A83 Rest and Be Thankful

LTS EIAR VOLUME 4, APPENDIX 19.3 - ROAD DRAINAGE AND THE WATER ENVIRONMENT BASELINE

Transport Scotland

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A19-3. Road Drainage and the Water Environment Baseline

A19-3.1. Introduction

A19-3.1.1. This document is a technical appendix to Volume 2, Chapter 19, Road Drainage and the Water Environment (RDWE). This assessment has been carried out in line with that discussed in Volume 4, Appendix 19.1, RDWE Legislation, Policy and Guidance and the methodology set out in Volume 4, Appendix 19.2, RDWE Methodology. These documents accompany an application by Transport Scotland (TS) to seek the consents necessary to construct, operate, and maintain the Proposed Scheme.

A19-3.1.2. The Proposed Scheme comprises the construction of new infrastructure to provide a sustainable Long Term Solution (LTS) to improve the resilience of the existing A83 trunk road to impacts from debris flows originating on steep slopes on the eastern side of Glen Croe, in proximity to the Rest and Be Thankful (RaBT) viewpoint. These LTS works apply to approximately 2.2km of the existing A83. The Proposed Scheme includes upgrading works to existing infrastructure, including the RaBT car park, B828 junction, watercourse crossings and drainage infrastructure.

A19-3.1.3. The Red Line Boundary (RLB) covers the entire area within which the Proposed Scheme is located, including temporary access roads, construction compounds, and laydown areas, as well as a new debris flow shelter (DFS), debris flow protection wall and upgrade works to existing infrastructure. The RLB is anticipated to outline the maximum extent of land within which the Proposed Scheme shall be constructed. A more detailed description of the Proposed Scheme design and construction methodology can be found in Volume 2, Chapter 4, The Proposed Scheme.

A19-3.1.4. To enable ongoing public access within Argyll, in parallel with the LTS design, improvements to the Old Military Road (OMR) shall be developed. These proportionate improvements are required to deliver a safer and more resilient temporary diversion route whilst the LTS construction work is underway (i.e. whilst the corresponding section of the A83 is closed), until the LTS becomes operational.

A19-3.2. Overarching Baseline Information

A19-3.2.1. This section of the report provides a summary of the physical characteristics of the catchments and wider water environment within which the Proposed Scheme is located. The detailed baseline assessments and the identification of potential receptors specific to the surface water resources and water quality, hydromorphology, and flood risk disciplines can be found in each of the subsequent subsections.

Topography

A19-3.2.2. The A83 passes around the base of The Cobbler and Beinn Luibhean hills through Glen Croe. The southern extent of the Proposed Scheme begins immediately north of the Cobbler Bridge (A83 crossing of the Croe Water). The elevation of the existing A83 from the southern to northern extents, including the RaBT car park, varies between 155 mAOD and 276 mAOD, generally rising to north.

A19-3.2.3. East of the A83, at the north east extent of Glen Croe, is Beinn Luibhean with a peak of approximately 858 mAOD. The Beinn Luibhean gradients are very steep; approximately 50% - 120% above the A83, 15% - 50% below the A83.

A19-3.2.4. The topography of the Study Area is influenced by the underlying geology and geomorphological processes. Further detail regarding the topography of the individual watercourses affected by the Proposed Scheme is provided below.

Geology and soils

A19-3.2.5. The geology and soils are described in detail within Volume 2, Chapter 12, Geology, Soils and Groundwater. However, a summary is provided below for hydrological and geomorphological context.

Bedrock geology

A19-3.2.6. As determined from available BGS mapping (shown in Volume 3, Figure 12.2, Bedrock Geology) the majority of Proposed Scheme is underlain by bedrock comprising the Beinn Bheula Schist Formation of Neoproterozoic age, which is part of the Southern Highland Group. An extensive igneous intrusion of the Siluro-Devonian South of Scotland Granitic Suite is situated between Beinn Luibhean and The Cobbler.

A19-3.2.7. Bedrock is noted to be at or near the ground surface at numerous locations in proximity to the Proposed Scheme, typically across areas of steep hillside. The exposure stretches from the where the A83 crosses the Croe Water (Cobbler Bridge) in the south-west, north-easterly up to Coire Croe as well as High Glencroe and the slopes to the immediate east of the RaBT carpark.

Superficial deposits

A19-3.2.8. BGS mapping (shown in Volume 3, Figure 12.1, Superficial Geology) indicates the majority of the Proposed Scheme is underlain by Glacial Till deposits which cover the steeper valley slopes within the southern highlands region. Alluvium, Hummocky/Glacial deposits and River Terrace Deposits are also present within the area of the Proposed Scheme downslope from the A83. The upper slopes and summits of the surrounding mountains of Beinn Luibhean and The Cobbler, have no mapped deposits, indicating that superficial deposits are thin or completely absent.

A19-3.2.9. The Glacial Till, which underlies the Proposed Scheme within Glen Croe and extends up into Coire Croe to the east, typically comprises unsorted and unstratified drift with generally over-consolidated, heterogenous mixtures of

clay, sand, gravel, and boulders varying widely in size and shape. The Till is also likely to underly the Alluvium and River Terrace Deposits.

Soil

A19-3.2.10. Soil types in the Study Area are related to the superficial geology and comprise multiple soil types, as detailed in Scotland's Soils online mapping resources. The soil type of the majority of the Study Area is the Strichen Association with the generalised soil type being classed as peaty podzols. More specifically, the component soils are peaty gleyed podzols with peaty gleys with dystrophic semi-confined peat. The landform where this soil type is prevalent is mostly hummocky valley and slope moraine in the vicinity of existing A83 and the OMR. Towards the peaks of The Cobbler and Beinn Luibhean the soil type remains the same but the landform type changes to hill sides with strong to very steep slopes, which are moderately to very rocky.

A19-3.2.11. There are also regions of Strichen Association soils where the generalised soil type has been classed as montane soils. The landform types at these locations are classed as mountains with gentle to very steep slopes, non- to very rocky. The regions with this soil type are located at the southern extent of the hydrological catchment area at The Brack and Cruach Fhiarach, to the east of Glen Croe at Ben Donich, further up the glen towards the peaks of The Cobbler and Beinn Luibhean and around Beinn an Lochain.

Land Use

A19-3.2.12. The dominant land use and associated land cover within study area adjacent to the A83 is rough grassland that is grazed at some locations, especially downslope of the existing A83. The Ben Luibhean slopes, above the existing A83 are not grazed and have been actively planted with saplings and seeds (seed drone test-bed at Rest and Be Thankful) to bind the soils, aiming to increase resilience to rainfall in an effort to reduce the debris flow risk. There are small areas of plantation forestry in proximity to the Proposed Scheme, with

more significant areas of forestry managed by Forestry and Land Scotland (FLS) to the south.

Watercourses

A19-3.2.13. The Proposed Scheme is located within the catchments of two Water Framework Directive (WFD) water bodies, the Croe Water and the Kinglas Water (see Volume 3, Figure 19.1, Water Framework Directive Waterbodies), with WFD status information provided in the following sub section.

A19-3.2.14. The Croe Water exhibits a range of morphological features with very little artificial modification as can be seen in Plate A19.3.1. The Croe Water, as designated by SEPA for the WFD, flows from north to south through the base of Glen Croe and is an active meandering channel with exposed cobbles and gravel bars (note that this is not as shown on Ordnance Survey mapping; which displays the Croe Water flowing under the A83 and OMR to the valley floor). The dominant riparian land use and cover is rough grassland. The channel slopes for the Croe Water are much shallower (~0.01 m/m) than they are for the watercourses draining the valley sides (~0.1 to 0.3 m/m where the watercourses cross the OMR).

Plate 19-3.1 Aerial Image of the Croe Water, showing river meanders on valley base

A19-3.2.15. The most substantial lateral inflow to the WFD designated Croe Water drains a catchment area of approximately 3.4 km^2 (watercourse ID: A83_ML_015_000, identified as Croe Water on OS mapping). The watercourse is steep (0.085 m/m) and high energy, with the bed and banks dominated by large cobbles and boulders characterised as a cascading system (Plate A19.3.2 below). The watercourse has two bridge crossings associated with the existing A83 and the OMR.

A19-3.2.16. A total of 26 watercourses are directly affected by the works to the A83, 22 of which pass beneath the A83 and 4 beneath the B828. Of these 26 watercourses, 24 are within Glen Croe and 2 are in the Kinglas Water catchment. The watercourses that drain the eastern and northern slopes of Glen Croe are very steep and are characterised as high energy cascades, mostly with bed material consisting of cobbles and boulders, with some bedrock cascades at the northern extent. The riparian land use/cover is predominantly rough grassland that is grazed in some locations, especially downstream of the existing A83. This general context also applies for the Kinglas Water tributaries.

A19-3.2.17. An additional 19 watercourses, all located within Glen Croe, are also affected by the improvements to the OMR (Plate A19.3.3 below). Eleven of these watercourses are located to the south of the Croe Water (A83_ML_015_000) with the other 8 watercourses, located to the north, draining the land between the A83 and OMR.

A19-3.2.18. Generally, the watercourse gradients are much steeper upslope of the existing A83 (~0.6 to 0.7 m/m), reducing as the watercourses approach the valley floor (~0.1 to 0.3m/m where the watercourses cross the OMR) and join the Croe Water (Volume 3, Figure 19.2, Water Feature References). These watercourses are currently crossed by the A83 and existing pressures and artificial modifications are evident such as catchpits, culverts, drop chambers and cascades with baffles which disrupt natural flows and sediment transfer processes. This is discussed in the Field study results, Section A19-3.4 and Annex 19-3-1 and Annex 19-3-2.

Plate A19.3.2 Croe Water (A83_ML_015_000), looking upstream from the existing OMR bridge (Dated: 09 December 2022)

Plate A19.3.3 Typical channels along the OMR route (Dated: 09 December 2022)

A19-3.2.19. Two watercourses, neither named on the OS 1:25,000 mapping, are located within the catchment of the Kinglas Water WFD water body. These watercourses drain the steep (~0.4 to 0.5 m/m), north-western slopes of Beinn Luibhean and discharge directly into Loch Restil. The channels are poorly defined upslope of the A83, with only a vegetated linear depression observable from the A83, suspected as providing intermittent, ephemeral flows (see Plate A19.3.4).

Plate A19.3.4 Image of A83_ML_035_000 that drains the north-western slopes of Beinn Luibhean to Loch Restil (Imagery Date: October 2023)

Watercourse crossings

A19-3.2.20. There are four bridge structures present within the corridor of the A83 in the Study Area. The Cobbler bridge (A83_15 Bridge) carries the A83 over Croe Water (Plate A19.3.5), this is a three-span structure with four piers supporting the central span. The road elevation is at 165 mAOD at the northern abutment falling to 163 mAOD at the southern abutment. The A83 is considered to have a very low risk of flooding from fluvial sources at this location, as described in Section A19-3.5. At the southern extent of the Study Area there are two further bridges carrying the A83 over the Croe Water (A83_03 and A83_04 Bridges), these are outwith the area of the Proposed Development. The Kinglas Water is

crossed by the Kinglas bridge (A83_60 Bridge), also outwith the area of the Proposed Development.

A19-3.2.21. Thirty-six watercourse crossing points along the OMR alignment have been confirmed by site visits, all in Glen Croe and within the Croe Water catchment. Three of these OMR crossings are bridge structures, with the OMR crossing of the Croe Water (OMR_13 Bridge) approximately 170m downstream of the A83 crossing (A83_15 Bridge, Cobbler Bridge) and consisting of three openings; a main box culvert with two side flood relief culverts (Plate A19.3.6). The main box culvert (approximately 5.5 m wide x 0.7 m high) has a soffit level of 126.55 mAOD and the two flood relief culverts (each approximately 0.5 m wide x 0.6 m high) have a soffit level of 126.7 mAOD.

Plate A19.3.5 A83_15 Bridge ('The Cobbler') across the Croe Water (A83_ML_015_000), looking upstream (Dated: 28 April 2022)

A19-3.2.22. The other two bridge crossings on the OMR consist of a stone masonry arch (OMR_30 Bridge) and a pipe culvert bridge (OMR_31 Bridge). There are 33 culvert crossings of the OMR which have been confirmed by site visits following information from Transport Scotland. These are typically single barrel or twin barrel pipe culverts with diameters ranging between 150 mm to 1000 mm, however, most commonly are sized between 450 mm to 900 mm. As part of the improvements to the OMR, a number of these crossing will be modified to accommodate carriageway widening and/or ensure that all crossings can convey at least the 50-year flow, whilst being resilient to sedimentation and scour erosion (See Annex 19-3-2 for more detail).

A19-3.2.23. In summary, there are 63 bridge and culvert crossing structures identified within the Study Area over the 45 watercourses discussed in the previous sub-section (some of which are crossed multiple times). These are shown on Volume 3, Figure 19.2, Water Feature References and comprise crossings of the A83, the OMR and B828. Crossings are identified in Table A19-3.1 with details regarding A83/B828 culvert dimensions and conveyance capacity provided, where known.

Plate A19.3.6 OMR crossing of the Croe Water (A83_ML_015_000), looking downstream at the inlet of the structure (Dated: 07 December 2022)

Table A19-3.1 Watercourses identified as crossed by the existing A83 or OMR with crossings type/ geometry and capacity (where available) (ordered from south to north)

Watercourse Id / Crossing Reference	Coincides with LTS works	OMR crossing	Watercourse categorisation	WFD catchment	Existing A83 (Baseline) Crossing Type / Geometry+	Culvert capacity (m^3/s)+	Capacity return period (years)*
A83_ML_Z05_B01	No	OMR_01	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_Z05_B02	No	OMR_02	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_Z05_B03	No	OMR_03	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_Z05_B04	No	OMR_04	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_Z05_B05	No	OMR_05	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_Z05_B06	No	OMR_06	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_008_A01	No	OMR_07	Major	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_010_B02	No	OMR_08	Minor A	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_011_000	No	OMR_09	Minor A	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_012_000	No	OMR_10	Major	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_014_000	Yes	OMR_11	Minor B	Croe Water	No hydraulically connected A83 crossing	n/a	n/a
A83_ML_012_B03	No	OMR_12	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_015_000	Yes	OMR_13	Major	Croe Water	Cobbler Bridge	Not Applicable	Not Applicable
A83_ML_016_000	Yes	OMR_14	Minor A	Croe Water	Pipe culvert, 0.6 m diameter	0.42	<20-yr
A83_ML_017_000	Yes	OMR_14	Minor A	Croe Water	Box culvert 0.9 m (W) x 1.0 m (H)	1.36	>200-yr
A83_ML_017_B01	No	OMR_15	Minor A	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_018_000	Yes	OMR_16	Minor A	Croe Water	Pipe culvert, 0.6 m diameter	0.25	<2-yr

Watercourse Id / Crossing Reference	Coincides with LTS works	OMR crossing	Watercourse categorisation	WFD catchment	Existing A83 (Baseline) Crossing Type / Geometry+	Culvert capacity (m^3/s)+	Capacity return period (years)*
A83_ML_019_000	Yes	OMR_17	Minor A	Croe Water	Pipe culvert, 0.45 m diameter	0.2	~5-yr
A83_ML_020_000	Yes	OMR_18	Minor B	Croe Water	Pipe culvert, 0.375 m diameter	0.13	<2-yr
A83_ML_021_000	Yes	OMR_18	Major	Croe Water	Pipe culvert, 0.6 m diameter	0.34	<2-yr
A83_ML_022_000	Yes	OMR_19	Minor B	Croe Water	Pipe culvert, 0.375 m diameter	0.13	>200-yr + CC
A83_ML_023_000	Yes	OMR_20/19	Minor A	Croe Water	Pipe culvert, 0.45 m diameter	0.2	>200-yr
A83_ML_024_000	Yes	OMR_21	Major	Croe Water	Box culvert 1.2 m (W) x 1.4 m (H)	3	>200-yr
A83_ML_024_B01	No	OMR_22	Minor A	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_025_000	Yes	OMR_23	Major	Croe Water	Pipe culvert, 0.9 m diameter	0.96	~30-yr
A83_ML_026_B01	No	OMR_24	Minor A	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_026_000	Yes	OMR_25	Minor A	Croe Water	Box culvert 1.4 m (W) x 1.5 m (H)	4.2	>200-yr + CC
A83_ML_026_B02	No	OMR_26	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_027_000	Yes	OMR_27	Major	Croe Water	Pipe culvert, 0.6 m diameter	0.36	<2-yr
A83_ML_028_000	Yes	OMR_28	Minor A	Croe Water	Pipe culvert, 0.46 m diameter	0.21	<2-yr
A83_ML_029_000	Yes	OMR_29	Minor A	Croe Water	Box culvert 1.7 m (W) x 1.3 m (H)	3.1	>200-yr + CC
A83_ML_030_000	Yes	OMR_30	Minor A	Croe Water	Pipe culvert, 0.5m diameter	0.2	~2-yr
A83_ML_031_000	Yes	OMR_30	Major	Croe Water	Box culvert 1.2 m (W) x 1.5 m (H)	3.95	>200-yr + CC
A83_ML_032_000	Yes	OMR_31	Major	Croe Water	Pipe culvert, 0.9m diameter	1.01	~10-yr
A83_ML_032_B01	No	OMR_32	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_032_B02	No	OMR_33	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_033_000	Yes	OMR_34	Minor B	Croe Water	Pipe culvert, 0.4 m diameter	0.15	~25-yr

Watercourse Id / Crossing Reference	Coincides with LTS works	OMR crossing	Watercourse categorisation	WFD catchment	Existing A83 (Baseline) Crossing Type / Geometry+	Culvert capacity (m^3/s)+	Capacity return period (years)*
A83_ML_033_B02	No	OMR_35	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_033_B03	No	OMR_36	Minor B	Croe Water	n/a (drains between A83 and OMR)	n/a	n/a
A83_ML_034_000	Yes	n/a	Minor B	Kinglas Water	Unknown	Unknown	Unknown
A83_ML_035_000	Yes	n/a	Minor B	Kinglas Water	Unknown	Unknown	Unknown
A83_B8_001_000	Yes	n/a	Minor A	Croe Water	0.65 m corrugated plastic pipe (B828 crossing measured by AWJV staff on site)	0.82	>200-yr
A83_B8_002_000	Yes	n/a	Minor B	Croe Water	0.45 m corrugated plastic pipe (B828 crossing measured by AWJV staff on site)	Unknown	Unknown
A83_B8_003_000	Yes	n/a	Minor B	Croe Water	0.30 m corrugated plastic pipe (B828 crossing measured by AWJV staff on site)	0.17	<2-yr
A83_B8_004_000	Yes	n/a	Minor B	Croe Water	0.50 m corrugated plastic pipe (B828 crossing measured by AWJV staff on site)	0.29	>200-yr

+Jacobs Baseline Culvert Hydraulic Assessment (Pre-DMRB Stage 2) - A83AAB-JAC-EWE-XX_XX-RP-LE-0005

*Updated AWJV hydrology used

Water Framework Directive (WFD)

A19-3.2.24. The WFD underpins the nature of the assessment overall and will drive much of the design for the drainage systems, crossing structures and any channel realignments. The reportable WFD waterbody status applies to designated main water bodies, defined broadly as those watercourses visible on a 1:50,000 scale Ordnance Survey (OS) map. However, the waterbody catchment comprises a network of tributaries, small watercourses and drains. Hydrologically they are linked and therefore modifications to this network can have a direct impact on the main waterbody status – potential impacts are therefore considered within this context.

A19-3.2.25. The Proposed Scheme does not intersect directly with any WFD classified water bodies and thus there will be no direct impacts; however, there is potential for indirect impacts on two WFD classified waterbodies - the Croe Water (ID: 10215) and Kinglas Water (ID: 10217) due to hydrological connectivity and proximity of works associated with the Proposed Scheme. The Kinglas Water is not located within the hydrological study extent. The WFD catchment boundaries are shown on Volume 3, Figure 19.1, WFD Waterbodies.

A19-3.2.26. The Croe Water is one of the main tributaries of Loch Long within the A83 corridor and has a rural catchment of approximately 18km^2 (CEH, 2022) that drains the area south of the RaBT car park. The main stem of the Croe Water (as per WFD designation) is approximately 7.7 km in length, draining a catchment from south of the RaBT car park in a south-easterly direction, discharging to Loch Long at Ardgartan. The Croe Water catchment includes 9 Minor A and 6 Minor B watercourses.

A19-3.2.27. The Croe Water is classified by SEPA as ‘Moderate’ overall status (2022), with quality elements relating to water quality, invertebrate and macroinvertebrates preventing attainment of target ‘Good’ status. The Croe Water is the only High

importance / sensitivity watercourse crossed by the Proposed Scheme (based on Ordnance Survey channel definition, rather than WFD mapping).

A19-3.2.28. The main stem of the Kinglas Water is approximately 12.6 km in length and is one of the main tributaries of Loch Fyne (coastal waterbody) with a catchment of approximately 30 km^2 (CEH, 2022). The outflow from Loch Restil (Easian Dubh) flows north, a headwater tributary of the Kinglas Water.

A19-3.2.29. The Kinglas Water is defined by SEPA as being a Heavily Modified Water Body (HMWB) due to physical alterations relating to hydroelectrical infrastructure in the catchment area. The Kinglas Water is classified as having a 'Poor Ecological Potential' overall status (2022), with hydromorphology, hydrology, overall ecology and biological quality elements currently impacting the target 'Good Ecological Potential' status. The Kinglas Water is however assessed as being of a 'High' water quality status (2022). The Easan Dubh which is a tributary of the Kinglas Water flows from the northernmost extent of Loch Restil. With all works for the Proposed Scheme to the south of (or at southern extent of) Loch Restil, there is no direct interaction with the Kinglas Water or Easan Dubh channels.

A19-3.2.30. All remaining watercourses that are crossed by the Proposed Scheme which are also tributaries of the Croe Water or Kinglas Water are of a Medium, importance / sensitivity.

A19-3.2.31. Loch Restil is a freshwater water body covering an area of approximately 0.1 km^2. The water body is not designated by SEPA under WFD and lies within the Kinglas Water catchment. The existing A83 runs adjacent to the eastern bank of the loch; however, it does not lie within the 0.5% Annual Exceedance Probability (AEP) (200-year) surface water flood extent for the loch (SEPA, 2020). Further, it is also designated within the Beinn an Lochain Site of Special Scientific Interest (SSSI); although the NatureScot SSSI citation is based on upland habitat, supporting blanket bog, rather than related to the water

environment. Loch Restil is considered as being of a High, importance / sensitivity on account of its inclusion within the Beinn an Lochain SSSI.

A19-3.3. Surface Water Resources and Water Quality

A19-3.3.1. The baseline condition of surface water sensitive receptors within the Study Area or with potential for hydrological connectivity with the Proposed Scheme has been described below, with regard to potential effects on water quality. Receptors include:

- Designated / protected sites
- Public water supplies
- Private water supplies and
- Major and minor watercourses.

A19-3.3.2. A review of Scotland's Environment mapped data on designated or protected sites in relation to the water environment identified that the Proposed Scheme Study Area is within or intersects the Croe Water Drinking Water Protected Area (DWPA) and the Beinn an Lochain SSSI. Although the Glen Etive and Glen Fyne Special Protection Area (SPA) is immediately to the north of the Kinglas Water, Loch Restil is likely to act as a hydrological buffer from the Proposed Scheme.

A19-3.3.3. No public water supplies have been identified in the Study Area.

A19-3.3.4. In relation to private water supplies, a single supply serving High Glen Croe has been identified as having potential to be adversely affected by the Proposed Scheme. High Glen Croe takes its water supply from a tributary of the Croe Water on the southwestern slope of Beinn Luibhean, downslope from the existing A83 and OMR.

A19-3.3.5. A second private water supply identified as serving Roadman's Cottage to the south of the Proposed Scheme has been scoped out of the assessment as it is located upstream of the A83 and to the south of the Croe Water. There are no

works associated with the Proposed Scheme which are likely to have an adverse impact on this supply.

A19-3.4. Hydromorphology

A19-3.4.1. As identified above, the Proposed Scheme is located within the catchments of two WFD water bodies, the Croe Water and the Kinglas Water. Within these catchments, 45 watercourses have been identified as hydrologically connected to the Proposed Scheme (within 1 km). This subsection provides a summary of several assessments and data that provide an insight to the geomorphological character and processes of the watercourses, based on both desk and field studies and hydraulic modelling.

Geomorphological erosion and stability risk

A19-3.4.2. A baseline assessment of the potential for geomorphological adjustments in each of the 22 watercourses crossed by the A83 has been undertaken to identify those at greatest risk from scour or erosion and debris flow events. The assessment has used a combination of topographical assessment, photographic evidence, and a previous geomorphology study (Jacobs (2022) A83 Rest and Be Thankful Geotechnical Support - Detailed Geomorphology and Debris Flow Assessment) in which the hillslope was characterised as Active, Unstable, Potentially unstable or Marginally stable. Summary results are presented in Table A19-3.2, with the full assessment available in Annex 19-3-3.

A19-3.4.3. Unsurprisingly, the highest risk watercourses coincide with the proposed locations of the DFS and debris flow protection wall, i.e. where there is the greatest potential for debris flow and movement of substantial volumes of erodible, poorly consolidated material.

Table A19-3.2 Watercourses erosion risk assessment summary

Risk category	Definition	Watercourses
High	Watercourses located on a geomorphologically active hillslope, with potential for debris flows and incised, steep, banks composed of erodible, poorly consolidated material.	5 in total: A83_ML_023_000 A83_ML_024_000 A83_ML_025_000 A83_ML_026_000 A83_ML_027_000
Medium	Located on a hillslope categorised as geomorphologically unstable, with evidence of debris flows and steep banks composed of erodible, poorly consolidated material.	7 in total: A83_ML_015_000 A83_ML_022_000 A83_ML_028_000 A83_ML_029_000 A83_ML_030_000 A83_ML_031_000 A83_ML_032_000

A19-3.4.4. The remaining 10 watercourses crossed by the A83 within the Proposed Scheme are assessed as at low risk of erosion and geomorphological adjustment. These watercourses are located on relatively stable slopes with little evidence of historical slope activity and have stable banks indicating reduced potential for significant channel erosion.

A19-3.4.5. The five watercourses assessed as having the highest potential for erosion have been modelled using hydraulic modelling software to predict the flow velocities through, and downstream of, the existing A83 crossing structures.

Hydraulic modelling

A19-3.4.6. Baseline 1D models were developed for each of the existing A83 culverts on high-risk watercourses using the crossing type and geometry listed in Table A19-3.1, channel cross-sections obtain from LiDAR data and the 200 year + Climate Change discharges provided in Table A19-3.3.

A19-3.4.7. The results presented in Table A19-3.4 illustrate very high velocities at the modelled 200 year + Climate Change discharges through the culverts. The very high velocities are inherently linked to steep channel gradients. It should be noted the modelling results presented for these watercourses have high uncertainty as the industry standard modelling software applied was not developed for these very steep environments, which reduces the output confidence. Therefore, the results are considered indicative but provide a comparison between watercourses for the purposes of this assessment.

Table A19-3.3 200 year + Climate Change discharges through the modelled culverts

Watercourse	A83_ML_023	A83_ML_024	A83_ML_025	A83_ML_026	A83_ML_027
200+CC Q (m^3/s)	0.24	3.62	2.13	1.02	2.26

Table A19-3.4 200 year + Climate Change baseline modelling estimated culvert and downstream channel velocities (m/s)

Watercourse	A83_ML_023	A83_ML_024	A83_ML_025	A83_ML_026	A83_ML_027
Culvert outlet	4.28	8.92	7.03	6.67	5.65
20m d/s	*	*	*	3.43	6.89
30m d/s	4.02	7.09	7.32	5.13	5.80

Watercourse	A83_ML_023	A83_ML_024	A83_ML_025	A83_ML_026	A83_ML_027
40m d/s	2.85	6.64	6.99	4.61	7.34
50m d/s	3.60	5.63	5.91	4.54	6.67

*Cross section not modelled due to data uncertainty

Ecology

A19-3.4.8. Ecological surveys have been undertaken for all watercourses which may be affected by the Proposed Scheme to determine their potential habitat for fish and other aquatic species and any requirements for mammal ledges through watercourse crossing structures (Volume 3, Figures 11.6.B and 11.8.A). The detail relating to these surveys is provided in Volume 2, Chapter 11, Biodiversity, as well as in Volume 4, Appendix 11.6, Aquatic Receptor Report and Volume 4, Appendix 11.8, Otter Report. A summary of the survey findings pertinent to the hydromorphology assessment are provided in this sub-section.

A19-3.4.9. The ecology surveys have indicated that upstream of the OMR, the fish habitat is poor, with low flows and high gradients making these reaches unsuitable for fish. Electric fishing surveys, undertaken in August 2023 recorded brown trout in the Croe Water (Watercourse Id: A83_ML_15_000) downstream of the OMR. The surveys did not record fish in any other watercourse directly impacted by the Proposed Scheme. However, brown trout were observed downstream of the OMR in A83_ML_008_A01 and A83_ML_011_000, which lie within the RLB associated with the OMR improvements. Ten watercourses within Glen Croe were identified as having suitable habitat for otters and two were identified as having suitable habitat for badgers (Table A19-3.4).

Table A19-3.5 Watercourses with identified ecological potential

Watercourse ID	Fish	Otter	Badger
A83_ML_011_000	Yes	No	No
A83_ML_008_A01	Yes	No	No
A83_ML_15_000 (Croe Water)	Yes	Yes	No
A83_ML_20_000	No	Yes	No
A83_ML_24_000	No	Yes	No
A83_ML_25_000	No	Yes	No
A83_ML_26_000	No	Yes	No
A83_ML_27_000	No	Yes	No
A83_ML_31_000	No	Yes	No
A83_ML_32_000	No	No	Yes
A83_ML_33_000	No	Yes	Yes

Field study

A19-3.4.10. The field study observations support the desk study assessment to aid understanding of the geomorphological processes and characteristics of each watercourse. The observations include:

- Artificial channel modifications
- Planform and boundary conditions (bed and banks)
- Bed sediment characterisation
- Existing fluvial processes and features and
- Riparian and in-channel vegetation.

A19-3.4.11. Each watercourse affected by the Proposed Scheme which coincides with the existing A83 and B828 are characterised within Annex 19-3-1. The watercourses which only coincide with the RLB associated with the OMR and are not crossed by the A83 are characterised in less detail in Annex 19-3-2.

A19-3.4.12. All watercourses are to some degree affected by anthropogenic pressures and modifications relating to bridge and culvert crossings of the A83 and/or OMR (as detailed in Table A19-3.2). There are, however, much more substantial modifications to the watercourses that have been implemented to provide protection and resilience from debris flows to the A83 and the downstream watercourses. These measures include catchpits upstream of the A83 and various types of downstream bed and bank protection and built cascades, including those presented in Plate A19.3.7 for watercourse A83_ML_023_000.

Plate A19.3.7 Examples of existing watercourse (A83_ML_023_000) modifications upstream and downstream of the A83 (Dated: 22 May 2024)


A19-3.4.13. The downstream protection features affect numerous watercourses with a variety of different forms, including concrete bed and bank protection and rock filled mattresses, as presented in Plate A19.3.8 for watercourses A83_ML_029_000 and A83_ML_023_000 respectively.

Plate A19.3.8 Examples of downstream built cascade and bank protection to watercourse A83_ML_029_000 (left) and A83_ML_023_000 (right) (Dated: 22 May 2024)

A19-3.4.14. It was observed during site walkovers that a number of watercourses connected via an upstream catchpit were partially bypassing their correct inlet and culvert structure beneath the A83 to discharge south through the adjacent culverts (Plate A19.3.9). Other instances of bypassing include A83_ML_016_000, where flow was observed to be bypassing the inlet to flow south adjacent to the A83 towards the Croe Water and Cobbler Bridge. Plate A19.3.10 shows the aforementioned catchpit that links watercourses A83_ML_026_000 to A83_ML_024_000 (green circle) and an engineered diversion upslope of the A83 which diverts flow from A83_ML_024_000 to A83_ML_023_000 to improve geotechnical slope stability.

Plate A19.3.9 Flow partially bypassing culvert beneath the A83 associated with A83_ML_025_000 (left) and flow from north to south in the catchpit towards inlet for A83_ML_024_000 (right)

Plate A19.3.10 Upstream channel diversions (circled red) and large A83 catchpit into which multiple watercourses flow (circled green) (Aerial imagery: April 2024)

Sediment characteristics

A19-3.4.15. Wolman pebble counts were performed on the watercourses affected by the LTS. The details of the counts specific to each watercourse are provided in the detailed watercourse characterisations presented in Annex 19-3-1. There are some differences in the sediment make up of watercourses, largely associated with the presence of bedrock or not in the channel/ upstream watercourse. However, generally more than 90% of the sediment in each of the watercourses was <100 mm in diameter.

Watercourse sensitivity classification

A19-3.4.16. A total of 45 watercourse receptors have been identified as potentially impacted by the Proposed Scheme. Of these 45 watercourses, 26 are directly affected by the LTS, 22 of which pass beneath the A83 and 4 beneath the B828. Of these 26 watercourses, 24 are within the Croe Water catchment and 2 are in the Kinglas Water catchment. An additional 19 watercourses, all located within Glen Croe (Croe Water catchment), are affected by the improvements to the OMR.

A19-3.4.17. The complete sensitivity classification of all 45 watercourses is provided in Table A19-3.5. The A83_ML_015 (Croe Water) is the only High Importance/Sensitivity watercourse receptor in the Study Area.

A19-3.4.18. 26 watercourses are classified as Low Importance/Sensitivity watercourse receptors. 19 of these watercourses are small, poorly defined and heavily vegetated drainage channels between the A83 and OMR, or along the B828 and are not affected by the A83 LTS proposals. A83_ML_033_000, A83_ML_030_000, A83_ML_026_000, A83_ML_019_000 and A83_ML_020_000 are watercourses that drain from above the A83 into Glen Croe and classified as Low Importance/ Sensitivity due to significant anthropogenic modifications. The two watercourses draining to Loch Restil (A83_ML_035_000 and A83_ML_034_000) area also classified as Low Importance/ Sensitivity as there is no well-defined channel, other than the

heavily vegetated depression which runs in parallel to the A83 and appears to collect the overland flows from the western slopes of the Ben Luibhean.

A19-3.4.19. The remaining 18 watercourses that are crossed by the Proposed Scheme which are also tributaries of the Croe Water or Kinglas Water are of a Medium, Importance/ Sensitivity as they exhibit some signs of artificial modifications and indications of recovery and re-establishment of natural morphological features and associated natural fluvial processes.

Table A19-3.6 Watercourses sensitivity classification

Watercourse	Sensitivity	Justification
A83_ML_Z05_B01	Low	This watercourse is watercourse is heavily modified with two sediment traps and numerous historic and recent realignments. Most recently the watercourse has been realigned as part of the improvement to OMR through a new culvert crossing.
A83_ML_Z05_B02	Low	This watercourse is heavily vegetated and from aerial imagery appears to have been cut into the slope to provide drainage between the A83 and the OMR with limited observable natural features.
A83_ML_Z05_B03	Low	This watercourse is heavily vegetated and from aerial imagery appears to have been cut into the slope to provide drainage between the A83 and the OMR with limited observable natural features. There is approximately 6 m of channel from the OMR culvert outlet to the Croe Water.
A83_ML_Z05_B04	Low	This watercourse is heavily vegetated and from aerial imagery appears to have been cut into the slope to provide drainage between the A83 and the OMR with limited observable natural features.
A83_ML_Z05_B05	Low	This watercourse is heavily vegetated and from aerial imagery appears to have been cut into the slope to provide drainage between the A83 and the OMR with limited observable natural features.

Watercourse	Sensitivity	Justification
A83_ML_Z05_B06	Low	This watercourse is heavily vegetated and from aerial imagery appears to have been cut into the slope to provide drainage between the A83 and the OMR with limited observable flow diversity.
A83_ML_008_A01	Medium	This watercourse is crossed by both the A83 and the OMR. There are signs of active geomorphological processes within the channel, including the deposition of sediment and gravels on the bed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by a culvert.
A83_ML_010_B02	Low	The culvert has been installed to coincide with the depression in the upslope field in which overland flows will concentrate. Historically there are signs of erosion where the depression joins a drain which has now been infilled with cobbles/larger material.
A83_ML_011_000	Medium	This watercourse is crossed by both the A83 and the OMR. There are signs of geomorphological features in the channel, including steps and pools.
A83_ML_012_000	Medium	This watercourse is crossed by both the A83 and the OMR. There are signs of active geomorphological processes within the channel, including the deposition of sediment and gravels on the bed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by a culvert.

Watercourse	Sensitivity	Justification
A83_ML_014_000	Medium	There is no clearly defined channel upslope of the A83 but a drain that is aligned parallel to the A83 appears to collect runoff from the southwestern slopes of The Cobbler (Ben Arthur) which are routed beneath the A83 to a downslope, channel. There are signs of sediment and gravel aggradation to the bed at the OMR culvert where the channel gradient has reduced and flows are constricted.
A83_ML_012_B03	Low	There is no clearly defined channel at this location but a drainage ditch captures overland flows from the toe of the slope between the OMR and A83 and conveys it through a culvert beneath the A83.
A83_ML_015_000 (Croe Water)	High	This watercourse is crossed by both the A83 and the OMR and exhibits a range of geomorphological features, including bedrock and boulder cascades, transitioning to step-pools at lower gradients.
A83_ML_016_000	Medium	This watercourse is crossed by both the A83 and the OMR. There are signs of active geomorphological processes within the channel, including the deposition of sediment and gravels on the bed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by a culvert. Flow was observed to be bypassing the A83 (T) culvert inlet, flowing south adjacent to the A83 towards the Croe Water and Cobbler Bridge.

Watercourse	Sensitivity	Justification
A83_ML_017_000	Medium	From the A83 culvert outlet, channel morphology bed features are predominantly cascades. Downstream the gradient reduces to approximately 23% throughout the remaining reach with channel morphology transitioning to a step-pool sequence.
A83_ML_017_B01	Low	There is no clearly defined channel but a drainage ditch captures the overland flows from the toe of the slope between the OMR and A83 and conveys it through a culvert beneath the A83.
A83_ML_018_000	Medium	The morphology of the upper and lower reaches primarily features step-pool sequences. Cattle poaching and collapsing banks are prevalent upslope of the OMR. Significant accumulation of sediment in the channel bed of gravel grain sizes and finer is present immediately upstream and downstream of the OMR, where slopes are more moderate, and flow constricted by the culvert.
A83_ML_019_000	Low	The channel morphology upslope of the OMR is heavily influenced by cattle poaching, resulting in a channel that is not well-defined with water flowing between clumps of mud and grass. Below the OMR there is substantial gravel deposition, and a well-defined plane-bed channel
A83_ML_020_000	Low	This Minor B watercourse converges with the A83_ML_021_000 Major watercourse approximately 17 m downslope of the A83 and approximately 5 m down from the A83_ML_020_000 culvert outlet.

Watercourse	Sensitivity	Justification
A83_ML_021_000	Medium	The first 10 m of the channel from the A83 culvert outlet comprises a built concrete cascade. The morphology of the upper reach primarily features step-pool sequences whereas the lower reach comprises a plane-bed channel. Gravel aggradation is abundant immediately upstream and downstream of the OMR, where channel gradient reduces and sediment transport capacity is lower.
A83_ML_022_000	Medium	The morphology of the upper reach comprises step-pool sequences, whereas the reach below the OMR comprises plane-bed or riffle-pool bed features. Immediately upstream of the OMR, the channel flows south along the back of a gravel-filled barricade (HESCO bund) installed to protect the OMR from debris flows/ landslips.
A83_ML_023_000	Medium	Upslope of the A83 is a significant catchpit formed from bedrock and concrete which has been created to attenuate debris flows and provide resilience to the operation of the A83. The A83 culvert outlet is a protruding plastic pipe that discharge to a 12 m spraycrete apron. This watercourse, all the way down to the OMR is over widened and deepened due to the conveyance of debris flows.

Watercourse	Sensitivity	Justification
A83_ML_024_000	Medium	The watercourse has an upstream catchpit that links this watercourse with A83_ML_025_000 and A83_ML_026_000. This watercourse is located within an active debris flow channel, with the last debris flow event experienced in October 2023. During debris flow events significant volumes of water and entrained sand and cobbles pass through the culvert causing the greatest rates of erosion and scour. This is exacerbated when a debris flow event blocks one or more culverts within the upstream catchpit meaning one culvert may have to convey flows that originate from multiple valleys and watercourses. In October 2023, watercourse A83_ML_024_000 conveyed flow from three watercourses due to culvert blockages.
A83_ML_024_B01	Low	The channel upstream of the OMR is a very straight maintained drainage ditch with a uniform profile which collects overland flows from between the A83 and OMR. Downstream of the culvert the channel seems to be well vegetated with limited evidence of erosion or deposition of bed material.

Watercourse	Sensitivity	Justification
A83_ML_025_000	Medium	The watercourse has a catchpit and three landslide and rock fall barriers immediately upstream of the A83. The upstream catchpit is a combined catchpit linking this watercourse with A83_ML_024_000 and A83_ML_026_000. The morphology of the upper reach extending to the OMR, primarily features cascades and step-pool sequences, whereas the reach below the OMR comprises a plane-bed and step-pool morphology. Significant fines and gravel aggradation on the bed is observed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by a culvert.
A83_ML_026_B01	Low	There is a culvert draining beneath the OMR which conveys flows that accumulate within a depression above the OMR capturing runoff from between the A83 and OMR.

Watercourse	Sensitivity	Justification
A83_ML_026_000	Low	The watercourse has a catchpit and landslide and rock fall barriers immediately upstream of the A83. The upstream catchpit is a combined catchpit linking this watercourse with A83_ML_024_000 and A83_ML_025_000. Channel bed gradient is steepest immediately upstream and downstream of the existing A83 culvert. Gabion reno mattress type protection has been installed over a 10 m reach to protect the bed and banks downstream of the culvert. Within the base of the mattress there is a geotextile to trap fines. There are gabions at the top of the reach offering some support to the slopes around and above the culvert outlet. The mesh within the channel is failing. Downstream of this reach there is a section that is lined with a geotextile that has been soil nailed (reinforcing element installed into the soil to stabilize slopes, excavations) to provide further protection with large boulders placed on top. Immediately downstream of this reach, a rockfall fence has been installed across the channel and filled with large boulder material to provide scour protection, however, this caused erosion and widening of the channel, upstream and downstream of the fence. Following this, the bed morphology is cascade and step-pool sequences.
A83_ML_026_B02	Low	There is a culvert draining beneath the OMR which conveys flows that accumulate within a depression above the OMR capturing runoff from between the A83 and OMR.

Watercourse	Sensitivity	Justification
A83_ML_027_000	Medium	The watercourse exhibits a very steep gradient. The morphology of the upper and lower reaches primarily features cascade sequences which transition to step pools as the gradient reduces.
A83_ML_028_000	Medium	The A83 culvert outfalls to a concrete cascade, which is in good condition. The watercourse exhibits a very steep gradient, with an average of 39% (up to 121%) in the upper reach, and 35% (up to 86%) in the lower reach. Although there are some steps in the gradient downstream from the culvert, there is an overall decline in channel steepness. The morphology of the upper and lower reaches primarily features a cascade to step-pool sequence.
A83_ML_029_000	Medium	This watercourse is heavily modified both upstream and downstream of the A83. Upstream of the A83 there is straight, 30 m, concrete cascade (1:1) that directs flow to the A83 culvert. Downstream of the A83 the culvert discharges to a ~17 m concrete cascade that doglegs flow to the north before a drop of approximately 1.5 m to the natural channel. Generally, the gradient declines in channel from upslope to downslope. The morphology of the upper and lower reaches primarily features step-pool sequences.
A83_ML_030_000	Low	This watercourse between the A83 and OMR consists of a fibreglass-lined channel. There are no natural processes occurring within this watercourse.

Watercourse	Sensitivity	Justification
A83_ML_031_000	Medium	There is a box culvert beneath the A83 that is constructed from stone blocks and has a bedrock base. This culvert discharges to a bedrock cascade which is the dominant morphology of the upper reach between the A83 and OMR culvert. The reach below OMR primarily features step-pool sequences, with some cascades in the steeper sections.
A83_ML_032_000	Medium	The watercourse between the A83 and the OMR consists of steep bedrock cascades with banks consisting of grass covered shallow soils. The reach downstream of the OMR shows a less steep morphology with step pool sequences.
A83_ML_032_B01	Low	There is a culvert draining beneath the OMR which conveys flows that accumulate within a drainage ditch that runs in parallel to the OMR capturing runoff from between the A83 and OMR.
A83_ML_032_B02	Low	There is a culvert draining beneath the OMR which conveys flows that accumulate within a drainage ditch that runs in parallel to the OMR

Watercourse	Sensitivity	Justification
A83_ML_033_000	Low	This watercourse is culverted the entire distance from upstream of the A83 to the OMR. The culvert discharges to an artificial drainage channel for approximately 2 m before it then enters a second culvert below the OMR. A defined channel does not begin until approximately 22 m downstream of the OMR (as observed from aerial imagery).
A83_ML_033_B02	Low	There is culvert draining beneath the OMR with a very small upstream area which includes the RaBT carpark. From the available photographic evidence there appears to be limited sediment being transported through the culvert so a catchpit is deemed unnecessary.
A83_ML_033_B03	Low	There is a culvert beneath the OMR which is draining a very small triangle of land within the hairpin bend of the OMR, discharging to a vegetated area of land.
A83_ML_034_000	Low	The A83 culvert inlet is located within a poorly-defined drainage channel that runs in parallel to the A83. It was not possible to locate the inlet during a site visit due to the vegetation and detritus within the drainage ditch. The buildup of in-channel vegetation is likely to be impacting the efficiency of the conveyance of flows into the culvert. The culvert outlet was observed to have collapsed.

Watercourse	Sensitivity	Justification
A83_ML_035_000	Low	The channel upstream of the A83 is poorly-defined and the culvert inlet is located within a heavily vegetated drainage channel. The culvert outlet is located approximately 7 m from, and 3 m above, the shore of Loch Restil. The downstream channel consists of an unstable channel that is eroding the fines and cobbles that make-up the bed and banks.
A83_B8_001_000	Medium	The channel upstream of the B828 exhibits a range of morphological features with variability in flow depth and velocity.
A83_B8_002_000	Low	The channels upstream and downstream of the B828 are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep and 1 m wide running in parallel with the B828 that crosses the slope, running south to north, and intercepting any upslope runoff.
A83_B8_003_000	Low	The channels upstream and downstream of the B828 are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep and 1m wide running in parallel with the B828 that crosses the slope, running south to north, and intercepting any upslope runoff

Watercourse	Sensitivity	Justification
A83_B8_004_000	Low	The channels upstream and downstream of the B828 are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep and 1 m wide running in parallel with the B828 that crosses the slope, running south to north, and intercepting any upslope runoff

A19-3.5. Flood Risk

A19-3.5.1. Flood risk baseline information was gathered to understand the current flood risk for the site in addition to any influencing factors that would need to be considered for the impact assessment.

A19-3.5.2. The Flood Risk Assessment (FRA) approach conceptually divides the Proposed Scheme into three areas; small hillside watercourses, the High Glen Croe tributary / Croe Water and Loch Restil, with this baseline section structured in this manner. Plate A19.3.11 shows these locations annotated on SEPA Flood Maps. See Volume 4, Appendix 19.6, Flood Risk Assessment for further details.

Flood Risk Receptors

A19-3.5.3. Receptors were identified for the baseline within the Study Area and are provided in Table A19-3.6. The Importance has been defined from DMRB LA 113 and SEPA Flood Risk and Land Use Vulnerability Guidance. The Annual Exceedance Probability (AEP) is noted, with lower percentages indicating reduced risk of flooding in any given year. Climate change (CC) predictions have been added to provide contingency, based on latest datasets.

A19-3.5.4. The flood risk was defined from the baseline flood model or where no flood model available, using SEPA Flood Maps.

Plate A19.3.11 SEPA Flood Map for the Study Area, Annotated with Local Feature

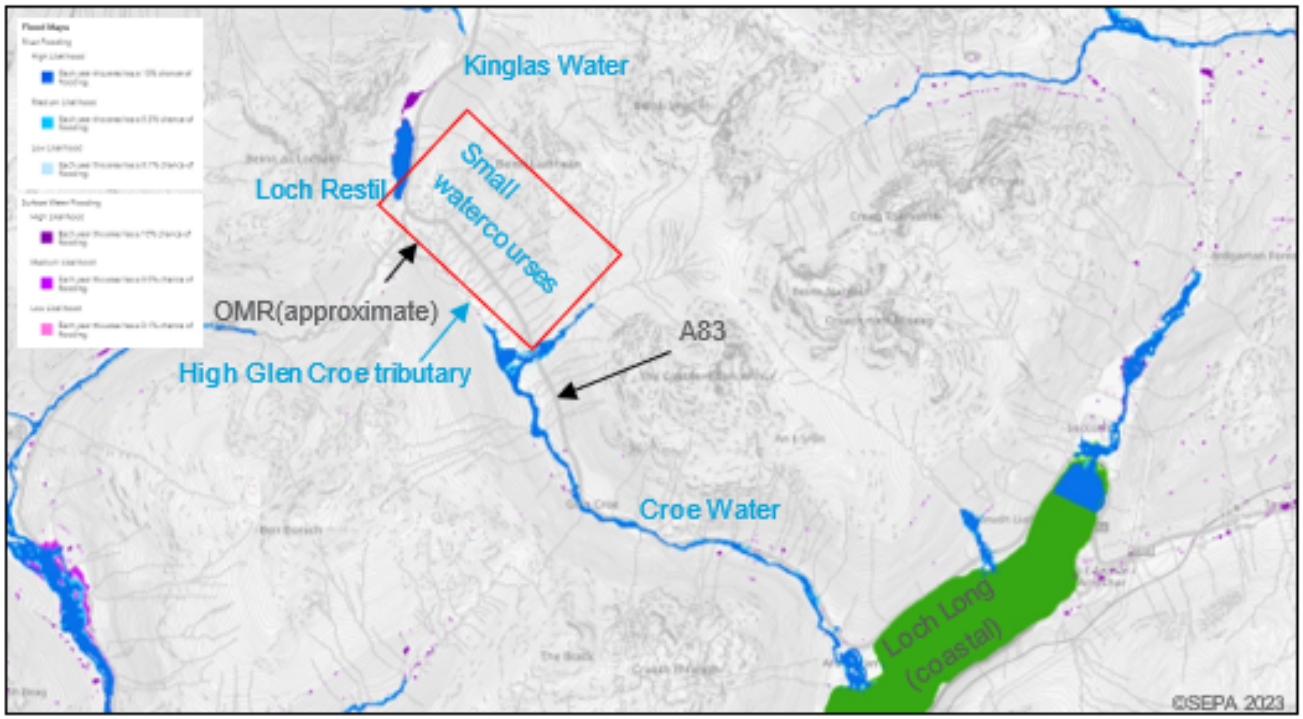


Table A19-3.7 - Summary of Flood Risk Receptors

Receptor*	Description	DMRB Importance Estimation	Land Use Vulnerability Classification	Source of Flooding	Flood Risk (SEPA flood maps)	Flood risk from site specific modelling
NN 24423 05554P01	Residential dwelling	High	Highly Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Receptor lies outside of flood 0.5%AEP plus CC flood extent
NN 24282 05565	Structure used for agricultural purposes	Medium	Least Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Receptor lies outside of flood 0.5%AEP plus CC flood extent
NN 24207 05681	Structure used for agricultural purposes	Medium	Least Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Receptor lies outside of flood 0.5%AEP plus CC flood extent
NN 24013 06056	Structure used for agricultural	High	Least Vulnerable Use	Croe Water	Low to medium risk (0.1% -	Receptor currently lies within 0.5% AEP plus

	purposes				0.5% AEP)	climate extent.
NN 23328 06978	Residential dwelling	High	Highly Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Receptor lies outside of flood 0.5%AEP plus CC flood extent
A83	Road	High	Highly Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Receptor currently lies within 0.5% AEP plus climate extent.
OMR	Road	High (given its diversion status)	Least Vulnerable Use	Small watercourses	Low to medium risk (0.1% - 0.5% AEP)	Receptor currently lies within 0.5% AEP plus climate extent.
BT Underground Lines	Underground Lines following OMR & A83	Very High	Essential Infrastructure	Croe Water	Low to medium risk (0.1%-0.5% AEP)	Receptor currently lies within 0.5% AEP plus climate extent.
NN 27547 03013	Caravan Holiday Park –	High	Highly Vulnerable Use	Croe Water	Low to medium risk (0.1% -	Not within model domain

	Forest Holidays Ardgartan				0.5% AEP)	
NN 27314 02812	Ardgartan Hotel	High	Highly Vulnerable Use	Croe Water	Medium to high risk within built up area (>0.5% AEP)	Not within model domain
NN 26959 03714	Dwelling (cabin/visitor centre)	High	Highly Vulnerable Use	Croe Water	Medium to high risk within built up area (>0.5% AEP)	Not within model domain
NN 26972 03816	Residential dwelling	High	Highly Vulnerable Use	Croe Water	Low to medium risk (0.1% - 0.5% AEP)	Not within model domain
NN 26777 03966	Residential dwelling	Medium	Least Vulnerable Uses (appears to be	Croe Water	Little or no risk (<0.1% AEP)	Not within model domain

			uninhabited from DTS)			
NN 26286 04062	Residential dwelling	High	Highly Vulnerable Use	Croe Water	Little or no risk (<0.1% AEP)	Not within model domain

Loch Restil

A19-3.5.5. Loch Restil was initially considered for flood risk during the stage 2 optioneering when different routes were being considered. However, subsequent to the Preferred Scheme being selected, Loch Restil has been screened out as the Proposed Scheme outwith the Croe Water catchment is much more limited in scope, with junction widening and improved sightlines, rather than extensive engineering works or carriageway widening. The initial stages of the study, including details of the hydrology and modelling for Loch Restil are included in Volume 4, Appendix 19.6, Flood Risk Assessment (Annex D).

Small Watercourses

Characterisation

A19-3.5.6. The small watercourses are incised channels running directly down the hillside of Beinn Luibhean. These slopes are characterised as steep, rugged terrain with no / little attenuation. The gradient is the major controlling factor over the velocity of any flows in the area.

Site visits / Drone footage

A19-3.5.7. Several site visits were conducted by members off the AWJV flood risk team in January 2023, March 2023 and April 2024, in addition to drone footage captured of the area. Observations from the site visits were used throughout the FRA process to inform professional judgement and understanding of the key factors relating to flood risk within the area.

A19-3.5.8. Plates A19.3.12-18 emphasise the steep terrain characteristics, with montane scrub vegetation dominating the hillside, providing minimal resistance to slow water flows. The small watercourses are typically incised channels, cutting vertically through the hillside, some of which are ephemeral in nature. Whilst these channels do provide flow paths, the open nature of the hillside is also

conducive to sheet flow outwith channels. Flow velocities are typically high, with shallow flow depths.

A19-3.5.9. Further analysis on the condition of the watercourses can be found in Annex 19-3-1, Detailed watercourse characterisations.

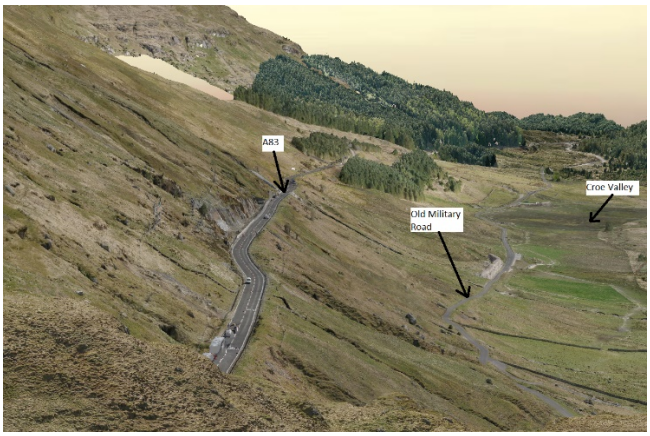


Plate A19.3.12 - Drone capture facing south, showing the A83, OMR and the hillside channels on the steep slopes of Beinn Luibhean above the Croe valley

Plate A19.3.13 - View of the Croe valley facing south from the Rest and Be Thankful car park. With OMR in the foreground and the A83 at higher elevation

Plate A19.3.14 - View of the A83 and Glen Croe, facing southwest from Beinn Luibhean

Plate A19.3.15 View north towards the Rest and Be Thankful car park from above the A83 in Glen Croe, with Beinn Luibhean on the right

Plate A19.3.16 – Further examples of channels downstream of the A83

Plate A19.3.17 – Further examples of channels and slopes downstream of the A83

Plate A19.3.18 View east, showing numerous incised channels on upper-mid slope of Beinn Luibhean, above and below the A83.

Existing structures on the small watercourses

A19-3.5.10. Water flows via hillside runoff or following watercourse channels down to the A83. Overland flow has the potential to spill directly across the road or be diverted via small roadside ditches towards upslope culvert inlets. These culverts are listed on Table A19-3.1.

A19-3.5.11. If the local culvert does not have the required capacity, flow shall back up and either:

- spill across the A83 and pass to the downslope
- flow south along small longitudinal drainage ditches and through another culvert that has capacity
- flow south along small longitudinal drainage ditches, before meeting a blockage and/or fully surcharged channel/culvert and then spilling onto and across the A83 or

- flow into installed catchpits, designed for debris flow retention but which provide additional capacity for flow attenuation, reducing potential for spill onto A83.

Hydrology

A19-3.5.12. Full details of the hydrological derivation can be found in Volume 4, Appendix 19.6 Flood Risk Assessment (Annex A). The purpose of the small watercourse hydrology was to provide inflows into the related culvert models. For each culvert, the catchment was delineated using global mapper GIS software, LiDAR and UAV survey data.

A19-3.5.13. Peak flow estimations were derived for each catchment using Flood Estimation Handbook (FEH) standard methodologies; FEH Rainfall Run off method and FEH Statistical approach (for catchments <5km^2), applying selected representative donor catchments.

A19-3.5.14. The statistical method was deemed suitable for the majority of the A83 culvert catchments, when scaled from a representative doner catchment, with relatively low flows relating to small sub-catchment sizes.

Historic Flood Information

A19-3.5.15. Correspondence from SEPA identified 10 records of pluvial flooding in the Rest and Be Thankful area since 2006, all related to flooding closing the A83 due to landslips following heavy rain.

A19-3.5.16. A collection of images of various debris / flood events have been provided in Plates A19.3.19-22. These provide visual evidence of both overland flow and high flows within channels, both of which have caused A83 flooding.

Plate A19.3.19 – Example of channel and overland flow crossing the A83 and OMR to the base of Glen Croe

Plate A19.3.20 – Overland flow passing onto the A83, outwith channels

Plate A19.3.21 – Overland flow spilling onto A83

Plate 19.3.22 – Surface water flow spilling onto A83

SEPA flood maps

A19-3.5.17. SEPA fluvial flood maps do not identify any flooding from the small watercourses on the slopes of Beinn Luibhean. The catchments are all smaller

than 3km^2; the threshold size of catchment that SEPA provide flood risk extents. The SEPA surface water flood maps also did not show any local flooding (which can also indicate flooding related to below threshold watercourses).

Flood Modelling

A19-3.5.18. 1D models were developed for a number of the watercourses. Full details of the modelling is provided in Volume 4, Appendix 19.6, Flood Risk Assessment (Annex B).

A19-3.5.19. The baseline model emphasised the controlling factor being the steep terrain. The models were used primarily for geomorphological comparison but enabled analysis of pre and post culvert flows to be undertaken and presented in Appendix 19.6.

Flood Defences

A19-3.5.20. No formal flood defences, flood mitigation measures listed in DMRB LA 113 (Section 3.68.1), nor other noticeable flood prevention measures were observed during the site walkover on 17 February 2023. It has therefore been assumed that there are no formal flood defence assets or schemes as defined in the Flood Risk Management (Scotland) Act 2009 in The Proposed Scheme's Study Area.

High Glen Croe tributary / Croe Water

Characterisation

A19-3.5.21. The Croe Water is the watercourse that flows from the eastern slope of Glen Croe and then meanders along the base of the valley, flowing generally south-east. The valley is flat and wide at the lower (southern) extent. The High Glen Croe tributary originates near the Rest and Be Thankful viewpoint, then flows down the upper valley to meet the Croe Water. At the confluence with the Croe Water the floodplain opens out a little before narrowing and remaining narrow for the remainder of its length. As the river flows south towards Loch Long it

becomes steeper and more incised, keeping its meandering profile with shoals and banks of unconsolidated material transferred from the slopes of Beinn Luibhean.

A19-3.5.22. Site visit and drone surveys of Glen Croe images are presented as Plates A19.3.23-26.

Existing Structures

A19-3.5.23. The in-channel hydraulic structures included in the Croe valley are specified Table A19-3.7 and locations are shown on Plate A19.3.27.

Plate A19.3.23 – View looking south down Glen Croe, with A83, OMR and Croe Water evident

Plate A19.3.24 – View east towards Beinn Luibhean, with the High Glen Croe tributary in the foreground (left). The Croe Water flows past the forestry, to meet this tributary

Plate A19.3.25 – View looking northwest towards the western side of Glen Croe, with the Croe Water floodplain at flat base of valley

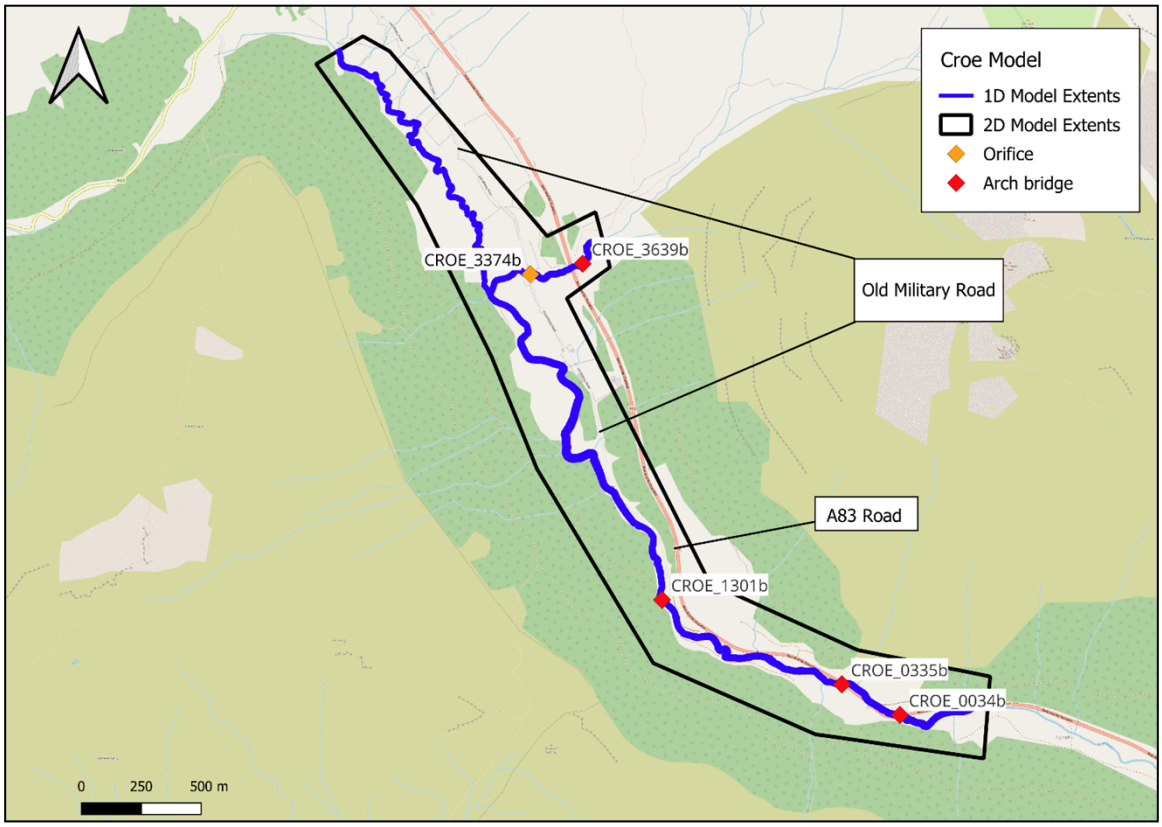
Plate A19.3.26 – View from the lower stretch of Glen Croe. The lower stretch of the watercourse is much steeper and straighter than that middle stretch

Table A19-3.8 Croe Valley hydraulic structures

Structure Number	Watercourse	Structure	Flood Modeller Node Name	Specification
1	Croe Water	Footbridge	CROE_3639b	Type – Arch bridge Bed Level – 165.28m AOD Width – 7.45m Springing Level – 168.28m AOD Crown Level – 168.28m AOD
2	Croe Water	Old Military Road crossing	CROE_3374b	Type – Rectangular Orifice Invert Level – 125.05m AOD Throat Soffit Level – 126.55m AOD
3	Croe Water	Bridge crossing for Glen Croe Lower Forestry Track	CROE_1301b	Type – Arch bridge Bed Level – 89.49m AOD Width – 7.77m Springing Level – 91.39m AOD Crown Level – 91.39m AOD

Structure Number	Watercourse	Structure	Flood Modeller Node Name	Specification
4	Croe Water	A83 Bridge 50	CROE_0335b	Type – Arch Bridge Bed Level – 80.34 m AOD Width Arch 1 – 6.30m Springing Level Arch 1 – 83.17m AOD Crown Level Arch 1 – 83.31m AOD Width Arch 2 – 5.96m Springing Level Arch 2 – 83.13m AOD Crown Level Arch 2 – 83.25m AOD
5	Croe Water	A83 Bridge 40 (Little Rest)	CROE_0034b	Type – Arch Bridge Bed Level – 59.47m AOD Width Arch – 13.16m Springing Level Arch – 66.18m AOD Crown Level Arch – 66.37m AOD

Plate A19.3.27 – 1D structure locations located in the Croe valley



Croe Model Hydrology

A19-3.5.24. The purpose of the Croe Water hydrology was to provide inflows required for the associated hydraulic model. Full details of the hydrology derivations and modelling software applied are available in Volume 4, Appendix 19.6, Flood Risk Assessment. Model inflows were required for the two upstream sub-catchments, as well as for three lateral inflow catchments.

A19-3.5.25. Peak flow estimations were derived for each catchment using FEH standard methodologies of FEH Rainfall Runoff Method and FEH Statistical Approach (where catchment >5 km^2).

A19-3.5.26. For all return periods apart from Qmed, including the 0.5% AEP event, the ReFH2 peak flows are greater than the FEH Statistical peak flows when comparing both the methods applied to the whole catchment at the downstream end and the summed sub-catchment inflows. Therefore, ReFH2 peak flows have been taken forward as they are more conservative and provide more consistent results across the catchments.

A19-3.5.27. A distributed method was chosen as the most appropriate, applying inflows to the five sub-catchments in the model. Hydrographs for the 50% AEP, 10% AEP, 3.33% AEP, 1% AEP, 0.5% AEP , 0.5% AEP + 46% climate change, events have been derived from the ReFH2 design parameters based on a distributed approach.

Historic flood information

A19-3.5.28. Consultation from SEPA and Argyll and Bute Council provided no records of flooding from the High Glen Croe tributary / Croe Water. A media search also suggested no historic flood event records related to the Croe Water.

SEPA flood Maps

A19-3.5.29. The Croe valley is represented in the SEPA flood maps as it is located in a catchment that is greater than 3 km^2. The Croe valley is at risk of river flooding for the low, medium and high likelihood events. The extents of the flooding begin upstream of the confluence of the High Glen Croe and the Croe Water, then continue down to Loch Long.

Flood Modelling

A19-3.5.30. The Glen Croe hydraulic modelling technical note (Volume 4, Appendix 19.6 Flood Risk Assessment, Annex C) provides details of the modelling approach used to assess the fluvial flood risk posed by the Croe Water and its primary tributary (‘High Glen Croe tributary’). The modelled area covers a 4.2 km stretch of the Croe Water in addition to a 1.7 km stretch of this tributary. The upstream extent of the Croe Water is approximately 220m upstream of the A83

crossing (NGR 224374, 706143) and the upstream extent of the tributary is 1.7 km upstream of its confluence with the Croe Water (NGR 223273, 706927). The downstream extent of the model is around 415m downstream from the section A83 crossing of the Croe Water (Little Rest bridge) near Creagdhu (NGR 225981, 704192).

A19-3.5.31. The modelling approach utilises data obtained from site surveys carried out between 2019 and 2021, as well as desk-based data obtained from Transport Scotland, SEPA and Fugro. The model was built as a combination of 1D/2D techniques using Flood Modeller Pro Version 5.1 and TUFLOW 2020, allowing for the transfer of water between the watercourses and the floodplains. Predictions were made regarding the peak water levels for the floodplain/modelled river reach for the following annual exceedance probability (AEP) events:

- 50% AEP (2-year);
- 10% AEP (10-year);
- 3.33% AEP (30-year);
- 2% AEP (50-year);
- 1.33% AEP (75-year);
- 1% AEP (100-year);
- 0.5% AEP (200-year); and
- 0.5% AEP (200-year) plus Climate Change (CC) allowance

A19-3.5.32. Further information on these baseline flood maps are provided in Volume 4, Appendix 19.6, Flood Risk Assessment, displayed on Volume 3, Figures 19.8 – 19.12. These maps also informed the baseline flood risk assessment for each receptor, as outlined in Table 19-3.6 above.

Annex 19-3-1 Detailed watercourse characterisations

(ordered south to north)

Watercourse ID	A83_ML_014_000
Corresponding OMR crossing ID	OMR_11
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.058
Watercourse length from A83 to OMR (m)	180
Existing A83 culvert (Capacity)	unknown

Cascade to step-pool sequence downstream of the OMR (looking downstream)

Description: There is no clearly defined channel upslope of the A83. Rather, there is a drain that runs in parallel to the A83 that collects the runoff from the southwestern slopes of The Cobbler (Ben Arthur) which are routed beneath the A83 to a small downslope channel. The channel gradient ranges between 20 to 30% (0.2 to 0.3 m/m), there is then approximately a 10m section where the topography slackens with gradients of 5-10%

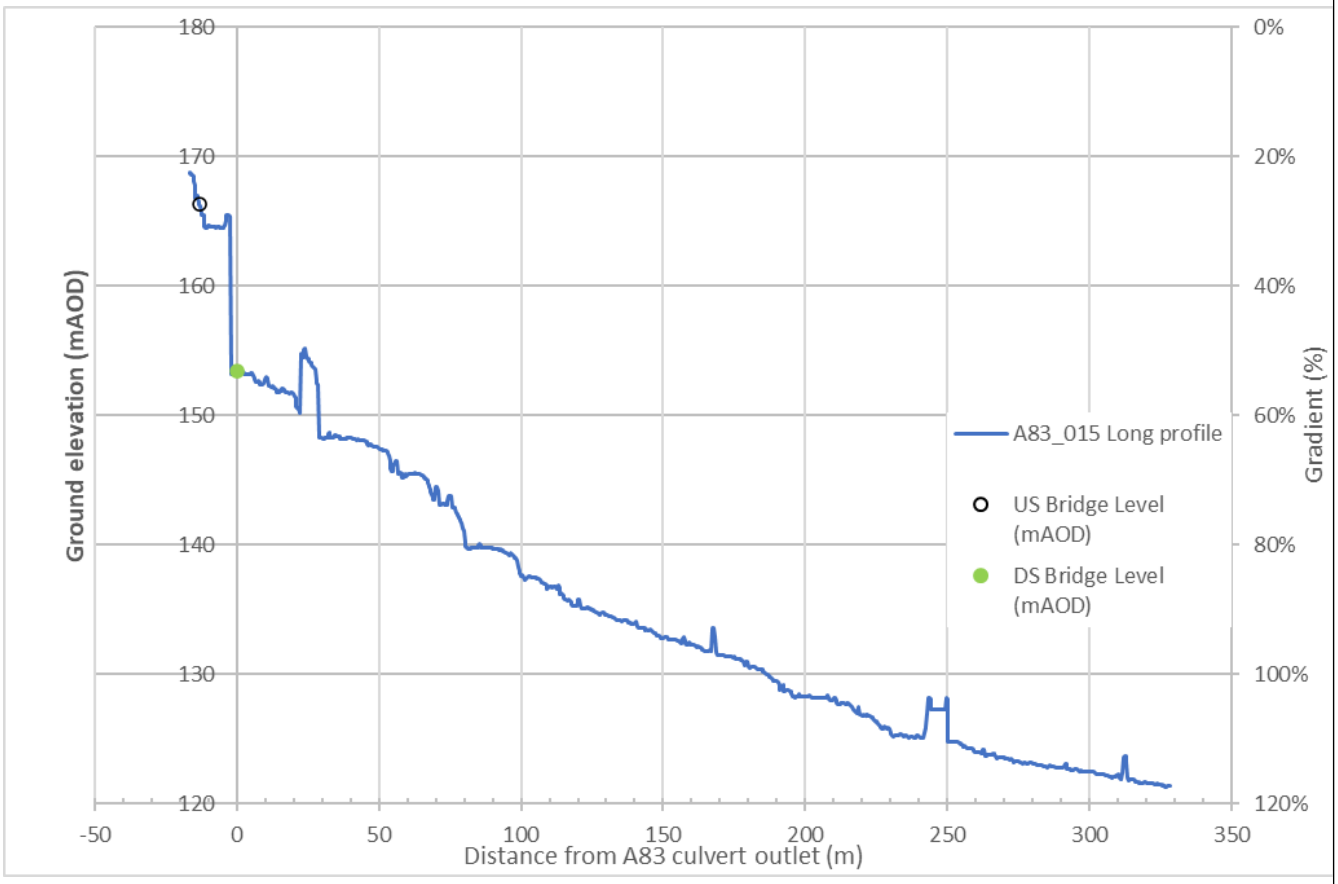
Sediment: No data collected in the field. Although this watercourse is within the RLB no LTS works are proposed that would directly or indirectly impact this watercourse.

Watercourse ID	A83_ML_015_000
Corresponding OMR crossing ID	OMR_13
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	3.39
Watercourse length from A83 to OMR (m)	220
Existing A83 culvert (Capacity)	n/a (Cobbler Bridge)
Cascade to step-pool sequence downstream of the OMR (looking downstream) 	Cascade to step-pool sequence upstream of the OMR (looking upstream towards the A83, the Cobbler bridge can be seen) 
Description: The A83 Cobbler Bridge crossing of the A83_ML_015_000 has two in channel piers. The watercourse is steep, with gradients of >23% (0.237 m/m) for the 100 m upstream of the A83/Cobbler bridge 17% (0.174 m/m) for the first 100m downstream of the A83/Cobbler Bridge. Approximately 35 m upstream of the Cobbler Bridge, there is a single-span footbridge. The reach upstream of the Cobbler Bridge consists of bedrock morphology, with numerous large boulders distributed along the reach and within the riparian area. Downstream of the Cobbler Bridge there is evidence of scour to both banks for approximately 9-10 m, in proximity to the bridge piers. The remainder of the downstream reach is largely stable, with some signs of erosion. The bankfull width was measured at 9.5 m downstream to the OMR.	

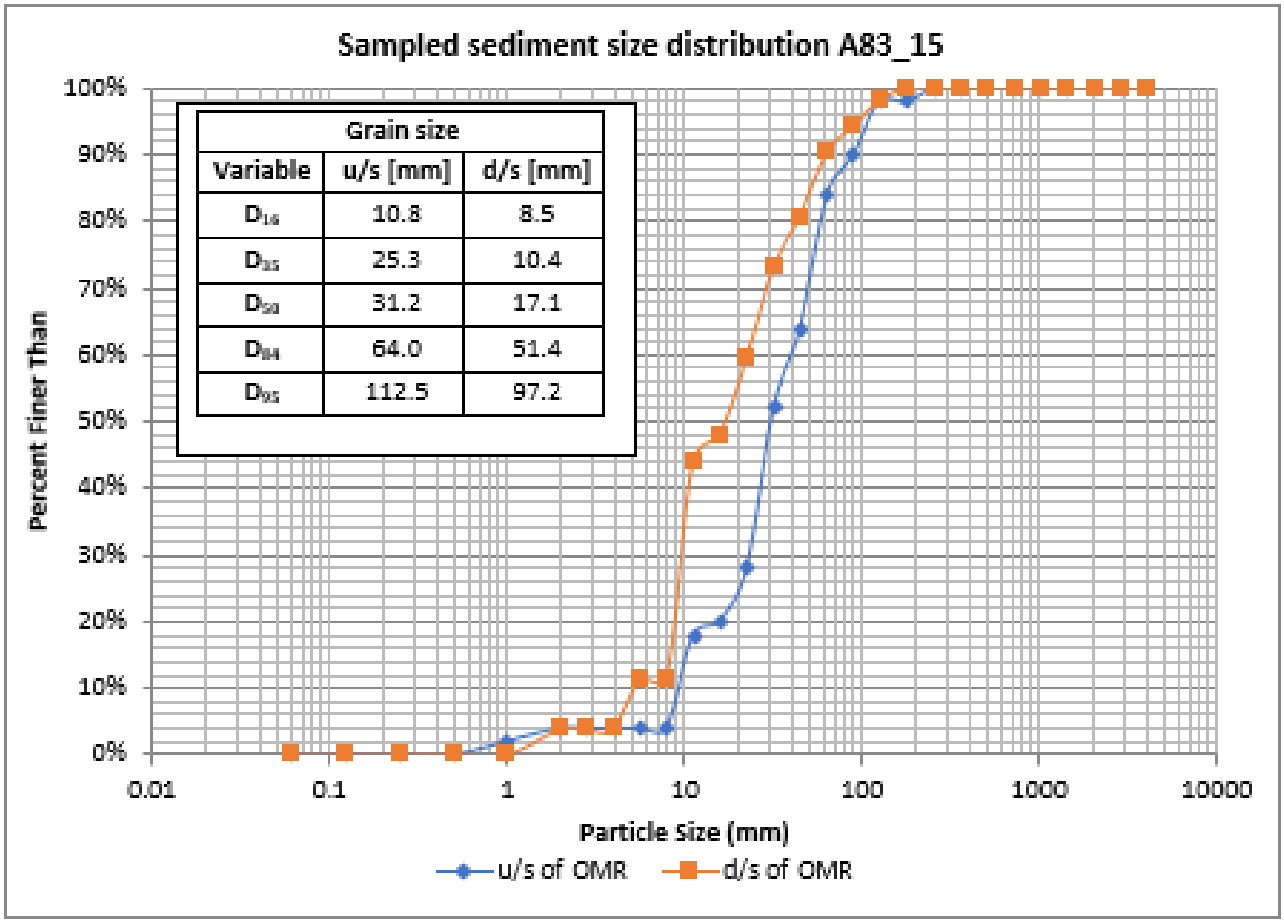
Processes: The existing bridge has sufficient capacity to convey flows larger than the bankfull. The Cobbler Bridge has not been surveyed due to access restrictions, but aerial imagery and terrain analysis do not indicate scour along the section downstream of the bridge. The section surveyed was immediately upstream of the OMR. Both upper and lower reaches comprise a mix of cascade and step-pool morphologies with a short section of bedrock channel below the Cobbler Bridge.

Sediment: Field-collected sediment samples indicate that the reach below the OMR contains finer sediments compared to the reach upslope of the OMR. In the upper reach, approximately 95% of the sediment in the channels is smaller than 112.5 mm, whereas in the lower reach, 95% is smaller than 97.2 mm. The median particle size (D50) is 31.2 mm in the upper reach and 17.1 mm in the lower reach, suggesting fluvial transport of these particle sizes over the normal range of flows. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming cascades in both the upper and lower reaches.

Long profile

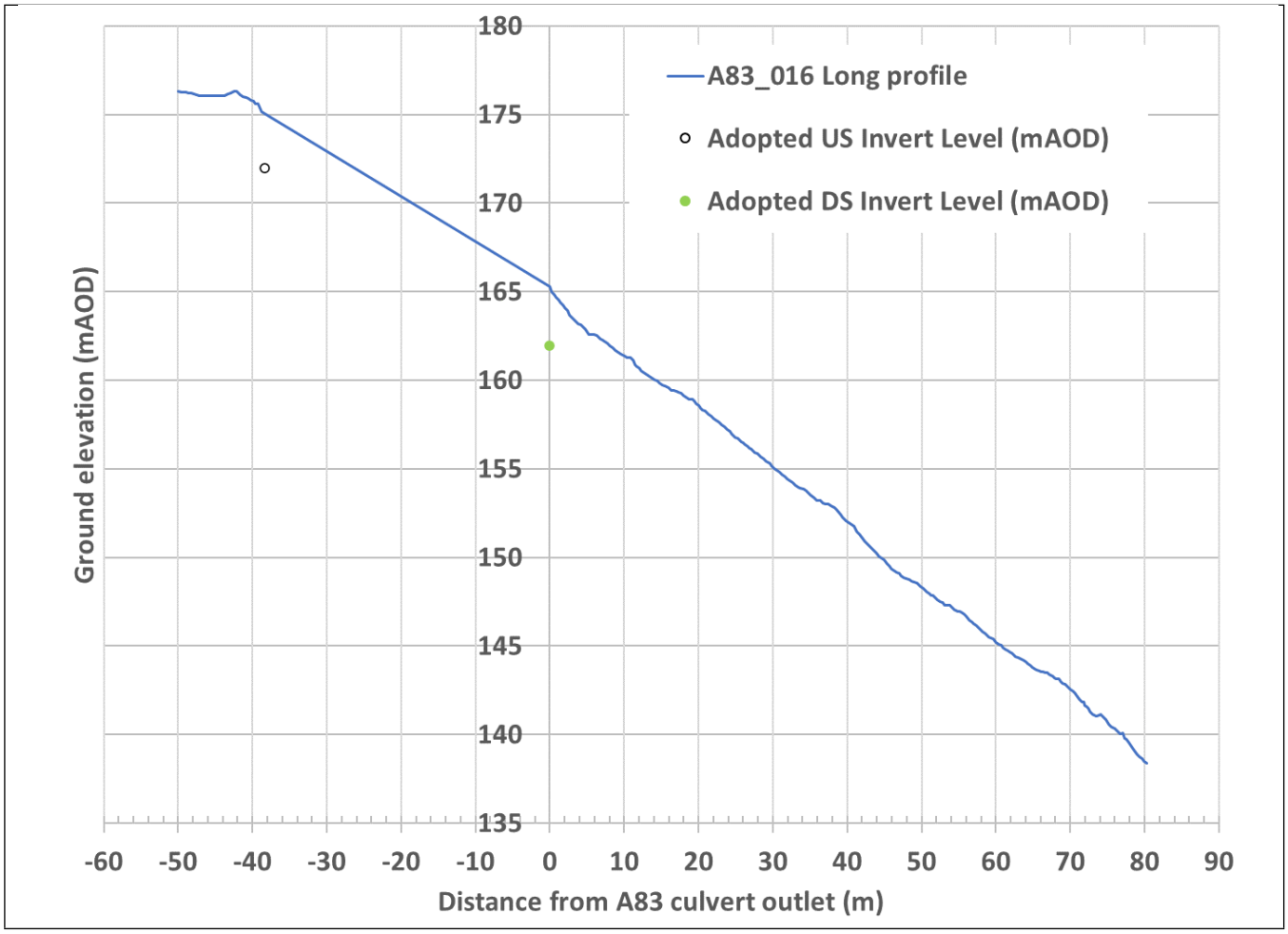


Riverbed grain size distribution

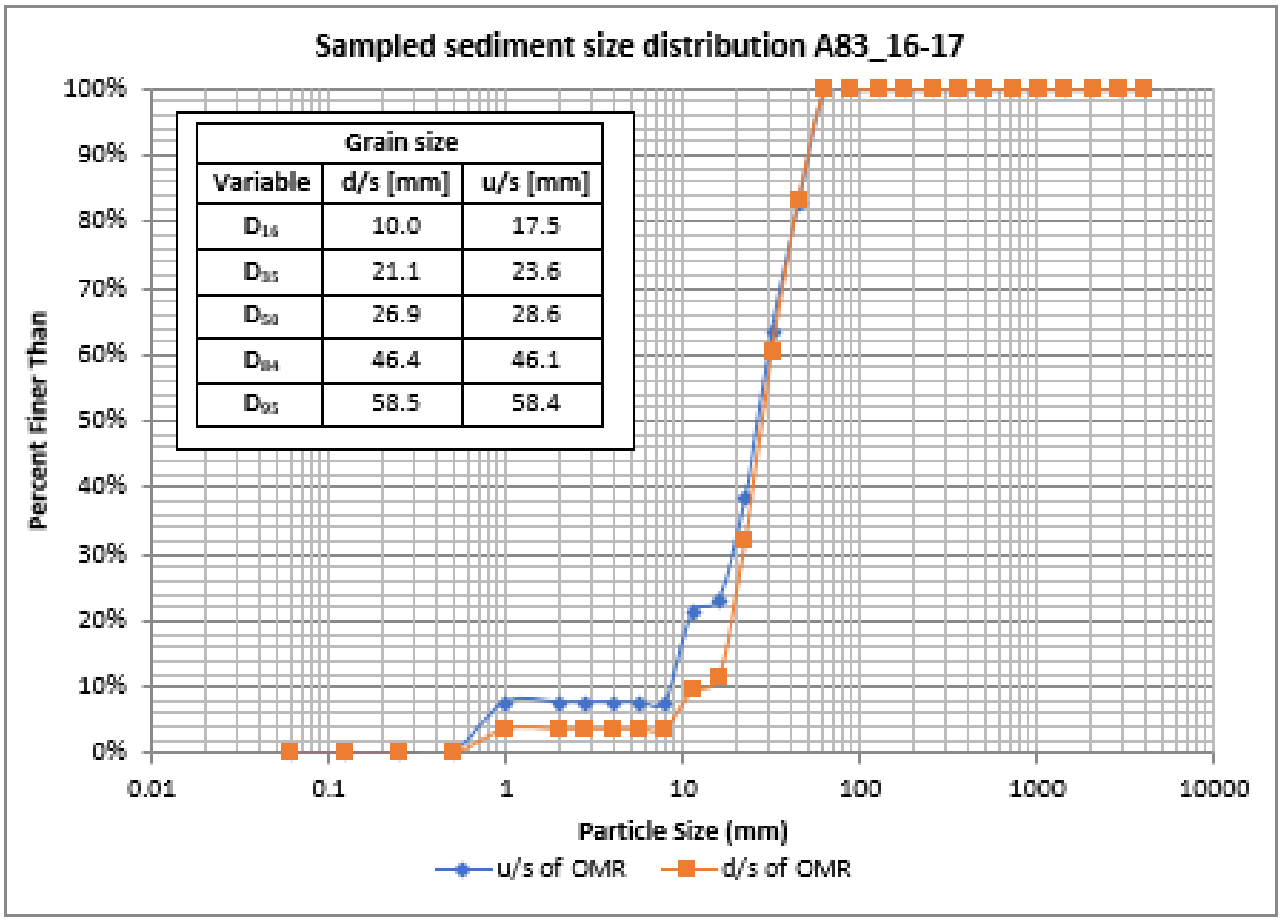


Watercourse ID	A83_ML_016_000
Corresponding OMR crossing ID	OMR_14
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.207
Watercourse length from A83 to OMR (m)	220
Existing A83 culvert (Capacity)	Pipe culvert, 0.6 m diameter (<20-yr fluvial event)
Looking downstream from the A83 culvert outlet for A83_ ML_016_000 	Aggradation of sediment on the watercourse bed and excavated sediment pile 
Description: A83_ML_016_000 and A83_ML_017_000 have a confluence approximately 120 m upstream of the OMR and 86 m downslope from the A83. The watercourse is very steep, with gradients of 20 to 90% in the upper 110 m of the reach and the morphology is generally step-pool sequences. The gradient reduces to approximately 60 to 20% for the next 110 m with morphology transitioning from step-pools to plane bed sequence as the gradient decreases in the base of Glen Croe. This watercourse has not experienced significant scour erosion resulting from debris flow events. Significant fines and gravel aggradation on the bed is observed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by two culverts in short succession. Processes: The existing culvert can only convey fluvial flows lower than a 20-year event. Very little flow was observed exiting the culvert under the A83, even during a wet period	

(May 2024). On the same visit, flow was observed to be bypassing the inlet, flowing south adjacent to the A83 towards the Croe Water/Cobbler Bridge, though it was not possible to trace the ultimate destination of this flow. The upper and middle reaches of the watercourses are primarily transporting sediment with some minor erosion. On the lower gradients, is a riffle-pool to plane-bed channel morphology with significant fines and gravel deposition (as attested by the sediment pile in the right figure). Sediment: The field-collected sediment samples show that 95% (D_{95}) of the sediment in channels is smaller than 58 mm and the D_{50} of the samples was 26.9-28.6 mm both up and downstream of the OMR implying that fluvial transport processes are dominant. Large boulders (>700 mm) were recorded in the watercourse which appears to have been eroded from the adjacent banks and terrace deposits and formed step-pool cascades, suggesting a combination of hillslope and fluvial processes. The riverbed substrate in the lower reach is consistent with a predominantly fluvial transport regime rather than debris flow processes.
Long profile


A83_016 Long profile
Adopted US Invert Level (mAOD)
Adopted DS Invert Level (mAOD)
Ground elevation (mAOD)
180
175
170
165
160
155
150
145
140
135
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
Distance from A83 culvert outlet (m)

Riverbed grain size distribution



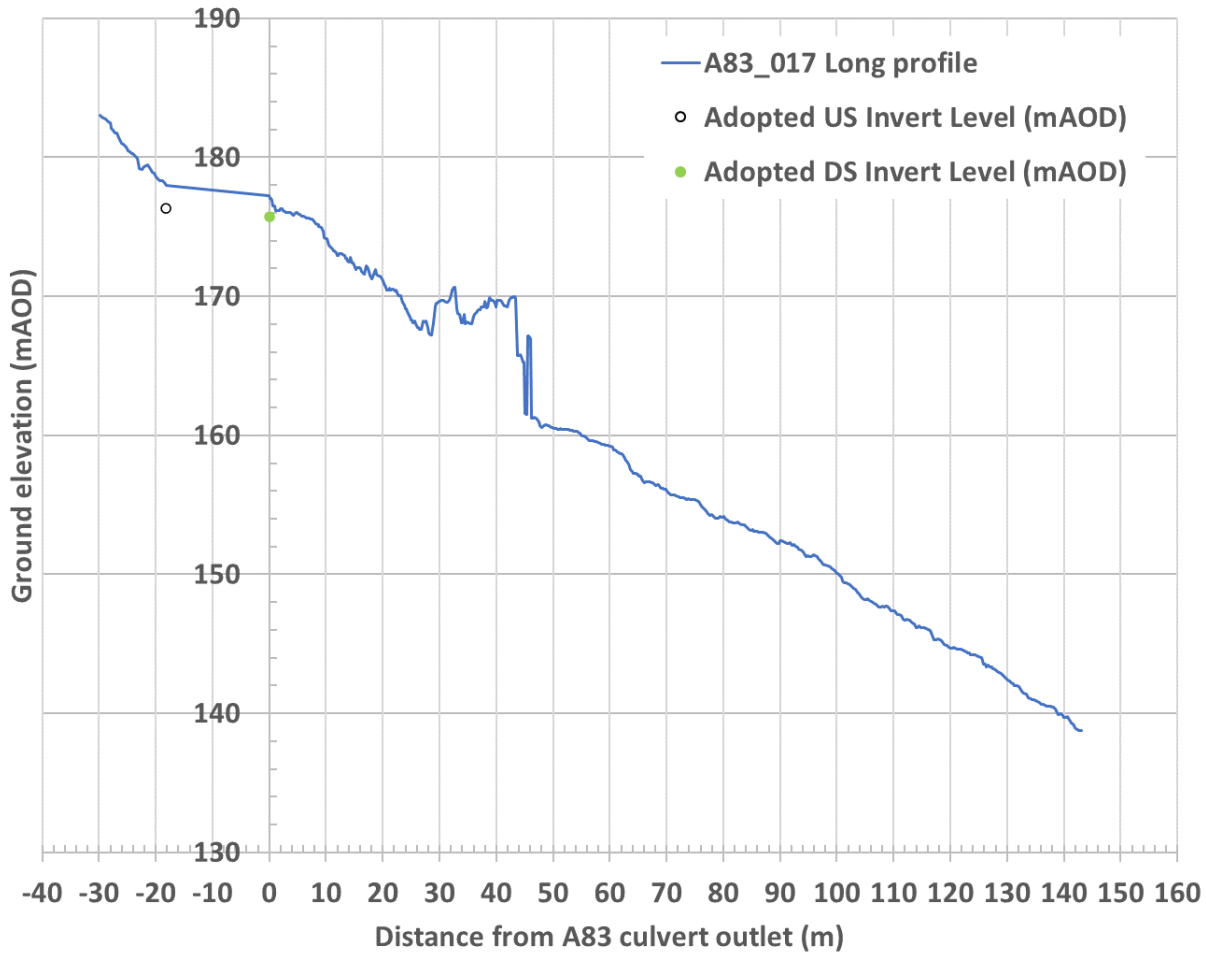
Watercourse ID	A83_ML_017_000
Corresponding OMR crossing ID	OMR_14
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.094
Watercourse length from A83 to OMR (m)	260
Existing A83 culvert (Capacity)	Box culvert 0.9 m (W) x 1.0 m (H) (>200-yr fluvial event)
Looking downstream from the A83 culvert outlet for A83_ ML_017_000 	Step-pool sequence downstream of the confluence with A83_ML_016_000 (looking downstream towards OMR) 
Description: The A83 outlet comprises an apron of placed, flat, boulders for approximately 2-3 m, with a 2 m drop to a heavily scoured channel (2/3 m deep). There is little evidence of bank erosion suggesting that the dense vegetation cover may be influencing bank stability at this location. The watercourse exhibits a very steep gradient, ranging from 0% to 100% in the upper 50 m of the reach and increasing to approximately 350% in the next 50 m downstream from the A83 culvert outlet, where channel morphology features are predominantly cascades. Beyond this point, the gradient reduces to about 23% throughout the remaining reach with channel morphology transitioning to a step-pool sequence. This watercourse has not experienced significant scour and erosion resulting from debris flow	

events. Significant fines and gravel aggradation on the bed is observed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by two culverts in short succession. The bankfull width measures 2.0 m in the upper reach and narrows to 1.2 m closer to the OMR.

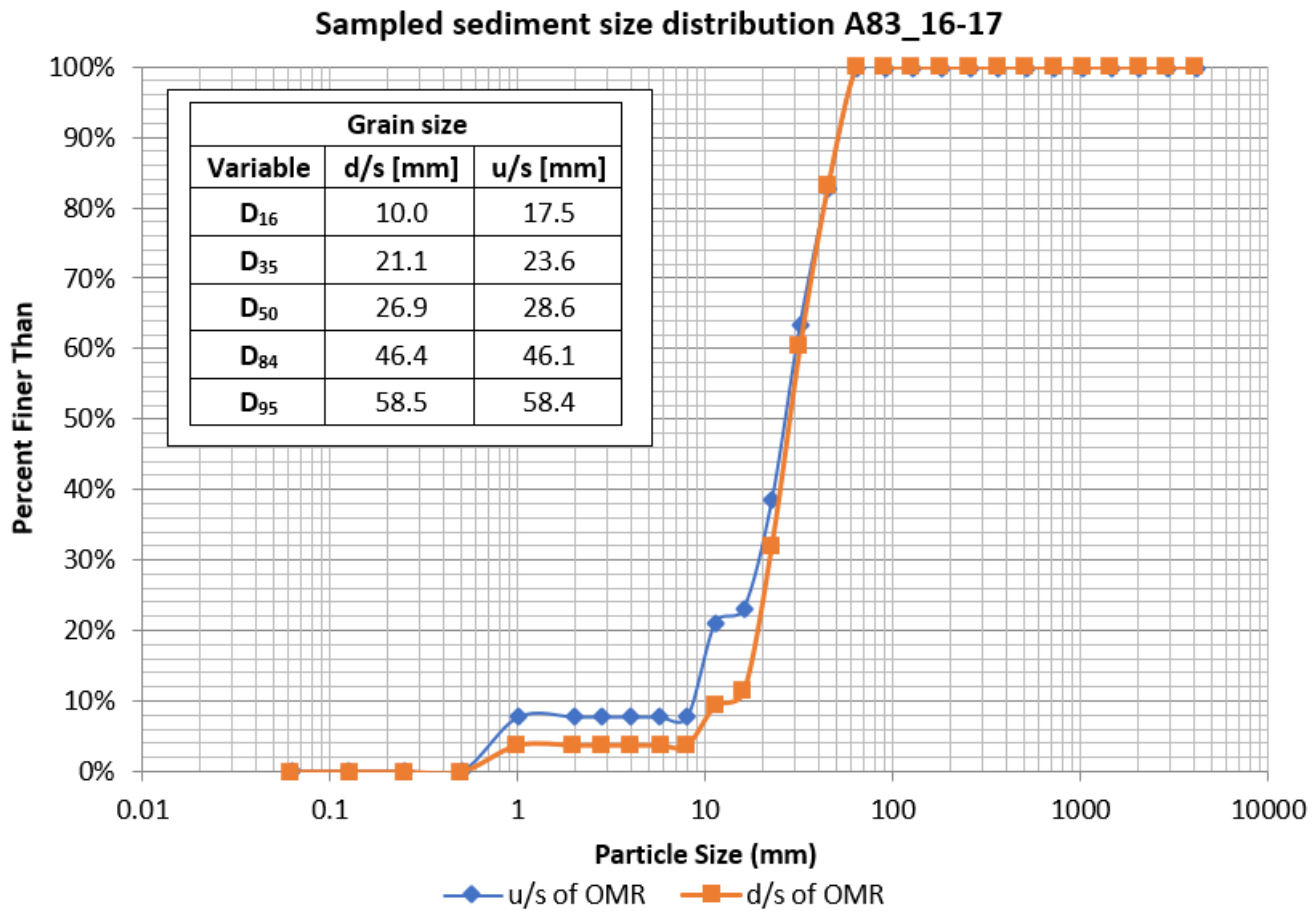
Processes: Though the channel immediately downstream of the A83 culvert outlet is heavily scoured (left hand picture above) no evidence of active scour was observed. The surveyed section, downstream from the confluence with the A83_ML_016_000, shows gravel aggradation. The upper reach, depicted in the left figure, features a step-pool sequence with no significant scour of the bed and banks. Conversely, the lower reach transitions to a riffle-pool and plane-bed channel with substantial gravel deposition around the OMR culvert.

Sediment: Field-collected sediment samples indicate that the lower reach contains coarser sediments compared to the upper reach. Approximately 95% (D_{95}) of the sediment in the channels is smaller than 36.2 mm in the upper reach, and 58.4 mm in the lower reach. The median particle a (D_{50}) ranges from 13.9 mm in the upper reach to 28.6 mm in the lower reach, suggesting dominant fluvial transport processes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming step-pool cascades in the upper reach, suggesting a combination of hillslope and fluvial processes. The riverbed substrate in the lower reach is consistent with a predominantly fluvial transport regime.

Long profile



Riverbed grain size distribution

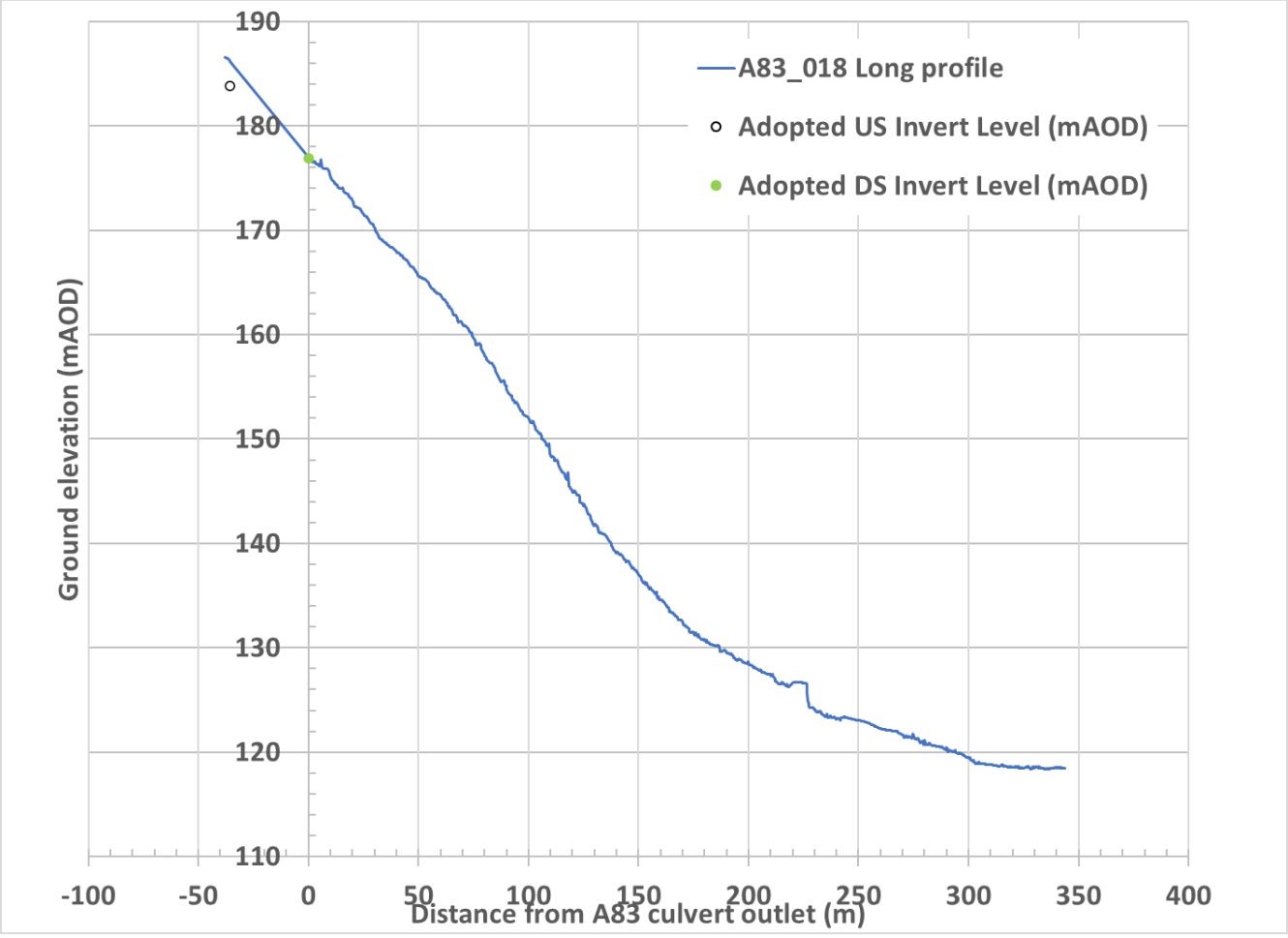


Watercourse ID	A83_ML_018_000
Corresponding OMR crossing ID	OMR_16
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.073
Watercourse length from A83 to OMR (m)	214
Existing A83 culvert (Capacity)	Pipe culvert, 0.6 m diameter

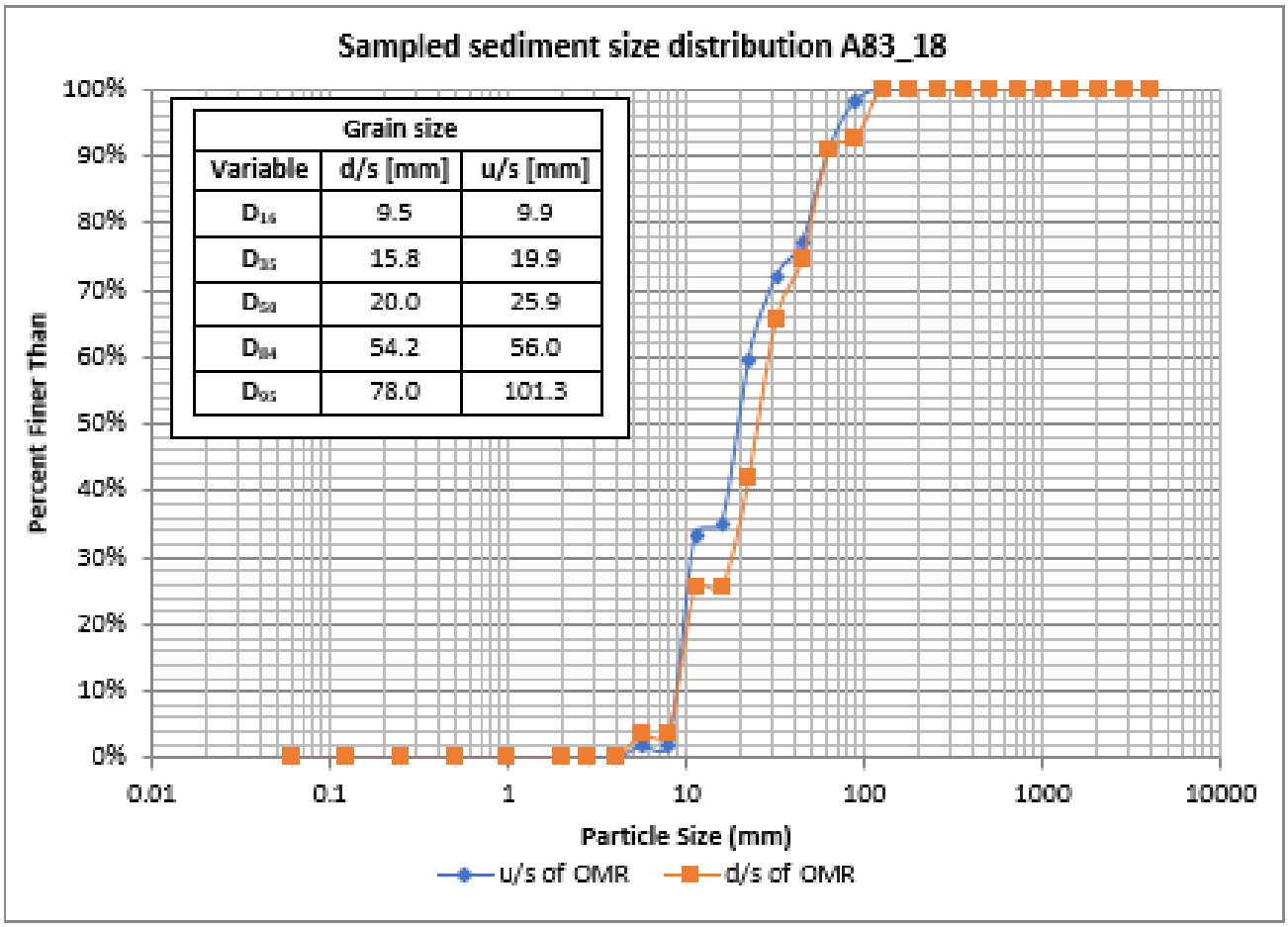
	(<2-yr fluvial event)
Step-pool sequence along the lower reach (looking downstream towards High Glencroe) 	Step-pool sequence along the upper reach (looking downstream towards OMR) 
Description: The watercourse exhibits a moderately steep gradient, with an average of 10% in the upper 70 m of the reach. Immediately downstream of the A83 culvert the gradient reaches 126%. Beyond this point, the gradient reduces to an average of 17% throughout the remaining reach. The morphology of the upper and lower reaches primarily features step-pool sequences. No significant scour erosion from debris flow events are observed, however, cattle poaching and collapsing banks were prevalent upslope of the OMR. Significant accumulation of sediment in the channel bed of gravel grain sizes and finer is present immediately upstream and downstream of the OMR, where slopes are more moderate, and flow constricted by the culverts. Processes: The current A83 culvert can accommodate fluvial flows up to a 2-year event, suggesting that impacts on flows can occur during relatively frequent flood events. Excessive scour erosion was not observed at the culvert outlet. The upper reach (right photo) features a step-pool sequence with moderate scour of the bed and banks. Similarly, the lower reach(left photo) has evidence of confinement but less scour and a more substantial sediment accumulation. Sediment: Field-collected sediment samples indicate that the lower reach contains coarser sediments compared to the upper reach. In the upper reach, approximately 95% of the	

sediment is smaller than 78.0 mm, while in the lower reach, 95% (D_{95}) is smaller than 101.3 mm. The median particle size (D_{50}) ranges from 20.0 mm in the upper reach to 25.9 mm in the lower reach, indicating dominant fluvial transport processes. The cobbles observed in the watercourse were likely eroded from adjacent banks and terrace deposits in the upper reach, forming step-pool cascades and suggesting hillslope processes.

Long profile



Riverbed grain size distribution



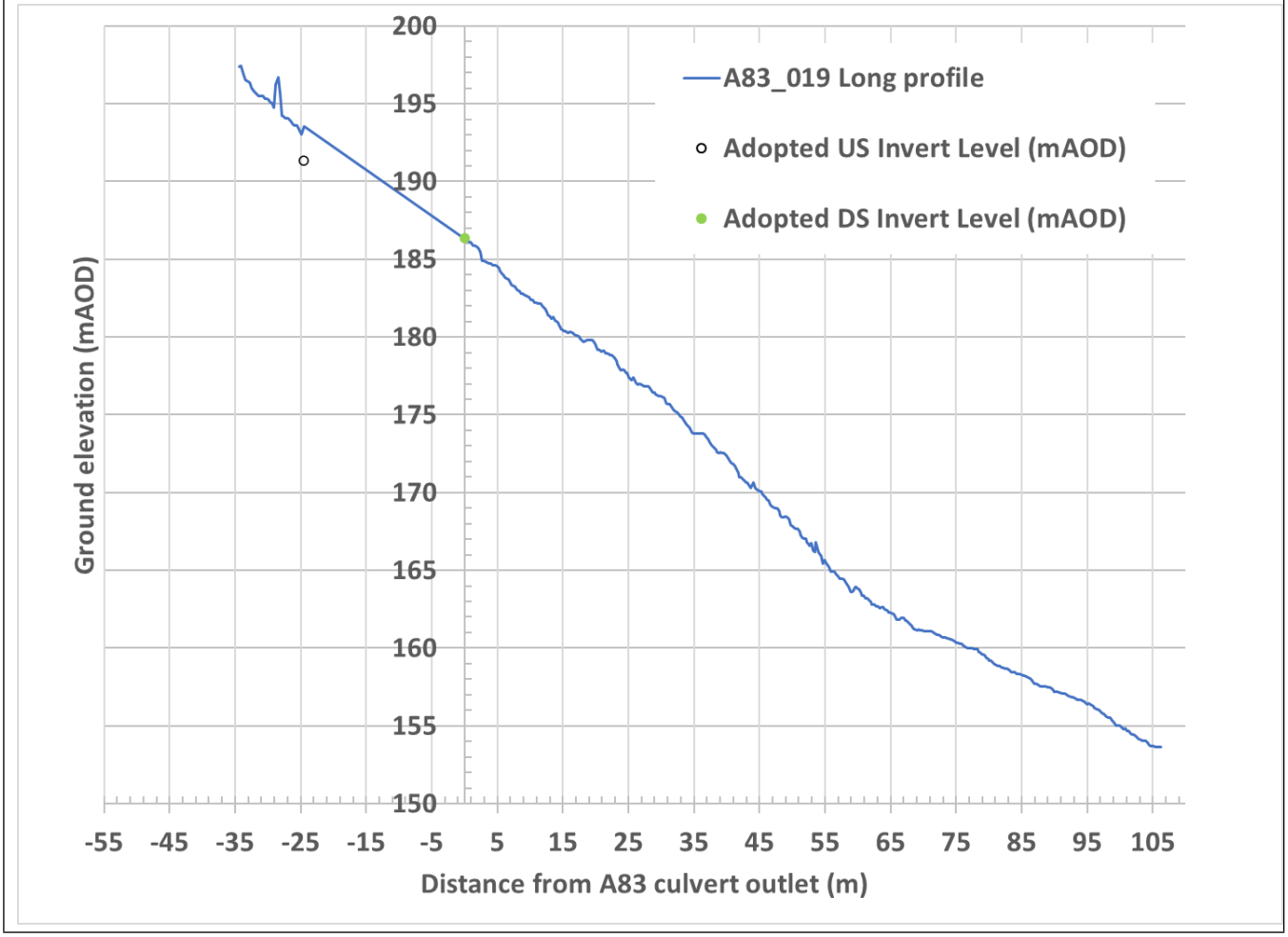
Watercourse ID	A83_ML_019_000
Corresponding OMR crossing ID	OMR_17
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.039
Watercourse length from A83 to OMR (m)	223
Existing A83 culvert (Capacity)	Pipe culvert, 0.45 m diameter (~5-yr fluvial event)
Looking downstream from A83 culvert outlet 	Poorly-defined channel with a cascade/step-pool morphology along the upper reach with significant cattle poaching (looking downstream towards the OMR) 
Description: The channel morphology upslope of the OMR is heavily influenced by cattle poaching resulting in a channel that is not well-defined with water flowing between clumps of mud and grass. The reach below the OMR displays a plane-bed morphology. Downstream of the A83 culvert the average channel gradient is 30% (up to 73%) which declines with distance downstream. Despite these steep gradients and peaks of slope below the culvert outlet, no significant scour erosion from debris or fluvial flow events have been observed.	

Significant fines and gravel aggradation on the bed is observed upstream and downstream of the OMR where bed slope is moderate and flow is constricted by the culvert.

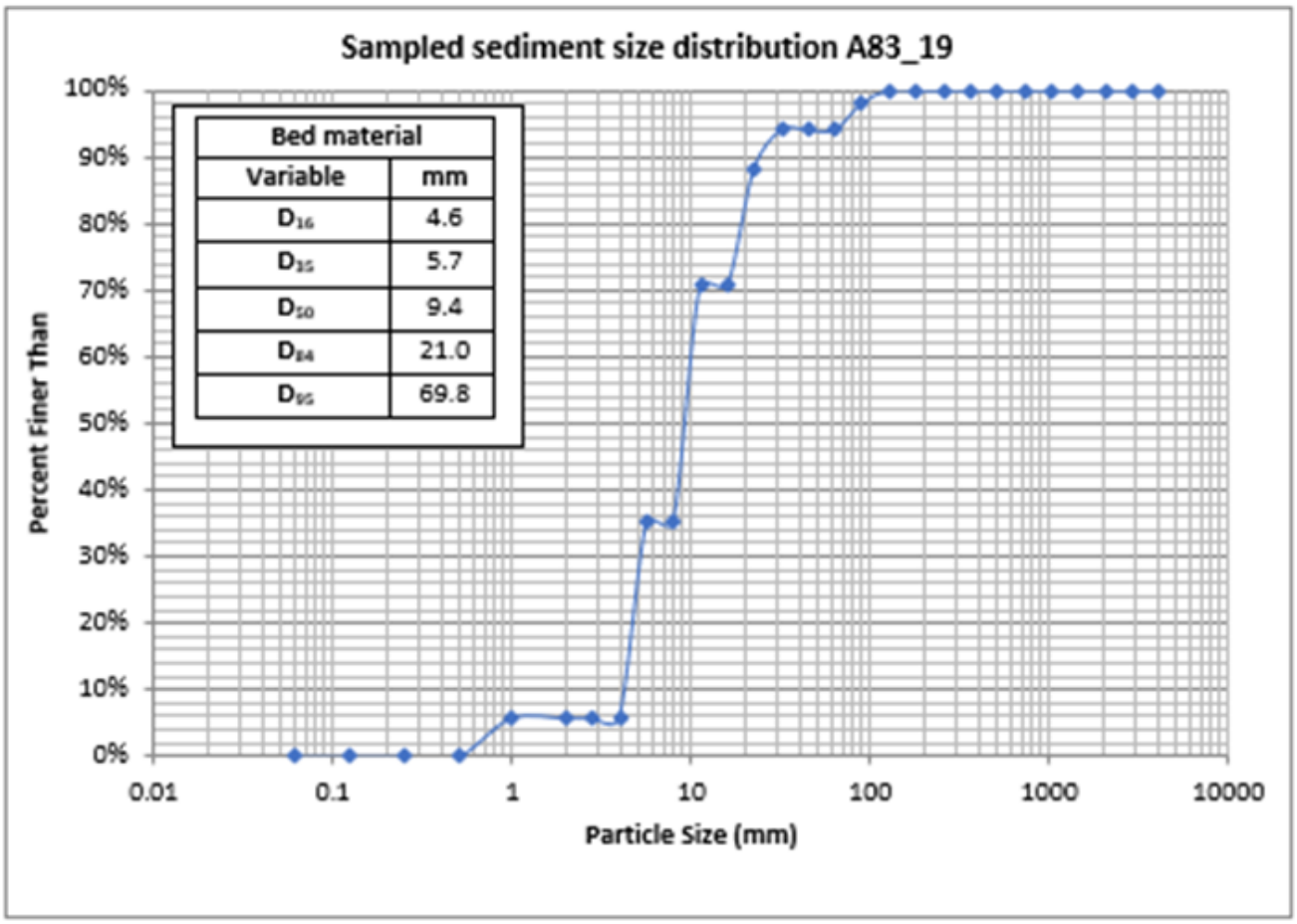
Processes: The A83 culvert can accommodate fluvial flows up to a 5-year event. The upper 20 m of reach below the A83 has a stable channel with well vegetated banks (left image). Below this is a fence which defines the boundary with sheep and cattle grazing land. The 185 m reach extending to the OMR (right photo) features heavily altered morphology due to cattle poaching. Below the OMR there is substantial gravel deposition, and a well-defined plane-bed channel. The riverbed substrate in the lower reach is consistent with a predominantly fluvial transport regime.

Sediment: Field-collected sediment samples from the lower reach indicate that the substrate ranges from cobble (69.8 mm) to fine gravel (4.6 mm). The cobbles observed in the lower reach were likely eroded from adjacent banks and terrace deposits in the upper reach.

Long profile

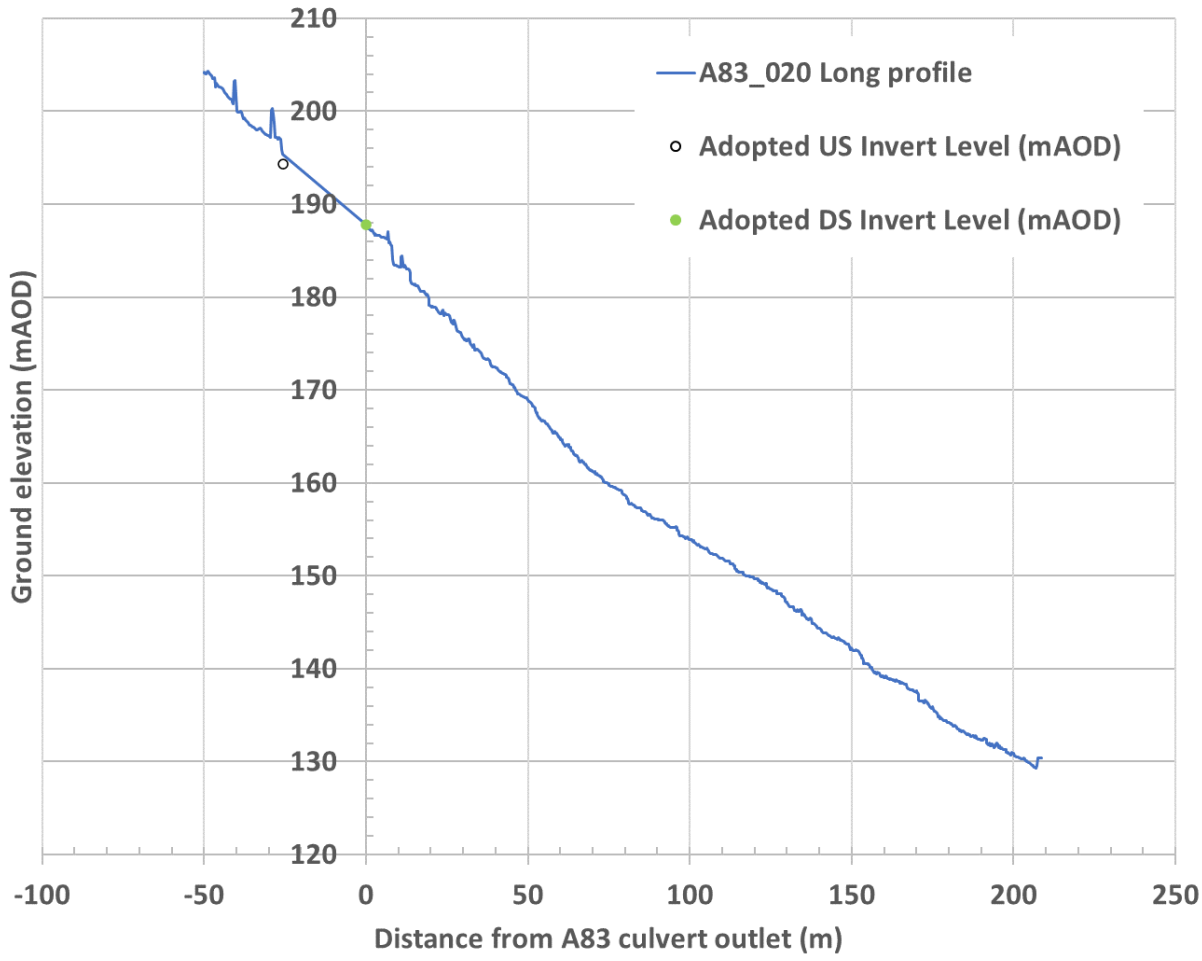


Riverbed grain size distribution

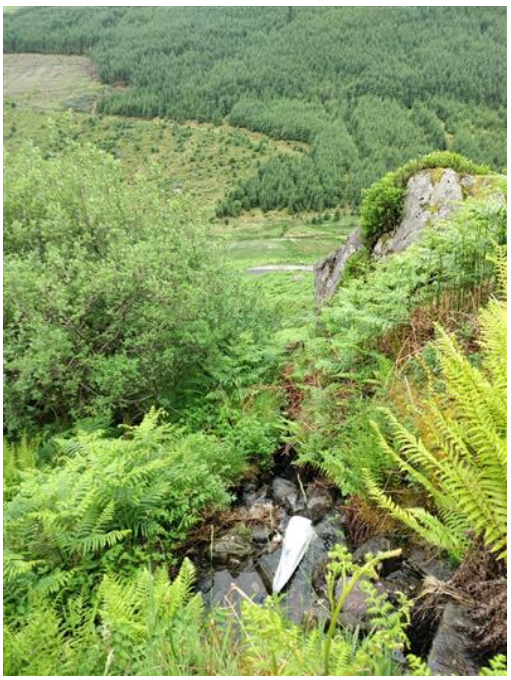


Watercourse ID	A83_ML_020_000
Corresponding OMR crossing ID	OMR_18
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.033
Watercourse length from A83 to OMR (m)	250
Existing A83 culvert (Capacity)	Pipe culvert, 0.375 m diameter (<2-yr fluvial event)
A83_ML_020_000 culvert outlet 	Plane-bed sequence along the lower reach (looking downstream towards the main channel) 
Description: The A83_ML_020_000, a Minor B watercourse, converges with the A83_ML_021_000, Major watercourse approximately 17m downslope of the A83 and approximately 5 m down from the A83_ML_020_000 culvert outlet. After the confluence, the watercourse exhibits a very steep gradient, with an average of 38% up to 131% in the section immediately downstream of the A83 culvert. Approximately 50 m downstream from	

the culvert outlet, the gradient reduces to an average of 25% throughout the remaining reach. The morphology of the upper reach primarily features step-pool sequences, whereas the lower reach comprises a plane-bed channel. Gravel aggradation is more abundant immediately upstream and downstream of the OMR, where slopes are less severe and sediment transport capacity is lower. Processes: The current culvert is assessed as conveying flows up to a 2-year event. There is no evidence of significant scour erosion downstream of the A83 culvert outlet (left hand picture). The upper reach of the watercourse features step-pool sequences. The lower reach, shown in the right figure, has evidence of confinement but with a plane-bed channel morphology, typical of lower gradients. Sediment: Field-collected sediment samples from downstream of the confluence with the A83_ML_021_000 indicate that the lower reach contains coarser sediments compared to the upper reach. In the upper reach, approximately 95% (D_{95}) of the sediment in the channels is smaller than 48.2 mm, whereas, in the lower reach, 95% is smaller than 96.3 mm. The median particle size (D_{50}) is 17.9 mm in the upper reach and 19.9 mm in the lower reach, suggesting dominant fluvial transport processes. Cobbles have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming step-pool cascades in the upper reach and the plane-bed downstream. The rounded gravel and cobble presence suggests a combination of hillslope and fluvial processes.
Long profile

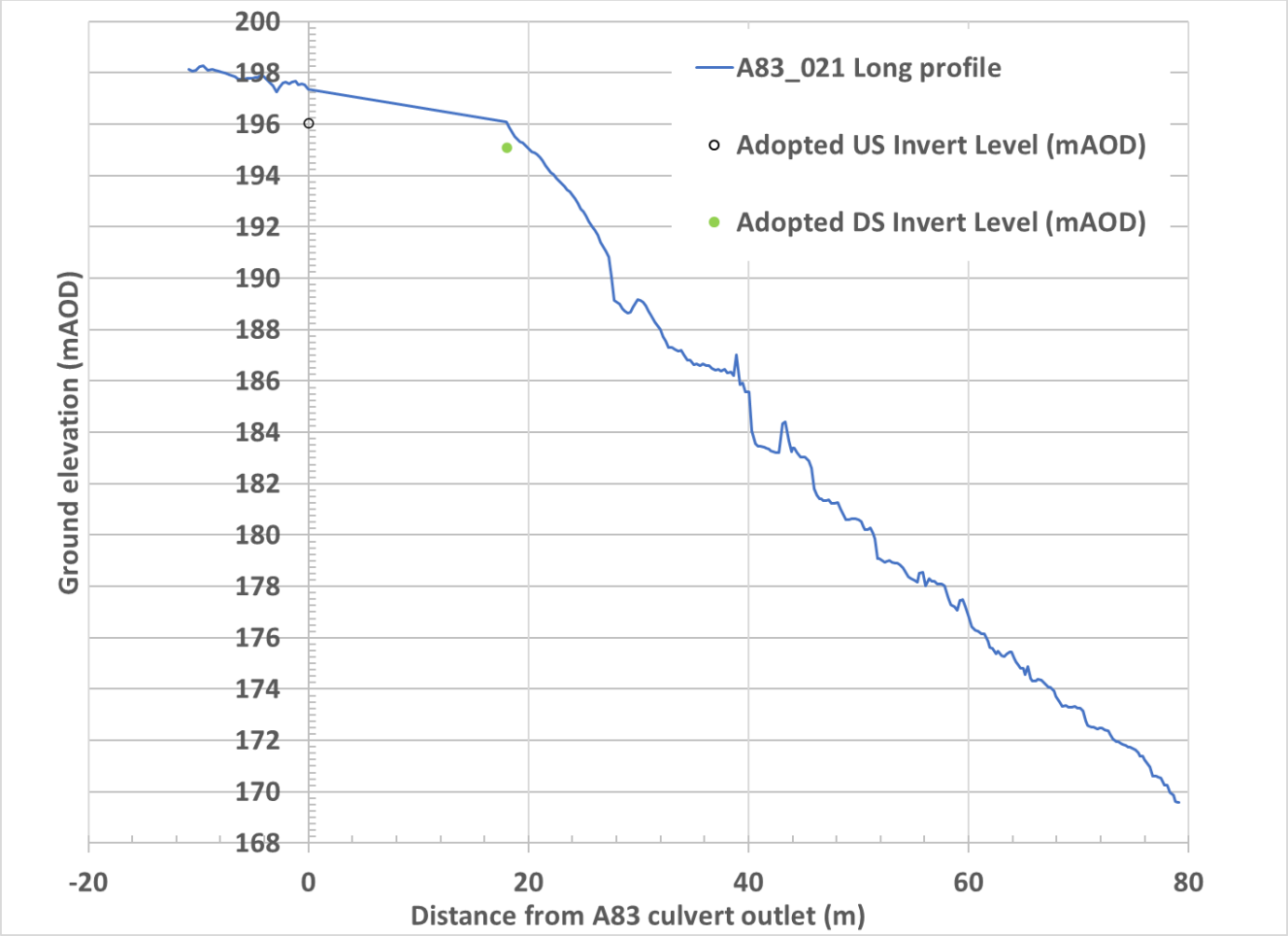


Riverbed grain size distribution (both samples taken downstream of the A83_ML_021_000 A83_ML_020_000 confluence. Plot provided as A83_ML_021_000	
Watercourse ID	A83_ML_021_000
Corresponding OMR crossing ID	OMR_18
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.096
Watercourse length from A83 to OMR (m)	253

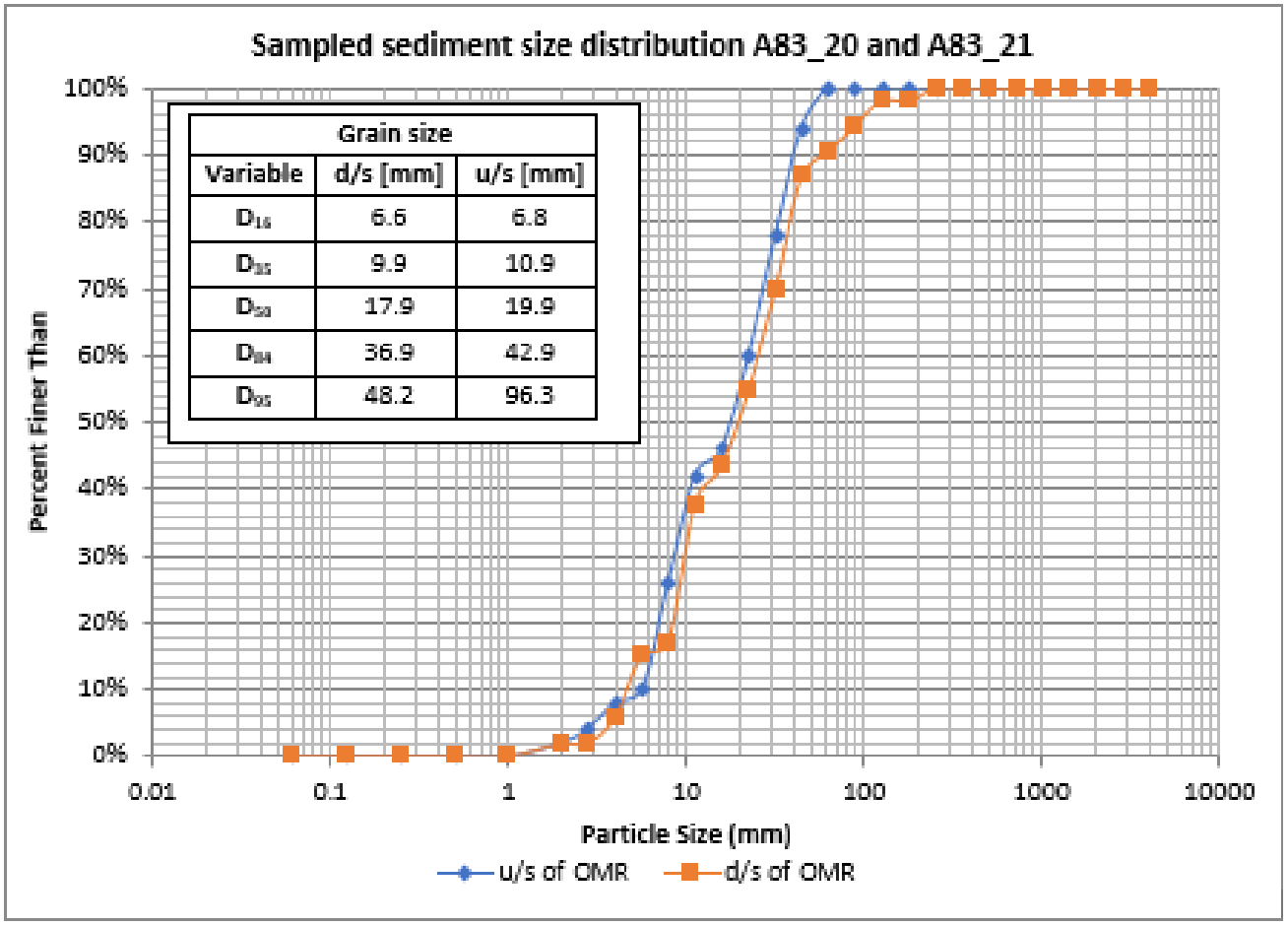
Existing A83 culvert (Capacity)	Pipe culvert, 0.6 m diameter (<2-yr fluvial event)
Looking upstream from the confluence of A83_ML_021_000 and A83_ML_020_000 at the concrete steps and the drop off to the natural channel. 	Looking downstream from the confluence of A83_ML_021_000 and A83_ML_020_000 at the natural step sequences. 
Description: The A83_ML_021_000, a Major watercourse, converges with the A83_ML_020_000, Minor B, watercourse approx. 17 m downslope of the A83 and approx. 14 m down from the A83_ML_021_000 culvert outlet. The first 10 m of the channel from the A83 culvert outlet are built on concrete step cascades which are 700 mm long x 200 mm high, for approximately the first 6m, which then steepen to 200 mm long x 200 mm high (1:1) for a further 4 to 5 m. The remainder of the watercourse is as described for A83_ML_020_000. Processes: As discussed above, the upper section immediately below the A83 features an engineered cascade before it then drops in to a natural channel where there is evidence of historic scour. The remainder of the watercourse is as described for A83_ML_020_000. Sediment: Field-collected sediment samples from downstream of the confluence with the A83_ML_021_000 indicate that the lower reach contains coarser sediments compared to the upper reach. In the upper reach, approximately 95% (D_{95}) of the sediment in the channels is	

smaller than 48.2 mm, whereas, in the lower reach, 95% is smaller than 96.3 mm. The median particle size (D_{50}) is 17.9 mm in the upper reach and 19.9 mm in the lower reach, suggesting dominant fluvial transport processes. Cobbles have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming step-pool cascades in the upper reach and the plane-bed downstream.

Long profile

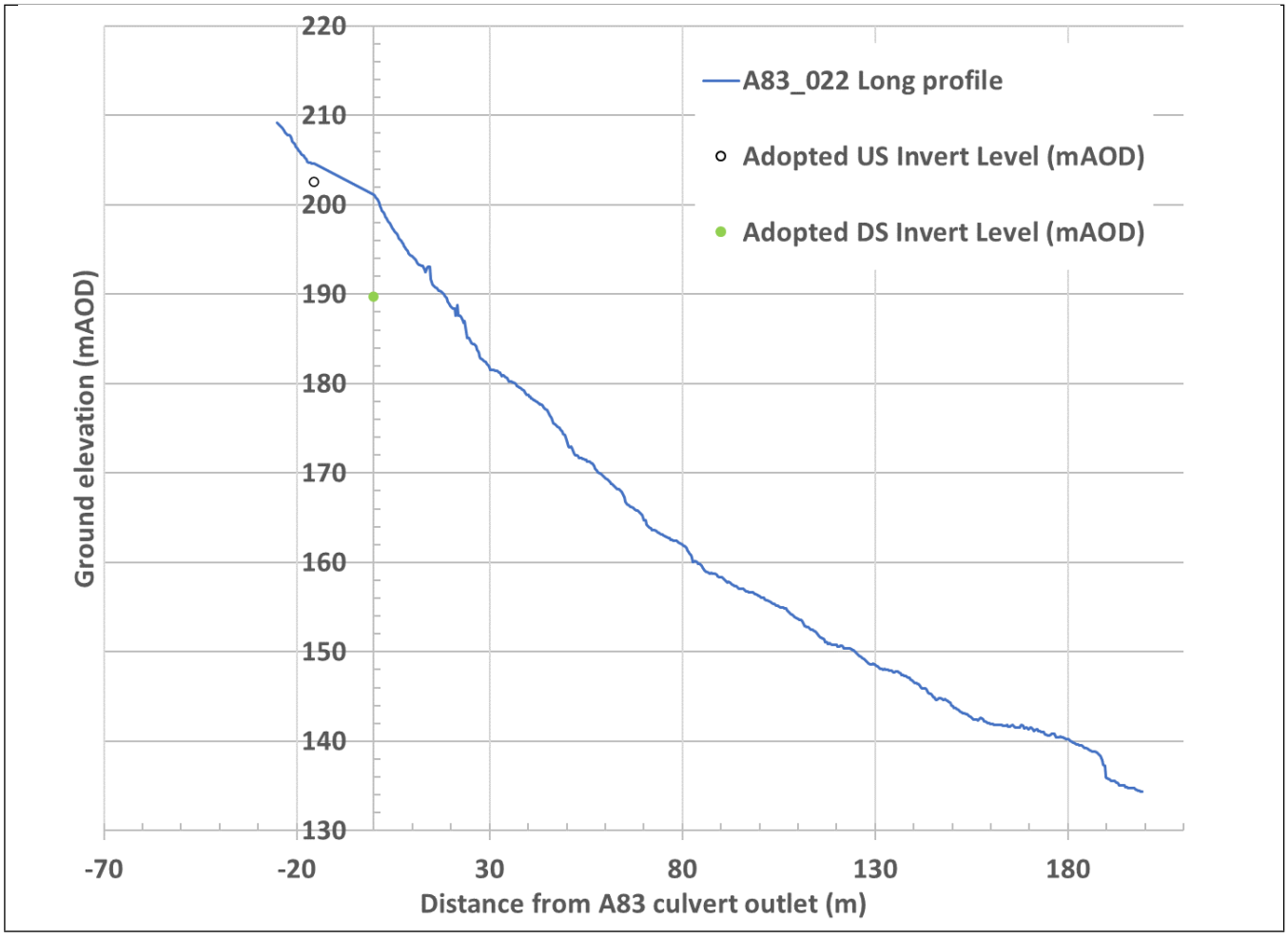


Riverbed grain size distribution



Watercourse ID	A83_ML_022_000
Corresponding OMR crossing ID	OMR_19
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km2)	0.005
Watercourse length from A83 to OMR (m)	250
Existing A83 culvert (Capacity)	Pipe culvert, 0.375 m diameter (>200-yr + CC fluvial event)
View from the A83 down the watercourse towards the HESCO bund 	Plane-bed/riffle-pool sequence along the lower reach and after the confluence with the A83_ML_023_000 (looking downstream towards the High Glencroe channel) 
Description: The watercourse exhibits a steep gradient, with an average of 54% up to 252% in the section immediately downstream of the A83 culvert. The morphology of the upper reach primarily features step-pool sequences, though the channel is well vegetated, whereas the reach below the OMR comprises a plane-bed/riffle-pool channel. Immediately upstream	

of the OMR, the channel flows south along the back of a gravel-filled barricade (HESCO bund) installed to protect the OMR from debris flows. This watercourse flows to the southeast and joins the diverted A83_ML_023_000 before passing through a culvert at the OMR via a (~2 m) drop chamber. There is significant gravel and fine sediment aggradation upstream of the culvert/HESCO bund at the OMR, as the slopes are less severe and the channel is less formally defined with flows spread over a wide area. No sediment profile has been assessed for this watercourse Processes: The current culvert can accommodate fluvial flows up to a 200-year event. Although direct surveying of the culvert has not been possible due to access restrictions, aerial imagery and terrain analysis show a defined channel downstream of the A83 culvert. The upper reach, depicted in the right figure, features a step-pool sequence. Similarly, the lower reach has evidence of confinement but with a plane-bed channel morphology.
Long profile


A83_022 Long profile
Adopted US Invert Level (mAOD)
Adopted DS Invert Level (mAOD)
Ground elevation (mAOD)
220
210
200
190
180
170
160
150
140
130
-70
-20
30
80
130
180
Distance from A83 culvert outlet (m)

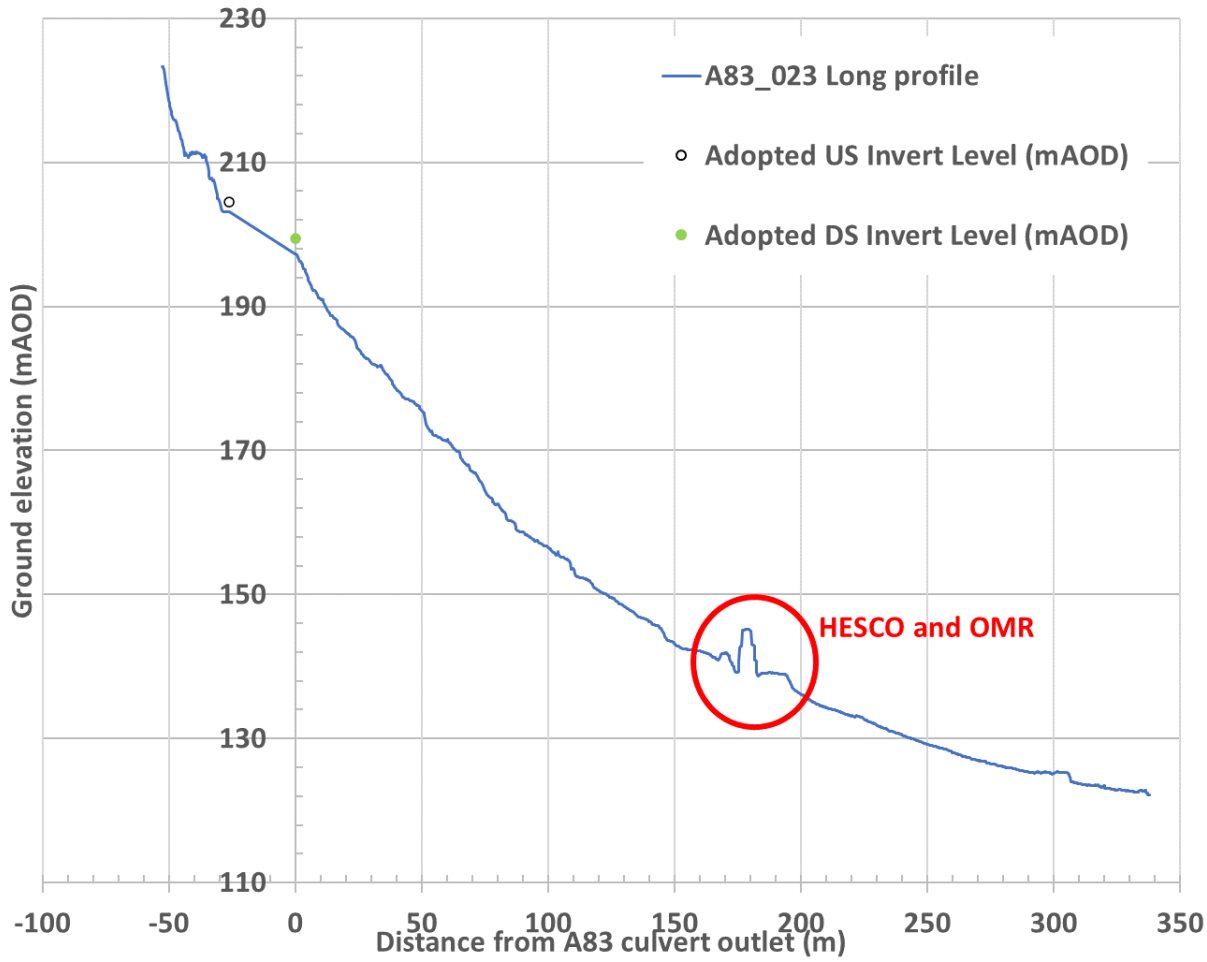
Watercourse ID	A83_ML_023_000
Corresponding OMR crossing ID	OMR_20
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	High
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.014
Watercourse length from A83 to OMR (m)	185
Existing A83 culvert (Capacity)	Pipe culvert, 0.45 m diameter (>200-yr fluvial event)
Catchpit upstream of the A83. Raised inlet with grated front and top face (Approx 3m x 3m with 190mm grate spacing). 	Looking down the watercourse from the A83 at the spraycrete apron and the heavily incised channel. 
Description: Upslope of the A83 is a catchpit formed from bedrock and concrete (left image) which has been created to attenuate debris flows and provide resilience to the operation of the A83. The watercourse exhibits a steep gradient, with an average of 54% (up to 187%) in the section downstream of the A83 culvert. The A83 culvert outlet is a protruding plastic pipe that discharge to a 12 m spraycrete apron. The downstream watercourse is over widened and deepened due to the conveyance of debris flows extending to the OMR. The catchpit and downstream apron were installed following a large debris flow event in 2020 which caused headward erosion which started to undermine the A83. The morphology of the upper reach primarily features cascade/step-pool sequences. Upstream of the OMR, the	

channel deviates from its previous route due to a 162 m long gravel-filled barricade (HESCO bund) installed to protect the OMR from landslips. Due to this diversion, the channel flows to the southeast and joins the A83_ML_022_000 before passing through a culvert at the OMR.

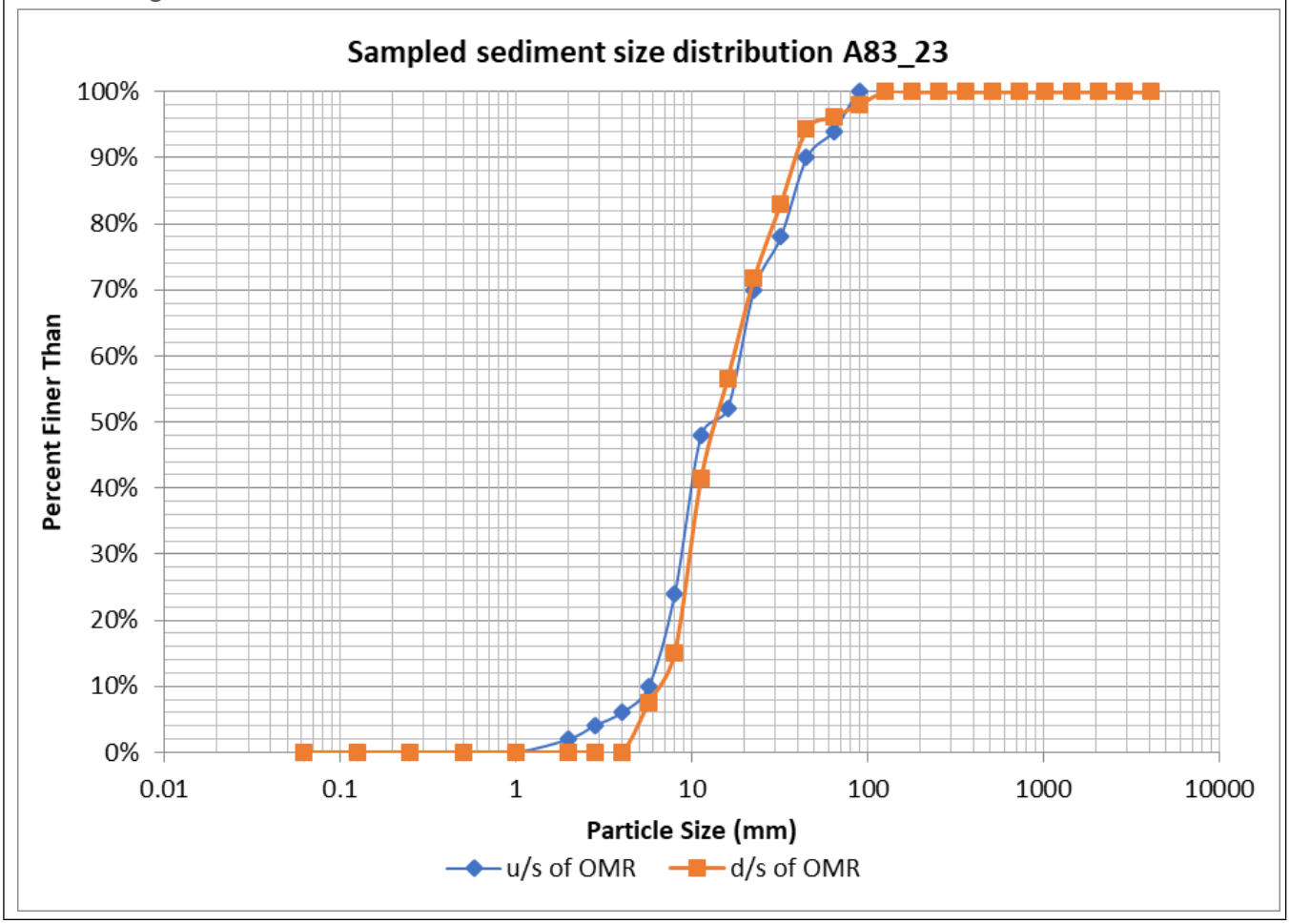
Processes: The channel at the northern extent of the HESC bound features step-pool sequences within an over-widened, debris flow channel. The fluvial channel is well established with no evidence of erosion into the over deepened cross section of the debris flow channel. Historically this channel would have continued directly under the OMR, however, is now diverted south due to the presence of the HESCO bund. The historic, downstream channel is now grass lined (right-hand figure) due to a lack of fluvial erosion and deposition.

Sediment: In the upper reach, approximately 95% (D95) of the sediment is 68.3 mm and the median particle size (D50) is 13.7 mm. There are occasional large boulders, exceeding 700 mm, in the watercourse, likely from erosion of nearby banks and terrace deposits, thereby forming step-pools and cascades in the upper reach. As stated, the downstream historical channel is now vegetated and the sediment profile of the A83_ML_022_000 is provided above.

Long profile



Riverbed grain size distribution



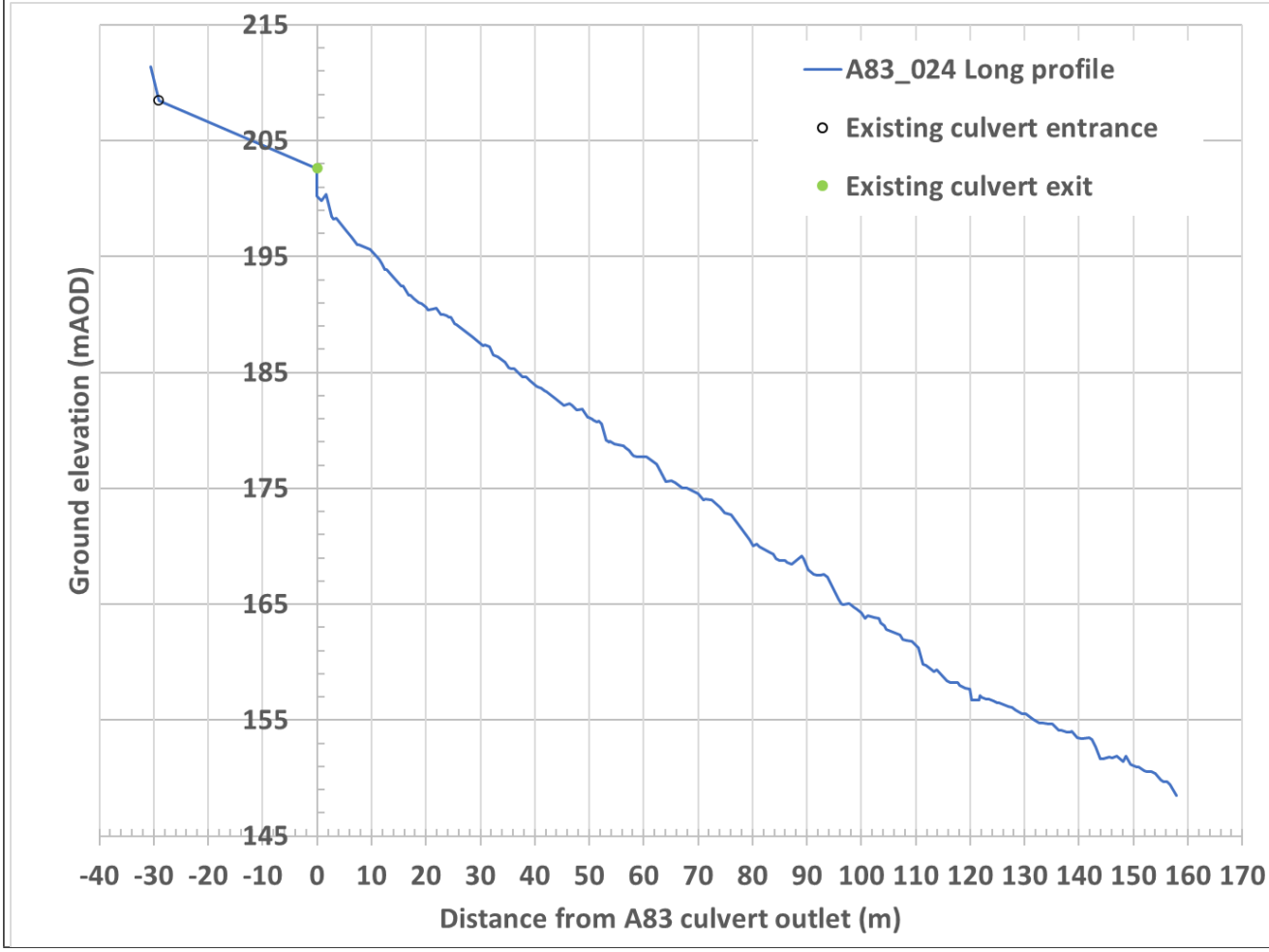
Watercourse ID	A83_ML_024_000
Corresponding OMR crossing ID	OMR_21
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	High
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.207
Watercourse length from A83 to OMR (m)	158
Existing A83 culvert (Capacity)	1.2 m (W) x 1.4 m (H) box (>200-yr fluvial event)
A83 culvert outlet perched due to scour 	Looking down the watercourse towards OMR 
Description: The watercourse has an upstream catchpit that links this watercourse with A83_ML_025_000 and A83_ML_026_000. The watercourse is very steep, with gradients of 40 to 50% in the upper 10 m of the reach, below the A83, reducing to approximately 30% for the next 110 m, with the final ~30 m above the OMR at a gradient of 20%. This watercourse has experienced significant scour erosion resulting from debris flow events, especially in the upper reach (first 30 m from the culvert exit). The bankfull width was measured at 7 m in the upper reach and at 1.8 m closer to the OMR. This watercourse is connected to the three northern watercourses via a debris flow catchpit upslope of the A83.	

Processes: The existing culvert has sufficient capacity to convey fluvial flows greater than the 200-year event, indicating that the jetting effects from hydrological flows at this culvert would most likely occur during very exceptional, infrequent, flood events. This watercourse is located within an active debris flow channel, with the last debris flow event experienced in October 2023. During debris flow events significant volumes of water and entrained sand and cobbles pass through the culvert causing the greatest rates of erosion and scour. This is exacerbated when a debris flow event blocks one or more culverts within the upstream catchpit meaning one culvert may have to convey flows that originate from multiple valleys/watercourses. This was the case in October 2023 with A83_ML_024_000 conveying three valleys worth of flow due to culvert blockages.

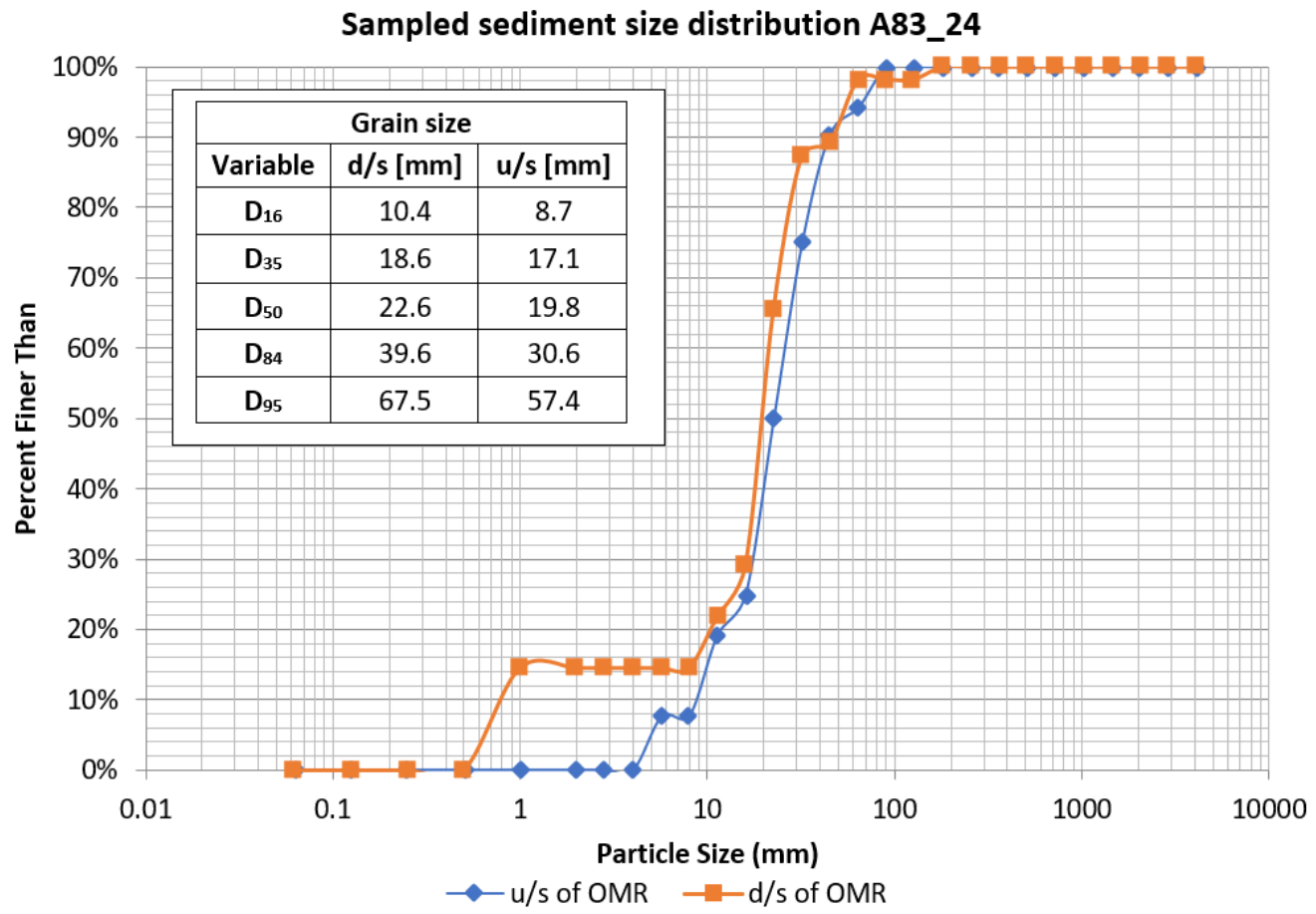
The A83 culvert outlet is now perched approximately 2.85 m above the downstream watercourse based on a comparison of the culvert invert (202.62 mAOD) and the low point in the latest DSM, immediately downstream of the culvert exit (199.77 mAOD). With increasing distance downstream, the impacts of excessive scour erosion appear to reduce, with the channel stabilising at a width of 2.5 to 3 m approximately 30 m down from the culvert exit.

Sediment: The field-collected sediment samples show that ~98-100% of the sediment in channels is smaller than 100 mm and the D_{50} of the samples was 19-23 mm implying that fluvial transport processes are dominant. Large boulders (>700 mm) were recorded in the watercourse which appear to have been eroded from the adjacent banks and terrace deposits and formed step-pool cascades observed along the whole of the watercourse. Step-pool dimensions vary with channel gradient where the steps in the upper reach vary in height from 700 mm to 1400 mm, consisting of 500 mm to 900 mm keystone boulders, and a step length of approximately 3000 mm. Whilst in the lower reach of the watercourse, the steps were a similar height (700-1200 mm), consisting of 400 mm to 1000 mm keystone boulders, with a larger step length range (1700 mm to 6300 mm; 3 steps measured).

Long profile



Riverbed grain size distribution

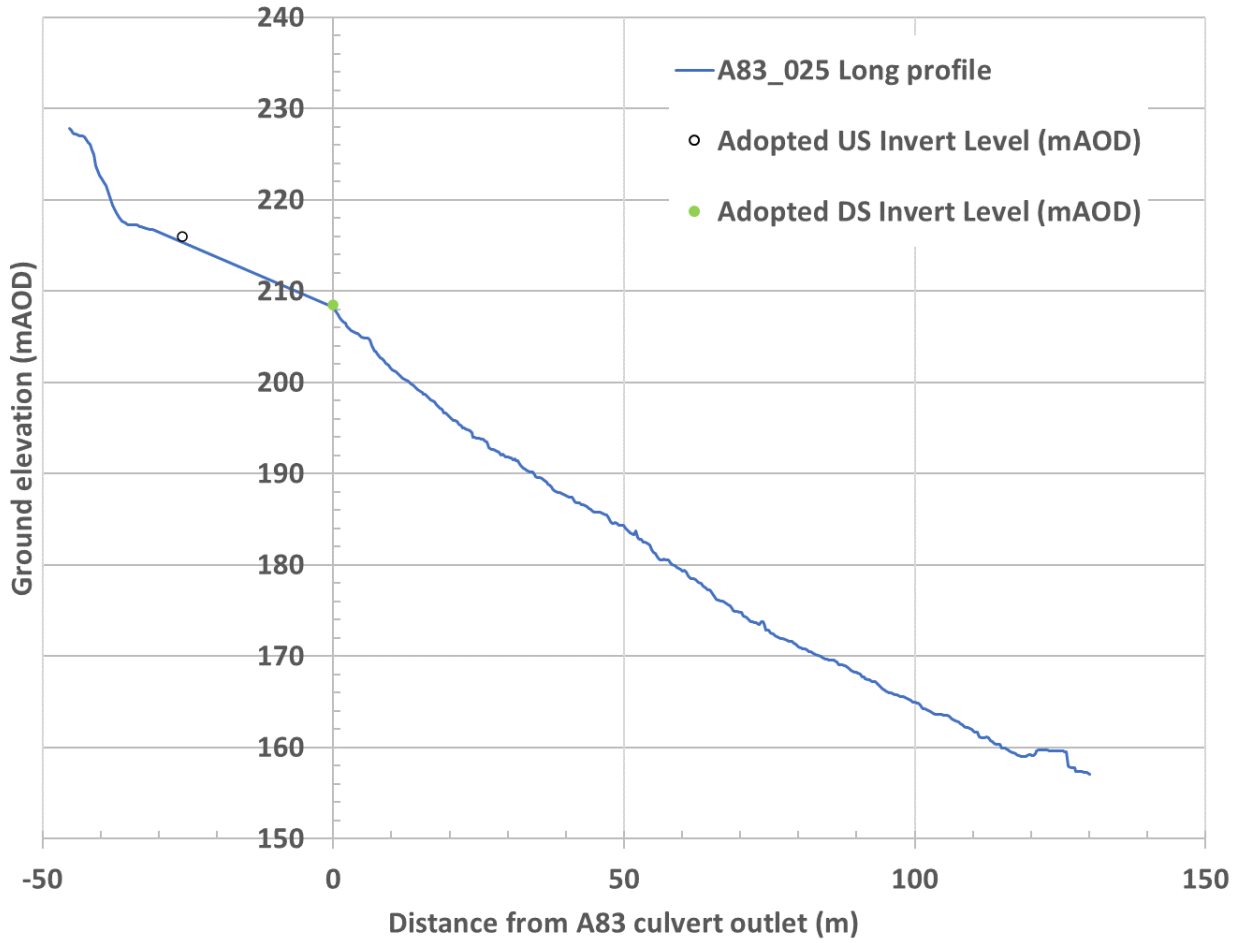


Watercourse ID	A83_ML_025_000
Corresponding OMR crossing ID	OMR_23
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	High
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.122
Watercourse length from A83 to OMR (m)	130
Existing A83 culvert (Capacity)	Pipe culvert, 0.9 m diameter

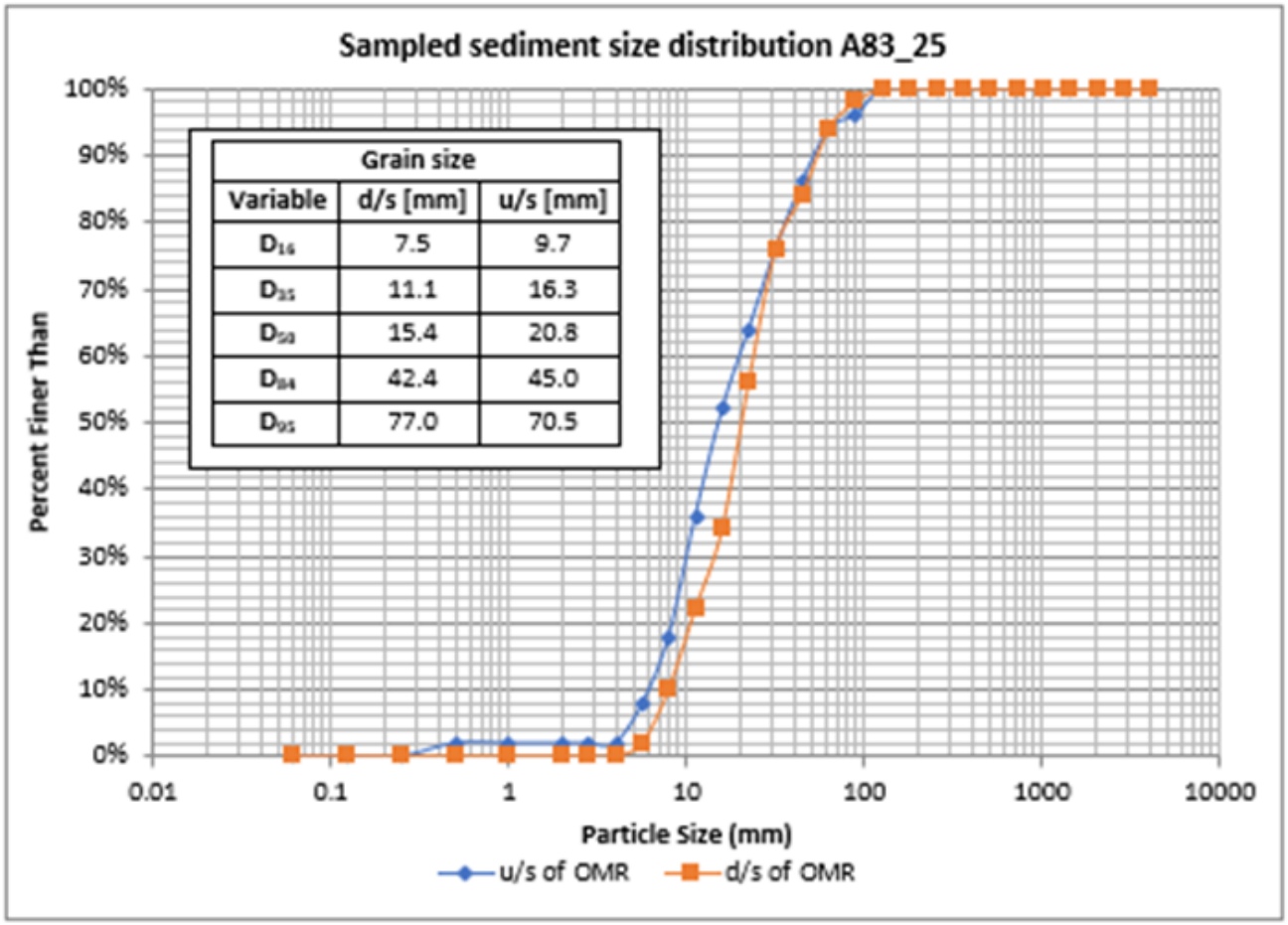
	(~30-yr fluvial event)
Looking upstream of the OMR towards the A83 	Looking downstream towards the OMR from the A83 culvert outlet 
Description: The watercourse has a catchpit and three landslide/rock fall barriers immediately upstream of the A83. The upstream catchpit is a combined catchpit linking this watercourse with A83_ML_024_000 and A83_ML_026_000. Downstream of the A83, the average channel gradient is approximately 39% (0.39m/m) with peaks up to 87% (0.87 m/m) throughout the remaining reach to the OMR. The morphology of the upper reach, to the OMR, primarily features a cascade/step-pool sequence, whereas the reach below the OMR comprises a plane-bed/step-pool channel. Significant fines and gravel aggradation on the bed is observed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by a culvert. Processes: The A83 culvert can convey fluvial flows up to a 30-year event. The channel between the A83 and OMR is significantly over widened and deepened due to debris flow events (evident in both photos). The upper reach, depicted in the right figure, features cascade/step-pool sequences. The lower reach has evidence of confinement but with a more gravel-bed channel morphology, typical of lower gradients. Sediment: Field-collected sediment samples from reaches above and below the OMR contain sediments with comparable size profiles. In the upper reach, approximately 95% of the sediment in the channels is smaller than 77.0 mm, whereas in the lower reach, 95% (D_{95})	

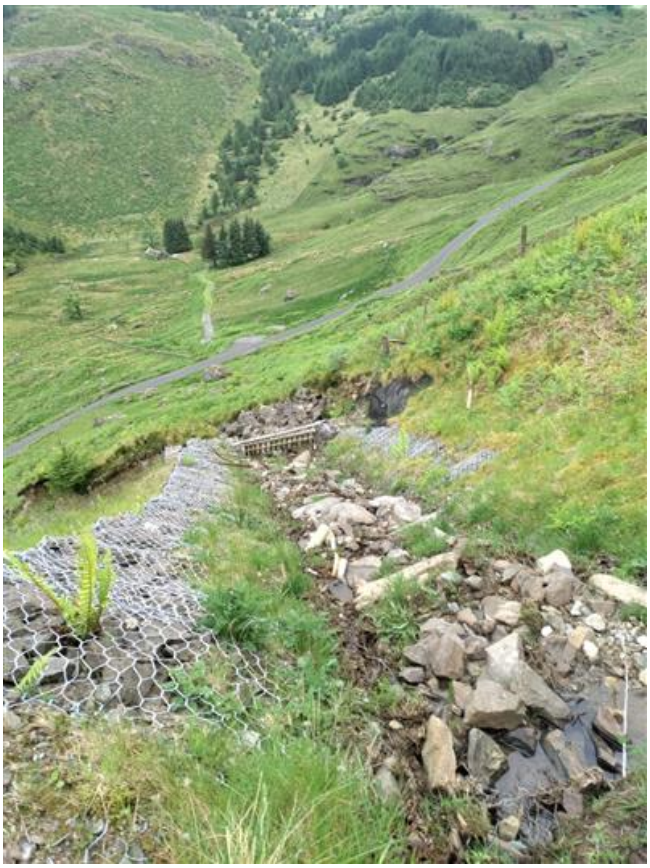
is smaller than 70.5 mm. The median particle size (D_{50}) is 15.4 mm in the upper reach and 20.8 mm in the lower reach, suggesting dominant fluvial transport processes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming step-pool/cascades in the upper reach.

Long profile



Riverbed grain size distribution



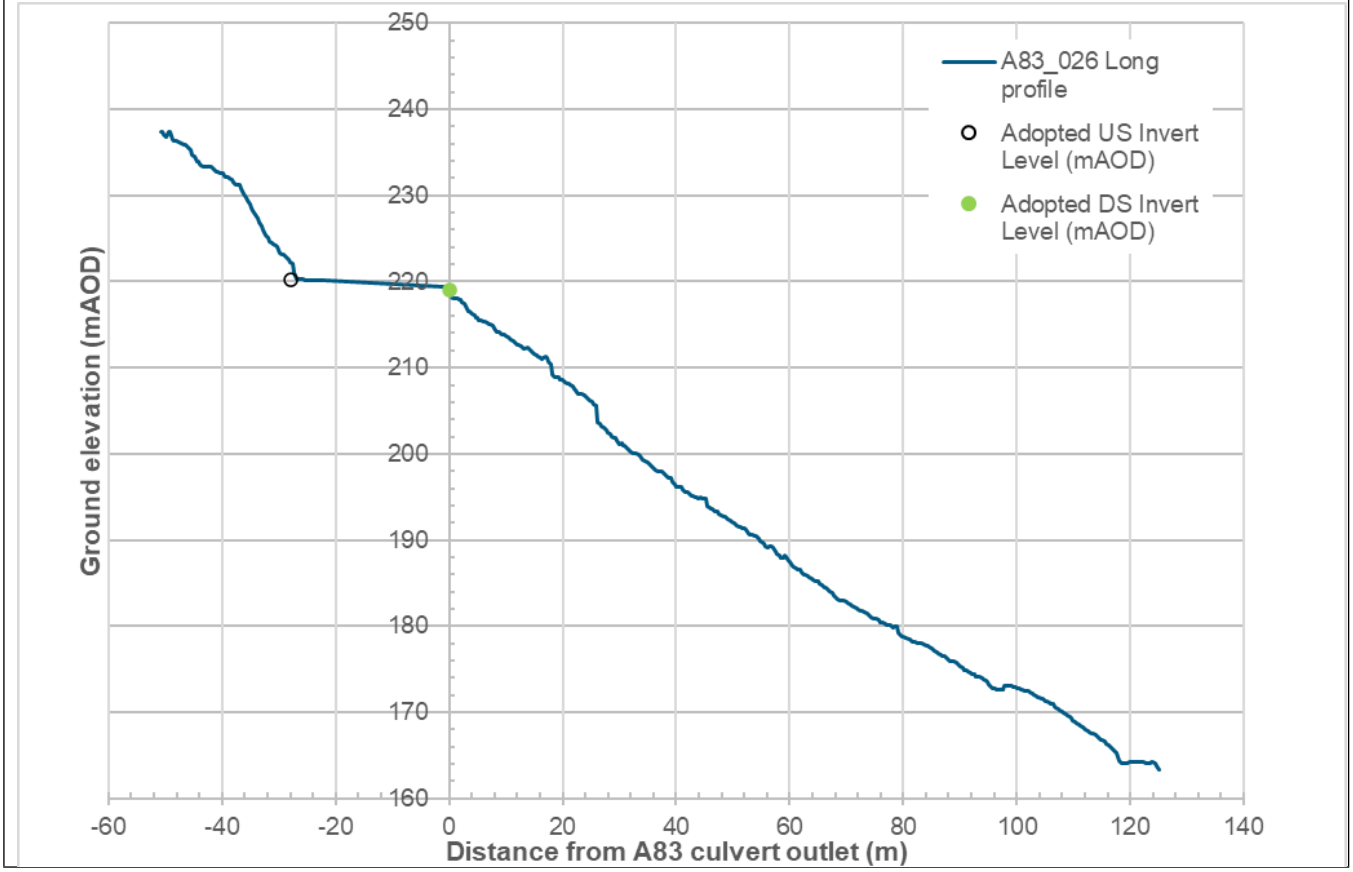
Watercourse ID	A83_ML_026_000
Corresponding OMR crossing ID	OMR_25
Watercourse categorisation	Minor A (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	High
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.058
Watercourse length from A83 to OMR (m)	123
Existing A83 culvert (Capacity)	Box culvert 1.4 m (W) x 1.5 m (H) (>200-yr + CC fluvial event)
Upper reach seen from the A83 showing reno mattress at the culvert outfall 	Lower reach (looking downstream towards the main channel) 

Description: The watercourse has a catchpit and landslide/rock fall barriers immediately upstream of the A83. The upstream catchpit is a combined catchpit linking this watercourse with A83_ML_024_000 and A83_ML_025_000. The watercourse exhibits a steep gradient, with an average of 55% (up to 121%) upstream of the A83 and 45% downstream (up to 126%). The peaks in the channel bed gradient are immediately upstream and downstream of the A83 culvert; gabion/reno mattress type protection has been installed over a ~10 m reach, protecting the bed and banks downstream of the culvert. Within the base of the mattress there is a geotextile to trap fines. There are gabions at the top of the reach offering some support to the slopes around and above the culvert outlet. The mesh within the channel is failing. Downstream of this reach there is a is a section of that is lined with a geotextile that has been soil nailed to provide further protection with large boulders placed on top. Immediately downstream of this reach a rockfall fence has been installed across the channel and filled with large boulder material to provide scour protection, however, this has caused erosion and widening of the channel upstream and downstream of the fence. Following this, the morphology of the cascade and step-pool sequence. Significant cobble and boulder aggradation on the bed is observed upstream and downstream of the OMR where bed slopes are moderate and flows constricted by two culverts in short succession.

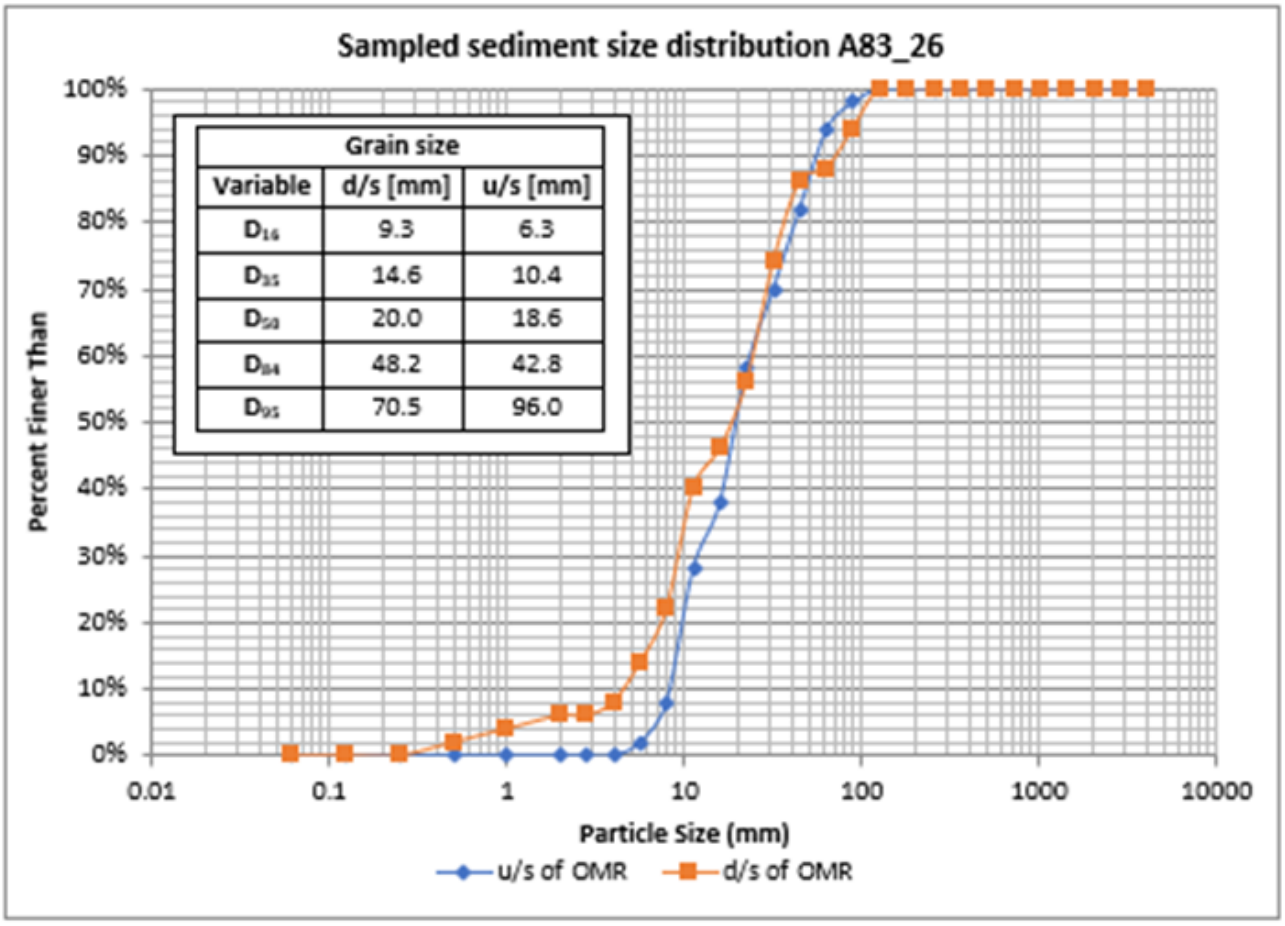
Processes: As discussed above the upper reach of the watercourse is heavily modified due to historic erosion and scour. A number of measures have been constructed which have been partially successful, though there is evidence of corrosion and breaks with the mattress mesh and erosion around the larger boulder material. The lower reach, downstream of the OMR, shows a less steep morphology. The upper reach, depicted in the left figure, features a cascade sequence with severe scour of the bed and banks. Similarly, the lower reach, shown in the right figure, has evidence of confinement but is more subtle and the substrate is slightly finer.

Sediment: Field-collected sediment samples indicate that the lower reach contains finer sediments compared to the upper reach. In the upper reach, approximately 95% (D_{95}) of the sediment in the channels is smaller than 70.5 mm, whereas in the lower reach, 95% is smaller than 96.0 mm. The median particle size (D_{50}) is 20.0 mm in the upper reach and 18.6 mm in the lower reach, suggesting dominant fluvial transport processes occur predominantly with these particle sizes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming cascades in the upper and lower reaches.

Long profile



Riverbed grain size distribution

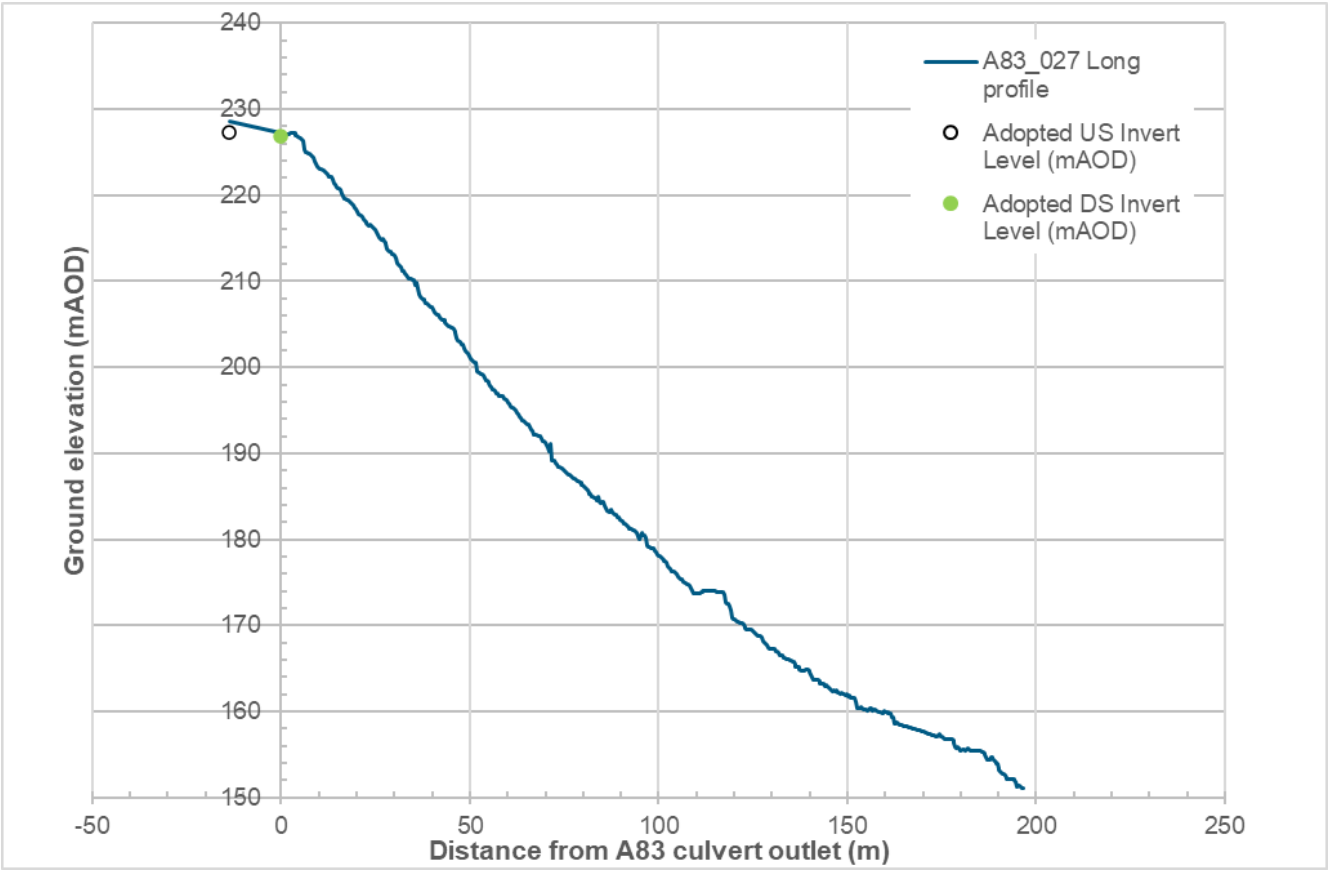


Watercourse ID	A83_ML_027_000
Corresponding OMR crossing ID	OMR_27
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	High
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.129
Watercourse length from A83 to OMR (m)	110
Existing A83 culvert (Capacity)	Pipe culvert, 0.6 m diameter

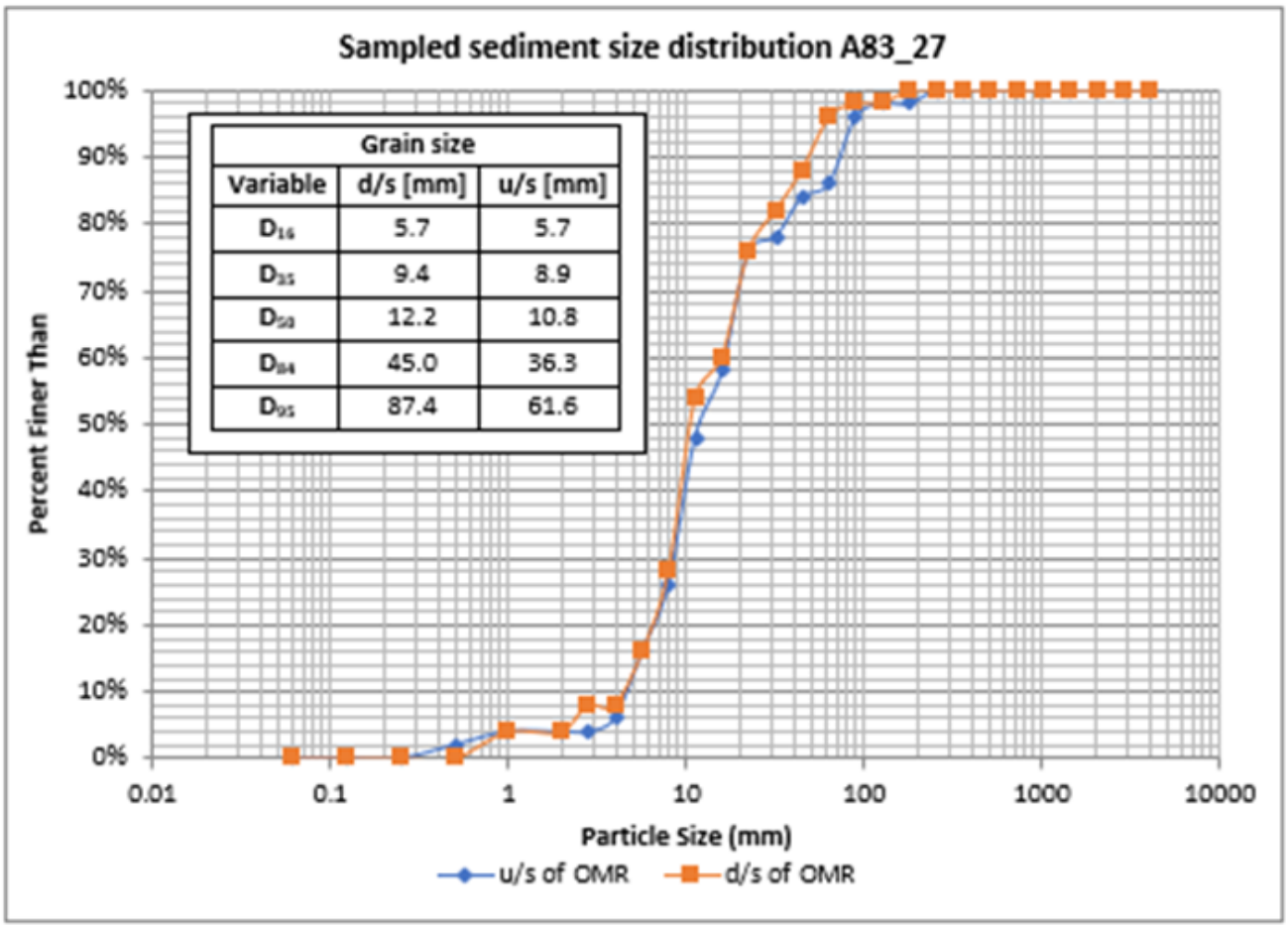
	(<2-yr fluvial event)
Upper reach seen from OMR (looking towards the A83) 	Lower reach (looking downstream towards the main channel) 
Description: The watercourse exhibits a very steep gradient, with an average of 38% (up to 100%). Although there are some peaks downstream from the culvert, there is an overall decline in channel steepness. The morphology of the upper and lower reaches primarily features a cascade sequence which transition to step pools as the gradient reduces. Processes: The current culvert can accommodate fluvial flows up to a 2-year event. The channel is very incised and in some locations there is active erosion, though on the whole, the channel is stable and well vegetated. The upper reach, depicted in the right figure, features a cascade sequence with severe scour of the bed and banks. Generally, the gradient reduces with distance from the A83 culvert and the morphology transitions to step pool sequences (Step measurements: 1.20 m w, 1.18 m h. Spacing 1.20 m l, 0.90 m l, 3 steps then a longer pool. Longer pool at the base of the cascade =1.35 m l depth: 0.40m h 0.50m h 0.20m h. (Upstream- downstream) key boulder diameter = 0.29 m, 0.20 m and 0.30 m). Sediment: Field-collected sediment samples indicate that the lower reach contains finer sediments compared to the upper reach. In the upper reach, approximately 95% (D_{95}) of the sediment is smaller than 87.4 mm, whereas, in the lower reach, 95% is smaller than 61.6 mm. The median particle size (D_{50}) is 12.2 mm in the upper reach and 10.8 mm in the	

lower reach, suggesting dominant fluvial transport processes occur predominantly with these particle sizes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming cascades in both the upper and lower reaches, and suggesting hillslope processes.

Long profile



Riverbed grain size distribution

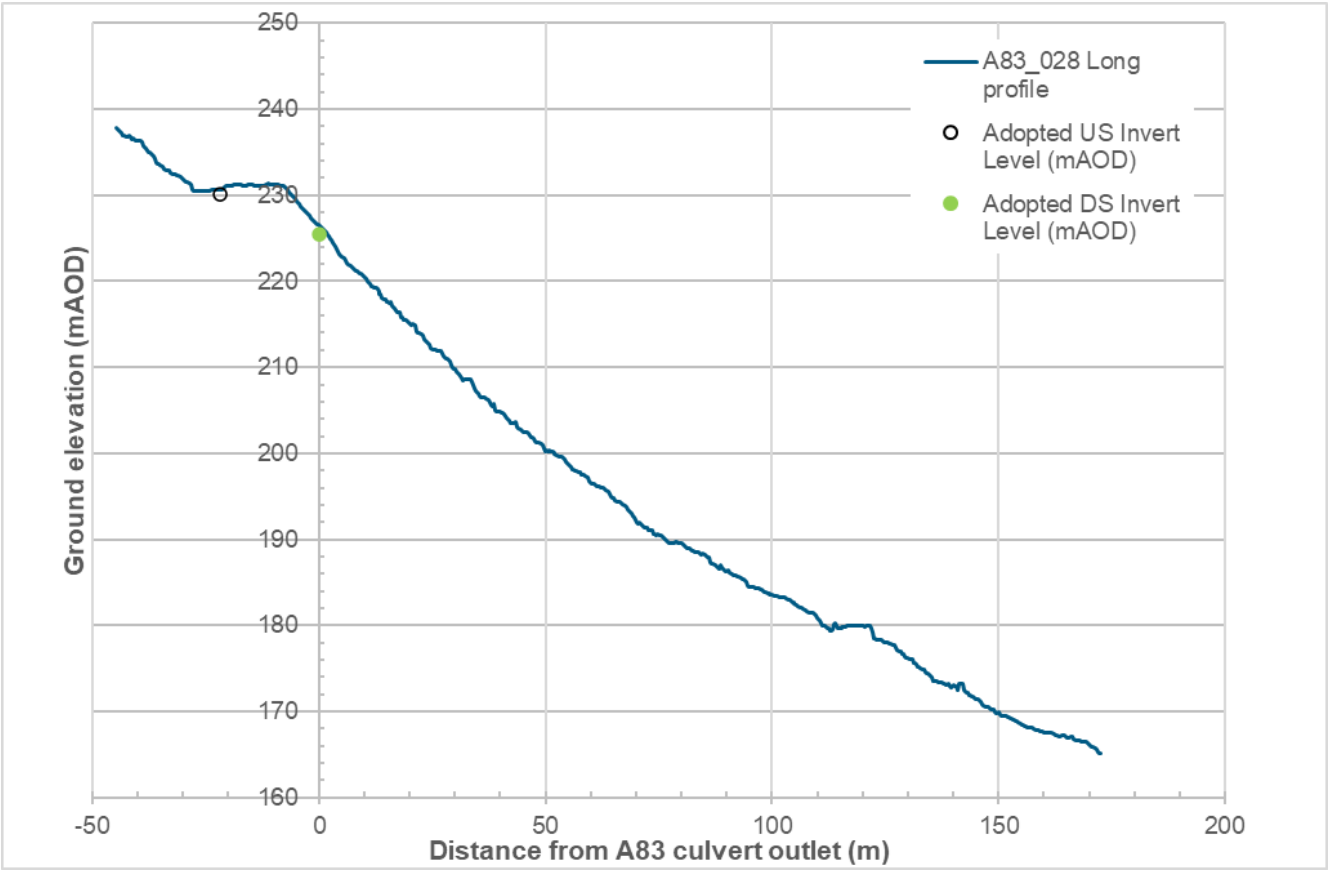


Watercourse ID	A83_ML_028_000
Corresponding OMR crossing ID	OMR_28
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.056
Watercourse length from A83 to OMR (m)	119
Existing A83 culvert (Capacity)	Pipe culvert, 0.46 m diameter (<2-yr fluvial event)
Upper reach (looking downstream towards the OMR) 	Lower reach (looking upstream towards the OMR) 
Description: The A83 culvert outfalls to a concrete cascade, which is in good condition and provides a solid base to a well vegetated channel. The watercourse exhibits a very steep gradient, with an average of 39% (up to 121%) in the upper reach, and 35% (up to 86%) in the lower reach. Although there are some peaks downstream from the culvert, there is an overall decline in channel steepness. The morphology of the upper and lower reaches primarily features a cascade to step-pool sequence.	

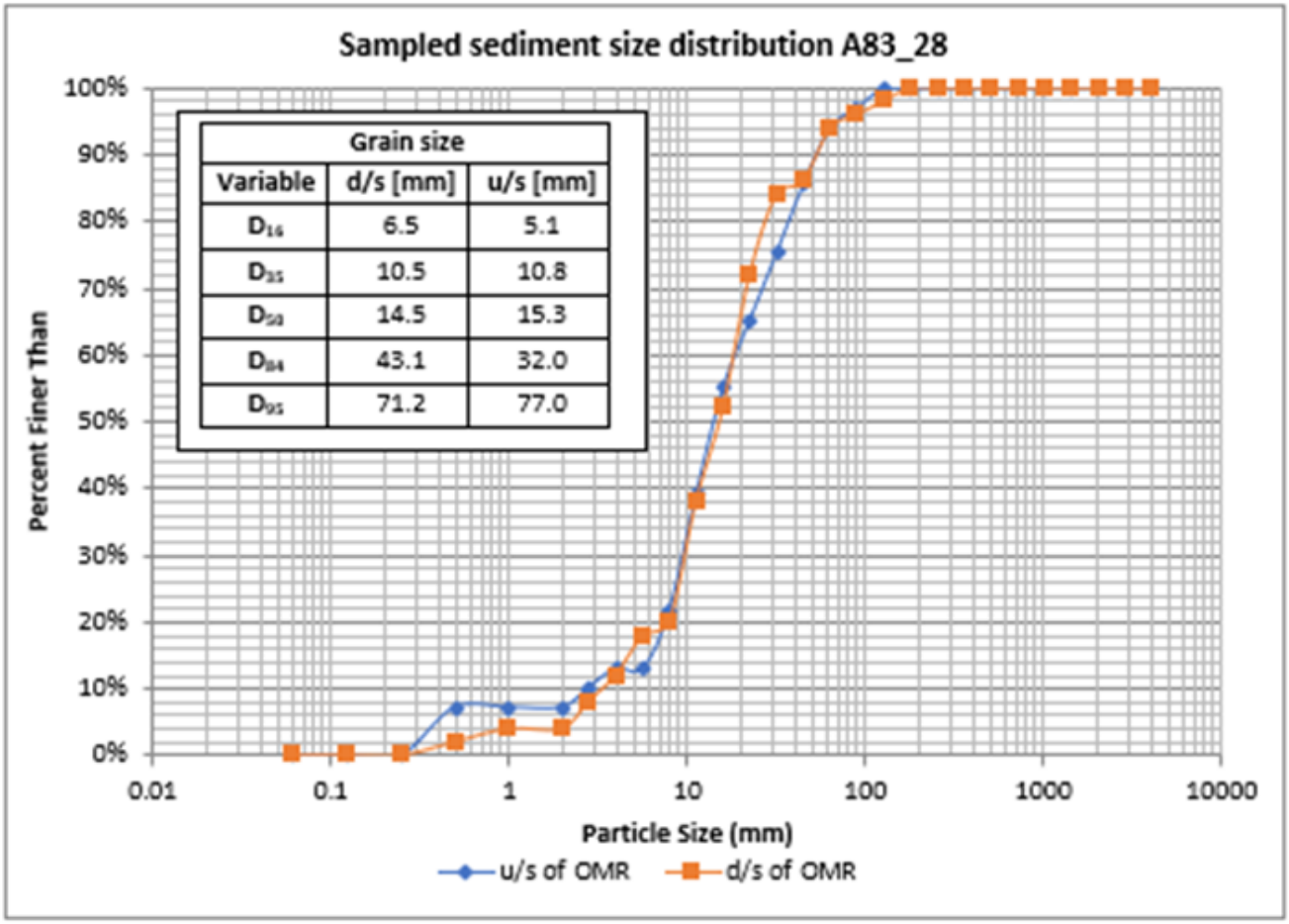
Processes: The current culvert can accommodate fluvial flows up to a 2-year event. The upper reach, depicted in the left figure, features a cascade/step-pool sequence with evidence of scour to the bed and banks. Similarly, the reach immediately upstream of the OMR, shown in the right figure, has evidence of confinement but is more subtle. The lower reach, downstream of the OMR, shows a less steep morphology.

Sediment: Field-collected sediment samples indicate that the lower reach contains slightly coarser sediments compared to the upper reach. In the upper reach, approximately 95% (D_{95}) of the sediment in the channels is smaller than 71.2 mm, whereas in the lower reach, 95% is smaller than 77.0 mm. The median particle size (D_{50}) is 14.5 mm in the upper reach and 15.3 mm in the lower reach, suggesting dominant fluvial transport processes occur predominantly with these particle sizes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming cascades in both the upper and lower reaches, and suggesting hillslope processes.

Long profile



Riverbed grain size distribution



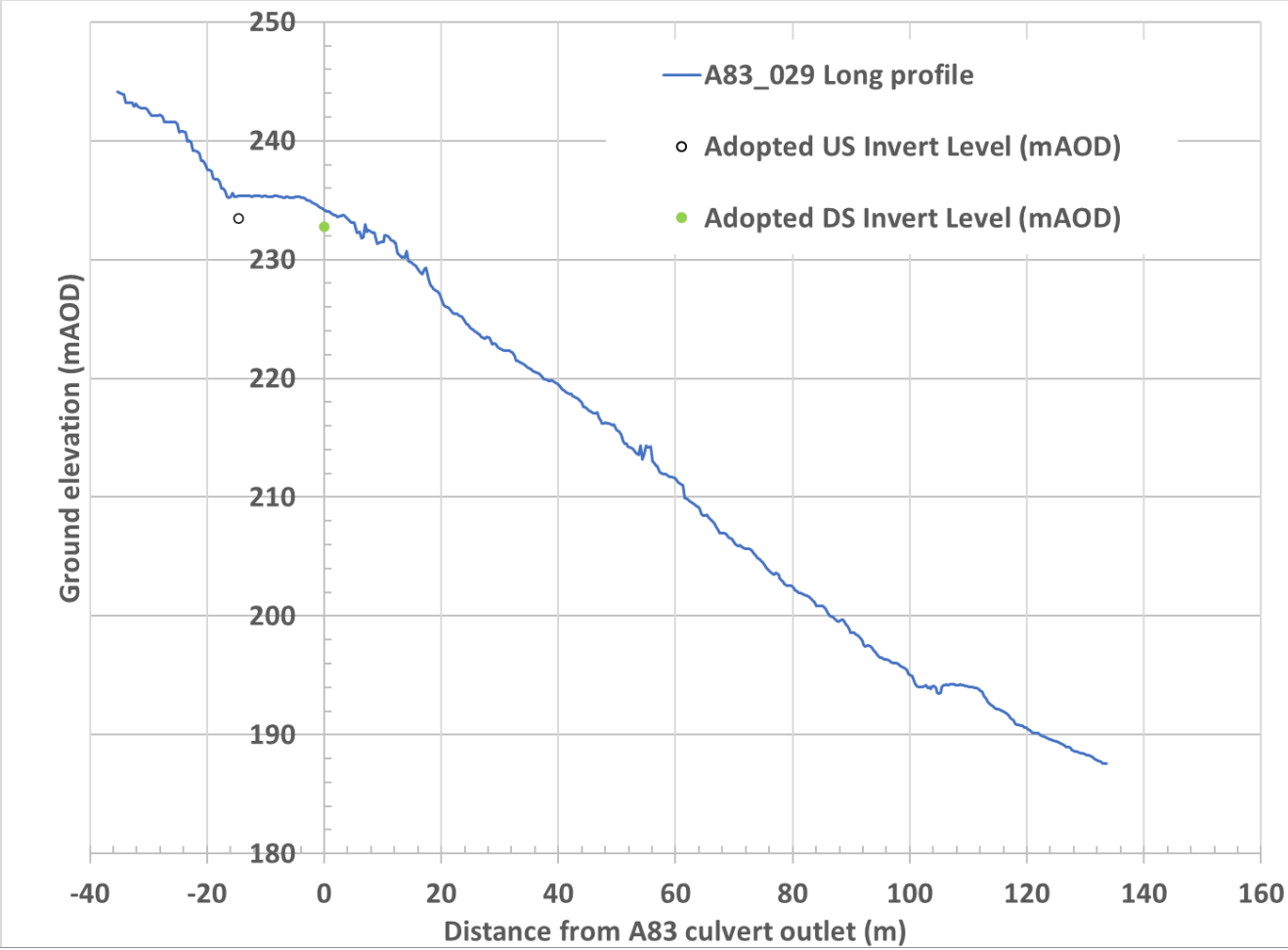
Watercourse ID	A83_ML_029_000
Corresponding OMR crossing ID	OMR_29
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.041
Watercourse length from A83 to OMR (m)	99
Existing A83 culvert (Capacity)	Box culvert 1.7 m (W) x 1.3 m (H) (>200-yr + CC fluvial event)
Upper reach, showing the transition from the cascade to the natural channel 	Lower down the final third of the watercourse towards the OMR 
Description: This watercourse heavily modified both upstream and downstream of the A83 (left figure). Upstream of the A83 there is straight, 30 m, concrete cascade (1:1) that directs flow to the A83 culvert. Downstream of the A83 the culvert discharges to a ~17 m concrete cascade that doglegs flow to the north before a drop of approximately 1.5 m to the natural channel. The watercourse exhibits a steep gradient, with an average of 48% (0.48 m/m), up	

to 115% (1.15 m/m) in the upper reach between the A83 and OMR, and 35% (0.35 m/m), up to 87% (0.87 m/m) in the reach below the OMR. Generally, the gradient declines in channel from upslope to downslope. The morphology of the upper and lower reaches primarily features step-pool sequences.

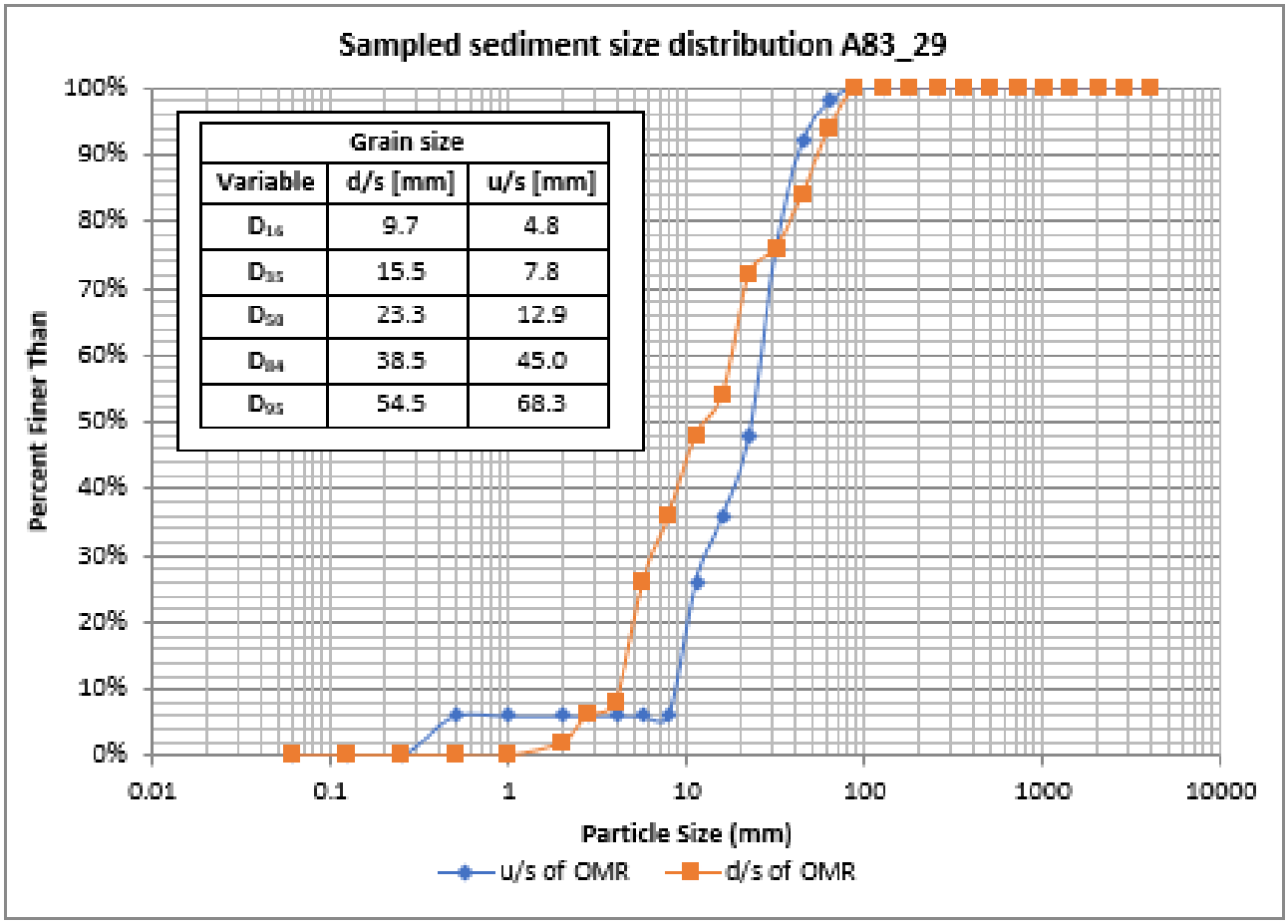
Processes: The current culvert can accommodate fluvial flows up to a 200-year event. As described above, the upper section of the watercourse from the A83 culvert outlet is heavily modified (left figure). The transition to the natural channel is abrupt, with a 1.5 m drop caused by historic erosion. This erosion does not seem to be on going and the remainder of the channel to the OMR is relatively stable, though there was evidence that high-flows may spill out of bank and flow over the grassed surface. Downstream of the OMR shows less steep morphology. The upper reach, depicted in the right figure, features a step-pool sequence.

Sediment: Field-collected sediment samples indicate that the reach below the OMR contains finer sediments compared to the upper reach (Above the OMR). In the upper reach, approximately 95% of the sediment in the channels is smaller than 54.5 mm, whereas in the lower reach, 95% is smaller than 68.3 mm. The median particle size (D_{50}) is 23.3 mm in the upper reach and 12.9 mm in the lower reach, suggesting dominant fluvial transport processes occur predominantly with these particle sizes. Large boulders (greater than 700 mm) have been observed in the watercourse, likely eroded from adjacent banks and terrace deposits, forming cascades in both the upper and lower reaches.

Long profile

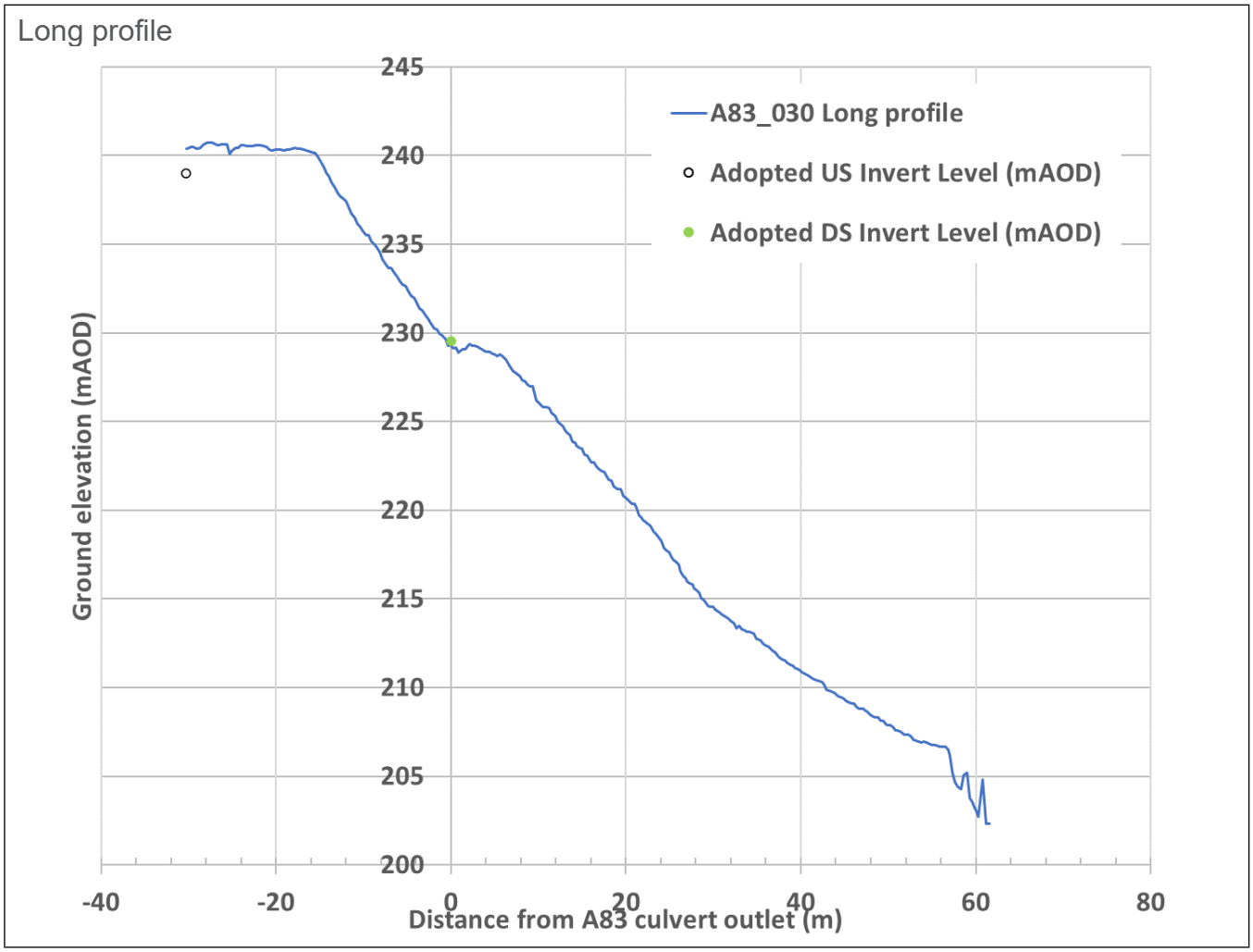


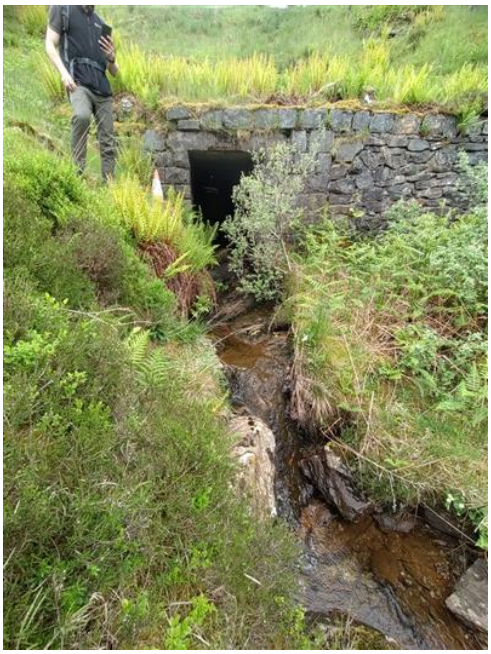
Riverbed grain size distribution



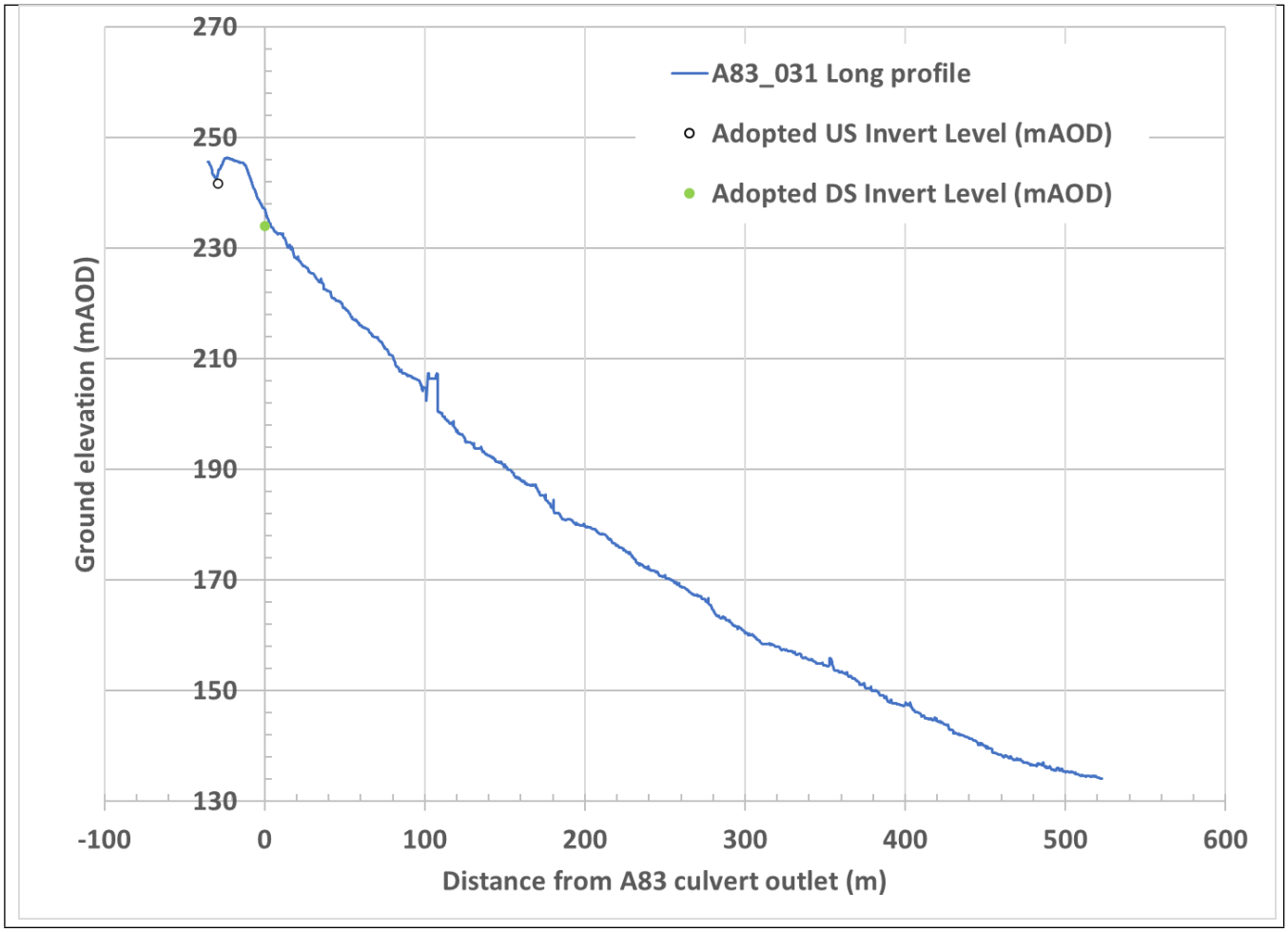
Watercourse ID	A83_ML_030_000
Corresponding OMR crossing ID	OMR_30
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.05
Watercourse length from A83 to OMR (m)	91
Existing A83 culvert (Capacity)	Pipe culvert, 0.5 m diameter

	(~2-yr fluvial event)
A83 culvert outlet 	Looking upstream towards the A83 
Description: The whole reach of this watercourse, between the A83 and OMR, consists of a fibreglass channel with a continuous lining of the bed and banks. The watercourse exhibits a steep gradient, with an average of 42% (0.42 m/m) and peaks over 100% (1.2 m/m) in the upper reach, above the OMR. This watercourse has a confluence with A83_ML_031_000 immediately upstream of the OMR. The watercourse downstream of the OMR is as described for A83_ML_031_000. Processes: The current A83 culvert can only accommodate fluvial flows up to the 2-year event. There are no signs of jetted flows through the A83 culvert. As described previously, the channel is lined by fibreglass and is very steep so there are no natural processes at all within this channel between the A83 and OMR.	

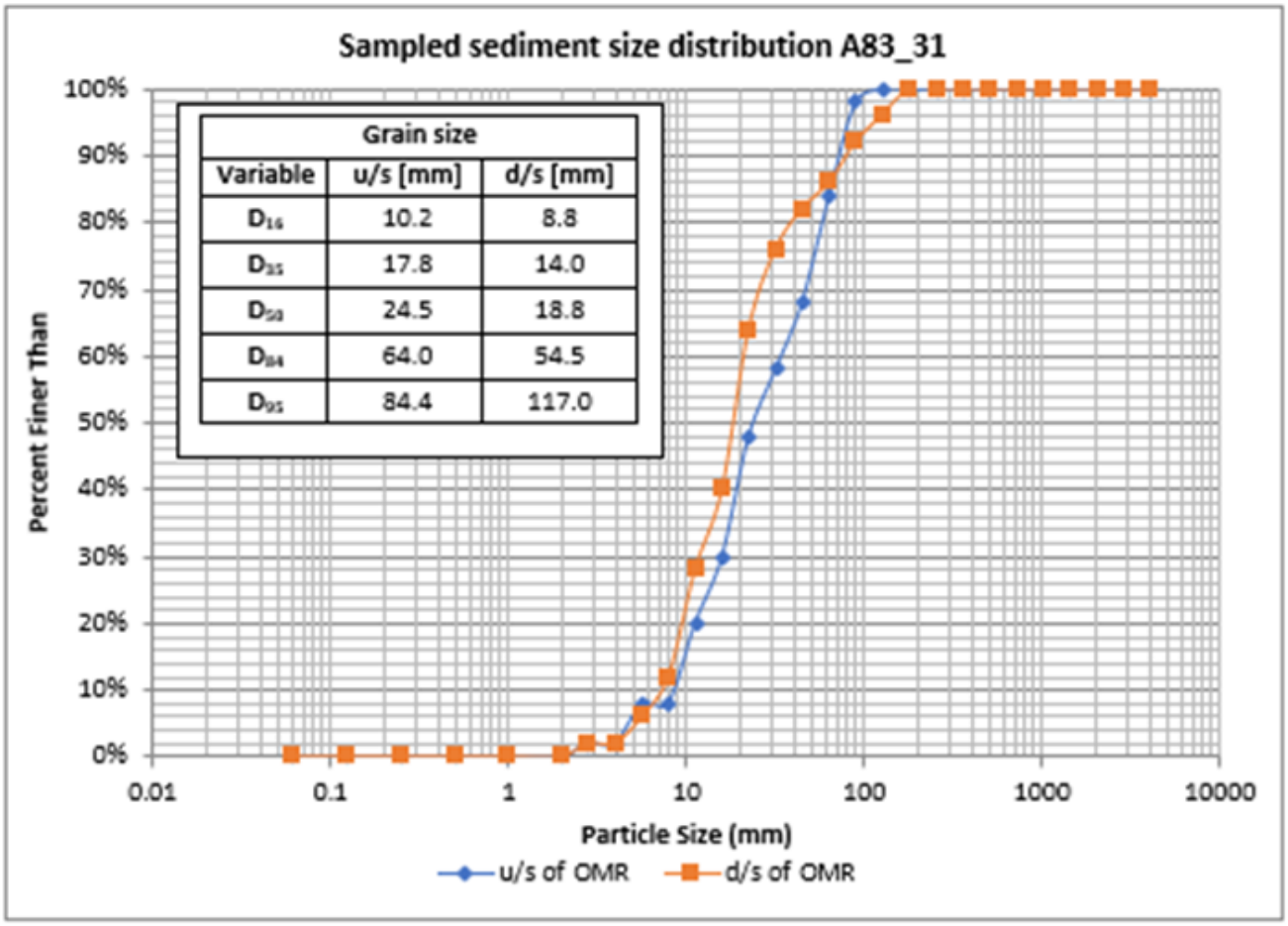

Long profile
A83_030 Long profile
Adopted US Invert Level (mAOD)
Adopted DS Invert Level (mAOD)
Ground elevation (mAOD)
245
240
235
230
225
220
215
210
205
200
-40
-20
0
20
40
60
80
Distance from A83 culvert outlet (m)

Watercourse ID	A83_ML_031_000
Corresponding OMR crossing ID	OMR_30
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.129
Watercourse length from A83 to OMR (m)	109
Existing A83 culvert (Capacity)	Box culvert 1.2 m (W) x 1.5 m (H) (>200-yr + CC fluvial event)
Upper reach (looking upstream towards the A83) 	Lower reach (looking downstream towards the main channel) 
Description: There is a box culvert beneath the A83 that is constructed from stone blocks and has a bedrock base. This culvert discharges to a bedrock cascade, which is the dominant morphology of the upper reach between the A83 and OMR culvert. The watercourse is very steep, with an average gradient of 36% (0.36 m/m) and peaks of more than 200% (2 m/m) in the upper reach. This watercourse has a confluence with A83_ML_030_000 immediately upstream of the OMR bridge crossing. The reach below the	

OMR has an average gradient of 17% (0.17 m/m) and peaks of more than 200% (2 m/m), though overall, there is a decline in channel steepness with distance downstream, towards the confluence of the High Glencroe watercourse. The lower reaches primarily feature a step-pool sequence, with some cascades in the steeper sections. Processes: The A83 culvert can accommodate fluvial flows up to a 200-year event. The culvert discharges to a sequence of step-pool cascades, consisting of large 1.5 m steps at 4 m interval. Within the 4 m interval, smaller, 0.4 m, steps were observed at approximately 1 m to 1.5 m spacing. The lower reach downstream of the OMR shows a less steep morphology (compared to upstream), with step pool sequences, as shown in the right-hand figure. Other than the culvert and OMR bridge crossing, the watercourse is natural and is not experiencing excessive scour/ erosion. Sediment: Field-collected sediment samples indicate that the lower reach contains finer sediments compared to the upper reach. In the upper reach, approximately 95% of the sediment in the channels is smaller than 84.4 mm, whereas in the lower reach, 95% is smaller than 117.0 mm. The median particle size (D_{50}) is 24.5mm in the upper reach and 18.8 mm in the lower reach, suggesting dominant fluvial transport processes occur predominantly with these particle sizes.
Long profile


270
250
230
210
190
170
150
130
-100
0
100
200
300
400
500
600
Ground elevation (mAOD)
Distance from A83 culvert outlet (m)
A83_031 Long profile
Adopted US Invert Level (mAOD)
Adopted DS Invert Level (mAOD)

Riverbed grain size distribution

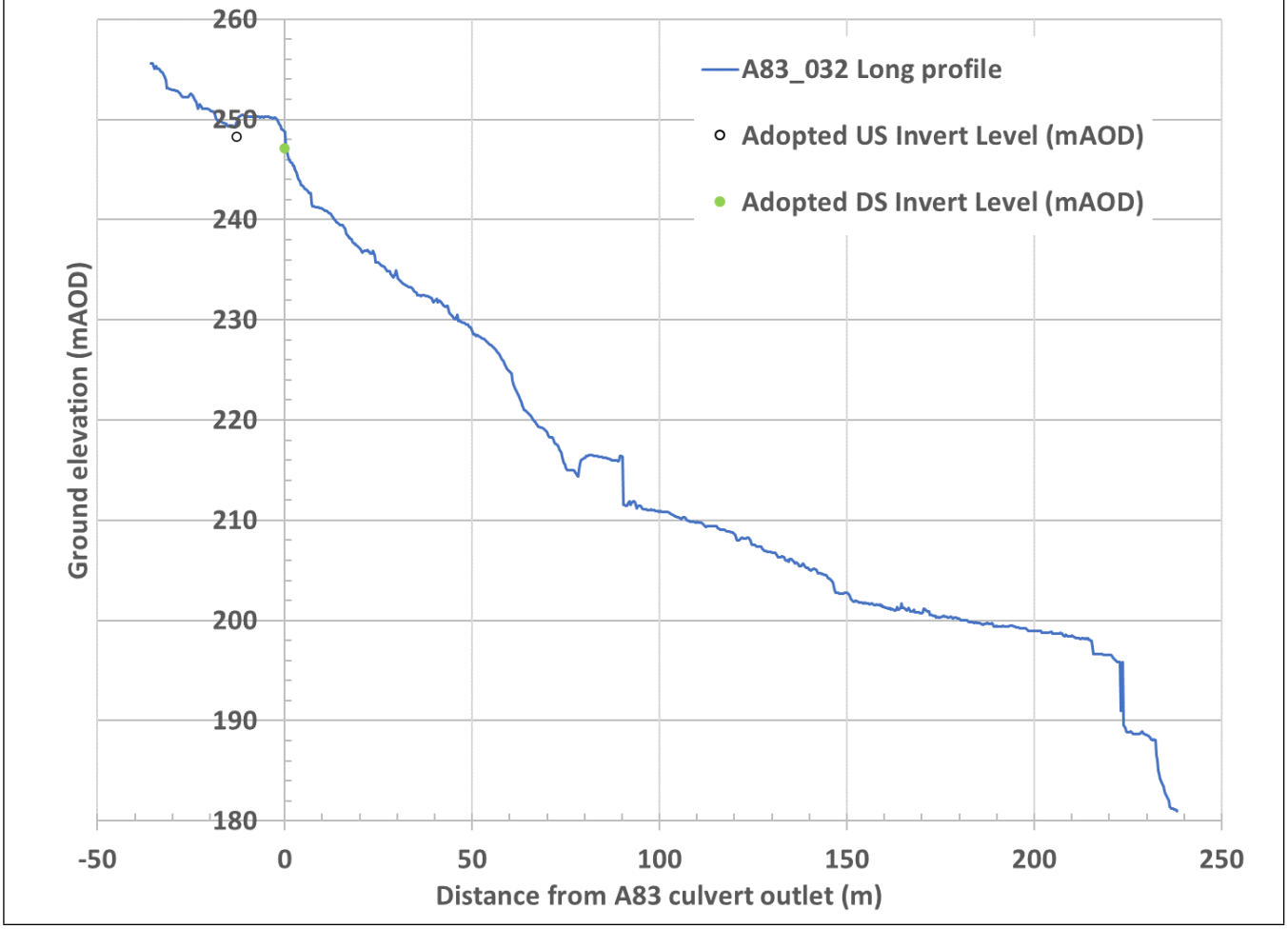


Watercourse ID	A83_ML_032_000
Corresponding OMR crossing ID	OMR_31
Watercourse categorisation	Major (On OS 1:50,000 scale map)
Geomorphological risk categorisation	Medium
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.162
Watercourse length from A83 to OMR (m)	84.5
Existing A83 culvert (Capacity)	Pipe culvert, 0.9 m diameter (~10-yr fluvial event)
Upper reach (looking upstream towards the A83) 	Lower reach (looking downstream towards the main channel) 
Description: A concrete culvert beneath the A83 is discharges to a bedrock cascade. The watercourse exhibits very steep gradients, with an average of 52% (0.516 m/m) and peaks up to 173%) in the reach above the OMR culvert, and 23% (peaks up to 212%) in the reach below the OMR. The reach upstream of the OMR comprises of a bedrock channel. The reach below the OMR primarily features step-pool sequences. Other than the culverts, the watercourse is natural and is not experiencing excessive scour/ erosion.	

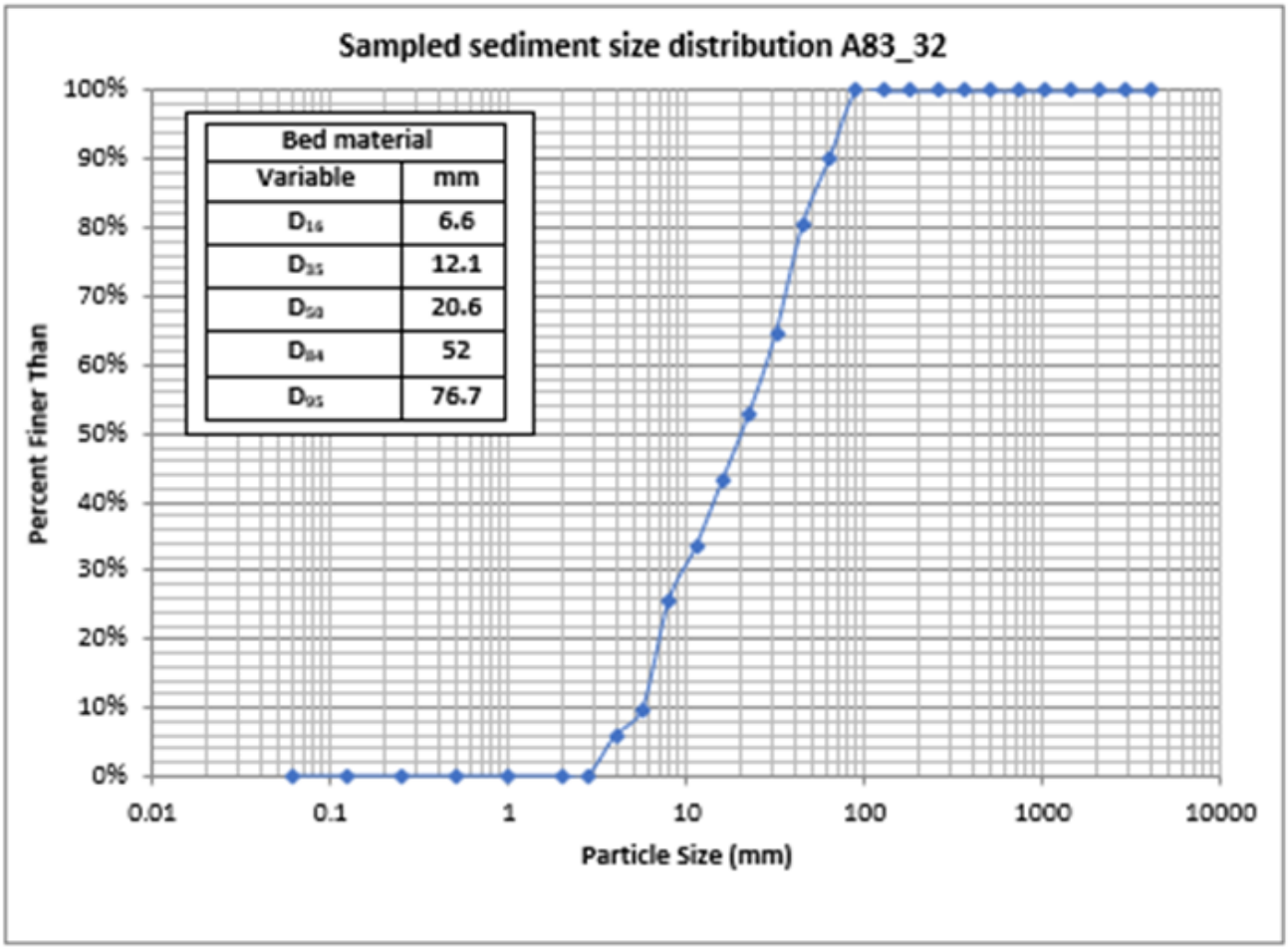
Processes: The A83 culvert can accommodate fluvial flows up to a 10-year event. Excessive erosion was not observed on this watercourse between the A83 and OMR. Watercourse between the A83 and the OMR consists of steep bedrock cascades. As can be seen in the left-hand photo, the channel is shallow with banks consisting of grass covered shallow soils. The reach downstream of the OMR shows a less steep morphology, with step pool sequences.

Sediment: Field-collected sediment samples indicate that the lower reach has a predominantly gravel fraction (D_{50} = 20.6 mm), with the upper and lower bounds between 6.6 mm (fine gravel) and 76.7 mm (cobble). The presence of a bedrock channel upstream of the OMR suggests a strong erosion rate of the bed.

Long profile

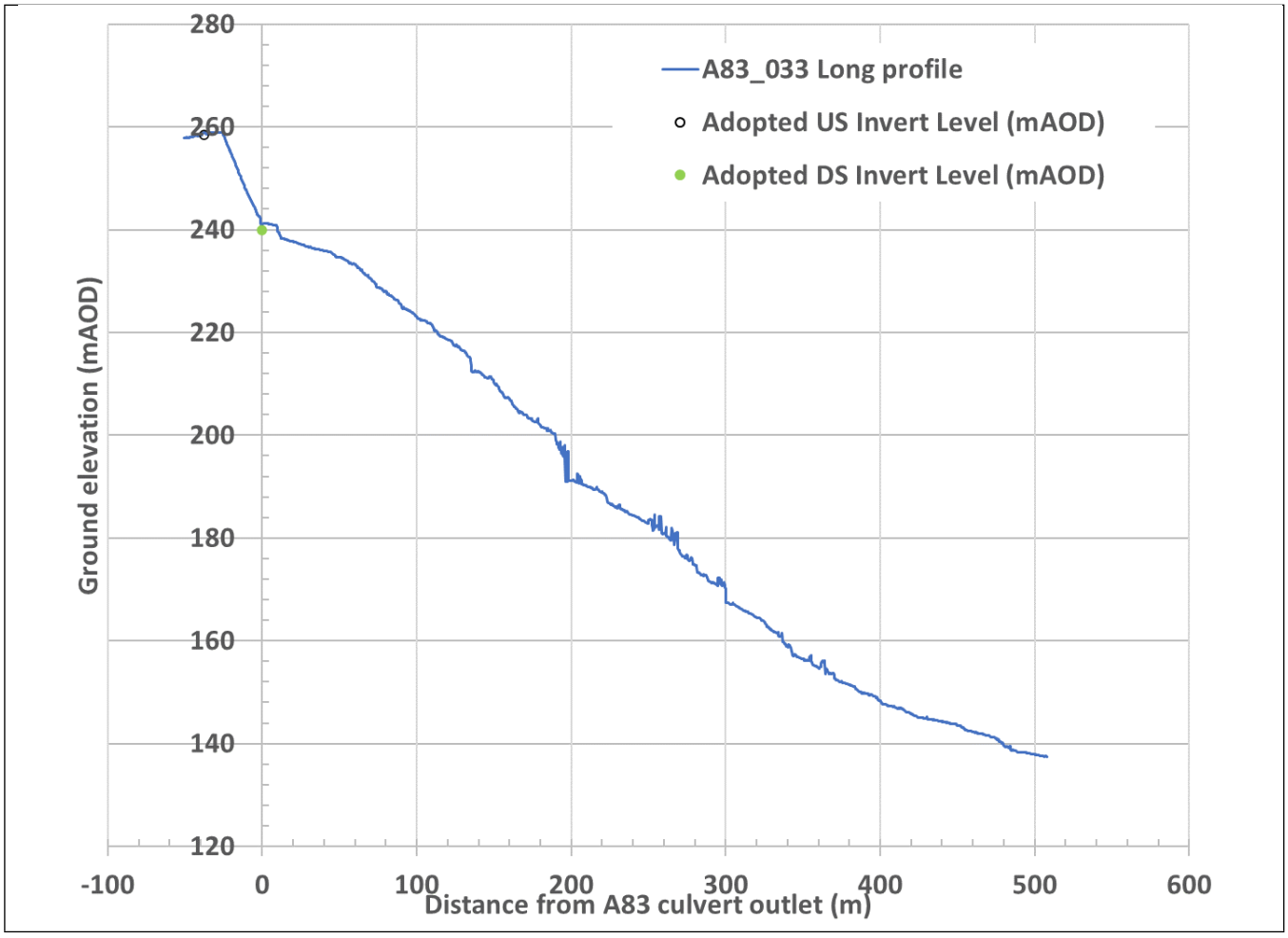


Riverbed grain size distribution



Watercourse ID	A83_ML_033_000
Corresponding OMR crossing ID	OMR_34
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	0.02
Watercourse length from A83 to OMR (m)	Approximately 25 m and wholly culverted
Existing A83 culvert (Capacity)	Pipe culvert, 0.4 m diameter (~25-yr fluvial event)
Aerial image of A83_ML_033_000 with the A83 and OMR shown 	A83 culvert outlet, immediately upstream of the OMR culvert inlet 

Description: This watercourse is wholly culverted from upstream of the A83 to the OMR. The culvert discharges to an artificial drainage channel, where the flow is 'open' to the daylight for approximately 2 m before it then enters a second culvert below the OMR. The watercourse exhibits steep gradients, at 40% (0.40 m/m) between the A83 and immediately downstream of the OMR. From the OMR to the base of Glen Croe (approx. 450 m), where the watercourse joins two other large tributaries to form the High Glencroe watercourse, the average gradient is 23% (0.227 m/m), with some very steep sections in between (up to 261% / 2.61 m/m). Processes: The current culvert can accommodate fluvial flows up to a 25-year event. As outlined above, the watercourse is culverted for nearly the whole of the reach beneath the A83 through to the downstream of the OMR, with only a short, 2 m, section of daylighted watercourse. Within the 2 m section of daylighted channel there is a variety of substate from sands through to cobbles (Right hand picture), though the sediments were not assessed in detail for this watercourse. Upslope of the A83 there is no well-defined channel, rather there is a wet/boggy, vegetated, thalweg that drains to the A83 (As observed from aerial imagery). The OMR culvert on this watercourse does not discharge to a well-defined channel, it discharges to a wet boggy area, which is at a comparatively low gradient of 13% (0.127 m/m). A formal, defined, channel does not begin until approximately 22 m downstream of the OMR (As observed from aerial imagery).
Long profile


A83_033 Long profile
Adopted US Invert Level (mAOD)
Adopted DS Invert Level (mAOD)
Ground elevation (mAOD)
280
260
240
220
200
180
160
140
120
-100
0
100
200
300
400
500
600
Distance from A83 culvert outlet (m)

Watercourse ID	A83_ML_034_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Kinglas Water (ID: 10217)
Catchment area to the A83 (km^2)	0.028
Watercourse length from A83 to OMR (m)	N/A
Existing A83 culvert (Capacity)	Unknown
Culvert inlet located in ill-defined drainage ditch 	Culvert outlet, looking downstream from above the culvert. 
Description: The A83 culvert inlet is located within an ill-defined drainage channel that runs in parallel to the A83. It was not possible to locate the inlet during a site visit due to the vegetation and detritus within the drainage ditch. The buildup of in channel vegetation is highly likely to be impacting the efficiency of the conveyance of flows into the culvert. The culvert outlet was observed to have collapsed. Flow was not seen; however, it could be heard bypassing the pipe at the downstream extent of the culvert. Downslope of the A83 the land is frequently very wet and drains to the western extent of Loch Restil. No 'in channel' sediment to characterise as upslope and downslope are vegetated extensively.	

Watercourse ID	A83_ML_035_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Kinglas Water (ID: 10217)
Catchment area to the A83 (km^2)	0.017
Watercourse length from A83 to OMR (m)	N/A
Existing A83 culvert (Capacity)	Unknown
Looking at the upstream slope draining to the A823 from the western Ben Luibhean slopes 	Culvert outlet, looking downstream from above towards Loch Restil. 
Description: The upstream channel is ill-defined and the A83 culvert inlet is located within a heavily vegetated drainage channel. The culvert outlet is located approximately 7 m from, and 3 m above, the shore of Loch Restil. The downstream channel consists of natural step-pools sequence that is eroding the fines and cobbles that make-up the bed and banks.	

Watercourse ID	A83_B8_001_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor A (On OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the B828 (km^2)	
Watercourse length from A83 to OMR (m)	n/a
Existing A83 culvert (Capacity)	n/a
Upstream watercourse 	Looking downstream from the B828 
Description: This crossing beneath the B828 consists of a 650 mm corrugated plastic pipe. The upstream channel has a gradient of approximately 10% (0.0986 m/m) with a much lower gradient of 0.16% (0.00165 m/m) over the first 20 m downstream of the culvert. The main upstream fluvial channel is joined by an artificial drainage ditch that runs in parallel to the B828 from the north-east capturing the upslope runoff. The bed substrate consists of cobbles and sands. The culvert is running clear and there is no deposition of material upstream or through the culvert barrel. The channel is well defined, both upstream and down, with well vegetated banks and no obvious signs of scour erosion.	

Watercourse ID	A83_B8_002_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the B828 (km^2)	
Watercourse length from A83 to OMR (m)	n/a
Existing A83 culvert (Capacity)	n/a
Photo looking upstream. 	Photo looking downstream. 
Description: This crossing beneath the B828 consists of 450 mm corrugated plastic pipe. The channels upstream and downstream are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep, 1 m wide running in parallel with the B828 that crosses the slope, running to the south west, and intercepting any upslope runoff. There is likely a bend or kink in the culvert alignment as no daylight could be seen through it. The culvert outlet protrudes by approximately 5 m from road embankment. The culvert outlet is elevated/ perched by approximately 1 m from the underlying ground. There are boulders and cobbles at the outlet where the flows drop to, however, there is no significant evidence of scour erosion.	

Watercourse ID	A83_B8_003_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	
Watercourse length from A83 to OMR (m)	N/A
Existing A83 culvert (Capacity)	
Upstream channel/drainage ditch 	Culvert outlet and downslope. 
Description: This crossing beneath the B828 consists of 300 mm corrugated plastic pipe. The channels upstream and downstream are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep, 1 m wide running in parallel with the B828 that crosses the slope, running to the south west, and intercepting any upslope runoff. No 'in channel' sediment to characterise as upslope and downslope are vegetated extensively.	

Watercourse ID	A83_B8_004_000
Corresponding OMR crossing ID	n/a
Watercourse categorisation	Minor B (Not on OS 1:25,000 scale map)
Geomorphological risk categorisation	Low
WFD Catchment	The Croe Water (ID: 10215)
Catchment area to the A83 (km^2)	
Watercourse length from A83 to OMR (m)	N/A
Existing A83 culvert (Capacity)	
Culvert Inlet 	Culvert outlet 
Description: This crossing beneath the B828 consists of a 500 mm corrugated plastic pipe. poorly defined outlet. disperses across the slope making a boggy area. The channels upstream and downstream are poorly defined, though, there is an artificial drainage ditch approx. 0.5 m deep, 1 m wide running in parallel with the B828 that crosses the slope, running south to north, and intercepting any upslope runoff. No 'in channel' sediment to characterise as upslope and downslope are vegetated extensively.	

Annex 19-3-2 Summary OMR watercourse characterisations

(ordered south to north)

Table A19-3.1 Watercourses crossed by the OMR that are not impacted by LTS works

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_Z05_B01 (OMR_01)		This watercourse has been modified by works that have already been undertaken to increase the resilience of the OMR to flooding. This work has included the construction of a new access road, approximately 85 m north of the existing access that links the A83 to the southern extent of the OMR. The watercourse has had to be realigned both in plan form and vertically to accommodate the new road and convey the water through a new culvert. These works are now complete (completed in 2024). The realigned watercourse consists of a two-stage channel cross section upstream of the culvert crossing that can accommodate lower/moderate flows and higher flows without excessive erosion. Boulder bed checks (250-300 mm) have been included, buried (flush with the bed), and installed every 3-4 m to minimise the risk of a knick point migration. The watercourse has been assessed as unsuitable for fish and otters.
A83_ML_Z05_B02 (OMR_02)		The channels are well vegetated, there are no obvious signs of erosion or deposition within the channel. The culvert is not being resized and is not affected by a build-up of material within the barrel, as long as the current level of maintenance is continued there is no need for additional measures. The culvert outlet is approximately 2 m to the Croe Water. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_Z05_B03 (OMR_03)		No improvements to the OMR are proposed that will affect this watercourse. The channels are well vegetated, there are no obvious signs of erosion or deposition within the channel. The culvert is not being resized and is not affected by a build-up of material within the barrel, as long as the current level of maintenance is continued there is no need for additional measures. There is only 6 m of channel from the culvert outlet to the Croe Water. The watercourse is unsuitable for fish and otters.
A83_ML_Z05_B04 (OMR_04)		No improvements to the OMR are proposed that will affect this watercourse. The channel is well vegetated, there are no obvious signs of erosion or deposition within the channel. The culvert is not being resized and is not affected by a build-up of material within the barrel, as long as the current level of maintenance is continued there is no need for additional measures. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_Z05_B05 (OMR_05)		No improvements to the OMR are proposed that will affect this watercourse. The channels are well vegetated, there are no obvious signs of erosion within the channel. However, the upstream photo show a lot of deposited material that looks like it has been removed from the channel, close to the culvert entrance. The culvert is not being resized and is not affected by a build-up of material within the barrel, as long as the current level of maintenance is continued at the upstream of the culvert there is no need for additional measures. The watercourse is unsuitable for fish and otters.
A83_ML_Z05_B06 (OMR_06)		No improvements to the OMR are proposed that will affect this watercourse. The channel is well vegetated, there are no obvious signs of erosion or deposition within the downstream channel. Upstream, in June, there was a lot of in channel vegetation that potentially needs managing to ensure culvert capacity is maintained if there were to be a high intensity summer storm. The culvert is not being resized and is not affected by a build-up of material within the barrel, therefore no need for additional measures. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_008_A01 (OMR_07)		No improvements to the OMR are proposed that will affect this watercourse. The channel is well vegetated, there are no obvious signs of erosion within the channel. The culvert is not being resized and is not affected by a build-up of material within the barrel. However, there was evidence that the upstream is maintained with sediment being removed and deposited on the bank. Either this continues to be managed to maintain culvert capacity or therefore no need for additional measures to ensure the resilience of the OMR. Electric fishing surveys undertaken in August 2023 recorded 35 brown trout in a 100 m^2 section below the OMR (preliminary data - age class / length not currently known). Upstream of the OMR fish habitat is poor, with low flows and high gradient (~ 19% average slope) which makes this section unsuitable for fish. Watercourse has suitability for otters.
A83_ML_010_B02 (OMR_08)		The OMR and therefore the culvert that passes beneath it will be widened/lengthened in the upslope direction. The channels are well vegetated, there are no obvious signs of erosion or deposition within the downstream channel. Large cobbles have been placed in the upstream approach likely to mitigate a scour issue. Other than the drain in parallel to the OMR there is no well-defined watercourse draining to the culvert. Rather, the culvert has been installed to coincide with the thalweg in the upslope field in which overland flows will concentrate. Historically there looks to have been some erosion where the thalweg joins the drain which has now been infilled with cobbles/larger material. There is no evidence of ongoing scour but this should be monitored. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_011_000 (OMR_09)		There is no significant build-up upstream of or within the culvert. There is no evidence of erosion downstream of the culvert, however the modelled exit velocity is high and d/s scour protection is recommended. The culvert is being extended upslope which is requires the 4 upstream watercourses to be realigned. Three of these are relatively minor drainage ditches which direct overland flows, generated within the field to the culvert. These three watercourses will have a keystone (250-300mm), bed checks, buried flush with the bed every 3-4 m to prevent headward cutting. The fourth channel will have step-pool features installed at 1.5 m spacing. Step constructed from boulder (sourced locally), consisting of a 450 mm keystone tied into the bed, with c.300 mm boulders used to form a crest, upstream and 150 mm proud of the keystone. Smaller boulders/cobbles placed behind the crest to raise upstream water level and form low flow notch. Electric fishing surveys conducted in August 2023 recorded 3 brown trout in a 100 m^2 section below the OMR (preliminary data - age class / length not currently known). Upstream of the OMR the watercourse is likely ephemeral and unsuitable for fish. The watercourse is not suitable for otters.
A83_ML_012_000 (OMR_10)		There is a significant build-up of sediment at the upstream extent of the culvert affecting approximately 80% of the cross-sectional area. The channel gradient at this culvert is comparatively shallow (0.9%) compared to some of the others. There is no evidence of downstream scour/erosion, therefore no requirement for protection measures. The culvert is being extended by 6.11 m in the upslope direction, requiring the upslope channel to be vertically realigned at up to 30% gradient over 15 m. To achieve this a 2 m wide step pool sequence is proposed, consisting of 0.45 m steps at 0.9 m intervals, with a low flow notch created by lowering the central keystones of the steps. A 3 m long by 2 m wide sedimentation area is included for at the upstream of the culvert for ongoing maintenance to maintain the culvert capacity. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_012_B03 (OMR_12)		This culvert is being extended in both the upstream (3.88 m) and downstream (4.81 m) directions. The upstream extension and earth works associated with the widening of the OMR requires the drainage ditch that currently runs in parallel with the OMR to be realigned. There is no significant inflowing channel to this culvert, rather, the drainage ditch captures the overland flows from the toe of the slope between the OMR and A83. There is no evidence of bed material being deposited upstream or within the culvert. No catchpit required. The channel downstream is well vegetated and there is no significant erosion, however modelled outlet velocities are high so d/s scour protection is recommended. The watercourse is unsuitable for fish and otters.
A83_ML_017_B01 (OMR_15)		This culvert is not being upsized, however is being extended by 14.35 m downslope. There doesn't seem to be an issue with upstream deposition and the barrel of the culvert is running clear, therefore no catchpit required. The channel downstream is incised but no erosion issue evident so no need for downstream protection. Large cobbles have been placed upstream, likely to mitigate scour effects. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_024_B01 (OMR_22)		The channel upstream of the OMR is a very straight maintained drainage ditch with a uniform profile which collects overland flows from between the A83 and OMR. Downstream of the culvert the channel seems to be well vegetated and there does not seem to be an obvious issue with erosion or deposition of bed material. The watercourse is unsuitable for fish and otters.
A83_ML_026_B01 (OMR_24)		There do not seem to be any issues with channel erosion or sediment deposition at either the upstream or downstream end of the culvert. The culvert is not being replaced so there does not seem to be a need for an upstream catchpit or downstream erosion protection. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_026_B02 (OMR_26)		The channel appears to be well vegetated both upstream and downstream of the culvert and there are no obvious signs of erosion or deposition. However, the downstream channel gradient is very steep and the disturbance involved in installing twin barrel culverts will make it worth installing some larger cobles/small boulders for 2/3 m downstream to protect the bed from erosion. The watercourse is unsuitable for fish and otters.
A83_ML_032_B01 (OMR_32)		This culvert is not being changed. Based on the aerial imagery there appears to be limited/no erosion downstream of the culvert and limited erosion/deposition of material upstream of the culvert. Therefore, the recommendation is that no catchpit or erosion protection measures are required. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_033_B01 (OMR_33)		Culvert OMR_33 is located within an artificial drainage channel, which is connected to the north to watercourse A83_ML_033_000 and culvert OMR_34. Large material looks to have been placed at the culvert entrance, potentially in an effort to act as a filter and stop material building up within the culvert. The culvert barrel looks to be largely free from material build up and there is no obvious downstream scour seen in the photos or aerial imagery. On this basis, as no changes are being made to the culvert there does not seem to be an additional requirement for an upstream catchpit or downstream erosion protection. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_033_B02 (OMR_35)		This culvert drains a very small upstream area, which includes the RaBT carpark, and from the available photographs there looks to be limited sediment/bed material being transported through the culvert and the barrel of the culvert appears to be free from any build-up of material. The modelling of this culvert indicates the exit velocities from the culvert are high at 1.46 m/s for the 50 year flow, which has the potential to cause erosion, therefore the placing of larger cobble/boulder material over the first 2/3 m at the culvert exit would help to dissipate the energy in the flow. The culvert is being dropped by 0.04 m to maintain the required depth of material between the culvert crown and the road deck, this will not require upstream watercourse realignments. The watercourse is unsuitable for fish and otters.

Watercourse ID (OMR Culvert reference)	Watercourse photo or aerial image	Watercourse characterisation and improvements to the OMR that could impact the watercourse
A83_ML_033_B03 (OMR_36)		This watercourse appears to be draining a very small triangle of land within the hairpin bend of the OMR. On a site visit there was no evidence of significant sediment being transported through the OMR culvert. The channel downstream of the OMR culvert is well vegetated and there doesn't seem to be a significant amount of active erosion, based on the site photos. The watercourse is unsuitable for fish and otters.

Annex 19-3-3 Watercourse erosion and stability risk assessment

(ordered south to north)

Table A19-3.1 Watercourse erosion and stability risk assessment

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_014_000	Low	This Minor B watercourse does not show evidence of excessive erosion between the A83 and OMR. The capacity/size of the current A83 culvert is unknown but there is no evidence of significant downstream erosion which would signify an adequately sized culvert. There are numerous natural drainage channels draining the slope but geomorphologically watercourses are stable. This channel is assessed as Low risk.
A83_ML_015_000	Medium	Immediately downstream of the Cobbler Bridge there is evidence of scour to both banks for approximately 9-10 m. The remainder of the downstream reach is largely stable, with some signs of erosion as would be expected for these types of watercourses. Classed as Medium risk due to erosion in proximity to the Cobbler Bridge piers.
A83_ML_016_000	Low	This Minor A watercourse does not show evidence of excessive erosion between the A83 and OMR. The upper section of the reach between the A83 and OMR is vegetated by dense trees and appears stable. This channel is assessed as Low risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_017_000	Low	This Minor A watercourse does not show evidence of excessive erosion between the A83 and OMR. The capacity/size of the current A83 culvert is a 0.9 m (w) x 1.0 m (H) Box culvert with a capacity of 1.36 m^3/s which is > Q_{200}+CC event. The upper section of the reach between the A83 and OMR is vegetated by dense trees and appears stable. This channel is assessed as Low risk.
A83_ML_018_000	Low	Upstream of A83, the channel has been diverted around a work compound to the culvert inlet. The culvert is a 0.6 m circular culvert with a capacity of 0.25 m^3/s which is < Q_2 event. Downstream of the A83, the channel is narrow and stable showing no clear signs of erosion or bank movement. The channel is sinuous in nature down to the OMR with no clear signs of bank movement or scour along its length. This channel is assessed as Low risk.
A83_ML_019_000	Low	Upstream of A83, the channel is well defined and passes under and through a debris fence. The culvert is a 0.45 m circular culvert with a capacity of 0.2 m^3/s which is < Q_{20} event. Downstream of the A83, the channel is narrow and well defined showing no obvious signs of erosion or bank movement. The channel has a sinuous planform down to the OMR with no clear signs of bank erosion or bed scour along its length. This channel is assessed as Low risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_020_000	Low	Upstream of A83, the channel is well defined and passes under / through a debris fence. The culvert is a 0.375 m circular culvert with a capacity of 0.13 m^3/s which is ~ 5yr event. Downstream of the A83, the channel is very short in length (circa 5 m) and shows no signs of erosion. It then discharges into the adjacent Major watercourse (A83_ML_021_000). This channel is assessed as Low risk.
A83_ML_021_000	Low	Upstream of A83 the channel is well defined and passes under / through multiple debris fences. The culvert is a 0.6 m circular culvert with a capacity of 0.34 m^3/s which is < Q_5 event. Downstream of the A83, the channel is showing no obvious signs of erosion or bank movement. This channel is assessed as Low risk.
A83_ML_022_000	Medium	Upstream of A83, the channel is well defined and passes under / through multiple debris fences. The culvert is a 0.375 m circular culvert with a capacity of 0.13 m^3/s which is > Q_{200}+CC event. Downstream of the A83, the channel is very narrow and straight. Where visible, the channel shows no obvious signs of erosion or bank movement. It is near a historically active section of the hillside, which could influence the route of the watercourse if overland flow was to occur. However, this culvert will not be reinstated as part of the works, with the flows routed south to A83_ML_021_000.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_023_000	High	Clear signs of slope movement above and below the A83. Concrete catchpit has been installed to help mitigate landslides. Channel upstream is very wide and is clearly associated with a lot of historic channel movement. Downstream of the A83, the channel is very incised, shows clear erosion on both left and right banks of the channel as well as evidence of large boulder material, suggestion the smaller material has been gradually removed due to high energy flow. This process is evident for approximate 90 m – 100 m downstream of the A83. This channel coincides with the least stable area of the Beinn Luibhean slope, with greatest volumes of material that can be mobilised. Currently diverted to A83_24 upslope of the A83. This channel is assessed as High risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_024_000	High	Clear signs of Slope movement above the A83. The upstream channel is incised but shows clear signs of historic channel deviation, evidenced by scarring. Upslope of the A83, there is a semi-engineered catchpit to mitigate landslide everts to the A83. The structure in place at this location is a Box culvert 1.2 m (w) x 1.4 m (H) with a capacity of 3 m^3/s which is >Q_{200}+CC event, though the downstream receiving channel is heavily eroded due to culvert jetting. Downslope of the A83, the channel is very incised, with clear signs of erosion on both left and right banks of the channel as well as evidence of large boulder material, suggesting the smaller material has been gradually removed during higher flows. This process is evident for the whole of the downstream reach. This channel is assessed as High risk.
A83_ML_025_000	High	Upstream of A83 the channel passes through a series of geotechnical debris flow fences before it flows into a semi-engineered catchpit, designed to mitigate landslide events to the A83. Downstream of the A83, the channel is heavily incised and shows clear signs of a large amount of historic erosion for its entire length. The channel shows clear signs of significant active erosion. This channel is assessed as High risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_026_000	High	Upstream of A83 the channel passes through a series of geotechnical debris flow fences before it flows into a semi-engineered catchpit, designed to mitigate landslide events to the A83. The A83 culvert is angled at approximately 35 degrees to the road. The artificial outlet structure is skewed in a northerly direction, relative to the natural channel flows in a more southerly direction; this has resulted in a large amount of erosion in the channel and to the banks. The full reach from the A83 to OMR is experiencing erosion, as evidenced by steep sides, large boulders, and a lack of vegetation. This channel is assessed as High risk.
A83_ML_027_000	High	The existing A83 culvert has been assessed as having capacity to convey $<Q_2$ event, which has potentially caused jetting of flows through the culvert, exacerbating erosion. Downslope of the A83 the culvert outlet is angled at approximately 25 degrees to the road in a northern direction. There are signs of historic erosion in this channel, evidenced by lots of large boulders and the channel is wider in the upper reach below the A83. However, the channel appears to have stabilised slightly and vegetation has begun to grow in the channel. With the potential for greater volumes of water passing to the downstream watercourse and deep deposits that can be mobilised, the channel is assessed as High risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_028_000	Medium	The existing A83 culvert has been assessed as having capacity to convey <Q_{20} event, which has potentially caused jetting of flows through the culvert, exacerbating erosion. Downslope of the A83, the channel is straight and shows signs of historic erosion as it is located in an obvious V shaped valley, though this is now vegetated and stabilised. With the potential for greater volumes of water passing to the downstream watercourse and deep deposits that can be mobilised, the channel is assessed as Medium risk.
A83_ML_029_000	Medium	Upstream of the A83 there is a very steep, engineered cascade. Once the flow exits the culvert it enters a heavily engineered concrete channel, that has two 90 degree turns which route the flows north. At the end of this channel is a steep drop with into a naturally formed cascade. This cascade is heavily incised with evidence historic erosion but is now stable as is the whole of the channel to the OMR. A 77 m reach, from the end of the concrete channel to the OMR heavily incised to an average depth of 1 to 2 m. This channel is assessed as Medium risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_030_000	Medium	The existing A83 culvert is a 0.5 m diameter pipe culvert with a capacity of 0.2 m^3/s which is equivalent to a $<Q_5$ flood event for the upstream catchment. The culvert is skewed at approximately 45 degrees to the road and extends a significant distance further than the width of the road (29 m). Downstream of the A83 the flows pass to an artificial, fibreglass lined channel that is routed to OMR culvert 30. This channel is assessed as Medium risk.
A83_ML_031_000	Medium	When flow exits the A83 culvert, it enters an 85 m reach of steep watercourse that is narrow and shows signs of historic erosion which has now vegetated. The watercourse has lots of pools and is sinuous in nature. As there are signs of historic erosion and the deposits can be unstable, the watercourse is assessed as Medium risk.
A83_ML_032_000	Medium	This watercourse is located within an area of comparatively shallow superficial deposits, with flows over bedrock evident both upstream and downstream of the A83. The latest 3D model and aerial imagery suggest that there is some erosion/scour downstream, of the A83 culvert which potentially may be due to the under sizing of this culvert. Due to the signs of erosion and its location with a geomorphologically unstable area the watercourse, especially the reach closest to the A83, identified as Medium risk.

Watercourse ID	Risk Rating	Risk assessment summary
A83_ML_033_000	Low	This watercourse is fully culverted between the A83 and the OMR. The culvert is very steep and there is only a small open section of channel/drainage ditch between the exit of the A83 culvert and the inlet to the OMR culvert (A83_ML_034_000). This channel is assessed as Low risk.
A83_ML_034_000	Low	This watercourse does not show any sign of excessive erosion and is located within geomorphologically 'Marginally stable' area. The reach between the A83 and Loch Restil has relatively low slope angle (~10%) compared when compared to many of the rest of the A83 watercourses. This channel is assessed as Low risk.
A83_ML_035_000	Low	There is only 10 m of watercourse between the A83 and Loch Restil. This reach does not show any sign of excessive erosion and is located within geomorphologically 'Marginally stable' area. This channel is assessed as Low risk.