APPENDIX 8.6

FLOOD RISK ASSESSMENT

TRANSPORT SCOTLAND

A82 Crianlarich Bypass

Flood Risk Assessment

July 2009

FINAL

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EXECUTIVE SUMMARY

Grontmij has been commissioned by TRANSPORT SCOTLAND to carry out a Flood Risk Assessment (FRA) for the preferred route option for the A82(T) Crianlarich Bypass. The FRA assesses the potential of the proposed road to impact on flows in the existing minor watercourses and informs the design process to ensure that the road would not be at risk of flooding or increase the flood risks to the surrounding areas.

The proposed road is approximately 1.3km long and it would cross seven small watercourses that drain into the River Fillan (part of the Tay Special Area of Conservation (SAC)) which is approximately 0.2km north east of the site. The road would cross the watercourses by way of three existing and five new culverts, and a drainage ditch would be constructed alongside the road.

The Scottish Environment Protection Agency (SEPA) requires an assessment of peak flows so that the risk of any flooding from the culverts is minimised. The peak flows generated by the 1 in 200 event, including 20% allowance for climate change, were estimated using IH 124 and ADAS methods for both the natural catchments and the proposed construction. The existing culverts would need to be able to pass peak flows of 4.09, 13.49 and 17.72m^3/s. The proposed culverts would need to pass peak flows in the range 1.08 to 6.21m^3/s.

The probability of fluvial flooding is less than 1 in 1000 years and the risks from the other sources are considered to be low. It is, therefore, considered that there would be no adverse impacts on the watercourses or surrounding areas, and that the bypass would not be at risk of flooding.

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1 INTRODUCTION

Background

This appendix supports the A82(T) Crianlarich Bypass Environmental Statement. It considers all sources of flood risk. Specifically, it is concerned with the potential of the new road to impact on the natural flow regime in the area, which could possibly result in a flood risk to the road itself and/or the surrounding area. A summary of the report and its findings is included in Chapter 8 of the Environmental Statement.

Scope of the Study

The study assesses the potential flood risks to the proposed road and the potential for the road to impact on hydraulic regime of the local watercourses. It does not consider the implications of the Water Environment (Controlled Activities) (Scotland) Regulations 2005; these are dealt with elsewhere. The study comprises the following activities: -

- Define scope
- Establish baseline conditions
- Appraise all sources of flooding
- Estimate peak flows in the watercourses
- Determine impacts

2 SETTING

Policy Framework

The proposed development is required to be considered against national planning guidelines as outlined in Scottish Planning Policy 7: Planning and Flooding, and its associated Planning Advice Note, PAN 69 and Development Plan documents. Current legislation and guidance at the national and local level were reviewed and the main points are summarised below.

2.1.1 National

The following pieces of national legislation and guidance are pertinent to the proposal.

SEPA Policy No.41

SEPA's, *Policy no. 41, A Planning Authority Protocol Development at Risk of Flooding: Advice and Consultation* outlines the statutory roles of both SEPA and the Planning Authorities, and provides a framework for consultation and advice. SEPA's remit in this respect is the statutory duty set out in the Environmental Act 1995. Section 25 (2) gives SEPA a duty, if requested by a planning authority, to provide that authority with advice, on the basis of such information as it holds, as to the risk of flooding in any part of the authority's area. However, SEPA Policy No. 41 makes it clear that in cases where SEPA becomes aware of a flood risk, even if the planning authority did not specifically request flooding comments, it will inform them of any risk of flooding.

Scottish Planning Policy 7 – Planning & Flooding

This provides the framework within which development proposals are assessed in terms of their vulnerability to, and potential to cause, flooding. It details the framework for local authority responses to planning applications in which there is a risk of flooding posed to, or by, a proposed development and how flood risk should be considered in a planning application. The general principles of the document are laid out in Paragraph 15, which states that; "developers and planning authorities must give consideration to the possibility of flooding from all sources" and that "new development should be free from significant flood risk and not materially increase the probability of flooding elsewhere". The risk framework (SPP7, p10, summarised in Box A) provides the planning response to development in the floodplain, including the appropriate level of flood protection that should be afforded to the site.

Box A: Summary of Risk Framework

- Areas of little or no risk (<0.1% probability or 1 in 1000): no constraints
- Areas of low to medium risk (>0.1% probability or 1 in 1000, <0.5% or 1 in 200): acceptable for most forms of development
- Areas of medium to high risk (>0.5% probability or 1 in 200): acceptable for brownfield development provided adequate flood defences are available, unacceptable for development of previously undeveloped areas

The drainage and culverts paragraphs 21 to 25, particularly 24 and 25 which are outlined below, are pertinent to this development.

Box B: SPP7 Policy on Culverts

24. Culverts are a frequent cause of local flooding, particularly if the design or maintenance is inadequate. Watercourses should not be culverted as part of a new development unless there is no practical alternative. If they are unavoidable they must be designed to maintain or improve existing flow conditions and aquatic life. Issues of ownership and long-term maintenance must be addressed.

25. Existing culverts should be opened whenever appropriate. If a new development involves drainage by an existing culvert, the applicant should demonstrate that the overall drainage provision will not add to flood risk on site and off site. A culvert may be acceptable as part of a flood prevention scheme or where it is used to carry a watercourse under a road, railway etc. All culverts should be designed with full regard to natural habitat and environmental concerns.

Planning Advice Note 69: Planning and Building Standards Advice on Flooding was produced to support SPP7 and it provides good practice.

Town & Country Planning (Scotland) Act 1997

Section 25 of the Town and Country Planning (Scotland) Act 1997 requires that all applications must be determined in accordance with the Development Plans, unless material considerations indicate otherwise. The Development Plan for this area encompasses Clackmannanshire and Stirling Structure Plan, the Loch Lomond and Trossachs National Park Plan and Stirling Council Local Plan.

2.1.2 Regional

The regional element of the Development Plan which covers the proposed site is Clackmannanshire and Stirling Structure Plan 2002 - 2017. This document sets out strategic planning policy on flooding and the following policy is particularly relevant.

Box C: Structure Plan Policy on Flooding

Policy ENV9:
Water Resources Management.

1 As a general principle the Councils will seek to secure the retention of remaining undeveloped flood plains, in the interests of floodwater retention, biodiversity, and amenity and in these areas development will not normally be permitted.
2 Development proposals in areas of known significant flood risk will not be permitted unless it can be demonstrated that no suitable alternative location exists, and if a flood risk assessment (prepared in consultation with SEPA) indicates that the risk can be satisfactorily mitigated by works which will not lead to increased flood risk elsewhere, or unacceptable habitat loss.
3 Ecological approaches to surface water management (Sustainable Urban Drainage) will be sought in association with new development.
4 Flood protection and run-off attenuation works in association with development will be permitted only if long-term maintenance and management arrangements are in place.
5 The Councils will not support development that may adversely affect the ecological, landscape and flooding characteristics of the Forth Estuary unless it can be clearly demonstrated that the overall integrity of the area will not be damaged or that appropriate mitigation measures can be implemented

In the Environmental Report, as part of the third alteration of the Structure Plan (Mabbett & Associates, 2007), flooding is mentioned under climatic issues. Stirling Council is aware that the potential for flooding is greatest alongside the rivers

Forth, Devon, Black Devon, Teith and Allan Water. They have commissioned flood risk studies of the River Teith at Callander and the River Forth through Stirling. There are no strategic flood risk assessments for the proposed area but the Council are aware that undeveloped rural land, such as the Fillan-Dochart Valleys, experiences regular fluvial flooding.

The Loch Lomond and Trossachs National Park Plan sets out the following policy on water management, including flooding. The Strategic Environmental Assessment of the Plan makes reference to SPP7 as a framework document.

Box D: Park Plan Policy on the Water Environment and Flooding

Policy WM1 - Safeguarding and Enhancing the Water Environment

A strategic approach to safeguarding and enhancing the Park's water environment will be delivered through a coordinated catchment-based approach to management, led by SEPA and delivered by a range of partners. This will include:

a. Ensuring that the River Basin Management Plan and the local Area Management Plans are developed and implemented in a way that is appropriate to the Park's status and the conservation and enhancement of the special qualities.
b. Ensuring that all decision-making considers the River Basin Management Plan where resultant actions are likely to have a significant impact on the water environment.
c. Ensuring that land-use activities and recreational activities on water do not have adverse effects on water quality and safeguard drinking water supplies.
d. Ensuring that all plans and strategies likely to affect the water environment include consideration of the potential impacts on the water environment and take account of the River Basin Management Plan and Area Management Plans.
e. Taking a holistic, catchment-based approach to flood management that favours sustainable solutions and includes planning for the effects of climate change.

The Authority is currently reviewing responses to its Consultative Draft Local Development Plan (November, 2008) as part of its statutory planning function. This sets out a more detailed range of policy statements aimed at further minimising any negative impacts on the water environment, incorporating regulations set out by SEPA under the Water Environment (Controlled Activities) (Scotland) Regulations 2005 and maintaining regulations under the Water Environment and Water Services (Scotland) Act 2003.

2.1.3 Local

With regard to the local element of the Development Plan, the relevant document is the Stirling Council Local Plan 1999 which contains the following relevant policies.

Box E: Local Plan Policy on Flooding

Policy E61

A flood risk assessment prepared in consultation with SEPA will require to be submitted in support of development proposals where:
(a) There is firm evidence of past flooding; or
(b) The proposal is located on a river bank (or on adjacent land at the same level unprotected by intervening higher ground). Where the Council is satisfied, on the basis of this assessment, that there is a likelihood of flooding on the development site, or on neighbouring land or downstream as a consequence of the development, planning consent may be refused, or granted subject to conditions requiring prevention and amelioration works to be carried out, and arrangements made to secure their continuing long-term maintenance

Reliable data on the incidence and level of flooding is not readily available, which makes it difficult to predict whether future development areas will be subject to flooding. This issue will be covered in the next review of the Local Plan (Stirling Council, 1999).

Within the specific Town and Village Plan relating to Crianlarich, Stirling Council (1999) is aware of the proposed A82 bypass and an indicative line is shown in the local plan. There is no mention of flooding concerns. It does, however, state the construction of the western bypass would have a considerable environmental impact on the village, which should be minimised through careful landscape design.

Consultations

Consultations were held with SEPA and Stirling Council on the scope of the flood risk assessment and to obtain any supporting information on the affected watercourses.

2.1.4 Scottish Environment Protection Agency

SEPA (Malcolm MacConnachie, February 2008) confirmed that the proposed road is not in the floodplain of the River Fillan and any flood risk is likely to result from the culverted watercourses. No strategic flood risk assessment is available. There is no flow gauging data for the watercourses; they are too small. SEPA require an assessment of peak flows in the watercourses using Flood Estimation Handbook (FEH) rainfall runoff methods, as appropriate for small catchments.

2.1.5 Stirling Council

The Council (Ian Young, February 2008) stated that there are no records or reports of any flooding in the last four years. There has been new development near Station Burn, which restricts access to the channel but no complaints or flooding have been recorded. In February 2003, the burn by the station was dredged to reduce the risk of flooding to the community hall.

Approach to the Assessment

The proposed road lies outside the 1 in 200 year floodplain, as shown in SEPA's indicative flood risk map (2009). The annual probability of flooding is less than 0.1% (1 in 1000 years). Therefore, the appropriate planning response (SPP7) is that there are no constraints due to watercourse, tidal or coastal flooding.

The proposed bypass could be at risk of flooding or result in flooding of the surrounding areas, if the drainage is not properly considered. Any flood risk is likely to arise from the culverted watercourses. The potential sources that could contribute to a flood risk are fluvial (increased flow in small catchments – climate change), pluvial (overland flow and surface runoff from the road) and groundwater (through flow).

One objective of this study is to estimate peak flows in the watercourses. To this end, the following were considered:

- available information on historic flooding in the area;

- level information;
- the effects of climate change; and
- the potential impact of the proposed bypass.

3 EXISTING SITE

Site Description

The route of the proposed bypass is to the west of the village and the existing trunk roads (see Figures 1.1 and 3.1a and b of the Environmental Statement). The slope of the hillside along the route is typically 1 in 11, but the upper slopes are much steeper. Steep sided mounds up to 10m in height are located along the route, with intervening hollows and basins, and several large surface channels. The southern area is more noticeably hummocky, with many large mounds separated by flatter hollows. The northern area generally comprises more evenly sloping ground. To the west, there is a coniferous plantation on the higher sloping ground and to the east there are several houses on lower ground that would back onto the proposed road. Photographs of the current site are shown in Figures 3.1 to 3.4.

Ground levels along the proposed route range from 165 to 197m AOD, which is a maximum of some 20m above the existing A82. There is a 28m drop at its closest point to the River Fillan (part of the Tay Special Area of Conservation (SAC)), which is some 0.2km north east of the bypass. There are eight small watercourses which drain in a north easterly direction into the River Fillan. The most northerly of these watercourses drains to an existing culvert on the A85 at the northern end of the bypass. Furthermore an ephemeral stream drains to an existing culvert on the A82, at the southern end of the bypass (see Figure 8.1 of the Environmental Statement).

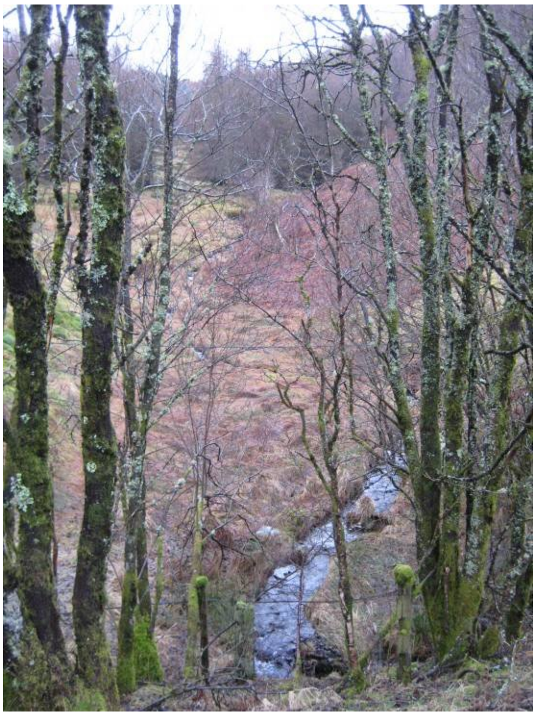

Figure 3.1: Most northerly stream which crosses the proposed bypass (looking upstream) (chainage 1235m)

Figure 3.2: View across proposed bypass route (looking north west)

Figure 3.3: Small stream (second most southerly) above proposed route (looking upstream, west-northwest) (chainage 250m)

Figure 3.4: Ephemeral stream which enter the southern culvert under A82 to Glasgow (looking upstream). (chainage 23m)

Drainage

The natural drainage is in a north easterly direction towards the River Fillan. The small watercourses which intersect the existing A82 and A85 are culverted underneath the roads. Downstream, there are further culverts underneath the railway and the more southerly watercourses are culverted under Crianlarich itself. Two of the northern watercourses flow into spreads, before entering the River Fillan. The existing culverts to the north and south of the proposed route are shown in Figures 3.5 and 3.6 respectively.

Figure 3.5: Current culvert under A82 to Fort William (looking downstream, north east) (chainage 1235m)

Figure 3.6: Current culvert under A82 to Glasgow (looking upstream, north west) (chainage 23m)

Historical Flooding

Stirling Council has no records of flooding or any complaints for the Crianlarich area. Similarly, a search on the British Hydrological Society website found no records of flooding. The British Geological Society identifies the proposed site as having no groundwater flood potential.

SEPA's indicative flood map shows that the proposed bypass is outside the 1 in 200 area at risk (see Figure 3.7).

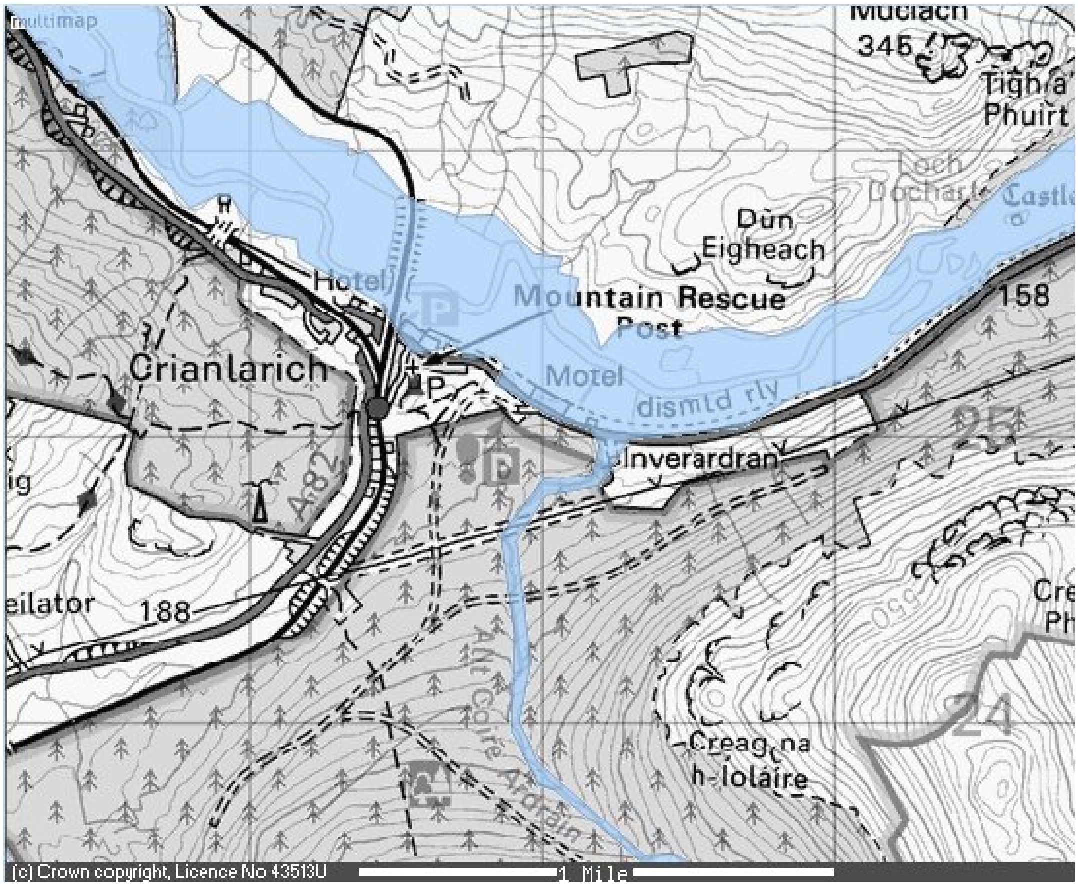

Figure 3.7: Indicative flood risk map of Crianlarich (source SEPA (2009)). *An estimate of the areas with a 0.5% (1:200) or greater probability of being flooded in any given year are shown in blue.*

Possible Flooding Mechanisms

The assessment of the possible flooding mechanisms is based on SPP7, SEPA's Technical Flood Risk Guidance along with CIRIA's C624 guidance, in conjunction with a water feature survey, which was undertaken by Grontmij in April 2008 (see Appendix 8.1).

Fluvial

There are eight watercourses which would cross the proposed bypass. None are identified by SEPA as presenting a flood risk. The floodplain of the River Fillan is approximately 170m to the east and 15m downhill of the proposed bypass. Therefore, there is no significant risk of fluvial flooding to the proposed bypass.

Tidal/Coastal

CIRIA guidance states that if a site is located above 10m AOD, it may be regarded as free from risk of flooding from the sea. The proposed site is approximately 160m above sea level and some 53km from the nearest shoreline and so it is considered that there is no risk of coastal/tidal flooding.

Groundwater

The Hydrogeology Map of Scotland (1988) shows the area is underlain by impermeable rocks (schistose semipelite and psammite), generally without groundwater, except at shallow depth. They offer little potential for water storage or transport. The superficial deposits of glacial till and river terrace deposits are likely to be in hydraulic continuity with the River Fillan and will provide transport and limited storage of groundwater. The water feature survey identified saturated ground at the northern and southern ends of the proposed route (see Appendix 8.1). It is likely that this is due to a period of intense rainfall prior to the survey. There is no documented evidence of groundwater flooding in the area and it is not considered to be a significant risk.

Overland Flow

The proposed site is located towards the bottom of a steep hillside and there is the potential for flooding from overland flow and/or ponding. However a drainage ditch would be incorporated along the western edge of the bypass which would intercept such flows and transfer them through appropriately sized culverts to the watercourses.

The existing trunk roads are 70 to 180m downhill of the proposed bypass and do not pose a risk.

Artificial Drainage Systems

There are no sewerage systems in the vicinity but there are artificial drainage channels uphill of the bypass. These comprise small established man made drains cut into the peat. The largest one was assessed as a separate drain (see Section 5). The smaller drainage channels were assessed as part of the watercourses they drain into.

These small drainage features do not pose a significant flood risk for the reasons given in respect of overland flows.

Infrastructure Failure

The watercourses that would cross the proposed road are culverted beneath the existing trunk roads. There are no records of flooding or blockages of the culverts.

The above findings are summarised in Table 3.1.

Table 3.1: Summary of Possible Flooding Mechanisms

Source/Pathway	Significant?	Comment/Reason
Fluvial	No	No record of fluvial flooding associated with the small watercourses.
Tidal/coastal	No	Not applicable: too far inland and site is above 10m AOD (CIRIA C624).
Groundwater	No	No past or potential record of groundwater flooding in the area.
Overland Flow	No	No documented evidence of flooding and catchment areas are too small to pose a significant risk.
Artificial drainage systems	No	No sewers in the vicinity of the proposed site and there are no records of flooding from small drainage features.
Infrastructure failure	No	No record of culvert blockages downstream of the proposed bypass

Taking the above into account, it is concluded that there are no significant risks of flooding to the proposed bypass.

4 DRAINAGE PROPOSALS

The scheme would utilise the two existing culverts at the northern boundary and one at the southern boundary of the proposed bypass (see Figures 3.5 and 3.6 respectively). There would be five new culverts, details of which are shown in Table 4.1.

Table 4.1: Culvert Details.

Culvert Location	Chainage (m)	Comments
1	23	Existing culvert
2	388	Proposed culvert – - 1200mm square internal dimensions box culvert with otter ledge
3	527	Proposed culvert – - 1200mm square internal dimensions box culvert with otter ledge
4	730	Proposed culvert - 1200mm square internal dimensions box culvert with otter ledge
5	915	Proposed culvert - 1200mm square internal dimensions box culvert with otter ledge
6	1105	Proposed culvert - 1200mm square internal dimensions box culvert with otter ledge
7	1060	Existing culvert
8	1235	Existing culvert

A drainage ditch would run along the western edge of the proposed road to intercept surface runoff (see Figures 3.1a and b of the Environmental Statement). The ditch would be profiled to direct flows to the culverts and into the natural watercourses. The proposed dimensions of the ditch are 0.5m deep and no greater than 1.5m base width, based on a trapezoidal shape. The dimensions and alignment of the ditch will be confirmed at the detailed design stage.

The slope of the carriageway is designed to allow runoff from the road to enter three pipe networks (A, B and C). Each network would flow into a separate detention area (two basins and a filter trench), which would limit flows to the greenfield rate. At present, both detention basins would have a minimum depth of 1.2m. The side slopes would be 1 in 4 (25%) and 1 in 3 (33.3%) for the southern and northern basins respectively. This complies with the SUDS manual guidance (CIRIA C697).

Environmental (noise) mitigation bunds are proposed on the eastern side of the bypass at chainage 200 to 450m, just north of the southern roundabout, and chainage 700 to 1050m (see Figures 3.1a and b of the Environmental Statement). A herring-bone arrangement of land drains would be provided for these.

The total footprint of the bypass is approximately 63,200m^2 excluding the drainage ditch. The road itself is 23,400m^2 in area and the surface runoff generated from this would flow into the detention basins and the filter trench via the drainage networks. Table 4.2 summaries the road features and their drainage paths. All of the runoff from the bypass would enter the watercourses.

Table 4.2: Summary of Proposed Road Features and Drainage Routes.

Areas to be drained	Approximate Area (m^2)	Drainage Route
Network A		
Proposed Road Area[1]	8454	Network A drainage to detention basin
Embankments	24	Network A drainage to detention basin
	329	Herring-bone drainage
Cuttings	1023	Network A drainage to detention basin
Environmental Bunds	961	Network A drainage to detention basin
	969	Drainage ditch
	4492	Herring-bone drains
Network B		
Proposed Road Area	9362	Network B drainage to detention basin
Embankments	138	Network B drainage to detention basin
	98	Drainage ditch
	1730	Herring-bone drainage
Cuttings	16233	Network B drainage to detention basin
Environmental Bunds	1567	Network B drainage to detention basin
	7222	Herring-bone drains
Network C		
Proposed Road Area	5565	Network C drainage to filter trench
Embankments	268	Drainage ditch
	180	Herring-bone drainage
Cuttings	4584	Network C drainage to filter trench
TOTAL (excluding drainage ditch)	63198	

To ensure that any groundwater flow, predominately after heavy rainfall, is intercepted and drained, herring-bone drainage would be incorporated into the design of the cuttings. Any additional water from subsurface soil flow would enter the drainage network of the road. The groundwater flow out from the cuttings from the superficial deposits range from 0.0002 to 0.001l/s. The calculations are detailed in Appendix 8.2 of the Environmental Statement. For the purposes of flood risk, the groundwater input is not considered to be significant.

[1] The proposed road area includes verges, roundabouts and pavement (road area).

5 HYDROLOGY

This section outlines the catchment characteristics, provides estimates of the peak flows through the culverts and identifies any impacts of the proposed bypass on the surrounding areas.

Catchment Characteristics

There are eight small watercourses, including one ephemeral, as shown in Figure 5.1. The catchments vary in size from 1 to 28ha. Their sources are, at most, some 980m south east of the site and they all drain into the River Fillan. The majority of the catchments are natural but Catchment 3 and parts of Catchment 2 have artificial drainage channels. The ephemeral watercourse is within an artificial channel, which flows to the existing southern culvert. It was assessed as a natural catchment (Catchment 1).

The catchments drain steeply sloping coniferous plantations and moorland. Beyond the bypass, Catchment 3 drains into spreads before it emerges in a channel beyond the existing road and railway. Upstream of their confluence with the River Fillan, the watercourses in catchments 5 and 6 flow into spreads and collects.

The proposed scheme would disrupt the natural surface drainage of the hillside. As discussed, the proposed bypass would require culverts and the surface runoff from the road would discharge into the watercourses via the detention areas. The runoff from the hillside would enter a ditch before flowing through the culverts (see Figure 5.2).

Catchment parameters were obtained from the FEH CD ROM Version 2. The FEH software recognised one catchment in the study area (see Appendix A). The mean altitude is 229m and the catchment steepness is 112m/km. The standard annual average rainfall (SAAR) is 2471mm. These parameters are shown in Appendix A. Individual catchment descriptors could not be obtained from FEH because it only recognises areas greater than $0.5km^2$. The FEH catchment parameters were used to estimate peak flows.

Estimation of Surface Flows

The total footprint of the scheme is approximately 6ha ($0.06km^2$) and the total area drained uphill of it is approximately 83ha ($0.83km^2$). The whole site is considered to be greenfield[2]. The SEPA[3] technical guidance recommends a range of FEH methods to estimate peak flows of varying return period. However, the catchments are too small ($< 0.5km^2$) for these approaches and, as such, two more appropriate methodologies were applied. For the small catchments described above CIRIA guidance documents recommend the use of IH 124 - Flood Estimation for Small Catchments. The Design Manual for Roads and Bridges (DMRB)[4] recommends the use of IH 124 for catchments less than $0.5km^2$. It also recommends the use of

[2] A Greenfield site is an undeveloped and undisturbed site.
[3] SEPA Technical Flood Risk Guidance For Stakeholders – Version 3
[4] DMRB Volume 11. Section 3. Part 10 – Road Drainage and the Water Environment – HA216/06.

the ADAS method[5] for very small catchments up to 0.4km^2. For comparative purposes, peak flows were calculated using both methodologies.

Figure 5.1 shows the existing flow routes and natural catchment boundaries and Figure 5.2 shows the drainage areas and the proposed surface water flow routes. The areas of the west facing embankments that drain into the ditch are negligible and subject to change therefore they are not included in the drainage areas. The drainage ditch will be profiled as illustrated on Figure 5.2 (green arrows). The catchment areas are outlined in Table 5.1

Table 5.1: Summary of Natural Catchments and Drainage Areas

Natural Catchment Area	Area ha	Drainage Area	Area ha	Culvert	Comments
1	8.07	1	8.32	1 (existing)	No change in catchment boundaries except for additional hillside runoff into ditch. The catchment relates to the ephemeral stream.
2	12.76	2	13.31	2 (proposed)	No change in catchment boundaries except for additional hillside runoff into ditch
3	10.77	3	10.49	3 (proposed)	No change in catchment boundaries except for additional hillside runoff into ditch
4	4.13	4	4.24	4 (proposed)	No change in catchment boundaries except for additional hillside runoff into ditch
5	1.16	5	1.40	5 (proposed)	No change in catchment boundaries except for additional hillside runoff into ditch
6	7.34	6	8.42	6 (proposed)	No change in catchment boundaries except for additional hillside runoff into ditch
7	8.61	7	19.7	7 (existing)	Catchment 7 is the natural catchment to culvert 7 (catchment to culvert 6 + additional area to culvert 7 (0.0127km^2)). Drainage Area 7 is the proposed drainage to culvert 7 which includes drainage area 6 (0.0842km^2) the road area and the embankments associated with network B (0.0286km^2)
8	28.07	8 and 8a	29.13	8 (existing)	Small change in catchment boundaries to include additional hillside runoff into ditch (0.2823km^2). Drainage to existing culvert incorporates drainage area 8, the road area of Network C and its cuttings (drainage area 8a – 0.009km^2) via a filter trench
TOTAL	**80.92**		**95.01**		

The IH 124 method uses the equation outlined in Box F to calculate the mean annual flood ($QBAR_{RURAL}$). QBAR can be scaled according to the FSR regional growth curves (Appendix B) to derive flows for different return periods. This equation was applied to all the areas outlined in Table 5.1

[5] DMRB Volume 4. Section 2. Part 1 –Drainage of Runoff from Natural Catchments – HA106/04.

Box F: IH 124 Equation

$$QBAR_{RURAL} = 0.00108 \cdot AREA^{0.89} SAAR^{1.17} SOIL^{2.17}$$

$QBAR_{RURAL}$ = mean annual flood for small rural catchments (m^3/s)
AREA = catchment area (km^2)
SAAR = standard average annual rainfall in mm for the period 1941 to 1970
SOIL = soil index (obtained from Flood Studies Report)

The ADAS method uses the equation outlined in Box G. This method takes into account the design storm rainfall and time of concentration for the required return period. The mean annual flow can be scaled as per IH 124 method.

Box G: ADAS Equation

$$Q = AREA(0.0443SAAR - 11.19)SOIL^{2.0} * \left[\frac{18.79T^{0.28} - 1}{10T}\right]$$

T is given by:

$$T = 0.1677\frac{W^{0.78}}{Z^{0.39}}$$

where:
Q = mean annual flow
AREA = catchment plan area in (km^2)
SAAR = standard average annual rainfall (mm)
SOIL = soil index (0.5 – very high runoff)
T = time of concentration (hours)

W = catchment width (m)
Z = average height of catchment divide (m)

The 1 in 200 year peak flows, taking into account climate change, were calculated and the results are shown in Table 5.2. Appendix B includes the calculations for the various return periods.

The limitations of the methodologies include the following:

- IH 124 method bases QBAR on a 0.5km^2 area. The methodology is recommended for catchments greater than 0.5km^2. For the purposes of this study, the mean annual flow was scaled according to the catchment/drainage area;
- the design flows result from surface runoff and take into account saturation of the soil;
- as the catchment area decreases, general methods and equations may become less applicable to a particular catchment;
- uncertainties surround the catchment boundaries;
- it is assumed that the soils are homogenous and based on a region wide soil ratio. Locally, there will be a variation in hydrological response from the different soil types;
- the FEH characteristics are based on a catchment of 0.93km^2, which is 18% greater than the whole drainage area to the proposed bypass;
- the estimate of flow using the IH 124 method for the additional drainage areas to the culverts is likely to be conservative because the method was developed to estimate peak flows in small catchments with *preformed*

channels. Natural catchments 1, 2, and 4 have only a small amount of preformed channel;
- the ADAS methodology was primarily developed to size field drainage pipes in entirely clay type catchments, atypical of the catchments in this study; and
- It assumed as a worst case scenario, under a storm event, that the runoff from the road (network B and the corresponding cuttings and embankment areas) would drain directly to culvert 7. In reality, the runoff from the proposed bypass would enter a detention basin and the flows into the watercourse would be limited to greenfield runoff.

Table 5.2: Estimation of Peak Flows for Natural Catchments and Drainage Areas

Method		IH 124	ADAS	IH 124	ADAS	IH 124	ADAS
		Q m^3/s		Q200 m^3/s		Q200 m^3/s (with climate change)	
Natural Catchment	1	0.22	1.09	0.66	3.26	0.79	3.91
	2	0.35	1.67	1.04	4.98	1.25	5.98
	3	0.30	1.60	0.88	4.78	1.06	5.73
	4	0.11	0.61	0.34	1.81	0.41	2.18
	5	0.03	0.26	0.09	0.77	0.11	0.93
	6	0.20	1.08	0.60	3.22	0.72	3.86
	7	0.24	1.23	0.70	3.65	0.84	4.39
	8	0.77	3.73	2.29	11.13	2.75	13.36
Proposed drainage area	1	0.23	1.14	0.68	3.40	0.82	4.09
	2	0.36	1.74	1.09	5.18	1.30	6.21
	3	0.29	1.47	0.86	4.39	1.03	5.27
	4	0.12	0.62	0.35	1.85	0.42	2.22
	5	0.04	0.30	0.11	0.90	0.14	1.08
	6	0.23	1.26	0.69	3.77	0.82	4.52
	7	0.54	3.77	1.61	11.24	1.93	13.49
	8	0.80	3.84	2.38	11.44	2.85	13.72

Due to the increase in the areas drained as a result of the proposed bypass, there would be an increase in peak flows. The ADAS method estimates a higher greenfield runoff; on average it is 4.5 times greater than that from IH 124.

Use of the ADAS method will lead to conservative estimates of peak flows. In addition, the ADAS approach is more suitable for the size of catchments/drainage areas affected by this project.

Impact of the Scheme to Surrounding Areas

Table 5.3 outlines the impact of the scheme on flows for a 1 in 200 year event with climate change. There would be a small increase (<5%) in flows for the watercourses in catchments 1, 2, 4 and 8. For catchment 3 there would be a small decrease in flows of 8%. The catchments of 5 and 6 would experience an increase in flows of approximately 14%. ,The greatest increase in flows of 68% would be in Catchment 7. This is due to the increased drainage area, resulting in an increase in the Q200 flow of 9.1m^3/s for culvert 7.

The existing culvert to the east of the northern roundabout (culvert 7 in Figures 8.1 of the Environmental Statement) would require sufficient capacity to convey peak flows from drainage area 6 and the flows from the Network B detention basin. An area of 2.86ha would drain from the proposed bypass (road, embankments and cuttings) into the detention basin, which would discharge at the greenfield runoff rate to culvert 7. This is similar for the existing culvert in the north (culvert 8) where it also require's sufficient capacity to convey peak flows associated with the upstream drainage cathcment (28.23ha) and the road drainage associated with Network C (0.9ha).The flows to culvert 7 and 8 were estimated without taking into account the detention basin and filter trench, to provide a worst case scenario.

Table 5.3: Impact on flows with the new drainage areas

Catchment Area	Area (km^2)	Q200 (+20%) (m^3/s)	Drainage Area	Area (km^2)	Q200 (+20%) (m^3/s)	Difference in flows (m^3/s)	% change
1	0.0807	3.91	1	0.0832	4.09	0.18	4.38
2	0.1276	5.98	2	0.1331	6.21	0.23	3.69
3	0.1077	5.73	3	0.1049	5.27	-0.47	-8.85
4	0.0413	2.18	4	0.0424	2.22	0.05	2.20
5	0.0116	0.93	5	0.0140	1.08	0.15	13.82
6	0.0734	3.86	6	0.0842	4.52	0.66	14.54
7	0.0861	4.39	7	0.1969	13.49	9.11	67.50
8	0.2807	13.36	8	0.2913	13.72	0.37	2.76

The peat slide hazard is unlikely within the drainage areas (see Appendix 7.3 of the Environmental Statement) therefore the potential for culvert blockage due to peat is negligible. The long term maintenance of the culverts will be assigned to remove any blockages, such as plant debris, if they should occur to ensure the water is free flowing at all times.

The risk of saturation (and overtopping) of the drainage ditch is negligible due to its topographical profile which will convey flows away from the ditch towards the culverts. The flow rates from the superficial deposits have been estimated at between 0.0002l/s and 0.001l/s (Appendix 8.2 of the Environmental Statement) which will not exceed the transfer capacity of the ditch and culverts provided the long term maintenance of the ditch and culverts ensures that water is free flowing at all times.

6 CONCLUSIONS

This study considers the flood risk to and from the proposed bypass. A principal element of this is the potential impact of the road on the flow regime in a number of the existing watercourses that need to be crossed. It derives peak flows to ensure that the culverts are properly sized and that the flood risk is minimised.

There are no risks to the bypass from the sources considered namely, fluvial, tidal, groundwater, overland, artificial drainage systems or infrastructure failure. The peak flows to the watercourses from surface water runoff were calculated using IH 124 and ADAS methodology taking account of both the natural catchments and drainage areas resulting from construction. The figures from ADAS were adopted. In addition to being conservative, they are considered to be more suitable for the size of the catchments. The existing culverts, which are to be retained under the current proposals, would need to be able to pass the 1 in 200 year flows (including climate change) of 4.09m^3/s (Culvert 1- south), 13.49m^3/s (Culvert 7 - east of northern roundabout) and 13.72m^3/s (Culvert 8 - north). The five proposed culverts would need to be able to pass peak flows in the range 1.08 to 6.21m^3/s.

It is considered that the following are required to mitigate the flood risk posed by, and to, the proposed road at detailed design stage:

- The existing and proposed culverts need to be able to pass the peak flows highlighted in this assessment.
- Flows from the new construction need to be attenuated to limit the flows to the watercourses to greenfield rates.

Any long term maintenance proposals should ensure that the drainage ditch and culverts are free from blockages and obstructions at all times.

Given the mitigation measures, it is considered that will be no adverse impacts on the watercourses or the surrounding areas, and that the proposed bypass would not be at risk of flooding.

REFERENCES:

BGS (2008) British Geological Society – Britain beneath our feet, Hazards - groundwater flooding http://www.bgs.ac.uk/education/britainbeneath/haz_flooding.html. Accessed May 2008.

British Hydrological Society (2008) Chronology of British Hydrological Events http://www.dundee.ac.uk/geography/cbhe/. Accessed May 2008.

CIRIA (2004) Development and flood risk – guidance for the construction industry. CIRIA C624 London, 2004.

Clackmannanshire and Stirling Council (2002) *Clackmannanshire and Stirling Structure Plan Written Statement, March 2002* http://www.stirling.gov.uk/sp-2004.pdf. Accessed May 2008.

FEH CD ROM v2.0 (2005). Centre for Ecology and Hydrology. Wallingford.

Loch Lomond and Trossachs National Park Authority (2007) *Loch Lomond and Trossachs National Park Plan, March 2007*.http://www.lochlomond-trossachs.org/looking-after/national-park-plan-2007-2012/menu-id-413.html. Accessed May 2009.

Loch Lomond and Trossachs National Park Authority (2008) Consultative Draft Local Plan, November 2008 http://www.lochlomond-trossachs.org/images/stories/Planning/PDF/LocalPlan/Draft%20Local%20Plan%20Chapters%201-5.pdf. Accessed May 2009.

Mabbett & Associates Ltd/Clackmannanshire Council Environmental Report (2007) *Clackmannanshire and Stirling, Structure Plan 3rd Alteration, Strategic Environmental Assessment, Environmental Report.* January 2007 http://www.stirling.gov.uk/environmental_assessment.pdf. Accessed May 2008.

Stirling Council (1999) Stirling Council *Local Plan 1999 Adopted by Stirling Council on 24 December 1999* http://www.stirling.gov.uk/index/services/planning/localplan/written_statement.htm. Accessed May 2008.

SEPA (2009) *Indicative River & Coastal Flood Map (Scotland)* - Crianlarich http://www.multimap.com/clients/browse.cgi?X=237500.767641602&Y=725000.642271401&width=550&height=450&client=sepa&gride=238559.767641602&gridn=725319.642271401&scale=50000&coordsys=gb&nosnap=true&overlay=layer2&greyscale=true&in.x=14&in.y=18. Accessed May 2009.

SEPA (2009) *Technical Flood Risk Guidance For Stakeholders Version 3* http://www.sepa.org.uk/flooding/flood_risk/planning__flooding.aspx. Accessed May 2009.

Transport Scotland (2004) *Design Manual for Roads and Bridges Volume 4. Section 2. Part 1 – Drainage of Runoff from Natural Catchments – HA106/04, February 2004.*

Transport Scotland (2006) *Design Manual for Roads and Bridges Volume 11. Section 3. Part 10 – Road Drainage and the Water Environment – HA216/06, May 2006.*

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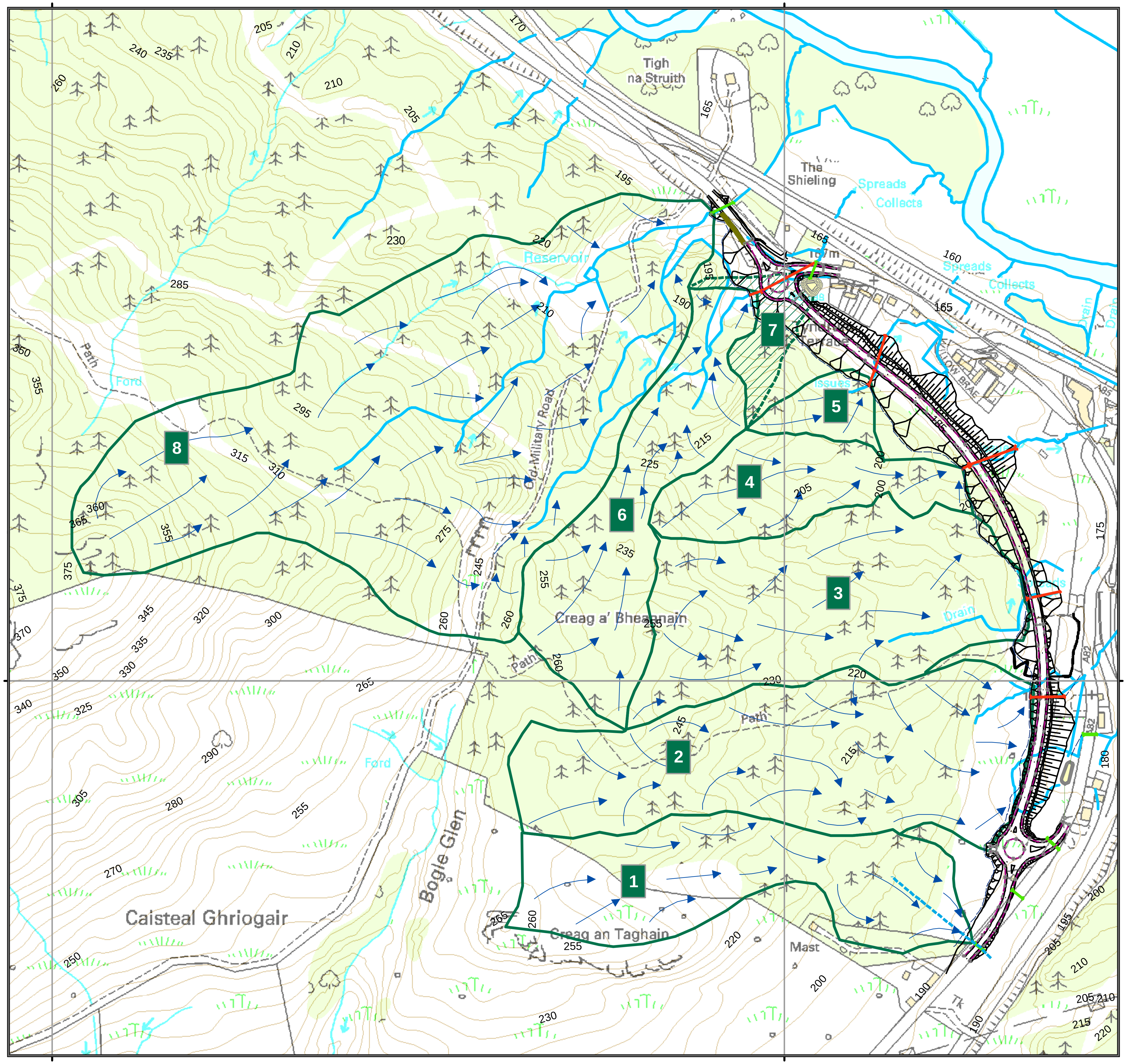

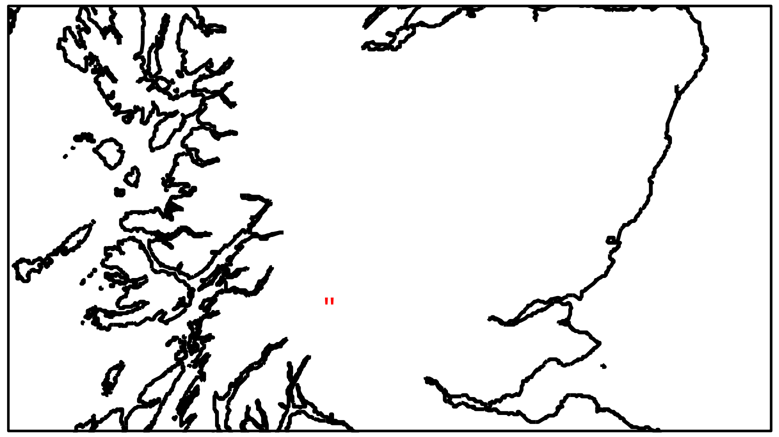

Legend

Catchment Flow Lines	Proposed Drainage
Ephemeral Stream	Ditch
Natural Catchment Boundary for culvert 7	Carrier Drain
Natural Catchment Boundary	Filter Drain
Surface Water Features	Proposed Culverts
5m Contours	Existing Culverts
Proposed A82 Crianlarich Bypass	Filter Trench
	Detention Basins

Catchment Boundaries and flow lines based on 1m contours

0 75 150 225 300 Meters

Rev	Amendments	By	Chkd	Apr'd	Date
0	First Issue	MC	ZR	JB	05/08
P1	Revised	FT	ZR	JB	10/08
P2	Final	FT	ZR	JB	05/09
P3	Final Revised	FT	ZR	JB	07/09

Client / Project

Transport Scotland

A82 Crianlarich Bypass

Figure 5.1: Natural Surface Water Catchment Boundaries And Current Surface Water Runoff Flow Routes

Drawing Status: Final

File Ref: Fig_5_1_Natural_flow_lines_P3
Original Size: A3

Drawing No: 1
Scale: 1:5,500

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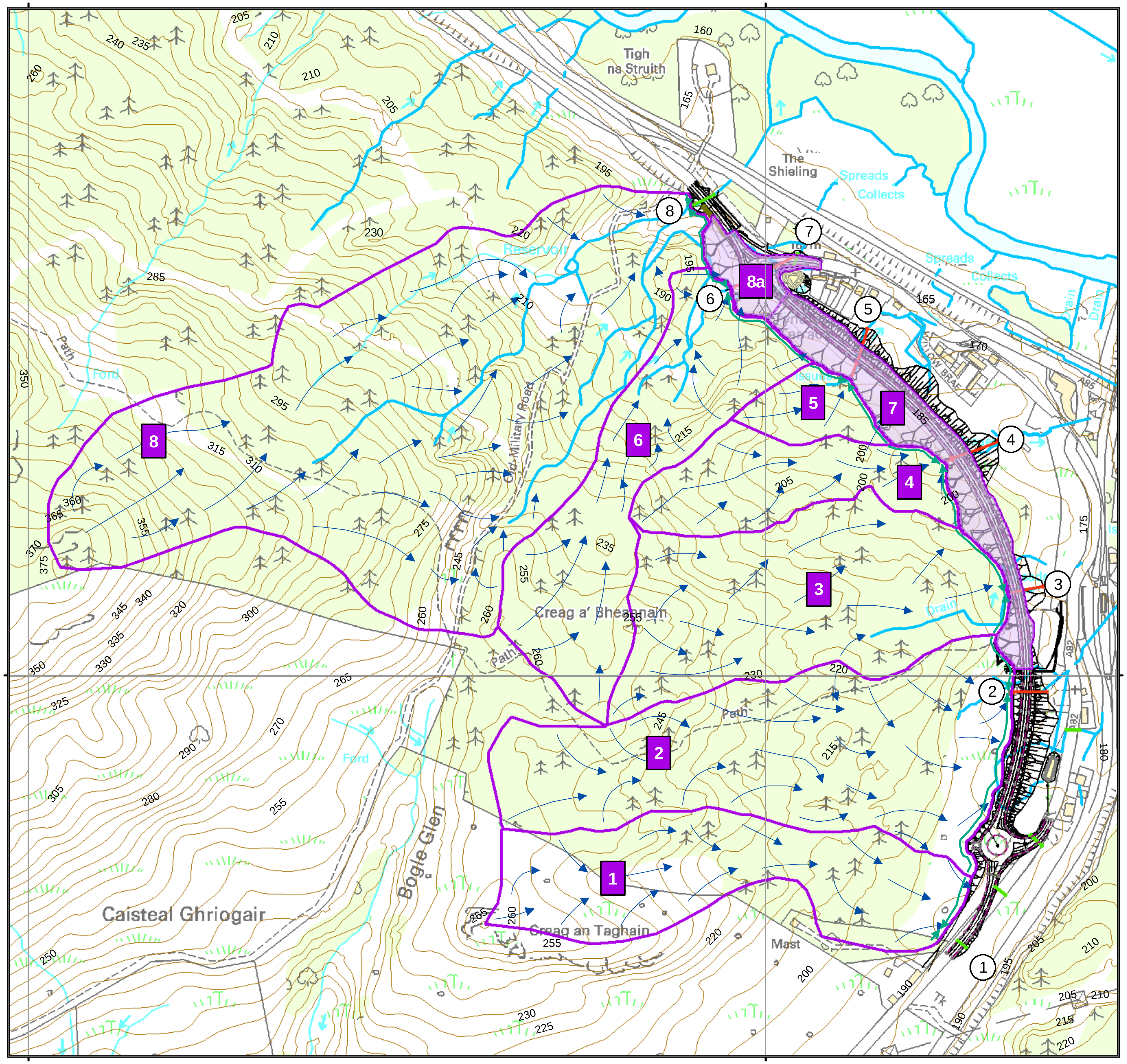

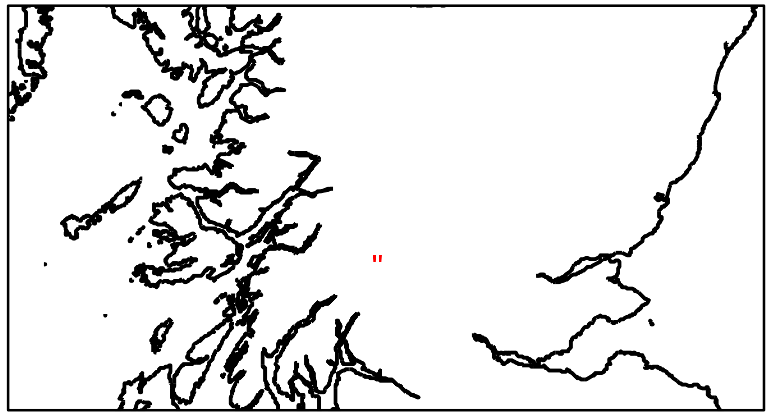

Legend

- Ditch Drainage Flow To Culverts
- Drainage Flow Lines
- Additional road drainage to culverts
- Proposed drainage areas
- Surface Water Features
- 5m Contours
- Proposed Drainage
- Ditch
- Carrier Drain
- Filter Drain
- Proposed Culverts
- Existing Culverts
- Filter Trench
- Detention Basins
- Proposed A82 Crianlarich Bypass

Drainage areas and flow lines based on 1m contours

0 100 200 300 400 Meters

Rev	Amendments	By	Chkd	Apr'd	Date
0	First Issue	MC	ZR	JB	05/08
P1-P3	Amended Draft	MC	ZR	JB	06/08
P4	Amended Draft	FT	ZR	JB	10/08
P5	Final	FT	ZR	JB	05/09
P6	Final Revised	FT	ZR	JB	05/09

Client / Project

Transport Scotland

A82 Crianlarich Bypass

Figure 5.2: Drainage Areas showing Surface Water Runoff Flow Routes and Flow Direction in Drainage Ditch

Drawing Status: Final

File Ref: Fig_5_2_Drainage Flow Lines_P6 Drawing No: 1

Original Size: A3 Scale: 1:5,500

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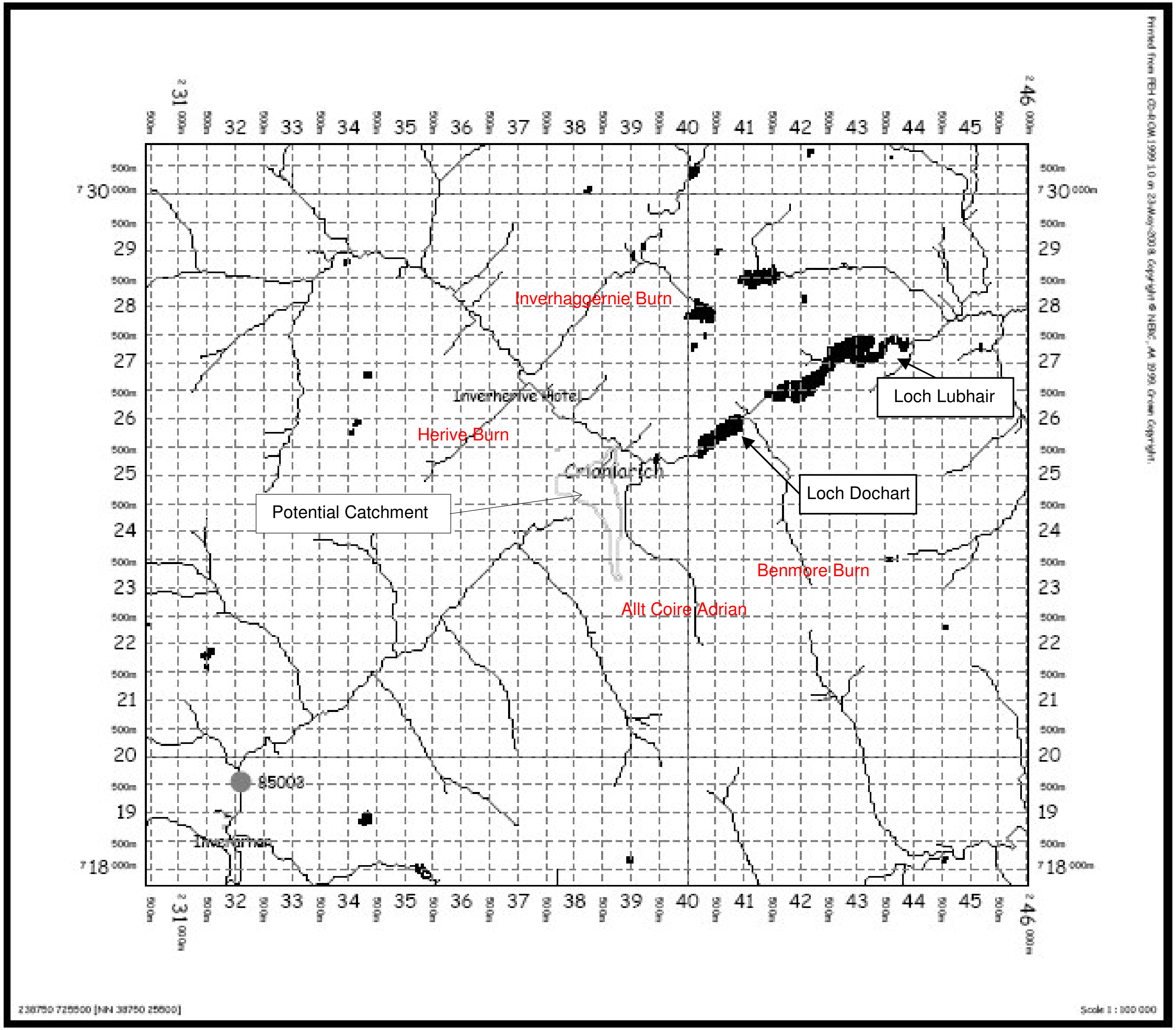
APPENDIX A: FEH CATCHMENT AND PARAMETERS



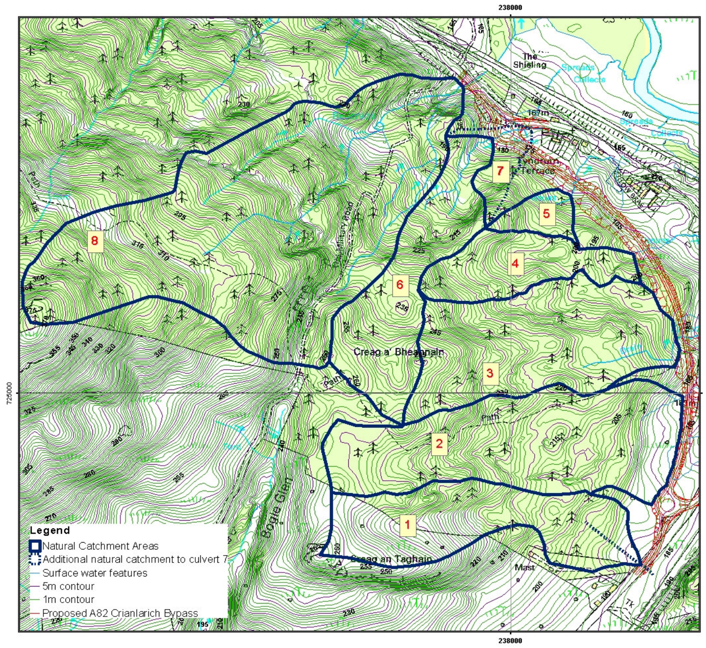
238750	725500
AREA	0.93
FARL	1
PROPWET	0.79
ALTBAR	229
ASPBAR	22
ASPVAR	0.54
BFIHOST	0.474
DPLBAR	1.26
DPSBAR	112.1
LDP	2.74
RMED-1H	11.5
RMED-1D	64.1
RMED-2D	91.9
SAAR	2471
SAAR4170	2180
SPRHOST	42.4
URBCONC	-999999
URBEXT1990	0
URBLOC	-999999
C	-0.015
D1	0.53
D2	0.453
D3	0.42
E	0.24
F	2.593
C(1km)	-0.015
D1(1km)	0.541
D2(1km)	0.462
D3(1km)	0.413
E(1km)	0.24
F(1km)	2.599

APPENDIX B GREENFIELD RUNOFF CALCULATIONS

Natural Catchments

Catchment Area	Area km^2	Area hectares
1	0.0807	8.07
2	0.1276	12.76
3	0.1077	10.77
4	0.0413	4.13
5	0.0116	1.16
6	0.0734	7.34
7	0.0861	8.61
8	0.2807	28.07

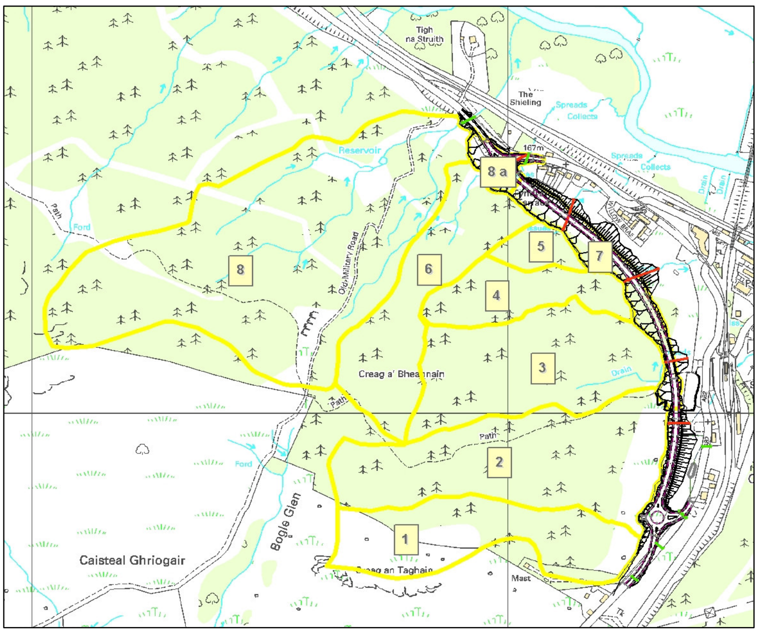
NB: Catchment 7 is the natural catchment to culvert 7 (catchment to culvert 6 + additonal area to culvert 7 ($0.0127km^2$))



Drainage Areas

Drainage Area	Area km^2	Area hectares
1	0.0832	8.32
2	0.1331	13.31
3	0.1049	10.49
4	0.0424	4.24
5	0.0140	1.40
6	0.0842	8.42
7	0.1127	11.27
8 & 8a	0.2913	29.13
Total	0.866	86.567

NB: Drainage Area 7 is the proposed drainage to culvert 7 which includes drainage area 6 ($0.0842km^2$) the road area and the embankments associated with network B ($0.0286km^2$). Drainage Area 8 ($0.2823km^2$) includes the additional road drainage associated with area 8a ($0.0090km^2$)



Values obtained from imported data in ArcGIS for ADAS calculations

Drainage / catchment area	Drainage Area km^2	Catchment width (top of catchment divide to	Average height of catchment divide (m)					
			length of catchment divide (m)	highest elevation (mAOD)	lowest elevation (mAOD)	Average height (mAOD)	Elevation at the point of discharge	Height at catchment divide (m)
1	0.0832	**687**	134	265	259	262	189	**73.0**
2	0.1331	**748**	164	259	257	258	186	**72.0**
3	0.1049	**588**	296	258	238	248	190	**58.0**
4	0.0424	**460**	222	238	217	227.5	186	**41.5**
5	0.0140	**176**	193	217	198	207.5	183	**24.5**
6	0.0842	**612**	202	260	254	257	177	**80.0**
7	0.1127							
8	0.2823	**1086**	656	375	251	313	165	**148.0**
Additional road area to 7 (Network C)	0.0286	**626**	20	187	185	186	171	**15.0**
Additional road area to 8 (8a) (Network C)	0.0090	**130**	49	182	168	175	165	**10.0**

IH 124

$$QBAR_{RURAL} = 0.00108 \cdot AREA^{0.89} SAAR^{1.17} SOIL^{2.17}$$

$QBAR_{RURAL}$ = mean annual flood for small rural catchments (m3/s)
AREA = catchment area
SAAR = standard average annual rainfall in mm for the period 1941 to 1970
SOIL = soil index (obtained from Flood Studies Report)

	Value	Unit	Source
SAAR	2471	mm	(FEH software)
SOIL	0.53	dimensionless	soil index obtained from Flood Studies Report

FROM CIRIA SUDs Manual C697

Return Period	UK Growth Curve Factors for Hydrometric Area 2 (Crianlarich)
2	0.91
5	1.11
10	1.42
25	1.81
50	2.17
75	2.38
100	2.63
200	2.98
500	3.45

Natural Catchment Area	Area (km^2)	$AREA^{0.89}$	$SAAR^{1.17}$	$SOIL^{2.17}$	QBAR per $0.5km^2$ (m^3/s)	QBAR scaled to area (QBAR x (Area km^2 / 0.5 km^2) m^3/s	Q50 m3/s = (QBAR x 2.17)	Q75 m3/s = (QBAR x 2.38)	Q100 m3/s = (QBAR x 2.63)	Q200 m3/s = (QBAR x 2.98)	Q50 l/s	Q75 l/s	Q100 l/s	Q200 l/s
1	0.0807	0.5396	9325.26	0.2522	1.3704	0.22	0.48	0.53	0.58	0.66	479.98	526.43	581.73	659.15
2	0.1276	0.5396	9325.26	0.2522	1.3704	0.35	0.76	0.83	0.92	1.04	758.61	832.02	919.42	1041.78
3	0.1077	0.5396	9325.26	0.2522	1.3704	0.30	0.64	0.70	0.78	0.88	640.30	702.27	776.03	879.31
4	0.0413	0.5396	9325.26	0.2522	1.3704	0.11	0.25	0.27	0.30	0.34	245.84	269.63	297.95	337.60
5	0.0116	0.5396	9325.26	0.2522	1.3704	0.03	0.07	0.08	0.08	0.09	68.85	75.51	83.44	94.55
6	0.0734	0.5396	9325.26	0.2522	1.3704	0.20	0.44	0.48	0.53	0.60	436.84	479.12	529.45	599.90
7	0.0861	0.5396	9325.26	0.2522	1.3704	0.24	0.51	0.56	0.62	0.70	512.08	561.64	620.63	703.23
8	0.2807	0.5396	9325.26	0.2522	1.3704	0.77	1.67	1.83	2.02	2.29	1669.58	1831.15	2023.50	2292.79

Drainage Area	Area (km^2)	$AREA^{0.89}$	$SAAR^{1.17}$	$SOIL^{2.17}$	QBAR per $0.5km^2$ (m^3/s)	QBAR scaled to area (QBAR x (Area km^2 / 0.5 km^2) m^3/s	Q50 m3/s = (QBAR x 2.17)	Q75 m3/s = (QBAR x 2.38)	Q100 m3/s = (QBAR x 2.63)	Q200 m3/s = (QBAR x 2.98)	Q50 l/s	Q75 l/s	Q100 l/s	Q200 l/s
1	0.0832	0.5396	9325.26	0.2522	1.3704	0.23	0.49	0.54	0.60	0.68	494.84	542.73	599.74	679.55
2	0.1331	0.5396	9325.26	0.2522	1.3704	0.36	0.79	0.87	0.96	1.09	791.44	868.03	959.21	1086.86
3	0.1049	0.5396	9325.26	0.2522	1.3704	0.29	0.62	0.68	0.76	0.86	623.74	684.10	755.96	856.56
4	0.0424	0.5396	9325.26	0.2522	1.3704	0.12	0.25	0.28	0.31	0.35	252.29	276.70	305.77	346.46
5	0.0140	0.5396	9325.26	0.2522	1.3704	0.04	0.08	0.09	0.10	0.11	83.00	91.03	100.59	113.98
6	0.0842	0.5396	9325.26	0.2522	1.3704	0.23	0.50	0.55	0.61	0.69	500.61	549.06	606.73	687.47
7	0.1969	0.5396	9325.26	0.2522	1.3704	0.54	1.17	1.28	1.42	1.61	1171.04	1284.36	1419.28	1608.15
8	0.2913	0.5396	9325.26	0.2522	1.3704	0.80	1.73	1.90	2.10	2.38	1732.28	1899.92	2099.49	2378.89

With Climate Change (+ 20%)

Catchment Area	Q100 m^3/s	Q200 m^3/s
1	0.70	0.79
2	1.10	1.25
3	0.93	1.06
4	0.36	0.41
5	0.10	0.11
6	0.64	0.72
7	0.74	0.84
8	2.43	2.75
Drainage Area	**Q100 m^3/s**	**Q200 m^3/s**
1	0.72	0.82
2	1.15	1.30
3	0.91	1.03
4	0.37	0.42
5	0.12	0.14
6	0.73	0.82
7	1.70	1.93
8	2.52	2.85

Calculation note:
Drainage area 7 incorporates flow from drainage area 6. The areas of the two catchments have been combined before IH124 calculations.
Drainage area 8 incorporates flow from drainag area 8 and additional road area 8a (network C).

ADAS

$$Q = AREA(0.0443 \bullet SAAR - 11.19)SOIL^{2.0} * \left[\frac{18.79T^{0.28} - 1}{10T}\right]$$

Q = mean annual flow
AREA (in km^2) is the catchment plan area
SAAR (in mm) is the standard average annual rainfall
SOIL = 0.5 (obtained from flood studies report)
T is the time of concentration (in hours)

where T = $$T = 0.1677\frac{W^{0.78}}{Z^{0.39}}$$

W is the max catchment width in metres
Z is the average height of the catchment divide in metres above the discharge level (ditch level)

	Value	Unit	Source
SAAR	2471	mm	(FEH software)
SOIL	0.5	dimensionless	soil index obtained from Flood Studies Report

FROM CIRIA SUDs Manual C697

Return Period	UK Growth Curve Factors for Hydrometric Area 2 (Crianlarich)
2	0.91
5	1.11
10	1.42
25	1.81
50	2.17
75	2.38
100	2.63
200	2.98
500	3.45

Catchment Area	Area (km^2)	W	Z	T	Q m^3/s	Q50 m^3/s	Q75 m^3/s	Q100 m^3/s	Q200 m^3/s	Q50 l/s	Q75 l/s	Q100 l/s	Q200 l/s
1	0.0807	705	73.0	5.24	1.09	2.37	2.60	2.87	3.26	2371	2600	2873	3256
2	0.1276	739	71.5	5.48	1.67	3.63	3.98	4.40	4.98	3630	3981	4399	4984
3	0.1077	538	60.0	4.58	1.60	3.48	3.82	4.22	4.78	3479	3816	4217	4778
4	0.0413	457	41.5	4.66	0.61	1.32	1.45	1.60	1.81	1320	1448	1600	1813
5	0.0116	174	27.5	2.58	0.26	0.56	0.62	0.68	0.77	563	617	682	773
6	0.0734	655	85.0	4.66	1.08	2.34	2.57	2.84	3.22	2344	2571	2841	3219
7	0.0127	750	46.0	6.59	0.15	0.32	0.35	0.38	0.44	317	348	384	436
8	0.2807	1048	151.5	5.37	3.73	8.10	8.89	9.82	11.13	8104	8889	9822	11130

7 (incorporating catchments 6+7)	0.0861				1.23	2.66	2.92	3.23	3.65	2661	2919	3226	3655

Drainage Area	Area (km^2)	W	Z	T	Q m^3/s	Q50 m^3/s	Q75 m^3/s	Q100 m^3/s	Q200 m^3/s	Q50 l/s	Q75 l/s	Q100 l/s	Q200 l/s
1	0.0832	687	73	5.14	1.14	2.48	2.72	3.01	3.40	2479	2719	3005	3405
2	0.1331	748	72	5.52	1.74	3.77	4.13	4.57	5.18	3769	4133	4567	5175
3	0.1049	588	58	4.98	1.47	3.20	3.51	3.87	4.39	3196	3506	3874	4389
4	0.0424	460	42	4.68	0.62	1.35	1.48	1.64	1.85	1350	1481	1636	1854
5	0.0140	176	25	2.72	0.30	0.65	0.72	0.79	0.90	653	716	792	897
6	0.0842	612	80	4.53	1.26	2.74	3.01	3.32	3.77	2743	3008	3324	3767
7	0.1127	130	15	2.60	2.51	5.45	5.97	6.60	7.48	5445	5972	6600	7478
8	0.2823	1086	148	5.57	3.66	7.94	8.71	9.62	10.90	7938	8706	9621	10901
8a	0.0090	130	10	3.04	0.18	0.39	0.43	0.47	0.53	389	426	471	534
7 (incorporating catchments 6+7)	0.1969				3.77	8.19	8.98	9.92	11.24	8188	8981	9924	11245
Total drainage to 8 (incorporating catchements 8 and 8a)	0.2913				3.84	8.33	9.13	10.09	11.44	8327	9133	10092	11435

With Climate Change (+ 20%)

Catchment Area	Q100 m^3/s	Q200 m^3/s
1	3.45	3.91
2	5.28	5.98
3	5.06	5.73
4	1.92	2.18
5	0.82	0.93
6	3.41	3.86
7	3.87	4.39
8	11.79	13.36

Drainage Area	Q100 m^3/s	Q200 m^3/s
1	3.61	4.09
2	5.48	6.21
3	4.65	5.27
4	1.96	2.22
5	0.95	1.08
6	3.99	4.52
7	11.91	13.49
8	12.11	13.72

Peak flow calculations for catchment 7 include catchment 6 flows as catchment runoff combines before culvert 7.
Peak flow calculations for drainage area 8 include drainage area 8 and flows from additional road area 8a.

IH 124

		IH 124					IH 124 with climate change				
Natural Catchment Area	**Area (km2)**	**QBAR m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**
1	0.0807	0.22	0.48	0.53	0.58	0.66	0.27	0.58	0.63	0.70	0.79
2	0.1276	0.35	0.76	0.83	0.92	1.04	0.42	0.91	1.00	1.10	1.25
3	0.1077	0.30	0.64	0.70	0.78	0.88	0.35	0.77	0.84	0.93	1.06
4	0.0413	0.11	0.25	0.27	0.30	0.34	0.14	0.30	0.32	0.36	0.41
5	0.0116	0.03	0.07	0.08	0.08	0.09	0.04	0.08	0.09	0.10	0.11
6	0.0734	0.20	0.44	0.48	0.53	0.60	0.24	0.52	0.57	0.64	0.72
7	0.0861	0.24	0.51	0.56	0.62	0.70	0.28	0.61	0.67	0.74	0.84
8	0.2807	0.77	1.67	1.83	2.02	2.29	0.92	2.00	2.20	2.43	2.75
Drainage Area	**Area (km2)**	**QBAR m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**
1	0.0832	0.23	0.49	0.54	0.60	0.68	0.27	0.59	0.65	0.72	0.82
2	0.1331	0.36	0.79	0.87	0.96	1.09	0.44	0.95	1.04	1.15	1.30
3	0.1049	0.29	0.62	0.68	0.76	0.86	0.34	0.75	0.82	0.91	1.03
4	0.0424	0.12	0.25	0.28	0.31	0.35	0.14	0.30	0.33	0.37	0.42
5	0.0140	0.04	0.08	0.09	0.10	0.11	0.05	0.10	0.11	0.12	0.14
6	0.0842	0.23	0.50	0.55	0.61	0.69	0.28	0.60	0.66	0.73	0.82
7	0.1969	0.54	1.17	1.28	1.42	1.61	0.65	1.41	1.54	1.70	1.93
8	0.2913	0.80	1.73	1.90	2.10	2.38	0.96	2.08	2.28	2.52	2.85

ADAS

		ADAS					ADAS with climate change				
Catchment Area	**Area (km2)**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**
1	0.0807	1.09	2.37	2.60	2.87	3.26	1.31	2.84	3.12	3.45	3.91
2	0.1276	1.67	3.63	3.98	4.40	4.98	2.01	4.36	4.78	5.28	5.98
3	0.1077	1.60	3.48	3.82	4.22	4.78	1.92	4.18	4.58	5.06	5.73
4	0.0413	0.61	1.32	1.45	1.60	1.81	0.73	1.58	1.74	1.92	2.18
5	0.0116	0.26	0.56	0.62	0.68	0.77	0.31	0.68	0.74	0.82	0.93
6	0.0734	1.08	2.34	2.57	2.84	3.22	1.30	2.81	3.09	3.41	3.86
7	0.0861	1.23	2.66	2.92	3.23	3.65	1.47	3.19	3.50	3.87	4.39
8	0.2807	3.73	8.10	8.89	9.82	11.13	4.48	9.73	10.67	11.79	13.36
Drainage Area	**Area (km2)**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**	**Q m^3/s**	**Q50 m^3/s**	**Q75 m^3/s**	**Q100 m^3/s**	**Q200 m^3/s**
1	0.0832	1.14	2.48	2.72	3.01	3.40	1.37	2.98	3.26	3.61	4.09
2	0.1331	1.74	3.77	4.13	4.57	5.18	2.08	4.52	4.96	5.48	6.21
3	0.1049	1.47	3.20	3.51	3.87	4.39	1.77	3.84	4.21	4.65	5.27
4	0.0424	0.62	1.35	1.48	1.64	1.85	0.75	1.62	1.78	1.96	2.22
5	0.0140	0.30	0.65	0.72	0.79	0.90	0.36	0.78	0.86	0.95	1.08
6	0.0842	1.26	2.74	3.01	3.32	3.77	1.52	3.29	3.61	3.99	4.52
7	0.1969	3.77	8.19	8.98	9.92	11.24	4.53	9.83	10.78	11.91	13.49
8	0.2913	3.84	8.33	9.13	10.09	11.44	4.60	9.99	10.96	12.11	13.72

Calculation Note:
Flows calculated using ADAS for catchment 7 combine flows calculated separately for catchments 6 and 7. The ADAS methodology requires catchment characteristics to be calculated as a first step and then the flows are summed. Using IH124, catchment 6 and 7 areas are summed prior to calculation. The same has been done for drainage area 8 which includes area 8a (Network C drainage) via filter trench.