

CARDIGAN TIDAL FLOOD RISK MANAGEMENT SCHEME

Appendix 10.2 – Baseline Geomorphology Technical Note



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CARDIGAN TIDAL FLOOD RISK MANAGEMENT SCHEME (TFRMS)

Baseline Geomorphology Technical Note

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1. Introduction

1.1 Background

Binnies UK Ltd (BUKL) have been appointed by Natural Resources Wales (NRW) to develop detailed designs and an EIA to support the Cardigan Tidal Flood Risk Management Scheme (TFRMS, 'the Scheme') to reduce Cardigan's risk of tidal flooding using green-grey estuarine infrastructure to provide a multi-functional Flood and Coastal Erosion Risk Management asset. The Scheme will do so whilst maintaining and enhancing the natural environment and community well-being, thereby fulfilling NRW's Well-Being Objectives and the Environment (Wales) Act.

The Scheme has been devised to address Cardigan's town and community risk of tidal flooding, having historically been affected by such events. These have inflicted a range of social, economic, and environmental impacts, such as in 2014 when 29 properties were flooded by the tide. The Scheme will reduce tidal flood risk for approximately 90 properties in the Strand area, including accounting for the predicted impact of climate change.

1.2 Site Location

Cardigan lies within the south of Ceredigion County, situated upon the River Teifi (Afon Teifi) on the west coast of Wales. The Afon Teifi itself has its source in Llyn Teifi in the Cambrian Mountains, and it forms much of the border between Ceredigion and Carmarthenshire. This study focuses on the flood defences along the right bank of the Afon Teifi between the bridges of Pont Y Priordy (A487) upstream, and Cardigan Bridge (Castle Street) downstream; a length of approximately 450m. The Scheme encompasses Strand, Gloster Row, and two slipways, and is divided into four areas (1-4, from downstream to upstream). Appendix A details the location plan of the Scheme.

1.3 Zone of Influence

The Zone of Influence (ZOI) of the Scheme is expected to be local to the Scheme footprint and adjacent channel, and the Scheme is classed as a "small-scale project" under NRW's guidance (Natural Resources Wales, 2025). Based on a review of hydraulic model results the Scheme is anticipated to have local impacts on estuarine hydrodynamics. The ZOI is therefore projected to cover 500m upstream and downstream of the Scheme, including the full channel width, to cover any changes in estuarine processes from the Scheme.

The area covered by the baseline conceptual understanding is the Teifi Estuary Water Framework Directive (WFD) waterbody, see Appendix C of the Water Framework Directive Compliance Assessment (Binnies, 2025).

1.4 Aims and Objectives

This report sets out the baseline conceptual understanding of the physical systems surrounding the Scheme, to allow assessment of the environmental impacts of the Scheme. It also details the geomorphological findings from a site walkover of the Scheme footprint.

2. Methodology

2.1 Overview

The methodology comprises the following elements:

- A desk-based review of available data and information to inform general catchment characteristics;
- Review of any existing reports relating to the ZOI or study site specifically;
- Geomorphological walkover survey and presentation of results.

2.2 Desk-based Catchment Evaluation

Establishing Baseline

A desk-based study was carried out in order to develop a broad understanding of the baseline condition of the catchment in terms of its hydromorphological and ecological functioning. Information that is not readily attainable through site survey, but is important for providing a context within a catchment setting, was gathered from a variety of open-source spatial data, and a review of academic literature and information provided by the client. The following data sources were employed in the study:

- (i) Contemporary and historical mapping
- (ii) Geology and soil data
- (iii) Aerial LiDAR
- (iv) Designated sites
- (v) Hydrological data
- (vi) Flood risk
- (vii) WFD status

2.3 Reach Walkover Survey

Survey Method

The walkover survey method employed in this study follows the principles of Fluvial Audit (FA) outlined by Dangerfield *et al.* (2005) as a means of broadly identifying the

prevailing geomorphological processes, sedimentary and flow dynamics, and causes of instability, operating within the channel corridor. Similarly, information on valley form and floodplain characteristics is recorded, in addition to anthropogenic influences that affect geomorphological form and function. The FA method also incorporates the desk study element described above, so that processes operating at the reach-scale can be understood within the wider context of the channel network and catchment as a whole.

Recording of Field Data

The geomorphological survey was conducted on 11th June 2025. High tides were forecasted at 09:00 and 21:18, with heights of 4.25m and 4.38m respectively (Tide Times, 2025). The survey was conducted at low tide. Survey data were recorded during the site visit using ArcGIS Field Maps, a mobile geographic information system (GIS). This recorded key geomorphological data to inform the optioneering process, generally adopting the principles of Fluvial Audit by recording:

- a) substrate characteristics;
- b) sediment dynamics;
- c) bank character and condition;
- d) engineering pressures and constraints; and
- e) prevailing flow types.

3. Catchment Desk-based Baseline Conceptual Understanding

3.1 Catchment Characteristics

The Afon Teifi begins in Llyn Teifi, and is approximately 122km in length, being one of the longest rivers in Wales. It forms a natural border between Carmarthenshire and Ceredigion from Lampeter to roughly Cilgerran, and between Ceredigion and Pembrokeshire from Cilgerran to the coast. The mouth of the estuary lies between the headlands of Gwbert (west) and Cemaes Head (east). Two significant spits are located at the mouth of the estuary; Poppit Sands in the west, and Pen-yr-Ergy in the east.

There are two significant tributaries to the Scheme area; the Afon Piliu, which joins the Teifi on the left bank just upstream of Pont Y Priordy, and the Afon Mwldan, on the right bank downstream of Cardigan Bridge.

3.2 Water Framework Directive Status

The Scheme area lies within the Teifi Estuary transitional waterbody (GB511006206900), which is currently achieving “Moderate” status overall. Its morphology status is “High”, and it is not designated as a heavily modified waterbody (HMWB). The Scheme area is also located above the Teifi and Coastal Ceredigion groundwater body (GB41002G203300), which achieves an overall “Moderate” status.

There are also multiple waterbodies upstream and one downstream. The downstream waterbody is the Mwldan river waterbody (GB110062039160), which is currently achieving “Poor” status overall. It is not designated as a HMWB, and its morphology status is “Not High”. Upstream, both the Teifi – Afon Ceri to estuary river waterbody (GB110062043563) and the Piliu – headwaters to the confluence with Teifi river waterbody (GB110062039070) are achieving “Moderate” overall status, and neither are designated as a HMWB. The Piliu to estuary does not achieve a high morphology status, and the Afon Ceri to estuary is not detailed.

The wider Teifi catchment features a total of 37 rivers, four lakes, one transitional, and one groundwater WFD waterbody (Natural Resources Wales, 2025).

3.3 Geology and Soils

The Teifi catchment is formed of very low-permeability bedrock (British Geological Survey), consisting predominantly of sandstones and mudstones. Soils are generally loamy and change to peaty in the uplands (LandIS, 2025).

3.4 Land Use

Land use within the immediate proximity of the Scheme area is predominantly urban, comprising the historic market town of Cardigan and the nearby village of St Dogmaels. Beyond this, local land use is dominated by agriculture. Teifi Marshes Nature Reserve also occupies approximately 107ha of the left bank upstream of the Scheme area, owned by the Wildlife Trust of South & West Wales (n.d.). Approximately 80% of the catchment at the gauging station on the Teifi at Glanteifi, located approximately 11 km upstream from the Scheme, is classed as grassland/pasture with a mix of woodland and cropland. Nearly 2% is classed as built-up areas (National River Flow Archive, 2025).

Historic land use in the wider catchment also includes mining, particularly metalliferous, which is associated with elevated pollution levels. A local example is slate mining at Cilgerran, some ~3.5km to the south-east of Cardigan and situated along the Teifi.

3.5 Designated Sites

Both the Afon Teifi Site of Special Scientific Interest (SSSI) and Special Area for Conservation (SAC) overlap with the Scheme area. The SSSI designation stems from the Teifi's varied river types and associated habitats, and also includes the Teifi Marshes Nature Reserve. Species of interest include otter (*Lutra lutra*), flowering plants, bottlenose dolphin (*Tursiops truncatus*), and many invertebrates. It is also designated for its breeding and wintering bird communities, and for its geomorphological features at Cenarth and Cors Caron.

The SAC is designated for species such as Atlantic salmon (*Salmo salar*), river lamprey (*Lampetra planeri*), and otter (*Lutra lutra*). It is also designated for its clear-water lakes or lochs with aquatic vegetation and poor to moderate nutrient levels, and for its floating vegetation often dominated by water crowfoots. This site also includes the Teifi Marshes Nature Reserve.

There are two further sites associated with the Scheme area through their hydrological links. Teifi Estuary Woodlands and Marshes SSSI is located 1.1km south-east, containing saltmarsh, flood meadows, mudflats, estuarine transition marshes, woodlands, and unimproved pastures. Coedmor NNR is located 1.5km south-east, and features remnants of a medieval woodland, the Afon Teifi, and marshes.

4. Baseline Physical Processes and Environmental Characterisation

4.1 Hydrodynamics

The Teifi is macrotidal and has a significant fluvial input. Tides are asymmetric and flood dominant, although it is noted that this can change during instances of increased fluvial discharge. Seaward of Poppit Sands, the dominant wave direction is west-northwest, but it is understood that wave input does not impact the Scheme area itself due to its position in the upper estuary.

Fluvial inflows were estimated for the site as detailed in the Cardigan Hydraulic Modelling Report (Binnies, 2024). The Flood Estimation Handbook statistical method was applied to estimate flood flows. Median annual maximum flood (QMED) was calculated from catchment descriptors and then adjusted using the Teifi at Glanteifi (62001) gauging station (NRFA, 2025) as a donor site. The Teifi at Glanteifi is located around 10km upstream of Cardigan, and its use as a donor site reduces the estimate of QMED from 366.4 m³/s to 250.3 m³/s. Table 1 details the estimated fluvial flows at the Scheme area.

Table 1, Afon Teifi Flood Flow

Annual Exceedance Probability (AEP)	Peak Flow (m ³ /s)
50% (QMED)	253
20%	330
10%	389
2%	542
1%	618

Low flows were estimated to be as detailed in Table 2.

Table 2, Afon Teifi Non-flood Flows

Percentage Exceedance	Flow (m ³ /s)
Q50 (flow exceeded 50% of the time)	19.9
Q1 (flow exceeded 1% of the time)	174

The tidal levels were derived using a combination of Admiralty Total Tide software and the Environment Agency Coastal Flood Boundary dataset (2018). These are detailed in Table 3.

Table 3, Teifi Estuary Tide Levels

Tide	Level (m AOD)
High Astronomical Tide (HAT)	2.86
Mean High Water Spring (MHWS)	2.28
Mean Low Water Spring (MLWS)	-1.74

One-dimensional unsteady-state hydraulic modelling was undertaken at the Scheme area (Binnies, 2024). The Afon Teifi flows into the sea at Cardigan Bay, and so a tidal downstream boundary was used. The tidal boundary was derived using a combination of Admiralty Total Tide software and the Environment Agency Coastal Flood Boundary dataset (2018). A typical tidal cycle representative of the area was taken from Admiralty Total Tide. Station 0489 (Port Cardigan) was used for this purpose. Model simulations were undertaken using constant fluvial inflows representing QMED, Q50 and Q1 conditions, combined with complete HAT and MHWS tidal cycles. This approach captures both flood and ebb tide conditions, enabling the assessment and reporting of maximum velocities. Table 4 details the cross-sectional averaged velocity ranges adjacent to the Scheme.

Table 4, Baseline Velocities adjacent to the Scheme

Fluvial Inflow	Tide	Min Velocity (m/s)	Max Velocity (m/s)
Q50	High Astronomical Tide (HAT)	0	1.149
	Mean High Water Spring (MHWS)	0	0.969
	Mean Low Water Spring (MLWS)	0	0.969

Q1	High Astronomical Tide (HAT)	0	1.417
	Mean High Water Spring (MHWS)	0.117	1.416
	Mean Low Water Spring (MLWS)	0.117	1.416
QMED	High Astronomical Tide (HAT)	0	1.639
	Mean High Water Spring (MHWS)	0.117	1.639
	Mean Low Water Spring (MLWS)	0.117	1.639

4.2 Sediments and Geology

The Teifi estuary is formed from a flooded river valley, which has subsequently been infilled with sediments. The bedrock geology of the site consists of Nantmel mudstone formation, formed during the Ordovician period, which continues upstream. Though not directly within the Scheme area, the bedrock geology just 300m downstream consists of Cwm Degwel and Net Pool mudstones, and the Dinas Island Formation, all of which are also Ordovician in origin.

The superficial geology underlaying the Afon Teifi in the Scheme area is not designated, but the banks on either side are denoted as tidal river or creek deposits, of clay, silt and sand from the Quaternary period. Most of the town of Cardigan is set over Devensian till diamicton, deposited by Irish Sea Ice in the Quaternary period (British Geological Survey, n.d.).

Given the Scheme area's estuarine location, the substrate consisted primarily of fine sediments forming mudflats, with some areas of dense and continuous saltmarsh along the right bank.

The very large proportion of intertidal area present in the estuary indicates that the estuary has in the past, been a sediment sink. It is possible that the estuary is now approaching or is at capacity with respect to sediment accumulation. Consequently, the Teifi may now be a very weak sediment sink of sands and fines or possibly a weak source of fine sized sediment to the open coast (Halcrow, 2002). Sediments observed

during the geomorphological walkover were not measured but were visually assessed to be dominated by fine materials (silt, sand, and mud).

The sources of sediment are not entirely clear, the embayed and cliffed nature of the coast outside the estuary mouth indicates that little sediment is sourced from the adjacent coast. The Afon Teifi is likely a significant contributor of fines into the estuary and may be supported by the presence of large sand flats and the sand spits indicate a probable offshore source of sand sized sediment. Maps of surficial geology offshore show that the seabed outside of the estuary comprises sands and muddy sands, indicating a potential source of sand sized material.

The geomorphological walkover identified that much of the right bank mudflats within the Scheme footprint were covered by rubble, potentially from boat ballast. Whilst subtidal sand and mud habitats are listed as a priority species, those within the Scheme area are of degraded quality due to the rubble. The extent of the rubble is displayed in Appendix B and photographs included within Appendix D, section b. The centre of the channel was difficult to discern; however, it is assumed to exhibit similar characteristics in addition to some larger sediments due to the elevated velocities. No sediment size measurements were taken during the walkover, but visual observations indicated fine silts dominated the present substrate alongside the rubble. Visual observations estimated sediment size ranges for the are silts 0.0039 to 0.0625 mm the rubble consist of cobbles sized material (64 to 256 mm).

4.3 Topography and Morphology

The mouth of the estuary features two spits located at Poppit Sands in the west and Pen yr Ergyd in the east, which provide an important morphological control on the estuary. Sediment transport is controlled by open coastal processes seaward of Poppit Sands as indicated by the rocky habitat. The estuary narrows significantly between Old Castle Farm Point (east bank) and St Dogmaels (west bank) which form rock headlands.

Analysis of historic maps spanning a ~200-year period reveals much of the same characteristics of the estuary, especially within the Scheme area and the ZOI. The most significant changes are to the shifting sandbanks, in the intertidal basin immediately upstream of Poppit Sands and Pen yr Ergyd spit, and the eastward migration of the mouth of the estuary. Additionally, Pen-yr-Ergyg spit appears to have grown in length, whilst Poppit Sands spit has shrunk (National Library of Scotland, n.d.). This is mirrored in LiDAR digital terrain models (DTMs), analysed for the years 2002 and 2023, which show dynamic changes to morphology towards the mouth of the estuary, but no significant changes to the Scheme area and ZOI between the 21 years.

Bathymetry of the Scheme area reveals that the channel dries along the banks at low water, leaving a shallow channel of approximately 1-2m depth. The downstream end towards Cardigan Bridge is generally shallower, except for a small portion immediately surrounding the bridge; likely a backfilling of sediment due to the controls exercised by the bridge. Downstream of the Scheme area has much more significant drying areas, particularly in the length between Bryn-y-mor on the right banks and Webley on the left bank (Evans and Wright, 2015). LiDAR of the Scheme area is unclear but highlights graded banks with steep flood defences.

The Scheme area already has significant bank protection. This spans nearly the full length of each side of the river and is comprised of a mix of stone walls and gabions as detailed in Appendices B and D. These limit the channel's ability to migrate and reduce the morphological diversity of the intertidal zone.

4.4 Vegetation and Habitats

The Phase 1 Habitat Survey (Appendix C) identified the following habitats in the Scheme area: continuous bracken, swamp, running water, intertidal mud/sand, continuous saltmarsh, amenity grassland, and scattered broadleaved trees. The primary form of vegetation within the channel is saltmarsh habitat upstream of the Gloster Row slipway. Saltmarshes are considered as sensitive habitats and offer significant ecological and environmental benefits, such as supporting rare species and acting as carbon sinks. There are also significant intertidal mudflat habitats within the channel, many of which have been degraded by waste materials such as rubble and ballast, as can be seen in Appendix E, section b. These are also considered as sensitive habitats and can support a range of species such as fish and wading birds. The surrounding area is predominantly urban with significant areas of amenity grassland.

4.5 Enhancement/Restoration Opportunities

The Scheme offers two particular enhancement opportunities which will benefit the wider Teifi. Firstly, the upstream defences will be set further back from the channel, which will allow for the creation of a larger intertidal area, developing saltmarsh habitat. This will support the ecological diversity of the wider Teifi as saltmarsh habitats form a part of the reason for its statutory designations.

There is also potential for enhancement of the intertidal mudflats. Whilst those towards the centre of the channel appeared in good condition, those along the current embankment are of poor quality due to the high concentration of rubble and modified sediments, as seen in Appendix D, Figure b-1, Figure b-2 and Figure b-3. Much of this will form the engineered riverbank as part of the Scheme. Any rubble-dominated

substrates beyond the engineered riverbank footprint could be investigated for clearance to enhance the ecological function of this habitat.

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