

An Evaluation of the River Tywi Special Area of  
Conservation (SAC) – between Llandovery and Llandeilo

ACBA7005 GIS and Habitat Management

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## 1 Introduction:

Rivers, watercourses, and riparian habitats, the transitional areas between terrestrial land and aquatic waterbodies, are not just overlooked but hold a unique and significant influence on the environment and biodiversity around them. The niche habitats provided by the conditions and vegetation create perfect homes for species and connect habitats, allowing for greater species distribution and biodiversity value (Dawson *et al.*, 2024; Khorrooshi *et al.*, 2016). These habitats also provide several ecosystem services, including providing food, regulating air and water quality, and supporting nearby ecosystems (Carmarthenshire County Council, 2019; Natural England, 2022). Due to their unique beauty and importance, many rivers and adjacent riparian riverbanks are protected under Special Areas of Conservation (SAC) under the 1992 European Habitats Directive 92/43/EEC (Carmarthenshire County Council, 2018). Therefore, to conserve these critical areas, much emphasis is placed on identifying the threats and challenges for management.

Climate change has been identified as a significant risk to Welsh biodiversity (Carmarthenshire County Council, 2024), wherein shifts in climate pose a substantial threat to the health and ecological status of rivers and riparian habitats across the nation. Projections from the Centre for Ecology and Hydrology predict further rises in daily average temperature by 3.4 °C and more severe weather patterns with increasing frequency of storms, flooding, and droughts (JBA Consulting, 2022; Natural Resources Wales, 2023, Afonydd Wales, 2021). This threatens to further degrade ecosystems by disrupting symbiotic relationships and natural balance (Woodland Trust, 2016). The weight of this threat is only emphasised by the state of climate emergency the Welsh Senedd declared in 2019, in which the 22 lead local authorities closely followed suit (Afonydd Wales, 2021; Carmarthenshire County Council, 2024).

Increased frequency and severity of precipitation and flood events have also been identified as a threat of national priority, according to the Welsh Government's National Strategy for Flood and Coastal Erosion Report (Welsh Government, 2020). Strategies to manage flood risk under the Flood and Water Management Act (2010) are now taking a holistic approach to consider basin and catchment-wide factors, thereby considering the entire hydrological cycle (Welsh Government, 2020). These strategies aim to build resilience within flood defence infrastructure, promoting sustainable development to manage the risk of flooding to vulnerable people and communities (JBA Consulting, 2022; Carmarthenshire County Council, 2024). Also highlighted in these strategies is the objective of restoring natural processes through schemes such as Natural Flood Management (NFM) and Working with Natural Processes (WWNP) (Roni *et al.*, 2019; Cooper *et al.*, 2021; Wales Biodiversity Partnership, 2020). Such actions plan to build natural resilience to climate change and mitigate flood risk by restoring ecological health and reconnecting habitats and processes to their wider ecological networks.

Therefore, this management plan aims to explore the environmental, social, and ecological factors of the River Tywi Special Area of Conservation (SAC) and

discuss the existing conservation objectives of the site. Information gathered in this report will be used to recommend a 10-year management plan for the site to restore ecological health and build resilience against climate change and flooding. This plan will make use of relevant GIS data to produce maps to help visualise high-risk areas and locate potential areas to implement conservation recommendations.

## 2 Site description of the river Tywi SAC

### 2.1 General description

The River Tywi is a lowland meandering river that runs from the foothills of the Cambrian mountains to the sea through Carmarthen Bay and Estuary (Natural Resources Wales, 2023; Ericksen Jones, 1951). The main river runs for approximately 120 km, entirely within Carmarthenshire County, with several tributaries and hydrological outputs from Llyn Brianne, situated 16 miles north of Llandovery (Thomas, Hatton-Ellis & Garrett, 2013). Figure 1 shows the extent of the River Tywi within the inset map. The catchment for this river covers much of the county and is surrounded by land dominated by agricultural practices (Natural Resources Wales, 2015).

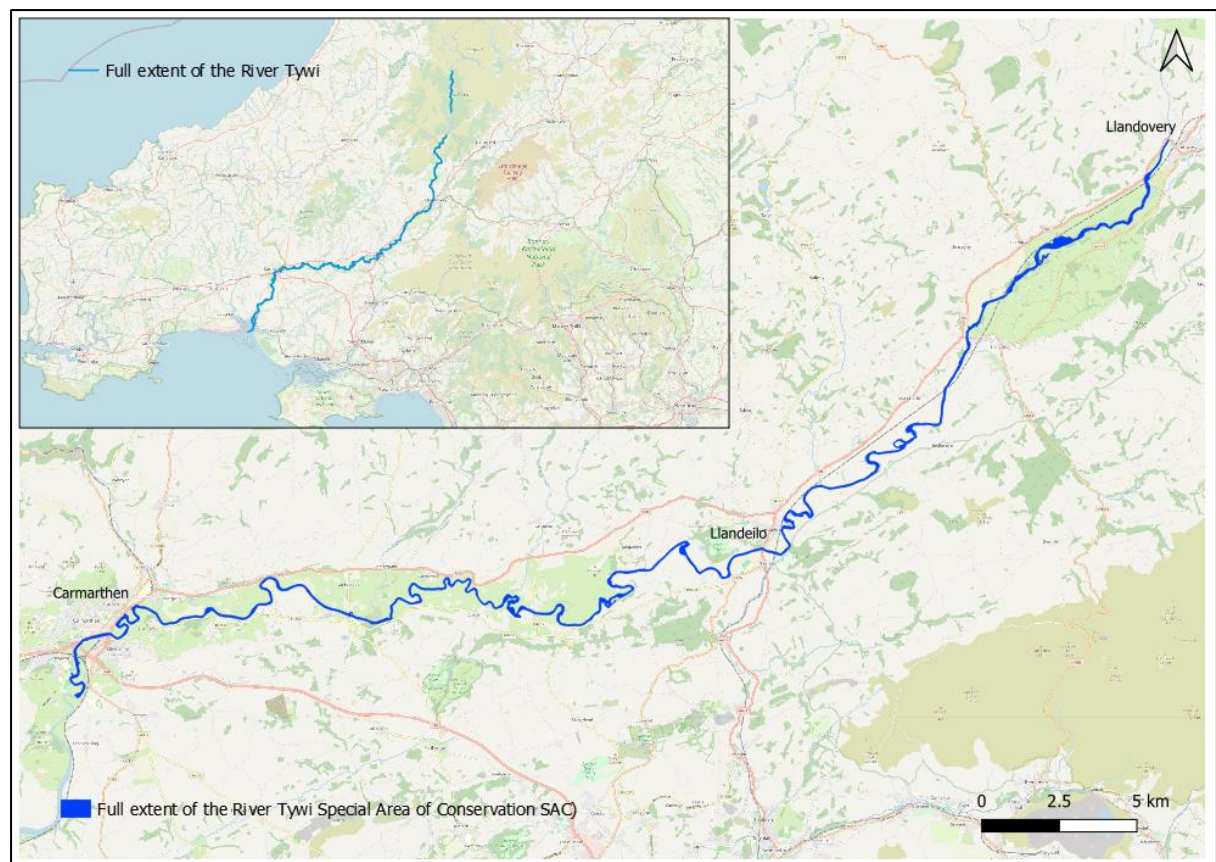


**Figure 1:** Location map of the river Tywi Special Area of Conservation (SAC) running from Llandovery to Carmarthen Estuary (dark blue polyline), with an inset map showing the full extent of the river Tywi, from source to sea (light blue polyline). Datasets taken from NRW's Main Rivers and Special Areas of Conservation (SAC) are available on DataMapWales (2022).

The Special Area of Conservation (SAC) only covers three-quarters of the River Tywi, which runs approximately 80 kilometres from Llandovery to the sea (Carmarthenshire County Council, 2018; Natural Resources Wales, 2023). The SAC is designated under the European Habitats Directive (Natural Resources

Wales, 2022) but protected under the Conservation of Habitats and Species Regulations 2017.

Due to the site's linear nature, this report only covers the portion of SAC between Llandovery and Llandeilo (Figure 2), wherein a 100m buffer has been applied to the SAC boundary. This scope has been chosen to allow for higher-resolution maps and a more thorough analysis of conservation strategies, as well as to consider a broader ecological context from the SAC itself. The area has been broken down into three units to appropriately display map elements, which will be referenced throughout the report (Figure 2).

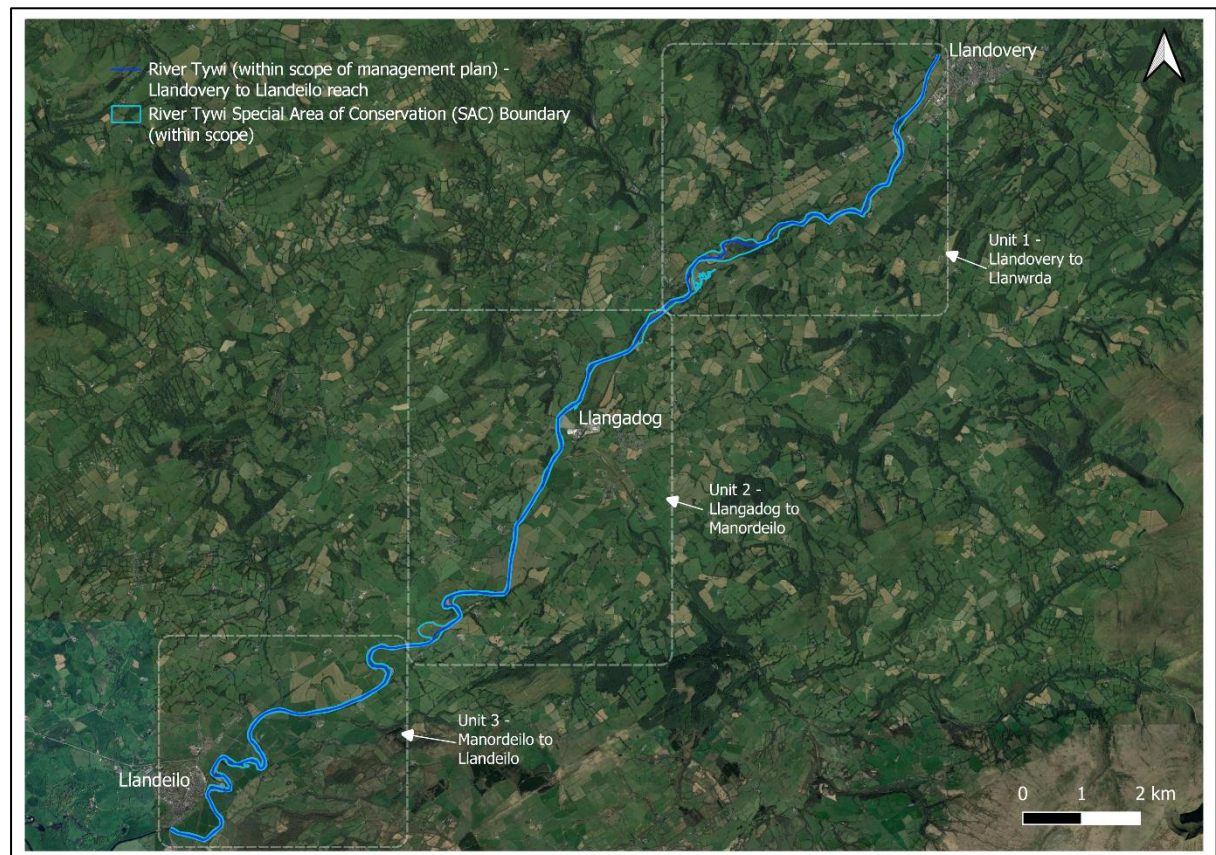


**Figure 2:** Location map of the river Tywi SAC from Llandovery to Llandeilo, with the main villages in close vicinity to the river. The dark blue line shows the river Tywi, while the boundary of Tywi SAC is light blue.

The River Tywi SAC, to this extent, is incredibly fluid, with varying extents of erosion and deposition resulting in a variety of riffles, runs, pools, and rapids (Carmarthenshire County Council, 2015; Ericksen Jones, 1951) running nearly 25 km and covering just under six km<sup>2</sup>. The meandering river runs along an active floodplain, low in the Tywi Valley, surrounded by steep slopes that run into thick forestry (Natural Resources Wales, 2014). While being scenically beautiful, the site is known for its ecological richness, wherein tourists visit far and wide to fish the infamous trout runs or explore the abundance of nature walks that nestle the valley – most notably the Black Mountains within Brecon Beacons National Park and the Cambrian mountains in which the river begins (Hurbis, 2023). The area is frequently travelled, with the heart of Wales

railway line and A40 trunk road mirroring the river (Natural Resources Wales, 2014). However, the strong cultural and social ties are what the area is known for, with the generations of agriculture farming the fertile lands adjacent to the river and aggregate extraction operations making use of the continual deposits of the River Tywi (Natural Resources Wales, 2022; Natural Resources Wales, 2014).

## 2.2 Bedrock and Soil Profile

The River Tywi SAC and its valley were formed at the last glaciation during the Pleistocene Epoch, wherein the valley deepened and deep valley walls were formed (Brewer, Johnstone & Macklin, 2009). The bedrock is almost entirely comprised of mudstone, siltstone, and sandstone, with the dominant formation consisting of the Llanvirn to Ashgill Rocks (JBA Consulting, 2022) (Figure 3, legend shown in Table 1). The Llanvirn to Ashgill and Llandeilo Flags formation consists of mudstone, which encompasses areas of rich river alluvium - known for their high fertility soils for crops. In comparison, sandstone reflects solid areas of beds, which are then exposed as small river cliffs in later years (Schofield *et al.*, 2009). Both of these have led to the generations of floodplain grazing and aggregate mining representative of the commercial land use of the SAC today.

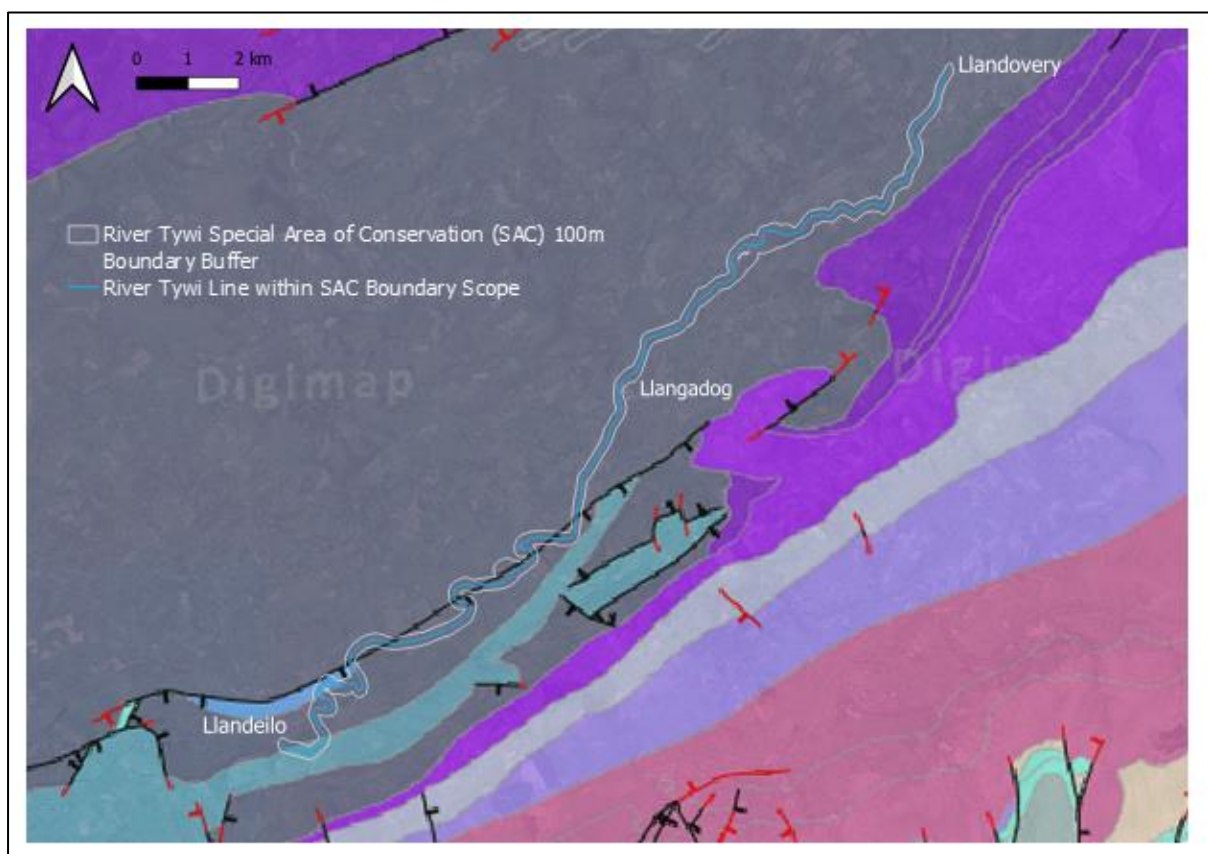


**Figure 3:** Bedrock profile of the river Tywi SAC from Llandovery to Llandeilo (Scale 1:250000). Black lines indicate contact faults, and red indicates no contact faults. Data taken from Edina Digimap.

**Table 1:** Legend for Figure 3 Bedrock profile of river Tywi SAC from Llandovery to Llandeilo. Data taken from Digimap Edina.

| Map colour indication                                                               | Rock Type                                     | Formation Name                                               |
|-------------------------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------------------|
|    | Rock and Sandstone                            | Llanvirn to Ashgill Rocks                                    |
|    | Limestone and Sandstone                       | Llandeilo Flags Formation                                    |
|    | Siliciclastic Argillaceous Rock               | Mydrim Shales Formation                                      |
|    | Siliciclastic Argillaceous Rock               | Didymograptus Bifidus Beds and Didymograptus Murchisoni Beds |
|    | Siliciclastic Argillaceous Rock               | Llandovery Rocks                                             |
|    | Siliciclastic Argillaceous Rock               | Wenlock Rocks                                                |
|    | Siliciclastic Argillaceous Rock               | Ludlow Rocks                                                 |
|    | Siliciclastic Argillaceous Rock and Sandstone | Raglan Mudstone Formation                                    |
|  | Siliciclastic Argillaceous Rock and Sandstone | St Maughans Formation                                        |
|  | Sandstone                                     | Senni Formation                                              |
|  | Sandstone                                     | Brownstone Formation                                         |
|  | Sandstone                                     | Plateau Beds and Quartz Conglomerate Group                   |
|  | Siliciclastic Argillaceous Rock and Limestone | Carboniferous Limestone Supergroup                           |
|  | Sandstone and Conglomerate                    | Old Red Sandstone Supergroup                                 |

The River Tywi SAC resides primarily on loamy and silty soils formed through alluvial and glacial deposits (Countryside Council for Wales, 1998; Cranfield University, 2024) (Figure 4). These freely draining floodplain soils are also highly fertile, again driving the generational use of floodplain land for arable crops and grazing at the site. Particularly within the scope area, these lowlands have been used for extensive dairy, beef, and farming, typical of the Welsh rural communities (Kean & Chadwich, 2021; Natural Resources, 2014). Additionally, many deposits of sand and gravel can be observed along the Tywi, allowing the continuation of mining practices (Brewer, Johnstone & Macklin, 2009).

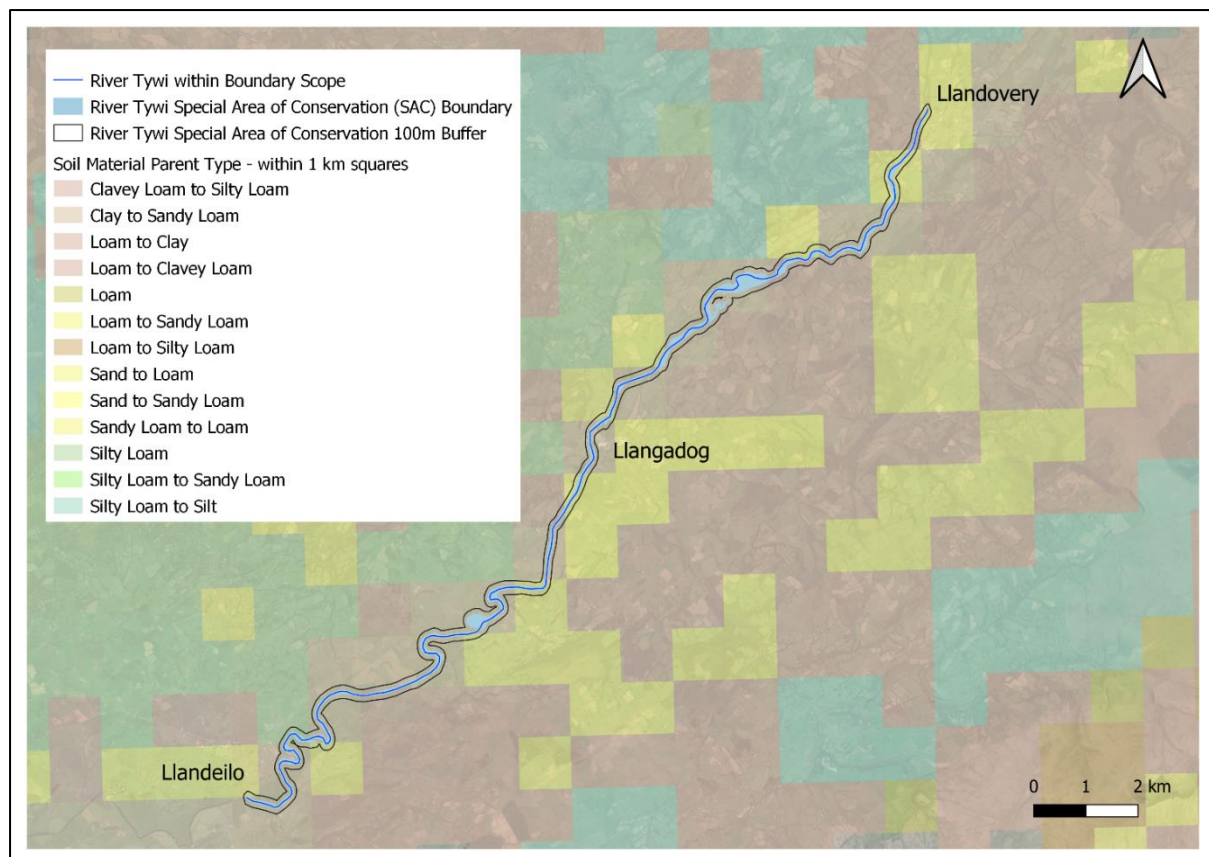


**Figure 4:** Soil profile of river Tywi SAC, with soil parent type shown in 1 km squares, with main villages along the river indicated also. Data taken from Digimap Edina.

## 2.3 Ecological features of the river Tywi SAC – Llandovery to Llandeilo

### 2.3.1 Habitats of the river Tywi SAC – Llandovery to Llandeilo

Several habitat types are present within the Tywi SAC, with several UK-priority Biodiversity Action Plan habitats also present (JNCC, 2011; Cranfield University, 2024; JNCC, 2008). The most abundant by far, according to the habitat data from Living Wales, is improved grassland. Covering nearly 62% of the total scope area, this habitat type only emphasises the extent of intensive agricultural practices within the SAC ( Figures 5, 6, and 7).

The extent of open water habitat is minimal over the scope area and pales in comparison to the 62% found in JNCC’s report for the whole of the River Tywi SAC (JNCC, 2015). Therefore, due to a lack of available habitat data for this region of the SAC, habitat types and coverage are only used as a reference to indicate trends.

Nevertheless, other habitats along the Tywi SAC include relatively high proportions of woodland and scrub, some areas of neutral grassland, and unclassified semi-natural herbaceous vegetation (Carmarthenshire County Council, 2015). Table 2 shows the coverage of these habitats and the proportion of area coverage.

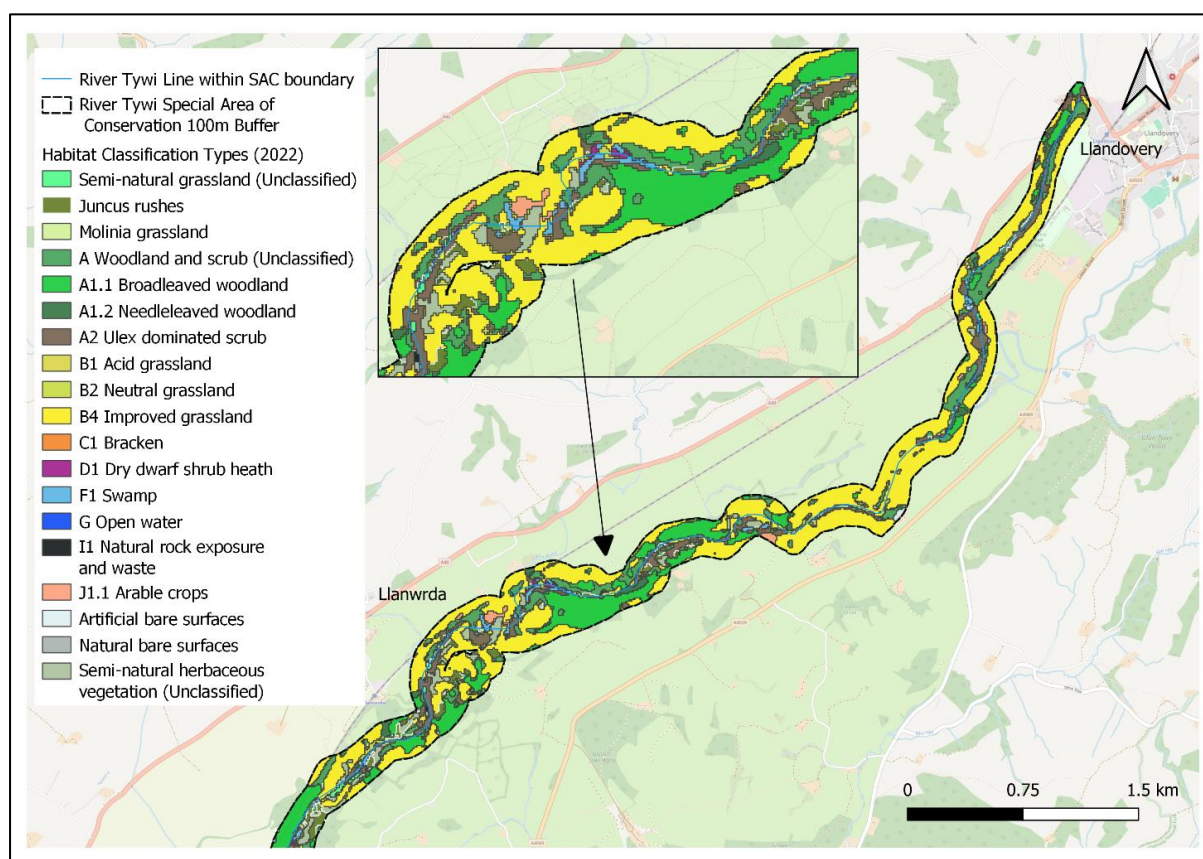


**Figure 5:** Habitat classification map of unit 1 of the river Tywi SAC with 100 metre buffer. Data taken from Living Wales EarthTrack geo-portal

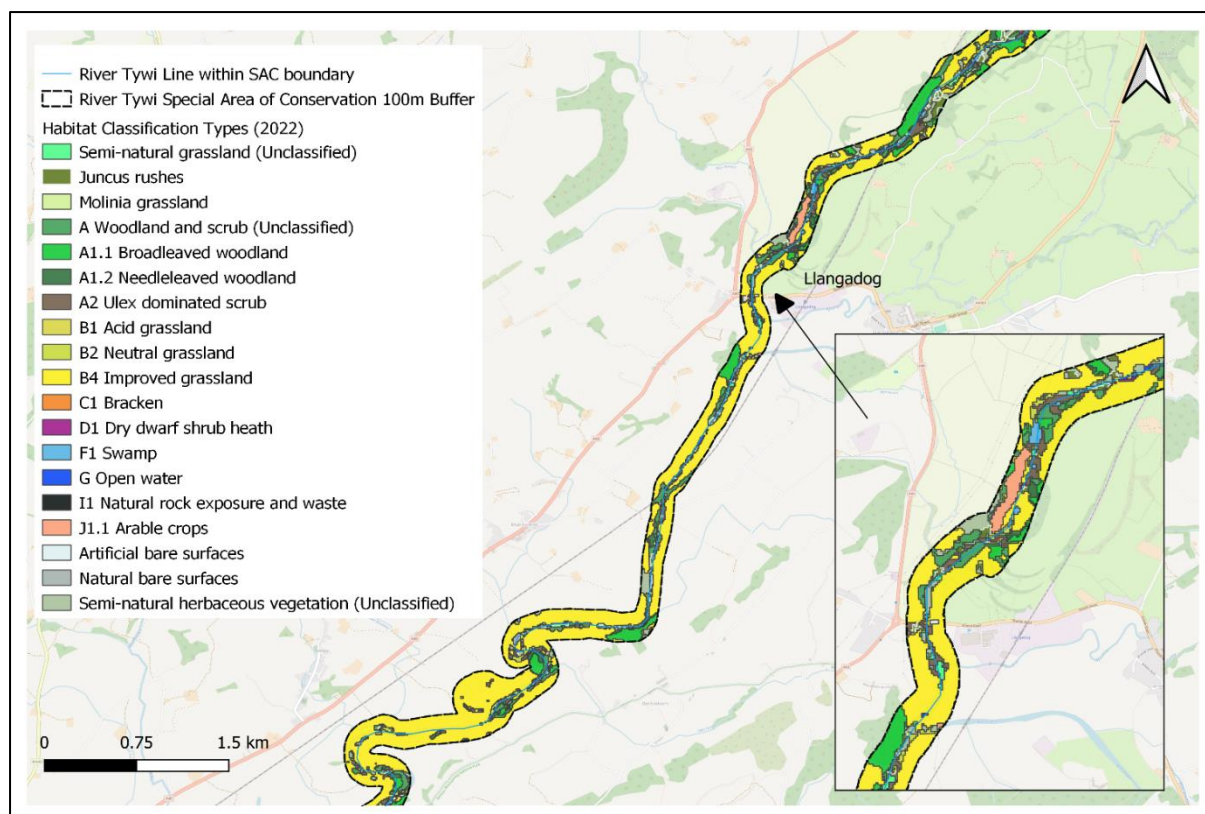


**Figure 6:** Habitat classification map of unit 2 of the river Tywi SAC with 100 metre buffer. Habitat data taken from Living Wales EarthTrack geo-portal.

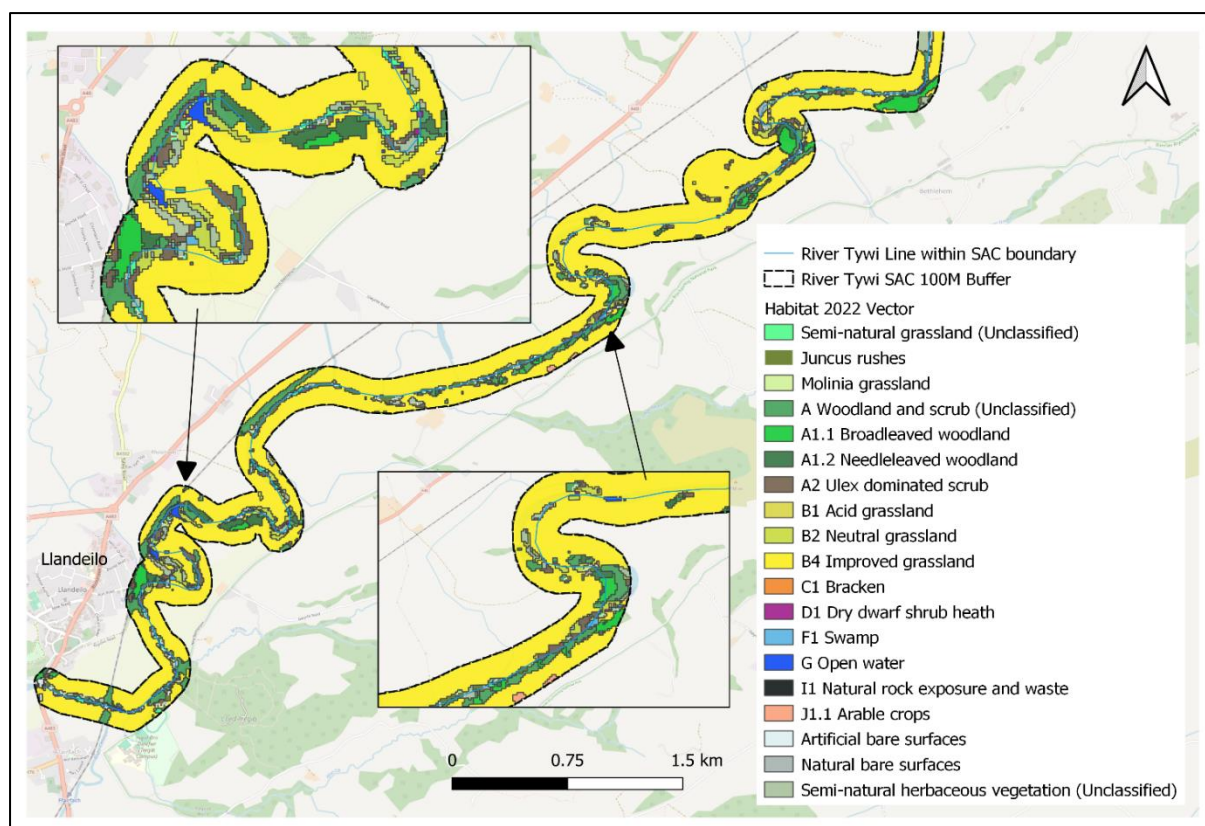


**Figure 7:** Habitat classification map of unit 3 of the river Tywi SAC with 100 metre buffer. Habitat data taken from Living Wales EarthTrack geo-portal.

**Table 2:** Area and proportion coverage of the various habitat types within the SAC buffer, relating to figures 5, 6, and 7. Values are taken to 2 decimal places.

| Habitat Classification Type                       | Area cover within Tywi SAC 100m buffer (km <sup>2</sup> ) | The proportion of the total area covered within the scope |
|---------------------------------------------------|-----------------------------------------------------------|-----------------------------------------------------------|
| Semi-natural grassland (Unclassified)             | 0.06                                                      | <b>0.98</b>                                               |
| Juncus rushes                                     | 0.21                                                      | <b>3.64</b>                                               |
| Molinia grassland                                 | 0.02                                                      | <b>0.05</b>                                               |
| A Woodland and scrub (Unclassified)               | 0.50                                                      | <b>8.55</b>                                               |
| A1.1 Broadleaved woodland                         | 0.51                                                      | <b>8.66</b>                                               |
| A1.2 Needle-leaved woodland                       | 0.12                                                      | <b>2.08</b>                                               |
| A2 Ulex dominated scrub                           | 0.37                                                      | <b>6.26</b>                                               |
| B1 Acid grassland                                 | <0.01                                                     | <b>&lt;0.01</b>                                           |
| B2 Neutral grassland                              | 0.11                                                      | <b>1.90</b>                                               |
| B4 Improved grassland                             | 3.63                                                      | <b>61.61</b>                                              |
| C1 Bracken                                        | <0.01                                                     | <b>0.03</b>                                               |
| D1 Dry dwarf shrub heath                          | 0.01                                                      | <b>0.22</b>                                               |
| F1 Swamp                                          | 0.05                                                      | <b>0.80</b>                                               |
| G Open water                                      | 0.02                                                      | <b>0.28</b>                                               |
| I1 Natural rock exposure and waste                | <0.01                                                     | <b>0.01</b>                                               |
| J1.1 Arable crops                                 | 0.04                                                      | <b>0.74</b>                                               |
| Artificial bare surfaces                          | 0.01                                                      | <b>0.24</b>                                               |
| Natural bare surfaces                             | <0.01                                                     | <b>0.10</b>                                               |
| Semi-natural herbaceous vegetation (Unclassified) | 0.23                                                      | <b>3.89</b>                                               |

The River Tywi is incredibly mobile, with areas of high-velocity rapids and slow, swirling pools with substrate deposition (JNCC, 2011). This variation creates a range of ecological niches with varying environments and vegetation. Exposed gravel and shingle beds support species such as the water forget me knot (*Myosotis scorpioides*) and yellow cresses (*Rorippa palustris*) (Countryside Council for Wales, 1998) and provide sufficient habitat for many protected invertebrates. The channel supports many submerged aquatic vegetation, with species such as water crowfoot (*Ranunculus pencillatus*) and water starwort (*Callitriche hamulut*), and is home to several protected fish species.

The wet woodlands present are typically dominated by common alder (*Alnus glutinosa*), willow (*Salix spp.*), and downy birch (*Betula pubescens*), which are known for preferring the wet, sandy soils associated with the Tywi floodplain. These areas support a range of species, including the elusive European otter (*Lutra lutra*) and the UK BAP priority species, the marsh fen (*Thelypteris palustris*) (JNCC, 2018). Wet

woodlands are also praised for their water attenuation capacities; therefore, they now face the pressure of degradation from diffuse pollutants and agricultural run-off (Woodland Trust, 2016).

As a consequence of intense and unsustainable farming practices, improved grasslands now dominate the terrestrial land surrounding the river Tywi, (Kerr & Nisbet, 2011; Natural Resources Wales, 2014; Carmarthenshire County Council, 2015). Historically, these areas were rich and biodiverse habitats, comprising wetlands and floodplain meadows (Carmarthenshire County Council, 2015), supporting several essential waders and invertebrates (JNCC, 2008). Therefore, there still exists potential to re-diversify these habitats to re-establish their associated ecosystem services; however, stakeholder engagement and consensus on the shift will be critical.

Figure 8 summarises the land use change within the Tywi SAC scope between 2018 and 2022 and illustrates the decrease in wet woodland (natural aquatic vegetation and water) to form grazable herbaceous grassland. The fields along the Tywi SAC are not necessarily used for crops (cultivated terrestrial vegetation) but show how clearing and ploughing of lands for agriculture have driven habitat change within the SAC (Kean & Chadwick, 2021; River Restoration Centre, 2021), as indicated by the increase in the bare surface and decreased in natural aquatic habitats.

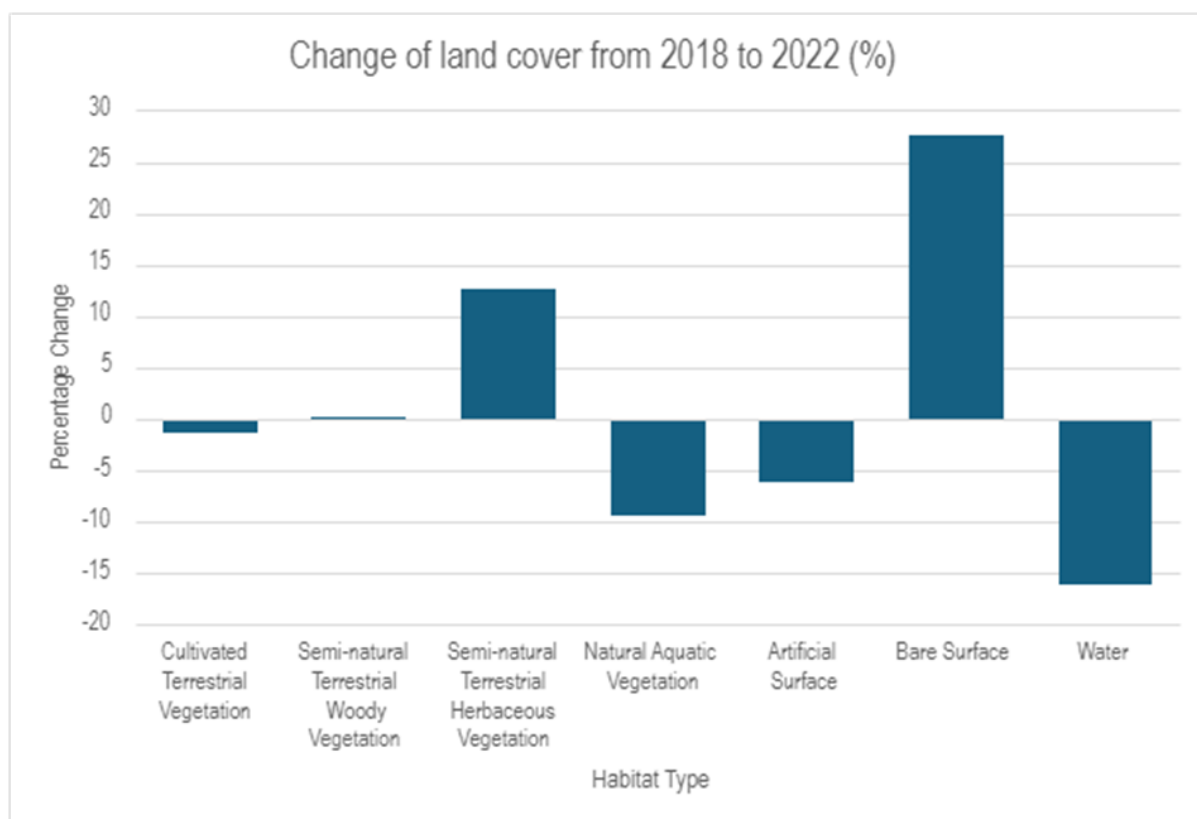


**Figure 8:** Graph illustrating the changes in land cover for the river Tywi SAC between 2018 and 2022. Change is presented by the proportion of land cover in percentage. Land cover data was taken from the Living Wales EarthTrack geo-portal and is based on the Food and Agriculture Organisation's (FAO) Land Cover Classification System (LCCS).

### 2.3.2 Species of the river Tywi SAC – Llandovery to Llandeilo

The River Tywi SAC is a significant reserve for both rare and protected species within Wales, with protections from the Wildlife and Countryside Act (1981), European Habitats and Species Directive (2010), and the Environment (Wales) Act (2016). Although designated for only five species, the site is a haven for biodiversity, connecting habitats from the sea to the valley. The NBN Atlas indicates over 3,500 species occurrences since the start of the century, and the number of occurrences per class is shown in Table 2 below (NBN Atlas, 2024).

Of these occurrences, 91% relate to the animal kingdom, in which invertebrate records dominated with over 1800 sightings. Some exciting species observed include the nationally scarce club-tailed dragonfly (*Gomphus vulgatissimus*) and the wolf spider (*Arctosa aneria*). The only recorded amphibian for the site is the common toad (*Bufo bufo*) (Welsh Government, 1981), while no reptiles have been observed since the start of the century.

Since 2000, 89 occurrences of bird species have been observed, with notable species including the Eurasian tree sparrow (*Passer montanus*), the bullfinch (*Pyrrhula pyrrhula*), the common starling (*Sturnus vulgaris*), and the grey heron (*Ardea cinerea*). Many of the birds within the SAC are protected (NBN Atlas, 2024); however, it is interesting to note that several protected species have breeding grounds just downstream of Llandovery (Countryside Council for Wales, 1998).

Many fish species are observed within the channel, with some known to migrate from the estuary to reach grounds past Llandeilo in accordance with their lifecycle (Garrett, 2015). Fish species have a particular part to play within the site, making up four total features for SAC designation. The twaite and allis shad (*Alosa fallax* and *Alosa alosa*, respectively) (Freyhof & Kottelat, 2008) are migratory fish species with important breeding and spawning sites between Carmarthen and Llangadog (JNCC, 2015) – and comprise Feature 1. Remaining fish features include the sea lamprey (*Petromyzon marinus* – Feature 2), river and brook lamprey (*Lampetra fluviatilis* and *Lampetra planeri* respectively - Feature 3), and the bullhead (*Cottus gobio* – Feature 4). Other notable species include Atlantic Salmon and Atlantic Trout (Natural Resources Wales, 2022), which is why the Tywi is infamous for its freshwater angling (Kean & Chadwick, 2021).

Lastly, many mammals are known to utilise the habitats within the reaches of the SAC. However, the most noteworthy is the European otter (*Lutra lutra*) population that is known to travel the full extent of the Tywi SAC from estuary reaches up to Llandovery, using various habitats for breeding, hunting, and resting (JNCC, 2015; NBN Atlas, 2024; Oleynikov *et al.*, 2022). This species makes up the fifth and final feature of the conservation objectives of the current management plan and is the only feature to reside outside the fish class.

**Table 2:** Total number of occurrence records for species classes within river Tywi between 2000-2024. Data taken from NBN Atlas (2024).

| Classes    | Total Occurrence Records (2000-2024) |
|------------|--------------------------------------|
| Mammals    | 7                                    |
| Birds      | 89                                   |
| Insects    | 1831                                 |
| Amphibians | 1                                    |
| Reptiles   | 0                                    |
| Fishes     | 111                                  |
| Fungi      | 2                                    |
| Plants     | 694                                  |

## 2.4 Elevation and topography

The River Tywi flows through a typically wide 'U'-shaped valley with a floodplain floor that quickly rises into steep valley walls (Figure 9). It then meanders around higher outcrops, remaining in the low-level plane.

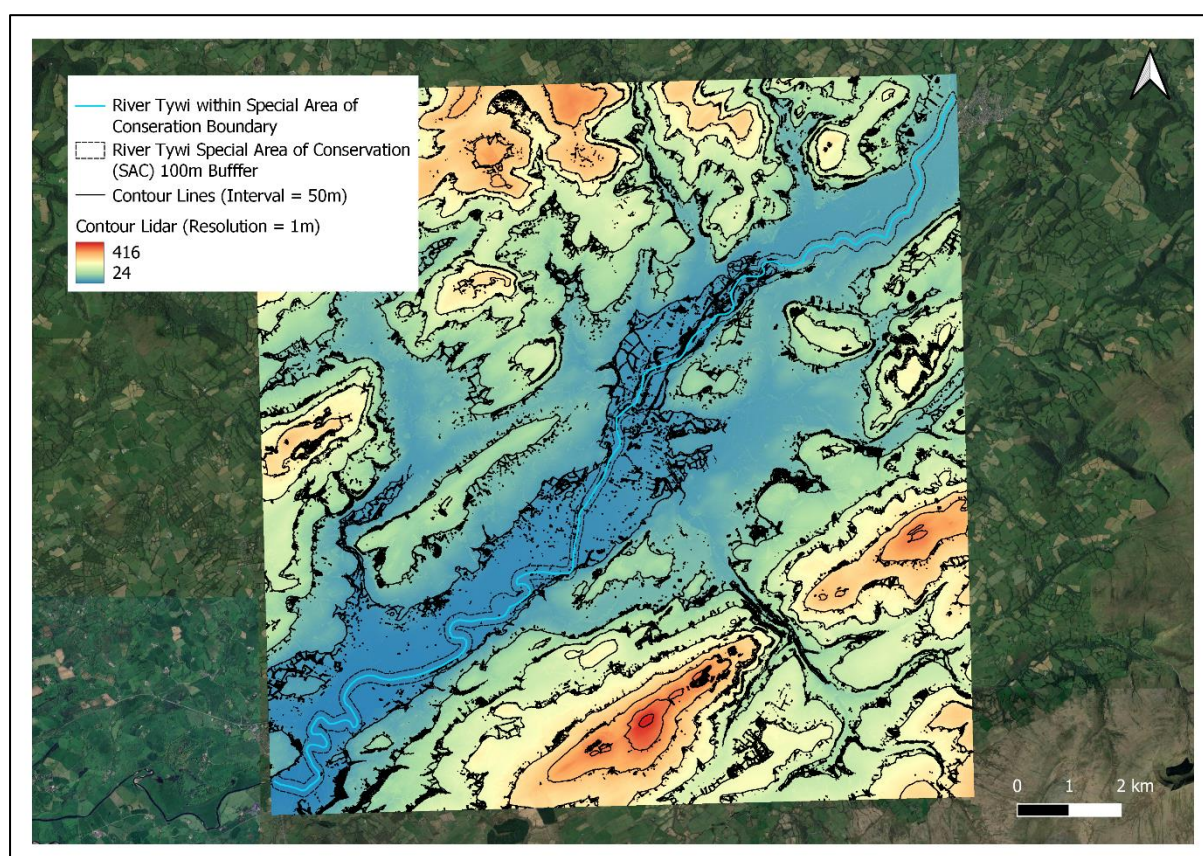


**Figure 9:** Elevation relief of the river Tywi SAC from Llandovery to Llandeilo, with contour lines (solid black) set at 50m intervals. The river Tywi SAC buffer is shown as a black dashed line. Contour Lidar, with a resolution of 1m, shows higher elevation in red and lower elevation in blue. LiDAR data from the Welsh Government's data is available on DataMapWales (2023).

The elevational drop is very marginal between Llandovery and Llandeilo, with an approximate 30m elevational difference (Natural Resources Wales, 2023), emphasising the low-level nature of the River Tywi between these two points. However, it is evident by the topography of the valley, with the hills surrounding the SAC measuring close to 400 metres above the site (Ericksen Jones, 1951; Natural Resources Wales, 2023), that the SAC is subjected to high-velocity run-off from a range of directions.

Interestingly, a 1951 study of the site (Ericksen Jones, 1951) (Figure 10) shows the river's tributaries alongside elevation gain, emphasising how the valley formation and elevation relief coincide with existing watercourses. Additionally, the elevation profile of the River Tywi (Figure 11) represents the sustained elevation between the two towns well.

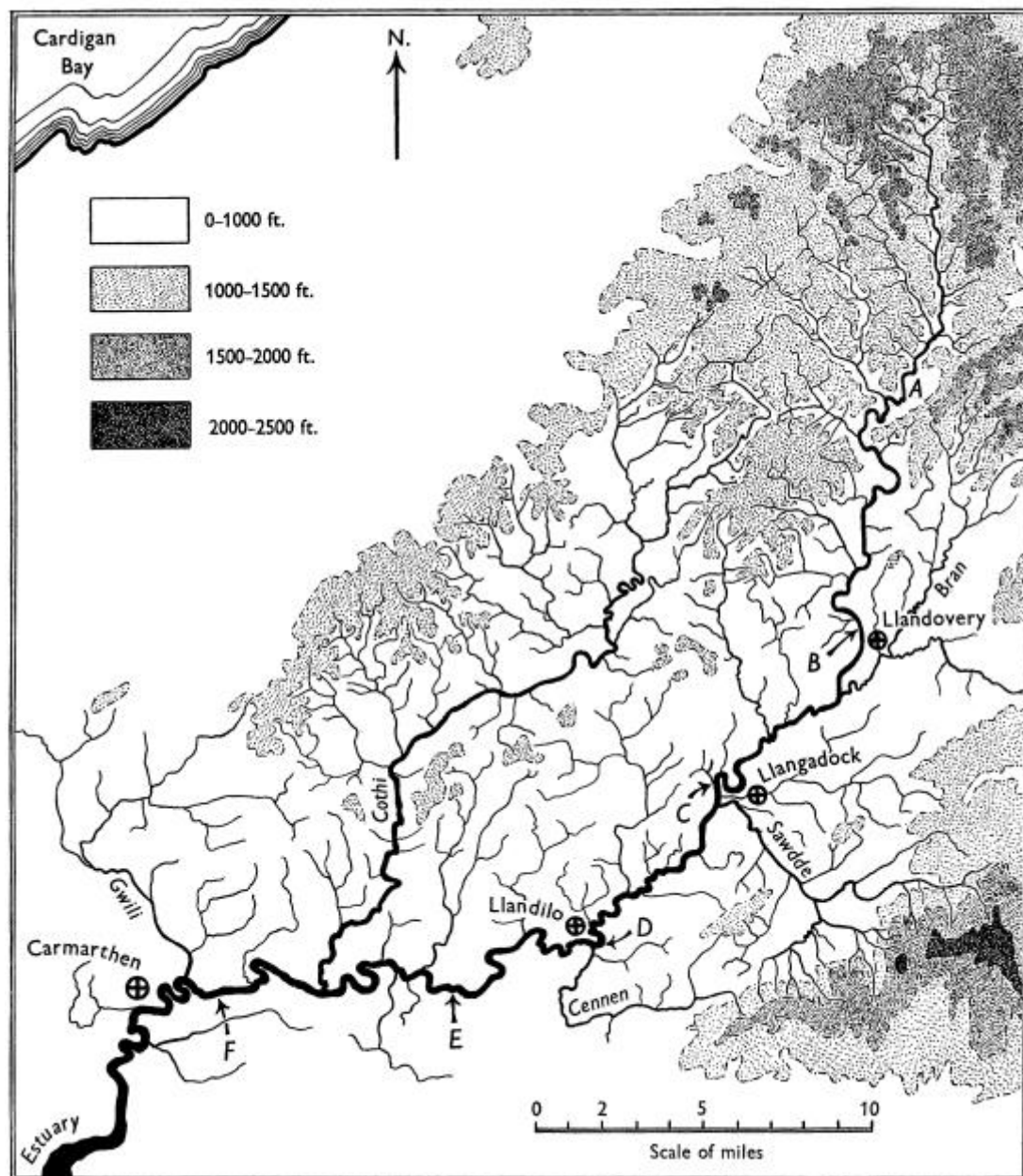


**Figure 10:** Historic 1951 Map of River Tywi (bold solid black line) and its tributaries (fine black lines), with shading indicating elevation relief in feet. Map taken from the 1951 ecological study of the river Tywi (Erickson Jones, 1951).

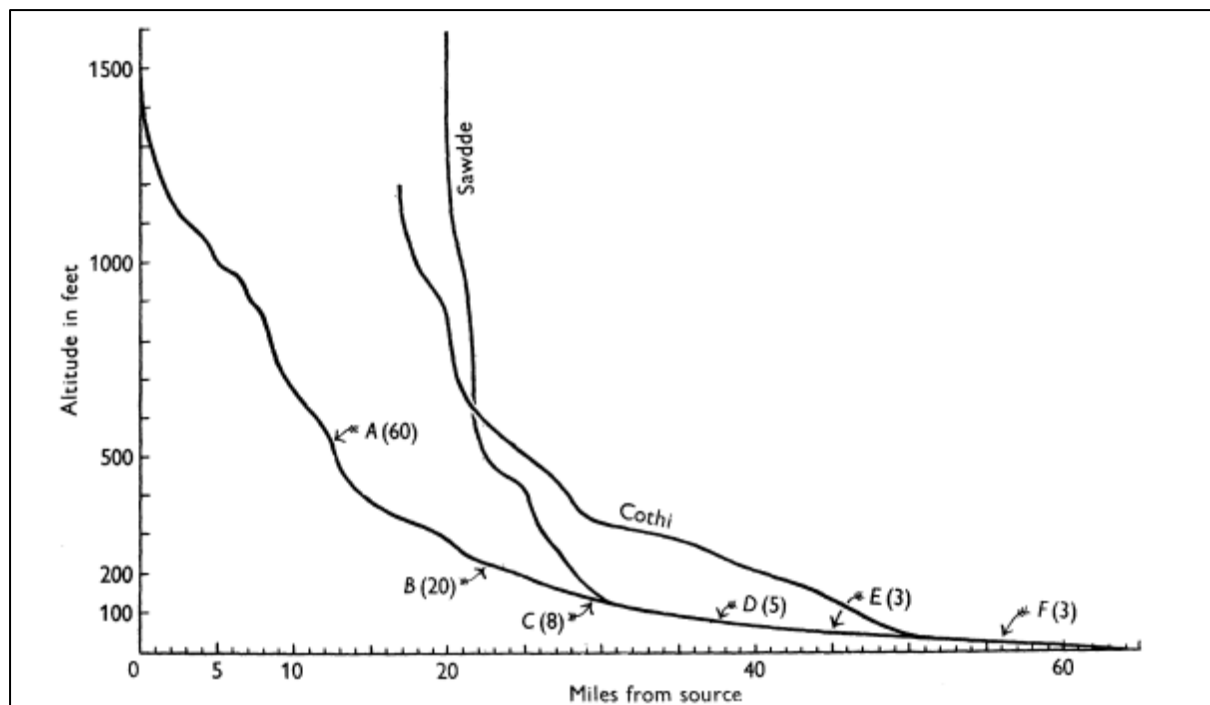


**Figure 11:** Elevation profile of the river Tywi from source to sea, with its two main tributaries, the Sawdde and Cothi. Elevation measured in feet and taken from the 1951 ecological study of the river Tywi (Ericksen Jones, 1951).

## 2.5 Flood risk and historical flooding

Flood risk is defined as the probability of flooding in any given year and is expressed as Annual Exceedance Probability (AEP) (Welsh Government, 2020; Natural Resources Wales, 2023). The flood risk categories according to AEP are listed in Table 4 below. These definitions are critical for managing and identifying flood risk.

In terms of catchment, the River Tywi basin drains all of the water from the Tywi Valley and accepts water from the Cambrian mountains. Therefore, it is acknowledged that the flood risk within the River Tywi SAC is already at increased higher than other areas within the County (Cranfield University, 2024).

**Table 4:** Definitions of flood risk, according to Annual Exceedance Probability (AEP)

| <b>Flood Risk</b> | <b>Probability</b>         | <b>Chance of occurrence</b> |
|-------------------|----------------------------|-----------------------------|
| Low               | < 1 in 100 but > 1 in 1000 | 3.3%                        |
| High              | < 1 in 30 but > 1 in 100   | 3.3-1%                      |
| Medium            | > 1 in 30                  | 1-0.1%                      |

### 2.5.1 Fluvial flood risk

The River Tywi SAC experiences frequent flooding and over-levelling of the banks. However, this is unsurprising considering the topography of the adjacent landscape and the number of tributaries entering the river, notably the Bran, Sawdde, and Dulais. Consequently, the Tywi SAC exists within an extensive high fluvial flood risk zone, evident in Figure 12. Figure 13 shows areas with medium and low flood risk.

Unlike other SAC areas, the site is predominantly rural, with few residential communities close to the river. Therefore, flood risk is only perceived where there is a risk of internal flooding or loss or damage to properties. Subsequently, only the significant villages with relatively high urban development close to the river are threatened by internal flooding during flood events – most notably Llandovery, Llangadog, and Llandeilo. The flood risk within these areas has been exacerbated by low river-level development and bottlenecking of the channel. Therefore, flood defences have been implemented to defend and protect these areas (Natural Resources Wales, 2015).



**Figure 12:** Extent of fluvial flood risk along river Tywi SAC from Llandovery to Llandeilo. Higher risk areas (1 in 30 AEP) are shown in dark blue, while lower risk areas (1 in 1000 AEP) are shown in light blue. Flood risk data from NRW's data is available on DataMapWales (2023).

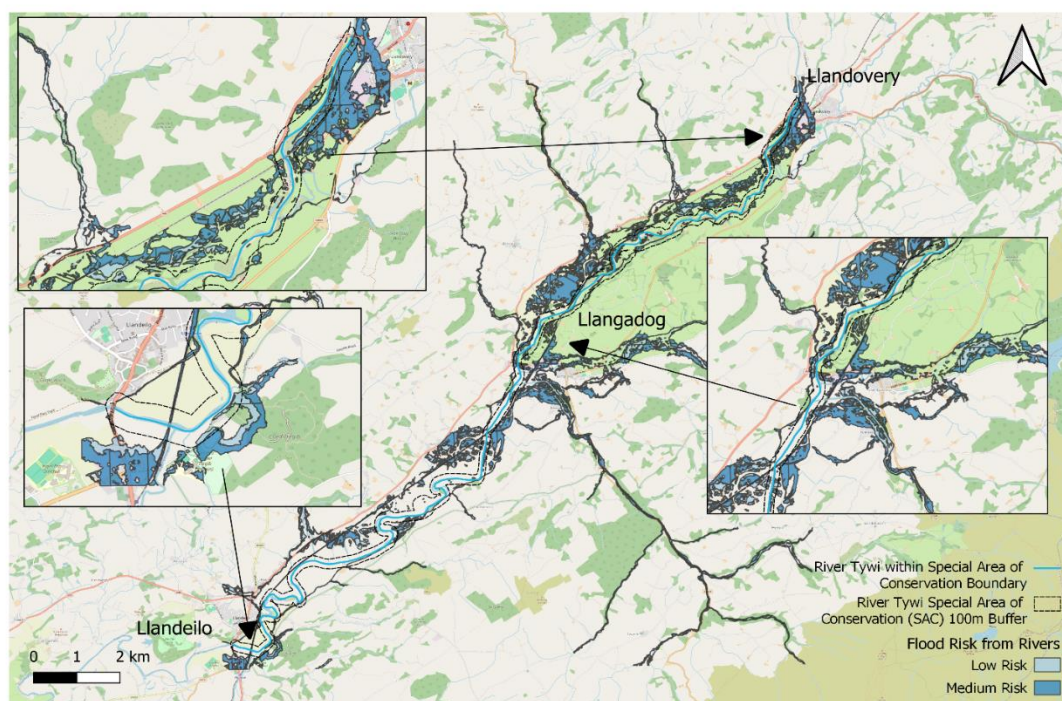


**Figure 13:** Extent of fluvial flood risk along river Tywi SAC between Llandovery and Llandeilo, showing medium risk (1 in 100 AEP) in medium blue and low risk (1 in 30 AEP) in light blue. Callout boxes are used to show further details of concentrated flood risk areas. Flood risk data from NRW's data is available on DataMapWales (2023).

### 2.5.2 Pluvial flood risk

Surface water run-off and its contribution to fluvial flooding is a significant concern for Tywi. Meanwhile, pluvial flooding on its own is more likely to impact residential and commercial properties that are set back by the river.

Figure 14 highlights how the steep valley walls and several tributaries leading into the Tywi create areas of clustered flood risk along the SAC. These patterns mirror similar observations seen in fluvial flood risk maps. Therefore, it is understandable how high precipitation events can increase the risk of fluvial in the low areas surrounding the site (Frost & Jones, 1987).

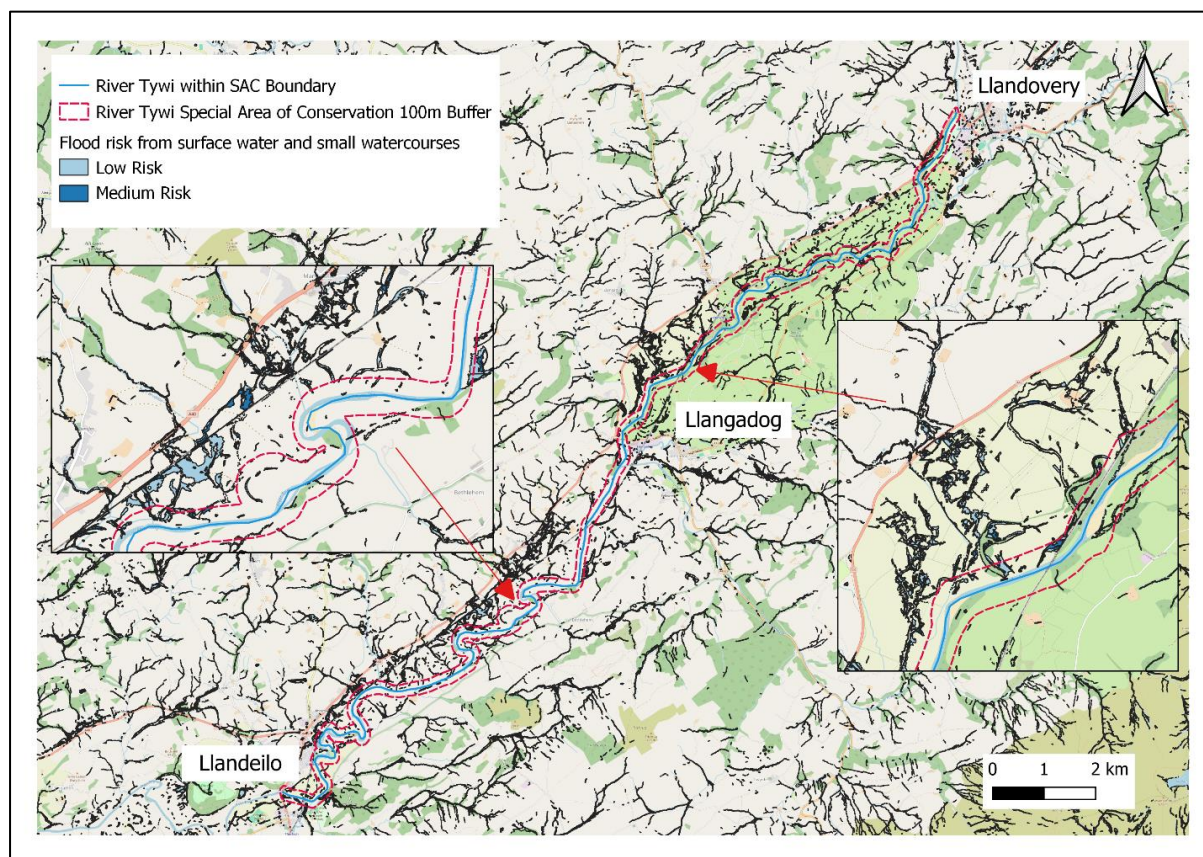


**Figure 14:** Extent of pluvial flood risk along river Tywi SAC between Llandovery and Llandeilo, showing medium risk (1 in 100 AEP) and low risk (1 in 30 AEP). Callout boxes are used to show further details of concentrated flood risk areas. Flood risk data from NRW's data is available on DataMapWales (2023).

### 2.5.3 Historical flooding

Many sources reflect on the devastating flood of October 1987 (Frost & Jones, 1987; Natural Resources Wales, 2015), wherein major hydrometeorological events led to the overtopping of the Tywi riverbanks, causing extensive flooding in Llandovery, Llanwrda, Llangadog, Rhosmaen, and Llandeilo. However, more recently, Carmarthenshire County and Wales have been experiencing more persistently wetter winters, increasing the likelihood of flooding. The rainfall of 2020, which set a Met Office record, and the recent storms of Henk and Gerritt (James, 2024) have been

attributed to the effects of climate change and only put weight on the increased risk of flooding predicted in the future (Natural Resources Wales, 2020).

### **3 Management of the river Tywi SAC**

#### **4.1 Current management of the river Tywi SAC**

Natural Resources Wales (NRW) Core Objectives for the River Tywi SAC is the primary document detailing the features and conservation objectives for the site's management. The site's overall vision aims to restore its natural processes and restore and maintain habitat and species to high-quality and favourable conditions. These standards are based on scientific targets and industry guidelines, including the Water Framework Directive (Thomas, Hatton-Ellis & Garrett, 2013) and the Common Standards Monitoring approach.

As mentioned previously, the SAC has five species features designated, of which four are protected fish species, while the remaining one is a protected mammal (Carmarthenshire County Council, 2018). There are no habitat features mentioned in the document. However, habitat availability and quality are considered throughout, as they influence the species' features. A priority of this document and criteria for categorising a feature as favourable (Thomas, Hatton-Ellis & Garrett, 2013) is to ensure that factors affecting the population are controlled or monitored. Therefore, it is assumed that restoring and enhancing these features will restore the SAC to high ecological quality (Wales Biodiversity Partnership, 2020).

Therefore, current works include monitoring the flow regime, water quality, and condition of physical habitat under Habitat Regulations Assessments and Phosphorus compliance targets (Kean & Chadwick, 2021; Hatton-Ellis & Jones, 2021) and carrying out systematic species surveys to indicate habitat use and population numbers. Works have concluded on removing artificial obstructions within the watercourse (Roni *et al.*, 2019), and due to their pressures on existing species and habitat health, removal of invasive species has been completed where necessary (Carmarthenshire Fishermen's Federation, 2017; BBC, 2013). Moreover, in line with the existing management plan, NRW is currently undertaking its 'Four Rivers for LIFE' project, which aims to continue similar works in the four main Welsh rivers, including the Tywi (Natural Resources Wales, 2024). This project coincides with the aims of the local flood risk management plan and Carmarthenshire Nature Partnership as it prioritises a healthy and resilient Wales, raising awareness on climate issues and restoring natural biodiversity (Natural Resources Wales, 2023). All fish species' features are unfavourable based on failure to meet flow targets. However, the European otter is classed as favourable based on distribution throughout the site (Natural Resources Wales, 2022).

The document identifies climate change as a critical stressor to the conservation objectives, noting that species distribution habitat suitability will be significantly altered (Natural Resources Wales, 2022). In response to this stressor, the plans rely on restoring natural processes to build climate resilience – yet no actions are given to fix these processes besides invasive and artificial barrier removal. Furthermore,

pollutants and agricultural diffuse are also identified as crucial threat to the condition and health of the SAC (River Restoration Centre, 2021). Yet, no mention is given to addressing these inputs aside from continuing to monitor these levels within the river. Therefore, in terms of putting theory into practice, more consideration is needed to address these concerns with practical and feasible objectives to reduce their impacts within the SAC.

The current management plan provides clear conservation objectives and targets to monitor the designated features, with reliable methodology and quantifiable performance indicators (Environment Agency, 2018). However, little regard is given to the natural restoration of habitats within the site or in a broader ecological context under natural processes. Lastly, more consideration should be given to the timescale of conservation objectives, alongside the inclusion of stakeholder engagement and responsible stakeholders' role in successful habitat management.

## **4.2 Proposed management of the river Tywi SAC**

### **4.2.1 Recommendations from existing management**

Continued monitoring of designated features and their associated factors is encouraged to gather up-to-date records for species distribution and site usage. The timeline for European otter, Allis and Twaite shad surveys is approaching; therefore, they should be carried out when appropriate (Chanin, 2003; Hillman, Cowx & Harvey, 2003). Finally, general water quality testing, particularly for nitrates and phosphates, should be completed within the next two years to ensure compliance assessments can be completed within the appropriate intervals (Hatton-Ellis & Jones, 2021).

Artificial barriers and invasive species should also be removed, including Himalayan balsam, giant hogweed, and Japanese knotweed. Removal projects could involve volunteers or engaged specialist groups. Still, they should only be undertaken, where appropriate, safely and strategically, without high risk of disturbance or destruction to habitat (Carmarthenshire Fishermen's Federation, 2017; Natural Resources Wales, 2023).

In addition, macroinvertebrate surveys and general habitat assessments should be undertaken throughout the site, as they indicate the status and health of habitats adjacent to the river.

### **4.2.2 WWNP Floodplain restoration potential**

Floodplain habitats are among the most ecologically supportive habitats in the world and have been found to contribute significantly to a vast array of ecosystem services (Roni *et al.*, 2019). Disconnection or degradation of these habitats can create habitat and species isolation, threatening the species and ecosystem services it supports (Kerr & Nisbet, 2011). Working with natural processes (WWNP) underlines many conservation and management strategies on a local and national level, with the vision to restore and protect the naturally occurring phenomena within the environment, reinstate the natural biodiversity, and build resilience to change (Natural Resources Wales, 2024).

Floodplain restoration potential represents opportunities to re-establish the physical and hydrological processes of floodplains adjacent to the watercourse (The Flood Hub, 2023). It comprises opportunities for floodplain reconnection and floodplain woodland planting. The former represents the potential to reinstall the connection between rivers and their adjoining floodplains (Environment Agency, 2018), while the latter refers to opportunities to plant vegetation to form floodplain woodlands (Cooper *et al.*, 2021). Figure 15 shows the potential for these two schemes in the upper unit of the river Tywi SAC.

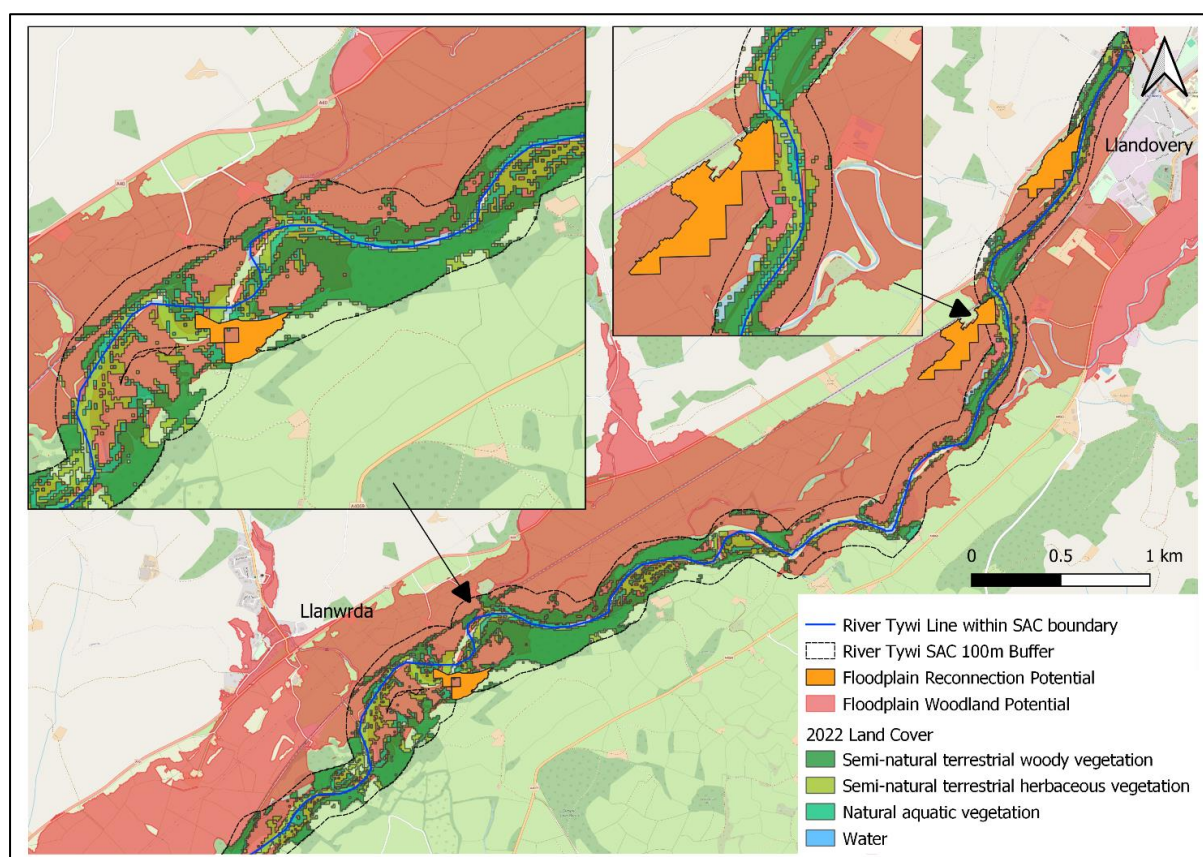


**Figure 15:** Working With Natural Processes (WWNP) floodplain restoration potential along river Tywi SAC Unit 1. The map indicates the potential for floodplain woodland planting (red) and floodplain reconnection potential (orange). The map also shows recent land cover types to inform where woodland and existing aquatic vegetation exist—data for floodplain restoration potential taken from NRW's datasets available on DataMapWales (2018).

There is vast potential for floodplain woodland planting along the Tywi SAC, which extends to cover a large proportion of the valley floor. Floodplain reconnection potential is limited to three distinct areas, which exist on old meander routes of the Tywi River (Environment Agency, 2018); the land cover data shows that these potential areas already exhibit natural aquatic vegetation and semi-natural woody vegetation. Subsequently, reconnection and woodland planting could be implemented together.

Planting and restoring native floodplain woodlands with willows, birches and alders (CIEEM, 2021; JNCC, 2008) have been found to have great successes in terms of

mitigating flood risk (Sealy *et al.*, 2023; West Cumbria Rivers Trust, 2017). Increasing surface roughness and aeration to the surrounding soil provides higher attenuation and storage of run-off, slowing velocity rates within the watercourse by nearly 40% (Cooper *et al.*, 2021). Similarly, restored and reconnected floodplains have been shown to support more biodiverse species communities (Seer, Brunke & Schrautzer, 2018). Thereby building the capacity of the habitat to adapt to climate change through restoring natural vegetation and habitats.

#### 4.2.3 Riparian Woodland Potential

Like floodplain woodland, riparian woodland refers to woodland adjacent to a watercourse but is limited to within the riparian zone (Cooper *et al.*, 2021). These relatively narrow areas provide sufficient habitats for various species and are strongly associated with some rare invertebrates (Woodland Trust, 2016). Generally located within 25 metres of a watercourse, riparian woodland can provide a buffer strip along a diverse range of flowing water bodies, as seen in Figures 16 and 17.

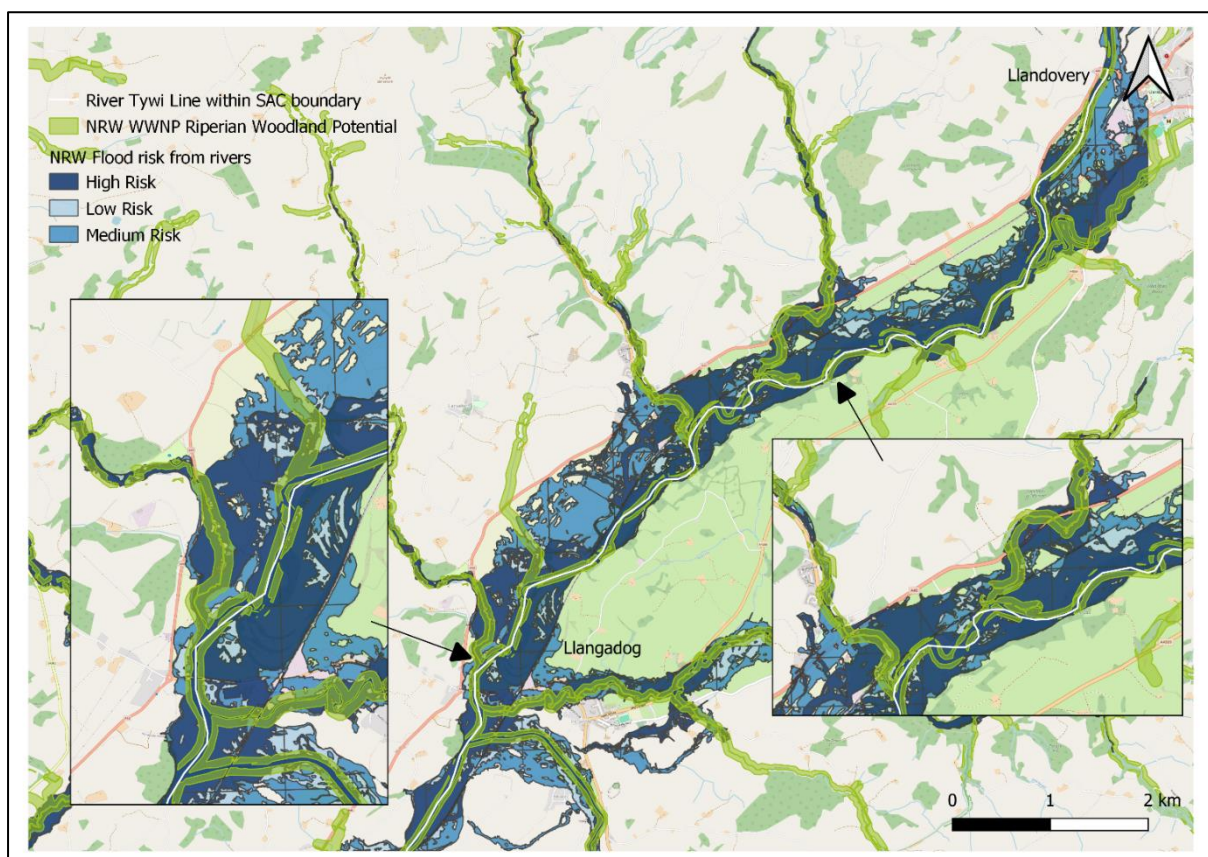


**Figure 16:** Working With Natural Processes (WWNP) riparian woodland potential along river Tywi SAC from Llandovery to Llangadog. The map also shows fluvial flood risk to highlight areas with the most potential to benefit from riparian planting—data taken from NRW's riparian woodland potential data available on DataMapWales (2018).

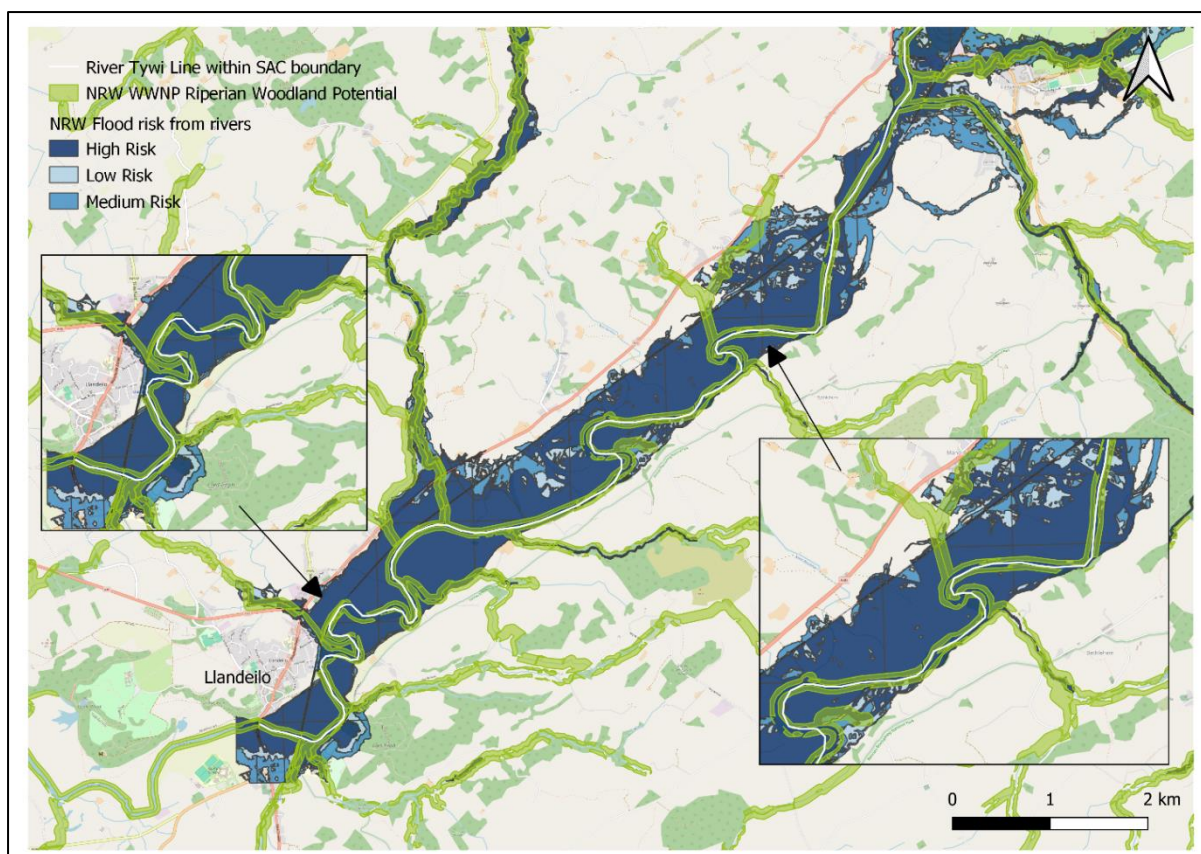


**Figure 17:** Working With Natural Processes (WWNP) riparian woodland potential along river Tywi SAC from Llangadog to Llandeilo. The map also shows fluvial flood risk to highlight areas with the most potential to benefit from riparian planting—data taken from NRW's riparian woodland potential data available on DataMapWales (2018).

Once established, these buffer strips work similarly to floodplain planting. However, as they typically exist closer to the river, riparian woodland along the Tywi would provide shade and tree cover over the river channel (Woodland Trust, 2016). Therefore, riparian planting opportunities to mitigate climate change exist by supporting the regulation of water temperatures and sequestration of carbon from the atmosphere (CIEEM, 2021; Ellis, 2020). Additionally, creating these habitats will allow for greater connectivity between the River Tywi and surrounding woodland, allowing greater potential for the distribution of important species such as the European otter (Vermaat *et al.*, 2021; Liles, 2016).

However, as Figures 16 and 17 identified, another great benefit for riparian woodland is the ability to attenuate, store and filter water. Wherein the ability of these habitats to filter up to 20% of nitrates from watercourses (Peter *et al.*, 2012), reduce pollutants by up to 80% (Forestry Commission, 2011), and increase flood storage depth by 20cm (Cooper *et al.*, 2021), addresses the significant concerns of flooding and agricultural runoff for the river Tywi SAC. However, it is important to note that woodland establishment can be costly regarding resources and labour and can take several years to fully mature. Therefore, smaller-scale conservation actions such as monitoring and removing barriers should be undertaken in the interim if these schemes are not approved.

## 5 Conclusion

Overall, the existing habitat management plan outlines clear objectives and methods to restore the ecological status of the river Tywi SAC to a high quality through the maintenance and restoration of natural processes. However, an ecological context of a broader scope is required to address issues such as agricultural pollution and climate change. By utilising datasets regarding the Working With Natural Processes principle, we can see that the river Tywi SAC has vast potential for restoring natural processes while addressing flood risk, agricultural run-off, and climate change mitigation. Thereby conserving and managing the ecology of the site simultaneously.

However, to implement these schemes, more engagement and collaboration with stakeholders are required to raise awareness of these issues and emphasise the need for local action, not just for the ecological benefit but also to benefit the agricultural and cultural services of the landscape. Moreover, due to the fluid nature of the river Tywi SAC, monitoring and analysing routine data is crucial to understanding the site's status condition while informing us of rising stressors. Early identification of potential issues will help to inform and adapt future management strategies, further building the site's resilience to climate change.

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