Appendix A11.5: Fluvial Geomorphology

1 Introduction

General Background

1.1.1 This technical appendix informs Chapter 11 (Road Drainage and the Water Environment) of the Environmental Statement (ES). It focuses on the fluvial geomorphology aspects of the study, providing a detailed understanding of the baseline environment and the assessment of impacts of the proposed scheme. The appendix focuses only on those water features that have been given a medium, high or very high sensitivity. Low sensitivity water features are not included in the appendix which are discussed in Appendix A11.1 (Baseline conditions) and Appendix A11.7 (Impact Assessment). In addition, WF173, WF172 and WF171 have also been screened out of this appendix; the assessment suggests that there is unlikely to be an impact on the fluvial geomorphology of these water features by the construction or operation of the proposed scheme.

1.1.2 For the purposes of the assessment, the term water feature includes all rivers, streams and ditches. The water features range in size from drainage channels to larger rivers. A glossary of terms is provided in Section 8 (Glossary).

1.1.3 Fluvial geomorphology has been included in the Environmental Impact Assessment primarily as a result of the EU Water Framework Directive (WFD, 2000/60/EC), transposed into Scottish Law by the Water Environment and Water Services (Scotland) Act 2003 (WEWS Act). The legislation aims to classify rivers according to their ecological and chemical status and sets targets for improvements. Ecological status is divided into three quality elements: biological; hydromorphological; and physico-chemical quality. For High Status water bodies, the WFD requires that there is no more than very minor human alteration to the hydromorphology quality elements including:

- the quantity, dynamics and velocities of flow;
- the continuity of the river: allowing sediment transport and migration of aquatic organisms; and
- the morphology of the river: channel patterns, width and depth variations, substrate conditions and both the structure and condition of the riparian zone (river corridor).

What is Fluvial Geomorphology?

1.1.4 Fluvial geomorphology is the study of the landforms and physical features associated with river systems (including their channels and floodplains); and the sediment supply and transport processes that create them. Fluvial processes create a wide range of morphological forms that provide a variety of habitats within and around river channels. As a result, geomorphology is integral to river management.

1.1.5 Fluvial geomorphology considers the processes of sediment transfer (erosion, transport and deposition) in river systems and also the relationships between channel forms and processes.

1.1.6 The geomorphological form of a river channel and valley floor is influenced by many different factors and complex inter-related processes. Controls influencing river systems are both external (including catchment geology, topography, soil type, climatic trends and land management practices) and internal (including bed and bank materials, vegetation characteristics, gradient and flow conditions). These variable controls and their interactions determine the character of fluvial processes, which in turn, influence individual channel forms and features.

1.1.7 As an unmodified system, a river evolves in response to natural influences. However, rivers are often affected by human activities. Channel modifications including artificial structures alter flow and sediment movement, typically resulting in changes to river morphology (form), laterally (channel width, floodplain connectivity) and/or longitudinally (planform, bed gradient or depth). Changes in one part of the river catchment either through natural or human activity can result not only in geomorphological adjustment over time at that point, but also in changes upstream and downstream.

1.1.8 An understanding of fluvial geomorphology adds value to the design of river modifications and structures (such as culverts, scour/bank protection and channel realignment) by identifying areas at risk of erosion and/or deposition. This leads to a potential reduction of maintenance costs by embedding mitigation to both protect assets and reduce/eliminate impacts on natural fluvial processes.

1.1.9 In support of statutory requirements to protect biodiversity, fluvial geomorphology also contributes to the understanding of habitat requirements, their sustainable management and mitigation of impacts resulting from development works.

Assessment Aims

1.1.10 The specific objectives of this assessment to are to:

- understand the baseline characteristics for each water feature;
- assess the potential impacts on each water feature affected by the proposed scheme against the baseline (with consideration of the sediment regime, channel morphology and natural fluvial processes);
- recommended mitigation measures to minimise potential impacts resulting from the proposed scheme; and
- understand and outline any residual impacts following the application of recommended mitigations.

1.1.11 The assessment also takes into consideration the potential impacts on the current status of the WFD water bodies which may be affected by the proposed scheme, including any WFD measures proposed upon that water body and the ability of the water body to meet its overall objective to achieve Good Status.

1.1.12 Where required, mitigation measures would be developed to prevent deterioration in status of the WFD water body quality elements (see paragraph 1.1.3) and/or overall status of the WFD water body. Furthermore, the assessment would investigate whether the proposed scheme would prevent the WFD water body from achieving/maintaining Good Status.

Study Area

1.1.13 The study area for the fluvial geomorphology assessment included a 500m length of the water features upstream and downstream of the proposed watercourse crossings. For some more sensitive water features, the study area was extended to 1km to allow for a more detailed assessment of the baseline characteristics and processes.

2 Approach and Methods

General Approach

2.1.1 Geomorphological impacts are assessed in terms of potential disturbance to the existing channel morphology; sediment regime; and fluvial processes.

2.1.2 The forms and processes occurring within river systems provide and sustain physical habitat for aquatic species, and may also influence water quality, the stability of infrastructure and flood risk with implications for local communities and businesses. Potential receptors, sensitive to geomorphological change are therefore both environmental and socio-economic.

2.1.3 To inform the impact assessment process, both desk-based and field data were collected and analysed. Given the dynamic nature of the main rivers in the study area, in particular those of high or very high sensitivity, additional investigations were undertaken, including a detailed erosion risk assessment (to inform optioneering and engineering design) and a specific geomorphological assessment for the Habitat Regulations Assessment report.

2.1.4 The methodology for the fluvial geomorphology assessment follows best practice guidance including:

- The Fluvial Design Guide (Environment Agency, 2010);
- Guidebook of Applied Fluvial Geomorphology (Sear et al., 2010); and
- Supporting Guidance (WAT-SG-21) Environmental Standards for River Morphology (SEPA, 2012).

2.1.5 Section 11.2 (Chapter 11: Road Drainage and Water Environment) provides a description of how the baseline information has been gathered as well as the criteria for assigning sensitivity, determining the magnitude of potential impacts and the significance of impact.

Additional Assessments

2.1.6 As part of the geomorphological assessment for the southern section of the A9 dualling programme (Pass of Birnam to Glen Garry), an additional assessment has been undertaken by geomorphologists on potential erosion risk at locations along the River Garry. The assessment focused on locations where the existing A9 infrastructure is currently at risk and/or the proposed scheme could be at risk from fluvial erosion in the future, considering both short and longer term timescales. A rapid erosion risk prioritisation tool (developed by Jacobs) was used to identify sites at risk of erosion. The tool considered the link between the hazard (erosion) and receptor (the scheme). The magnitude of impact was then assessed, along with the likelihood of erosion, and an assessment of the effectiveness of any existing management (if applicable). The potential erosion risk was then ranked using a risk matrix and a risk rating assigned (from Risk Rating 1 – no risk to Risk Rating 9 – high risk).

2.1.7 Site work was then undertaken for those sites rated as medium to high risk (Risk Rating 5-9) to further develop the assessment and verify the results. Stream power and sediment transport calculations were also undertaken to inform the detailed assessment of these higher risk sites providing an understanding of the capacity of the channel to erode and transport sediment. The sites were then reassessed and a new risk rating given (if deemed necessary). For those still considered high risk (Risk Rating 7-9) mitigation proposals were developed ranging from monitoring to soft engineering (for example green bank protection) or where no alternative exists, a hard (or grey) engineering solution.

2.1.8 An additional geomorphological baseline and impact assessment has also been undertaken to inform the Habitat Regulations Assessment. This focused on the potential impacts of structures, outfalls and discharges to designated habitats and species as part of the River Tay Special Area of Conservation (SAC) as well as fresh water pearl mussel. The assessment considers the significance of changes in geomorphological processes to SAC habitat characteristics both within the channel and floodplain, extending 1km upstream and downstream of the proposed scheme. Relevant results are provided in Chapter 12 (Ecology and Conservation).

Limitations to Assessment

2.1.9 Baseline conditions reported in this study are informed by site walkover information, gathered at specified time periods and the coinciding water levels. Although these data allow assessment of in-channel features and provide an understanding of the nature of the channel at varying levels, it should be noted that most water features have only been visited on one occasion.

2.1.10 Weather conditions during site walkovers determined that some water features were surveyed during high flows, thereby limiting the visibility of some bed substrate and/or morphological features being recorded. During the February, March and June 2015 surveys, above average flow was observed in most catchments following recent rainfall. During the April 2015 surveys, conditions in advance of and during the surveys were dry and warm, leading to observed low flow conditions in small catchments, dry soils and limited overland flow to water features.

2.1.11 This assessment has been based on the DMRB guidance, standard good practice and guidance notes from SEPA, supported and further developed using professional judgement.

2.1.12 The mathematical modelling of sediment input, transfer or deposition, during road operation or construction, was beyond the scope of this assessment due to the lack of available data (flow, channel morphology, sediment load) around which to build the models, and, with the exception of the River Garry (WF100), due to the small size of most water features.

2.1.13 The upstream and downstream assessment boundaries were determined by the extent of likely impacts caused by the proposed scheme and access constraints. The extent of the field survey also varied according to these constraints. However, all site investigations considered the channel upstream and downstream of the proposed scheme over a distance of 500m to 1km. The distance of survey was proportional to the size of the water feature.

2.1.14 It is not possible to fully assess the potential impacts of construction before the finalisation of the programme of works details, including the location of temporary access roads and timing of construction. However, an assessment was made of the likely potential impacts during construction upon each water feature affected based upon best available data at the time of writing.

3 Baseline

3.1.1 The following sections describe the details of the baseline conditions for the fluvial geomorphology attributes of each medium, high or very high sensitivity water feature potentially impacted by the proposed scheme. An assessment of the baseline condition of all water features including those with low sensitivity can be found in Appendix A11.1 (Baseline Conditions).

Water Feature Descriptions

River Garry (WF100)

3.1.2 The River Garry (WF100) is very large watercourse and a major tributary of the River Tummel in the Scottish Highlands. The river flows from Loch Garry in an easterly direction towards Blair Atholl where it then flows south-east to its confluence with the River Tummel. The river passes through a predominantly rural catchment, with only a few hamlets and small villages located along its length. The hamlets include Calvine and Pitagowan and the villages include Blair Atholl and Killiecrankie.

3.1.3 The land use along the river corridor varies throughout its length from the loch to the River Tummel. It predominantly consists of lengths of woodland, providing a tree lined corridor along the river, and lengths of agricultural land (mostly pastoral). Most of the River Garry is tree lined providing in-channel shading as well as some stability to the banks (where they consist of earth, sand and gravels).

3.1.4 The River Garry throughout its length is bordered on both banks by steep valley sides. The river corridor widens towards Pitagowan, with the river having the potential to migrate across the wider floodplain through processes such as lateral erosion and deposition.

3.1.5 Historically, the River Garry is likely to have been a wandering gravel bed river with an unconstrained sediment supply and fluvial regime that migrated laterally across its floodplain. Historical map analysis of the River Garry within the study area shows changes since 1867 when the first map is available.

3.1.6 Historical map analysis from the upstream extent of the study area (Dalnacardoch) to the downstream extent (Killiecrankie) shows in-channel island adjustment around Dalinturuaine where deposits appear to have shifted and reduced in size since 1867. Further downstream, there appears to have been minimal change from the confluence with the Allt Crom Bhruthaich to Calvine, most likely due to natural channel confinement (i.e. bedrock). However, from the River Bruar confluence to the River Tilt confluence, significant channel adjustment can be observed on mapping with adjusting in-channel deposits, creation and abandonment of secondary channels and lateral migration within the floodplain.

3.1.7 Historical adjustment of deposits upstream and downstream of Essangal Bridge can also be observed from mapping since 1867, with the in-channel deposits adjusting from the left to right bank, particularly in maps dating from after the completion of the existing A9, albeit localised redistribution of the shingle deposits. The mapping shows meander migration upstream of the Killiecrankie road bridge, as well as the formation of an island on the meander downstream of Killiecrankie (adjacent to the Highland Main Line railway).

3.1.8 Since the development of the Tummel Valley hydro-electric power scheme in 1935, the River Garry has been heavily influenced by flow regulation. This regulation involves surface water abstraction and a diversion pipe from Loch Garry and the Garry Intake upstream of the proposed scheme, both diverting flow from the River Garry and suppling water to Loch Errochty and Loch Tummel. This has resulted in significant flow reductions in the River Garry. Regulated flow releases from the dam at Loch Errochty also impact on the flow regime downstream of Struan Weir, where Errochty Water confluences with the Garry. This results in depleted flows within the river upstream of Struan with extremely low flows during drier periods; and an artificially modified flow regime downstream of Struan. However, it is noted that a future strategy for the reach of the River Garry between the Garry Intake and the confluence with Errochty Water includes reducing abstraction and improving low flow conditions.

3.1.9 Different WFD classifications and objectives for the upper and lower Garry reaches reflect the influence of the hydropower scheme upon the hydrology and fluvial geomorphology. As a result, WF100 has been split into two reaches for the purposes of the impact assessment: WF100 (upper) from Garry intake to Errochty Water and WF100 (lower) from Errochty Water to Killiecrankie.

3.1.10 At the upstream extent of the Killiecrankie to Glen Garry study area, the River Garry is an open channel within a narrow floodplain. There is evidence of the channel having the potential to laterally migrate with some erosion of the banks. Extensive deposits were noted, likely increased by the regulated flows, detailed above. Downstream of Crom Bhruthaich (ch18000), the river passes into a bedrock gorge, which is characterised by bedrock cascades and limited channel adjustment.

3.1.11 From Struan (ch134400) downstream, the river valley opens up into a wide floodplain, until a small length of bedrock gorge from Essangal (ch4300) to Killiecrankie. Through this wide alluvial valley, there is evidence of large depositional point bars, side bars and mid-channel bars, with erosion of the channel banks. Some secondary channels, activated in higher flows, were also noted, as well as abandoned secondary channels within the floodplain. The features observed during the site walkovers support the historical analysis suggesting the river laterally migrates across its floodplain. The river typically had a pool-riffle sequence throughout, with the downstream extent extensively affected by the flow regulation at Errochty Dam.

3.1.12 A number of weirs are located along the river throughout the study area, with lengths of bank reinforcement particularly around infrastructure and villages. The most significant of these is the weir at Struan immediately upstream of the Errochty Water-River Garry confluence, which marks the boundary between the WFD water bodies and the WF100 (upper) and WF100 (lower) reaches. The Struan Weir was partially removed in January 2017 by SSE as part of the strategy to restore connectivity and reintroduce more natural flow conditions to the River Garry. There are a number of bridge structures crossing the river, including those of the existing A9 at Essangal and near Pitagowan.

Photograph 1: Typical cross-section of WF100

Photograph 2: WF100 upstream of Bruar where the channel lies within a bedrock gorge (looking downstream)

3.1.13 The River Garry within the study area is split into three WFD water bodies, the most upstream of which is outside of the proposed scheme, but within the study area. These are outlined in Table 1 with a summary of the classification, status of the key quality elements applicable to the fluvial geomorphology assessment.

Table 1: River Garry Water Framework Directive classification

WFD Quality Element	River Garry from Loch Garry to Garry Intake	River Garry from Garry Intake to Errochty Water confluence	Errochty Water confluence to Loch Faskally
Water body ID	6912	6911	6836
Overall classification	Bad Ecological Potential	Bad Ecological Potential	Good Ecological Potential
Designation as Artificial or Heavily Modified Water Body (A/HMWB)	HMWB	HMWB	HMWB
Pressures on water body	Flow regulation Morphological	Flow regulation Morphological	Flow regulation
Hydromorphology status	Bad	Bad	Moderate
Morphology	Good	Good	Good
Overall hydrology	Bad	Bad	Moderate

3.1.14 An erosion risk assessment was undertaken for the River Garry. The first site, located at ch4700, was identified due to significant erosion of a local access track which was migrating towards the existing A9. Since the site work was undertaken, the erosion has been mitigated with bank protection measures and, therefore, this site has been discounted from further assessment. The second site, located at ch8700-9000, was identified due to historical channel adjustment having occurred at the site and evidence found of undercutting of the bank, with the channel eroding towards the A9. The erosion at this site was assessed to potentially be occurring over a longer timescale and as a result is not a direct risk to the existing A9 or proposed scheme over the next 10years. Therefore, the recommendation for the site is for ongoing monitoring and to allow natural adjustment to occur. The third site, located at ch9900-10150, was at highest risk from the River Garry eroding, with the existing A9 being currently at risk of fluvial erosion. As described in Chapter 4 (Iterative Design Development), the design of the proposed scheme has relocated the mainline of the proposed scheme further south to provide further protection and reduce the risk of future erosion risk to the proposed scheme.

<u>WF84 (Allt Eachainn)</u>

3.1.15 Allt Eachainn (WF84) is a medium watercourse which has its source on the western slope of Ben Vrackie, a mountain to the east of the existing A9. WF84 has a steep gradient and confined channel at the base of two steep valley sides, with an average width of approximately 2m. The land use in the upstream catchment predominantly comprises of moorland. Approximately 350m upstream of the existing A9, WF84 flows around a disused reservoir and water works. A small tributary joins the watercourse on the left bank downstream of the reservoir site.

3.1.16 Historical map analysis shows minimal change in the watercourse, with the planform remaining consistent since 1867. The reservoir and water works appear on mapping from 1900 with the existing A9 being developed later in that century.

3.1.17 Upstream of the existing A9, WF84 predominantly consists of bedrock cascades, with some lengths of a boulder and cobble step-pool sequences (particularly in the upstream part of the catchment). The planform is slightly sinuous, but most lies within a straight corridor.

3.1.18 As WF84 passes under the existing A9, there is a large bedrock cascade dropping into a concrete structure, which forms the inlet to the culvert. Downstream, the watercourse is influenced by bed and bank reinforcement associated with the road and Highland Main Line railway crossings, as well as a number of drainage outfalls likely to come from the existing A9. The gradient of the channel slackens as it passes under another road bridge and the Highland Main Line railway before its confluence with the River Garry. The slacker gradient and a change in geology means the channel was typically observed to have a step-pool sequence in this downstream extent consisting of boulders and cobbles.

Photograph 3: Bedrock cascade looking downstream into culvert under the existing A9

Photograph 4: Downstream of the existing A9 crossing (looking downstream)

<u>WF87 (Troopers Den Burn)</u>

3.1.19 WF87 is a small watercourse which has its source in the moorland located on Meall na Moine, which flows for approximately 2.2km before discharging into the River Garry. The channel has a steep gradient and relatively sinuous planform and measures approximately 1.3m wide. The surrounding land use is mainly coniferous and deciduous woodland with moorland in the upstream reach.

3.1.20 Upstream of the existing A9 crossing, the water feature predominantly consists of step-pool and riffle-pool sequences with gravel substrate. Immediately upstream and downstream of the existing A9 crossing, the water feature had a straight planform and uniform cross-section. Downstream of the B8079, the channel alternated between having an exposed bedrock bed and cobble substrate.

3.1.21 Historical map analysis shows minimal change in the water feature, with the planform remaining consistent since 1867.

Photograph 5: Upstream of existing A9 (looking downstream)

Photograph 6: Riffle-pool sequence upstream of existing A9 (looking upstream)

WF89 (Lower Allt Girnaig)

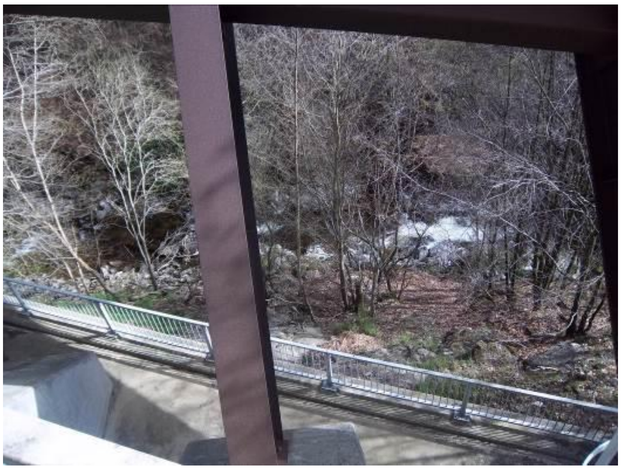
3.1.22 WF89 is a large watercourse which has its source on the southern slope of Beinn a' Ghlo at approximately 900m AOD. The water feature flows in a general south east direction for approximately 13km before discharging into the River Garry at Killiecrankie. The land use in the upstream section of the water feature is mainly rough pasture and moorland, with deciduous woodland in the downstream reach. A number of small drainage channels feed into the water feature throughout its course.

3.1.23 At the existing A9 crossing of the Allt Girnaig, the watercourse has a sinuous planform with exposed bedrock and boulder bed and an average width of approximately 3.5m. The watercourse typically has a step-pool sequence and is located within a steep ravine with a vegetated riparian buffer, measuring 20-30m on both banks, consisting of predominantly deciduous trees mixed with coniferous. The channel passes under large bridge structures for the existing A9, B8079 and Highland Main Line railway.

3.1.24 Analysis of historical mapping shows that the channel has remained largely stable since 1967. There is some evidence of localised lengths of erosion and deposition, as well as meander migration, particularly in the upstream reach.

3.1.25 WF89 is classified as a WFD water body, which is currently achieving Moderate overall status and High physical condition status.

Photograph 7: WF89 at the existing A9 bridge looking from the right bank to the left bank



Photograph 8: Looking downstream of the B8079 bridge crossing

WF98 (Allt Chluain)

3.1.26 Allt Chluain (WF98) is a medium watercourse which has its source on Carn Liath, where a number of small channels drain into Loch Moraig, from here the watercourse flows south for approximately 3km before flowing into the River Garry at Aldclune.

3.1.27 The watercourse has a relatively straight planform. The channel has gravel and cobble substrate, with some gravel and sand deposits and sections of exposed bedrock. The watercourse has a step-pool sequence and measures approximately 3.5m wide. The watercourse at the location of the existing A9 crossing has a vegetated riparian buffer of approximately 10m on both banks consisting of grasses and trees, potentially providing stability to the surrounding slopes. At the existing A9 crossing, a section of gabion mattresses has been eroded from the left bank and is falling apart in the centre of the channel. The watercourse is culverted under the Highland Main Line railway and B8079, and is crossed by a clear span bridge for the existing A9 and a local access route.

3.1.28 Historical mapping shows that the planform of the water feature has not changed significantly since first records in 1867.

Photograph 9: Step-pool sequence with some in-channel woody material (looking upstream)

Photograph 10: Collapsed gabion baskets in channel (looking downstream)

WF102

3.1.29 WF102 is a small watercourse, which has its source between Creag Odhar and Tulach Hill and measures approximately 1.1km from source to confluence with the River Garry. The watercourse has a predominantly sinuous planform with a step-pool sequence and gravel/pebble substrate.

3.1.30 The surrounding land use is typically deciduous woodland in the upstream reach of the catchment and pastoral agricultural land in the downstream reach. The water feature has a continuous vegetated riparian buffer on both banks consisting of trees, providing some stability to the channel banks. The watercourse is culverted under the existing A9 and a local access route and is crossed by a ford in the headwaters.

3.1.31 Historical mapping shows that the planform of the water feature has not changed significantly since first records in 1867.

Photograph 11: Typical channel cross-section (looking upstream)

WF103

3.1.32 WF103 is a small watercourse, which has its source on Tulach Hill, where it flows north for approximately 2km before flowing into the River Garry south of Blair Atholl. The catchment land use consists predominantly of moorland with some deciduous woodland in the downstream length.

3.1.33 The channel was observed to be approximately 1m wide and was incised with a slightly sinuous planform and step-pool sequence. The bed substrate typically consists of pebble and cobble; some sand deposits were noted. The vegetated riparian corridor within the lower part of the catchment consisted of a continuous lining of trees. The watercourse is culverted under the existing A9 and a local access route.

3.1.34 Analysis of historical mapping shows that the planform of WF103 has been subject to some alterations. In 1867, the source of the watercourse was approximately 130m to the west of the existing channel. The existing planform is then visible on maps subsequent to 1973.

Photograph 12: Step-pool sequence upstream of existing A9 (looking downstream)

Photograph 13: Steep channel with step-pool sequence (looking upstream)

WF104

3.1.35 WF104 is a small watercourse, which measures approximately 450m in length with average width of approximately 1.3m. The catchment land use consists of moorland in the upstream reaches and deciduous woodland in the downstream reaches. The watercourse has a straight planform, step-pool sequence and predominantly gravel substrate with a continuous tree lining on both banks. The watercourse is culverted under the existing A9 and a local access track and is crossed by a ford in the upstream reach above the existing A9.

3.1.36 Historical mapping shows that the planform of the water feature has not changed significantly since first records in 1867.

Photograph 14: Typical channel cross-section with step-pool sequence (looking upstream)

Photograph 15: Deciduous woodland (looking downstream)

WF111

3.1.37 WF111 is a small dynamic watercourse with an average width of approximately 0.4m, which has its source on Tulach Hill. The watercourse flows north under a local access track and the existing A9 for 800m to the River Garry south of Black Island. Catchment land use consists of moorland in the upstream section and deciduous woodland in the downstream sections. The watercourse has a step-pool sequence, cobble and pebble substrate.

3.1.38 Immediately upstream of the existing A9, the channel has formed a low-flow channel within a re-sectioned, concrete lined section of the water feature. The water feature flows into a manhole chamber before flowing under the existing A9 in a culvert.

3.1.39 Historical mapping shows that the planform of the water feature has not changed since first records in 1867.

Photograph 16: Typical channel cross-section south of the existing A9 (looking upstream)

Photograph 17: Section of bank reinforcement immediately upstream of the existing A9 (looking downstream)

WF114

3.1.40 WF114 is a small, incised watercourse with an average width of approximately 0.4m, which has its source to the east of Balnastuartach farm. The water feature flows north east for 610m under the existing A9 and a local access track to the River Garry south of Black Island. The channel has a step-pool sequence, with gravel and cobble substrate and eroding banks in the form of mass failure, slumping and poaching. The channel also has a hydraulic jump of approximately 0.75m south of the existing A9.

3.1.41 Historical mapping shows that WF114 flowed into the historic planform of Allt Bhaic prior to the construction of the existing A9.

Photograph 18: Typical channel cross-section upstream of the existing A9 (looking upstream)

Photograph 19: Typical channel cross-section downstream of the existing A9 (looking upstream)

WF115 (Allt Bhaic)

3.1.42 Allt Bhaic (WF115) is a medium watercourse with an average width of approximately 3.5m and has its source on the eastern side of Meall Reamhar at Meall na Glaic Domhainn. Here, the watercourse is referred to as Allt a' Choire Bhuidhe. The watercourse flows east for approximately 2km where it flows into Loch Bhac. From Loch Bhac, WF115 flows north for a further 5km before flowing into the River Garry to the west of Black Island. Catchment land use consists predominantly of coniferous woodland upstream of the loch and open moorland downstream of the loch. The watercourse has a sinuous or meandering planform for the majority of its course, with an intermittent riparian buffer zone. Upstream of the existing A9, several sections of the river bank have been reinforced with large cobbles and boulders.

3.1.43 Within the study area, the watercourse has a riffle-pool sequence, cobble and gravel substrate and is crossed by the existing A9, a local access track in the downstream section and by several forest tracks in the upstream section.

3.1.44 Analysis of historical maps shows that the Allt Bhaic historically flowed south east approximately 90m upstream of its existing confluence with the River Garry. From here, the channel ran parallel to the River Garry for approximately 0.5km before flowing into the River Garry south of Black Island. Between 1867 and 1900, the watercourse was realigned to flow into the River Garry at its current location. With the exception of this change, the channel has remained largely stable since 1867 with some localised sections of erosion and deposition and meander migration evident, particularly in the upstream sections.

3.1.45 WF115 is a WFD water body which is currently achieving Moderate overall status and High physical condition status.

Photograph 20: Looking upstream south of the existing A9

Photograph 21: Looking upstream north of the existing A9

WF121

3.1.46 WF121 is small field/woodland drainage channel measuring approximately 0.4m wide, which has its source approximately 900m south of the River Garry. The watercourse has a predominantly straight planform, gravel and cobble substrate and a step-pool sequence. Several gravel deposits are present in the downstream section as the gradient decreases. The channel is culverted under the existing A9 and a local access track.

3.1.47 Historical mapping shows that the planform of the water feature has not changed since first records in 1867.

Photograph 22: Typical channel cross-section south of the existing A9 (looking downstream)

Photograph 23: Large gravel deposit observed north of the existing A9 (looking upstream)

WF123 (River Bruar)

3.1.48 River Bruar (WF123) is a large watercourse and a tributary of the River Garry which has its source on Uchd a' Chlàrsair. From here, the water feature flows 17km south though Glen Bruar and Glen Banvie Wood to its confluence with the River Garry at Pitagowan. Catchment land use is predominantly open moorland and grassland in the upstream reach and mixed coniferous and deciduous woodland in the downstream reach. The watercourse has a meandering planform within both the upstream and downstream reaches.

3.1.49 Several dams are present in the headwaters of the watercourse and multiple bedrock waterfalls are present within a deep gorge within the downstream section. At Pitagowan the watercourse opens out into a shallow gravel and cobble bed river with a riffle-pool sequence. At this location, several depositional features are present. The River Bruar passes under the B8079, the Highland Main Line railway and several smaller access routes and forest tracks.

3.1.50 Analysis of historical mapping shows that WF123 has been subject to considerable meander and secondary channel migration, particularly within the upstream section. There have also been some changes related to the construction of dams north of Keepers Lodge and Ruidh Riabhach between 1900 and 1971 including the creation of dam ponds and upstream changes to channel planform.

3.1.51 The River Bruar (WF123) is a WFD water body which is classified as a Heavily Modified Water Body. It is currently achieving an overall status of Bad Ecological Potential and Good physical condition status.

Photograph 24: Section of exposed bedrock immediately upstream of the A8079 road (looking upstream)

Photograph 25: Large sand and gravel deposit observed immediately upstream of confluence with the River Garry (looking from right bank to left)

WF132

3.1.52 WF132 is a small watercourse which flows from WF133 north of Calvine. The watercourse flows south under the existing A9 and B847 to its confluence with the River Garry south of the Highland Main Line railway. The watercourse has a straight planform, which is likely to have been historically modified with evidence of bank reinforcement. During the site visit, there was some channel adjustment with evidence of erosion and deposition. The watercourse had a cobble and gravel bed with a step-pool sequence in the upstream reach.

3.1.53 Historical mapping shows that the planform of the watercourse has not changed significantly since first records in 1867.

Photograph 26: Typical channel cross-section with pipes in channel bed (looking downstream)

Photograph 27: Typical channel cross-section (looking upstream)

WF133

3.1.54 WF133 is a small watercourse which has its source on Elrig Bheithe and flows south for approximately 1km where it flows into WF132 and WF134 at Calvine. Catchment land use consists of mixed coniferous and deciduous woodland and open moorland. The watercourse has a sinuous planform, which is deeply incised in places. The channel has a step-pool sequence with a cobble and gravel bed. Where the channel splits and forms WF132, the channel becomes narrower. The watercourse is culverted under the existing A9 to where it is then referred to as WF134. Historical mapping shows that the planform of the watercourse has not changed significantly since first records in 1867.

Photograph 28: Typical channel cross-section north of the existing A9 (looking upstream)

Photograph 29: Typical channel cross-section north of the existing A9 (looking downstream)

WF140

3.1.55 WF140 is a dynamic medium watercourse which consists of Allt Chrannaich, two smaller drainage channels and a 325m section of the existing A9 road drainage. Allt Chrannaich has its source to the east of Clunes Wood approximately 700m north of the River Garry. Catchment land use consists of open moorland in the upstream sections and mixed coniferous and deciduous woodland in the downstream section.

3.1.56 The watercourse has a sinuous planform with a step-pool sequence and a cobble and gravel bed with some boulders. The channel downstream of the existing A9 had a concrete channel, which has been undermined exposing the bedrock below. Upstream of the existing A9, the two other channels to the east of Allt Chrannaich are sinuous and measure approximately 0.3m wide. Historical mapping shows that the planform of the water feature has not changed significantly since first records in 1867.

Photograph 30: Typical channel planform north of the existing A9 (looking upstream)

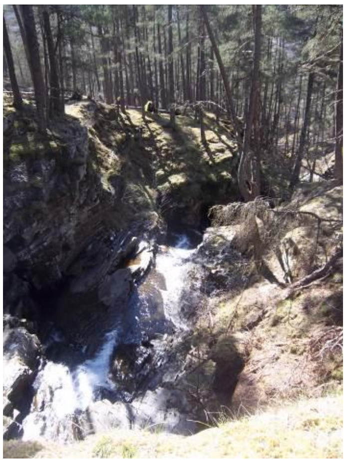
Photograph 31: Typical channel cross-section with exposed bedrock south of the existing A9 (looking upstream)

WF142 (Allt a' Chrombaidh)

3.1.57 WF142 is a dynamic watercourse with its source on Carn a'Chullaich, where it flows south through Gleann a'Chrombaidh for approximately 7km to its confluence with the River Garry at Drochaid na h-Uinneige. Catchment land use consists predominantly of open moorland with a section of deciduous woodland in the downstream section. The watercourse has a meandering planform with sections of deep gorge and bedrock waterfalls and cascades, particularly in the downstream section at Clunes Wood. The water feature is crossed by a clear span bridge for the existing A9 and a local access track.

3.1.58 Analysis of historical mapping shows that the channel has remained largely stable since 1867 with exception of some localised sections of erosion and deposition and meander migration evident, particularly in the upstream sections. The Allt a' Chrombaidh (WF142) is a WFD water body which is currently achieving Good overall status and Good physical condition status.

Photograph 32: Typical channel cross-section north of the existing A9 (looking downstream)



Photograph 33: Exposed section of bedrock north of the existing A9 and existing A9 bridge crossing (looking downstream)

WF149 (Allt nan Cuinneag)

3.1.59 Allt nan Cuinneag (WF149) is a medium watercourse which has its source on Fiacail Mhòr. From here, the watercourse flows south for approximately 1.8km before flowing under the existing A9 and a further 140m under a local access road to its confluence with the River Garry. Catchment land use consists primarily of open moorland with some deciduous woodland in the downstream section. The upstream section has stable meanders and no riparian buffer. The downstream section is set within bedrock and has a step-pool sequence with some gravel and cobbles present. The riparian zone within this section consists of trees and bushes. Immediately downstream of the existing A9 there is a large concrete spillway structure. With the exception of some minor lateral adjustment and meander migration in the upstream section, the planform of WF149 has not changed significantly since first records in 1867.

Photograph 34: Bedrock section of channel north of the existing A9 (looking upstream)

Photograph 35: Cascade and step-pool sequence (looking upstream)

WF151

3.1.60 WF151 is a small watercourse which has its source 150m north east of the existing A9. The watercourse flows under the existing A9 and west for a further 130m to its confluence with the River Garry. The watercourse is also culverted under a local access track. The watercourse upstream of existing A9 has a sinuous planform with a cobble/gravel bed. The water feature then passes under the existing A9 in a concrete channel, which continues approximately 40m downstream where a knickpoint (a sharp change in channel slope) has developed. The water feature has eroded the concrete chute into a natural cobble/gravel bedded channel which meanders to the confluence with the River Garry.

3.1.61 The watercourse is first shown on historical mapping in 1975. The planform of the channel has not changed significantly since.

Photograph 36: Typical channel cross-section north of the existing A9 (looking upstream)

Photograph 37: Typical channel cross-section south of the existing A9 (looking upstream)

WF88/167 (Allt Crom Bhruthaich)

3.1.62 Allt Crom Bhruthaich (WF88/167) is a large watercourse which has its source north of Fiacail na Creige. The watercourse flows 2.75km south east where it is culverted under the existing A9. The water feature flows a further 250m under a local access road to its confluence with the River Garry. Catchment land use predominantly consists of open moorland. The watercourse had a meandering planform in the upstream section and sinuous in the downstream section. The upstream section appeared to be severely impacted by abstraction with no water in the channel at the time of survey. A number of waterfalls were present in the downstream section. The channel had a boulder and cobble substrate and a steep gradient.

3.1.63 Analysis of historical mapping shows that WF88/167 has undergone some lateral adjustment and meander migration through erosion and deposition since 1867, particularly in the upstream section.

Photograph 38: Existing A9 Allt Crom Bhruthaich Underbridge (looking upstream)

Photograph 39: Section of channel immediately upstream of the existing A9 crossing (looking upstream)

WF154

3.1.64 WF154 is a small watercourse with its source approximately 600m north east of the existing A9. The watercourse flows south east for 850m, under the existing A9 and a local access route before its confluence with the River Garry. Catchment land use consists of open moorland. The watercourse upstream of the existing A9 has a sinuous planform with cobble and gravel substrate and measures approximately 1m wide at bankfull. The channel in this location has a step-pool sequence. Downstream of the existing A9, the channel has sections of exposed bedrock and a straighter planform. The channel has some boulders present in the channel, which could be due to anthropogenic influences.

3.1.65 Analysis of historical mapping shows that WF154 has undergone some lateral adjustment and meander migration through erosion and deposition since 1867, particularly in the upstream section.

Photograph 40: Upland land use north of the existing A9 (looking upstream)

Photograph 41: Typical channel substrate north of the existing A9 (looking upstream)

WF156

3.1.66 WF156 is a small watercourse which has its source in Dalnamein Forest. The watercourse flows south for approximately 650m south under the existing A9 and a local access track to its confluence with the River Garry north of Dalinturuaine. The watercourse has an irregularly meandering planform with a bedrock, cobble and gravel bed and step-pool sequence in the upstream section. In the downstream section the water feature widens to approximately 1.5m, has a uniform channel cross-section and riffle-pool sequence. Analysis of historical mapping shows that some minor changes to the planform were made to the south of access track between 1988 and the present day.

Photograph 42: Typical channel cross-section and substrate north of the existing A9 (looking upstream)

Photograph 43: Typical channel cross-section south of the existing A9 (looking upstream)

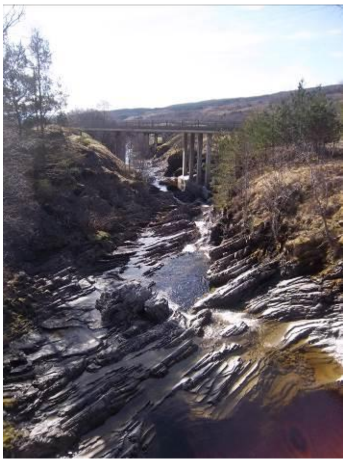
WF158 (Allt Anndeir)

3.1.67 Allt Anndeir (WF158) is a large watercourse which has its source on A'Chaoirnich, where it is referred to as Allt Glas Choire. The watercourse flows south for 10.8km to its confluence with a tributary, Allt a' Chreachain. The reach downstream of the confluence is referred to as Allt Anndeir and flows for approximately 1.7km to its confluence with the River Garry east of Dalnamein Lodge. Catchment land use consists of open moorland and coniferous woodland.

3.1.68 In the upstream section the watercourse has a stable meandering planform with a wider river corridor consisting of gravels, pebbles and cobbles. The channel in the downstream section has a bedrock bed and step-pool sequence. There are also several small cascades within this section of the water feature. WF158 is crossed by a clear span bridge for the existing A9 and a local access road.

3.1.69 Analysis of historical mapping shows that WF158 has undergone some lateral adjustment and meander migration through erosion and deposition since 1867, particularly in the upstream section. Allt Anndeir (WF158) is a WFD water body which is classified as a Heavily Modified Water Body and is currently achieving an overall status of Bad Ecological Potential and High physical condition status.

Photograph 44: Section of exposed bedrock and existing A9 bridge crossing (looking downstream)



Photograph 45: Confluence with the River Garry downstream of the existing A9 crossing (looking downstream)

WF159

3.1.70 WF159 is a small watercourse which has its source from a series of drains and a wetland area (TN194) identified as a Groundwater Dependent Terrestrial Ecosystem (GWDTE) (refer to Appendix A10.2: Ecological Receptors with Potential Groundwater Component) north of the existing A9 at Tigh-na-Coille. The watercourse flows parallel to the existing A9 for 350m before flowing under the existing A9 and a local access road and south east or a further 620m to its confluence with the River Garry at Dalnamein Lodge. Catchment land use consists of open moorland and coniferous woodland.

3.1.71 The series of drains have straight planforms and feed into the main channel which has a wider and more defined channel with reinforced banks. The main channel has a straight planform with evidence of some channel adjustment. The channel has a boulder, cobble and gravel bed with some side bars and undercutting of banks. The channel is incised in places. Historical mapping shows that the planform of the water feature has not changed significantly since first records in 1867.

Photograph 46: Reinforced channel cross-section south (downstream) of the existing A9 (looking upstream)

Photograph 47: Channel cross-section north (upstream) of the existing A9 (looking upstream)

WF164 (Allt Geallaidh)

3.1.72 Allt Geallaidh (WF164) is a medium watercourse which has its source on Carn a' Mhurraich and flows south for 7km under the existing A9 and a local access route to its confluence with the River Garry. Catchment land use consists of open moorland and mixed coniferous and deciduous woodland.

3.1.73 WF164 has a stable meandering planform with sections of bedrock step-pool sequences and some cobbles. Within the downstream section there are waterfalls, with water cascading over bedrock. There are some sections of bank reinforcement at the existing A9 Allt Geallaidh Underbridge (a single span culvert with concrete deck and invert installed below the channel bed, sized to the channel width) consisting of large gabion baskets and gabion mattresses, which are undermined in some locations. A small dam and a weir are also present on the water feature. WF164 is also crossed by a single span bridge for a local access road.

3.1.74 At the time of observation, a low flow channel had exposed large sections of the river bed and gravel side bars upstream and downstream of the existing A9 crossing. Within the underbridge, a large bench/bar feature occupied approximately half of the existing channel bed, diverting the low flow channel against the artificial left bank as shown in photograph 49.

3.1.75 Analysis of historical mapping shows that WF164 has undergone some lateral adjustment and meander migration through erosion and deposition since 1867, particularly in the upstream section.

Photograph 48: Section of exposed bedrock upstream of existing A9 (looking upstream)

Photograph 49: Existing A9 Allt Geallaidh Underbridge crossing and large gravel bar (looking upstream)

WF165 (Allt Carn na Saidhe)

3.1.76 Allt Carn na Saidhe (WF165) is a medium watercourse which has its source on A'Bhuidheanach Bheag. The watercourse flows in a general southerly direction for approximately 14km, under the existing A9 and a local access road (crossed by two single span bridges) before flowing into the River Garry north of Garbh-bhruach Shios. Upstream of the existing A9 the water feature has a sinuous planform with some areas of deposition and cobble and pebble substrate with a low flow channel. Downstream of the existing A9 is a modified lined trapezoidal channel with some natural features such as cobble deposits. A dam and a pond are also present on the water feature.

3.1.77 Analysis of historical mapping shows that WF165 has undergone some lateral adjustment and meander migration through erosion and deposition since 1867, particularly in the upstream section.

Photograph 50: Typical channel cross-section south of the existing A9 (looking downstream)

Summary

3.1.78 Following the assessment of the baseline condition for each water feature, a sensitivity level has been assigned based on the methodology outlined in Section 11.2 (Approach and Methods) of Chapter 11 (Road Drainage and the Water Environment) of the ES. Table 2 below provides a summary of the medium, high and very high sensitivity water features.

Table 2: Overview of fluvial geomorphology sensitivities of Medium and above

Water Feature ID	Qualifying criteria for sensitivity of water features	Sensitivity
142	Water feature sediment regime provides a mosaic of habitat types suitable for species sensitive to change in sediment concentration and turbidity. Water feature includes varied morphological features with no sign of channel modification. Water feature displays natural fluvial processes and natural flow regime, which would be highly vulnerable to change as a result of modification.	Very High
100 (upper and lower); 89; 115; 123; 158; 164	Water feature sediment regime provides habitats suitable for species sensitive to changes in sediment concentration and turbidity. Water feature exhibiting a natural range of morphological features, with limited signs of artificial modifications or morphological pressures. Predominantly natural water feature with a diverse range of fluvial processes that is highly vulnerable to change as a result of modification.	High
84; 87; 98; 102; 103; 104; 111; 114; 121; 132; 133; 140; 149; 151; 167; 154; 156; 159; 165	Water feature sediment regime provides some habitat suitable for species sensitive to change in suspended sediment concentrations or turbidity. Water feature exhibiting some morphological features. Water feature with some natural fluvial processes, including varied flow types.	Medium

4 Potential Impacts

4.1.1 The potential impacts of the proposed scheme on fluvial geomorphology have been divided into construction and operational impacts. The construction impacts are those associated with activities undertaken during the construction phase and are therefore considered to have shorter-term effects. The operational impacts are considered to be longer-term impacts.

4.1.2 The following assessment of potential impacts is based on the proposed scheme without considering mitigation. Where embedded mitigation has been included within the design, this is accounted for in the potential impacts assessment. This includes (but is not limited to):

- geomorphology design input to outfall locations;

- geomorphology input to channel realignments (consideration of optimum lengths, gradients, alternative routing etc.);
- geomorphology input to culvert extensions and new or replacement culverts on minor watercourses to ensure appropriate channel gradients and continuity (upstream and downstream);
- recommendations for optimal bridge designs e.g. clear span, set back abutments; and
- flood risk input to sizing of culverts.

4.1.3 The most significant risks of potential impacts on the fluvial geomorphology of water features are associated with:

- Increases in fine sediment delivery to water features with potentially detrimental effects on sensitive species. These could result during construction and operation of the proposed scheme.
- Reductions in the morphological diversity of river channels, for example due to culverting, bank and bed protection and realignment works.
- Alteration of the natural functioning of the river channel (natural fluvial processes), for example prevention of channel migration due to bank protection, bridge pier installation or culverting. The interruption of natural fluvial processes may have negative consequences upon WFD targets due to detrimental effects on habitat diversity.
- Accelerated fluvial activity such as an increase in the rate of bank erosion in response to channel engineering, such as unsympathetic channel realignment. Accelerated bank erosion leading to an increase in fine sediment delivery, can have impacts where sites of importance for freshwater ecology are located downstream.

General Impacts

4.1.4 An outline of the potential general impacts on the fluvial geomorphology elements (sediment regime, channel morphology and natural fluvial processes) of the water features during both construction and operation are provided in Chapter 11 (Road Drainage and the Water Environment). The following provides a summary of the potential impacts likely to occur:

<u>Construction</u>

- vegetation clearance and topsoil stripping;
- in-channel construction (including structures such as culverts, outfalls and bridges);
- channel realignments and diversions (including release of flow into new channels); and
- construction with the floodplain.

<u>Operation</u>

- culverting (including culvert extensions and replacements);
- outfall structure and associated discharges;
- bridge structure;
- permanent realignment (or diversions); and,
- changes to flow paths and catchment areas.

Site Specific Impacts

4.1.5 An impact assessment for both the construction and operation of the proposed scheme has been undertaken for all water features and is provided in Appendix A11.7 (Impact Assessment). Table 3 provides a more detailed understanding of the impacts on fluvial geomorphology for the medium, high and very high sensitivity water features. The assessment has considered the existing baseline (as outlined in Section 3: Baseline) and the key fluvial geomorphology elements (sediment regime, channel morphology and natural fluvial processes).

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Table 3: Specific impact assessment for construction and operation on fluvial geomorphology

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
WF100 (River Garry)	**Release of suspended sediments** Potential fine sediment input to watercourse from direct construction activities within the channel and indirectly from works within the tributaries. This could lead to changes of the morphological features present, including smothering of bed substrate and depositional features. **Works within the vicinity of the water feature** Works within the vicinity and along the banks of the River Garry altering channel banks and reducing floodplain area. This would alter the lateral connectivity of the water feature. **New bridge (River Garry Underbridge)** New bridge (clear span) construction at Pitaldonich (ch11200) requiring works over the channel and within the floodplain. Leads to temporary changes in lateral connectivity during construction and potential for disturbance of in-channel morphological features. **New bridge (Essangal Underbridge)** The design of the Essangal Underbridge (ch4300) includes piers within the channel cross-section, therefore in-channel works would be required during their construction. This would also lead to the removal of lengths of natural bed and banks to accommodate the structure. There is the potential for increased risk of fine sediment delivery downstream during in-channel works smothering bed substrate. Due to removal of natural features, potential for movement of coarse material downstream. Excavation of the river bed to install scour protection would further disturb the channel bed. Works in the channel are likely to require a dry working area leading to some form of dam being put in place within the channel, further disturbing the channel bed. **Outfalls** Permanent removal of a length of natural bank and bed at each outfall, with localised changes to flow dynamics and the potential for alterations in sediment processes. Lateral connectivity with the floodplain altered as a result of new headwall. Permanent removal of riparian vegetation. Potential for localised erosion of bed and banks around headwall structure.	moderate adverse	**New bridge (River Garry Underbridge)** Located at Pitaldonich, ch11200. The new bridge abutments are proposed to be located within the floodplain of the River Garry, altering lateral connectivity. Changes to flow processes during out of bank flows as a consequence could alter morphological processes within the channel upstream, at the crossing itself and downstream. This is of particular importance in flood conditions where the longer extent of bridge abutment is likely to increase the velocity of flows downstream. Approximately 200m downstream, the river channel is actively eroding the outside of the bend, which could be altered as a consequence of the new abutments. There ae also side roads proposed on each bank further altering lateral connectivity. **New bridge (Essangal Underbridge)** The pier in the floodplain and in the channel is likely to lead to localised impacts around the bridge and some channel adjustment downstream. This would include: scour around the pier; erosion of the upstream face of the existing deposit on the left bank; deflection of flows towards the right bank potentially causing incision against the existing bank reinforcement; scour of the upstream pool; partial loss of the existing riffle feature as a result of the pier; and, potential deposition downstream of eroded material. Annex 1 provides a geomorphological note detailing the potential impacts as a result of the new in-channel pier. **Outfalls** There are eight proposed outfall structures located along the River Garry (WF100). This would lead to the permanent removal of the natural bed, banks and vegetated riparian corridor. Subsequently this would lead to changes in flow processes and sediment movement. Three of the outfalls are located within a length of the River Garry that has a bedrock bed and banks. Therefore, these are not considered to have a significant effect on the channel cross-section. However, these would still require the removal of the vegetated riparian corridor.	moderate adverse
WF84 (Allt Eachainn)	**Release of suspended sediments** Potential for fine sediment input from carriageway widening activities, including removal of riparian vegetation.	Negligible	No activities anticipated to impact fluvial geomorphology	Negligible
WF87 (Troopers Den Burn)	**Release of suspended sediments** Fine sediment input from culvert extension construction, channel realignment and the general construction of the mainline widening and realigned side road (i.e. from bare earth surfaces). This could lead to changes of the morphological	moderate adverse	**Realigned side road** The realigned side road would alter floodplain connectivity, potentially leading to changes in runoff and subsequently flow and sediment processes during high flows. **Culvert extension**	minor adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
	features present, including smothering of bed substrate and depositional features. **Culvert extension** Alteration to the steep watercourse banks and natural bedrock bed as a result of the culvert extension. There would also be disturbance of the existing morphological features within the channel (notably the natural step-pool sequence). **Channel realignment** Disturbance to the existing morphological feature during construction of the realignment and potential infilling of channel to link with the proposed new culvert.		The extended culvert would alter the existing channel cross-section and remove existing riparian vegetation (including established trees). The extended culvert bed and apron would remove the natural bed substrate. The culvert would also change the gradient of the channel by slackening it and creating a steeper length downstream of the apron. This would alter existing flow processes, subsequently leading to changes in the potential for erosion downstream and the morphological features present (including deposits).	
WF89 (Lower Allt Girnaig)	**Release of suspended sediments** Potential for fine sediment input to watercourse from construction of new bridge and new side roads (i.e. from bare earth surfaces). **New bridge** Works within the vicinity and at the top of the valley slopes of the watercourse associated with the bridge construction. Potential for the disturbance of the adjacent riparian vegetation (particularly established trees). **Outfall (two in total)** Permanent removal of a length of natural slope at each outfall, with localised changes to flow dynamics and the potential for alterations in sediment processes. Permanent removal of riparian vegetation.	minor adverse	**New bridge** The new bridge abutments would remove a short length of the watercourse valley slope. However, this is not considered to be extensive or within close proximity to the watercourse cross-section. **Outfall (two in total)** Potential for flow pathways to be created down the steep valley slopes from the outfalls located at the top. As a result, fine sediment could be entrained as the water flows down the slope and enter the channel. This, combined with potential silt input from outfall discharges, could alter sediment processes and the structure of the bed substrate.	minor adverse
WF98 (Allt Chluain)	**Release of suspended sediments** Potential fine sediment input to river from construction activities from new access track (leading to bare earth surfaces), with associated changes to morphological features. The increased fine sediment could smother existing bed substrate and alter sediment processes. **Bridge extension, new bridge and access track** Embankment construction for new access track within bridge extension, requiring works within the channel disturbing valley slope, banks, step-pool sequence and substrate. Removal of riparian vegetation around the bridge extension. **Outfall** Disturbance a length of natural bank and bed at outfall location, with localised changes to flow dynamics and the potential for alterations in sediment processes. Permanent removal of riparian vegetation as a result of the structure altering localised slope stability. **Channel realignment (tributary)** Alteration to downstream movement of sediment to sensitive watercourse when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	minor adverse	**Bridge extension, new bridge and access track** New access track potentially alters runoff entering the watercourse, as the existing access track has collapsed into the channel and has no formal drainage. The changes to runoff reaching the water feature could consequently alter flow and sediment processes particularly during high flows. Re-profiling of the existing steep valley slope for the bridge extension and new bridge could alter the existing morphological processes. The channel is currently unstable and there is the potential for erosion of the right bank which could undermine the new side road embankment due to proximity to the river edge. **Outfall** Permanent removal of the natural bed, banks and vegetated riparian corridor. As a result, this would lead to changes in flow processes and sediment movement. **Channel realignment (tributary)** Realignment of small watercourse feeding in to main channel, leading to a slight lengthening in the channel altering the gradient. The increased gradient is likely to lead to slacker flows and increased potential for siltation. However, this is unlikely to have a significant impact due to the modified nature of the channel.	minor adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
WF102	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side roads (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes. **Culvert extension** Works within the watercourse for culvert extension and new culvert, leading to removal of earth banks and gravel and pebble bed. The culvert works would also lead to the removal of the vegetated riparian corridor, including established trees. **Channel realignment** Modification to existing channel planform. Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	moderate adverse	**Culvert extension** The culvert extension would remove a long length of bed and banks, including existing step-pool sequence. The culvert gradient would also be decreased as a result, altering the flow processes. The new side road would also alter the floodplain connectivity leading to changes in runoff and potentially flow and sediment processes particularly during high flows. **Channel realignment** Potential changes to the localised channel gradient where channel is lengthened. However, proposed works are minimal and unlikely to have a significant impact.	moderate adverse
WF103	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes. **New (2) and replacement (1) culverts** Works within the watercourse for new and replacement culverts, leading to removal of earth banks, sand deposits and cobble bed. Removal of vegetated riparian zone, including established trees. **Channel realignment** Realignment of channel within the vicinity of the new culverts to allow for the change in channel gradient under the proposed road. Removal of channel morphological features. Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	moderate adverse	**New side road** The new side road alters the floodplain connectivity both upstream and downstream of the A9, leading to changes in runoff and potential flow and sediment processes particularly during high flow. **New (2) and replacement (1) culverts** Three new/replacement culverts would allow the watercourse to pass under the new side road and main carriageway. The culverts would lead to the removal of a long length of natural bed and banks, including existing step-pool sequence and natural cobble and pebble bed substrate. The new culverts would also alter the lateral and longitudinal connectivity within the watercourse, including the continuity of the vegetated riparian corridor. **Channel realignment** Changes in the channel gradient within the vicinity of the new culverts leading to changes in flow and sediment processes. Loss of natural morphological features in new channel.	moderate adverse
WF104	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes. **New (2) and replacement (1) culverts** Works within the watercourse for the new and replacement culverts would lead to the removal of the natural earth banks and gravel bed. The works would also remove the vegetated riparian zone, including established trees. **Channel realignment**	moderate adverse	**New side road** The new side road would alter floodplain connectivity leading to changes in runoff and potential flow and sediment processes, particularly during high flow. **New (2) and replacement (1) culverts** The three new culverts would remove a long length of bed and banks, including existing step-pool sequence and natural cobble and pebble bed substrate. The new culverts would also alter the lateral and longitudinal connectivity within the watercourse, including the continuity of the vegetated riparian corridor. **Channel realignment**	moderate adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
	Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.		Changes in the channel gradient within the vicinity of the new culverts leading to changes in flow and sediment processes. Loss of natural morphological features in new channel.	
WF111	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes. **New (1) and replacement (1) culverts** Removal of earth banks and cobble and pebble bed as a result of construction works with the channel. **New upstream cascade feature** <u>A new cascade feature will be required to train the flow of water to the culvert entrance. This will be developed at specimen design stage as a bedrock / naturalised or concrete (stone pitched) cascade.</u> **Channel realignment** Modification to existing channel planform. Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	moderate adverse	**New (1) and replacement (1) culverts** New/replacement culverts leading to permanent removal of a length of dynamic channel with natural bed and banks. There would also be the potential for alteration to the channel downstream of culvert (including erosion or deposition) as a result of channel adjustment in response to the modifications a. **Channel realignment** Changes in the channel gradient within the vicinity of the new culverts leading to changes in flow and sediment processes. Loss of natural morphological features in new channel.	moderate adverse
WF114	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening. **Replacement culvert** Removal of earth banks and cobble and gravel bed as a result of in-channel works and regrading of the channel to tie-in with the new re-graded culvert. **Channel realignment** Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	moderate adverse	**Replacement culvert** The replacement culvert would lead to the removal of a length of natural bed and banks. A cascade feature would be required to drop the existing channel into the new culvert. This could alter the flow and sediment processes and potentially lead to scour around the banks and inlet of the culvert. **Channel realignment** Changes in the channel gradient within the vicinity of the new culvert leading to changes in flow and sediment processes. Loss of natural morphological features in new channel. There is also a requirement for a small tributary to the main channel (a drainage channel) to be realigned as well. This has the potential to alter flow pathways and subsequently flow processes in the main channel.	moderate adverse
WF115 (Allt Bhaic)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening. The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **New bridge (replacement)** The demolition of the existing bridge and construction of the new bridge would require the disturbance of the existing earth banks and cobble and gravel bed, as well as extensive in-channel working potential destabilising the	moderate adverse	**New bridge (replacement)** New bridge abutments leading to the removal of an additional length of natural bank. The abutments and new structure would lead to the complete removal of an area of eroding bank and small deposit. The channel at this location appears to be adjusting due to impacts of the existing bridge and historical modification; similar impacts could occur upstream of the new bridge in response to the modification of the channel. **Channel realignment**	moderate adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
	watercourse. Channel adjustment could occur as a result in response to the construction works and temporary modification to the channel cross-section. **Channel realignment** Realignment of small drains forming two tributaries of the main channel, leading to fine sediment input to Allt Bhaic. Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment. **Outfall (two in total)** Disturbance a length of natural bank and bed at the outfall locations, with localised changes to flow and sediment processes.		Potential changes to the localised channel gradient where channel is lengthened along the toe the embankment. However, proposed works are minimal and unlikely to have a significant impact, particularly due to the modified nature of the channels. **Outfall (two in total)** Potential changes to input of fine sediment from outfall discharge. Changes to flow processes in the watercourse as a result of discharges, although this is unlikely to lead to erosion as a result of the controlled greenfield discharges proposed. Outfalls staggered to avoid potential for cumulative impacts as a result of the discharges being focused within one part of the channel.	
WF121	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **Replacement culvert** Removal of earth banks, step-pool sequence and natural substrate as a result of in-channel works.	minor adverse	**Replacement culvert** Replacement culvert leading to permanent removal of a length of gravel and cobble bed, associated step-pool sequence and banks. Removal of riparian vegetation, including established trees. There would also be the potential for alteration to the channel downstream of the culvert (including erosion or deposition) as a result of channel adjustment in response to the modifications. The watercourse would likely be altered upstream and downstream to tie in with the culvert replacement, potentially altering the channel gradient as a result.	minor adverse
WF123 (River Bruar)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction in the proximity of the watercourse.	negligible	No activities anticipated to impact fluvial geomorphology	negligible
WF132	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces) and new access track. The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **Culvert replacement (partial)** Disturbance of banks and cobble bed, as well as natural morphological features such as the step/pool sequence. Potential for channel adjustment upstream as a result of in-channel working.	minor adverse	**Culvert replacement (partial)** Potential for alteration to the channel downstream of the culvert (including erosion or deposition) as a result of channel adjustment in response to the modifications.	negligible adverse
WF133	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features.	negligible adverse	No activities anticipated to impact fluvial geomorphology	negligible adverse
WF140	**Release of suspended sediments**	minor Adverse	**Replacement culvert**	minor Adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
	Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes. **Replacement culvert** Removal of banks and bed as a result of in-channel construction works. **New upstream cascade feature** A new cascade feature will be required to train the flow of water to the culvert entrance. This will be developed at specimen design stage as a bedrock / naturalised or concrete (stone pitched) cascade. **Channel realignment** Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment		The replacement culvert would lead to the removal of a length of natural bed and banks to the north of the existing A9 carriageway. The extension would also alter lateral connectivity for a longer length around the existing A9. Potential for changes in the watercourse corridor (i.e. v-shaped valley) from culvert structure. **Channel realignment** Realignment of the small drains entering the main channel. This could potentially alter the length and gradient of the drains, with subsequent changes in the fluvial processes and morphological features in main channel.	
WF142 (Allt a' Chrombaidh)	**Release of suspended sediments** Potential fine sediment input to river from construction activities (i.e. from bare earth surfaces) with associated changes to morphological features. The increased fine sediment could smother existing bed substrate and alter sediment processes. **New bridge (replacement)** Works within the vicinity and along the banks of WF142 altering channel slopes and floodplain area during construction of new bridge.	negligible	**New bridge (replacement)** Proposed bridge abutments set at the top of the vertical bedrock banks, potentially altering runoff entering the watercourse and removing a localised sediment source. However, the impact of the abutments is considered to be insignificant.	negligible
WF149 (Allt nan Cuinneag)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction of bridge extension and mainline widening. **Bridge extension** Alteration to watercourse banks and bed through construction works. Disturbance/removal of existing morphological features within the channel (particularly bedrock features) and potential changes to flow processes.	minor adverse	**Bridge extension** The extension of bridge downstream would be over a length of bedrock step-pools. The bridge would lead to the removal of some lateral connectivity, potentially leading to high flows being passed through the length quicker. As well as this the downstream extent of the new structure would lead to the infill of an existing bedrock cascade.	minor adverse
WF151	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **Culvert extension** Removal of banks and bed during construction works. **Channel realignment** Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	minor adverse	**Culvert extension** The culvert extension would replace a length of concrete channel, further removing lateral connectivity of the watercourse with its floodplain and the vegetated riparian corridor. The culvert extension would be located approximately 20m upstream of a knickpoint, which could potentially continue migrating upstream and undermine the A9 structure. The rate of upstream retreat could also be exacerbated by the additional modification to the water feature bed and banks. Changes in fluvial processes would potentially lead to further erosion **Channel realignment** Modification to existing channel planform and potential lengthening of channel course. This could lead to changes in the channel gradient and subsequent impacts on flow and sediment processes.	moderate adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
WF167 (Allt Crom Bhruthaich)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the water feature and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). As the water feature is typically dry, the sediment would be deposited and could smother existing bed substrate. However, this is likely to be temporary until the next flow is released down the channel. **New bridge (replacement)** Alteration of channel banks from construction works with potential removal of bed substrate.	minor adverse	**New bridge (replacement)** The new bridge abutments would alter the existing channel cross-section, with removal of some lateral connectivity; although the channel is confined within a valley downstream. Bridge design requires the new structure to span further downstream over an established bar, with some flow directed to the left bank which is currently eroding. These features would be removed as a result of the bridge replacement. Channel adjustment could be possible during releases down the river, although the dry nature of the channel during the majority of the year would limit the potential for erosion and deposition.	minor adverse
WF154	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **Replacement culvert** Removal of banks and bed during construction works within the channel. **Channel realignment** Excavation of the floodplain to form the new realigned channels. Alteration to downstream movement of sediment when constructed realigned channels (tributaries of the main channel) are connected, with water passing down the channel entraining newly exposed sediment.	moderate adverse	**Replacement culvert** The replacement culvert would lead to the removal of the natural bed and bank as well as the lateral connectivity with the floodplain within the defined valley. This would lead to changes in the flow and sediment processes. Potential for channel adjustment upstream and downstream of the new culvert as a direct consequence of the modifications due to the steeper nature of the water feature created. **Channel realignment** Changes to the gradient of the channel, altering flow processes and morphological features.	moderate adverse
WF156	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes and morphological features. **New (1) and replacement (1) culverts** Removal of banks and bed. Removal of vegetated riparian corridor. Excavation of the floodplain to form new realigned channels. **Channel realignments** Alteration to downstream movement of sediment when constructed realigned channels connected, with water passing down the channels entraining newly exposed sediment.	moderate adverse	**New access track** The new side road would alter the floodplain connectivity leading to changes in runoff and potential flow and sediment processes, particularly during high flow. **New (1) and replacement (1) culverts** The two new/replacement culverts would lead to the removal of the natural bed and banks, as well as disturbing the natural step-pool sequence. The proposed scheme would also require the permanent removal of riparian vegetation (particularly notable upstream of the existing A9). Potential for channel adjustment upstream and downstream of the new culverts as a direct consequence of new/extended structures within the water feature, particularly due to the steeper nature of the channel. **Channel realignments** Potential for change in flow and sediment processes from new realignments. Changes to the gradient of the channel would alter the flow processes and morphology.	moderate adverse
WF158 (Allt Anndeir)	**Release of suspended sediments**	minor adverse	**New and replacement bridges**	minor adverse

Source of Impact	Construction impacts	Magnitude of impact	Operational impacts	Magnitude of effect
	Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). **New and replacement bridges** Removal of banks. Removal of vegetated riparian corridor. Excavation of the floodplain to form new realigned tributary to the main channel. **Outfalls (two in total)** Disturbance of a length of natural bank at each outfall, with localised changes to flow processes during the works. Permanent removal of riparian vegetation. **Channel realignment (tributary)** Alteration to downstream movement of sediment to sensitive watercourse when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.		Potential for alteration of lateral floodplain connectivity due to new embankments and bridge abutments. However, the watercourse sits within a bedrock gorge and modification to the banks would be unlikely to have a significant impact. **Outfalls (two in total)** The two outfalls would alter the flow processes in the channel as a result of the discharges. The discharges are also located in a length where there are mobile deposits; the new flows have the potential to locally alter the morphological processes. **Channel realignment (tributary)** Realignment of small watercourse feeding in to main channel, leading to a slight lengthening in the channel altering the gradient. The increased gradient is likely to lead to slacker flows and increased potential for siltation. However, this is unlikely to have a significant impact due to the modified nature of the channel.	
WF159	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening and new side road (i.e. from bare earth surfaces). **Replacement culvert** Removal of banks during construction works. The site would require the excavation of the floodplain to form new realigned channel. **Channel realignment** Alteration to downstream movement of sediment when constructed realigned channel connected, with water passing down the channel entraining newly exposed sediment.	minor adverse	**Replacement culvert** The replacement culvert would lead to the removal of a length of natural bed and banks. The extension would also alter lateral connectivity with the floodplain. However, the channel is already modified and any changes are unlikely to lead to a significant impact. **Channel realignment** Potential for change in flow and sediment processes from new realignment as a result of changes to the gradient of the channel.	minor adverse
WF164 (Allt Geallaidh)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). **New bridge (replacement)** Removal of banks and changes to channel cross-section during construction works. **Outfall** Disturbance a length of natural bank and bed at the outfall locations, with localised changes to flow and sediment processes.	moderate adverse	**New bridge (replacement)** The bridge design requires new abutments on both banks. The left bank is reinforced upstream and there would be no additional impact of the new abutment. Downstream the bridge abutment would remove a short additional length of natural bank that is currently eroding. There would be the potential to alter the existing deposit at the toe of the bank; however, this is likely to be an adjustment feature associated with the straightening downstream of the bridge and not a natural feature. **Outfall** The new outfall would be located upstream of the existing bridge with the potential for scour from the discharges altering flow processes around the existing structure.	minor adverse
WF165 (Allt Carn na Saidhe)	**Release of suspended sediments** Temporary increase in fine sediment delivery from construction within the watercourse and associated earthworks and vegetation clearance with the mainline widening (i.e. from bare earth surfaces). The increased fine sediment could smother existing bed substrate and alter sediment processes.	negligible	No permanent structures are located within the channel, with mainline widening located over 65m from the water feature. No impact anticipated.	negligible

Significance of Impacts

4.1.6 The specific impact assessment has identified that there would likely be significant potential impacts (i.e. **Moderate** or above), without considering mitigation, on the following water features:

Construction

- WF100 (lower) (River Garry) – **Large** significance: as a result of fine sediment input from works within the channel and all tributaries in the catchment. Also the two proposed bridges and eight outfalls would require works within the channel and floodplain, altering morphological processes and features.
- WF87 (Troopers Den Burn) and WF111 – **Moderate** significance: as a result of fine sediment input from works within the channel and removal of morphological features (including a step-pool sequence) during construction.
- WF102, WF103, WF104, WF114 and WF156 – **Moderate** significance: as a result of fine sediment input from works within the channel and removal of morphological features during construction.
- WF115 (Allt Bhaic) – **Moderate** significance: as a result of fine sediment input from works within the channel and extensive modifications to the water feature channel as a result of demolition and construction of new bridge.
- WF154 – **Moderate** significance: as a result of fine sediment input from works within the water feature and the removal of a large section of existing earth road drain.
- WF164 (Allt Geallaidh) – **Moderate** significance: as a result of demolishing the existing bridge and construction of new bridge resulting in the input of fine sediment to the water column. The construction could also potentially cause disturbance to existing morphological features within the channel, in particular bedrock features including a large depositional feature.

Operation

- WF100 (lower) (River Garry) – **Moderate** significance: as a result of new bridge structure at Pitaldonich and addition of bridge piers in the channel and floodplain at the Essangal Underbridge, altering lateral connectivity, channel morphology and flow processes. Work by Gregory and Brookes (1983) indicates that channels constrained by bridges can cause erosion over time for distances up to in excess of 10 times the river channel width. This is largely due to the constriction caused by a bridge at varying flow conditions. As a result, potential impacts at Pitaldonich could extend up to approximately 300m downstream (approximately one third of the morphological reach) and up to approximately 400m at Essangal (20% of the morphological reach). For the River Garry Underbridge at Pitaldonich this could mean impacts extending downstream into another morphological reach.
- WF102, WF103, WF104, WF111, WF114 and WF132 – **Moderate** significance: due to the removal of natural river bed and banks. The structures would alter geomorphological features (including bed substrate and associated flow types), flow patterns, constrict flow, confine the channel and remove/alter of lateral and longitudinal connectivity.
- WF115 (Allt Bhaic) – **Moderate** significance: as a result of the proposed bridge extension completely removing an existing adjusting area of eroding bank and deposition, as well as the potential for removal of other morphological features.
- WF151 – **Moderate** significance: due to the removal of natural river bed and banks. The structures would alter geomorphological features (including bed substrate and associated flow types), flow patterns, constrict flow, confine the channel and remove/alter of lateral and longitudinal connectivity. There is also the potential to increase the rate of erosion at a knickpoint downstream of the proposed re-grading, which could destabilise the water feature further.
- WF154 and WF156 – **Moderate** significance: due to the removal of natural river bed and banks. The structures would alter geomorphological features (including bed substrate and associated flow types), flow patterns, constrict flow, confine the channel and remove/alter of lateral and longitudinal connectivity. Potential for channel adjustment upstream and downstream as a direct consequence of the new structures due to the steeper nature of the water feature.

5 Mitigation

5.1.1 A number of standard mitigation measures would be implemented to reduce the impact of the construction and operation of the proposed scheme. An overview of the standard mitigation identified for reducing the potential impacts on the fluvial geomorphology of the water features can be found in Section 11.5 of Chapter 11 (Road Drainage and Water Environment) and Table 21.5 (Chapter 21: Schedule of Environmental Commitments).

5.1.2 Taking into account the standard mitigation, it is considered that for the majority of the water features the impacts are reduced to non-significant and no further mitigation is required. However, there are a number of water features where additional specific mitigation is required for the construction phase, detailed design and operation of the proposed scheme, to further mitigate for the fluvial geomorphology impacts. The medium, high and very high sensitivity water features requiring specific mitigation are outlined in Table 4. The low sensitivity water features requiring specific mitigation can be found in Appendix A11.7 (Impact Assessment).

Table 4: Site specific mitigation for construction and operation (for medium, high and very high sensitivity water features)

Water feature	Mitigation details
Construction	
WF100	**Mitigation Item P05-W24 -** To avoid exacerbating bank erosion, construction works will remain 10m from the River Garry where possible. Exceptions include where works are required within the channel; but these will be avoided during heavy rainfall or flood events. In-stream works will be minimised by the use of a dry working area. Any pumping or abstraction from the dry working area will require adequate treatment as per the standards detailed under Mitigation Item P05-W15. Works involving disturbance of the channel bed will not be permitted prior to the establishment of a dry working area. In addition, a rapid evacuation plan will be required including daily weather updates and a response plan to ensure that in the event of rising water levels, plant and personnel can rapidly vacate in stream working areas.
WF111	**Mitigation Item P05-W25** - As part of the proposed channel realignment, any natural bed substrate removed during construction would be stored for re-use in the small diversion and proposed cascade to tie-in with the culvert inlet.
WF115	**Mitigation Item P05-W26** - During construction, the tracking of machinery along the banks (left bank in particular) will be avoided to reduce the potential for excessive erosion. Removal of the existing structure is likely to require in-channel works. As a result, erosion control measures such as creating a dry-working area, replanting of the banks prior to completion of works, and steady release of flows down into the new channel will be implemented.
Operation	
WF100	**Mitigation Item P05-W29** - Design of the Essangal Underbridge scour protection will include approximately 0.9m of natural bed material above the scour protection. The scour protection will have a smooth transition with the natural bed morphology (as far as practicable). The upstream and downstream extent of the scour protection will be angled downwards to tie in with the existing bed profile, minimising scour risk of the natural bed. Specific mitigation for the River Garry Underbridge will include re-planting of vegetation around outfall structures (Mitigation Item P05-LV9) and tying in with natural vegetation, including planting of trees where they are removed for enabling works.
	Mitigation Item P05-W51 - Between approximately CH9900 and CH10500, a requirement has been identified to protect the dualled carriageway from potential channel migration and erosion from the River Garry (WF100) at this location. The proposed solution would be a gravity wall combined with a rock armour toe which would be constructed at the rear of the verge adjacent to the proposed southbound carriageway. The exact details of the protection works will be influenced by the ground conditions and in particular the presence, or otherwise, of bedrock at river bed level. They will also be influenced by the presence, or otherwise, of a solution to safeguard the existing A9 that is currently being investigated by the Trunk Road Operator. A further phase of detailed ground investigation will be undertaken and details of any measures implemented to protect the existing A9 will be given to the Contractor, to inform the detailed design of the mitigation for the proposed scheme.
WF87	**Mitigation Item P05-W45** - Re-establish riparian vegetation along realigned channel. Bed of new extended culvert to include baffles to encourage deposition of natural material. Baffle to be 300mm deep. Channel realignment to re-use bed substrate removed from existing channel to recreate a natural cross-section. Realignment will mimic step-pool sequence from existing water feature.
WF89	**Mitigation Item P05-W30** - Create flow pathways to the channel of the water feature from the outfalls located at the top of the steep valley to prevent erosion or the slopes. Reinstate riparian vegetation.
WF98	**Mitigation Item P05-W46** - Re-establish riparian vegetation along realigned channel. Set-back bridge abutments for new extended bridge as far back as practicable from back top. Sensitive design of right bank re-profiling to allow for access track under existing bridge. Use of soft engineering to protect asset and prevent erosion. Removal of debris (man-made) and some select woody material from the upstream channel to improve channel capacity and minimise potential erosion of the banks.

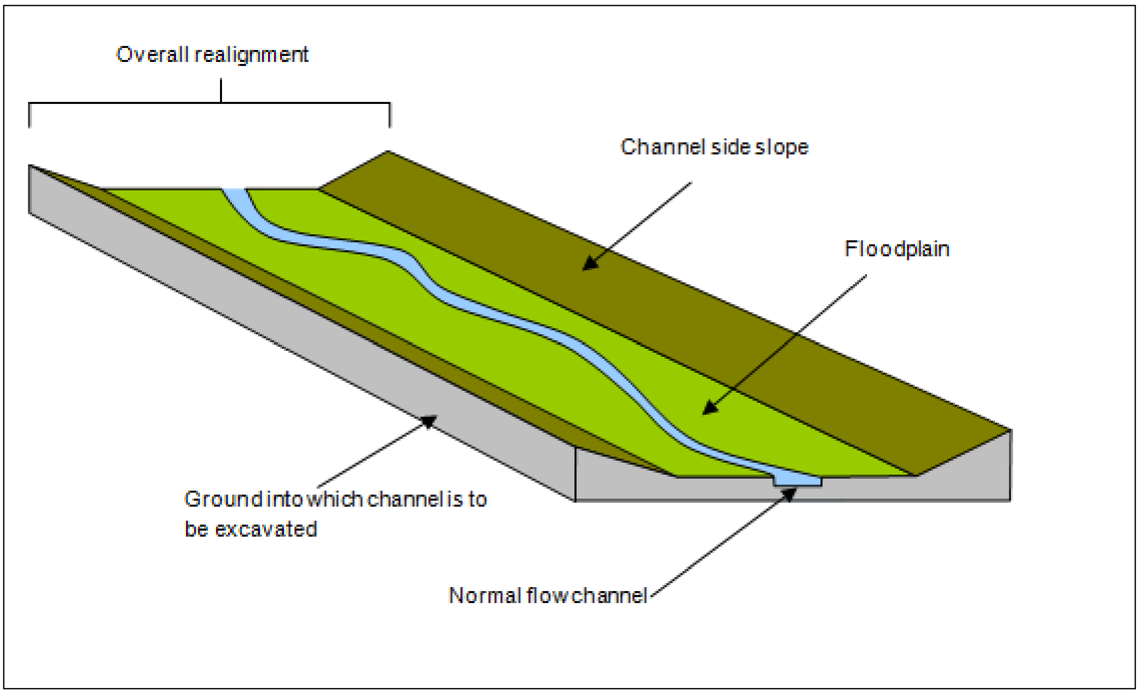
Water feature	Mitigation details
WF102	**Mitigation Item P05-W31** - Creation of a 'natural' step-pool sequence using boulders to tie-in the existing channel to the new inlet upstream. Re-establish riparian vegetation.
WF103 and WF104	**Mitigation Item P05-W32** - Re-grade upstream length between side road culvert and main carriageway culvert to tie-in the water feature with the new inlet. Use of natural step-pool sequence (i.e. using boulders to form steps) to grade the channel and minimise potential for scour. Re-establish an appropriately vegetated riparian corridor, particularly where trees have been removed.
WF108 WF149, WF158 and WF164	**Mitigation Item P05-W33** - Re-establish riparian vegetation along realigned channel, particularly tree lining.
WF111	**Mitigation Item P05-W34** - Re-grade upstream length to tie-in the water feature with the new inlet. Use of natural step-pool sequence (i.e. using boulders to form steps) to grade the channel and minimise potential for scour. Diversion would have a natural planform, tying in with the side road culvert.
WF114	**Mitigation Item P05-W44** - Upstream of the main carriageway culvert re-grade channel with a natural step-pool sequence (cascade) avoiding use of hard engineering. Culvert invert to be tied into natural channel bed using natural substrate (using that removed during construction). Baffles (approximately 300mm) to be placed through new culvert on alternating sides extending approximately 0.5m from edge to centre of culvert. Creation of a scour pool downstream of new outlet recommended.
WF115	**Mitigation Item P05-W35** - Sensitive design of channel cross-section to allow for low and high flows. Tie-in of the new channel cross-section to the upstream and downstream existing water feature to minimise potential erosion. Fencing along channel margins to prevent the erosion of bank tops from livestock trampling, limit erosion of earth banks and providing a buffer along the water feature. Further information on fencing requirements is detailed in **Mitigation Items SMC-CP6 and SMC-CP7.**
WF121	**Mitigation Item P05-W47** - New cascade upstream of main carriageway culvert inlet to be formed of a natural step-pool cascade.
WF132 WF134	**Mitigation Item P05-W37** - Channel downstream of culvert outlet to be regraded using a 'natural' step-pool cascade to prevent potential for scour. Channel tie-in upstream of culvert inlet to include at least two 'natural' step-pools to minimise potential for scour.
WF140	**Mitigation Item P05-W48** - Cascade upstream of new culvert inlet would be designed with a natural step-pool sequence. Maintain length of water feature where possible.
WF151	**Mitigation Item P05-W38** - Tie-in the culvert extension with a step-pool sequence downstream to reduce and even out the gradient changes, preventing excessive erosion. Detailed design of the channel realignment to create a channel suitable for the gradient and prevent excessive erosion. The naturalised channel and removal of existing concrete bed will also mitigate for the proposed concrete culvert.
WF154	**Mitigation Item P05-W39** - Replacement of existing cascade with a natural step-pool cascade, removing hard engineering. Tie-in new culvert outlet with existing channel using step-pools within the design to check the gradient.
WF156	**Mitigation Item P05-W40** - Design of diversion and step-pool cascade to be as natural as possible, with no hard engineering. Replacement box culvert to include baffles (300mm high) to create a naturalised bed.
WF159	**Mitigation Item P05-W49** - Tie-in to the inlet and outlet to remove ineffective reinforcement and re-creating a natural channel to provide betterment and a more stable channel. Diversion to mimic upstream channel characteristics with a naturalised design, limiting use of hard engineering.
WF88/ WF167	**Mitigation Item P05-W50** - Reduce the impact of the extended bridge abutments at WF88/167 will include the re-introduction of any sediment removed from the river bed or established deposits to ensure it remained within the catchment.

Conceptual Design

5.1.3 The mitigation detailed above outlines some design recommendations for the water features to mitigate against the operational impacts of the proposed scheme. These primarily relate to the realignment of the water features and the use of cascades to grade the channel into the new culverts. The following provides some indicative designs to be taken forward to detailed design for these features.

5.1.4 Diagram 1 provides a conceptual design for a water feature realignment, where the channel cross-section is varied to create a more naturalised channel. The design would allow for low flows (within the centre channel), deposition and potential channel adjustment without losing surrounding land.

Diagram 1: Conceptual illustration of a two-stage channel with a straight overall form by sinuous low flow channel (not drawn to scale)



5.1.5 Diagrams 2, 3 and 4 provide an indicative conceptual design illustrating the potential design and layout of the proposed natural cascade (step-pool sequence) detailed above. The design replicates the natural bed (i.e. gravel or cobble) and uses large boulders to form the steps that check the gradient in a steepened length that requires a cascade. Between each step, a pool is created, proportional to channel geometry, acting to slow flows and dissipate energy. The conceptual design provides a cascade that would be closer to mimicking existing channel characteristics and, therefore, would provide benefits for the morphology of the water features. The design would need to be developed during detailed design and made specific to each water feature to ensure it functions effectively.

Diagram 2: Conceptual diagram illustrating, in profile, plan view and cross-section, the constituents of a step-pool bed morphology for bedrock channel b) 'naturalised' design; and c) an over-engineered design for high erosion risk sites

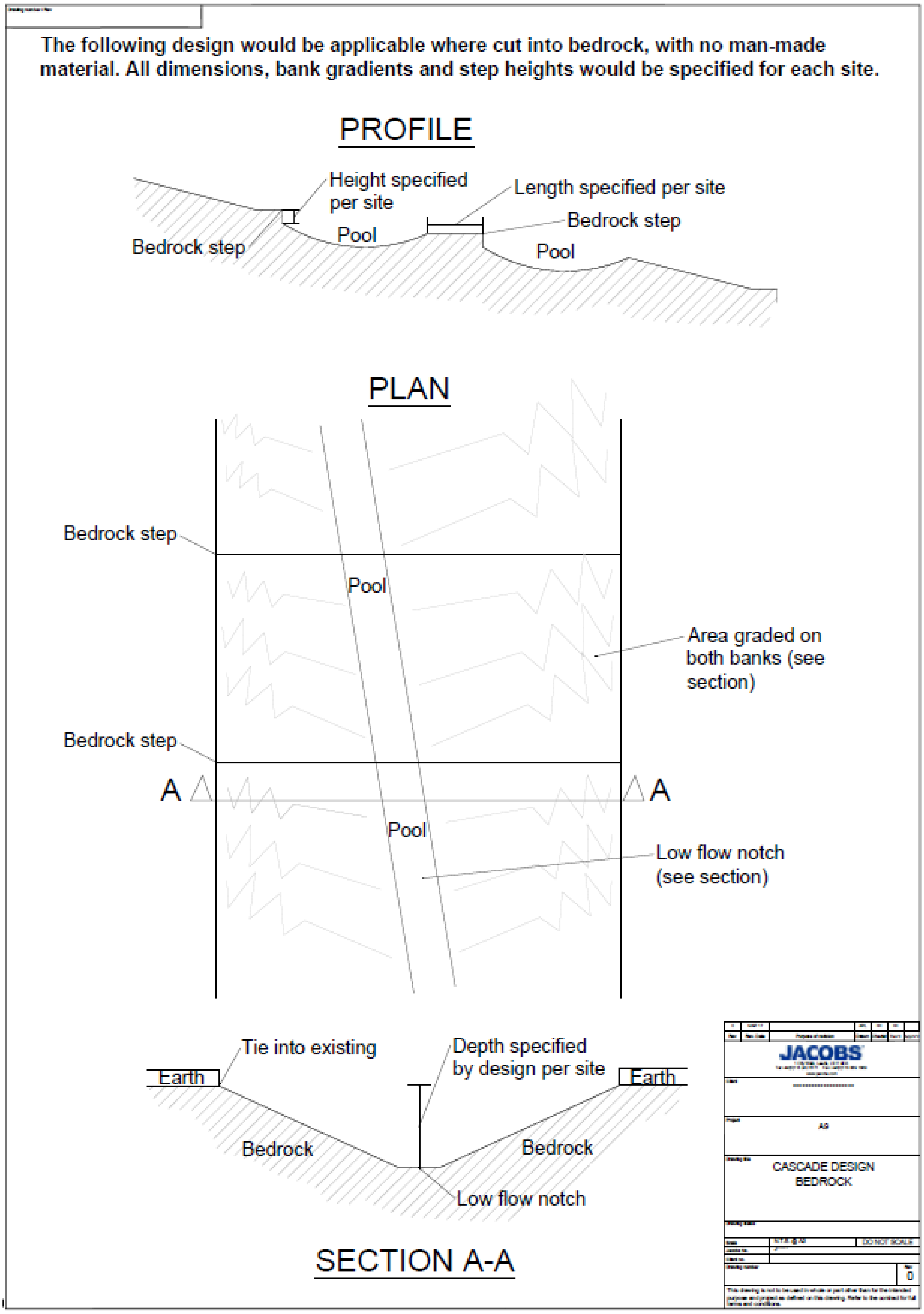


Diagram 3: Conceptual diagram illustrating, in profile, plan view and cross-section, the constituents of a step-pool bed morphology for 'naturalised' design

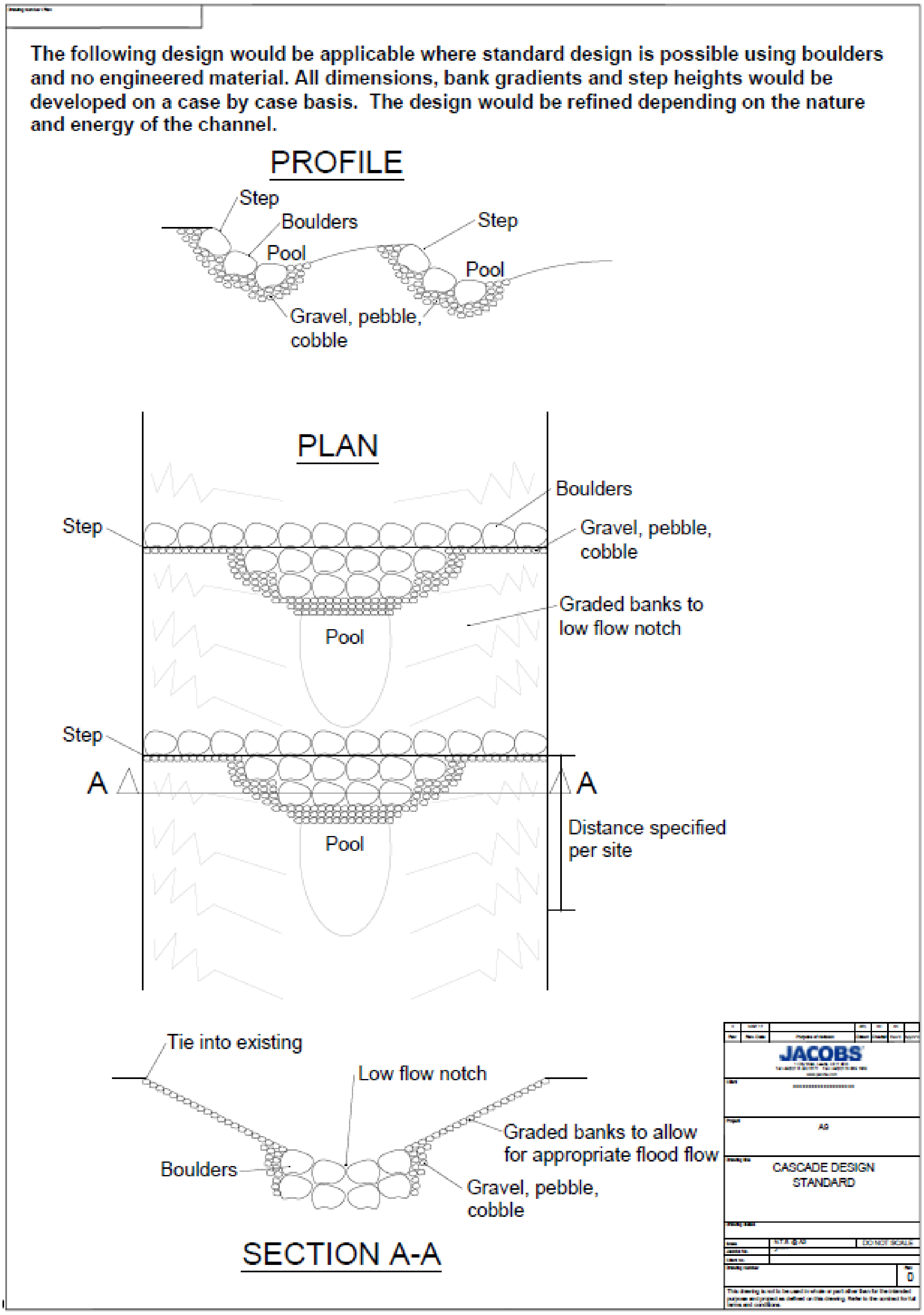
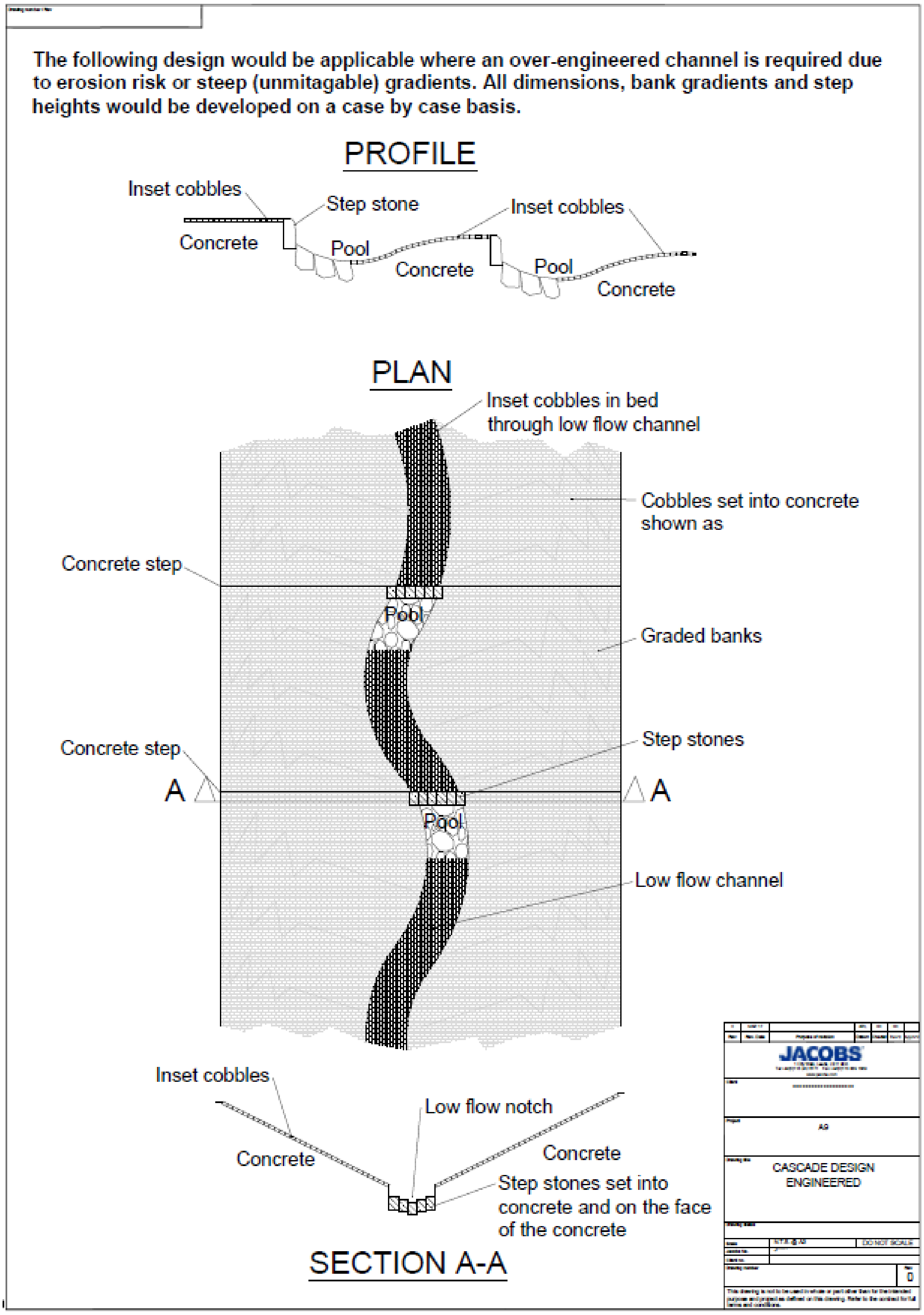


Diagram 4: Conceptual diagram illustrating, in profile, plan view and cross-section, the constituents of a step-pool bed morphology for an over-engineered design for high erosion risk sites



6 Residual Impacts

Construction Residual Impacts

6.1.1 Following the assessment of all of the construction activities likely to impact the water features along the proposed scheme, it has been concluded that there are no residual impacts of **Moderate** significance or above expected provided all mitigation is adhered to.

Operational Residual Impacts

6.1.2 No residual significant fluvial geomorphology impacts are expected from the operation of the proposed scheme provided all mitigation is adhered to.

6.1.3 For the lower reach of the River Garry (WF100 (lower)), a residual impact of **Slight** significance was determined due to the localised impacts of the proposed eight outfalls and two bridges. Analyses of the potential impacts of these structures, along with historical analysis, has shown localised adjustment would occur following the initial construction phase. In addition, mitigation set out would be further developed, in consultation with SEPA, during the CAR licencing process and detailed design.

6.1.4 In addition, these localised impacts would not be considered significant at the River Garry (Errochty Water Confluence to Loch Faskally) WFD water body scale. The River Garry is a naturally dynamic river system, whereby alteration to the spatial pattern of fluvial erosion and deposition, along with channel migration and alteration, is an inherent characteristic of this river type. Thus, it is anticipated that the river would respond to these proposed modifications, which could be sudden during or following construction, and would stabilise over time as the river reaches a new dynamic equilibrium. Thus these impacts would reduce both over distance and time.

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8 Glossary

Term	Definition
Adjustment	The modification of river channel morphology, both vertically and in platform, through erosion and deposition, which occurs in response to a modification to a channel caused by external factors such as human interference, climate or land use.
Bar	A general term referring to a depositional feature, usually formed of gravel deposited in a river.
Berm	Permanent deposits that have developed on the margin of the channel consisting of bench like features which effectively create a two-stage channel.
Channel capacity	The volume of water that can be contained within a given section of river channel.
Catchment	The total area of land that drains into any given river.
Channel	The course of a river including the bed and banks.
Cobble	Particle of diameter 64mm to 256mm, approximately "fist" sized.
Continuity	Relates to how continuous the flow or sediment transfer is within a particular water feature. Culverts often break the continuity through promoting deposition. Lateral connectivity refers to the connection between the channel and the floodplain at either bank. Longitudinal connectivity refers to the upstream and downstream connection throughout a channel.
Culvert	Artificial structure, often concrete, for carrying water underground or under bridges.
Discharge	The volume of water flow per unit time usually expressed in cubic metres per second (m3 s-1)
Dynamic (active) rivers	Rivers with high energy levels; which are prone to change their channel characteristics relatively rapidly.
Embankment	Artificial flood bank built for flood defence purposes, which can be flush with the channel or set back on the floodplain.
Ephemeral stream	Usually low order, water only during and immediately after heavy rainfall.
Erosion	The process by which sediments are mobilised and transported by rivers.
Equilibrium	Where erosion and deposition are balanced. This is achieved through morphological adjustment which maintains sediment transport continuity.
Fine sediment	Sediment of grain diameter finer than 2 mm.
Floodplain	Area of the valley bottom inundated by water when a river floods
Flow processes	Description of how the flow in a river varies over time and how frequently and for how long high flows (floods) and low flows (during droughts) occur.
Fluvial	The branch of geomorphology that describes the characteristics of river systems and examines the processes sustaining geomorphology them.
Geomorphology	The study of features and processes operating upon the surface of the Earth.
Gravel	Particle of diameter between 2 mm and 64 mm.
Hydrological	Referring to the flow of water, specifically its routeing and speed.

Term	Definition
Incised channel	Where the riverbed is well below the floodplain due to downwards erosion (incision).
In-channel	That part of the channel covered by water in normal flow conditions.
Meander	A bend in the river formed by natural river processes e.g. erosion and deposition.
Mid-channel bars	Gravel or other shallow deposits in the middle of straight sections of water feature.
Migration	Lateral movement of channel across floodplain through bank erosion and deposition.
Modification	Channel features that have been created by management interventions and often involve river engineering.
Poaching	Trampling by livestock.
Pool	Discrete areas of deep water typically formed on the outside of meanders.
Reach	A length of an individual river which shows broadly similar physical characteristics.
Realignment	Alteration of the planform channel (often by straightening) to speed up flows and reduce flood risk.
Riffle	A shallow, fast flowing section of water with a distinctly disturbed surface forming upstream-facing unbroken standing waves, usually over a gravel substrate.
Riparian	Land on the side of the river channel.
River corridor	Land to either side of the main river channel, including associated floodplain(s).
Runoff	Water entering a channel via overland flows following rainfall events, flowing down the slope to the channel.
Sedimentation	The accumulation of sediment (fine or/and coarse) which was formerly being transported.
Scour	Erosion caused resulting from hydraulic action.
Sediment transport	The movement of solid particles (i.e. sediment), typically due to a combination of gravity acting on the sediment and/or the movement of the fluid in which the sediment is entrained.
Stream Power	A measure of the specific energy acting in a channel to determine the river's capacity to transport sediment and perform geomorphic work, e.g. erosion.
Side bars	Gravel or other shallow deposits along the edges of straight sections of river channels.
Siltation	Deposition of fine sediment (comprising mainly silt) on the channel bed often promoting vegetation growth if it is not flushed downstream regularly.
Sinuous	A channel displaying a meandering course. High sinuosity relates to a channel with many bends over a short distance; low sinuosity is often used to describe a fairly straight channel.
Toe (of the riverbank)	Where the riverbed meets the bank.
Water Framework Directive	Under this Directive, Member States must achieve good ecological status/potential and prevent deterioration in the status of surface waters. Ecological status is to be assessed using a number of parameters, including hydromorphological (or fluvial geomorphological and hydrological) quality elements: • Hydrological regime – the quality and connection to groundwater reflect totally or neat totally undisturbed conditions. • River continuity – the continuity of the river is not disturbed by human activities and allows the undisturbed migration of aquatic organisms and sediment transport. • Morphological conditions – channel patterns and dimensions, flow velocities, substrate conditions and the structure and condition of the riparian zone correspond totally or nearly totally to undisturbed conditions.

Annex A

Introduction

8.1.1 The following note provides an overview of the potential channel changes that may occur as a consequence of the proposed bridge structure at Essangal. The current preferred option will mirror the existing bridge consisting three new piers and two abutments located immediately downstream of the existing bridge. One of the piers will be in the wetted channel, one will be located on the shingle bar along the left bank and one in the floodplain to the east near the Highland Mainline Railway.

8.1.2 It should be noted that the interpretation made in this report is based on professional judgement informed by supporting literature and information. No specific geomorphological calculations or models have been used at this stage. A high level review of potential hydraulic impacts has, however, been taken from numerical river modelling and design details depicted on engineering drawings. It is recommended that this note is used to inform ongoing discussions amongst the Geomorphologists, Ecologists, Hydrologists and Engineers at detailed design stage.

Potential Channel Change

Overview

8.1.3 High level historical analysis of map records indicates that, at some time prior to 1867, the River Garry downstream of the current Essangal bridge crossing had a wandering gravel-bed planform. The 1892 map record shows an extensive shingle deposit, similar to the present day, albeit composed of bare/sparsely vegetated shingle. In addition, former river channels and former cut-off channels are depicted on the map within the shingle deposit. It is likely that early river engineering works, involving embanking the river along both banks, and the construction of access tracks and the Highland Mainline Railway, caused the channel to adjust to a single-thread channel form throughout this reach.

8.1.4 Through the historic map record to the present day, the river has remained predominantly stable throughout this reach. The extensive shingle deposit downstream of the existing Essangal crossing pre-dates bridge construction. From 1867 to the present day, this shingle bar has retained a similar size and shape; this suggests only localised adjustments occurred following the construction of the existing A9 Essangal crossing. A reduction in fluvial disturbance since 1867, possibly due to a combination of local river engineering works, mentioned above, along with river regulation and abstractions, has caused vegetation succession of the shingle bar over time. The Aldclune and Invervack Meadows SSSI is now dominated by tree species due to the lack of fluvial disturbance, thus impacting on its condition status.

Flow Conditions

8.1.5 Contemporary flow conditions both upstream and downstream of the existing Essangal bridge are described below. Approximately 350m upstream of the existing bridge, glide flow dominates with a deep pool. 100m upstream of the existing A9 bridge, the river meanders to the south. At the meander bend, a large point bar feature is present on the right (inside) bank with a short riffle feature at the apex of the meander bend. Immediately downstream, a rock outcrop is present on the left bank, which deflects flow away from the outside of the meander bend and back towards the right bank. At this location, glide flow dominates. The channel deepens downstream of the bedrock, particularly in the centre of the channel. Towards the margins on the left bank, there is another rock outcrop downstream of the pool area. These rock outcrops appear to have significant impacts on localised flow conditions and the geomorphological features. These bedrock outcrops deflect flows across to the right bank, thus preventing the point bar from further depositing along the entire length of the inside of the meander bend, as would normally be anticipated. The presence of these rock outcrops is also likely to contribute to the deposition of the shingle bar present on the left bank downstream of the bridge (a feature which has been present across all historical maps).

8.1.6 On aerial imagery, a mid-channel bar is also present on the left bank between the two rock outcrops; however, this was not noted on site during the geomorphological walkover. This transient depositional feature is likely to be caused by the slowing down of flows along the left bank caused by the rock outcrops. This is contrary to what would normally be expected on the outside of mender bends, where flows are typically faster.

8.1.7 In addition to the deflection of flows towards the right bank caused by the rock outcrops, the in-channel pier also funnels some of the flows towards the right bank, with some flows deflected off the pier towards the left bank. At the location of the existing bridge crossing, an extensive riffle feature is present, forming a change in the gradient of the river bed. This shallow section of riffle is likely to have been present throughout the historical records, suggested by the presence of a ford crossing on maps dating to 1867. Flows are dominated by broken standing waves along the riffle. A small side bar deposit is present on the right bank in the vicinity of the riffle; although this is a transient feature, which may be mobilised during high flow events.

8.1.8 Downstream of the riffle, run flows are dominant and focused mainly to the right of the channel, and continues approximately 200m downstream. Where vegetation is becoming established on the exposed area of the shingle bar downstream of this length, the predominant flow type returns to a glide, with a riffle/run sequence further downstream. At the downstream limits of anticipated potential impacts, the flow conditions return to riffle habitat immediately upstream of another outcrop of bedrock on the left bank.

8.1.9 Following the proposed bridge extension, the following impacts on flow are anticipated. Upstream of the bridge, flow patterns are not anticipated to alter notably. The pool-riffle-pool feature is likely to remain, along with the point bar feature on the inside of the meander bend upstream of the bridge. The rock outcrops will continue to deflect flows away from the left bank towards the right bank. The most notable changes to flow conditions will occur at the location of the proposed bridge extension and associated scour protection. Here, flow is likely to be more constrained due to the proposed in-channel pier. Flows are likely to become more turbulent as a result. In addition, due to the reduced channel width, the river is likely to adjust by eroding the leading edge of the shingle bar to recover the lost channel width. This could cause localised alteration to the spatial pattern of flows and depositional features. Part of the riffle will be lost to accommodate the proposed new pier. Flow types in this vicinity could therefore vary; if the feature is re-created flows may mimic the existing broken standing waves, which would be directed towards the right bank. Due to the bank reinforcement, these flows are then likely to be deflected across to the shingle bar on the left bank. Flow energy would gradually dissipate likely within 150m of the proposed bridge, with flow dominated by a run.

Potential Impacts

8.1.10 Diagram 1 provides a schematic diagram highlighting the maximum potential extent of change as a consequence of the proposed bridge. Following construction of the proposed bridge extension, there may be the potential for:

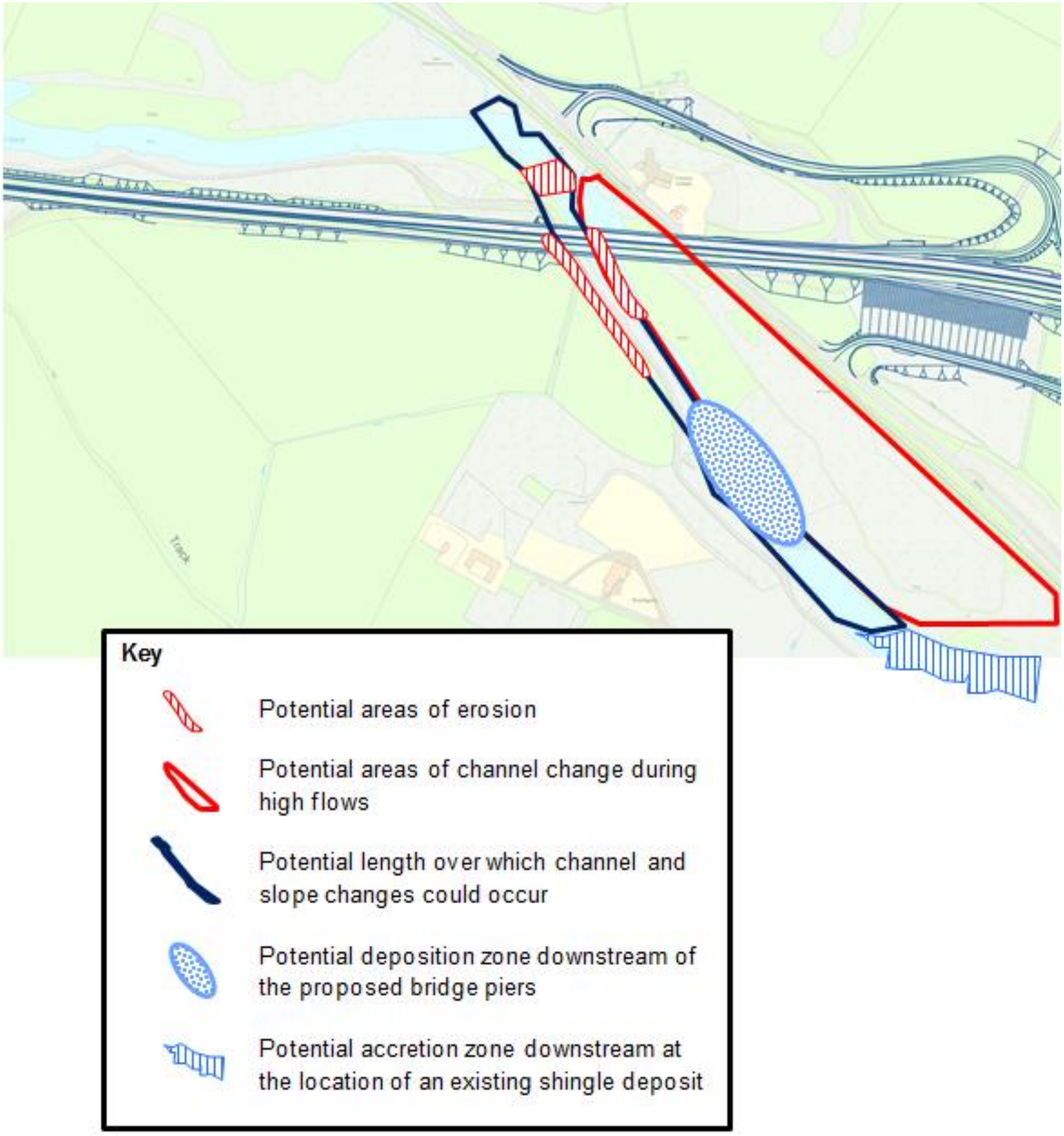
- Localised shingle bar migration along the left bank, with potential re-working of the shingle bar at the upstream extent. Here, the leading edge of the shingle deposit may be transported downstream following the construction of the bridge extension. This impact may occur due to the extended pier cutting across the flow of the water, causing flow deflection in addition to reducing the effective low flow channel in the vicinity. The river may erode the leading edge of the shingle bar in order to maintain the channel width. The mobilised substrate is likely to be transported a short distance downstream before being re-deposited. This impact is likely to occur during the initial river re-adjustment phase post-construction before establishing a new equilibrium.
- Accretion of channel substrate eroded from the leading edge of the bar feature. It is likely that the deposition would occur on the existing depositional feature. This impact is likely to occur in the short-term during initial re-adjustment of the river post-construction. This may be mitigated for during reinstatement of the shingle bar by appropriate re-profiling of the river bed and shingle bar.
- Potential for channel bed erosion along the existing right bank reinforcement downstream of the existing A9 bridge due to changes in direction and patterns of flow caused by the pier and associated scour protection. From here, flow may also be deflected towards the shingle deposit adjacent to the left bank, where energy is likely to dissipate. Here, further localised adjustment, with re-working on the substrate, may occur. Impacts would likely be localised. The downstream impact may vary depending upon flow conditions, with higher, more turbulent flows having impacts further downstream in contract to lower flow conditions.
- Formation of a step change in channel gradient and/or a riffle as a response to the change in channel gradient by partial loss of the riffle downstream of the bridge.

- Potential for scour at the upstream leading edge of the proposed bed reinforcement. This may cause localised deepening the existing pool. This would be mitigated for in design by grading at the termination edge to prevent both undermining and scour. The scour protection would also be 0.9m below river bed level, thus scour is not anticipated due to embedded mitigation.

8.1.11 Reach adjustments due to the construction of the bridge extension may likely occur over the short-to-medium term before attaining a new dynamic equilibrium however, the majority of potential impacts are anticipated to be localised around the proposed structure, as indicated in Diagram 1.

8.1.12 The maximum likely extent of impacts downstream of bridges, based on literature, can be up to approximately 300-400m (approximately ten times the existing channel width) (Gregory and Brookes, 1983). Effects occur in part from the vena contracta effect i.e. the squeezing of flow through an orifice narrower than the river width. The existing bridge is currently constricting flow; this constriction would occur over a longer distance due to the proposed bridge extension along with associated flow deflection towards the right bank. With the available qualitative evidence, the extent of impacts is, however, anticipated to be mostly localised. Furthermore, historical analysis indicates minimal and localised impacts following the construction of the existing A9 bridge at Essangal, thus evidence suggests a similar outcome. Impacts would also diminish with distance downstream. Any impacts extending to the maximum estimated extent downstream is likely to be further accretion at an existing shingle deposit. It is most likely that impacts extending this far downstream would occur during high magnitude events.

Diagram 1: Overview of potential channel change zones in response to the proposed structure. (Note adjustments are mostly anticipated to be localised and occur over the short-term as the river adjusts to the new pier, with the maximum extent of change occurring over a 300-400m length. Impacts would also diminish with distance downstream).



<u>View of changes around bridge piers (including scour protection)</u>

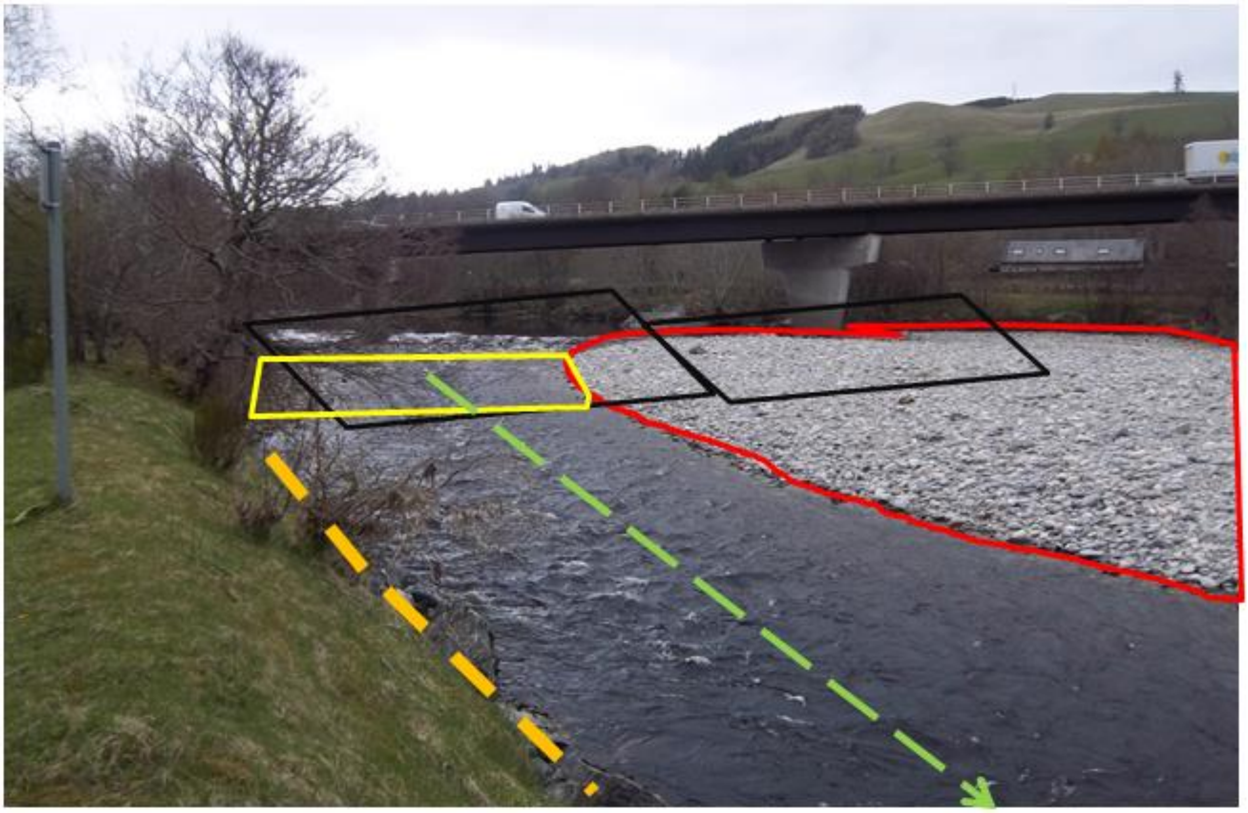
8.1.13 The following section provides an overview of the potential changes around the bridge which could, in turn, lead to the changes outlined in Section 2.1.

8.1.14 Diagram 2 highlights the key areas of change around the bridge piers. There would potentially be:

- Extension of the bridge pier reducing the area of the riffle feature (shown in Diagram 2 in yellow). Impacts on the riffle feature downstream of the existing pier and replacement with hard engineering should be minimised due to scour protection following the profile of the existing bed, buried to a depth of 0.9m.
- Disturbance to the top layer of an extensive deposit to install scour protection (shown in Diagram 2 in red colour). Mitigation includes burying the scour protection to a depth of 0.9m and overlaying with natural substrate.

- Change to erosion around piers due to scour protection with substrate deposited downstream with localised channel response downstream (area shown in Diagram 2 by a broken green arrow).
- Potential undermining of existing bank reinforcement (depending on depth of foundations) from incision of the bed (shown in Diagram 2 in broken orange line).
- Potential flow deflection from the zone of existing right bank reinforcement with flow deflected towards the shingle deposit. Energy is likely to dissipate along the lateral margins of the shingle deposit with accretion of the bar feature with the eroded substrate.

Diagram 2: Photographic representation of areas of channel bed and banks potentially impacted by new piers

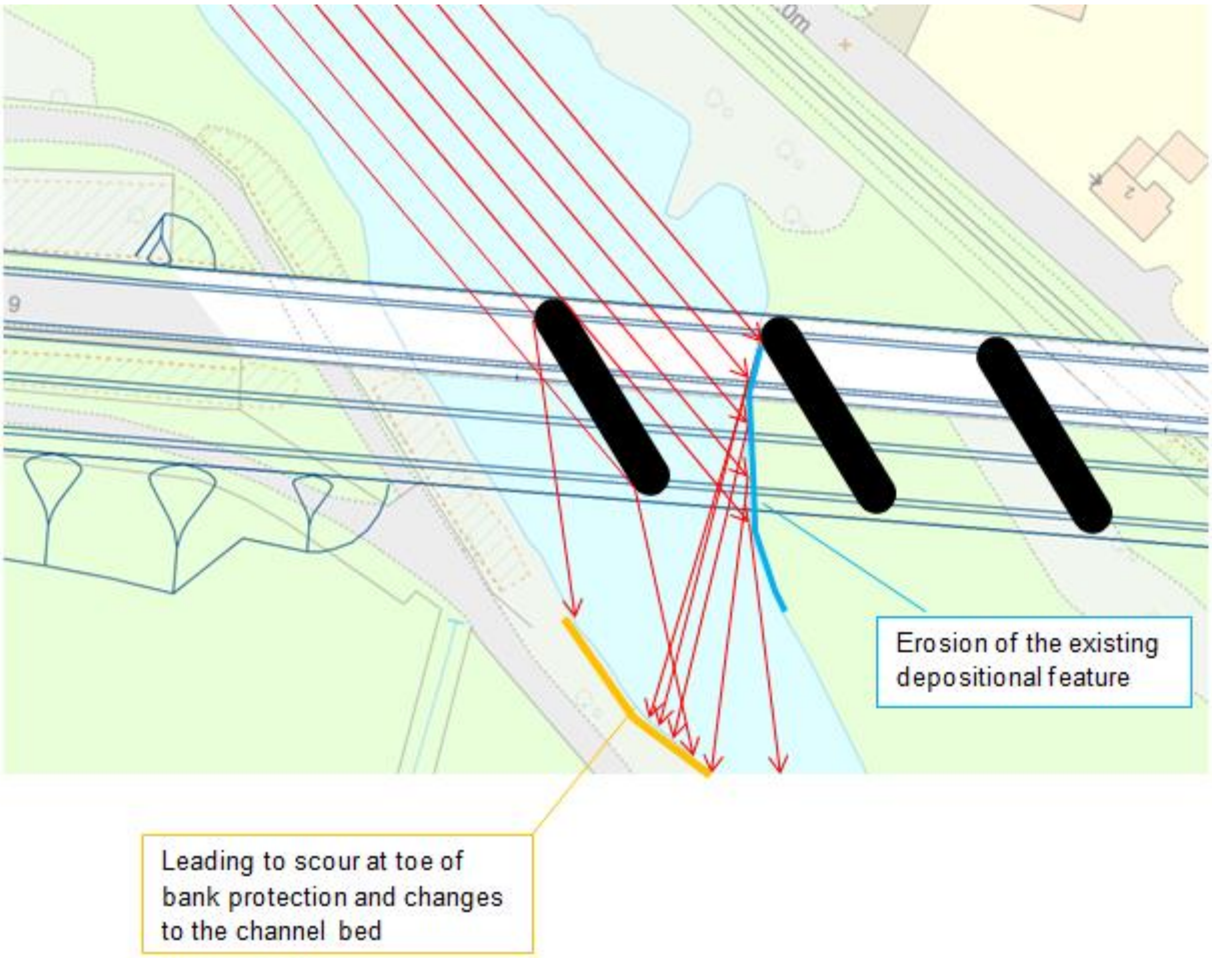


8.1.15 Figure A11.8.9 (in Appendix A11.8: Watercourse Crossings Report) and Diagram 3 below provide a more detailed schematic plan of the potential channel change around the bridge piers and the consequent downstream adjustment. This may include the potential for:

- Winnowing of the layer of bed material on top of scour protection (i.e. erosion and stripping of bed material leaving large riprap/boulders).
- Channel adjustment at the downstream toe of the scour protection, which may include scour of the bed with eroded substrate being deposited downstream. However, the scour protection will be buried to a depth of 0.9m and designed to follow the existing bed profile, which should mitigate for these potential impacts.
- Incision of the bed around the toe of the existing bank reinforcement due to changed flow direction (see Diagram 3).
- Scour may occur at the upstream extent of the scour protection, which could potentially result in localised deepening of the existing pool. Data available suggests that any scour would be localised and not extend upstream to the existing pool. Embedded mitigation to prevent scour includes scour protection being buried 0.9m below river bed level and dipped at the leading edge to prevent scour. Natural channel substrate would be overlain on top of the scour protection. With this mitigation, the risk of scour is low and is unlikely to impact on the pool.
- Localised adjustment of depositional features, including erosion of the upstream leading edge of the existing shingle bar deposit and accretion of substrate on the existing shingle bar deposit. Localised

alteration of flow patterns is also likely, which will diminish over distance from the impact. These alterations of flow would drive the erosion and deposition processes and resulting adjustments.

Diagram 3: Predicted flow directions due to deflection following proposed bridge extension, supported by literature (Brookes, 1988; page 199, based on Leliavsky's principles (1955))



Summary

8.1.16 In summary, the geomorphological impacts associated with the proposed bridge are likely to be predominantly localised and also likely diminish with distance downstream. In addition, any geomorphological response to the proposed bridge will likely occur over a 5-10 year period, by which time the river will possibly have reached a new dynamic equilibrium. Data suggests scour upstream of the bridge would be localised; this is mitigated for in design to prevent/reduce the risk of scour. These measures should prevent scour impacting on the upstream pool area.

8.1.17 Geomorphological impacts extending further downstream, i.e. 300-400m, will likely only occur during high magnitude events, however it will be difficult to differentiate post-event change occurring as a result of natural river processes following large floods and those attributable to the proposed bridge. Impacts associated with high magnitude flood events would occur over the long-term (decadal).

8.1.18 Any localised channel change as a result of the proposed bridge extension is likely to be within bounds of any changes that may occur under natural conditions for this river type following a high flow event. It is important to stress that, with or without the proposed bridge extension, considerable alteration to the channel form and processes may occur following a high magnitude flow event. The impacts of such an event may alter the spatial distribution of fluvial forms and processes within this reach and beyond.

8.1.19 This report is based purely on the evidence available. Factual evidence of any increase in the vena contracta effect to determine whether the proposed bridge extension would cause erosion above the current baseline is unavailable. Predictions may be made regarding the potential impacts on flow paths, using Leliavsky's (1955) principles; again impacts would be localised and the erosion and deposition processes are inherent of this river type and occur naturally within this reach; the proposed bridge extension is likely to alter the spatial pattern of these processes around the structure.

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