Appendix 11.4

Hydromorphology Assessment Part 6

Annex 11.4.5 EIA Hydromorphological Assessment Tables

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
-2	High	Good	Drain outfall	No	Small loss of natural bank due to outfall- more uniform form and loss of sediment supply	No change (Bad to Bad)	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					No loss of natural bed												
					Fixing of channel position by outfall- harder for channel to adjust to changes in sediment supply and discharge												
					Little change of continuity of sediment transfer (excessive erosion or deposition)												
					Small change in flow (velocity and/or discharge) conditions from outfall												
					Little change in sediment dynamics												
1	Low	Good -Water flow and levels High- Physical condition	1 additional box culvert (1x7m), and replacement and extension of existing culvert (1x87m). Change from pipe culvert to box culvert. Culvert to be upsized. 120m of very steep realignment and 1 SUDS outfall	No	Loss of natural bank - more uniform form (channel realignment and new culvert) and loss of sediment supply due to extension of culvert and new outfall	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Neutral (beneficial)		0.5-1.5 Km	Very small		Minor	Neutral (beneficial) with additional mitigation through channel reprofiling upstream of crossing
					Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow												
2- Allt Coire Mihic-sith	High	Good -Water flow and levels High- Physical condition	Extension of existing bridge and 1 SUDS outfall	No	Loss of natural bank- more uniform form and loss of sediment supply in drain outfall locations and in areas of new bank protection	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply in drain outfall locations												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfalls, bank protection and bridge extension)												
					Little change in flow (velocity and/or discharge) conditions		0.5-1.5 Km	Very small		Minor	Slight adverse		0.5-1.5 Km	Very small		Minor	Slight beneficial due to regrading of bed improving sediment transfer
					Little change in continuity of sediment transfer												
					Little change in sediment dynamics												
4	Low	Good -Water flow and levels High- Physical condition	1x replacement and extension of pipe culvert (1x50m), 155m realignment, 1x drain outfall, removal of catch pit	No	Loss of natural bank - more uniform form (channel realignment and outfall) and loss of sediment supply due to longer, replacement culvert	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert extension												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall and culverts)												
					Improved flow (velocity and/or discharge) conditions due to removal of catch pit												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
					Improved continuity of sediment transfer due to removal of catch pit												
					Improved in sediment dynamics due to removal of catch pit												
5	Low	Good -Water flow and levels High- Physical condition	Extension of pipe culvert (1x65m), 145m very steep realignment, 1x drain outfall	No	Loss of natural bank - more uniform form (channel realignment and outfall) and loss of sediment supply due to longer, replacement culvert	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert extension												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall and culverts)												
					Little change in flow (velocity and/or discharge) conditions due to works												
					Little change in continuity of sediment transfer												
					Little change in sediment dynamics												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
6	Low	Good -Water flow and levels High- Physical condition	Replacement of pipe culvert with extended Box culvert (1x30m), 35m very steep realignment, 2x drain outfall	No	Loss of natural bank - more uniform form (channel realignment) and loss of sediment supply due to extension of culvert and new outfall	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall												
					Little change in flow (velocity and/or discharge) conditions												
					Improved continuity of sediment transfer due to natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert												
7	Low	Good -Water flow and levels High- Physical condition	1x reduced length pipe culvert (1x57m), 300m realignment, 1x drain outfall, removal of existing catch pit	No	Loss of natural bank - more uniform form (channel realignments and outfall)	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Increased natural bed- more diverse form, range of substrate and sediment supply due to reduced culvert length												
					Some fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall)												
					More natural flow (velocity and/or discharge) conditions due removal of catch pit		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved downstream continuity of sediment transfer due to removal of catch pit												
					Improved sediment dynamics due to removal of catch pit												
8- Allt Ruidh nan Sgoilearan	High	Good -Water flow and levels High- Physical condition	1x Pipe to box culvert with increased capacity (1x47m), 33m realignment, 2x drain outfall	No	Loss of natural bank - more uniform form (channel realignment and culvert) and loss of sediment supply due to replacement of culvert and outfalls	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Slight beneficial		0.5-1.5 Km	Very small		Minor	Slight beneficial
					Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
10	Low	Good -Water flow and levels High- Physical condition	1x replacement pipe culvert (no change in length), 165m realigment, removal of catch pit	No	Loss of natural bank - more uniform form (channel realignment)	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form due to realignment												
					Ongoing fixing of channel position												
					More natural flow (velocity and/or discharge) conditions due to removal of catch pit												
					Improved downstream continuity of sediment transfer due to removal of catch pit												
					Improved sediment dynamics due to removal of catch pit												
12	Medium	Good -Water flow and levels High- Physical condition	2x replacement of pipe culverts with extended box culvert (1x31m), 60m channel realighment, removal of catchpit	No	Loss of natural bank - more uniform form (channel realignment and culvert) and loss of sediment supply due to replacement of culverts	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culverts and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culverts												
					Improved flow (velocity and/or discharge) conditions due to removal of catch pit		0.5-1.5 Km	Very small		Minor	Slight beneficial		0.5-1.5 Km	Very small		Minor	Slight beneficial
					Improved continuity of sediment transfer due to natural substrate within culverts and removal of catch pit												
					Change in sediment dynamics- Improved due to natural substrate of culvert and removal of catch pit												
13- Allt Fuar Bheann	High	Good -Water flow and levels High- Physical condition	1x upsizebox culvert (38m), 2 drain outfalls and 1 SUDS outfall	No	Loss of natural bank - more uniform form (culvert) and loss of sediment supply due to replacement of culvert and outfalls	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Slight beneficial		0.5-1.5 Km	Very small		Minor	Slight beneficial
					Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
14	Medium	Good -Water flow and levels High- Physical condition	1x pipe culvert extention (1x31m) , 80m realignment , 1x drain outfall, removal of catch pit	No	Loss of natural bank - more uniform form (channel realignment and outfall) and loss of sediment supply due to longer, replacement culvert and additional culvert	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culverts												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall and culverts)												
					Improved flow (velocity and/or discharge) conditions due to catchpit removal		0.5-1.5 Km	Very small		Minor	Slight beneficial		0.5-1.5 Km	Very small		Minor	Slight beneficial
					Improved continuity of sediment transfer due to catchpit removal												
					Improved sediment dynamics due to catchpit removal												
20	Low	Good -Water flow and levels High- Physical condition	Removal of crossing and diversion from small catchment into crossing 21	No	Loss of artifical channel	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Small change in flow (velocity and/or discharge) conditions downstream												
					Reduced continuity of sediment transfer due to catch pit removal												
					Reduced sediment dynamics downstream												
23- Allt a' Chaorainn	High	Good -Water flow and levels High- Physical condition	Replacement of arch culvert with concreate bed with bridge and natural bed. Drains	No	Loss of natural bank- more uniform form and loss of sediment supply in drain outfall locations and areas of bank protection	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply in drain outfall location, but much greater area of natural bed due to replacement of culvert												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfalls and bank protection)												
					Improved flow (velocity and/or discharge) conditions due to replacement of culvert with more natural channel. Increased discharge downstream of crossing due to additional flow from drains (catchments 19-22)												
					Improved continuity of sediment transfer due to replacement of culvert												
					Improved sediment dynamics due to replacement of culvert												

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27	Medium	Good -Water flow and levels High- Physical condition	Replacement of pipe culvert with extended box culvert (1x63m), 110m, Channel realignment, outfalls	No	Loss of natural bank - more uniform form (channel realignment and culvert) and loss of sediment supply due to replacement of culvert and outfalls Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall Improved flow (velocity and/or discharge) conditions due to natural substrate in culvert Improved continuity of sediment transfer due to natural substrate within culvert Change in sediment dynamics- Improved due to natural substrate of culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
28	Medium	Good -Water flow and levels High- Physical condition	Pipe culvert (1x40m), 90m Channel realignment , 2x Drain outfalls.	No	Loss of natural bank - more uniform form (channel realignment and outfall) and loss of sediment supply due to longer, replacement culvert Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall and culvert) Little change in flow (velocity and/or discharge) conditions due to works Little change in continuity of sediment transfer Little change in sediment dynamics	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
31- Allt an Creagach	High	Good -Water flow and levels Good- Physical condition	Pipe culvert replaced with upsized and extended box culvert (37m) and 175m channel realignment	No	Loss of natural bank - more uniform form (channel realignment) and loss of sediment supply (longer replacement culvert) Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (culvert) Improved flow (velocity and/or discharge) conditions due to upsized culvert Improved continuity of sediment transfer due to improvements in size and natural substrate of culvert Change in sediment dynamics-Improved due to more natural flow and bed through culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral

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32/33	Medium	Good -Water flow and levels Good- Physical condition	Pipe culvert (1x50m), 90m Channel realignment .	No	Loss of natural bank - more uniform form (channel realignment) and loss of sediment supply (longer replacement culvert)	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (culvert)												
					Little change in flow (velocity and/or discharge) conditions due to works												
					Little change in continuity of sediment transfer												
					Little change in sediment dynamics												
34	Low	Good -Water flow and levels Good- Physical condition	Pipe culvert extention, with increased capasity (1x58m), Channel realignment	No	Loss of natural bank - more uniform form (channel realignment) and loss of sediment supply (longer replacement culvert)	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (culvert)												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert												
					Improved continuity of sediment transfer due to upsized culvert												
					Change in sediment dynamics-Improved due to more natural flow through culvert												
39	Low	Good -Water flow and levels Good- Physical condition	Replacement and extention of pipe culvert (1x36m), 50m Channel realignment including 1 replacement cascade, 1 Drain outfall	No	Loss of natural bank - more uniform form (channel realignment and outfall) and loss of sediment supply due to longer, replacement culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfall and culvert)												
					Little change in flow (velocity and/or discharge) conditions due to works		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Little change in continuity of sediment transfer												
					Little change in sediment dynamics												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
40	Low	Good -Water flow and levels Good- Physical condition	Replacement and extention of pipe culvert (1x35m), 20m Channel realignment including removal of the catch pit, 2 Drain outfalls	No	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to removal of catch pit Change in flows due to addition of crossings in catchment		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved continuity of sediment transfer due to natural substrate within culverts and removal of catch pit												
					Change in sediment dynamics- Improved due to natural substrate of culvert and removal of catch pit Change in sediment dynamics (more natural) due to addition of crossings in catchment												
42	Low	Good -Water flow and levels Good- Physical condition	43m of Pipe culvert and 5m of channel diverstion, removal of catchpit, 3 drain outflows	No	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to removal of catch pit Change in flows due to addition of crossings in catchment		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved continuity of sediment transfer due to removal of catch pit												
					Change in sediment dynamics- more natural due to removal of catch pit												

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43	Low	Good -Water flow and levels Good- Physical condition	Replacement of pipe culvert with longer, upsized 35m Box culvert, 660m of channel realighment and 2 drain outfalls	Yes- Length of channel realignment	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	0.5-1.5 Km	Small (failed ToSI)	Long (more than 6 years)	Moderate	Slight adverse	Good to Moderate	0.5-1.5 Km	Small (failed ToSI)	Long (more than 6 years)	Moderate	Slight beneficial with additional mitigation applied to channel realignment
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to removal of catch pit and upsized culvert with natural bed			Very small		Minor	Neutral			Very small		Minor	Neutral
					Improved continuity of sediment transfer due to natural substrate within culvert, upsized culvert and removal of catch pit												
					Change in sediment dynamics- Improved due to natural substrate and upsize of culvert and removal of catch pit												
44	Low	Good -Water flow and levels Good- Physical condition	Replacement upsized pipe culvert (1x34m), 70m Channel realignment, 2 Drain outfalls	No	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved continuity of sediment transfer due to upsized culvert												
					Change in sediment dynamics- more natural due to upsized culvert												

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46	Low	Good -Water flow and levels Good- Physical condition	Replacement and extention of pipe culvert (1x40m), to be upsized, 160m Channel realignment, Drain outfalls	No	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved continuity of sediment transfer due to upsized culvert												
					Change in sediment dynamics- more natural due to upsized culvert												
49	Low	Good -Water flow and levels Good- Physical condition	Replacement pipe culverts to be extended and upsized (1x33 m and 1x15m), 50m Channel realignment	No	Loss of natural bank - more uniform form (channel realignment, outfalls and culvert) and loss of sediment supply due to replacement of culvert	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert and realignment												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfalls												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Neutral		0.5-1.5 Km	Very small		Minor	Neutral
					Improved continuity of sediment transfer due to upsized culvert												
					Change in sediment dynamics- more natural due to upsized culvert												
51	Medium	Good -Water flow and levels Good- Physical condition	Replacement of pipe culvert with longer, upsized box culvert (1x60m), 80m Channel realignment and 1 drain outfall	No	Loss of natural bank - more uniform form (channel realignment) and loss of sediment supply due to extension of culvert and new outfall	Good to Moderate	<0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	>0.5 Km	Negligible	Long (more than 6 years)	Negligible	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culvert and outfall												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert		0.5-1.5 Km	Very small		Minor	Slight beneficial		0.5-1.5 Km	Very small		Minor	Slight beneficial
					Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
52- Allt Coire Chaorainn	High	Good -Water flow and levels Good- Physical condition	Replacement bridge set back from channel banks and with increased capasity. Drain outfalls	No	Loss of natural bank- more uniform form and loss of sediment supply in drain outfall locations and bank protection	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply in drain outfall locations												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to outfalls, but the increased width of the bridge improves the ability of the channel to adjust laterally when compared to the baseline												
					Improved flow (velocity and/or discharge) conditions due to upsize of bridge												
					Improved continuity of sediment transfer due to upsize of bridge												
					Improved sediment dynamics due to upsize of bridge												
57	Medium (artifical channel)	Good -Water flow and levels Good- Physical condition	2 new box culverts under track. Replacement and extention of pipe culvert with an upsized box culvert under mainline, 70m of realignment, 5 drain outfalls and 1 SUDS outfall	No	Loss of natural bank - more uniform form (channel realignment and new culverts) and loss of sediment supply due to extension of culvert and new outfall	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culvert, realignment and outfall												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culverts and outfalls												
					Improved flow (velocity and/or discharge) conditions due to upsized culvert												
					Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert												
					Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow												
59- Allt Coire Chuirn	High	Good -Water flow and levels Good- Physical condition	2 bridge crossings to be set back from the channel. Replacemtn bridge to have greater capasity than existing. Drains	No	Loss of natural bank- more uniform form and loss of sediment supply in drain outfall locations and bank protection	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral
					Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply in drain outfall locations												
					Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge (outfalls and bridge extension and bank protection)												
					More natural flow (velocity and/or discharge) conditions												
					More natural continuity of sediment transfer												
					More natural sediment dynamics												

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
61	Low	Good -Water flow and levels Good- Physical condition	2x new box culvets (1x6m and 1x20m). 1x upsized, extended box culvert to replace pipe culvert (1x46m) and 85m realignment and 4 drain outfalls	No	Loss of natural bank - more uniform form (channel realignment and new culverts) and loss of sediment supply due to extension of culvert and new outfalls Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culverts, realignment and outfalls Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culverts and outfalls Improved flow (velocity and/or discharge) conditions due to upsized culvert Improved continuity of sediment transfer due to upsized culvert and natural substrate within culvert Change in sediment dynamics- Improved due to natural substrate of culvert and more natural flow	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral
62	Medium	Good -Water flow and levels Good- Physical condition	2x new pipe culvets (1x17m and 1x11m). Replacement, entention and upsizing of pipe culvert, and 29m realignment	No	Loss of natural bank - more uniform form (channel realignment and new culverts) and loss of sediment supply due to extension of culvert Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to culverts and realignment Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to culverts Improved flow (velocity and/or discharge) conditions due to upsized culvert Improved continuity of sediment transfer due to upsized culvert Change in sediment dynamics- Improved due to upsized culvert	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral
63	Medium	Good -Water flow and levels Good- Physical condition	Replacement of culvert with bridge	No	Increased length of natural bank-less uniform form Increased length of of natural bed, increased range of substrate and sediment supply Allows for more dynamic channel to adjust to changes in sediment supply and discharge Improved continuity of sediment transfer Improved flow (velocity and/or discharge) conditions Improved sediment dynamics	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligable	Neutral

Receptor	Sensitivity of Receptor	Existing WFD Status	Summary of work based on Design Freeze	Is the Threshold of Significant Impacts test failed?	Impact (based on Design Freeze-4th Iteration)	Worst case degree of change in WFD Status	Spatial extent of Impact	Scale of Impact	Duration of Impact	Magnitude of Impact	Significance (without mitigation)	Residual worst case degree of change in WFD Status	Residual Spatial Extent	Residual scale of Impact	Residual Duration	Residual Magnitude	Residual impact significance following all mitigation
64-Allt Coire Bhotie	High	Good -Water flow and levels Good- Physical condition	1 new bridge 1 bridge to replace culvert Outfalls	No	Loss of natural bank - more uniform form in areas of outfalls. Replacement bridge will allow more diverse bank from Increased length of natural bed substrate and form as culvert is replaced with bridge Reduced fixing of channel position as culvert is replaced with bridge Improved flow (velocity and/or discharge) conditions due to upsized crossing Improved continuity of sediment transfer due to natural substrate within channel and upsized crossing Change in sediment dynamics- Improved due to natural substrate and upsized crossing	Good to Moderate	<0.5Km	Negligable	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral- Beneficial as culvert removed and more natural channel created
Allt Beul an Sporain	High	Good -Water flow and levels Good- Physical condition	1 track bridge	No	Loss of natural bank- more uniform form and loss of sediment supply Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge Change in flow (velocity and/or discharge) conditions Change in sediment dynamics	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral	Good to Moderate	<0.5Km	Negligible	Long (more than 6 years)	Negligible	Neutral
River Truim from source to Allt Cuaich	High	Good -Water flow and levels Good- Physical condition	15 outfalls and 5 areas of embanment toe (set back erosion) protection totaling 550m	No	Loss of natural bank- more uniform form and loss of sediment supply due to outfalls. Note that erosion protection is set back from the channel along the toe of embankments where is is required. Loss of natural bed- more uniform form, reduced range of substrate and reduced sediment supply due to outfalls Fixing of channel position- harder for channel to adjust to changes in sediment supply and discharge due to set back erosion protection. Erosion protection is set back from the channel banks to allow channel space to move while protecting the toe of the embankment from excessive erosion Small change in flow (velocity and/or discharge) conditions due to outfalls Small change in sediment dynamics due to outfalls	Good to Moderate	<0.5Km 0.5-1.5 Km <0.5Km	Negligable Very small Negligable	Long (more than 6 years)	Negligable Minor Negligable	Neutral Slight adverse Neutral	Good to Moderate	<0.5Km 0.5-1.5 Km <0.5Km	Negligable Very small Negligable	Long (more than 6 years)	Negligable Minor Negligable	Neutral Slight adverse Neutral
Allt Dubhaig	High	Good -Water flow and levels High- Physical condition	Potentail change in flows from tributries (1 to 22)	No	Small change in flow (velocity and/or discharge) conditions due to works on tributaries Small imporvement in continuity of sediment transfer Small imporvement in sediment dynamics as more natural flow and sediment supply from tributires	Good to Moderate	1.5-5 Km	Small	Long (more than 6 years)	Moderate	Moderate beneficial as channel will recive more natural flows from tributaries	Good to Moderate	1.5-5 Km	Small	Long (more than 6 years)	Moderate	Moderate beneficial

Annex 11.4.6 Geomorphological Channel Design

Background

This note is intended to provide a summary of geomorphological information on the characteristics of different River Types found in the UK. This information is intended to provide guidance to the engineering team to aid in the design of sustainable channel realignments, with suitable morphology for the river setting.

Fluvial Concepts Theory

The established conceptual model of river system operation suggests that their key driving variables are the inputs of water and sediment. These independents interact with boundary characteristics (slope/ topography, bed and bank materials, and riparian vegetation) to generate the channel form (e.g. Knighton, 1998; Sear & Newson, 2010). As a consequence of these interactions a variety of channel forms (geometric characters) exist. These are described across a number of planes of adjustment, within which there are a number of representative parameters. Knighton (1998) classifies these broadly as:

- cross-sectional form (size and shape parameters, e.g. width, depth, area etc.)
- bed configuration (e.g. sand or gravel beds)
- channel pattern (form of channel as viewed from above, e.g. straight, meandering or braided; descriptive parameters include sinuosity, meander arc length etc.)
- channel bed slope (i.e. gradient, which is related to channel pattern).

The adjustment of these channel geometry parameters and that of the shorter-term variations of flow geometry, are interdependent; therefore, a change in one parameter may manifest a response in others such that a river channel can perform its function, i.e. the transference of energy and matter, ideally in dynamic equilibrium (if conditions permit). Variations result in complex patterns of form, flow, and materials across both space and time.

This conceptual basis is important, as it establishes that channel design has to take into consideration the complexities of the river environment, and that by understanding these principles, more effective channels may be designed to work with nature.

Planform Type

Mean valley slope and design bankfull discharge can be used to determine the most likely/ desirable channel planform type (**Figure 11** and **Table 1**).

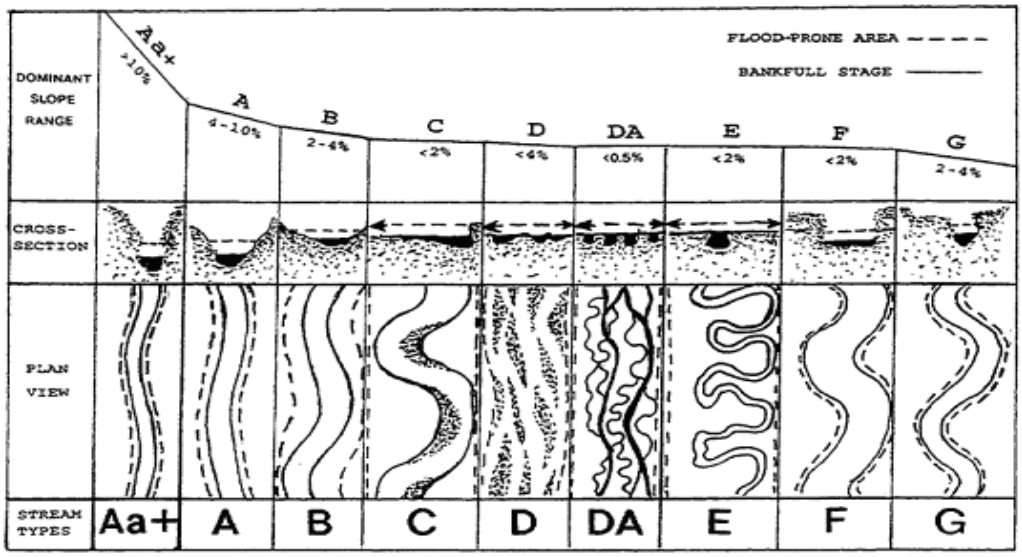

Figure 11: Longitudinal, cross sectional and plan views of major stream types (Rosgen, 1994)

Table 1 Channel characteristics based on Rosgen, 1994.

Characteristics	Type Aa+	Type A	Type B	Type C
General	Very steep, deeply entrenched, debris transport streams	Steep, entrenched, step- pool streams, high energy	Moderately entrenched, moderate gradient, riffle dominated channel with infrequent pools, stable planform and long profile	Low gradient, meandering, point bar, riffle/pool, alluvial channel with broad floodplain
Entrenchment ratio (width of flood prone area/bankfull channel width)	<1.4	<1.4	1.4-2.2	>2.2
Width/depth ratio	<12	<12	>12	>12
Sinuosity	1.0-1.1	1.0-1.2	>1.2	>1.4
Slope (m/m)	>0.1	0.04-0.1	0.02-0.039	<0.02
Slope (%)	>10	4-10	2-3.9	<2
Meander width ratio (beltwidth /bankfull width)	N/A	1-3	2-8	4-20

Bed Morphology

Channel bed slope is a major driver of channel bed form (Rosgen, 1994); hence bed slope, planform and bed morphology are highly interrelated in natural channels. In order to best account for this association, mean channel bed slope and proposed planform information can be used in association with the literature (**Figure 12** and **Table 2**) to suggest appropriate channel bed morphology.

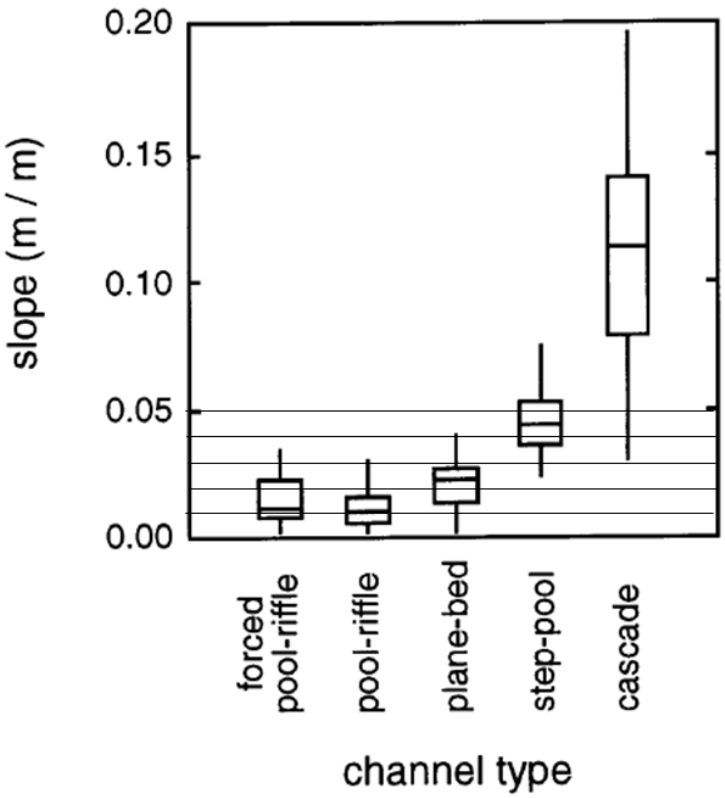

Figure 12: Slope distribution for different channel reaches (Montgomery and Buffington, 1997)

Table 2 River Types (based on SEPA, 2011)

Geology	Slope		Sinuosity	Type
Bedrock	Any		Any	Bedrock, Cascade
Not Bedrock	>0.1		Any	Bedrock, Cascade
	>0.03	≤0.1	Any	Step-pool, Plane Bed
	>0.005	≤0.03	≤1.1	Step-pool, Plane Bed
			>1.1	Plane-riffle, Braided, Wandering
	>0.001	≤0.005	Any	Plane-riffle, Braided, Wandering
	>0.0005	≤0.001	≤1.4	Plane-riffle, Braided, Wandering
			>1.4	Actively Meandering
	>0.0001	≤0.0005	Any	Actively Meandering
	≤0.0001		Any	Low Gradient Passive Meandering

Characteristics of Cascade Morphology

The channel should typically have the characteristics outlined below and in **Figures 13, 14 and 15** (Montgomery and Buffington, 1997):

- Tumbling flow around large clasts
- Steep slopes (over 0.1 m/m)
- Confined channel by valley sides
- Low sinuosity
- Lack of in channel storage
- Bed dominated by large particle size
- Supply limited channels

Figure 13: Example cascade (Montgomery and Buffington, 1997)

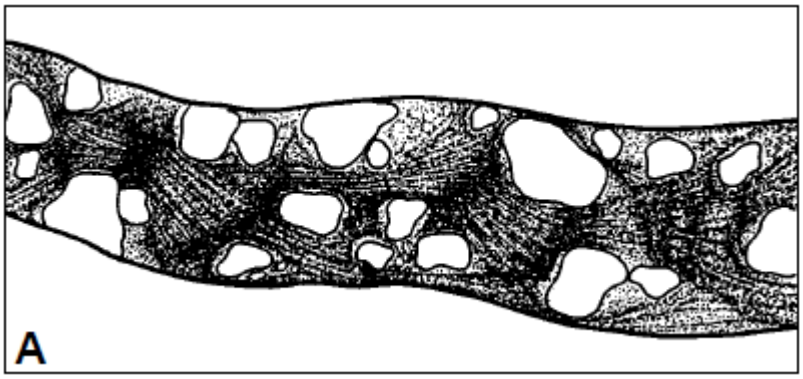

Figure 14: Example cascade planform (Montgomery and Buffington, 1997)

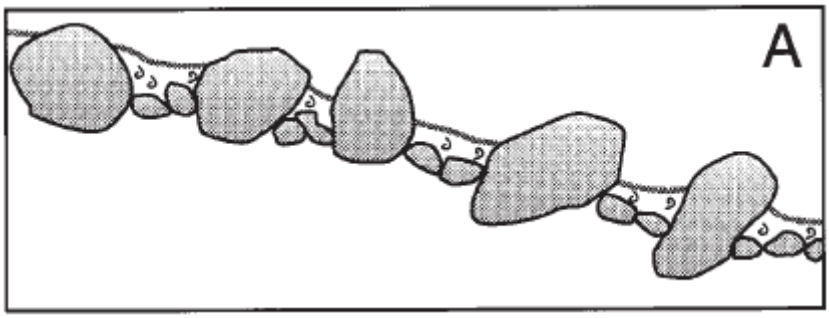

Figure 15: Example cascade long profile (Montgomery and Buffington, 1997)

Characteristics of Step-Pool Bed Morphology

These channel types form on steep slopes, with energy dissipation through tumbling flow over and around large clasts (cobbles and boulders) (**Figure 16**). Bed material is a mix of stable coarse casts, and finer material that gets trapped around the coarse material, and mobilised during flood flows (Montgomery and Buffington, 1997). These systems have a high transport capacity relative to sediment supply and will rapidly supply sediment downstream in the event that is available (i.e. supply limited system).

The channel should typically have the characteristics outlined below and in **Figures 17, 18 and 19** (Knighton, 1998, and Montgomery and Buffington, 1997):

- pools and alternating bands of channel-spanning flow obstructions typically occur at a spacing of every 1–4 channel widths;
- typical gradients of 0.03–0.1 m/m
- low sinuosity
- fast water at steps/falls and chutes, slow water at pools.
- step spacing increasing with decreasing channel bed slope, with $L=0.31s^{-1.19}$ where s=mean slope m/m and L=Step wavelength parallel to mean slope
- step height is controlled by the largest particle, and pool scour (with approximately 1/3 of the mean step height due to pool scour)
- pool width approximately 20% greater than steps (Thomas *et al*, 2000)
- boulders, interlocked with each other and the bed, and arranged in a broad v-shape, with the apex of the weir pointing upstream to prevent bank erosion.

Figure 16:. Example of a step pool channel (Montgomery and Buffington, 1997)

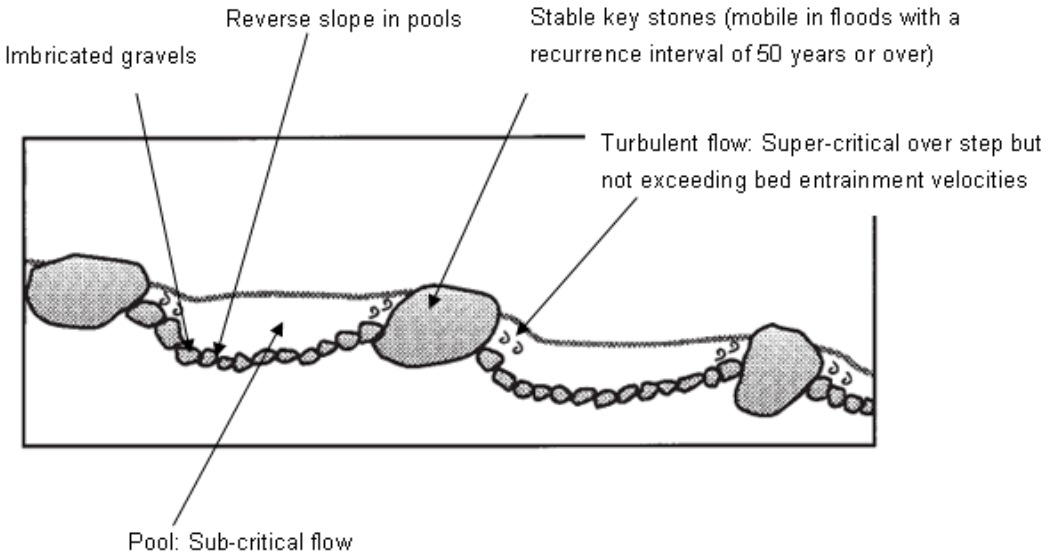

Figure 17: Example long profile of step –pool channel (based on Montgomery and Buffington, 1997)

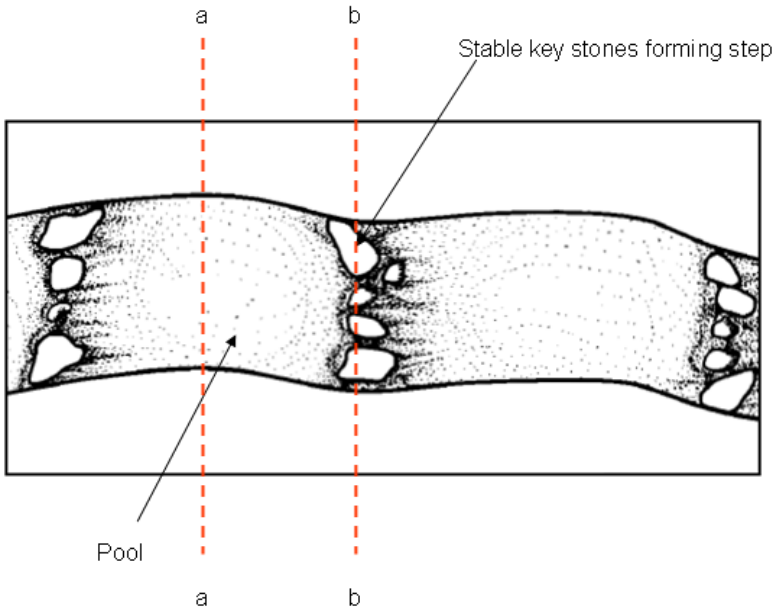

Figure 18: Example planform for a step –pool channel (based on Montgomery and Buffington, 1997)

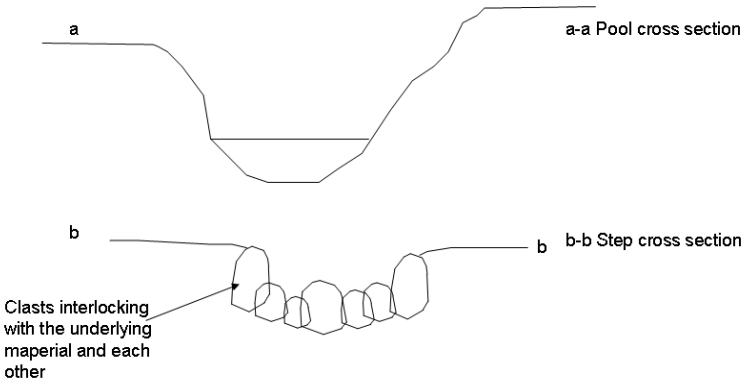

Figure 19: Example cross sections for a step- pool channel

Longitudinal spacing of step and pool sections is important for stability and function of the channel. Step crest wavelength (L) (**Figure 20**) can be calculated by $L=0.31s^{-1.19}$ where (s=mean slope m/m). The shape and size of the transition between each step and pool also needs to be carefully considered.

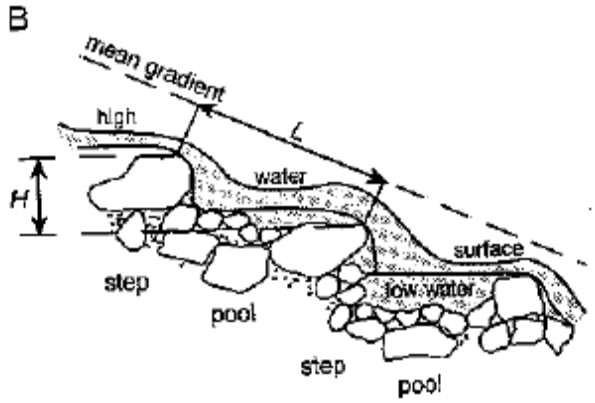

Figure 20: Example positioning of steps and pools (Knighton, 1998)

Characteristics of Plane bed

The channel should typically have the characteristics outlined below and in **Figures 21, 22 and 23** (Montgomery and Buffington, 1997):

- Large values of relative roughness (90th percentile grain size to bankfull flow depth)
- Lack of discreet bars and bed forms
- Straight channels
- Moderate to high slopes
- Dominated by cobble and gravel bed

Figure 21: Example of a plane bed channel (Montgomery and Buffington, 1997)

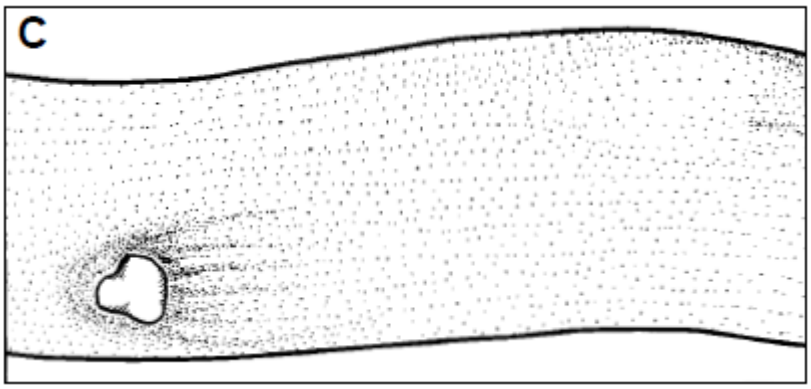

Figure 22: Example of a plane bed channel planfrom (Montgomery and Buffington, 1997)

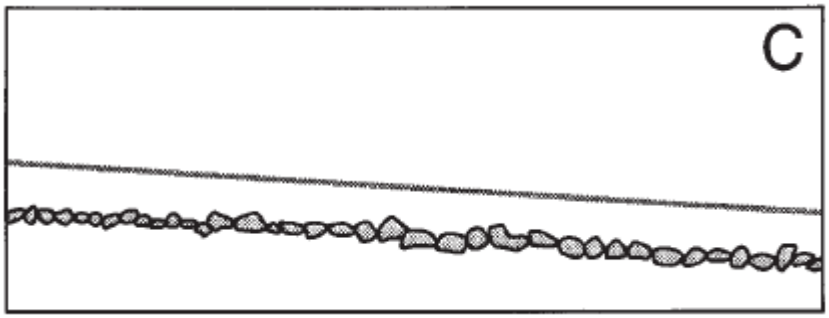

Figure 23: Example of a plane bed channel long profile (Montgomery and Buffington, 1997)

Characteristics of Plane-Riffle Bed Morphology

Plane - riffle bed channels have characteristics that fall between pool-riffle and plane bed types (SEPA, 2011). Typically, this will include deposition on the inside of bends forming small point bars and poorly defined shallow pools on the outside of bends. These will then be separated by both riffles and plane bed extents, at inflexion locations between the bends (**Figures 24, 25 and 26**). More detailed characteristics of pools and riffles are outlined in Table 3; however it should be noted that this information originates form research on pool-riffle channels, not plane- riffle channels, and therefore should only be used with this in mind. Other characteristics will fit with the proposed Type A planform, of width/depth ratios less than 12 and sinuosity between 1 and 1.2 (**Table 1**).

Plane – riffle bed morphology will require a collection of cross sections. Bends will need greater cross sectional asymmetry (**Figure 26**) to create small pools on the outside of bends and bars on the inside; with wider, shallower straighter sections, to form riffles and plane bed units.

Shields (1996) recommends:

- outer banks of bends should have slopes of 1V [V= vertical]: 2H [H= horizontal] or steeper to cause convergence of high flows;
- inner banks, where point bars may develop should have bank slopes of 1V: 3H or less;
- inflexion points are shallower and more symmetrical in shape.

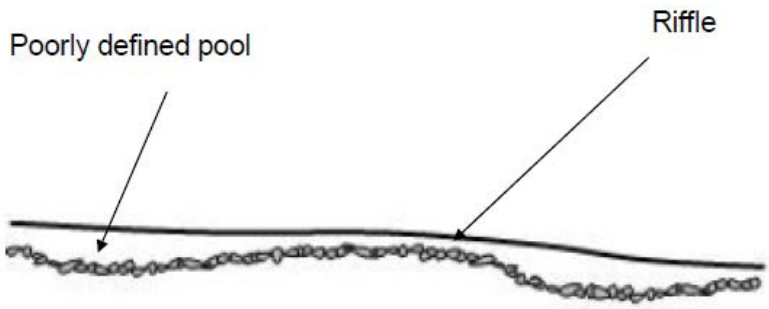

Figure 24: Example long profile of a plane – riffle channel (SEPA, 2011)

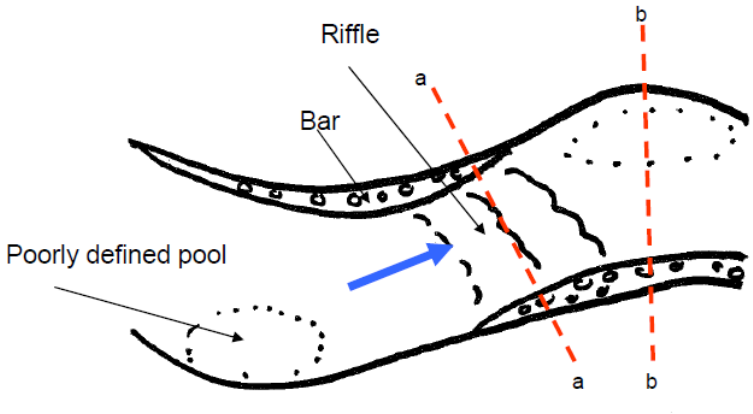

Figure 25: Example planform of a plane – riffle channel

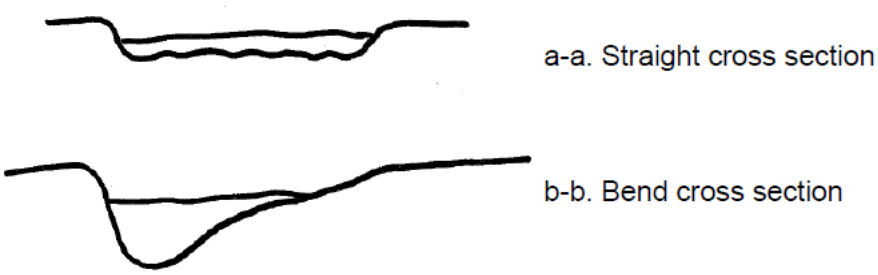

Figure 26: Example cross sections for plane- riffle channels

Table 3 Recommendations for the reinstatement of pools and riffles, focussing on key geomorphic attributes (Thorne et al., 2010; Brookes & Sear, 1996)

Feature	Characteristic	Recommendation
Pool	Size	Occupy over 50% of the river length 25% narrower than associated riffles At least 0.3 m below the mean bed elevation Maximum scour depths typically don't exceed 4 times the depth in the approach channel upstream
	Shape	Asymmetrical cross sections Shallow progressively downstream to the next riffle, with the deepest point within the upstream half of the pool's length
	Location	Located at bends in the meander planform (around and downstream of a bend apex)
	Sedimentology	Bed composed of loose and un-compacted mixed gravels (and coarser), overlain by fines during low flows
Riffle	Size	Collectively occupy 30-40% of river length 0.3 to 0.5m above mean bed level 25% wider than associated pools
	Shape	Near symmetrical cross sections Variable planform geometries
	Location	Locally steep, shallow section of the channel profile Slopes typically 0.005 to 0.200 m/m At cross over points in the meander planform
	Longitudinal riffle spacing	3 to 10 times the bankfull channel width between riffle crests (1 wavelength), but more typically 5 to 7 widths apart. Although some variability in spacing would be natural Shorter spacing where bed slopes are higher In straight reaches they are found in alternate channel side locations
	Sedimentology	Coarse armour, overlying mixed gravel substrate. This may be created by flow winnowing away some fines Avoid uniform size gradations and over-large substrate Size gravels according to that in similar undisturbed reaches, or within the floodplain or palaeochannels High proportion of angular gravels to permit particle interlocking. But avoid excessive imbrication as this limits their ecological benefits Ideally locally derived substrate
	Riffle stability	In the absence of coarse sediment supply from upstream material should be static under all flows or replaced periodically

The location and sequencing of these cross sections is important to achieving the required planform and long-profile morphology. In planform there is a need for the asymmetrical bend cross sections to alternate between the right and left bank side of the channel, with the deeper section always on the outer bank side (OB), and the shallower bank on the inner bank (IB) (**Figure 27**). These bend sections then join the straight sections via a transitional section, that flairs smoothly between the two which have differing side slope angles (**Figure 27**). The spacing of the morphological units (cross sections) is also important to create a suitable long profile (**Figure 24**). The straighter sections (riffles/ planes) should be located at inflexion locations between bends (pools).

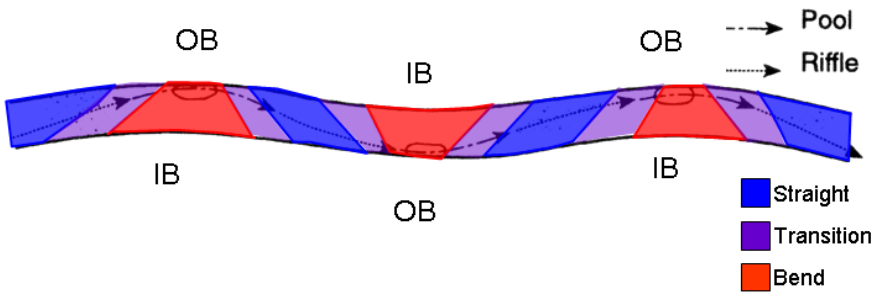

Figure 27: Example locations of plane- riffle cross sections

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