MOTT MACDONALD

Enniscorthy Flood Defence Scheme

Geomorphology Study

12th May 2017

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Executive summary

Enniscorthy is a town of approximately 11,000 residents, located in County Wexford in the south east of Ireland. The town is situated on the banks of the River Slaney, and Enniscorthy has a long history of flooding, with extreme flood events occurring in 1974, 1965, 2000 and 2015.

The Office for Public Works, in conjunction with Wexford County Council have proposed the installation of a flood defence scheme. The proposed scheme includes a combination of several flood defence measures, to be installed along a 3.5km stretch of the River Slaney as it flows through Enniscorthy. The measures include river bed reprofiling/deepening (dredging), river widening, construction of a compound channel downstream and a sediment trap upstream of the town, removal of a low bridge and construction of various flood walls including glass-panels.

As part of the Environmental Impact Assessment (EIA) and scheme design, a geomorphology assessment has been undertaken to evaluate the current bed morphology and sediment processes in the River Slaney, and to assess how the proposed scheme will impact these features. The geomorphology study included a 3km walkover survey of the study reach from upstream of Enniscorthy to the confluence with the River Urrin. Observations from the survey were used with outputs from flood risk hydraulic modelling to understand current controls on sediment transport and identify the potential for changes following the proposed works.

The main conclusions of the assessment found that the impact of the proposed works on *long-term* geomorphological and sediment transport processes of the river will be relatively limited. This is due to the Slaney being a low energy river, with minimal evidence of geomorphological activity occurring under current conditions. Controls on dynamic river processes are mostly external to the river itself and include topography, geology and the substantial tidal influence.

There will however be a *short-term* but significant direct impact on the river through the reprofiled reach (c. 3-4km) arising from extensive disturbance to the bed and banks from the bed reprofiling and river widening elements of the scheme. There is expected to be a direct loss of natural river bed features; sensitive working methods, river bed reinstatement and marginal habitat establishment should be included in the works information to ensure this allows the river bed to recover as quickly as possible following the works. Recommendations have been made to limit the impacts of the scheme, and for a 'naturally' designed sediment deposition zone upstream of the town which is sensitive to habitat requirements of freshwater pearl mussel.

In terms of longer-term maintenance, analysis suggests that the proposed works may increase the likelihood of deposition within the channel due to the reduced and more consistent bed slope and slightly lower velocities. However, observations of current processes do not indicate that there would be an expectation for repeated reach scale frequent dredging to maintain the design standard of protection. Therefore the impacts on the river bed at the reach scale are expected to be a 'one-off' rather than being repeated every 5 or 10 years. Sediment transport is unpredictable as it relies on the flows that occur and availability of material from upstream, therefore monitoring of the river bed level at key locations should be undertaken using a simple annual level survey, and a maintenance plan developed based on 'trigger levels' where bed levels appear to be changing dramatically and there is a clear increased flood risk. The hydraulic model could be used to establish this.

1 Introduction and Method

The River Slaney is located in the south east of Ireland, flowing south from the Wicklow Mountains through the counties of Wicklow, Carlow and Wexford before entering the Irish Sea at Wexford town. The town of Enniscorthy is located on the banks of the River Slaney, 30km upstream of the river's mouth in Wexford town.

Enniscorthy has a long history of flooding, with extreme flood events occurring in 1974, 1965, 2000 and most recently in 2015. These flood events have resulted in significant damage to surrounding properties and infrastructure, as well as presenting a health and safety risk to the Enniscorthy community.

The Office of Public Works (OPW) in conjunction with Wexford County Council (WCC) have undertaken a study of flooding in Enniscorthy, and proposed the installation of a major flood defence scheme to mitigate against flooding in the town. An initial scheme was proposed in 2009, and improved in 2012 following a design review. The scheme moved forwards towards a final design in 2016. This new proposed scheme will be installed along a 3.5km stretch of the Slaney as it flows through Enniscorthy, and includes a combination of several measures to reduce flood risk:

- Road bridge removal and relocation;
- Construction of a compound (two-stage) channel (downstream of town centre);
- River widening;
- Creation of a sediment trap / deposition zone (at upstream of scheme extent);
- River deepening/re-profiling (dredging); and
- Installation of walls and glass panelled flood defences on both banks.

Mott MacDonald have been commissioned by OPW and WCC to produce an Environmental Impact Assessment to support the planning process for the proposed flood defence scheme. As part of the Environmental Impact Assessment, a geomorphological study has been completed.

The primary objective of this study is to consider the morphological impacts on the river bed and processes from the proposed river bed re-profiling. This includes an evaluation of current bed morphology, including river bed substrate types, areas of erosion and deposition and the influence of river form on sediment deposition. It will consider:

- impacts and sustainability of the proposed new bed slope and dredging;
- operation and maintenance of a potential sediment trap upstream of the town; and
- potential impacts downstream of the proposed works.

1.1 Geomorphology survey

A geomorphology walkover survey was conducted from the 6 – 7th April 2017. A 3.5km stretch of the river was surveyed on foot from the upstream extent of the proposed flood scheme at NGR SL906999 to NGR SL899978 at the downstream extent (study area shown in Figure 1). In addition, spot checks of the upstream catchment as the river flows through Bunclody, Clohamon and Ballycarney were made to provide contextual information about the upper catchment conditions and any significant geomorphological features.

The weather conditions at the time of the survey were cloudy with sunny intervals (temperature highs of 10°C and 14°C on 6th/7th April respectively), with dry conditions during the survey. These conditions followed a week of very low precipitation, therefore flow in the river was relatively low at the time of surveying (approximately 0.8m level at Scarawalsh, 0.65m at Enniscorthy Bridge and 0.6m at Seamus Rafter Bridge[1]). This gave a clear view of most of the channel and exposed some of the depositional bar features through the town.

Access to the river was good, with accessible footpaths and pavements located along most of the 3.5km stretch. Access to the isolated floodplain between the railway line and left bank of the river was granted by Irish Rail, and this area was surveyed on the morning of April 7th.

During the survey, photographs of key geomorphological features were captured, together with simple high level mapping of the sediment sources and sinks within the channel. Additional notes were taken on;

- sediment regime (erosion/deposition/transfer zones);
- channel geometry (channel width, depth, planform);
- boundary conditions (bed and bank material;
- flow conditions (flow type, depth); and,
- Influence of existing structures on sediment transport processes.

Typical sediment size fractions were estimated based on deposited material on the bank top/floodplain, and from exposed bars within the river channel.

1.2 Desk study

In addition to the walkover, a catchment desk study was conducted. This study included a review of existing reports including information on fluvial geomorphology and catchment characteristics of the River Slaney; primarily the *'River Slaney (Enniscorthy) Drainage Scheme Environment Impact Statement'* (Royal Haskoning, 2009) and the *'Report on the River Slaney (Enniscorthy Town) Drainage Scheme'* (Office for Public Works, 2015). Ecological reports for the scheme were also reviewed, specifically the Aquatic Ecology Survey[2] and the Freshwater Pearl Mussel Survey[3]. In addition, a review of current and historical maps of the reach and wider catchment were examined, with historic maps viewed on the Wexford County Council iMAPs Map Viewer[4], and on Ordnance Survey Ireland[5].

1.3 Sediment transport analysis

Outputs from the design hydraulic model (HECRAS) for 1yr and 100yr flow return periods were used to undertake simple, quantitative geomorphological calculations (Hjulström curve and Stream Power). This improved the understanding of the principles driving current sediment transport processes and patterns in the River Slaney. To assess whether the proposed river bed reprofiling works could significantly change sediment transport through the study reach, the baseline scenario model outputs were compared to the scenario with the proposed flood scheme design in place (i.e. with the amended bed levels and wider cross-section). More detail on these calculations and the results are provided in Section 3.

[1] River level information sourced from www.waterlevel.ie

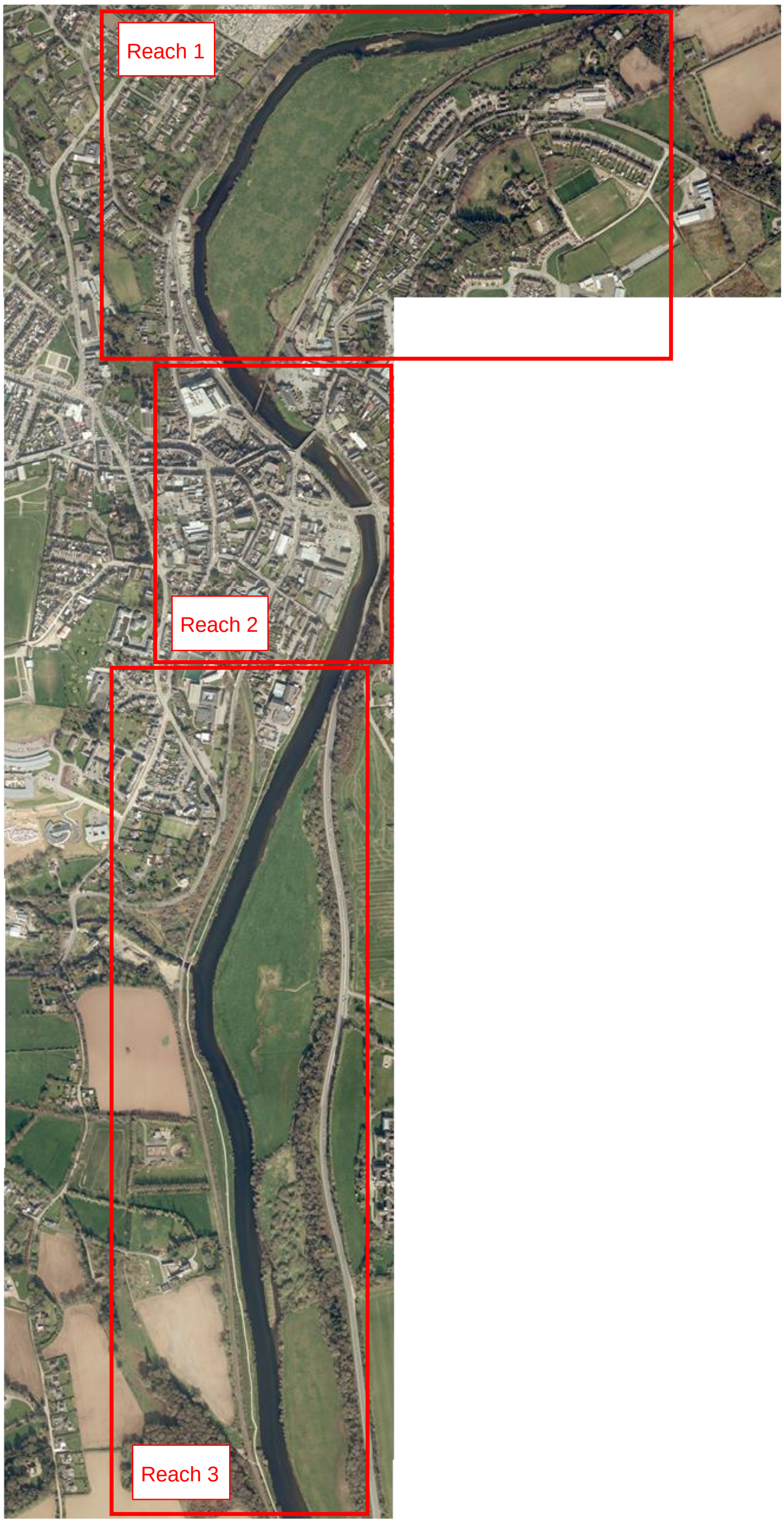
[2] Enniscorthy Flood Defence Scheme Aquatic Ecology Survey (Ecofact Environmental Consultants, 2016)

[3] Survey of Habitat Condition for the Freshwater Pearl Mussel *Margaritifera Margaritifera*, in the River Slaney at Enniscorthy, Co Wexford (Moorkens, E, 2016)

[4] Historic map information viewed on https://maps.wexford.ie/imaps/

[5] Ordnance Survey Ireland maps viewed on https://www.osi.ie/

Figure 1: Survey Extents (and three reaches studied)



Source: Photography published under licence from the Ordnance Survey of Ireland. Licence 2017/34/CCMA/Wexford County Council.

2 Geomorphological assessment

2.1 River Slaney catchment

2.1.1 Catchment overview

The River Slaney is around 120km in length, and drains an overall catchment area of 1980km^2[6]. The Slaney rises on the western side of the Wicklow Mountains, with headwaters flowing down from Lugnaquilla Mountain in a westerly direction through the Glen of Imall towards Knockanarrigan and Stratford-on-Slaney. After about 15km the river changes direction, flowing south through the towns of Baltinglass and Tullow. As the river flows through Tullow it is approximately 20m in width and the surrounding land use is predominantly agricultural. Between Tullow and Scarawalsh, the Slaney flows through several towns and increases in size as it picks up flow from five tributaries; the River Dereen, River Clashavey, Derry River, River Clody and River Bann. As the river flows through Scarawalsh, it is approximately 35m in width. South of Scarawalsh, the river flows south, meandering across agricultural land for 6.5km towards Enniscorthy. The last major tributary input upstream of Enniscorthy is the confluence with the River Ballyedmond.

The River Slaney flows through the centre of Enniscorthy, where the river bed and banks have been previously modified and substantial parts of the floodplain built upon. At Enniscorthy the Slaney starts to have a tidal influence. During high tides, the river discharge can be delayed in moving downstream, with a degree of a tidal 'impounding' effect through Enniscorthy. This effect has been linked to flooding when high tides coincide with a large river flow. South of Enniscorthy the river continues to flow south, and has confluences with two further tributaries, the Rivers Urrin and Boro. Each of these tributaries flow in from the west, transporting water (and sediment) from the Blackstairs Mountains.

Just over 4km downstream of the confluence with the River Boro, the morphology of the Slaney changes, as the channel becomes significantly wider and partly braided in the more active estuarine zone as it approaches the coast. Along this reach there are multiple in-channel depositional bar features as the tidal influence on flow increases. Just over 30km downstream from Enniscorthy, the Slaney enters a wide estuary and discharges into the Irish Sea at Wexford Harbour.

2.1.2 Geology

The northern Slaney catchment consists mostly of granite bedrock, which runs between the Wicklow and Blackstairs Mountains which form the western boundary of the catchment, whilst the southern catchment is underlain with a variety of metamorphic and volcanic bedrock[7]. At Enniscorthy, the bedrock consists mainly of volcanic rocks including felsics, basalt, gabbro and granites[8]. These highly resistant rock types constrain the movement of the river across its floodplain in places, particularly where there are rocky outcrops, such as on the right bank of the Slaney upstream of the railway bridge in Enniscorthy. The rock will also control the ultimate bed level of the river, restricting downcutting and incision.

[6] Slaney catchment statistics obtained from https://www.catchments.ie/data/#/catchment/12?_k=zca3oh

[7] Slaney catchment geological information obtained from http://dcenr.maps.arcgis.com/apps/MapSeries/index.html

[8] Geological Survey Ireland, Bedrock Geology 100k Layer obtained from http://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228

The floodplain sediments adjacent to the river in Enniscorthy consist of alluvium, formed from previous deposition from the river. There are also glacio-fluvial terraces adjacent to the watercourse just upstream of Enniscorthy and in the 25km upstream beyond Bunclody[9]. These glacial sediments can provide a source of sediment within the river from upstream, as they are composed of mixed materials which can be easily eroded once exposed.

Ground investigations within the scheme extent have been conducted to provide more detailed information on the local geological composition within and adjacent to the scheme. Details are included in the Geotechnical Report[10]. The floodplain north of the town has topsoil to 0.5m deep underlain by mixed alluvial deposits, showing where the river channel has previously moved across the floodplain and been built up by material from previous much larger floods. Silt and sand deposits are underlain by coarser granular deposits; sand and gravel with occasional cobbles and boulders to 4.5m bgl. Bedrock is slatey-mudstone and was encountered at 5.2m bgl (-3.38mOD).

2.1.3 Land use

The Slaney catchment is comprised mostly of extensive agricultural land (a mix of both pasture and arable, with more of the former in the upper and the latter in the lower catchment). There are several urban areas, the largest being Enniscorthy in the lower reaches of the Slaney, and Wexford Town situated on the estuary. Other urban areas include Baltinglass, Tullow and Kilrane.

Based on observations from the upper catchment spot checks, there appears to be a high potential for nutrient-rich fine sediment inputs into the River Slaney within the upstream reaches, mainly via surface run-off across agricultural land and/or poaching/trampling of banks by livestock. Observations from during the survey and from aerial photos suggest that there are limited buffer strips to reduce fine sediment inputs into the watercourse in the upper catchment., which could benefit aquatic ecology and reduce sediment transport down to Enniscorthy.

2.1.4 Topography and hydrology

The Slaney catchment has a varied topography, with mountains in the north and western boundaries. The headwaters of the river form between 600 – 800m AOD, flowing west towards Stratford-on-Slaney and Baltinglass at approximately 140m AOD. By Tullow the river has dropped to around 100m AOD, and by Scarawalsh around 50m AOD. Through Enniscorthy and beyond, the river flows at approximately sea level. It is a further 30km downstream to the sea at Wexford, which means the Slaney has a substantial length where the bed level is at or lower than sea level. This is a major control on sediment transport and geomorphological processes through its lower reaches

Throughout its course, the River Slaney has relatively limited floodplain extents, partly caused by high ground to the west of the catchment. These conditions, considered relatively unusual for rivers in southern Ireland[11], mean that the Slaney is a very 'flashy' river that responds quickly to precipitation inputs, and has limited floodplain attenuation during flood events.

2.2 Water Framework Directive and ecology

New modifications to rivers such as flood schemes need to consider the potential impacts of the works on waterbody status under the Water Framework Directive (WFD). This includes effects

[9] Geological Survey Ireland, Quaternary Map http://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228
[10] Enniscorthy Flood Defence Scheme Ground Investigation Contract Interpretative Report (PGL Priority Geotechnical, 2017)
[11] River Slaney (Enniscorthy) Drainage Scheme Environmental Impact Statement (Royal Haskoning, 2009)

of works on hydromorphology (river flows and physical forms); biology (such as macrophytes, fish and invertebrates), and physico-chemical conditions (nutrient and acidification levels, turbidity and others). Flood scheme works can often affect hydromorphology and biological elements.

The proposed works are located within two WFD waterbodies, the 'Slaney 170' (IE_SE_128022300) and the 'Upper Slaney Estuary' (IE_SE_040_0300)[12]. The 'Slaney 170' waterbody extends as far as Enniscorthy bridge before becoming the 'Upper Slaney Estuary'. Both waterbodies are reported in the most recent (2015) River Basin Management Plan data to have 'good' overall status, with 'good' classifications for both ecological and chemical components. Both waterbodies are identified as protected areas, as they lie within the Slaney River Valley Special Area of Conservation (SAC), Wexford Harbour and Slobs Special Protection Area (SPA).

The 'Upper Slaney Estuary' waterbody is also identified as 'At Risk', which indicates that the waterbody is at risk of deteriorating or being less than 'Good' status in the future. Although there is no specific reason stated for the waterbody being 'At Risk', the 'oxygenation conditions' were assessed to be 'moderate' under the 2010-2015 WFD classification phase. The 'Slaney 170' waterbody is not identified as 'At Risk', but the 'dissolved oxygen' element was assessed as a 'fail' in the 2010-2015 WFD classification phase, whilst 'nitrate' and 'nitrogen conditions' were assessed to be 'moderate.

Table 1: WFD status

Waterbody name and ID	Type	Protected area?	WFD risk	WFD status (2010- 2015)
Slaney 170 IE_SE_128022300	River	Yes	Not at risk	Ecological status - good Chemical surface water status - good
Upper Slaney Estuary IE_SE_040_0300	Transitional	Yes	At risk	Ecological status – good Chemical surface water status – good

Source: www.catchments.ie

The Enniscorthy Flood Defence Scheme Aquatic Ecology Survey[13] provides a preliminary assessment of aquatic habitats within the study area, highlighting that *"the footprint of the proposed scheme provides an important habitat for River Lamprey"* (a key conservation interest for the Slaney River Valley SAC). Adult and juvenile salmon were noted to be present in the river. The results from the River Hydromorphology Assessment Technique, (RHAT) noted that the river has been modified within the study area, and that there are some areas of erosion upstream between Clohamon and Enniscorthy. It was also noted that a major source of silt and fine sediments in the river are from farming activity within the upper catchment, with recommendations that these inputs should be tacked at source with the use of buffer strips and soft engineering.

Of additional ecological sensitivity for the scheme is the recorded presence of freshwater pearl mussels. A survey completed in 2016 found over 50 live mussels and a further survey was undertaken to assess habitat conditions at the upstream extent of the scheme area, including oxygenation conditions in the river bed, presence of organic matter, surface and infiltrated silts and the condition of the river bed[14]. This found that the area of habitat at the very top end of the

[12] All WFD status information sourced from www.catchments.ie

[13] Enniscorthy Flood Defence Scheme Aquatic Ecology Survey (Ecofact Environmental Consultants, 2016)

[14] Survey of Habitat Condition for the Freshwater Pearl Mussel *Margaritifera Margaritifera*, in the River Slaney at Enniscorthy, Co Wexford (Moorkens, E, 2016)

scheme extent had suitable conditions for juvenile mussel survival. The survey also indicated that while some mussels had been washed down from the upstream catchment in high flows, others showed little damage and were likely to be a locally functional population. This area is upstream of the extent of proposed dredging, but is important for consideration of the upstream sediment trap area as it could change the currently suitable river bed conditions.

2.3 Historical map review

A review of historic maps (dating to the mid-19th century), reveals that the River Slaney as it flows through Enniscorthy appears to have retained a relatively stable channel form (Table 2). The river's planform has not changed measurably for the past 150+ years, which indicates at a broad scale that the Slaney has been geomorphologically inactive for this period, although more localised changes in the river bed may have occurred during high flows.

The Slaney's relatively non-dynamic channel through Enniscorthy is partly a product of the bedrock constraints on the right bank of the river. The exposed bedrock outcrop on the outer meander of the channel north of the railway bridge has prevented the channel from migrating to the north-west. In addition to this geological constraint, the limited evidence of channel dynamics indicates a low energy river, primarily due to the very low slope in this part of the catchment. Alluvial floodplain sediments and fluvioglacial terraces in the wider valley indicate the river has been active in the past. Contemporary (present-day) flow and sediment supply is lower, and the channel has reached a state of relative stability or 'equilibrium'.

Table 2: Historical Map Review

Map	Key features
OS Ireland 6-inch colour ***1829 - 1842***	• River channel through Enniscorthy is almost identical to present day, no major planform differences • 'Overflow channel' on floodplain just north of Enniscorthy, flowing adjacent to railway line (as it does in the present day) • Mid-channel bar / depositional feature as the river meanders right just north of the town, feature approximately 20/30m upstream of present location
Cassini ***1830's – 1930's***	• Channel through Enniscorthy retains the same planform features • 'Overflow channel' on floodplain just north of Enniscorthy • Mid-channel bar / depositional feature in same location as present day, but appears as part of the left bank rather than mid-channel • Depositional/marginal habitat feature on left bank north of railway bridge, corresponds with present day marginal reeds • Floodplain on both banks (below confluence with River Urrin) noted as 'liable to flooding'
OS Ireland 25-inch colour ***1888 – 1913***	• Channel through Enniscorthy retains the same shape and planform features • 'Overflow channel' on floodplain, area where channel splits is 'liable to floods' • Mid-channel depositional feature is not so clearly defined on this map, there appears to be a depositional area/overflow channel on the left bank • Distinctive overflow / cut-off channel on left bank, at southern end of the meander (north of the railway line), this feature can be identified in the present day as a 'dipped' or 'two-stage' part of the floodplain • Floodplain on both banks (below confluence with River Urrin) noted as 'liable to flooding'

Source: Ordnance Survey Ireland GeoHive (2017)

2.4 Baseline fluvial geomorphology

The River Slaney through Enniscorthy is considered to be a low to moderate energy system. This is due to the river's relatively straight planform and shallow long profile along this reach. Limited erosion activity appears to be occurring within the study reach. However, the Slaney is also relatively confined within its valley, which means that it responds quickly and with high energy during flood events, and is therefore capable of transferring considerable amounts of sediment through the town during flood flows when the entire valley bottom is inundated.

A summary of the baseline geomorphological features and processes observed during the walkover is provided in Table 3, Table 4 and Table 5 below, with photographs inserted after each table. These have been split into three separate distinctive reaches (see Figure 1):

- Upstream survey extent north of Enniscorthy to Railway Bridge;
- Railway Bridge to Riverside Park Hotel through town centre; and
- Riverside Park Hotel to downstream survey extent (below Urrin confluence).

Table 3: Summary of geomorphology survey observations for Reach 1

Reach 1 – upstream survey extent to railway bridge (Figures 2-6)	
Typical dimensions and materials • Channel approximately 30-40m wide and between 1-4m deep • Reach consists of one large meander – channel is not actively meandering • Large alluvial floodplain on left bank, bedrock exposed adjacent to right, constraining lateral movement • Varied bed levels in both long-profile and in cross-section • River bed composed of coarse gravels which appear to be stable (compacted gravels interspersed with dark vegetation) • Pockets of finer sediments at toe of riverbanks / along river margins • Right bank (outer meander) is steep grassy/exposed earth bank • Left bank (along inner meander) steeply incised grassy/exposed earth bank with some signs of slumping	***Features observed*** • One long but narrow mid-channel bar (2-3m wide x 50m long) composed of coarse gravel, partly vegetated • Several small marginal reed beds along the left bank • Secondary channel (potentially artificial, or remnant of older high flow channel) within left bank floodplain adjacent to railway line. In normal flow conditions channel filled with ponded water, pools and extensive aquatic vegetation providing ecological habitats • Flow type glide throughout the channel with riffle/run flow around mid-channel bar • Very limited trees, could indicate historical removal • Depression in left river bank, indicating former floodplain terrace
Modifications and land use • Left bank adjacent to infrequently accessed land (owned by Irish Rail) • Floodplain on left bank composed of rough, unmanaged grassland with scattered trees and bushes • Right bank adjacent to well used footpath, made ground and woodland • Angling access along right bank (regular angling activity) • Several discharge pipes (from surface water drainage) along right bank • Invasive species Himalayan Balsam and Japanese Knotweed present (particularly along the right bank adjacent to footpath)	***Geomorphological processes*** • Reach overall is stable, but where the channel has widened through local bank erosion, deposition is now occurring • Localised bank erosion (short lengths of slumping) and in-channel deposition processes, deposition predominant at upstream end • Bank erosion mechanism does not appear to be scour, but possibly drawdown action on steep bank from rapidly lowering water level following a flood – material slumped from the bank has deposited at the toes and not yet been eroded • Reach is acting as a sink for coarser gravels due to the generally low, but inconsistent gradient • Potential transfer for fine-medium gravel during high flows

Figure 2: View upstream, exposed bedrock on right bank restricting lateral movement of channel

Source: Mott MacDonald (2017)

Figure 3: View right to left bank of mid-channel bar at upstream extent of study reach

Source: Mott MacDonald (2017)

Figure 4: View of left bank slumping - exposed earth bank on inner meander

Source: Mott MacDonald (2017)

Figure 5: View downstream towards Enniscorthy from right bank

Source: Mott MacDonald (2017)

Figure 6: Geomorphology Summary (Reach 1) ***(note proposed works shown are part of current scheme design)***

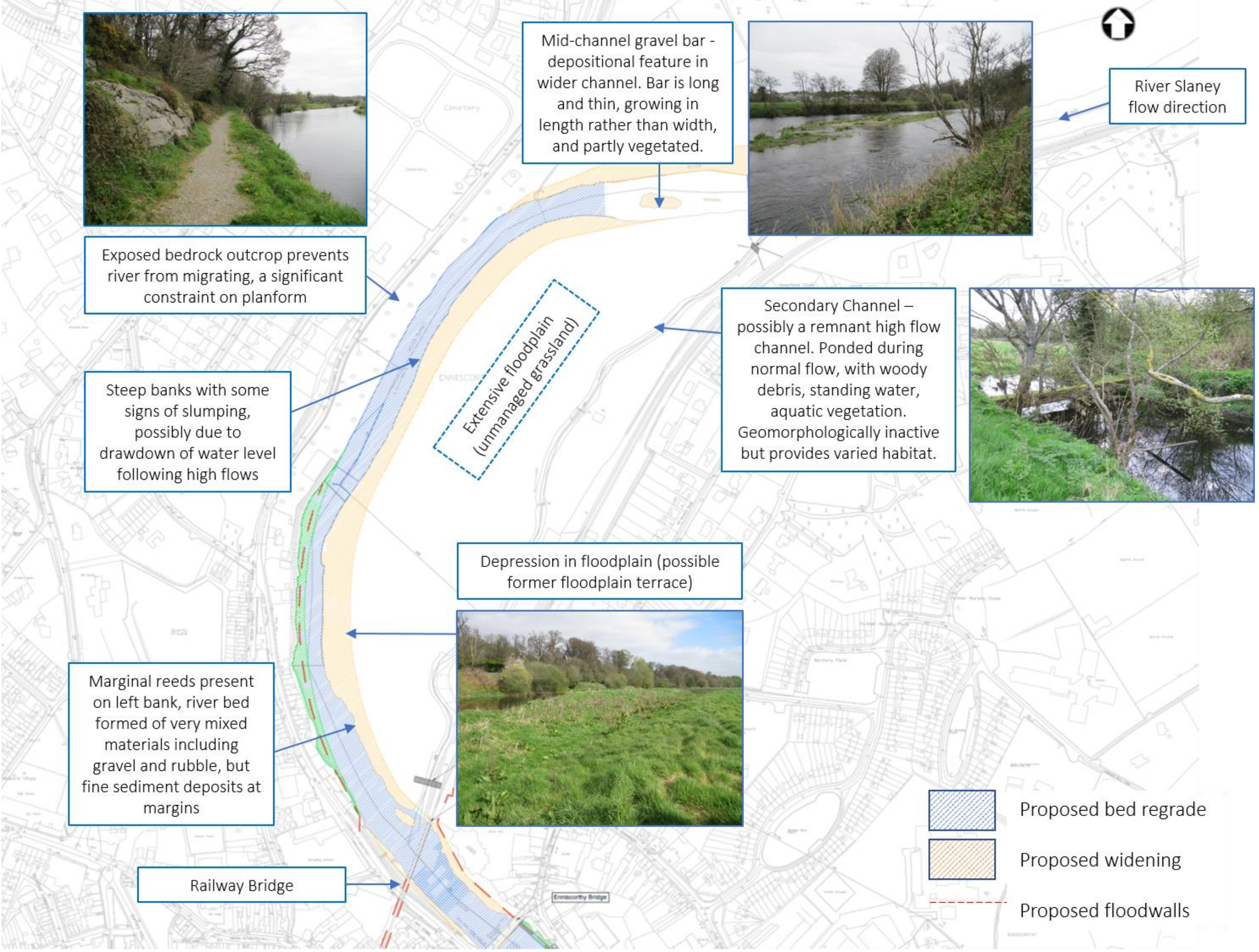


Table 4: Summary of geomorphology survey observations for Reach 2

Reach 2 – Railway bridge to Riverside Park Hotel (Figures 7-11)

Typical dimensions and materials	**Features observed**
• Channel 35-40m wide, depth 1-4m • Relatively straight planform compared with upstream • Visual observations indicate consolidated sediments, particularly between Railway Bridge and Enniscorthy Bridge • Visible coarse gravel sediments (10-20mm) deposited between Enniscorthy and Seamus Rafter Bridges • Coarse sand deposits under left arch of Enniscorthy Bridge, indicate transport of fine sediments during flood events	• Several depositional features between Railway Bridge, Enniscorthy Bridge and Seamus Rafter Bridge (side and mid-channel bars) • Riffle/run flow types present upstream of Enniscorthy Bridge • Glide flows dominate beyond the Seamus Rafter Bridge with no clear erosional or depositional features
Modifications and land use	**Geomorphological processes**
• Urbanised area of Enniscorthy town, footpaths and roads on both banks (little vegetation, very limited riparian habitats) • No floodplains, surrounding land adjacent to river heavily urbanised • Three bridges (railway bridge, Enniscorthy Bridge and Seamus Rafter Bridge) each with multiple piers installed into the riverbed affecting flow • River banks reinforced (both left and right bank) between Enniscorthy Bridge and Seamus Rafter Bridge with a stone wall (2-3m high) • Downstream of Seamus Rafter Bridge left bank modified with taller stone wall (5-6m) retaining the main road, whilst right bank retains natural grass bank, re-profiled in the past	• Exposed abutments underneath Enniscorthy Bridge indicate erosive power of flow – bridge piers cause a noticeably large hydraulic jump at low flow, as bridge piers flume/channel flow • Despite the potential for scour immediately around the bridge abutments, deposition dominates within this reach as indicated by depositional features (mid channel bars) and the river bed appearing elevated compared to up and downstream • Likely to be a transfer reach for finer sediments during flood events but with some gravel deposited

Figure 7: View right to left bank at railway bridge looking towards side channel on left bank

Source: Mott MacDonald (2017)

Figure 8: View upstream at Enniscorthy Bridge, note change in bed level through piers

Source: Mott MacDonald (2017)

Figure 9: View downstream - gravel bars between Enniscorthy and Seamus Rafter Bridges

Source: Mott MacDonald (2017)

Figure 10: Downstream view of Seamus Rafter Bridge, low clearance which constricts high flow

Source: Mott MacDonald (2017)

Figure 11: Geomorphology Summary (Reach 2) ***(note proposed works shown are part of current scheme design)***

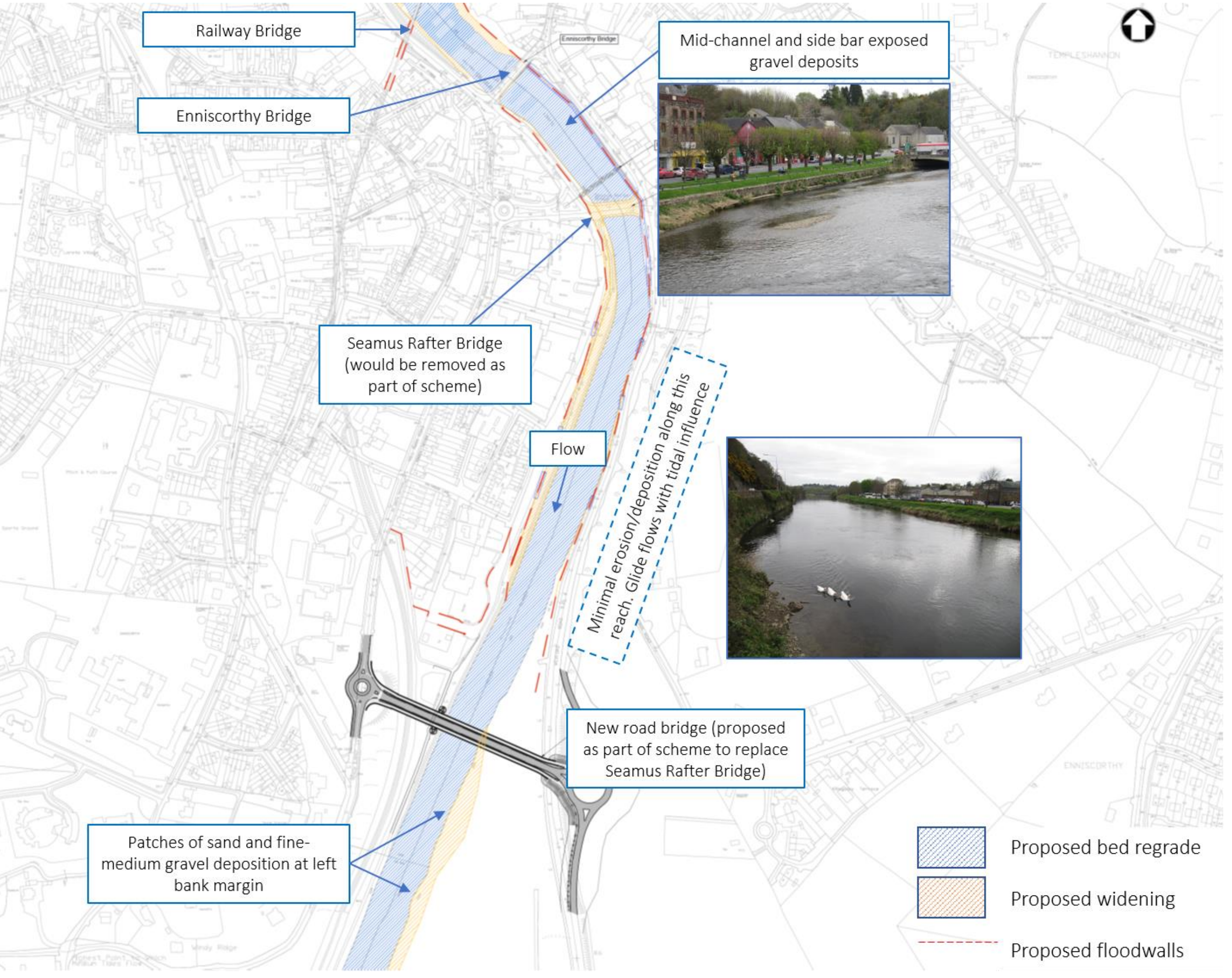


Table 5: Summary of geomorphology survey observations for Reach 3

Reach 3 – Riverside Park Hotel to downstream survey extent (Figures 12-16)	
Typical dimensions and materials • Channel width 40 - 50m, channel depth generally at least 3m • Relatively straight planform with gradual meander towards downstream extent • Consistent cross-section profile throughout this reach (rectangular/trapezoidal shaped channel) – previous bank re-profiling • Limited exposed bank material due to higher water level and grass /vegetation cover	***Features observed*** • Glide flow dominates, channel is deeper with no clear in-channel depositional features • River Urrin joins the River Slaney contributing additional flow. No specific features were noted to change at this point although the model bed level indicates a drop in bed level • Relatively extensive riparian tree cover along right bank, but no trees along left bank floodplain
Modifications and land use • Both banks consist of grassy earth lined with various marginal vegetation • Extensive floodplain (semi-managed grassland) on left bank • Railway line and N30 road run adjacent to right bank, with managed woodland and residential properties built on the former floodplain. Further downstream there is an arable field and a waste water treatment works.	***Geomorphological processes*** • Limited evidence of active processes (erosion or deposition), suggesting limited recent change occurring in the channel • Clear tidal influence with high tides holding back and slowing downstream flow

Figure 12: View downstream - floodplain on left bank downstream of town

Source: Mott MacDonald (2017)

Figure 13: View upstream – marginal reeds and deposition on left bank

Source: Mott MacDonald (2017)

Figure 14: View upstream - confluence with River Urrin, slow flow, influenced by tidal level

Source: Mott MacDonald (2017)

Figure 15: View left to right bank - extensive tree cover on right bank

Source: Mott MacDonald (2017)

Figure 16: Geomorphology Summary (Reach 3) ***(note proposed works shown are part of current scheme design)***

3 Sediment transport analysis

3.1 Introduction

An analysis of sediment transport processes in the River Slaney has been conducted using two simple geomorphological techniques; the **Hjulström curve** and **stream power analysis**. These methods were used because they use a combination of field observations and hydraulic model data inputs without requiring additional sampling, and are based on straightforward principles of flow velocity and river energy and their effects on sediment transport.

The Hjulström curve analysis provides a semi-quantitative description of sediment erosion, transport and deposition processes depending on grain size and velocity, and the stream power analysis provides a semi-quantitative assessment of energy available in the channel to erode/deposit sediments.

The results from these simple geomorphological methods can be used to assess:

- Current sediment transport processes in the river; and
- Whether these processes could be significantly affected by proposed riverbed reprofiling.

To conduct the analyses, quantitative data for relevant parameters was obtained from the HECRAS hydraulic model. The output values from this one-dimensional model are averages for each cross-section so they do not show variations in velocity from the centre of the channel compared to the banks. Data for thirteen model chainages within the scheme extent were used, including locations of most potential sensitivity to bed level changes.

Sediment transport does not usually occur during low flows, as the volume and speed is not competent to erode and transport particles from upstream. There is no model information available for velocities at low flow, therefore this assessment has not considered low flow scenarios.

No data was available to directly quantify how much historical change has occurred in the river bed level through Enniscorthy, but it is understood from local experience (Mott MacDonald, *pers. comm*) that there has not been any substantial mechanical removal of sediment in the last 50 years.

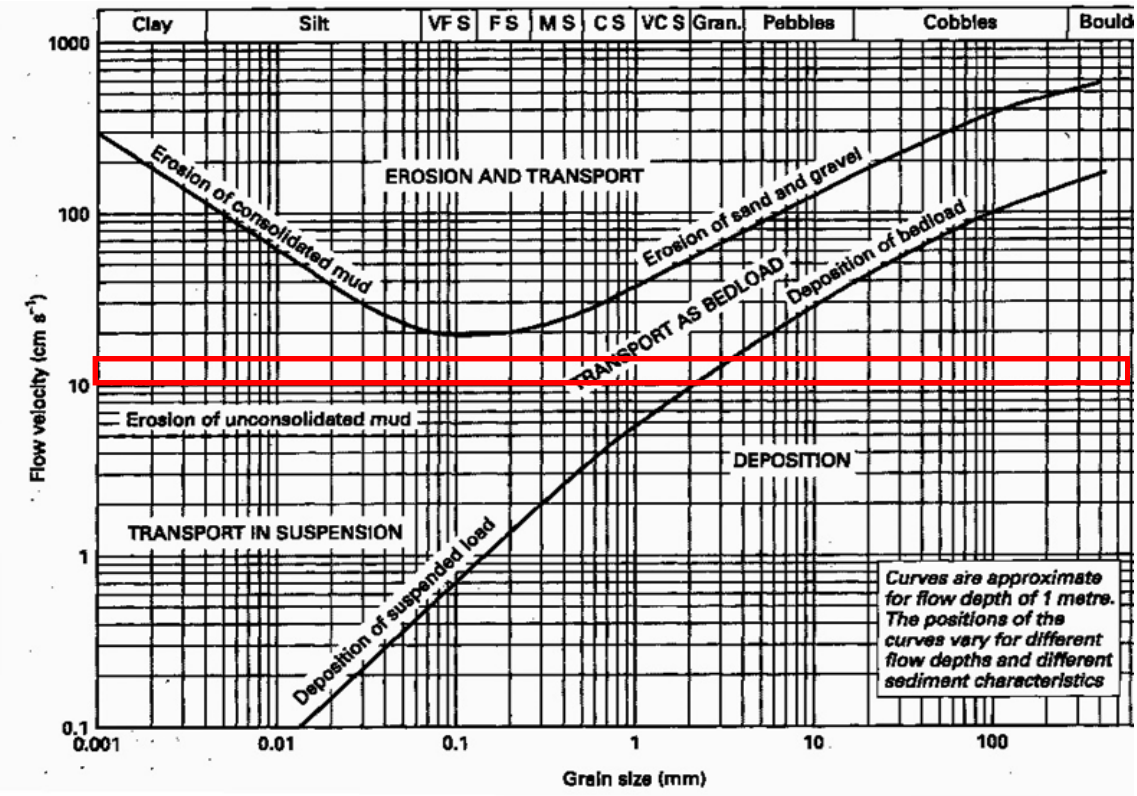
3.2 Hjulström curve analysis

To determine indicative thresholds for erosion, transport and deposition, the Hjulström curve (see Figure 17) has been used. The Hjulström curve indicates an empirically evidenced relationship between sediment particle size and flow velocity, based on limited field observations. The curve provides a simple way of indicating if a river is likely to erode (entrain), transport (in suspension or bedload) or deposit various size particles at any given velocity.

There are limitations and approximations with this technique. The relationships are approximate values, applying to flow depth of 1m. Deeper flow will tend to exert greater shear stress on the bed, making sediment entrainment more likely than is indicated by the curve. Also, the relationship is based on only velocity and grain size as variables, when other physical and environmental factors play a part in determining sediment transport.

To conduct the Hjulström curve analysis, velocity data from the HECRAS model was obtained, for both the ‘pre- works’ and ‘post works’ scenarios, and for the 1yr and 100yr flow return periods. These events provide an indication of a high but relatively frequent ‘in-bank’ flow (1yr), that can be most relevant for sediment transport, and also a very large flood event (100yr). As a method of validation, observations of sediment size from the geomorphology walkover survey were compared to the Hjulström analysis results to ground-truth the findings.

Figure 17: Hjulström curve



Source: Adapted from Hjulström, F (1935). Red box indicates typical modelled velocity range through Enniscorthy.

The results from the Hjulström curve analysis are provided in Table 6. Model results show velocity in a typical range of 1 to 1.5 m/s^{-1}, which falls within the zone of transport for particles <3mm and deposition of sediments >3mm. This suggests that gravel particles are likely to be deposited on the river bed through Enniscorthy, if flows have been sufficient to provide inputs from upstream. Notably, according to the Hjulström curve, no erosion is predicted to be active within this range of velocities.

Comparing the 1yr and 100yr modelled events, flow velocity results do not alter substantially between different return periods. Typically, the 100yr event has flow velocities around 0.5 m/s^{-1} higher than the 1yr event, so would be expected to transport more fine (sand and very fine gravel) sediment throughout most of the reach.

Comparing pre- and post works, most of the modelled changes in velocity predict a minor decrease in flow speed post works, as to be expected with the wider cross-section and more gradual bed slope. Two areas with a potential increase in velocity post works occur at the upstream extent of the scheme (>0.53 m/s^{-1} increase in velocity), and between Enniscorthy and Seamus Rafter Bridges (up to 0.35 m/s^{-1} increase in velocity). This is primarily as Seamus Rafter Bridge would be removed, so it would no longer act as a constraint to flow. In all cases, the increases in velocity are less than 1 m/s^{-1}, and are not predicted to result in significant erosion or transport of gravel-sized sediments.

The results from the Hjulström analysis correlate with observations made during the geomorphological walkover survey. The survey made few observations of active erosion within the survey area, with the exception of some localised bank erosion (slumping) in the upstream natural floodplain. Deposits of exposed gravel within mid-channel bars (20-40mm estimated particle diameter) were observed in the channel bed. This indicates that under some higher flow conditions the river is capable of transporting gravel, while in normal flow only finer sediments will be moved, and then only if there is a supply from upstream. Coarse sand was observed on the footpath underneath the left pier of Enniscorthy Bridge, suggesting this had been transported (and then deposited out of bank) during a recent period of high flow. The size of this sand was estimated to be 1mm which correlates well with the expected transport of sand illustrated by the Hjulstrom analysis.

Table 6: Hjulström curve analysis results

Chainage / Model Node (upstream to downstream)	Location	Existing velocities m/s		Design velocities m/s		Change in m/s		Comment (1 year flood)	Comment (100 year flood)
		1yr	100yr	1yr	100yr	1yr	100yr		
6950	Channel just upstream of 'overflow' channel split on LB at northern tip of floodplain	0.95	1.02	1.62	1.55	0.67	0.53	Increase in velocity - change within transport zone of curve, sediments up to 3.8mm diameter transported	Increase in velocity - change within transport zone of curve, sediments up to 3.6mm diameter transported,
6700	Channel just downstream of 'overflow' channel split, just upstream of mid-channel bar	0.77	0.91	1.26	1.24	0.49	0.33	Increase in velocity - change within transport zone of curve, sediments up to 2.75mm diameter transported	Negligible change[15]
6650	Channel as it flows either side of mid-channel bar	1.25	1.56	1.05	1.33	-0.2	-0.23	Negligible change	Negligible change
6200	Channel approximately halfway through floodplain on LB	1.48	1.98	0.98	1.43	-0.5	-0.55	Reduced velocity - change within transport zone of curve, sediments up to 2mm diameter transported	Reduced velocity - change within transport zone of curve, sediments up to 3.2mm diameter transported
5705	Channel just upstream of railway bridge in Enniscorthy	1.36	1.67	0.89	1.41	-0.47	-0.26	Reduced velocity - change within transport zone of curve, sediments up to 1.8mm diameter transported	Reduced velocity - change within transport zone of curve, sediments up to 3.2mm diameter transported
5675	Channel just downstream of railway bridge in Enniscorthy	1.16	1.58	0.8	1.24	-0.36	-0.34	Negligible change	Reduced velocity - change within transport zone of curve, sediments up to 2.75mm diameter transported
5571	Channel just upstream of Enniscorthy Bridge	1.36	1.88	1.15	1.79	-0.21	-0.09	Negligible change	Negligible change
5529	Channel just downstream of Enniscorthy Bridge	1.02	1.61	1.09	1.73	0.07	0.12	Negligible change	Negligible change
5395	Channel just upstream of Seamus Rafter Bridge	1.21	1.74	1.32	2.09	0.11	0.35	Negligible change	Increase in velocity - change within erosion zone for fine sediment; erosion of particles between 0.065mm and 0.25mm diameter Change within transport zone of curve for fine gravel; sediments up to 6.5mm diameter transported,
5341	Channel just downstream of Seamus Rafter Bridge	1.46	2.17	1.33	2.13	-0.13	-0.04	Negligible change	Negligible change
5000	Channel adjacent to Riverside Park Hotel	1.26	1.93	1.1	1.68	-0.16	-0.25	Negligible change	Reduced velocity - change within transport zone of curve, sediments up to 4.4mm diameter transported
4300	Channel just downstream of River Urrin confluence	1.42	1.98	0.89	1.31	-0.53	-0.67	Change within transport zone of curve, sediments up to 1.8mm diameter transported (-1.5mm decrease)	Reduced velocity - change within transport zone of curve, sediments up to 3.3mm diameter transported
3000	Channel at downstream survey extent	1.23	1.75	1.22	1.73	-0.01	-0.02	Negligible change	Negligible change

[15] Negligible change defined as change in sediment size entrained of <1mm

3.3 Stream power analysis

To assess the energy available for sediment transport (erosion and deposition) in the River Slaney, stream power analysis has been used. Stream power is a critical geomorphic variable that uses parameters to calculate the 'energy' available within a river. Stream power is therefore an indicative measure of the rate of energy available to a river to overcome friction and transport sediment. The equations and parameters used in stream power calculations are given below. The unit stream power is usually used for discussion, as this allows the stream power to be related directly to channel width.

Total stream power Ω (W/m^2):

$$\Omega = p\ g\ Q\ S$$

p = water density (9810 N m^{-3})

g = acceleration due to gravity (9.8m s^{-1})

Q_{bkf} = bankfull discharge ($m^3\ s^{-1}$)

S = channel slope

Unit stream power ω (W/m^{-1}):

$$\omega = \Omega / w$$

Ω = total stream power

w = channel width

In addition to velocity, other data from the HECRAS model used for the stream power calculation included:

- Bed gradient
- Estimate of 'bankfull' flow
- Peak water level
- Water surface slope

The bankfull discharge required for calculation of stream power was approximated to the 1 year return flow (volume of flow expected to happen on average once a year). This is the lowest of the modelled flow scenarios. This was checked by comparing the water level with the cross-section capacity, and for most cross sections this seemed to provide a reasonable approximation of a high 'in-bank' flow.

There are limitations and approximations with using stream power analysis. Any stream power tool is a crude assessment of a river's geomorphological power, and as such it should ideally be used as a back up to professional judgement.

Average stream power values provide a useful comparison to other studied rivers and published literature. Academic research by Ferguson (1981)[16] and Brookes (1987)[17] indicates that many lowland rivers are geomorphologically 'inactive', with insufficient stream power to significantly

[16] Ferguson, R.I (1981) Channel form and channel changes, in Lewin J (ed) British Rivers, George Allen and Unwin, London. Chapter 4, 90-125

[17] Brookes, A (1987) River channel adjustments downstream from channelization works in England and Wales, Earth Surface Processes and Landforms, 12: 337-351

erode their banks and bed. They are likely to have stream powers ranging from 1 – 60w/m^2 (with a 15w/m^2 median). Higher stream powers indicate a more active, energetic condition with rivers usually undergoing some forms of 'erosive adjustment'. Brookes (1987) conducted a series of experiments on channel adjustment in England and Wales, finding that rivers with 'low' stream powers most often had values lower than 35w/m^2.

The results from the stream power analysis are provided in Figure 18 and Table 7. For the pre-works (current) condition, specific stream power ranged from 12 – 66 w/m2, with the average value at 30 w/m2. For the post-works (post reprofiling) condition, specific stream power ranges from 0 – 59 w/m2, with the average value at 16 w/m2. In both sets of data, there is only one location with a high enough predicted stream power indicative of potential erosion, all other values indicate low energy areas where deposition is likely to dominate. This explains the observations of it being largely inactive in terms of present-day geomorphological adjustment, and the findings correspond well with the Hjulström analysis.

Comparing stream power values for pre- and post works conditions, there is a clear predicted decrease in stream power after river bed re-profiling (see Figure 18 and Table 7). These results are in line with what would be expected, indicating that river bed reprofiling (deepening and smoothing out high and low points in the channel) will reduce the river's energy as it flows through Enniscorthy.

There is one location with a predicted increase in stream power, at the upstream extent of the model at nodes 6700 and 6600. This is in the area around the existing large mid-channel bar feature. There is a naturally steeper bed slope in this reach of the channel and if the model bed levels are accurate the level drops by nearly 1m over a short distance. Bed reprofiling immediately downstream would increase the water surface slope in this location, with a corresponding increase in stream power. This will need to be considered when designing the proposed upstream sediment trap deposition area, to ensure that it is as effective as possible.

Figure 18: Stream power analysis results

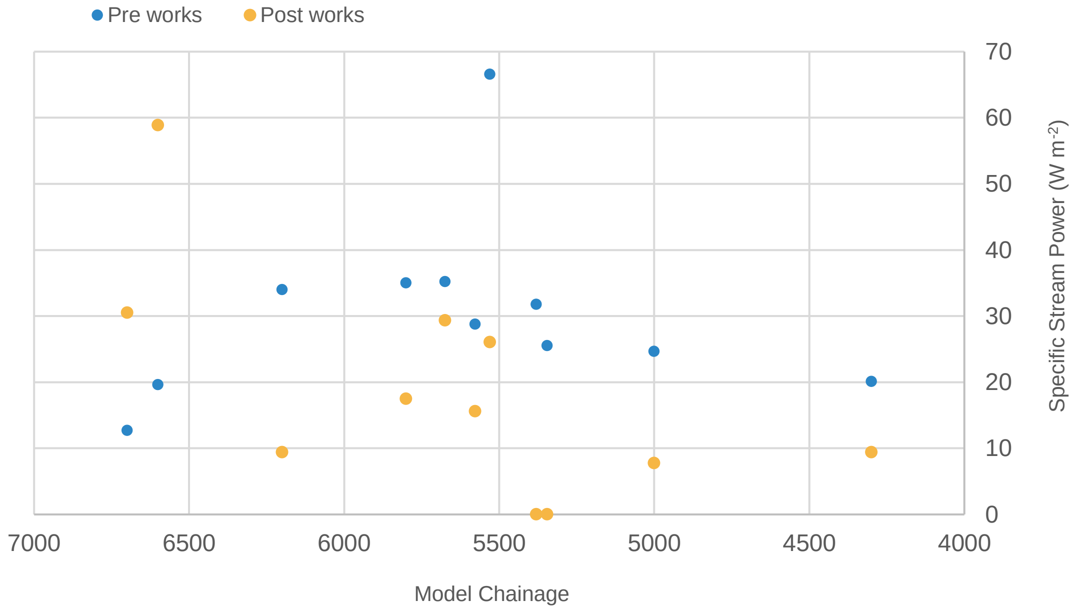


Table 7: Stream power analysis results

Model Node	Chainage	Q1yr Water Level from model (m OD)	s = Water surface slope calc	Q = Discharge from model (m^3/s)	B = Top Water Width from model x-section (m)	Specific Stream Power ω (Wm^{-2})
Pre- bed reprofiling						
6900	6988.95	4.21	n/a	195	38.6	n/a
6700	6788.95	4.11	0.0005	195	75.3	12.70
6600	6688.95	4.07	0.0004	195	39	19.62
6200	6288.95	3.78	0.0007	195	40.8	33.99
5800	5888.95	3.3	0.0012	195	65.6	34.99
5675	5752.55	3.12	0.0013	195	71.7	35.21
5577.5	5655.05	3.03	0.0009	195	61.44	28.74
5530	5582.46	2.9	0.0018	195	51.46	66.57[18]
5380	5432.46	2.79	0.0007	195	44.21	31.73
5345	5345	2.74	0.0006	195	42.9	25.49
5000	5000	2.52	0.0006	195	49.5	24.64
4300	4300	2.22	0.0004	224.5	47	20.08
Post bed reprofiling						
6900	6988.95	3.32	n/a	195	41.6	n/a
6700	6788.95	3.07	0.0013	195	75.3	31.76
6600	6688.95	2.95	0.0012	195	39	58.86
6200	6288.95	2.7	0.0002	195	40.8	9.38
5800	5888.95	2.57	0.0006	195	65.6	17.50
5675	5752.55	2.55	0	195	71.7	0.00
5577.5	5655.05	2.49	0.0005	195	61.44	16.61
5530	5582.46	2.46	0.0007	195	51.46	26.55
5380	5432.46	2.37	0.0000	195	44.21	0.00
5345	5345	2.34	0.0000	195	42.9	0.00
5000	5000	2.22	0.0002	195	49.5	7.73
4300	4300	2.06	0.0002	224.5	47	9.37

[18] Red values denote highest values within the data set, which are areas where erosion may occur, all other values indicate low energy areas where deposition is likely to dominate

4 Discussion and Recommendations

4.1 Current geomorphological and sediment conditions

Under normal flow conditions, the River Slaney is a fairly low energy river; a product of its relatively straight planform and shallow long profile. This is reflected in minimal erosion or other active geomorphological activity occurring in the river, as there is little energy to conduct geomorphological 'work' in terms of erosion or transport of sediment. This is different during flood conditions, as the Slaney responds quickly and with high energy because it is confined within its valley and has limited floodplain extents.

The 'flashy' nature of the Slaney catchment means that the lower reaches of the river are liable to flooding within its limited floodplain, which means that floodplain flows can be fast and deep. This contrasts with typical flow conditions when the river is largely inactive. Due to the increase in flow and energy during flood events, there is some potential for sediment transport and resulting geomorphological changes to occur, although recent evidence for this was limited during the geomorphological survey.

The Slaney's planform has remained consistent over the last 150 years and it is considered to be in a state of equilibrium (i.e. it does not have either an excess or starvation of sediment supply compared to its discharge).

Sediment transport patterns and processes are a direct product of the amount of energy the river has during normal flow conditions. Stream power calculations demonstrate that the Slaney has a low amount of energy and there is minimal erosion in the channel because of the low energy and characteristically low flow velocities that occur. During the walkover survey, observations of relatively consolidated gravel – indicating an armoured or imbricated bed - were made (embedded larger gravels covered with dark weeds/moss) indicating that the sediment has been stable for some period of time, and also that there has been limited recent fresh gravel transfer from upstream throughout the reach.

In terms of sediment transport and deposition, both visual survey observations and sediment transport analysis indicate that only fine (silt-sand) sediments are consistently transported by the river. During larger flows, some gravel may be transported, but the analysis completed suggests that once deposited the river will only have energy to move it again in very significant flood events. The velocity range for current conditions in large flows is 1 to 1.5 m/s^{-1}, which suggests that particles <3 mm will be transported, whilst particles >3 mm will be deposited. These values indicate that gravel particles (c. 10mm - 100mm) will be deposited on the river bed through Enniscorthy, as observed during the survey.

4.2 Potential impacts and recommendations

When considering the effects that the proposed scheme might have on both short and long term river geomorphology in the Slaney, specific elements of the scheme which might affect geomorphology have been assessed. These are:

- Reprofiling the riverbed / modifying the bedslope
- River widening
- Bridge removal
- Creation of a sediment trap

A summary of the potential geomorphological effects and recommendations for the final design are included in Table 8.

Table 8: Potential geomorphological effects of proposed flood scheme

Proposed Action	Potential Geomorphological Effects	Evidence
River bed reprofiling: modifying bed slope by dredging	- Reprofiling will remove high and low points (riffles and pools) in the bed (thus 'smoothing out' the river bed profile) - Direct impact on long profile of the river, by averaging the slope - Creation of more consistent velocity and flow variability within the channel - Velocity analysis shows it will not change high flow velocity. Low flow velocity could be affected, but sediment processes would not occur during low flows. - Stream power predicted to reduce, leading to higher likelihood of deposition over time, if there is supply from upstream. - **Recommendation** that during reprofiling, bed is reinstated with some variability, to enable river bed habitats to develop over time	Geomorphology survey Design information Hjulström analysis Stream power analysis
River widening including compound / 2-stage channel	- Widening (by cutting/lowering ground from the river bank) will increase the cross-section area - This will spread flow over a wider area and reduce flow depth - A combination of increasing width and reducing bed slope will reduce the stream power - As the river is sized for its normal flow, it may adjust to widening by depositing fine sediment especially at the margins - The presence of fine sediments and reeds at bank margins indicates that further widening might increase these features - A compound (or '2-stage) channel would only have an effect during periods of high flow - **Recommendation** that low marginal berms are created as part of the final designs to avoid over-widening the channel and reduce the cut volume required.	Design information Stream power analysis Geomorphology survey
Seamus Rafter Bridge removal	- Removing the bridge will directly influence flow in the channel at high flows by removing the obstruction caused by its low soffit and piers - Minor increase in velocity predicted - Together with bed reprofiling, may reduce deposition of sand and gravel in the section downstream of Enniscorthy Bridge	Hjulström analysis Geomorphology survey
Creation of a sediment trap / deposition zone (at upstream of scheme extent)	- Existing deposition zone / mid-channel bar could be enlarged to enable more sediment to be trapped upstream of the town - **Recommendation** that this is designed to work with the natural form and processes – conceptual design is given in Section 4.3	

In summary, the impact that the proposed works will have on sediment transport processes in the River Slaney are considered to be relatively limited. This is primarily because the river is a low energy river with very limited geomorphic activity occurring under current conditions, and the proposed works will not substantially change this characteristic.

There is potential for localised changes to existing erosion and deposition processes, given the significant change to the long-profile of the river by re-profiling. However, the potential changes to erosional processes are negligible under normal flow conditions, and only minor changes are likely to occur during significant flood events (1 in 100yr events).

There is potential for deposition to occur following bed reprofiling and due to the inherent controls on flow due to tidal levels. Observations suggest that contemporary upstream supply of coarser sediments through to Enniscorthy is relatively inconsistent and would only occur during large floods. As a result, deposition is not likely to take place at a rate where significant frequent repeat dredging would be needed to maintain flood defence levels. The proposal for a sediment trap/deposition zone upstream of the town would also reduce the risk of deposition. Geomorphological advice on the design of this area is provided in Section 4.3.

Although the reprofiling is not predicted to result in unsustainable repeat dredging, it will have a significant 'one-off' impact on the river bed. The dredging will result in the loss of natural river bed features (mid-channel bars, pools, general bed undulations and riffles, and areas of marginal deposition). These natural features create niches of ecological value, and so their removal has the potential have a negative impact on ecology, as well as a loss of aesthetic value of varied flow type created by the bed features. The restoration of these features can be incorporated with sensitive construction procedures, such as retaining undisturbed margins (for example on the inner bend upstream of the town), and by ensuring the 'reprofiled' river bed is reinstated with suitable sediment and ensuring it is not completely smooth.

4.3 Risk to Water Framework Directive objectives

The proposed flood defence works pose some risk to causing a change in WFD status for the two identified waterbodies which are currently classed as 'Good'. This is primarily due to the significant river bed dredging activity which will directly disturb the bed and associated ecology and habitats. However, whilst this action will cause temporary loss of natural riverbed features, the river bed should recover with time, reducing the longevity of impacts. It is also not predicted that widescale dredging would need to be frequently repeated, which would disturb the river bed habitats frequently and prevent ecological recovery. Furthermore, if sensitive construction methods and mitigation are followed as recommended in Table 8, (retaining undisturbed margins, reprofiling with suitable sediments) the impact on ecological habitats will be minimised.

In addition to dredging, the proposed river widening (by cutting out riverbanks) has potential significantly impact ecological habitats within the river, by completely removing the marginal aquatic habitats and niches of ecological value that exist within the riverbanks. Again, if in-river working is undertaken sensitively the impacts can be kept to a minimum. For example, if the riverbanks are profiled using a two-stage bank design and have marginal vegetation reinstated/planted, this which will retain habitats and prevent creating of an overwide channel with unnatural uniform banks.

Whilst the proposed works will undoubtedly impact the river bed conditions of the Slaney within the study area, the level of risk they pose to the WFD status of the two waterbodies is less clearly defined. The poorest ranking elements for both WFD waterbodies are associated with nutrients and dissolved oxygen, rather than hydromorphological quality; which suggests that the ecological status of each waterbody is at greater risk from changes to these elements which will remain unaffected by the proposed scheme. Therefore, whilst the proposed scheme is likely to temporarily impact the morphological of the waterbodies, the effects are very unlikely to permanently affect WFD status by causing a long term decline in ecological status. Due to the predominant tidal influence on flow and sediment transport conditions downstream of Enniscorthy, the effects are expected to be confined to the study reach only.

4.4 Recommendations for upstream deposition zone design

Given the depositional nature of the river through Enniscorthy, the proposed scheme design includes creating a sediment deposition zone or trap in the upstream extent of the scheme. The idea is that this area would enable the majority of sediment arriving from upstream to be deposited, reducing need for future removal within the town.

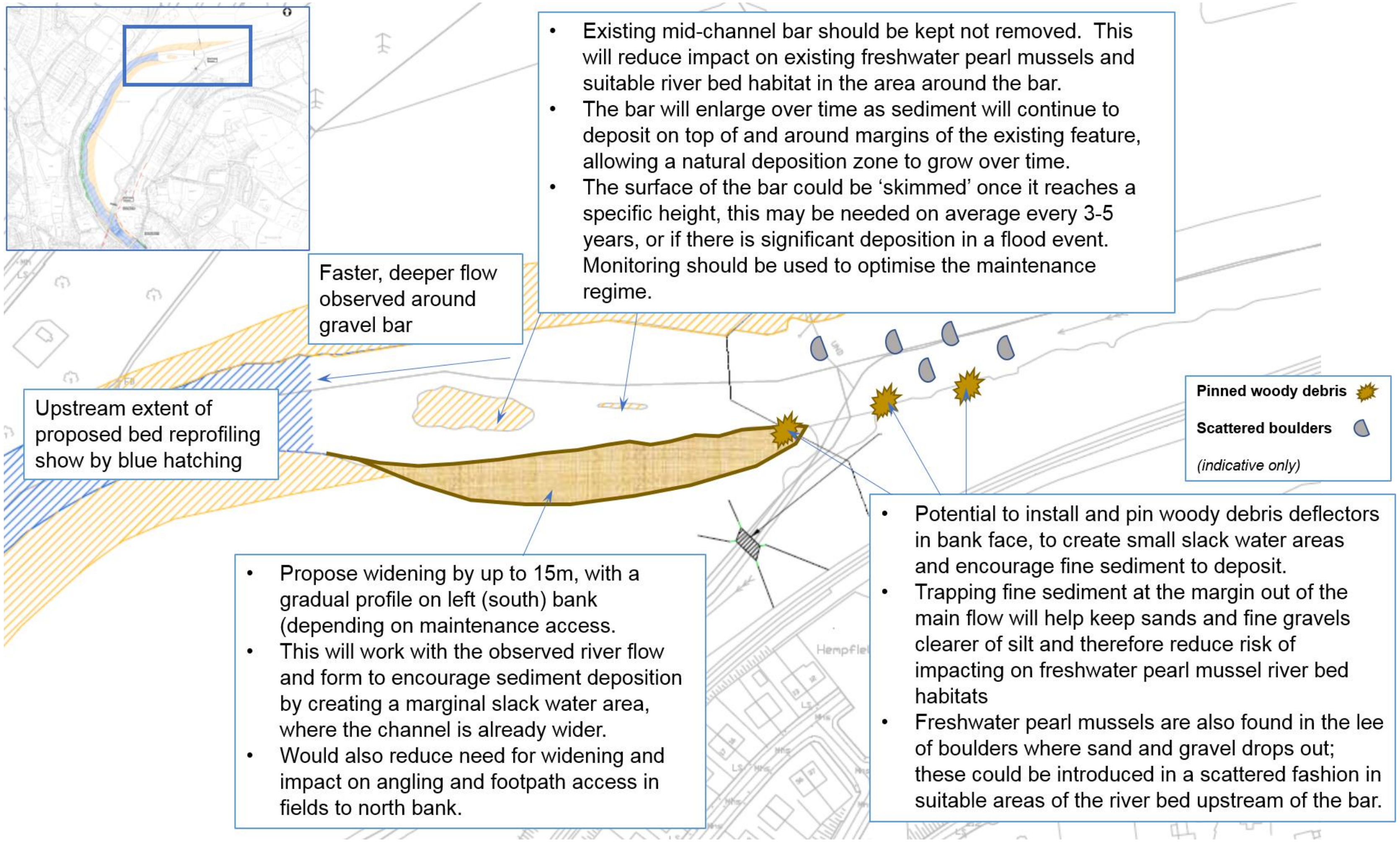
The location identified is nearby to the existing mid-channel gravel bar, which has formed in an area where the channel is currently about 10m wider than up and downstream. The bar is partly vegetated, which indicates it is quite stable. The shape of the bar is about 30m long by 3m wide, with deep and quite fast flow either side. These features indicate that the bar has grown by deposition length-ways, and there is potential to increase deposition by further channel widening, increasing the cross-section area.

Freshwater pearl mussels are known to be present close to the sediment trap area. Creating a larger zone for deposition of sand and finer gravels would potentially be of benefit to pearl mussels, as long as suitable substrate and flow conditions are maintained and the area does not become overly silted. This could be achieved by designing the area in a way that flow would be slow and deeper at the margin, creating a suitable zone for silt deposition, and a faster, shallower flow area where sand and gravels would deposit more centrally.

In addition to an in-channel deposition zone, shallow floodplain ‘scrapes’ (no deeper than 0.5m) could be excavated on the adjacent floodplain area to increase opportunities for deposition of finer sediment transported during floodplain inundation. Similar features are present on the left bank floodplain downstream of Enniscorthy, and these can provide valuable floodplain habitats.

Recommendations for the sediment trap design are illustrated on Figure 19.

Figure 19: Sediment trap concept design



5 Conclusions

A geomorphology study has been completed to evaluate the current bed morphology, sediment processes and patterns in the River Slaney and an assessment of how these will be impacted by the proposed works as part of the Enniscorthy flood defence scheme. The study included a geomorphology walkover survey of the River Slaney for 3-4km through Enniscorthy, combined with a desk study of the wider catchment and use of two sediment transport analysis techniques.

The main conclusions of the assessment found that the impact of the proposed works on the geomorphology of the river will be relatively limited; primarily because the Slaney is a low energy river with minimal geomorphological activity occurring under current conditions. There is some potential for minor changes to current localised erosion and deposition processes within the river resulting from the reprofiling and river widening elements of the scheme, with some loss of natural river bed features. Whilst this outcome may temporarily pose a risk to WFD status by impacting on river bed morphology and ecology, permanent impacts on WFD status or objectives are very unlikely.

The analysis suggests that although proposed works may lead to increased likelihood of deposition within the channel, current processes do not indicate that dredging would need to be repeated frequently to maintain a standard of protection. Recommendations have been made to limit the impacts of the scheme, and for a ‘naturally’ designed sediment deposition zone upstream of the town.

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