APPENDIX B: GEOMORPHOLOGICAL REPORT

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Rannoch Moor and Glen Coe Bridge Replacements

Geomorphological Report

Babtie Group – October 2006

1. Introduction

The Scottish Executive Development Department is developing proposals to replace seven bridges on the A82 Trunk Road in the Rannoch Moor and Glen Coe area. BEAR Scotland are developing the schemes and have commissioned Babtie Group to undertake an environmental scoping report for the proposals. This report provides the geomorphological contribution to the environmental scoping.

The bridges are located within a national scenic area and those in Glen Coe within Site of Special Scientific Interest. Three sites have been identified in Glen Coe by the Geological Conservation Review (GCR) as being important for their fluvial geomorphology; these are a 1.5 kilometre section of the River Coe above Loch Achtriochtan, the Coire nan Lochan fan and the slope forms below the Aonach Eagach ridge.

Rannoch Moor is designated as a Ramsar Site (Convention on Wetlands) and contains the most extensive complex of blanket and soligenous/valley mire in Britain.

During the consultation process concerns were raised as to the potential impact of increased sediment delivery to the river channel during demolition and construction operations. The Lochaber District Salmon Fishery Board and Lochaber Fisheries Trust expressed concern as to the impact of sediment release on water quality and fish. Scottish Natural Heritage (SNH) and the Scottish Environmental Protection Agency (SEPA) also expressed concern about potential impacts of sediment release on the notified environmental features (SSSI/cSAC) downstream, particularly the fluvial geomorphological features upstream of Loch Achtriochtan.

The purpose of the geomorphological assessment is to determine the likely impacts of bridge replacement on the fluvial geomorphology of the rivers affected by each scheme, with specific reference to the sediment regime of the rivers.

2. Methods

The approach combines a desk study and single day site visit. This represents a reconnaissance style assessment rather than a detailed geomorphological dynamics assessment which is beyond the scope of the appraisal. The desk based approach conducted prior to and following the field visits consisted of a review of existing project documentation, maps of the site and a review of existing geomorphological publications. The desk study was designed to place the river channels in each bridge location into the wider context of the river channel upstream and more importantly downstream. The field visits focused on determining specific baseline conditions, including contemporary channel morphology, channel bed and bank characteristics and the quantities and grade of sediment stored within the river channel. Data collection involved note taking, the production of geomorphological maps, and photography. The interpretations and predictions made in this report are based on professional judgement and past experience.

3. Baseline Conditions

The following section describes the baseline conditions at each bridge proposed for replacement in order of priority for replacement (highest at the top).

3.1. A82 660 Ba

Ba Bridge is located on Rannoch Moor and spans the River Ba (GR 230920 749460) as it flows between Lochan na Stainge and Loch Ba. The channel has a relatively low gradient with low stream power. The river banks are low, being less than one metre in height. Bank materials consist of bedrock and loose boulders interspersed with peat underlain by glacial till. The banks are covered by grass with occasional heather. The river bed consists of cobbles and gravel, with occasional moss covered boulders, overlying bedrock. A thin accumulation of silt was observed overlying the coarse bed, reflecting the low flow power in this location. No gravel bars are present. The bedrock geology consists of granite. The landscape reflects the repeated glaciations of the moor during the Quaternary which ice scoured bedrock and frequent moraines which date to at short cold phase at the end of the last glaciation between 11,000 and 10,000 years ago known as the Loch Lomond Stadial. During this period an icecap formed over the western highlands and was centred on Rannoch Moor.

3.2. A82 810 Achnambeithach

Achnambeithach Bridge (GR 213740 756630) spans the River Coe approximately 300 metres downstream from Loch Achtriochtan. At the bridge location the River Coe is located in a narrow bedrock gorge, which is spanned by the bridge. Only the centre of the three arches normally contains flow. Immediately downstream the channel enters a large pool and bedrock confinement diminishes. The channel is of moderate to high gradient and with bed material consisting of cobbles and boulders which are fresh in appearance indicating some bed mobilisation at high stage. At the bridge locations the banks consist of steep bedrock slopes with occasional vegetation within fractures and joints.

3.3. A82 830 Allt Fhiodhan

Allt Fhiodhan Bridge (GR 210850 758020), located in lower Glen Coe spans the Allt Fhiodhan a left bank tributary of the River Coe to the north of Meall Mor. The Allt Fhiodhan is a high gradient mountain stream and appears to be incised into stabilised and wooded valley side deposits. The banks are relatively gentle and often ill-defined and consist of vegetated cobble and boulders. Bedrock outcrops appear to be absent and the bed sediments consist mainly of gravel, cobbles and boulders. With the exception of the larger boulders, which are moss covered, the bed sediment is relatively clean suggesting relatively frequent bed sediment mobilisation. There are no significant gravel bars the reach being dominated by sediment transfer. The surrounding riparian land is densely wooded with grass and ferns on the woodland floor.

The Allt Fhiodhan bridge confines the river channel in this location, there is a 50% reduction in channel width under the bridge, the channel has adjusted to the existing bridge structure (Figure 3.1). A riffle formed from interlocking cobbles has been pinned by the upstream concrete bridge foundations.

Figure 3.1 View looking downstream to Allt Fhiodhan Bridge, note the reduction in channel capacity and the presence of the riffle within the concrete foundations immediately upstream of the bridge.

3.4. A82 620 Allt Chonghlais

Allt Chonghlais Bridge (GR 229740 738360) is located below the western slopes of Beinn Dòrain 1.5 kilometres south of Bridge of Orchy. The bridge spans the Allt Kinglass, which in the location is a relatively high gradient mountainous river. The channel has incised through Quaternary and Holocene drift deposits in this location and the channel bed consists of exposed bedrock. The bank material ranges from bed rock to unconsolidated Quaternary sediments. The surrounding land is terraced with two distinct levels visible: an upper terrace, upon which the present road is constructed and a lower terrace. The surrounding land is wooded with thick grass and ferns. There is relatively little mobile sediment visible in the channel, as the bedrock bed and relatively high gradient ensuring that sediment is rapidly flushed through the reach during high flows.

3.5. A82 770 Alltanrigh

Alltanrigh Bridge (GR 217580 756580) is located in the Pass of Glen Coe below the southwest slopes of A' Chailleach. The stream in this location is a steep ephemeral mountain torrent, a right bank tributary of the River Coe. The Alltanrigh Bridge confines the channel reducing channel width from over 10 metres upstream to 6 metres. Downstream from the bridge the channel progressively widens. The banks are generally less than 0.5 metres in height and are often difficult to discern. The channel is filled with very large quantities of coarse, gravel, cobbles and boulders, vegetation (grass and shrubs) occurs occasionally and appears to be associated with bedrock outcrops in the channel. The bridge itself appears to be partially constructed on bedrock. The fresh appearance of the gravel indicates that sediment transfer rates are high. The channel appears to be set within a larger vegetated debris fan (Figure 3.2), similar in nature to the slope forms below the Aonach Eagach ridge. The high sediment supply results from the reworking of the sediments contained within the debris fan. The current bridge structure is narrow in comparison to the active width above and below, and as a result debris within the channel has built up against the retaining walls of the road approaches (Figure 3.3).

Figure 3.2 View looking upstream from the Alltanrigh Bridge

Figure 3.3 View looking upstream from under the Alltanrigh Bridge.

3.6. A82 680 Allt Nan Guibhas

Allt Nan Guibhas Bridge (GR 226430 753930) is located on the western portion of Rannoch Moor below the slopes of Creag Dhubh which lies approximately 1 km to the south. The sinuous stream is of moderate gradient with an average width of 2.5 metres. The banks are of low height approximately 0.75 metres high and consist of gravel with occasional boulders with intervening peaty soil, and occasional bedrock outcrops. The surrounding vegetation is predominantly grass and heather. The stream bed is composed of coarse gravels and cobbles with frequent point bars. The gravel bars are of fresh appearance and there is little vegetation within the channel and no accumulations of fine sediment; this suggests that coarse sediment transport occurs during high flows. The exiting bridge span is narrower that the channel upstream and downstream and the resulting flow confinement has resulted in scour downstream forming a pool. As with Ba the landscape is character is determined by the granite bedrock and the legacy of glaciation.

3.7. A82 Allt Molach

Allt Molach Bridge (GR 227730 752980) is located on the western side of Rannoch Moor, below the north east slopes of Meall a' Bhuiridh which lies approximately 2.5 km to the south west. In the vicinity of the bridge the Allt Molach is narrow stream (width varies between 1 and 2 metres) of low sinuosity and relatively gentle gradient. As a result of this low gradient stream powers are low, and this is confirmed by the presence of vegetation on the channel bed which indicates limited bed sediment mobilisation. The channel bed consists of gravels with occasional cobbles covered by a thin silt layer. No gravel bars are present which combined with apparent bed stability suggests coarse sediment transfer rates are very low. The river banks are low being less than one metre in height and are composed of boulders with intervening peat and peaty soils. The surrounding undulating moorland is covered by grasses close to the channel and heather on the drier areas. At the bridge site the channel has been over-widened due to bridge construction and this has resulted in the deposition of low vegetated berms on both the upstream and downstream sides of the bridge. As with Ba and Allt Nan Guibhas, the landscape is character is determined by the granite bedrock and the legacy of glaciation.

4. Predicted Impacts

4.1. Principal geomorphological impacts generic to each scheme

While altering the configuration of bridge piers (where present) can change the hydraulic conditions within the channel, and as such the channel morphology, the strong bedrock control means this is likely to be of minor importance at each site. The most significant geomorphological impact of bridge replacement is likely to be restricted to increases in the supply of sediment to the river channel. It is assumed no sediment will be removed from the channel during bridge replacement. The impact of enhanced coarse and fine sediment delivery to the river channel is considered below:

4.1.1. Coarse sediment (boulders, cobbles, gravels)

Increases in coarse sediment delivery to river channels can lead to bed aggradation and the development of depositional features (bars) may occur downstream. This can alter the existing channel bed structure to the detriment of the aquatic ecology. Deposition is likely to be most pronounced immediately downstream as coarse sediment transfer distances tend to be short and restricted to flood events. The occurrence of very large infrequent floods may however transfer coarse sediment large distances.

4.1.2. Fine sediment (sand, silt, clay)

Increased delivery of silt and clay (finer than 0.062 mm) which can be carried in suspension may cause discolouration of the water and have a detrimental effect on water quality. The fine sediment (particularly sand and silt) is likely to be deposited downstream, particularly in pools downstream, where flow velocity is low. This sediment can infiltrate the voids within the cobble/gravel bed reducing the availability of suitable fish spawning sites. Should the volume of fine sediment delivered be large the whole gravel bed may become smothered by fine sediment reducing the visual and ecological quality of the channel.

4.1.3. Mechanisms of sediment delivery

The geomorphological impacts of bridge replacement are likely to be restricted to the demolition and construction phase, and are unlikely to persist following the works assuming the current landscape remains the same and all construction materials are removed. As the work will consist of a number of elements the geomorphological impacts of each are considered individually below.

4.1.4. Construction of temporary bridges

Temporary bridge construction is likely to be necessary for both the Achnambeithach and Allt Chonghlais schemes. Construction of the temporary bridge may disturb the surrounding slopes. While these slopes are often underlain by bedrock they are mantled by colluvium (fractured and weathered bedrock) and a soil. Disturbing this material may result in some transfer of sediment from the slopes to the channel. This is likely to consist of both coarse and fine sediment. The additional coarse sediment supply may result in some localised deposition and bar formation, although this will depend on the quantity and size of the sediment delivered to the channel.

4.1.5. Access roads

Demolition is likely to involve accessing the river channel. This may involve construction of an access road to the river channel from the road. As access ramps will have to be removed to restore the original character of the landscape, they are likely to be constructed of aggregate, principally boulders with finer gravel used to provide the road way. Where this material abuts the channel it will be vulnerable to entrainment by flow. The finer gravel used to provide the surface of the ramp will be especially vulnerable as this material will be of a comparable size to the finer gravels in the channel. The finer gravel used to provide the surface of the ramp will be especially vulnerable, particularly where this material is of a smaller size than the dominant sediment size in the channel. The dominant sediment size in the channel provides an indication of the size of bed sediment which can be transported. Entrainment is particularly likely during high flow events when stream power is high. Entrainment of this material must be avoided due to the potential for channel aggradation downstream and because this material is likely to be fresher (cleaner and more angular) and of a uniform lithology which, if not sourced locally, will contrast with that of the natural bed load. Entrainment and deposition of this material will detract from the appearance of the river channel.

4.1.6. Bridge demolition

Demolition of the existing bridge and piers may introduce large quantities of coarse sediment to the river channel, the size of which will vary from large blocks of stone from the bridge to smaller fragments of concrete from the pier footings. The amount of material released to the river channel during demolition will depend upon the method employed, for example explosives are likely to introduce smaller and more widely scattered debris than toppling and breaking piers and foundations mechanically.

The use of machinery in the river channel to facilitate demolition is likely to lead to the disturbance of the river bed sediments. Disturbing the coarse sediments will result in the loosening of the channel bed structure; this will increase the likelihood of sediment movement during high flows and where the channel bed is not formed by bedrock, may lead to localised increases in bed erosion potentially increasing sediment transfer downstream. Where sediments are currently located preferentially around the piers, due to localised effects of the bridge structure, removal of the piers will result in the mobilisation of this material which is likely to move downstream. However, the volume of material involved is likely to be very small, and it is not envisaged that this will have a significant downstream impact.

4.1.7. Construction of the new bridges

Construction of the new bridges may also involve the use of machinery in the channel which is likely to cause a loosening of the channel bed structure. However, providing all stone blocks are cut to size prior to being moved into the channel (reducing the likelihood of sediment delivery during cutting) construction is not likely to result in major geomorphological impacts.

4.1.8. Construction site practices

Demolition and construction will involve the delivery, storage and removal of large quantities of stone and aggregate. Inappropriate storage and handling of this material may result its transfer to the river channel. For example, storing piles of sediment in close proximity to the channel will render the material vulnerable to entrainment during floods, or susceptible to being washing into the channel during periods of rainfall. In addition localised soil erosion may occur as surface runoff resulting from heavy rainfall flows around piles of materials.

The movement of heavy machinery around the site may destabilise the soils and unconsolidated materials on slopes and verges, increasing the likelihood of this material being delivered to the river channel. Vehicle movements will also transfer fine sediments around the site which may be washed into the channel. Locating wheel wash facilities inappropriately may also facilitate the transfer of sediment liberated during wheel washing to the channel. The confined nature of the site, narrow road and steep slopes increases the potential for these impacts.

4.2. Additional impacts specific to individual schemes

4.2.1. A82 660 Ba

As the River Ba in this location is low gradient with relatively low stream power coarse sediment delivered to the river channel, particularly blocks of stone from the original bridge is likely to be deposited locally and is unlikely to be moved downstream even during high flow events. Blocks and aggregates left in the channel will persist in the bridge location which will detract from the visual quality of the channel. While these blocks may provide localised shelter for fish, scour around these blocks at high flow may be problematic, particularly where these are located close to the banks.

The low river banks will make access to the channel relatively easy for in-channel works; however the peat and tills which compose the banks are highly susceptible to disturbance. Degradation of the river banks will introduce both inorganic and organic fine sediment to the channel which, given the low stream powers is likely to be deposited onto the gravel substrate reducing the suitably of the river bed for fish spawning. Re-mobilisation of this material during high flows is likely to result in the delivery of sediment to Loch Ba 100 metres downstream.

4.2.2. A82 810 Achnambeithach

Removal of the bridge piers is unlikely to have a significant effect on the channel morphology as these are located on bedrock and normal flow is not constrained by the piers. During high flow the absence of the bridge piers will effectively increase the channel capacity reducing the confinement of the flow and may result in some reduction in flow power, however given the confined nature of the channel and relatively high gradient this is unlikely to result in any deposition of natural bed load in this location.

A deep pool is located immediately downstream from the bridge, this may act as a sediment sink for sediment introduced due to disturbance of surrounding slopes. Coarse sediment and blocks are likely to collect in this location and where the quantities large enough this may detract from the visual quality due to the fresh nature of the sediment where new aggregate become entrained or blocks of bridge stone are deposited. Deposition of fine sediment downstream may cover the existing gravel/cobble bed to the determinant of fish habitats. However as described above it is likely that this disturbance will be relatively short lived as the sediment delivery returns to normal and fine sediment is dispersed.

4.2.3. A82 830 Allt Fhiodhan

The concrete bridge footings act to confine the channel and have resulted in a 50% reduction in channel width, which appears to have influenced the river bed morphology. A riffle composed of interlocking cobbles has been pinned by the bridge footings (Figure 1). Removing the bridge footings will effectively widen the channel in this location and could destabilise this riffle. A phase of bed regrading is likely to occur following any channel widening associated with bridge replacement. Bed regrading is likely to involve some bed sediment movement during high flows, which will continue until a stable bed configuration is achieved. If this adjustment were to occur during replacement works it may complicate the replacement process and necessitate some in channel works which may increase fine sediment transfer downstream. Assuming the new bridge is of the same width as the original bridge the impact of the readjustment is likely to be localised and short lived, being restricted to the period of replacement.

4.2.4. A82 620 Allt Chonghlais

As with Achnambeithach Bridge, the piers are sited on bedrock and the channel morphology is disturbed by bedrock controls and as such removal is unlikely to lead to alterations in channel morphology. This site may however be particularly vulnerable to disruption to the gorge slopes as they appear to be composed of unconsolidated Quaternary sediments which may be readily mobilised during construction works.

4.2.5. A82 770 Alltanrigh

The Alltanrigh Bridge confines the channel of a wide and steep boulder-bed mountain stream. There is evidence that the bridge retaining walls are holding back storage sediment. Removal of the bridge might lead to destabilisation of the sediments in the channel, resulting in an increase in coarse sediment transfer and a readjustment of the bed. As flow appears to be ephemeral it is possible that this will only occur if replacement works coincide with a storm event. The magnitude of any readjustment will depend upon the flow conditions and the quantity of material retained by the bridge, and this is likely to vary through time.

In addition, the steep nature of the channel in this location and loose cobble/bounder bed means that the channel bed is likely to be disrupted by the movement of machinery in the channel bed. Disruption to the bed is likely to be restricted to a loosening of the current bed structure making the bed sediment more vulnerable to entrainment during high flows. As this is an ephemeral channel and competent flows are limited to storm flows readjustment will be restricted to such events, and is likely to involve transport of material downstream. The extent of re-adjustment during storm flow is difficult to predict but is likely to be localised in nature.

The river channel at Alltanrigh is very similar in nature to those associated with the slope forms below the Aonach Eagach Ridge (McEwen, 1997). Although the channel at Alltanrigh is not included within the GCR designation, the channel in this location should be regarded as having a similar geomorphological value as those within the GCR site and disturbance should be kept to a minimum.

4.2.6. A82 680 Allt Nan Guibhas

As the channel is of relatively low gradient in this location and the bridge does not appear to be interacting with sediments stored within the channel the potential impacts on the river channel will be restricted to the generic impacts identified above. However if the new bridge has a span greater than the existing structure a reduction in downstream scour may occur leading to deposition in the scour pool.

4.2.7. A82 Allt Molach

As this channel in this location has a low gradient additional impacts are likely to be similar to those at Ba Bridge.

4.3. The extent and duration of geomorphological impacts

The extent of the impacts associated with these bridge replacement operations on the fluvial geomorphology of the affected rivers are difficult to determine. As the principle geomorphological impacts are likely to result from increases in sediment supply the extent of disturbance will be closely related to the volume and size of sediment introduced to the river channel. Fine sediment particularly silt and clay will be readily mobilised during the relatively frequent high flows and transferred downstream.

The impacts of coarse sediment inputs will also be related to the quantity and calibre of material delivered to the channel. Impacts are likely to have most significant impacts immediately downstream from the bridges, and will diminish with distance downstream as material is deposited. Of all the bridges only that at Alltanrigh is located upstream of the Achtriochtan GCR site, and as such is the only scheme which could have an impact at this site. The Alltanrigh Bridge is located 1.5 km upstream of the Achtriochtan reach. Any significant disturbance to the channel at the bridge site may involve the transfer of some coarse sediment into the River Coe, which could potentially be transferred to the Achtriochtan site. However, the initial investigation suggests this is unlikely involve quantities sufficient to cause any noticeable change in the fluvial geomorphology at this site.

4.4. Uncertainties

The magnitude and extent of the impacts of bridge construction on the fluvial geomorphology of each river will depend upon the quantity and size range of sediment delivered to the channel, which will depend on the construction practices employed. Calculating the volumes of sediment likely to be delivered to the channel was beyond the scope of the study. Further investigations will be required to determine the volumes of sediment likely to be delivered and their likely impact. It is recommended that such investigations be undertaken following the selection of site specific replacement methodologies to be implemented. In addition the severity of impacts will also be controlled by the nature of the flows experienced at the site during construction operations. The occurrence of large floods will increase the likelihood of adverse geomorphological impacts. As a detailed geomorphological assessment was beyond the scope of this investigation the scenarios described above are based on professional judgement and experience. These provide a guide to the potential impacts of bridge construction on the fluvial geomorphology allowing appropriate mitigation measures to be suggested.

5. Mitigation Measures

The demolition and construction operations should be conducted in a manner designed to minimise the delivery of sediment to the river channel. The following general recommendations will help to minimise the disturbance caused during replacement of each bridge:

5.1. Construction of the temporary bridges

Slope disturbance should be kept to a minimum. Where this is unavoidable, unconsolidated material (soil and loose rocks) which is likely to be disturbed could be carefully removed or stabilised prior to vehicle access and construction. This material could be stored and replaced following the completion of construction. However, following replacement this material will be vulnerable to erosion until vegetation colonisation occurs. Access to these slopes should therefore be prevented to reduce the likelihood of erosion. Fine netting could also be placed over the slope to help maintain soil stability prior to vegetation re-colonisation.

5.2. Access road

Aggregate used for the ramp way should be of a size sufficient to minimise the likelihood of entrainment. As a guide material should of a size greater than that currently located in contemporary river bed sediment. Where possible, gabions could be used to reinforce the sides of the access ramps to prevent the entrainment of material from the ramp, although these will have to be removed following completion of construction. The installation and removal of gabions could prove difficult due access constraints at each the bridge site.

5.3. Bridge demolition

In order to minimise the impact of demolition on the river channel, all debris from the bridge must be removed from the sites and care must be taken to ensure this material does not enter the river channel.

The use of machinery in the river channel should be kept to a minimum and care should be taken to minimise disturbance to the bed sediments and surrounding slopes and river banks.

5.4. Construction of the new bridges

As with demolition operations, the use of machinery in the river channel should be kept to a minimum and care should be taken to minimise disturbance to the bed sediments and surrounding slopes and river banks (during access).

5.5. Construction site practices

Vehicle movements will be unavoidable. Where possible silt traps could be provided using suitable geotextile matting. Wheel wash facilities should be constructed to ensure that waste water is not allowed to drain directly into the channel. Effluent from wheel washes should either be removed or treaded prior to release into water courses. The use of settling ponds or geotextile matting to trap silt could be used to treat effluent. Materials, particularly aggregate, should not be stored close to the river channel or the surrounding steep slopes to ensure that this material is not entrained by flow or washed into the channel during rainfall.

5.6. Timing of replacement works

Window of works between June and September provides the most suitable period for construction from a geomorphological perspective. As high flow events also occur during the summer months care should be taken to ensure no in-channel operations occur during period of high flow or when heavy rain is forecast.

Although three bridges are located in the River Coe catchment (Alltanrigh, Achnambeithach and Allt Fhiodhan) and two are located in the River Etive catchment (Allt Nan Guibhas and Allt Mollach), the distances between the bridges mean that carrying out bridge replacement at the same time or in sequence are unlikely to lead to any combined geomorphological impacts downstream.

5.7. Mitigation measures specific to individual schemes

5.7.1. Allt Fhiodhan

Due to the potential for disturbance to the river bed morphology at the Allt Fhiodhan Bridge it is recommended that replacement does not involve the removal of the entire of the existing concrete bridge footings. It is recognised the load bearing central portions of each are likely to be replaced, however if possible the outer portions of the footings should not be removed as leaving these in place will minimise changes to the existing channel morphology. While this outer portion of the footing will degrade over time and will eventually fail this will occur gradually and will allow this channel time to adjust without a sudden change in the channel stability. The design and construction of the new bridge should take the future loss of the outer bridge footings into consideration, so this does not result in damage to the new bridge. If alterations are to be made to the dimensions of the bridge involving the loss of the footings more detailed geomorphological investigations will be required to determine an appropriate method of replacement.

5.7.2. Alltanrigh

This bridge replacement will have to be conducted with great care to ensure that disturbance to the channel sediments be kept to a minimum. The interaction between the bridge and the channel morphology in this location make some disturbance inevitable if works are not restricted to simply replacing the bridge decking. If alterations to the bridge dimension have to be made either during works or on a permanent basis the channel morphology will be vulnerable to re-adjustment, particularly through bed sediment mobilisation. As the river channel in this location is likely to be particularly vulnerable to bridge replacement it is recommended that further geomorphological investigations be conducted at this site following determination of replacement requirements, and that geomorphological guidance is sought during the design and construction phases of the replacement of this bridge.

6. Residual Impacts

Despite the implementation of these mitigation measures some sediment delivery to the river channel and bed disturbance is likely to be unavoidable. Some temporary water discolouration during demolition and construction is likely to occur, however the volumes of sediment released are unlikely to have a significant impact on the fluvial geomorphology of the river channel. If the mitigation measures are taken into account this should prevent large volumes of sediment being supplied to the river channel there are unlikely to be any significant negative impacts on the fluvial geomorphology of the rivers. The site at Achtriochtan for example, is unlikely to be significantly affected by the bridge replacement operations.

The Allt Fhiodhan and Alltanrigh bridges are likely to be most sensitive to bridge replacement and it is recommended that further geomorphological investigations be conducted at each site following the determination of replacement requirements. For example, at both these sites replacement of the entire bridge is likely to result in channel disturbance which may be severe if the replacement work coincided with a large flood event.

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Glossary

Soligenous — Dependant on ground water for its formation.

Ephemeral — A stream which contains water only during and immediately after a rainstorm.

Bar — Generic term used to describe ridge-like accumulations of sediment within river channels. These develop on the bed of the river but may become exposed at low flow. Bar size is determined by sediment supply rate, with their height reflecting the depth of generating flows.

Quaternary — Period of geological time spanning the last 1.6 million years.

Till — Sedimentary material deposited by a glacier, consisting of rock fragments of varying size typically set within a matrix of fine clay-silt sized material.

7. Reference

McEwen, L.J., 1997. Glen Coe: river and slope forms, Highland. In Gregory, K.J., (Ed*) Fluvial Geomorphology of Great Britain (GCR Volume No. 13)*. Chapman and Hall, London, pp 72-76.