Appendix A11.3: Flood Risk Assessment

1 Introduction

Purpose

1.1.1 This Flood Risk Assessment (FRA) report provides detailed information on the assessment of flood risk relevant to the A9 dualling between Killiecrankie and Glen Garry, also referred to as the proposed scheme. It informs Chapter 11 (Road Drainage and the Water Environment (RDWE)) of the ES.

1.1.2 The purpose of this FRA report is to document the assessment undertaken to:

- investigate existing flood risks;
- identify potential flood risk impacts associated with the proposed scheme; and where necessary,
- give consideration to appropriate flood mitigation / flood management measures.

1.1.3 As a result, the FRA will demonstrate that the proposed scheme design has adequately addressed any 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 explicitly in conjunction with the:

- Chapter 11 Road Drainage and the Water Environment of the Environmental Statement;
- Appendix A11.1 (Baseline Conditions);
- Appendix A11.2 (Surface Water Hydrology);
- Appendix A11.4 (Hydraulic Modelling Report);
- Appendix A11.5 (Fluvial Geomorphology);
- Appendix A11.6 (Water Quality);
- Appendix A11.7 (Impact Assessment); and
- Appendix A11.8 (Watercourse Crossing Report).

Context

1.1.5 The existing A9 between Perth and Inverness covers a total length of 177km. This consists of approximately 48km of existing dual carriageway and 129km of single carriageway to be upgraded to dual carriageway as part of the A9 dualling programme. Transport Scotland has sub-divided the A9 dualling programme into several projects, four of which, Jacobs UK Ltd are delivering:

- Project 2: Pass of Birnam to Tay Crossing;
- Project 3: Tay Crossing to Ballinluig;
- Project 4: Pitlochry to Killiecrankie; and
- Project 5: Killiecrankie to Glen Garry.

1.1.6 The majority of the existing A9 corridor traverses a hilly and mountainous environment with steep hillsides and valleys, and runs alongside and crosses some of the largest rivers in Scotland, with several significant tributaries and numerous smaller watercourses flowing beneath the existing carriageway. Many of these watercourses are of high ecological value, including nature conservation designations at both National and International level.

1.1.7 Parts of the existing A9 are currently located in areas considered to be at risk of flooding. Therefore, without mitigation measures the proposed scheme could alter existing hydraulic regimes and flood mechanisms, which may result in undesirable ecological, social and economic impacts.

Flood Risk Legislation, Policy & Guidance

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

Flood Risk Management (Scotland) Act 2009

1.1.9 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.

1.1.10 The Act places a duty on responsible authorities (Scottish Ministers, 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.

1.1.11 With reference to the proposed scheme, local authorities are required to consider flood risk management plans that are produced under the Act (Section 41). 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 Regulations (Scotland) 2009 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 (SPP)

1.1.12 Through the Flood Risk Management Act, SPP (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 SPP is to avoid development in areas at risk of flooding.

1.1.13 The SPP proposes a flood risk framework to guide development to the appropriate flood risk areas linked to annual probabilities. However, given the scale of the proposed scheme, and the fact that the works involve dualling an existing road, it would be unavoidable to develop the proposed scheme completely outwith areas currently at risk of flooding.

1.1.14 The SPP therefore 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% Annual Exceedance Probability (AEP) (200-year)), 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 not to impede flood flow.

Design Manual for Roads and Bridges (DMRB)

1.1.15 The Design Manual for Roads and Bridges (DMRB) provides a comprehensive system, which accommodates current design standards, advice notes and other published documents relating to the design, assessment, operation, maintenance and improvement of trunk roads and motorways. Volume 11: DMRB (Highways Agency et al., 2009) provides guidance on the assessment and management of the impacts that road projects may have on the water environment, including flooding.

1.1.16 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. Where this is not possible, and a route alignment encroaches on 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.

SEPA Technical Flood Risk Guidance for Stakeholders

1.1.17 The Technical Flood Risk Guidance for Stakeholders document (SEPA, 2015) 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 20% to account for the impacts of climate change. This should be over and above any separate allowance for freeboard, which is recommended as between 500mm and 600mm.

Flood Risk Assessment Approach

1.1.18 In order to ensure that the proposed scheme has considered flood risk at all stages of the design process, DMRB 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. In accordance with the DMRB, the development of the proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'. This FRA documents the findings of the assessment undertaken on the final design only.

Table 1 : Flood Risk 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. This includes high-risk sources of flooding as identified in the route-wide Strategic Flood Risk Assessment (SFRA) including rivers, small watercourses and existing A9 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.
DMRB Stage 3 Detailed Assessment	The 'Detailed Assessment' will focus on potential effects of the preferred alignment route option and where necessary consider appropriate flood mitigation measures to achieve a neutral flood risk.	To inform the Scheme design and the Environmental Statement.	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.

1.1.19 This FRA has adopted a range of assessment techniques, ranging from preliminary hydraulic calculations to detailed 1D-2D hydraulic modelling, to quantify the existing risk of flooding and potential flood risk impacts of the proposed scheme. To aid the discussion, and where necessary, the FRA includes a brief overview of the adopted techniques. Further detail of the hydrology and hydraulic modelling techniques adopted are contained within the following documents:

- Chapter 11 Appendix A11.2 (Surface Water Hydrology); and
- Chapter 11 Appendix A11.4 (Hydraulic Modelling Report)

1.1.20 Generally, as the proposed scheme has progressed from the DMRB Stage 1 assessment through to DMRB Stage 3 assessment, so has the level of supporting flood risk evidence, as outlined in Table 1. In line with the impact assessment criteria (Annex A: Impact Assessment Criteria), the detailed assessment of flood risk focuses 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.

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

Flood Sources

1.1.22 The assessment of flood risk has considered the following sources of flooding:

- **Fluvial (Principal Watercourses):** Flooding originating from principal watercourses, including the River Garry, Allt Bhaic and the River Bruar, which have the potential to pose the most significant flood risks within the study area (Section 3: Principal Watercourses).
- **Fluvial (Minor Watercourses):** Flooding originating from minor watercourses, with localised or less significant flood risk issues (Section 4: Minor Watercourses).
- **Surface Water (Pluvial):** Urban or rural flooding resulting from high intensity rainfall, with runoff travelling overland and ponding in local topographic depressions before the runoff enters any watercourse, drainage systems or sewer (Section 5: Surface Water).
- **Groundwater:** 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 (Section 6: Groundwater).
- **Sewer and Water Mains**: Flooding due to surcharging of man-made drainage systems. A review undertaken as part of the A9 Strategic Flood Risk Assessment (SFRA) indicated that the existing A9 is within an essentially rural area and that the extent and coverage of the existing sewer network in this area is limited. The proposed scheme would not result in additional flow being discharged into the existing sewer or mains network, therefore the risk of flooding is unlikely to change and consequently this source of flooding has only been briefly discussed (Section 7: Failure of Water-Retaining Infrastructure).
- **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.
- **Failure of Water Retaining Infrastructure:** Flooding due to the collapse and/or failure of man-made water retaining features such as hydro-dams, water supply reservoirs, canals, flood defences structures, underground conduits, and water treatment tanks or pumping stations (Section 7: Failure of Water-Retaining Infrastructure).
- **Coastal:** 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 does not traverse areas considered to be at risk of coastal flooding and would not increase the risk of coastal flooding. Therefore, the FRA has not considered this source of flooding further.
- **Construction Risks:** Risk associated with all sources of flooding, which could influence the construction phase (Section 8: Construction Phase).

1.1.23 Throughout this report flood events are represented by 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. i.e. AEP refers to the chance that a flood of a particular size is experienced or exceeded during any 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) event’.

1.1.24 This FRA uses the SEPA Flood Maps (2014) to assess the risk of both fluvial and surface water 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) events respectively.

1.1.25 The functional floodplain is defined by the SEPA 0.5% AEP (200-year) flood extent. It should be noted that the SEPA flood mapping can be indicative in nature and does not include a climate change uplift factor and so the 0.5% AEP (200-year) flood extent outline shows the areas considered to be at flood risk for this flood event at the present time.

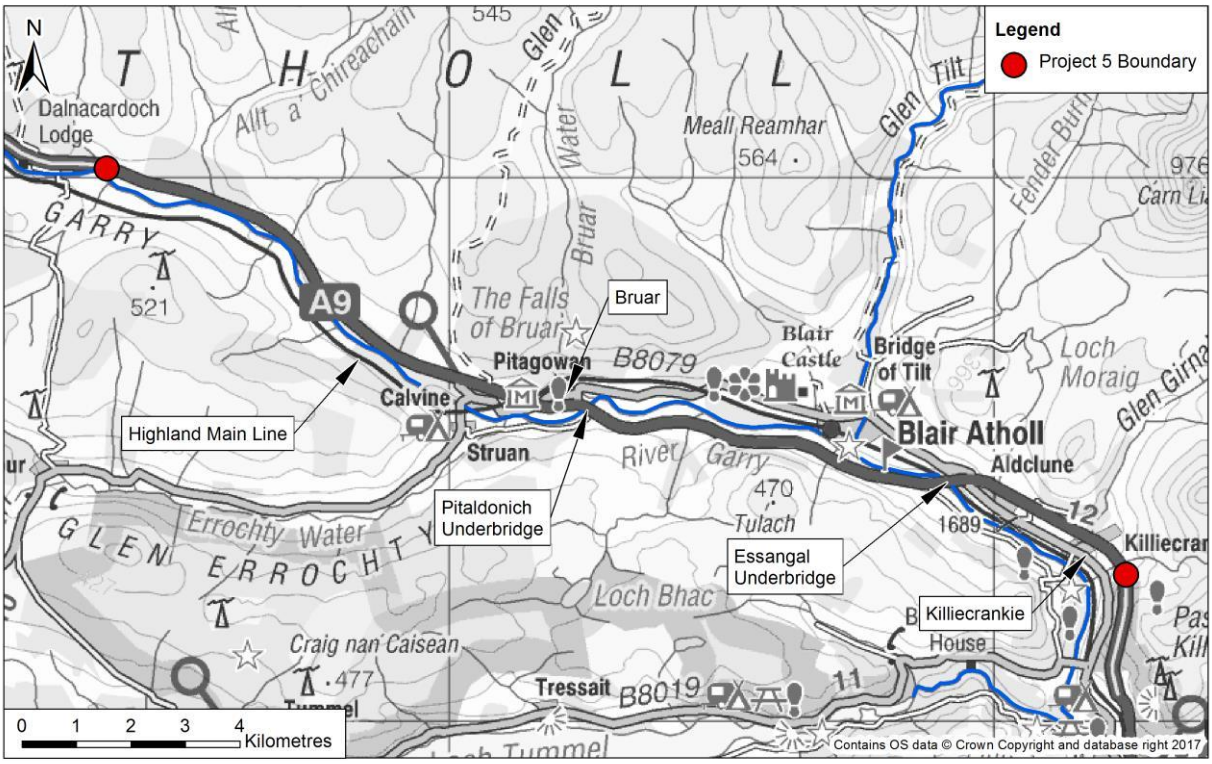
1.1.26 Where detailed hydraulic modelling has been undertaken as part of this FRA, the modelled flood extents will supersede the flood extents as presented in the SEPA Flood Map. The FRA has also considered the potential impacts of climate change on fluvial flood depths and extents. In line with current fluvial guidance (published by DEFRA), peak flow estimates for the 0.5% AEP (200-year) event have been increased by 20%, which will be denoted by 0.5% AEP (200-year) plus CC. This is known as the 'design flood event'.

2 A9 Corridor

The Existing A9

2.1.1 This FRA covers the existing A9 between Killiecrankie and Glen Garry as shown in Diagram 1, which includes approximately 21.6km of single carriageway to be dualled as part of the proposed scheme.

Diagram 1 : A9 Corridor - Killiecrankie to Glen Garry



2.1.2 The existing A9 runs through the southern portion of the Grampian Mountains and can be characterised by steep open hillsides and low valley floodplains of the River Garry containing grazing farmland and many areas of native and ancient woodland. There are few densely populated areas along the proposed scheme. Blair Atholl is the largest town, with smaller communities including Killiecrankie, Aldclune, Pitagowan, Bruar, Struan and Calvine.

2.1.3 To the south of the existing Essangal Underbridge, the existing A9 crosses open hillside and is elevated to the north, above the villages of Killiecrankie and Aldclune, the River Garry floodplain and the Highland Main Line railway, which runs parallel to the south of the existing A9.

2.1.4 Once the existing A9 crosses the River Garry and the Highland Main Line railway at the existing Essangal Underbridge, the A9 closely follows the southern bank of the River Garry, with the River Garry at a lower elevation to the A9 mainline. Whilst the existing A9 is initially significantly higher than the floodplain, once it reaches a point to the north of Blair Atholl (located on the north bank), the road level falls to a similar level to that of the adjacent floodplain as it crosses the Allt Bhaic watercourse and then crosses the River Garry again at the Pitaldonich Underbridge.

2.1.5 Hereafter and travelling north, the existing A9 lies on a low embankment, following the alignment of the River Garry through Pitagowan and Calvine until it reaches the end of the proposed scheme extent. The River Garry is the largest river between Killiecrankie and Glen Garry (with a catchment area of approximately 745km² at Killiecrankie). It discharges from the north-eastern end of Loch Garry near the Pass of Drumochter, and flows through Glen Garry in a broadly south-easterly direction towards Blair Atholl and Killiecrankie until its confluence with the River Tummel. The River Garry is a major tributary of the River Tummel, which itself is a tributary of the River Tay. The existing A9 crosses twelve principal watercourses including the River Garry twice at the existing Essangal Underbridge (Photograph 1) and the existing Pitaldonich Underbridge (Photograph 2).

Photograph 1: Essangal Underbridge

Existing Essangal Underbridge looking over to eastern bank of the River Garry

Photograph 2: Pitaldonich Underbridge

Existing Pitaldonich Underbridge crossing looking over to eastern bank of the River Garry

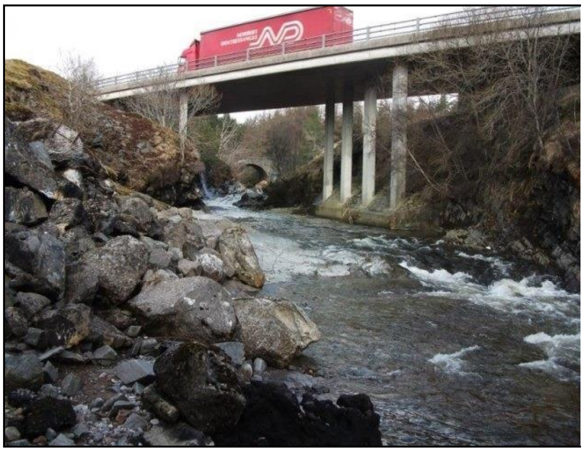
2.1.6 The larger of the remaining principal watercourses include the Allt Anndeir (61.4km²), Allt Bhaic (11.1km²), Allt Chluain (7.43km²), Allt Eachainn (3.62km²), Allt Girnaig (39.5km²) and the River Bruar. The existing A9 traverses many of these via large single span bridges (Photograph 4).

2.1.7 Considerable man-made alteration to a number of these catchments have taken place, with notable attenuation and diversions of flows as a result of the development of hydropower (most notably the Tummel Valley hydropower scheme) and numerous lochs / reservoirs (some of which are reservoirs forming supplies to the hydropower schemes). These catchment changes influence downstream flow regimes, including both flood and low flows along the River Garry.

Photograph 3: Typical Minor Watercourse Culvert Crossing

Existing A9 culvert - minor watercourse at WF159 looking downstream

Photograph 4: Principal Tributary Bridge Crossing



Existing Dalnamein Underbridge - principal tributary bridge crossing at WF158 looking upstream

2.1.8 Between Killiecrankie and Glen Garry, there are an additional 79 water features within the A9 corridor. A number of these water features have not been considered within this FRA. These include: two that are located along a section of dualled carriageway; one that flows underneath the Highland Main Line railway; seven which are diverted before flowing underneath the existing A9; seven found to be mammal passes, pre-earthwork drainage or not located on site; and seven located on the opposite bank to the A9.

2.1.9 The remaining 55 water features are typically unnamed streams or 'minor' watercourses, confined to narrow, often deeply incised channels with relatively small catchment areas (<0.5km²). 54 of these minor watercourses flow underneath the existing A9 through circular culverts ranging in diameter of between 400mm and 1.2m before discharging into the River Garry (Photograph 3). One watercourse flows underneath the existing Aldclune junction.

2.1.10 Other notable watercourses within the existing A9 corridor are the River Tilt, which flows southwards to join the River Garry between Blair Atholl and the Bridge of Tilt, and the Banvie Burn, which also flows southwards to join the River Garry at Blair Atholl. Neither of these watercourses have any interface with the existing A9 as the Blair Atholl bypass section of the existing A9 (between Essangal and Bruar) is located on the opposite bank of the River Garry.

2.1.11 The existing A9 also traverses through areas of designated native woodland and ancient woodland located either directly adjacent to or within close proximity the route of the existing A9, along with several Sites of Special Scientific Interest (SSSI). In addition to this, the River Tay Special Area of Conservation (SAC) encompasses the River Garry, downstream of the confluence with Errochty Water at Calvine, plus the River Tilt, Banvie Burn south of Old Blair, and the downstream reaches of Allt Bhaic and Allt Girnaig. The Tulach Hill and Glen Fender Meadows SAC is also located to the south of the existing A9 and River Garry between Killiecrankie and downstream of Pitaldonich Underbridge at Bruar.

The Proposed Scheme

2.1.12 The proposed scheme between Killiecrankie and Glen Garry (Project 5) is an online option, covering 21.6km of single carriageway to be dualled, and includes widening the existing single carriageways along with junction, access road and drainage improvements.

2.1.13 The subsections below provide an overview of the key features of the proposed scheme. Chapter 5 (The Proposed Scheme) contains a full description of the proposed scheme while Annex E (Flood Risk Assessment Figures) of this Appendix contains a map illustrating the horizontal alignment of the proposed scheme features.

<u>A9 Dualling, Junctions, Access Roads and Tracks</u>

2.1.14 The proposed scheme generally includes widening the existing northbound carriageway between Killiecrankie to Calvine (including widening the existing embankment to the south) and widening the existing southbound carriageway north of Calvine. This would involve new cuttings into steep hillside and wider embankments in both areas. Grade separated junctions are included at Aldclune and Bruar.

2.1.15 The proposed scheme would also include the provision of modified or new local surfaced access roads and unsurfaced access tracks, which would include new access roads to SuDS features and access tracks serving a small number of properties.

<u>Principal Watercourse Crossings</u>

2.1.16 To support the widening of the existing A9, the proposed scheme would include alterations to twelve existing bridge structures. This would include the retention and extension like-for-like for three crossings (one of which also includes a new downstream structure), retention and construction of new parallel structures for three crossings and the demolition and replacement of the remaining five, as listed below.

- Eachainn Underbridge (ch800) (Allt Eachainn, WF84) – retain existing structure unaltered.
- Troopers Culvert (ch1250) (Troopers Den Burn, WF87) – retain existing structure (minor wingwall demolition) and extend.
- Allt Girnaig Underbridge (ch1550) (Allt Girnaig, WF89) – retain existing structure and construct a new parallel structure.
- Allt Chluain Underbridge (ch3350) (Allt Chluain, WF98) – retain existing structure and extend, and construct a new structure to accommodate northbound diverge slip.
- Essangal Underbridge (ch4300) (River Garry, WF100) – construct a new three span bridge to the retained existing structure.
- Allt Bhaic Underbridge (ch9200) (Allt Bhaic, WF115) – demolish existing structure and replace.

- Pitaldonich Underbridge (ch11300) (River Garry, WF100) - retain existing bridge for use as southbound merge slip and construct new parallel offline bridge upstream for mainline referred to as the River Garry Underbridge.
- Allt A'Chrombaidh Underbridge (ch15100) – demolish existing structure and replace.
- Clunes Burn Underbridge (ch16500) – retain existing structure (minor wingwall demolition) and extend.
- Allt Crom Bhruthaich Underbridge (ch18200) – demolish existing structure and replace.
- Dalnamein Underbridge (ch19800) – demolish existing structure and replace.
- Allt Geallaidh Underbridge (ch22000) – demolish existing structure and replace.

2.1.17 Appendix A11.8 (Watercourse Crossing Report) contains further detail and justification for the design of each structure.

Minor Watercourse Crossings

2.1.18 Within the study area, the existing A9 mainline crosses 54 'minor' watercourses, from small open channels such as field drains, to much larger watercourses. To support the dualling of the A9, the proposed scheme includes the extension or replacement of many culverts that convey these flows.

2.1.19 The design process for the watercourse crossings is complex, taking account of a range of design criteria and constraints to develop the most appropriate crossing for each watercourse. The primary technical standards driving the design of culverts are DMRB HA107/04 Design of Outfall and Culvert Details (2004) and the CIRIA Culvert design and operation guide (C689) (2010). However, in addition to these technical standards there are other drivers that influence the culvert design which include:

- Flood risk - In the event that a culvert is either extended (based on current geometry) or replaced, the impact on flood sensitive receptors may change by either retaining more water on the upstream side of the A9 or by passing more water through the culvert. Extending a culvert in the absence of any other change may increase flood levels upstream, while replacing an existing culvert with a larger one will increase the flow downstream, possibly reducing the water level upstream and increasing the water level downstream.
- Maintenance requirements - Maintenance of culverts to meet DMRB standards (as defined by HA107/04) requires consideration of a minimum culvert size. This culvert may be larger than the culvert size required from a hydraulic perspective, in which case increasing the culvert size may have an impact on flood sensitive receptors downstream.
- Ecological considerations - When designing new culverts, consideration is given to the provision of adequate integrated mammal passage, which if required will influence culvert size. In addition, consideration is given to maintaining a natural bed level within the culvert barrel by burying the culvert invert, such that the culvert is sized to carry both flood flow and river bed sediment.
- Geomorphological considerations - When increasing the size of a culvert there is the potential for influencing sediment transport, which occurs during a flood, thereby impacting on either erosion or sedimentation in the vicinity of the culvert, both upstream and downstream.
- Highway drainage design - The culvert design, in terms of both gradient and cross-section, needs to be considered so that it does not conflict with the proposed scheme i.e. the proposed road structure and highway drainage system.

2.1.20 For all areas, these influencing factors need to be considered together on a case-by-case basis to develop the most appropriate culvert design for each crossing. This design process is iterative, such that the final design meets the fundamental design standard, which is that the proposed scheme remains free from flooding in the 0.5% AEP (200-year) design flood event plus an allowance for climate change (increase in flow of 20%), and freeboard (typically 600mm). In this context, freeboard is defined as the difference between the proposed scheme road level and the peak water level during the 0.5% AEP (200-year) plus climate change event.

2.1.21 During the design process, the decision-making hierarchy adopted is to retain the existing culvert or to extend the existing culvert on a 'like-for-like' basis to accommodate the proposed scheme. Only where this was not possible, due to engineering or environmental considerations listed above, the existing culvert would be replaced with a new culvert. There are a number of locations where the proposed scheme will result in earthworks 'cut' into the adjacent hillside, or the invert of the new watercourse crossing will be lowered to pass beneath the proposed road drainage system. In both cases this will result in a steepened watercourse requiring a 'cascade' to safely convey the design flood event, without compromising the integrity and existing landform of the hillside and/or operation of the proposed scheme.

2.1.22 The design approach for the watercourse crossings, which takes account of the culvert design guidance, allows for a degree of flexibility and engineering judgement to be applied to the culvert design, to take into account the various influencing factors outlined above. The final designs for the watercourse crossings included within this FRA are all compliant with this guidance, with a focus on design considerations set out in CIRIA C689 and DMRB HA107/04. Appendix A11.8 (Watercourse Crossing Report) contains further detail and justification for the design of each structure.

Surface Water Drainage

2.1.23 The proposed scheme would include the construction of new drainage features to treat and attenuate surface water runoff, including Pre-earthwork Drainage (PED), road drainage networks and SuDS features and associated pipe work, outfall structures and access tracks. The proposed scheme includes 22 SuDS features, which are likely to include detention basins, retention ponds and wetlands, designed to collect, treat and attenuate the peak flow from the proposed road drainage system prior to discharge to the nearest watercourse via an outfall.

Proposed Scheme Design Principles and Standards

2.1.24 The design of the proposed scheme has developed over the three DMRB assessment stages considering a range of design principles and standards and locational and environmental issues relevant to road projects. Table 2 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 2: Proposed scheme flood risk design principles and standards

Proposed Scheme	Design Principles and Standards	Description
MainlineA9 Dualling, Junctions, Access Roads and Tracks	• 0.5% AEP (200-year) Functional Floodplain • 0.5% AEP (200-year) plus CC flood event plus 600mm freeboard	Avoid locating the proposed scheme and any associated works within the functional floodplain. Set the mainline, junctions and surfaced access roads above the design flood event level. Unsurfaced access tracks would remain unchanged from existing elevations and as a result could have lower flood design standards.
Principal Watercourse Crossings	• 0.5% AEP (200-year) Functional Floodplain • 0.5% AEP (200-year) plus CC flood event plus 600mm freeboard	Avoid locating the proposed scheme and any associated works including bridge piers and abutments within the functional floodplain. Where the proposed scheme intends to replace existing structures, soffit levels are set above the design flood event level.
Minor Watercourse Crossings	New (or replaced) mainline and access road culverts • Designed to freely pass the 1% AEP (100-year) flood event plus appropriate freeboard, and tested to pass the 0.5% AEP (200-year) design flood event with appropriate culvert freeboard. New (or replaced) side road (unsurfaced tracks) culverts • 2% AEP (50-year) flood event plus appropriate culvert freeboard Culvert Freeboard • The freeboard design standard for culverts up to or equal to 1.2m in	In line with DMRB, all new (or replaced) mainline and access road culverts are designed to freely pass the 1% AEP (100-year) flood event (with appropriate freeboard within the culvert barrel). All new (or replaced) culverts are tested to pass the 0.5% AEP (200-year) design flood event with appropriate culvert freeboard, taking account of other factors influencing culvert design. In line with DMRB, all new (or replaced) side road (unsurfaced tracks) culverts are designed to freely pass the 2% AEP (50-year) design event (with appropriate culvert freeboard within the culvert barrel). The design standard for unsurfaced access track culverts is lower than for mainline culverts as these

Proposed Scheme	Design Principles and Standards	Description
	diameter or height shall be D/4 where D is the diameter for circular culverts, or the height for non-circular. For culverts with a diameter or height greater than 1.2m, the freeboard should be in the range 200mm to 500mm (CIRIA, C689).	tracks are mainly unsurfaced, with a low traffic volume, which only serve as access to a few agricultural properties. Unsurfaced access tracks are also to be set at existing ground level (which may be elevated), to avoid changing the local risk of flooding. The impact of the proposed scheme on flooding has been assessed against the design flood event.
Pre-earthwork Drainage (PED)	• 1.3% AEP (75-year) rainfall runoff 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. Where practicable, the sizing of PED drainage at the top of the cuttings should be increased to accommodate the design flood event to minimise the risk of overtopping and flood risk to the road.
Road Drainage System	• 100% AEP (1-year) rainfall event, without surcharging • 20% AEP (5-year) rainfall event, plus a 20% allowance for climate change, without exceed the chamber cover	As per DMRB (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 and compensatory storage to be provided for all loss of capacity.
	• 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 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	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, provide the same volume and be at the same level relative to the design flood level as the volume that is lost. In designing compensatory flood storage, the beneficial (or detrimental) 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 Guidance only explicitly requires Compensatory Flood Storage to be provided up to the 0.5% AEP (200-year) flood event.

Flood History

2.1.25 A review of the historical flood records provided by SEPA indicates that most of the known flooding issues occur within the floodplain of principal watercourses and smaller water features and away from the existing A9 corridor. Where the source of flooding is provided, it was generally caused by exceedance flows (fluvial), heavy rainfall (pluvial) or rapid snowmelt.

2.1.26 Between Killiecrankie and Glen Garry, historical flood incidents recorded are located away from the existing A9 and include fluvial flooding through Blair Atholl. Transport Scotland's Operating Company has reported surface water flooding along the stretches of the existing A9 within cuts adjacent to steep hillsides. This includes large proportions of the mainline between Killiecrankie and Glen Garry, with frequent surface water flooding in the northern section of the existing A9 around Dalreoch.

Strategic Flood Risk Assessment (SFRA)

2.1.27 A route-wide SFRA was prepared as an addendum to the Strategic Environmental Assessment (Transport Scotland, 2014), which provides an overview of flood risk from all sources for the A9 dualling programme between Perth and Inverness.

2.1.28 The SFRA (2014) referred to the Potentially Vulnerable Area (PVA 08/01) in Blair Atholl identified by SEPA as part of the National Flood Risk Assessment under the Flood Risk Management (Scotland) Act. The reports of flooding in Blair Atholl were noted as frequent, with 65% attributable to fluvial and 35% to surface water. The groundwater flooding potential was graded as “very low to low”. There have been instances of fluvial flooding recorded in 1993 and 2006 from the River Garry.

2.1.29 The SFRA (2014) also noted that there are 85 properties in Blair Atholl within the SEPA Flood Map 0.5% AEP (200-year) extent. Within Blair Atholl, there are seven properties within 500m of the existing A9, but these are not within the SEPA Flood Map 0.5% AEP (200-year) flood extent.

TAYplan Level 1 Strategic Flood Risk Assessment

2.1.30 The Level 1 TAYplan SFRA (The Strategic Development Planning Authority (SDPA), 2014) aims to bring sustainable economic development to the region by ensuring new development is avoided. The TAYplan Level 1 SFRA (SPDA, 2014) did not highlight any areas of significant flood risk between Killiecrankie and Glen Garry.

JACOBS

3 Principal Watercourses

Introduction

3.1.1 This FRA categorises principal watercourses as those having the potential to pose the most significant flood risk impact along the existing A9 corridor, these include the River Garry and its largest tributaries including the Allt Anndeir, Allt Bhaic, Allt Chluain, Allt Eachainn, Allt Girnaig, and the River Bruar.

3.1.2 In general, the majority of the proposed scheme between Killiecrankie and Aldclune (ch700 to ch4000), Shierglas and Balnastuartach (ch5000 to ch8800) and between Pitagowan and Glen Garry (ch12000 to ch22300) is located outwith the 0.5% AEP (200-year) functional floodplain of the River Garry, as illustrated by the SEPA Flood Map (Annex E: Flood Risk Assessment Figures).

3.1.3 Based on a high level assessment of principal tributary crossings (Annex C: Principal Tributaries Crossing Assessment), it is considered that the proposed scheme presents a low or negligible impact on flooding, and the assessment of fluvial flood risk for these principal tributaries has not been considered in further detail as part of this FRA.

3.1.4 The assessment of fluvial flooding therefore focuses on locations where the proposed scheme includes new or extended bridges and embankments that transverse the floodplain of the remaining principal watercourses. In these areas, the proposed scheme has the potential to significantly impact flood risk as the watercourses are large and the flow mechanisms are hydraulically complex. Between Killiecrankie and Glen Garry this includes:

- Location 1 - Essangal Underbridge at the River Garry (ch4000 to 5000)
- Location 2 - Allt Bhaic Underbridge at the River Garry / Allt Bhaic confluence (ch8800 to ch10000)
- Location 3 - Pitaldonich Underbridge (ch10700 to ch12000)

<u>Assessment Approach</u>

3.1.5 In light of limitations associated with the SEPA Flood Map, two numerical models have been developed covering the areas of focus, including the:

- River Garry and its floodplain between ch2900 to ch5500, which includes the Essangal Underbridge, referred to as Model V as shown in Diagram 2; and
- River Garry, Allt Bhaic and the River Bruar and their floodplain between ch7600 to ch12300, which includes the Allt Bhaic Underbridge and the Pitaldonich Underbridge, referred to as Model V/VI as shown in Diagram 3 and Diagram 4.

3.1.6 Each model adopts a linked one-dimensional (1D)/two-dimensional (2D) technique, where the model represents the river channel as a 1D component using Flood Modeller software and it is linked dynamically to the floodplain, which is represented in 2D, using TUFLOW software.

3.1.7 To assess existing flood risks and potential impacts of the proposed scheme, the modelling considers two development scenarios: the ‘baseline (existing A9) scenario’ and the ‘proposed scheme (no mitigation) scenario’. Appendix A11.4 (Hydraulic Modelling Report) provides further detail of the hydraulic model build process, but in summary, to represent the proposed scheme, modifications to the baseline model generally included:

- horizontal and vertical changes to the existing A9 and embankments to accommodate the new carriageway, which includes embedded mitigation to prevent the carriageway from flooding;
- modifications to existing A9 structures and inclusion of new hydraulic structures (bridges and culverts) in the river channel; and
- inclusion of proposed scheme features within the floodplain, including junctions, access roads and tracks, and road drainage features, such as SuDS features.

3.1.8 Both model scenarios were then simulated for a range of flood events including the design flood event, which is commensurate with SEPA recommendations (SEPA, 2015). Appendix A11.2 (Surface Water

Hydrology) provides further detail of the flood hydrology. Table 3 details peak flow estimates for a range of flood probabilities at specific locations along the modelled watercourses.

Table 3: Peak flood flows (m^3/s) for a range of flood probabilities

Catchment	50% AEP (2-year)	3.33% AEP (30-year)	1% AEP (100-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus CC
River Bruar	49	85	105	110	132
Allt Bhaic	4.6	8.8	10.7	12.0	14.4
River Garry ch12300	194	334	412	433	519
River Garry ch7600	227	391	482	545	654
River Garry ch5550*	404	677	850	974	1169
River Garry ch2900	405	679	852	976	1171
*downstream of River Tilt confluence					

3.1.9 Once simulated, 1D and 2D model outputs were extracted and mapped, with specific comparison made to:

- peak flood hydrograph and level within the channel;
- peak flood depth within the floodplain;
- spatial flood extent; and
- flood inundation volume.

3.1.10 Annex E (Flood Risk Assessment Figures) contains mapping illustrating the baseline scenario and the proposed scheme scenario (no mitigation) flood depths across the modelled floodplain. The mapping also illustrates the impacts on maximum flood level during the design flood event, categorised using the classifications presented in Table 4. Appendix A11.4 (Hydraulic Modelling Report) contains peak water levels for each model cross-section.

Table 4: Fluvial flood risk impacts

Potential flood impact		Change in Peak Flood Level
	Major adverse	Increase in peak flood level > 100mm
	Moderate adverse	Increase in peak flood level >50mm
	Minor adverse	Increase in peak flood level >10mm
	Negligible	Negligible change in peak flood level <+/- 10mm
	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

3.1.11 The following sections describe the baseline flood risk and potential flood impacts of the proposed scheme in detail.

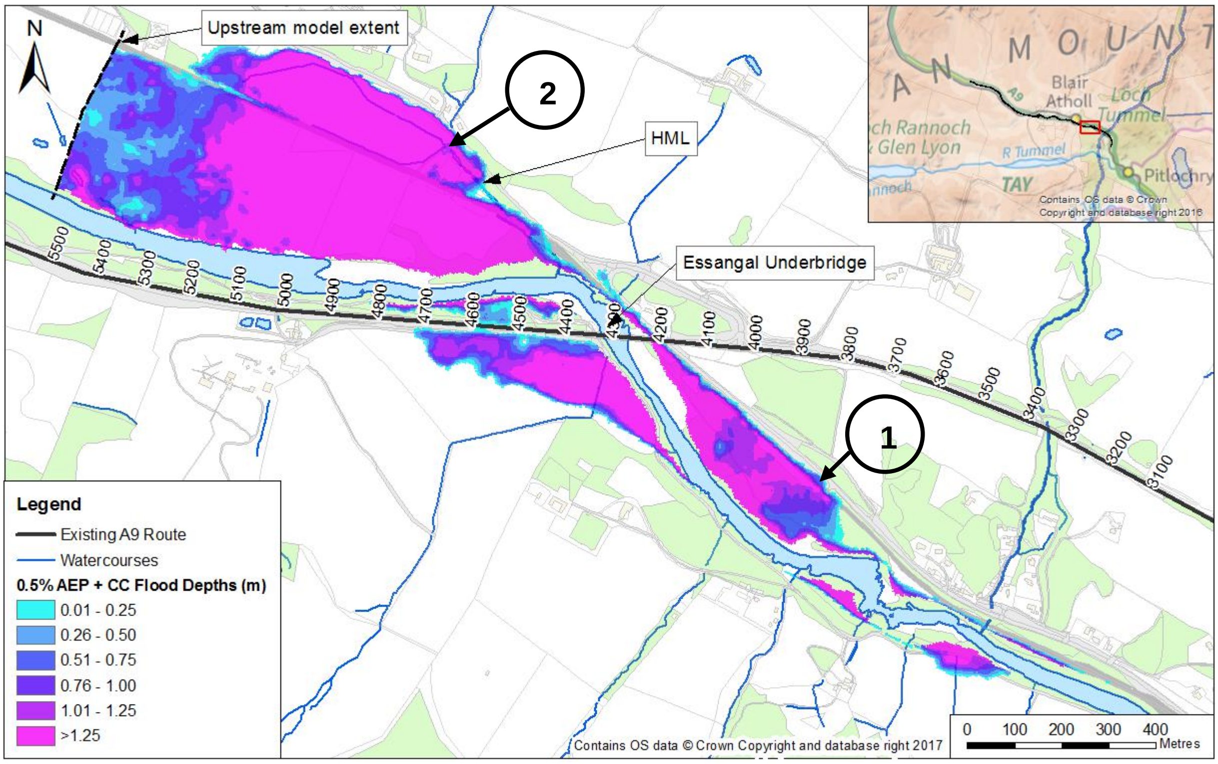
Baseline Risks

3.1.12 Using the two hydraulic models, this section provides an overview of baseline flood risks along the existing A9 corridor at the three key locations of interest.

Location 1 – Essangal Underbridge

3.1.13 Immediately downstream of the existing Essangal Underbridge, hydraulic modelling shows that the River Garry spills out of bank with an onset of flooding of the 3.33% AEP (30-year) event. Floodwater spreads onto the southern floodplain of the River Garry and flows west towards the raised A9 embankment and then onto the northern floodplain towards the embankment of the Highland Main Line railway. Flood depths in the northern floodplain can exceed 1.25m, with the Highland Main Line railway embankment overtopping during the design flood event as shown in Diagram 2, Area 1.

Diagram 2: Essangal Underbridge – baseline flood depths



3.1.14 Upstream of the Essangal Underbridge, hydraulic modelling predicts extensive floodplain extents similar to the SEPA Flood Map (2014). Floodwater also enters the area adjacent to the B8079 during the 3.33% AEP (30-year) flood event via overtopping of the Highland Main Line railway and through a small culvert, which results in flooding to Chestnut Cottage as shown in Diagram 2, Area 2. During the design flood event, Chestnut Cottage floods to a depth of 1.5m. The remaining properties in this area are located outwith the flood extent of the design flood event, but certain sections of the B8079 are shown to be at risk of flooding.

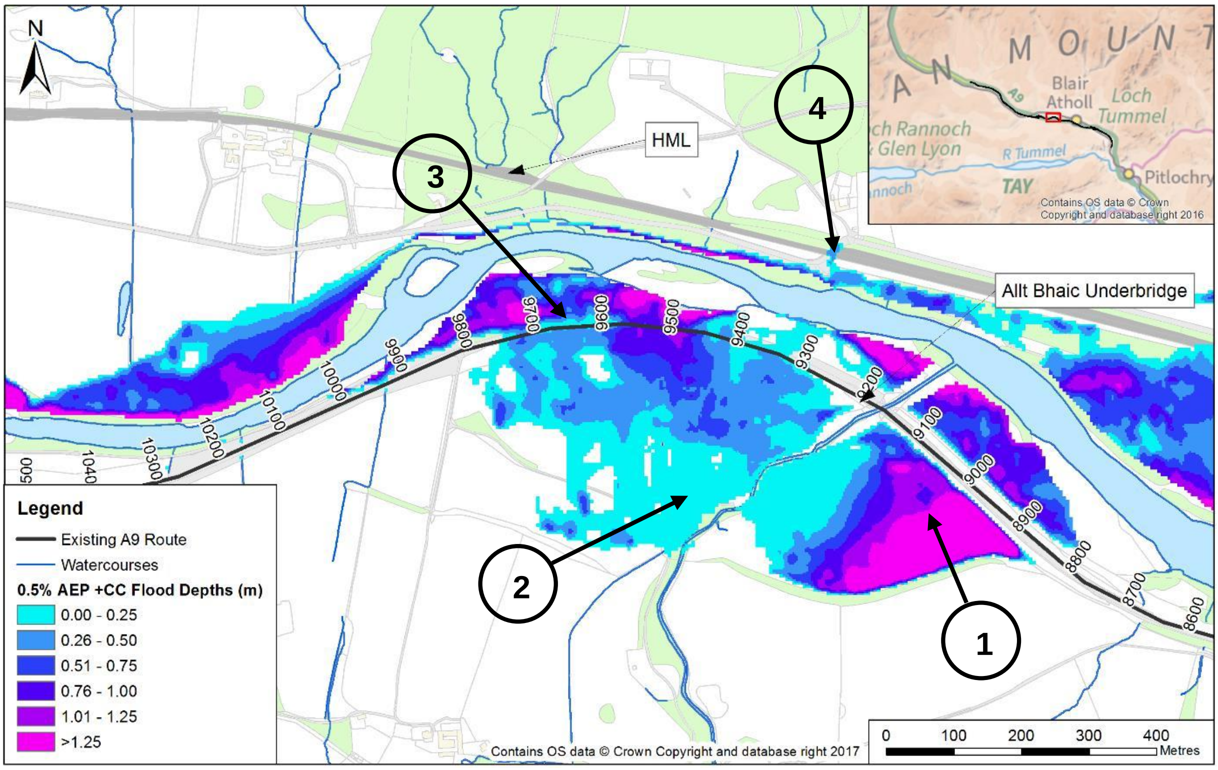
3.1.15 During the design event, the modelling shows that the existing A9 mainline is at risk of overtopping from the River Garry, with a 20m section of the road flooded to a depth of 100mm between ch4580 and ch4600. Analysis of the model results shows that a peak flow of 0.9m^3/s passes over the existing A9 at this location, with a corresponding total volume of 6,300m^3. The Essangal Underbridge itself is not shown to greatly influence water levels upstream of the structure during the flood events modelled, with less than a 25mm head loss predicted immediately upstream of the structure during the design flood event.

Location 2 - Allt Bhaic Underbridge

3.1.16 This section of the existing A9 corridor includes the confluence of the Allt Bhaic with the River Garry. At this location, the existing A9 road level falls to a similar level to the adjacent floodplain as it crosses the Allt Bhaic watercourse.

3.1.17 Upstream of the existing A9 crossing, the Allt Bhaic spills out of bank onto its eastern floodplain as shown in Diagram 3, Area 1. From the 50% AEP (2-year) event and above, floodwater spreads eastwards and downhill towards the raised embankment of the existing A9, behind which it is impounded and ponds. The existing A9 is not at risk of overtopping between ch8800 and ch9100 during the design flood event; however, flood depths exceed 2.5m as ground levels fall towards the east.

Diagram 3: Allt Bhaic Underbridge – baseline flood depths



3.1.18 The Allt Bhaic is also shown to spill out of bank onto its western floodplain, with floodwater spreading north-westerly towards the existing A9 embankment as shown in Diagram 3, Area 2. Flood depths are much lower on the western floodplain area compared to the eastern floodplain of the Allt Bhaic, with flood depths reaching approximately 1m during the design flood event. This is due to difference in ground levels between the two floodplain areas. The eastern floodplain area also floods before the western area because of a low right bank (relative to the left bank) on a short reach of the Allt Bhaic.

3.1.19 During the 3.33% AEP (30-year) event, the hydraulic modelling shows that floodwater from the River Garry overtops an 80m length of the existing A9 at ch9500, with flood depths reaching approximately 200mm along the mainline (Diagram 3, Area 3). Once overtopped, floodwater enters the western floodplain of the Allt Bhaic and contributes to flooding in this area as mentioned above.

3.1.20 During the design flood event, the length of existing A9 overtopped increases to 470m between ch9300 and ch9800, with flood depths reaching approximately 1m. The hydraulic model predicts that approximately 300,000m³ of floodwater overtops the existing A9 during this event, from both the River Garry and Allt Bhaic, with flood flows reaching up to 15m³/s. This represents a significant risk to road users and risk to life.

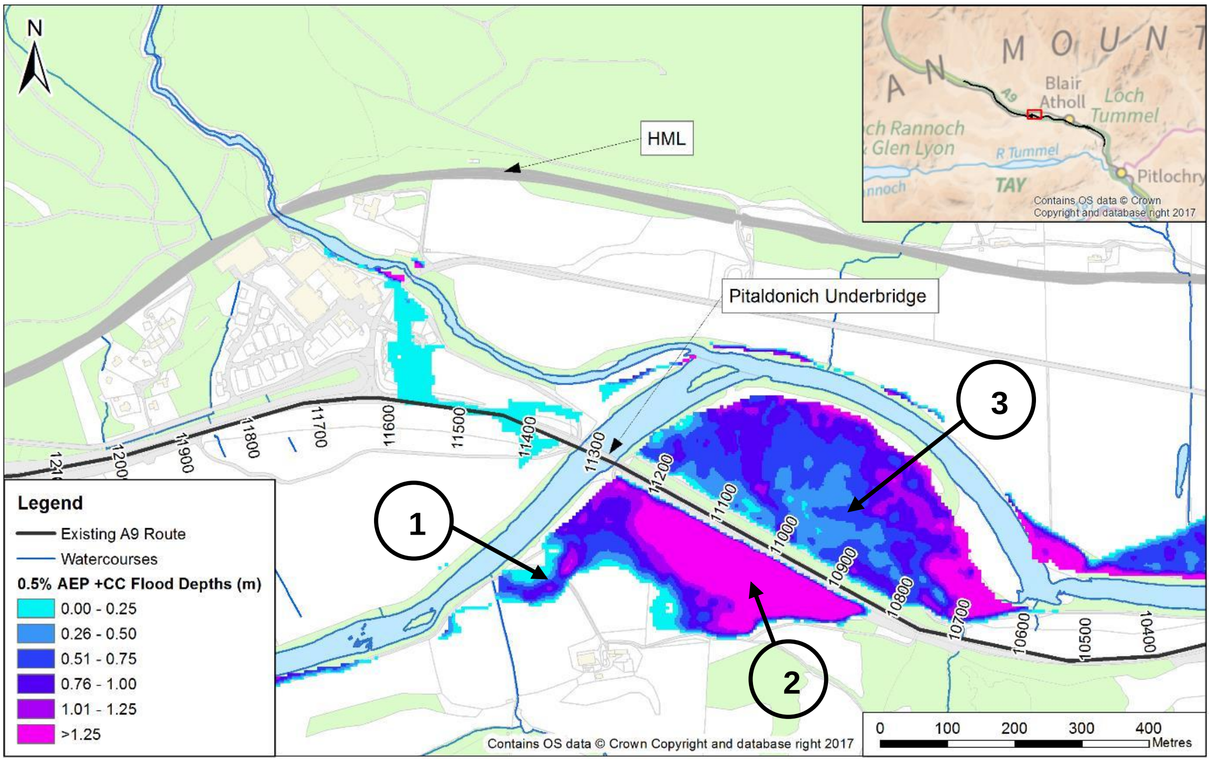
3.1.21 Within the northern River Garry floodplain, on the opposite bank to the existing A9, out of bank flooding onsets during the 3.33% AEP (30-year) event. The hydraulic model indicates that during the design flood event this out of bank flow would result in flooding of the B8079 underpass of the Highland Main Line railway (ch9300), with flood depths reaching approximately 500mm, making the underpass unpassable to vehicles as shown in Diagram 3, Area 4.

Location 3 – Pitaldonich Underbridge

3.1.22 As the existing A9 begins to rise towards the Pitaldonich Underbridge, it crosses the River Garry floodplain, separating the floodplain into two distinct areas. Immediately upstream of Pitaldonich Underbridge, the hydraulic model shows the River Garry to spill out of bank onto the eastern floodplain from the 3.33% AEP (30-year) event and above. At this location, floodwater spreads in an easterly direction and pools against the southern side of the existing A9 embankment. Floodwater cuts off an access track to properties at Pitaldonich and Tomban during the 0.5% AEP (200-year) event, with flood depths reaching approximately 800mm along the track during the design event as shown in Diagram 4, Area 1.

3.1.23 Flood depths along the A9 embankment can exceed 3m during the design flood event as shown in Diagram 4, Area 2. However, there remains a minimum freeboard of 1m available to the existing A9 level and therefore there is no risk of overtopping.

Diagram 4 : Pitaldonich Underbridge – baseline flood depths



3.1.24 Immediately downstream of the Pitaldonich Underbridge, the hydraulic model shows the River Garry to spill out of bank onto the western floodplain. At this location, floodwater spreads in an easterly direction and ponds against the north side of the existing A9 embankment as shown in Diagram 4, Area 3. Whilst there are no residential receptors at risk within this floodplain, the Aldclune and Invervack Meadows SSSI, River Tay Special Area of Conservation (SAC) and areas of designated Ancient Woodland Inventory are within the floodplain.

Baseline Summary

3.1.25 The hydraulic modelling shows that the onset of flooding along the River Garry and Allt Bhaic floodplains occurs around the 3.33% AEP (30-year) event. During the design flood event, the floodplains of both the River Garry and Allt Bhaic become fully inundated with significant flood depths experienced throughout.

3.1.26 There is currently only one property identified at risk of flooding (Chestnut Cottage), upstream of the Essangal Underbridge. The remaining floodplain is primarily agricultural land. In addition, the hydraulic modelling shows that a number of sections of critical transport infrastructure are at risk of flooding from the River Garry including the Highland Main Line railway, the B8079 and the existing A9, along with access tracks to properties.

3.1.27 The risk of flooding is therefore high along both the River Garry and Allt Bhaic. Under the criteria adopted for the impact assessment, both watercourses are classified as a Very High Sensitivity.

Potential Impacts

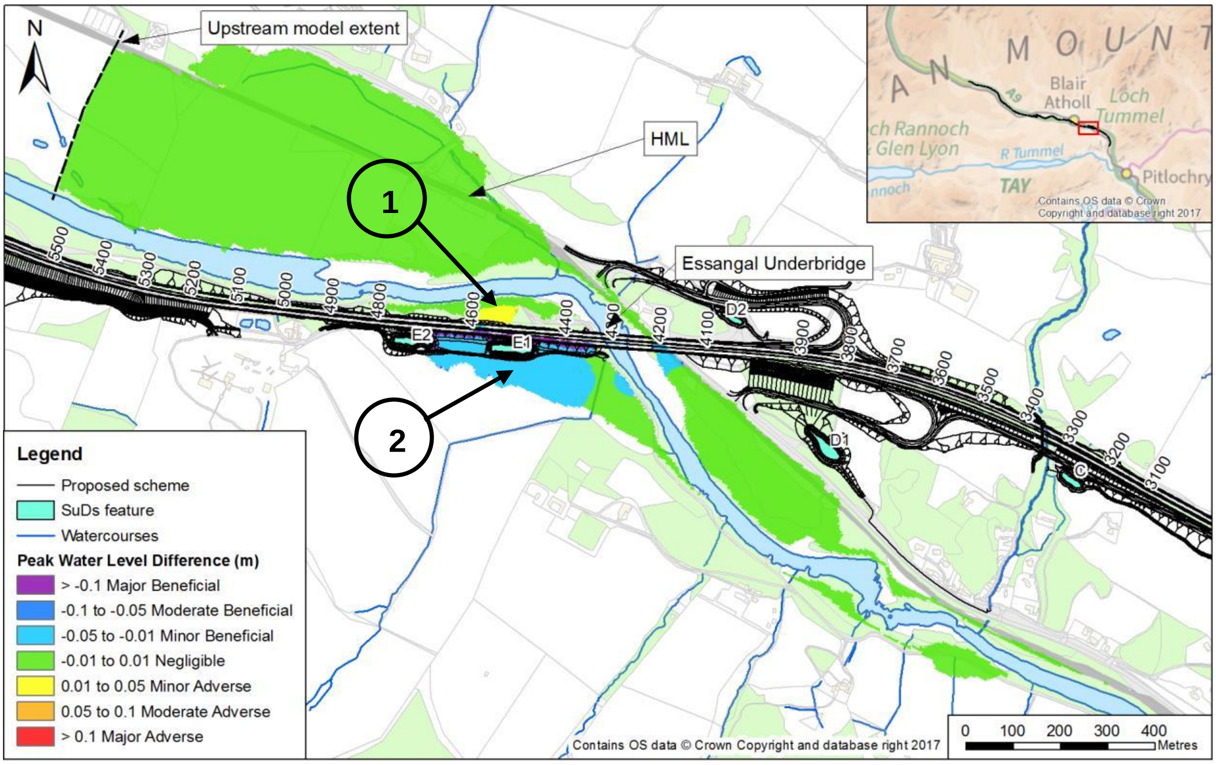
3.1.28 Using the two hydraulic models to investigate flooding, this section provides an overview of the proposed scheme (no mitigation) impacts on flooding at the three key locations of interest.

<u>Location 1 – Essangal Underbridge</u>

3.1.29 This section of the proposed scheme includes widening of the existing A9 embankment to accommodate a new northbound carriageway, and two SuDS features (E1 and E2) on the right bank of the River Garry (with respect to the direction of river flow). The proposed scheme would retain the existing three span bridge (supporting the southbound carriageway) while a new three span bridge would be constructed to mirror the existing structure parallel and immediately downstream (supporting the northbound carriageway). This bridge structure would require piers within the River Garry, adjacent to the piers of the existing bridge.

3.1.30 The overall impact of the proposed scheme on flooding through this section is negligible as shown in Diagram 5; however, the proposed scheme does result in both localised beneficial and adverse flood impacts with some subtle changes in the flood mechanism.

Diagram 5: Essangal Underbridge (Proposed Scheme) - (no mitigation) peak water level difference



3.1.31 Table 5 provides the actual change in peak water levels within these floodplain areas across a range of flood probabilities as a result of the Proposed Scheme.

Table 5: Essangal Underbridge (Proposed Scheme) – peak water level impacts in floodplain

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level – Area 1 (mAOD)	-	-	122.093	122.541
Peak Water Level – Area 2 (mAOD)	-	119.928	120.780	121.191
Proposed Scheme				
Floodplain loss (m^3)	-	-	4,610	7,610
Peak Water Level Impact – Area 1 (mm)	-	-	+1	+28
Peak Water Level Impact – Area 2 (mm)	-	-1	-3	-16

3.1.32 The proposed scheme results in a net loss of floodplain storage of up to approximately 7,610m^3. This is due to widening the A9 mainline embankment and the construction of new SuDS features and access roads on the floodplain.

3.1.33 The proposed scheme also includes raising the A9 mainline above the design flood event water level, which prevents 6,300m^3 of floodwater from overtopping it through the western floodplain as observed during the baseline scenario.

3.1.34 Although 7,610m^3 of floodplain storage is lost, the proposed scheme reduces peak water levels by 16mm in a localised area south of the A9 embankment as shown in Diagram 5, Area 2. However, an increase in the peak water level of approximately 28mm is observed over a much smaller area as shown in Diagram 5, Area 1 on the northern side of the A9 embankment.

3.1.35 Further upstream, the proposed scheme has been shown to have limited impacts to flood sensitive receptors, with peak flood levels to Chestnut Cottage and the B8079 marginally increase by approximately 2mm, and to the Highland Main Line by 3mm. All receptors remain at similar risk of flooding as that observed during the baseline scenario.

3.1.36 Table 6 provides an overview of peak water level impacts to flood sensitive receptors across a range of flood probabilities.

Table 6 : Essangal Underbridge (Proposed Scheme) – peak water level impacts at receptors

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level – Chestnut Cottage (mAOD)	-	121.707	122.524	122.991
Peak Water Level – Highland Main Line (mAOD)	-	119.535	120.280	120.625
Peak Water Level – B8079 (mAOD)	-	-	122.550	123.012
Proposed Scheme				
Peak Water Level Impact – Chestnut Cottage (mm)	-	0	0	+2
Peak Water Level Impact – Highland Main Line (mm)	-	0	+1	+3
Peak Water Level Impact – B8079 (mm)	-	-	0	+2

3.1.37 Whilst the proposed scheme has been designed so that the mainline A9 is not at risk of flooding during the design flood event, a residual risk remains during extreme flood events beyond this design standard. Where possible the carriageway of the mainline level has been set above this level, plus 600mm freeboard, thereby allowing for flood events in excess of the design flood event. However, in this area, there is a short length (<100m) over which the freeboard is reduced slightly (in the range of 350-500mm of freeboard) due to the technical constraints associated with the vertical alignment of the road tying into the Essangal Underbridge.

Location 2 - Allt Bhaic Underbridge

3.1.38 This section of the proposed scheme includes widening of the existing A9 embankment to accommodate a new northbound carriageway, a new access track for non-motorised users (NMU) to Balnastuartach and two SuDS features (G and H) on opposite banks of the Allt Bhaic. The proposed scheme also includes widening of the existing Allt Bhaic Underbridge from 16m to 41m to accommodate a new dual carriageway for northbound traffic. The proposed scheme lengthens the crossing from 11.1m to 20.8m to accommodate the NMU access track, which is routed underneath the mainline along the western bank of the Allt Bhaic.

3.1.39 Diagram 6 helps illustrate the impact of the proposed scheme on peak water levels through this section of floodplain. Table 7 provides actual peak water level impacts within the floodplain.

Diagram 6: Allt Bhaic Underbridge - proposed scheme (no mitigation) peak water level difference

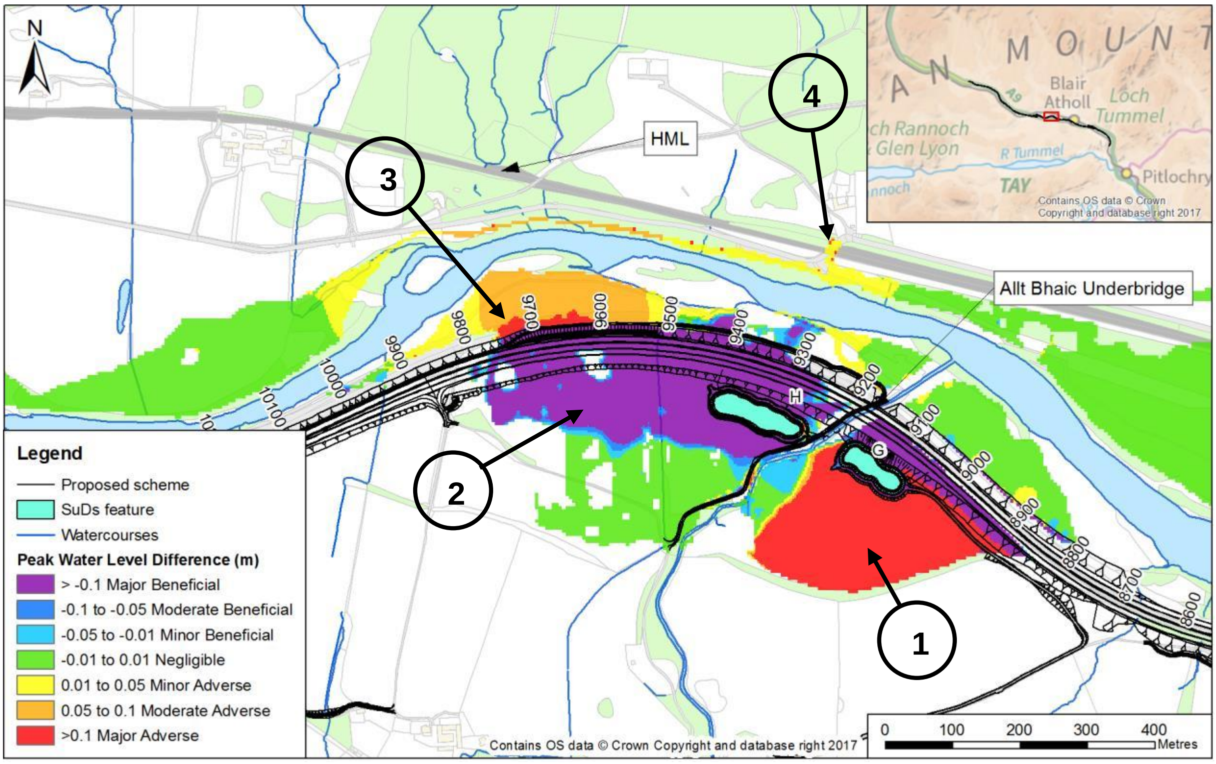


Table 7: Allt Bhaic – peak water level impacts in eastern floodplain

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level – Area 1 (mAOD)	136.162	137.496	137.610	137.686
Proposed Scheme				
Floodplain loss (m^3)	1,300	9,100	10,000	10,900
Peak Water Level Impact – Area 1 (mm)	+116	+354	+543	+507

3.1.40 On the eastern floodplain of the Allt Bhaic, the proposed scheme results in a net loss of floodplain storage of up to approximately 10,900m³. This reduction in floodplain storage is due to the widened mainline embankment and the construction of SuDS feature G and access roads on the floodplain. Consequently, this results in an increase in peak water level of approximately 507mm to mainly agricultural land during the design flood event. Here, floodwater is constrained by the natural topography, with flood depths increasing rather than increasing in extent. Under DMRB guidance, this translates into a large area of major adverse impact to agricultural land as shown in Diagram 6, Area 1.

3.1.41 On the western floodplain of the Allt Bhaic, the proposed scheme results in a net loss of floodplain storage of approximately 20,600m³ during the design flood event. This is due to widening the A9 mainline embankment and the construction of SuDS feature H and access roads on the floodplain. In addition, the proposed scheme includes raising the A9 mainline by approximately 4m above the design flood event water level, which prevents approximately 300,000m³ of floodwater from overtopping it.

3.1.42 Both changes to baseline conditions, results in overall flood depth reduction during the design flood event in the western floodplain of the Allt Bhaic. The prevention of overtopping also contributes to a reduction in the in-channel water levels by 42mm as shown in Diagram 9 and peak flows along the Allt Bhaic from 27.0m³/s to 13.1m³/s as shown in Diagram 10. Under DMRB guidance, this translates into a large area of major beneficial impact to agricultural land and to road users as shown in Diagram 6, Area 2.

3.1.43 Raising the A9 road level results in an increase in peak water levels by approximately 350mm on the northern side of the A9 embankment through the River Garry floodplain as shown in Diagram 6, Area 3. In-channel flows along the River Garry increase from 617.4m³/s to 633.1m³/s as shown in Diagram 8; however, this only results in marginal increase in peak in-channel water levels of approximately 8mm as shown in Diagram 7. Under DMRB guidance, this translates into an area of moderate adverse impact on the floodplain. Table 8 provides actual peak water level impacts to flood sensitive receptors.

Table 8: Allt Bhaic – peak water level impacts at receptors

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level – Area 4 B8079 (mAOD)	-	-	-	137.838
Proposed Scheme				
Peak Water Level Impact – Area 4 B8079 (mm)	-	-	-	**+29**

3.1.44 The B8079 underpass to the Highland Main Line railway floods to a depth of 500mm during the design flood event. As a result of the proposed scheme, flood depths through the underpass increase by 29mm, but the probability of flooding does not change. Whilst the risk of flooding to the underpass is not considered to change, under DMRB guidance, this translates into an area of minor adverse impact to the B8079.

Location 2 – cumulative impacts

3.1.45 The cumulative impact of the proposed scheme downstream has been considered. Diagram 11, Diagram 12 and Table 9 show that the local impacts (raising the road level and the loss of local floodplain storage) do not result in an increase in peak in-channel water levels or flows at the downstream extent of the hydraulic model. The reason for the minimal impact is because during both the baseline and proposed scheme scenarios, floodwater would ultimately end up back in the River Garry, regardless of whether it overtops the A9 and enters the Allt Bhaic (baseline scenario) or is retained within the River Garry floodplain (proposed scheme scenario).

Table 9: River Garry – impact on peak water level and flow at downstream model node

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level (mAOD)	130.77	131.56	132.07	132.30
Peak Flow (m³/s)	232.24	395.34	520.04	579.86
Proposed Scheme				
Peak Water Level Impact (mm)	0	+3	+1	+2
Peak Flow Impact (m³/s)	+0.04	+0.81	+0.29	+0.52

Diagram 7: River Garry stage hydrograph - upstream of confluence with Allt Bhaic

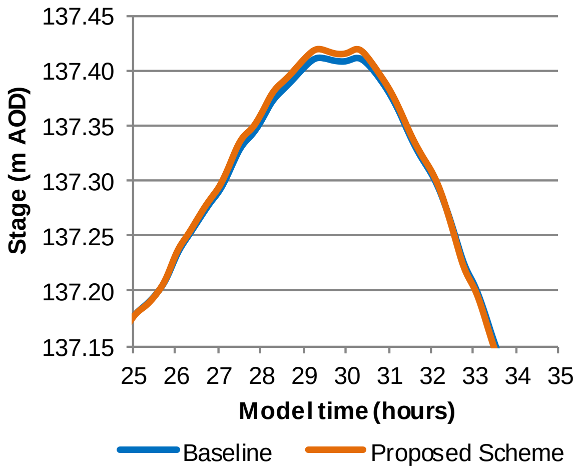


Diagram 8: River Garry flow hydrograph – upstream of confluence with Allt Bhaic

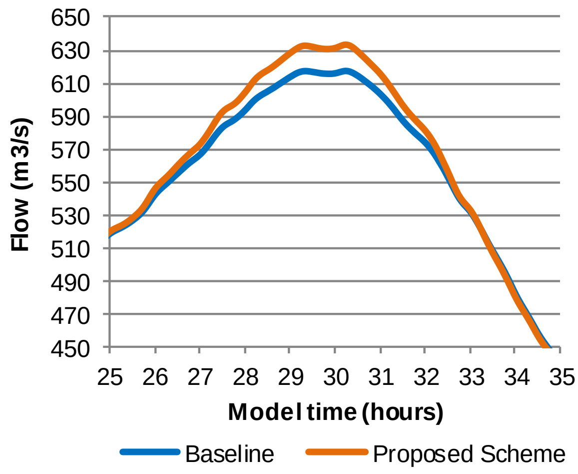


Diagram 9: Allt Bhaic stage hydrograph - upstream of confluence with River Garry

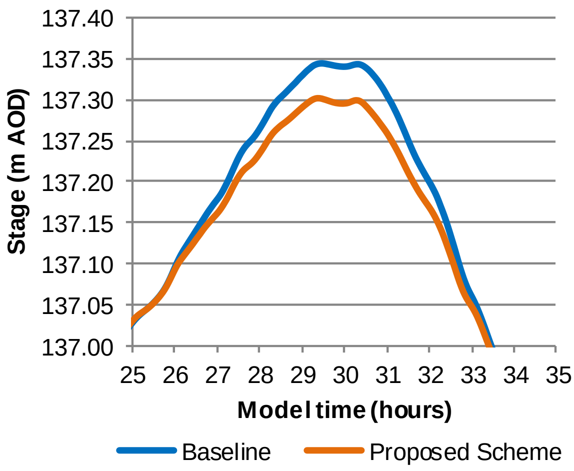


Diagram 10: Allt Bhaic flow hydrograph - upstream of confluence with River Garry

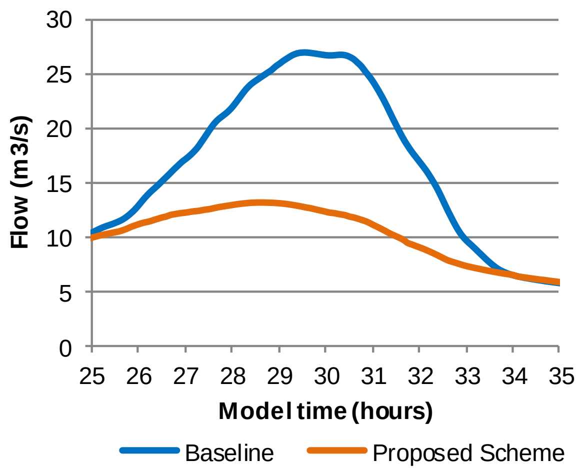


Diagram 11: River Garry stage hydrograph - downstream of confluence with Allt Bhaic

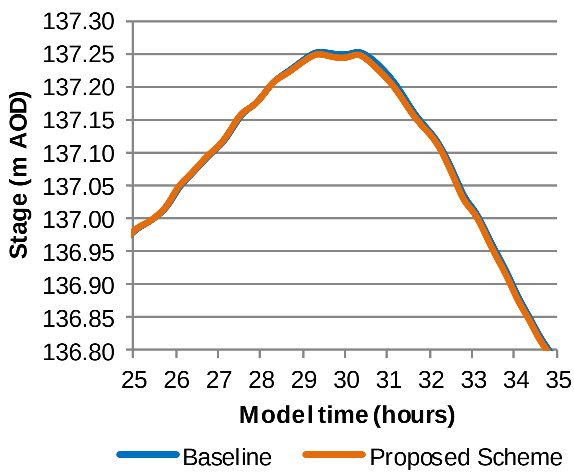
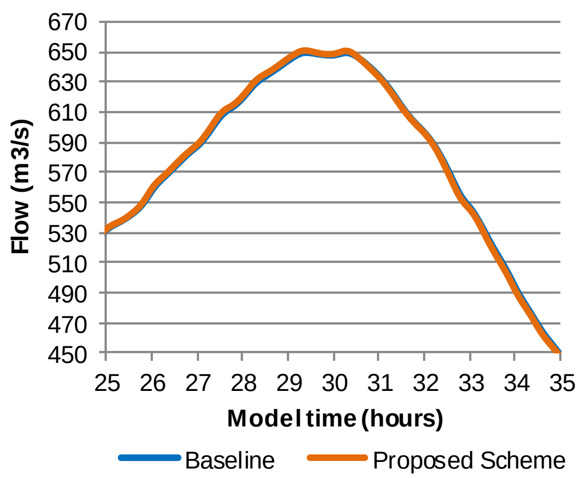


Diagram 12: River Garry flow hydrograph – downstream of confluence with Allt Bhaic



Location 3 – Pitaldonich and River Garry Underbridges

3.1.46 This section of the proposed scheme includes widening of the existing A9 embankment to accommodate the new northbound and southbound carriageway and new bridge crossing approximately 10m upstream of the existing Pitaldonich Underbridge, referred to as the River Garry Underbridge. The proposed scheme retains the existing Pitaldonich Underbridge, which will act as the southbound merge slip road from the new Bruar junction.

3.1.47 The River Garry Underbridge will comprise a new single span bridge structure 78m wide; with a soffit level approximately 2.3m lower than the existing bridge, at 147.7mAOD. One culvert runs along the left bank and one culvert on the right bank to accommodate formalised access tracks.

3.1.48 Diagram 13 helps illustrate the impact of the proposed scheme on peak water levels through this section of floodplain. Table 10 provides actual peak water level changes within the floodplain.

Diagram 13: Pitaldonich and River Garry Underbridges - proposed scheme (no mitigation) peak water level difference

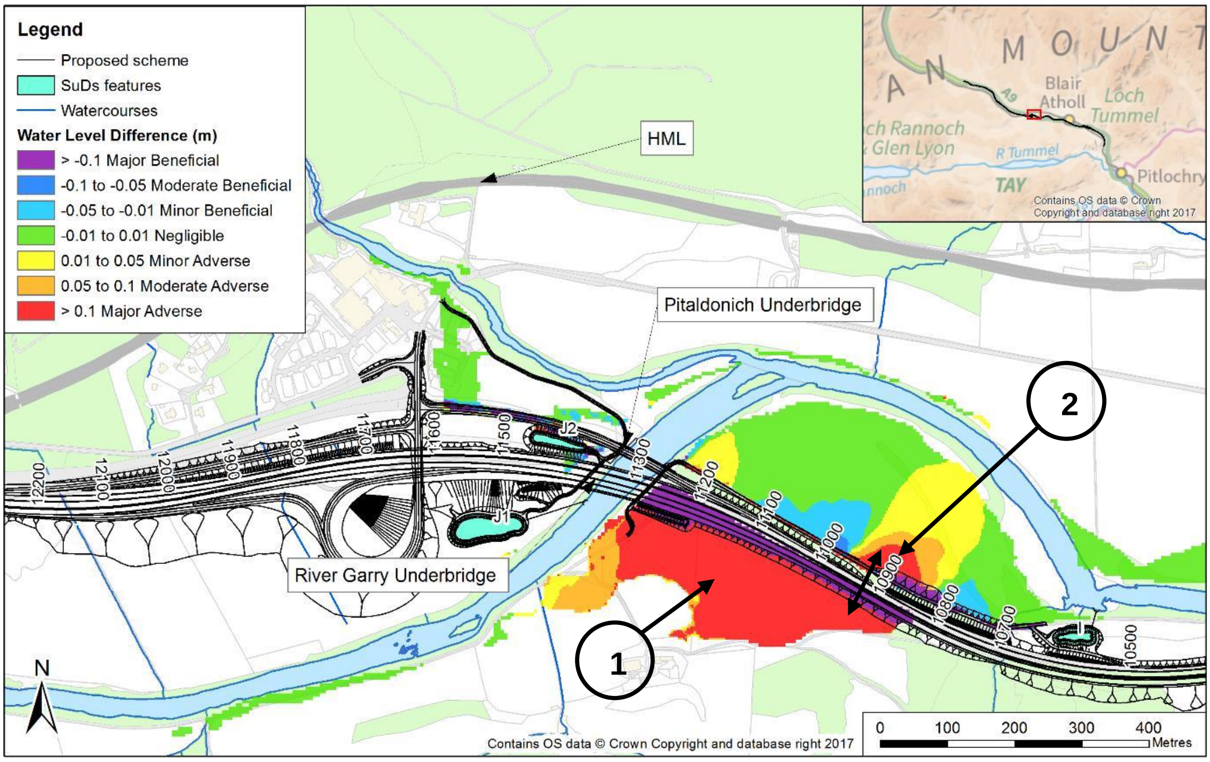


Table 10: River Garry – peak water level impacts in upstream floodplain

	50% AEP (2-year)	3.33% AEP (30-year)	0.5% AEP (200-year)	0.5% AEP (200-year) plus climate change
Baseline				
Peak Water Level – Area 1 (mAOD)	-	146.246	146.825	147.129
Proposed Scheme				
Floodplain loss (m^3)	-	12,100	17,100	20,100
Peak Water Level Impact – Area 1 (mm)	-	-153	+147	+237

3.1.49 Upstream of the River Garry Underbridge, the proposed scheme results in a net loss of floodplain storage of up to approximately 20,100m^3 during the design flood event. This is due to widening the mainline embankment into the floodplain to support the new carriageway towards the new bridge crossing.

3.1.50 During the 3.33% AEP (30-year) event, the modelling results show that the proposed scheme actually reduces peak water levels by approximately 153mm upstream of the bridge crossing. However, during the design flood event, peak water levels increase by approximately 237mm, with depths increasing from approximately 3m in the baseline scenario to 3.24m in the proposed scheme scenario. Downstream of the Pitaldonich Underbridge, the peak in-channel water levels also increase by 10mm, which forces more water to spill onto the downstream floodplain around ch10900. The hydraulic modelling results show that the new bridge structure does not impact flood levels during the design flood event.

3.1.51 Under DMRB guidance, this translates into an area of major adverse impact to agricultural land as shown in Diagram 13, Area 1.

3.1.52 Downstream of the Pitaldonich Underbridge, the proposed scheme includes a new NMU access track junction within the floodplain, which results in a further loss of floodplain storage of approximately 3,100m^3 during the design flood event. The proposed scheme also includes modifications to an existing minor watercourse culvert (WF122) at ch10900. The modifications include lengthening the culvert from 35m to 66m and enlarging the culvert diameter from 380mm to 900mm to accommodate the provision of a mammal ledge as shown in Diagram 13, Area 2.

3.1.53 During the design flood event, peak flow through the culvert increases from 0.3m^3/s in the baseline scenario, to 2.0m^3/s in the proposed scheme scenario. This increase in peak flow is a result of both the change in culvert dimensions and geometry, plus elevated headwater levels at the culvert inlet.

3.1.54 To assess the impacts of the proposed culvert changes on peak water levels downstream of the bridge crossing, an additional hydraulic model scenario was carried out by reducing culvert dimensions back to baseline conditions, but with the proposed scheme topographical changes included. The modelling found that during the design event, the peak water level increases downstream of the River Garry Underbridge are still present and are approximately the same as observed in the baseline scenario. As a result, the change in culvert dimensions is not considered to cause an adverse impact downstream, as the contributing flow through the culvert is proportionally very small compared to the volume of floodplain flow from the River Garry.

Potential Impacts Summary

3.1.55 Hydraulic modelling results show that the proposed scheme has local impacts on flood risk; however, the proposed Essangal Underbridge, Allt Bhaic Underbridge and the River Garry Underbridge crossings have an overall neutral impact on flooding during the design flood event.

3.1.56 Generally, the increase in peak floodplain water levels are a result of floodplain lost due to widening the A9 mainline embankment and the construction of new SuDS features and access roads on the floodplain. The greatest increases are seen on the eastern floodplain of the Allt Bhaic and within the floodplain upstream of the River Garry Underbridge. Here flood depths increase is to mainly agricultural land and River Tay SAC to a range of depths between approximately 200mm and 500mm. Flood extents do not significantly increase due to local topographical constraints.

3.1.57 Flood sensitive receptors that are at risk of flooding during the baseline scenario, such as the Highland Main Line railway, the B8079 and Chestnut Cottage upstream of the Essangal Underbridge remain at risk, with peak water levels increasing by approximately 2-3mm at all locations mentioned during the design flood event.

3.1.58 These local impacts have been shown not to result in a cumulative impact downstream along the River Garry, with downstream modelled reaches showing negligible changes in both peak flows and water levels. The proposed scheme has been shown to have a major beneficial impact to road users, with the mainline being raised above the design flood event. In all sections, a 600mm freeboard has been achieved, apart from a short length (<100m) over which the freeboard is reduced slightly with freeboard levels in the range of 350 to 500mm remaining due to the constraints with the vertical alignment of the road tying into Essangal Underbridge.

Mitigation Measures

3.1.59 The hydraulic modelling results show that (without mitigation) the proposed scheme would locally increase peak water levels along the River Garry and Allt Bhaic. With the aim of achieving a neutral impact, this section considers additional flood mitigation measures.

<u>Longlisted Measures</u>

3.1.60 Based on the detailed understanding of modelled baseline flood risks and potential impacts, a long list of potential mitigation measures has been considered. To identify a shortlist of 'preferable' measures, a multi-criteria analysis approach was adopted to appraise each measure against a range of technical, economic, environmental and health and safety criteria. Annex D (Mitigation Measures – Multi Criteria Analysis) contains the long list of potential mitigation measures considered.

3.1.61 It must be noted that in many cases, the provision of mitigation measures may not always be applicable or achievable when considering the full range of issues relevant to road projects, such as spatial, geological, environmental, ecological, and land ownership constraints. If a neutral impact to flood sensitive receptors cannot be achieved, and a residual impact could remain, justification has been provided for a 'do-nothing' approach within the final scheme design.

<u>Shortlisted Measures</u>

3.1.62 The hydraulic modelling shows that during the design flood event, new floodplain features, including embankments, access roads and SuDS features cause a direct loss of floodplain storage and prevent existing overtopping flow paths and as a result water level increases are observed. Therefore, the shortlisted mitigation measures focus on the provision of flood relief culverts and compensatory flood storage by the direct replacement of lost floodplain volume, or a do-nothing approach if storage is not feasible.

3.1.63 The final shortlist of measures considered, are:

- **Location 1 - Essangal Underbridge**
  - Do-nothing
  - Flood relief culverts
  - Compensatory flood storage upstream of the A9 mainline carriageway
- **Location 2 - Allt Bhaic Underbridge**
  - Do-nothing
  - Flood relief culverts
  - Compensatory flood storage on the eastern floodplain of the Allt Bhaic upstream of the A9 mainline carriageway
- **Location 3 - Pitaldonich and River Garry Underbridges**
  - Do-nothing
  - Compensatory flood storage on the eastern floodplain of the River Garry upstream of Pitaldonich Underbridge

<u>Flood Relief Culverts Considered</u>

3.1.64 The baseline modelling identifies two locations where fluvial floodwater could build up and spill over the existing A9 mainline. This includes a 20m section of road within the western floodplain of the River Garry upstream of the Essangal Underbridge, and a 470m section of the road between the River Garry and Allt Bhaic floodplains upstream of the Allt Bhaic Underbridge.

3.1.65 As part of the proposed scheme, the existing A9 mainline embankment will be raised above the design flood event level, plus 600mm freeboard where achievable. This provides benefits in terms of flood mitigation to the proposed scheme and reduction in floodwater entering agricultural land, downstream of the embankment. This has however been shown to increase peak water levels within the River Garry floodplain upstream of the A9 embankment from between 28mm and 350mm at the two locations.

3.1.66 To mitigate this potential impact, the use of flood relief culverts was initially shortlisted at each location with the aim of reducing the head level of water building up behind the raised A9 embankments as well as mimicking the existing flood flow pathways and reducing adverse impact upstream. This was consequently discounted early on in the design process due to the reasons described below:

- Upstream of the Essangal Underbridge, the existing A9 mainline lies on a 3m raised embankment bisecting the upper and lower western floodplain of the River Garry; as such, overtopping of the A9 only occurs during the 0.5% AEP (200-year) plus climate change event. At this location, the proposed embankment will only be raised by approximately 200mm and it will therefore not be possible to set flood relief culverts at the same level as the existing carriageway level.
- Upstream of the Allt Bhaic Underbridge, the existing A9 mainline lies on a 1.5-2.0m embankment, which runs parallel to the River Garry and bisects the River Garry and Allt Bhaic floodplain into two areas. Floodwater overtops the existing A9 mainline laterally during the 3.33% AEP (30-year) event. In both the baseline scenario and with the proposed scheme, floodwater ultimately ends up at the same location, either by overtopping of the A9 or via the Allt Bhaic channel approximately 600m downstream, or by remaining within the River Garry floodplain. The only difference is the partial loss of storage, which was been shown not to have an impact further downstream along the River Garry. Including flood relief culverts here will therefore provide little benefit overall. The western floodplain of the Allt Bhaic south of the A9 continues to flood directly from the Allt Bhaic albeit to a lesser extent and depth.
- The inclusion of flood relief culverts at floodplain level at the foot of the embankment upstream of the Essangal Underbridge and Allt Bhaic Underbridge was also considered, but would increase the frequency of flooding to agricultural land on the receiving floodplain downstream and would require significant engineering works. There would also be the residual risk of blockages, which could reduce culvert efficiency and increase maintenance requirements.
- In all options, when considering flood relief culverts, the existing rates of overtopping of the A9, particularly at Allt Bhaic Underbridge, would result in high flows through the culverts and therefore spill protection would be required to protect the downstream face of the embankment and to prevent scouring of the receiving floodplain.

Compensatory Flood Storage Considered

3.1.67 In accordance with the guidelines presented in SEPA Technical Guidance, compensatory flood storage should provide ‘like for like’ compensatory flood storage, replacing the lost conveyance capacity/storage volume of the functional floodplain and counteract the displacement of floodwater. In order to achieve this, the location and design of compensatory storage should:

- be close to (hydraulically and hydrologically) the point of lost floodplain;
- provide the same volume; and
- be at the same level relative to the design flood level as that lost.

3.1.68 The volume of compensatory flood storage potentially required was determined by dividing the area of new proposed scheme features within the floodplain into ‘slices’ and the volume of each slice calculated up to the design flood level.

3.1.69 Whilst the SEPA guidance indicates that compensatory storage is required to replace floodplain storage lost up to the 0.5% AEP (200-year) flood level, a precautionary approach has been considered such that additional storage is assessed to include for climate change impacts to align with best practice principles of long-term sustainability. It is also emphasised that it can be more appropriate to consider compensatory flood storage designed around events that are more frequent, to deliver greater flood risk benefits at the onset of flooding. Any compensatory flood storage design focused on lower magnitude events would however be tested for its appropriateness in higher order events.

3.1.70 To determine the technical effectiveness of the compensatory flood storage, following the methodology detailed above, the floodplain topography as represented in the proposed scheme (no mitigation) hydraulic model was modified to create new areas of storage. The findings of the proposed scheme (with mitigation) hydraulic modelling are discussed below.

Location 1 – Essangal Underbridge

3.1.71 Widening the existing A9 embankment and the construction of new SuDS features and access roads in the western floodplain downstream of the Essangal Underbridge, results in a loss of approximately 7,680m^3 of floodplain storage during the design flood event. Whilst it would be expected that this could significantly increase floodplain water levels, by raising the road level, 6,300m^3 of floodwater is prevented from overtopping the mainline into this floodplain area, which results in an overall negligible impact throughout the existing floodplain. Only a small area of flood level increase of approximately 28mm is observed on the northern side of the A9 embankment.

3.1.72 To offset this impact, a significant volume of compensatory flood storage would potentially be required (6,300m^3), which equals the volume of floodwater that overtops the existing A9 mainline in the baseline scenario. Initial investigations show that there are insufficient areas at suitable levels available north of the A9 embankment to provide like-for-like compensatory flood storage. The provision of compensatory flood storage in this location would also require the removal of designated native woodland.

Location 2 - Allt Bhaic Underbridge

3.1.73 Due to the increase in peak water levels on the eastern floodplain of the Allt Bhaic, compensatory flood storage has been considered as a potential flood mitigation measure at this location. Diagram 14 illustrates the location of the proposed compensatory flood storage area, whilst Table 11 contains the volume of storage to be provided across a range of levels (in 500mm ‘slices’). Other locations for the storage area have been considered in Annex C (Mitigation Measures – Multi Criteria Analysis); however, this option was considered the most preferable given the area’s potential to reduce flood levels and the location on the edge of the existing floodplain.

3.1.74 The proposed scheme hydraulic model was used to test the effectiveness of providing compensatory flood storage at this location, such that the same volume of floodplain storage (as a minimum) was provided at the same level lost as shown in Table 11. It should be noted that significant excavation would be required to reach these levels, which would result in major changes to existing landforms and topography.

3.1.75 The hydraulic modelling results shows that the compensatory flood storage area gives partial benefits during the 3.33% AEP (30-year) event, with peak water levels reducing by approximately 100mm on the proposed scheme (no mitigation) levels. However, flood level increases of 360mm remain when compared to the baseline scenario.

3.1.76 During the design flood event, the compensatory flood storage has been shown to provide minor reductions in peak water levels during the first 12 hours of the rising limb of the flood hydrograph along the Allt Bhaic. However, once the design flood event reaches its peak after 14 hours, the compensatory flood storage area does not have a beneficial impact on peak water levels, when compared to the proposed scheme (no mitigation) scenario.

3.1.77 The hydraulic modelling results indicate that the additional storage provided becomes active too early in the flood hydrograph. As a result, the storage area is therefore not effective around the peak of the flood event, when flood levels need to be reduced. Consequently, it is concluded that in its current design configuration, a level-for-level approach to providing compensatory storage in this area, would only be partially effective, but would not achieve a neutral impact during the design flood event.

3.1.78 In order to achieve the benefits required, a flow control structure (such as a high level weir arrangement) would be required, which would prevent the compensatory flood storage area from filling until closer to the peak of the design flood event. A corresponding outflow control would also be required to allow the storage area to drain down once the flood event has receded. This could be considered incompatible with the existing agricultural land use.

Diagram 14: Allt Bhaic - compensatory flood storage location

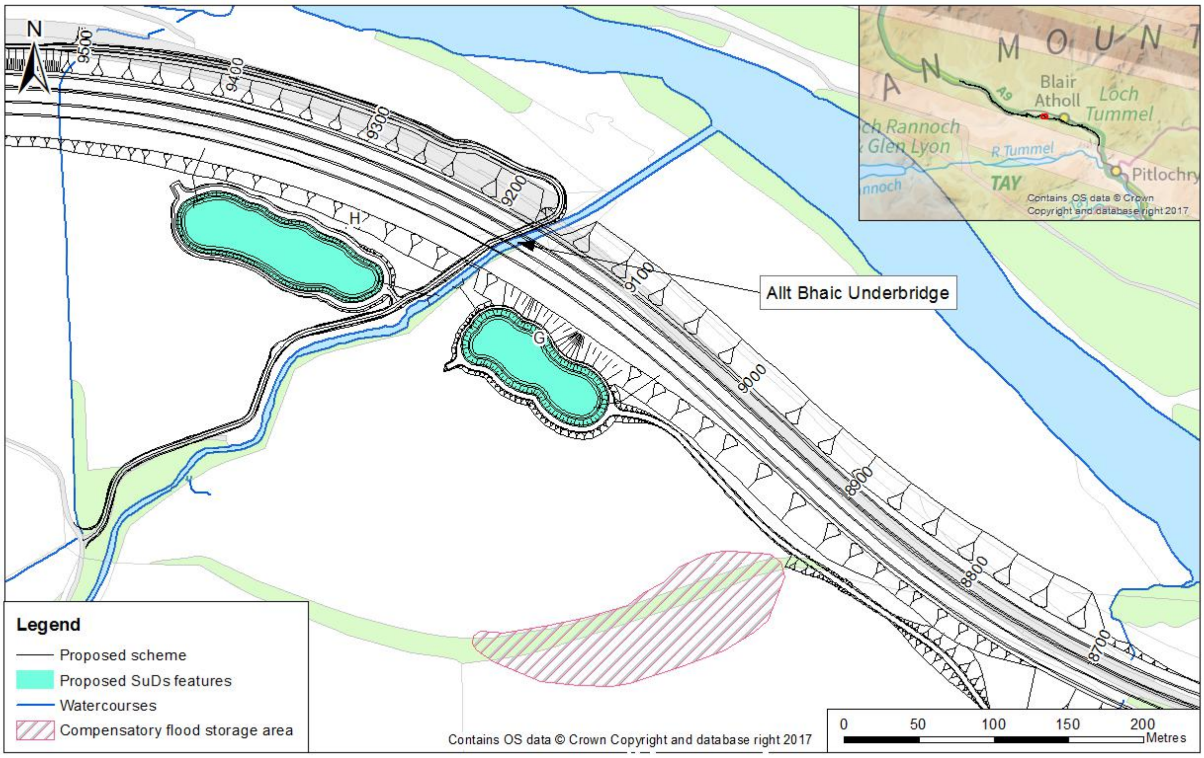


Table 11 : Allt Bhaic - compensatory flood storage volume

Slice (m AOD)		Storage Volume (m^3)
From	To	
135.0	135.5	5
135.5	136.0	662
136.0	136.5	1,640
136.5	137.0	2,888
137.0	137.5	3,919
137.5	138.0	1,747
Total		**10,856**

Location 3 – Pitaldonich and River Garry Underbridges

3.1.79 Due to the increase in peak water levels on the eastern floodplain of the River Garry at Pitaldonich, compensatory flood storage has been considered as a potential flood mitigation measure at this location. Diagram 15 illustrates the location of the proposed compensatory flood storage area, whilst Table 12 contains the volume of storage to be provided across a range of levels (in 500mm 'slices'). Other locations for the storage area have been considered in Annex C (Mitigation Measures – Multi Criteria Analysis); however, this option was considered the most preferable given the area's potential to reduce flood levels and the suitability of the land, both in terms of its location on the edge of the existing floodplain and the low impact on the existing land use (currently grazing farmland).

3.1.80 The proposed scheme hydraulic model was used to test the effectiveness of providing compensatory flood storage in this location, such that the same volume of floodplain storage (as a minimum) was provided at the same level lost as shown in Table 12. Floodplain losses downstream of the Pitaldonich and River Garry Underbridges as shown in Table 13 were not included in the initial testing as the upstream loss was considered to be the main driver in both upstream and downstream peak water level increases.

Diagram 15: Pitaldonich and River Garry Underbridge - compensatory flood storage location

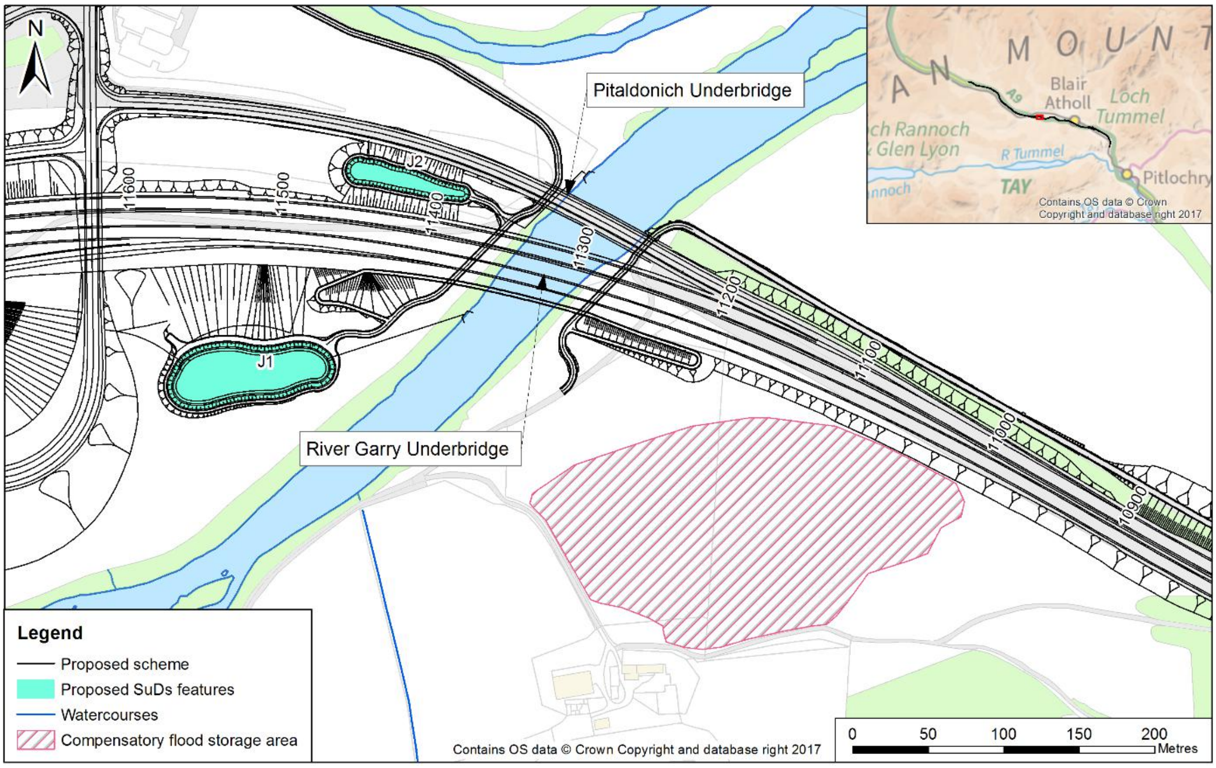


Table 12: Pitaldonich and River Garry Underbridges – upstream compensatory flood storage volume

Slice (m AOD)		Storage Volume (m^3)
From	To	
143.0	143.5	6
143.5	144.0	231
144.0	144.5	1,030
144.5	145.0	2,007
145.0	145.5	2,657
145.5	146.0	3,399
146.0	146.5	4,799
146.5	147.0	4,995
147.0	147.5	998
	Total	**20,116**

Table 13: Pitaldonich and River Garry Underbridges – downstream compensatory flood storage volume

Slice (m AOD)		Storage Volume (m3)
From	To	
141.5	142.0	24
142.0	142.5	130
142.5	143.0	357
143.0	143.5	527
143.5	144.0	1,255
144.0	144.5	765
144.5	145.0	14
145.0	145.5	10
145.5	146.0	26
Total		**3,108**

3.1.81 The hydraulic modelling results show the compensatory flood storage area to have partial benefits during the 3.33% AEP (30-year) event, with peak water levels reducing by approximately 40mm below the baseline flood levels. During the design flood event, the compensatory storage area has been shown to provide minor reductions in peak water levels during the first two hours in which this area floods. Following this, peak water levels actually exceed the equivalent baseline water level, further increasing peak water levels above the proposed scheme (no mitigation) scenario.

3.1.82 Similar to the effects of the compensatory storage area in the Allt Bhaic floodplain, this storage area would also become active too early in the flood hydrograph. Consequently, the storage area is not effective around the peak of the flood event, when flood levels need to be reduced.

3.1.83 It is therefore concluded that in its current design configuration, a level-for-level approach to providing compensatory storage in this area would only be partially effective, but would not achieve a neutral impact during the design flood event. Similar to the Allt Bhaic floodplain, in order to reduce peak flood levels to baseline levels, a flow control structure is likely to be required to regulate when the storage area begins to fill.

Preferred Mitigation Option

3.1.84 In all locations along the River Garry and Allt Bhaic impacted by the proposed scheme, the do-nothing approach for compensatory flood storage is considered the preferred option because:

- existing flood risk areas are restricted to natural floodplain currently used as agricultural land (grazing and forage production) and consequently the impact due to flooding is considered to be low;
- allowing areas of the land to continue to flood, albeit to a greater depth and possibly with greater frequency, would not adversely impact farm operations on the agricultural land as the land would be available for agricultural use post-scheme by the landowners and their tenants (refer to Chapter 8: People and Communities – Community and Private Assets);
- areas of land, such as the western floodplain of the Allt Bhaic and the floodplain near Pitaldonich, would see a reduction in flood risk; and
- during the design flood event, there remains sufficient freeboard between the peak floodplain water level and the proposed scheme mainline.

3.1.85 Discussion with the landowner has taken place and there is an agreement in principle to the predicted impacts to their land. Discussion with the tenants is proposed. In addition, the area of land subject to an increase in flood levels during the design flood event would be included in the Compulsory Purchase Order. The land would be returned to the landowner with appropriate burdens restricting development and protecting the area for flood storage. The land would therefore be available for agricultural use (grazing and forage production) by the landowner and their tenants post-scheme.

Residual Risks

3.1.86 With the preferred mitigation option in place, flood risks will remain unchanged from the proposed scheme (no mitigation) scenario (see flood extents and depths shown within Figures A11.3.3a-c contained in Annex E: Flood Risk Assessment Figures). The proposed scheme will remain free from flooding during the design flood event. A residual risk would remain during extreme flood events beyond this design standard, which could place the proposed scheme at risk of flooding.

3.1.87 Where possible the proposed scheme mainline level has been set above the design flood event, plus 600mm freeboard, thereby allowing for flood events in excess of the design flood event and reducing these residual risks. Over the length of the proposed scheme there is a short length (<100m) over which the freeboard is reduced slightly with between 350 and 500mm of freeboard remaining due to the constraints with the vertical alignment of the road tying into Essangal Underbridge. Possible adaptation measures over this short length may be required in future if it is demonstrated in the coming decades that climate change impacts are more significant than currently projected.

4 Minor Watercourses

Introduction

4.1.1 Between Killiecrankie and Glen Garry, there are 55 minor watercourses, which the existing A9 crosses. They are typically smaller unnamed streams, confined to narrow, often deep channels with relatively small catchment areas (<0.5km²). The majority of these minor watercourses pass through agricultural land and flow underneath the existing A9 through circular culverts ranging in diameter between 400mm and 1.2m. During the design flood event, the peak flow estimates for these watercourses range from $0.08m^3/s$ to $4.42m^3/s$.

4.1.2 The risk of flooding from these watercourses is generally low, as they typically flow through rural areas away from flood sensitive receptors. The greatest risks are usually associated with the watercourse crossings, especially in those cases where the existing capacity of the culvert impedes flood flow and where there is limited upstream flood storage. This could place neighbouring receptors (including the existing A9) at risk of more significant flooding.

4.1.3 The proposed scheme would include modifications to existing watercourse crossings where the mainline embankments would be widened to accommodate the dual carriageway. The proposed scheme would also include new watercourse crossings where localised offline alignment of the mainline is required and where new access road and access tracks are proposed.

4.1.4 It is generally considered that the proposed scheme would have a negligible impact on flooding at these watercourse crossings, and in fact could have a beneficial impact where culverts are to be replaced based on DMRB design criteria to pass the design flood event. However, there is potential for the proposed scheme to have adverse impacts as a result of loss of floodplain, or an increase in pass forward flow by enlarged culverts.

<u>Assessment Approach</u>

4.1.5 Annex E (Flood Risk Assessment Figures) presents figures that illustrate the location of minor watercourses and the location of existing A9 watercourse crossings (e.g. bridge, culvert, pipe etc.). Each watercourse has been given a unique water feature reference number (e.g. WF117) as many of the watercourses are unnamed.

4.1.6 The SEPA Flood Map does not often include these watercourses as their drainage catchments areas are less than 3km². Whilst it might be possible to infer their flood flow paths and extent using the SEPA Surface Water Map, there is a lack of baseline information available to assess the risk of flooding from these watercourses and structures in the level of detail suitable for this FRA. This FRA has therefore adopted a staged approach to the assessment of flood risk, which develops in detail focusing on the higher risk minor watercourses.

4.1.7 Firstly, the FEH Statistical method for ungauged catchments and the FEH Rainfall-Runoff method was adopted to estimate the peak design flow for each minor watercourse, with the design flow adopted the highest value predicted by the two methods. Appendix A11.2 (Surface Water Hydrology) provides further details of the hydrological approach and results.

4.1.8 Secondly, following the methodology presented in CIRIA's Culvert Design and Operation Guide (CIRIA, 2010), a preliminary assessment was adopted for each of the watercourse crossing structures, the aim of which is to assess for both the baseline and the proposed scheme scenario the:

- flow condition of the existing watercourse crossing structures (i.e. free-flow or surcharged); and
- upstream headwater level (HWL) required to pass the steady-state design flow through the structure.

4.1.9 At this stage, the preliminary assessment assumed the structure would simply be extended to accommodate the mainline of the proposed scheme. Whilst the CIRIA approach is likely to estimate a conservative upstream HWL (e.g. it does not take into account flood hydrograph shape, flood volume, local topography and attenuation provided by adjacent floodplain), by comparing results, it does provide a useful initial tool in which to assess existing flood risks and the potential flood impacts of the proposed scheme.

4.1.10 Once the preliminary assessment was complete, its findings, along with a wide range of design criteria and environmental and ecological constraints were used to inform the initial design of the watercourse crossing including the like-for-like extension or replacement of the structure.

4.1.11 Where the preliminary assessment suggested a low risk of flooding, or low impact, that watercourse crossing was not considered for further detailed hydraulic analysis, as the approach is sufficiently robust so as not to require a more detailed assessment.

4.1.12 Where the preliminary assessment suggested that the initial design could have an adverse flood impact, either by increasing upstream HWL or by passing additional flow downstream, the hydraulic analysis of these watercourse crossings has been considered in further detail. This has included further GIS analysis or hydraulic modelling to better define baseline flood risks and potential impacts.

4.1.13 The findings of the detailed assessment were then used to refine the final design of the watercourse crossing and to assess additional mitigation measures if required.

Preliminary Assessment

4.1.14 Annex D (Hydraulic Performance Assessment) contains the complete results of the preliminary assessment. The subsections below provide an overview of the preliminary assessment, which provides the basis for informing whether a more detailed hydraulic assessment is required.

Baseline Hydraulic Performance – Mainline

4.1.15 Table 14 provides an overview of the baseline assessment, when tested against the design flood event.

Table 14: Baseline hydraulic performance – mainline

Minor Watercourse Crossing	Total	Culvert Free Flow	Culvert Surcharged		
			HWL < Bank Level	HWL > Bank Level	Road at risk**
Mainline	54*	32	5	17	16

*WF178 was not included in the baseline assessment as it was found to be buried and no assessment could be made

**Road at risk when out of bank flow is predicted and the HWL exceeds or is within 600mm of the road level

4.1.16 The assessment confirms approximately 60% of the existing A9 mainline watercourse crossings have adequate capacity albeit with limited culvert freeboard. Approximately 30% of the crossings are under capacity and may pose a potential risk of flooding to the existing A9.

4.1.17 These under capacity crossings are distributed relatively evenly along the existing A9, although notable clusters are found between Blair Atholl and Bruar and within Calvine. Whilst the derived upstream HWL is a conservative estimate, due to local topography (which in many locations slopes down towards the existing A9), any out of bank flow originating from the culvert inlet could potentially place the existing A9 at risk of flooding.

Proposed Scheme Hydraulic Performance – Mainline

4.1.18 From a flood management perspective, the aim was to retain the flow regime of the existing culvert to maintain the balance between local flood risk and the flood risk to downstream receptors. For that reason, like-for-like culvert extension or replacement was the preferred option for the proposed scheme. However, this was not always applicable or achievable due to a range of wider environmental and road design considerations.

4.1.19 Taking these into account, the proposed scheme includes:

- six like-for-like culvert extensions (i.e. same dimensions and gradient);
- 47 replaced culverts design under DMRB, of which 17 retained existing dimensions; and

- one culvert crossing removed with the watercourse diverted to an adjacent watercourse.

Change in Hydraulic Performance

4.1.20 As outlined in Section 2.2 (The Proposed Scheme), all replaced or new A9 crossings are designed in the first instance to freely pass (i.e. without surcharging) the peak flow during the 1% AEP (100-year) event plus appropriate culvert freeboard. All new access track crossings are designed to freely pass the peak flow during the 2% AEP (50-year) event plus appropriate culvert freeboard.

4.1.21 To assess the potential impacts on flooding, the hydraulic performance of each crossing was tested against the design flood event. Table 15 provides an overview of the proposed scheme assessment.

Table 15: Proposed scheme hydraulic performance – mainline

Minor Watercourse Crossing	Total	Culvert Free Flow	Culvert Surcharged		
			HWL < Bank Level	HWL > Bank Level	Road at risk*
Mainline	53**	51	0	2	1
*Road at risk when out of bank flow is predicted and the HWL exceeds or is within 600mm of the road level **One watercourse is being diverted and the existing watercourse crossing removed					

4.1.22 The impacts of the proposed scheme on flooding are complex with many locations experiencing different impacts upstream compared to those downstream. As can be seen in Table 17, the impact of the proposed scheme upstream is generally beneficial, with the replacement (and enlargement) of undersized culverts now showing free flow conditions in 51 of 53 modified culverts during the design flood event, when compared to 33 out of 54 during the baseline scenario.

4.1.23 However, based on the preliminary assessment, two watercourse crossings (WF96 and WF117) are predicted to remain surcharged. Whilst there is 5.3m of freeboard available between the HWL at WF96 and the proposed scheme mainline, it is unclear from the preliminary assessment if there is a risk present. The HWL at WF117 is estimated to be above the road level and therefore could place the proposed scheme at risk of overtopping. Both of these watercourses therefore require a more detailed hydraulic assessment.

Change in HWL

4.1.24 Although the proposed scheme reduces the risk of flooding to the A9, 28 of the 53 watercourse crossings see an increase in upstream HWL. Table 16 summarises the impacts of the proposed scheme on upstream HWL, when each watercourse crossing was tested against the design flood event. These 28 watercourse crossings will therefore require more detailed hydraulic assessment.

Table 16: Impacts of the proposed scheme mainline on upstream HWLs

Potential flood impact		Change in upstream HWL	Number of Watercourse crossings
	Major adverse	Increase in HWL > 100mm	15
	Moderate adverse	Increase in HWL >50mm	5
	Minor adverse	Increase in HWL >10mm	8
	Negligible	Negligible change in HWL <+/- 10mm	2
	Minor beneficial	Reduction in HWL >10 mm	2
	Moderate beneficial	Reduction in HWL >50mm	2
	Major beneficial	Reduction in peak flood level > 100mm	19

Change in Pass Forward Flow

4.1.25 Downstream of the watercourse crossings, the proposed scheme has the potential to increase flood flows as a result of enlarging an existing crossing, which may have been holding flows back during the baseline scenario.

4.1.26 The preliminary assessment identifies 21 watercourse crossings where peak flow may increase downstream when compared to the baseline scenario (i.e. the culvert now conveys the design flood event). However, in all but eight of the watercourses, no downstream flood sensitive receptors were identified and therefore the impact of the proposed scheme is considered low. However, all 21 of these watercourse crossings have been examined through more detailed hydraulic assessments.

Proposed Scheme Hydraulic Performance – Access Roads

4.1.27 There are 25 proposed access road watercourse crossings of minor watercourses. Eleven crossings are located directly adjacent to the proposed A9 mainline and therefore the mainline culvert would be extended beneath the access road. Apart from the WF178 crossing, the remaining 14 access road and junction watercourse crossings are new formal structures and are designed under DMRB to freely pass the 2% (50-year) event plus appropriate culvert freeboard.

4.1.28 When tested against the design flood event, the preliminary assessment identifies 13 of the 15 culverts would also experience free flow conditions albeit with reduced culvert freeboard, as summarised in Table 17. Only two watercourse crossings, both of which are over WF103, have the potential to surcharge during this design flood event. However, the resulting upstream HWL is shown to remain in bank.

Table 17 : Proposed scheme hydraulic performance – access roads

Minor Watercourse Crossing	Total	Culvert Free Flow	Culvert Surcharged		
			HWL < Bank Level	HWL > Bank Level	Road at risk*
Access Tracks	14	12	2	0	0
*Road at risk when out of bank flow is predicted and the HWL exceeds or is within 600mm of the road level					

4.1.29 The risk of flooding from these watercourse crossings is therefore low and the proposed scheme is shown to have a negligible flood impact. This FRA does not consider these access track watercourse crossings further, but they are reported in Annex D (Hydraulic Performance Assessment).

Detailed Assessment

Adverse Impacts on Upstream Flooding

4.1.30 Table 18 provides an overview of the 30 watercourse crossings where the preliminary assessment identifies a potential increase (>10mm) in upstream HWL and the remaining freeboard to the proposed scheme carriageway level.

4.1.31 At 22 of the 30 crossings, the preliminary assessment estimates that the peak flow would remain in bank and the crossing would be in free flow conditions. There is also greater than 600mm freeboard available between the HWL and the proposed scheme mainline level. Whilst there is an adverse impact predicted on HWL at these watercourse crossings, the impact of this on flood risk is low, and no further mitigation is recommended.

4.1.32 At four of the 30 watercourse crossings (WF102, WF104, WF141, and WF153), the preliminary assessment estimates a freeboard between the upstream HWL and the proposed scheme mainline level of less than 600mm. At WF102 and WF141, the lack of freeboard is a direct result of the culvert inlet being located above the level of the proposed scheme mainline. Both these watercourse crossings are in free flow conditions during the design flood event, and the risk of flooding to the proposed scheme is low. At WF104 and WF153, the freeboard is only marginally below the 600mm requirement, and due to the simplified approach adopted, the HWL is likely to be a conservative estimate. At these locations, the impact on flood risk is low and no further mitigation is recommended.

4.1.33 At two of the 28 crossings (WF87 and WF117), the preliminary assessment estimates the watercourse crossing would surcharge during the design flood event and the resulting HWL could place the proposed scheme mainline at risk of overtopping. WF87 is not considered to pose a risk to the A9 due to the significant freeboard to the A9 but residential properties are located upstream of the crossing, which could be affected by the increase in flood level. A further crossing (WF96), which surcharges during the design flood event, would affect an existing A9 underpass, although the A9 is unaffected. These three crossings are discussed further below.

Table 18: Minor watercourses - adverse impacts on upstream HWL

Water Feature	Baseline HWL (mAOD)	Proposed Scheme Impact on HWL (mm)	Flood Impact	Remaining Freeboard to Proposed Scheme Mainline Level (m)
WF87	155.55	+454	Major adverse	8.53
WF95	162.25	+321	Major adverse	3.81
WF96	160.23	-1	Negligible	5.30
WF101	128.78	+38	Minor adverse	1.58
WF102	142.68	+190	Major adverse	-1.47 (inlet above road level)
WF103	141.46	+216	Major adverse	2.25
WF104	143.25	+442	Major adverse	0.56
WF105	143.11	+58	Moderate adverse	1.28
WF106	146.36	+203	Major adverse	1.18
WF107	145.76	+966	Major adverse	1.21
WF117	147.66	-3.49	Major beneficial	-0.64
WF118	141.26	+179	Major adverse	1.98
WF119	145.25	+26	Minor adverse	1.41
WF134	203.44	+17	Minor adverse	-6.17
WF137	210.52	+241	Major adverse	2.24
WF139	210.62	+381	Major adverse	1.31
WF141	208.76	+62	Moderate adverse	-13.43 (inlet above road level)
WF143	213.33	+11	Minor adverse	0.77
WF144	225.68	+173	Major adverse	1.17
WF147	234.59	+59	Moderate adverse	1.18
WF148	237.74	+138	Major adverse	0.79
WF151	248.64	+34	Minor adverse	10.20
WF152	260.97	+350	Major adverse	1.15
WF153	263.24	+33	Minor adverse	0.52
WF155	263.98	+284	Major adverse	1.61
WF157	258.92	+53	Moderate adverse	2.99
WF159	266.40	+245	Major adverse	3.38
WF160	267.17	+28	Minor adverse	1.13
WF162	267.56	+82	Moderate adverse	1.12
WF163	278.20	+11	Minor adverse	2.29

WF87

4.1.34 WF87 (Troopers Burn), flows through Old Faskally Farm prior to passing beneath the existing A9. It has a catchment area of 1.27km² comprising the south-western slope of Meall an Daimh, which generates a peak flow of 4.42m³/s during the design flood event. The existing crossing is a large 2.5m high x 3.96m wide box culvert.

4.1.35 The baseline preliminary assessment estimated the maximum capacity of culvert to be 16.17m³/s and as a result, the crossing would experience free flowing conditions. There is also 8.98m of freeboard between the peak HWL and the mainline level. To accommodate the widening of the mainline, the culvert would be extended 24m downstream as part of the proposed scheme. The culvert would remain free flowing, but the predicted HWL is predicted to increase by approximately 450mm. Although, this would not place the A9 at risk of overtopping, there are a number of residential properties 100m upstream of the crossing, which could be at greater risk of flooding.

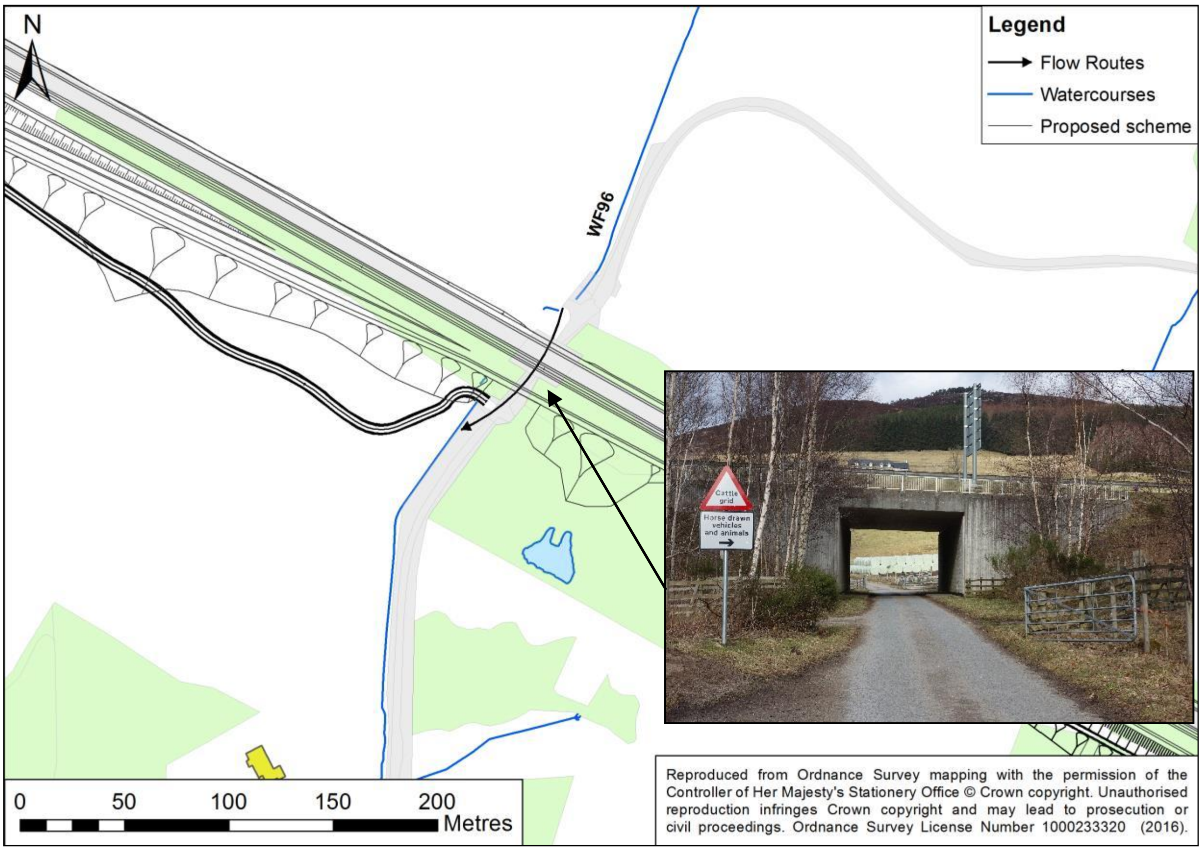
4.1.36 To assess flooding mechanisms in detail, additional 1D hydraulic modelling was undertaken using Flood Modeller Software. The detailed modelling found that the upstream water levels would be reduced by 3mm as a result of proposed scheme, with a negligible increase immediately downstream of the culvert outlet of approximately 8mm. However, given that free flow conditions will remain in the culvert and no additional flow will be passed forward, levels would remain unchanged downstream where WF87 crosses the B8079 and the Highland Main Line railway. The impact of the proposed scheme is therefore considered to be negligible, with no increase in flood risk to the A9 or residential properties and no further mitigation measures are recommended.

WF96

4.1.37 WF96 rises immediately north east of the Mains of Orchil and flows through the Killiecrankie Battlefield site. The 0.27km^2 catchment comprises mainly rough grazing and generates a peak flow of 0.82m^3/s during design flood event. It passes beneath the existing A9 via a 0.65m diameter pipe culvert.

4.1.38 The preliminary assessment indicates that the culvert beneath the existing A9 would surcharge during the design flood event, with out of bank flooding flows predicted to pass beneath the existing A9 via an underpass prior to re-entering the channel downstream (Diagram 16).

Diagram 16: WF96 - predicted flood flow routes



4.1.39 The proposed scheme includes the retention of the existing culvert without the need to extend it to accommodate widening the A9 mainline. The preliminary assessment indicates that although the culvert would surcharge during the design flood event, with floodwater passing through the underpass, it would not put the A9 at risk. As a result, the proposed scheme has negligible impact of flooding and the baseline flood mechanisms would remain unchanged.

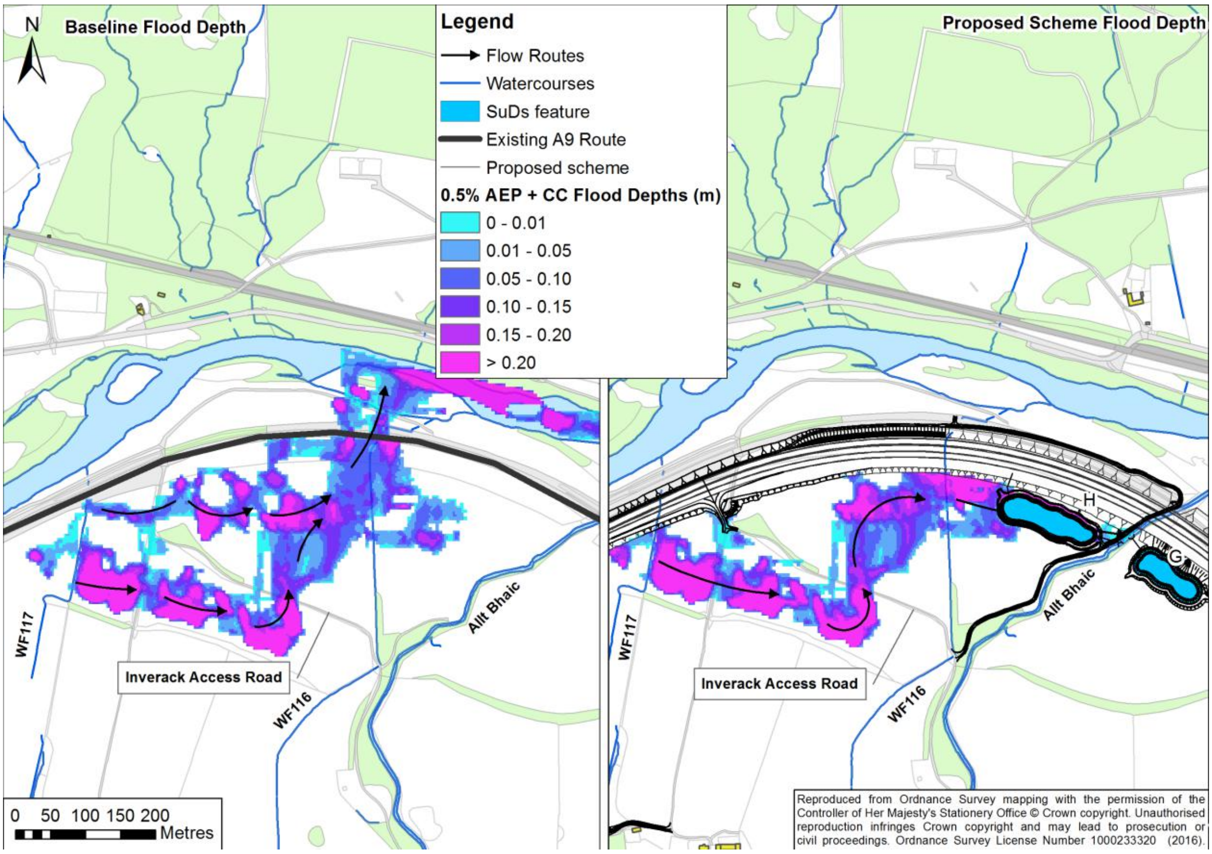
WF117

4.1.40 WF117 is a drainage channel that runs through fields located in the western floodplain of the Allt Bhaic. It has a catchment area of 0.74km^2 and during the design flood event it is estimated to have a peak flow of 2.52m^3/s. It flows under the existing A9 via a 600mm diameter pipe culvert.

4.1.41 To accommodate the northbound widening of the mainline, the culvert would be replaced and extended (but the existing diameter retained due to drainage and proposed mainline level clashes). The preliminary assessment estimates that the proposed scheme would reduce upstream HWL, but the resulting levels would still pose a risk of overtopping to the proposed scheme. To assess flood risks in further detail, additional 1D-2D hydraulic modelling was undertaken.

4.1.42 During the design flood event, the baseline hydraulic modelling confirms WF117 would spill out of its extremely low eastern bank at two locations upstream of the existing A9, with floodwater flowing in an easterly direction. The flows would overtop the Inverack access road and passes through agricultural land towards WF116 to the east (Diagram 17). The depth of floodwater within the floodplain could reach approximately 200mm, with velocities of less than 0.5m/s. The Inverack access road is predicted to flood to a depth of approximately 156mm. Once floodwater reaches WF116, it is likely to interact with flood flow originating along WF116 and the Allt Bhaic. Here, there is a risk that floodwater could overtop the existing A9 mainline as predicted by the hydraulic modelling of WF117 and the Allt Bhaic in Section 3.2 (Baseline Risks).

Diagram 17: WF117 – peak flood depths



4.1.43 With the proposed scheme in place, the hydraulic modelling shows that WF117 would still result in out of bank flooding; however, the widening of the mainline and provision of the access track prevents the flow path closer to the A9 from occurring. As a result, flood depths along the access track increase by approximately 15mm. Flood risk remains low indicating that the route to the properties at Inverack and Balnastuartach remains passable by vehicles. The proposed scheme has also raised the mainline level along this section, preventing the A9 from overtopping providing major beneficial impacts. Floodwater from WF117 now remains within the floodplain until it reaches the Allt Bhaic.

4.1.44 Whilst the proposed scheme marginally changes overland flow paths through the floodplain between WF117 and the Allt Bhaic, overall it results in major beneficial flood impact as the A9 is no longer at risk of flooding, with approximately 1m freeboard remaining. No further mitigation measures are recommended.

Adverse Impacts on Downstream Flooding

4.1.45 The preliminary assessment has identified 23 watercourse crossings where the proposed scheme has a potential adverse impact on downstream flooding. On further inspection, at 15 of the 23 watercourse crossings there are no flood sensitive receptors located downstream of the A9 mainline crossing. Therefore, even though additional flow may be passed forward, the impact of this on downstream flooding is considered low and these have not been considered further. There are however several watercourse crossings with flood sensitive receptors (e.g. properties and existing infrastructure crossings) downstream that could be impacted by an increase in flow. These have been assessed in further detail below.

WF92

4.1.46 WF92 is located approximately 500m west of Killiecrankie. It is a small watercourse with a peak design flood event flow of $3.62m^3/s$. Upstream of the A9, the catchment of $0.7km^2$ comprises mainly rough pasture and woodland. Two other minor watercourses (WF91 and WF93) discharge into WF92 via existing pre-earthworks drainage. Downstream of the A9, the watercourse flows for approximately 500m through woodland and pastoral farmland before flowing underneath the B8079 and the Highland Main Line railway and discharging into the River Garry.

4.1.47 The preliminary assessment estimated that the 900mm diameter culvert underneath the existing A9 has an approximate capacity of $1m^3/s$, which equates to a flood event with frequency between the 50% AEP (2-year) and 20% AEP (5-year), when combining peak flows from WF 91, 92 and 93. As part of the proposed scheme, the A9 culvert would be replaced with a larger 1.8m diameter culvert based on the culvert design criteria. This may consequently impact the existing hydraulic regime and flood risk to flood sensitive receptors.

4.1.48 A hydraulic model of WF92 was therefore developed to confirm baseline risks and assess potential impacts of the proposed scheme. The model represents the watercourse and floodplain in 2D, with the terrain model based on a combination of topographical survey of the existing A9 culvert and channel, and LiDAR data representing the floodplain. The culvert beneath the B8079 and railway could not be surveyed due to restrictions in land access, therefore a 600mm diameter circular culvert has been assumed based upon site observations. Downstream of the existing A9, detailed topographic survey data is limited. However, sensitivity testing undertaken shows that the modelled flood depths and extents are not responsive to major changes to this uncertainty (including increasing channel width and depth by 50% and increasing the B8079 culvert by 50%).

4.1.49 During the baseline scenario, the hydraulic model confirms that the existing A9 culvert surcharges during the 3.33% AEP (30-year) event, which results in a small area of ponding upstream of the existing A9 embankment. During the design flood event, the peak pass forward flow downstream is $2.09m^3/s$, whereas $1.17m^3/s$ spills from the channel upstream of the culvert entrance and travels overland in an easterly direction along the edge of the existing A9 embankment, as shown in Diagram 18. 500m to the east of WF92, the overland flow path overtops the existing A9 and continues south west through woodland surrounding Druimuan (a residential property at Inspection Point 4, Diagram 18). At this location the flow path is wide and shallow (<100mm during the design flood event). Once floodwater reaches the B8079, it is intercepted and conveyed south-east along the B8079 carriageway before overtopping the Highland Main Line railway and entering the River Garry.

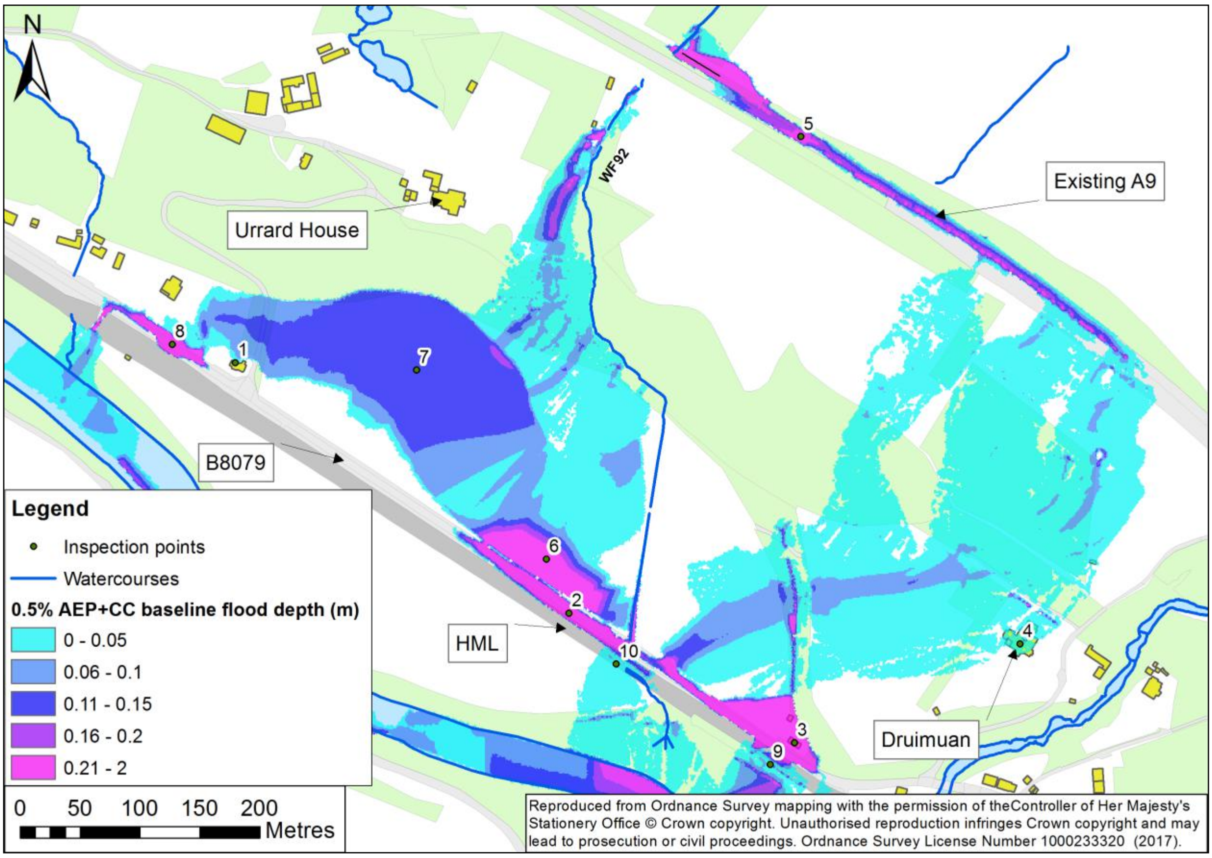
4.1.50 Along this flow path to the River Garry, two properties are at risk of shallow flooding including a residential property at Druimuan as shown at Inspection Point 4, Diagram 18 and a residential property on the B8079 (Inspection Point 3, Diagram 18).

4.1.51 Downstream of the A9, the topography is initially relatively steep falling towards the south before flattening out significantly immediately upstream of the B8079 road, HML railway and River Garry. Modelling of the downstream channel indicates that floodwater would also spill out of channel at a number of locations inundating a large proportion of the floodplain north of the B9079. A third flow path is also formed on the western edge of the floodplain during the 3.33% AEP (30-year) event, conveying 0.3m^3/s over an access road to Urrard House and onto the B8079 before passing beneath the Highland Main Line railway via an underpass. During the 1% AEP (100-year) event, this flow path would result in shallow flooding (<10mm) to a residential property at Inspection Point 1, Diagram 18.

4.1.52 Any remaining flood flow reaching the B8079 would surcharge the culvert during the 3.33% AEP (30-year) event, and overtop this road to a depth in excess of 300mm during all flood events modelled, which would result in the road becoming impassable to vehicles.

4.1.53 Diagram 18 illustrates maximum flood depth during the baseline design flood event.

Diagram 18: WF92 - baseline flood depths



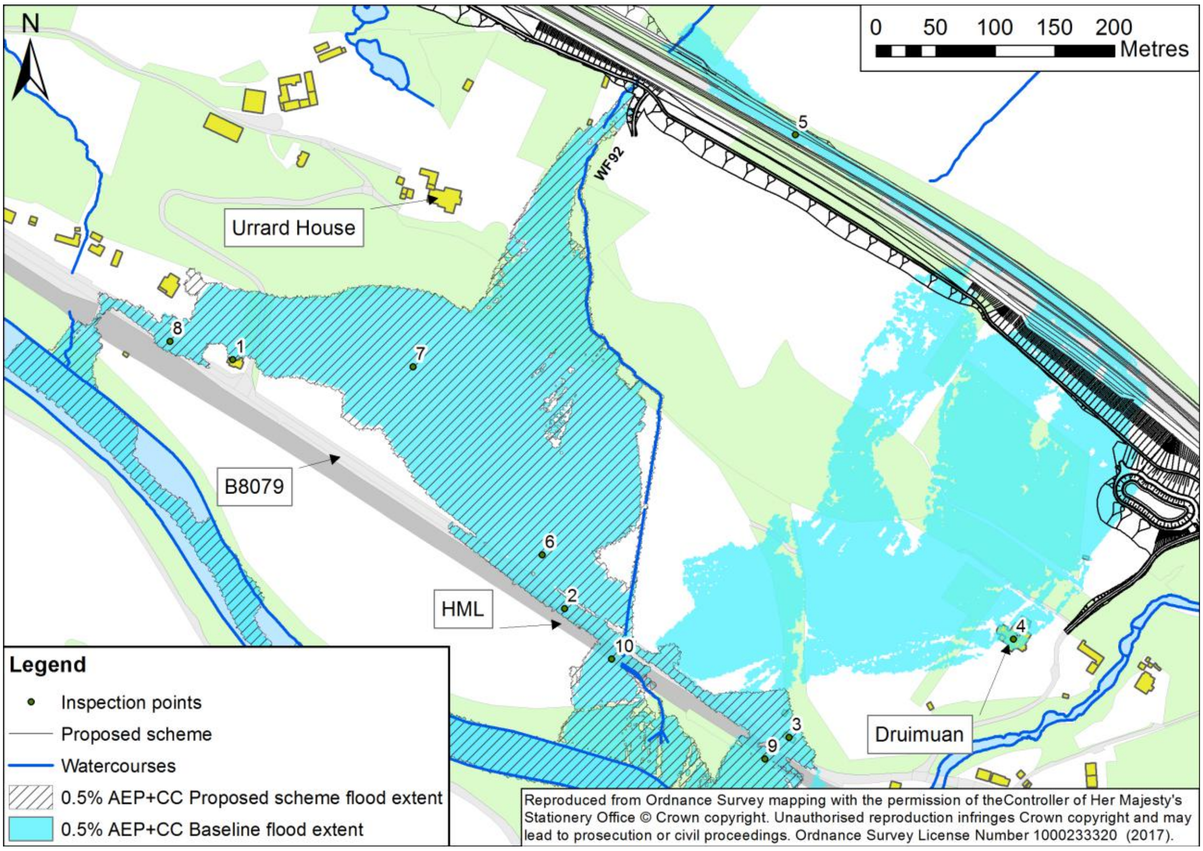
4.1.54 During the proposed scheme scenario, it will be necessary to extend the existing culvert to accommodate the widening of the A9 mainline. In doing so, a new culvert will be required to convey the peak design flood event flow of 3.26m^3/s. Hydraulic modelling shows that this would prevent the overland flow path along the A9 embankment from occurring and therefore protect the residential property at Druimuan (Inspection Point 4, Diagram 19). However, a new larger culvert will pass more flow downstream placing the residential property adjacent the Urrard House access road, the B8079 road and the HML railway at greater risk as shown in Table 19.

Table 19: WF92 - peak water level impacts without mitigation

Inspection Point	Baseline Flood Depth (mm)	Proposed Scheme Flood Depth (mm)	Depth Difference (mm)	Flood Impact
1	10	26	16	Minor adverse
2 (B8079)	338	373	35	Negligible
3	752	728	-24	Minor beneficial
4	8	0	-8	Negligible
5 (A9)	232	0	-232	Major beneficial

Inspection Point	Baseline Flood Depth (mm)	Proposed Scheme Flood Depth (mm)	Depth Difference (mm)	Flood Impact
6	303	336	32	Minor adverse
7	118	142	25	Minor adverse
8 (B8079)	506	550	44	Minor adverse
9 (HML)	20	15	-5	Negligible
10 (HML)	25	41	16	Minor adverse

Diagram 19: WF92 – baseline and proposed scheme (without mitigation) flood extent comparison



4.1.55 A number of alternative design options and additional mitigation measures have been considered at WF92 to either ensure the status quo or offset the adverse impacts of the chosen design including:

- **Option 1 - Upstream flood storage.** The topography of the land upstream of the A9 rises steeply to the north and consequently is unlikely to be suitable to incorporate a flood storage basin without significant excavation and re-profiling of the hillside. This option has therefore been discounted.
- **Option 2 - Downstream flow controls.** Providing a flood embankment along the access road to Urrard House will protect the residential property, but will however not offset impacts within the floodplain and to the B8079 road and the HML railway. Additional culverts underneath the B8079 road and the HML railway have also been modelled and shown to provide little benefit in draining the floodplain. These options have therefore been discounted.
- **Option 3 – Upstream flow diversion.** This option has been designed to mimic the baseline situation, by diverting excess floodwater to the Allt Girnaig watercourse via a 0.7m diameter concrete pipe, to prevent uncontrolled upstream flooding and flood risk to the proposed scheme. This option was considered the preferred solution as it provides greater control on flow rates and discharge locations to ensure a ‘neutral’ flood risk impact. This option is described in further detail below.

4.1.56 To enable the diversion of flows to the Allt Giraig, a hydraulic control will be required at the entrance to the new culvert to limit the pass forward flow to existing flow rates along the watercourse downstream of the crossing. This can be achieved with a penstock gate or fixed orifice housed in an appropriately sized chamber. The provision of a penstock gate will allow some degree of flexibility during commissioning of the system, but will require a future ongoing maintenance regime.

4.1.57 The chamber will also house a 'side' weir set at an appropriate level to allow excess floodwater to be diverted by pipe. The pipe will follow the existing flow route along the A9 embankment, but will discharge to an adjacent Allt Girnaig (WF89) located approximately 725m to the east of WF92. The magnitude of the flood flow to be diverted is 1.17m^3/s for the design flood event. Careful consideration will be required regarding the design of the chamber to maintain environmental connectivity in terms of mammal passage and fish passage, noting that mammal passage may be maintained by providing an adjacent 'dry' mammal pass.

4.1.58 The river bed level of the Allt Girnaig (WF89) watercourse is approximately 30m lower than that of WF92 and it is anticipated that the diversion pipe will run parallel to the mainline of the proposed scheme, located in the southbound verge at an approximate 1:70 gradient before a steeper fall towards its outlet into Allt Girnaig (WF89). A 0.7m diameter pipe will be required to pass the required 1.17m^3/s design flow, and due to its length it will be necessary to provide appropriate manhole access at approximately 100m centres for maintenance and inspection purposes.

4.1.59 Diverting floodwater from WF92 into the Allt Girnaig (WF89) will increase the flow of water within the receiving watercourse. The predicted peak flow in the Allt Girnaig (WF89) during the design flood event is 70m^3/s. Assuming concurrent peak flows in both watercourses, diverting 1.17m^3/s represents a 1.7% uplift in peak flow in the Allt Girnaig watercourse for the design flood event.

4.1.60 The Allt Girnaig (WF89) is contained within a deep and steeply sided incised channel between the existing A9 road and its downstream confluence with the River Garry. It passes through the village of Killiecrankie and is crossed by the B8079 road and HML railway. SEPA flood maps indicate that the predicted flood extents, including the 0.1% AEP (1000-year) flood event, are contained within the channel and no properties currently fall within the flood extents. Taking a typical channel cross section and simply applying Manning's equation, the 1.17% uplift in peak flow is estimated to increase the water level by 10mm, during the design flood event. This increase in water level is unlikely to significantly change the existing flood extent given the shape and depth of the existing channel.

4.1.61 It is also recognised that the timing of the peak flow in both WF92 and Allt Girnaig (WF89) catchments at their respective crossings of the A9 will not occur at the same time. During the 0.5% AEP (200-year) flood event in each catchment; the time to peak for WF92 at the A9 crossing is 1.3 hours, whereas the time to peak for the Allt Girnaig (WF89) is 5.6 hours. Notwithstanding the small amount of time associated with water flowing from WF92 to the Allt Girnaig (WF89), it is very likely that the impact of the peak flow associated with WF92 will occur during the rising limb of the Allt Girnaig (WF89) flood hydrograph and be passed downstream prior to the peak flow occurring in the Allt Girnaig (WF89).

4.1.62 In addition, the duration of the WF92 flood hydrograph is 3 hours and the onset of flow from WF92 to the Allt Girnaig (WF89) occurs at 2.09m^3/s. At time 1.75 hours, the flow in WF92 falls below 2.09m^3/s, hence no flow will be discharging into the Allt Girnaig (WF89) at the time of the peak in this watercourse, i.e. at 5.6 hours.

4.1.63 Further hydrological analysis would be required to consider the response from both catchments when subjected to the same rainfall event; however, it is likely that the impact of diverting floodwater from WF89 to Allt Girnaig (WF89) in terms of its magnitude and timing will be similar to that outlined above.

4.1.64 Therefore, at this stage it is considered likely that the flood risk impact of diverting excess floodwater from WF92 to the Allt Girnaig (WF89) is of 'negligible' magnitude and 'neutral' significance. This option also alleviates the existing flooding occurring to the east of WF92 and in particular the existing flood risk to the residential property at Druimuan, whilst maintaining a 'neutral' impact to the existing flood risk in the downstream reach of WF92.

4.1.65 Further outline design will be undertaken in support of the Controlled Activity Regulation licence application, taking into account good practice guidance for ecological and geomorphological mitigation measures, where considered necessary.

WF132, 134 and 136

4.1.66 Calvine is a particular flood prone area along the existing A9 corridor due to the number of minor watercourses (WF132, WF134 and WF136) passing underneath the existing A9 and through the village towards the River Garry to the south. All three minor watercourses originate in the hillside above Calvine. WF132 and WF134 start out as one single stream, WF133, that splits and diverges into two distributaries immediately prior to crossing the A9. These two streams have a total catchment area of 0.66km^2 with a combined peak flow of 3.58m^3/s during the design flood event. Based on channel size, it is assumed that the flow is divided equally between the two watercourses and flow underneath the existing A9 via surveyed 1m diameter culverts. WF136 flows underneath the existing A9 through a 670mm diameter culvert.

4.1.67 During the baseline scenario, the preliminary assessment estimated that all three culverts would surcharge during the design flood event, resulting in HWLs at WF134 and WF136 above the existing A9 mainline level. As a result, the watercourses pose a risk of flooding to the existing A9 and the properties to the south. Due to the existing flood risks and the potential for the proposed scheme to further increase flooding to sensitive receptors, all three minor watercourses were modelled in detail.

4.1.68 The baseline modelling shows that the existing A9 mainline culvert at WF132 would be in free flowing conditions, contrary to the findings of the culvert capacity assessment. Flow would then remain in channel until the watercourses reaches the B847, where flow would back up. The modelled capacity of the B847 culvert along WF132 is 0.76m^3/s. Floodwater would then overtop the B847, flow south inundating properties (Diagram 20, ID16 and ID17) and the Highland Main Line railway.

4.1.69 The existing A9 mainline culvert at WF134 has a maximum capacity of 1.35m^3/s and would surcharge during the design flood event (1.79m^3/s). Out of bank flow would then pass underneath the existing A9 via an underpass (Photograph 5). Floodwater would then place a number of properties at risk, with flood depths ranging from 40mm to 220mm. There are also a number of crossings over WF134 with limited capacity (0.51m^3/s at the access to Calvine School House), which are likely to surcharge more frequently than the existing A9 culvert.

4.1.70 The existing A9 mainline culvert at WF136 would also surcharge during the design flood event; however, out of bank flooding is shown to flow eastwards overtopping the existing A9 mainline before flooding properties in the west of Calvine. The modelling also shows that any flow remaining in WF136 would also exceed the capacity of the culvert beneath the B847, with floodwater flowing along the B847 and contributing to flow from WF134.

Photograph 5: Underpass east of WF134

Diagram 20: WF132, WF134 and WF136 - baseline flood depths

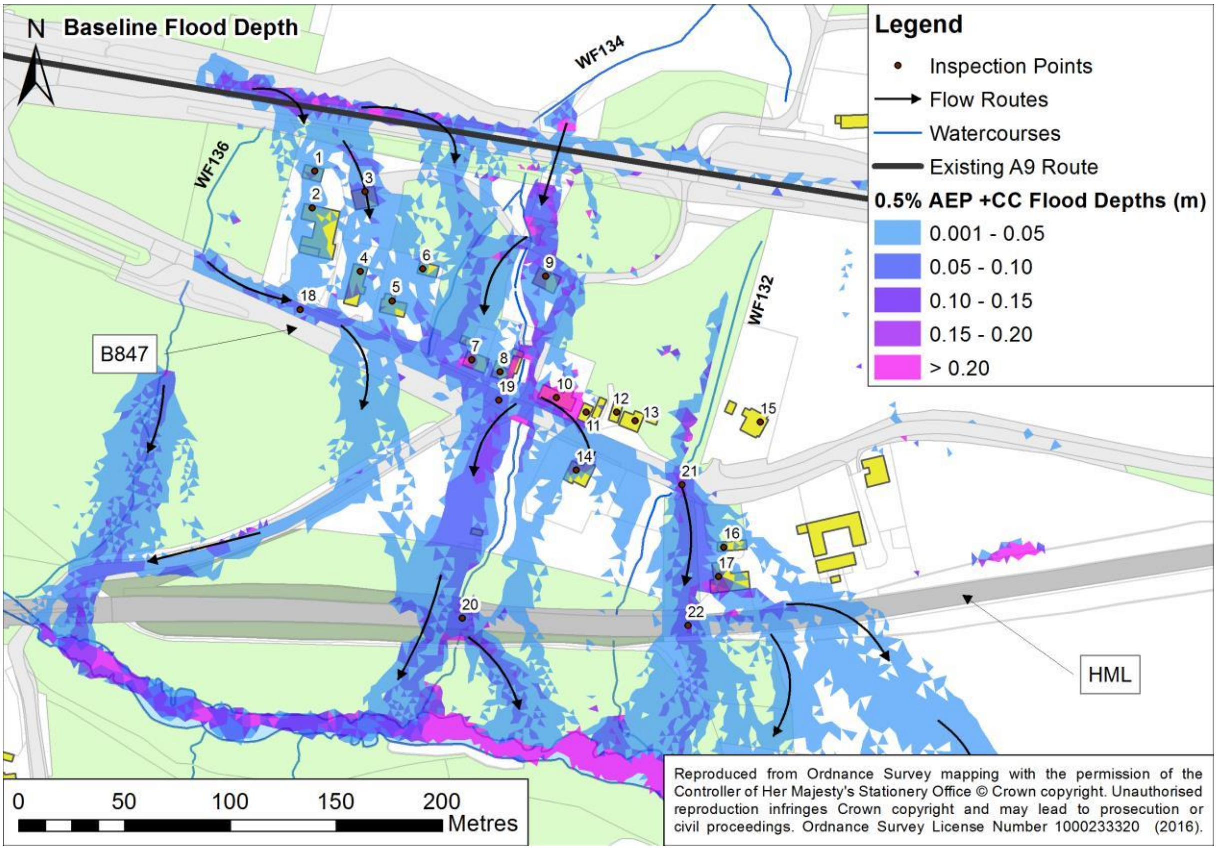
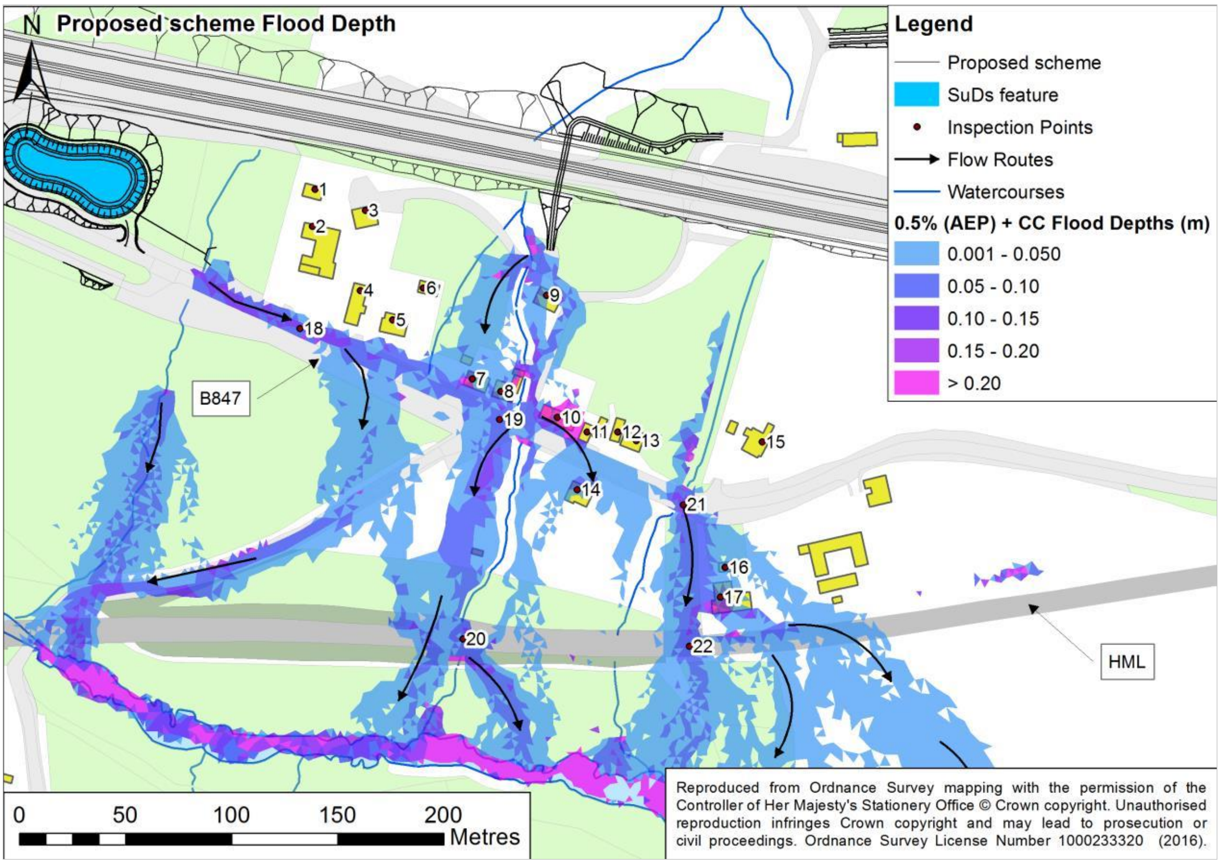


Diagram 21: WF132, WF134 and WF136 - proposed scheme flood depths



4.1.71 As part of the proposed scheme, the existing A9 culvert at WF132, WF134 and WF136 would be replaced to support the widening of the A9 mainline. In all three cases, the replacement culvert would be enlarged although it is noted that at WF132, the replacement is only partial.

4.1.72 The proposed scheme would have no impact on flooding along WF132 as the existing mainline culvert already passed the peak flow during the design flood event. The proposed scheme modelling shows that the mainline culvert at WF134 and WF136 would now pass the design flood event, which would prevent the flooding of the proposed scheme mainline and the underpass.

4.1.73 The extent of flooding immediately downstream of the A9 would be reduced, with a number of residential properties no longer at risk of flooding during the design flood event as shown at Inspection Points 1 to 6, Diagram 21. Flood flow would now remain in channel until the watercourses reach small property access road culverts, which would remain unchanged and under capacity when compared to the baseline scenario.

4.1.74 Table 20 contains peak baseline and proposed scheme flood depths at properties and key locations during the design flood event. Generally, in the baseline scenario, flood depths throughout Calvine do not exceed 300mm, with floodwater along the B847 not predicted to pose a risk to people or local road users.

4.1.75 The proposed scheme is also shown to have a minor to major beneficial impact on flooding through Calvine, apart from along the B847, which sees a maximum 60mm increase in flood depths. Flood frequency is expected to remain unchanged as the culvert under the B847 will still be expected to surcharge during frequent events. As a result, no further mitigation measures are proposed along these watercourses.

Table 20 : WF132, WF134 and WF136 - baseline and proposed scheme flood depths

Inspection Points	Baseline Flood Depth (mm)	Proposed Scheme Flood Depth (mm)	Depth Difference (mm)	Flood Impact
1	39	0	-39	Minor beneficial
2	32	0	-32	Minor beneficial
3	97	0	-97	Moderate beneficial
4	46	0	-46	Minor beneficial
5	25	0	-25	Minor beneficial
6	48	0	-48	Minor beneficial
7	113	86	-27	Minor beneficial
8	37	34	-3	Negligible
9	52	24	-28	Minor beneficial
10	217	200	-17	Minor beneficial
11	0	0	0	Negligible
12	1	0	-1	Negligible
13	1	0	-1	Negligible
14	51	47	-4	Negligible
15	0	0	0	Negligible
16	13	16	+3	Negligible
17	65	66	+1	Negligible
18 (B847)	58	115	+57	Moderate adverse
19 (B847)	75	66	-9	Negligible
20 (HML)	96	80	-16	Minor beneficial
21 (B847)	132	130	-2	Negligible
22 (HML)	78	77	-1	Negligible

WF140

4.1.76 WF140 is a small watercourse approximately 800m west of Calvine with a catchment area covering 0.54km^2 of mainly moorland. It has a peak flow of 2.76m^3/s during the design flood event, which is then conveyed beneath the existing A9 through a 1.2m diameter culvert.

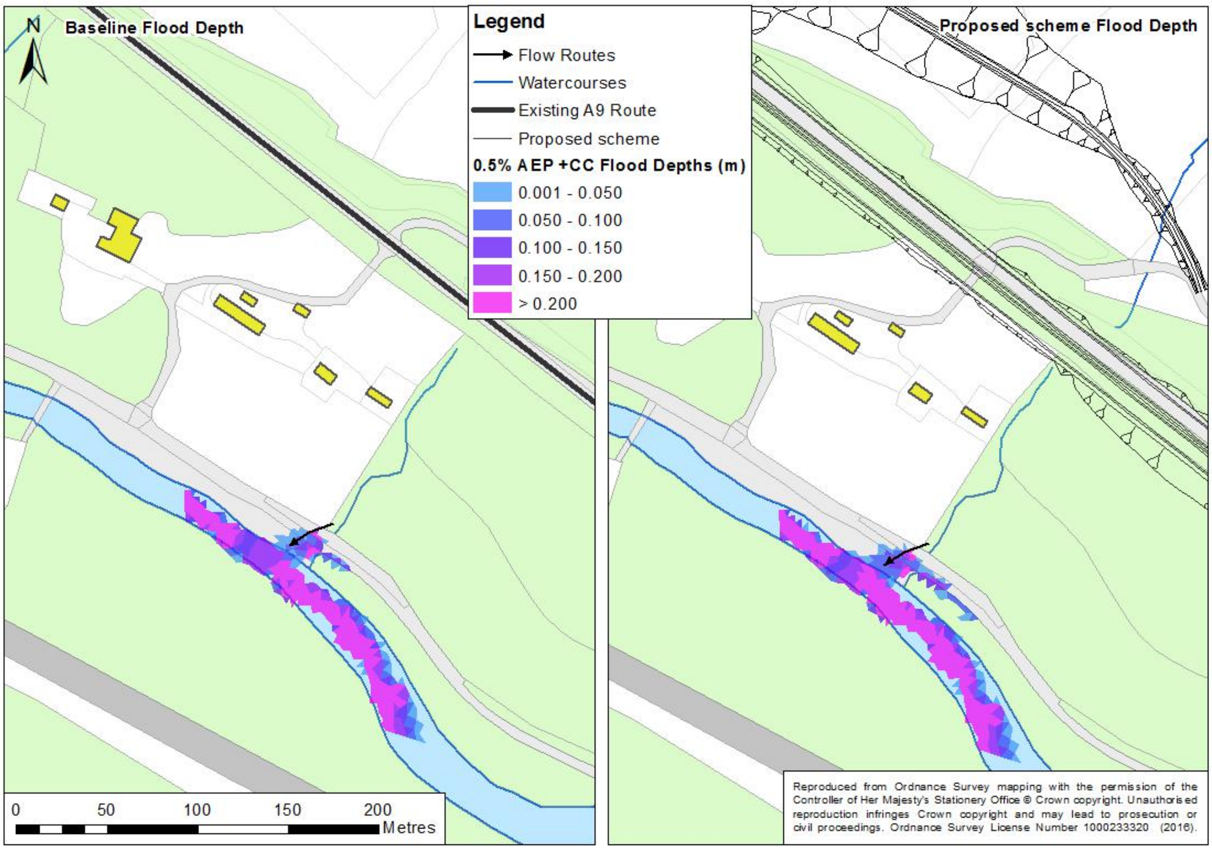
4.1.77 During the baseline scenario, the preliminary assessment indicates that the culvert beneath the existing A9 has the capacity to convey 2.5m^3/s, which is just below the peak design flood event flow of 2.76m^3/s. A review of the local topography suggests that any flood flow would overtop the existing A9 before re-entering the watercourse downstream. Downstream of the existing A9, the watercourse flows underneath the U521 via a 1.3m diameter culvert. However, survey undertaken indicates that this culvert is blocked with debris, which has reduced its capacity.

4.1.78 As part of the proposed scheme, the existing A9 culvert would be replaced with a new culvert designed under DMRB design criteria. During the proposed scheme scenario, the hydraulic performance assessment indicates that the new culvert would freely pass the design flood event, which would reduce upstream HWL by 300mm and prevent the proposed scheme from overtopping. This would however result in a minor increase in peak flow downstream along the watercourses from 2.5m^3/s to 2.76m^3/s. However, as floodwater is likely to overtop the existing A9 in the baseline scenario and re-enter the watercourse downstream, the peak flow reaching the U521 crossing downstream is unlikely to change when compared to the baseline and the flood impact to the U521 is likely to be negligible. As such, no further mitigation measures are proposed.

WF145

4.1.79 WF145 flows immediately east of Clunes Cottage. It has a catchment area of approximately 0.59km^2, comprising mainly moorland and rough grazing. During the baseline scenario, the preliminary assessment indicates that the culvert beneath the existing A9 mainline would surcharge during the design flood event and that the existing A9 would be at risk of overtopping from this watercourse.

Diagram 22: WF145 - baseline and proposed scheme flood depths



4.1.80 As part of the proposed scheme, WF146 would be diverted into WF145 upstream of the mainline crossing, increase peak flows into the culvert from 2.98m³/s to 3.28m³/s. To accommodate this, the proposed scheme would also replace and enlarge this culvert from 1.2m to 1.5m in diameter. Due to the location of flood sensitive receptors downstream, including Clunes Cottage and the U521, further detailed hydraulic modelling was performed as shown in Diagram 22.

4.1.81 The baseline modelling shows that the existing A9 mainline culvert has enough capacity to convey the peak flow associated with the design flood event and the existing A9 is not at risk of overtopping. Downstream of the A9, the modelling shows that the U521 culvert (800mm diameter) would however surcharge resulting in the floodwater overtopping the U521 before entering the River Garry. The peak flood depths along the local access road reach approximately 125mm.

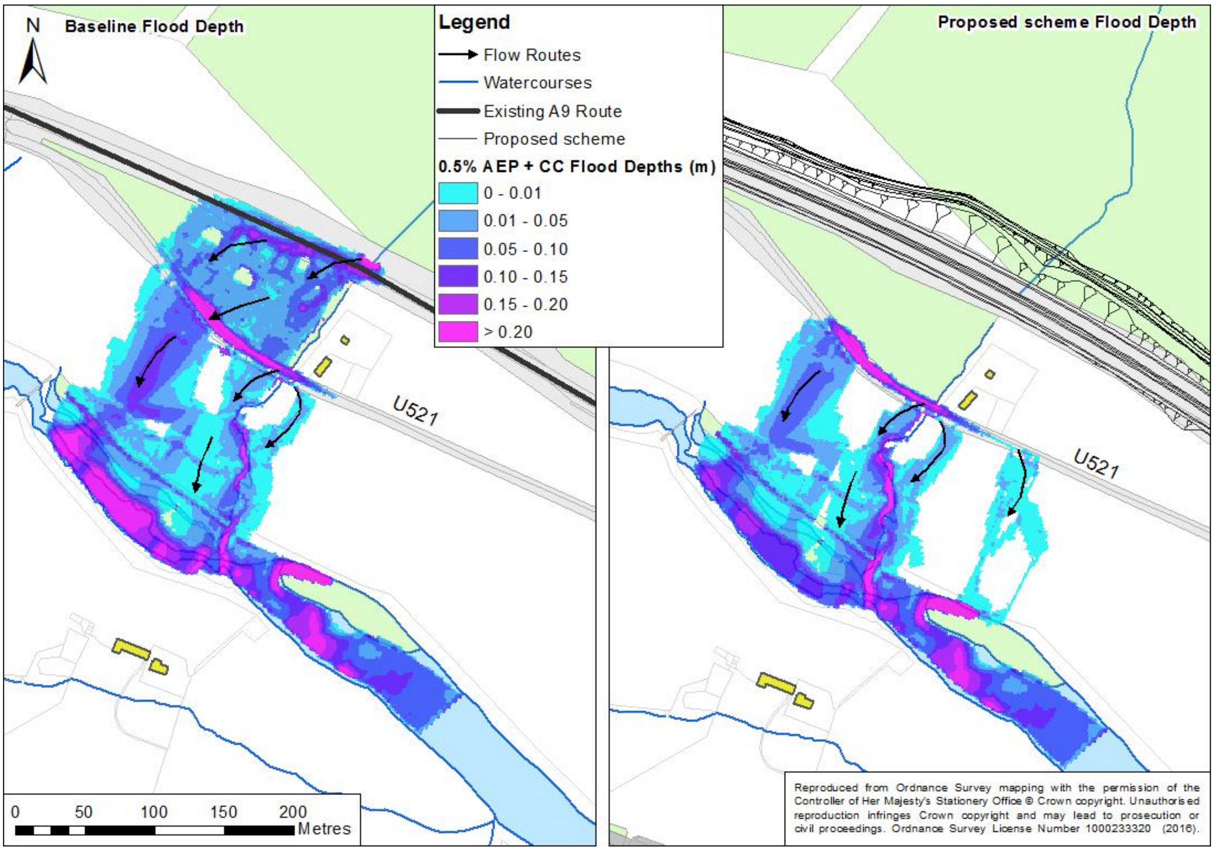
4.1.82 The proposed scheme modelling shows that proposed alterations to the culvert would accommodate the increase in peak flows from both WF145 and WF146. This increase in peak flow would also not impact Clunes Cottage, with flows remaining in-channel during the design flood event.

4.1.83 Downstream of the proposed scheme, the U521 culvert would remain surcharged, with peak flood levels increasing by approximately 40mm. This difference was calculated at the U521 culvert inlet. Peak flood depths would remain below 200mm and the U521 would remain passable by vehicles. Modelling indicates that the access road culvert has the capacity to pass the peak flow associated with the 3.33% AEP (30-year) event and therefore the frequency of flooding to the road would remain low. As a result, no further mitigation measures are proposed.

WF156

4.1.84 WF156 is a small watercourse that originates in the east of the Dalnamein Forest approximately 800m east of Dalnamein Lodge. It has a catchment area of 0.56km², which is mainly coniferous plantation. The peak flow during the design flood event is estimated to be 2.89m³/s.

Diagram 23: WF156 - baseline and proposed scheme flood depths



4.1.85 To assess flood risks in detail, further detailed hydraulic modelling was carried out for WF156. During the design flood event, the baseline hydraulic modelling confirms that the existing A9 mainline culvert would surcharge, with approximately 1.19m^3/s conveyed through the culvert downstream. The remaining 1.70m^3/s would flow over the existing A9, flooding the western floodplain of WF156 (Diagram 23). Flood flows are also shown to exceed the capacity of the U521 culvert (which is known to be largely blocked with debris) and overtop the road, with flood depths reaching approximately 380mm, which would be unsafe for road users. However, the property at Dalreoch is not predicted to be flooded.

4.1.86 As part of the proposed scheme, the existing A9 mainline culvert would be replaced and designed to follow DMRB design criteria, with the new culvert enlarged to 1.8m in diameter. Regrading of WF156 would also be required downstream of the A9 mainline to align with the outlet of the new culvert. Debris that has accumulated in the existing U521 culvert would also be removed, increasing its capacity from 0.5m^3/s to 1.55m^3/s. As a result, the proposed scheme hydraulic modelling shows that during the design flood event, the proposed A9 mainline culvert would experience free flow conditions with the peak flow of 2.89m^3/s being conveyed through the culvert downstream towards the U521 culvert. Upstream of the U521 culvert there is significant reduction in flood extents on the western floodplain, with the property at Dalreoch located on the eastern floodplain remaining outwith the flood extent.

4.1.87 However, despite the increase in capacity, the U521 culvert would continue to surcharge resulting in floodwater overtopping the U521 as experienced in the baseline scenario. Flood depths along the U521 would reduce by approximately 30mm, but the length of road flooded would increase to the east along the U521 and open land, albeit to limited flood depths (<10mm). As flood depths along the U521 remain high above 300mm, the proposed scheme is considered to have a negligible flood impact and no additional mitigation measures are proposed.

4.1.88 Possible additional measures to prevent the U521 culvert from blockage may be required in the future if it is demonstrated that this continues to be an issue. Targeted maintenance would be preferred over a debris screen. However, should debris block the culvert, floodwater would flood the western floodplain and not place the property at Dalreoch at risk.

Mitigation Measures

4.1.89 The assessment has shown that the proposed scheme provides major beneficial flood impacts to the A9. This is primarily the direct result of replacing a number of culverts, which were previously under capacity when tested against the design flood event. Where an increase in upstream HWL is predicted, this is limited to open green space and no flood sensitive receptors are affected. As a result, no further mitigation measures are proposed upstream of the A9 mainline along these minor watercourses.

4.1.90 Where the proposed scheme increases pass forward flow as a result of culvert replacements, the detailed assessment has shown that there are minor to moderate adverse impacts to downstream receptors, mainly to existing road crossings. However, many of these road crossings are already at risk of flooding in the baseline scenario and no mitigation measures are proposed.

4.1.91 This is with the exception of WF92, where increased pass forward flows would result in minor adverse impacts to one residential property. Here, additional mitigation measures are recommended, which includes a flow control structure and diversion pipe to convey exceedance flow to the Allt Girnaig watercourse.

Residual Risks

4.1.92 In the context of the proposed scheme, the residual flood risk would include:

- blockages of culverts by debris that reduce its capacity to convey flows;
- severe flood events as a result of intense rainfall or rapid snow melt, which exceed the design capacity of the culverts;
- Moderate adverse impacts to the B847 through Calvine; and
- Minor adverse impact to the U521 at WF145 and WF156.

4.1.93 The focus of the design for culverts under the A9 mainline has been the 1% AEP (100-year) flood event in accordance with DMRB guidance. However, when these culvert designs are tested against the 0.5% AEP (200-year) event (taking account of CIRIA C689 guidance), all culverts that are extended or replaced are shown to be freely discharging with sufficient culvert freeboard. The residual risk in this context therefore applies for events greater than the 0.5% AEP event.

4.1.94 There are no proposals to install debris/security screens at the culvert locations. Generally, the enlargement of a significant number of culverts (and provision of appropriate culvert freeboard) along the proposed scheme would help reduce the residual risk of blockage when compared to the baseline scenario. It would be important that the Trunk Road Operator 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 schedules.

5 Surface Water

Introduction

5.1.1 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.

5.1.2 The 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 can also influence surface water risks by increasing the velocity of overland flow and depth of ponding.

Baseline Risks

5.1.3 The existing A9 follows the valley of the River Garry, which has steep hillsides in some locations. As a result, the hillsides are likely to generate significant volumes of runoff during high intensity rainfall events that would flow towards the existing A9.

5.1.4 As part of a typical carriageway design, roadside filter drains or Pre-Earthworks Drainage (open ditches) adjacent to earthworks or the mainline collect surface water runoff from hillsides. Therefore, incidences of surface water flooding on the existing A9 tie in closely with existing road drainage efficiency (associated with capacity exceedance and blockages) and where the existing A9 cuts into the steep hillsides. The existing A9 would also form an obstruction to natural overland flow routes where raised on embankments, preventing surface water runoff draining through the usual routes and into nearby watercourses.

5.1.5 This FRA has adopted a preliminary assessment to identify areas along the existing A9 at risk of surface water flooding, by overlaying three key datasets, including:

- **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.
- **Overland Flow Path Analysis** – the analysis has used a 'rolling ball' technique based on topographic data from a Digital Terrain Model (DTM) to produce a series of theoretical surface water flowpaths. Essentially, the flow path generated represents the path of 'low spots' over the ground along which water would flow if the ground was impermeable. The analysis identifies areas at particularly high surface water flood sensitivity based upon the catchment area and the gradient of the flow paths within that location, with those flow paths associated with large catchments and/or steep gradients resulting in high flow path significance.
- **Historical Flood Incidents** –Transport Scotland has reported surface water flooding along the stretches of the existing A9 within cuts adjacent to steep hillsides, which include large proportions of the mainline between Killiecrankie and Glen Garry, with frequent surface water flooding in the northern section of the existing A9 around Dalreoch.

5.1.6 The preliminary assessment concludes that the majority of the existing A9 between Killiecrankie and Glen Garry sits on a raised embankment, which reduces the risk of the road becoming flooded by surface water. In these cases, the SEPA Surface Water Flood Map and the overland flow path analysis identifies surface water ponding against the embankment, or the embankment diverting overland flow routes to the nearest minor watercourse, as listed in Table 21.

5.1.7 The areas of surface water flooding listed in Table 21 are mainly associated with flooding along minor watercourses rather than direct surface water runoff. Since both the SEPA Surface Water Flood Map and the overland flow path analysis do not take into account existing drainage features such as the existing A9 road drainage or culverts running underneath the existing A9, the flood mapping is likely to provide a conservative estimate of risk. Based upon the information presented above, this FRA concludes that there is an existing low risk of surface water flooding along the A9 corridor.

Table 21: Locations of potential surface water flooding

A9 Chainage	Description
ch1900-2800	The SEPA Flood Map identifies surface water ponding on the upstream side of the existing A9 embankment. The existing A9 watercourse crossings at WF92 and WF96 are shown to surcharge during the design flood event, some ponding of water upstream of the existing A9 could occur, which would support the SEPA's surface water model outputs. However, these are still likely to be a conservative estimate of upstream flooding. Regardless of the precise flood extents, there are no upstream flood sensitive receptors at risk in these locations and the A9 is not at risk of overtopping. Section 3 contains detailed assessment of WF92 and WF96.
ch6500-7100	The SEPA Flood Map identifies surface water ponding on the upstream side of the existing A9 embankment. The existing A9 watercourse crossings at WF104, and WF107 are shown to freely pass the design flood event, therefore the extent of surface water flooding represented within SEPA's surface water model is likely to be an overestimate of risk.
ch7400-7500	The SEPA Flood Map identifies a potential surface water flow path running across the existing A9. The flow path is considered to be associated with WF108, which is shown to surcharge during the design flood event. The flood mapping is likely to be accurate in this location, with the existing A9 shown to be at risk of overtopping. There are however, no other flood sensitive receptors located immediately upstream of the existing A9.
ch8800	The SEPA Flood Map identifies a large area of surface water ponding on the southern side of the existing A9 embankment within the fluvial floodplain of the Allt Bhaic. However, the existing A9 is not shown to be at risk of flooding as it is raised on an embankment.
ch13500-17100	The SEPA Flood Map identifies a potential surface water flow path running along the existing A9; however, floodwater is likely to be associated with the minor watercourses crossing of the existing A9 in this location. The culverts associated with watercourse WF136, WF140 and WF145 are shown to surcharge during the design flood event, which would result in flooding upstream of the crossing supporting SEPA's surface water model outputs at these locations. However, WF137, WF139, WF141, WF143, WF144, WF147and WF148 are all shown to freely pass the design flood event and the flooding predicted upstream of these crossing on the SEPA flood map is likely to be significantly overestimated.
ch17100-17600	The SEPA Flood Map identifies a potential surface water flow path running along the existing A9. No sensitive receptors have been identified immediately upstream of the existing A9 but the existing A9 does appear to be at risk. As pre-earthworks drainage upstream of the existing A9 is not represented within SEPA's surface water model, it is likely that the flooding predicted along the A9 in this location is overestimated.
ch18300-18800	The SEPA Flood Map identifies a potential surface water flow path running along the existing A9. No sensitive receptors have been identified immediately upstream of the existing A9, but the existing A9 does appear to be at risk. As pre-earthworks drainage upstream of the A9 and the culvert for WF154, which has been assessed to freely pass the design flood event, the risk of surface water flooding predicted by the SEPA's surface water model are likely to be overestimated in these locations.
ch20100-20400	The SEPA Flood Map identifies a potential surface water flow path running along the existing A9. No sensitive receptors have been identified immediately upstream of the existing A9, but the existing A9 does appear to be at risk. As pre-earthworks drainage upstream of the A9 and the culvert for WF160, which has been assessed to freely pass the design flood event, the risk of surface water flooding predicted by the SEPA's surface water model are likely to be overestimated in these locations.

Potential Impacts

5.1.8 The proposed scheme has the potential to impact existing surface water flooding, by:

- constructing new features over existing overland flow paths, which could impede the movement of water causing local changes to catchment drainage patterns and local flood risks; and

- dualling existing single carriageways and the construction of new roads and junctions, which would result in a greater area of paved surface; without attenuation this could increase the rate at which runoff reaches receiving watercourses. While the increase from one drainage outfall alone may not make a significant difference to the receiving watercourse, the cumulative effect of all the outfalls in the proposed scheme, or the effects of its construction, may affect flood risk elsewhere in the catchment.

Surface Water Drainage

5.1.9 The proposed scheme includes the 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

5.1.10 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 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 and compromising its structural integrity.

5.1.11 In both cases, PED is usually located in catchments without defined watercourses, where the proposed scheme would intercept overland flow prior to it making its way to a nearby watercourse. The PED would then ensure drainage towards an open watercourse, which would help minimise alterations to local hydrological regimes.

5.1.12 In accordance with DMRB, the design of PED would convey the 1.3% AEP (75-year) rainfall runoff event from the intercepted catchment, which is usually adopted for catchments without defined watercourses. Whilst this is not the case along large stretches of the proposed scheme and large numbers of minor watercourses are present, it would be used along the length of the A9 dualling programme for consistency.

5.1.13 Where PED is located at the top of cut slopes, there is the potential for water to overspill down the earthworks towards the proposed scheme during events with a return period greater than the 1.3% AEP (75-year). However, where practicable, the sizing of PED at the top of the cuttings should be increased to accommodate the design flood event to minimise the risk of overtopping and flood risk to the road. Furthermore, the design of these slopes would ensure that there would be some infiltration into the slope and verge to minimise the volume running onto the mainline of the proposed scheme and requiring to be conveyed by the proposed scheme road drainage. Measures to encourage infiltration on the cut slope would also limit the potential for erosion. As a result, the risk of flooding to the proposed scheme from rainfall runoff is considered low.

Road Drainage

5.1.14 In line with DMRB, the design of the road drainage system would accommodate a short duration, high intensity 100% AEP[1] (1-year) rainfall event, without surcharging. The design would also ensure the 20% AEP (5-year) rainfall event would not exceed the chamber cover and flood the carriageway. This includes a 20% uplift allowance for the effects of future climate change.

Sustainable Drainage Systems

5.1.15 All runoff from the proposed scheme carriageways would be collected and treated via 22 SuDS features, which are likely to include detention basins, retention ponds and wetlands, prior to discharging to a watercourse via an outfall. The location of SuDS features are shown on the figures contained in Annex E (Flood Risk Assessment Figures). These SuDS features will provide an improvement when compared to the existing (attenuated) drainage network.

[1] the AEP convention here is used for convenience. The actual AEP for the 1-year event is approximately 63%.

5.1.16 Where the proposed scheme includes SuDS, they have been designed with the following design principles in mind:

- All SuDS features are designed to treat and attenuate the peak flow from the new road drainage system for a range of floods up to a 0.5% AEP (200-year) rainfall event, including an allowance for climate change;
- A 300mm freeboard depth over and above the 0.5% AEP (200-year) water level has been used to set any attenuation basin spill level height;
- Where possible, SuDS features have been located outwith the functional floodplain;
- Where SuDS features are located within the functional floodplain, the potential for compensatory flood storage has been considered (Section 3.4: Mitigation Measures) for all loss of floodplain capacity, including an allowance for climate change;
- SuDS features have been designed not to be inundated with fluvial floodwater during the 3.33% AEP (30-year) fluvial event and where required, the bund heights have been raised in order to prevent this from occurring;
- If practically possible, outfall levels have been set above the 3.33% AEP (30-year) peak water level in the receiving watercourse; and
- In order to provide sufficient attenuation, the outfall rate is controlled to the 50% AEP (2-year) ‘greenfield’ runoff rate.

5.1.17 There are conflicting design priorities between sizing the SuDS features, sizing the embankment to prevent overtopping and minimising (if possible) the flood impact of the feature whilst considered a wider range of spatial and environmental constraints. The SuDS design process has therefore been an iterative one.

5.1.18 This FRA has informed the SuDS design process by providing modelled baseline flood extents and peak water levels for the design flood event. Where the watercourse has not been modelled, a simple assessment has been undertaken using the SEPA Flood Map, survey data and Manning’s equation.

5.1.19 Table 22 contains a full list of SuDS features and outfall invert levels along with associated peak fluvial flood levels (either extracted from hydraulic models results or calculated using Manning’s equation).

5.1.20 Whilst it has been possible to locate the majority of the SuDS features outwith the fluvial functional floodplain, seven SuDS features are to be located within this zone due to other overriding design considerations such as topographical, geotechnical and environmental constraints. However, during the design flood event, only SuDS feature J2 would become inundated by floodwater passing from the River Bruar. SuDS features E1, G, H and P are located within the extent of the fluvial 3.33% AEP (30-year) design event; however, their bund heights have been set above the derived peak water levels and the SuDS features would not be inundated by fluvial floodwater.

5.1.21 While effort has been made to place outfalls above the 3.33% AEP (30-year) flood level of the receiving watercourse, outfall invert levels from SuDS features E1, G, H and I are all set below this level. This is mainly due to local topographical constraints which make positioning of outfalls above this level impractical without increasing ground levels within. At outfall locations E1, G and H the invert level would be submerged by between 1.46 and 0.5m indicating that the entire pipe would be submerged. Outfall I’s invert level would be exceeded by 0.01m indicating that the soffit level would not be exceeded.

5.1.22 The four drainage outfalls that would be submerged during the 3.33% (30-year) rainfall event have the potential to restrict the discharge rates from the SuDS features. This restriction to discharge rates could result in the attenuation storage capacity of the SuDS features being exceeded during intense rainfall events that coincide with a 3.33% (30-year) or greater fluvial flood.

5.1.23 The overtopping of the SuDS feature would result in uncontrolled discharge of road runoff into the receiving watercourse. However:

5.1.24 The SuDS features have capacity to store the 0.5% (200-year) plus climate change rainfall event plus 300mm of freeboard. Therefore, there is additional attenuation capacity hold water that may not be able to discharge into the receiving watercourse to deal with restrictions to discharge rates.

5.1.25 The maximum level of the SuDS feature would be at least 1m above the 3.33% (30-year) flood level. Therefore, in a situation where the pond was filled to capacity, the positive hydraulic head would ensure that there would be some flow from the pond into the receiving watercourse.

5.1.26 The factors detailed above would ensure that during a 0.5% (200-year) plus climate change rainfall event, which coincides with a 3.33% (30-year) fluvial event, the SuDS features would be unlikely to overtop. Therefore, runoff rates from the A9 would not increase and the impact on flooding downstream is considered to be negligible.

5.1.27 The risk of submerged drainage outfalls to the proposed scheme is considered to be negligible. The proposed road drainage is designed to convey the 100% (1-year) rainfall event and would therefore be subject to surface water flooding during the 0.5% (200-year) rainfall event. The impact of downstream components of the drainage infrastructure surcharging would not exacerbate this flooding.

Downstream Impacts

5.1.28 The proposed scheme includes online dualling with existing road levels largely retained and is therefore unlikely to alter the existing hydrological flow paths of surface water runoff and ponding areas with no adverse impacts predicted.

5.1.29 The proposed scheme also interacts with a considerable number of minor watercourses. Where possible, PED and road drainage catchments would discharge to the nearest watercourses to mirror natural flow routes and would therefore not likely alter existing surface water catchments.

5.1.30 The attenuation volumes provided in the form of SuDS features would also ensure that there is no increase in flood risk downstream along the receiving watercourse because of an increase in runoff rates and volumes due to the extended area of impermeable surfaces.

5.1.31 By following the overarching design principles where possible and ensuring flood risk has been considered at all stages of the design process, the impact of the proposed scheme on surface water flooding is considered negligible.

Table 22 : SuDS features and outfalls levels

SuDS Feature	Chainage	Bund Height (mAOD)	Discharge Location	Outfall Invert Level (mAOD)	Source of Derived Flood Levels	SuDS within 3.33% AEP (30-year) Floodplain	Peak 3.33% AEP (30-year) Floodplain Water Level (mAOD)	SuDS within 0.5% AEP (200-year) plus CC Floodplain	Peak 0.5% AEP (200-year) plus CC Floodplain Water Level (mAOD)	Peak 3.33% AEP (30-year) Water Level (mAOD) within Receiving Watercourse
A	ch1375	157.12	Allt Girnaig	151.00	Flood Map	No	-	No	-	134.60
B	ch1650	150.99	Allt Girnaig	148.70	Flood Map	No	-	No	-	134.82
C	ch3250	155.40	Allt Chluain	153.51	Flood Map	No	-	No	-	148.75
D1	ch3800	122.85	Allt Chluain	118.74	Flood Map	No	-	No	-	116.07
D2	ch4050	135.57	WF178	121.87	Flood Map	No	-	No	-	120.21
E1	ch4500	121.21	WF99	118.66	FRA Model	Yes	119.93	Yes	121.17	120.12
E2	ch4725	122.98	WF99	120.29	FRA Model	No	-	Yes	121.17	120.12
F	ch6750	135.19	River Garry	128.78	Flood Map	No	-	No	-	128.48
G	ch9100	138.74	Allt Bhaic	137.05	FRA Model	Yes	137.88	Yes	138.20	137.54
H	ch9300	138.92	Allt Bhaic	137.03	FRA Model	Yes	138.83	Yes	138.90	137.54
I	ch10575	144.78	River Garry	142.65	FRA Model	No	-	No	-	142.66
J1	ch11500	147.99	River Garry	146.68	FRA Model	No	-	No	-	146.51
J2	ch11400	148.64	River Garry	146.16	FRA Model	No	-	Yes	152.10	146.07
K	ch12475	156.95	River Garry	154.65	Flood Map	No	-	No	-	152.92
L	ch13650	201.25	WF136	199.39	FRA Model	No	-	No	-	198.47
M	ch14850	203.21	River Garry	195.00	Flood Map	No	-	Yes	194.42	193.16
N	ch15400	212.19	River Garry	202.00	Flood Map	No	-	No	-	196.22
O	ch16250	233.11	River Garry	215.28	Flood Map	No	-	No	-	214.81
P	ch18225	263.24	River Garry	261.30	Flood Map	No	256.53	Yes	257.30	256.53
Q	ch19575	257.26	WF88	254.97	Flood Map	No	-	No	-	252.20
R	ch19825	258.30	WF158	256.33	Flood Map	No	-	No	-	252.20
S	ch22225	281.64	WF164	279.76	FRA Model	No	-	No	-	283.45

Mitigation Measures

5.1.32 This FRA considers that with the surface water drainage systems in place as part of the proposed scheme; no additional mitigation measures are required. Since no additional mitigation measures are proposed, the surface water risks and impacts would remain unchanged from that described in above under Potential Impacts.

Residual Risks

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

- severe runoff events as a result of intense rainfall or rapid snow melt, which exceed the design capacity of the PED (>1.33% AEP (75-year)), road drainage (>20% AEP (5-year)) or SuDS features (0.5% AEP (200-year) plus climate change);
- blockages within the drainage infrastructure or high water levels in receiving watercourses that reduce its capacity to convey flows from adjacent land and the carriageway or from SuDS features into receiving watercourses; and
- the failure of proposed SuDS (embankment failure), which could result in a sudden release of water and flooding the receptors downstream.

5.1.34 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.

5.1.35 The design of SuDS features also includes a 300mm freeboard of additional storage above the peak attenuated water level to manage the residual risk of blockages and to provide some 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.

5.1.36 A detailed assessment of the impact of failure or overtopping of the SuDS features has not been undertaken. In the vast majority of 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 directly into the watercourse. The volume of water flowing into large watercourses, such as the River Garry, would be insignificant in comparison to average flows and would have a negligible impact on flood risk downstream.

5.1.37 SuDS feature D1 and D2 are located upstream of residential properties at Aldclune and Essangal respectively. SuDS feature L is located upstream of the B847 and SuDS feature N and SuDS feature O are located upstream of the access road to Clunes Cottage. Freeboard built into the design and the provision of dedicated overflow channel helps manage the impact of overtopping. Ongoing routine inspection and maintenance of the SuDS features would reduce the likelihood of failure. The residual risk posed by the SuDS features is therefore considered to be low.

6 Groundwater

Introduction

6.1.1 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 present itself 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.

6.1.2 In order to develop a conceptual understanding of groundwater flooding associated with the proposed scheme, hand-dipped groundwater level data from 169 borehole-monitoring installations along the proposed scheme corridor has been collated and reviewed, as well as continuous data-logger records at thirteen of these locations. The length of the data record varies between boreholes as they were installed during two distinctive phases of ground investigation: the first between September 2015 and January 2017 and the second between January 2017 and July 2017.

6.1.3 By assessing recorded groundwater levels along the corridor of the proposed scheme, a screening assessment was carried out to identify those areas at greatest risk of groundwater flooding, potential impacts and to identify where potential mitigation may be required. This included a detailed review of all parts of the proposed scheme that would involve excavations below existing ground level, including cuttings and the locations of proposed SuDS features.

6.1.4 Chapter 10 (Geology, Soils, Contaminated Land and Groundwater) undertakes this screening and fully assesses groundwater issues in relation to the proposed scheme.

Baseline Risks

6.1.5 Throughout the A9 route corridor, superficial deposits are shown to range in thickness from 0.2m to 29m, with glacial till forming the hillsides of the River Garry valley, and alluvium and river terrace deposits underlying most of the valley bottoms (from Calvine to Killiecrankie and west of Dalnamein Lodge). The bedrock in the existing A9 corridor comprises metamorphic rocks belonging to the Dalradian Supergroup.

Groundwater in the Superficial Deposits

6.1.6 Glacial till is typically composed of poorly sorted sands and gravels within a clay matrix, and is generally considered to have low permeability. As a result, recharge rates into the underlying bedrock aquifer in these locations are likely to be low. After periods of intense or prolonged rainfall, this is likely to contribute to significant waterlogging and surface water ponding. In valley floor areas, underlain by alluvium and river terrace deposits, groundwater levels may emerge at surface level because of rising groundwater levels in the superficial. Near watercourses, there may also be a connection between surface water and groundwater and rising surface water levels may contribute to locally increasing groundwater levels, and vice versa.

6.1.7 The A9 route corridor is linear and consequently the ground investigations cannot fully define groundwater flow directions across the surrounding area. However, the general groundwater flow direction is expected to broadly follow the topography and, at the shallow, local scale, this would generally be towards the River Garry. This topographically controlled flow could also contribute to the development of elevated groundwater levels in low-lying areas.

6.1.8 Ground investigation data, obtained from the monitoring installations along the A9 route corridor, identifies eleven locations where maximum groundwater levels have reached less than 0.4m below ground level (bgl). At five of these locations (ch1150, ch1875, ch2850, ch14350 and ch16350), the observed shallow groundwater levels lie within the superficial deposits, which in all instances comprise of shallow sands and gravels, overlying low permeability bedrock.

6.1.9 Data logger information recorded in four of the boreholes screened in the superficial deposits (BH48100, KPB1065, PGB1006, PGB1056) show a series of rapid groundwater responses, consisting of level increase events with subsequent decreases.

6.1.10 It should be noted that one location (borehole PGB1031 at ch14350) displays seasonal conditions with groundwater levels reaching ground surface at times. However, another nearby groundwater level monitoring location (PGB1030) recorded a maximum groundwater level of 2m bgl, with PGB1030 being closer to the River Garry than PGB1031. The seasonal groundwater conditions recorded at PGB1031 are therefore expected to be very localised. In addition, this is supported by data-logger information from PGB1031 where the groundwater level monitoring pattern appears inconsistent at times with the River Garry stage fluctuations, with correlations only observed during some high flow (and therefore expected high rainfall) events.

6.1.11 Shallow groundwater conditions at ch16350 (PGB1043) are present in the vicinity of the River Garry and may be reflective of a strong hydraulic connection with the river system. At ch11400 (borehole PGB1006), the presence of a data-logger reveals that despite groundwater levels ranging between 2 and 3m bgl, fluctuations of groundwater levels and river stages are a good match with a slight time delay for groundwater. In this area, it is therefore clear that a strong hydraulic connection exists between groundwater and the River Garry. Other shallow groundwater conditions recorded in drift deposits are in close proximity to small burns or field drains, at ch1150 (KPB1002), ch1875 (BH45600) and ch2850 (BH46550). However, none of these areas are associated with known flooding or predicted flood risk.

6.1.12 The data confirms the potential for encountering shallow groundwater levels in the superficial deposits in the valley bottoms and suggest that shallow groundwater levels can respond rapidly to rainfall events. The data also shows a variable degree of connectivity between groundwater and the River Garry throughout the valley. Groundwater may therefore both contribute to and extend the duration of other sources of flooding, such as surface water flooding (in areas prone to waterlogging), or fluvial flooding, in low-lying areas adjacent to watercourses. However, the data available at this stage does not provide any evidence of shallow groundwater currently contributing to flooding in the study area.

Bedrock Groundwater

6.1.13 Table 23 lists six of the eleven locations where maximum groundwater levels are less than 0.4m bgl, originate from boreholes screened into bedrock. These constitute areas of artesian / sub-artesian bedrock groundwater conditions.

Table 23: Summary of high piezometric groundwater levels recorded in bedrock

Borehole Reference	Chainage	Maximum Recorded Groundwater Level (m bgl)	Comments
BH51400	ch7525	0	Artesian conditions recorded. Location lies within Widening 6 (8m deep cutting), which is expected to reach bedrock. Artesian pressures may be released by Widening 6, although this is expected to be localised.
BH54350	ch10600	0.3	Located 10m away from Widening 9 (3m deep cutting) which is expected to reach bedrock and may release sub-artesian groundwater pressure.
BH56000	ch12175	0.4	Nearest cutting (Widening 11) is 650m away and is unlikely to release sub-artesian pressure.
PGB1032	ch14650	0.25	Sub-artesian conditions recorded. Adjacent to the west end of Widening 12, which is expected to reach bedrock and may release artesian pressure in this area.
BH64575	ch20875	0	Artesian conditions recorded. Shallow borehole so water bearing fractures likely at shallow depth. 500m from nearest excavation (Widening 18), which is unlikely to release artesian pressure.
BH65070	ch21275	0	Artesian conditions recorded. 400m from nearest excavation (Widening 19), which is unlikely to release pressure from these artesian conditions.

6.1.14 Such conditions differ from groundwater emergence, as artesian pressures may be difficult to control and could generate large quantities of groundwater, which if released at the ground surface, could place personnel and works items at significant risk. It is these areas that present the highest groundwater flood risk due to the high pressures, flows and volumes of water involved, which could pose a significant risk to people and development. However, given that there are no existing mechanisms in place that could release the artesian / sub-artesian pressures, the existing risk of groundwater flooding from the bedrock aquifer, prior to any development, is considered low.

6.1.15 Data-loggers were installed in two boreholes screened in bedrock (PGB1026 and PGB1069) because of the presence of very thin drift deposits at these locations. PGB1026 recorded deep groundwater levels (13 to 14m bgl) but a good correlation with nearby river stages, while PGB1069 recorded shallower groundwater conditions (3 to 4m bgl) but a more ad-hoc correlation with nearby river stages, which resembles the behaviour of PGB1031. These findings demonstrate that groundwater in bedrock may also be hydraulically connected to flows in the River Garry to a certain degree.

Limitations

6.1.16 The groundwater-monitoring data used to inform this baseline assessment has been collected at discrete locations over a 16-month period (September 2015 to January 2017) for the initial investigation and a 7-month period (January 2017 to July 2017) for the second investigation. While these periods provide an indication of annual seasonal variation it does not necessarily indicate the maximum groundwater levels that may develop from year to year. Consequently, there may be potential for groundwater related flooding beyond the current conceptual understanding of groundwater flood risk.

Potential Impacts

6.1.17 As the proposed scheme is located at or below ground level (i.e. cuttings) in several locations, there is a risk that groundwater flooding could affect the proposed scheme during both its construction and operational phases, if not managed. The key element of the design of relevance to groundwater flooding is the depth of excavations required where new road cuttings are proposed.

6.1.18 Chapter 10 (Geology, Soils, Contaminated Land and Groundwater) provides the results of a separate road cutting screening exercise, which has identified 34 cuttings that are likely to intercept groundwater. Of particular relevance are the six locations where artesian / sub-artesian bedrock groundwater conditions are likely to be encountered. It should be noted that none of the excavations associated with SuDS features are expected to intercept high piezometric groundwater levels.

6.1.19 Borehole data suggests that Widenings 6, 9 and 12 could create a pathway for artesian pressures to be released, which could contribute to a greater groundwater flood risk in these locations. However, the information available at this stage suggests that these pressures, and any subsequent impacts, would be localised.

Mitigation Measures

6.1.20 Despite the expected release of artesian and sub-artesian bedrock groundwater pressures at the three above-mentioned locations, it is anticipated that groundwater flood risk can be mostly managed through typical best practice design and mitigation. Table 24 includes likely mitigation measures to be incorporated into the proposed scheme.

6.1.21 Based on the presence of areas of local artesian and semi-artesian conditions, as well as the uncertainties associated with the existing ground investigation data, it is also recommended that a groundwater level-monitoring programme be implemented before and during construction to identify any potential future groundwater flood risk issues.

Table 24: 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. This

Embedded Mitigation Measures	Description
	measure is also applicable to the areas where local artesian and sub-artesian bedrock groundwater pressures may be released, although uncertainty remains on the volumes of groundwater which may be intercepted and whether specific control measures may need to be put in place.
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. Localised artesian/sub-artesian bedrock groundwater conditions are expected at Widenings 6, 9 and 12. However, further information is required to determine whether additional mitigation is required at these locations.
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

There is a low residual flood risk due to the potential that mitigation measures would be unable to cope with groundwater flows that could emerge as a result of localised artesian pressures being released. The contractor should be aware of these possible groundwater releases and should design future drainage systems to accommodate any potential groundwater flows.

7 Failure of Water-Retaining Infrastructure

Introduction

7.1.1 Flooding due to the collapse and/or failure of man-made water-retaining infrastructure such as a dam, water supply reservoirs, canals, flood defences, underground conduits (e.g. sewers), and water treatment tanks or pumping station is considered to be a residual risk.

7.1.2 It is not possible to attach a probability of collapse and/or failure to water-retaining infrastructure, as it would be dependent on the combined effect of a number of factors such as their condition, existing maintenance regimes and other outside influences. However, it would be significantly lower than the design flood event, which is used to assess the risk of fluvial and pluvial flooding.

7.1.3 That said, a collapse and/or failure would result in a vast amount of water suddenly being released at potentially extremely high velocities, resulting in potentially catastrophic consequences. Released water would follow local topography towards low-lying areas or into nearby watercourses. As the existing A9 crosses the valley floodplain and spans a number of watercourses, the proposed scheme is potentially at risk from this flood source.

7.1.4 At DMRB Stage 2, a preliminary assessment was undertaken to identify the location of water-retaining infrastructure and assess the potential for the proposed scheme to affect residual risks associated with infrastructure failure. The findings of this assessment are provided below. However, as the residual risk from these sources is considered low, no further detailed assessment has been carried out at DMRB Stage 3

Baseline Risks

Reservoirs

7.1.5 The reservoirs of Loch Rannoch, Loch Ericht, Loch Garry and Loch Errochty (among others) are located upstream of the proposed scheme. In addition, Scottish Water identifies two small service reservoirs at Pitagowan and Killiecrankie.

7.1.6 The normal operation of these dams poses a negligible risk to the existing A9. The failure of dams associated with these reservoirs is likely to result in the inundation of large extents of the existing A9 as illustrated by SEPA’s Reservoir Flood Maps (2015). However, continued maintenance of these structures by SSE Generation Ltd would ensure that this is an extremely unlikely event.

Aqueducts

7.1.7 The A9 dualling programme SFRA identifies that a tunnel transferring water from the north of Glen Garry towards Loch Errochty crosses the existing A9. No works are proposed in this area and no mechanism has been identified by which this aqueduct could impact the proposed scheme.

Water & Wastewater Treatment Works

7.1.8 The Killiecrankie Water Treatment Works (WTW) is located approximately 500m to the east of Killiecrankie. The WTW consists of both buried water tanks and an open reservoir (approximately 80m by 40m in plan area). The total volume of water stored in the tanks and reservoir is not known; however, both water tanks and reservoir do not appear to be 'raised' above adjacent ground level, hence the risk of failure resulting in a sudden release of water is considered to be low.

7.1.9 Any sudden release of water from the site is likely to follow the course of the Allt Eachainn (WF84) towards the existing A9. However, given that the likelihood of a sudden release of water is low and the volume of water stored above ground level is low, this source of flooding has not been considered further.

7.1.10 Blair Atholl is served by a Wastewater Treatment Works (WwTW) located to the north of the River Garry. The existing A9 is located to the south side of the River Garry in this location and therefore there is no potential risk of flooding from the WwTW to the existing A9.

7.1.11 Scottish Water data records the presence of rising sewer mains connecting areas of Blair Atholl to the WwTW to the east. The existing A9 is on the opposite side of the River Garry in this location and therefore there is no potential risk of flooding from the failure of the pumping station or rising mains to the existing A9.

Sewers

7.1.12 Scottish Water records a foul sewer network near Blair Atholl. Although many properties along the existing A9 corridor are known to use septic tank systems, it is likely that small networks of foul sewerage are present along the route of the existing A9.

7.1.13 Although detailed modelling of the sewer network in this area has not been undertaken, the small catchment area of the sewer systems makes it unlikely that volumes of water sufficient to pose a risk to the existing A9 would be released in the event of sewers surcharging. In addition, the distance between the existing A9 and larger settlements such as Blair Atholl makes it unlikely that water from this source would flow onto the existing A9. The risk from this source of flooding is low and has not been considered further.

Other

7.1.14 According to SEPA, there are no formal flood defences located along any watercourses adjacent to the existing A9. There are also no canals near the existing A9. As a result, there is no risk of flooding to the existing A9 from these sources.

Potential Impacts

7.1.15 The proposed scheme would not include any works that would alter or affect water-retaining infrastructure. The impact of the proposed scheme on this source of flooding is negligible and as a result, no mitigation is proposed.

8 Construction Phase

Introduction

8.1.1 Detailed construction plans and method statements were 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.

8.1.2 This section of the FRA therefore 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

8.1.3 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.

8.1.4 Table 25 outlines the broad categories of temporary works required during the construction phase and highlights some of the potential impacts of the temporary works with respect to flooding.

Table 25: 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.

8.1.5 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.

8.1.6 The overall guiding principle should be to avoid any temporary works within the functional floodplain where possible. The SEPA Flood Maps provide an excellent starting point as they help illustrate the extent of flooding from fluvial and surface water sources during low, medium and high likelihood events. The SEPA Flood Maps should then be supplemented by information contained in this report, including locations at high risk of groundwater flooding, which may not be covered by the SEPA Flood Maps.

8.1.7 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.

Mitigation Principles

General Guidance

8.1.8 The Contractor should follow the below 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

8.1.9 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 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

8.1.10 Given that the Contractor follows and correctly implements the principles outline 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.

8.1.11 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.

8.1.12 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.

9 Conclusion

Summary

9.1.1 This FRA has been produced to support the Environmental Statement for the proposed scheme for the dualling of the A9 between Killiecrankie and Glen Garry. The proposed scheme has been developed over a number of assessment stages in broad accordance with the requirements of the DMRB, the requirements of Scottish Planning Policy and SEPA's Technical Guidance for Flood Risk Assessments. The proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'.

9.1.2 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.

9.1.3 Table 26 to Table 30 provide a summary of the FRA findings.

Table 26: Principal Watercourses Summary

Risk	Summary
Baseline	There is a very high risk of fluvial flooding to the existing A9 from the River Garry and Allt Bhaic and both watercourses are classified as being very high sensitivity water features. During the design flood event, specific locations at risk of flooding include: • The existing A9, which is at risk of overtopping immediately upstream of the Essangal Underbridge and the Allt Bhaic Underbridge; • The Highland Main Line Railway line and the B8079, which is also at risk of overtopping upstream of the Essangal Underbridge; • One residential property (Chestnut Cottage) upstream of the Essangal Underbridge along the B8079; • Agricultural land located within the River Garry and Allt Bhaic floodplain.
Potential Impacts	The proposed scheme has been shown to have both beneficial and potentially adverse flood 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; and • Preventing the mainline overtopping would reduce peak flood extents and depths within the Allt Bhaic floodplain. **Negligible flood impacts:** • Local loss of floodplain storage throughout this project area has been shown to have negligible flood Impacts downstream of the Essangal Underbridge. **Adverse flood impacts:** • The proposed scheme results in a loss of floodplain storage as it traverses the River Garry and Allt Bhaic floodplain, which results in peak flood depth increases upstream and downstream of the Pitaldonich and River Garry Underbridges and on the eastern floodplain of the Allt Bhaic. There is also a small area of increased flood depths immediately upstream of the Essangal Underbridge. Areas impacted are confined to the floodplain and include agricultural land already at risk of flooding during the baseline scenario. • The proposed scheme does not increase the risk of flooding to flood sensitive receptors including properties or the Highland Mainline Railway line.
Mitigation Measures	Flood relief culverts were reviewed, but would increase the flood risk and cause scour issues to the receiving floodplain. A residual risk of culvert blockages would also be introduced. Compensatory flood storage was also investigated, but this was not shown to provide the necessary flood depth reductions during the design flood event. In all locations along the River Garry and Allt Bhaic impacted by the proposed scheme, the do-nothing approach is considered the preferred option. Existing flood risk areas are restricted to natural floodplain currently used as agricultural land and consequently the impact due to flooding is considered low. Allowing areas of the land to continue to flood, albeit to a greater depth and possibly with greater frequency, would not adversely impact farm operations on the agricultural land as the land would be available for agricultural use post-scheme by the landowners and their tenants. The area of land subject to an increase in flood levels during the design flood event would be included in the Compulsory Purchase Order. The land would be returned to the landowner with appropriate burdens restricting development and protecting the area for flood storage.

Risk	Summary
Residual Risks	The residual fluvial flood risks remaining are associated with flood events of greater magnitude than the design standard of the proposed scheme. A freeboard allowance has been included in the design to reduce these risks.

Table 27: Minor Watercourses Summary

Risk	Summary
Baseline	According to the preliminary assessment carried out for all existing A9 mainline crossings of minor watercourses, during the design flood event: • 32of the 54 existing A9 mainline watercourse crossings have adequate capacity albeit with limited freeboard; • 6 of the 54 existing A9 mainline watercourse crossings are under capacity but are not considered to pose a risk to the A9 as there is more than 600mm of freeboard between predicted headwater levels and the existing A9; and • 16 of the 54 existing A9 mainline watercourse crossings are under capacity and pose a potential risk of flooding to the existing A9. These are distributed relatively evenly along the existing A9 although clusters are found between Blair Atholl and Bruar and within Calvine.
Potential Impacts	The proposed scheme has been shown to have both beneficial and adverse flood impacts during the design flood event. **Beneficial flood impacts:** • Generally, the proposed scheme has beneficial flood impacts upstream of the mainline watercourse crossings; • 51 of the 53 proposed scheme mainline crossings now have enough capacity to pass the design flood event, which provide major beneficial impacts to 15 watercourse crossings, and as a result, the proposed scheme is not at risk of flooding from any of the minor watercourses assessed. • The proposed scheme provides major beneficial impacts at Calvine, with six properties no longer shown to be at risk of flooding from minor watercourses. • The proposed scheme would prevent flooding to a residential property at Druimuan and would have a minor beneficial effect on flood depths at another property on the B8079 west of Killiecrankie. **Negligible flood impacts:** • The proposed scheme has been shown to potentially increase the amount of pass forward flow downstream of the A9 mainline as a result of culvert modifications. Where there is the potential for this to impact flood sensitive receptors, these have been assessed in detail, with the results showing the scheme would not have an adverse impact. **Adverse flood impacts:** • A detailed assessment has shown that the proposed scheme has minor to moderate adverse impacts to the B8079 at WF92, the B847 through Calvine and the U521 at WF145 and WF156. However, these roads are already at risk of flooding and the proposed scheme would not change the frequency of flooding or local access over what is observed in the baseline scenario.
Mitigation Measures	As the proposed scheme has generally a beneficial or negligible impact of flooding from minor watercourses, the only flood mitigation measures proposed relate to WF92. Here it is proposed that a flow control structure is used to divert exceedance floodwater towards the Allt Girnaig watercourse, via a new 0.7m diameter concrete pipe. This would ensure flood risks are reduced upstream of the A9, whilst maintaining the neutral impacts downstream.
Residual Risks	Residual flood risks along minor watercourses are primarily associated with: • Culvert blockage; and • Flood events greater than the design capacity of the watercourse crossing. In addition to these there would be a minor increase in flood levels along the B8079 where WF92 crosses it.

Table 28: Surface Water Summary

Risk	Summary
Baseline	Generally, the preliminary assessment identifies a low risk of flooding to the existing A9. SEPA Flood Map shows several locations where direct runoff ponds against the existing A9 embankment, ponds on the surface of the A9, or flows across the A9. However, the mapping is likely to be conservative as it does not take into account the road drainage or minor watercourse crossings.
Potential Impacts	As the proposed scheme is an online dualling option, existing surface water flow paths and areas of ponding are likely to remain the unchanged. **Beneficial flood impacts:** The proposed scheme would include new surface water drainage features include PED, road drainage and SuDS, 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 would provide a beneficial impact on surface water flooding when compared to the baseline scenario.

Risk	Summary
Mitigation Measures	Additional mitigation measures beyond that provided within the proposed is not recommended.
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; • Blockages within the drainage infrastructure or SuDS features; or restrictions in flow due to high water levels in receiving watercourses and • Failure of a SuDS feature embankment. 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. The SuDS feature design also 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. There is also an overflow facility provided in each of the outlet controls, again to provide resilience to the design should any blockages or other restrictions occur. Ongoing routine inspection and maintenance of the SuDS features would reduce the likelihood of failure.

Table 29: Groundwater Summary

Risk	Summary
Baseline	Along the existing A9 corridor, there is a risk of shallow groundwater flooding along the valley floor areas, which could contribute to, and extend the duration of other sources of flooding, such as surface water or fluvial flooding in these low-lying areas. However, data collected at this stage suggest the risk of shallow groundwater flooding is low.
Potential Impacts	The proposed scheme has the potential to be at risk of groundwater flooding during both construction and operation phase, especially where the deep excavations are proposed for new road cuttings. However, the information available at this stage suggests that these pressures, and any subsequent impacts, would be localised. **Negligible flood impacts:** It is anticipated that groundwater flood risk can be mostly 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	It is recommended that a groundwater level-monitoring programme be implemented before and during construction, allowing potential impacts to be eliminated through additional mitigation if they arise.
Residual Risks	Residual groundwater flood risk is negligible and no further mitigation is proposed.

Table 30: Failure of Water-Retaining Infrastructure Summary

Risk	Summary
Baseline	The risk of flooding to the existing A9 from reservoirs, aqueducts, WTW, WwTW and sewers are considered to be low.
Potential Impacts	**Negligible flood impacts:** The proposed scheme would not include any works that would alter or affect water-retaining infrastructure and as a result the impact of the proposed scheme is considered to be negligible.
Mitigation Measures	No additional mitigation measures are proposed.
Residual Risks	The residual risk of flooding from water-retaining infrastructure would remain unchanged from the baseline scenario and no additional mitigation measures are proposed.

9.1.4 There are also likely to be a number of activities during 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.

9.1.5 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.

10 References

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Annex A: Impact Assessment Criteria

Sensitivity

The sensitivity of water features associated with the existing risk of flooding or its hydrological importance.

This FRA considers the existing A9 as a flood sensitive receptor. This approach differs from that approach presented in the EIA, which considers the impact of the proposed scheme on other sensitive flood receptors, assuming that the proposed scheme is not a sensitive flood receptor, as it would ultimately be designed to be operational during the design flood event.

This is important because it allows the focus of the EIA to be on the surrounding area rather than considering the impact of the proposed scheme on the A9 itself. However, from a flood risk perspective, the mainline of the proposed scheme must be considered as a sensitive receptor so that it can be designed to remain operational and safe for users during times of flood.

Table 31: 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 at risk or critical social infrastructure units such as the existing A9, hospitals, schools, safe shelters or other land use of great value at risk. Water feature with hydrological importance to: i) sensitive and protected ecosystems of international status; ii) critical economic and social uses (e.g. water supply, navigation, recreation, amenity).
High	A water feature with direct flood risk to the adjacent populated areas, with between 1 and 100 residential properties and/or more than 10 industrial premises at risk from flooding. Water feature with hydrological importance to: i) national designation sensitive and protected ecosystems; ii) locally important economic and social uses (e.g. water supply, navigation, recreation, amenity).
Medium	A water feature with a possibility of direct flood risk to less populated areas without any critical social infrastructure units such as hospitals, schools, safe shelters 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 with minimal hydrological importance to: i) sensitive or protected ecosystems; ii) economic and social uses; iii) with a low probability of flooding of residential and industrial properties.

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.

Table 32: Hydrology and flood risk magnitude of impact criteria

Sensitivity		Criteria
	Major Adverse	Increase in peak flood level 0.5% AEP (200-year) > 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) <+/- 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) >100mm

Impact Significance

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

Table 33: 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: Principal Tributaries Crossing Assessment

Introduction

The existing A9 crosses eleven principal watercourses. To support the widening of the existing A9 road carriageway, the proposed scheme would include alterations to all twelve existing structures. This would include the retention and extension of five structures like-for-like and the demolition and replacement of the remaining seven.

The impact of the proposed scheme on key watercourse crossings including the Essangal Underbridge (ch4300) and the River Garry Underbridge (ch11300) and the Allt Bhaic Underbridge (ch9200) have been assessed using hydraulic modelling and discussed in detailed in Section 3 (Principal Watercourses).

This Annex includes a high-level assessment of the remaining nine principal watercourse crossings. This assessment concludes that the proposed scheme has a low or negligible impact on flooding at these crossings.

Assessment Methodology

This high-level assessment is based purely on the comparison of the existing A9 and proposed scheme crossing details against the SEPA Flood Map.

The SEPA Flood Map is strategic in nature and therefore there are limitations associated with it, which leads to difficulties in representing very steep and upland catchments, areas with low resolution DTM such as NEXTMap, small or narrow river channels and hydraulic structures and flood defence assets. The SEPA Flood Map also does not show flooding for very small watercourses (i.e. catchment areas <3km²).

Assessment Results

Table 34 documents the findings of this high-level assessment, which have also been documented in the Environment Statement (Appendix A11.8: Watercourse Crossing Report).

Table 34: Principal tributary crossing assessment

Water Feature	Structure	Proposed Scheme	Likely Hydraulic Impacts	Flood Impact
WF84 ch800	Eachainn Underbridge	Retain existing structure unaltered	• No impact	No impact
WF87 ch1250	Troopers Culvert	The proposed scheme includes retaining the existing structure (minor wingwall demolition) and extension with same internal dimensions as existing.	• Potential increase in headloss through structure due to extension. • Extended embankment may result in minor loss of floodplain storage; however, SEPA Flood Maps do not cover this watercourse to make assessment. • Any impacts are unlikely to affect nearby sensitive receptors due to their elevation difference from watercourse.	Negligible
WF89 ch1550	Allt Girnaig Underbridge	The proposed scheme includes retaining the existing structure constructing a new parallel structure with same internal dimensions as existing, which includes piers located in-bank and within floodplain.	• Pier extensions are in-line with existing piers; however, are within SEPA Flood Map extents. • Potential negligible increase in headloss through structure due to piers and abutment extension.	Negligible
WF98 ch3350	Allt Chluain Underbridge	The proposed scheme includes retaining the existing structure and extending with same	• SEPA Flood Map extends to width of existing opening and as a result, there may be a negligible loss in floodplain storage.	Negligible

Water Feature	Structure	Proposed Scheme	Likely Hydraulic Impacts	Flood Impact
		internal dimensions as existing. Includes new parallel structure further downstream for slip road with same width as existing structure.	• Potential increase in headloss through structure due to extension of abutments. • New parallel structure may increase headloss through this reach, but effect likely to be insignificant during extreme flood events only.	
WF100 ch4300	Essangal Underbridge	See Section 3 (Principal Watercourses)		
WF115 ch9200	Allt Bhaic Underbridge	See Section 3 (Principal Watercourses)		
WF100 ch11300	Pitaldonich Underbridge	See Section 3 (Principal Watercourses)		
WF142 ch15100	Allt A'Chrombaidh Underbridge	The proposed scheme includes the demolition of the existing structure and a new wider structure constructed. The new structure would be marginally wider, but the proposed soffit level matches existing.	• Extended embankment may result in negligible loss of floodplain storage (based on SEPA Flood Map). • Potential negligible impact on headloss through structure due to extension. However, this is likely to be negated by width increase.	Negligible
WF149 ch16500	Clunes Burn Underbridge	The proposed scheme includes retaining the existing structure (minor wingwall demolition) and extension with same internal dimensions as existing.	• Extended embankment may result in minor loss of floodplain storage; however, SEPA Flood Maps do not cover this watercourse to make assessment. • Potential negligible impact on headloss through structure due to extension.	Negligible
WF158 ch19800	Dalnamein Underbridge	The proposed scheme includes the demolition of the existing structure and the construction of the new structure. The new structure would have no piers in the watercourse (un-like existing), but the proposed soffit level would be lower than existing. The right bank would be lowered for a pony track.	• SEPA Flood Map extends beyond top of bank at the existing bridge; however, this is likely due to poor filtering of DTM. Extended upstream embankment may result in negligible loss of floodplain storage. • Removing the existing piers would reduce the headloss through the bridge. • The existing height of the bridge makes it highly unlikely that the (slightly) lowered soffit level would impact water levels. • Addition of the pony track would increase flow area through the bridge and marginally decrease the equivalent flood level above the track.	Negligible
WF164 ch22000	Allt Geallaidh Underbridge	The proposed scheme includes the demolition of the existing structure and the construction of the new structure, which is marginally wider than existing. The proposed soffit level of the new structure matches existing.	• Watercourse has been subject to hydraulic modelling, which shows that the design flood event would remain in bank. • The proposed structure is therefore not considered to have an impact of floodplain storage due to embankment extension. • Potential increase in headloss through structure resulting from extension likely to be negated by width increase.	Negligible
WF167/ 88 ch18200	Allt Crom Bhruthaich Underbridge	The proposed scheme includes the demolition of the existing structure and the construction of the new structure, which is significantly wider than existing.	• Extended embankment may result in negligible loss of floodplain storage (based on SEPA Flood Map). • Potential increase in headloss through structure resulting from extension likely to be negated by width increase. • No sensitive flood risk receptors downstream.	Negligible

Annex C: Mitigation Measures – Multi Criteria Analysis

Table 35: Multi Criteria Analysis

3 = High Positive Outcome	2 = Positive Outcome	1 = Minor Positive Outcome	0 = No Change	-1 = Minor Negative Impact	-2 = Negative Impact	-3 = Severe Negative Impact

Ref	Mitigation Measure	Description	Technical: Buildability	Technical: Effectiveness	Economic: Initial Costs	Economic: Maintenance Costs	Environmental: Environment	Environmental: Social	Health & Safety: Construction & Maintenance	Health & Safety: Public Use	Total Viability Score	Rank
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
Location 2 – Allt Bhaic Underbridge												
2.1	Do Nothing	No flood mitigation measures implemented.	No construction works required	No mitigation of scheme flood risk impacts. Permanent increase in flood risk from scheme	Landowner agreements and Compulsory Purchase Order as a result of flood risk increase may incur a cost	No maintenance required	Negligible impact	Negative public perception of allowing flood risk increase and not providing mitigation	Nothing to build or maintain means construction and maintenance risks are avoided	Increased risk to life in event of flood	**-3.00**	2
			3	-3	-1	3	0	-3	2	-2		
2.2	Compensatory Storage (Location 1)	Compensatory storage provided within farmland, on left bank of River Garry (ch10100)	Technically feasible, but requires construction on the opposite side of the river to the main works, adding logistical challenges.	Near location of lost floodplain storage. Levels not available to provide all of floodplain storage lost by scheme.	High initial costs. The storage area is on the opposite side of the river to the main works, extending the site boundary and increasing traffic movement.	Minor maintenance required	**Landscape** Negative long-term landscape and visual impacts due to adverse impacts on natural landform and loss of mature riparian trees and woodland. **Ecology** FSA encroaches upon area listed on the NWSS and would result in loss of this habitat. FSA looks like it might encroach upon area designated as River Tay SAC and would result in loss of this terrestrial habitat. The exact boundary of the FSA in relation to that of the SAC is required to confirm this. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed **CPA** No farm business survey details available. Looks to be used for grazing livestock. Assume topsoil retained and replaced and agricultural capability maintained. Land at more risk of flooding but as grassland, will not compromise its use in supporting grazing animals. Would only be able to be used for grazing. **Geomorphology** Functioning of a wandering gravel-bed river would need accounting for in design.	Positive public perception (assuming no major environmental impacts)	Major works required.	No impact	**-7.00**	3
			1	1	-3	-1	-2	3	-2	0		
2.3	Floodwater Conveyance Culverts	Culverts through A9 embankment to re-establish existing link between floodplain north of	Technically feasible - sufficient gradient available between inlets and outlets.	May be difficult to replicate baseline flood risk south of A9 embankment. Culverts must be sized to restrict flow to the existing	Low upfront costs (compared to flood storage)	Regular maintenance required	**Landscape** Limited landscape and visual impact. **Ecology**	Positive public perception (assuming no major environmental	Major highway works required	Increased risk to life in event of flood	**-7**	**3**

Ref	Mitigation Measure	Description	Technical		Economic		Environmental		Health & Safety		Total Viability Score	Rank
			Buildability	Effectiveness	Initial Costs	Maintenance Costs	Environment	Social	Construction & Maintenance	Public Use		
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
		A9 embankment to floodplain to south (ch9600)		0.5%AEP+CC event flow over the embankment - any higher and flood risk may increase on Allt Bhaic. In effect trying to replicate existing flow route from River Garry, into Allt Bhaic and back into River Garry. Flow ultimately ends up back in River Garry. Culverts will be at risk of blockage.			No direct ecological impacts. If the culvert(s) is large enough to incorporate a mammal ledge, there could be a positive ecological outcome. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed. **CPA** Incidence of flooding on farmland south of the scheme may be increased. Also potential debris on land to the south.	impacts and effective as a mitigation measure)				
			3	-2	-1	-2	0	3	-1	-2		
2.4	Compensatory Storage (Location 2)	Compensatory storage provided within farmland on right bank of Allt Bhaic (ch8900)	Technically feasible. Aerial photography shows a steep step in ground level (possible rock outcrop) along central boundary. Requires further investigation.	Near location of lost floodplain volume. Preliminary assessment indicates sufficient storage available but requires excavation below existing ground level.	Moderate initial costs. Requires excavation in an area not covered by exiting design footprint.	Neutral	**Other** Requires removal of some established trees. **Landscape** Limited landscape and visual impact **Ecology** No direct ecological impacts. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed. **CPA** Assume topsoil retained and replaced and agricultural capability maintained. Land at more risk of flooding but as grassland, will not compromise its use in supporting grazing animals. May be debris left post flooding, which would need to be cleared before grazing resumed. Would only be able to be used for grazing.	Positive public perception (assuming no major environmental impacts)	Moderate scale of work required. Excavation adjacent to proposed design footprint.	No impact	**-1**	**1**
			1	1	-2	0	-1	3	-2	0		
2.5	Floodwater Conveyance Culverts	Culverts through A9 embankment (ch9000)	Technically feasible. May be simpler to construct than compensatory storage area.	Flows and flood risk increased downstream. At risk of blockage	Low upfront costs (compared to flood storage)	Regular maintenance required	**Landscape** Limited landscape and visual impact **Ecology** No direct ecological impacts. If the culvert(s) is large enough to incorporate a mammal ledge, there could be a positive ecological outcome. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed. **CPA** Incidence of flooding on farmland south of the scheme may be increased. Also potential debris on land to the south.	Negative public perception of passing on flood risk increase (if increased elsewhere)	Major highway works required	Increased risk to life in event of flood	**-16**	**5**
			2	-3	0	-2	-1	-3	-1	-2		
Location 3 – River Garry Underbridge												

JACOBS

Ref	Mitigation Measure	Description	Technical		Economic		Environmental		Health & Safety		Total Viability Score	Rank
			Buildability	Effectiveness	Initial Costs	Maintenance Costs	Environment	Social	Construction & Maintenance	Public Use		
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
3.1	Do Nothing	No flood mitigation measures implemented.	No construction works required	No mitigation of scheme flood risk impacts. Permanent increase in flood risk from scheme upstream and downstream of Pitaldonich and River Garry Underbridges.	Landowner agreements and Compulsory Purchase Order as a result of flood risk increase may incur a cost	No maintenance required	Negligible impact	Negative public perception of allowing flood risk increase and not providing mitigation Flood risk increase impacts local property access	Nothing to build or maintain means construction and maintenance risks are avoided	Increased risk to life in event of flood	-3	2
			3	-3	-1	3	0	-3	2	-2		
3.2	Compensatory Storage (Location 1)	Compensatory storage provided within farmland on right bank of River Garry (ch11200)	Hillside not as steep as Option 3.3, so smaller volume of excavation required. Site is adjacent to existing work area. Small volume of excavation required approx 1 m below egl, but the majority is between 0m (by the embankment) to 1.5m (to the south west extent). Ground would be reprofiled to relocate existing landform.	Near location of lost floodplain volume. Preliminary assessment indicates sufficient storage available at this location to mitigate risk upstream of River Garry Underbridge. Further assessment required to determine if this will fully mitigate risk downstream of Pitaldonich and River Garry River Garry Underbridges - further storage may need to be provided.	Moderate initial costs. Requires excavation in an area not currently within the design footprint. Opportunities to use excavated material in design?	Neutral	**Landscape** Potentially some landscape and visual impact (at Pitaldonich and Core Path BAST/124/2), particularly during construction, though if area can be returned to pasture with boundaries reinstated and any earthworks slopes are graded to shallow slopes (typically 1:6 or flatter) long term impacts would be fairly minor. Should be designed / adjusted to avoid loss of trees at the northern edge. **Ecology** No direct ecological impacts. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed. **CPA** Assume topsoil retained and replaced and agricultural capability maintained. Land at more risk of flooding but as grassland, will not compromise its use in supporting grazing animals. Can only be used for grazing. May be debris left post flooding, which would need to be cleared before grazing resumed. Field also used for silage. Increased flood risk and depth of floodwater would compromise its use for silage making.	Positive public perception (assuming no major environmental impacts)	Moderate works on hillside and within floodplain required	No impact	-2	1
			0	1	-2	0	-1	3	-1	0		
3.3	Compensatory Storage (Location 2)	Compensatory storage provided within farmland on right bank of River Garry (ch10900)	Steep hillside at this location. Significant volume of excavation required to provide storage at level required. Requires diversion of existing farm access tracks	Near location of lost floodplain volume. Preliminary assessment indicates sufficient storage available at this location. Further assessment required to determine if this option will fully mitigate risk downstream of Pitaldonich and River Garry Underbridges - further storage may need to be provided.	Higher initial costs than option 3.2 (location 1). Requires excavation in an area not currently within the design footprint and required over-excavation to generate volume of storage needed at the required elevation. Opportunities to use excavated material in design.	Neutral	**Other** Encroaches upon area of designated Ancient Woodland. **Landscape** Negative long-term landscape and visual impacts due to adverse impacts on natural landform / hillside and loss of mature woodland. **Ecology** FSA encroaches upon area listed on the AWI and would result in loss of this habitat. FSA encroaches upon area listed on the NWSS and would result in loss of this habitat. The FSA boundary falls within 70m of a main badger sett (at the nearest point) -	Negative public perception resulting from environmental impacts Impacts access to property	Moderate works on hillside and within floodplain required - more substantial than option 3.2	No impact	-18	6

Ref	Mitigation Measure	Description	Technical: Buildability	Technical: Effectiveness	Economic: Initial Costs	Economic: Maintenance Costs	Environmental: Environment	Environmental: Social	Health & Safety: Construction & Maintenance	Health & Safety: Public Use	Total Viability Score	Rank
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
							should the location change and/or access routes are within 30m, then the sett would likely be disturbed. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed **CPA** Increases available area for grassland and grazing animals. Access track lost leads to stopped up access to A9. Access tracks provided as part of design would be sufficient to support agricultural operations. Can only be used for grazing. May be debris left post flooding, which would need to be cleared before grazing resumed. Assuming at same level as existing field, could be used for silage.					
			-2	1	-3	0	-3	-3	-2	0		
3.4	Compensatory Storage (Location 3)	Compensatory storage provided on left bank of River Garry within farmland (ch11700)	Technically feasible but requires excavation up to 3m below egl. Site is adjacent to existing work area.	Hydraulics are more complex at this location - storage is lost upstream of Pitaldonich and River Garry Underbridges below elevation of right bank level. Cannot be like-for-like replacement of storage lost at same elevation. Storage would need to be provided in combination with storage at lower levels at Options 3.2 or 3.3. Further assessment required to determine if this option will fully mitigate risk downstream of Pitaldonich and River Garry Underbridges - further storage may need to be provided.	Moderate initial costs. Requires excavation in an area not currently within the design footprint. Potential opportunities to use excavated material in design. Nearby area of contaminated land would need to be avoided, otherwise significant costs may be incurred	Neutral	**Other** Partially within area of contaminated land, gravel pit. Approximately 50m away from an undesignated archaeological remains and historic buildings region. **Landscape** Reduces potential for proposed grading out of Bruar Junction embankments to integrate with natural landform. Appears to remove riparian trees which would have a negative landscape and visual effect. If this can be avoided, there would still be an impact on landform, but hard to determine without further detail (cross sections etc). **Ecology** FSA encroaches upon area listed on the NWSS and would result in loss of this habitat. FSA encroaches upon area designated as River Tay SAC and would result in loss of this terrestrial habitat. Indirect impacts on ecology via changes to fluvial geomorphology and the structure, function and supporting processes of the River Tay SAC will need to be assessed. **CPA** Assume topsoil retained and replaced and agricultural capability would be reduced because of slope and proximity to river. Land at more risk of flooding but as grassland, will not compromise its use in supporting grazing animals. Can only be used for grazing.	Positive public perception (assuming no major environmental impacts)	Moderate works on hillside and within floodplain required	No impact	-12	4
			2	-3	-2	0	-2	3	-2	0		
3.5	Floodwater Conveyance Culverts	Culvert within floodplain conveying water through existing and proposed A9 road	Technically feasible. Would require multiple new culverts with headwalls spanning the new road	Flows and flood risk increased downstream. Flood risk impacts of the scheme may be fully mitigated upstream of	Lower upfront costs (compared to flood storage)	Regular maintenance required	**Landscape** Limited landscape and visual impact. **Ecology** No direct ecological impacts. If the culvert(s) is large enough to incorporate a mammal ledge, there could	Negative public perception of passing on flood risk increase	Would require several large diameter culverts to be installed	Increased risk to life in event of flood	-9	3

Ref	Mitigation Measure	Description	Technical: Buildability	Technical: Effectiveness	Economic: Initial Costs	Economic: Maintenance Costs	Environmental: Environment	Environmental: Social	Health & Safety: Construction & Maintenance	Health & Safety: Public Use	Total Viability Score	Rank
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
		embankment (ch11000)	alignment. May be simpler to construct than compensatory storage area.	River Garry Underbridge but will be increased downstream of Pitaldonich Underbridge Culverts will be at risk of blockage Does not provide like for like storage replacement			be a positive ecological outcome. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed **CPA** Assume no loss of agricultural land. Conveyance may lead to scouring of topsoils and deposit of debris on land north of the A9. Existing land use south (grazing and silage) and north (grazing) of the A9 maintained.					
			3	-3	1	-2	0	-2	-1	-2		
3.6	Compensatory Storage (Location 4)	Compensatory storage provided within farmland on left bank of River Garry(ch11000)	Technically feasible - but many unknowns at this stage. Narrow site - approximately 50 m distance from top of bank to road. River bank very steep (7.5 m vertical drop over 20 m distance). Storage area is slightly more remote from the main works area; so specific access would need to be created.	Preliminary assessment indicates sufficient storage available but requires excavation below existing ground level This option may fully mitigate flood risk impacts of the scheme downstream of Pitaldonich Underbridge but will not on its own address impacts upstream of River Garry Underbridge.	High initial costs	Minor maintenance required to ensure long term stability of bank.	**Other** River bank reprofiling - loss of trees. Within River Tay SAC. **Landscape** Landscape impact from loss of riparian trees **Ecology** FSA encroaches upon area designated as River Tay SAC and would result in loss of this terrestrial habitat. Indirect impacts on fluvial geomorphology and the structure, function and supporting processes of the River Tay SAC will need to be assessed. **CPA** No specific impacts on agricultural use assuming stability of bank maintained. Potential loss of agricultural land to access track to area. **Geomorphology** Storage in close proximity to banks of a wandering gravel-bed river - risk of future river channel change which may compromise the compensatory flood storage	Negative public perception of allowing flood risk increase upstream of Pitaldonich and River Garry Underbridges Flood risk increase upstream of Pitaldonich and River Garry Underbridges impacts local property access	Major works required. Working near water.	Increased risk to life in event of flood (upstream of Pitaldonich and River Garry Underbridges)	**-27**	**7**
			-1	-2	-3	-1	-2	-2	-2	-2		
3.7	Compensatory Storage (Location 5)	Compensatory storage provided within farmland on left bank of River Garry (ch10800)	Technically feasible. River bank very steep.	Preliminary assessment indicates sufficient storage available, but in danger of providing storage downstream of area affected, thus having no impact This option on its own will not address impacts at upstream of the Pitaldonich and River Garry Underbridges.	High initial costs. May require greater purchase of land than option 3.3	Minor maintenance required to ensure long term stability of bank.	**Landscape** Loss of riparian trees and landscape impact on landform of river corridor, but hard to determine without further detail (cross sections etc.). **Ecology** FSA looks like it might encroach upon area designated as River Tay SAC and would result in loss of this terrestrial habitat. The exact boundary of the FSA in relation to that of the SAC is required to confirm this. Indirect impacts on fluvial geomorphology and the structure, function and supporting processes of the River Tay SAC will need to be assessed. **CPA** No specific impacts on agricultural use assuming stability of bank maintained. Potential loss of agricultural land to access track to area. **Geomorphology**	Negative public perception of allowing flood risk increase upstream of the Pitaldonich and River Garry Underbridges Flood risk increase upstream of the Pitaldonich and River Garry Underbridges impacts local property access	Major works required. Working near water.	Increased risk to life in event of flood (upstream of Pitaldonich and River Garry Underbridges)	**-30**	**8**

Ref	Mitigation Measure	Description	Technical		Economic		Environmental		Health & Safety		Total Viability Score	Rank
			Buildability	Effectiveness	Initial Costs	Maintenance Costs	Environment	Social	Construction & Maintenance	Public Use		
		Criteria Score Weighting	2	3	3	2	1	1	1	1		
							Storage in close proximity to banks of a wandering gravel-bed river - risk of future river channel change which may compromise the compensatory flood storage. Bank erosion is visible on the aerial imagery in the proposed flood storage location.					
			-1	-3	-3	-1	-2	-2	-2	-2		
3.8	Compensatory Storage (Location 6)	Compensatory storage provided within farmland on right bank of River Garry, directly adjacent to widened A9 embankment (ch11000)	Trimming of existing ground level required throughout field. Reduced volume of excavation compared to other compensatory storage locations. Site neighbours existing work area. Shallow excavation only.	Adjacent to location of lost floodplain storage. Preliminary assessment indicates sufficient storage available at all levels storage lost. This option may fully mitigate flood risk impacts of the scheme downstream of the Pitaldonich Underbridge but will not on its own address impacts upstream of the River Garry Underbridge.	Low to moderate initial costs. Requires excavation in an area now covered by design footprint but can be returned to previous landuse once completed. Excavated material could potentially be used in the works.	Neutral	**Landscape** Adverse landscape and visual impact, during construction and in the longer term, particularly due to loss of native trees, which are an important feature of the landscape. **Ecology** FSA encroaches upon area designated as Aldclune and Invervack Meadows SSSI and would result in loss of this habitat. FSA encroaches upon area listed on the NWSS and would result in loss of this habitat. FSA encroaches upon area listed on the AWI and would result in loss of this habitat. FSA looks like it might encroach upon area designated as River Tay SAC and would result in loss of this terrestrial habitat. The exact boundary of the FSA in relation to that of the SAC is required to confirm this. If there are changes to fluvial geomorphology this could result in indirect impacts on ecology and on the structure, function and supporting processes of the River Tay SAC, which will need to be assessed **CPA** Assume topsoil retained and replaced and agricultural capability maintained. Land at more risk of flooding but as grassland, will not compromise its use in supporting grazing animals. May be debris left post flooding which would need to be cleared before grazing resumed. Would only be able to be used for grazing. **Geomorphology** Functioning of a wandering gravel-bed river would need accounting for in design.	Minimal visual impact (field will look largely same as present) Negative public perception of impacting environmentally sensitive site Negative public perception of allowing flood risk increase upstream of the Pitaldonich and River Garry Underbridges. Flood risk increase upstream of the Pitaldonich and River Garry Underbridges impacts local property access	Major works required. Working near water.	Increased risk to life in event of flood (upstream of Pitaldonich and River Garry Underbridges)	**-15**	**5**
			2	-2	-1	0	-3	-3	-2	-2		

Annex D: Hydraulic Performance Assessment

Approach

The culvert capacity and stage/discharge relationship for all minor watercourses (not identified for detailed numerical modelling) were derived using the culvert analysis methodology presented within CIRIA C689. The methodology calculates the upstream headwater level (HWL) at the culvert for a range of discharges up to the design flood event and involved the following steps:

- computation of average channel gradient and the culvert inlet/outlet levels using the topographic survey data;
- computation of average channel geometry downstream of the culvert, e.g., bottom width (b), top width (B), side slope using at least three channel cross sections downstream of the culvert using the topographic survey sections;
- manning roughness ‘n’ for channel and culvert sections is based on the photographs taken by the surveyor from the site, information gathered during site visits and using CIRIA guidelines; and
- culvert inlet/outlet and minor loss coefficients from CIRIA C689 guidelines

The results of the minor watercourse crossing hydraulic performance assessment for both the baseline and proposed scheme (no mitigation) scenarios are contained within a spreadsheet provided outside of this FRA report. The spreadsheet includes the crossing location, diameter, soffit level, invert level, upstream bank level and existing and proposed A9 level, peak flow during the 0.5% AEP (200-year) plus climate change event (the design flood event) and derived HWL. When compared, the data helps identify:

- free-flow or surcharged conditions;
- in-bank or out-of-bank flow;
- locations where the A9 is at risk of overtopping (HWL > A9 level – 600mm freeboard); and
- impacts of the proposed scheme.

Assumptions & Limitations

The preliminary assessment is based on the following assumptions:

- the methodology adopted to estimate HWLs is presented in CIRIA’s Culvert Design and Operation Guide.
- both upstream and downstream channel cross-sections are identical based on a simplified trapezoidal representation of the observed geometry.
- all structures are considered free of debris, straight, in good operational order and culvert inlets and outlets are designed appropriately to minimise hydraulic head loss.
- the Manning’s roughness coefficients for the culvert and channel section are based on available guidance in Chow, 1959.
- the assessment assumes that the tailwater level (TWL) immediately downstream of the culvert is determined by the downstream channel using ‘normal’ water depth calculated using Manning’s equation. The impact of any other downstream structure exerting a hydraulic control on the culvert has not been considered; and
- where the predicted HWL exceeds the channel level or structure diameter/height, in particular for small diameter culverts, the predicted HWL is likely to be conservative estimate as the upstream channel cross sectional area is confined to the channel width. No account is taken regarding the shape of the design hydrograph and consequently the flood volume, or the attenuation afforded by flood storage on adjacent floodplain or overtopping of the carriageway. These assumptions make the preliminary assessment a conservative estimate of water levels.

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Table 36: Baseline hydraulic assessment – A9 Mainline Culverts

	Baseline Culvert Geometry – A9 Mainline						Baseline Culvert Hydraulic Performance – A9 Mainline					
Ref	Culvert length (m)	Inlet Invert Level (mAD)	Culvert dia/height (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Baseline Road Level (mAD)	Design Q200 + CC Flow (m^3/s)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9
87	62.90	154.30	2.50	156.80	155.02	164.48	4.42	155.55	Free-Flow	1.25	Out Bank	8.93
92	35.50	161.66	0.90	162.56	161.90	164.58	3.62	166.47	Surcharged	-3.91	Out Bank	-1.89
95	39.00	161.69	0.65	162.34	0.00	165.90	0.00	162.25	Free-Flow	0.09	Out Bank	3.65
96	44.20	159.18	0.65	159.83	159.96	165.43	0.82	160.23	Surcharged	-0.40	Out Bank	5.20
97	31.10	158.89	0.85	159.74	160.52	159.81	1.38	160.21	Surcharged	-0.47	In Bank	-0.40
101	31.10	127.97	1.00	128.97	131.09	130.07	1.01	128.78	Free-Flow	0.19	In Bank	1.29
102	47.20	141.98	1.00	142.98	143.38	146.02	0.76	142.68	Free-Flow	0.31	In Bank	3.34
103	39.50	140.73	1.00	141.73	142.12	144.14	0.95	141.46	Free-Flow	0.27	In Bank	2.68
104	54.10	142.78	0.60	143.38	142.98	144.27	0.15	143.25	Free-Flow	0.13	Out Bank	1.03
105	30.30	142.70	0.44	143.14	143.96	144.70	0.13	143.11	Free-Flow	0.03	In Bank	1.59
106	27.00	145.82	0.65	146.47	146.18	148.13	0.35	146.36	Free-Flow	0.12	Out Bank	1.78
107	40.00	145.58	0.30	145.88	147.41	150.90	0.44	145.76	Free-Flow	0.12	In Bank	5.14
108	29.20	151.06	0.49	151.55	152.56	152.71	0.66	152.93	Surcharged	-1.38	Out Bank	-0.22
109	40.50	159.85	0.66	160.51	160.67	151.55	0.58	160.63	Surcharged	-0.12	In Bank	-9.08
110	45.10	151.14	0.60	151.74	152.05	148.54	0.42	151.72	Free-Flow	0.02	In Bank	-3.18
111	48.40	151.58	0.65	152.23	152.37	147.55	1.06	153.27	Surcharged	-1.04	Out Bank	-5.72
112	57.59	152.78	0.66	153.44	153.78	145.51	0.88	154.03	Surcharged	-0.59	Out Bank	-8.52
113	37.24	145.77	0.60	146.37	147.71	144.22	0.99	147.75	Surcharged	-1.38	Out Bank	-3.53
114	27.40	144.05	0.60	144.65	145.25	143.45	0.79	145.20	Surcharged	-0.56	In Bank	-1.75
116	28.60	136.82	0.60	137.42	137.73	138.80	1.11	139.25	Surcharged	-1.83	Out Bank	-0.44
117	23.80	139.63	0.60	140.23	141.04	141.62	2.52	147.66	Surcharged	-7.43	Out Bank	-6.04
118	21.60	140.78	1.00	141.78	141.13	143.19	0.31	141.26	Free-Flow	0.53	Out Bank	1.94
119	25.80	144.41	1.00	145.41	144.89	143.93	1.06	145.25	Free-Flow	0.16	Out Bank	-1.32
120	61.30	152.98	1.20	154.18	153.48	146.32	1.20	154.11	Free-Flow	0.07	Out Bank	-7.79
121	24.50	147.35	1.00	148.35	148.81	146.69	1.57	148.72	Surcharged	-0.38	In Bank	-2.03
122	35.00	143.10	0.38	143.48	143.14	148.10	2.60	229.39	Surcharged	-85.91	Out Bank	-81.29
125	20.10	158.16	0.57	158.73	159.18	159.32	0.87	160.28	Surcharged	-1.55	Out Bank	-0.96
127	30.50	163.99	0.65	164.64	165.34	167.65	2.93	173.59	Surcharged	-8.95	Out Bank	-5.94
128	68.00	178.04	0.55	178.59	178.87	180.08	0.82	179.91	Surcharged	-1.32	Out Bank	0.17
131	24.20	198.33	0.45	198.78	199.28	198.27	0.60	198.63	Free-Flow	0.15	In Bank	-0.36
132	67.10	207.78	1.00	208.78	209.19	200.65	1.79	209.05	Surcharged	-0.27	In Bank	-8.40
134	24.30	202.16	1.00	203.16	202.89	202.94	1.79	203.44	Surcharged	-0.28	Out Bank	-0.50
136	28.00	206.11	0.67	206.78	206.88	205.35	1.65	209.38	Surcharged	-2.60	Out Bank	-4.03
137	84.90	209.71	1.30	211.01	209.78	207.45	1.15	210.52	Free-Flow	0.49	Out Bank	-3.07
139	22.30	209.65	1.22	210.87	210.11	211.32	1.71	210.62	Free-Flow	0.25	Out Bank	0.70
140	34.60	209.89	1.20	211.09	211.12	211.32	2.76	211.36	Surcharged	-0.27	Out Bank	-0.04
141	31.50	207.44	1.50	208.94	208.19	210.20	0.00	208.76	Free-Flow	0.18	Out Bank	1.44
143	18.80	212.40	1.20	213.60	212.90	213.79	0.00	213.33	Free-Flow	0.27	Out Bank	0.46
144	40.00	224.85	1.40	226.25	226.01	226.02	1.33	225.68	Free-Flow	0.57	In Bank	0.34
145	28.70	230.07	1.20	231.27	231.37	231.60	2.98	231.76	Surcharged	-0.49	Out Bank	-0.16
147	27.70	233.75	1.20	234.95	235.48	235.55	1.15	234.59	Free-Flow	0.36	In Bank	0.96
148	55.20	237.08	1.20	238.28	238.06	239.55	0.65	237.74	Free-Flow	0.54	In Bank	1.81
151	61.70	247.68	1.20	248.88	250.07	258.69	1.42	248.64	Free-Flow	0.24	In Bank	10.05
152	29.00	260.55	1.20	261.75	262.13	261.73	0.30	260.97	Free-Flow	0.78	In Bank	0.76
153	37.50	262.41	1.20	263.61	263.58	263.28	1.14	263.24	Free-Flow	0.37	In Bank	0.04
154	21.10	265.14	1.50	266.64	266.93	266.90	2.25	266.45	Free-Flow	0.19	In Bank	0.45
155	27.50	263.38	1.20	264.58	264.81	265.92	0.67	263.98	Free-Flow	0.60	In Bank	1.94
156	24.70	260.46	0.68	261.14	261.84	261.56	2.89	270.87	Surcharged	-9.73	Out Bank	-9.31
157	36.10	258.33	1.00	259.33	258.88	259.56	0.63	258.92	Free-Flow	0.41	Out Bank	0.64
159	30.80	265.35	1.68	267.03	265.90	270.07	2.30	266.40	Free-Flow	0.63	Out Bank	3.67

	Baseline Culvert Geometry – A9 Mainline						Baseline Culvert Hydraulic Performance – A9 Mainline					
Ref	Culvert length (m)	Inlet Invert Level (mAD)	Culvert dia/height (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Baseline Road Level (mAD)	Design Q200 + CC Flow (m^3/s)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9
160	20.10	266.17	1.08	267.25	267.57	268.17	1.40	267.17	Free-Flow	0.07	In Bank	1.00
161	22.60	266.10	1.08	267.17	267.71	268.71	1.31	267.06	Free-Flow	0.11	In Bank	1.65
162	20.40	266.78	1.20	267.98	268.85	268.98	1.06	267.56	Free-Flow	0.42	In Bank	1.42
163	26.30	277.52	1.20	278.72	279.04	278.62	0.77	278.20	Free-Flow	0.52	In Bank	0.42

Table 37: Proposed scheme hydraulic assessment – A9 Mainline Culverts

	Proposed Culvert Geometry – A9 Mainline						Proposed Culvert Hydraulic Performance – A9 Mainline					
Ref	Culvert length (m)	Inlet Invert Level (mAD)	Culvert dia/height (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Proposed Road Level (mAD)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9	Comment
87	118.00	154.55	2.50	157.05	155.27	164.78	156.25	Free-Flow	0.80	Out Bank	8.53	Modelling undertaken - see Chapter 4
92	47.30	161.46	2.00	163.56	163.30	164.52	162.90	Free-Flow	0.66	In Bank	1.62	Modelling undertaken - see Chapter 4
95	70.00	161.44	0.80	162.49	162.34	166.13	162.32	Free-Flow	0.17	In Bank	3.81	Further assessment - see Table 18
96	55.30	159.18	0.65	159.83	159.96	165.53	160.23	Surcharged	-0.40	Out Bank	5.30	Further assessment - see Chapter 4
97	culvert to be removed					159.81	culvert to be removed					Culvert removed, no assessment
101	48.40	127.97	1.00	128.97	131.09	130.40	128.82	Free-Flow	0.15	In Bank	1.58	Further assessment - see Table 18
102	56.00	147.05	1.00	148.10	148.50	146.47	147.93	Free-Flow	0.17	In Bank	-1.47	Further assessment - see Table 18
103	48.70	141.30	1.00	142.50	143.00	144.50	142.25	Free-Flow	0.25	In Bank	2.25	Further assessment - see Table 18
104	58.70	143.05	0.60	144.10	143.70	144.52	143.96	Free-Flow	0.14	Out Bank	0.56	Further assessment - see Table 18
105	58.70	143.10	0.60	143.70	146.10	144.85	143.57	Free-Flow	0.13	In Bank	1.28	Further assessment - see Table 18
106	62.70	145.91	1.00	147.11	147.51	147.83	146.65	Free-Flow	0.46	In Bank	1.18	Further assessment - see Table 18
107	70.70	147.63	0.80	148.98	148.68	149.99	148.78	Free-Flow	0.20	Out Bank	1.21	Further assessment - see Table 18
108	54.70	151.16	1.00	152.16	152.16	152.61	151.87	Free-Flow	0.29	In Bank	0.74	No DS receptors, low risk
109	50.00	150.21	0.90	151.11	152.01	151.85	150.90	Free-Flow	0.22	In Bank	0.95	No DS receptors, low risk
110	37.30	147.32	0.90	148.22	148.82	148.68	147.89	Free-Flow	0.34	In Bank	0.79	No DS receptors, low risk
111	49.30	145.80	1.00	147.00	147.70	147.71	146.87	Free-Flow	0.13	In Bank	0.84	No DS receptors, low risk
112	66.00	145.00	1.20	146.20	146.80	146.92	145.69	Free-Flow	0.51	In Bank	1.22	No DS receptors, low risk
113	54.70	143.75	1.00	145.10	145.90	145.90	144.96	Free-Flow	0.14	In Bank	0.94	No DS receptors, low risk
114	43.30	141.80	1.20	143.00	143.60	145.24	142.43	Free-Flow	0.57	In Bank	2.81	No DS receptors, low risk
116	65.30	137.45	1.20	138.80	138.60	141.27	138.48	Free-Flow	0.32	In Bank	2.79	No sensitive receptors, low risk
117	58.00	140.95	0.60	141.85	142.66	144.84	145.49	Surcharged	-3.64	Out Bank	-0.64	Modelling undertaken - see Chapter 4
118	49.30	144.61	1.20	145.96	146.46	147.25	145.26	Free-Flow	0.70	In Bank	1.98	Further assessment - see Table 18
119	70.70	146.50	1.00	147.55	147.50	148.78	147.37	Free-Flow	0.18	In Bank	1.41	Further assessment - see Table 18
120	74.70	148.50	1.20	149.70	150.50	150.69	149.40	Free-Flow	0.30	In Bank	1.29	Low risk
121	52.00	148.95	1.50	150.45	153.95	151.31	150.04	Free-Flow	0.41	In Bank	1.28	Low risk
122	66.00	143.17	0.90	144.22	143.90	150.72	143.92	Free-Flow	0.30	Out Bank	6.80	Low risk
125	179.00	158.49	1.20	159.84	160.02	165.12	159.24	Free-Flow	0.60	In Bank	5.88	No DS receptors, low risk
127	145.30	163.88	1.80	165.88	165.43	168.85	165.55	Free-Flow	0.33	Out Bank	3.30	No DS receptors, low risk
128	79.30	172.50	0.60	173.10	174.50	180.62	0.00	Free-Flow	173.10	In Bank	180.62	No DS receptors, low risk
131	35.20	196.55	0.45	197.15	198.30	198.25	0.00	Free-Flow	197.15	In Bank	198.25	Low risk
132	56.70	207.58	1.40	209.18	209.19	200.77	208.79	Free-Flow	0.39	In Bank	-8.02	Modelling undertaken - see Chapter 4
134	66.70	207.80	1.40	209.40	208.73	202.93	209.10	Free-Flow	0.30	Out Bank	-6.17	Modelling undertaken - see Chapter 4
136	27.60	203.25	1.20	204.60	205.60	205.78	204.43	Free-Flow	0.17	In Bank	1.35	Modelling undertaken - see Chapter 4
137	84.90	204.30	1.30	205.80	207.80	207.60	205.35	Free-Flow	0.45	In Bank	2.24	Further assessment - see Table 18
139	58.70	208.70	1.20	210.20	211.28	211.36	210.05	Free-Flow	0.15	In Bank	1.31	Further assessment - see Table 18
140	34.00	209.25	1.50	210.75	211.38	211.24	210.42	Free-Flow	0.33	In Bank	0.82	Modelling undertaken - see Chapter 4
141	118.00	222.20	1.60	223.80	223.67	210.15	223.58	Free-Flow	0.22	In Bank	-13.43	Further assessment - see Table 18
143	29.30	212.25	1.20	213.60	213.87	213.96	213.19	Free-Flow	0.41	In Bank	0.77	Further assessment - see Table 18
144	38.70	224.00	1.40	225.60	226.40	226.17	225.00	Free-Flow	0.60	In Bank	1.17	Further assessment - see Table 18
145	37.50	229.80	1.50	231.30	231.85	231.85	231.20	Free-Flow	0.10	In Bank	0.65	Modelling undertaken - see Chapter 4
147	36.70	233.65	1.20	235.00	235.30	235.73	234.55	Free-Flow	0.45	In Bank	1.18	Further assessment - see Table 18

	Proposed Culvert Geometry – A9 Mainline						Proposed Culvert Hydraulic Performance – A9 Mainline					
Ref	Culvert length (m)	Inlet Invert Level (mAD)	Culvert dia/height (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Proposed Road Level (mAD)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9	Comment
148	109.40	238.20	1.20	239.40	239.70	239.79	239.00	Free-Flow	0.40	In Bank	0.79	Further assessment - see Table 18
151	73.30	247.68	1.20	248.88	250.07	258.87	248.67	Free-Flow	0.21	In Bank	10.20	Further assessment - see Table 18
152	68.00	260.40	1.20	261.75	262.13	262.32	261.17	Free-Flow	0.58	In Bank	1.15	Further assessment - see Table 18
153	90.60	262.54	1.20	263.74	263.71	263.92	263.40	Free-Flow	0.34	In Bank	0.52	Further assessment - see Table 18
154	50.20	264.44	1.60	266.04	266.23	266.93	265.74	Free-Flow	0.30	In Bank	1.19	Low risk
155	62.40	263.38	1.20	264.73	264.95	265.87	264.26	Free-Flow	0.47	In Bank	1.61	Further assessment - see Table 18
156	38.10	259.45	1.80	261.25	260.83	262.68	260.60	Free-Flow	0.65	In Bank	2.08	Modelling undertaken - see Chapter 4
157	57.90	256.73	1.00	257.73	258.73	260.36	257.37	Free-Flow	0.36	In Bank	2.99	Further assessment - see Table 18
159	55.20	265.51	1.68	267.51	266.38	270.19	266.81	Free-Flow	0.70	Out Bank	3.38	Further assessment - see Table 18
160	52.40	266.90	1.20	268.25	268.45	269.06	267.93	Free-Flow	0.32	In Bank	1.13	Further assessment - see Table 18
161	35.00	267.16	1.20	268.51	268.92	269.30	268.10	Free-Flow	0.41	In Bank	1.20	Low risk
162	31.70	267.54	1.20	268.89	269.76	269.52	268.41	Free-Flow	0.49	In Bank	1.12	Further assessment - see Table 18
163	38.40	277.52	1.20	278.72	279.04	280.50	278.21	Free-Flow	0.51	In Bank	2.29	Further assessment - see Table 18

Table 38: Proposed scheme hydraulic assessment – side roads

Proposed Culvert Geometry – Side Roads						Proposed Culvert Hydraulic Performance – Side Roads					
Ref	Culvert Inlet Invert Level (mAD)	Culvert Size di (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Proposed track level (mAD)	Design Q200 + CC Flow (m^3/s)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to Road Level (m)
92/ACC/DS	Within mainline culvert					Within mainline culvert					
95/ACC/DS	Within mainline culvert					Within mainline culvert					
96/ACC/DS	Within mainline culvert					Within mainline culvert					
178/Junction	121.10	1.20	122.30	122.44	124.143	1.29	122.22	Free-Flow	0.08	In Bank	1.92
102/ACC/US	148.51	0.90	149.41	151.05	150.09	0.95	149.42	Surcharged	0.00	In Bank	0.68
102/ACC/DS	129.19	0.90	130.09	130.77	130.56	0.95	130.13	Surcharged	-0.04	In Bank	0.43
103/NMU/US	152.45	0.75	153.20	153.52	153.53	0.15	152.89	Free-Flow	0.31	In Bank	0.64
103/ACC/DS	125.47	0.75	126.22	126.20	130.74	0.15	125.92	Free-Flow	0.30	In Bank	4.82
104/NMU/US	Mainline culvert extended					Mainline culvert extended					
104/ACC/DS	Within mainline culvert					Within mainline culvert					
105/ACC/DS	Within mainline culvert					Within mainline culvert					
106/ACC/DS	160.95	0.75	161.70	162.10	162.41	0.42	161.59	Free-Flow	0.11	In Bank	0.82
107/ACC/DS	159.20	1.05	160.25	160.71	160.89	1.06	160.03	Free-Flow	0.22	In Bank	0.86
110/NMU/US	159.35	0.90	160.25	159.68	160.77	0.88	160.25	Free-Flow	0.00	Out Bank	0.52
111/NMU/US	151.15	1.05	152.20	151.45	152.73	0.99	151.99	Free-Flow	0.21	Out Bank	0.73
112/NMU/US	172.62	1.35	173.97	172.81	174.70	2.52	173.95	Free-Flow	0.02	Out Bank	0.75
113/NMU/US	140.80	1.20	142.00	144.11	143.73	1.20	141.72	Free-Flow	0.28	In Bank	2.02
117/ACC/US	171.85	1.20	173.05	173.32	174.03	1.57	172.92	Free-Flow	0.13	In Bank	1.11
120/ACC/DS	Within mainline culvert					Within mainline culvert					
121/ACC/US	Within mainline culvert					Within mainline culvert					
121/ACC/DS	248.29	1.50	249.79	249.14	250.21	3.29	249.68	Free-Flow	0.11	Out Bank	0.53
122/ACC/DS	Diverted					Diverted					
145/ACC/US	269.27	1.50	270.77	270.25	271.78	2.89	270.59	Free-Flow	0.18	Out Bank	1.19
146/ACC/US	259.35	0.90	260.25	262.50	262.26	0.63	260.06	Free-Flow	0.19	In Bank	2.21

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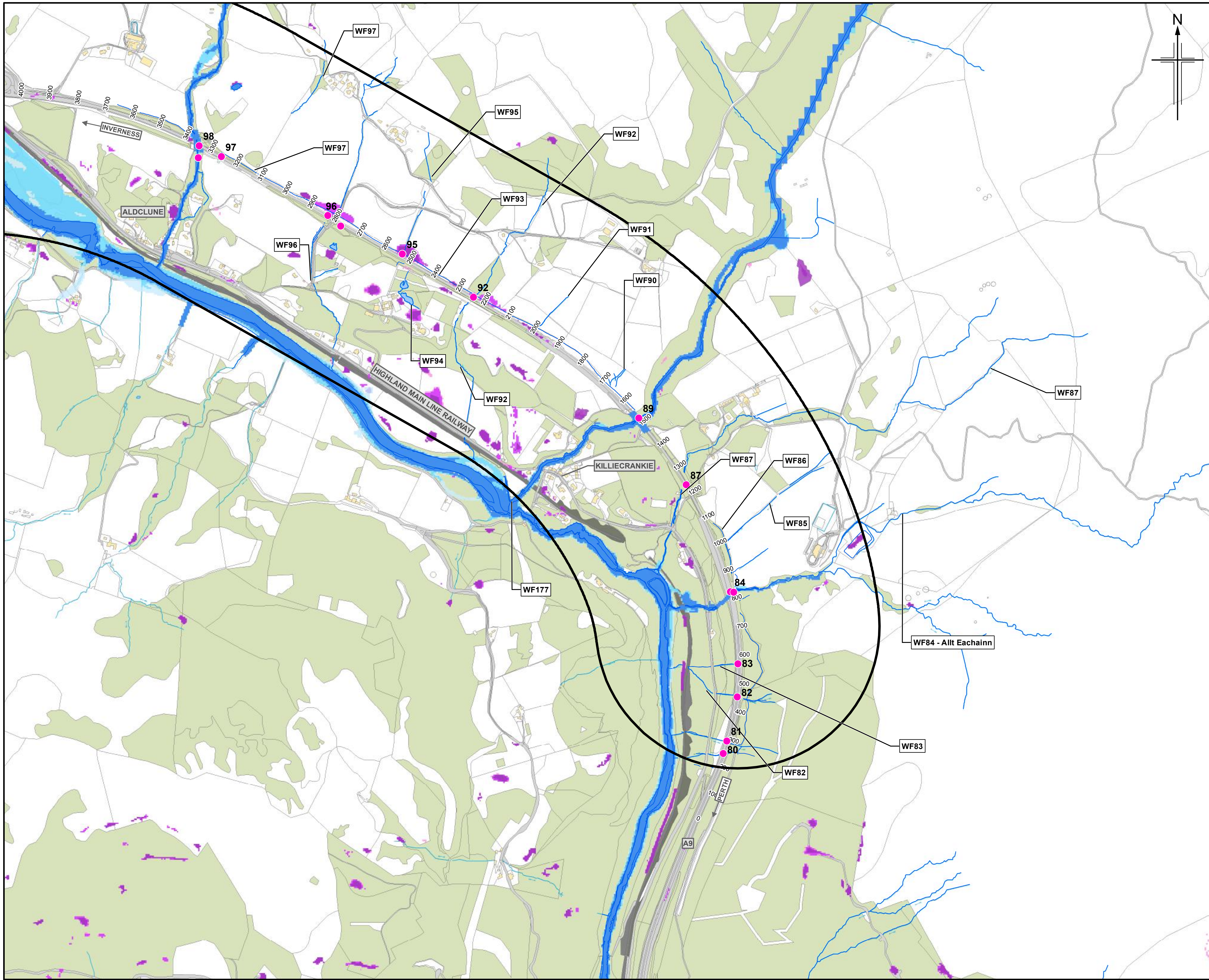
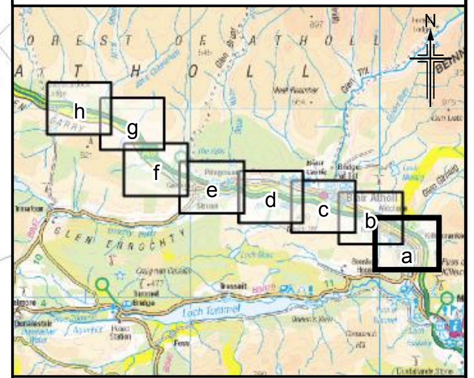
Annex E: Flood Risk Assessment Figures

- Figures A11.3.1a-h - SEPA Flood Map – Baseline Scenario
- Figures A11.3.2a-c - Baseline Flood Depth Map – Baseline Scenario
- Figures A11.3.3a-c - Fluvial Flood Depth Map with Scheme (No Mitigation)
- Figures A11.3.4a-c - Proposed-Scheme (No Mitigation) Flood Impact Map

Figure A11.3.1a





Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

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PERTH TO INVERNESS
Killiecrankie to Glen Garry

Drawing title

Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 1 of 8

Drawing Status	FINAL
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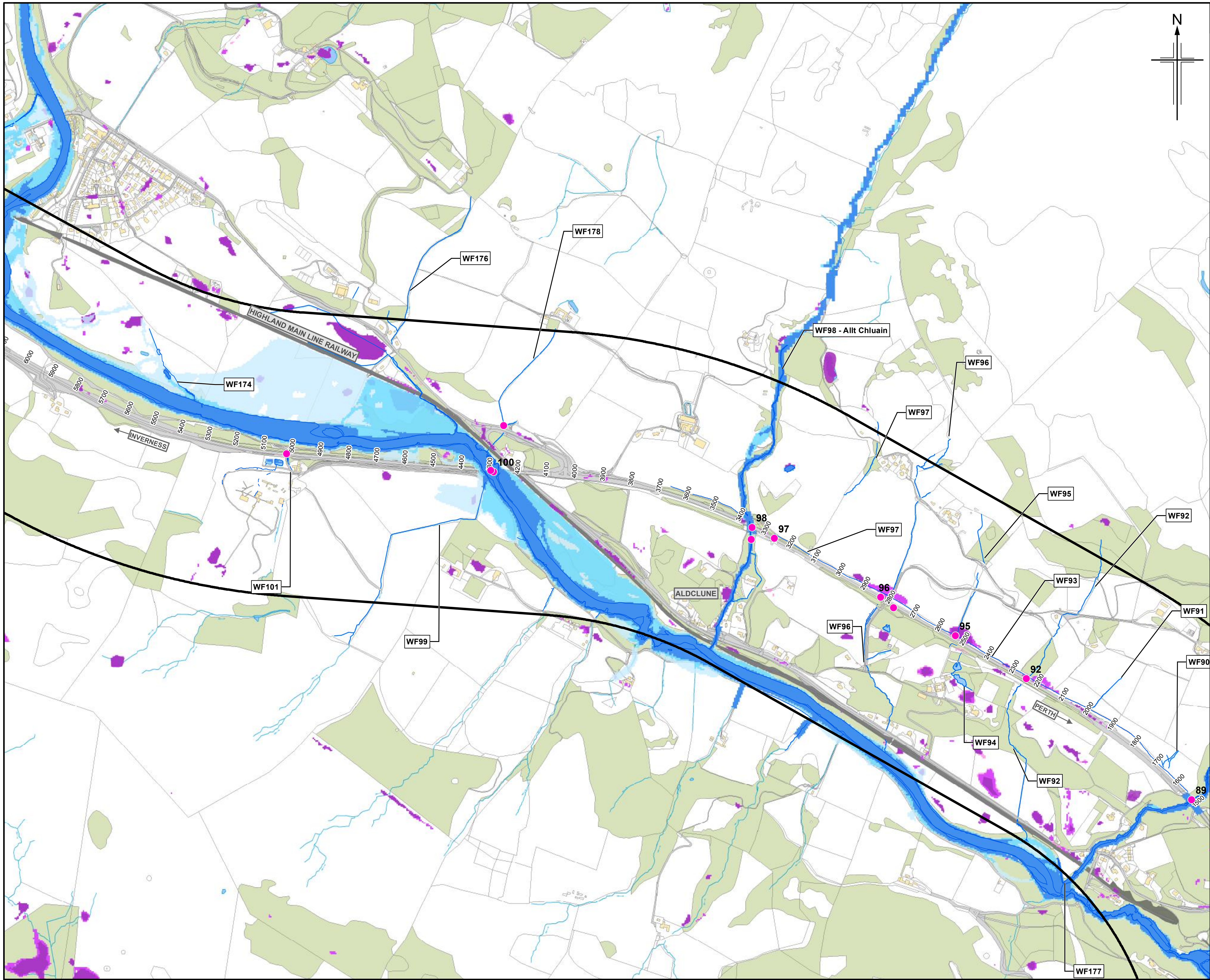

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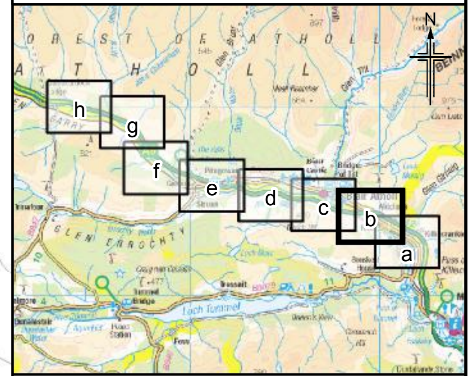
Figure A11.3.1b



Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

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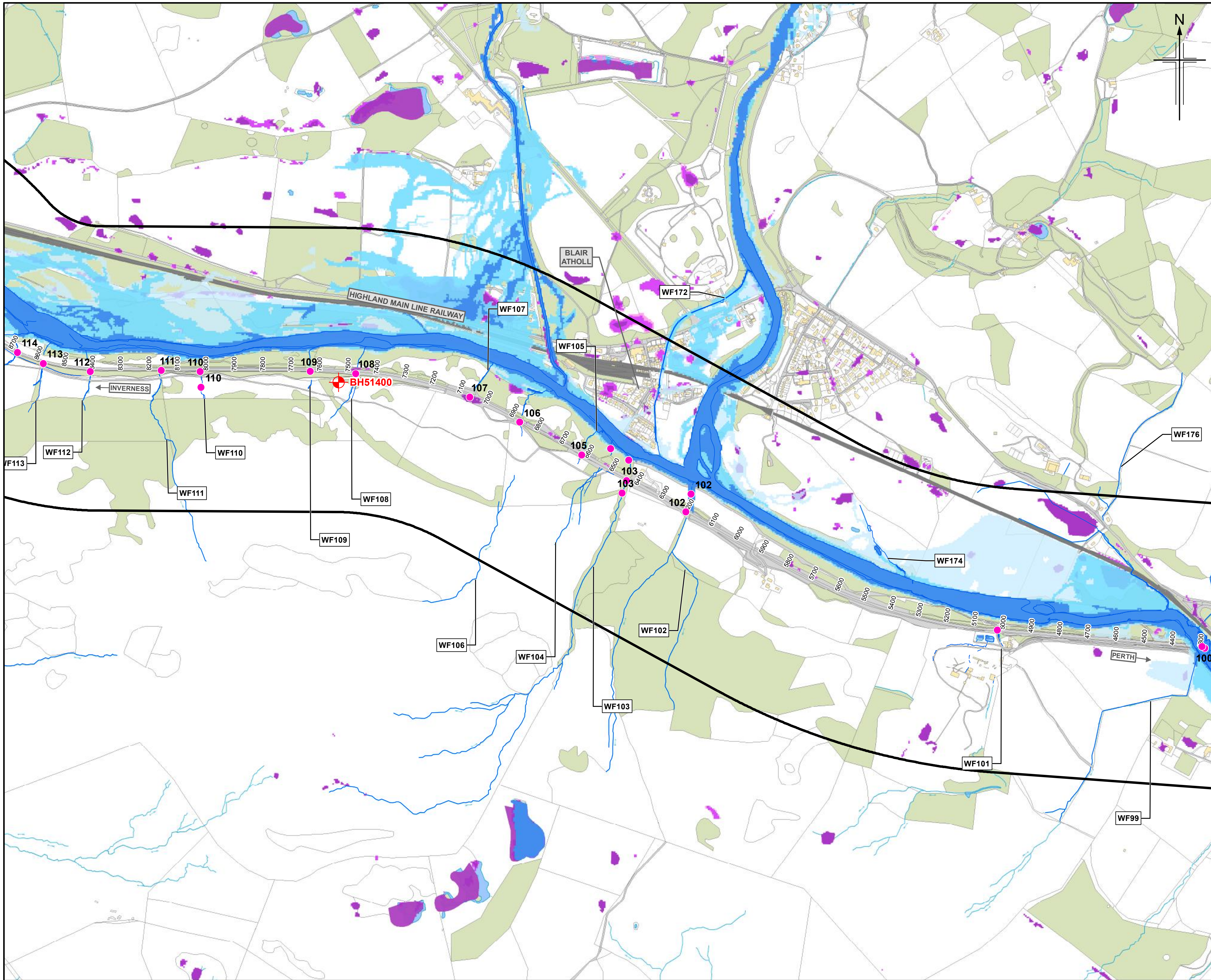

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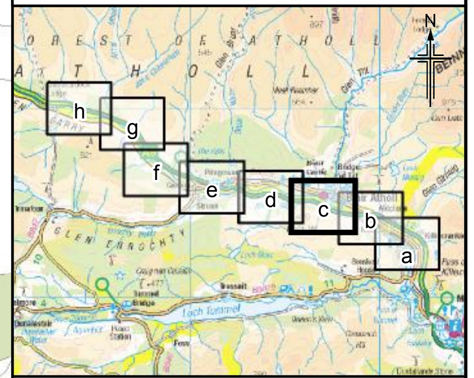

Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
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SEPA Surface Water Extent

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SEPA Flood Map
Baseline Scenario

Sheet 3 of 8

Drawing Status	FINAL	
Scale	1:12,500 @ A3	DO NOT SCALE
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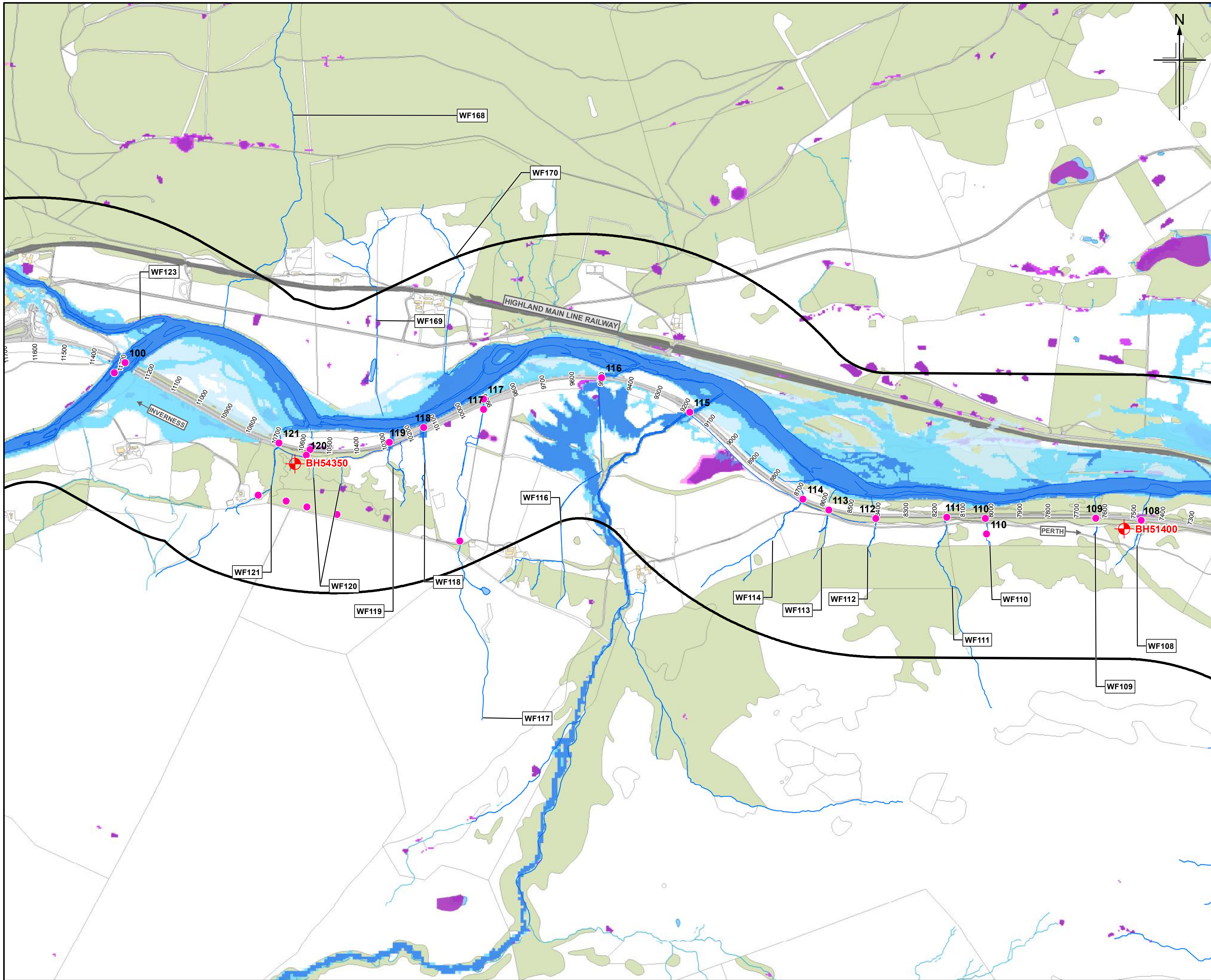
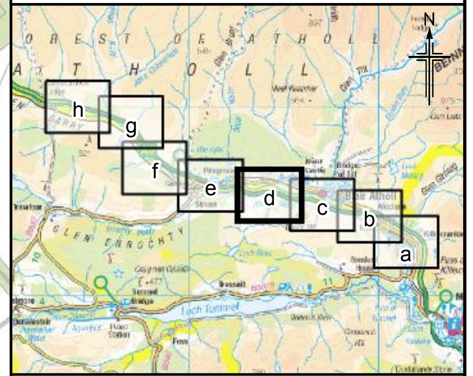
Drawing number	Figure A11.3.1c	Rev 0

0 0.25 0.5 1 kilometres

Figure A11.3.1d





Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

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- Low Likelihood - 0.01% Annual Exceedance Probability Plus Climate Change Allowance

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Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 4 of 8

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0 0.25 0.5 1 kilometres

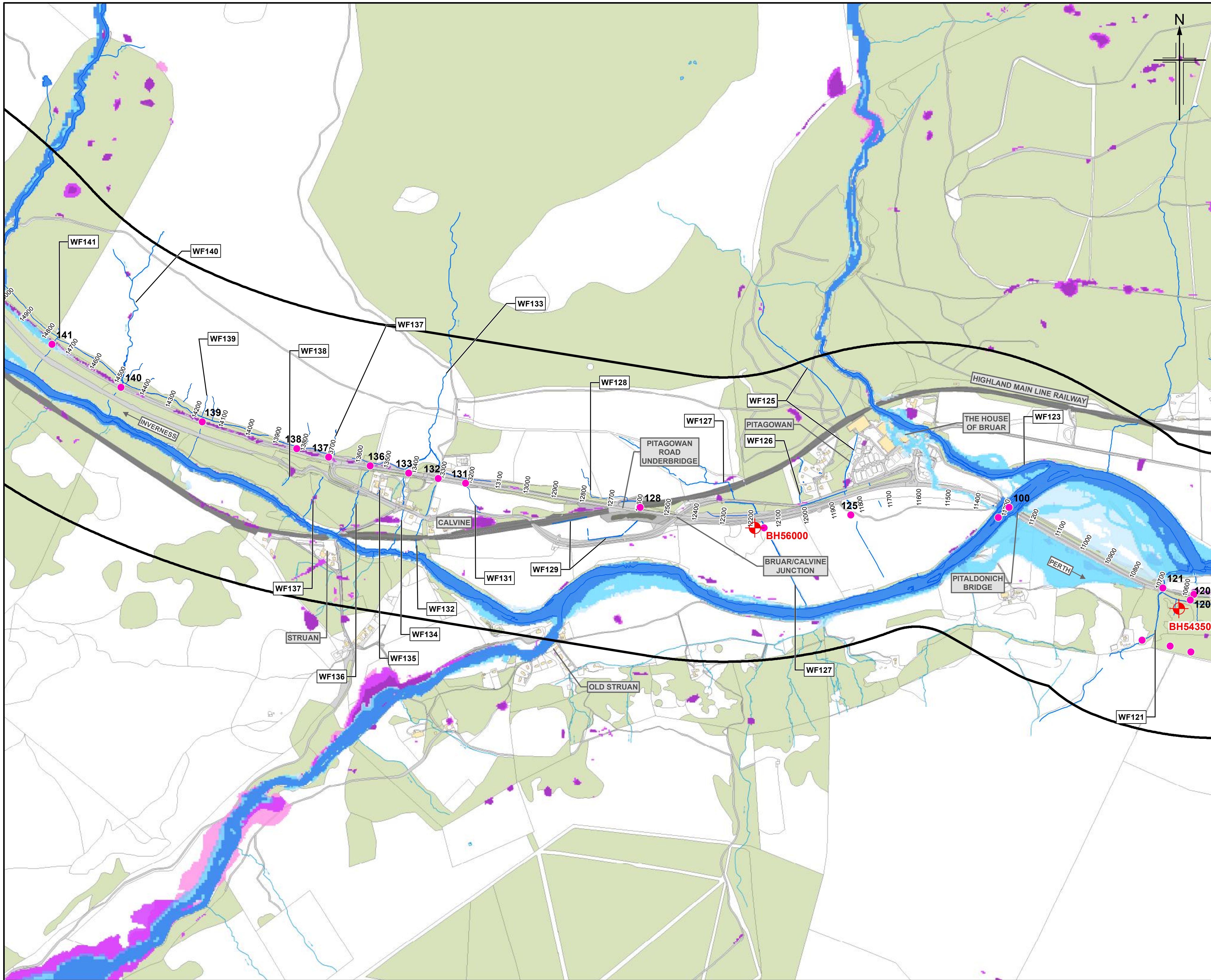

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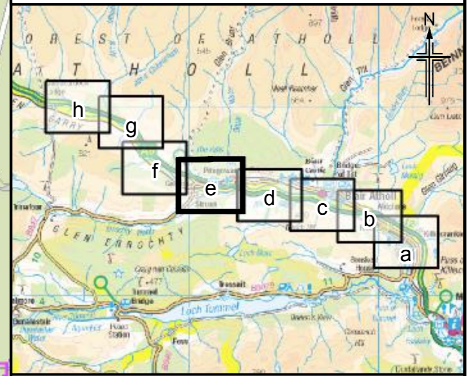
Figure A11.3.1e



Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

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- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

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PERTH TO INVERNESS
Killiecrankie to Glen Garry

Drawing title

Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 5 of 8

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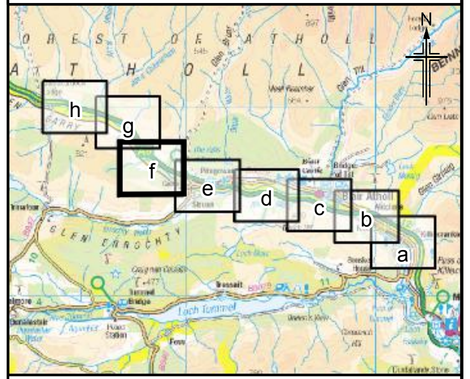
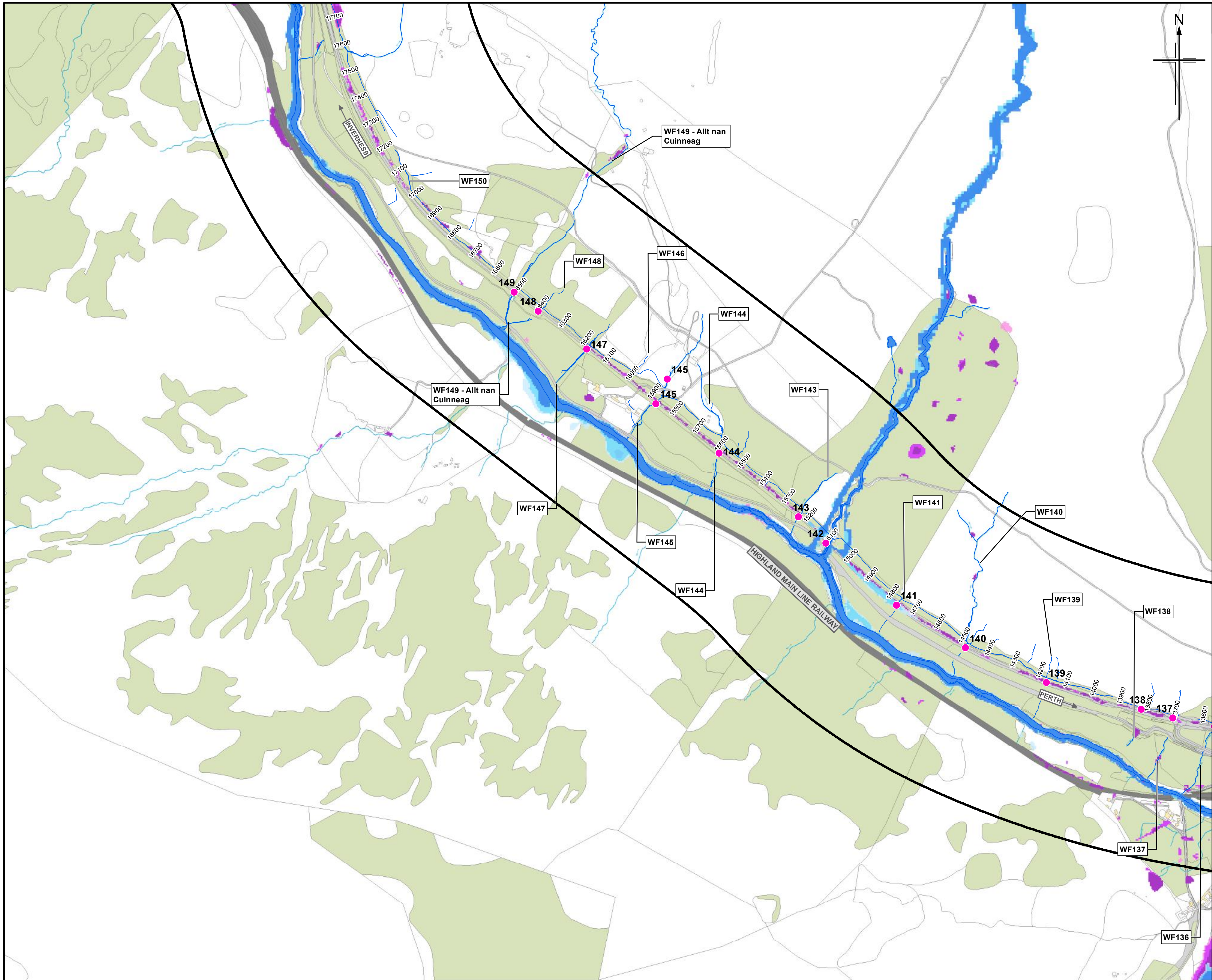
Figure A11.3.1f





Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
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Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 6 of 8

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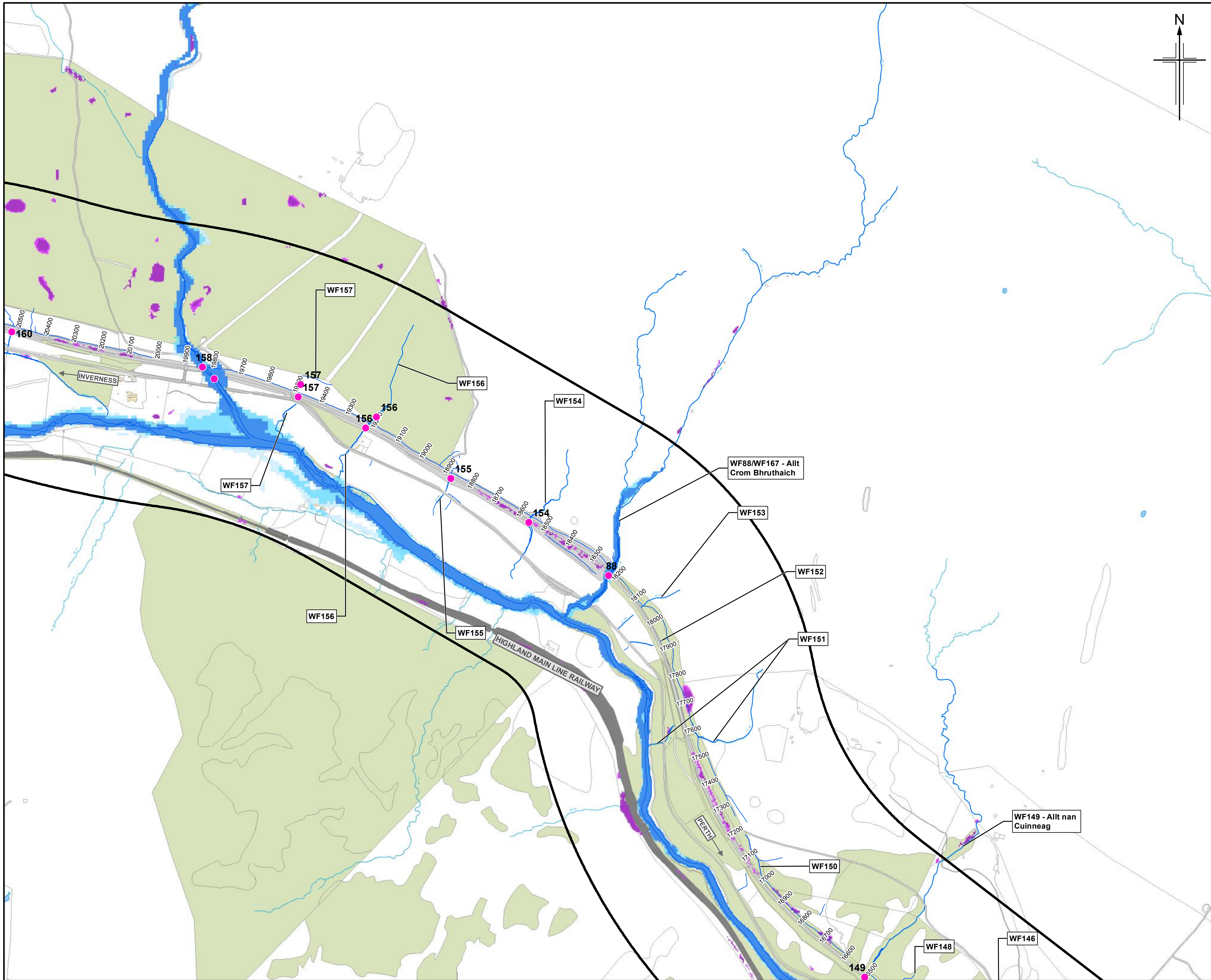

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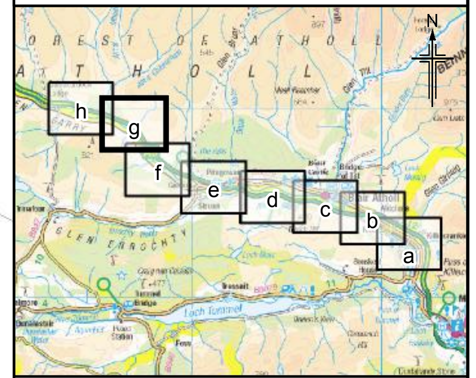

Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

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Drawing title

Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 7 of 8

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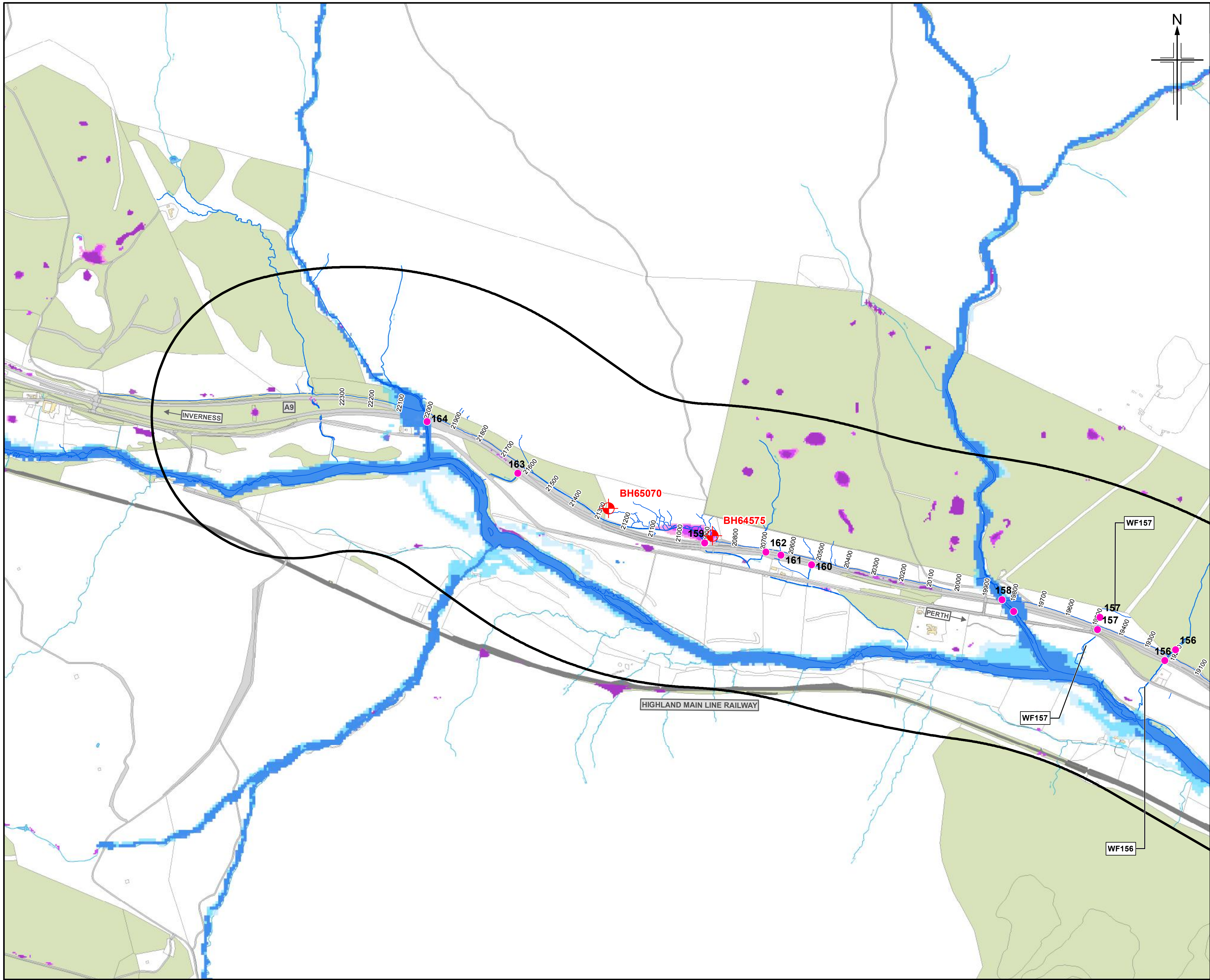

Figure A11.3.1h

Legend

- 500m Study area
- Watercourses
- Watercourse crossing
- Borehole

SEPA Area That May Flood - River

- High Likelihood - 10% Annual Exceedance Probability
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- Low Likelihood - 0.01% Annual Exceedance Probability

SEPA Surface Water Extent

- High Likelihood - 10% Annual Exceedance Probability
- Medium Likelihood - 0.5% Annual Exceedance Probability
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PERTH TO INVERNESS
Killiecrankie to Glen Garry

Drawing title

Killiecrankie to Glen Garry
SEPA Flood Map
Baseline Scenario

Sheet 8 of 8

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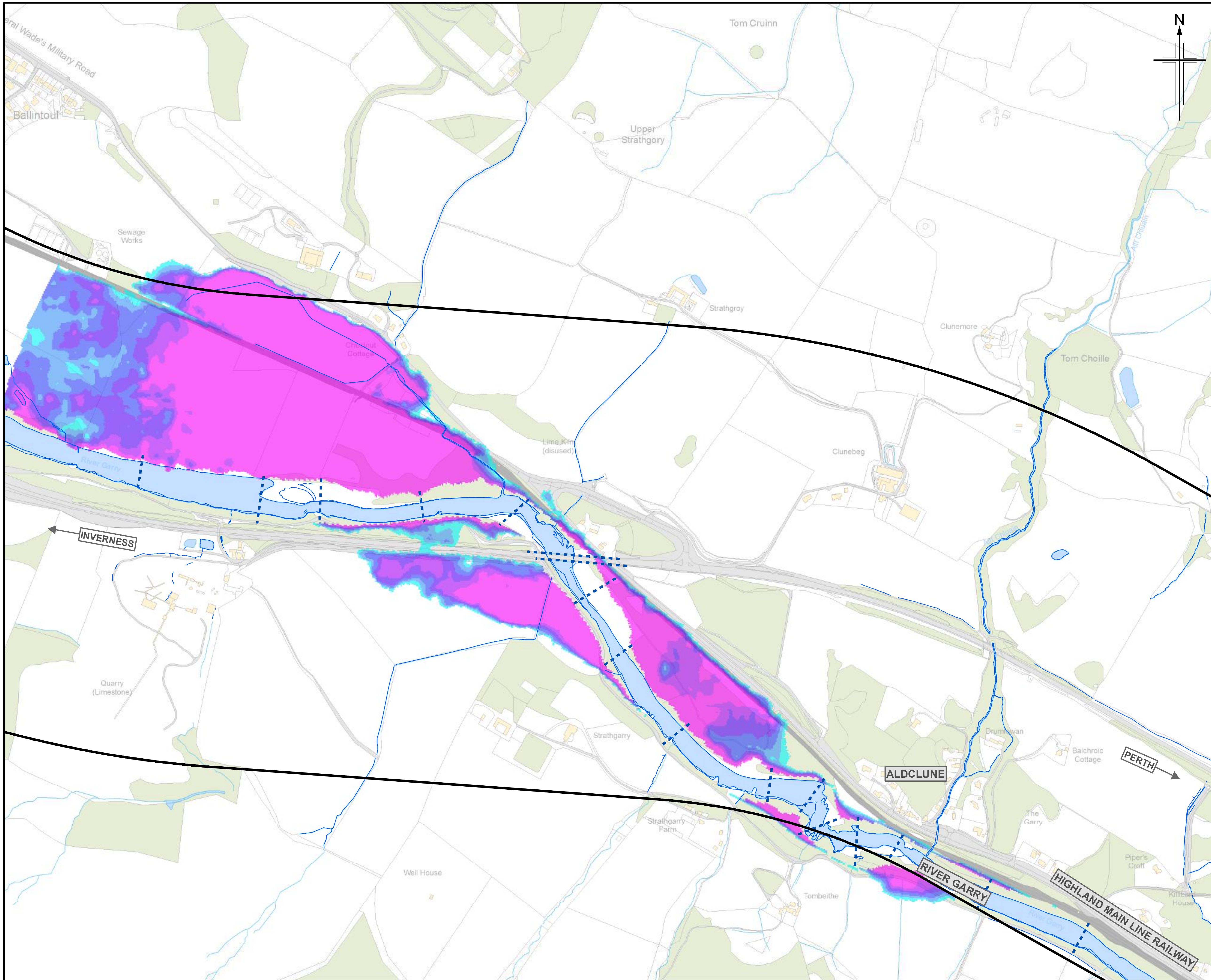
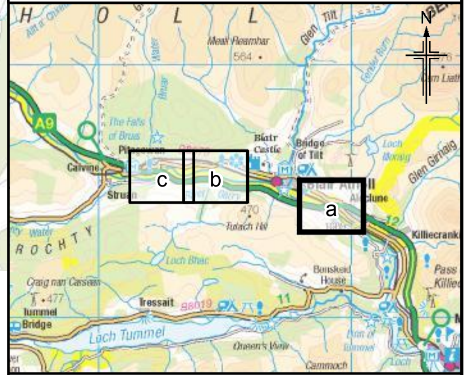


0 0.25 0.5 1 kilometres

Figure A11.3.2a



Legend

- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
- 1m - 1.25m
- > 1.25m

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**Killiecrankie to Glen Garry
Fluvial Flood Depth Map
Baseline Scenario**

Sheet 1 of 3

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Drawing number	Figure A11.3.2a	Rev 0

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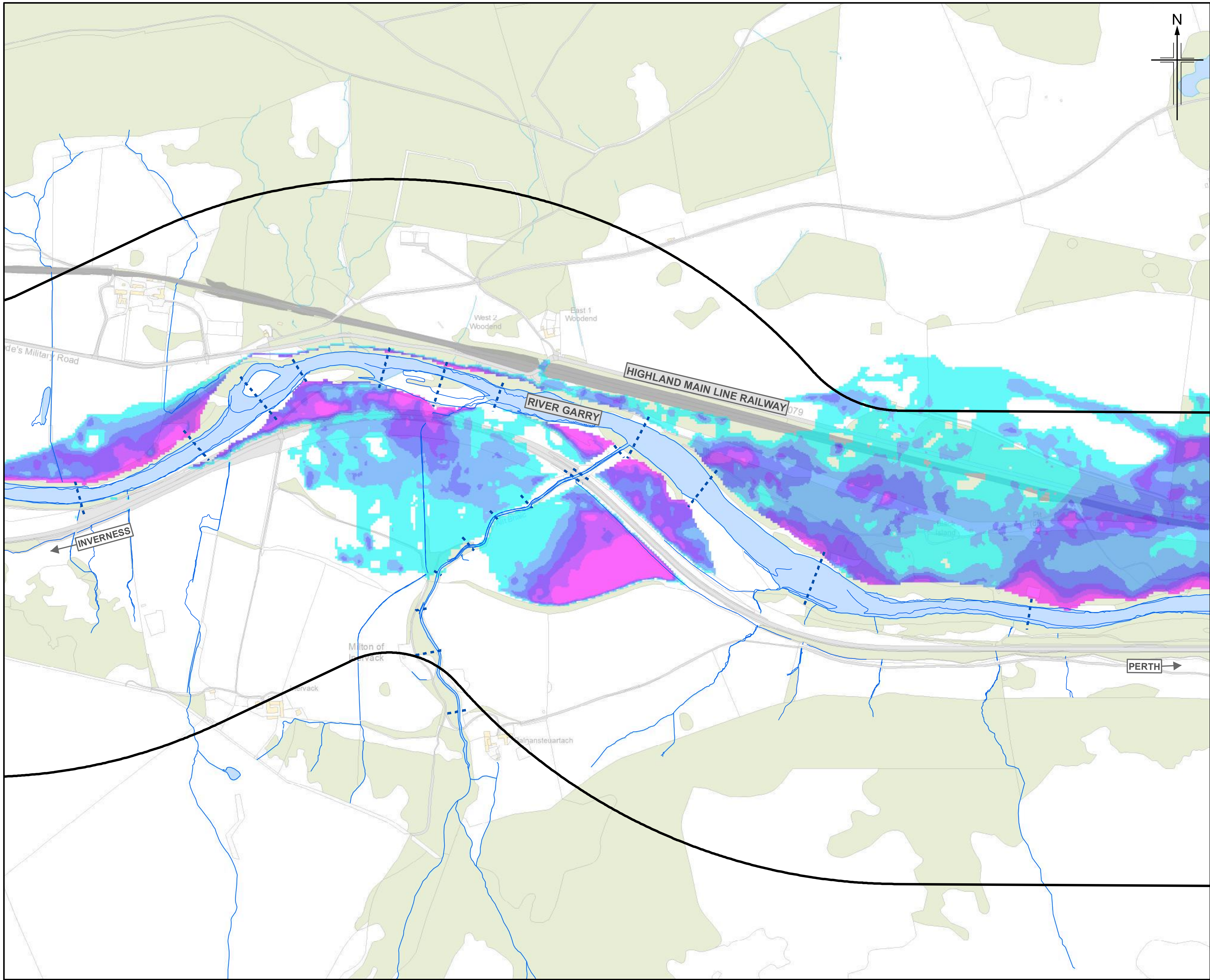
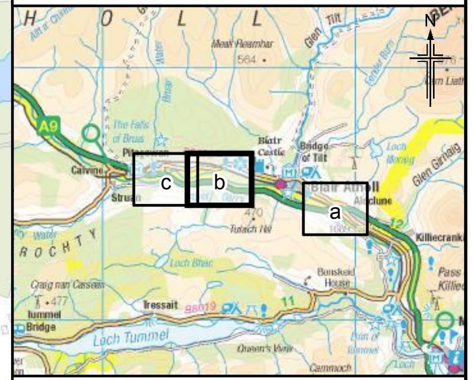


Figure A11.3.2b



Legend

- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
- 1m - 1.25m
- > 1.25m

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	NOV 2017	ES Publication	HCH	CD	CI	RC

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TRANSPORT SCOTLAND
COMHDHAIL ALBA

Project

A9 DUALLING
PERTH TO INVERNESS
Killiecrankie to Glen Garry

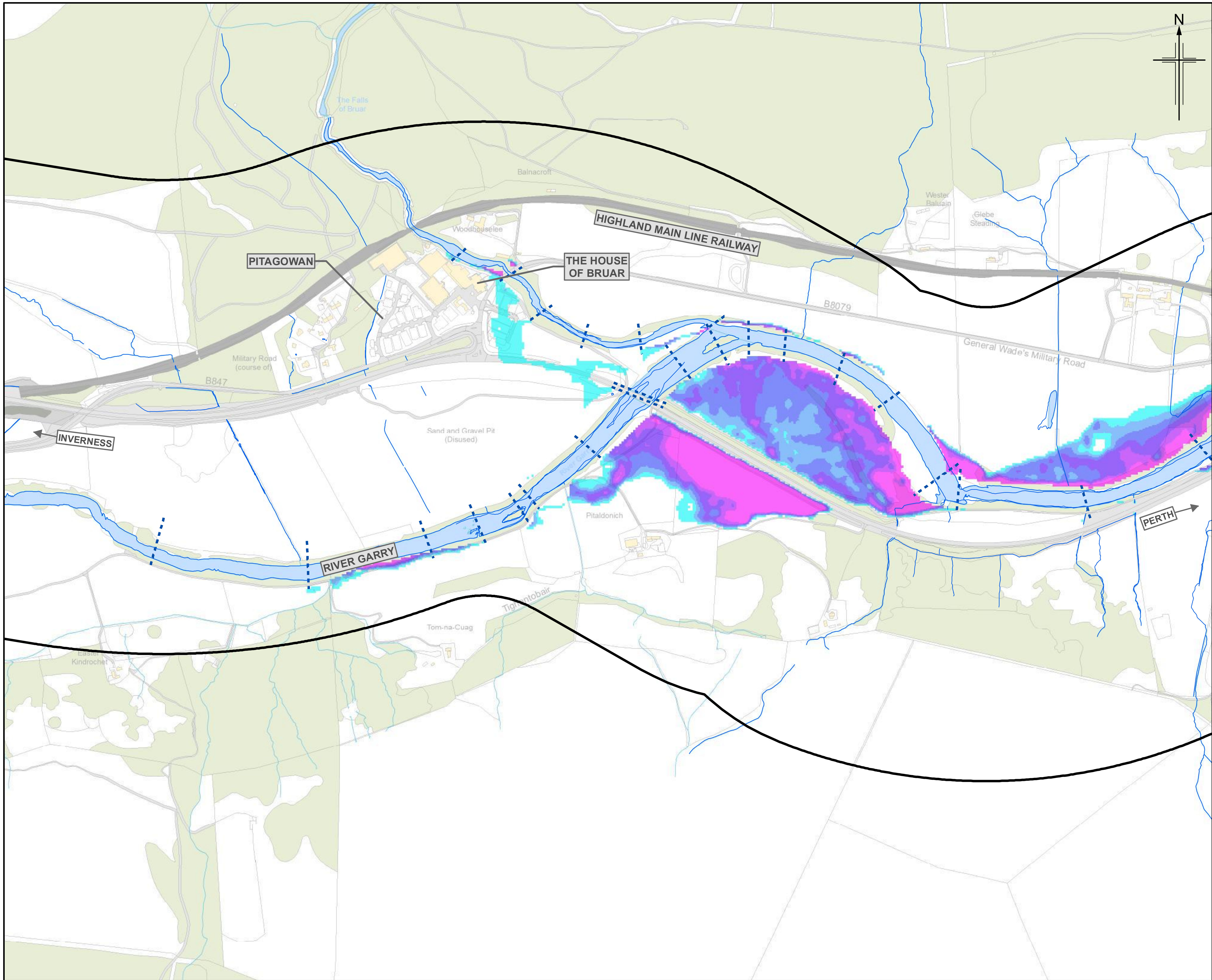
Drawing title

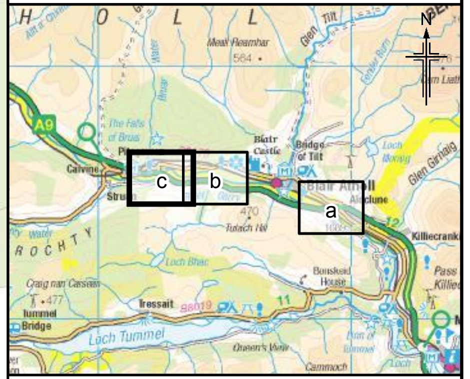
Killiecrankie to Glen Garry
Fluvial Flood Depth Map
Baseline Scenario

Sheet 2 of 3

Drawing Status	FINAL		
Scale	1:7,500	@ A3	DO NOT SCALE
Jacobs No.	B2140005		
Drawing number	Figure A11.3.2b		Rev 0

Figure A11.3.2c





Legend

- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the baseline scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
- 1m - 1.25m
- > 1.25m

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Killiecrankie to Glen Garry

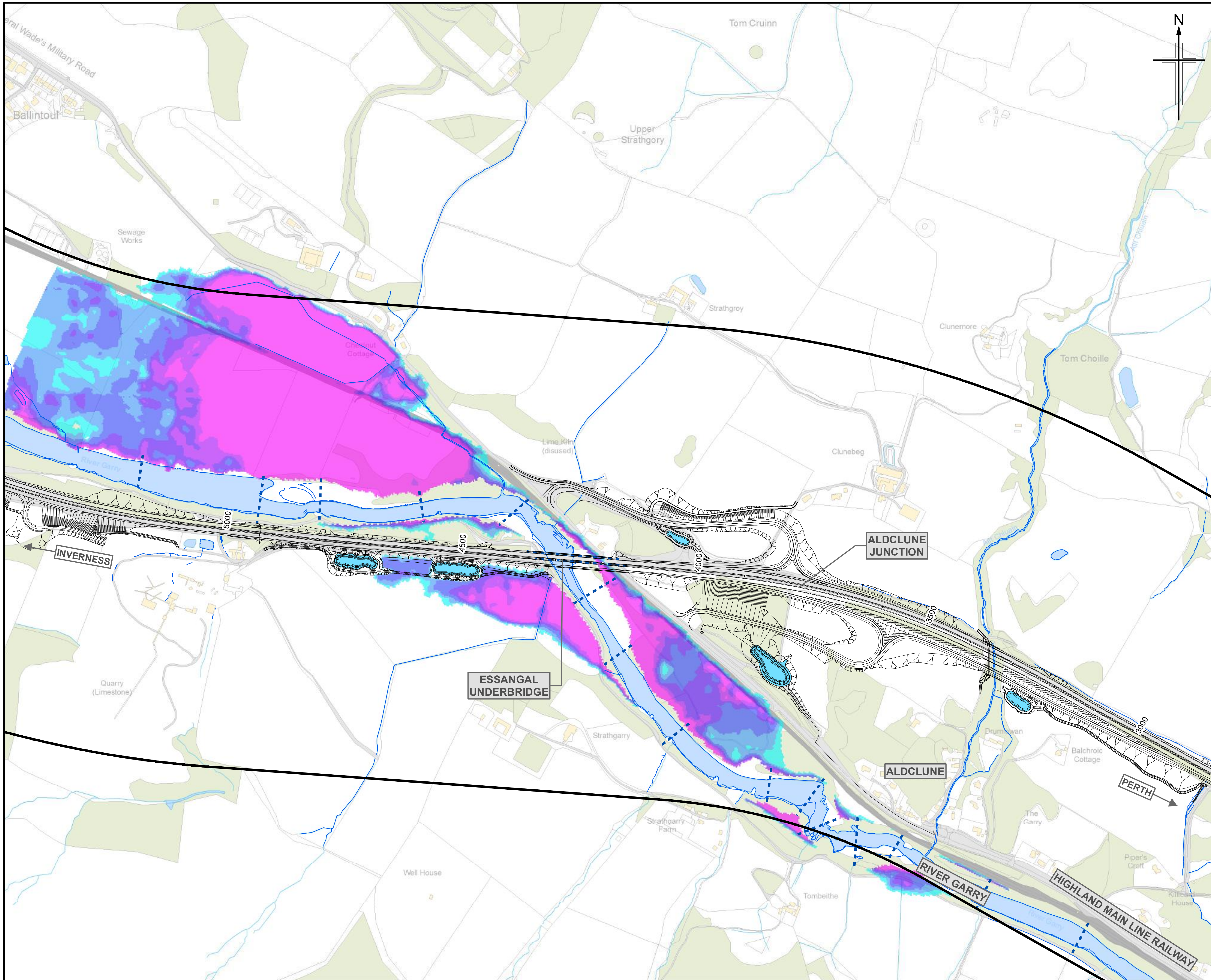
Drawing title

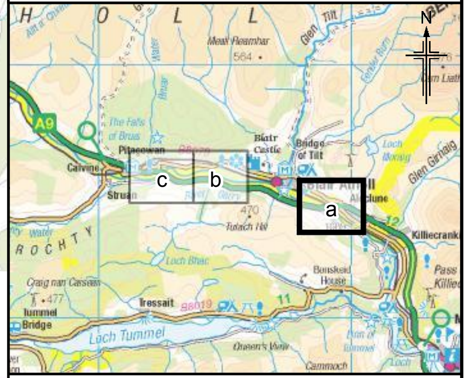
Killiecrankie to Glen Garry
Fluvial Flood Depth Map
Baseline Scenario

Sheet 3 of 3

Drawing Status	FINAL	
Scale	1:7,500 @ A3	DO NOT SCALE
Jacobs No.	B2140005	
Drawing number	Figure A11.3.2c	Rev 0

Figure A11.3.3a





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
- 1m - 1.25m
- >1.25m

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Project
A9 DUALLING
PERTH TO INVERNESS
Killiecrankie to Glen Garry

Drawing title
Killiecrankie to Glen Garry
Fluvial Flood Depth Map
With Scheme (No Mitigation)

Sheet 1 of 3

Drawing Status	FINAL	
Scale	1:7,500 @ A3	DO NOT SCALE
Jacobs No.	B2140005	
Drawing number	Figure A11.3.3a	Rev 0

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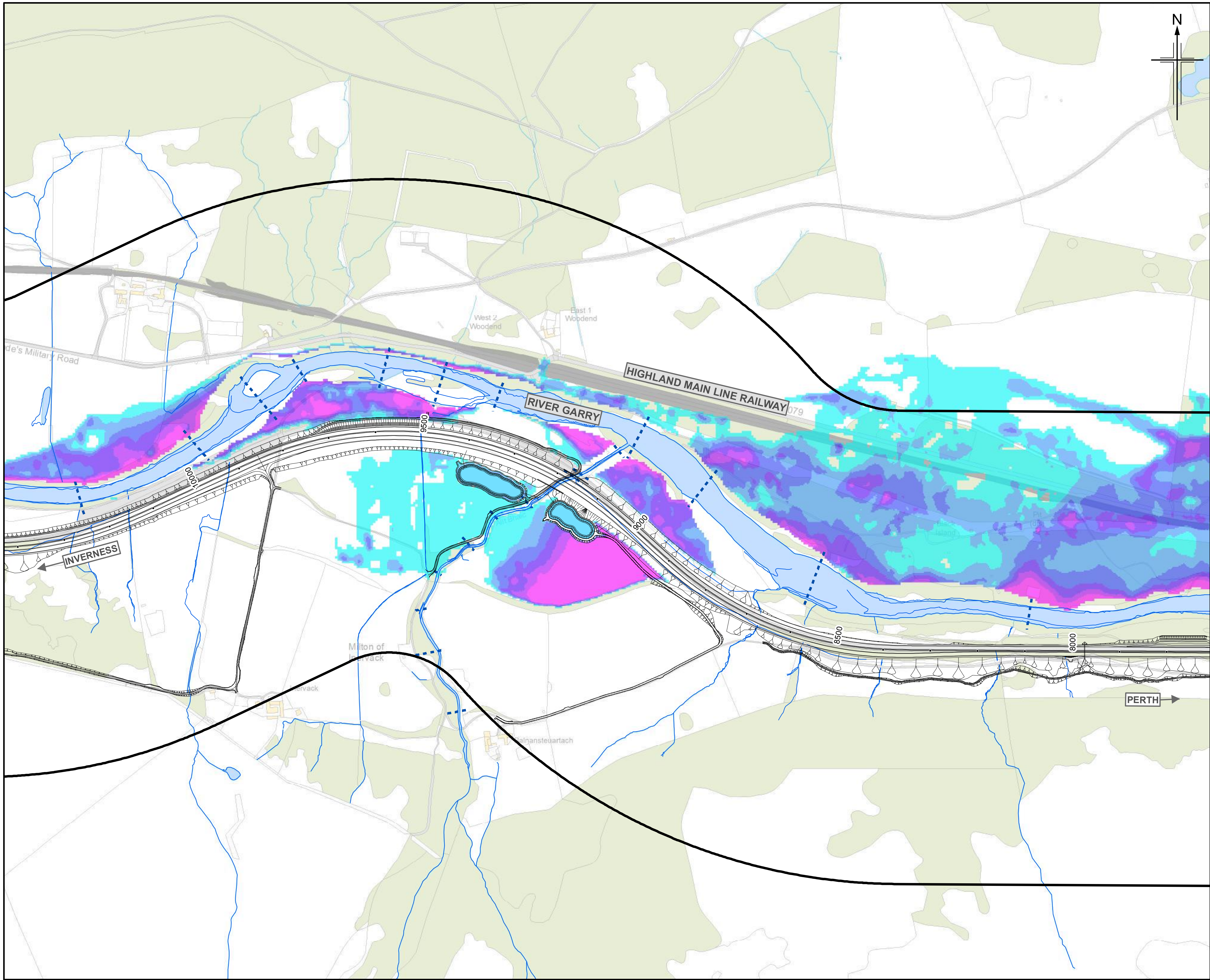
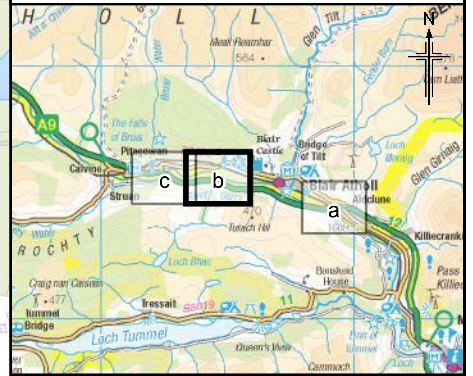
0 0.25 0.5 1 kilometres

Figure A11.3.3b





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
- 1m - 1.25m
- >1.25m

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PERTH TO INVERNESS
Killiecrankie to Glen Garry

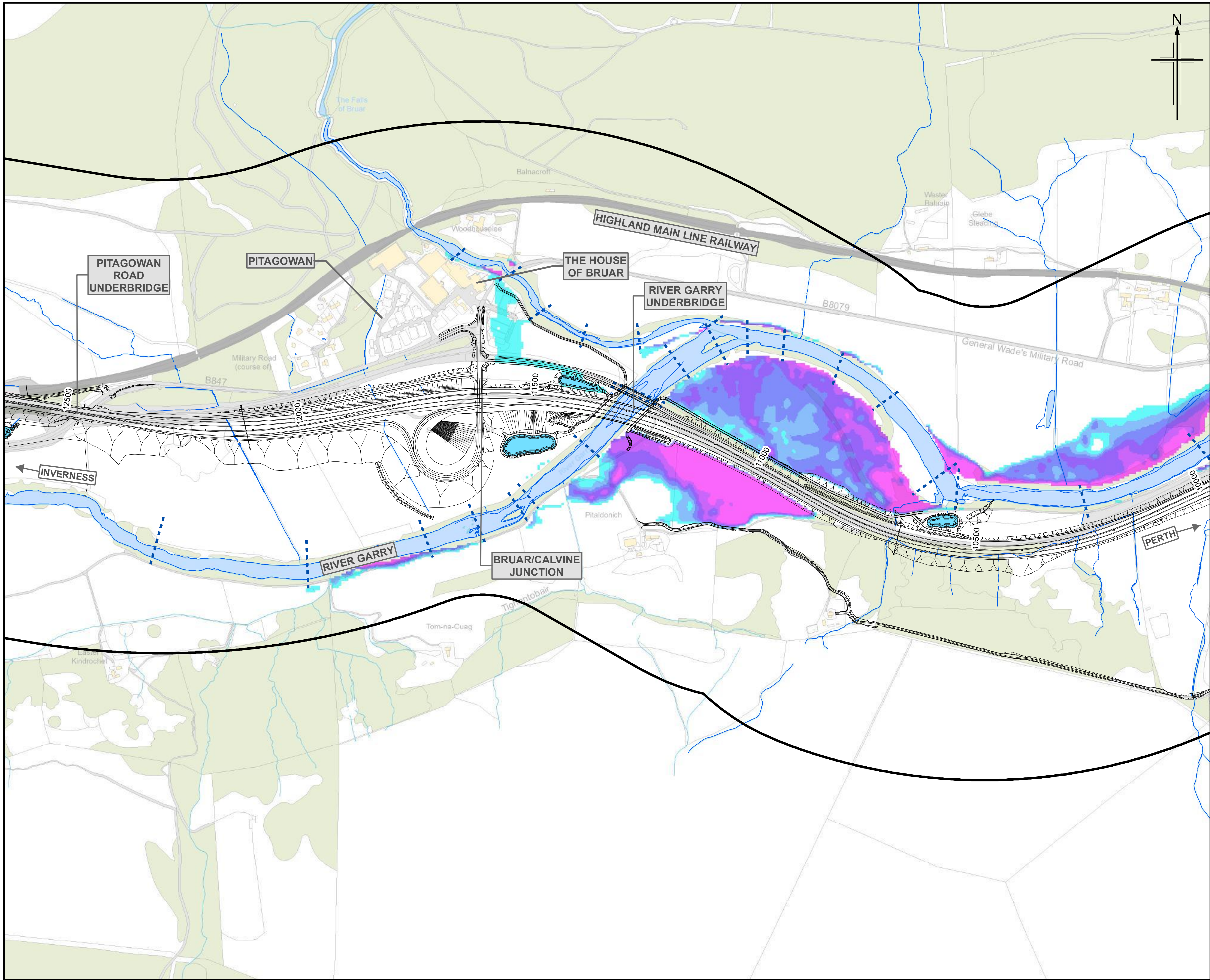
Drawing title

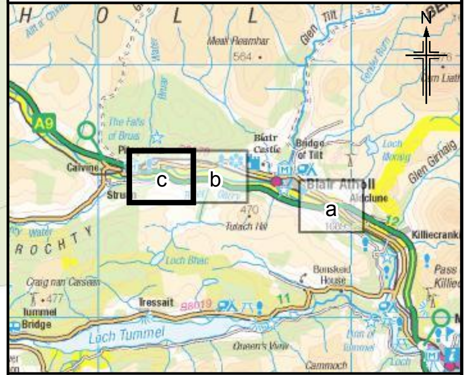
Killiecrankie to Glen Garry
Fluvial Flood Depth Map
With Scheme (No Mitigation)

Sheet 2 of 3

Drawing Status	FINAL
Scale	1:7,500 @ A3 — DO NOT SCALE
Jacobs No.	B2140005
Drawing number	Figure A11.3.3b — Rev 0

Figure A11.3.3c





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the proposed scheme (no mitigation) scenario

- 0m - 0.25m
- 0.25m - 0.5m
- 0.5m - 0.75m
- 0.75m - 1m
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- >1.25m

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Project: A9 DUALLING PERTH TO INVERNESS Killiecrankie to Glen Garry

Drawing title

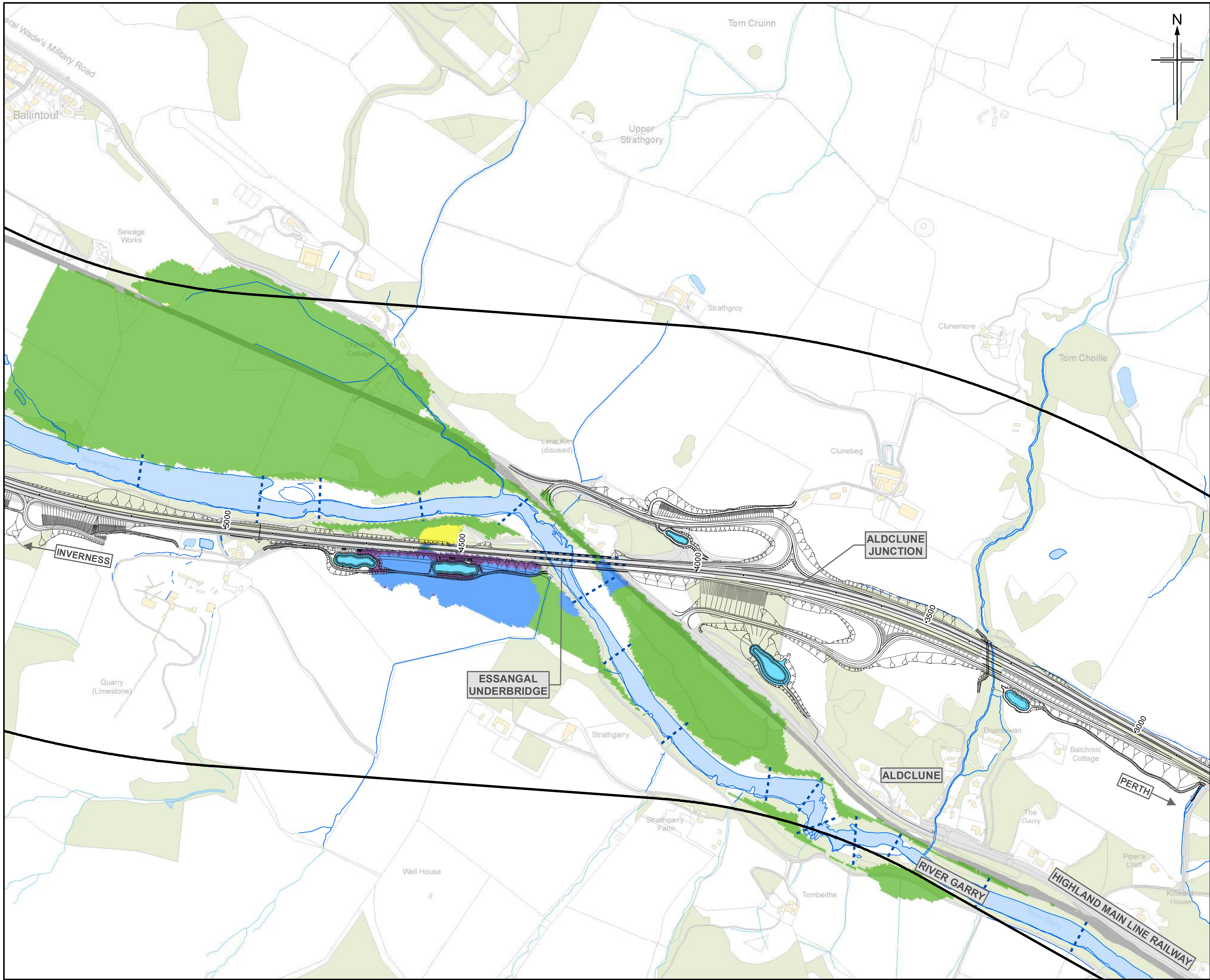
Killiecrankie to Glen Garry
Fluvial Flood Depth Map
With Scheme (No Mitigation)

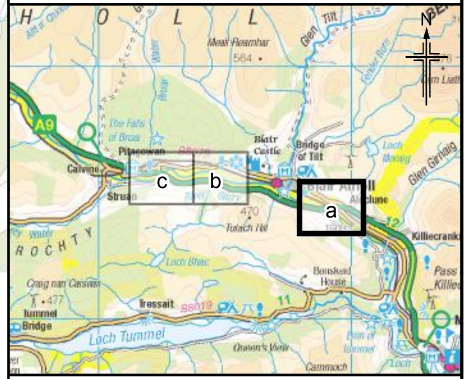
Sheet 3 of 3

Drawing Status	FINAL	
Scale	1:7,500 @ A3	DO NOT SCALE
Jacobs No.	B2140005	
Drawing number	Figure A11.3.3c	Rev 0

0 0.25 0.5 1 kilometres

Figure A11.3.4a





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

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Project: A9 DUALLING PERTH TO INVERNESS Killiecrankie to Glen Garry

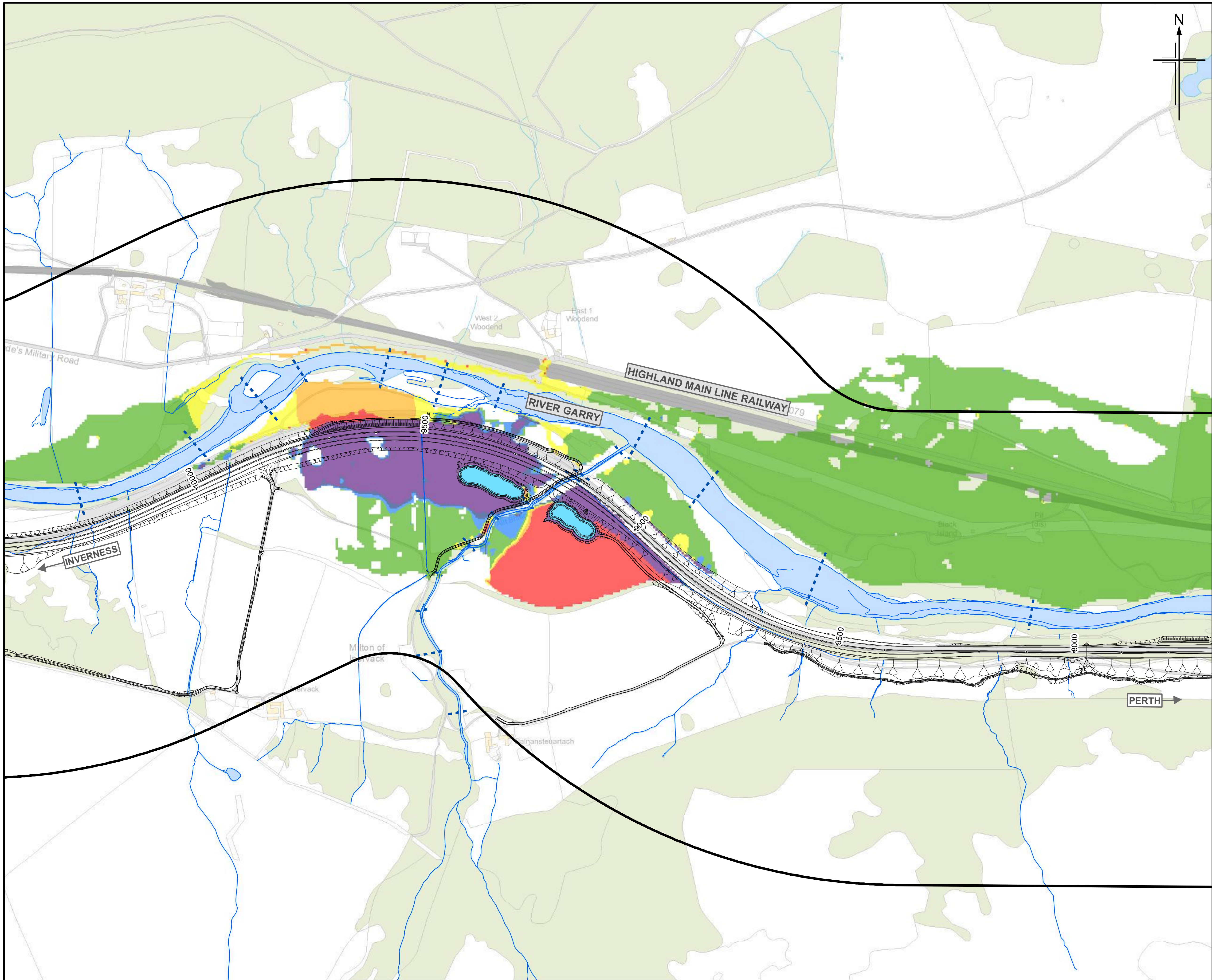
Drawing title

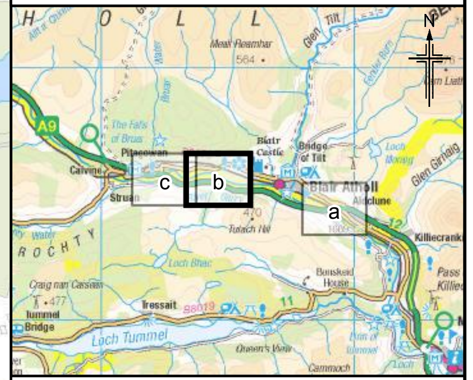
**Killiecrankie to Glen Garry
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)**

Sheet 1 of 3

Drawing Status	FINAL	
Scale	1:7,500 @ A3	DO NOT SCALE
Jacobs No.	B2140005	
Drawing number	Figure A11.3.4a	Rev 0

Figure A11.3.4b





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

- > -0.1 Major Beneficial
- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
- -0.01 to 0.01 Negligible
- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

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PERTH TO INVERNESS
Killiecrankie to Glen Garry

Drawing title

Killiecrankie to Glen Garry
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)

Sheet 2 of 3

Drawing Status	FINAL	
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Drawing number	Figure A11.3.4b	Rev 0

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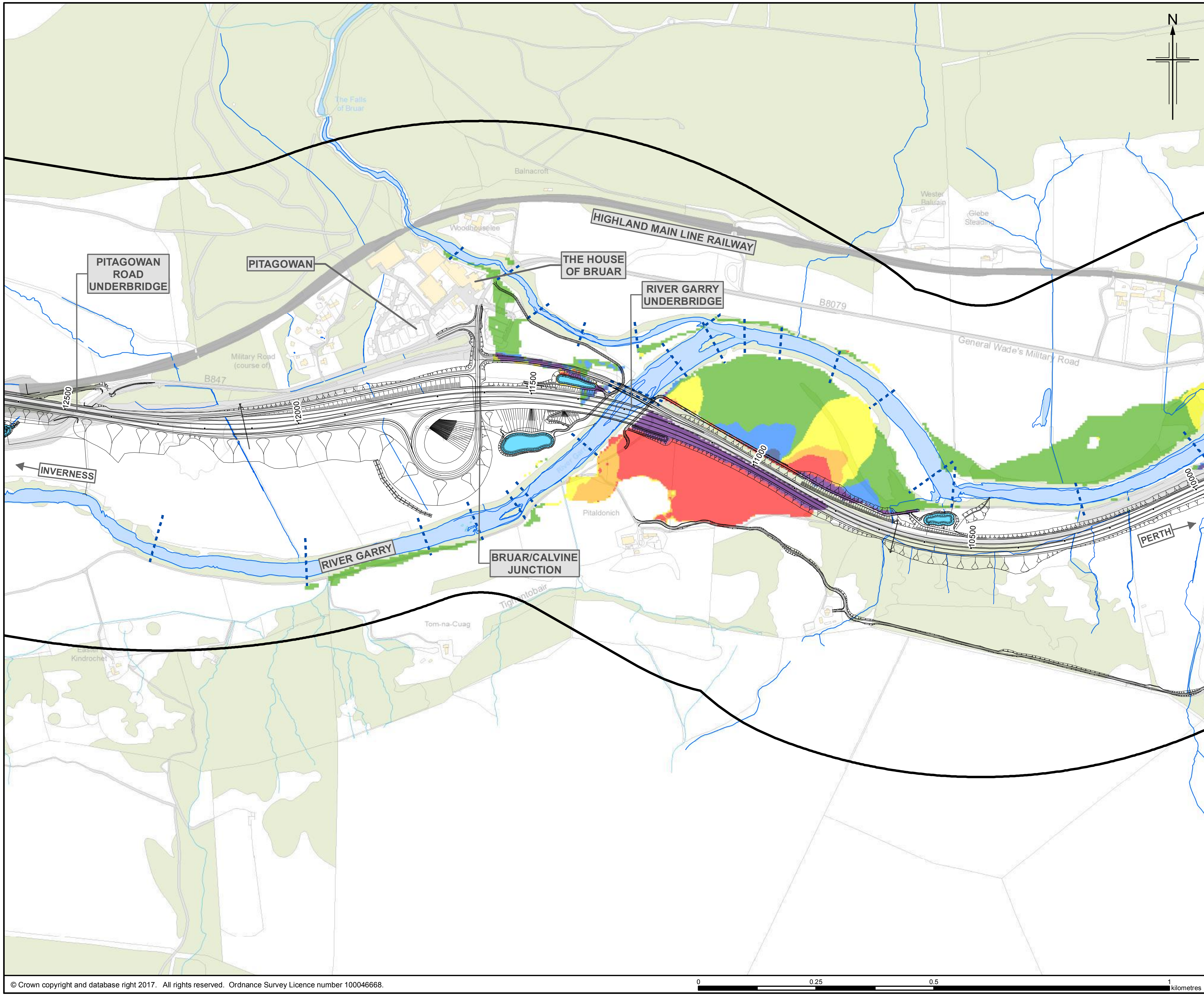
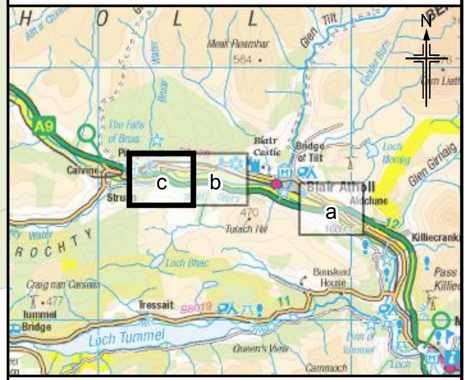
Figure A11.3.4c





Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS feature
- 500m Study area
- Watercourses
- Flood model cross section

Flood Level Difference (m) during the 0.5% AEP (200-year) plus CC event

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- -0.1 to -0.05 Moderate Beneficial
- -0.05 to -0.01 Minor Beneficial
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- 0.01 to 0.05 Minor Adverse
- 0.05 to 0.1 Moderate Adverse
- > 0.1 Major Adverse

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Killiecrankie to Glen Garry

Drawing title

Killiecrankie to Glen Garry
Fluvial Flood Depth Impact Map
With Scheme (No Mitigation)

Sheet 3 of 3

Drawing Status	FINAL
Scale	1:7,500 @ A3 — DO NOT SCALE
Jacobs No.	B2140005
Drawing number	Figure A11.3.4c
Rev	0

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