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 Pitlochry and Killiecrankie, also referred to as the proposed scheme. It informs Chapter 11 (Road Drainage and the Water Environment (RDWE)) of the Environmental Statement (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, determine whether the proposed scheme would remain safe and operational during times of flood and ensuring where achievable 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 following:

- Chapter 11: Road Drainage and the Water Environment of the ES;
- Appendix A11.1: Baseline Conditions;
- Appendix A11.2: Surface Water Hydrology Report;
- 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: Minor Watercourse Crossings 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, the southern section which, Jacobs UK Ltd are delivering including:

- Luncarty to Pass of Birnam;
- Pass of Birnam to Tay Crossing;
- Tay Crossing to Ballinluig;
- Pitlochry to Killiecrankie; and
- 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 it 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 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 involves dualling an existing road, it would be unavoidable to develop the proposed scheme completely out of 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: (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, the DMRB states that the 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 2009.

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 1.1 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 DMRB Stage 3 design only as reported in this ES.

Table 1.1: Flood risk assessment stages

Stage	Assessment Detail	Purpose	Alignment with the requirements of SEPA Technical Guidance
DMRB 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 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 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 proposed 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 one-dimensional (1D)/two-dimensional (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:

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

1.1.20 Generally, as the proposed scheme has progressed from DMRB Stage 1 assessment through to DMRB Stage 3 assessment, so has the level of supporting flood risk evidence, as outlined in Table 1.1. 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 Tummel, Loch Faskally and the River Garry, 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 saturating the drainage system (either natural or man-made), with excess water travelling overland and ponding in local topographic depressions before the runoff enters any watercourse, drainage systems or sewer (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, 2013) 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 feature such as a dam, water supply reservoirs, canals, flood defence 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 a 2, 5, 10, 30, 50, 100, 200 and 1000-year return period, respectively. 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 (2015) 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 the ‘design flood event’ at the present time.

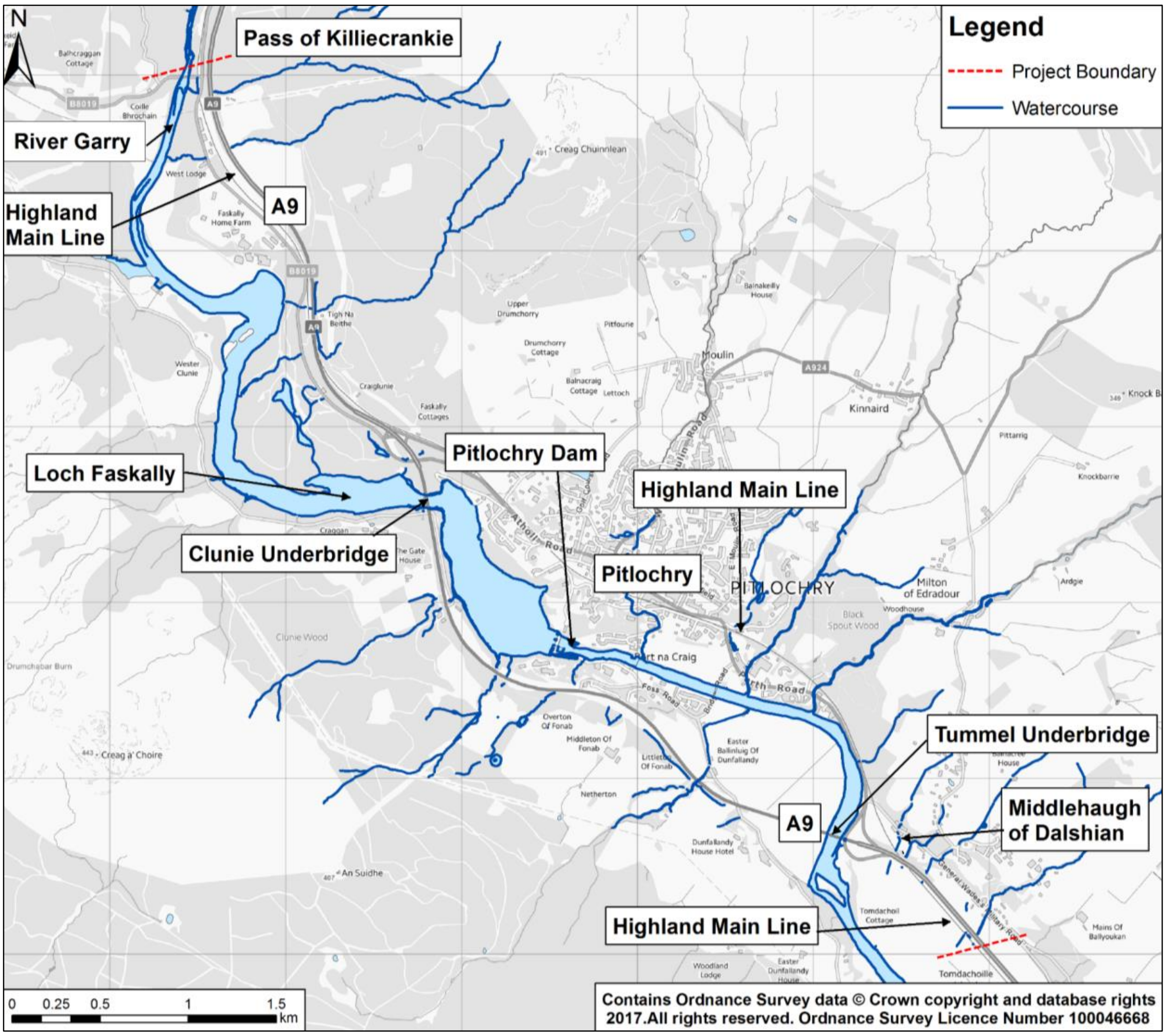
1.1.26 Where detailed hydraulic modelling has been undertaken as part of this FRA, the modelled flood extents will supersede the flood extents as presented in the SEPA Flood Map. The FRA has also considered the potential impacts of climate change on fluvial flood depths and extents. In line with current fluvial guidance (published by SEPA, 2015a), peak flow estimates for the 0.5% AEP (200-year) event have been increased by 20% as an allowance for climate change (CC), which will be denoted by 0.5% AEP (200-year) plus CC. This is referred to as the ‘design flood event’.

2 A9 Corridor

The Existing A9

2.1.1 This FRA covers the existing A9 between Pitlochry and Killiecrankie (Diagram 2.1), which includes approximately 6.4km of single carriageway to be dualled as part of the proposed scheme.

Diagram 2.1: A9 Corridor – Pitlochry to Killiecrankie



2.1.2 The proposed scheme corridor can be characterised by steep open hillsides and low valley floodplains of the River Tummel containing grazing farmland and many areas of designated native woodland and ancient woodland. Pitlochry is the largest town, with smaller communities including Middlehaugh of Dalshian, Port-na-Craig and Faskally and isolated dwellings including Littleton of Fonab and Middleton of Fonab.

2.1.3 The southern extent of this section of the existing A9 runs along the north side of the River Tummel, parallel to the Highland Main Line (HML) railway, before crossing the River Tummel at the existing Tummel Underbridge. To the north-west of the Tummel Underbridge, the existing A9 runs south of the River Tummel, traversing areas of woodland and rural land. The existing A9 then crosses Loch Faskally via Clunie Underbridge, continuing northwards running parallel to the HML.

2.1.4 Loch Faskally is a reservoir upstream of the Pitlochry Dam, which is located immediately to the south of Pitlochry and forms part of the Tummel Valley hydro-electric scheme. Downstream of the dam the water continues as the River Tummel, a tributary of the River Tay. Loch Faskally is fed by two main tributaries:

the River Tummel which outflows from Loch Tummel to the west; and the River Garry, which discharges from the north-eastern end of Loch Garry near the Pass of Drumochter approximately 35km upstream of the confluence with Loch Faskally.

2.1.5 A total of 28 watercourses are located within the proposed scheme corridor, shown in Diagram 2.4.

2.1.6 The existing A9 could potentially interact with three larger watercourses classified as 'principal' watercourses (River Garry, River Tummel and Loch Faskally).

2.1.7 There are 25 smaller watercourses that the scheme has the potential to interact with. A further watercourse (WF62) was found to be absent during site visits; this was presumed to be an old drainage path of WF63, which was filled in since the construction of the original A9. WF63 does not cross the existing A9 but runs in a culvert parallel to the road embankment and discharges directly into the River Tummel. The smaller watercourses are classified as 'minor' watercourses; typically, small un-named burns and field drains which drain the adjacent hillside and usually cross the existing A9 through pipe culverts.

Diagram 2.2: **Tummel Underbridge**

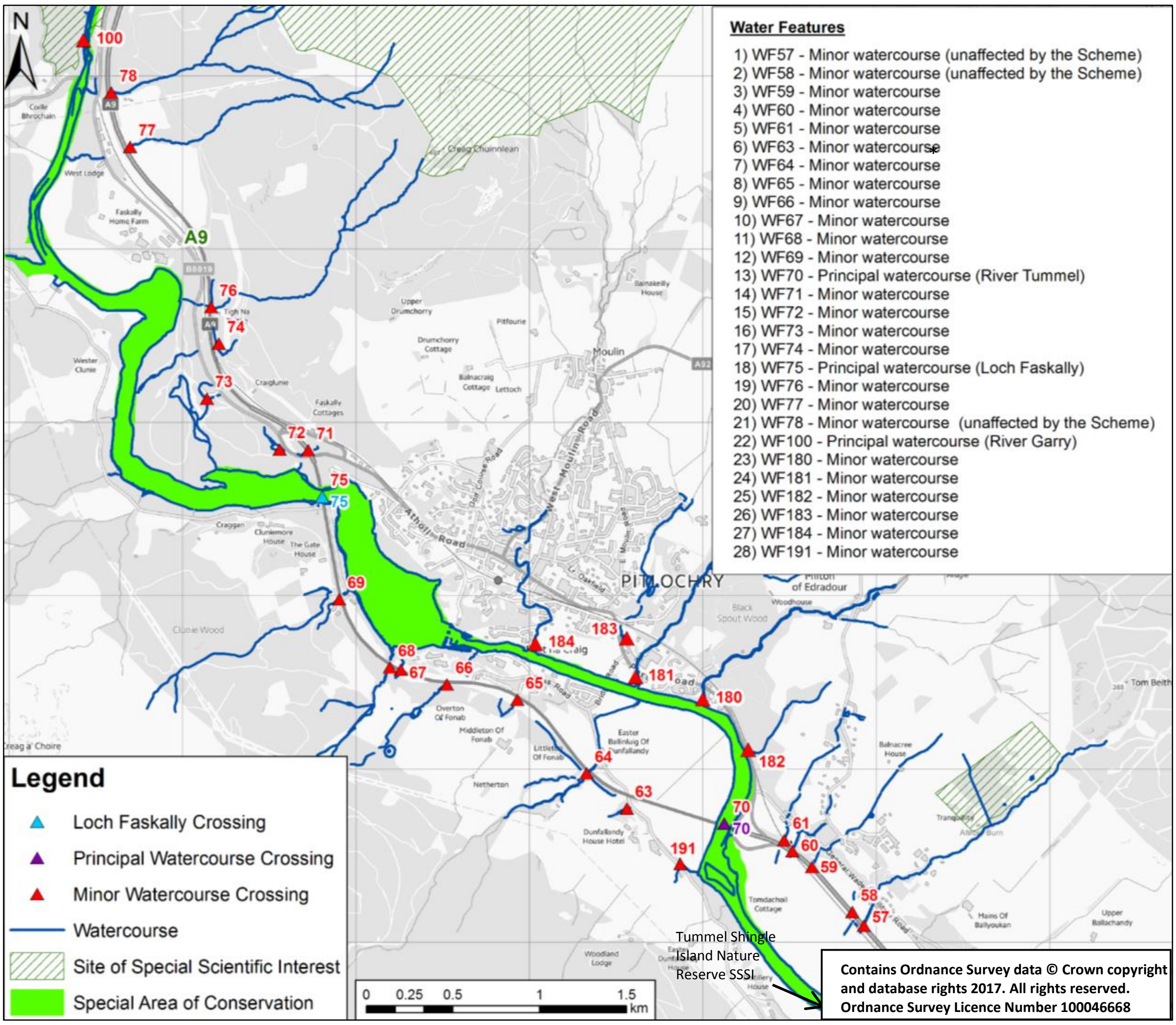
Existing Tummel Underbridge - looking south

Diagram 2.3: Clunie Underbridge

Existing Clunie Underbridge – looking south

2.1.8 The proposed scheme corridor is an environmentally sensitive area, with many areas of native woodland and ancient woodland located either directly adjacent to or within close proximity of the existing A9, along with the River Tay Special Area of Conservation (SAC) which encompasses the River Tummel, Loch Faskally and the River Garry. Another sensitive receptor includes the Tummel Shingle Islands Nature Reserve Site of Special Scientific Interest (SSSI) which is also a SAC, located approximately 500m to the south-east of the proposed scheme.

Diagram 2.4: Watercourses – Pitlochry to Killiecrankie



* WF62 was found not to exist

The Proposed Scheme

2.1.9 The proposed scheme between Pitlochry and Killiecrankie is partly 'online' and partly 'offline' and includes widening of the existing A9 road carriageway (from two to four lanes) and other improvements over a distance of approximately 6.4km including to junctions, access roads and drainage.

2.1.10 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 C (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>

2.1.11 Between Pitlochry and Killiecrankie, the online section includes widening the existing northbound carriageway between Middlehaugh of Dalshian and Port-na-Craig and widening the existing southbound carriageway north of Port-na-Craig to the crossing with Loch Faskally, generally with minimal areas of in-cutting. The offline section of proposed dual carriageway runs from the existing A9 and B8019 junction, north of the Clunie Underbridge through properties at Craiglunie and Tigh na Beithe, re-joining the existing A9 alignment near to Faskally Caravan Park. The offline section generally requires cuttings into a steep hillside on the southbound side.

2.1.12 The proposed scheme also includes junction improvements, including new exit and entry ramps to and from the A924 Pitlochry North Junction and the A924 Pitlochry South Junction, and left in/left out junctions at the C452 Foss Road and C452 Clunie-Foss Road Junction.

2.1.13 The proposed scheme also includes the provision of modified or new local surfaced access roads and unsurfaced access tracks. This includes new access roads to Sustainable Drainage Systems (SuDS) features and access tracks serving a few properties (mainly agricultural properties). No access tracks cross the proposed scheme.

Principal Watercourse Crossings

2.1.14 Within the study area of the proposed scheme, the existing A9 crosses two principal watercourses; the River Tummel (Tummel Underbridge) and Loch Faskally (Clunie Underbridge). The River Garry is not crossed by the existing A9.

2.1.15 To support the widening of the existing A9, the proposed scheme includes the construction of new bridges adjacent to the existing structures at both locations. The proposed additional structure across the River Tummel consists of a single span bow string arch, parallel to the existing free span bridge with two piers that lie within the channel cross-section. The proposed additional bridge over Loch Faskally is a free span steel bridge parallel to and mirroring the existing structure (Clunie Underbridge).

2.1.16 Due to the widening of the existing carriageway, the new structure over the River Tummel requires embankments to provide sufficient height on the approach to the crossing, which will involve construction within the functional floodplain. Where possible, works within the floodplain have been minimised through the proposed scheme design process.

2.1.17 As part of the design process, the main road, junctions and surfaced access roads will be set above the peak fluvial flood level during the 0.5% AEP (200-year) event, plus a 20% allowance for climate change and 600mm freeboard. Unsurfaced access tracks will remain unchanged from existing elevations and as a result may have lower flood design standards (but will not have an increased risk of flooding). Bridge abutments have been set out of the floodplain.

2.1.18 Appendix A11.8 (Minor Watercourse Crossings Report) contains further detail and justification for the design of each structure.

Minor Watercourse Crossings

2.1.19 As described in Section 2 (A9 Corridor) above and in Diagram 2.4, there are 25 minor watercourses that the scheme has the potential to interact with. The larger of these tributaries includes an un-named watercourse (WF64) crossed by the existing A9 near the farm buildings of Wester and Easter Ballinluig of Dunfallandy and the Allt an Aghastair (WF76), which flows into Loch Faskally.

2.1.20 Eight minor watercourses (WF63, WF73, WF180-WF184 and WF191) do not cross the existing A9. WF63 downstream of C452 Foss Road is currently culverted and runs along the northbound side of the existing A9 until it discharges into the River Tummel. However, the existing culvert and existing outfall into the River Tummel conflicts with the proposed scheme widening and has therefore been assessed further to include the flows from WF63 discharging into WF191. Consequently, WF63 and WF191 are assessed together in the proposed scenario. WF73 originates downslope of the A9 and does not interfere with the proposed scheme and has therefore not been assessed further.

2.1.21 Watercourses WF74 and WF76 have been assessed as one as they cross the existing A9 via a single culvert eventually discharging into Loch Faskally. The exception to this is the baseline hydraulic performance assessment (paragraphs 4.1.17 to 4.1.21 of Section 4: Minor Watercourses) where they were assessed separately to determine their individual flow conditions and risk to the existing A9.

2.1.22 In addition, WF57, WF58 and WF78 are located at the project boundaries and where the existing A9 is already dualled and are not affected by the proposed scheme. The assessment therefore only considers 14 minor watercourse crossings where changes may be required or 15 minor watercourses for the baseline hydraulic performance assessment.

2.1.23 The proposed scheme would include the replacement of C452 Clunie-Foss Underbridge over minor watercourse WF69 which will be raised and realigned with the abutments set outside of the floodplain.

2.1.24 To support the widening of the existing A9 road carriageway, the proposed scheme will include an assessment of 14 culverts, including culvert extensions, new culverts and cascades and realignment of the culvert associated with WF63.

2.1.25 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:

- Horizontal and vertical alignment of the proposed scheme, specifically the influence on online/offline construction and the invert level of the road drainage to avoid clashes with the watercourse crossing;
- Maintenance requirements to meet DMRB standards (as defined by HA107/04);
- Ecological considerations, such as the need to provide adequate mammal passage through culverts;
- Geomorphological considerations related to potential erosion and sedimentation issues upstream and downstream of the watercourse crossings; and
- Existing flood risks, including fluvial interactions with the River Tummel, and the potential impact on upstream and downstream flood sensitive receptors in the event that a culvert is either extended (based on current geometry) or enlarged.

2.1.26 For all project 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. During the design process, the decision-making hierarchy adopted was to retain the existing culvert as the preferred option. Where this was not possible, due to engineering or environmental considerations listed above, the next preferred option was to extend the culvert on a ‘like-for-like’ basis to accommodate the proposed scheme. Similarly, where this was not possible, the existing culvert would be replaced with a new culvert. There are a number of locations where the proposed scheme will result in earthworks to be ‘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.

2.1.27 Appendix A11.8 (Minor Watercourse Crossings Report) contains further detail and justification for the design of each structure.

Surface Water Drainage

2.1.28 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 and associated pipe work, outfall structures and access tracks. The proposed scheme includes five SuDS retention ponds, 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

2.1.29 The design of the proposed scheme has developed over the three DMRB assessment stages (Table 1.1) with reference to a range of design principles and standards, and locational and environmental issues relevant to road projects. Table 2.1 provides a list of flood risk design principles and standards considered during the development of the proposed scheme to minimise potential flood risk impacts.

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Table 2.1: Proposed scheme flood risk design principles and standards

Proposed Scheme	Design Principles and Standards	Description
Mainline A9 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 • 1% AEP (100-year) flood event plus appropriate freeboard New (or replaced) side road (unsurfaced tracks) culverts • 2% AEP (50-year) flood event plus appropriate freeboard Freeboard • The freeboard design standard for culverts up to or equal to 2.4m in 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 2.4m, the freeboard shall be 600mm	In line with DMRB, all new (or replaced) mainline and access road culverts are designed to freely pass the 1% AEP (100-year) design 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 freeboard within the culvert barrel). The flood design standard for unsurfaced access track culverts is lower than for mainline culverts as these 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.
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.

Flood History

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

2.1.31 The Chronology of British Hydrological Events (2017) records seven historical flood events along the River Tummel, three of which are known to have impacted Pitlochry. SEPA noted that flood events occurred in Pitlochry in 1978, 1993 and 2015 and the TAYplan Strategic Flood Risk Assessment (SFRA) noted an additional two historic flood incidents in 2002, as detailed in Table 2.2. The records do not indicate whether the existing A9 was affected.

Table 2.2: Flood history

Date	Source	Description
1847	The Chronology of British Hydrological Events	Heavy floods recorded in the River Tummel at Innerhadden.
1903	The Chronology of British Hydrological Events	Heavy rains and strong winds, including snowmelt impacted large areas over the Tay catchment, including Pitlochry. Many roadways were recorded as impassable.
21 December 1912	The Chronology of British Hydrological Events	Heavy rains and snowmelt impacted large areas over the Tay catchment, including Pitlochry. River Tay recorded as abnormally high two weeks before the floods.
May 1913	The Chronology of British Hydrological Events	The Tay floods of 1913 were due to abnormally heavy rainfall over large areas of the Tay catchment with the River Tummel responding quickly to the heavy rains.
22 January 1928	The Chronology of British Hydrological Events	Wettest January on record. Snowmelt impacted large areas over the Tay catchment including Pitlochry
September 1947	The Chronology of British Hydrological Events	A large flood event overnight caused approximately £250,000 of damage. The flood on the River Tummel (during the construction of the Pitlochry hydro-electric scheme) breached the coffer dam, collapsed the left bank and toppled construction machinery. The floodwaters overtopped the piles and washed away derricks and large amounts of soil.
22 February 1978	The Chronology of British Hydrological Events	High river flows recorded towards the end of January due to prolonged rainfall and cold conditions which culminated in a flooding on the 22 February across the Tay catchment.
14 November 1978	SEPA	On the 14 November snowmelt impacted the River Tummel. The flood levels on the River Tummel were the highest ever recorded since the construction of the hydro-electric dam in the 1950's.
16 January 1993	SEPA and TAYplan SFRA	Parts of Pitlochry were flooded from the River Tummel in January 1993. The Greenfield site on the left bank upstream of Aldour Bridge was flooded and the waste water treatment works on the opposite side of Bridge Road was flooded. In addition, flooding problems in Duke of Edinburgh Drive and Fonab Crescent were reported.
30 July 2002	TAYplan SFRA	On 30 July 2002 there was a thunderstorm in the Pitlochry area that caused significant damage in and around Pitlochry. Roads and pavements were damaged and rail services halted due to breached embankments. West Moulin Road and Atholl Road were affected. The local Co-op was flooded and it was reported in the local newspaper that food items were washed as far down as the War Memorial Gardens. The Dunfermline Building Society basement was also reportedly flooded.
06 August 2002	TAYplan SFRA	On 6 August 2002 there was a further heavy rainfall event which again caused flooding in Moulin. The worst affected areas were Edradour Distillery, East Haugh, Dunfallandy and Balnaguard. The Black Spout Bridge was washed out which carries the main road into Pitlochry from the south was washed out and a section of a railway embankment collapsed. There were several landslips reported in the area with one house at East Haugh being inundated with mud and stones.
05 and 30 December 2015	SEPA and local news articles	Fluvial flooding associated with Storm Desmond on 5 December and Storm Frank on 30 December along the River Tummel. The A924 slip road into Pitlochry from the A9 was closed due to the River Tummel bursting its banks on 5 December.

Strategic Flood Risk Assessment (SFRA)

2.1.32 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.

2.1.33 The SFRA (2014) for the A9 dualling programme referred to the Potentially Vulnerable Area (PVA 08/03) in Pitlochry identified by SEPA as part of the National Flood Risk Assessment under the Flood Risk Management (Scotland) Act 2009.

2.1.34 The reports of flooding in Pitlochry were noted as frequent with 79% attributable to fluvial and 21% as surface water flooding and a groundwater flooding potential grading of low to moderate. The SFRA (2014) also noted that over 10 properties in Pitlochry within 500m of the existing A9 were at fluvial flood risk that was noted as flood risk of 'very high' importance to the local area.

2.1.35 The SFRA (2014) noted that the existing bridge crossings near Pitlochry are approached by extending embankments that lie within the existing floodplain potentially limiting the river flows during high flow events.

2.1.36 The key recommendation from the SFRA (2014) was to:

"Avoid increasing overall flood risk in the dualling corridor and on sensitive receptors that are 'hydrologically influenced' by the A9 dualling".

Preliminary Flood Risk Assessment

2.1.37 Preliminary Flood Risk Assessments (PFRA) (Transport Scotland, 2014) were undertaken as part of the route-wide SFRA which included Pitlochry as a flood risk area. The PFRA highlighted frequent reports of flooding in Pitlochry over the last 19 years with approximately 12% of the reported properties situated within the SEPA indicative Flood Map (estimated at 263 of 2,154 properties) estimated to be at risk from the 0.5% (200-year) flood event.

2.1.38 The PFRA indicated that the existing flood risk is believed to be from fluvial flooding from the River Tummel, from Moulin Burn and backing up of the River Tummel into watercourses in Pitlochry. The PFRA detailed that the existing river crossings appeared to be constricting flow with embankments that partially divide the floodplain, noting that any new bridge crossings could potentially impact the existing flood risk of properties at Pitlochry. The PFRA also stated that surface water runoff from the hills will flow towards Pitlochry prior to entering the River Tummel, however the existing A9 itself was not stated to be at risk of surface water flooding.

TAYplan Level 1 Strategic Flood Risk Assessment

2.1.39 A Level 1 TAYplan SFRA (The Strategic Development Planning Authority (SDPA), 2014) was completed in November 2014 with its primary aim to avoid locating new development in areas of flood risk and to bring sustainable economic development to the region.

2.1.40 The TAYplan Level 1 SFRA (SDPA, 2014) highlighted that parts of Pitlochry were flooded from the River Tummel in January 1993. The wastewater treatment works was flooded on Bridge Road along with Duke of Edinburgh Drive and Fonab Crescent. On 30 July 2002 Moulin Road and Atholl Road were affected. On 6 August 2002 there was another heavy rainfall event causing flooding in Moulin, East Haugh and Dunfallandy affecting seven properties. During this event the Black Spout Bridge over Edradour Burn was washed away and a section of the railway embankment of the HML collapsed, however the existing A9 itself was not affected.

3 Principal Watercourses

Introduction

3.1.1 The 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 Tummel (WF70), Loch Faskally (WF75) and the River Garry (WF100).

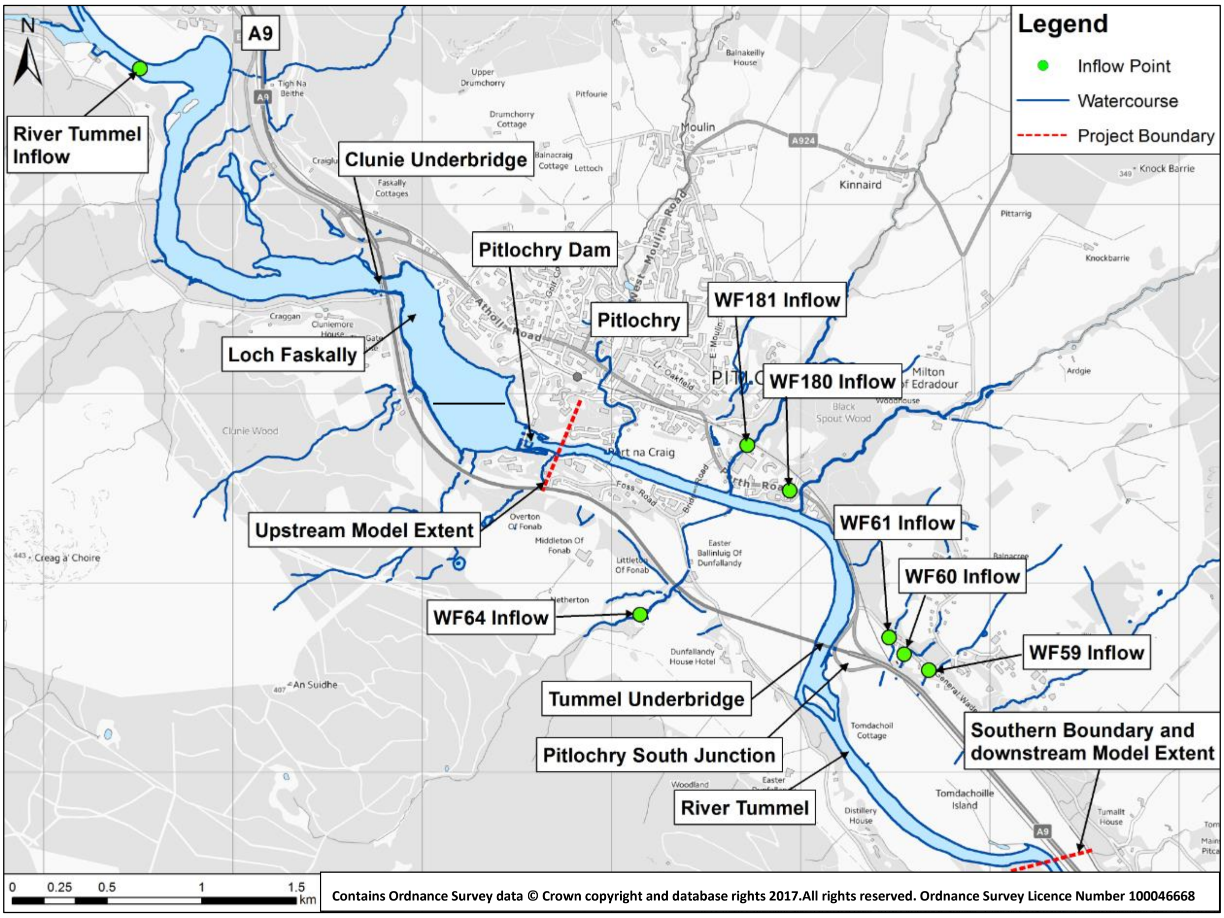
3.1.2 In general, the majority of the proposed scheme between Pitlochry and Killiecrankie is located outside the 0.5% AEP (200-year) fluvial flood envelope shown in the SEPA Flood Map (2015) (Annex C: Flood Risk Assessment Figures). This is with the exception of the section of the A9 that transverses the floodplain as it crosses the principal watercourses, in particular the River Tummel at the Tummel Underbridge (ch1000) and Loch Faskally at the Clunie Underbridge (ch4250). The floodplain extent associated with the River Garry does not extend to the existing A9 and is therefore not considered in further detail as part of this FRA.

3.1.3 The assessment of fluvial flooding therefore focuses on the new underbridge alongside the existing Tummel Underbridge (ch1000) and the new embankments that transverse the floodplain. Given the magnitude of the River Tummel in terms of its size, peak flow and hydraulic complexity, the proposed scheme has the potential to significantly impact flooding in the vicinity of the Tummel Underbridge.

Assessment Approach

3.1.4 In light of limitations associated with the SEPA Flood Map (2015), this FRA has developed a numerical hydraulic model to assess the River Tummel (ch0000 to ch2500), south from Pitlochry Dam to the Southern Boundary of the proposed scheme, including the Tummel Underbridge and floodplain near the Pitlochry South junction, as shown in Diagram 3.1.

Diagram 3.1: Model extents and flow estimation locations



3.1.5 The hydraulic model adopts a linked 1D-2D technique. The river channel is represented as a 1D component using Flood Modeller software that is linked dynamically to the floodplain, which is represented in 2D using TUFLOW software.

3.1.6 To assess existing flood risks and potential impacts of the proposed scheme, the FRA considers two development scenarios: the baseline (existing A9) scenario and the 'proposed scheme' (no mitigation) scenario. The proposed scheme however does include embedded mitigation such as culverts and drainage infrastructure. The ES (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 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, retaining walls and road drainage features, such as SuDS features.

3.1.7 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). The hydrological inflows simulated used the critical storm duration of the River Tummel (18.25hrs) in order to assess the flood risk. Appendix A11.2 (Surface Water Hydrology Report) provides further detail of the flood hydrology. Table 3.1 details peak flow estimates for a range of flood probabilities at specific locations along the modelled watercourses. The flows in the River Tummel downstream of Loch Faskally are lower than those upstream of Loch Faskally, which reflects flood routing through the reservoir.

Table 3.1: Peak flood design flows (m^3/s)

Catchment	50% AEP (2-year)	3.33% AEP (30-year)	1% AEP (100-year)	0.5% AEP (200-year)	0.5% AEP (200-year) + CC
Loch Faskally (WF75) (Clunie Underbridge)	571	1,009	1,228	1,371	1,645
WF 181	6.15	12.8	16.8	19.4	23.3
WF 180	7.18	15.7	21.0	24.7	29.7
WF 59	0.27	0.63	0.80	0.92	1.10
WF 60	0.23	0.54	0.69	0.79	0.95
WF 61	0.19	0.45	0.57	0.66	0.79
WF 64	1.21	2.60	3.39	3.98	4.77
Residual 1 (between two A9 crossings)	7.57	16.5	22.1	26.1	31.3
Residual 2 (downstream of D/S A9 crossing)	1.99	4.21	5.80	6.47	7.77
River Tummel (WF70) (Tummel Underbridge)	561	990	1,206	1,346	1,615

3.1.8 Once simulated, model outputs within the modelled river reach 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.

3.1.9 Annex C (Flood Risk Assessment Figures) contains mapping illustrating the baseline scenario and the proposed scheme (no mitigation) scenario flood depths across the modelled floodplain. The mapping also illustrates the impacts on maximum flood level difference between baseline and proposed scheme, categorised using Table 3.2, during the design flood event. Appendix A11.4 (Hydraulic Modelling Report) contains peak water levels for each model cross-section.

Table 3.2: 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 >10mm
	Moderate Beneficial	Reduction in peak flood level >50mm
	Major Beneficial	Reduction in peak flood level >100mm

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

Baseline Risks

3.1.11 Using the findings of the hydraulic modelling, this section provides an overview of baseline flood risks, upstream and downstream of the Tummel Underbridge (ch0000 to ch2500) from 450m downstream of Pitlochry Dam to the Southern Boundary. Diagrams 3.2 and 3.3 show the flood risks associated with the 3.33% AEP (30-year) event and the design flood event respectively. Upstream of the Pitlochry Dam no hydraulic modelling was undertaken as Loch Faskally is well maintained under the Reservoirs (Scotland) Act 2011 by Scottish and Southern Energy (SSE) and ensures a low risk of flooding from this source. Further information relating to the baseline risks of flooding associated with the collapse and/or failure of reservoirs is detailed in paragraphs 7.1.5 to 7.1.12 of Section 7 (Failure of Water-Retaining Infrastructure).

3.1.12 The hydraulic modelling extents show a similar extent of flooding to the SEPA Flood Map (2015) for the 0.5% AEP (200-year) flood, although the model includes an allowance for climate change. The minor differences can be principally attributed to a reduction in the peak flows along the River Tummel as described in the hydrology report, potentially differences in the DEM used and boundary constraints of the A9, A924 General Wade's Military Road, HML and Foss Road.

3.1.13 Immediately upstream of the Aldour Bridge (Bridge Road), hydraulic modelling predicts the sports field on the left bank and properties along Fonab Crescent on the right bank to be at risk during the 3.33% AEP (30-year) flood event onwards at depths up to 0.6m and 1.2m respectively, increasing to 3m during the design flood event. Foss Road is also impacted in the design flood event to a depth of up to 0.4m.

3.1.14 Immediately downstream of the Aldour Bridge, hydraulic modelling shows that backflows from the River Tummel along Kinnaird Burn spill initially on the right bank of Kinnaird Burn (WF181) and behind the modified embankment during the 3.33% AEP (30-year) flood event onwards, impacting the Wastewater Treatment Works (WwTW) at depths up to 0.9m. On the right bank upstream of the existing Tummel Underbridge agricultural land is impacted up to a depth of 1.6m during the 3.33% (AEP) flood event.

3.1.15 During the 0.5% AEP (200-year) event, flood depths downstream of Aldour Bridge extend across from the WwTW impacting all properties along Duke of Edinburgh Drive at a depth of up to 0.6m. Aldour Industrial Estate is impacted at a depth up to 1.8m, caused by overtopping of the River Tummel on the left bank and backflow along Kinnaird Burn and WF180 respectively. The A924 becomes at risk during the 0.5% AEP (200-year) event in this location, reaching depths of up to 0.5m. In the design flood event the extents are largely constrained by the A924, reaching depths of 0.8m, and the River Tummel with depths in the WwTW reaching 2.5m, however the distillery north of the A924 is shown to be impacted up to a depth of 1.4m.

Diagram 3.2: Tummel Underbridge - Baseline scenario, 3.33% AEP (30-year) event

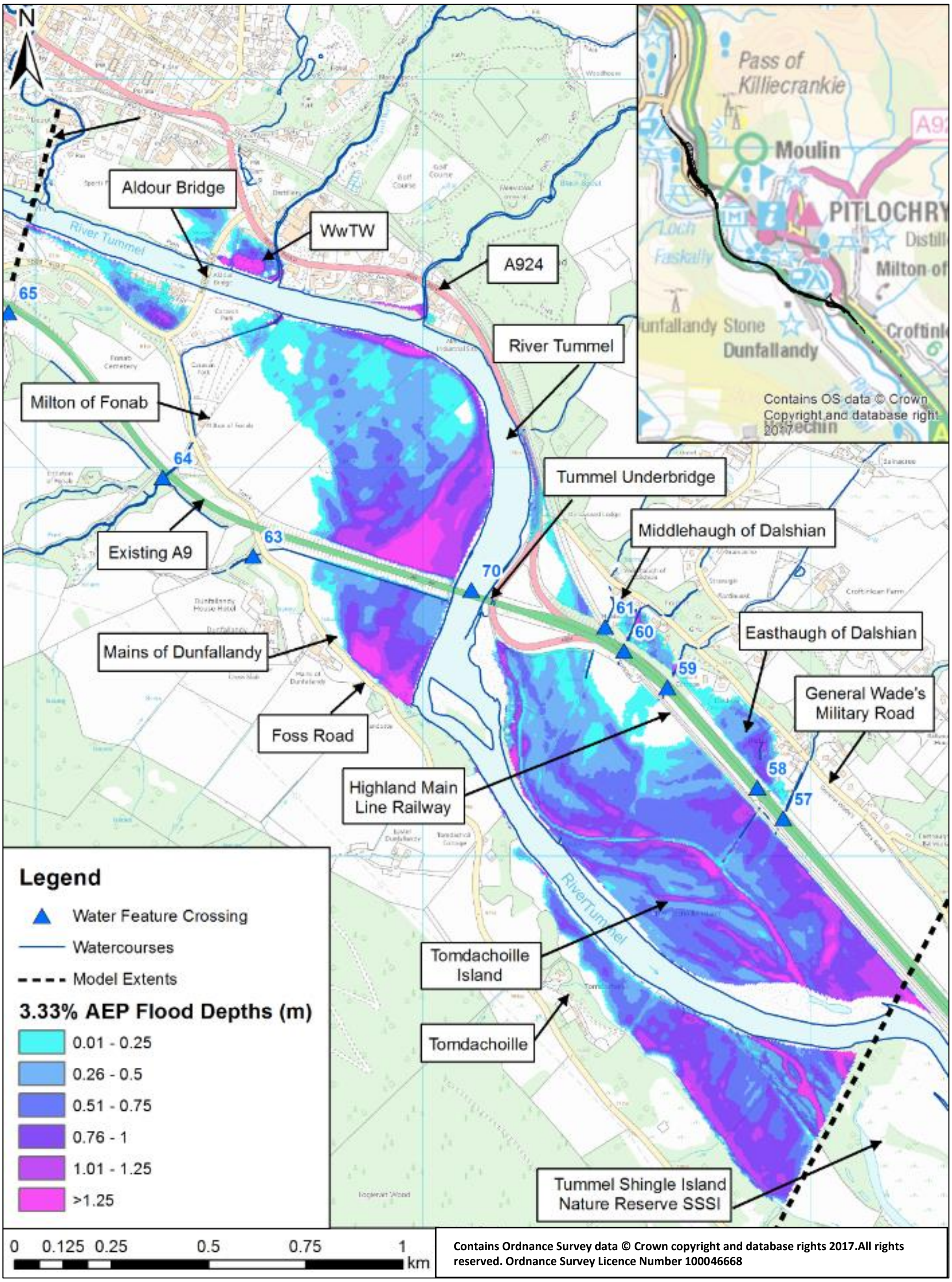
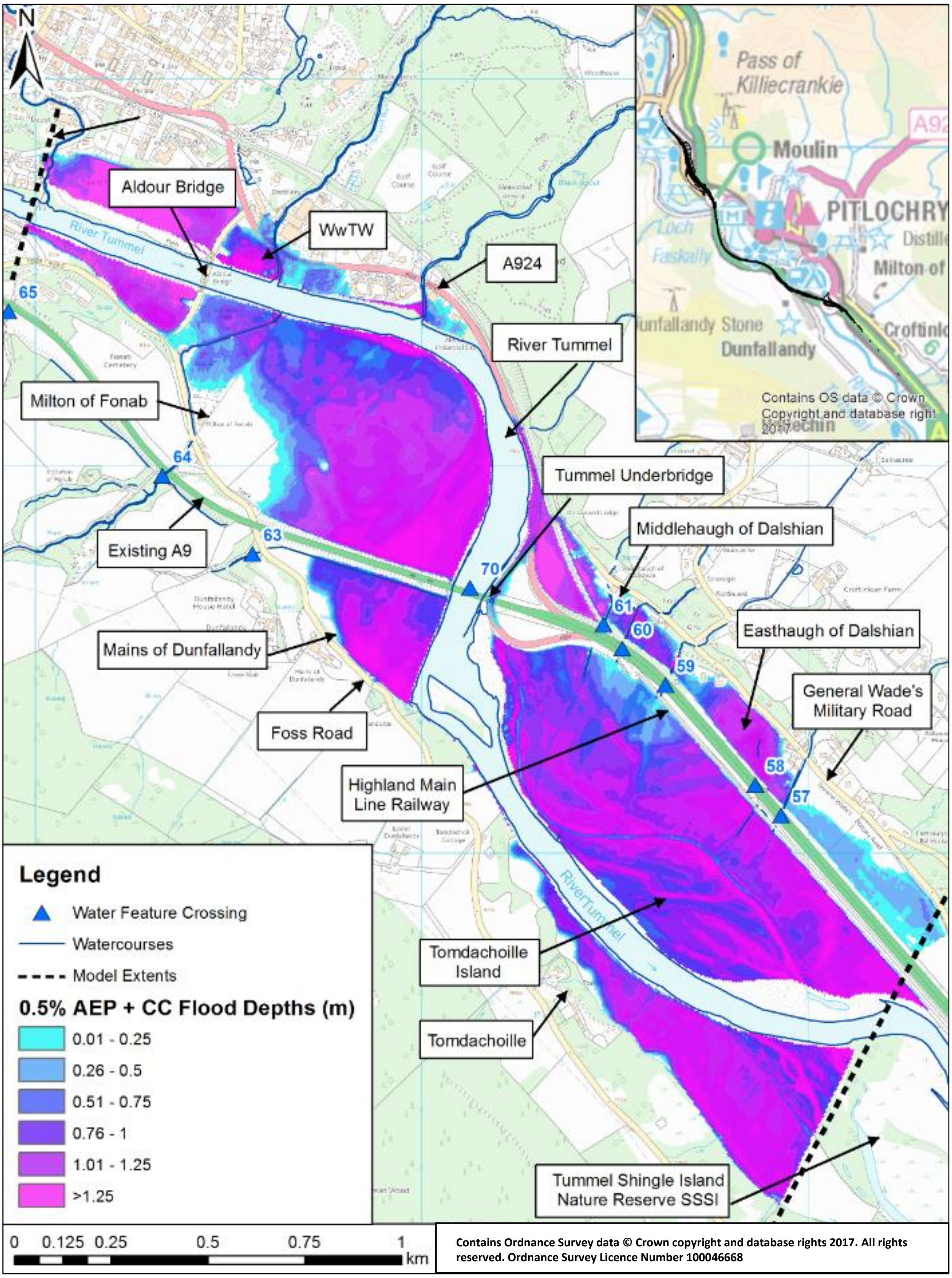


Diagram 3.3: Tummel Underbridge - Baseline scenario, 0.5% AEP (200-year) +CC event



3.1.16 On the right bank, upstream of the Tummel Underbridge, in both the 0.5% AEP (200-year) event and design flood event the floodwaters extend across the rural area between the River Tummel and Foss Road reaching depths in excess of 2.5m.

3.1.17 In events greater than the 3.33% AEP (30-year) the River Tummel is predicted to overtop on the left bank, upstream of the Tummel Underbridge, along the A924 at a depth up to 0.7m and ponding in the basin between the HML and the A924 at a depth of up to 2m. Between the 3.33% AEP (30-year) and 0.5% AEP (200-year) event the railway underpass near Donavourd Lodge conveys the flows under the HML, impacting properties and access roads lying behind the A9 embankment to the south and General Wade's Military Road to the north. The modelled flood extents extend from Middlehaugh of Dalshian to East Haugh Hotel where depths reach 2m during the 0.5% AEP (200-year) event and up to 2.2m during the design flood event.

3.1.18 Flows from WF59-61 are currently culverted under the existing A9 via three separate culverts that have limited capacity to pass the design flows. Downstream of the existing A9 culvert, WF59 flows in a short open channel adjacent to the HML where it enters a second culvert. WF59 then discharges to second shorter open channel section and is then culverted to the River Tummel.

3.1.19 Downstream of the existing A9 and HML culvert, WF60 discharges to a short open channel section and is then also culverted to the River Tummel via a small pipe. Downstream of the existing A9 and HML culvert, WF61 discharges to a small open channel approximately 75m in length. WF61 is then culverted via an un-surveyed pipe that is anticipated to converge with the pipe for WF60 prior to discharging to the River Tummel.

3.1.20 Each of the pipes associated with WF59-WF61 have insufficient capacity to convey peak flows and surcharge, impacting culvert conveyance from Middlehaugh of Dalshian. During the 3.33% AEP (30-year) flood event, flood depths reach 1.5m impacting five properties on the left bank of WF60. During the 0.5% AEP (200-year) flood event the modelled flows from the River Tummel coincide with the flows from the railway underpass near Donavourd Lodge impacting properties along Middlehaugh of Dalshian and East Haugh Hotel up to depths of 2m. Land between Middle Cottage and Dalshian Farmhouse, but not the properties themselves, are predicted to reach flood depths of up to 0.6m and 1.5m respectively.

3.1.21 During the 3.33% AEP (30-year) flood event, immediately downstream of the existing Tummel Underbridge the River Tummel overtops on both the left and right banks impacting primarily agricultural land and grassland and again on the right bank further downstream near Tomdachoille reaching depths of up to 1.7m. In the 0.5% AEP (200-year) event and design flood event, the hydraulic modelling predicts the agricultural land on the right bank reaches depths up to 2.8m and 3.2m, respectively, constrained by Foss Road, the existing A9 and the River Tummel. Overtopping on the left bank envelops the agricultural land which is constrained by the HML, reaching depths up to 2m for both 0.5% AEP scenarios. Overtopping of the right bank of the River Tummel downstream near Tomdachoille is exacerbated by a topographic ridge which impounds flood water and prevents flows re-entering the River Tummel, with depths typically reaching between 1m to 2.5m for all three modelled flood events.

<u>Baseline Summary</u>

3.1.22 The existing A9 carriageway and the HML is not at risk in the baseline scenario. The main flood risk to properties from the 3.33% AEP (30-year) event or greater lies to the north of the existing A9 between WF57 and WF61, upstream of Aldour Bridge along Fonab Crescent, downstream of Aldour Bridge impacting a WwTW and properties along Duke of Edinburgh Drive and the A924 immediately upstream of the Tummel Underbridge. As a result, the risk of flooding from the River Tummel and minor watercourses is high and the Environmental Statement has classified as a 'Very High' sensitivity watercourse.

Potential Impacts

3.1.23 Using the findings of the hydraulic modelling, this section provides an overview of the proposed scheme (no mitigation) impacts on flood risks, upstream and downstream of the Tummel Underbridge (ch0000 to ch2500) from 450m downstream of Pitlochry Dam to the Southern Boundary. Diagrams 3.4 and 3.5 show the flood risk associated with the 3.33% AEP (30-year) event and the design flood event, respectively.

3.1.24 During the 3.33% AEP (30-year) event and the design flood event there is largely a negligible flood impact (<2mm) across the River Tummel floodplain, notably towards the upstream model extent where a number of receptors are located, namely Fonab Crescent, Foss Road, Aldour Gardens, Aldour

Industrial Estate, Duke of Edinburgh Drive, Caravan Park and the WwTW, located immediately upstream and downstream of Aldour Bridge.

Diagram 3.4: Tummel Underbridge – Proposed scheme scenario, 3.33% AEP (30-year) event

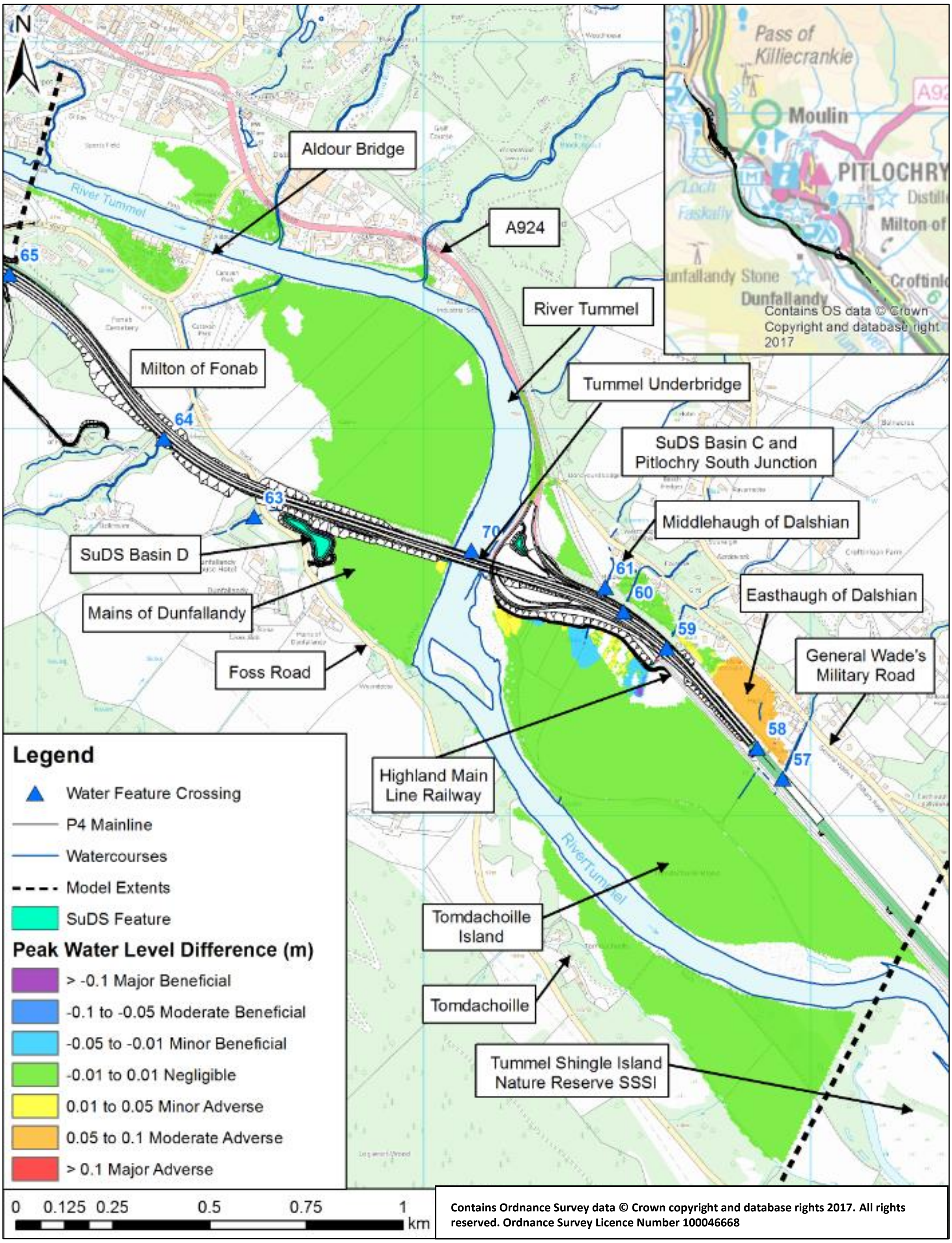
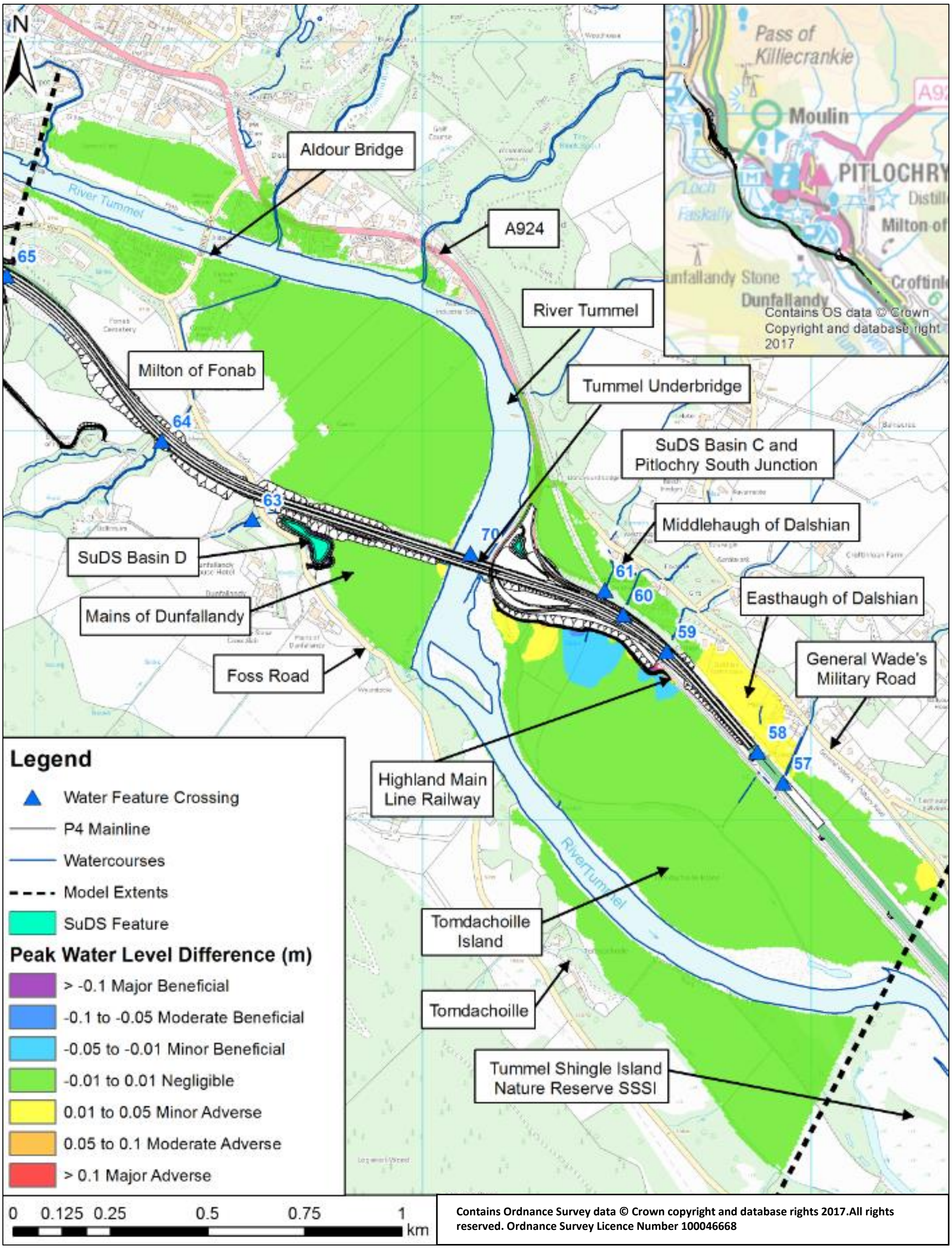


Diagram 3.5: Tummel Underbridge – Proposed scheme scenario, 0.5% AEP (200-year) + CC event



3.1.25 During the 3.33% AEP (30-year) event, the proposed scheme features within the floodplain on the left bank immediately upstream of the Tummel Underbridge and SuDS Pond C result in a net loss of floodplain storage of approximately 517m³ between ground levels of approximately 74.1m and 76.6m AOD. The loss of floodplain is attributable to the embankment widening of the Pitlochry South junction southbound carriageway and the bridge embankment on the right bank. Consequently, the proposed scheme increases flood risk by <2mm to this area of agricultural land which is bounded by the A924 to the west and the HML to the east. The Middlehaugh of Dalshian is marginally impacted with peak water levels increasing between 6mm to 14mm. Flows extend along to Middle Cottage where there is a ridge of high land. Flows are predicted to spill over, increasing water levels by up to 16mm immediately south of Middle Cottage. An additional bund beside Dalshian Farmhouse causes water to spill over in a 'weiring' effect to the land surrounding East Haugh Hotel with water levels increasing up to 65mm during the 3.33% AEP (30-year) flood event when compared to the baseline scenario.

3.1.26 The proposed scheme features within the floodplain on the right bank downstream of the Tummel Underbridge result in a loss of floodplain storage of approximately 10,779m³ between ground levels of approximately 74m and 77.5m AOD. The loss of floodplain is attributable to the northbound carriageway widening and embankment works, SuDS Pond D and raised access track which are partially located within the 0.5% AEP (200-year) modelled extent. The proposed scheme results in a 1mm decrease in peak flood levels during the 3.33% AEP (30-year) event on the agricultural land (Mains of Dunfallandy), and a water level increase by up to 6mm during the design flood event when compared to the baseline scenario which is considered a negligible impact on flood risk. However, to the north-east of Mains of Dunfallandy, localised water levels increase by up to 35mm during the 3.33% AEP (30-year) and design flood event.

3.1.27 Additionally, there are small areas of adverse impact, immediately downstream on the left bank of the Tummel Underbridge which is due to the embankment widening associated with the Pitlochry South junction improvements resulting in a net loss of floodplain storage of approximately 14,805m³ between ground levels of approximately 73.5m and 76.25m AOD. Peak flood levels increase between 11mm to 70mm for these areas during the design flood event and between 11mm to 59mm during the 3.33% AEP (30-year) event when compared to the baseline scenario. These agricultural areas are located adjacent to the River Tay SAC and downstream of WF60 which have been assessed as not being sensitive to increased flood depths.

3.1.28 Similarly, the Mains of Dunfallandy is not considered to be sensitive to increased flood depths with floodplain compensation deemed impractical at both locations because:

- the impact due to flooding is considered low;
- would not adversely impact farm operations on the agricultural land; and
- neighbouring areas would not see a reduction in flood risk.

3.1.29 Discussion with the landowners has taken place regarding the predicted impacts to their land. In particular, the area of land subject to an increase in flood levels during the design flood event and which has been included in the Compulsory Purchase Order. The land may be returned to the landowner (though not guaranteed) with appropriate burdens restricting development and protecting the area for flood storage. Should the land be returned to the landowner, it may be available for future agricultural use by the landowner.

3.1.30 The proposed scheme also includes a new access track in the floodplain immediately south of the embanked Pitlochry South junction northbound carriageway and minor watercourse works associated with WF59-61. The hydraulic modelling shows a decrease in flood risk to the agricultural land immediately downstream of WF59 and WF61 and within the Tummel floodplain, decreasing water levels by up to 184mm during the 3.33 AEP (30-year) event and up to 107mm during the design flood event when compared to the baseline scenario. This betterment to agricultural land is due to the redistribution of flow from the additional ditches that provide a flow path for water passing through the culverts associated with WF59-61. Further assessment regarding these minor watercourses and the interaction with the River Tummel are detailed in Section 4.

3.1.31 In summary, the proposed scheme hydraulic modelling shows that without mitigation the scheme has both beneficial and adverse impacts of flooding, which can be attributed to raising the existing A9 carriageway and new proposed scheme features within the floodplain. Adding an additional bridge structure parallel to the Tummel Underbridge has a negligible impact on flooding.

3.1.32 However, the proposed scheme includes the construction of new embankments, access roads and drainage features (e.g. SuDS ponds) within the functional floodplain, which results in a direct loss of floodplain storage, and as a result, local impacts on flood risks. Consequently, adverse impacts are identified specifically associated with the increase in depth of flooding within the River Tummel floodplain. Flood extents are not shown to differ significantly from the baseline as ground levels rise steeply outside the functional floodplain.

3.1.33 Whilst the proposed scheme hydraulic modelling confirms there is no risk to the proposed scheme or HML, the proposed scheme affects the risk of fluvial flooding to agricultural land on both banks, downstream of the Tummel Underbridge. As a result, additional mitigation measures are proposed, with the overall aim of achieving a neutral impact.

Mitigation Measures

3.1.34 The proposed scheme hydraulic modelling confirms that the scheme will increase flood depths across the River Tummel floodplain, notably upstream and downstream of the Tummel Underbridge. This is due to culvert extensions, the displacement of floodwaters and a loss of floodplain capacity caused through the proposed scheme widening and includes the Pitlochry South junction improvements, new access roads and tracks and SuDS Pond D encroaching on to the floodplain. The additional bridge parallel to the Tummel Underbridge has a neutral impact on flooding.

3.1.35 The proposed scheme hydraulic modelling includes minor watercourses WF59-61, as there are fluvial interactions with the River Tummel and consequently flood risk impacts are interlinked. Therefore, a collaborative set of mitigation measures are proposed, which includes a flood relief culvert under the proposed scheme immediately adjacent to WF61 and improved open-channel drainage paths from the downstream ends of the embankment culverts at WF59-WF61 to the River Tummel.

3.1.36 To avoid increasing the frequency of flooding within the River Tummel floodplain, it is proposed that the existing embankment is retained at the location where the ditch outfalls into the River Tummel and the final 10m is a 1.2m diameter culvert which drains under the embankment, with a non-return flap valve at the outfall to avoid return flows from the River Tummel onto the floodplain before the banks are overtopped.

3.1.37 These mitigation measures are detailed further in paragraphs 4.1.98 to 4.1.117 of Section 4 (Minor Watercourses) of this FRA.

Residual Risks

3.1.38 Some residual risks associated with the River Tummel remain even after the mitigation measures have been incorporated. As there are principal watercourse and minor watercourse interactions, the mitigation measures are detailed in paragraphs 4.1.98 to 4.1.117 of Section 4 (Minor Watercourses) of this FRA.

3.1.39 Residual risks remain immediately upstream and downstream of the Tummel Underbridge which is detailed further in paragraphs 4.1.118 to 4.1.122 of Section 4 (Minor Watercourses) of this FRA.

3.1.40 Whilst the proposed scheme has been designed to ensure the main road remains free from flooding during the design flood event, a residual risk remains during extreme flood events of greater magnitude. The carriageway of the proposed scheme main road has been set above the peak water level, plus 600mm freeboard to provide an additional safety margin during more extreme events. Based on the probability of extreme design events greater than the design event, the risk of floodwater overtopping the proposed scheme is considered low and no additional mitigation is proposed.

4 Minor Watercourses

Introduction

4.1.1 Between Pitlochry and Killiecrankie, there are 25 minor watercourses, which drain the adjacent hillside towards the River Tummel, Loch Faskally and the River Garry at the valley bottom. They are typically smaller unnamed streams, confined to narrow, often deeply incised channels with relatively small catchment areas (typically smaller than 1 km²), see Appendix A11.1 (Baseline Conditions). The majority of these minor watercourses flow underneath the existing A9 through circular culverts ranging in diameter between 0.3m and 1.8m.

4.1.2 As detailed in paragraphs 2.1.19 to 2.1.27 of Section 2 (A9 Corridor), the assessment considers 14 minor watercourse crossings. The range of peak 0.5% AEP (200-year) plus climate change flows within the watercourses range between $0.13m^3/s$ and $4.8m^3/s$.

4.1.3 As the minor watercourses generally pass through uncultivated agricultural land, their flood sensitivities are typically deemed to be low. However, for the proposed scheme where the minor watercourses flow underneath the existing A9, there is the potential for local impacts of the crossing, which could place neighbouring sensitive receptors (including properties, environmental designations, critical infrastructure and the A9 itself) at risk of flooding. This is especially the case where the existing capacity of the culvert impedes flood flow and there is limited upstream flood storage and freeboard available.

4.1.4 The proposed scheme would include modifications to existing water crossings where the main road embankments would be widened to accommodate the dualled carriageway. The proposed scheme would also include new watercourse crossings where the mainline carriageway differs from the existing and where new access roads and access tracks are proposed.

4.1.5 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 and sized in compliance with the DMRB. However, there is potential for the proposed scheme to have adverse impacts. For example, changing culvert geometry and building within the floodplain, could increase upstream water levels, reduce floodplain storage volume or pass additional flood flow downstream. This is a particular issue where there are sensitive flood receptors nearby.

Assessment Approach

4.1.6 The FRA Flood Maps (Flood Risk Assessment Figures) and Diagram 2.4 illustrate the distribution 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. WF64) as many of the watercourses are unnamed.

4.1.7 The SEPA Flood Map (2015) does not often include these watercourses or ditches 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 higher risk minor watercourses.

4.1.8 Firstly, the Flood Estimation Handbook (FEH) statistical method (which is used to estimate the flood frequency curve for ungauged sites using data from a group of similar sites) was used to estimate the flood for ungauged catchments. The FEH Rainfall-Runoff method (Centre for Ecology and Hydrology, 1999) were used to estimate the peak design flow for each minor watercourse, with the design flow adopting the highest value predicted by the two methods. Appendix A11.2 (Surface Water Hydrology Report) provides further details of the hydrological approach and results.

4.1.9 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.

4.1.10 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.

4.1.11 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.

4.1.12 Where the preliminary assessment suggested a low risk of flooding or low impact, the 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.

4.1.13 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. In particular, watercourses WF71-76 to the north of Clunie Underbridge have been modelled using a 1D Infoworks ICM numerical hydraulic model of the proposed condition instead of the hydraulic spreadsheet calculations to better represent the more complex interactions of the proposed piped systems and to help define baseline flood risks and potential impacts.

4.1.14 The hydraulic model does not include any significant storage features, and a steady-state approach with peak flows as determined by hydrological analysis was therefore considered appropriate. Although the calculations for the baseline (hydraulic spreadsheet calculations) and the proposed condition (hydraulic model) are different, as they are both based on steady-state approaches this provides some consistency between the two scenarios.

4.1.15 The hydraulic modelling of the proposed condition was undertaken for the 1% AEP (100-year) event and the design flood event. 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.

Simple Assessment

4.1.16 The subsections below provide details of the hydraulic performance assessment, which have been used to scope further detailed assessment in paragraph 4.1.26 below (Detailed Assessment).

<u>Baseline Hydraulic Performance</u>

4.1.17 Table 4.1 provides an overview of the baseline hydraulic performance assessment of the minor watercourse crossings, when tested against the peak flow during the design flood event.

Table 4.1: Baseline hydraulic performance - peak 0.5% AEP (200-year) plus climate change flow

Minor Watercourse Crossing	Total (Crossings)	Hydraulic Performance			
		Culvert Free Flow	Culvert Surcharged		A9 at Risk
			HWL < Bank Level	HWL > Bank Level	HWL > A9 Level**
Mainline	15*	8	1	5	5

*Water features 74 and 76 are assessed separately to determine their individual flow conditions and risk to the existing A9. Therefore, there are 15 minor watercourses as opposed to 14.

**A9 at risk when predicted HWL exceeds or is within 600mm of the carriageway level

4.1.18 Of the 15 minor watercourses, six existing watercourse crossings were shown to have adequate capacity to pass the design flood event, including 600mm culvert freeboard and nine watercourse crossings were shown to be under capacity.

4.1.19 Five of the watercourse crossings pose a risk of flooding to the existing A9 carriageway of which four experience free flow conditions. However, there is insufficient freeboard between the baseline road level and the HWL to ensure the road is not at risk. The fourth watercourse crossing is surcharging with the HWL just below grade with the existing A9.

4.1.20 The under capacity crossings are clustered in two locations, at the upstream extent of the proposed scheme, north of Clunie Underbridge (WF71, WF74 and WF76) and at the downstream extent of the proposed scheme between Middleton of Fonab and Easthaugh of Dalshian (WF59-65 (excluding WF63)). The estimate peak design flows along these minor watercourses are typically low and vary from 0.90-3.89m^3/s in the upstream cluster to 0.79-4.77m^3/s in the downstream cluster.

4.1.21 This is likely to be a conservative estimate of baseline flood risks, since no account is taken of the shape of the flow hydrograph and consequently the flood volume. However, due to local topography, which in many locations slopes down towards the existing A9 main road, any out of bank flow originating from the culvert inlet could place the A9 at risk of flooding.

<u>Proposed Scheme Hydraulic Performance</u>

4.1.22 Along the existing A9, the proposed scheme includes:

- 10 like-for-like culvert extensions (i.e. same dimensions and flow capacity); and
- 4 replaced culverts design under DMRB, of which 1 retained existing dimensions.

Change in Hydraulic Performance

4.1.23 As outlined in paragraphs 2.1.9 to 2.1.29 of Section 2 (A9 Corridor), all replaced or new A9 crossings are designed to freely pass the peak flow during the 1% AEP (100-year) event plus appropriate freeboard. All new access track crossings are designed to freely pass the peak flow during the 2% AEP (50-year) design event plus appropriate freeboard. The hydraulic performance of each crossing is then tested against the peak flow during the design flood event. Table 4.2 provides an overview of the proposed scheme assessment.

Table 4.2: Proposed scheme hydraulic performance - peak 0.5% AEP (200-year) plus climate change flow

Minor Watercourse Crossing	Total	Hydraulic Performance			
		Culvert Free Flow	Culvert Surcharged		
			HWL < Bank Level	HWL > Bank Level	HWL > A9 Level*
Mainline	14	14	0	0	0
*A9 at risk when predicted HWL exceeds or is within 600mm of the carriageway level					

4.1.24 The impacts of the proposed scheme on flooding are complex with many locations experiencing different impacts upstream compared to those downstream. Upstream impacts are generally beneficial with the replacement (and enlargement) of undersized culverts along the existing A9, with the proposed scheme now showing free flow conditions in all 14 modified culverts during the design flood event, when compared to eight of 15 in the baseline scenario.

4.1.25 Downstream of the A9 watercourse crossing, the proposed scheme has the potential to increase flood flows as a result of enlarging the existing crossing at WF69 and WF71, which may have been holding floodwater back during the baseline scenario. However, the hydrographs show both watercourses peak 15 hours before the peak in the River Tummel and therefore any increased flow is unlikely to increase joint flood risks to receptors downstream, therefore the impact of the proposed scheme is considered low.

Detailed Assessment

4.1.26 The Hydraulic Performance Assessment (Annex B) assesses all watercourse crossings where the proposed scheme has a potential adverse impact on flood risk during the design flood event. Watercourses with a low flood risk impact are summarised in Table 4.3. The exceptions are WF71-72 which have been hydraulically modelled and therefore discussed in more detail alongside those watercourses with a moderate to very high flood risk impact.

Table 4.3: Minor Watercourses with a low potential impact

ID	Works Proposed	Analysis Undertaken	Baseline Scenario			Proposed Scheme Scenario			Receptors at Risk	Summary
			Surcharge or Free Flow	Upstream Flow Condition	Risk to A9	Surcharge or Free Flow	Upstream Flow Condition	Risk to A9		
WF64	Culvert extension (both sides) from 39m to 65m Upstream channel realignment for ~212.5m Existing culvert diameter of 1.75m retained	Culvert Assessment	Free Flow	In Bank	No	Free Flow	Out of Bank	No	None	Following this extension, it is estimated that the A9 does not flood during the design event. There are out of bank flows upstream in the proposed scheme scenario, however with no sensitive flood receptors affected and the A9 deemed not at risk this is considered acceptable.
WF67	Culvert extension from 36m to 64m Existing culvert diameter of 0.8m retained. 2.1m deep chamber at culvert entrance to be retained in the proposed condition	Culvert Assessment	Free Flow	In Bank	No	Free Flow	In Bank	No	None	Following this extension, it is estimated that the A9 does not flood during the design event
WF68	Culvert extension from 52m to 55m Existing culvert diameter of 1.75m retained.	Culvert Assessment	Free Flow	In Bank	No	Free Flow	In Bank	No	None	Following this extension, it is estimated that the A9 does not flood during the design event
WF69	Culvert extension from 73m to 75m Existing culvert diameter of 1.75m retained. Culvert installation at a lower elevation to accommodate the road widening on the downslope bank. Consequently, a new cascade feature is proposed in the upstream channel. Downstream, regrading and scour protection works are proposed within the reach of watercourse which lies under the C452 Clunie-Foss Road underbridge.	Culvert Assessment	Free Flow	In Bank	Yes	Free Flow	In Bank	No	None	Following this extension, it is estimated that the A9 does not flood during the design event. There is no increase in pass forward flow during the design flood event; hence downstream flood risk is not impacted by the proposed scheme.

WF59-WF61: Baseline Scenario

4.1.27 Watercourses WF59-61 are currently culverted under the existing A9 and the flood mechanism is linked as explained in paragraph 3.1.18 of Section 3 (Principal Watercourses). Because of this, the baseline scenario has been modelled using a linked 1D/2D technique, where the river channel is represented as a 1D component using Flood Modeller Pro and the floodplain is represented using TUFLOW. This modelling approach helps to determine the mechanisms of flooding, depths of flooding and the sensitive receptors at risk. Appendix A11.4 (Hydraulic Modelling Report) details the full hydraulic modelling methodology.

4.1.28 Baseline hydraulic modelling shows that during a 3.33% AEP (30-year) event, the flows from WF60 discharge to a separate small 0.25m diameter pipe downstream of the existing A9, which impedes culvert discharge causing backflow through the 0.44m diameter culvert causing five properties to be flooded at Middlehaugh of Dalshian to a maximum depth of 1.5m (see Diagram 4.1).

4.1.29 At WF59 the baseline hydraulic modelling shows the flows at the inlet of the two 0.59m diameter culverts to back up and overtop on the right bank, merging with the flows from WF60. These flows extend east flooding the land between Middle Cottage and Dalshian Farmhouse up to depths of 0.2m and 0.5m respectively and East Haugh Hotel at a depth of up to 1.1m.

4.1.30 During the 0.5% AEP (200-year) flood event the floodwaters remain at a similar extent to the 3.33% AEP (30-year) event, as the Dalshian area is constrained by the existing A9 to the south, the HML to the west and General Wade's Military Road to the north, see Diagram 4.2. Flood depths at Middlehaugh of Dalshian increases to 2m. Flood depths between Middle Cottage and Dalshian Farmhouse increase to 0.6m and 1.5m respectively. Flood depths at East Haugh Hotel increase and extend to 2m south-west of the hotel.

4.1.31 The increase in flood depths is due to the floodwaters from the River Tummel impeding flows through the culvert associated with WF59 and joining with the backflow from WF60 due to the small 0.25m diameter pipe downstream of WF60. The floodwaters from the River Tummel do not impact WF61 during the 0.5% AEP (200-year) event. In events greater than the 3.33% AEP (30-year) the River Tummel is predicted to overtop on the left bank, upstream of Tummel Underbridge, and flow across the A924 at a depth up to 0.7m resulting in ponding in the basin between the HML and the A924 to a depth up to 2m. A railway underpass near Donavourd Lodge also conveys the design flood event flows under the HML which coincides with WF61 and the floodwaters associated with WF59 and WF60. The modelled flood extents extend from Middlehaugh of Dalshian to East Haugh Hotel where depths reach 2m during the 0.5% AEP (200-year) event and up to 2.2m during the design flood event, as shown in Diagram 4.3.

Diagram 4.1: Water features 59-61 – 3.33% AEP (30-year) baseline modelled depths

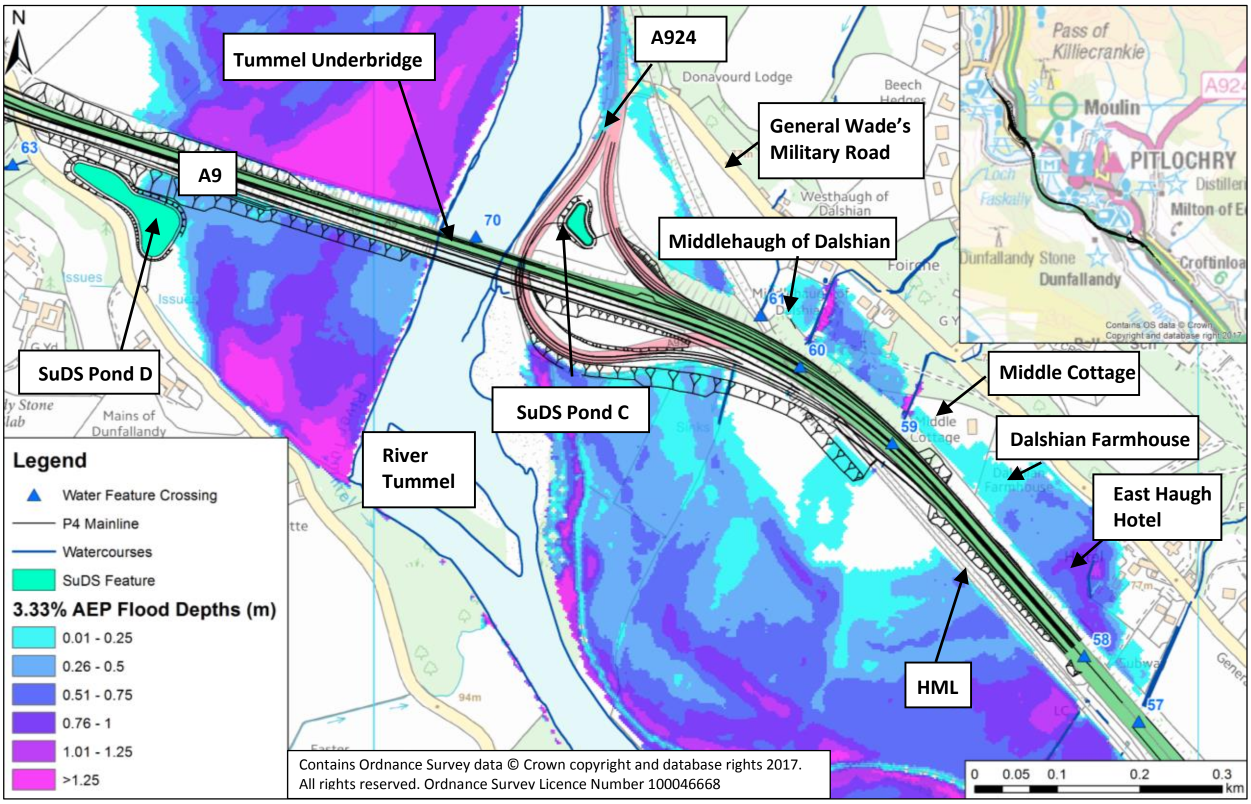


Diagram 4.2: Water features 59-61 – 0.5% AEP (200-year) baseline modelled depths

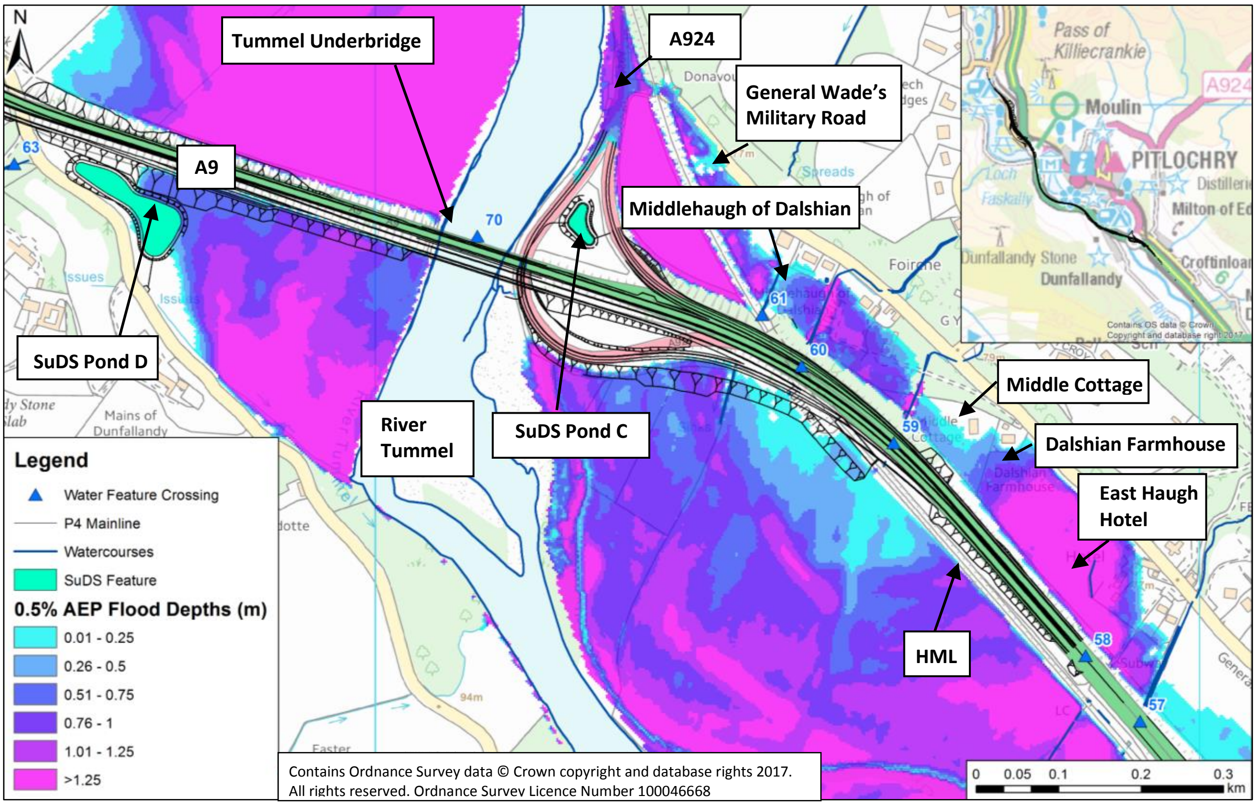
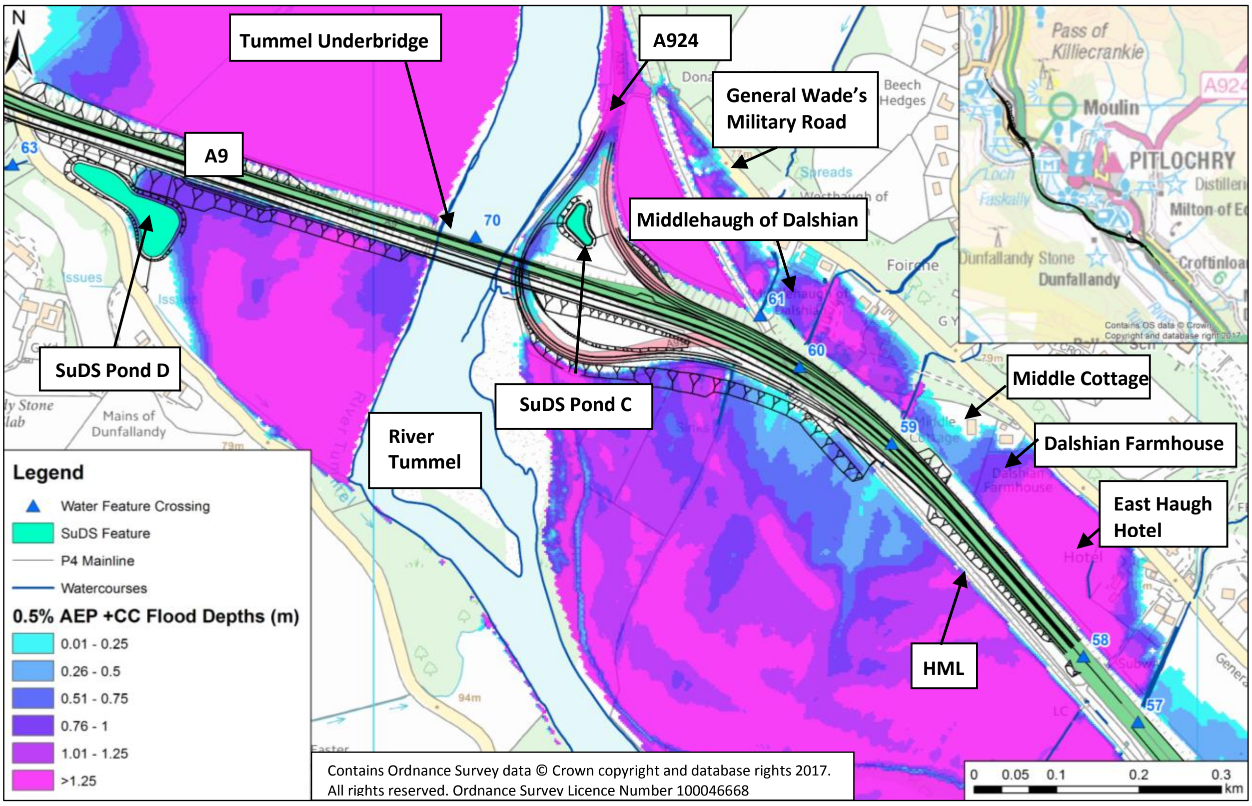


Diagram 4.3: Water features 59-61 – Design flood event baseline modelled depths



WF59-WF61: Proposed Scheme Scenario

4.1.32 In the proposed scheme scenario (without mitigation), the existing A9 will be widened on the northbound (southern) side along with the Pitlochry South junction works near WF59-61. The culverts associated with WF59, WF60 and WF61 are proposed to be extended in length from 72.6m to 85.8m, 63m to 92.6m and 67m to 113.4m respectively.

4.1.33 The proposed scheme includes SuDS Pond C, which is located upstream of the Tummel Underbridge, on the left bank where the Pitlochry South northbound and southbound junctions merge, and SuDS Pond D, which is located downstream of the Tummel Underbridge, off the right bank and to the north of Mains of Dunfallandy. Associated access tracks for each SuDS Pond will be constructed along with an access track to the farmland to the south of WF59-61.

4.1.34 Two hydraulic modelling scenarios were completed in Flood Modeller Pro and TUFLOW: (i) minor watercourses WF59-61 in isolation and (ii) WF59-61 run in conjunction with the River Tummel. The hydraulic modelling was run to ensure that all risks from the minor watercourses are understood and to determine the primary flood risk mechanisms and interactions. The hydraulic modelling concludes that the River Tummel is the primary mechanism of flooding adversely impacting the properties during the design flood event. The modelled results for WF59-61, when compared to the baseline, largely show an increase in water levels with the greatest impact located at the East Haugh of Dalshian. The increase in water levels is largely due to the culvert extensions associated with WF59-61 that increases water levels upstream and causing a significant increase in volume retained in this area.

4.1.35 The flood behaviour of WF59-61 are intrinsically linked to the River Tummel. Flows from WF59-61 are currently culverted under the existing A9 and HML; all three watercourses flow via un-surveyed pipes prior to discharging to the River Tummel, these pipes are insufficient to convey design flows during the 3.33% AEP (30-year) event or greater. In addition, during the 3.33% AEP (30-year) flood event the River Tummel is predicted to overtop on the left bank, upstream of the Tummel Underbridge, whereby flows are conveyed along and over the A924 and ponding in the natural basin. During the 0.5% AEP (200-year) flood event or greater, the modelled flows from the River Tummel coincide with the flows from the railway underpass near Donavourd Lodge impacting properties in the Dalshian area.

4.1.36 The River Tummel also overtops on the left bank downstream of the Tummel Underbridge and in the design event or greater, the downstream tailwater level is sufficiently high to restrict the outflows on WF59-61, thereby causing backflow through the culverts and exacerbating the risk to properties in the Dalshian area. For WF60 the outlet is also submerged in the 3.33% AEP (30-year) event and 0.5% AEP (200-year) events, causing backflow through the culvert and contributing to the risk in the Dalshian area.

4.1.37 Hydraulic modelling was undertaken for the proposed scheme scenario, including the River Tummel and minor watercourses for the 3.33% (30-year) event, 0.5% (200-year) event and the design flood event and compared with the baseline scenario in terms of water level differences and impacts to the proposed scheme and nearby receptors.

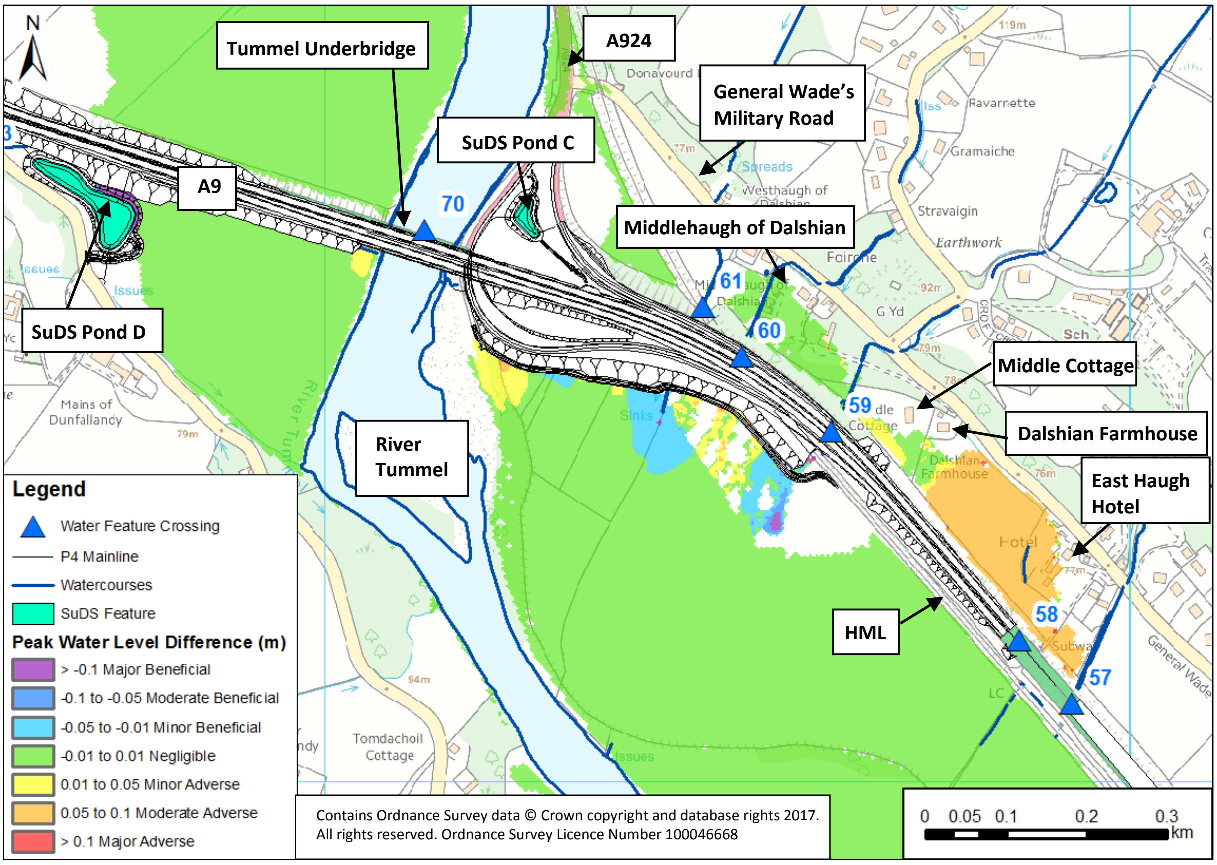
4.1.38 In this scenario during the 3.33% AEP (30-year) event there is a negligible to moderate increase in water levels in the Dalshian area of approximately 7mm in Middlehaugh of Dalshian, a negligible to minor increase in water levels of up to 16mm to the land around Middle Cottage and a moderate increase in water levels of up to 65mm, see Diagram 4.4. Flows weir over the high strip of land into the basin at East Haugh Hotel before discharging into WF58. The increase in water levels is due to the culvert extensions associated with WF59-61 where an increase in water levels upstream causes a significant increase in volume delivered to this area and therefore a more significant water level increase.

4.1.39 The impact on water levels downstream of the Tummel Underbridge during the 3.33% AEP (30-year) event shows a negligible decrease in water levels of <1mm on the right bank of the River Tummel (Mains of Dunfallandy), downstream of Tummel Underbridge in the location of SuDS Pond D. However, to the north-east of Mains of Dunfallandy, localised water levels increase by up to 35mm during the 3.33% AEP (30-year) due to the proposed scheme widening and construction of SuDS Basin Pond D reducing the amount of floodplain storage.

4.1.40 There is a negligible impact largely on the left bank across the agricultural land. However, the left bank immediately downstream of the Tummel Underbridge overtops during the 3.33% AEP (30-year) event creating an increase in water levels of 11-59mm. The increase in water level is due to the widening of the road embankment into the floodplain which alters the flow vectors and reduces the amount floodplain storage.

4.1.41 Downstream of WF59-61 there are small areas with minor to moderate decreases in water level of 11-59mm and minor to major increases in water level up to 184mm. The areas of detriment have neighbouring areas of betterment where the flow realignment reduces flow. This is due to localised topographic changes and a sheltering effect caused by the scheme's intrusion on to the floodplain. At WF60 the proposed culvert outfall is located at relatively lower ground, compared to the baseline scenario, thereby improving pass forward flow, causing a negligible change in water level immediately upstream and a water level increase immediately downstream.

Diagram 4.4: Water level difference – 3.33% AEP (30-year) proposed scheme scenario



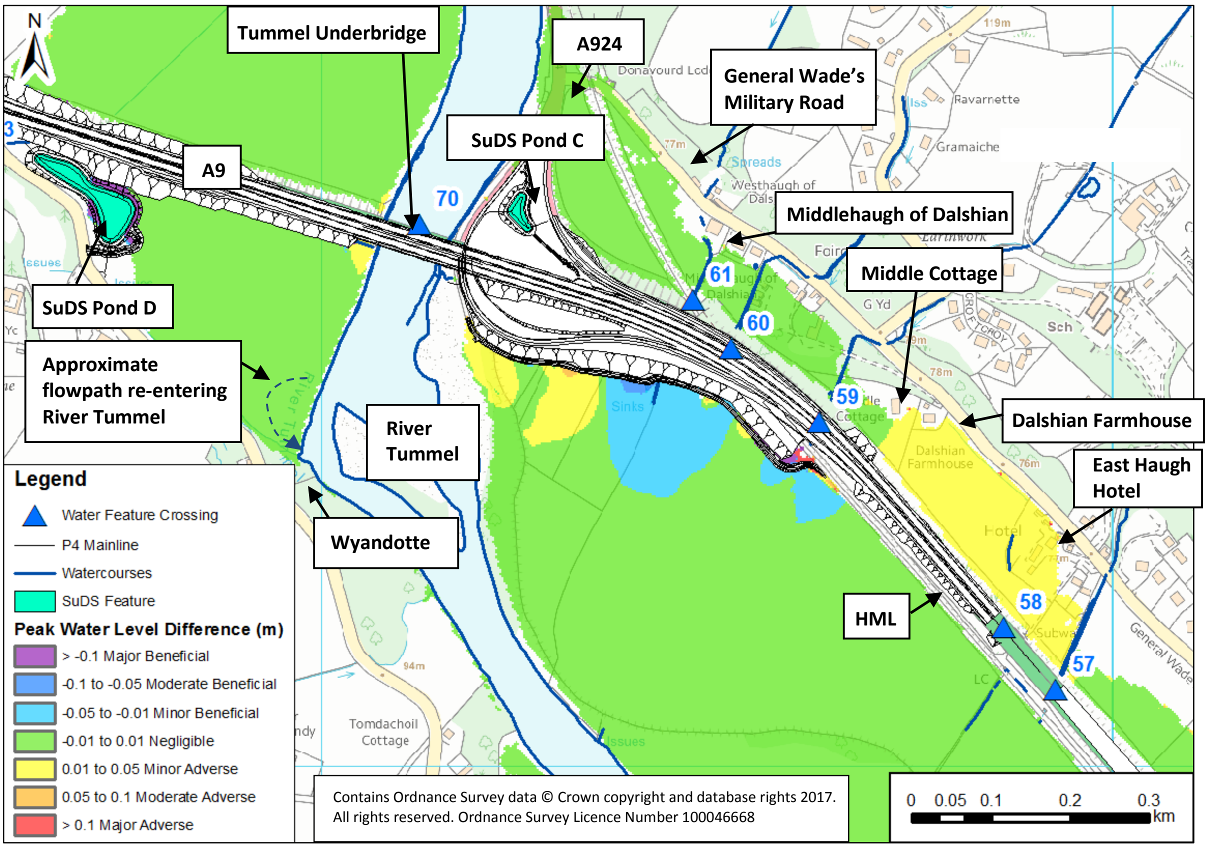
4.1.42 In the proposed scheme scenario during the 0.5% AEP (200-year) event the impact on water levels in the Dalshian area is negligible between the A924 and Middle Cottage with a 1-9mm increase in water levels, as shown in Diagram 4.5. Between Dalshian Farmhouse and East Haugh Hotel there is a moderate 12-13mm increase in water level as the small increase in flows weir over the ridge of high land. The adverse flood risk in the Dalshian area is due to the culvert extensions associated with WF59-61 which by design restricts flow and causes an increase in water level upstream and the contributing flows delivered via the underpass.

4.1.43 The impact on water levels downstream during the 0.5% AEP (200-year) event shows a minor increase in water levels of 2-8mm on the right (west) bank of the River Tummel, downstream of Tummel Underbridge around proposed SuDS Pond D. The north-east section of Mains of Dunfallandy remains a moderate risk with water levels increasing by up to 35mm, compared to the 3.33% AEP (30-year) event, due to the proposed scheme widening and construction of SuDS Basin Pond D reducing the amount of floodplain storage.

4.1.44 The hydraulic modelling shows the River Tummel to overtop on the right bank immediately downstream of the Tummel Underbridge. The floodwaters initially extend towards SuDS Pond D however the left bank near Wyandotte is at a lower elevation than upstream and allows some of the floodwater to re-enter the River Tummel, as highlighted in Diagram 4.5.

4.1.45 Downstream of WF59-61 there remains small areas with minor to moderate decreases in water level of 11-59mm, compared to the 3.33% AEP (30-year) flood event, located beside minor to major increases in water level up to 60mm. This is due to localised topographic changes and a sheltering effect caused by the scheme's intrusion on to the floodplain. At WF60 the proposed culvert outfall is located at relatively lower ground, compared to the baseline scenario, thereby improving pass forward flow, causing a negligible change in water level immediately upstream and a water level increase immediately downstream.

Diagram 4.5: Water level difference – 0.5% AEP (200-year) proposed scheme scenario



4.1.46 In the proposed scheme scenario, during the design flood event the impact on water levels in the Dalshian area is negligible with a 1-5mm increase as shown in Diagram 4.6. The slight water level rise is due to a small increase in flow delivered via the underpass along with a net reduction in culvert efficiency when the River Tummel is in full flood. In the design event the culvert outfalls are drowned and therefore the culvert outfall arrangements have less effect when compared to the 3.33% AEP (30-year) and 0.5% AEP (200-year) flood events.

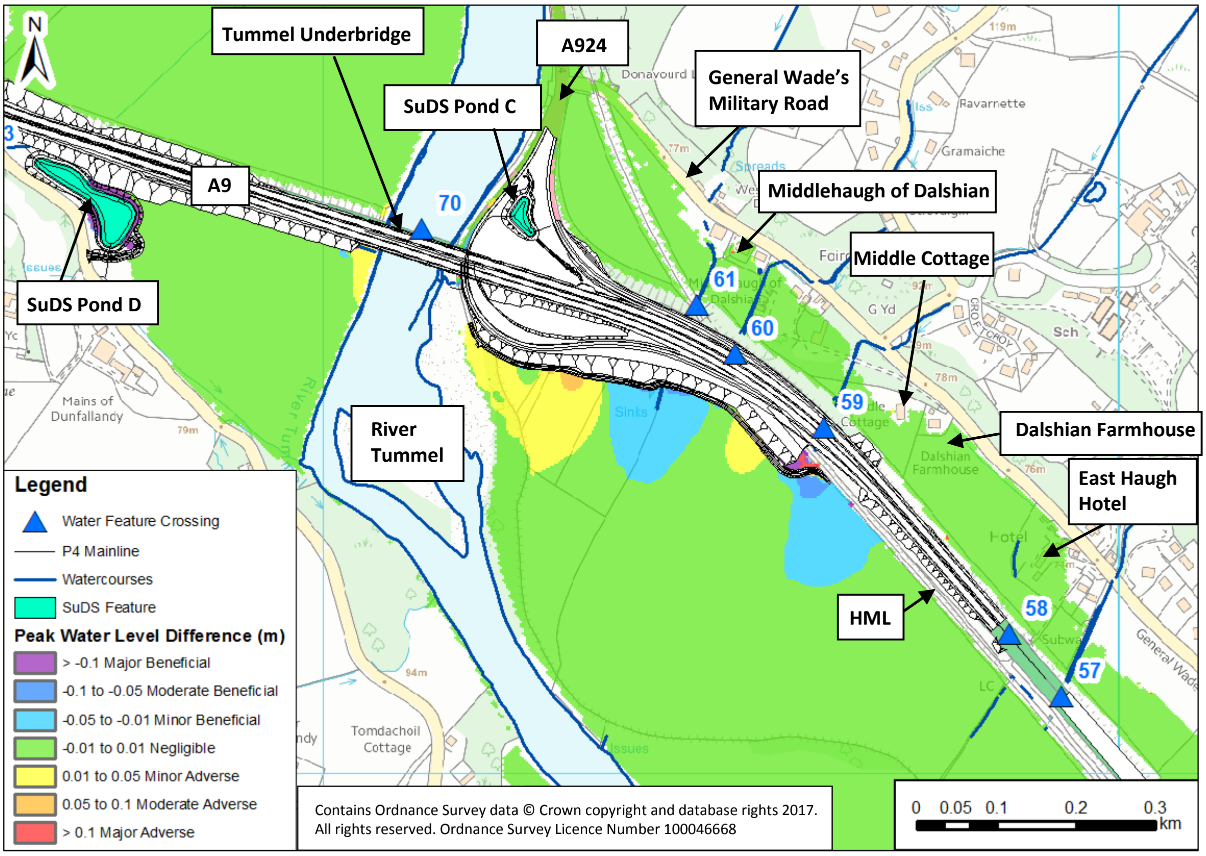
4.1.47 The impact on water levels downstream during the design flood event shows a negligible increase in water levels of up to 6mm on the right bank of the River Tummel, downstream of Tummel Underbridge in the location of SuDS Pond D. However, to the north-east of Mains of Dunfallandy, localised water levels increase by up to 35mm. The increase in water levels is due to the proposed scheme widening and construction of SuDS Basin Pond D reducing the amount of floodplain storage available.

4.1.48 The 11-70mm decrease in water levels, downstream of the Tummel Underbridge on the left bank is restricted to the area downstream of the outlets of culverts WF59-61 and immediately downstream of the River Tummel Underbridge. The increase in water levels is largely due to the proposed scheme widening on the northbound side which encroach onto the floodplain, displacing floodwater and reducing the amount of floodplain available for storage. In addition, the flows from the Mains of Dunfallandy do not remain in this area during the design flood event, with flow returning to the River Tummel due to changes in bank height and passing over to the left bank, thereby increasing risk compared to the 3.33% AEP (30-year) and 0.5% AEP (200-year) flood events.

4.1.49 These minor areas of increased water levels are located beside minor to moderate decreases in water levels up to 85mm. This is due to localised topographic changes and a sheltering effect caused by the scheme's intrusion on to the floodplain. Similar to the 3.33% AEP (30-year) and 0.5% AEP (200-year) flood events, the proposed culvert outfall associated with WF60 is located at relatively lower ground, compared to the baseline scenario, thereby improving pass forward flow, causing a negligible change in water level immediately upstream and a water level increase immediately downstream.

4.1.50 Mitigation measures to address the adverse flood risk impacts have been assessed in paragraphs 4.1.98 to 4.1.117 of Section 4 (Minor Watercourses) of this FRA, with the overall aim of achieving a 'no change' scenario, i.e. neutral scheme impact.

Diagram 4.6: Water level difference – Design flood event proposed scheme scenario



WF63 (including WF191)

4.1.51 In the existing condition watercourse WF63 does not cross the A9. Instead it is culverted below Foss Road, and then continues in the culvert to the toe of the A9 embankment, where it changes course and runs along the toe of the A9 embankment, discharging from a culvert outlet into the River Tummel.

4.1.52 Following the widening of the northbound carriageway which removes the existing culvert for WF63 to the north of Foss Road, a new culvert is proposed from the existing culvert inlet upslope of Foss Road following the southern boundary of SuDS Pond D and Foss Road, discharging into an existing watercourse (WF191) that flows along the northern side of Foss Road into the River Tummel.

4.1.53 The culvert is proposed to be increased in diameter from 0.3m to 1.05m, with a 0.15m embedment in the culvert. Its overall length will reduce from 512m to 495m. It is proposed to reduce the channel invert level by 0.6m to retain a similar soffit level to the existing condition. The channel bed upstream of the culvert inlet will therefore need to be regraded to accommodate this. This will allow for an increased flow and storage capacity in this section of the watercourse.

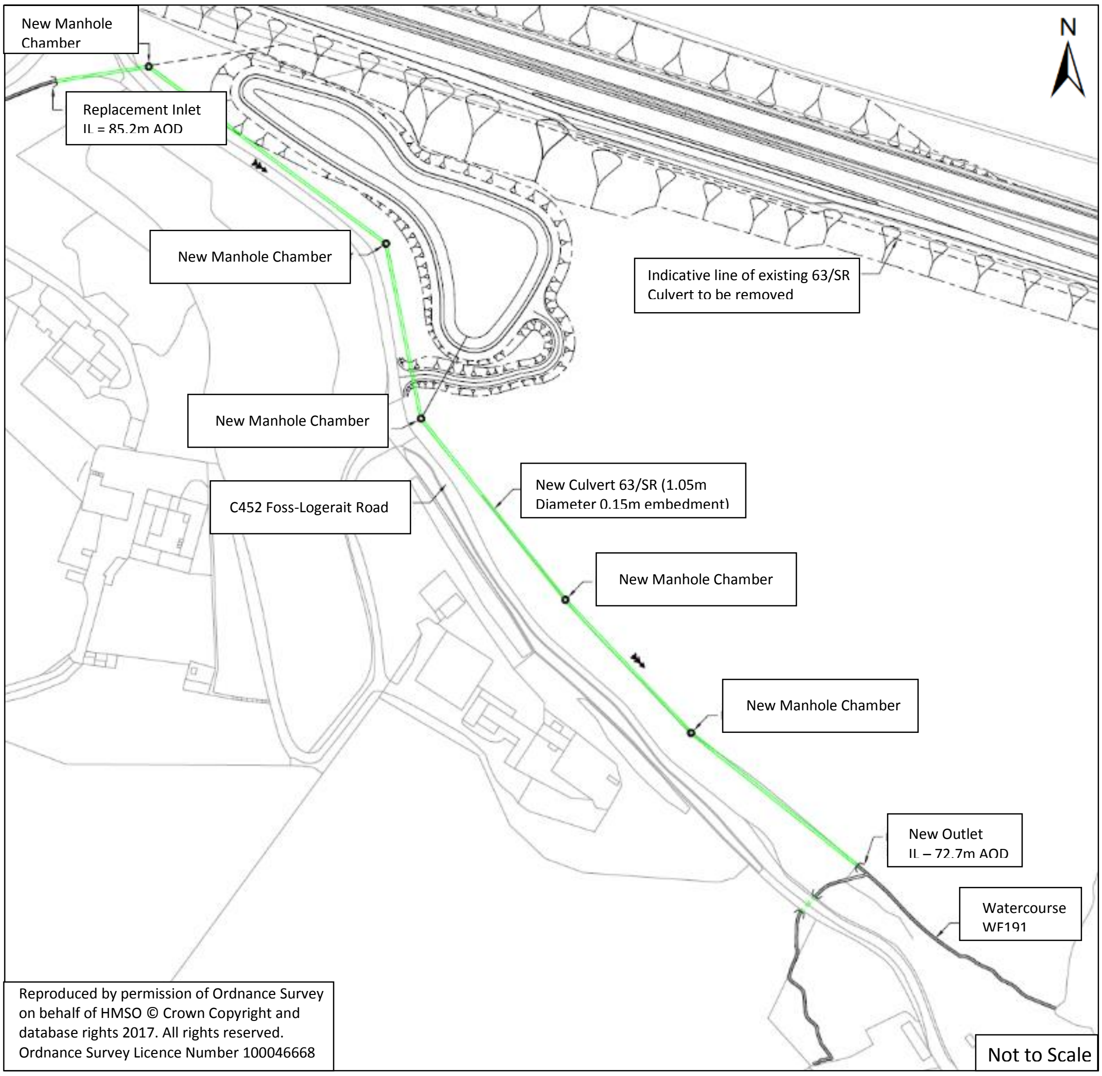
4.1.54 The 0.5% AEP plus climate change design flow in the watercourse is estimated to be 0.89m^3/s, but the full-bore capacity of the existing culvert is estimated to be only 0.07m^3/s. Therefore, in the baseline the culvert surcharges and the watercourse spills from its bank, resulting in overland flow downslope, across Foss Road, into the field that borders the A9 embankment (Mains of Dunfallandy), and then overland eastwards into the River Tummel.

4.1.55 In the proposed scenario during the design flood event, the theoretical freeboard (headroom) to the culvert soffit is 0.12m and the head water level is contained in bank at the culvert inlet, but it is likely that flood water will still spill out of bank upstream of the inlet, which is only about 0.5m above the channel bed, before it reaches the theoretical headroom (as it does in the baseline condition). A water level at approximately 0.5m above the bed (with a 1.05m diameter culvert and an embedment depth of 0.15m this is 0.4m below the culvert soffit) complies with the recommended minimum freeboard in the DMRB for new culverts (D/4, i.e. 0.26m minimum).

4.1.56 With watercourse WF63 discharging into the existing watercourse WF191 in the proposed scenario (see Diagram 4.7 below) the total flow in WF191 can be expected to increase for any given event. However, situated in the River Tummel floodplain at Mains of Dunfallandy, there are no sensitive flood receptors at risk along that part of WF191. Foss Road is adjacent to the watercourse, but is elevated on a steep hill slope above the watercourse. At its lowest point (adjacent to the proposed WF63 culvert outfall) Foss Road is at approximately 77m, 4.3m higher than the new outfall invert of WF63 into WF191, and 1.3m higher than the design flood level on the River Tummel in the proposed scenario. Any flooding from the watercourse will spill into the River Tummel floodplain and into the River Tummel before it floods the road. As the lack of a significant risk is clear from an inspection of its location in the Tummel floodplain and the local topography, no further analysis of WF191 is considered necessary.

4.1.57 With an increased culvert size and a flow capacity greater than that in the upstream channel the proposed WF63 culvert will no longer be a constraint to the capacity in watercourse WF63. The risk of flooding to downstream receptors including Foss Road and the A9 is therefore reduced compared to the baseline. The risk of flooding of sensitive receptors from WF191 remains negligible in the proposed scenario.

Diagram 4.7: Proposed arrangement WF63 / WF191



WF65

4.1.58 The culvert at this location is proposed to be replaced and extended from 149m to 157m to accommodate the construction of an additional northbound carriageway on the upstream side of the existing A9 crossing and parallel access on both sides. The culvert diameter remains 1.15m. Following this replacement, it is estimated that the A9 does not flood during the design flood event.

4.1.59 The new culvert will be constructed to a new lower profile. This will require a replacement cascade feature at the culvert inlet to lower the watercourse to a revised culvert inlet level. It is proposed to regrade the downstream watercourse over approximately 36m from the culvert outlet to tie-in with the existing downstream channel bed level.

4.1.60 In the baseline scenario during the design flood event, the flows are in bank upstream due to the surrounding steep woodland and a confined stepped cascade to the culvert inlet, however the culvert surcharges with the peak head water level 0.17m above the culvert soffit, remaining 0.32m below the watercourse bank. The existing A9 is approximately 0.7m higher than the peak headwater level and does therefore not flood during the design flood event.

4.1.61 With properties situated immediately downslope (north) of the A9 embankment the proposed replacement culvert has been designed not to increase the pass forward flows for the design floods. Flows upstream remain in bank with peak headwater levels approximately 0.36m below the upstream bank level. The freeboard to the proposed A9 road level increases to 1.7m, mainly through lowering of the culvert, thereby reducing the risk of flooding the road. The freeboard to the parallel access road upslope of the A9 is as much as 4m as it reaches a high point near the culvert inlet.

4.1.62 An underpass linking the upslope (southern) parallel access road to Foss Road to the north of the A9 is proposed about 100m west of the culvert entrance. The flood risk to the underpass in the proposed condition is low as design flows stay in bank.

WF66

4.1.63 The culvert at this location is proposed to be largely replaced to accommodate the construction of an additional southbound carriageway on the downstream side of the existing A9 crossing. The culvert diameter is proposed to be 1.8m (marginally larger than the existing pipe which was surveyed to be 1.75m), and the existing length of 127m is sufficient to incorporate the wider A9. Following this replacement, it is estimated that the A9 would not flood during the design flood event.

4.1.64 The new culvert will be constructed to a new lower profile with a shallower gradient. This will require a replacement cascade feature at the culvert inlet to lower the watercourse to a revised culvert inlet level.

4.1.65 The existing outlet and a short culvert section upstream of the outlet will be retained in order to avoid the need for engineering works within the boundary of the “Explorer’s Garden”, a local ornamental garden and tourist attraction. To achieve this, it is proposed to break in to the existing culvert upstream of the garden boundary and construct a new access manhole and direction change manhole. The upstream culvert will then be replaced to the lower vertical profile.

4.1.66 In the baseline scenario during the design flood event there is free flow within the culvert and flows upstream are within bank with sufficient freeboard (headroom) of 0.81m between peak headwater levels and inlet soffit level. The existing A9 lies lower than the watercourse bank (0.17m above the head water level) but flooding of the road will only occur when the bank level is exceeded, so the effective freeboard to the road is also 0.81m. The risk of flooding to the road is considered low as the watercourse and culvert contain the flow during a design flood event, with sufficient headroom to the culvert soffit to pass debris.

4.1.67 In the proposed scheme scenario during the design flood event there is free flow within the culvert with sufficient freeboard (headroom) of 0.82m between peak headwater levels and the inlet soffit level. The reported small increase in headroom compared to the baseline is due to a change in flow regime in the hydraulic calculations. Flows upstream remain in bank. Due to the lowering of the culvert at the inlet the freeboard between the head water level and the road increases to 1.2m, despite the fact that the road is proposed to be lowered by 0.1m. The risk of flooding of the A9 will therefore be reduced in the proposed condition.

WF71-76

4.1.68 Watercourses WF71, 72, 74 and 76 to the north of Clunie Underbridge have been modelled using a 1D Infoworks ICM numerical hydraulic model of the proposed condition instead of the hydraulic spreadsheet calculations used for most other minor watercourses. The modelling was necessary to be able to represent the more complex interactions of the proposed piped systems. This model was used for the design of the culvert systems as well as for the assessment of flood risk for the proposed condition.

4.1.69 The hydraulic model does not include any significant storage features, and a steady-state approach with peak flows as determined by hydrological analysis was therefore considered appropriate. Although the calculations for the baseline (hydraulic spreadsheet calculations) and the proposed condition (hydraulic model) will inevitably be different, given that they are both based on steady-state approaches this provides some consistency between the two scenarios.

4.1.70 The hydraulic modelling of the proposed condition was undertaken for the 1% AEP (100-year) event and the design flood event. For all culverts in the proposed condition the 1% AEP event would provide the headroom to the culvert inlet soffit recommended in the DMRB (of at least the internal diameter divided by 4). For the design event there would be a smaller but still positive headroom, with at least 600m freeboard to the proposed road level.

WF71

4.1.71 This watercourse serves a catchment of 0.24km^2. The culvert crossing the offline section and existing A9 is proposed to be replaced and extended from 70m to 118m to accommodate the offline section of the A9. It is proposed to be enlarged from 0.59m to 1m to allow for the design flood event flows. The culvert then joins with the existing steeply inclined culvert under the A924 with a diameter of 2.2m shown in Diagram 4.8 flowing southwards. In the proposed condition the modelling shows that the A9 is not at risk during the design flood event. However, pass forward flows from WF71 into the 2.2m diameter culvert towards Loch Faskally are likely to increase for events that exceed the existing full-bore culvert capacity as existing storage effects will be reduced in the proposed condition. With no sensitive flood receptors between the culvert outlet and the loch this is considered acceptable from a flood risk and geomorphology perspective.

4.1.72 In the baseline scenario during the design flood event, the flows are out of bank upstream with the peak head water level 0.18m above the upstream bank level (the headwall parapet). The culvert surcharges with head water levels rising to 108.70m AOD, 0.94m above the inlet soffit level. Upstream of the culvert inlet the watercourse is bounded by the A924 to the north, east and south and the A9 to the west which are approximately 2m to 8m higher than the culvert. The existing A9 is approximately 7.2m higher than the peak headwater level in the design flood event.

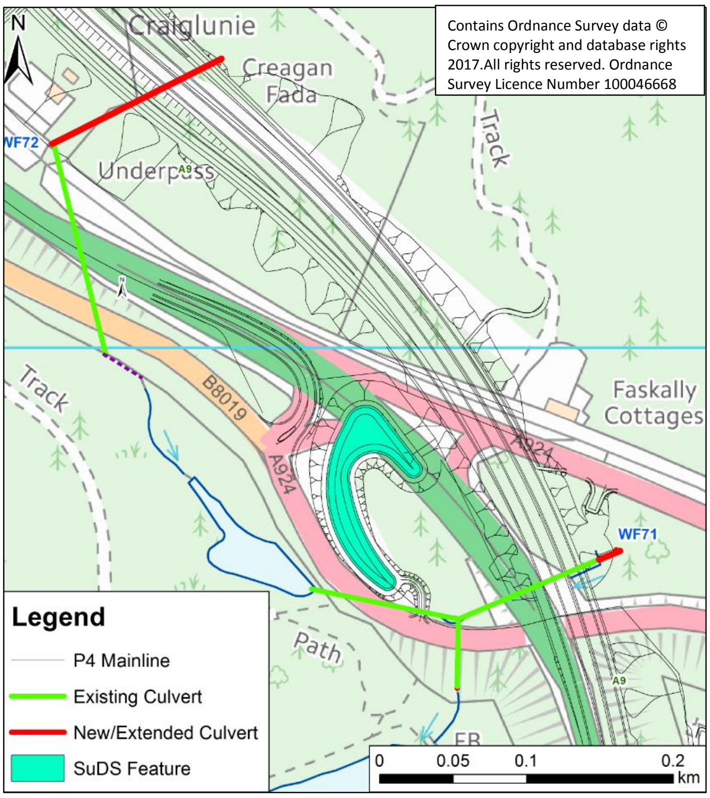
4.1.73 In the proposed scheme scenario during the design flood event, 1D hydraulic modelling was undertaken to determine the culvert requirements needed to pass the flows under free flow conditions under the existing and offline section of the A9 and into the existing culvert that outfalls downstream of the A924 into Loch Faskally. The hydraulic modelling incorporates the flows from WF72 that join with the flows from WF71 in the 2.2m diameter A924 culvert.

4.1.74 The proposed condition peak upstream and downstream flows through the culvert crossing of the existing A9 and offline section is 0.9m^3/s for the design flood event. There is a reduction in head water level of approximately 2.1m compared to the existing condition. In the proposed condition there is a freeboard (headroom) of 0.18m to the culvert soffit, and there is an increased freeboard of 11.9m to the A9 road level, largely attributable to the proposed raising of the A9 by approximately 3.1m at the watercourse crossing.

4.1.75 The proposed condition peak flow at the existing 2.2m diameter culvert under the A924 is 1.28m^3/s, which is the contribution from WF71 and WF72 combined. The peak water level is modelled to be 0.29m above the inlet invert level. There is sufficient freeboard of 4.3m between the A924 and the peak head water level. The downstream peak water level is 0.65m above the outlet invert level where a hydraulic jump marks the transition from supercritical flow in the pipe to subcritical flow in the open section draining to Loch Faskally.

4.1.76 The hydraulic modelling concludes that the proposed culverts can pass the flows during the design flood event without flooding any sensitive receptors, including the A9.

Diagram 4.8: Water features 71 and 72



WF72

4.1.77 This watercourse serves a very small catchment of 0.02km^2. The existing culvert at this location is proposed to be retained but extended with a new culvert section on the upstream side to accommodate the offline section of the A9. The existing culvert has a 1.2m diameter and is 139m in length. The proposed new culvert has a diameter of 0.75m and length of 118m and joins to the existing culvert via a proposed new chamber. The existing culvert outfalls into an open channel that drains into a small pond and through a culvert under the A924 before it joins with the flows from WF71. As described above for WF71 the 2.2m diameter steeply inclined culvert crosses under the A924 again, as shown in Diagram 4.8. The hydraulic performance of the latter culvert is discussed with watercourse WF71 above.

4.1.78 In the baseline scenario during the design flood event there is free flow within the culvert and flows upstream are within bank with sufficient freeboard (headroom) of 0.52m between the peak headwater levels and inlet soffit level, and a freeboard of 0.67m below the upstream bank level.

4.1.79 In the proposed scheme scenario during the design flood event, 1D hydraulic modelling was undertaken to determine the new culvert requirements needed to pass the flows under the offline section of the A9 and into the existing culvert that outfalls downstream of the B8019.

4.1.80 The peak design flood event flow through the proposed new culvert is 0.38m^3/s with a freeboard of 0.19m between the peak head water level and the culvert soffit. The hydraulic modelling shows there to be sufficient freeboard of 3.1m between the offline section of the A9 and the head water level.

4.1.81 The hydraulic modelling concludes that the culverts can pass the flows of the design flood event without flooding any sensitive receptors, including the A9.

WF74-76

4.1.82 WF74-76 form a network of channels upstream of the A9, both in the baseline condition and in the proposed condition. In the baseline scenario, once it meets the A9, WF76 (Allt an Aghastair) flows along the east side of the A9, partly through open watercourses and partly through a series of culverts below access tracks, into WF74. The critical culvert is one with an effective diameter of 1.0m. Flow then enters an existing pipe below the A9 and General Wade's Military Road into an open watercourse which drains to Loch Faskally, as shown in Diagram 4.9. The existing culvert transitions from a diameter of 1.90m at the inlet to 1.75m at the outlet. In hydraulic calculations a diameter of 1.75m has been assumed throughout its length. An additional unnamed watercourse feeds into WF76 approximately 150m north of WF76. This is referred to as WF76a in this FRA.

4.1.83 As described above flows from WF74 and WF76 are conveyed to the large culvert under the existing A9 and General Wade's Military Road. The resulting 0.5% AEP (200-year) + CC design discharge is free-flowing within the culvert with a freeboard between the head water level and the culvert soffit (headroom) of 0.26m. The existing A9 is approximately 9.5m higher than the peak headwater level and is deemed not at risk during the design flood event.

4.1.84 In the baseline scenario during the design flood event for the smallest of culverts in the WF76 alignment parallel to the existing A9 (with a diameter of 1m) the flows are out of bank upstream of the culvert with the peak headwater level 1.21m above the upstream bank level. The culvert surcharges with water levels rising to 1.22m above the culvert soffit and only 0.28m below the existing A9 road level.

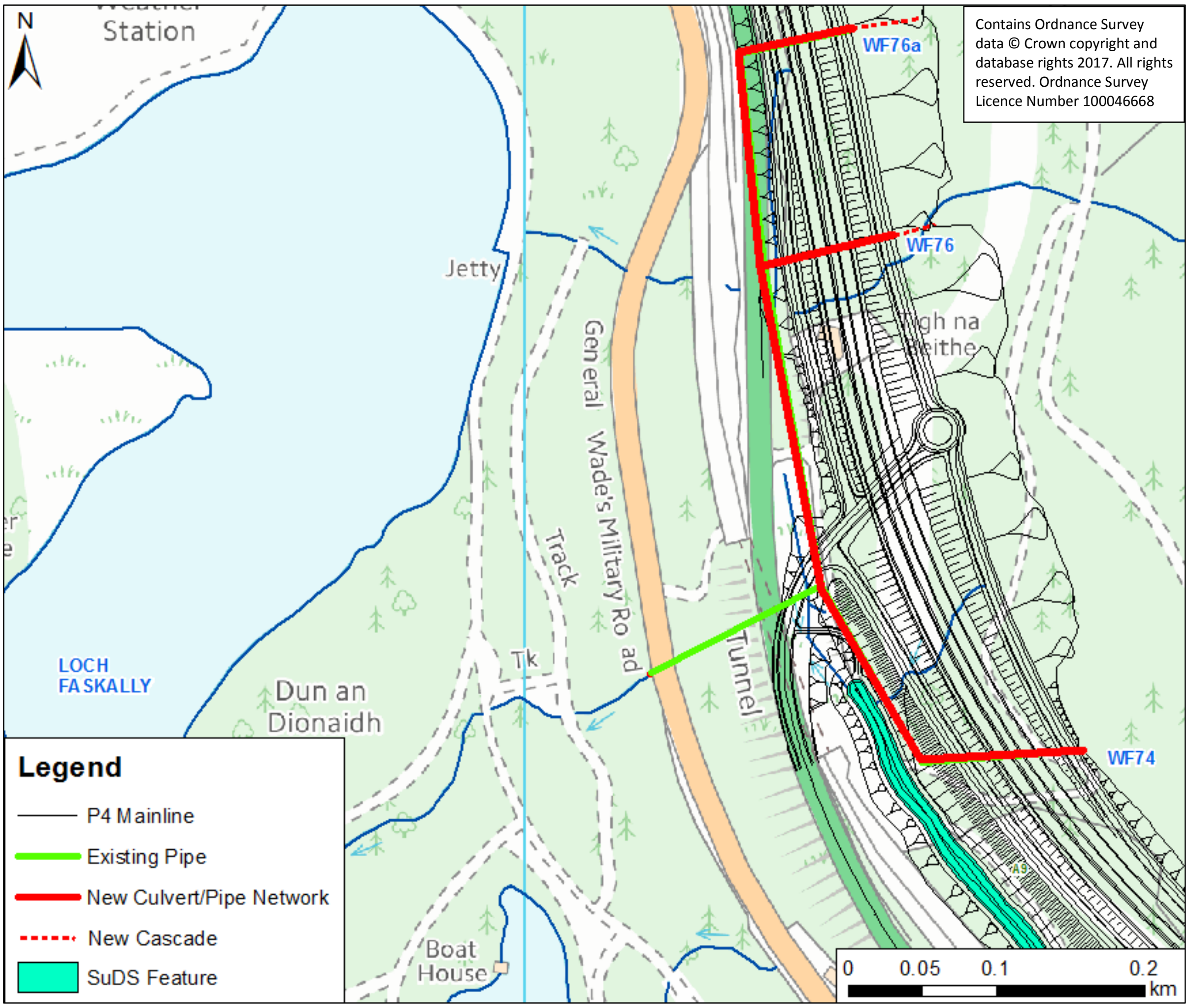
4.1.85 In the proposed scheme scenario, the new A9 is situated upslope (east) of the existing A9 as shown in Diagram 4.9. Therefore, new culverts are required, with two new cascades at the upstream side of the proposed culvert inlets for WF76 and WF76a to lower the watercourse sufficiently below the proposed new A9 level. The lines shown in red in Diagram 4.9 are proposed new culverts. The proposed culverts that are broadly parallel to the proposed A9 and convey catchment runoff to the existing culvert under the existing A9 and General Wade's Military Road cannot be open watercourses because of the limited space available due to the proposed A9 and its embankment, an access road and a proposed SuDS pond.

4.1.86 Each cascade will meet a new culvert that is 85m to 74m in length for WF76 and 76a respectively which will be constructed along the offline section of the A9. A new pipeline at the downstream outlet will capture the flows from WF76 and WF76a and convey the flow alongside the toe of the downstream embankment to connect with an existing pipe under the HML and General Wade's Military Road just north of WF74.

4.1.87 The natural watercourse of WF74 upslope of the existing A9 will be entirely removed in the proposed condition, as it is entirely covered by the proposed scheme footprint. A new culvert (WF74) that is 113m long is proposed about 100m south of the natural watercourse, with its entrance at the low point in the proposed landscaping upslope of the A9. Drains along the top of the excavation (pre-earthworks drains or PEDs) are proposed along the embankment in the natural catchment to WF74 to capture runoff from the original catchment and to direct it to the proposed WF74 culvert. The drainage will be designed in accordance with DMRB Standards.

4.1.88 WF74 and WF76 will not connect to the existing chamber at the upstream side of the pipe under the existing A9, but to a proposed new chamber a few metres upstream of the existing chamber, to allow space for a new access road to the A9. The existing chamber is to be removed.

Diagram 4.9: Water features 74 and 76



4.1.89 In the proposed scheme scenario during the design flood event, 1D hydraulic modelling was undertaken to determine the new culvert requirements needed to pass the flows under the proposed new A9.

4.1.90 In the proposed condition during the design flood event the WF76 culvert (1.5m diameter) is free flowing with a freeboard to the culvert soffit (headroom) of 0.14m above the head water level. The freeboard to the bank is the same as that to the road level (this is a proposed access road parallel to the A9) and is 2.6m. The proposed A9 is higher and has a freeboard of 5.2m above the head water level.

4.1.91 In the proposed condition during the design flood event the WF74 culvert (0.75m diameter) is free flowing with a freeboard to the culvert soffit (headroom) of 0.15m above the head water level. The flows stay in bank with a freeboard to the A9 access road of 2.3m and to the proposed A9 itself of 6.2m.

4.1.92 For the 1m diameter proposed culvert at WF76a the design flood event peak flow is 0.87m^3/s. The proposed culvert is free flowing, with a freeboard between the head water level and the soffit level (headroom) of 0.22m. The flow stays in bank with a freeboard to the bank and road of 2.7m

4.1.93 The combined flows for WF74-76 are conveyed through the new proposed chamber and are piped for 129m under the access road, proposed A9 and General Wade's Military Road, eventually discharging into the River Tummel. The combined design flood event flow in this culvert is 4.31m^3/s. The hydraulic modelling shows there to be sufficient freeboard of 1.24m between the head water level and the culvert soffit.

4.1.94 It can be concluded that in the proposed condition, the watercourses included in the WF74-76 system are not at risk of flooding sensitive receptors, including the proposed scheme, during the design flood event.

WF77

4.1.95 The culvert at this location is proposed to be retained and extended from 160m to 184m to accommodate the new access track on the upstream side of the existing A9 crossing. The culvert diameter remains 1.76m. Following this extension, analysis indicates that the A9 would not flood during the design flood event.

4.1.96 In the baseline scenario during the design flood event the head water level remains in bank, and 0.55m below the soffit of the culvert. Furthermore, there is ample freeboard between the peak head water level and the A9 of 1.5m.

4.1.97 In the proposed scheme scenario during the design flood event there is free flow within the culvert with a slightly reduced freeboard of 0.50m between peak headwater levels and the inlet soffit level, still in compliance with the DMRB recommendation of a headroom of a quarter of the diameter to minimise the risk of blockages. Flows upstream remain in bank. In the design event the freeboard to the watercourse bank is 0.62m. Although the road is lower than the bank (only 0.19m above the design head water level), floodwater will need to exceed the bank level before it can flood the road. The freeboard to the road is reduced compared to the baseline because of the extension of the culvert upslope, raising the culvert invert more than the proposed raising of the road level.

Mitigation Measures

4.1.98 Flood risk to sensitive receptors including the A9 does not increase as a consequence of the scheme at all but five of the minor watercourses where the scheme crosses the A9, and at the River Tummel around the Tummel Underbridge:

- At two minor watercourses where the risk of flooding to the A9 increases due to the scheme (WF67 and WF68) the probability of flooding is very low in the baseline - lower than 0.5% annually including an allowance for climate change, and remains lower than that in the proposed condition. No further mitigation is recommended in these areas.
- The other three minor watercourses where the risk of flooding to sensitive receptors could be increased are around the Tummel Underbridge (involving the River Tummel and minor watercourses WF59-61). In this area proposed condition, flood depths could be increased marginally for events up to the 0.5% AEP design flood if no mitigation measures were incorporated (up to 11mm for the 0.5% AEP design event).

4.1.99 The scheme includes increases in the size of the A9 road embankments onto the Tummel Underbridge, in particular in the Mains of Dunfallandy area on the right bank of the River Tummel immediately downstream of the Tummel Underbridge. In addition, SuDS Pond D is also proposed in the same area. As these structures are proposed in the Tummel floodplain the flood storage capacity will be reduced.

4.1.100 As a consequence of the reduced flood storage volume, water levels on the River Tummel are expected to rise slightly (up to 9mm) for the 3.33% AEP and 0.5% AEP floods. Hydraulic modelling has shown that as a consequence the Dalshian area to the northeast of the A9 embankment east of the Tummel Underbridge may have a marginally increased risk of flooding for extreme floods (floods that exceed the 0.5% AEP design flood event without an allowance for climate change).

4.1.101 There are two pathways of flooding at Dalshian:

- The principal pathway is that the rise in River Tummel flood levels cause an increase in water levels on the Easthaugh of Dalshian floodplain area, which reaches the culverts under the A9 embankment from the downslope side, and causes backing up of floodwaters from the minor watercourses.
- A secondary pathway is that the rise in water levels on the Tummel in low floods creates a flow path from its left bank upstream of the Tummel Underbridge, through an underpass of General Wade’s Military Road under the HML railway, towards Dalshian.

4.1.102 According to the hierarchy of preferred solutions the following mitigation measures were considered:

- **Avoid** – the embankment and SuDS pond are required to accommodate the dualled carriageway and treat road runoff. Other locations for the SuDS basins were considered but discarded as less suitable or effective.
- **Reduce** – the embankment and SuDS pond have gone through a reconsideration process in an attempt to reduce their footprint. Design good practice and safety have limited the effectiveness of this process and a residual loss of floodplain storage cannot be avoided.
- **Mitigate** – Level for level compensatory flood storage close to the area where the flood storage is lost. The Mains of Dunfallandy and Dalshian area is very flat and contained by a secondary road, and no suitable level for level compensatory storage could be found.
- **Mitigate** – Compensatory flood storage close to the area where the flood storage is lost, using modelling to demonstrate the beneficial effect to provide neutral effect on overall flood risk.

  This was partly considered as a suitable area for compensatory storage was identified on the opposite bank of the Mains of Dunfallandy, immediately upstream of Tummel Underbridge between the railway and the Pitlochry South junction. Hydraulic modelling was undertaken whereby the area was lowered by 0.5m, and an outfall with flow constriction added to slowly drain away flood waters, operating during the 3.33% AEP (30-year) flood event or greater. The modelling concluded that this mitigation measure did not provide any benefits.
- **Mitigate** – As a residual negative effect of flooding remained, a more targeted approach was sought, by identifying the sensitive flood receptors at risk. The sensitive receptors at risk are properties and a hotel on the upslope (north-eastern) side of the existing A9 embankment at Middlehaugh of Dalshian and East Haugh House Hotel, between the A9 embankment to the south west and General Wade's Military Road to the north-east.

<u>Compensatory Flood Storage Considered</u>

4.1.103 In accordance with the guidelines presented in SEPA Technical Guidance, compensatory flood storage should replace 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.

4.1.104 The volume of compensatory flood storage 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 and including the design flood event.

4.1.105 As shown in Diagram 4.10 there are seven areas upstream and downstream of the Tummel crossing where the widening of the proposed scheme results in a loss of floodplain storage. Table 4.4 shows the level-for-level area of floodplain lost and volume of floodplain compensation potentially required.

Diagram 4.10: Areas of floodplain lost

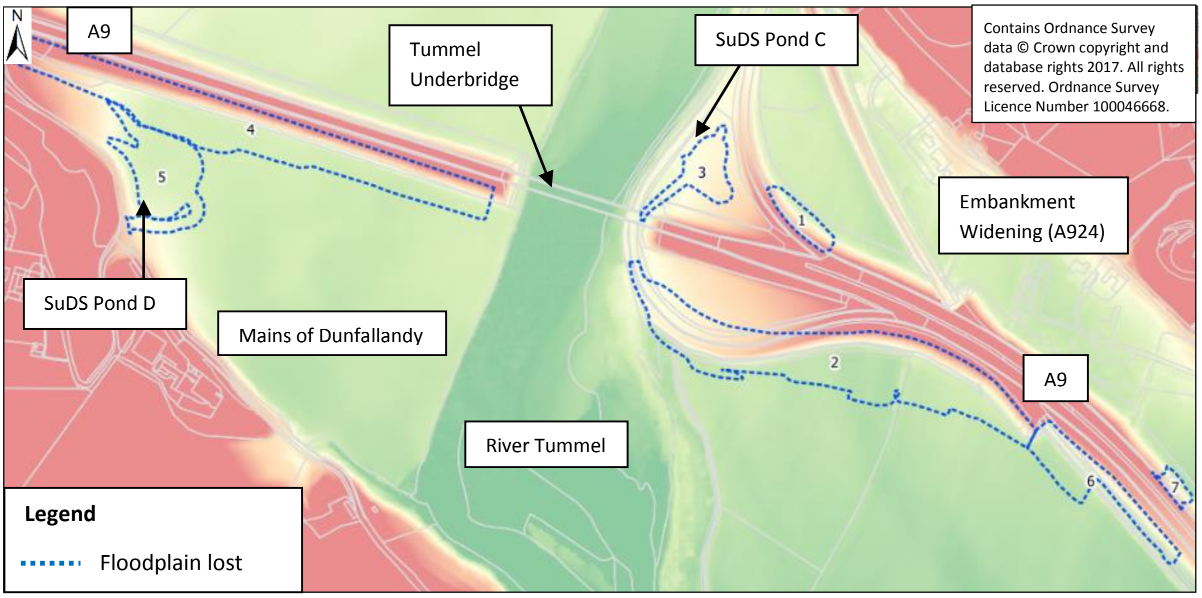


Table 4.4: Floodplain compensation calculations

Area	Description	Level (mAOD)	Floodplain Area Lost (m^2)	Volume Required (m^3)*
1	Embankment widening at Pitlochry South Junction (A924)	74.1	0	0
		74.6	18	2
		75.1	167	43
		75.6	277	155
		76.1	362	314
		76.6	442	**517**
2	Widening of northbound carriageway and associated embankment	73.25	0	0
		73.75	2147	378
		74.25	6291	2340
		74.75	8821	**6239**
3	Location of SuDS Pond C and associated access track	No floodplain loss		
4	Widening of northbound carriageway and associated embankment	74.26	7	0
		74.76	3163	554
		75.26	7219	3662
		75.76	7937	**7458**
5	Location of SuDS Pond D and associated access track	74.26	0	0
		74.76	490	19
		75.26	3633	1229
		75.76	4596	**3321**
6	Embankment widening	72.72	0	0
		73.22	2	0
		73.72	679	53
		74.22	1581	**664**
7	Embankment widening	No floodplain lost		
Total Volume Lost (m^3)				**18,199**

*Bold entries represent the total volume lost for areas 1-7

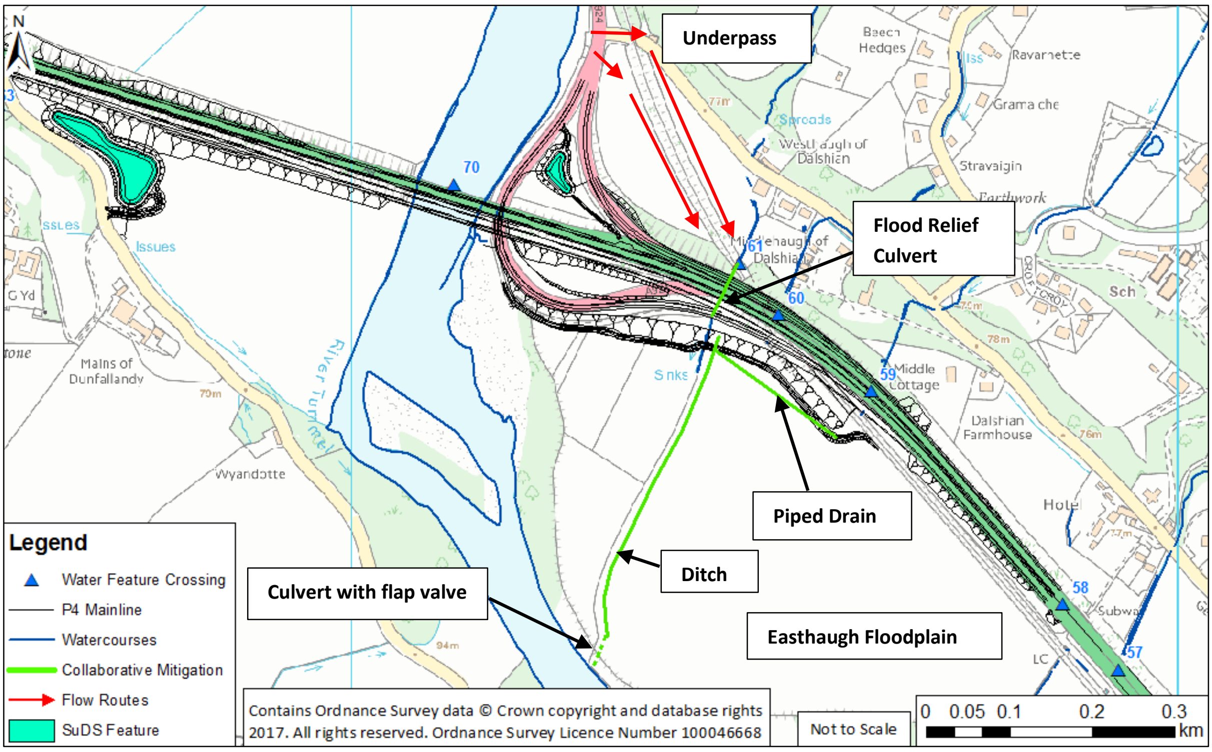
4.1.106 To offset the impacts of the proposed scheme in this area, a significant combined volume of compensatory storage would be required (18,199m^3). Initial investigations show there to be insufficient areas at suitable levels in the vicinity to provide a like-for-like compensatory flood storage to provide the volume required. Consequently, hydraulic modelling was undertaken to determine whether a neutral or beneficial effect on overall flood risk can be achieved in this area.

Collaborative Mitigation Measures

4.1.107 As hydraulic modelling has shown that the flood risk to properties at Dalshian is caused by a combination of flooding from the River Tummel and flooding from WF59, WF60 and WF61 crossing the A9 embankment (no flooding of properties occurs when runoff from the minor watercourses is omitted), it was tested whether one or more additional culverts through the A9 embankment could alleviate flooding locally. Hydraulic modelling of different culvert locations showed that a flood relief culvert adjacent to the existing culvert at WF61 reduced flood depths throughout the Dalshian area, i.e. at all properties, compared to the baseline condition.

4.1.108 The flood relief culvert, shown in Diagram 4.11, conveys flows from the River Tummel, upstream of the Tummel Underbridge, through the underpass to the proposed flood relief culvert at WF61. To achieve the beneficial effect from the additional flood relief culvert it is required that the discharge of flows from the culverts at the downslope side of the A9 embankment (in the Easthaugh floodplain) is improved. This is realised with interceptor pipes along the downslope side of the A9 embankment connecting WF59 and WF60 to WF61 and an open channel from the proposed new and existing culverts at WF61 along a field boundary to the River Tummel in a south-westerly direction.

Diagram 4.11: Collaborative mitigation measures at Tummel Underbridge / WF59-61 area



4.1.109 In the existing condition the Easthaugh floodplain is separated from the Tummel with embankments that flood relatively regularly (the modelling suggests about once every two years). To avoid increasing the frequency of flooding of the floodplain, the embankment is proposed to be retained at the location where the ditch outfalls into the River Tummel in the proposed condition. The final 10m of is therefore proposed to be a 1.2m diameter culvert which drains under the embankment, with a non-return flap valve at the outfall to avoid return flows from the River Tummel onto the floodplain before the banks are overtopped.

4.1.110 The additional mitigation measures incorporated in the scheme for WF59-61 and the River Tummel provide a neutral scheme impact or result in a betterment, in particular in the Dalshian area, see Diagrams 4.12 and 4.13. These specific mitigation measures are also detailed in Table 11.18, mitigation item P04-W24 of the ES.

4.1.111 Analysis of modelled flood events identified that the proposed mitigation measures during a 3.33% AEP (30-year event) have a minor beneficial impact on flood risk to the properties located on the upslope of the existing WF60 culvert. This impact is due to the proposed downstream network which allows for the increased conveyance of water through the culverts associated with WF59 and WF60 reducing the peak water level by up to 23mm and 14mm respectively. Similarly, the properties at East Haugh House Hotel show a major beneficial impact on flood risk with water levels decreasing by up to 166mm during the 3.33% AEP (30-year) event.

4.1.112 During the design flood event, water levels reduce by up to 39mm at Middlehaugh of Dalshian and up to 22m at Middle Cottage, Dalshian Farmhouse and East Haugh Hotel providing a largely minor beneficial impact on flood risk which is due to the increased capacity at WF61. Water levels at the Mains of Dunfallandy are shown to largely reduce by up to 2mm during the 3.33% AEP (30-year) event and slightly increase by approximately 5mm during the design flood event, which shows the proposed scheme widening and SuDS Pond D has a negligible impact in this area. To the north-east of Mains of Dunfallandy, localised water levels increase by up to 23mm during the 3.33% AEP (30-year) and design flood event due to the proposed scheme widening and construction of SuDS Pond D reducing the amount of floodplain storage.

4.1.113 Downstream on the left bank there is largely a small decrease in water levels of up to 10mm and a reduction of up to 68mm near the proposed flood relief culvert outfall, and up to 85mm and 58mm downstream of WF59 and WF60 respectively, during the design flood event. Similarly, water levels decrease between 11mm to 196mm downstream of WF59-61 during the 3.33% AEP (30-year) flood event. The reduction in water levels is due to the proposed downstream network allowing water from WF59 and WF60 to discharge into WF61 and along the open ditch to the River Tummel outfall. Water levels increase by up to 27mm immediately downstream of the Tummel Underbridge on the left bank, due to the proposed scheme widening reducing the amount of floodplain storage available and altering the localised flowpaths. There is a thin area of land where water levels increase by 11mm to 59mm upstream of the River Tummel culvert outfall. This is due to the 1.2m diameter pipe causing a slight increase in peak water level during the design flood event, because the water level in the River Tummel prevents the flap valves from opening causing a backup into the proposed ditch.

4.1.114 There are no particular sensitive flood receptors in the agricultural areas that experience increased water levels. There are no further significant changes in water levels in the floodplain other than in areas within the scheme footprint.

4.1.115 It was considered that the benefits to sensitive flood receptors in the Dalshian area for a wide range of design floods outweigh the marginal detriment to flood levels contained within small pockets of the Easthaugh agricultural floodplain where there are no sensitive flood receptors. This is summarised in the table below.

4.1.116 The scheme does not have any impact on flood levels on principal watercourses (River Tummel, Loch Faskally or River Garry) outside of the areas shown in Diagrams 4.12 and 4.13 below.

Summary

4.1.117 With mitigation measures in place the risk of flooding of sensitive receptors during the design flood event (and also during the 3.33% AEP event) in the Dalshian area will be reduced by the proposed scheme. No further mitigation is required.

Diagram 4.12: Mitigation measures - Water level difference, 3.33% AEP (30-year) compared to baseline

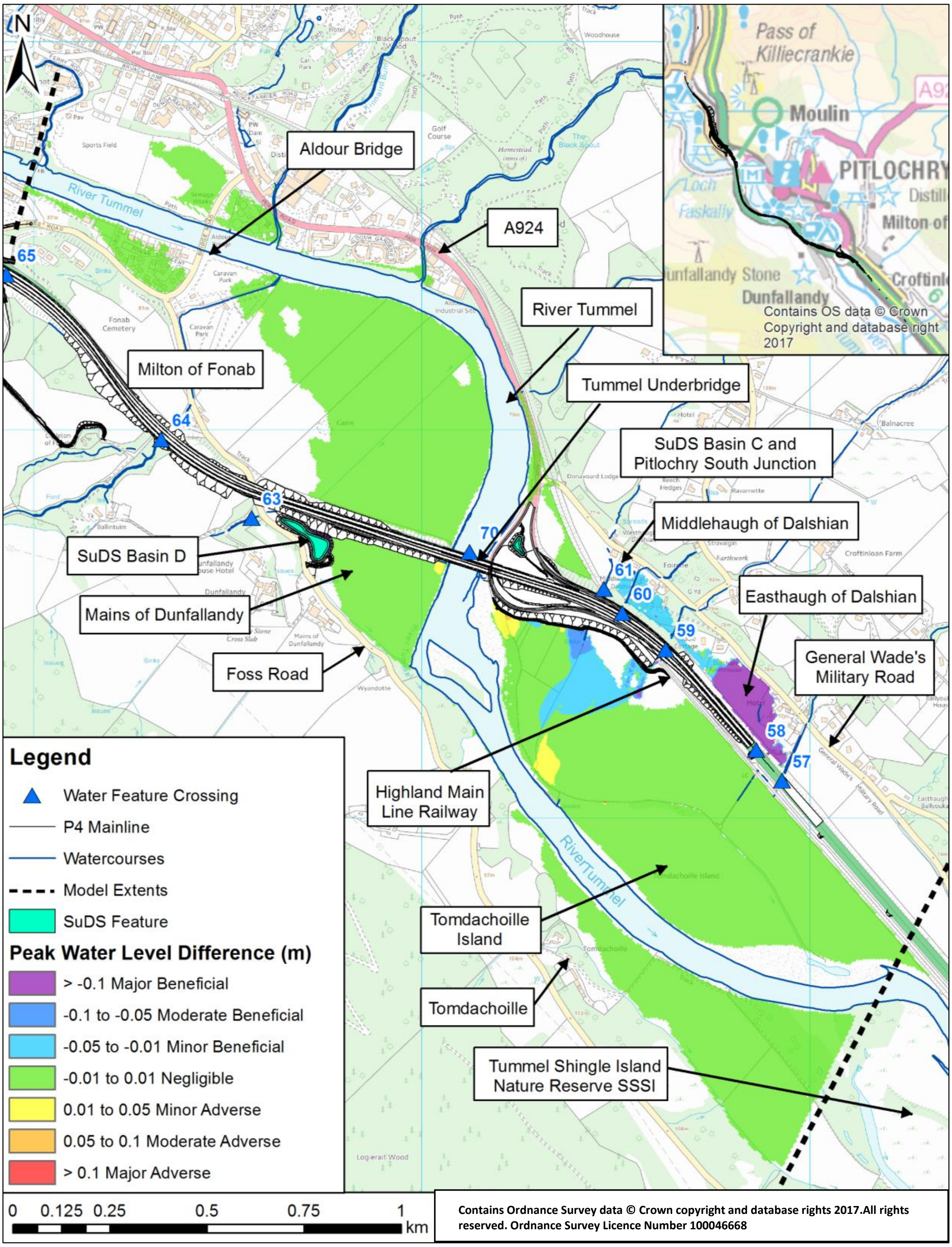
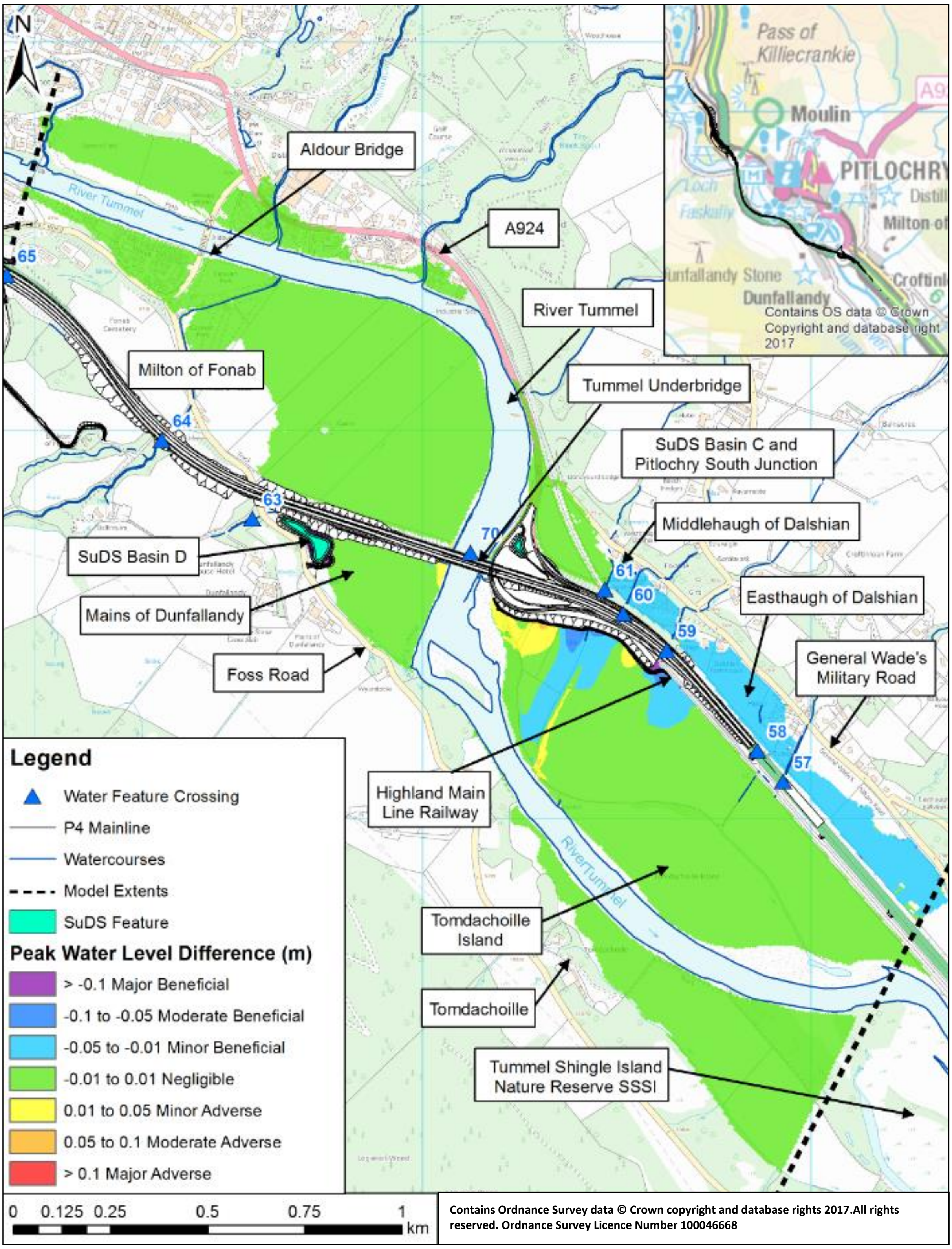


Diagram 4.13: Mitigation measures - Water level difference, design flood event compared to baseline



Residual Risks

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

- Blockages of culverts by large debris that reduce its capacity to convey flows. This FRA confirms that the scheme is robust to reduced flows, but flooding of sensitive receptors including the A9 could occur if a blockage is excessive.
- Severe flood events as a result of intense rainfall or rapid snow melt, which exceed the design capacity of the culverts. It has been confirmed that all minor watercourse culverts in the proposed will not cause flooding of the road or other sensitive receptors for floods up to the 0.5% AEP (200-year) design event, but some flooding from minor watercourses could occur for exceedance events.
- Additional flooding to the agricultural land downstream of the Tummel Underbridge on the left bank when the design flood event flows from WF59-61 coincide with the flooding associated with the River Tummel. The probability of coincidental flooding between WF59-61 and the River Tummel is very low and therefore no further mitigation is proposed.

4.1.119 There are no proposals to install trash/security screens at any of the culverts.

4.1.120 It is proposed to replace existing culverts with larger ones at WF63, 69 and 71, and to add a flood relief culvert adjacent to WF61. This will reduce the risk of blockages in these watercourses.

4.1.121 Where the proposed scheme increases pass forward flow as a result of culvert replacements, the detailed assessment has shown that no flood sensitive receptors experience an increase in flood risk, over what is currently experienced in the baseline scenario. Therefore, no additional mitigation measures are recommended.

4.1.122 It will be important that the relevant management company carry out routine inspection and ongoing maintenance of the culverts. The information contained in this FRA could be used to identify the sensitive locations and prioritise any inspection schedule within the A9 operation and maintenance plan.

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 running 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 amount 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 steep valley side of the River Tummel and Loch Faskally. As a result, the underlying hard rock geology and steep hillsides are likely to generate significant volumes of runoff during a high intensity rainfall event that would flow towards the proposed scheme. Excessive surface water runoff itself may pose a flood risk especially if running at a high velocity. Surface water runoff combined with localised depressions in the ground topography may result in the 'ponding' of water sometimes to a significant depth.

5.1.4 As part of a typical carriageway design, roadside filter drains or Pre-Earthworks Drainage (open ditches) adjacent to 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 simple assessment to identify areas along the existing A9 at risk of surface water flooding, by overlaying three main 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 Flowpath 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 flowpath 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 risk of surface water flooding based upon the catchment area and the gradient of the flowpaths within that location, with those flowpaths associated with large catchments and/or steep gradients resulting in high flowpath significance.
- **Historical Flood Incidents** – historical flood datasets provided by SEPA contain no records of surface water flood incidents along the existing A9 within this project area.

5.1.6 The simple assessment concludes that for the majority of the project area, the existing A9 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 flowpath analysis identifies surface water ponding against the embankment, or the embankment diverting overland flow routes to the nearest watercourse.

5.1.7 The simple assessment does identify a number of locations where the existing A9 that could be at risk of surface water flooding, shown in Table 5.1.

5.1.8 The areas of surface water flooding listed in Table 5.1 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 flowpath 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, the FRA concludes that there is an existing low risk of surface water flooding along the existing A9 corridor.

Table 5.1: Locations of potential surface water flooding

Chainage	Comment
ch0000-0350	Large ponded area of surface water shown on the southbound carriageway around the area of East Haugh. The A9 water crossings at WF59-61 are shown to interact with the River Tummel during the 3.33% AEP (30-year) event or greater and impact the land in the Dalshian area which in part support SEPA's surface water model output. However as there are fluvial and surface water interactions the SEPA Map is likely to be an underestimation of risk. Furthermore, the hydraulic modelling shows no risk to the A9, therefore the surface water risk is related solely to the Dalshian area.
ch4800-4900	Small isolated area of surface water ponding west of Faskally Cottages and immediately adjacent to southbound carriageway and junction with the A924. Surface water ponded area is not associated with a watercourse. As pre-earthworks drainage upstream of the 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. No other sensitive receptors are present in this location.
ch5000-5100	Small isolated area of ponding on the southbound carriageway near Craiglunie. Surface water ponded area is not associated with a watercourse. As pre-earthworks drainage upstream of the 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. No other sensitive receptors are present in this location.
ch5500-5600	The SEPA Flood Map identifies four conjoined surface water flowpaths on the western slopes that flank the existing A9 and are shown to overtop the road. The flow path is considered to be associated with WF74 and WF76 which have been modelled and shown to surcharge during the baseline design flood event, impacting the existing A9. However, the proposed scheme is offline at this location with two new cascades at the upstream side of WF74 and WF76 to lower the watercourse sufficiently below the proposed scheme. The associated pre-earthworks drainage upstream will capture runoff upstream from the original catchment and re-direct it to the proposed WF74 culvert. Consequently, the A9 is considered no longer at surface water risk. No other sensitive receptors are present in this location.
ch6100-6200	Small isolated area of ponding on the northbound carriageway near Faskally Home Farm. Surface water ponded area is not associated with a watercourse. As pre-earthworks drainage upstream of the 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. No other sensitive receptors are present in this location.
ch6300-6400	Moderate isolated area of ponding on the northbound and southbound carriageways near the caravan park in Faskally. Surface water ponded area is not associated with a watercourse. As pre-earthworks drainage upstream of the 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. No other sensitive receptors are present in this location.

Potential Impacts

5.1.9 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, which without attenuation, could increase the rate at which runoff reaches receiving watercourses. Whilst 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

5.1.10 The proposed scheme includes the following 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-Earthwork Drainage

5.1.11 Pre-Earthworks Drainage (PED) is permanent drainage infrastructure designed to collect hillside runoff at the toe of road embankments where the adjacent land falls towards the earthworks and 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. Essentially PED is located where there is a risk of surface water runoff affecting the earthworks or adjacent land.

5.1.12 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 will then ensure drainage towards an open watercourse, which would help minimise alterations to local hydrological regimes.

5.1.13 In accordance with DMRB, the design of PED would convey the 1.3% AEP (75-year) rainfall runoff event from the catchment they would be intercepting, 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.

5.1.14 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 drainage at the top of the cuttings, e.g. between WF76-78, will 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

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

Sustainable Drainage Systems (SuDS)

5.1.16 All runoff from the proposed scheme carriageways would be collected and treated via SuDS prior to discharge. SuDS implementation will help ensure minimal changes in surface water runoff rates that could be associated with an increase in impermeable surfaces associated with the proposed scheme. 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 500mm freeboard depth over and above the 0.5% AEP (200-year) water level has been used to set the bund height;
- where possible, SuDS features have been located outside of the functional floodplain;
- where SuDS features are located within the 0.5% AEP (200-year) functional floodplain, compensatory flood storage has been considered 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, 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 An iterative process has been undertaken when sizing the SuDS features, sizing the pond embankment to prevent overtopping and minimising (if possible) the flood risk impact of the feature whilst consideration is given to a wider range of spatial and environmental constraints.

5.1.18 This FRA has informed the SuDS design process by providing modelled baseline flood extents and peak water levels. Where the FRA has not modelled the receiving watercourse or floodplain in which the pond sits (along minor watercourses), a simple assessment has been undertaken using the SEPA Flood Map, survey data and Manning's equation to inform the design process. The proposed scheme includes five SuDS features within this project area. Whilst it has been possible to locate the majority of the ponds out of the 0.5% AEP (200-year) + CC floodplain, SuDS Pond D is to be located within the floodplain due to other overriding design considerations.

5.1.19 Table 5.2 contains a list of SuDS ponds and outfall levels along with associated peak flood levels (either extracted from hydraulic models results or calculated using Manning's equation).

5.1.20 For Drainage Catchments A and B, a SuDS pond within the functional floodplain without being able to compensate the loss of storage, would undermine any positive impacts on water quality provided by a SuDS pond with a greater level of attenuation. Consequently, Drainage Catchments A and B will be tied in with the existing A9 drainage network and have no formal attenuation prior to outfall. Treatment on these catchments will be improved compared to the existing situation, as Drainage Catchment A will incorporate filter drains and a Hydrodynamic Vortex Separator, and Drainage Catchment B will incorporate a filter strip and filter drain.

5.1.21 For Drainage Catchment D, the catchment was split into D1 and D2 to avoid placing a SuDS pond entirely within the 3.33% AEP (30-year) flood extent. For catchment D1, which is the first 350m section of the catchment which couldn't drain back to the relocated SuDS pond, treatment is to be provided by filter drains and a Hydrodynamic Vortex Separator, with attenuation provided by Geocellular Storage. Treatment and attenuation on Drainage Catchment D2 will be provided by filter drains and a SuDS retention pond.

5.1.22 Drainage Catchments E and F discharge directly into Loch Faskally with no attenuation due to topographical constraints, and the potential adverse and disproportionate impacts on ancient woodland from the required earthworks for a SuDS basin. Drainage Catchments A, B, E and F are not detailed in Table 5.2 as they have no formal attenuation facilities beyond filter drains. Drainage Catchment D1 is not detailed in Table 5.2 as attenuation is provided by Geocellular Storage instead of a SuDS pond.

5.1.23 In this project area, the proposed scheme includes online and offline dualling. The online dualling section from the Southern Boundary to Clunie Underbridge is unlikely to alter the existing hydrological flow paths of surface water runoff and ponding areas with no adverse impacts predicted. The offline dualling section around Pitlochry North Junction and north of Clunie Underbridge will likely alter the existing hydrological flow paths of surface water runoff however PED, highway drainage and SuDS will ensure no increase in flood risk.

5.1.24 This project area also includes 25 minor watercourses. Where possible, PED and highway drainage runs will discharge to the nearest watercourses to mirror natural flow routes and will therefore not likely alter existing surface water catchments.

5.1.25 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.

5.1.26 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.

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Table 5.2: SuDS retention pond and outfalls levels

Basin ID	Chainage	Bund Height (mAOD)	Discharge Location	Outfall Level (mAOD)	Source of Derived Flood Levels	Pond within 3.33% AEP (30-year) Floodplain	Peak 3.33% AEP (30-year) Floodplain Water Level (mAOD)	Pond 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*
C	ch0840-0890	78.400	River Tummel (WF70)	74.72	FRA Model	No	-	No	-	76.02
D2	ch1330-1490	77.175	River Tummel (WF70)	74.00	FRA Model	Yes	75.12	Yes	75.76	75.12
G	ch4550-4700	113.400	Loch Faskally (WF75)	89.18	Flood Map	No	-	No	-	-
H	ch5070-5300	130.885	WF74	128.99	Flood Map	No	-	No	-	-
I	ch6280-6450	131.200	WF77	129.06	Flood Map	No	-	No	-	-

* The design of SuDS Pond C does not include tide locking. As a result, downstream water levels could become higher than the outfall level, meaning flows could potentially back-up within the pond and overflow once the overflow level is passed.

* At SuDS Pond G, H and I the associated watercourses are culverted and outside of a flood risk area, therefore no applicable floodplain water level can be calculated. The outfall associated with SuDS Pond G is unknown however the water level is controlled by Pitlochry hydro-electric dam.

Mitigation Measures

5.1.27 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 Section 5 (Surface Water).

Residual Risks

5.1.28 In the context of this proposed scheme, the residual surface water risks will 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)), highway drainage (>20% AEP (5-year)) or SuDS features (0.5% AEP (200-year) + CC).
- blockages within the drainage infrastructure that reduce its capacity to convey flows from adjacent land and the carriageway or from SuDS features into receiving watercourses; and
- the failure of proposed SuDS (embankment failure), which could result in a sudden release of water and the flooding the receptors downstream.

5.1.29 In the event of intense rainfall or rapid snowmelt that exceeds the standard design capacity of the PED, where practicable the sizing of the PED drainage at the top of the proposed road cuttings, e.g. between WF76-78, will be increased to accommodate the design flood event to minimise the risk of overtopping and flood risk to the road.

5.1.30 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.

5.1.31 The design of SuDS features includes a 500mm 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. Ongoing routine inspection and maintenance of the SuDS features will reduce the likelihood of failure.

5.1.32 In summary, the residual risks posed by the SuDS features are therefore considered to be low and no further mitigation is required.

5.1.33 A detailed assessment of the impact of failure or overtopping of the SuDS features has not been undertaken. The SuDS features are located in close proximity to watercourses, with no sensitive receptors between the two. In these cases, should the pond embankment fail, the water would flow directly into the watercourse. The volume of water flowing into large watercourses, such as the River Tummel, would be insignificant in comparison to average flows and would have a negligible impact on flood risk downstream.

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 hazard can be presented if construction works, or long-term, large-scale developments, such as highway 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 59 borehole-monitoring installations along the proposed scheme corridor has been collated and reviewed, as well as continuous data-logger records at two 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 August 2015 and December 2015 and the second between September 2016 and December 2016. Monitoring was conducted between September 2015 and January 2016 in 24 boreholes and between October 2016 and May 2017 in 35 boreholes.

6.1.3 By assessing recorded groundwater levels along the scheme corridor, a screening assessment was carried out to identify those areas at greatest risk of groundwater flooding, potential scheme 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 basins. Chapter 10 (Geology, Soils, Contaminated Land and Groundwater) undertakes this screening and fully assesses groundwater issues in relation to the proposed scheme.

Baseline Risks

6.1.4 Throughout the study area, superficial deposits are shown to range in thickness from <1m to 30m. Alluvium underlies the valley bottom areas throughout the majority of the proposed scheme corridor, with river terrace deposits in the northern section of the proposed route, around Faskally, and in a small isolated area between ch2200 and ch2900, immediately south of Pitlochry. Glacial till underlies the hillsides of the River Tummel valley, to the northeast of Strathtay and in the high ground to the north and east of Pitlochry. Bedrock comprises metamorphic rocks, primarily belonging to the Southern Highland Group, in the central and southern regions of the proposed scheme area, with units of metamorphosed limestone, lava, schist and quartzite in the north.

<u>Groundwater in the Superficial Deposits</u>

6.1.5 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 into the underlying bedrock aquifer, in locations where glacial till is present, is likely to be low. After periods of intense or prolonged rainfall, this is likely to contribute to significant waterlogging and surface water ponding in low lying areas and enhanced run off in other areas.

6.1.6 In valley floor areas, underlain by alluvium and river terrace deposits, groundwater levels may emerge at ground level because of rising groundwater levels in the superficial deposits. In the vicinity of 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.

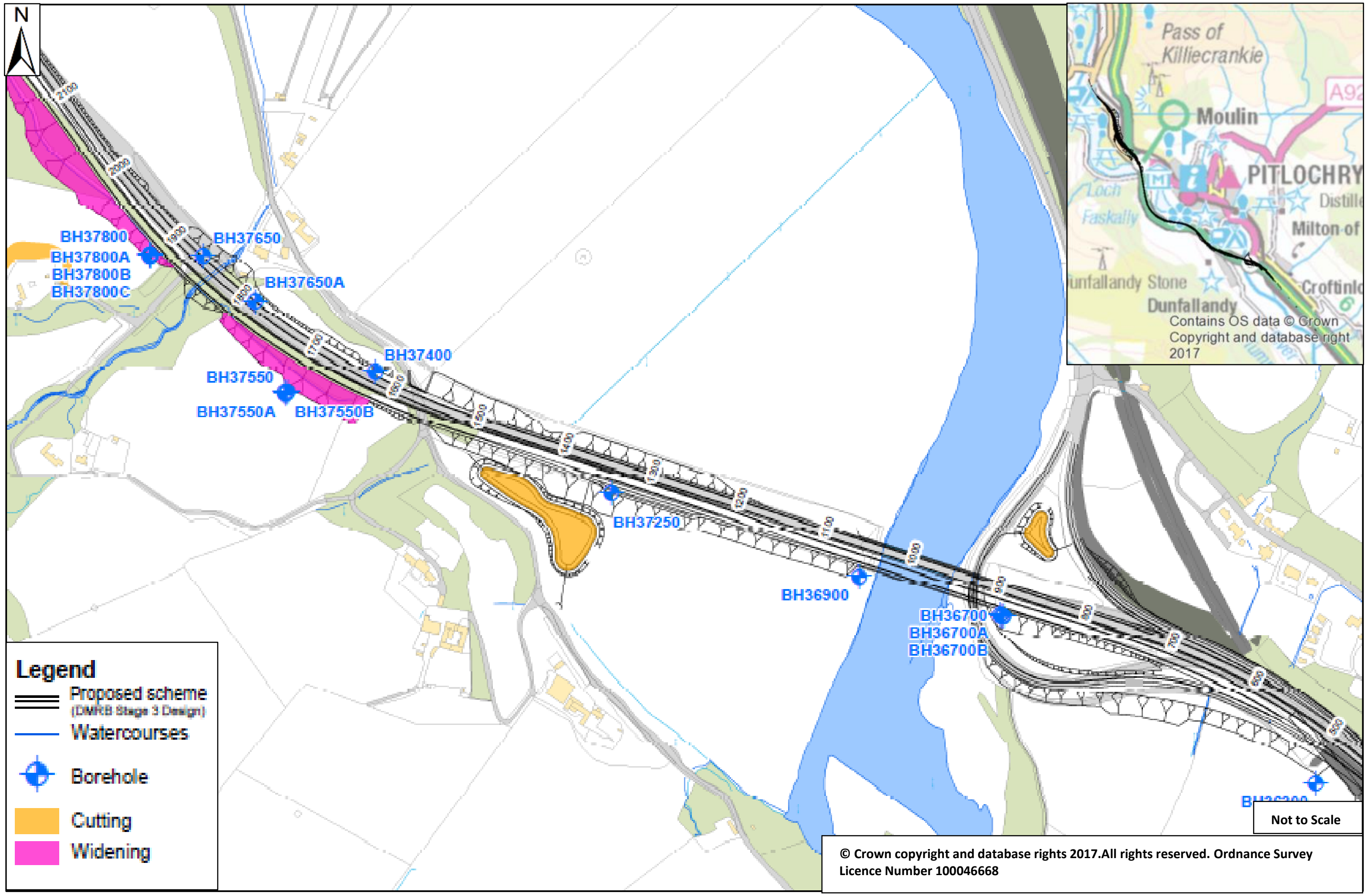
6.1.7 The A9 development corridor is linear and consequently the ground investigations cannot fully define groundwater flow directions across the surrounding area. However, the general groundwater flow direction throughout the project area is expected to broadly follow the topography and, at the shallow, local scale, this would generally be towards the River Tummel/Loch Faskally. 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 proposed scheme corridor, identifies two locations where maximum groundwater levels are at or less than 0.4m below ground level (bgl). One of these locations (ch1300) lies within the superficial deposits, specifically alluvium, overlying low permeability bedrock. The installation (BH37250) lies in an area considered by SEPA to be at high risk of fluvial flooding, lying within the 1 in 200 year Flood Zone (indicating a greater than 0.5% probability of flooding in any one year), adjacent to the River Tummel and in close proximity to a small burn or field drain (see Diagram 6.1). It should be noted however that borehole PKB1008, located in the same area, recorded groundwater levels up to 1.0m below ground level and BH36900 and PKB1007 (ch1050), also installed within the superficial deposits and lying within the 1 in 200 year Flood Zone adjacent to the River Tummel, recorded a maximum groundwater level of 1.3m bgl. Two months of logger data recorded in PKB1007 from December to February 2016 indicated a maximum groundwater level of 1.8mbgl.

6.1.9 Groundwater levels at or less than 1.0m below ground level in the superficial deposits were also recorded at several other locations. In several boreholes in the area between ch5100 and ch5450, including PKB1032, PKB1042 and PKB1043. Also in BH36300 (ch450), BH39300 (ch3450), BH40500 (ch4225) and BH41800 (ch5900).

6.1.10 The information reviewed helps to confirm the likelihood of encountering shallow groundwater levels in the alluvium adjacent to the River Tummel. In such locations, groundwater may 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 this area.

Diagram 6.1: Key location for groundwater levels in the superficial deposits



Bedrock Groundwater

6.1.11 Groundwater flow in the bedrock metamorphic rocks will occur primarily through fractures. Permeability is expected to be low and variable, dependent on the density and interconnection of fracture networks. Recharge rates into the bedrock may also be low and variable, due to the low bedrock permeability and may contribute to the development of waterlogging and surface water ponding in low lying areas and enhanced run-off in other areas.

6.1.12 One of the boreholes where maximum groundwater levels were found to be at or less than 0.4mbgl, during the monitoring period was screened entirely in bedrock.

6.1.13 The second location where maximum groundwater levels were found to be at or less than 0.4mbgl, during the monitoring period, is in BH41200 (ch5300) which is screened entirely in bedrock. Several other boreholes in this area (PKB1042, PKB1043, BH41400) recorded maximum groundwater levels around one metre below ground level or less. The data indicates this area to be comprised of shallow bedrock beneath thin superficial river terrace deposits, with shallow bedrock and superficial groundwater likely to be in continuity. As noted above, several boreholes also recorded shallow groundwater levels in the superficial deposits in this area (between ch5100 and ch5450).

6.1.14 Shallow bedrock groundwater levels were also recorded around ch4200 (PKB1020). However, the data available at this stage does not provide any evidence of shallow groundwater currently contributing to flooding in this area.

Limitations

6.1.15 It should be noted that the groundwater-monitoring data used to inform this baseline assessment has been collected over two finite periods (four months from September 2015 to January 2016 and seven months from October 2016 to May 2017) and predominantly comprises manual dips, rather than continuous logger data. 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

6.1.16 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 development 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.

6.1.17 A separate road cutting screening exercise has been undertaken in Chapter 10 (Geology, Soils, Contaminated Land and Groundwater), which has identified 13 cuttings that are likely to intercept groundwater. Of particular relevance are the six areas where shallow groundwater conditions have been recorded. These areas are summarised in Table 6.1.

Table 6.2 : Summary of shallow groundwater levels recorded

Borehole Reference	Chainage	Maximum Recorded Groundwater Level (mbgl)	Comments
BH36300	ch450	0.94	Shallow groundwater recorded in superficial deposits. No cuttings in the vicinity.
BH37250, PKB1008	ch1300 – ch1400	0.4	Shallow groundwater recorded in superficial deposits. Lie in low lying area, at edge of flood plain and within 1:200 year Flood Zone. SUDS Basin D is located in this area.

Borehole Reference	Chainage	Maximum Recorded Groundwater Level (mbgl)	Comments
BH39300	ch3450	0.63	Shallow groundwater recorded in superficial deposits on low slopes above A9 and Loch Faskally. Sideroad Cutting 5 (CS5) is located down slope from this area, close to Loch Faskally, and will be 3m deep. Some groundwater drainage into this cutting may occur.
BH40050, PKB1020	ch4200	0.54	Shallow groundwater recorded in both bedrock and superficial deposits. Close to Loch Faskally. No cuttings in the vicinity.
BH41400, BH41200, PKB1032, PKB1042, PKB1043	ch5100 – ch5450	0.37	Shallow groundwater recorded in both bedrock and superficial deposits. Cuttings 3 and 4 run through this area and will be up to 24m deep. These cuttings are likely to induce significant groundwater drainage.
BH41800	ch5900	0.49	Shallow groundwater recorded in superficial deposits on low slopes above A9. Cuttings 3 and 4 are in this area and will be up to 24m deep. These cuttings are likely to induce significant groundwater drainage. (Sideroad Cutting 9 (CS9) is also in this area but groundwater drainage is expected to be dominated by Cutting 3.)

6.1.18 One of the proposed SuDS Ponds, Basin D, lies within an area of shallow groundwater, with recorded groundwater levels of 0.4m below ground level, which suggests that there is a risk of groundwater flooding in this area. Basin D is expected to be excavated to 4.5mbgl and so it is likely that it will intercept the shallow groundwater table within the superficial deposits during construction, and management of the resultant groundwater discharge will be required. However, as SuDS basins are expected to be lined it is not anticipated to induce groundwater discharge during operation.

6.1.19 Two areas where shallow groundwater levels have been recorded coincide with Cutting 3 and Cutting 4. Associated with an area of shallow groundwater levels between ch5100 and ch5450, borehole BH41200 (ch5300) recorded the shallowest levels, with a maximum groundwater level of 0.37mbgl, with 3m of superficial deposits overlying bedrock at this location. However, the cutting lies more than 110m east of this location. At or close to the cutting location, PKB1043 recorded a maximum groundwater level of 0.59mbgl. At the northern end of Cutting 3, BH41800 recorded a maximum groundwater level of 0.49mbgl. Cutting 3 and Cutting 4 are therefore likely to create a strong groundwater drainage effect (due to the proposed depth of 24m for Cutting 3 and 15m for Cutting 4, as identified in Chapter 10: Geology, Soils, Contaminated Land and Groundwater) and the consequent dewatering requirements will need to be considered.

Mitigation Measures

6.1.20 Despite the potential drainage of groundwater at Cutting 3, Cutting 4 and Basin D, it is considered that groundwater flood risk can be mostly managed through mitigation embedded into the design of the proposed scheme. Table 6.2 details the embedded mitigation measures likely to be incorporated into the proposed scheme. With these in place, the impact of the proposed scheme on groundwater flood risk is considered low.

Table 6.2: Groundwater embedded mitigation measures

Embedded Mitigation Measures	Description
Dewatering of cuttings	During the construction phase, the proposed scheme will include standard excavation dewatering practices involving passive and/or active dewatering, as required. It would protect construction personnel, works, plant and machinery associated with construction of the new cuttings. However, at this stage uncertainty remains on the volumes of groundwater which may be intercepted.
Drainage of cuttings	To protect flood sensitive receptors from groundwater flooding during the operational phase, groundwater seepage would be collected by the proposed highway drainage system.
PED	PED should be sized appropriately to intercept and accommodate all shallow groundwater flows entering the works area to protect flood sensitive receptors.

Embedded Mitigation Measures	Description
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.

6.1.21 Other than at cuttings, it is considered unlikely that groundwater flooding will pose a significant issue along the proposed scheme corridor. Although it may contribute to surface water flooding in some areas, as noted above. It is considered that embedded mitigation proposed as part of the proposed scheme, would be sufficient to manage all of the above mentioned groundwater flooding issues.

6.1.22 However, due to the presence of deep cuttings and the remaining uncertainties associated with the existing ground investigation data to date, it is recommended that a groundwater level monitoring programme is implemented before and during construction to identify any potential future groundwater flood risk issues.

Residual Risks

6.1.23 There is a low, residual groundwater flood risk that temporary drainage systems would be unable to cope with the groundwater flows that could emerge as a result of localised drainage of groundwater at deep cuttings, in particular Cutting 3. It is assumed that the contractor is aware of these possible groundwater releases, and as such, would design any 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 will be dependent on the combined effect of a number of factors such as their condition, existing maintenance regimes and other outside influences. However, it will be significantly lower than the 0.5% AEP (200-year) design 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 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 traverses 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.

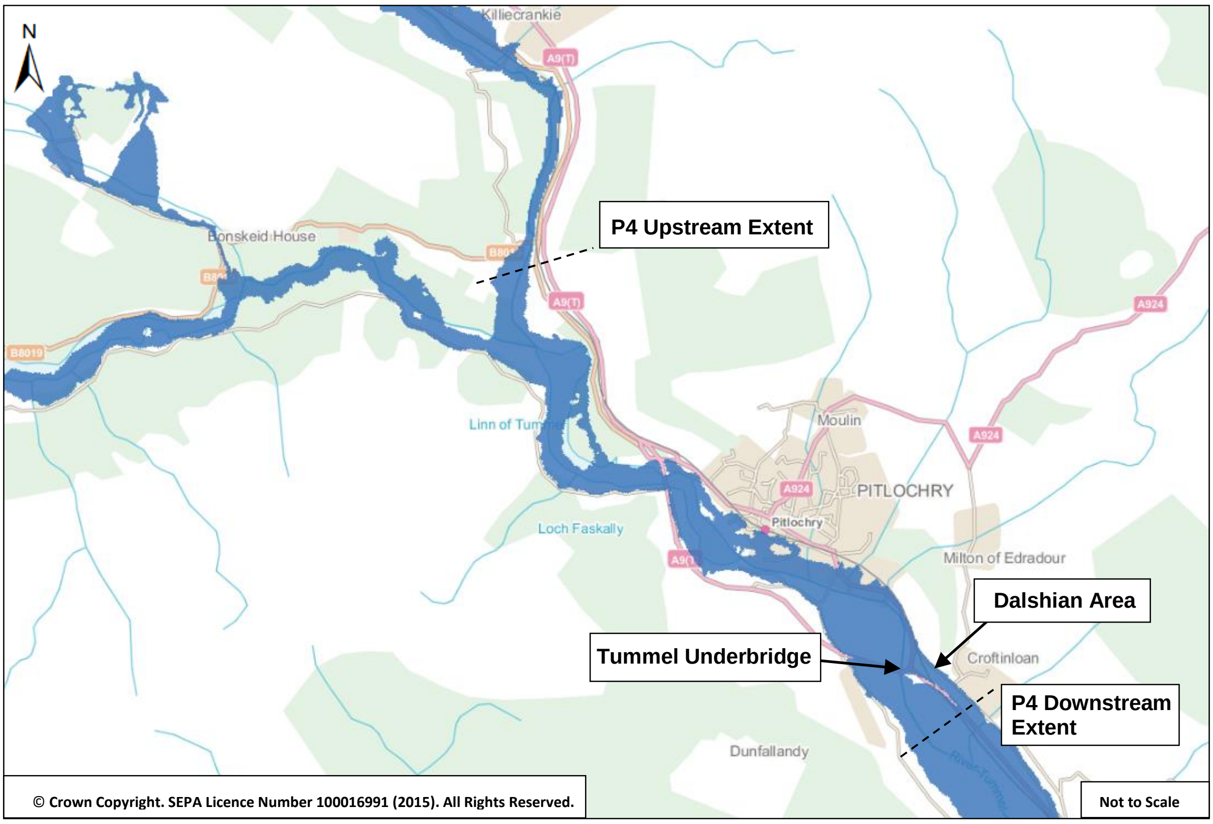
Baseline Risks

<u>Reservoirs</u>

7.1.5 The reservoirs of Loch Rannoch, Loch Ericht, Loch Garry, Loch Faskally and Loch Errochty (among others) are located upstream of the proposed scheme. Loch Faskally Reservoir is situated on the River Tummel upstream of Pitlochry and within the proposed scheme boundary.

7.1.6 The normal operation of these dams poses a negligible risk to the existing A9. The SEPA Reservoir Flood Map (2015b) shows the failure of the upstream dams and the impact on the A9, as shown in Diagram 7.1. The SEPA map shows the A9 to largely be unaffected from reservoir failure, with the exception of the A9 around the Tummel Underbridge and Dalshian area. However, under the Reservoirs (Scotland) Act 2011, the continued maintenance of these structures by SSE Generation Limited will ensure that this is extremely unlikely event, and as a result, there is a low risk of flooding from this source.

Diagram 7.1: Reservoir inundation map



<u>Aqueducts</u>

7.1.7 The A9 dualling programme SFRA (2013) identifies no aqueducts within the project area and therefore there is a low risk of flooding from this source.

<u>Water & Wastewater Treatment Works</u>

7.1.8 Pitlochry is served by Killiecrankie Water Treatment Works (WTW), located approximately 2km from the Northern Boundary and 500m to the east of Killiecrankie and the existing A9. 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 Pitlochry is served by a WwTW located at the junction of Bridge Road (Aldour Bridge) and Perth Road on the left bank of the River Tummel. The baseline hydraulic modelling predicts the WwTW is at risk from a 3.33% AEP (30-year) event. The modelling shows that after a storm duration in excess of 13 hours, the flows from the River Tummel start to backflow along Kinnaird Burn and overtops on the right bank and behind the modified embankment impacting the WwTW up to a depth of 0.8m.

<u>Sewers</u>

7.1.10 Pitlochry aside, the A9 corridor is predominantly rural and sewer network information in the area is limited. Scottish Water records a foul sewer network in Blair Atholl, located approximately 6km to the north of the proposed scheme and in Logierait approximately 4km to the south of the proposed scheme. 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.

7.1.11 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. Consequently, the risk from this source of flooding is considered low and has not been considered further.

Other

7.1.12 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

7.1.13 The proposed scheme would not include any works that would alter or exacerbate risk to the 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 during this phase cannot therefore be 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 the flood risk 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 8.1 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 8.1: 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, 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, PED	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 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.

Protection Standard

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 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 below 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 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 ditches along access road / temporary diversion edges to collect run off and direct to treatment facilities.

Temporary Drainage

- Assess requirements for discharge rate control as part of the construction works.
- Run off that is expected to contain sediment should be directed towards a suitably sized temporary settlement pond before being discharged to 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 advice provided 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.

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9 Conclusion

Summary

9.1.1 This FRA has been produced to support the ES for the proposed scheme for the dualling of the A9 between Pitlochry and Killiecrankie.

9.1.2 The proposed scheme has been developed over a number of assessment stages in broad accordance with the requirements of the DMRB, the requirements of SPP (SPP, 2014) and SEPA's Technical Flood Risk Guidance for Stakeholders (2015a). The proposed scheme is currently at DMRB Stage 3 'Detailed Assessment'.

9.1.3 This FRA demonstrates that the proposed scheme design has adequately addressed any local flood risk issues, and shown that the A9 will remain safe and operational during times of flood, with the exception of surface water risk. 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.

9.1.4 The FRA has focused on the 0.5% AEP (200-year) plus climate change event (the design flood event). Table 9.1 - 9.5 provide a summary of the flood risk assessment findings.

Table 9.1: Principal watercourses summary

Risk	Summary
Baseline	The existing A9 and HML are not at risk during design flood event, however specific locations at risk of flooding during this event include: • Dalshian area (Middlehaugh of Dalshian, Middle Cottage, Dalshian Farmhouse and East Haugh Hotel); • Agricultural land located within the River Tummel floodplain upstream and downstream of Tummel Underbridge; • Junction of the A924 and General Wade's Military Road where the northbound and southbound junction join, upstream of the Tummel Underbridge; • Fonab Crescent and Foss Road upstream of Aldour Bridge • Aldour Industrial Estate, Duke of Edinburgh Drive, Caravan Park and the WwTW downstream of Aldour Bridge; and. • Junction between Aldour Bridge and the A924.
Proposed Scheme Impacts (without mitigation)	The proposed scheme has been shown to have both beneficial and adverse flood impacts during the 0.5% AEP (200-year) + CC event. The A9 and HML remain free from risk during the 0.5% AEP (200-year) event. **Beneficial flood impacts:** • The hydraulic modelling shows a decrease in water levels of up to 184mm to the agricultural land immediately downstream of WF59-61 and within the Tummel floodplain during the 3.33% AEP (30-year) and up to 107mm during the design flood event, when compared to the baseline scenario. **Negligible flood impacts:** • There is largely a negligible flood impact (<2mm) across the River Tummel floodplain with the exception of immediately upstream and downstream of the Tummel Underbridge. The areas of negligible impact include Fonab Crescent, Foss Road, Aldour Industrial Estate, Duke of Edinburgh Drive, Caravan Park and the WwTW around Aldour Bridge. • The proposed scheme results in a 1mm decrease in peak flood levels during the 3.33% AEP (30-year) event on the agricultural land (Mains of Dunfallandy), and a water level increase by up to 6mm during the design flood event Hydraulic modelling shows the modifications to the Tummel Underbridge have a neutral impact on flooding. **Adverse flood impacts:** • The proposed scheme results in a loss of floodplain storage on both banks, upstream, and downstream of the Tummel Underbridge, resulting in up to an 16mm increase in water levels between Middlehaugh of Dalshian and Middle Cottage and up to 65mm around East Haugh Hotel during the 3.33% AEP (30-year) event. • To the north-east of Mains of Dunfallandy, localised water levels increase by up to 35mm during the 3.33% AEP (30-year) and design flood event.

Risk	Summary
	• Downstream on the left bank of the Tummel Underbridge, peak flood levels increase between 11mm to 70mm for these areas during the design flood event and between 11mm to 59mm during the 3.33% AEP (30-year) event • Areas impacted are largely confined to the floodplain and include agricultural land already at risk of flooding during the baseline scenario.
Mitigation Measures	The hydraulic modelling includes WF59-61 as there are fluvial interactions with the River Tummel, therefore collaborative mitigation measures have been considered and detailed in Table 9.2 (Minor Watercourse Summary).
Residual Risks	The residual fluvial flood risks remaining are associated with flood events of greater magnitude than the design flood event. A freeboard allowance has been included in the design to reduce these risks. The impact of the proposed scheme will also remain.

Table 9.2: Minor watercourses summary

Risk	Summary
Baseline	According to the simple hydraulic performance assessment carried out for all existing A9 main road crossings of minor watercourses, during the design flood event: • 6 of the 15 existing minor watercourse culverts have adequate capacity with the DMRB recommended amount of headroom below the culvert soffit; and • 9 of the 15 existing minor watercourses culverts are under capacity. These include WF59-61 at the southern end of the scheme, 65 in the central part of the scheme and WF71, WF74 and WF76 at the northern end. Of these one watercourse (WF76) poses a potential risk of flooding to the existing A9 Hydraulic modelling of the interactions between WF59-61 and the River Tummel shows the River Tummel to overtop on the left bank in the 3.33% AEP (30-year) design event, causing flooding in the area of Westhaugh and Middlehaugh of Dalshian, and at the East Haugh Hotel where depths reach 2m. This detrimentally influences the flood risk associated with WF59-61 in these areas.
Proposed Scheme Impacts (without mitigation)	The proposed scheme has been shown to have both beneficial and adverse flood impacts during design flood event. The change in flood risk impacts, compared to the baseline scenario, is due to the proposed scheme widening on the northbound side and the placement of SuDS Pond D which encroach onto the floodplain, displacing floodwater and reducing the amount of floodplain available for storage. **Beneficial flood impacts:** • The simple assessment shows all 14 of the proposed scheme mainline crossings now have enough capacity to pass the peak flow during the 0.5% AEP (200-year) event plus appropriate freeboard. Upstream impacts are generally beneficial with the replacement (and enlargement) of undersized culverts along the existing A9. • The detailed assessment shows downstream of WF59-61 there are small areas with minor to moderate decreases in water level of 11-59mm alongside areas of detriment during the 3.33% AEP (30-year) event. • The 11-70mm decrease in water levels, downstream of the Tummel Underbridge on the left bank is restricted to the area downstream of the outlets of culverts WF59-61 and immediately downstream of the River Tummel Underbridge during the design flood event and sitting beside areas of detriment. **Negligible flood impacts:** • The impact on water levels downstream of the Tummel Underbridge during the 3.33% AEP (30-year) event shows a negligible decrease in water levels of <1mm on the right bank of the River Tummel (Mains of Dunfallandy). • In the proposed scheme scenario during the 0.5% AEP (200-year) event the impact on water levels in the Dalshian area is negligible between the A924 and Middle Cottage with a 1mm to 9mm increase in water levels. • The impact on water levels downstream during the 0.5% AEP (200-year) event shows a minor increase in water levels of 2mm to 8mm on the right (west) bank of the River Tummel, downstream of Tummel Underbridge. • During the design flood event the impact on water levels in the Dalshian area is negligible with a 1-5mm increase. • The design flood event shows a negligible increase in water levels of up to 6mm on the right bank of the River Tummel, downstream of Tummel Underbridge. Analysis of the consequences of the scheme (unmitigated) on flood risk to sensitive receptors shows that there is a potential that five of the 14 watercourses would result in a potential increase in risk. Two of these (WF67 and 68) show a small reduction in freeboard to the proposed scheme’s road level, but they have sufficient freeboard left in the culvert (headroom) and sufficient freeboard to the road to give confidence that they do not flood the A9 in the 0.5% AEP (200-year) event. The other three (WF59-61) are adverse impacts to the Dalshian area detailed below. **Adverse flood impacts:**

Risk	Summary
	• The detailed assessment has shown that the proposed scheme has an impact to the Dalshian area during the 3.33% AEP (30-year) event with an increase in water levels of 7mm in the Middlehaugh of Dalshian, 16mm around Middle Cottage and up to 65mm at East Haugh Hotel. • Between Dalshian Farmhouse and East Haugh Hotel there is a moderate 12mm to 13mm increase in water level during the 0.5% AEP (200-year) flood event. • On the left bank immediately downstream of the Tummel Underbridge overtops during the 3.33% AEP (30-year) event creating an increase in water levels of 11mm to 59mm. • Downstream of WF59-61 there are small areas with minor to major increases in water level up to 184mm during the 3.33% AEP (30-year) event and up to 60mm during the 0.5% AEP (200-year) event, both sitting alongside areas of betterment. • The 85mm increase in water levels, downstream of the Tummel Underbridge on the left bank is restricted to the area downstream of the outlets of culverts WF59-61 and immediately downstream of the River Tummel Underbridge during the design flood event and sitting beside areas of betterment.
Mitigation Measures	As the A9 dualling proposals cause an increase in the water levels on the River Tummel, this raises flood levels at properties at Dalshian by up to 65mm during the 3.33% AEP (30-year) event, up to 13mm during the 0.5% AEP (200-year) event and up to 5mm during the design flood event. Therefore, a combination of measures is proposed to reduce the risk to these properties. These measures include: • An additional relief culvert under the A9 immediately adjacent to WF61; and • Improved drainage paths from the downstream ends of the A9 embankment culverts at WF59, 60 and 61 to the River Tummel, with a piped outfall into the river which features a flap valve. As a consequence of these measures water levels at properties have reduced for the 3.33% AEP event by up to 23mm at the properties in Middlehaugh of Dalshian and up to 39mm during the design flood event, providing betterment. The properties at East Haugh House Hotel show a large beneficial impact on flood risk with water levels decreasing by up to 166mm during the 3.33% AEP (30-year) event and up to 22mm during the design flood event. Water levels reduce by up to 22mm at Middle Cottage and Dalshian Farmhouse during the design flood event. The Mains of Dunfallandy show a 2mm reduction and 5mm increase in water levels during the 3.33% AEP (30-year) and the design flood event respectively, indicating a negligible impact on flood risk.
Residual Risks	As a consequence of the mitigation measures to reduce the risk of flooding in the Dalshian area, the flood depths for the 3.33% AEP event are increased on the Easthaugh floodplain, in particular on Tomdachoille Island (with localised increases in water levels up to 59mm). As these areas do not feature sensitive flood receptors but agricultural land, this is considered acceptable in relation to the benefits obtained at the properties of Dalshian. Other residual flood risks along minor watercourses are primarily associated with: • Culvert blockage; and • Flood events greater than the design capacity of the watercourse crossing.

Table 9.2: Surface water summary

Risk	Summary
Baseline	Generally, the simple 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.
Proposed Scheme Impacts (without mitigation)	Where the proposed scheme is an online dualling option, the existing surface water flow paths and areas of ponding are likely to remain the unchanged. Where the scheme is offline there is the potential for an increased risk of surface water flooding, however the embedded mitigation means that the impact of the proposed scheme is considered to be negligible. **Beneficial flood impacts:** The proposed scheme will include new surface water drainage features include PED, highway 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 will provide a beneficial impact on surface water flooding when compared to the baseline scenario. Where practicable, the sizing of PED drainage at the top of the cuttings, e.g. between WF76-78, will be increased to accommodate the 200-year plus climate change event to minimise the risk of overtopping and flood risk to the road.
Mitigation Measures	Additional mitigation measures beyond that embedded within the proposed scheme design are required but are not investigated as part of this FRA.
Residual Risks	Generally, residual surface water risks are considered high and include: • Severe rainfall events, which exceed the capacity of the PED, highway drainage or SuDS ponds; • Blockages within the drainage infrastructure or SuDS ponds; and • Failure of a SuDS pond embankment.

Risk	Summary
	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 however there is still the potential for ponding that could spill on to the proposed scheme. 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 pond design also include a 500mm freeboard above the design flood event 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. Ongoing routine inspection and maintenance of the SuDS ponds will reduce the likelihood of failure.

Table 9.3: 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.
Proposed Scheme Impacts (without mitigation)	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 highway 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 detailed differential settlement assessment should be undertaken prior to construction in cutting areas, supported by additional GI data gathering to assess the groundwater flows and the groundwater effects on surface water. Where properties are confirmed at potential risk, condition surveys and monitoring of building and groundwater level changes are recommended. 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 9.4: 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.
Proposed Scheme Impacts (without mitigation)	**Negligible flood impacts:** The proposed scheme will not include any works that will 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 will remain unchanged from the baseline scenario and no additional mitigation measures are proposed.

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

9.1.6 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 and would be included in the proposed scheme such that flood risk is managed appropriately up to the design flood. It is concluded that the proposed scheme would meet relevant planning and design standards in terms of flood risk.

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Annex A: Impact Assessment Criteria

Sensitivity

The sensitivity of watercourses 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 Environmental Impact Assessment (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 A1: Hydrology and flood risk sensitivity criteria

Sensitivity	Criteria
Very High	Water feature with direct flood risk to the adjacent populated areas, with greater than 100 residential properties 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. Minor watercourses with an indirect and localised flood risk to critical infrastructure (including existing A9), during 0.5 % AEP plus CC event, due to undersized culverts. 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 A2: 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 watercourse and the magnitude of impact.

Table A3: Hydrology and flood risk impact significance matrix*

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

*Note, that even though the resulting impact significance may be neutral using the environmental assessment criteria above, that mitigation may still be proposed to address any increase in water levels.

Annex B: 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 head water 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.

Table B1: 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 (m³/s)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9
59	72.6	74.09	0.59 (x2)	74.92	74.99	82.10	0.70	75.10	Surcharged	-0.17	Out of Bank	7.01
60	63	73.88	0.44	74.32	75.15	83.82	0.10	81.41	Surcharged	-7.09	Out of Bank	2.41
61	67	74.42	0.67	75.09	75.52	84.18	0.33	75.52	Surcharged	-0.43	Out of Bank	8.66
63*	512	Does not cross existing A9.					Does not cross existing A9.					
64	41	89.49	1.75	91.24	91.91	92.00	5.31	91.11	Free-Flow	0.13	In Bank	0.89
65	149	101.85	1.15	103.00	103.49	104.18	1.19	103.17	Surcharged	-0.17	In Bank	1.01
66	127	106.63	1.8	108.43	108.15	107.80	5.65	107.62	Free-Flow	0.81	In Bank	0.18
67	36	109.01	0.8	109.81	109.04	109.70	0.74	109.38	Free-Flow	0.43	In Bank	0.32
68	52	103.57	1.75	105.32	104.54	109.60	5.64	104.53	Free-Flow	0.79	In Bank	5.07
69	73	108.92	1.75	110.67	110.01	110.50	5.36	110.04	Free-Flow	0.63	In Bank	0.46
71	70	107.17	0.59	107.76	107.91	115.40	0.36	108.70	Surcharged	-0.94	Out of Bank	6.70
72	139	116.70	1.2	117.90	118.06	118.00	2.07	117.39	Free-Flow	0.52	In Bank	0.6
74**	121	122.77	1.75	124.52	123.74	130.50	5.22	124.26	Free-Flow	0.26	Out of Bank	6.24
76**	121	132.50	1.00	133.50	133.51	135	1.12	134.72	Surcharged	-1.22	Out of Bank	0.28
77	160	132.88	1.75	134.64	133.98	136.14	5.22	134.09	Free-Flow	0.55	In Bank	2.05

*WF63 does not cross existing A9 but requires culvert realignment for the proposed scheme
** WF74 and WF76 cross under the existing AQ9 via a single culvert, however these watercourses were assessed independently in the baseline scenario to determine their individual flow conditions

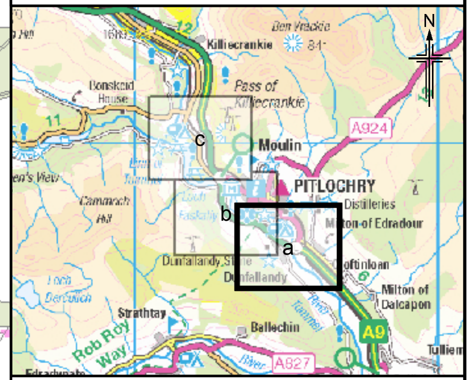
Table B2: Proposed scheme hydraulic assessment – A9 Mainline Culverts

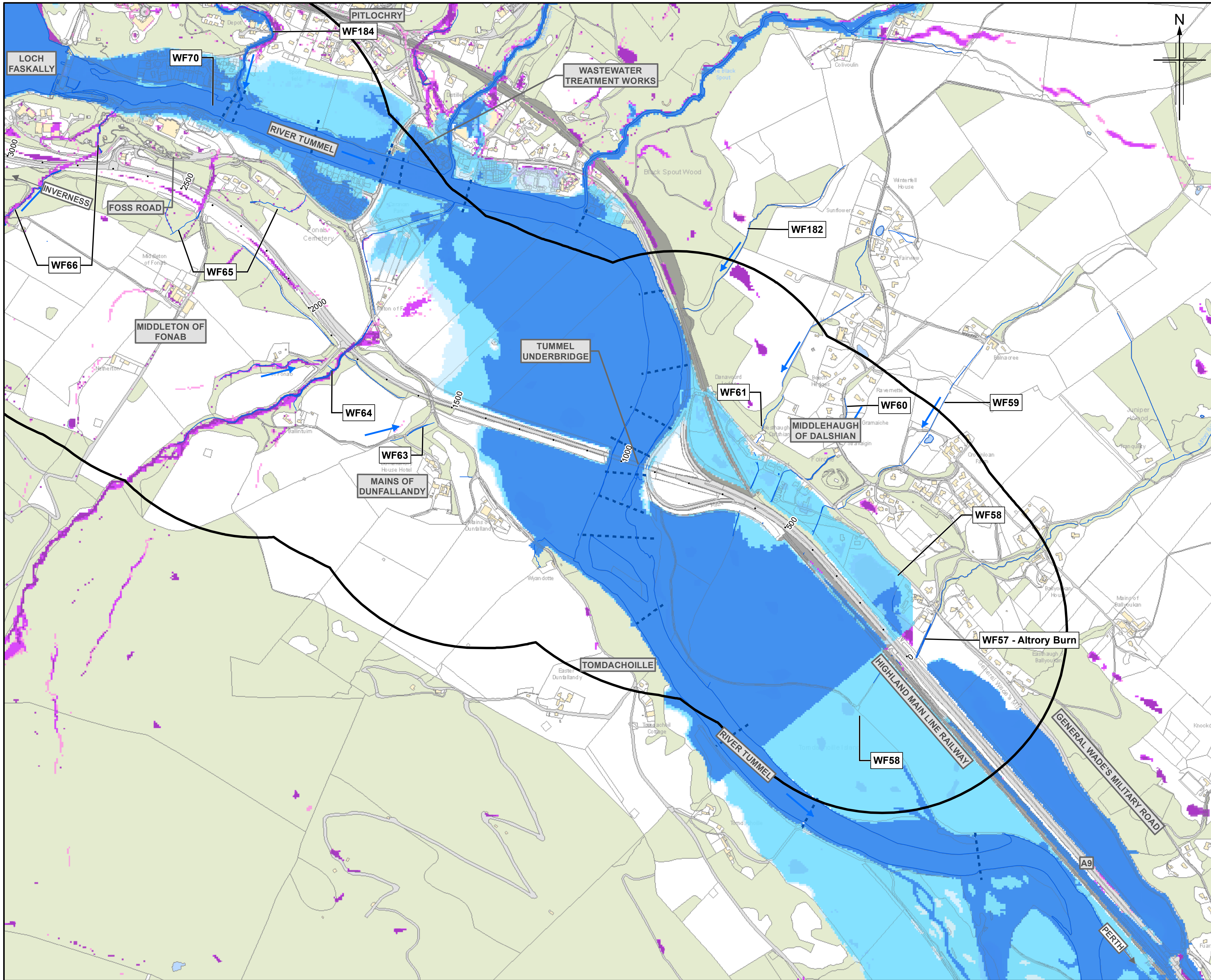
	Proposed Culvert Geometry – A9 Mainline						Proposed Culvert Hydraulic Performance – A9 Mainline					
Ref	Culvert length (m)	Inlet Invert Level (mAD)	Culvert dia/height (m)	Inlet Soffit Level (mAD)	Upstream Bank Level (mAD)	Proposed Road Level (mAD)	Q200+CC HWL (mAD)	Surcharged or Free-Flow	Culvert Freeboard (m)	Upstream Flow Condition	Freeboard to A9	Comment
59	Further assessment: detailed numerical modelling undertaken						Further assessment: detailed numerical modelling undertaken					Low risk
60	Further assessment: detailed numerical modelling undertaken						Further assessment: detailed numerical modelling undertaken					Low risk
61	Further assessment: detailed numerical modelling undertaken						Further assessment: detailed numerical modelling undertaken					Low risk
63*	Replacement of existing culvert to new alignment to bypass SuDS Pond D						Replacement of existing culvert to new alignment to bypass SuDS Pond D					Low risk
64	65	90.840	1.8	92.59	91.43	98.67	92.45	Free-Flow	0.14	Out of Bank	6.22	Low risk
65	157	100.550	1.6	102.15	102.19	106.41	101.69	Free-Flow	0.46	In Bank	4.72	Low risk
66	122	105.500	1.8	107.30	107.02	108.90	106.48	Free-Flow	0.82	In Bank	2.42	Low risk
67	64	109.000	0.8	109.80	111.46	111.50	109.43	Free-Flow	0.37	In Bank	2.07	Low risk
68	55	103.550	1.8	105.35	104.57	109.15	104.56	Free-Flow	0.79	In Bank	4.59	Low risk
69	75	108.050	1.8	109.85	109.19	111.69	109.27	Free-Flow	0.58	Out of Bank	2.42	Low risk
71	116	106.20	1.05	107.25	107.20	118.95	106.62	Free-Flow	0.63	In Bank	12.33	Low risk
72	117.8	134.75	0.75	135.50	137.90	138.40	134.95	Free-Flow	0.55	In Bank	3.45	Low risk
74/76***	Further assessment: numerical modelling undertaken						Further assessment: numerical modelling undertaken					Low risk
77	184	134.81	1.80	136.61	135.07	139.88	136.11	Free-Flow	0.50	Out of Bank	3.77	Low risk

*WF63 does not cross existing A9 but requires culvert realignment for the proposed scheme
** WF72 does not cross the existing A9 therefore baseline road level and freeboard is not applicable
*** WF74 and WF76 cross under the proposed scheme via a single culvert and are therefore assessed as one

Annex C: Flood Risk Assessment Maps

Figure A11.3.1a





Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

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

SEPA Surface Water Flood 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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A9 DUALLING
PERTH TO INVERNESS
Pitlochry to Killiecrankie

Drawing title

Pitlochry to Killiecrankie
SEPA Flood Map
Baseline Scenario

Sheet 1 of 3

Drawing Status	FINAL	
Scale	1:10,000 @ A3	DO NOT SCALE
Jacobs No.	B2140004	
Drawing number	Figure A11.3.1a	Rev 0

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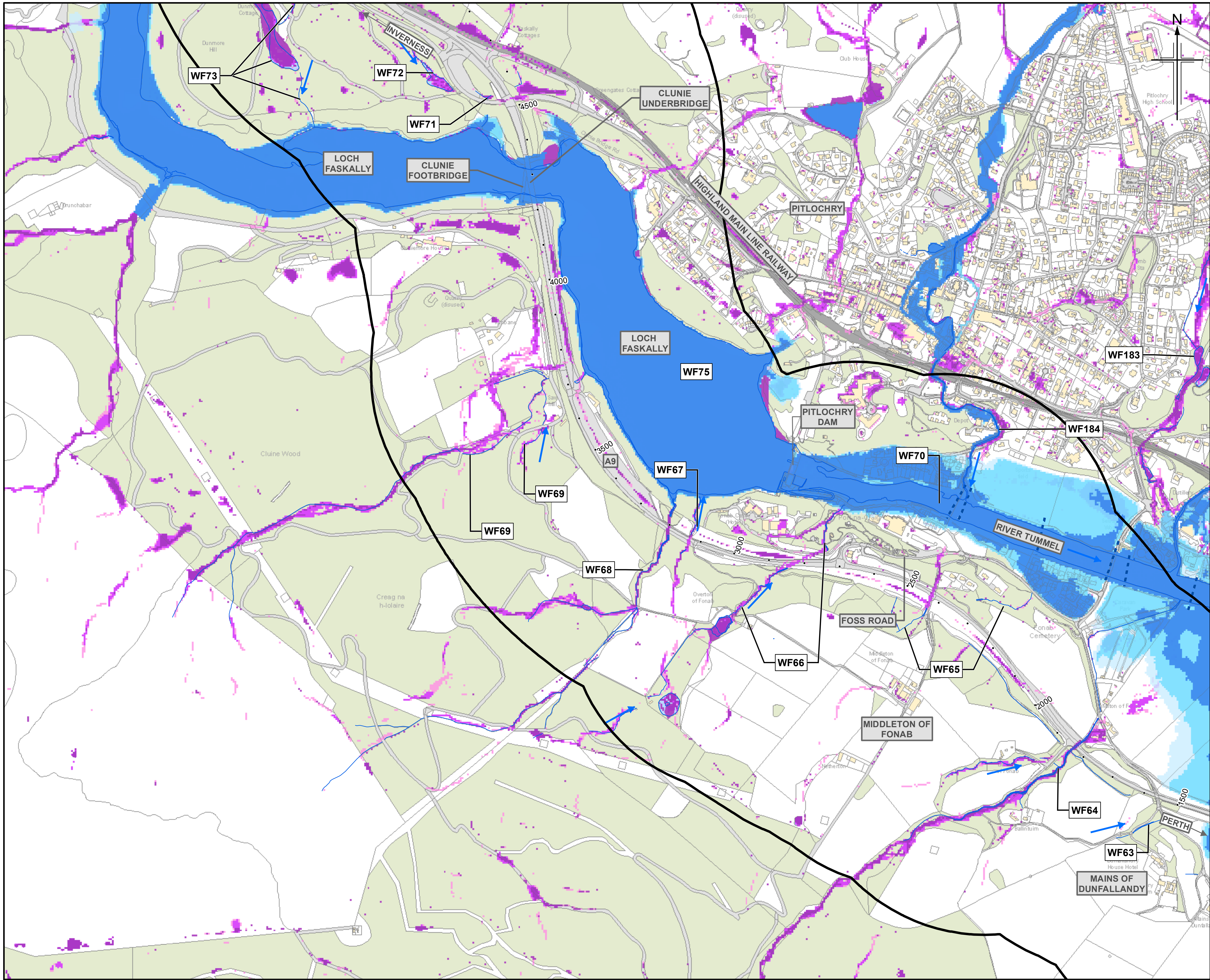

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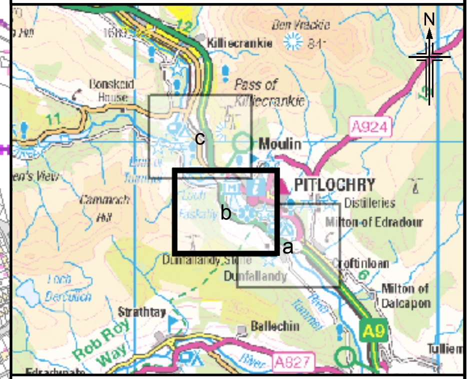

Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

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

SEPA Surface Water Flood 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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SEPA Flood Map
Baseline Scenario

Sheet 2 of 3

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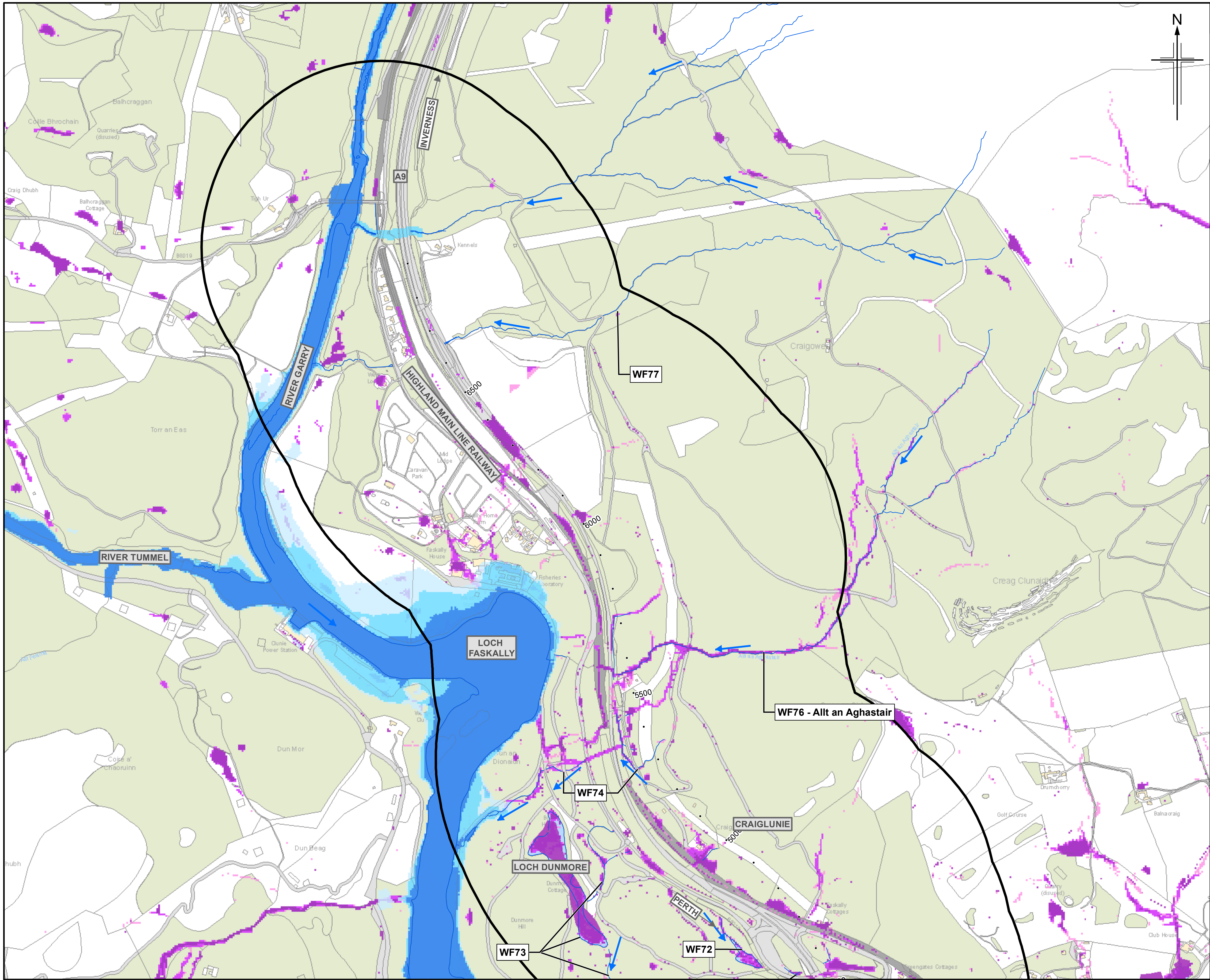

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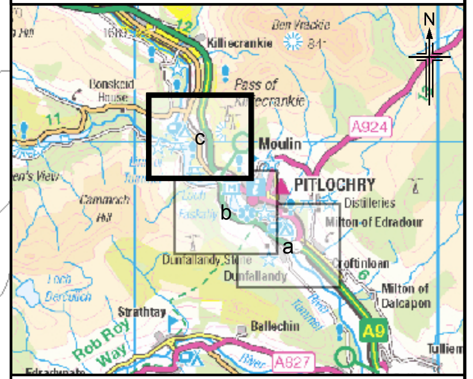

Legend

- 500m Study area
- Minor watercourses
- Water flow direction

SEPA Fluvial Flood Extent

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

SEPA Surface Water Flood 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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Pitlochry to Killiecrankie
SEPA Flood Map
Baseline Scenario

Sheet 3 of 3

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Rev	0

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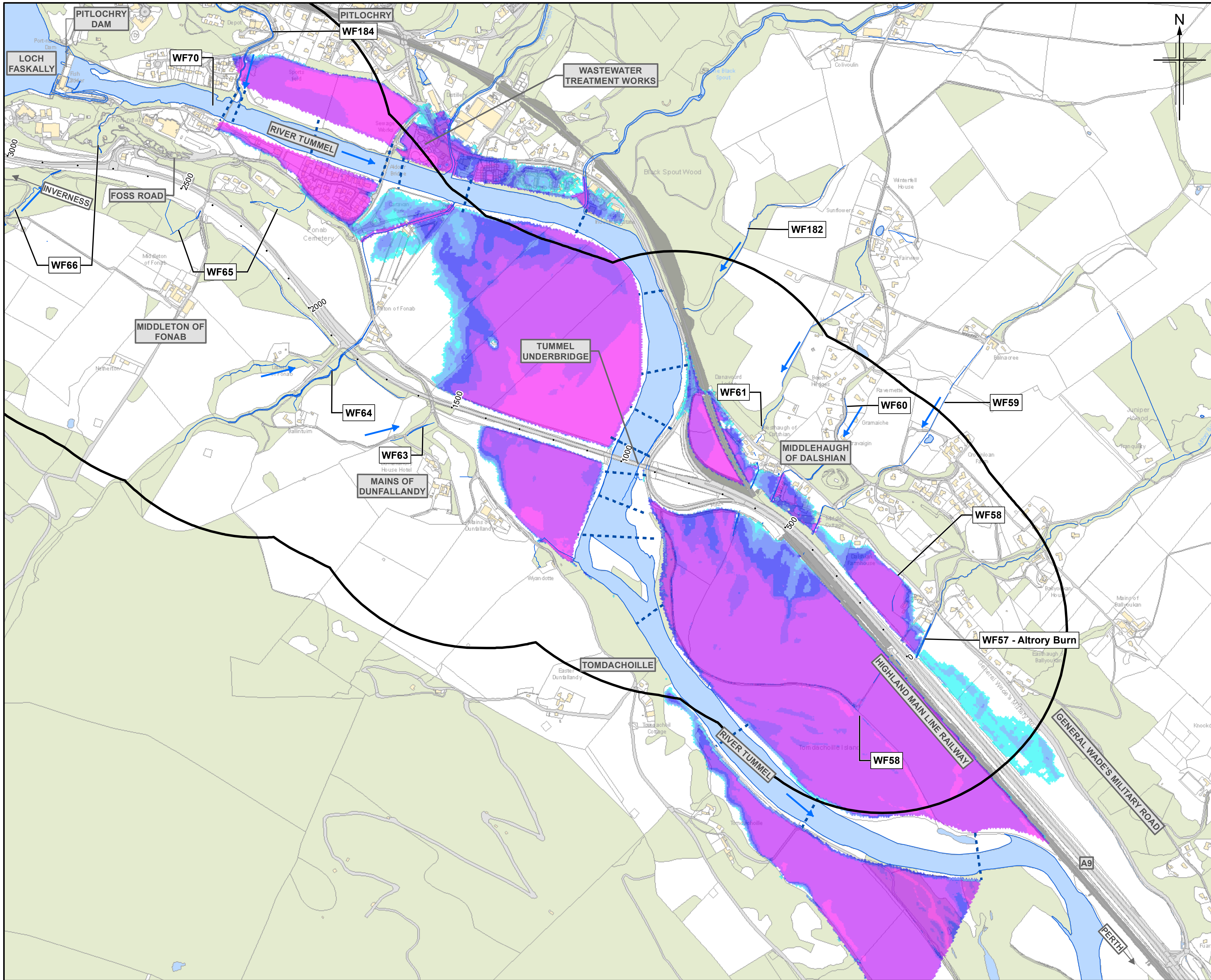
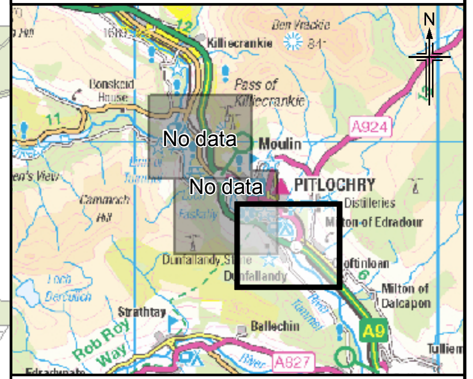
Figure A11.3.2





Legend

- 500m Study area
- Minor watercourses
- Water flow direction
- Flood model cross section

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

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

0 0.25 0.5 1 kilometres

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Pitlochry to Killiecrankie
Fluvial Flood Depth Map
Baseline Scenario
(200-year Climate Change)
Sheet 1 of 1

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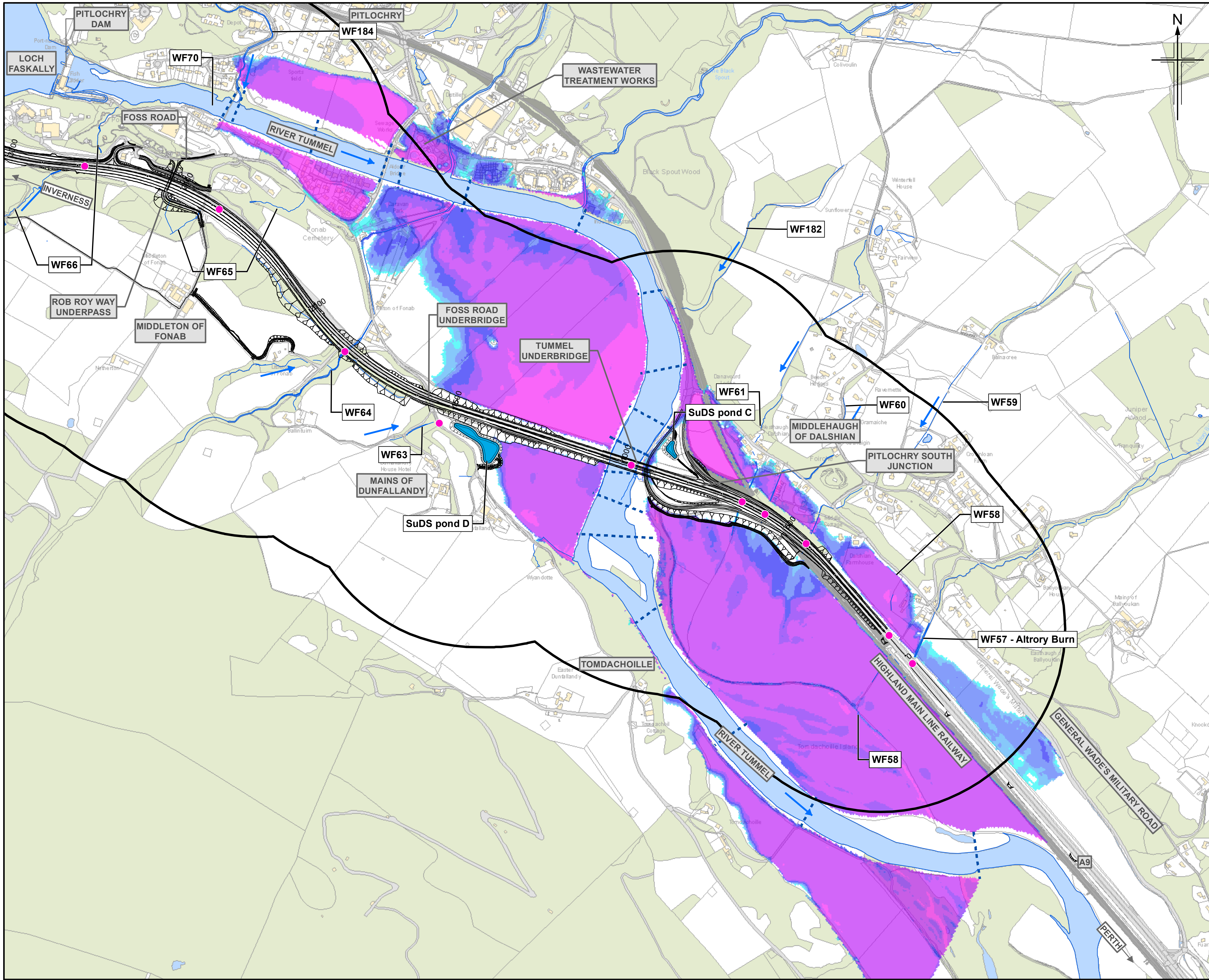

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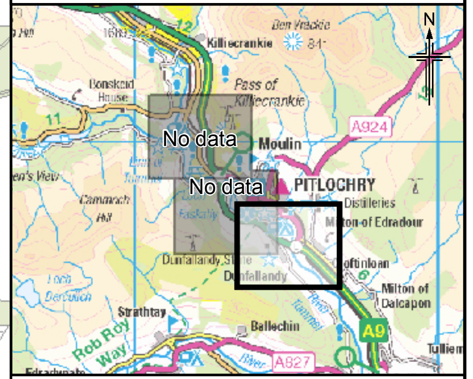

Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS Retention pond/wetland
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

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

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Note: Hydraulic modelling of the principal watercourses was only completed for the River Tummel downstream of Pitlochry Dam. Please refer to FRA for further detail.

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Pitlochry to Killiecrankie

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

Sheet 1 of 1

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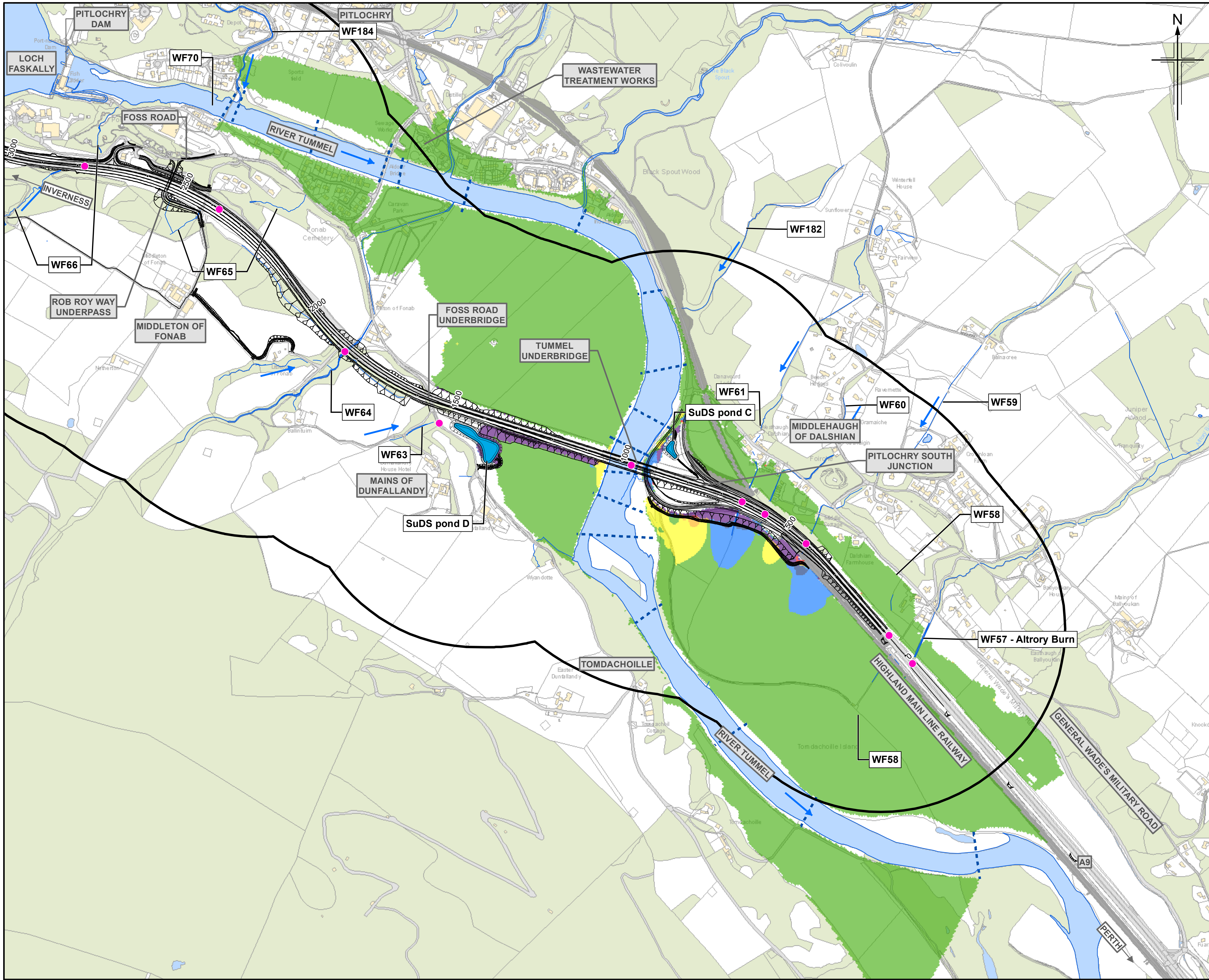

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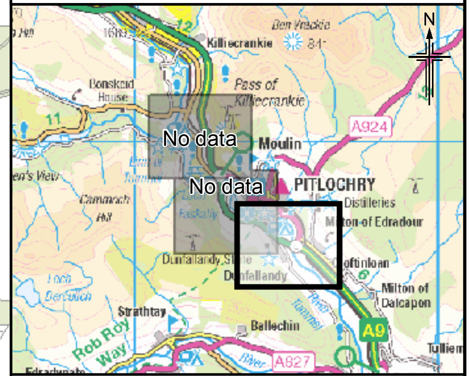

Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS Retention pond/wetland
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- 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

Note: Hydraulic modelling of the principal watercourses was only completed for the River Tummel downstream of Pitlochry Dam. Please refer to FRA for further detail.

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Drawing title
Pitlochry to Killiecrankie Fluvial Flood Depth Impact Map With Scheme (No Mitigation)

Sheet 1 of 1

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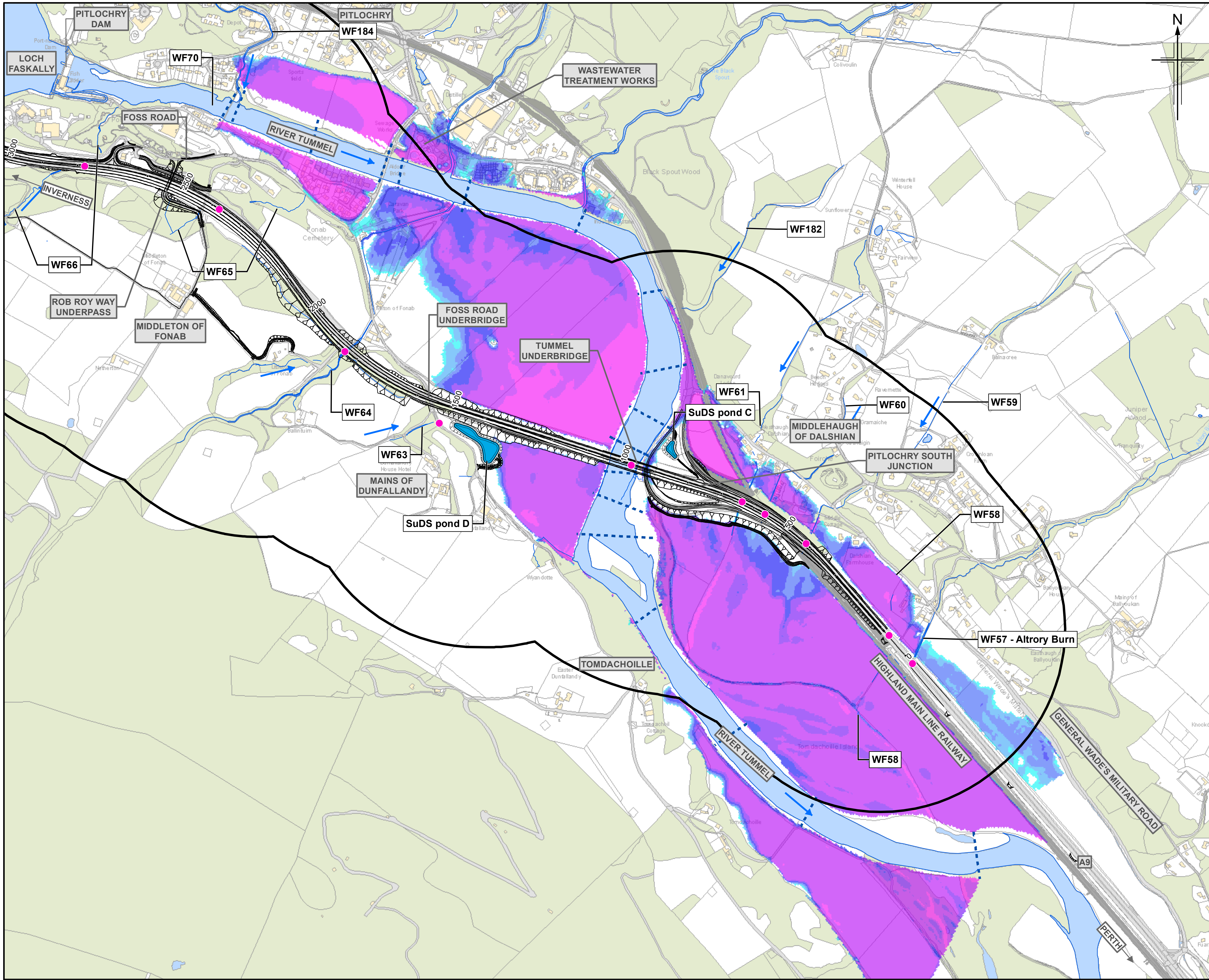
Rev	0



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0 0.25 0.5 1 kilometres

Figure A11.3.5

No data
No data

Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS Retention pond/wetland
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- Flood model cross section

Modelled flood depths during the 0.5% AEP (200-year) plus CC event in the proposed scheme (with mitigation) scenario

- <0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- 1 - 2
- >2

Note: Hydraulic modelling of the principal watercourses was only completed for the River Tummel downstream of Pitlochry Dam. Please refer to FRA for further detail.

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Pitlochry to Killiecrankie
Fluvial Flood Depth Map
With Scheme (With Mitigation)

Sheet 1 of 1

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Drawing number	Figure A11.3.5
Rev	0

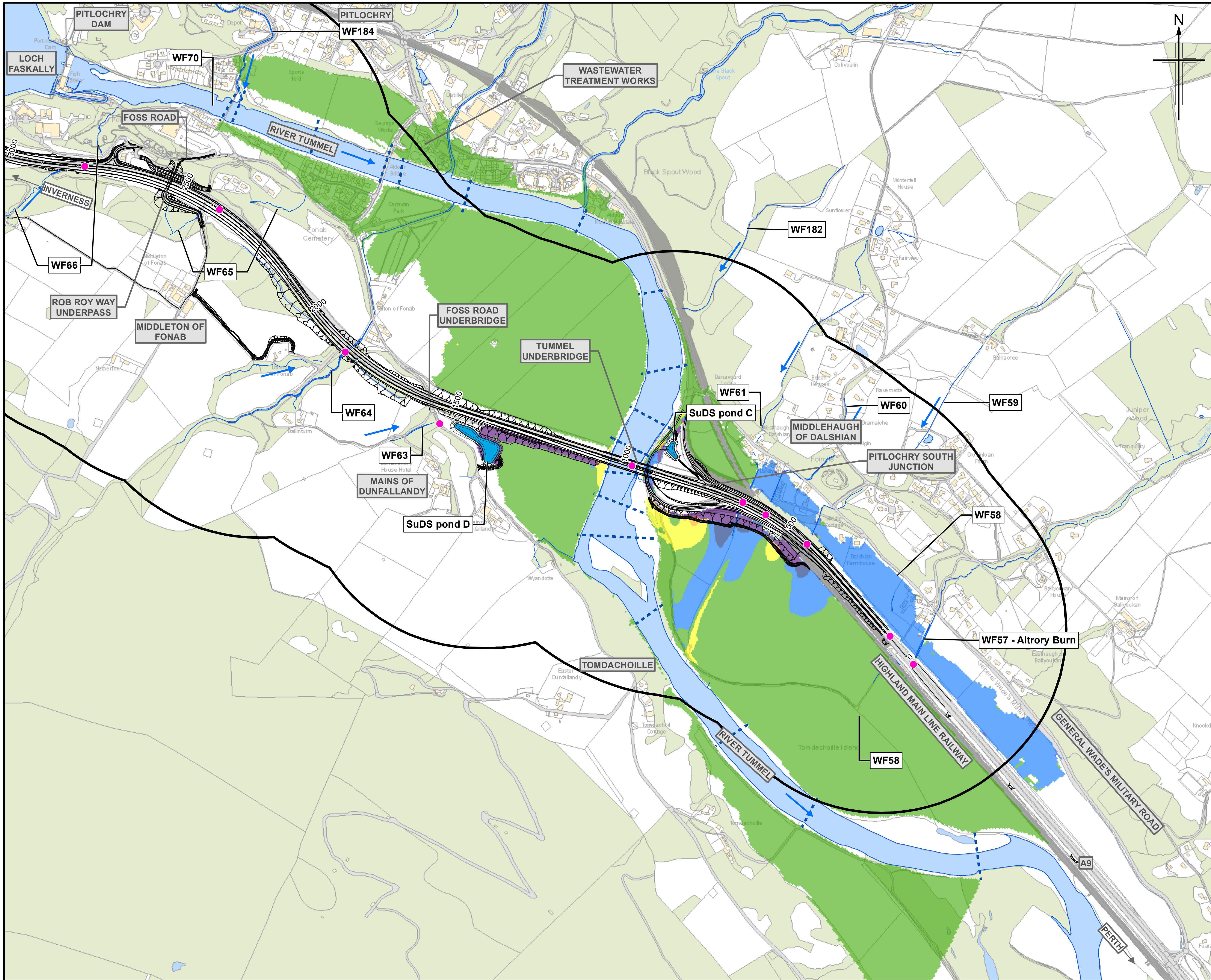

Figure A11.3.6

Legend

- Proposed scheme (DMRB Stage 3 design)
- SuDS Retention pond/wetland
- 500m Study area
- Minor watercourses
- Water flow direction
- Watercourse crossing
- 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

Note: Hydraulic modelling of the principal watercourses was only completed for the River Tummel downstream of Pitlochry Dam. Please refer to FRA for further detail.

Rev.	Rev. Date	Purpose of revision	Orig/Dwn	Checkd	Rev'd	Apprv'd
0	DEC 2017	ES Publication	HCH	ARP	ARP	IG

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TRANSPORT SCOTLAND
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Project
A9 DUALLING
PERTH TO INVERNESS
Pitlochry to Killiecrankie

Drawing title
Pitlochry to Killiecrankie
Fluvial Flood Depth Impact Map
With Scheme (With Mitigation)

Sheet 1 of 1

Drawing Status	FINAL
Scale	1:10,000 @ A3 — DO NOT SCALE
Jacobs No.	B2140004
Drawing number	Figure A11.3.6
Rev	0