or geology can affect the volume of runoff, whist the capacity and condition of the drainage network can affect how much water remains on the surface. The topography of the land and location of urban features such as buildings and road networks would also influence surface water flood risk by increasing the velocity of overland flow and depth of ponding.

Baseline Risks

4.1.3 The catchment areas of Scretan Burn (SWF04) and Cairnlaw Burn (SWF08) to the south of the Highland Main Line Railway consists of some gently sloping hillsides that will generate increased runoff during high intensity rainfall events. The proposed scheme is also located on the outskirts of Inverness and has some surrounding areas of urbanisation which are highly likely to generate increased runoff during a high intensity rainfall event. This includes runoff from housing developments, business premises, Inverness Campus, and road infrastructure. There are also areas of flat land, which may be prone to ponding, especially where there are localised depressions surrounding existing infrastructure. The Highland Main Line Railway is an example of this, where raised embankments prevent surface water runoff draining downslope and into nearby watercourses. The area of the proposed scheme also consists of large areas of agricultural land with local access roads. Drainage in these areas therefore may be ineffective or not incorporated into road infrastructure.

4.1.4 Historical incidences of surface water flooding have been reported within the area of the proposed scheme (see Table 4). This includes numerous surface water flooding incidents within the Cradlehall area and at several locations near the Inshes overbridge. The A9 and the B9006 Culloden Road have also been reported to flood due to surface water flooding.

4.1.5 This FRA has adopted a preliminary assessment to identify areas along the proposed scheme corridor at risk of surface water flooding using the following information and methodology:

- SEPA Surface Water Flood Map – the mapping identifies areas with a 'high' (10% AEP (10-year)), 'medium' (0.5% AEP (200-year)) or 'low' (0.1% AEP (1,000-year)) probability of surface water flooding.
- Historical Flood Incidents – surface water flood records provided by The Highland Council and SEPA within the area of the proposed scheme.

4.1.6 Areas at risk of surface water flooding as identified by the SEPA Surface Water Flood Map (SEPA 2018) for the 0.5% AEP (200-year return period) event are summarised below in Table 15. Historic flooding incidents have been reported in Table 4.

Table 15: SEPA Surface Water Flood Map (SEPA 2018) Locations of Potential Flooding

Proposed Scheme Chainage	Description
ch150 to ch912 (A9 southbound lane gain/drop)	The SEPA Surface Water Flood Map identifies pluvial flooding along the stretch of the existing A9 where the A9 southbound lane gain/drop will be constructed. No sensitive receptors other than the A9 trunk road itself and the B9006 Culloden Road have been identified in the immediate area. As pre-earthworks drainage in this location is not represented within SEPA's surface water model, it is likely that the flooding predicted in this location is overestimated.
ch80 to ch120 (Existing Inshes Overbridge (PS01))	The SEPA Surface Water Flood Map identifies pluvial flooding adjacent to a short section of the B9006 Culloden Road east of the existing Inshes Overbridge (PS01). No sensitive receptors have been identified in the immediate area, but the B9006 Culloden Road is located to the north and south of this location.

Proposed Scheme Chainage	Description
ch55 to ch150 (Inshes to Cradlehall Roundabout (Link 1))	The SEPA Surface Water Flood Map identifies pluvial flooding on the stretch of the U1058 Caulfield Road North where a section of the proposed scheme is located. As pre-earthworks drainage in this location is not represented within SEPA's surface water model, it is likely that the flooding predicted in this location is overestimated.
ch25 to ch120 (Cradlehall Roundabout to Eastfield Way Roundabout (Link 2))	The SEPA Surface Water Flood Map identifies pluvial flooding north of the U1058 Caulfield Road North area in an undeveloped area of land. No sensitive receptors have been identified in the immediate area.
ch370 to ch410 (Cradlehall Roundabout to Eastfield Way Roundabout (Link 2))	The SEPA Surface Water Flood Map identifies areas of pluvial flooding on the south side of the Highland Main Line Railway embankment within the vicinity of the proposed Cradlehall Railway Bridge (PS03). Pluvial flooding is also shown on the Highland Main Line Railway in some locations. Eleven properties in Cradlehall south of the Highland Main Line Railway have also been identified to be at surface water flood risk. Pluvial flooding in the vicinity of these properties is not necessarily hydraulically connected to the ponding in the vicinity of the proposed scheme and the Highland Main Line Railway.
ch520 to ch560 (Cradlehall Roundabout to Eastfield Way Roundabout (Link 2))	The SEPA Surface Water Flood Map identifies pluvial flooding on the northern side of the Highland Main Line Railway embankment (running south-east to north-east), close to the location of the proposed Cradlehall Railway Bridge (PS03). Surface water flooding is also shown on the northern side of the railway line in some locations and along the railway embankment. The Highland Main Line Railway is therefore at surface water flood risk as well as the proposed scheme.
ch40 to ch75 (Eastfield Way Roundabout to Smithton Junction (Link 4))	The SEPA Surface Water Flood Map identifies pluvial flooding in the location of the proposed Cairnlaw Burn culvert C06. No sensitive receptors have been identified in the immediate area other than the proposed scheme, which may be at potential flood risk.
ch230 to ch235 (Eastfield Way Roundabout to Smithton Junction (Link 4))	The SEPA Surface Water Flood Map identifies an area of pluvial flooding in the location of a proposed access under the proposed scheme. There are currently no sensitive receptors at flood risk.
ch850 to ch880 (Eastfield Way Roundabout to Smithton Junction (Link 4))	The SEPA Surface Water Flood Map identifies pluvial flooding in the location of the proposed Cairnlaw Burn culvert C07. No sensitive receptors have been currently identified in the immediate area. The land to the north of this location is also proposed to be converted to housing and retail space as part of the Stratton development (Phases 1F and 2A).
ch1090 to ch1113 (Eastfield Way Roundabout to Smithton Junction (Link 4))	The SEPA Surface Water Flood Map identifies pluvial flooding on the south side of the proposed scheme's connection to the A96 Smithton Junction (as part of the A96 Dualling Inverness to Nairn (including Nairn Bypass Scheme)). The pluvial flood area extends to the south of Cairnlaw Burn (SWF08) at this location and along Tower Burn (SWF10). Currently houses are being built within the vicinity of Tower Burn as part of the Stratton Development which could be at potential risk.
ch424 Non-Motorised User (NMU)	The SEPA Surface Water Flood Map identifies pluvial flooding in the location of the proposed NMU route north of the Highland Main Line Railway, along approximately 128m of its length.
ch35 to ch80 (Eastfield Way Roundabout to Inverness Retail and Business Park (Link 3))	The SEPA Surface Water Flood Map identifies pluvial flooding in the vicinity of the connection between the Inverness Retail and Business Park access road and the proposed scheme.
ch295 to ch305 (Eastfield Way Roundabout to Inverness Retail and Business Park (Link 3))	The SEPA Surface Water Flood Map identifies pluvial flooding in the vicinity of the proposed Scretan Burn culvert C04. Surface Water flooding is shown to the north and south along Scretan Burn (SWF04) in the vicinity of the proposed scheme. No sensitive receptors have been identified in the immediate vicinity of the culvert.
ch480 to ch555 (Eastfield Way Roundabout to Inverness Retail and Business Park (Link 3))	The SEPA Surface Water Flood Map identifies pluvial flooding in the vicinity of the confluence between the indirect tributary of Scretan Burn (SWF06) and the tributary of Scretan Burn (SWF05). No sensitive receptors have been identified in the immediate area.

4.1.7 The preliminary assessment concludes that the majority of the proposed scheme corridor except for the Highland Main Line Railway is on a gradual slope with depressions, which increases the risk of roads and properties becoming inundated by surface water. The SEPA Surface Water Flood Map (SEPA 2018) and the Historical Flooding records (see Table 4) identifies pluvial flooding against the embankment of the Highland Main Line Railway as well as at other low-lying locations.

4.1.8 Many of the areas of surface water flooding listed in Table 15 are associated with flooding along minor watercourses rather than direct surface water runoff. As the SEPA Surface Water Flood Map (SEPA 2018) does not take into account existing drainage features such as the existing road drainage or culverts running underneath the existing tracks and paths, the SEPA surface water flood mapping is likely to provide a conservative estimate of risk.

4.1.9 Based upon the information presented above, this FRA concludes that there is a localised risk of surface water flooding in the area of the proposed scheme.

Potential Impacts

4.1.10 The proposed scheme has the potential to impact existing surface water flood risk by:

- constructing new features over existing overland flow paths, which could impede the movement of water causing local changes to catchment drainage patterns and consequently flood risk;
- increasing runoff rates from areas impacted by the proposed scheme during construction, with potential for compaction of ground, changes in gradients and changes in vegetation levels;
- increasing runoff rates during operation through introducing new impermeable areas into natural drainage catchments; and
- surface water flooding caused by inappropriately sized drainage systems surcharging during both construction and operation.

4.1.11 In addition, a risk of increased surface water flooding has been identified as a result of discharging to an existing drainage network from the A9 southbound lane gain/lane drop and proposed Inshes Overbridge (PS02) drainage catchment. Intrusive surveys were undertaken to determine the nature, capacity and outfall location of the existing drainage network at this location.

Mitigation

4.1.12 The proposed scheme includes surface water drainage features used to manage the risk of surface water flooding along the proposed scheme carriageway and the impact of the proposed scheme on flood risk elsewhere. These features are summarised below.

Pre-Earthworks Drainage

4.1.13 Pre-Earthworks Drainage (PED) is permanent drainage infrastructure located where there is a risk of surface water runoff affecting the earthworks or adjacent land. It is designed to collect hillside runoff at the toe of road embankments where the adjacent land falls towards the earthworks and where there would be a risk of ponding around the proposed scheme footprint. PED is also located at the top of cut slopes where the adjacent land falls towards the slope to prevent runoff flowing down the cut, compromising its structural integrity and causing a flood risk to the proposed scheme.

4.1.14 PED is designed to intercept overland flow and convey this to the nearest watercourse, whilst also maintaining natural hydrological catchment connectivity. PED would be designed to ensure flows are not be transferred to another catchment. In accordance with DMRB, the design of PED would ensure conveyance of the 1.3% AEP (75-year) rainfall runoff event from the intercepted surface water catchment.

Road Drainage Capacity

4.1.15 In accordance with DMRB, the design of the road drainage system would accommodate a short duration, high intensity 100% AEP (1-year) rainfall event, without surcharging and the 20% AEP (5-year) rainfall event up to a maximum surcharge level of 400mm without impacting the formation layers of the road pavement.

Discharges to Existing Road Drainage Network

4.1.16 Drainage surveys were undertaken to determine a suitable outfall location for the drainage catchment associated with the A9 southbound lane gain/lane drop (catchment H). These surveys indicated that discharging to the existing drainage network was the only feasible option due to the road levels and site constraints. The existing drainage network was found to outfall to the Inner Moray Firth via the Raigmore Interchange. The existing network was modelled in MicroDrainage using the survey information.

4.1.17 As the discharge is ultimately to an estuary, the priority for the drainage design at this location was to prevent any increase in surface water flooding in the downstream pipe network and around the Raigmore Interchange. Discharge rates were manually adjusted until the 3.33% AEP (30-year) rainfall event was attenuated in the overall drainage network, whilst also ensuring that there was no increase in the 0.5% AEP (200-year) flood level within the downstream pipe network.

Sustainable Drainage Systems

4.1.18 All runoff from the proposed scheme carriageways would be collected and treated via SuDS features, which are likely to include filter drains, swales and wetlands prior to discharging to a watercourse via an outfall. The location of SuDS features is indicated in Annex B.

4.1.19 The proposed SuDS have adopted the following design principles:

- All SuDS features, with the exception of the A9 southbound lane gain/lane drop catchment, are designed to treat and attenuate the peak flow from the new road drainage system up to the 0.5% AEP (200-year) rainfall event, including an allowance for climate change.
- The A9 lane gain/land drop drainage, which will replace the existing A9 southbound carriageway drainage system, has a drainage area marginally larger than the existing drainage catchment. SuDS are being retrofitted within the existing A9 drainage network as land constraints and topography limit the options for SuDS design at this location. The proposed drainage design attenuates surface runoff from the catchment up to the 3.33% AEP (30-year) plus CC event, results in no increase in flooding on the 0.5% AEP (200-year) event, and provides both additional treatment and attenuation to a level better than the existing provision. Further detail is given in Section 3 within SuDS and Water Quality Appendix A13-3.
- All SuDS features have been located outwith the functional floodplain (0.5% AEP (200-year) flood extent.
- A 300mm freeboard depth over and above the design peak water level has been used to set the spill level height associated with SuDS features.
- If practicable, outfall levels from the SuDS features have been set above the 3.33% AEP (30-year) peak water level in the receiving watercourse. Where it has not been possible to achieve this, they have been kept as high as possible.
- In order to provide sufficient attenuation, the outfall peak flow rate has been restricted to the 50% AEP (2-year) ‘greenfield’ runoff rate where practicable.

4.1.20 This FRA has informed the SuDS design process by providing modelled baseline flood extents and peak water levels for the design flood event.

4.1.21 Table 16 contains a full list of SuDS features and outfall levels along with associated peak fluvial flood levels (extracted from hydraulic model results). Appendix A13.3 (SuDS and Water Quality) also provides further detail on the SuDS design, maintenance and attenuation requirements.

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Table 16: SuDS Systems and Associated Outfalls

Drainage Catchment	Outfall NGR	Proposed Management Train	Attenuation Storage (m^3)	Discharge Location	Attenuation Standard Adopted	Greenfield Runoff Rate (QMED) (l/s)	Outfall Level (mAOD)
A	NH 70736 46591	Swale and Retention Pond	1,739	Cairnlaw Burn (SWF08)	1 in 200 year plus 20 % CC Greenfield	10.3	7.757
B	NH 70267 45950	Swale and Wetland	1,371	Cairnlaw Burn (SWF08)	1 in 200 year plus 20 % CC Greenfield	5.7	18.950
C	NH 70155 45232	Swale and Wetland	911	Cairnlaw Burn (SWF08)	1 in 200 year plus 20 % CC Greenfield	5.3	32.407
D	NH 69743 44944	Swale and Filter Drain (Enhanced Swale)	166	Scretan Burn (SWF04)	1 in 200 year plus 20 % CC Greenfield	2.6	33.430
E	NH 69716 44806	Wetland and Filter Drain	1,019	Scretan Burn (SWF04)	1 in 200 year plus 20 % CC Greenfield	7.3	35.127
F	NH 69503 45388	Swale and Wetland	768	Beechwood Burn (SWF03)	1 in 200 year plus 20 % CC Greenfield	4.1	23.001
G	NH 69082 44773	Swale and Filter Drain (Enhanced Swale)	n/a	Beechwood Burn (SWF03)	1 in 200 year plus 20 % CC Greenfield	1.5	28.100
H	NH 68698 45800	Filter Drain and Swale	n/a	Inner Moray Firth via existing drainage	1 in 30 year plus 20 % CC Existing	311.3	2.560

Residual Risks

4.1.22 In the context of the proposed scheme, the residual surface water flood risks would include:

- severe runoff events resulting from intense rainfall or rapid snow melt, which exceed the design capacity of the PED (greater than 1.33% AEP (75-year)), road drainage (greater than 20% AEP (5-year)) or SuDS features (greater than 0.5% AEP (200-year) plus climate change); and
- blockages within the drainage infrastructure that reduce its capacity to convey flows from adjacent land and the carriageway or from SuDS features into receiving watercourses.

4.1.23 Where PED is located at the top of cut slopes (which are limited in extent for the proposed scheme), there is the potential for water to overspill down the earthworks towards the proposed scheme during events with a rainfall return period event greater than the 1.3% AEP (75-year). However, flows would generally be low due to the catchment sizes associated with PED. Any residual runoff would likely either infiltrate whilst flowing down the cutting embankment or be intercepted by the roadside drainage and conveyed to SuDS. The risk of surface water flooding to the proposed scheme, caused by PED, is considered to be low.

4.1.24 In the event of extreme events or blockages causing the drainage system to surcharge, the geometry of the mainline of the proposed scheme has been designed in such a way as to shed runoff from the edges of the road and to avoid ponding on the mainline itself ensuring that disruption to traffic is minimised.

4.1.25 The design of wetlands/retention ponds also includes a 300mm freeboard of additional storage above the peak attenuated water level to manage the residual risk of blockages and to provide additional storage capacity should it be required. There is also an overflow facility provided in each of the outlet controls, again to provide resilience to the design should any blockages occur. The residual risk posed by these two scenarios is therefore considered to be low. Furthermore, adherence to a maintenance schedule as indicated in Appendix A13.3 (SuDS and Water Quality) and specified in Chapter 13 (Road Drainage and the Water Environment) would reduce the risk of blockage.

4.1.26 A high-level assessment of the impact of failure or overtopping of the wetlands/retention ponds has been undertaken, the results of which are included in Table 17. In most cases, SuDS features are located in close proximity to watercourses, with no sensitive receptors between the two. In these cases, should the SuDS feature embankment fail, the water would flow towards the floodplain or directly into the watercourse itself.

Table 17: SuDS Features – Impact of Failure of Overtopping

Drainage Catchment	SuDS Feature	Impact of failure/overtopping	Residual Risk (magnitude)
A	Swale (ch960-ch1020 Eastfield Way Roundabout to Smithton Junction)	The swale would be located adjacent and running parallel to and downslope of the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow downslope towards Cairnlaw Burn (SWF08).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure.
B	Swale (ch90-ch500 Eastfield Way Roundabout to Smithton Junction)	The swale would be located adjacent and running parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow downslope towards Cairnlaw Burn (SWF08).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure.
B	Swale (ch500-ch580 Eastfield Way Roundabout to Smithton Junction)	The swale would be located adjacent and running parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. Water would pool beside the road embankment and potentially inundate part of the proposed scheme.	Appropriate PED to the north of the swale would also convey flows that may leave the swale during failure. This would leave a 'moderate/major' residual risk to the proposed scheme. However, adherence to a maintenance schedule as

Drainage Catchment	SuDS Feature	Impact of failure/overtopping	Residual Risk (magnitude)
			indicated in Appendix A13.3 (SuDS and Water Quality) and specified in Chapter 13 (Road Drainage and the Water Environment) would reduce this risk to 'minor'.
B	Swale and wetland (ch760-ch800 Eastfield Way Roundabout to Smithton Junction)	The swale would be located adjacent and running parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow downstream towards Cairnlaw Burn (SWF08). The wetland would be located adjacent to the proposed scheme. The wetland would be formed in an existing area of land gently sloping toward SWF08 (Cairnlaw Burn) and formed through excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. Water would also flow toward Cairnlaw Burn (SWF08).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure
C	Swale (ch580-ch644 Cradlehall Roundabout to Eastfield Way Roundabout)	The swale would be located adjacent and running parallel the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. Overtopping would likely cause water to flow towards Tributary of Scretan Burn (SWF05).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure
C	Swale and wetland (ch0-ch70 Eastfield Way Roundabout to Smithton Junction)	The swale would be located adjacent and running parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow directly downhill towards Cairnlaw Burn (SWF08) or the Indirect tributary of Scretan Burn (SWF06). The wetland would be located adjacent to the proposed scheme. The wetland would be formed in an existing area of land gently sloping toward SWF06 and formed through excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow toward Cairnlaw Burn or SWF06.	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure
D	Swale (ch180-ch370 Cradlehall Roundabout to Eastfield Way Roundabout)	The swale would be located adjacent and parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would be attenuated by the proposed flood mitigation area (SB4).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure.
E	Wetland (ch25 Cradlehall Roundabout to Eastfield Way Roundabout)	The wetland would be located by the proposed scheme. The wetland would be formed in an existing depression through further excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would pool in the existing depression before flowing toward Scretan Burn (SWF04).	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure
F	Swale and Wetland (ch100-ch300 U280 Eastfield Way)	The swale would be located adjacent and parallel to the proposed scheme. The swale would be formed by excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, the proposed scheme is on an embankment water would likely flow downslope towards the associated wetland and Beechwood Burn (SWF03). The wetland would be located adjacent to the proposed scheme. The wetland would be formed in an existing area of land gently sloping toward Beechwood Burn and formed through excavation and graded earthwork slopes. Overtopping could occur due to outlet blockage. However, water would flow toward Beechwood Burn and be conveyed downstream.	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure.
G	Swale (ch50 - ch100	The swale would be located adjacent and parallel to the proposed scheme, in the vicinity of the car park for	There is a 'minor' residual risk to the Inverness Campus local

Drainage Catchment	SuDS Feature	Impact of failure/overtopping	Residual Risk (magnitude)
	Inverness Campus access road)	Inverness Campus. The swale would be formed by excavation of existing ground and graded earthwork slopes. Overtopping could occur due to blockage of the outlet. Water would likely flow downhill towards Beechwood Burn (SWF03). However, there is a risk that water could inundate the local parking as well as the Inverness Campus access road.	access road and nearby parking infrastructure.
G	Swale (ch125 – ch250 Inverness Campus access road)	The swale would be located adjacent and parallel to the proposed scheme. The swale would be formed by excavation of existing ground and graded earthwork slopes. Overtopping could occur due to blockage of the outlet. Water would likely be contained in the topographical depression adjacent to the swale.	These is a 'negligible' risk of flooding to sensitive receptors as a result of failure
H	Swale (existing Raigmore interchange)	The swale would be located downstream of the proposed scheme, in the centre of the existing Raigmore Interchange. The swale would be formed by excavation of existing ground. Overtopping could occur due to blockage of the outlet. Water would likely pool in the Raigmore Interchange Island before flowing onto the road.	There is a 'minor' residual risk to the Raigmore interchange.

5 Groundwater Flooding

Introduction

5.1.1 Groundwater flooding occurs where water levels beneath the ground, rise above the ground surface. In some instances, groundwater can emerge at surface level, following heavy rainfall events, and contribute to existing flooding from other sources. Alternatively, a greater risk can be presented if construction works, or long-term, large-scale developments, such as road schemes, intersect areas with shallow groundwater levels or create pathways for deeper confined artesian pressures, which because of development, can be released at ground level and cause widespread flooding.

5.1.2 To develop a conceptual understanding of groundwater flooding associated with the proposed scheme, groundwater level data from 24 borehole-monitoring installations along the proposed scheme corridor has been collated and reviewed. An additional five boreholes were monitored between August and December 2008, with three located in the south, one in the centre and one in the north of the study area. A preliminary screening assessment has been adopted to identify those areas at greatest risk of groundwater flooding and to identify where potential mitigation may be required.

5.1.3 Chapter 12 (Geology, Soils, Contaminated Land and Groundwater) provides a full assessment of groundwater issues in relation to the proposed scheme.

Baseline Risks

5.1.4 Throughout the proposed scheme area, superficial deposits recorded in ground investigations range in thickness from 2.7m to 28.3m. Bedrock geology within the study area is comprised primarily of the Hillhead Sandstone Formation which is described as a red and grey, planar-bedded, quartzose sandstone with interbeds of micaceous siltstone and silty mudstone (BGS Online Geoviewer 2018). Drift deposits within the study area include: made ground; alluvium; a variety of Flandrian and late Devensian raised marine deposits; and late Devensian glacial deposits (Causeway Geotech Ltd 2018).

Groundwater in the Superficial Deposits

5.1.5 In areas underlain by alluvium and glaciofluvial deposits, groundwater levels may also emerge at surface level because of rising groundwater levels in the superficial deposits.

5.1.6 The proposed scheme corridor is linear and consequently the ground investigations cannot fully define groundwater flow directions across the surrounding area. Groundwater flow within the superficial deposits is likely to follow surface topography towards the local surface watercourses. The direction of flow of any bedrock groundwater is unconfirmed, but is expected to be generally to the north-west, towards the coast.

5.1.7 Ground investigation data obtained from the 24 monitoring installations identifies eight locations where maximum groundwater levels are less than 1m below ground level (bgl). These are summarised in Table 18 below. All of these installations are screened within the superficial deposits, which in all instances comprise of shallow sands and gravels, with some areas of silt, over sandstone bedrock. BHISD06, BHISD11 and BHISD14 are in close proximity to a small burn or field drain, BHISD10B is located in close proximity to the SEPA 10% AEP (10-year) year floodplain and BHISD05, BHISD12, BHISD14 and BHISD16 are located in close proximity to the 0.1% AEP (1000-year) SEPA floodplain.

Table 18: Monitoring Locations with Maximum Groundwater Levels of Less Than 1mbgl.

Borehole Reference	Maximum Recorded Groundwater Level (mbgl)	Minimum Recorded Groundwater Level (mbgl)	Range (m)
BHISD05	0.35	1.46	1.11
BHISD06	0.51	1.38	0.87
BHISD10B	0.99	1.77	0.78
BHISD11	0.84	1.23	0.39
BHISD12	0.91	1.16	0.25
BHISD14	0.70	1.62	0.92
BHISD16	0.99	1.07	0.08
BHISD24	0.78	1.61	0.83

5.1.8 Data logger information is available for boreholes BHISD07, BHISD17, BHISD23, BHISD025 and BHISD26 between May 2018 and January 2019 (data from a fifth borehole, BHISD29A, has not been used in this assessment as the borehole appears to have been dry for most of the monitoring period). A summary of the groundwater levels recorded by the data loggers is provided in Table 19. The annual variation in groundwater level recorded was up to around 1m. Winter levels were generally closer to ground level than summer levels.

Table 19: Summary of Groundwater Levels Recorded in the Superficial Deposits

Borehole Reference	Minimum Recorded Groundwater Level	Maximum Recorded Groundwater Level	Range
BHISD05	1.46	0.94	0.52
BHISD06	1.38	0.75	0.63
BHISD09	3.76	2.98	0.78
BHISD14	1.62	0.81	0.81
BHISD18	2.38	1.45	0.93
BHISD20	DRY	9.26	-

5.1.9 Encountering shallow groundwater levels in shallow deposits is therefore considered likely and groundwater could contribute to, and extend the duration of other sources of flooding, such as fluvial flooding, in the areas adjacent to watercourses. However, the data available at this stage does not provide any evidence of shallow groundwater currently significantly contributing to flooding in the area of interest.

Bedrock Groundwater

5.1.10 Of the 24 monitoring installations, there are two boreholes screened within the bedrock as well as the overlying superficial cover. Based on the available information, there are not considered to be any areas of existing artesian or sub-artesian bedrock groundwater conditions and existing groundwater flood risk from the bedrock aquifer is low.

Limitations

5.1.11 It should be noted that the groundwater-monitoring data used to inform this baseline assessment predominantly comprises manual dips, rather than continuous logger data. These data may not represent the full range of groundwater levels that could develop in this area and the current conceptual understanding of groundwater flood risk is therefore limited.

Potential Impacts

5.1.12 As the proposed scheme is located at, or below ground level (cuttings) at some locations, there is a risk that groundwater flooding could affect the proposed scheme during both its construction and operational phases, if not managed.

5.1.13 Chapter 12 (Geology, Soils, Contaminated Land and Groundwater) provides the results of a separate road cutting screening exercise, which has identified twelve cuttings likely to intercept groundwater. As discussed in Section 5.1.1, cuttings associated with large-scale road schemes have the potential to create pathways for deeper confined artesian pressures in the bedrock to be released at ground level and cause widespread flooding. Given that all the proposed cuttings are either unlikely to intercept bedrock or have a low likelihood of intercepting bedrock (Cutting 2 only (ch1000 – ch1100)) and given that there are no known areas of existing confined artesian or sub-artesian bedrock groundwater pressures; groundwater flood risk from the bedrock aquifer, even after development, is low.

5.1.14 The cuttings likely to intercept the shallow groundwater table in the superficial deposits will need to deal with the dewatering requirements as identified in Chapter 12: Geology, Soils, Contaminated Land and Groundwater chapter of the EIAR.

Mitigation Measures

5.1.15 Despite the absence of artesian or sub-artesian bedrock groundwater conditions along the proposed scheme corridor, groundwater flood risk to the excavations anticipated to intercept the shallow groundwater table in the superficial deposits will need to be mitigated. This can be mostly managed through typical best practice road design and mitigation. Table 20 includes likely mitigation measures to be incorporated into the proposed scheme.

Table 20: Groundwater Mitigation Measures

Embedded Mitigation Measures	Description
Dewatering of cuttings	During the construction phase, the proposed scheme would include standard excavation dewatering practices involving passive and/or active dewatering, as required. It would protect construction personnel, works, plant and machinery associated with the new cuttings.
Drainage of cuttings	To protect flood sensitive receptors from groundwater flooding during the operational phase, groundwater seepage would be collected by the proposed road drainage system.
Pre-earthworks drainage	Pre-earthworks drainage should be sized appropriately to intercept and accommodate all shallow groundwater flows entering the works area to protect flood sensitive receptors.
Foundation design to permit groundwater flow	All foundations expected to intercept high groundwater levels should be designed to allow existing groundwater flow paths to function. This would prevent an increase in groundwater flood risk to flood sensitive receptors elsewhere.

Residual Risks

5.1.16 There is a low residual flood risk that mitigation measures would be unable to cope with the groundwater volumes intercepted by the proposed cuttings. It is assumed that the contractor would be aware of the shallowness of the groundwater table in the superficial deposits, and as such, would design any future drainage systems to accommodate any potential groundwater flows and volumes.

6 Construction Phase Flood Risk

Introduction

6.1.1 Detailed construction plans, locations of site compounds and method statements are not available at the time of preparing this FRA and the appointed contractor would develop these at a later stage. The assessment of flood risk is therefore not site specific. It is the contractor's responsibility to assess the flood risk to work areas, to assess the flood risk resulting both to and from temporary works, and to provide appropriate mitigation measures where necessary.

6.1.2 This section of the FRA provides an overview of potential flood risks for the contractor to consider during the construction phase, to set out high-level requirements with respect to managing flood risk, and to provide general guidance to assist the contractor in doing this.

Potential Short-term Impacts

6.1.3 Temporary works can themselves be at risk of flooding and have the potential to impact flood risks both to work areas and to receptors beyond the work site. Critically, there is a risk to life from flooding to those working on-site, and the construction works also have the potential to affect the existing risk to life from flooding beyond the construction site. The design of the temporary works therefore needs to consider these factors.

6.1.4 Table 21 outlines the broad categories of temporary works required during the construction phase and highlights the key potential impacts of the temporary works with respect to flooding.

Table 21: Typical Construction Elements

Temporary Works	Description	Potential Short-Term Impacts
Temporary earthworks	Including excavation for access road cuttings, pre-earthworks drainage, trenches; and filling for access roads, site compound areas and temporary spoil storage.	Excavation works could result in the pooling of pluvial runoff, the emergence of groundwater, the creation of an impounded body of water or a water mains strike. Works associated with filling could result in the diversion of overland flow routes, a reduction in floodplain storage, impacts on floodplain conveyance, and increased volumes of surface water runoff.
Temporary drainage	Including site compound drainage, temporary road drainage, pre-earthworks drainage.	Temporary drainage could increase both the rate and volume of pluvial runoff to a receiving watercourse or sewer and has the potential to transfer sediment to the receiving watercourse or sewer (potentially affecting the flooding mechanisms of the watercourse).
Works within or adjacent to watercourses	Including temporary river works, such as over-pumping, diversions, damming; and temporary access crossings, requiring culverting or bridging of watercourses.	Temporary work located within or adjacent to watercourses could affect the frequency, depth, extent and duration of fluvial flooding.
General site activities	Including site compounds and the storage of construction materials and equipment; and works traffic.	The location of site compounds and the storage of construction materials and equipment on-site could potentially reduce floodplain storage and divert flood flow routes. Placing working sites within the floodplain could also place human life at risk. Works traffic could also damage existing sewers or land drains, and could also compact ground, which could increase pluvial runoff.

Mitigation Principles

6.1.5 The contractor should ensure that the temporary works are protected from flooding during a high-risk event undertaken during the construction phase and that the temporary works do not increase the risk of flooding beyond the site during a similar event.

6.1.6 The overall guiding principle should be to avoid any temporary works within the functional floodplain, the 0.5% AEP (200-year) extent, where reasonably practicable. The SEPA Flood Map (SEPA 2018) provides a basis for this, as they help illustrate the extent of flooding from fluvial and surface water sources during 'low', 'medium' and 'high' likelihood events. The SEPA Flood Map should then be supplement by information contained in this report, including updated fluvial flood extents (as produced using 1D/2D hydraulic modelling) and for example locations at high risk of groundwater flooding, which may not be covered by the SEPA Flood Map.

6.1.7 Where it is not practical to avoid temporary works in areas at risk of flooding, the contractor should take into account the depth of flooding, potential floodplain flows and local site conditions to place more vulnerable works in lower risk areas. The contractor must also provide measures to mitigate the risk of flooding using the below mitigation principles as a starting point.

General Guidance

6.1.8 The contractor should follow the following general guidance concerning the management of flood risk during the construction period of the proposed scheme:

- Prepare a Flood Response Plan.
- Sign up to the Floodline, Scotland's flood warning service provided by SEPA, and also be responsible for monitoring forecasts and weather conditions on-site.
- Consult with SEPA when working within a river or within 50m of bank top is proposed and ensure the activities are licensed under the Water Environment (Controlled Activities) Regulations (CAR), if applicable.
- Monitor water levels when working within or near rivers.
- Prepare emergency evacuation plans for each construction area given issue of a Flood Warning or following rapid rises in river level or continuous heavy rainfall, identifying safe access and egress routes and refuge points.
- Provide standby pumping equipment to remove any surface water runoff that enters the working area.
- Ensure site drainage is not discharged to a local sewer.
- Contact SEPA during a flooding event greater in magnitude than the temporary works are designed to, particularly where receptors could be at increased risk of flooding.

Temporary Work Guidance

6.1.9 The contractor should also follow the following guidance regarding to temporary works and flood risk:

Temporary Earthworks

- Review local groundwater data prior to extensive excavations.
- Where dewatering of excavations is undertaken, discharge overland or to a watercourse (with appropriate treatment where necessary) at the relevant greenfield runoff rate.
- Undertake initial desk-based services searches before digging on-site. The contractor should also undertake appropriate survey (CAT scans, GPR survey, etc.) on-site to verify the location or presence of underground services before digging.

- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes.
- Locate stockpiles outside of areas susceptible to prominent surface water flows. Where this is not possible, stockpiles should be constructed with regular spaces between heaps (with each stockpile not exceeding 25m in length) to preserve existing low points and flow paths, and to prevent surface water backing up behind the structure and being re-directed elsewhere.
- Store excavated materials outside of the floodplain. Excavated material should only be placed in 'at risk areas' when required for use.
- Construct haul roads and access roads as close to ground level as possible when crossing the floodplain.
- Construct temporary drainage measures along access road / temporary diversion edges to collect runoff and direct to treatment facilities.

Temporary Drainage

- Assess requirements for discharge rate control and treatment as part of the construction works.
- Drainage receiving runoff, which is expected to contain sediment, should be directed towards a suitable sized temporary settlement pond that provides sufficient treatment before being discharged to a watercourse.

Works within or adjacent to Watercourses

- Design temporary river works, which involve the diversion of a watercourse (e.g. fluming or over-pumping), to convey the design flood event to be agreed with SEPA. A lower standard may be acceptable if the works would be in place for a shorter period than the overall construction phase.
- Design cofferdams and other in-river temporary works to minimise the impact on river conveyance and prevented from flooding internally.
- Where temporary access crossings include the use of a culvert, design to convey the peak flow during the design flood event, to be agreed with SEPA. Multiple pipes should not be used, where reasonably practicable, to reduce the risk of blockage.
- Where temporary access crossings include the use of bridges, design the soffit above the peak water level during the design flood event plus 600mm freeboard to be agreed with SEPA. Bridge piers should not be located within the watercourse.

General Site Activities

- Minimise trafficking and loading of unprotected site areas. Consider protecting large site areas subject to heavy traffic loads and methods to alleviate soil compaction post works, as soil compaction may lead to an increased runoff rate.
- Avoid trafficking areas with known vulnerable services. Assess ground loading in these areas and provide additional cover protection if necessary. Plan abnormal load routes.
- Store construction materials outside of the floodplain. Construction material should only be placed in 'at risk areas' when required for use.
- Raise offices and other site facilities outwith the functional floodplain. Where not suitable, raise offices above the peak water level for the chosen design flood event to be agreed with SEPA. Facilities could be elevated on stilts, or in some cases, located on the higher areas of the compound.

Residual Risks

6.1.10 Given that the contractor follows and correctly implements the principles outlined in this section of the report, the main residual flood risks during the construction phase of the proposed scheme are considered to be:

- fluvial or surface water events, which exceed the design standard of the temporary works or general site work;
- blockages within temporary surface water drainage; and
- failure (including blockage) of temporary works within watercourses.

6.1.11 In the event of flood events of greater magnitude than the design standard, or blockages causing temporary drainage systems to surcharge, flooding within construction areas could occur. The main risk is likely to be to the site operatives in this event; however, assuming that conditions on-site, weather forecasts, flood warnings and river levels are monitored appropriately, and site evacuation plans are in place, the residual risk is considered low.

6.1.12 In the majority of cases, failure of temporary works within watercourses is unlikely to result in a significant detrimental impact to the flood risk on the watercourse affected, as flows are unlikely to be impacted. Again, the main risk is likely to be to site operatives in this event; however, assuming that the contractor has emergency plans in place given failure of works where operatives are at significant risk, then the residual risk is considered low.

7 Conclusions

Summary

7.1.1 This FRA supports the Environmental Impact Assessment Report for the construction of the A9/A96 Inshes to Smithton scheme. The proposed scheme has been developed using assessment stages in accordance with the requirements of the DMRB, Scottish Planning Policy, SEPA's Technical Flood Risk Guidance for Stakeholders and The Highland and Argyle Council's Flood Risk and Drainage Impact Supplementary Guidance and Local Flood Risk Management Plan. The proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'.

7.1.2 This FRA demonstrates that the proposed scheme design has adequately addressed any local flood risk issues, ensuring that the mainline would remain safe and operational during times of flood. Where achievable, the proposed scheme has a neutral or better effect on overall flood risk. However, where this has not been possible, taking cognisance of environmental, engineering and economic constraints, additional mitigation measures have been proposed, or justification as to why potential flood impacts are acceptable when considering the potential consequence of that impact.

7.1.3 Table 22 to Table 24 provides a summary of the FRA findings.

Table 22: Fluvial Flooding Summary

Risk	Summary
Baseline	There is a risk of fluvial flooding to sensitive receptors in the existing corridor from Cairnlaw Burn (SWF08), Scretan Burn (SWF04), and their tributaries. Specific areas at risk of flooding are discussed below: **Cradlehall to Ashton Farm:** Flooding to properties in Cradlehall, Inverness Campus, various local roads, parts of the Cradlehall Business Park and extensive flooding to agricultural land. **Ashton Farm to Smithton Junction:** Extensive flooding to agricultural land and to sections of Ashton Farm access track. **Inverness Retail and Business Park to Moray Firth**: Flooding to agricultural land east of Inverness Retail and Business Park. Areas of flooding immediately upstream and downstream of Aberdeen to Inverness Railway Line culvert.
Potential Impacts	The proposed scheme has been shown to have both beneficial and potentially adverse impacts during the design flood event **Beneficial Flood Impacts:** • The proposed scheme mainline has been raised above the design flood event and as a result, the proposed scheme would remain safe and operational during times of flood. • Additional storage and attenuation have been provided as part of the proposed scheme. • The existing flood risk to the Inverness Campus has been reduced **Negligible Flood Impacts:** • Local loss of floodplain storage throughout this project area has been shown to have negligible flood impacts across the wider floodplain within the proposed scheme. • Downstream flows and stage for Cairnlaw Burn (SWF08) are slightly improved due to attenuation provided by the proposed scheme. • Downstream flows and stage for Scretan Burn (SWF04) are slightly improved due to attenuation provided by the proposed scheme. **Adverse Flood Impacts:** <u>Cradlehall to Ashton Farm</u> There are four areas of 'major adverse' impact as a result of the proposed scheme. However, all of these areas are part of the flood mitigation strategy and will be purchased as part of the proposed scheme. <u>Ashton Farm to Smithton Junction</u> There is one area of 'minor to moderate adverse' impact as a result of the proposed scheme. However, this area will be purchased as part of the proposed scheme.

Risk	Summary
	<u>Inverness Retail and Business Park to Inner Moray Firth</u> There is one area of 'major adverse' impact as a result of the proposed scheme. However, this area will be purchased as part of the proposed scheme and flood risk to the road in this location will be prevented by ensuring a closed parapet is tied into the existing flood embankment (see paragraph 3.1.69).
Mitigation Measures	In addition to embedded mitigation, the following measures will be implemented to mitigate flood risk resultant from the proposed scheme: • two Flood Relief Culverts. • Ground re-profiling. • three areas of bank raising (CB2, SB4 and SB2). • one Flood Storage Area (SB4). • one Flood Mitigation Area (CB2)
Residual Risks	The residual fluvial flood risks remaining are associated with flood events of greater magnitude than the design standard of the proposed scheme or blockage of any of the culverts that connect floodplain areas on either side of the proposed scheme.

Table 23: Surface Water Summary

Risk	Summary
Baseline	Generally, the preliminary assessment identifies a 'medium'/'high' risk of flooding to infrastructure and properties in the existing corridor. The SEPA Flood Map (SEPA 2018) shows several locations where direct runoff ponds near sensitive receptors (such as the Highland Main Line Railway and houses in the Cradlehall area). However, the mapping may be conservative as it does not take into account the road drainage or minor watercourse crossings.
Potential Impacts	**Beneficial Flood Impacts:** The proposed scheme would include new surface water drainage features including PED, road surface water drainage networks and SuDS measures, to manage and mitigate the risk of surface water flooding along the proposed scheme carriageway and the impact of the proposed scheme on flood risk elsewhere. These would provide a beneficial impact on surface water flooding when compared to the baseline scenario. **Adverse Flood Impacts:** The construction of the proposed scheme will sever surface water pathways in some areas. However, this is unlikely to lead to an increase in flood risk to sensitive flood receptors.
Mitigation Measures	Additional mitigation measures beyond that provided within the proposed scheme are not required.
Residual Risks	Generally, residual surface water risks are considered 'low' and include: • Severe rainfall events, which exceed the capacity of the PED, road drainage or SuDS features; and • Blockages within the drainage infrastructure or SuDS features. In the event of extreme events or blockages, the geometry of the proposed road surface has been designed in such a way as to shed runoff from the edges of the road and to avoid ponding on the carriageway itself ensuring that disruption to traffic is minimised. Where SuDS features are outside the functional floodplain, the design includes a 300mm freeboard above the peak attenuated water level to manage the residual risk of blockages and to provide some additional storage capacity should it be required. Therefore, there would be no increase in flood risk to sensitive receptors. There is also an overflow facility provided in each of the outlet controls, again to provide resilience to the design should any blockages occur. Ongoing routine inspection and maintenance of the SuDS features would reduce the likelihood of overtopping due to blockage.

Table 24: Groundwater Summary

Risk	Summary
Baseline	Within the proposed existing corridor, there is a risk of groundwater flooding from valley alluvium, marine deposits and glacial deposits, which could contribute to, and extend the duration of other sources of flooding, such as surface water or fluvial flooding in low-lying areas. However, data collected at this stage does not provide any evidence of shallow groundwater flooding significantly contributing to flooding in the area of interest.
Potential Impacts	The proposed scheme has the potential to be at risk of groundwater flooding during both construction and operation phase, especially where excavations are proposed for new road cuttings. Where excavations are proposed to bedrock there are no known confined artesian or sub-artesian bedrock groundwater pressures and therefore groundwater flood risk from the bedrock is considered low. However, twelve cuttings are likely to intercept groundwater. Given that all the proposed cuttings are either unlikely to intercept bedrock or have a 'low' likelihood of intercepting bedrock and given there is no known areas of existing confined artesian or sub-artesian bedrock groundwater pressures; groundwater flood risk from the bedrock aquifer even after development is low. **Negligible Flood Impacts:** It is anticipated that any groundwater flood risk can be managed through typical best practice road design and mitigation embedded into the design. As a result, the proposed scheme is considered to have a 'negligible' impact on groundwater flooding**.**
Mitigation Measures	• During the construction phase, the proposed scheme would include standard excavation dewatering practices involving passive and/or active dewatering, as required. It would protect construction personnel, works, plant and machinery associated with the new cuttings. • To protect flood sensitive receptors from groundwater flooding during the operational phase, groundwater seepage would be collected by the proposed road drainage system. • Pre-earthworks drainage should be sized appropriately to intercept and accommodate all shallow groundwater flows entering the works area to protect flood sensitive receptors. • All foundations expected to intercept high groundwater levels should be designed to allow existing groundwater flow paths to function. This would prevent an increase in groundwater flood risk to flood sensitive receptors elsewhere.
Residual Risks	There is a 'low' residual flood risk that mitigation measures would be unable to cope with the groundwater volumes intercepted by the proposed cuttings. It is assumed that the contractor would be aware of the shallowness of the groundwater table in the superficial deposits, and as such, would design any future drainage systems to accommodate any potential groundwater flows and volumes.

7.1.4 There are also likely to be a number of activities during the construction phase of the proposed scheme that could affect flood risks and potential mitigation measures have been identified. However, the detailed assessment of the risks and appropriate mitigation measures would be best identified and managed by the contractor on a case-by-case basis depending upon the construction techniques to be used and the location.

7.1.5 In summary, a comprehensive assessment of the risk to and from the proposed scheme has been undertaken. Mitigation measures to manage any identified flood risks have been assessed such that flood risk is managed appropriately up to the design flood event. It is concluded that the proposed scheme would meet relevant planning and design standards in terms of flood risk.

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Annex A: Impact Assessment Criteria

Sensitivity

The sensitivity of water features is associated with the existing risk of flooding or its hydrological importance as described in Table A1 below.

Table A1: Hydrology and flood risk sensitivity criteria

Sensitivity	Criteria
Very High	Water feature with direct flood risk to the adjacent populated areas, with greater than 100 residential properties and/or critical social infrastructure units (such as the A9 Perth – Inverness Trunk Road (A9), A96 Aberdeen – Inverness Trunk Road (A96) and the Highland Main Line / Aberdeen to Inverness Railway Line), hospitals, schools, safe shelters or other land use of great value at risk during the design 0.5% AEP (200-year) plus CC event. Water feature with hydrological importance to: (i) sensitive and protected ecosystems of international status; and/or (ii) critical economic and social uses (e.g. water supply, navigation, recreation, and amenity).
High	Water feature with direct flood risk to adjacent populated areas, with between 1 and 100 residential properties and/or more than 10 industrial premises at risk from flooding during the 0.5% AEP (200-year) plus CC design flood event. Minor watercourses with an indirect and localised flood risk to critical infrastructure (including the A9, A96 and the Highland Main Line Railway / Aberdeen to Inverness Railway Line), during 0.5 % AEP plus CC event, due to undersized culverts. Water feature with hydrological importance to: (i) national designation sensitive and protected ecosystems; and/or (ii) locally important economic and social uses (e.g. water supply, navigation, recreation, and amenity).
Medium	A water feature with a possibility of direct flood risk to less populated areas (no residential properties or critical infrastructure units at risk) with 10 or fewer industrial premises and/or utilisable agricultural fields. A water feature with some but limited hydrological importance to: i) sensitive or protected ecosystems; ii) economic and social uses; iii) the flooding of 10 or fewer industrial properties.
Low	A water feature passing through uncultivated agricultural land. A water feature which is assessed as not being a flood risk to critical infrastructure for the 0.5% AEP (200-year) plus CC design flood event. A water feature with minimal hydrological importance to: (i) sensitive or protected ecosystems; and/or (ii) economic and social uses.

Magnitude of Impact

The impact magnitude influenced by the timing, scale, size and duration of change to the baseline conditions, as well as likelihood of occurrence of the potential impact. For flood risk, this is assessed based on the increase in flood level during the design flood event as shown in Table A2.

Table A225: Hydrology and Flood Risk Magnitude of Impact Criteria

Sensitivity		Criteria
	Major Adverse	Increase in peak flood level 0.5% AEP (200-year) greater than 100 mm
	Moderate Adverse	Increase in peak flood level 0.5% AEP (200-year) 50 - 100 mm
	Minor Adverse	Increase in peak flood level 0.5% AEP (200-year) 10 - 50mm
	Negligible	Negligible change in peak flood level 0.5% AEP (200-year) less than +/- 10 mm
	Minor Beneficial	Reduction in peak flood level 0.5% AEP (200-year) 10 - 50mm
	Moderate Beneficial	Reduction in peak flood level 0.5% AEP (200-year) 50 - 100mm
	Major Beneficial	Reduction in peak flood level 0.5% AEP (200-year) greater than100mm

Impact Significance

The significance of impact is determined as a function of the sensitivity of the water feature and the magnitude of impact as shown in Table A3.

Table A3: Hydrology and flood risk impact significance matrix

Magnitude / Sensitivity	Negligible	Minor	Moderate	Major
Very High	Neutral	Moderate/Large	Large/Very Large	Very Large
High	Neutral	Slight/Moderate	Moderate/Large	Large/Very Large
Medium	Neutral	Slight	Moderate	Large
Low	Neutral	Neutral	Slight	Slight /Moderate

Note that even though the resulting impact significance may not be considered significant in the context of the EIA Regulations mitigation may still be proposed to address any increase in water levels.

Annex B: Flood Risk Assessment Figures

Figure A13.1.1 Scheme Layout

Figure A13.1.2a-c: SEPA Flood Map Baseline Scenario

Figure A13.1.3a-e: Modelled Fluvial Flood Depth Map Baseline Scenario

Figure A13.1.4a-e: Modelled Fluvial Flood Depth Map with Proposed Scheme (No Mitigation)

Figure A13.1.5a-d: Modelled Fluvial Flood Depth Impact Map with Proposed Scheme (No Mitigation)

Figure A13.1.6a-e: Modelled Fluvial Flood Depth Map with Proposed Scheme (with Mitigation)

Figure A13.1.7a-d: Modelled Fluvial Flood Depth Impact Map with Proposed Scheme (with Mitigation)

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Annex C: Peak model inflows in Cairnlaw Burn (SWF08) and Scretan Burn (SWF04) and their modelled tributaries for Run 2

Table C1: Run 2a Peak Model Inflows for the Storm Duration of 5.7 hrs

Watercourse	50% AEP (2-year) (m^3/s)	3.33% AEP (30-year) (m^3/s)	0.5% AEP (200-year) (m^3/s)	0.5% AEP (200-year) plus CC (m^3/s)
SWF08 (Cairnlaw Burn) and modelled tributaries				
Inflow 1 (Cairnlaw Burn)	0.89	2.01	3.12	3.74
Inflow 2 (Cairnlaw Burn – tributary)	0.02	0.04	0.06	0.07
Inflow 7 (SWF09)	0.17	0.40	0.64	0.77
Inflow 8 (Tower Burn)	0.90	2.04	3.20	3.84
R12 (lateral flow)	0.07	0.15	0.23	0.28
R13 (lateral flow)	0.06	0.14	0.22	0.26
R14/15 (lateral flow)	0.07	0.15	0.24	0.29
Cumulative total	**2.17**	**4.93**	**7.71**	**9.25**
Scretan Burn				
Inflow 3a (84.5%) (Scretan Burn)	1.49	3.33	5.12	6.15
Inflow 3b (Scretan Burn)	0.25	0.56	0.87	1.04
Inflow 4 (Beechwood Burn)	0.46	1.04	1.65	1.97
Inflow 5a (Tributary of Scretan Burn)	0.13	0.30	0.46	0.55
Inflow 5b (Tributary of Scretan Burn)	0.01	0.03	0.04	0.05
Inflow 6 (Indirect tributary of Scretan Burn)	0.55	1.25	2.00	2.40
R1 (lateral flow)	0.05	0.11	0.17	0.21
R2 (lateral flow)	0.10	0.22	0.34	0.41
R3 (lateral flow)	0.09	0.19	0.31	0.37
Cumulative total	3.11	7.03	10.96	13.15

This run (Run 2a) was undertaken to reconcile flow at culvert C01, C08 and C04 only.

Table C2: Run 2b Peak Model Inflows for the Storm Duration of 3.9 hrs

Watercourse	50% AEP (2-year) (m^3/s)	3.33% AEP (30-year) (m^3/s)	0.5% AEP (200-year) (m^3/s)	0.5% AEP (200-year) plus CC (m^3/s)
SWF08 (Cairnlaw Burn) and modelled tributaries				
Inflow 1 (Cairnlaw Burn)	0.93	2.09	3.34	4.00
Inflow 2 (Cairnlaw Burn – tributary)	0.02	0.04	0.06	0.08
Inflow 7 (SWF09)	0.18	0.41	0.69	0.83
Inflow 8 (Tower Burn)	0.87	1.96	3.15	3.78
R12 (lateral flow)	0.07	0.15	0.25	0.30
R13 (lateral flow)	0.06	0.14	0.23	0.27
R14/15 (lateral flow)	0.07	0.15	0.24	0.28
Cumulative total	**2.21**	**4.94**	**7.95**	**9.54**
SWF04 (Scretan Burn)				
Inflow 3a (84.5%) (Scretan Burn)	1.00	2.23	3.51	4.21
Inflow 3b (Scretan Burn)	0.17	0.38	0.60	0.71
Inflow 4 (Beechwood Burn)	0.53	1.19	1.94	2.33
Inflow 5a (Tributary of Scretan Burn)	0.14	0.33	0.52	0.63
Inflow 5b (Tributary of Scretan Burn)	0.01	0.03	0.04	0.05
Inflow 6 (Indirect tributary of Scretan Burn)	0.52	1.16	1.93	2.31
R1 (lateral flow)	0.05	0.11	0.18	0.22
R2 (lateral flow)	0.07	0.15	0.23	0.28
R3 (lateral flow)	0.08	0.17	0.28	0.34
Cumulative total	**2.58**	**5.74**	**9.23**	**11.08**

This run (2b) was undertaken to reconcile flow at culverts C05, C06 and C07 only.

Table C3: Run 2c Peak Model Inflows for the Storm Duration of 1.5 hrs

Watercourse	50% AEP (2-year) (m^3/s)	3.33% AEP (30-year) (m^3/s)	0.5% AEP (200-year) (m^3/s)	0.5% AEP (200-year) plus CC (m^3/s)
SWF08 (Cairnlaw Burn) and modelled tributaries				
Inflow 1 (Cairnlaw Burn)	0.71	1.69	2.61	3.13
Inflow 2 (Cairnlaw Burn – tributary)	0.01	0.03	0.05	0.06
Inflow 7 (SWF09)	0.17	0.41	0.65	0.78
Inflow 8 (Tower Burn)	0.70	1.66	2.56	3.07
R12 (lateral flow)	0.05	0.12	0.19	0.23
R13 (lateral flow)	0.05	0.11	0.18	0.21
R14/15 (lateral flow)	0.05	0.12	0.19	0.23
Cumulative total	**1.74**	**4.15**	**6.42**	**7.71**
SWF04 (Scretan Burn)				
Inflow 3a (84.5%) (Scretan Burn)	0.77	1.81	2.78	3.33
Inflow 3b (Scretan Burn)	0.13	0.31	0.47	0.57
Inflow 4 (Beechwood Burn)	0.36	0.86	1.34	1.61
Inflow 5a (Tributary of Scretan Burn)	0.15	0.36	0.56	0.68
Inflow 5b (Tributary of Scretan Burn)	0.01	0.02	0.04	0.04
Inflow 6 (Indirect tributary of Scretan Burn)	0.41	0.97	1.52	1.82
R1 (lateral flow)	0.04	0.11	0.17	0.20
R2 (lateral flow)	0.05	0.12	0.19	0.22
R3 (lateral flow)	0.06	0.14	0.21	0.26
Cumulative total	1.99	4.70	7.27	8.72

This run (2c) was undertaken to reconcile flow at Culvert C02 and C03 only.