

Lower Shannon Hydromorphology: Fluvial Audit

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This report describes work commissioned by the Office of Public Works as part of the Lower Shannon feasibility study.

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Purpose

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Abbreviations

CFRAMs	Catchment Flood Risk Management strategy
CORINE	Coordination of information on the environment, landcover mapping.
DTM	Digital Terrain Model
FSU	Flood Studies Update
FRS	Flood Relief Scheme
GIS	Geographical Information Systems
LAWPRO	Local Authority Water Programme
LiDAR	Light Detecting and Ranging (normally for terrain mapping)
OPW	Office of Public Works
QMED	Median Annual Flood
SSP	Specific Stream Power (Watts per metre)
TSP	Total Stream Power (Watts)

1 Introduction

1.1 Study Context

JBA Consulting UK (JBAU) commissioned by JBA Consulting Ireland (JBAI) on behalf of the Office of Public Works (OPW) to undertake a hydromorphological audit of the Mulkear River catchment, with the aim of identifying key locations of sediment sources and stores, and understanding the sediment transport regime within the Mulkear River catchment.

The geomorphological field survey complements other elements of the study, such as the desktop review and GIS modelling, to allow a conceptual geomorphological model of the Mulkear River catchment to be established.

The deliverables from this study build on previous studies and contribute towards ongoing works undertaken on the Lower Shannon which aim to identify drivers behind the issue of sedimentation within the Lower Shannon.

1.2 This Report

This report details the works undertaken to develop the Mulkear River catchment conceptual geomorphological model. The structure of the report is as follows:

- Section 2 outlines the methodology for the fluvial audit including initial desktop research, geomorphological field survey and GIS analysis, and how the findings from these components were integrated to provide a conceptual model for the Mulkear River catchment. Limitations relevant to the field survey and to the fluvial audit overall are also acknowledged.
- Section 3 presents the findings of the desk study that provided key contextual information for other components of the study.
- Section 4 summarises the observations from the geomorphological field survey.
- Section 5 details further information about known catchment issues obtained via conversations with the OPW following the field survey.
- Section 6 outlines the results of the geospatial analysis.
- Section 7 presents a conceptual geomorphological model for the Mulkear catchment that draws together the findings from all components of the fluvial audit.
- Sections 8 and 9 summarise the findings of the fluvial audit and provide recommendations to mitigate identified sedimentation problems within the catchment. Recommendations for additional works to improve the understanding of catchment function and/or for ongoing monitoring may also be made if identified during the analysis.

2 Methodology

This fluvial audit combines multiple data sources to establish an understanding of the contemporary (present day) functioning of the Mulkear River catchment and reach-scale geomorphological processes. The fluvial audit comprises desk- and field-based elements.

The desk-based analysis utilises datasets which include information on catchment geology, soil type, hydrology, land use and anthropogenic modification, as well as considering how historic channel change may have occurred through natural geomorphic process e.g. channel migration. The contemporary geomorphological processes occurring within the catchment can then be inferred by considering environmental and human controls past and present.

The geomorphological field survey audited several locations within the Mulkear River catchment to identify local geomorphological processes and identify potential sources, stores and transportation reaches for fine and coarse sediment.

GIS analysis was then completed to map potential erosion and sediment source hotspots and develop a catchment-wide understanding of where sediment was likely generated and/or transported downstream.

The fluvial audit then links together the desk-based analysis with field observations and contributes to the development of a conceptual model of system functioning. The conceptual model provides a visual representation of important geomorphological processes which may be contributing to sediment load to the Lower Shannon from the Mulkear River catchment.

Further methodological details on the geomorphological field survey and GIS analysis are provided below.

2.1 Geomorphological Field Survey

2.1.1 Reach Selection

The geomorphological field survey is split into distinct reaches, this allows an efficient but detailed survey to be undertaken. Four individual rivers have been selected for this study: the main Mulkear River, the Newport River, the Annagh River, and the Bilboa River.

Due to the rural, agricultural and forested land use of much of the Mulkear River catchment, reaches targeted for survey were primarily dictated by viable land access and local road infrastructure/parking availability. The survey also aimed to visit differing land use types within the river catchments, providing a useful description of the overall functioning of the catchment. By considering areas of the catchment that were not visited but have similar characteristics to those which were visited, potential measures can be recommended with a higher degree of confidence than purely desk-based assessment alone.

A discussion between JBAI and Ruairi O Conchuir of the Local Authority Water Programme (LAWPRO) helped identify the target catchments. Ruairi has been involved previously with the now disbanded Mulkear LIFE programme which was set up to identify priority habitat areas within the Mulkear catchment and create small buffer zones to protect the habitats. Ruairi advised that targeting large landowners such as Coilte (mainly forestry) would provide the highest chance of a successful result as smaller landowner liaison is likely to be disproportionate to gain.

The main Mulkear River was selected, to establish if the condition of the river changed significantly at a certain point as well as being the overarching pathway of sediment to the Old Shannon. Six sites on the Mulkear River were visited with an additional visit to the Annacotty Weir.

Ruairi advised that the Annagh river has the most extensive coverage of invasive vegetation species. The Annagh catchment also includes extensive forestry within parts of the catchment and it is therefore a good proxy for other areas of the Mulkear catchment. Four sites on the Annagh River were visited.

The Bilboa River was identified as a potential source of coarse sediment for the Mulkear river and also has extensive agricultural land use, so it was selected as a good proxy for elsewhere within the Mulkear and useful from a coarse sediment source perspective. Four sites on the Bilboa river were visited.

Ruairi advised that the Newport River has an issue with invasive vegetation species mid-catchment. A review of aerial photography highlighted the potential for coarse sediment to be stored within the Newport River. Notably, the catchment has a mixture of rural-type land use and was therefore considered useful to study for contrasting with the Annagh which has predominantly forestry land use, and the Bilboa which is predominantly agricultural with scattered deciduous woodland. Four sites on the Newport River were visited.

An additional spot check was made at one bridge location on the River Deed (also mapped as the Dead River). The Deed was highlighted as having potential erosion issues and could be a fine sediment source, however a desktop review indicated that access was significantly more complicated for the Deed due to the heavily agricultural catchment management.

In addition to planned checks, spot checks were carried out where quick access from main roads was possible, including two on the River Newport, two on the Mulkear River and one on the Bilboa River. The aim of these checks was to quickly capture photography of the river condition which could be reviewed later against other observations.

Locations of the walkovers undertaken in the Mulkear River catchment are shown in Figure 2-1.

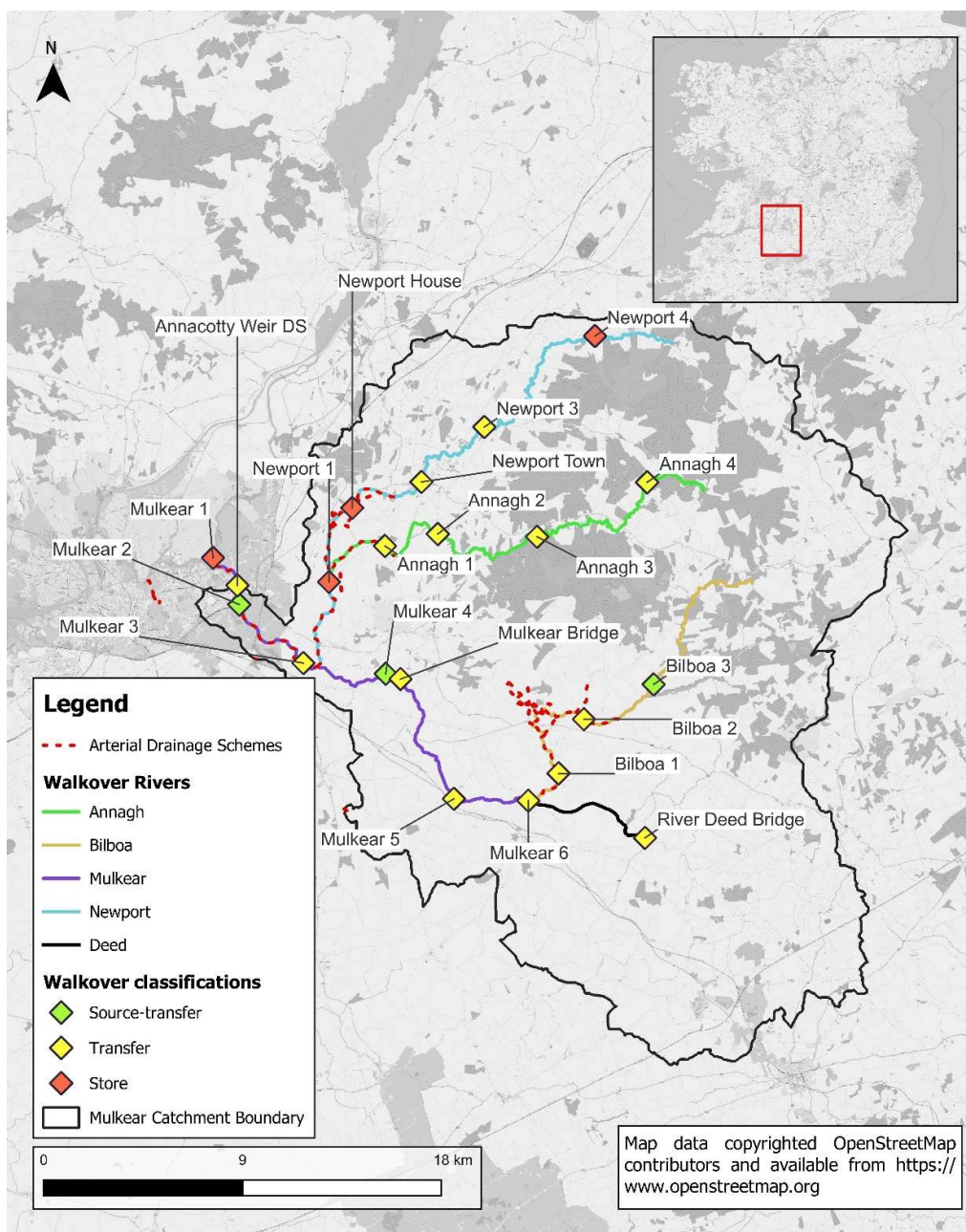


Figure 2-1 Locations of site walkovers and the River Deed spot check.

2.1.2 Field Survey Constraints

Due to dense vegetation growth, including a significant abundance of giant hogweed on steep, sometimes vertical banks, safe access to the river channel in several locations could not be attempted. Best efforts have been made to observe the river and record processes and features; however, a distance has been retained in many instances. A small survey drone which includes a high-resolution camera was taken to site, this allowed accessing certain locations feasible which otherwise would not have been. However, even the drone needs to retain a safe fly distance so in some locations good visual description of the channel bed and sediment type and abundance has not been possible.

2.2 GIS analysis

Following the field survey, GIS analysis was completed to map potential erosion and sediment source hotspots and develop a catchment-wide understanding of where sediment was likely generated and/or transported downstream. Existing data sets such as the FSU river lines, FSU QMED, and topographic data were examined to calculate the specific stream power under bankfull conditions. This provided a measure of river energy that was examined against data sets like CORINE land cover and GSI Quaternary Sediments, while in consideration of the physical setting of each reach, to infer the likelihood of fine and coarse sediment erodibility across the catchment. The potential for fine and coarse sediment generation was then combined into an Overall Erosivity Index that ultimately defined river reaches as depositional (low sediment yield), transportational (moderate yield) and erosional (high yield).

2.3 General Study Limitations

This fluvial audit study is a qualitative review of catchment characteristics and functioning. Whilst best efforts have been made to establish a baseline understanding that can be applied to elsewhere within the catchment, it is acknowledged that not every type of land use and reach of river has been observed. Therefore, recommendations of the study to alleviate issues should be ground checked before proceeding to implementation.

3 Desk Study

3.1 Catchment Description

The Mulkear River catchment is described as a flashy catchment with intense response to runoff events. Local landowners (JBA verbal communication, 2022) describe the river flow as 'milk chocolate' during storm events indicating high turbidity and a significant load of fine sediment during storms.

The Mulkear has a large catchment area 646 km² (OPW Hydro-Data website) at the Annacotty Weir gauge, close to the outlet of the catchment into the Old Shannon. The catchment has a moderately high annual average rainfall amount (SAAR is 1166 mm) and has a steep topographic gradient ranging from 690 m Above Ordnance Datum (AOD; Poolbeg Datum) in the uplands to 0 m in the lowlands, with the majority of the topographic gradient lost within the upland portion of the catchment (Figure 3-1).

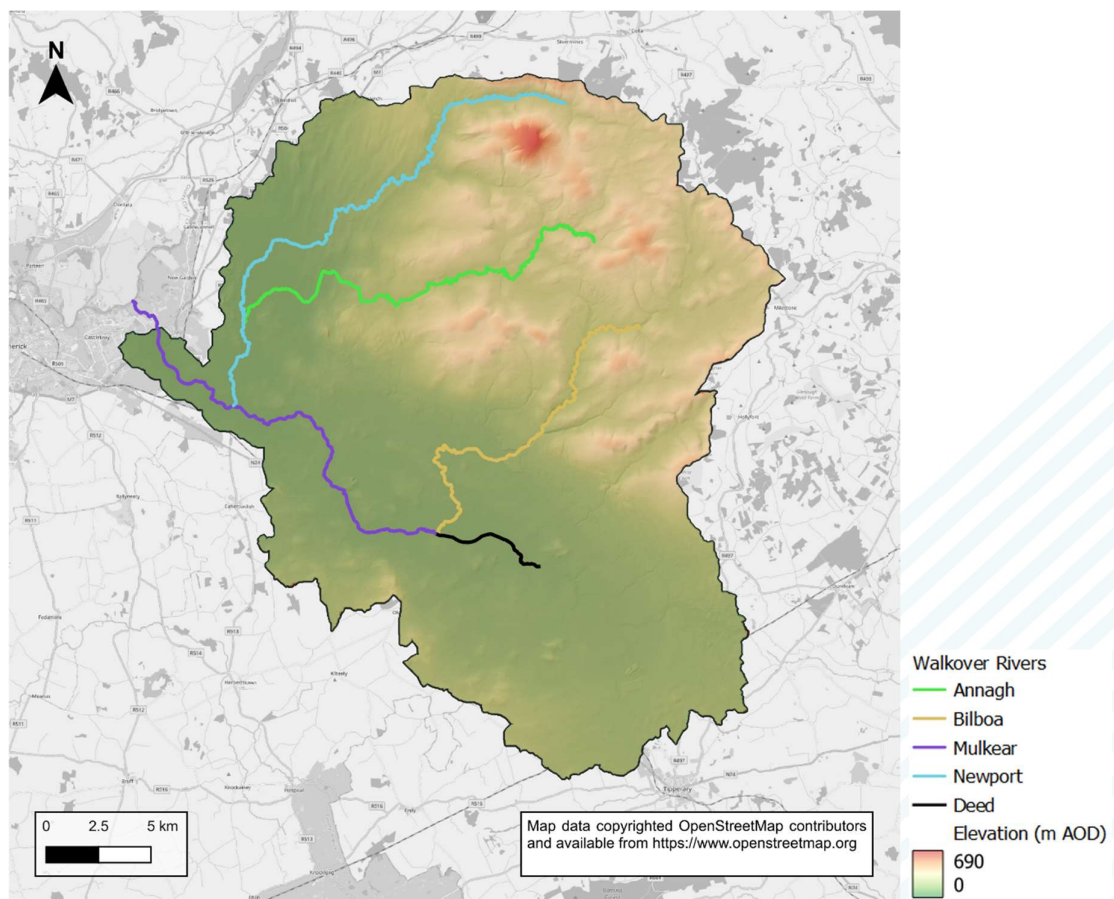


Figure 3-1 Mulkear River catchment topography with site location rivers overlain.

The lower Mulkear River is underlain by sedimentary bedrock geology comprising various limestone formations including Lough Gur Formation (limestone), Rathkeale Formation (limestone and shaly mudstone), Ballysteen Formation (dark muddy limestone, shale) and Waulsortian Limestones (unbedded lime-mudstone). The uplands of the Mulkear catchment feature less permeable sedimentary geology including the Keeper Hill Formation (sandstone, grit and claystone) and Hollyford Formation (greywacke, siltstone and grit).

The superficial geology the Mulkear catchment comprises a mix of upland peats, lowland alluvial sands and gravels, and glacial till. This mix of low permeability, erodible sediments and steep topography in the uplands helps to generate significant

runoff and potential sediment generation during storm events. Some areas in the Mulkear catchment also have exposed bedrock outcrops (Figure 3-2).

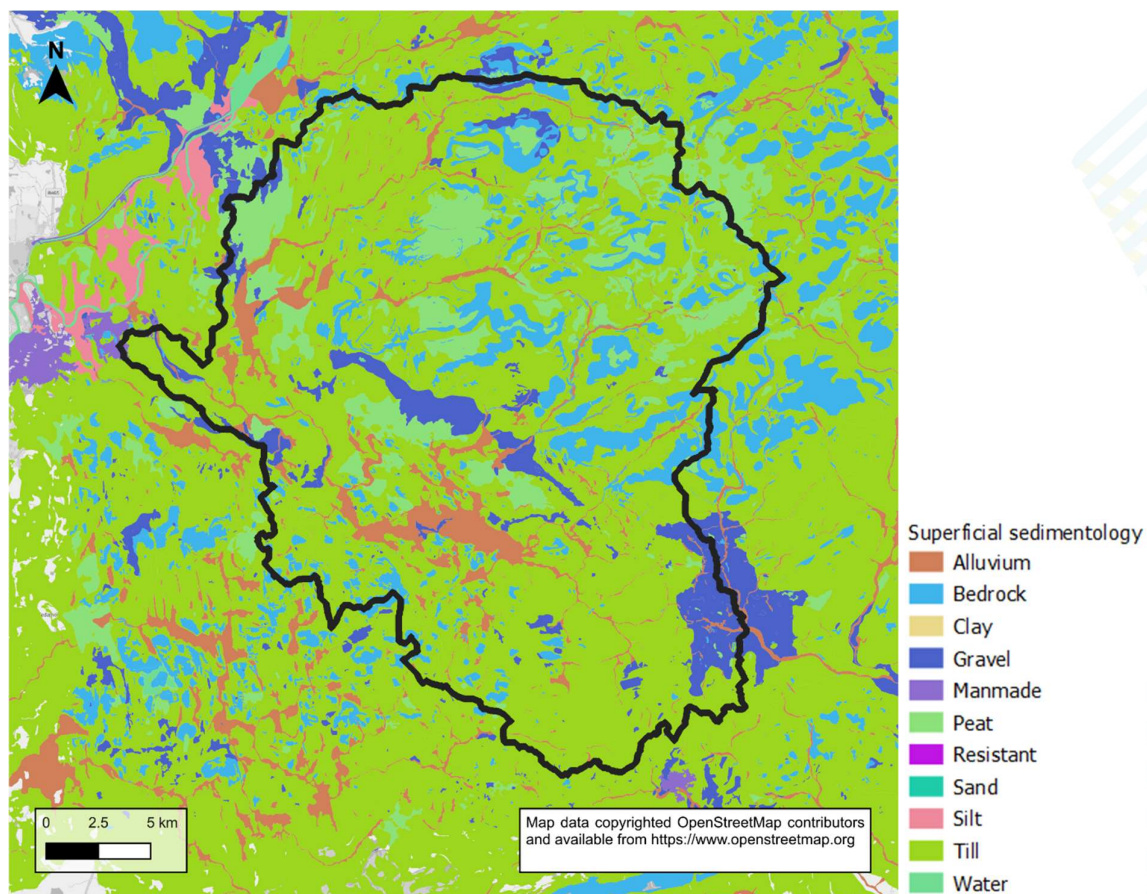


Figure 3-2 Superficial sediment typology simplified from Geological Society Ireland Quaternary Geomorphology Deposit Mapping (2022)

Land use within the catchment is predominantly rural with agricultural land cover, and forestry is prevalent within upland steeper areas of the catchment (Figure 3-3). Notable within the uplands is the presence of mineral extraction sites, suggesting large areas of land will have high potential to generate local sources of fine sediment which could easily be carried into the fluvial system as wash load during runoff events.

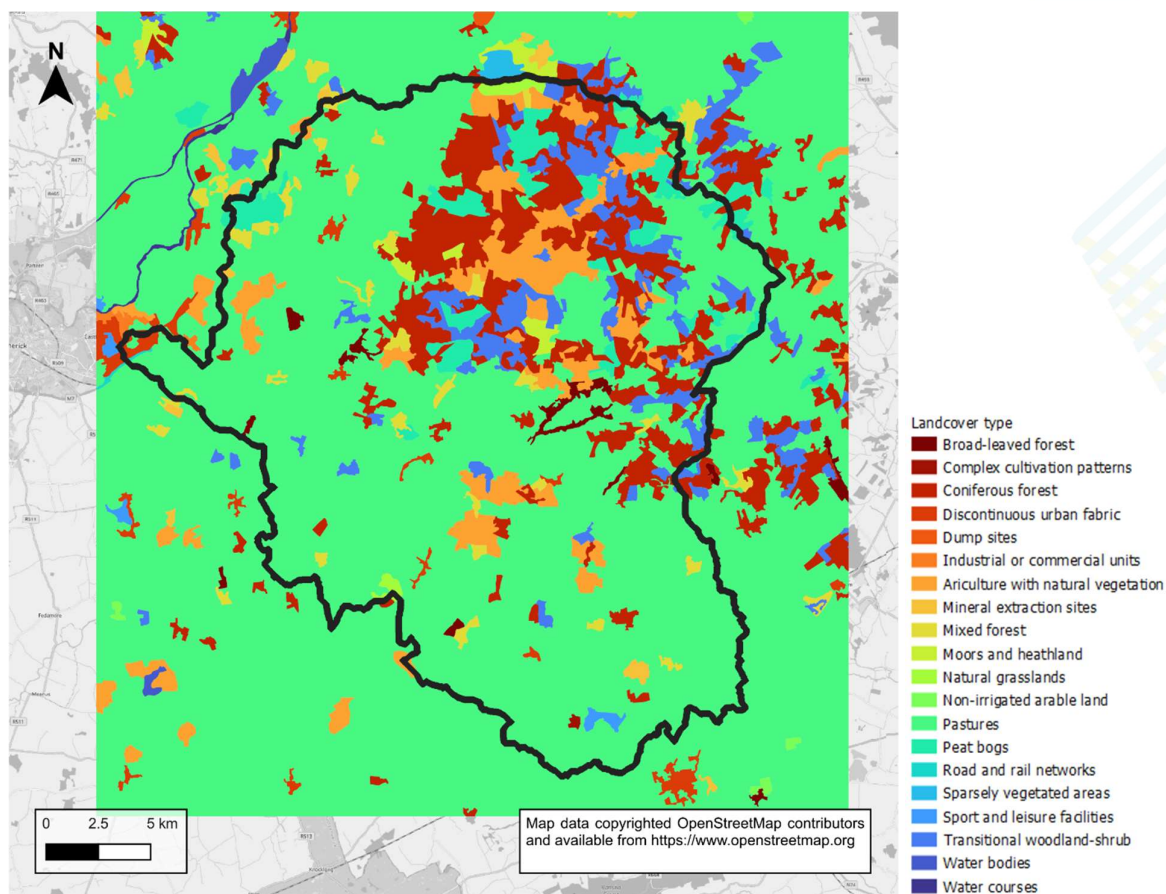


Figure 3-3 Landcover types, taken from the Corine Land Cover Mapping (2018) dataset.

3.2 Review of Historical Mapping

A review of available historical mapping has been undertaken. The main data source used is the First Edition Ordnance Survey Ireland Black and White mapping found on Geohive.ie, which has been compared with contemporary aerial imagery found on google earth.

The contemporary Mulkear River and tributaries throughout the catchment appear to be similar in planform to the First Edition 6-inch Black and White OS Mapping (surveyed 1837-1888), with much of the river evidently straightened to improve land availability prior to completion of the original mapping. This practice has continued throughout the preceding 150-200 years and now large sections of the river are deeply incised and straightened; the main Mulkear River is the same as its historic planform throughout most of its extent.

Although evidence is rare, some tributaries and particularly the Bilboa river do exhibit signs of a more active past. Flood relief works will have altered the planform of several reaches of rivers and the presence of embankments will have altered the layout of the river network. The historic Bilboa river planform appears to mirror its present-day self in many locations; there are also several locations where meander neck-cutoff has occurred. The river Bilboa also has a flood relief channel constructed near the town of Cappamore ITM: 578295 651403, this feature was not shown in earlier mapping, but is present within the contemporary aerial imagery (Figure 5-4). Verbal communication (JBA Ireland to JBA UK, 2022) confirms that the feature needs to be cleared of coarse sediment occasionally, indicating a rich supply from the Bilboa.



Figure 3-4 River Bilboa flood relief channel (Google Earth, 2022).

Changes in planform of the Annagh river are also unremarkable, save for one location near Lackamore ITM: 579841 660379 where historic mapping shows a much more meandering planform, this has been straightened to make way for forestry.

The contemporary River Newport is very similar to its historic planform. Notably the river has been straightened through a reach north of Ballymackeough near ITM: 570519 661823 (Figure 3-5), where it historically branched and formed an island, adjacent land use is farmed, and it assumed the river has been straightened to improve land availability. There is little other evidence of channel realignment within the Newport catchment occurring within the historic mapping, again this is likely due to having occurred before the mapping was created.

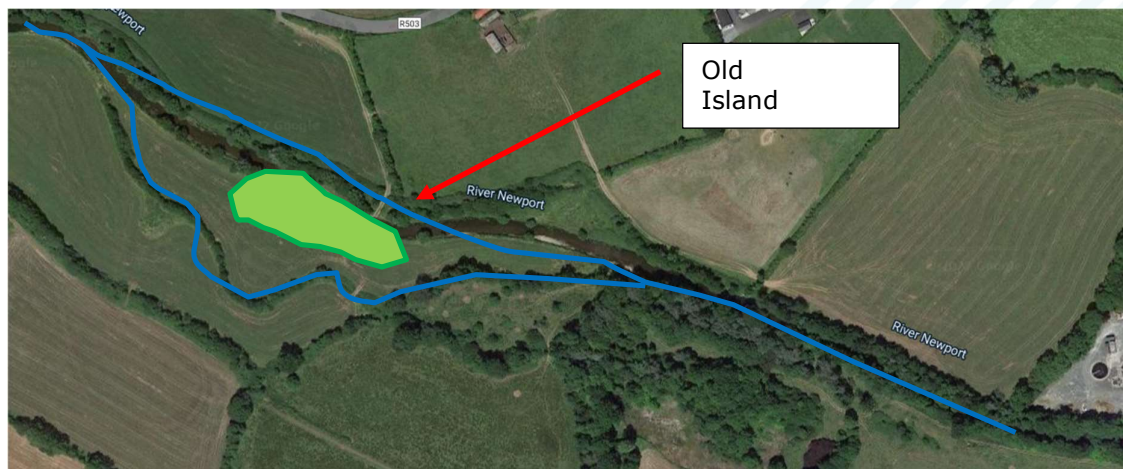


Figure 3-5 Historic River Newport planform at Lackmore (Google Earth 2022)

Broadly, the rivers have not migrated much since the first edition 6-inch Black and White mapping, however, as described above this is likely due to agricultural land-use within the catchment pre-dating the mapping, so no major land use changes have occurred within the last 150-200 years.

There are 2 arterial drainage schemes on the Mulkear River: (1) Ballymackeogh and (2) Cappamore. The Ballymackeogh Flood Relief Scheme was constructed in 1998 and has regular maintenance carried out since. This scheme covers the lower reaches of the Newport River and River Annagh.

The Cappamore Flood Relief Scheme was completed in 2000, also has regular maintenance carried out since its completion, the works were undertaken with guidance from Inland Fisheries Ireland (IFI). This scheme covers the lower reaches of the Bilboa River.

The formal flood risk schemes and dredging is assumed to have dampened the potential for any lateral migration to occur within the river catchment.

4 Geomorphological Field Survey

4.1 Mulkear River

The Mulkear River walkover started at a location close to the confluence of the Old Shannon, working upstream. The Mulkear lower reach (ITM: 563212 658634) is generally characterised by deep, turbid and sluggish gliding typology which transitions from slightly more energetic flow types further upstream. A consistent theme throughout the Mulkear is that the channel is deeply incised and wide; this is likely due to historic dredging and continued incision due to the high flow conveyance focusing geomorphologically competent flows on the bed rather than promoting lateral mobility. The walkover locations were shown in Figure 2-1.

The survey was undertaken on the 16 August 2022 following a runoff event which was preceded by a prolonged period of extremely dry weather, the water level percentile at Annacotty weir was low, around a Q60 event visible in Figure 4-1.

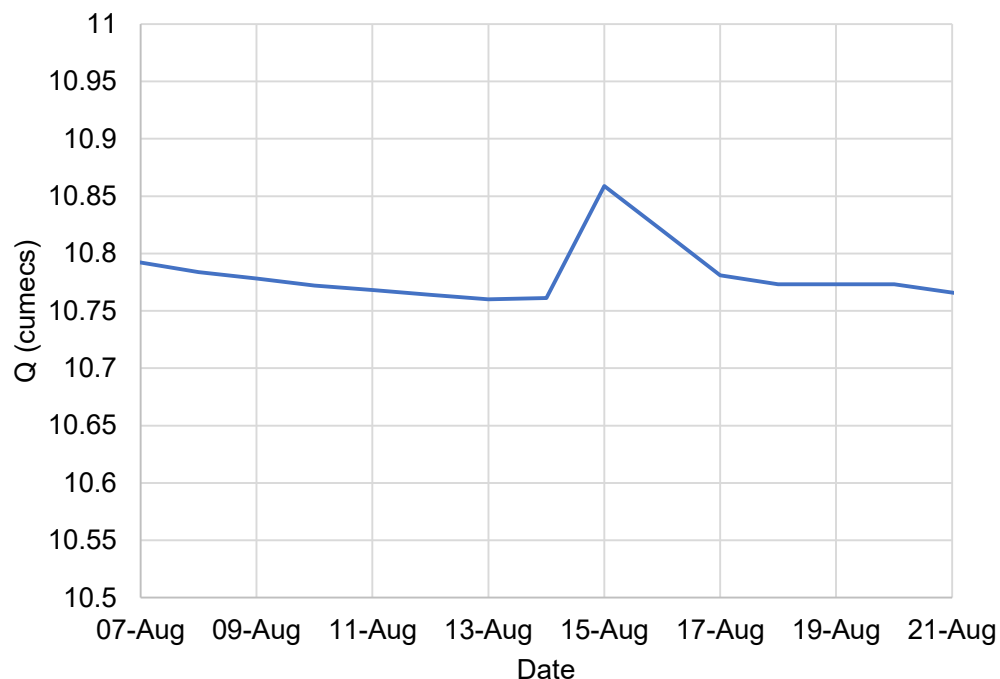


Figure 4-1 Annacotty Weir (25001) Water Level Chart for Survey Week 15 to 19 August 2022

4.1.1 Mulkear 1

Mulkear 1 reach is characterised by deep, turbid and slow flow (Figure 4-2 and Figure 4-3). The channel in this location is incised and is typically 1.5m below the adjacent banks, not considering the flood embankments, which are around 2m above the normal bank.

Whilst not extensive, riverbank poaching was observed and assumed to be from local livestock (Figure 4-4). This poaching will contribute a reasonable amount of fine sediment during either a localised land runoff event overbank from local fields, or during a geomorphologically competent event.

Throughout the reach the riverbanks and adjacent riparian land are typically vegetated with a mix of mature trees, brush, scrubland and mixed length grasses. However, Himalayan Balsam (*Impatiens glandulifera*) coverage is extensive and can be frequently found in significant stands along the majority of the reach banks. During winter when flows are at their highest and the Himalayan Balsam dies back, the potential for large amounts of fine sediment to enter the channel are greatly increased.

Flow is more sluggish and turbid towards the confluence with the Lower Shannon. This reach could not be directly accessed due to dense stands of Giant Hogweed (*Heracleum mantegazzianum*) which are scattered amongst dense and high bankside vegetation, including riparian trees. Giant Hogweed without treatment can dominate local vegetation coverage and prevent native grasses from occupying the space, thus increasing the risk of erosion of fine sediment which is left exposed.

Compared with the river further upstream the sluggish flow in this reach is caused by the backwater impact of the Lower Shannon and the shallower gradient of this reach of the Mulkear. The lower velocity reach has a longer residence time for fine sediment than further upstream, explaining the more turbid characteristics of the flow. Flow is likely to be approaching settling velocity for fine sediment and the presence of the mid-channel bar forming downstream of the confluence with the Old Shannon. It is possible that the higher suspended sediment concentration within this reach was washed down during the runoff event preceding 16 August 2022 and has begun to settle within the Mulkear 1 and Lower Shannon during the survey dates.



Figure 4-2 Large stand of Himalayan Balsam visible to the left of the picture and bankside poaching visible to the right (Right bank)



Figure 4-3 Very turbid sluggish flow within the Mulkear River approaching the Old Shannon confluence.



Figure 4-4 Further bankside poaching from livestock visible within the Mulkear River 1 survey reach (Right Bank).

4.1.2 Annacotty Weir Downstream

Immediately downstream from Annacotty Weir (ITM: 564258 657622) on the Mulkear River the flow type was varied, showing rippled flow and some run typology (Figure 4-5).

Coarse sediment is present in the form of a gravel-pebble bed substrate, a marginal coarse sediment bar is situated on the left bank (Figure 4-6). Some large boulder-sized sediment is present in the channel, although this is assumed not been transported recently and is either remnant of a decommissioned/failed structure or of glacial origin.

River flow was very clear on the day of survey and the bed was visible, therefore any fine sediment generated during the runoff event preceding 16 August 2022 had already passed the Annacotty Weir and reached the lowest reaches of the Mulkear River.

Although not visible within the survey extents, this location is approximately 500m downstream from the site of Ballynaclough weir, this structure has already been removed by the Mulkear LIFE scheme.



Figure 4-5 Mulkear River Immediately downstream from Annacotty Weir.



Figure 4-6 Gravel bar on left bank of Mulkear River downstream of Annacotty Weir (Source: Google Maps streetview 04/06/2024).

4.1.3 Mulkear 2

The Mulkear 2 site location (ITM: 564354 656744) comprises a reach downstream from a motorway bridge; this includes a fish Pass (Figure 4-7) adjacent to the M7 road bridge. Due to the dense woodland on the banks much of the river could not be accessed. Flood trash was evident on the caged rip-rap within the second stage of the Mulkear channel under the M7 road bridge, indicative of geomorphologically competent flows having occurred.



Figure 4-7 Scattered flood trash (leaves/reeds etc.) evident up to the bankfull location on the rip-rap (left bank).

The channel is incised and around 15-17m wide, but this is due to significant modification comprising the M7 road structure and surrounding supporting infrastructure i.e., piling for bridge support. Evidence of coarse sediment input from the banks downstream from the

river exists; gravel and cobble sized material (Figure 4-8) is exposed within the matrix on the left bank. The cobble sized material is less mobile with evidence of mosses and lichens on the clasts, but clean gravels were observed suggesting these can be eroded and transported during events exceeding the low-flow bank height.

Several locations on the left bank had visible fine sediment exposed; a kick-test indicated that this was slightly crumbly, whilst maintaining some resistance. Therefore, the sediment source can be eroded during high energy events (Figure 4-9 and Figure 4-10) but is unlikely to be continually contributing fines into the river at this location during the normal low flow regime. Shading from mature trees is potentially preventing grasses colonising within the exposed parcels of fine sediment on the banks, exposed roots also indicate erosion during high flow events.

The reach had some evidence of large boulder sized material embedded within the banks, this appears to be natural material and is assumed to be remnant glacial material (Figure 4-11), the material is currently immobile evidenced by significant moss and lichen growth.



Figure 4-8 Gravel-pebble and cobble sized material visible on the left bank.



Figure 4-9 Sand-gravel and gravel-pebble sized material also exposed on the left bank.



Figure 4-10 Evidence of fine sediment input, exposed roots and silt/sand parcels are visible. (Left bank).



Figure 4-11 Large boulder material - lower particle b-axis (left to right) was approximately 600mm (although entire particle is not visible).

A large outfall is located in this reach (Figure 4-12), slightly downstream from the motorway and is assumed to be draining adjacent agricultural land. During high runoff events, depending on the pathways, this outfall has the potential to contribute fine sediment; local access roads and compound parking areas were dusty, and it is assumed the motorway drainage also connects into this outfall. At the time of survey the outfall was contributing to baseflow, however the flow was clear and did not appear to contain any fine sediment.



Figure 4-12 Outfall draining into Mulkear 2 downstream from the motorway.

4.1.4 Mulkear 3

River water at the location of Mulkear 3 (ITM: 567209 654163) was clear and the bed substrate was visible, however due to the distance which needed to be maintained from the channel it was not possible to estimate sediment sizes (Figure 4-13). Some larger boulder sized material does exist, forming a rock-riffle type feature. It appears this is a remnant weir structure, and the material is assumed to be artificial.

Flow typology remained typically glide, with some localised more energetic and rippled flow (Figure 4-14). Channel substrate appears to contain some finer sediment, which corresponds with sand coloured sediment observed elsewhere in the catchment.

Invasive species coverage is extensive, with Himalayan Balsam, Giant Hogweed and Japanese Knotweed (*Reynoutria japonica*) covering much of the banks at this location.

The survey was undertaken from the left bank which had generally shorter vegetation coverage, the right bank included many riparian trees providing shade to the channel.

The channel geometry was again very incised, circa 2.5m below top of bank and comprising a channel width varying between 10-15m, widening to around 20m for a short distance (Figure 4-15) which has evidence of fine sediment deposition on the right bank forming a bar feature that has additionally begun to establish short grasses.



Figure 4-13 Channel bed can be seen (water looks brown but this is bed sediment), invasives are abundant but right bank is shaded by trees.



Figure 4-14 Some rippled flow, with eddying evident and shading provided by trees on the right bank of Mulkear 3.



Figure 4-15 Channel widens out to approximately 20m - right bank has evidence of fine sediment accumulating and material has started to establish short grasses.

4.1.5 Mulkear 4

Mulkear 4 (ITM: 570876 653685) comprised a spot check of a single location due to access to the channel being constrained by almost vertical banks. The channel was circa 10m wide and around 1.5m below the lower right bank, flow was sluggish and gliding and abundant organic material (Figure 4-16) had started to accumulate within the channel margins and around trees, suggesting the reach is lower energy.

Bed substrate was typically in the cobble to boulder range, with a b-axis of approximately 128-300mm (visual observation) in size, but appeared immobile with the presence of established mosses and lichens on much of the clasts. Common water crowfoot or a similar species was visible (without flowers) within much of the channel. A thin veneer of silty material appeared across most of the bed (Figure 4-17), although it is assumed that this reach temporarily stores finer material and releases it during high flow events. Gravel-pebble material was visible in a small number of locations and is assumed to be smothered with the silt veneer. It is likely that this gravel-pebble sized material is transported into the reach during high flow events but then hidden by finer material which is deposited during the normal flow duration curve.

Some very large >1m diameter sized boulder material is visible within the riverbanks, again this appears immobile due to the presence of well-established mosses and lichens and is assumed to be from glacial deposition (Figure 4-18).

Some fine sediment remains exposed on the river banks, but this is generally less than elsewhere within the catchment, and is not believed to be poached by livestock or continually contributing to the fine sediment load in the Mulkear River.



Figure 4-16 Clear water, but silt veneer exists on bed. Organic material accumulating (bottom right) within sluggish flow.



Figure 4-17 Cobble sized bed material covered with thin veneer of silt. This reach appears to temporarily store silt sized material.



Figure 4-18 Very large boulder stacked on top of finer material, larger than 1m wide. Rucksack for scale is approximately 60cm tall.

4.1.6 Mulkear Bridge

A spot check was made from a local bridge on the Mulkear River close to Abington Cemetery (Figure 4-19, ITM: 571536 653449). The Mulkear River at the location is unique, with a bedrock outcrop just upstream of the bridge, potentially exposed due to historic modification or gravel extraction, however the river shows interesting diversity compared with elsewhere on the Mulkear (Figure 4-20).

Whilst a veneer of finer silt type material was observed towards the margin on the river right bank, the flow was clear suggesting fines are either transported through the thalweg and have already passed this location or are stored as a veneer within the margins.

Flow patterns were swirling, upwelling and rippled, with organic and woody material trapped behind the bridge providing shelter for aquatic fauna. Some more energetic run flow typology was observed.

Adjacent land use was heavily agricultural, with extensive moderately-steep fields of monoculture crop usage (Figure 4-21 & Figure 4-22) and adjacent land drainage ditches. The fields indicated many locations of exposed soil which could be eroded during a localised runoff event and contribute fines into the river. Although fine sediment was exposed near to the river poaching was not immediately evident, this is likely due to selective land management as the fields were visibly used for crop harvest rather than grazing.

The right bank upstream from the bridge was visibly failing, slumping into the river channel, likely due to continued undercutting and winnowing of the finer material during geomorphologically competent events.



Figure 4-19 Bedrock channel bed at Mulkear Bridge (spot check) including veneer of finer material toward the right bank channel margin (bottom of picture).



Figure 4-20 Varied flow types and organic debris present in the Mulkear.



Figure 4-21 Right bank failing and slumping into the river. Additionally exposed fine sediment which could contribute to sediment load during local runoff event.



Figure 4-22 Monoculture land use – when crops are harvested fine sediment may be exposed.

4.1.7 Mulkear 5

Mulkear at reach 5 (ITM: 573921 648114) is deeply incised (>3m), local land use is agricultural grazing and industrial, and the channel is around 3-5m wide.

Flow is generally sluggish glide typology and the reach is generally very straight. A small rock-riffle type feature is present but this appears to be remnants of a previous weir.

A bridge within the reach (ITM: 574014 648075) interrupts flow and causes fine sediment and sand deposition downstream (Figure 4-23). The flow clears at the bridge but a veneer of fine sediment remains on some of the bed.

Invasive plants line most of the banks, particularly Giant Hogweed and Himalayan Balsam, but also stands of Japanese Knotweed (Figure 4-24), suggesting that when these plants die back bank sediments will be exposed.

The reach appears to be a store for fine sediment during low-flow conditions, however the channel geometry suggests it would be flow-efficient and sediment transport capable during a geomorphologically competent event.

Evidence of coarse sediment on the channel bed was minimal; potentially a gravel bed was shrouded below the silt veneer.



Figure 4-23 Fine sediment bar feature immediately downstream of the bridge. Additionally fine sediment veneer on the channel bed.



Figure 4-24 Stands of Giant Hogweed and Himalayan Balsam on the left bank and Japanese Knotweed present on right bank.

Figure 4-24 shows fine sediment exposed for a short distance on the left bank (between the tree shade area and the Giant Hogweed to the left) indicating that during die-back this could become a much greater extent of potential fine sediment input.



Figure 4-25 Small rock-riffle type feature. Assumed to be remnants of an old weir.

4.1.8 Mulkear 6

Mulkear 6 (ITM: 577234 648029) is downstream from the confluence with the River Bilboa, the Bilboa is understood (through discussion with Ruari O'Conchiur) to be a source of coarse sediment to the Mulkear.

The Mulkear at this location is deeply incised with very steep banks, up to around 4m deep, and 45–90-degree steep in profile (Figure 4-26). It is likely that the incision process began due to dredging and has continued due to high flow events being contained within channel.

Steep banks in many locations have unvegetated fine sediments exposed which are likely to contribute to ongoing channel widening and fine sediment supply downstream during geomorphologically competent events. Poaching is evident within this reach of the Mulkear, appearing to be from horses.

The channel is more sinuous than downstream and with fine-medium sized gravels occupying most of the channel bed and bar features forming on meander bends.

The flow was generally clear on the day of survey, except for the location downstream from the River Deed confluence (Figure 4-27 and Figure 4-28). Even though flow was low within both channels a visible fine sediment plume was being contributed into the Mulkear River from the River Deed, identifying the River Deed as a key source of fine sediment even during the normal flow duration curve.



Figure 4-26 Overwide and deep channel. Fine sediment exposed on left bank with gravel bar feature on the inside of meander bend.



Figure 4-27 Looking downstream of confluence with River Deed (Deed not visible, entering from left).



Figure 4-28 Drone imagery: Mulkear River (left) and River Deed (right) confluence, Mulkear flow approaching confluence is relatively clear whilst deed is very turbid. Fine sediment plume can be seen mixing at confluence.

4.2 River Bilboa

The River Bilboa survey started at the downstream end of the River Bilboa (ITM: 577618 647898) and worked upstream incorporating four consecutive sites. Generally, flow was low and tranquil, although varied lower energy (glide, run) flow biotopes were visible within the surveyed extents.

Coarse sediment was observed throughout the River Bilboa, in agreement with the prior advice that it is a source of this calibre of substrate to the Mulkear.

The planned Bilboa 4 site walkover could not be attempted due to livestock and poor land access.

4.2.1 Bilboa 1

The river at Bilboa 1 (ITM: 578585 649244) is characterised by a modified channel including steep 45-degree side slopes and a weir structure for flow gauging (Figure 4-29). Deposited fine sediment was visible at a relatively high elevation compared with the normal low-flow channel. This had infilled the access steps to the gauging weir indicating that large volumes of fine sediment are transported through the Bilboa into the Mulkear during high flow events.

Upstream from the gauging weir crest there was an abundance of stored coarse sediment which is assumed to fall from suspension during transport events, i.e., high flow runoff events (Figure 4-30). Towards the centre of the weir where the gauging notch is situated velocity was high and coarse sediment storage was less pronounced, away from the notch the depth of the stored coarse sediment was up to the crest of the weir. The gauge board was located upstream of the weir and the coarse sediment had infilled to a depth of 0.6m on the stage board. A later check of the CFRAMs hydrology report for Unit of Management 25 and 26 indicated that this gauge, (25004) Bilboa at New Bridge, was a gauge which had datum changes associated with it and was no longer actively maintained. This information suggests that coarse sediment transportation and storage at the gauge location is a systematic quality of the River Bilboa.

Within the reach upstream and downstream of the gauge location coarse sediment bars were widespread (Figure 4-31), and some pool features were observed on the outside of meandering features. A mixture of trees, shrubs and grasses populated both banks, with scattered areas of exposed fine sediment. Himalayan Balsam was present but less extensive than as observed within the main Mulkear River.

Although the gauging weir is a visible sediment trap, the relatively low elevation of the crest and abundance of coarse sediment downstream suggests it is not a major barrier to sediment transport during high flow events.

Approximately 1km downstream from this location a flood embankment breached in January 2018, reported by OPW written communication. This location was not visited during the walkover. A review of the nearest dated google earth aerial imagery was undertaken, namely May 2017 and June 2028, no flood damage to land is discernible between the two dates.

Approximately 100m upstream from this location OPW written communication advised that an informal flood defence along the road was replaced in 2020.

OPW written communications advise that siltation is cleared from this location periodically, the most recent clearing has been 2016, and it will likely be cleared within the next 2-3 years. This statement agrees with site observations that the River Bilboa is a key sediment supply to the Mulkear.



Figure 4-29 Gauging weir crest - coarse sediment slightly below water level upstream.



Figure 4-30 Glide typology with coarse sediment bed and tree vegetation upstream from gauging weir.



Figure 4-31 Partially vegetated coarse sediment mid-channel bar feature with partial riffle forming.

4.2.2 Bilboa 2

The river in this reach is characterised by an engineered weir structure and reinforced banks (ITM: 579715 651660) understood to be constructed for abstraction of gravel with supply to the local area. A marginal bar feature exists upstream from the weir structure and the river is approximately 20m wide. The flow downstream from the weir structure is more sinuous and deeper than the impounded flow upstream from the structure (Figure 4-32, Figure 4-33 and Figure 4-34). This suggests that the structure is a barrier to transport of cobble sized material; although some cobble-sized material was present downstream from the structure this was less abundant.

A large bridge structure is situated upstream of the weir with scouring of coarse sediments around the piers observed, although not of significant depth as to undermine the structure (Figure 4-35).

The reach further upstream is sluggish, exhibiting only glide typology (Figure 4-36). Marginal bar and berm features are beginning to form but these are less pronounced than the reach downstream from the weir structure.

The channel bed immediately upstream of the weir crest exhibits a thick ~1-2cm veneer of silty material (Figure 4-34), this material is likely to be transported downstream during a high flow event but accumulates during normal flows.

OPW written communication advises that the gravel trap at this location requires annual cleansing with significant quantities being removed. Gravel removal is also required upstream and downstream from the nearby deflector at ITM: 578410, 651613, which is situated on the flood relief channel.



Figure 4-32 Mid-channel bar formed downstream from weir crest. Rippled flow types visible, marginal bar on right bank.



Figure 4-33 Mid-channel bar feature upstream from weir crest. Typically gravel-pebble to cobble sized material.



Figure 4-34 Silty material upstream from weir crest and more dynamic flow downstream.



Figure 4-35 Coarse bed material scoured from bridge upstream from weir structure (structure not undermined).



Figure 4-36 Silty veneer on material in upstream section of reach. Very shallow sluggish flow typology.

4.2.3 Bilboa Bridge

A spot check was undertaken from the L5036 road bridge crossing of the River Bilboa (ITM: 581526 651928). The character of the river was comparable with the Bilboa 2 reach, however the general clast size of sediment increased with visible boulder sized material within the river (Figure 4-37 and Figure 4-38). The river remained around 20m wide, likely characteristic of historic management associated with the bridge and adjacent land use. Rippled flow types, typically runs, were visible downstream from the bridge. A small rock dam had been created upstream from the bridge structure which was impounding low flow. The dam was visibly restricting silt movement during low-flows, however it was constructed of loose stone (likely by local children) and during high flows it would probably be washed out.



Figure 4-37 Impounded and sluggish flow upstream from bridge. Small rock dam visible in lower right of image extended across channel.



Figure 4-38 Flow downstream the bridge.

4.2.4 Bilboa 3

Further upstream (ITM: 582820 653211) in this reach the general sediment size increases again with abundant boulder sized material and varied flow types, including step pools and boulder sized riffle type sequences (Figure 4-39). The river is situated at the bottom of a gorge with woodland dominating both banks. The river may be slightly incised as the bed is 500mm below the low-flow banks at some locations, although it is generally much less incised than elsewhere.

The Bilboa has banks with exposed sand sized sediment (Figure 4-40) in some locations although this was within a matrix of cobble-boulder material and fine sediment stores were minor and within channel margins only. In several locations bedrock outcrops create geomorphologically interesting features and scour pools downstream (Figure 4-41).



Figure 4-39 Character of river at Bilboa 3 - dense vegetation with boulder step-pools and rippled flow types.



Figure 4-40 Sandy material within channel margins, slightly undercut bank.



Figure 4-41 Example of bedrock outcrop with pool downstream.

4.3 Newport River

The Newport River was identified from mapping as a potential coarse sediment source to the Mulkear River as well as having known invasive problems within the mid-catchment, and was therefore selected for walkover on the third day of the survey. The survey started at the downstream end of the Newport River. Intense agricultural land use and dense bankside vegetation prevented survey at the planned locations, and therefore walkover locations were changed on-site. However, at Newport 2 cattle with calves prevented survey.

OPW written communication advises a tributary that joins the Newport River at ITM: 568400, 660169, is actively eroding upstream from a nearby road bridge at ITM: 568559, 660642.

Generally, flow was shallow and tranquil, although varied lower energy (glide, run) flow biotopes were visible within the surveyed extents.

Varied bed substrate was observed within the Newport River with a bedrock outcrop visible at one location. Coarse sediment was abundant and fine sediment is visible in some locations.

4.3.1 Newport 1

This site location was situated at Annagh Bridge as the central point, over the Newport River (ITM: 568348 657777). Upstream from the bridge the river exhibited homogenous flow typology (Figure 4-42), typically glides, with some slightly more energetic rippled flow further upstream from the bridge.

A small mid-channel bar feature comprised of gravel sized material (Figure 4-43) is present upstream from the bridge which has started to establish short vegetation. A large gravel bar on the right bank is present which was completely obscured with vegetation during the survey.

Bed substrate was typically gravel to cobble sized and bankside vegetation was dense, typically a mix of shrubs and established deciduous trees.

Downstream from the bridge the river widens out but starts to exhibit a more anabranching type planform with several bar features and several normal flow channels. Shallow riffle features are also present and deep pools are visible further downstream.

It appears that the bridge structure itself is a key control on flow typology with less diverse flow typology transitioning to anabranching channels and riffle-pool sequences past the bridge location.

OPW written communication advises that flood works are proposed upstream from this location, and the reach of the Annagh upstream from the near confluence has an ongoing invasive species management coordinated run by OPW. There are properties at flood risk within this area.

OPW written communication advises that the channel at this location is 2 stage geometry, but the lower section of the channel is heavily overgrown with trees, and these trees are causing erosion to the riverbanks. These trees may be providing geomorphological, and habitat benefit by increasing flow diversity but also impacting conveyance and reliability of flood asset infrastructure.



Figure 4-42 Upstream from Annagh Bridge with mid-channel gravel bar and a vegetated bar on the right bank (left of picture).



Figure 4-43 Downstream from the bridge mid-channel bars, anabranching channels and shallow riffle crests visible.

4.3.2 Newport House Spot Check

Upstream from the Newport 2 location (ITM: 569386 661077) an opportunity to access the river was identified and a spot check was made at a local farm which had an access track to the river.

At this location the channel had been modified on the left bank and included a large boulder constructed revetment. Local landowners advised that this had previously been constructed by the Office of Public Works (OPW) to prevent lateral migration further left. The channel was very wide, approximately 8m at the bed, 10m at the second stage of the channel and 20m at the bankfull stage, around 5m depth to bankfull. Only 200-300mm depth of flow (Figure 4-44) was experienced on site.

The second and third stages of the channel (Figure 4-45) had been artificially created by the landowner in response to fine sediment deposition following floods which were deposited over the right bank. A few kick tests of the ground indicated that the material on the right bank was fine sandy-silt type material. This location is likely to both transport sediment during high flows and become depositional as floods reside or during minor runoff events.

Channel bed material was generally sand to gravel-pebble sized material (Figure 4-46) with no discernible morphological features or sequences identifiable.

Bankside poaching was prevalent and visible on both sides of the river where livestock access for drinking.

OPW written communication identifies that the section of right bank embankment at this location is being considered for refurbishment, the property is known to be at risk of flooding. The reach downstream of this location is a particularly overwhelmed with giant hogweed and Japanese knotweed.

OPW written communication advises erosion is occurring at flood relief asset Sluice#24, situated approximately 240m upstream from this location, with properties on both banks of the River Newport at risk of flooding. No dates were provided, but flooding has historically breached the embankment to the north-east near ITM: 570530, 661643 flowing overland to flood properties near Sluice#24.



Figure 4-44 Example channel bed material.



Figure 4-45 Second and third stages of the channel (right bank looking upstream).



Figure 4-46 Channel reinforcement boulder material (looking across to left bank).

4.3.3 Newport Town Bridge spot check

Upstream from the road bridge the Smalt River and Newport River confluence, both streams are cobble bed at this location (ITM: 572468 662232, Figure 4-47). Generally, the river appears to be deeply incised and the immediate floodplain is inset well-below adjacent floodplain and land; this may be due to anthropogenic modification with church buildings upstream of the bridge set at a lower level and evidence of potentially ancient accessways/steps to the river.

Downstream from the bridge the riverbed is again much lower than adjacent floodplain and a large bedrock outcrop is observed with cascading bedrock-pool type features (Figure 4-48). Whilst morphologically interesting the character of the river upstream and downstream further suggests anthropogenic modification may be the overriding process for exposing the bedrock.

Further downstream from the bedrock outcrop the river exhibits an anabranching gravel-cobble type morphology with coarse sediment mid-channel bars, some of which have established vegetation. The character of the river both upstream and downstream of the bedrock outcrop suggests that the Newport River should have a cobble bed at this location, but this cannot establish as the outcrop is transportation before the channel gradient reduces and cobbles are deposited downstream the mid-channel features.



Figure 4-47 Confluence of Newport and Smalt upstream from bridge.



Figure 4-48 Bedrock outcrop before gravel deposition.

Further downstream from the outcrop and focused towards the channel margins, very large boulder sized material >600mm diameter (b-axis approximation) was abundant

(Figure 4-49). Mosses and lichens shroud the particles suggesting it is highly immobile and likely glacial in origin. This observation supports the theory that the bedrock outcrop is exposed due to anthropogenic modifications as the glacial material is no longer overlain by the alluvial sediments, due to incision or gravel extraction. Generally, the reach is likely to transport fine to gravel-pebble sized material downstream.



Figure 4-49 Left bank downstream boulder sized material.

4.3.4 Newport 3

The Newport 3 planned location could not be readily accessed, and the location was moved to a road bridge location upstream from the planned location (ITM: 575272 664680).

Coarse sediment is abundant within the bed of the river, typically gravel-pebble to cobble sized material but mid-channel bars forming from finer material are also present (Figure 4-50). The channel again exhibits anabranching characteristics with mid-channel bars and several low-flow channels.

Coarse sediment, where visible, was generally clean or fresh in appearance and lacking typical signs of immobility, suggesting that it is regularly transported (Figure 4-50 and Figure 4-51).

Silty material is visible across some of the riverbed in the form of a thin veneer; this is contrasting to the visibly clean coarse sediment, suggesting that like elsewhere within the Mulkear catchment this location is depositional during the normal flow duration curve and transportational during high flow events.

Bank reinforcement comprising concrete block construction is evident on the right bank downstream from the bridge and the base of the bridge is also exposed suggesting that local bed material is scoured out from the structure (Figure 4-52). The bridge is not being undermined however and some finer gravel sized material is deposited around the bridge piers.

Dense riparian trees comprising shrubs and deciduous trees provide shading and will provide some bank stability to the channel at this location.



Figure 4-50 Mid-channel, partially vegetated bar feature upstream from anabranching Section.



Figure 4-51 Silty veneer visible on some sections of channel bed.



Figure 4-52 Base of bridge is visible and gravel sediment deposited around pier.

4.3.5 Newport 4

The reach is downstream from an access bridge that is assumed to have been constructed to provide access to forestry areas further upslope within the catchment (ITM: 580206 668734).

The reach is characterised by gravel-pebble to cobble sized material with banks approximately 300-500mm above the channel bed (Figure 4-53 and Figure 4-54). The reach appears to have been straightened historically likely due to agricultural land use. The main channel reach displays signs of attempting to becoming more sinuous, whilst remaining single thread.

A single secondary low-flow channel exists adjacent to the left bank, but unlike elsewhere on the river this does not appear to be part of a developing anabranching system.

A large ~3m high coarse sediment feature exists above the right bank and this is most likely to be dredging arisings (Figure 4-54). This material is vertically triangular and trapezoidal in longitudinal shape. Removal of this material may be starving the downstream reaches of coarse sediment preventing an anabranching system from fully developing.

Generally, the river at this location appears to have greater floodplain connection than elsewhere on the Newport and whilst the bed is below the riverbanks, some bank locations are shallower allowing more regular inundation.

Poaching is evident but is less extensive than elsewhere within the Mulkear River catchment and no large stands of invasive plants were observed.

Bankside vegetation generally comprised short grass-type plants with some scattered trees occupying both left and right banks.

The reach appears generally depositional, this may partially be due to the extraction of the channel bed which prevents the river from creating a more transportational main flow channel geometry.

A riffle-pool feature existed downstream from the confluence of the small secondary channel and the main-flow (Figure 4-55).



Figure 4-53 Small secondary channel on left bank.



Figure 4-54 Shallow channel flow with large potentially dredged material store on right Bank.



Figure 4-55 Confluence of secondary channel and main channel with riffle-pool sequence.

4.4 River Annagh

The River Annagh is generally characterised by low gradient and wide reaches with a gravel-pebble sized coarse sediment bed. Invasive species comprising Giant Hogweed and Himalayan Balsam are prevalent within the catchment.

4.4.1 Annagh 1

Annagh 1 exhibits a wide gravel bed throughout a reach characterised by engineered vertical banks with a road bridge structure and piers in the channel towards the centre of the reach (ITM: 570841 659380). The channel substrate is generally gravel-pebble sized material with some sand sized material towards the margins and adjacent to the bridge pier locations associated with lower velocity and deposition.

Flow depth was around 300mm during the day of survey on the stage board at the bridge (Figure 4-56), however depth varied through the channel and was generally shallow.

Further downstream from the bridge a shallow pool-riffle sequence was observed. Banks, where not vertical, were ~45-degree and covered with a mix of mature deciduous trees and smaller shrubs.

Gravel bar features were abundant indicating coarse sediment is stored within the reach during normal flows; clean particles suggest these bars are regularly mobile (Figure 4-57). Fine sediment was present in several locations, although not abundant and is likely to be transported through the reach during the majority of flows.

Discussion with OPW confirms the reach further downstream from the location has very steep banks, including steep flood embankments. A mixture of invasive species prevalent throughout the catchment are common in the reach downstream.



Figure 4-56 Looking from bridge to downstream pool-riffle sequence.



Figure 4-57 Typical bar and bed substrate composition.

4.4.2 Annagh 2

This reach (ITM: 573202 659913) was geomorphologically different to elsewhere on the Annagh and other sites visited within the Mulkear River.

The river is characterised by a high and low energy bedrock cascade and pool sequence, deeply inset around 30m below bank tops within a bedrock gorge (Figure 4-58, Figure 4-59 and Figure 4-60). Some minor remnant bridge structures cast into the bedrock suggest anthropogenic modification, potentially past mine workings, but there is generally little evidence of specific land use changes (Figure 4-61).

Where individual clasts of sediment are present these are large boulder type sediments and may be either glacial in origin or rearranged locally during extremely high flows.

Organic material has accumulated within channel margins and is being stored within areas of the channel where velocity approaches zero, however it is assumed this material will be washed downstream during high flows. The reach is generally transportational due to high energy flow occurring throughout all times of year and a general lack of stored sediment.

On the banks a mix of ferns and low shrubs were observed and the tall deciduous tree canopy covers most of the river channel.



Figure 4-58 General character of reach.



Figure 4-59 Cascading and step-pool bedrock features.



Figure 4-60 Additional bedrock and boulder step pools.



Figure 4-61 Although difficult to see, centre feature appears to be an old bridge footing indicating this reach may have historic mining usage.

4.4.3 Annagh 3

This site exhibited characteristics more typical of elsewhere within the Mulkear River catchment, with a single thread river channel approximately 2m below top of bank and a gravel/cobble bed substrate (ITM: 577630 659790).

Surrounding land use within the wide-flat valley is generally anthropogenic with forestry dominating the hillslopes. The forestry land cover was on typically sandy ground material with some minor gravel-pebble material within the matrix (Figure 4-62).

The adjacent low-lying valley floor is assumed to be regularly inundated as the habitat template was scattered with aquatic reed/grass species (Figure 4-63). Although where surveyed the river was approximately 2m below top of bank, potentially it is well connected elsewhere and/or groundwater connectivity is greater within this reach.

Drone survey showed that both upstream and downstream of the bridge location a distinct pool-riffle sequence has developed with anabranching flow occurring at one bar location (Figure 4-64).



Figure 4-62 Forestry on top of sandy substrate with some gravel-cobble material.



Figure 4-63 Annagh River floodplain with aquatic plants.



Figure 4-64 Drone imagery upstream from Annagh 4 bridge. Riffle-pool sequence with anabranching flow on bar and fencing to protect riparian strip from horses (not known if this is intentional).

Within the forestry area, there are many hillslope streams, characterised by cobble beds and the winnowing away of finer sediment during rapid runoff events. Due to the prevalence of these streams within the large amount of forest areas, they will contribute a large amount of finer sediment to the Mulkear River catchment. A useful analogue site for potential sediment runoff control was observed at one of these streams; a log-jam feature had formed at a break in channel long-profile, where the hillslope stream had begun to

plateau. Upstream from this feature there was deposition of smaller gravels, sand and fine sediment, downstream this type of finer sediment was significantly less abundant (Figure 4-65).

Whilst widespread application of this technique would be required to have a notable effect, the relative simplicity and local availability of woody material could mean that introducing widespread small logjams within forestry areas could provide a cost-effective natural management solution.

OPW communications with National Parks and Wildlife Services (NPWS) ranger in the area indicates that forestry activity is a known contributor to turbidity within the Mulkear.



Figure 4-65 Small logjam with fine and fine-gravel deposition upstream.

4.4.4 Annagh 4

Annagh 4 is the most upstream reach surveyed and is rural in character with forestry further up the valley hillslopes away from the survey area (ITM: 582528 662217). The reach is characterised by a single-thread embanked watercourse, with a gravel-cobble bed substrate. Several access and farm track structures are located within the reach, which typically have deposits of cobble sized material downstream.

Riverbanks are typically characterised by short grasses, with some scattered aquatic grass/reed species. The bank sediment is much sandier than the bed and the riverbanks are around 500mm or greater above the channel bed; the sand type material appears to be overbank deposition (Figure 4-66). This overbank deposition suggests that the floodplain is aggrading and disconnecting the river channel further from the floodplain. However, a kick test indicated that bank sediment is relatively crumbly, during winter and vegetation dieback it is likely that some of this sandy bank material could readily erode and contribute a large sediment pulse to the Mulkear River catchment. Some wooded debris was situated on top of the river bank deposits, this was not locally sourced and is potentially flood supplied.

Riverbanks of the Annagh were poached by cattle and the interaction between the river and the fine sediment source was strongly evident in this reach (Figure 4-67).

The gravel cobble bed did indicate signs of morphologically diverse flow, with the start of a riffle-pool sequence and some energetic run typology (Figure 4-68).

Although observed only at this site, the landowner was undertaking works on a large portion of land for construction; entire fields of fine sediment were exposed and runoff pathways were visible to local road gullies (Figure 4-69). There were no visible measures in place to control fine sediment runoff. Should this type of practice occur elsewhere within the catchment it could be a cumulative issue for fine sediment input.



Figure 4-66 Overbank sandy-silty deposits. Some aquatic grass species visible.



Figure 4-67 Bankside poaching to the River Annagh and Condition of Bed at Location.



Figure 4-68 Start of riffle-pool sequence looking downstream.



Figure 4-69 Landowner construction works and exposed fine sediment.

A local tributary feeding the Annagh at this location had similar characteristics, although was more deeply incised (~2m). Channel banks had fine sediment exposed and are a likely source during high flow (Figure 4-70).



Figure 4-70 Tributary draining into Annagh with fine sediment and incision issues.

4.5 Wolman Pebble Counts

As safe access to the river channel was limited, widespread sediment sampling has not been undertaken. However, five Wolman pebble counts samples were undertaken on bar features within the Mulkear catchment to help characterise the coarse sediment distribution within the system. The coarse sediment distributions at each of the five locations is summarised in Table 4-1.

Table 4-1 Wolman Pebble Count Statistics.

Site	X (ITM)	Y (ITM)	Particle size percentile (mm)		
			D15	D50	D85
Annacotty Weir (left bank bar)	564270	657625	4.1	15.2	24.4
Bilboa 2 (mid channel bar)	579715	651660	23.9	55.9	85.5
Newport 4 (left bank/central bar between secondary channel and main flow)	580206	668734	13.8	31.5	58.0
Annagh 1 (left bank bar)	570841	659380	7.3	13.5	21.1
Annagh 4 (right bank bar)	573202	659913	19.9	39.7	71.2

The Wolman pebble count statistics illustrate the distribution of sediment sizes of the sampled sizes by classifying these into percentiles, the D15 percentile is the calculated particle size which 15% of the sample density is finer than, the D50 is the 50% or median particle size which half of the sample density is finer than and as such there is only 15% of the total sample density larger than the D85. The largest sediment sizes overall were

found within the Bilboa river, which corresponds with the verbal recommendation from Ruari O'Conchuir that this is a source of coarse sediment to the Mulkear.

The majority of the material downstream of Annacotty weir is finer than elsewhere in the catchment, it is likely this material is readily mobilised during high flows and transported further downstream.

4.6 Hydromorphological pressures

Hydromorphological pressures are defined as activities (historical or modern) that influence the natural form and function of a river. The field survey identified several pressures at the survey locations within the Mulkear river and tributaries, which are likely to be affecting the natural sediment erosion, transport, and deposition processes within the catchment. These include:

Channel modification including changes to river planform (such as straightening) and dredging activities that maintain a desired channel geometry. These kinds of channel modifications can create over-deepened rivers that are less connected to their floodplain, meaning flows are contained primarily in-channel creating more potential for bank and bed erosion. Dredging can also destabilise banks, raising the risk of slumping during high flow conditions. Suspected dredging activities were observed on the Newport River and are known to occur at the flood relief channel on the River Bilboa near Cappamore. Dredging does not typically form part of arterial drainage maintenance activities. However, silt and debris may have been removed from the channel as part of maintenance activities to maintain conveyance capacity and bed levels as per the scheme drawings. Floodplain disconnection was evident at each of the tributary systems and along the Mulkear main stem.

Impoundments are created by in-channel flow regulating structures (such as weirs) and were observed at all rivers in the Mulkear catchment except the Annagh. Large impoundments were observed at Annacotty Weir on the Mulkear, and at the weir and gravel trap structures on the Bilboa at Bilboa 2. These structures create low energy environments upstream and affect the continuity of downstream sediment transport. The weir at Bilboa appears to be restricting the transport of cobble sized material downstream.

Bank protection measures are designed to prevent natural bank erosion processes and lateral movement of a river by enforcing a desired planform. By restricting natural sediment processes, these measures can prevent the development of in-channel depositional geomorphological features and therefore disrupt the river's natural supply and storage dynamic. Boulder-reinforced banks and timber bank protection measures were observed on the Newport River. That several of the timber protection measures are failing indicates that lateral migration is a natural part of how this system manages its sediment supply, and efforts to constrain these processes are not sustainable.

Evidence of **poor sediment management** related to construction at a property in the Annagh catchment was observed and could be indicative of practices elsewhere in the wider Mulkear catchment. Without adequate runoff management to manage flow pathways into watercourses, such works can act as sources of fine sediment.

A **lack of stock fencing** leaves banks vulnerable to frequent disturbance, leading to unstable and more easily eroded and collapsible banks. This bank poaching creates additional fine sediment inputs to the channel and, consequently, higher rates of in-channel siltation. Multiple examples of unfenced banks were observed in the Mulkear catchment across all tributaries and the Mulkear River main stem.

Invasive non-native species not only present a management challenge for biodiversity but can also leave riparian zones and banks exposed during winter dieback, leaving them more vulnerable to erosion. Himalayan Balsam, Giant Hogweed and Japanese Knotweed were observed particularly along the Mulkear River, Newport River, and River Annagh.

Forestry is a key land use in the upland environments of the Newport, Annagh, and Bilboa tributaries and is potentially linked to excessive sediment supply. In general terms, concerns between forestry and sediment issues relate to land drainage practices and the

type of felling management regime employed. Firstly, the installation of new drainage channels and/or straightening of natural channels is likely to funnel more water into the river network and create additional opportunities for erosion. Secondly, felling and post-felling practices that are not supported by robust fine sediment management have been linked to elevated concentrations of fine sediment in other Irish rivers (EPA, 2016). Many hillslope streams were observed in the upland Mulkear catchment that exhibited evidence of fine sediment being eroded from the bed that would be transported downstream during rapid runoff events. Forestry is therefore identified as a possible source of excess fine sediment in the Mulkear catchment.

4.7 Summary

The walkover of the Mulkear River and tributaries has identified several key locations where sediment is stored, sourced and potential transport reaches. The main catchment-wide observations are:

- The presence of embanked rivers which will increase bankfull river flow and sediment transport.
- Invasive species vegetating banks which will out-compete natural vegetation and leave bank sediments exposed during winter.
- Poaching of banks is widespread but tends to be localised to point sources.
- Evidence of historic and ongoing dredging practices will disrupt sediment transport and prevent the rivers from reaching equilibrium conditions.
- Excessive fine sediment input appears to be sourced from forestry runoff (e.g. as captured behind the log jam located within the Annagh catchment) and the River Deed.
- There is evidence of notable erosion of some embankments at the Mulkear Ballymackeogh Flood Relief Scheme.

Coarse sediment is abundant within the Mulkear River catchment, downstream fining is evident from review of the Wolman pebble counts undertaken, with finer material downstream from the Annacotty weir than elsewhere in the catchment. The site observations and particle size measurements undertaken confirm that coarse sediment is also likely to be contributing to sedimentation within the Old Shannon, however it is likely to be sand to fine gravels (2-16mm typical b-axis size) rather than larger gravels to cobble sized material (>64mm typical b-axis size).

5 OPW Known Catchment Issues

Following initial completion of the draft fluvial audit report OPW held a meeting with JBA and provided comments on known catchment issues which were not included within the walkover visits. The additional information has been included within this section to improve catchment knowledge. Locations are outlined at Figure 5-1.

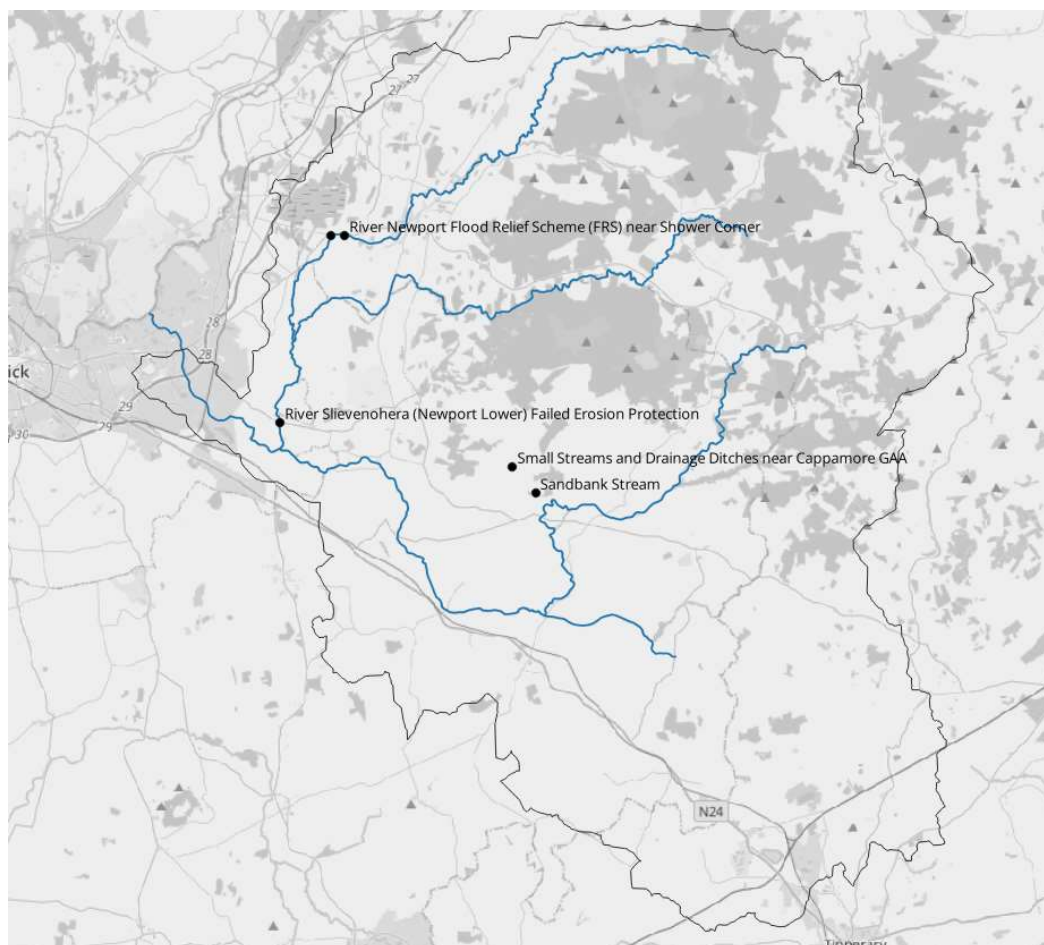


Figure 5-1 Locations of known catchment issues.

5.1 River Newport Flood Relief Scheme (FRS) near Shower Corner

A section of the River Newport from ITM: 570224, 661875 to 569737, 661855 has embankments which are poorly built, have been eroding, and are slipping into the river. OPW and JBA Ireland visited the site during week commencing 10 April 2023, flows were relatively elevated, so many of the slippages could not be safely, or clearly seen.

Channel and bank substrate visible were sandy clays.



Figure 5-2 Bank slippages along the River Newport.



Figure 5-3 Bankside fencing/protection which is slipping into the River Newport.

5.2 River Slievenohera (Newport Lower) Failed Erosion Protection

A section of the Newport River immediately upstream from the R506 road ITM: 567867, 654980 was visited during week commencing 10 April 2023, flows were relatively elevated, so much of the failed erosion protection is difficult to see.

Here bank slippages occur due to erosion behind failed timber ramparts, previously installed to provide erosion protection, OPW advised lots of tree growth in-channel.



Figure 5-4 Bank Slippage happening on River Slievenohera.



Figure 5-5 River Slievenohera has eroded behind failed timber ramps.

5.3 Small Streams and Drainage Ditches Near Cappamore Gaelic Athletic Association (GAA) Grounds

OPW written communication (April 2023) identified that local minor tributaries near the Cappamore GAA (ITM: 577055, 652362) are subject to ongoing processes. One tributary is perched and the embankment is eroding near ITM: 576418, 653350, another known locally as Sandbank Stream has regular silt and gravel clearance reported near ITM: 577269, 652300.

A linear channel flanking the southern extent of the GAA ground near: 576990, 652326 has very low flow and siltation is an ongoing issue, this requires cleaning infrequently.

6 GIS analysis

6.1 Overview

A detailed Geographical Information Systems (GIS) analysis has been undertaken to assess potential sediment sources and transport routes throughout the Mulkear catchment. The full analysis is presented within Appendix A and is summarised here.

The analysis corroborates information from the following datasets:

- Estimated river energy i.e. Specific Stream Power (SSP) calculated using a catchment wide dataset of the Index Flood (QMED) calculated from OPW Flood Studies Update data, local topographic slope and published equations.
- OPW FSU map of river lines.
- Land cover mapping (CORINE) to identify key locations of fine sediment input.
- An estimate of potential sources of coarse sediment (Geological Survey Ireland Quaternary Geomorphology Layer, adapted to a map of coarse sediment sources).

QMED is used here as an approximation for bankfull conditions and is assumed to represent the maximum energy condition of the river channel during flood conditions.

Site observations have been used to validate or contrast the GIS analysis findings.

The process follows a categorical approach whereby the map of river lines are overlain with the different datasets described above, rankings from 1 to 3 are given to each of the following categories: 1) river energy (SSP); 2) sinuosity; 3) potential for fine sediment input; 4) potential for coarse sediment input, and; 5) likely river confinement. Within each category the parameter is assigned a ranking from 1 to 3 (i.e. 1 = low, 2 = medium, 3 = high), which are then integrated to produce a final matrix of values for fine sediment erodibility and coarse sediment availability (see Tables A-5 and A-6). The fine sediment erodibility score for a given reach was based on the input scores for potential for fine sediment input and SSP. Sinuosity and the potential for coarse sediment input were used to define likely river confinement which was then used as an input, along with SSP and the potential for coarse sediment input, to determine the final reach scores for coarse sediment availability. This methodology has then been summarised as a catchment-wide conceptual model to identify locations which are likely to provide sediment inputs and/or transport delivered sediment further downstream.

6.2 Outputs

The key output from the GIS analysis was a map of the overall erosivity, or potential for sediment transport and supply, across the Mulkear River catchment. This GIS result shows consistent results with the field survey, with high yield and erosion shown within the uplands and moderate erosion/transport shown within the lower reaches. Interestingly most of the Mulkear mainstem is shown as high transport/erosional, again agreeing well with site observations and concluding that the sediment transport regime is likely imbalanced towards erosional, with at least finer material being readily transported through the catchment.

During the field survey, downstream of Annacotty Weir was identified as likely to store coarse sediment under normal flow conditions that were observed (see shaded triangles in Figure 6-1). This GIS analysis, by focusing on QMED/bankfull flow, has identified this reach as erosional at higher flows. The hydraulic modelling planned as part of this overall package of work will also examine this reach and provide further clarity on how sediment may be interacting with the channel here.

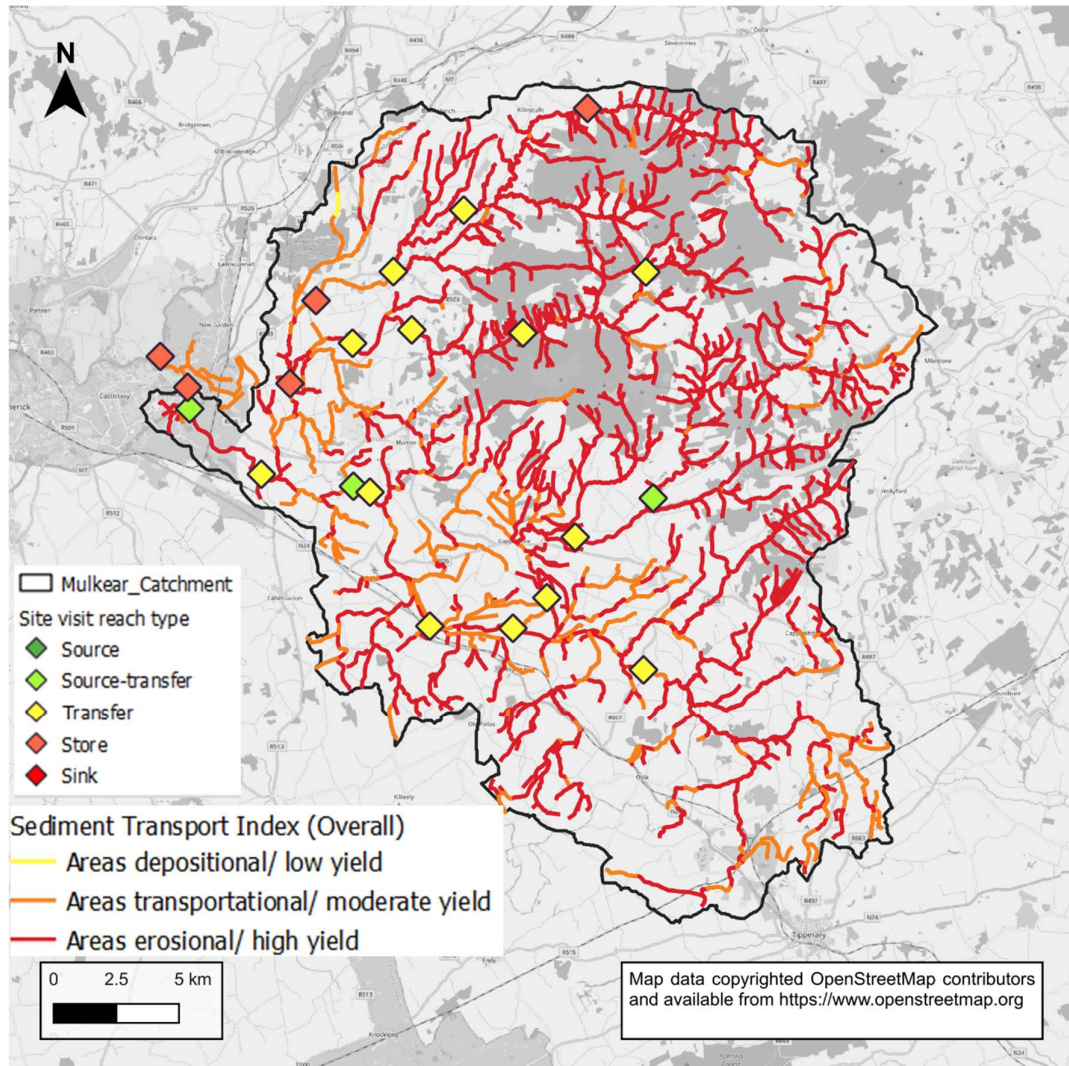


Figure 6-1 Potential for Sediment Transport and Supply across the Mulkear Catchment (Nb. Site visit reach classification is for normal flow conditions)

7 Conceptual Model of the Mulkear catchment

7.1 Conceptual model (Mulkear catchment)

The analysis shows that the majority of the catchment is considered transport competent, meaning that most finer grade sediment delivered to the Mulkear is likely to be transported into the Old Shannon, larger calibre coarse sediment is likely to remain stored in the Mulkear as bar features. The upper reaches of the catchment, which consist of upland forested areas are identified as providing significant amounts of sediment to the catchment. These two findings agree well with site observations. The conceptual catchment model is provided in Figure 7-1.

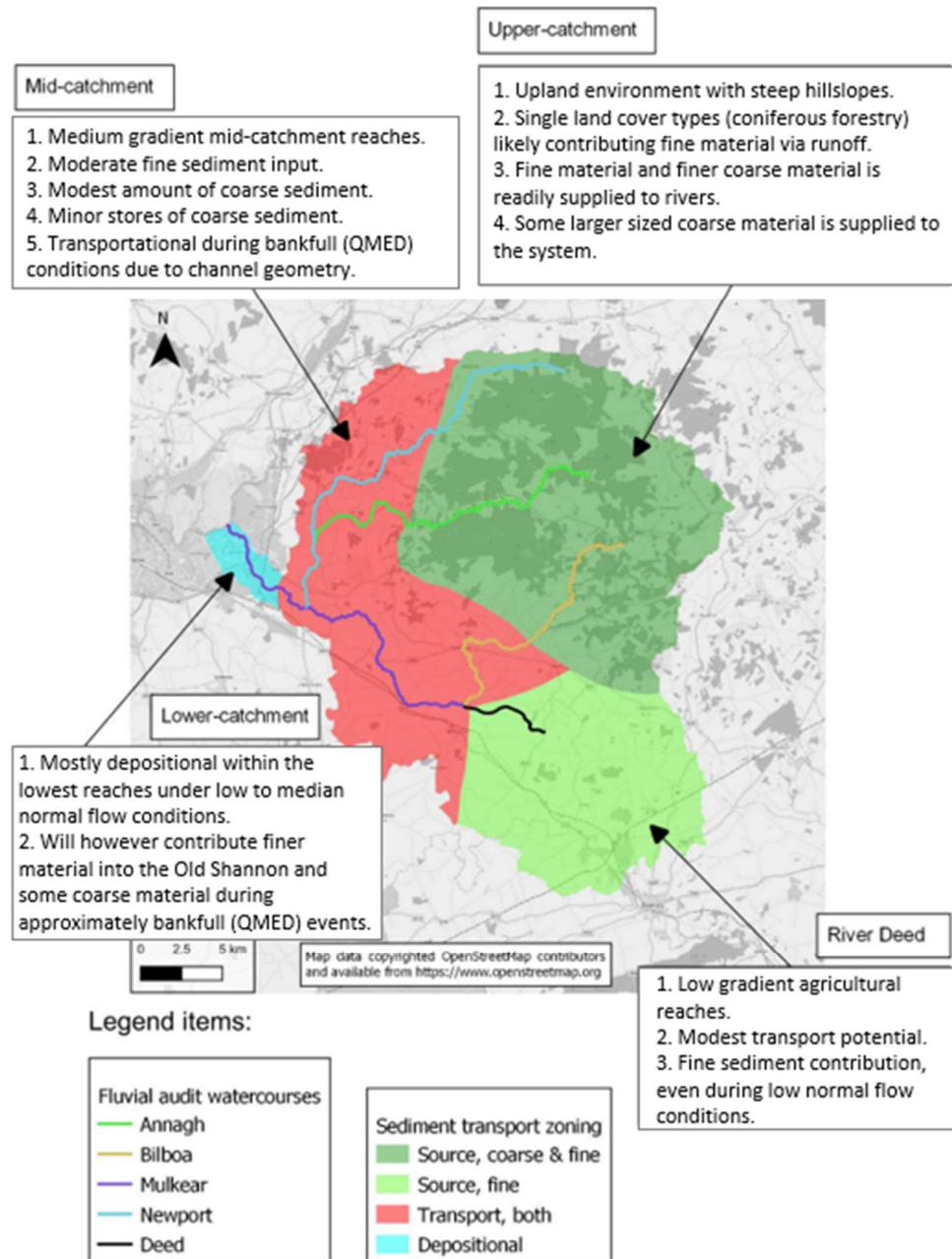


Figure 7-1 Conceptual Catchment Model.

8 Conclusions

This assessment suggests that the Mulkear is contributing both fine and coarse sediment to the Old Shannon and that both sediment classes are potentially contributing to the ongoing sedimentation within the Old Shannon downstream from the Mulkear confluence.

Site observations and GIS broad scale mapping indicate that upland reaches are likely contributing a large amount of sediment to the catchment, this could potentially be managed through natural methods.

Management of fine sediment introduction into the channel is likely to be dependent on multiple measures, these comprise of:

- Addressing upland fine and small calibre coarse sediment input, potentially through the use of log-jams to block runoff pathways and increase upland deposition.
- Management of fine sediment input from the River Deed, the source of fine sediment to the Deed itself is not known, however it is assumed to be from agricultural practices due to the land use within the catchment.
- Management of bankside poaching to prevent local sources of fine sediment. This could include creating localised drinking access for livestock which is fenced off from the main river flow to break the pathway of fine sediment.
- Management of agricultural fields adjacent to the Mulkear and its tributaries to prevent contribution of fine sediment from overland flow during rainfall runoff events.
- Changes to the cross-sectional geometry of the Mulkear River to reduce the bankfull flow energy and thus reduce the likelihood of fine sediment being eroded from the banks during high flow events. This could include creation of inset floodplain areas to encourage localised deposition of sediment, rather than transporting it directly into the Old Shannon.
 - This approach may be particularly constrained where the Arterial Drainage Act requires the river (defences) to remain in effective condition and repair.
- Bankside planting of native species where areas of exposed fine sediment are identified to prevent further erosion.
- Development of an invasive species plan. Invasive species, particularly Himalayan Balsam and Giant Hogweed are prevalent throughout much of the catchment. These species out compete native plants and leave riverbanks exposed and prone to erosion during high flow events. Although challenging, ongoing management and ideally permanent removal of these species is likely to be required to address fine sediment delivery from riverbank erosion.

9 Recommendations

This fluvial audit identifies key sources which are contributing to sediment delivery to the Old Shannon from the Mulkear River.

Key locations are identified which could be targeted to improve not just sediment delivery to the Old Shannon, but the overall hydromorphology of the Mulkear Catchment:

- Reducing the bankfull river energy of the incised and dredged reaches which may also increase the area available for temporary flood storage,
- Blocking sediment delivery pathways in the uplands to prevent fine sediment delivery,
- Removing invasive species within the catchment which will reduce bank sediment exposure during dieback and increase local biodiversity if coupled with planting of native species.

Hydraulic modelling is ongoing, when initial model is developed it will be used to test options to understand their impact on local and catchment scale sediment transport dynamics.

Once reviewed by the OPW this study should be used to produce a list of measures which are viable when considered alongside other constraints within the Mulkear Catchment. The two principal constraints which may influence option selection are likely to be landowner consent and cost associated with any large-scale works.

10 References

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A GIS Conceptual Analysis

The catchment conceptual geomorphological model applies a GIS based methodology and uses a stream power indexing-based approach similar to Bizzi and Lerner (2015) to map potential erosion/sediment source hotspots within a river catchment.

The outputs from the model are overlain with key sediment transport typologies observed during the site walkover to validate or contrast predictions made with the GIS exercise.

The outputs from the model should assist with informed decision making about sediment management decisions within the Mulkear River catchment and provide a wider understanding of how specific locations may influence processes elsewhere within the catchment.

A.1 Methodology

A detailed Geographical Information Systems (GIS) analysis has been undertaken to assess potential sediment sources and transport routes throughout the Mulkear catchment. The full analysis is presented within Appendix A and is summarised here.

The analysis corroborates information from the following datasets:

- Estimated river energy i.e. Specific Stream Power (SSP) calculated using a catchment wide dataset of the Index Flood (QMED) calculated from OPW Flood Studies Update data, local topographic slope and published equations.
- OPW FSU map of river lines.
- Land cover mapping (CORINE) to identify key locations of fine sediment input.
- An estimate of potential sources of coarse sediment (Geological Survey Ireland Quaternary Geomorphology Layer, adapted to a map of coarse sediment sources).

Site observations have been used to validate or contrast the GIS analysis findings.

The process follows a categorical approach whereby the map of river lines are overlain with the different datasets described above, rankings from 1 to 3 are given to each of the following categories; 1 river energy (SSP), 2 sinuosity, 3 potential for fine sediment input, 4 potential for coarse sediment input and 5 likely river confinement. The rankings for the various categories are then compared by averaging to create a scale ranking (again 1, 2 and 3; i.e. low, medium and high) for fine sediment erodibility and coarse sediment availability. This methodology has then been summarised as a catchment-wide conceptual model to identify locations which are likely to provide sediment inputs and/or transport delivered sediment further downstream.

Specific stream power is a measure of river energy and is a useful indicator of identifying locations which may be prone to erosion (Bagnold, 1966 & 1977; Bizzi and Lerner, 2015). Total stream power is defined as:

$$TSP = \rho g Q S$$

Where TSP is total stream power (W), ρ is the specific weight of water (1000kg/m³), g is the acceleration due to gravity (9.81 m/s²), Q is river discharge (measured or estimated, m³/s) and S is bed slope taken to mean energy gradient.

Specific stream power is total stream power indexed against river width. This is a much more useful indicator than total stream power as it provides an estimate of stream energy dissipated against the wetted channel. The greater the value of SSP the larger the potential for erosion or sediment transport potential exists. Specific stream power is defined as:

$$SSP = \frac{TSP}{W}$$

Where SSP is Specific Stream Power (W/m), W is river width (m), as estimated or measured and TSP is as above. The calculated SSP is shown in Figure A-1.

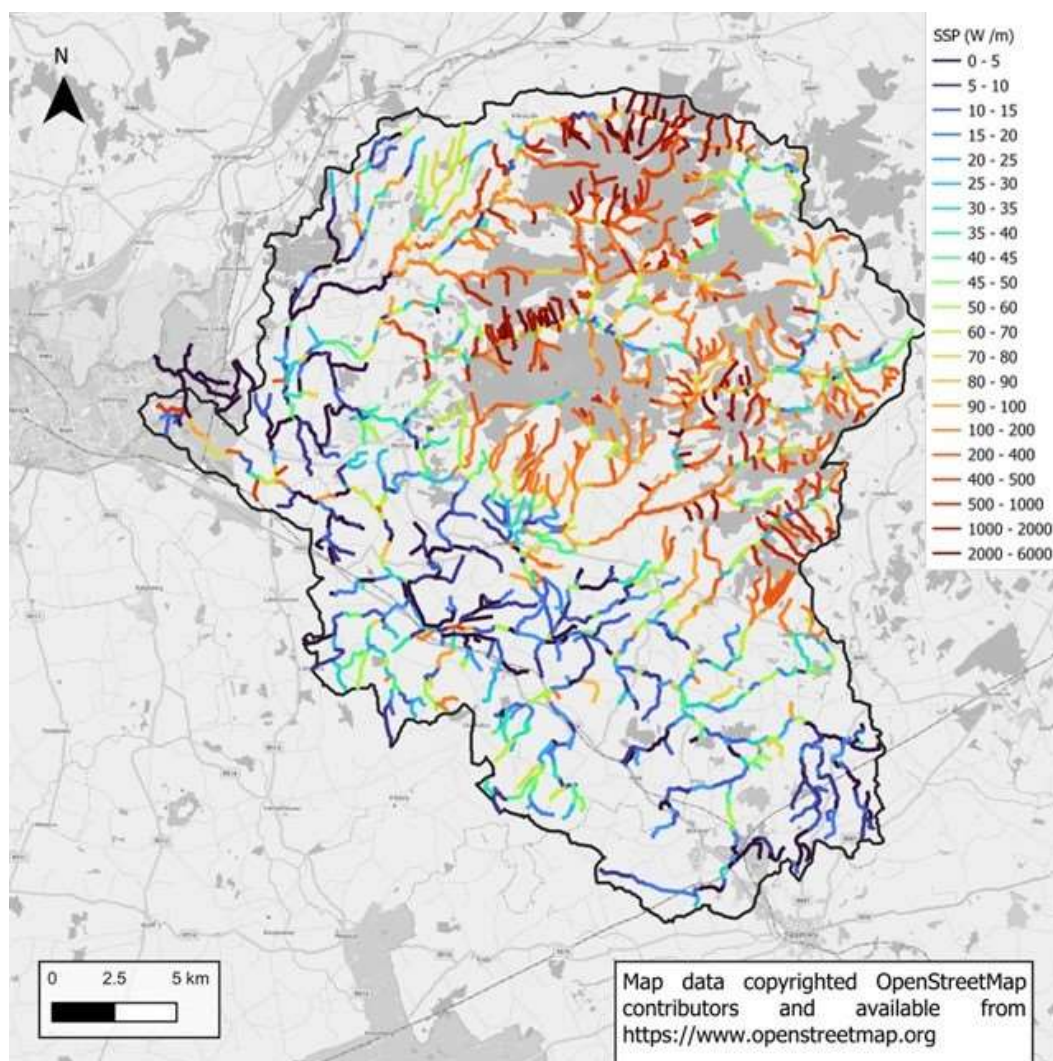


Figure A-1 Specific Stream Power calculated across the Mulkear catchment for the QMED flow (W/m).

A.1.1 QMED

The underlying data driving a catchment wide estimate of specific stream power is an estimate of bankfull river flow throughout the catchment; this dataset simply isn't available for the Mulkear catchment. The EPA Flood Studies Update FSU data portal includes a dataset which has catchment descriptors that can be used to produce an estimate of QMED at locations throughout the Mulkear River Catchment, this dataset was downloaded in September 2022; 1614 QMED estimate locations were investigated for the analysis.

The OPW FSU guidance on calculation of QMED was followed and the equation for QMED rural which is described in presentation 04 – Calculation of the Index Flood (Nicholson & OPW, 2014) was undertaken. It is recommended that estimates are adjusted using a pivotal site, however this was not done for two reasons:

- Pivotal sites would vary dependent on location within the Mulkear Catchment and undertaking a pivotal site analysis for 1614 locations would be significantly time inefficient.
- Applying different pivotal site adjustments would not allow for a uniform methodology of QMED estimate across the catchment.

- The QMED rural estimate considers rainfall, catchment slope, drainage density, an index of arterial drainage, flood attenuation from reservoirs and lakes, and soil type.

A.1.2 Slope

A GIS analysis was undertaken to derive slope based on river lengths and underlying elevation.

The FSU river lines for the Mulkear catchment (downloaded September 2022) were used to determine length, but these were first split at the locations of the 1614 FSU QMED estimation points to allow multiple estimates of slope throughout the digitised river extent. Splitting at QMED points also allows a more specific QMED estimate to be assigned to each line section of the tributary, rather than a generalised estimate for the whole line.

The Ireland 5m DTM provided by the OPW was used to provide elevation estimates, LiDAR exists for the lower reaches of the Mulkear, however not enough of the catchment is covered to provide consistent estimates of slope throughout so the 5m dataset was adopted.

A.1.3 River Width

A freely available dataset to derive river width is not available for the Mulkear River, or more widely Ireland. As such, a regime style equation from Hey and Thorne (1986) has been adopted to provide an estimate of river width based on QMED. The equation is presented below:

$$RW = 3.42 \times Q_{med}^{0.46}$$

Where *RW* is river width (m), and *Q_{med}* is an estimate or measurement already obtained (m³/s), in this case from the FSU estimate based on catchment descriptors. Whilst this approach is limited in that the river width estimate is theoretical rather than measured, it provides a relative estimate against QMED which allows a broad comparison of how energy within the river catchment varies spatially.

A.1.4 Fine Sediment Generation

To provide an indication of the potential fine sediment generation into the Mulkear River a land-use based approach has been followed. The CORINE land cover map (2018) has been used to assign landcover information to the FSU river lines in GIS. Potential fine sediment contribution to the Mulkear River catchment has been classified as Low, Medium or High based on the landcover classes in the Mulkear River. Assumptions have been made to simplify the landcover types into the rankings based on general landcover types, alongside site observations, i.e., forestry is understood to contribute large amounts. The landcover types and associated fine sediment contributions are provided below:

Table A-1 CORINE land cover for the Mulkear Catchment and assumed fine sediment input.

Landcover type	Contribution
Discontinuous urban fabric	Low
Industrial or commercial units	Low
Road and rail networks and associated land	Low
Mineral extraction sites	Moderate
Dump sites	Moderate
Sport and leisure facilities	Low
Non-irrigated arable land	Moderate
Pastures	Moderate

Complex cultivation patterns	Moderate
Agriculture with natural vegetation	Low
Broad-leaved forest	Low
Coniferous forest	High
Mixed forest	Low
Natural grasslands	None
Moors and heathland	None
Transitional woodland-shrub	Low
Sparsely vegetated areas	High
Inland marshes	None
Peat bogs	None
Water courses	None
Water bodies	None

A.1.5 Coarse Sediment Typology

To determine both the potential for coarse sediment to be input into the Mulkear River catchment via in-channel erosion, and to help produce an indicator for potential channel stability, an estimate of the coarse sediment strata was required. The Geological Survey Ireland Quaternary Sediments shapefile was utilised to provide a simplified landcover map of coarse sediment typology within the Mulkear River, again similar to coarse sediment generation, a rating was applied depending on likelihood this sediment type could be eroded. Due to the amount of different lithologies, these were first classified into common types, e.g., gravel, till, sand before determining erodibility.

Resistant types were given a score of 1, moderately erodible a type of 2 and erodible a type of 3, the associated lithology and scores are shown below.

Table A-2 Coarse sediment erodibility.

Lithology	Class	Erodibility
Eskers comprised of gravels of acidic reaction	Gravel	Erodible
Gravels derived from Devonian sandstones	Gravel	Erodible
Gravels derived from Limestones	Gravel	Erodible
GLPSsS, Gravels derived from Lower Palaeozoic sandstones and shales	Gravel	Erodible
Scree	Gravel	Erodible
Lacustrine sediments	Gravel	Erodible
Spoil Heap	Gravel	Erodible
Alluvium	Alluvium	Moderately Erodible
Till derived from basic igneous rocks	Till	Moderately Erodible
Till derived from Devonian sandstones	Till	Moderately Erodible
Till derived from limestones	Till	Moderately Erodible
Till derived from Lower Palaeozoic sandstones and shales	Till	Moderately Erodible
Till derived from Lower Palaeozoic and Devonian sandstones	Till	Moderately Erodible
Till derived from Namurian sandstones and shales	Till	Moderately Erodible
Kartsified bedrock outcrop or subcrop	Bedrock	Resistant

Urban	Manmade	Resistant
Blanket Peat	Peat	Resistant
Cut over raised peat	Peat	Resistant
Fen Peat	Peat	Resistant
Water	Water	Resistant

A.1.6 Confinement

Establishing confinement at catchment scale is relatively complex, as such a simplified method has been adopted which considers the coarse sediment typology and sinuosity of the river. The approach follows the assumption that a sinuous river flowing through a sand or gravel bed is likely to be relatively unconfined, whereas a straight river flowing through a more resistant material is likely to be confined. Again, local knowledge supersedes this assessment, however it allows a broad scale analysis to be undertaken.

Sinuosity was determined for each river segment using the line length and Pythagorean theorem to establish the straight-line distance between the upstream and downstream extent of each segment. The Sinuosity Index is simply the line length divided by the straight-line distance. Classifications of sinuosity are 1=low (1 to 1.05), 2=medium (1.05 to 1.3) and 3=high (1.3+) (Brierly and Fryirs, 2005). These classifications are universally applicable, however sinuosity alone is not a great measure of channel energy due to variability of river sediments and reinforcement.

This methodology to measure sinuosity may not follow the direct valley centreline in all instances due to using a semi-automatic GIS analysis. However, due to the density of features within the FSU river lines dataset, sinuosity is calculated at a relatively high density and is rarely estimated over very long river distances. The measure of sinuosity is therefore assumed to be representative.

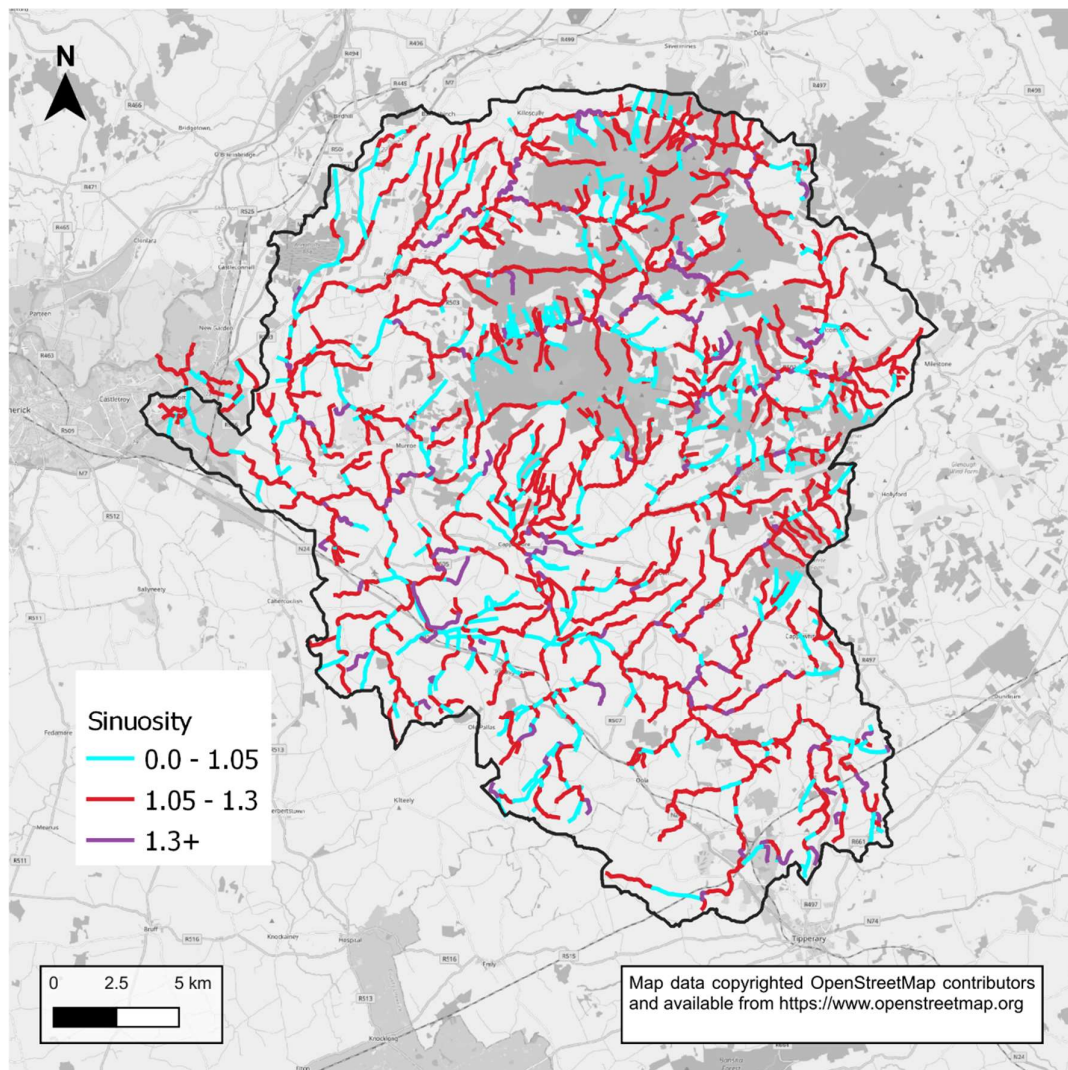


Figure A-2 Sinuosity within the Mulkear River catchment

Of note is that many of the piedmont region streams are of low sinuosity, which suggests widespread straightening of channels has occurred within mid-sections of the catchment to encourage efficient transport of flow and sediment, most likely for agricultural practices.

The result for the confinement is derived using a matrix of coarse sediment availability (low 1, medium 2 and 3 high) and sinuosity scores.

Values for each of the matrix scoring are rounded to the closest integer to provide a 1, 2 or 3 based scoring which results in the majority of matrix categories being considered moderate. Whilst this is a potential limitation to the study discretisation, as high values of stream power are predicted this limitation is not considered to mask any important sources or sediment transport pathways.

The categories are 1=Straight river with resistant sediment type, 2=Moderately confined, 3=Broadly unconfined and erodible sediment. Confinement scoring is provided in Table A-3.

Table A-3 Summary of Confinement Scoring

	Coarse sediment typology		
Sinuosity	1	2	3
1	1	2	2
2	2	2	2
3	2	2	3

A.1.7 Coarse sediment erodibility

To develop an estimate of the coarse sediment erodibility the coarse sediment reach erodibility has been again compared with the confinement ranking, again using a matrix to score values from 1 to 3. This approach assumes that confined rivers with low coarse sediment availability (scoring 1) will contribute less coarse sediment than unconfined rivers with higher coarse sediment availability (3), Table A-4).

The coarse sediment erodibility matrix is then compared with the SSP category matrix to establish which FSU rivers lines are located within areas of low coarse sediment availability and low stream power (ranking 1), moderate (ranking 2) and high erodibility and streampower (ranking 3), (Table A-5).

Table A-4 Summary of coarse sediment erodibility scoring stage 1

	Coarse sediment erodibility		
Confinement	1	2	3
1	1	2	2
2	2	2	2
3	2	2	3

Table A-5 Summary of SSP and erodibility score to produce final coarse sediment erodibility.

	SSP Category		
Erodibility	1	2	3
1	1	2	2
2	2	2	2
3	2	2	3

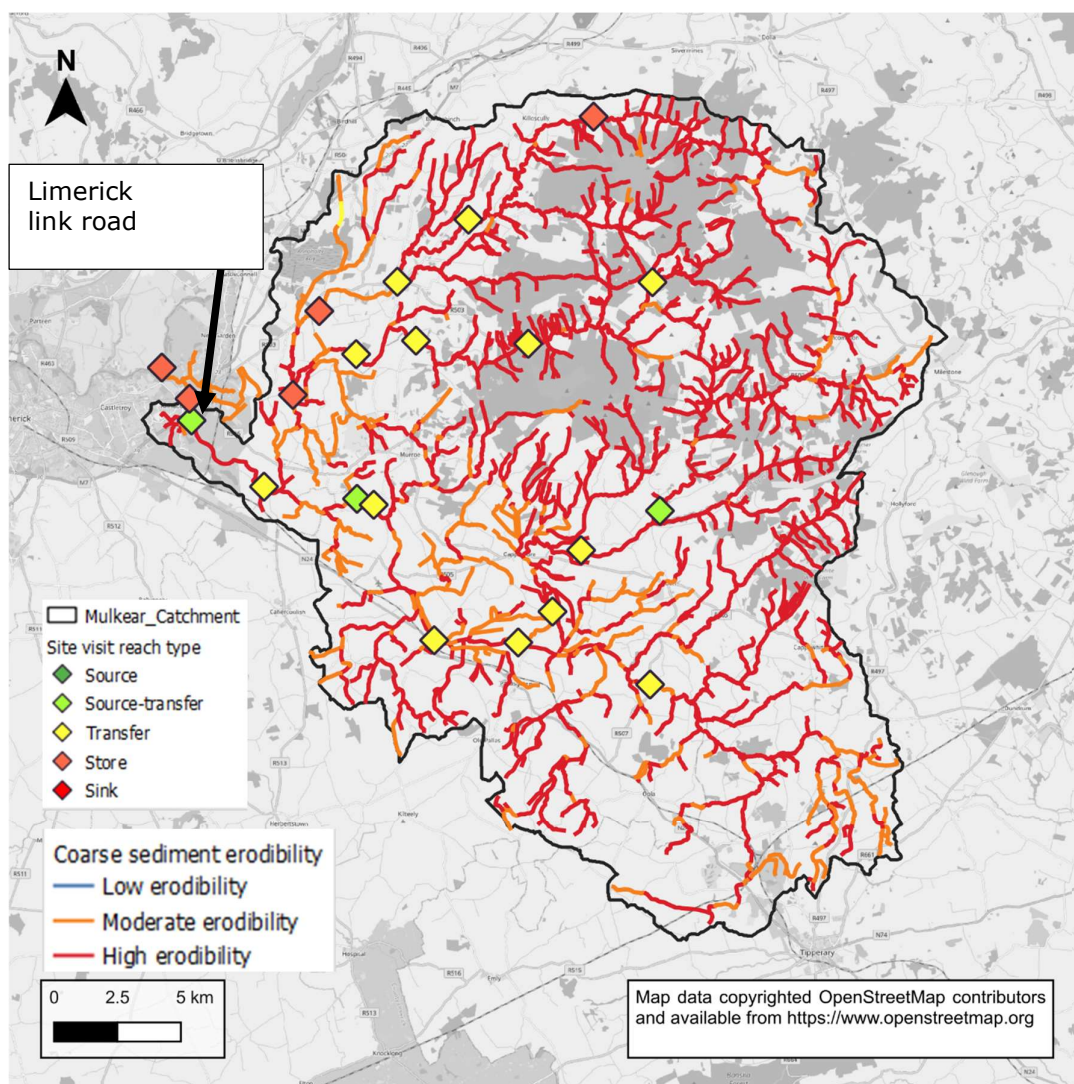


Figure A-3 Coarse sediment erodibility mapping, overlain with walkover observation typologies.

The coarse sediment erodibility mapping has been overlain by reach typologies in terms of coarse sediment transport observed from the site walkovers. Identified sources of fine sediment as well as transfer competent reaches are only found in moderate or high areas of potential erodibility, whilst stores are only found within moderate areas. There is potential that the discretisation could be improved to increase the number of categories and potentially a low to moderate category may sub-divide source and transfer reaches. However, for the case of catchment-wide indication of potential coarse sediment erodibility the map is a useful tool.

Sources are only found in very high erosivity areas, except for immediately downstream of Limerick link road, where coarse sediment was identified exposed within the channel banks. At this location it is likely that the local channel realignment in this location creates a high hydraulic force to shear away bank sediment during floods and contributes coarse material to the bedload, this localised phenomenon could not be captured within a broad scale mapping approach.

Generally, the trend is for less erosive reaches (for coarse sediment) towards the outlet of the Mulkear catchment, compared with the higher energy uplands. It is noteworthy that there are few low erosivity reaches predicted in general, which is consistent with site

observations and suggests that coarse sediment delivered from the upland hillslope processes may readily pass through the system to the lower reaches of the Mulkear and into the Old Shannon. This observation supports the hypothesis that coarse sediment delivery is also contributing to sedimentation within the Old Shannon downstream of the Mulkear confluence.

A.1.8 Fine Sediment Generation

An estimate of potential fine sediment generation has been created by comparing an estimate of the potential for fine sediment input (1 low, 2 medium and 3 high) based on landcover types from the CORINE mapping. These values are compared using the same matrix based approach with the SSP categories to provide rankings (1 low, 2 medium and 3 high) of fine sediment contribution, essentially high SSP with large fine sediment availability would result in a 3 ranking and conversely low SSP and low fine sediment availability 1. Rankings are provided in Table A-6.

Table A-6 Summary of SSP and Fine Sediment Generation Score to Produce Final Fine Sediment Generation.

	SSP Category		
Fine sediment generation	1	2	3
1	1	2	2
2	2	2	2
3	2	2	3

Unsurprisingly the highest generation of fine sediment is anticipated to come from the upland areas which are both steeper and comprise forestry land-use, with moderate amounts of fine sediment coming from the lower reaches of the Mulkear Catchment (Figure A-4). This is consistent with site observations, which show that while local areas of deposition and storage do exist throughout the Mulkear River catchment, most fine sediment is delivered from the uplands.

The site visit was undertaken the day after a notable runoff event. As described in Section 4.1.1 the slackest reach (Mulkear 1) showed evidence of fine sediment in suspension, however further upstream the flow was generally clear and fines were assumed to be already flushed through following the high flow event, which broadly agrees with the mapping.

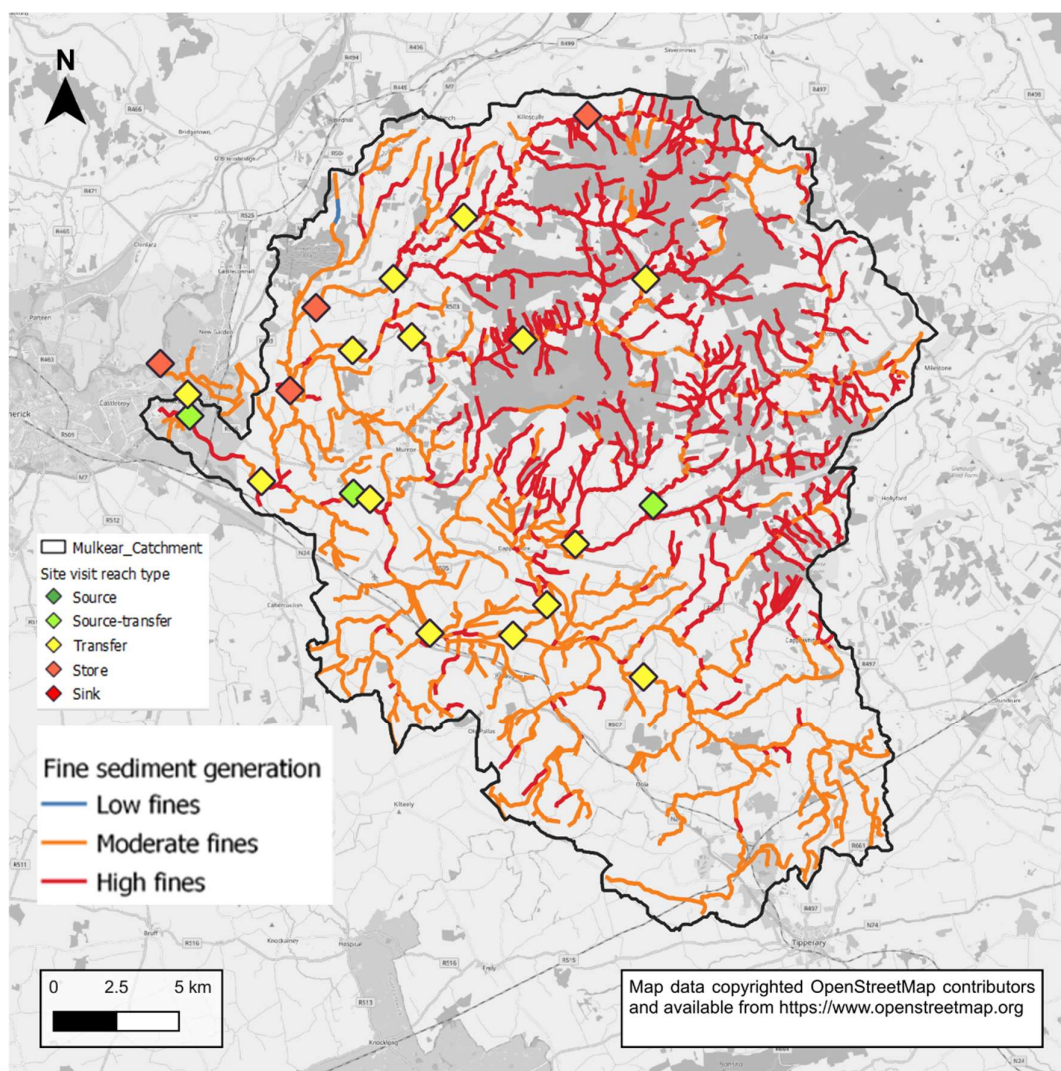


Figure A-4 Fine sediment generation reaches, site observations for fine sediment overlay.

A.1.9 Overall Erosivity

To provide an index of overall catchment sediment transport, the average of fine sediment generation and coarse sediment erodibility has been calculated by comparing the matrix of fine sediment availability and coarse sediment erodibility. Again, a ranking of 1 to 3 has been applied: FSU river lines which have a high ranking (3) for coarse sediment availability and a high ranking (3) for fine sediment availability score (3). Lower rankings are given to locations without either high fine or coarse sediment inputs, although these areas are limited within the Mulkear catchment.

The GIS result shows consistent results with the previous stages of the assessment, with high yield and erosion shown within the uplands and moderate erosion/transport shown within the lower reaches. Interestingly most of the Mulkear mainstem is shown as high transport/erosional, again agreeing well with site observations and concluding that the sediment transport regime is likely imbalanced towards erosional, with at least finer material being readily transported through the catchment.

During the field survey, downstream of Annacotty Weir was identified as likely to store coarse sediment under normal flow conditions. This GIS exercise, focusing on QMED/bankfull flow, has identified this reach as erosional at these higher flows. The hydraulic modelling

planned as part of this overall package of work will also examine this reach and provide further clarity on how sediment may be interacting with the channel here.

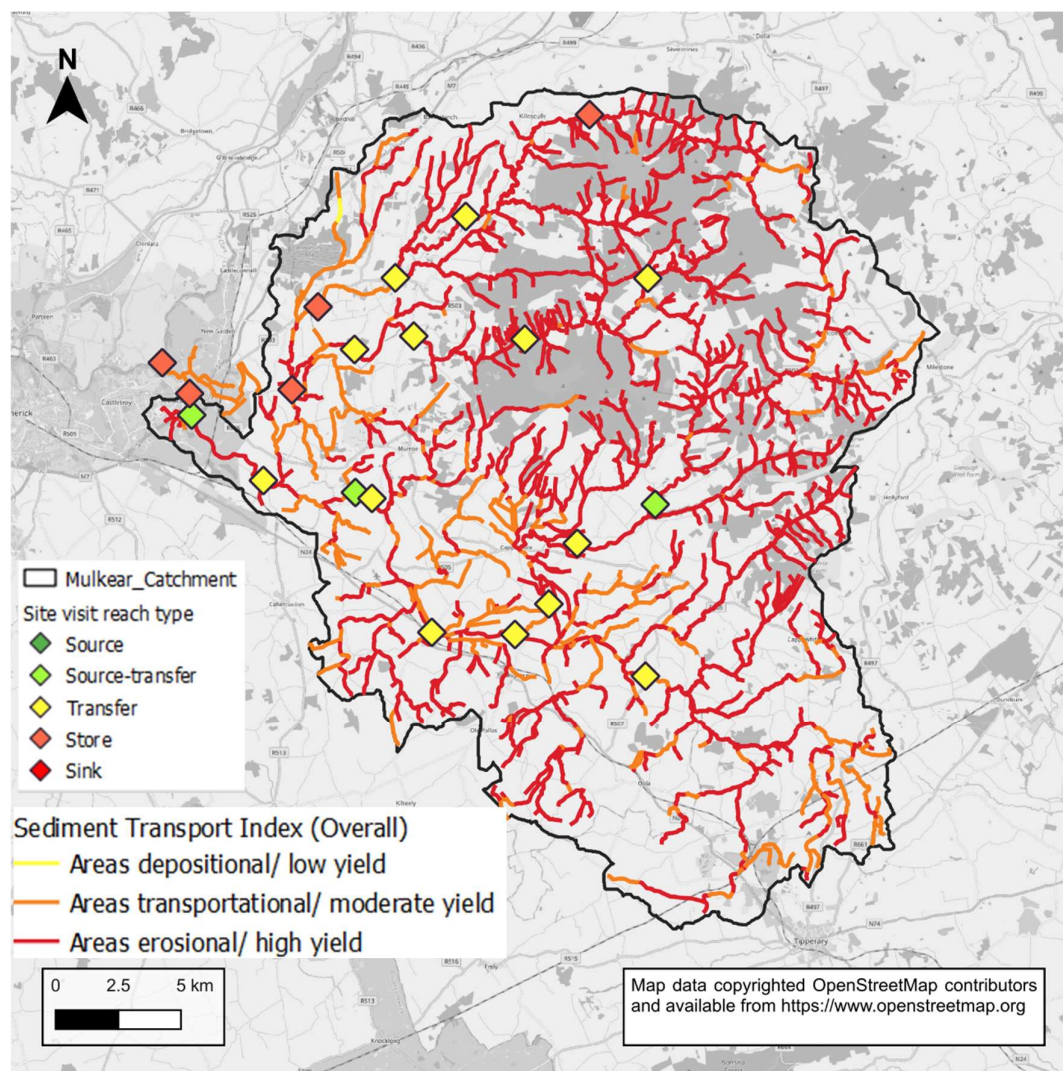


Figure A-5 Potential for Sediment Transport and Supply across the Mulkear Catchment (Nb. Site visit reach classification is for normal flow conditions)

A.1.10 Fine Sediment Yield

Due to the lack of long-term monitoring within the Mulkear River catchment, annual sediment yield is unknown. However, the fine sediment yield study by Natural England (2008) provides generalised average fine sediment yields in tons per year for a range of catchment types. These yields have been used to generate a broad-scale estimate for the Mulkear River, by associating the in the Water Framework Directive Sub-catchment shapefile which make up the Mulkear River catchment with an assumed fine sediment yield per km².

Natural England 2008 did not include many densely forested catchments like those observed throughout the Mulkear. Therefore, the upland areas within the Mulkear River have been considered 'Upland: Rough pasture' with the remaining catchment considered 'Lowland: Agriculture', and the WFD sub-catchment area has been used to discretise the catchment based on the sizes shown in Table A-7. The categories used have been highlighted green for ease of reading within the table.

Table A-7 Average Fine Sediment Yields Adapted from Table 5 of Natural England (2008).

Catchment type	Size	Number	Sediment yield range t km ⁻² year ⁻¹	Sediment yield average t km ⁻² year ⁻¹
Upland: Rough pasture	<10km ²	20	3– 286	109
	10-100 km ²	3	51 – 169	111
Upland: Agriculture	<10km ²	4	6.7 – 49.7	27
	10-100 km ²	3	35 – 46	41
Lowland: limited anthropogenic impact	<10km ²	1	4 – 9	7
Lowland: Agriculture	<10km ²	19	8 – 131	51
	10-100 km ²	18	2 – 58	28
	100-1000 km ²	27	1 – 311	46
	1000-10 000 km ²	10	4 – 59	31
Lowland: Urban	<10km ²	1	10	10
	10-100 km ²	1	20	20

It is also acknowledged that Natural England (2008) rivers were generally within England and therefore local geological, climatological and land use types will vary compared with the Mulkear. However, the approach is considered a useful high-level screening tool to consider where the greatest impact for reducing fine sediment input at source may be.

To convert an estimate of tons to a volume an assumed wet sediment density of 2000kg³ has been adopted, similar to the approach by Williams *et al.* (2021). This allows for a conceptualising the amount of fine material with may be delivered to the Old Shannon from the Mulkear River.

The exercise shows that there are some areas of the catchment which conceptually contribute significant volumes (>1000m³ year) of fine sediment to the Mulkear River catchment. The total estimated yield is 20508m³ year⁻¹, whilst this an estimate, even if it is +/- 90% (2000-39000m³) the potential yield remains high.

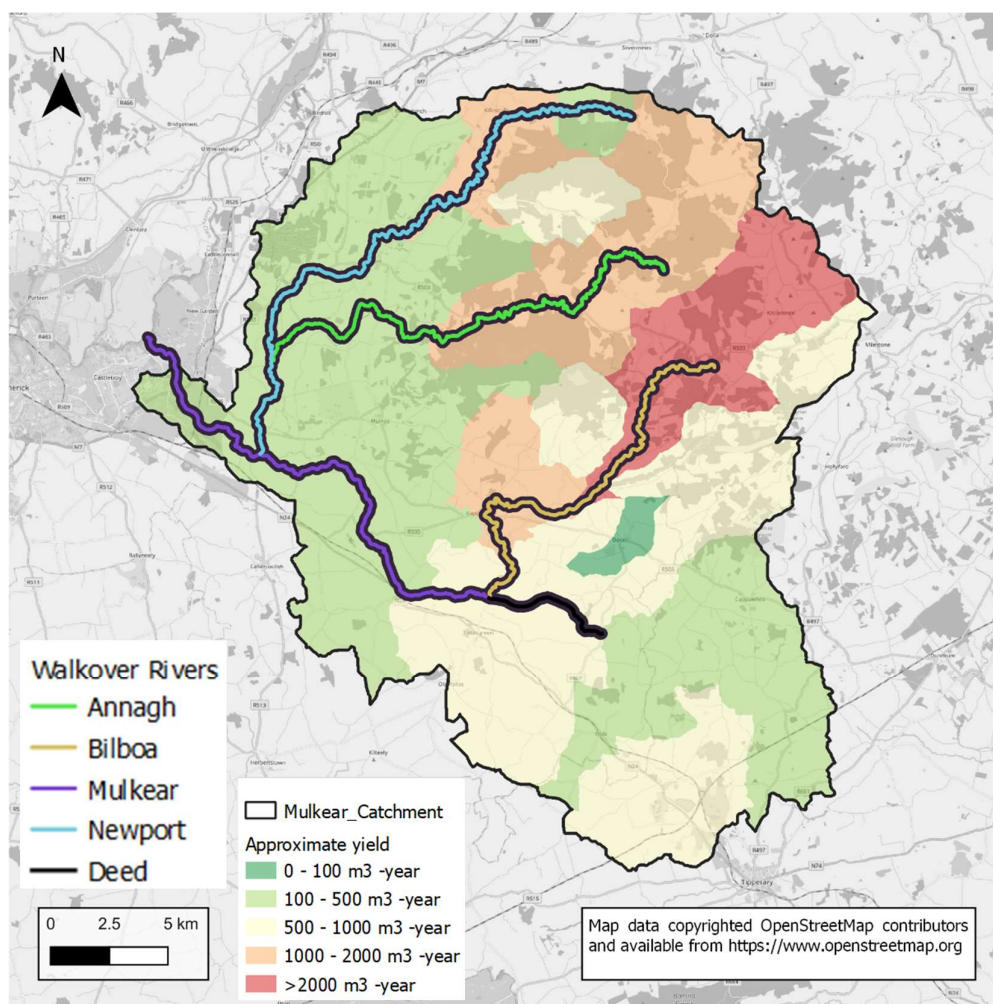


Figure A-6 Estimated Fine Sediment Yield per Catchment Area for the Mulkear River.

A.1.11 Inferring Transport Routes

The predicted specific stream power (SSP) developed in the earlier GIS process has been used alongside a rearrangement of an equation to estimate critical stream power for a given particle size, critical stream power is the threshold SSP required to trigger incipient motion of the given particle size.

The purpose of this exercise is to indicate areas within the Mulkear River where predicted entrainment is either above or below the particle size for various sediment sizes including: fine sediment (here assumed as sand of 2mm and finer), coarse sediment (gravel up to very coarse gravel >2mm to <64mm), and cobble (>64 mm).

This approach can be used to provide a broad scale assessment of sediment transport routes to the Old Shannon by comparing locations of high yield to flow lines with entrainment predicted. For example, if the flow line from the source catchment to the Shannon is consistently above 2mm, then it is assumed this source catchment could contribute fine sediment to the Old Shannon.

The equation used within the study to predict sediment transport using specific stream power is presented in Ferguson (2005). The equation in Ferguson (2005) is itself an improved version of the original Bagnold (1966) sediment transport equation based on specific stream power. The rearranged equation presented here takes specific stream power and estimates a particle size which could be mobilised and is presented here:

$$Di = SSP \times S^{0.17} / 0.104$$

Where Di is the estimated particle size entrained in mm, SSP is the specific stream power in watts per metre, and S is the reach slope taken to be the energy gradient.

Whilst this exercise does not present a detailed sediment transport analysis, it is useful to present alongside the fine sediment yield mapping as an indication of whether or not fine sediment is likely to be transported from the upper reaches to the lower reaches of the Mulkear River and potentially the Old Shannon. The map created from this exercise is presented in Figure A-7.

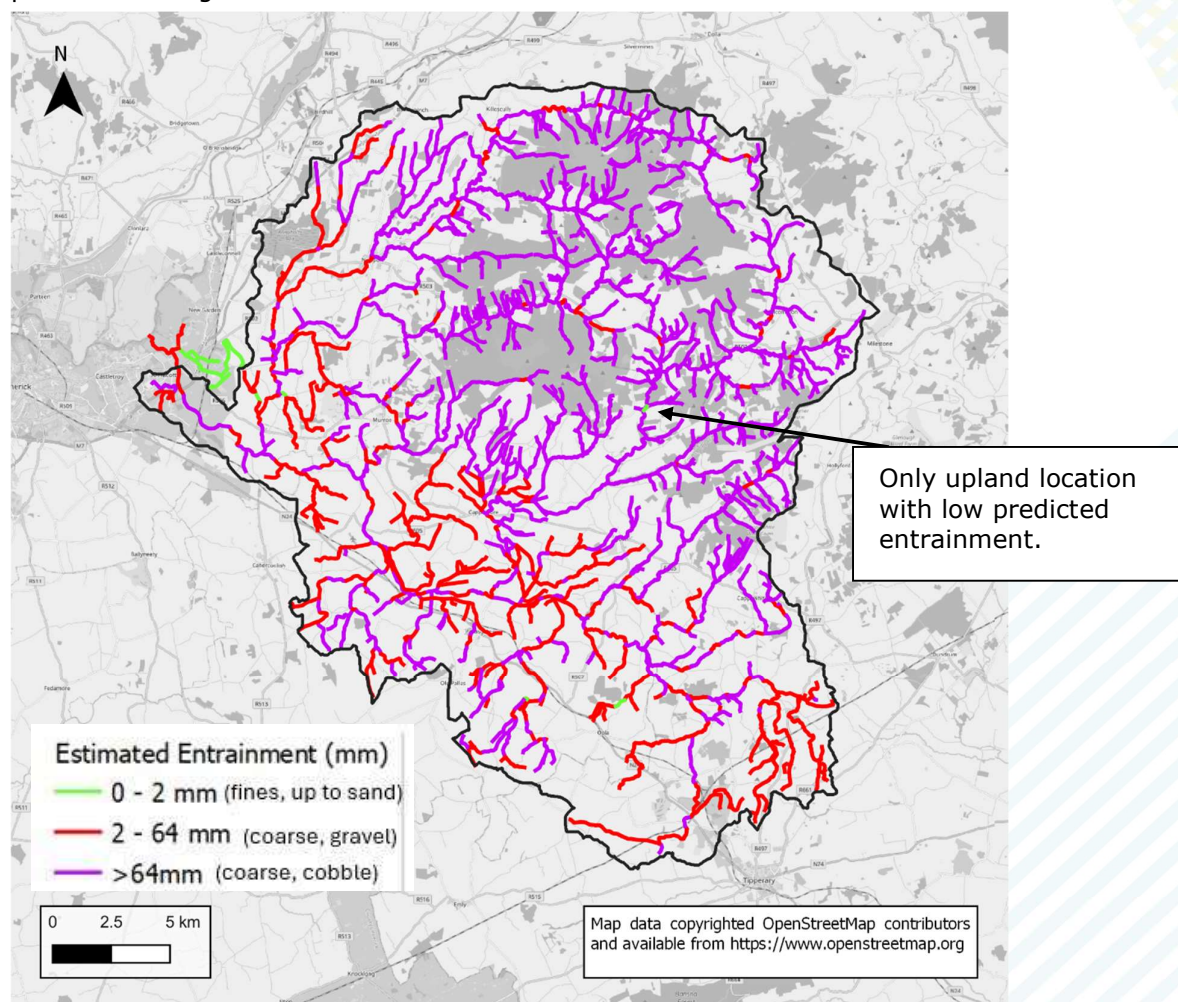


Figure A-7 Specific Stream Power Predicted Entrainment for the Mulkear River.

The entrainment estimates indicate that there is competence within the catchment to transport fine and coarse sediment from the upper reaches to the lower reaches of the catchment, with only one short location within the highest yield area a potential sediment store (entrainment <2mm), this is highlighted on the figure. It feels unlikely that this single location would attenuate the supply of fine sediment alone, but further ground surveys could be carried out to review the reach.

Generally, the analysis undertaken and the site observations agree that both fine and coarse sediment supply from the upper reaches of the Mulkear River is capable of being transported to the lower reaches and there is potential for a large amount of material to be supplied.

A.2 GIS Approach References

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