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Reservoir Discontinuance - Brithdir Mawr Reservoir

Aber Eilun and Afon Alun walkover survey and WFD assessment

Report for Dwr Cymru Welsh Water

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1 Brithdir Mawr Reservoir, the Aber Eilun and Afon Alun

Brithdir Mawr Reservoir is located in North Wales, ~6.1km to the west of Mold at an elevation of ~255mAOD. The reservoir drains a catchment area of 1.97km^2, mostly the upland areas of the Clwydian Range located immediately to the west, the highest points being Moel Famau (at 554mAOD) to the west of the reservoir and Ffrith Mountain (at 377mAOD) to the north of the reservoir.

Within the reservoir catchment the main watercourse is the Aber Eilun. This forms the southernmost inflowing tributary to the reservoir. Another smaller tributary flows into the reservoir from the north. The Aber Eilun rises at an elevation of ~381mAOD at a source on the eastern flank of Moel Famau and flows from this source to the Afon Alun over a total length of 3.45km. From its source it flows in an easterly direction for 1.45km before flowing into Brithdir Mawr Reservoir. From the reservoir it flows in a south easterly direction for 0.31km until it meets a tributary. From this tributary it then flows in a roughly easterly direction for 1.68km until the confluence with the Afon Alun. Other than Brithdir Mawr Reservoir, there are no online lakes of ponds on the reach.

Geology along the reach is characterised by a mix of Ordovician mudstones, siltstones and sandstones in the upper reaches and Carboniferous limestones in the lower reaches[1]. From the reservoir to ~0.92km downstream the reach is underlain by mudstones, siltstones and sandstones of the Ordovician Elwy Formation. From this point to 1.61km the reach is predominantly underlain by mudstones and siltstones of the Ordovician Nantglyn Flags Formation (although a small section of the reach between 1.31km to 1.40km is underlain by Carboniferous limestones and argillaceous rocks of the Foel Formation). From 1.61km to 1.75km the reach is underlain by the Carboniferous Leete Limestone Formation and from 1.75km to the end of the reach the bedrock is the Carboniferous Loggerheads Limestone Formation.

Land cover within the catchment upstream of the reservoir is predominantly upland moorland and heath, with some grassland and woodland. Land cover along the Aber Eilun downstream of Brithdir Mawr Reservoir is dominated by improved grassland, however from around 1.76km the river flows almost entirely through predominantly deciduous woodland (with improved grassland dominating outside of the woodland) until the confluence with the Afon Alun.

The reservoir has a surface area of 7,000m^2 and a total capacity of 21,265m^3 (of which 824m^3 is occupied by silt and aquatic vegetation) (Stillwater Associates, 2019[2]). There are two outflows from the reservoir, the main overflow which is a stepped overflow down the southern edge of the dam face and an auxiliary overflow which drains the reservoir from its north eastern edge and around the base of the reservoir embankment. The auxiliary overflow joins the main overflow at the southern edge of the reservoir embankment and passes forward flow into the Aber Eilun.

The reservoir no longer provides benefit to Welsh Water and could also require significant capital investment to ensure that the reservoir complies with UK dam safety standards. As such, Welsh Water have commissioned Stillwater Associates to undertake a study to assess the feasibility of decommissioning the reservoirs. Ricardo Energy and Environment are working with Stillwater Associates to provide environmental investigations with respect to the decommissioning investigation.

As part of the investigation an understanding of the potential impact of the decommissioning of Brithdir Mawr Reservoir on the downstream watercourses, the Aber Eilun and Afon Alun, is required. As such a walkover survey of both river reaches was undertaken to collect information to understand the existing condition of the watercourses, the features present in the watercourse and use these to understand, what, if any, impacts may occur.

[1] British Geological Survey, Geology of Britain. http://mapapps.bgs.ac.uk/geologyofbritain/home.html. Accessed 10 September 2021.
[2] Stillwater Associates Ltd., (2019). Brithdir Mawr Reservoir. Discontinuance Feasibility Assessment Report. Dwr Cymru Welsh Water. April 2019. 206pp.

1.1 Brithdir Mawr Reservoir – decommissioning option

The decommissioning of the reservoir would entail removal of a section of the reservoir embankment by excavating a notch which is 10m wide at its base and with a 3m wide section for a low flow channel. The original watercourse will be reinstated to its original course through the reservoir and the notch (Stillwater Associates, 2019[3]). Some silt removal from the original watercourse within the reservoir basin is planned as part of the activities. It is likely that some temporary or permanent sediment traps or detention basins will also be created to manage fine sediment release. Rehabilitation and seeding of the remaining drained reservoir basin is also proposed. The decommissioning would effectively create a more naturalised hydrological and sedimentological regime downstream of the dam, although there would still remain other controlling factors in the watercourse.

2 Walkover surveys and assessment

As part of the wider decommissioning project two walkover surveys have been conducted, one of the Aber Eilun downstream of Brithdir Mawr Reservoir and one of the Afon Alun downstream of the confluence with the Aber Eilun. The reasoning for these walkovers is to:

- Understand the potential impacts from the decommissioning of the reservoir on both watercourses.
- Undertake a WFD assessment on the WFD waterbody covering the Afon Alun (and including the Aber Eilun) to understand the potential impacts to WFD status resulting in the decommissioning of the reservoir.

The information collected during both walkovers will be used to understand the existing conditions of the watercourse, the features present in the watercourse and ascertain what impacts the decommissioning of Brithdir Mawr Reservoir would have on the downstream watercourses and if there is an impact on WFD status within the relevant waterbodies. An overview of each watercourse is presented below, followed by a WFD assessment.

2.1 Aber Eilun – watercourse baseline description

On the 14 April 2021, a walkover of the Aber Eilun was conducted in order to collect information to understand the existing conditions of the watercourse, the features present in the watercourse and ascertain what impacts the decommissioning of Brithdir Mawr Reservoir would have on the downstream watercourse. The walkover covered the two inflowing streams to Brithdir Mawr (from ~75m upstream of where each flowed into the Brithdir Mawr Reservoir) and the downstream watercourse between the spillway of Brithdir Mawr and the confluence with the Afon Alun (1.57km).

During the site visit, the reach was broken up into seven individual reaches (A to H) based on changes in geomorphology, hydrology and anthropogenic features. These reaches are displayed in **Figure 2-1** and key features of interest on the watercourse are detailed in **Figure 2-2**.

[3] Stillwater Associates Ltd., (2019). Brithdir Mawr Reservoir. Discontinuance Feasibility Assessment Report. Dwr Cymru Welsh Water. April 2019. 206pp.

Figure 2-1 Brithdir Mawr Reservoir and Aber Eilun to Afon Alun walkover – study reaches

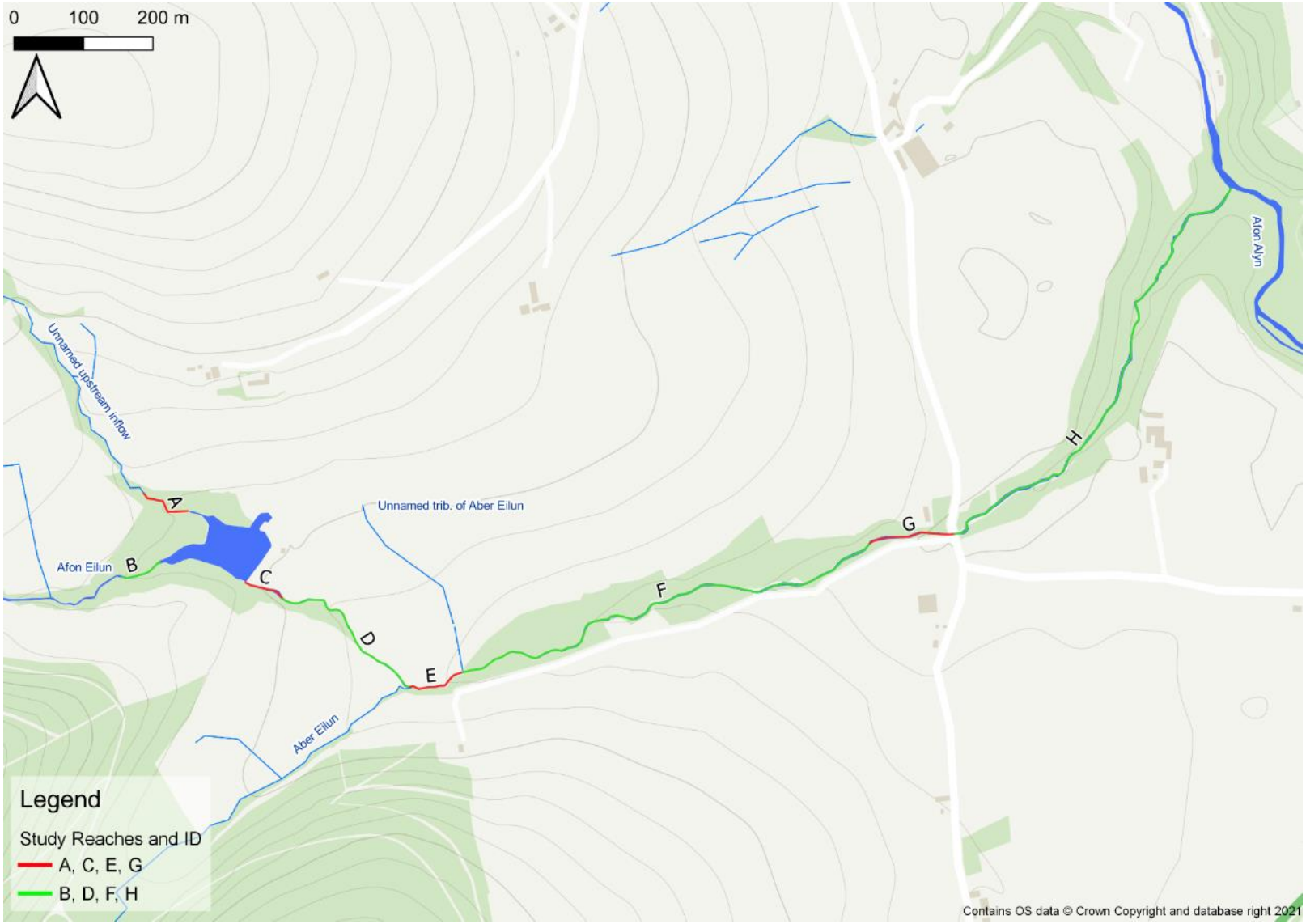
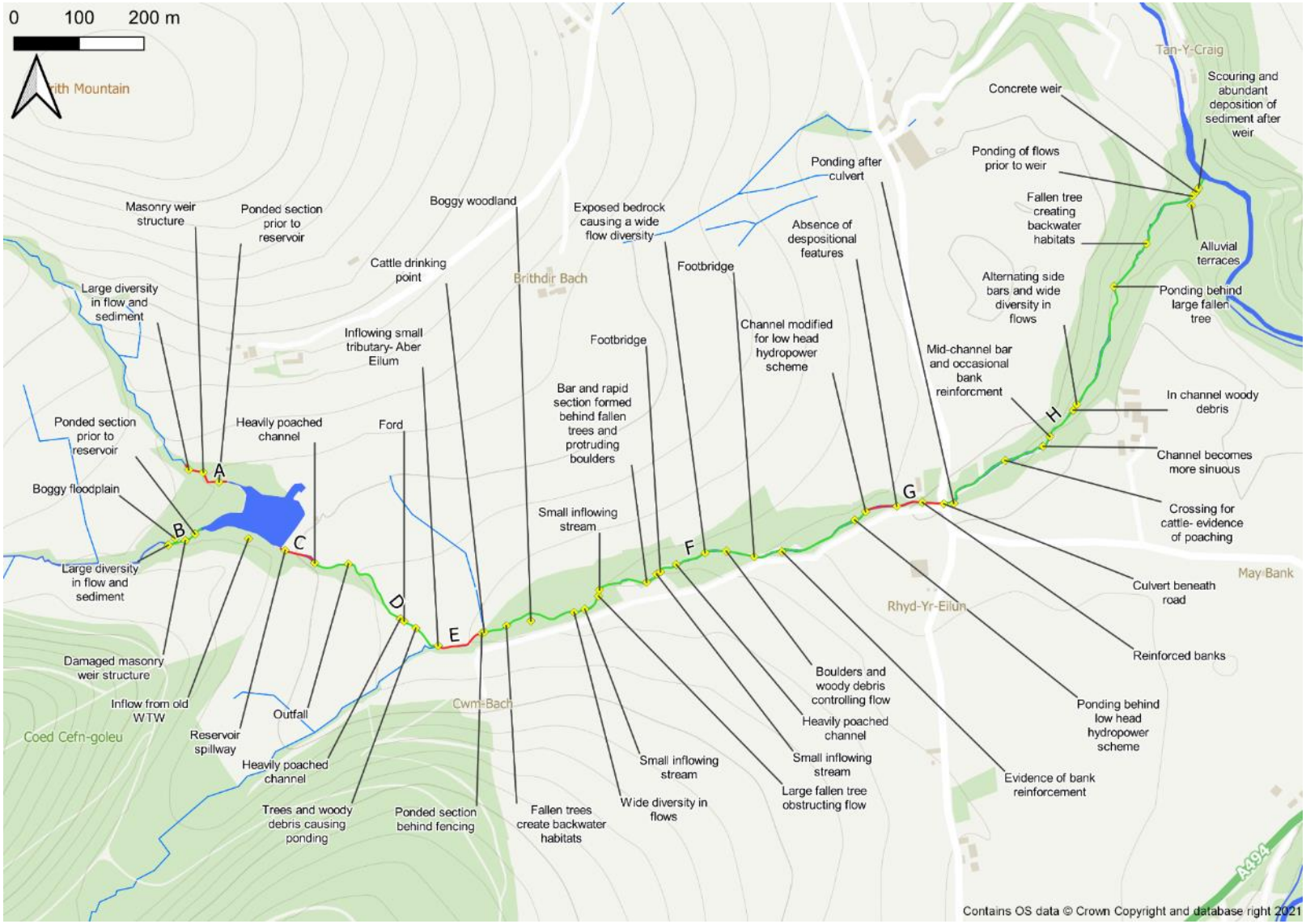


Figure 2-2 Brithdir Mawr Reservoir and Aber Eilun to Afon Alun walkover – key features



2.1.1 Reach A

Reach A covers a 75m stetch of the northern inflow to Brithdir Mawr and runs from 75m upstream of the inflow to Brithdir Mawr Reservoir and ends at the inflow to Brithdir Mawr Reservoir. The reach is underlain by mudstone and siltstones of the Ordovician Elwy Formation which are overlain by till. Along its course Reach A falls 10.8m with a slope of 8.2°. **Table 2-1** shows five character photos of the reach.

Table 2-1 Reach A character photos

a) Looking upstream from the start of the study reach.

b) Looking downstream from the start of the study reach.

c) A view looking upstream ~50m along the reach demonstrating abundant woody debris in the channel.

d) A view looking upstream from the end of the study reach towards the masonry weir. Well established berm on the left bank.

e) Looking towards Brithdir Mawr Reservoir from the left bank. Masonry weir visible to the right of the image.

The short reach, which flows through deciduous woodland, originates where the channel enters the woodland from an upstream agricultural grassland setting. There is evidence of the upstream agricultural influence with occasional agricultural debris (i.e. plastic buckets) in the channel. The channel itself has a wide diversity of flows, with wooded debris and trees in the channel providing both ponded sections and the occasional narrowing of the channel resulting in higher energy flows. Generally, the channel has a stepped profile; with runs and rapids over these steps, however, this transitions to a riffle-pool sequence downstream of the weir. The banks are steep and clayey and are actively eroding. The narrow floodplain is wet and boggy along the reach. There is a good diversity in sediment, with cobble being dominant towards the upstream end and fine gravel and pebble becoming more dominant downstream (particularly after the weir). There are abundant sediment bars, mainly controlled by obstructions in the channel (large protruding boulders and in channel woody debris). Cross-section measurements show the channel to have a bankfull width of ~2m and bankfull height of ~0.3m, with a water width of ~0.7m and a water depth of ~0.09m on the day of the survey. A weir is located on the channel immediately prior to the inflow into Brithdir Mawr Reservoir. The bed level upstream of the weir is ~1m higher than downstream of the weir. This is due to the presence of the weir acting as a sediment barrier and controlling bed level locally. A large berm is present downstream of the weir on the left bank which is ~3m wide and ~0.3m high. The reach terminates where the stream enters Brithdir Mawr Reservoir where there is a significant reduction in the energy of the flows as the channel widens.

2.1.2 Reach B

Reach B covers a 75m stetch of the southern inflow to Brithdir Mawr and runs from 75m upstream of the inflow to Brithdir Mawr Reservoir and ends at the inflow to Brithdir Mawr Reservoir. The reach is underlain by mudstone and siltstones of the Ordovician Elwy Formation which are overlain by till. Along its course Reach B falls 6.9m with a slope of 5.3°. **Table 2-2** shows five character photos of the reach.

Table 2-2 Reach B character photos

a) Looking upstream from the start of the study reach.

b) Looking downstream from the start of the study reach.

c) A view looking upstream ~20m along the reach. Agricultural debris is visible.

d) A view looking upstream from the end of the study reach towards the damaged stone weir.

e) Looking downstream towards Brithdir Mawr Reservoir from the end of the reach.

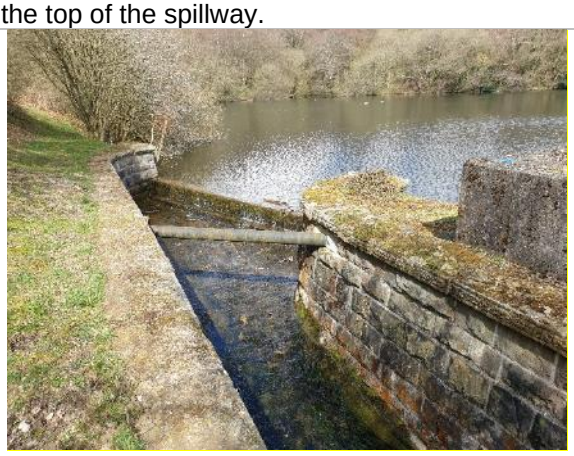
The reach, which flows through upland woodland originates where the channel enters the woodland from a previous agricultural grassland setting. The features largely mirror those in Reach A. There is evidence of the upstream agricultural influence with occasional agricultural debris (i.e. plastic buckets) in the channel. The channel itself has a wide diversity of flows with wooded debris and trees in the channel providing both ponded sections and the occasional narrowing of the channel resulting in higher energy flows. Initially, the channel has a stepped profile; however, this transitions to a riffle sequence downstream. There is evidence of active erosion of the clayey banks throughout this reach. The narrow floodplain towards the end of the reach is wet and boggy. There is a good diversity in sediment with

cobble being dominant towards the upstream end and fine/pebble becoming more dominant downstream (particularly after the weir). There are abundant sediment bars and these are mainly controlled by obstructions in the channel (mainly large woody debris). Cross-section measurements show the channel to be slightly narrower than that in Reach A, with a bankfull width of ~1.9m and bankfull height of ~0.3m and with a water width of ~1.5m and a water depth of ~0.06m on the day of survey. A small stone weir is located towards the end of the reach. The bed level upstream of the weir is ~0.75m higher than downstream of the weir. The reach terminates where the stream enters Brithdir Mawr Reservoir where there is a significant reduction in the energy of the flows as the channel rapidly widens.

2.1.3 Reach C

Reach C is ~60m in length and is comprised of the spillway from Brithdir Mawr Reservoir to the downstream watercourse. The reach is underlain by mudstone and siltstones of the Ordovician Elwy Formation which are overlain by till. Along its course Reach C falls 10.4m with a slope of 9.8°. **Table 2-3** shows two character photos for this reach.

Table 2-3 Reach C character photos

a) Looking towards Brithdir Mawr Reservoir from the top of the spillway.	b) Looking up the spillway from the end of the reach.
	

This reach is short and comprised entirely of the masonry spillway. The spillway is completely modified and has a steep, stepped, gradient. Flows are mixture of runs, rapids and falls over the steps. Brithdir Mawr Reservoir was spilling on the day of the survey. The reach terminates at the end of the spillway where the channel passes beneath a fence into agricultural land.

2.1.4 Reach D

Reach D stretches 0.25km along the downstream watercourse of Brithdir Mawr Reservoir from the end of the spillway of Brithdir Mawr Reservoir to the confluence with the Aber Eilun. The reach is underlain by mudstone and siltstones of the Ordovician Elwy Formation which are overlain by till. Along its course Reach D falls 14.2m with a slope of 3.3°. **Table 2-4** shows four character photos of this reach.

Table 2-4 Reach D character photos

a) Looking upstream from ~60m along the reach. Note outfall visible on left bank.	b) Looking upstream from ~0.12km along the reach. Note control of channel and bars by presence of trees in the channel.
	
c) Looking downstream towards the end of the reach. Ford and evidence of poaching.	d) Looking upstream from the end of the reach towards the confluence with the Aber Eilun.
	

This reach flows through improved grassland which is used entirely for the grazing of cattle. There is evidence of poaching along the entire reach. The channel is dominated by protruding coarse sediment with abundant sediment bars, with several of these bars forming around obstructions in the channel. Bed substrate is dominated by cobbles, with occasional areas of fine sediment deposition, especially around the margins and adjacent to areas of bankside poaching. For the majority of the reach, earth banks are moderately sloped to vertical and are often actively eroding. The flows are dominated by moderate energy flows of riffles and runs with the occasional ponding behind trees and debris in the channel. A ford is present ~0.23km from the end of the reach. The channel is relatively wide for the flow it conveys with the wetted width being ~3m and the flow depth being ~0.1m. The reach terminates at an inflowing tributary on the right bank.

2.1.5 Reach E

Reach E consists of an ~85m section of the Aber Eilun from the confluence with an inflowing tributary to a point where the channel enters a wooded area and the physical characteristics of the watercourse change significantly. The reach is underlain by mudstone and siltstones of the Ordovician Elwy Formation which are overlain by till. Along its course Reach E falls 4.5m with a slope of 3.0°. **Table 2-5** shows two character photographs for this reach.

Table 2-5 Reach E character photos

a) Looking downstream from the mid-point of the reach.	b) Looking upstream from the end of the reach. Cattle drinking point and small inflowing tributary.
	

This short reach has similar characteristics to Reach D, although the woodland around the channel is slightly denser. The reach flows through improved grassland that is used for the cattle grazing, with evidence of bankside poaching through, though most is concentrated on the right bank. Poaching is particularly dominant on the right bank at the end of the reach where a cattle drinking point has been established. The channel is dominated by protruding coarse sediment with abundant bars and depositional features, many of which are controlled by the presence of obstructions such as large woody debris and debris dams on fences. Bed substrate is dominated by cobbles with occasional areas of fine sediment deposition, notably where a fence has led to the accumulation of woody debris. The earth banks are relatively shallow and are often actively eroding. The flows are dominated by moderate energy flows, mostly runs and riffles, with occasional ponding behind trees and debris in the channel. A small tributary joins on the left bank at the reach at the end which, on the day of the survey, was conveying very little flow. A cross-section was taken at the end of the reach where the bankfull width was 3.1m and bankfull height of 0.4m and a wetted width 1.6m and water depth 0.13m. The reach terminates where the channel exits the agricultural land and flows into deciduous woodland.

2.1.6 Reach F

Reach F consists of a 0.66km stretch of the Aber Eilun from where the Aber Eilun enters deciduous woodland to the point the channel is modified for a low head hydropower scheme. The upstream and middle sections of the reach are underlain by mudstone and siltstone of the Ordovician Elwy Formation, whilst the downstream section of the reach is underlain by limestone of the Carboniferous Llanarmon Limestone Formation. The superficial geology is till throughout the reach. Along its course, Reach F falls 21.6m with a slope of 1.87º. **Table 2-6** shows six character photos for this reach.

Table 2-6 Reach F character photos

a) Looking downstream from the upstream end of the reach. Note large woody debris and sediment bars.	b) Looking downstream from ~0.15km along the reach. Note large woody debris, sediment bars and diversity of flow and sediment.
	
c) A view looking upstream from ~0.38km along the reach.	d) A view looking upstream from ~0.43km along the reach. Pipe within the channel is leading to erosion of the left bank adjacent to it.
	
e) A view looking south across the channel from ~0.5km along the reach. A heavily poached section with some fine sediment input. This reach is a series of bedrock steps.	f) A view looking upstream from 0.6km along the reach with a small island in the centre of the channel.
	

This reach is predominately surrounded by deciduous woodland, with boggy sections around the channel, particularly in the upper sections of the reach. The channel morphology and features are commonly controlled by the presence of trees and woody debris within the channel. The woody debris supports the development of a wide range of mostly moderate energy flows (runs and riffles with

occasional falls and pools) and backwater habitats. Earth banks are generally steep and vary in elevation throughout the reach and are actively eroding. The banks tend to be higher and steeper than in upstream reaches. This reach boasts an abundance of sediment bars, depositional features which display a wide diversity of sediment sizes, though they are predominantly pebble to cobble sizes. The bed sediment distribution is also diverse, ranging from very fine sands to boulders, however, pebble and cobble sizes are dominant. There are a two footbridges and multiple fences that cross the channel and a pipe located within the channel ~0.43km downstream. The bridges exert little impact, while the fences do act to trap debris on their upstream faces and the pipe is exerting control on erosion of the adjacent left bank. There is a small section ~0.5km downstream where cattle poaching is extensive. This area of poaching is likely a source of fine sediment during rainfall events. There are several small tributary streams which flow into the Aber Eilun along this reach which provide a source of finer sediments. At ~0.5km downstream the channel bed is composed of bedrock and flows transition into high energy rapids; however throughout the reach flows are predominantly run and riffle. Several cross sections were taken along this reach showing that the channel has a bankfull width of ~2.7-3.1m, bankfull depth ~0.5-0.9m, wetted width of ~1.7-1.8m and water depth of ~0.1-0.2m. Towards the bottom of the reach the channel bank reinforcement becomes frequent. The end of the reach was inaccessible as the channel passed into a private garden, ending where water was ponding upstream of a low head hydropower scheme.

2.1.7 Reach G

Reach G is a short reach that contains a 0.13km stretch of the Aber Eilun between the low head hydropower scheme to the point that the Aber Eilun is culverted under a small road. The reach is underlain by limestone of the Carboniferous Llanarmon Limestone Formation. The superficial geology is composed of till throughout the reach. Along its course Reach G falls 10.7m with a slope of 4.9º. **Table 2-7** demonstrates shows four character photos for this reach.

Table 2-7 Reach G character photos

a) A view looking North towards the top of the hydropower scheme at the dry channel which used to be the course of the Aber Eilun until flow was diverted to operate the hydropower scheme.	b) Looking North, across the channel towards the hydropower scheme.
	
c) A view looking upstream midway along the reach.	d) A view looking upstream from the end of the reach.
	

This reach flows through a private garden. The entire reach has modified banks with occasional reinforcement. A low head hydropower scheme is located at the start of the reach. The hydropower scheme consists of a water wheel and dam, with a head difference estimated at ~2m. This is identified as a significant barrier in the channel. Water is ponded upstream of the hydropower scheme, however a bypass channel around the right bank of the hydropower scheme exists but this was dry on the day of the survey and visual evidence suggests it only conveys high flows. Downstream of the hydropower scheme the channel in this reach is devoid of any depositional features and was dominated by coarse cobble-sized sediment. There are frequent protruding boulders and occasional woody debris creating very localised flow diversity; however, the diversity is significantly reduced when compared with the upstream reach. The channel is consistently around 2m wide throughout the reach and widens again close to the culvert at the end of the reach where flows begin to pond. The reach terminates where the Aber Eilun enters a culvert which conveys the flow beneath a local road.

2.1.8 Reach H

Reach H consists of a ~0.7km stretch of the Aber Eilun from the outfall of the culvert beneath a local road and the confluence between the Aber Eilun and the Afon Alun, the end of the walkover extent. The upper sections of the reach are underlain by limestones of the Carboniferous Llanarmon Limestone Formation, with a small section underlain by Carboniferous limestones and argillaceous rocks of the Foel Formation. The majority of the remainder of the reach is underlain by the Carboniferous Leete Limestone Formation with a small area around the confluence with the Afon Alun underlain by the Carboniferous Loggerheads Limestone Formation. The superficial geology is composed initially of head

deposits in the uppermost sections of the reach before the reach is underlain predominantly by glaciofluvial sands and gravels before being underlain by alluvium immediately around the mouth of the reach as it flows into the Afon Alun. Along its course Reach G falls 16.9m with a slope of 1.4°. **Table 2-8** shows eight character photographs for this reach.

Table 2-8 Reach H character photos

a) Looking upstream towards the culvert at the start of the reach.	b) Looking downstream from 80m along the reach.
	
c) A view looking downstream from 0.22km along the reach.	d) A view looking upstream from 0.5km along the reach.
	
e) A view looking downstream from 0.55km along the reach.	f) A view looking downstream from 0.57km along the reach.
	

g) A view looking downstream from 0.62km along the reach.	h) A view looking upstream from the end of the reach towards the weir.
	

This reach is set initially in improved grassland but then is wholly within deciduous woodland within a deep and steep sided valley with a relatively wide, wooded floodplain when compared to upstream reaches. The reach originates at the culvert. At the downstream end of the culvert the flow is pooled within a wide section of channel, likely due to scour from the culvert in high flows. Within a few meters downstream of the culvert flow energy increases, with run and riffles flows becoming dominant and remain dominant for the entirety of the reach. There are abundant sediment bars and depositional features along this reach, many of which are controlled by the presence of large woody debris, (commonly fallen trees) and protruding boulders. These features create a wide diversity of flow types and create much habitat, including backwaters and occasional rapid sections. The reach displays a wide diversity of sediment sizes. Given the barrier imposed by the low head hydropower scheme this suggests that either the impact of the scheme has not yet been transmitted to this reach or that lateral input (evidenced by abundant eroding banks and areas of mass movement due to tree falls supplying sediment to the channel) is of a significant magnitude to ameliorate the impacts of the hydropower scheme on sediment movement within the reach. Poaching is rare along this reach and is confined to one point where there is a cattle crossing (~0.13km downstream). Prior to the Aber Eilun joining the Afon Alun, several terraces are visible in the surrounding floodplain. There is significant ponding upstream, and scouring downstream, of a weir located 0.68km downstream at the end of the reach. Here the channel bed level drops by ~1m between the upstream face and downstream face of the weir. Cross sections taken throughout the reach show a bankfull width of ~4.5-4.8m, a bankfull height of ~0.4-0.9m, wetted width of ~2.3-3.4m and water depth of ~0.06-0.12m. The reach, and study area, terminates where the Aber Eilun flows into the Afon Alun.

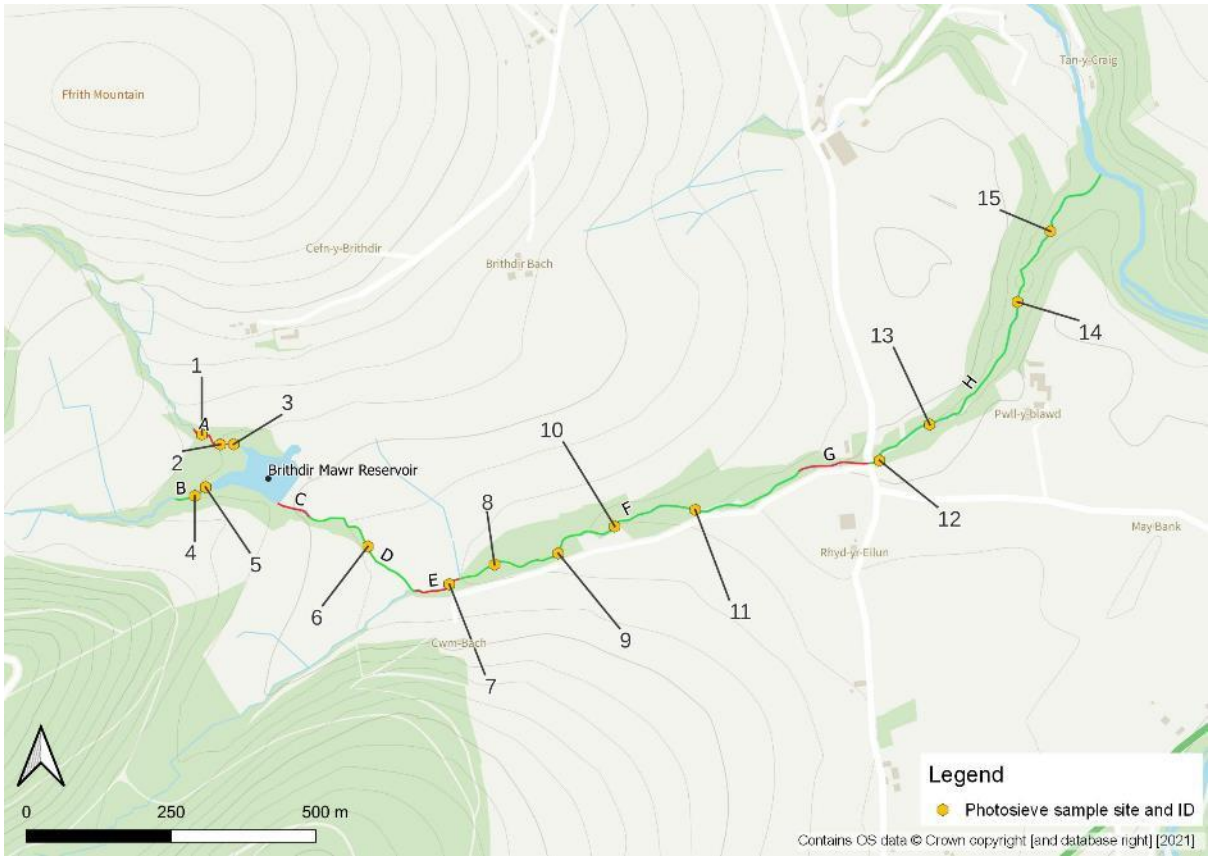
2.1.9 Sediment particle size analysis

In order to understand changes in sediment size along the reach in the limited time available for the walkover survey a photosieving technique was adopted. This entailed placing a known scale (in this case a 30cm steel rule) on exposed bed sediments around bars and taking a photograph of the sediments and scale (ensuring the image focal plane was as parallel to the channel bed as possible). Each photo was then geolocated on return to the office and particle b-axes measured using the image analysis software Fiji[4].

A total of 15 images along the study reach (**Figure 2-3**) (three in Reach A, two in Reach B and 10 in Reaches C to H) were analysed to measure sediment particle b-axes in centimetres. The resulting data was statistically analysed and plotted to provide an understanding of particle size distribution and changes in this distribution along the study reach. The results are discussed below.

[4] Schindelin, J., Arganda-Carreras, I., Frise, E., Kaynig, V., Longair, M., Pietzsch, T., Cardona, A. (2012). Fiji: an open-source platform for biological-image analysis. Nature Methods, 9(7), 676–682. doi:10.1038/nmeth.2019

Figure 2-3 Map of photosieving locations in the two tributaries of Brithdir Mawr and the downstream Aber Eilun



Summary particle size data for the 15 photosieve sites is provided in **Table 2-9**.

Table 2-9 Summary particle size data for the study reaches

Sample site	Reach ID	Distance downstream (km)	No. of particles measured	Particle b-axis size (cm)		
				Lower quartile (25th)	Median	Upper quartile (75th)
1	Reach A	0.017	169	1.02	1.49	2.18
2		0.061	230	0.39	0.50	0.72
3		0.076	180	0.99	1.55	2.27
4	Reach B	0.036	100	0.74	1.32	2.21
5		0.07	189	0.72	1.12	1.77
6	Reach D	0.192	200	0.74	1.20	2.22
7	Reach E	0.375	200	0.70	1.02	1.59
8	Reach F	0.46	357	0.78	1.17	2.17
9		0.58	175	0.97	1.44	2.37
10		0.702	201	1.11	1.85	2.84
11		0.85	200	1.12	1.76	2.85
12	Reach H	1.197	133	1.98	3.02	5.72
13		1.31	207	1.25	1.98	3.55
14		1.589	206	1.32	1.98	3.11
15		1.735	205	0.69	1.03	1.55

The median particle size ranges from 0.50-1.55cm in Reach A and B upstream of the reservoir to 1.02-1.85cm in Reach C to F and 1.03-3.02cm in Reach H (downstream of the online hydropower scheme at the end of Reach F and culvert at the end of Reach G).

In Reach A and Reach B there is a small range of variation in particle sizes, with sizes remaining relatively invariant, with the exception of Site 2 in Reach A which shows a decline in median particle size. In Reaches D to F the median particle size and interquartile ranges remain relatively constant throughout, though there is a small increase with distance downstream from the reservoir. Median particle sizes throughout Reaches A to F are relatively similar.

Reach H shows a notable change in particle size, specifically site 12 which shows a jump to a median size of 3.02cm compared to 1.76cm at Site 11 upstream. Particle sizes decline at Sites 13 and 14 but still remain higher than measured upstream, before declining to 1.03cm, smaller than the majority of upstream sample sites.

A graphical representation of the particle dimension data as box plots is presented in **Figure 2-4** and **Figure 2-5**.

Figure 2-4 Particle size data derived from photosieves of exposed sediment in Reach A and Reach B

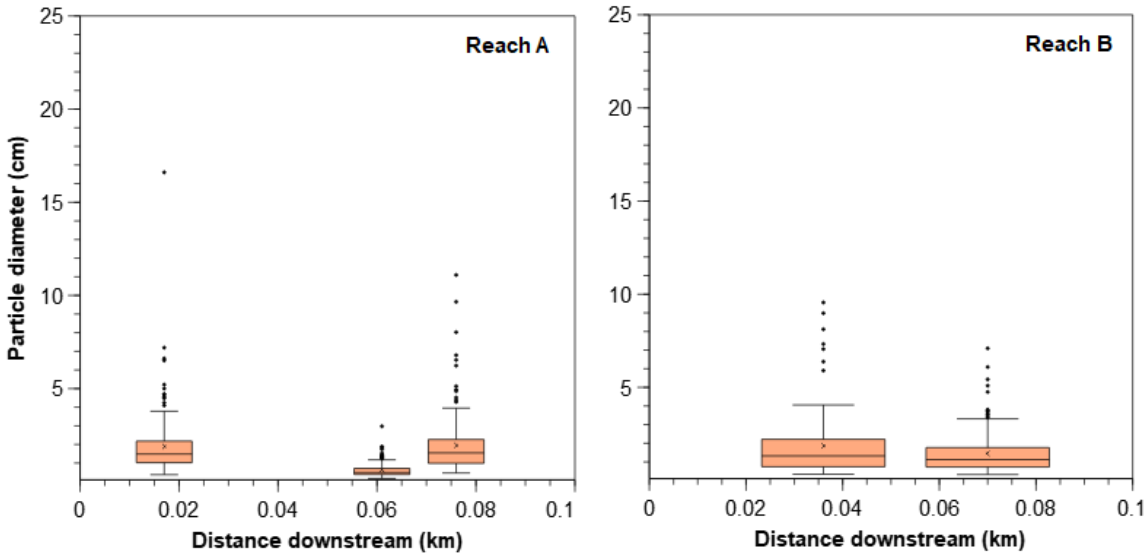
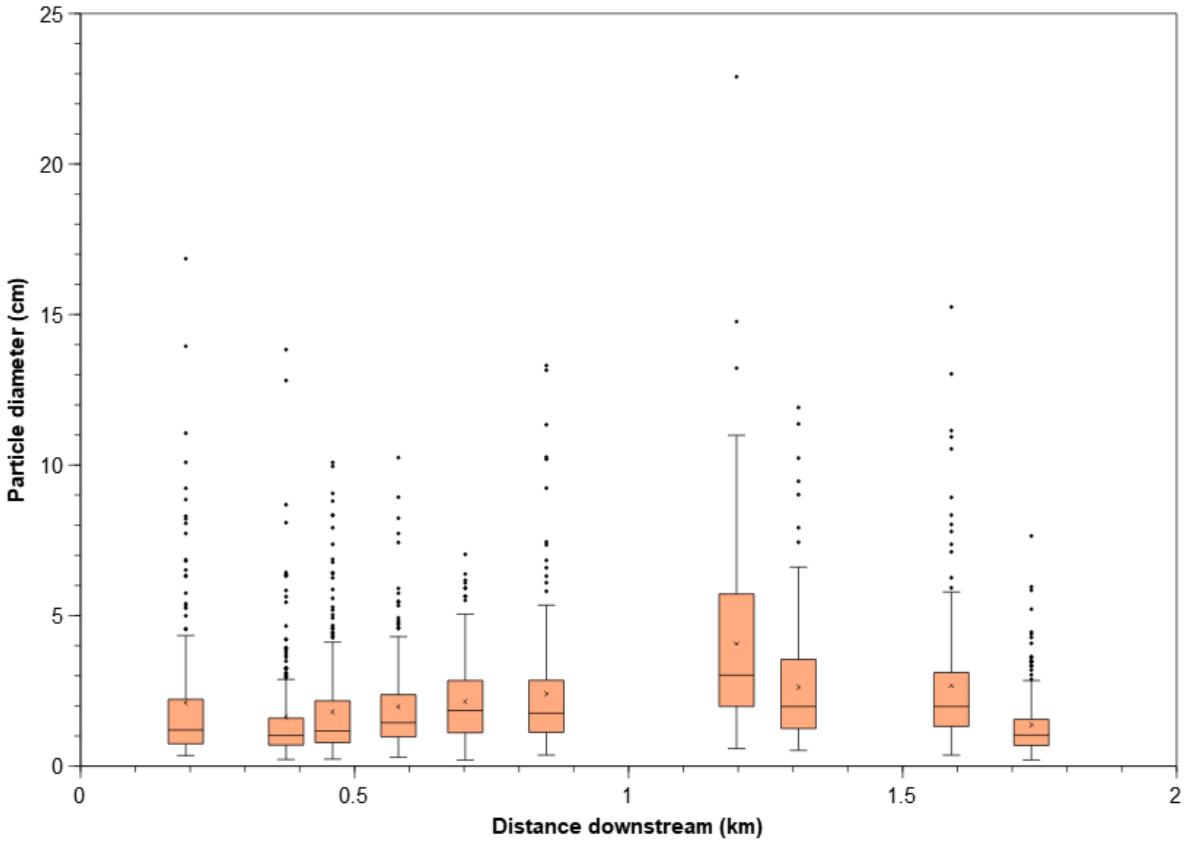


Figure 2-5 Particle size data derived from photosieves of exposed sediment in Reaches C to H



The graphical data supports the general conclusions on downstream changes in particle size reached above, with Reaches A and B and Reaches C to F showing relatively invariant particle size changes in a downstream direction, followed by a sharp increase and gradual decline in Reach H. The particle size ranges are more clearly visible on the plots and again show relatively limited change in a downstream direction (with the exception of Sites 11 and 12 in Reach H). It should be noted that the size ranges of

the sites downstream of the reservoir are generally much larger than those upstream of the reservoir in Reaches A and B. This is likely to be reflective of a narrower range of sources supplying sediment to these reaches compared with an increasing range of sources downstream of the reservoir as the catchment size increases and land cover types change. However, given the relative similarity in median particle sizes upstream and downstream of the reservoir it could be suggested that the sediment sources provide fairly similar distributions of sediment. As noted above, the sites downstream of the reservoir show a small increase in median particle size with increasing distance from the reservoir. This is due to increasing lateral sediment supply. The fact that the increase is not of a greater magnitude (which might be expected given the presence of a significant sediment barrier upstream) is likely due to the extensive bank erosion supplying coarse sediment into the river immediately downstream of the reservoir which rapidly ameliorates the depletive effects of sediment decoupling caused by the reservoir.

The significant outlier in the sediment dataset is Site 11. This site lies downstream of the online hydropower scheme (at the end of Reach F) and the culvert beneath the road (at the end of Reach G). The increase likely represents armouring of the bed due to winnowing of finer sediments from the bed in response to a very limited supply of sediment from upstream due to the presence of these barriers. The subsequent reduction in median particle size downstream of Site 11 is most likely to be due to an increase in sediment input from lateral sources, particularly bank erosion which was frequent in this reach.

2.1.10 Potential impacts on the watercourse from decommissioning

The evidence collected during the walkover survey suggest that the key issues in the Aber Eilun study reach are predominantly due to the presence of barriers within the watercourse (it is noted that the reservoir is a significant barrier although due to decommissioning this will likely cease to be the case). Specifically, the key barriers are:

1. Low level stone masonry weir identified towards the end of Reach A.
2. Low level stone masonry weir identified towards the middle of Reach B.
3. Low head online hydropower scheme and associated dam at the end of Reach F.
4. Culvert beneath a road at the end of Reach G.
5. High level concrete weir at the end of Reach H prior to the inflow to the Afon Alun.

All of these structures form a barrier to flow, sediment movement and ecology, particularly migration of fish species. They are all considered to exert significant influence on flow, sediment and migration within the system. As noted above, at the online hydropower scheme at the end of Reach F there appears to be a high flow bypass channel around the right bank. However at the time of the survey this was dry and appears to only offer some connectivity at high flows.

Based on the proposed decommissioning options for the reservoir, this will likely have the following impacts on the watercourse:

1. Locally improve connectivity by reinstating the original channel of the Aber Eilun through the reservoir.
2. Greatly improved connectivity down to the end of Reach F for flow, sediment and ecology, including for fish migration.
3. Improved connectivity could lead to enhanced sediment supply throughout the watercourse up to Reach F, and possibly into Reaches G and H under very high flows which can transport sediment past barriers.
4. Local expansion of the availability and accessibility of habitats upstream of Brithdir Mawr Reservoir (up to the barriers in Reach A and B).
5. Enhance the availability of habitats (over time) due to reinstatement of the original channel of the Aber Eilun and with the benefit of locally improved riparian areas within the decommissioned reservoir which, as well as increasing terrestrial habitat, could increase in-river habitat, e.g. shading, vegetation, input of organic matter for food etc.
6. Loss of lake habitat and potential water buffering capacity of the reservoir which could lead to increased transmission of peak flows during high flow events (although, noting that the

Stillwater Associates report (2019)[5] indicates that the existing reservoir provides negligible flood attenuation for the range of floods considered in the report), however this would lead to a more naturalised flow regime and possibly improve habitats already present in the river.

There are the potential for short term impacts to the Aber Eilun from the decommissioning of the reservoirs, for example decommissioning of the reservoir dam and bunding and the potential for fine sediment ingress into the downstream watercourse, incorrect restoration of the channel[6] through the reservoir etc. However, these can be wholly mitigated by good construction practices and good planning prior to commencement of decommissioning of the reservoir. It is noted that sediment management during decommissioning and possibly into the long term is part of the proposed scheme[7].

It is likely that the decommissioning of the reservoir will have negligible impacts on the downstream watercourse due to the presence of the aforementioned barriers. Also, despite the potential significant improvements to the Aber Eilun to be had from the decommissioning of the reservoir, benefits will be concentrated locally downstream of the reservoir (wholly to the end of Reach F, ~1.05km downstream) and will focus on improvements to channel connectivity and habitat development, since the number of significant barriers identified in the study reaches will annul any benefits gained across the whole reach. The two barriers identified in Reach A and Reach B will also act to prevent upstream connectivity. For maximal environmental benefits from the decommissioning the issues created by the barriers identified should also be addressed.

2.2 Afon Alun – watercourse baseline description

On the 15 July 2021, a walkover of ~3.4km of the Afon Alun between Loggerheads Country Park and Cilcain Bridge (~0.14km downstream of the Nant Gain confluence) was conducted in order to collect information to understand the existing conditions of the watercourse, the features present in the watercourse and ascertain what impacts the decommissioning of Brithdir Mawr Reservoir would have on the Afon Alun watercourse downstream of the confluence with the Aber Eilun. Part of this walkover included 0.94km reach upstream of the confluence with the Aber Eilun which helped build an understanding of the baseline conditions.

During the site visit, the reach was broken up into seven individual reaches (I to Q) based on changes in geomorphology, hydrology and anthropogenic features. These reaches are displayed in **Figure 2-6**. A breakdown of the hydrological features, notably flowing reaches, losing flow, reaches comprised of pools of varying connectivity, dry reaches and the locations of potential sinkholes and a large spring are shown in **Figure 2-7**. Key features of interest on the watercourse are detailed in **Figure 2-8**.

[5] Stillwater Associates Ltd., (2019). Brithdir Mawr Reservoir. Discontinuance Feasibility Assessment Report. Dwr Cymru Welsh Water. April 2019. 206pp.
[6] In reservoirs it is common for a palaeochannel (which represents the river channel prior to the construction and filling of a reservoir) to still exist at the base of the reservoir. Therefore, if this is the case at the Cilcain Reservoirs, this could be integrated into the restoration of the site and the channel directly used reducing the need for significant restoration.
[7] Stillwater Associates Ltd., (2019). Brithdir Mawr Reservoir. Discontinuance Feasibility Assessment Report. Dwr Cymru Welsh Water. April 2019. 206pp.

Figure 2-6 Afon Alun – study reaches

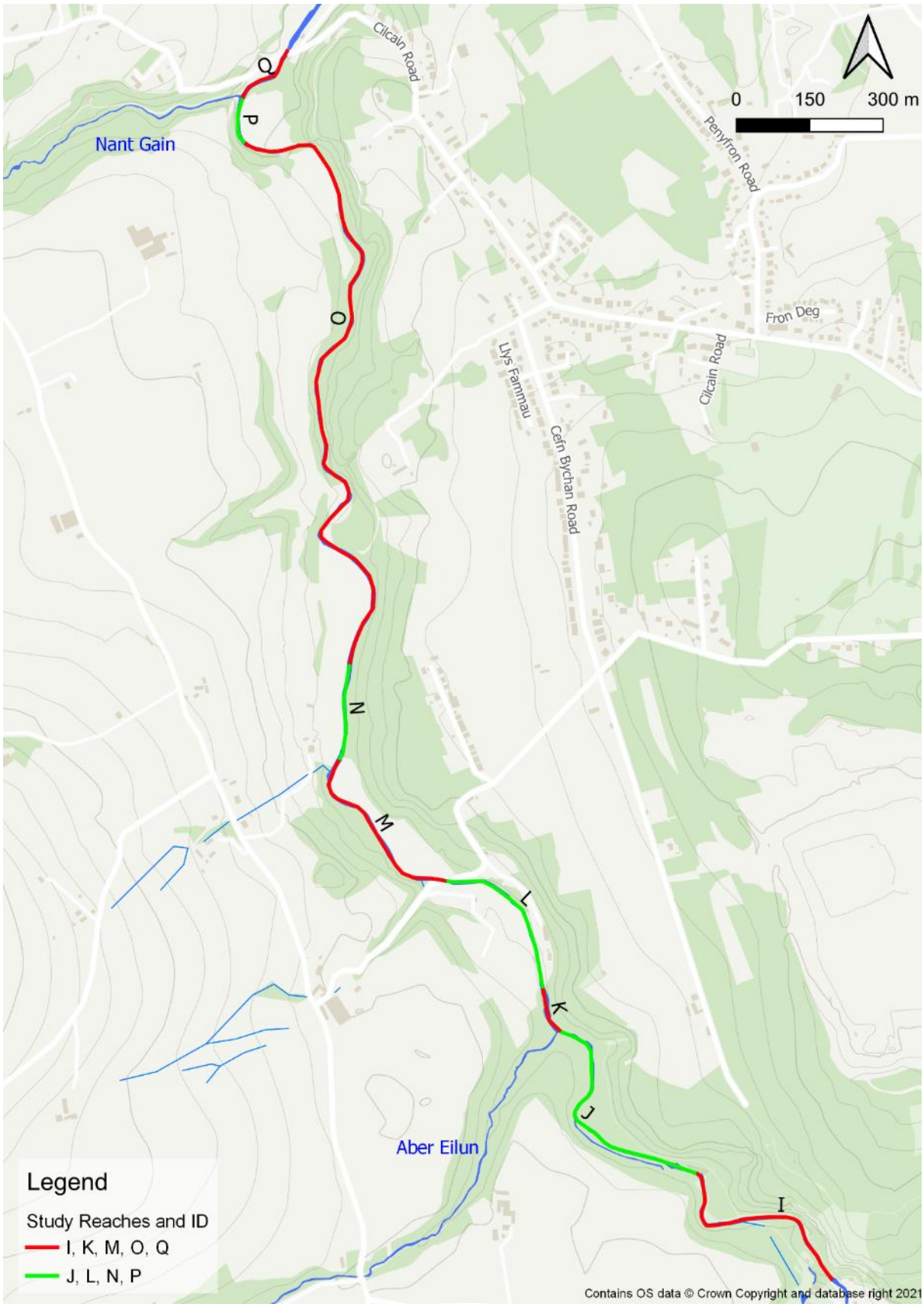


Figure 2-7 Afon Alun – hydrological features

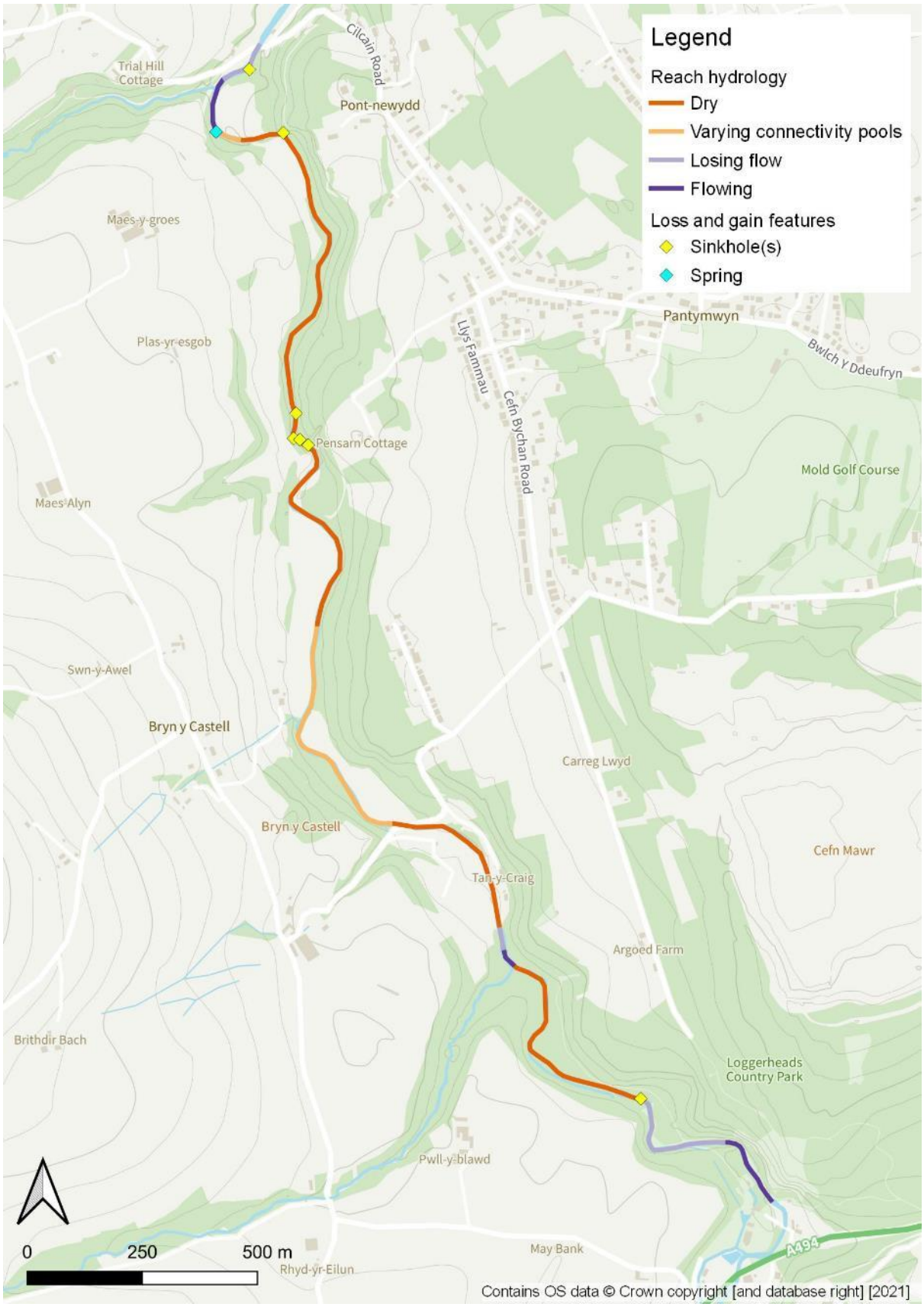
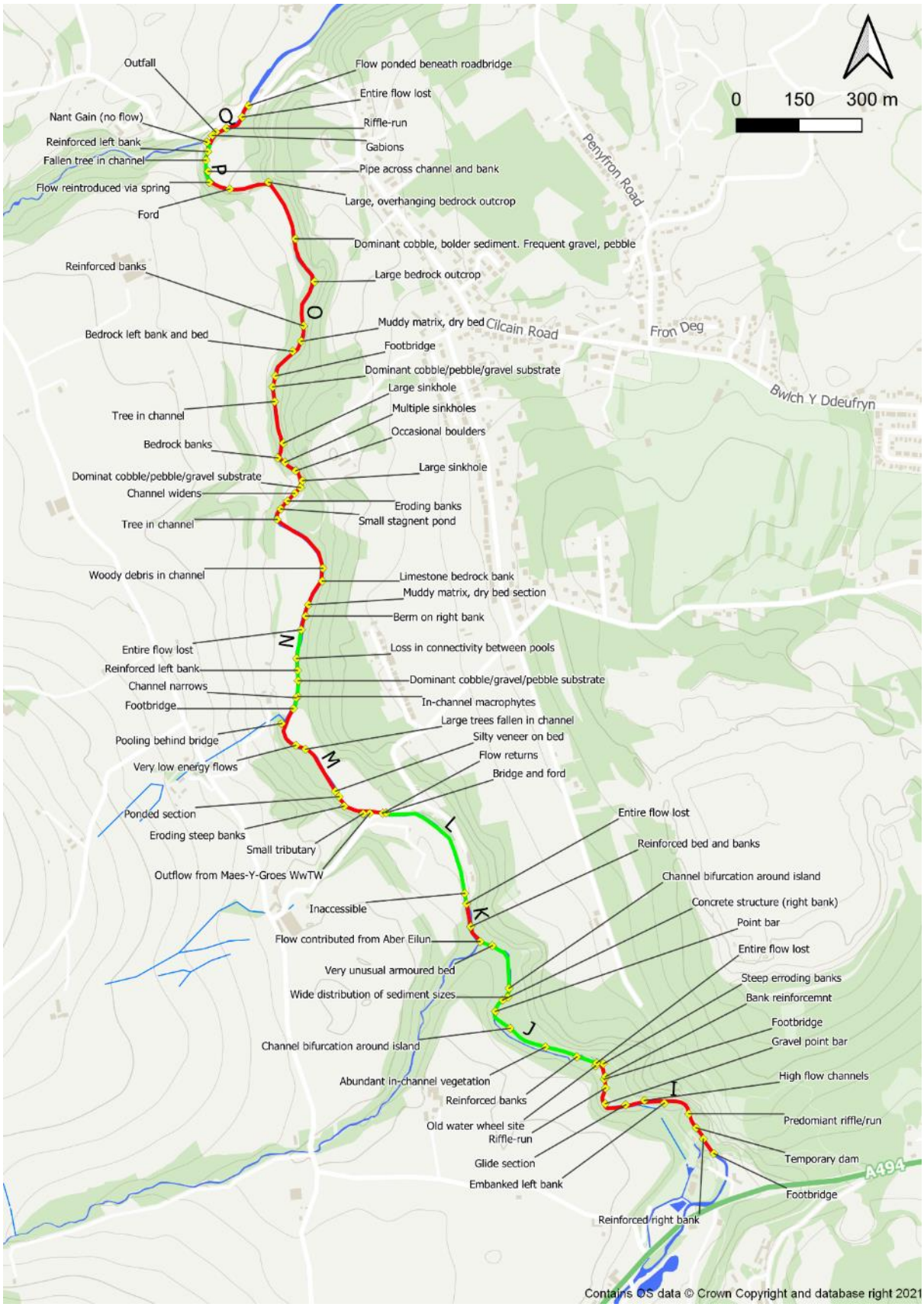


Figure 2-8 Afon Alun – key features



2.2.1 Reach I

Reach I covers a 0.45km stetch of the Afon Alun from Loggerheads Country Park (~1km upstream of the Aber Eilun confluence) to the point where the Afon Alun became dry on the day of the survey (~0.5km upstream of the Aber Eilun confluence). The reach is underlain by the Carboniferous Leete Limestone Formation and the Llanarmon Limestone Formation which is partially overlain by alluvium. There are sections of the reach where there are no superficial deposits, particularly on the right bank. Along its course Reach I falls 2.2m with a slope of 0.28°. **Table 2-10** shows four character photos of the reach.

Table 2-10 Reach I character photos

a) Looking downstream ~60m downstream from the start of the study reach.	b) Looking downstream from ~0.1km downstream from the start of the study reach. Note the temporary weir positioned in the channel. This will likely be displaced by higher flows.
	
c) A view looking downstream ~0.26km downstream from the start of the study reach. Note the diversity of sediment.	d) A view looking downstream ~0.38km downstream from the start of the study reach. Note the diversity of sediment and variation in flows caused by protruding sediment.
	

This reach is set in deciduous woodland and is situated next to a well utilised public footpath on the right bank. There are extensive vertical bedrock cliffs on the right bank at the start of the reach. There is abundant anthropogenic modification present, with most of the banks being reinforced and multiple footbridges crossing the reach. Approximately 0.1km downstream from the start of the reach a low weir structure has been created which spans the river and causes a ponding of flows. This structure was not a permanent feature and is likely to be breached by subsequent high flow events. However, there was a small area of concrete reinforced bed on the left bank downstream of this feature where some degree of downcutting of the bed on the downstream face had occurred. At the upstream end, the channel has a wide diversity of flows caused by protruding bed sediment, dominantly runs and riffles, and there are

frequent sediment bars. These flows lose energy towards the end of the reach where glides and pools become the dominant flow type. The apparent change in flow could indicate potential loss to groundwater. Where the banks are not reinforced, they are dominantly composed of earth. There is a wide diversity of sediment throughout the reach, however cobble and pebble substrate dominate. The floodplain is relatively narrow and there is frequent evidence of over bank flows under high flow events. Generally, flow in the reach was shallow on the day of the survey and the channel width was ~4-6m. The reach terminates where the flow in the Afon Alun was completely lost to the ground.

2.2.2 Reach J

Reach J covers a 0.5km stretch of the Afon Alun from the point all flow was lost to the ground to the confluence with the Aber Eilun. The reach is underlain predominantly by the Carboniferous Leete Limestone Formation. At the downstream end the reach is underlain by the Carboniferous Loggerheads Limestone Formation. Superficial geology along the reach is predominantly composed of alluvium. Along its course Reach J falls 2.6m with a slope of 0.3°. **Table 2-11** shows four character photos of the reach.

Table 2-11 Reach J character photos

a) Looking upstream from the start of the study reach. Note flow vanishing into the sinkhole.	b) Looking downstream from ~75m downstream from the start of the reach.
	
c) A view looking downstream from ~0.35km downstream from the start of the reach showing a bifurcation in the channel around an island.	d) A view looking upstream from ~0.48km downstream from the start of the reach. Note the significant bed armouring which seems to be anthropogenic in nature, possibly linked to an old weir.
	

This reach is set entirely in deciduous woodland with a relatively steep valley. On the day of the survey the reach was completely dry due to the loss of all flow down a sinkhole located on the right bank at the end of Reach I. There were sections where there was an abundance of vegetation growth within the channel which may indicate that the reach has been dry for an extended duration (likely to be since the

middle of June 2021[8]). There is abundant anthropogenic modification, with most of the banks being reinforced. Towards the end of the reach there is a section (~10m in length) where the bed is significantly armoured, potentially where a weir structure used to be situated. Where the banks are not reinforced, they are dominantly earth and there is evidence of erosion. There is a wide diversity of sediment throughout the reach, dominated by cobble and pebble with some gravel substrate. Due to there being no flow, identifying depositional features was fairly difficult, however sediment bars were visible throughout the reach (based on changes in bed topography and sediment variability). There are two instances where the channel bifurcates around well established, large island features, especially at ~0.35km downstream from the start of the reach. Generally, the channel width was ~4-6m. The reach terminates at the confluence with the Aber Eilun where flow is reintroduced to the channel.

2.2.3 Reach K

Reach K covers a 0.1km stetch of the Afon Alun from the Aber Eilun confluence to the point the entire flow contributed by the Aber Eilun is lost. The reach is underlain by the Carboniferous Loggerheads Limestone Formation, overlain by alluvium. Along its course Reach K falls 3.6m with a slope of 2.06°. **Table 2-12** shows three character photos of the reach.

Table 2-12 Reach K character photos

a) Looking upstream into the Aber Eilun from the confluence with the tributary and the Afon Alun. Note the flow from the Aber Eilun wetting the reach.

b) Looking downstream from the start of the reach. Note the flow in the reach contributed by the Aber Eilun which is insufficient to fill the entire channel of the Afon Alun.

c) A view looking downstream from ~15m downstream from the start of the reach.

This reach is set in deciduous woodland. At the upstream end, flow input from the Aber Eilun wets a portion of the Afon Alun channel towards the left bank. In this section there are a range of flow types

[8] Alyn at Rhydymwyn flow gauge. https://rivers-and-seas.naturalresources.wales/Station/4186?parameterType=1 Accessed 10 September 2021.

present, though mostly glides, runs and occasional riffles. Some sediment bars are present. The flows contributed by the Aber Eilun are rapidly lost to the ground downstream of the confluence, and, as this continues glides and pools become the dominant flow type until the flow is entirely lost. There is a wide diversity of sediment throughout the reach, dominated by cobble, pebble and gravel substrate. Anthropogenic modification is frequent, with many of the left banks being reinforced. Where the banks are not reinforced, they are composed of earth. Channel widths are ~4-6m. The reach terminates where the flow in the Afon Alun completely disappears.

2.2.4 Reach L

Reach L covers a 0.34km stetch of the Afon Alun from 0.1km downstream of the Aber Eilun confluence to where flow returns at Meas-Y-Groes Sewage Treatment Works (STW). The reach is underlain predominantly by the Carboniferous Loggerheads Limestone Formation, however at the downstream end the reach is underlain by the Carboniferous Leete Limestone Formation. The superficial geology is predominantly alluvium, however, there are some areas where there is no superficial geology along the reach (particularly on the right bank). Along its course, Reach L falls 3.7m with a slope of 0.6°. **Table 2-13** shows three character photos of the reach.

Table 2-13 Reach L character photos

a) Looking downstream from the start of the study reach. Note the flow from the Aber Eilun has mostly been lost and is represented by shallow and stagnant pools in the bed.	b) Looking upstream from the end of the reach. Note the dry channel and bank reinforcement on the right bank due to the presence of a road.
	
c) A view looking downstream from the end of the reach. Note some ponded flow on the left bank, the ford with concrete bed and the metal footbridge. The Meas-Y-Groes STW is located on the left bank.	
	

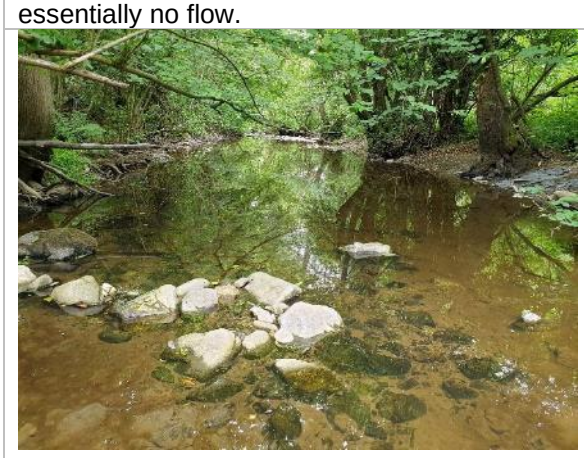
Much of Reach L is inaccessible as it is adjacent to a private garden and STW with signs specifying no entry, however, parts could be viewed from the nearby Leete Path which runs along the right bank of the reach. The reach is set in deciduous woodland setting and, on the day of the survey the reach was

completely dry. From the top and bottom end of the inaccessible reach, it was noted that there was an vegetation growing in the channel, indicating a prolonged period without flows. While access to the reach was limited, visual evidence indicated that there is frequent bank modification through reinforcement and resectioning. The relative straightness of the reach and the surrounding anthropogenic structures (STW on the left bank and a house and grounds on the right bank) could indicate some channel straightening. At the end of the reach there is a ford with a reinforced concrete bed and a footbridge which cross the river. At the start and end of the reach sediment distributions appeared to be diverse, although pebble and cobble sizes were dominant with occasional boulders. The channel width was ~6m and fairly uniform throughout the reach. The reach terminates at the outfall of Meas-Y-Groes STW and a small tributary (possibly a road storm drainage ditch) where flow is reintroduced to the channel.

2.2.5 Reach M

Reach M consists of a ~0.39km section of the Afon Alun from the Meas-Y-Groes STW discharge to where a footbridge crosses the channel. The reach is underlain predominantly by the Carboniferous Leete Limestone Formation with the occasional section underlain by the Carboniferous Loggerheads Limestone Formation. The superficial geology is predominantly alluvium. Along its course Reach M falls 3.9m with a slope of 0.6º. **Table 2-14** demonstrates six character photographs for this reach.

Table 2-14 Reach M character photos

a) Looking towards the Meas-Y-Groes STW outfall at the start of the reach. No distinct outfall is apparent, with flow seemingly seeping out of the structure.	b) Looking downstream from the start of the reach. Notice the coarse substrate and pooled flow and the extensive bankside slumping and fallen trees on the left bank.
	
c) Looking downstream from ~0.18km downstream of the start of the reach. Here the channel is nearly fully wetted however there is essentially no flow.	d) Looking downstream from ~0.29km downstream of the start of the reach. Note the sediment bars and large woody debris leading to much sediment and flow diversity.
	
e) Looking upstream from ~0.32km downstream of the start of the reach. Note the thread of channel flowing from the large woody debris upstream. Most of the pooled sections in this reach have some degree of connectivity.	f) Looking downstream at the end of the reach. Note the pooling of flow and the footbridge.
	

This reach is set in deciduous woodland. At the start of the reach is a structure linked to the STW which appears to be a discharge point. However, there was no specific outfall point and flow was seemingly seeping out of the brick structure. This flow was input to the channel and appeared to create localised flow in the previously dry channel. Throughout this reach there appears to be a gradual gain of flow, with the reach being composed of a series of pools with varying degrees of interconnectivity. At the upstream end these pools were mostly stagnant, however some glide flow was noted in the downstream pools, especially where the flow was modified by large woody debris and sediment features. Apart from the input from the STW, the source of the gain in flow throughout the reach is not known, although the pooling suggested that the groundwater surface could be close to, or at, the river bed on the day of the survey. At the start of the reach the left bank is very steep and actively eroding via mass movement which has led to multiple trees falling into the channel. The associated sediment input, fallen trees and large woody debris creates significant diversity in flow and sediment size distribution in the channel and helps to create sediment bars. There is a wide diversity of sediment throughout the reach, but this is dominated by pebble and cobble substrates. Where the flow is ponded in the mid sections of the reach the bed is covered in a silt veneer. There is occasional anthropogenic modification but this is concentrated at the very start of the reach around STW. The reach terminates at a footbridge where there is a distinct change in geomorphological characteristics as the Afon Alun passes out of the steep sided valley and into a wider and shallower valley form.

2.2.6 Reach N

Reach N consists of a ~0.19km section of the Afon Alun from a footbridge to where the Afon Alun became dry again on the day of the survey. The reach is underlain predominantly by the Carboniferous Leete Limestone Formation. The superficial geology is predominantly alluvium. Along its course Reach N falls 0.7m with a slope of 0.2°. **Table 2-15** demonstrates six character photographs for this reach.

Table 2-15 Reach N character photos

a) Looking downstream from the start of the reach. Note the in channel vegetation and the presence of sky indicating a change in valley form.	b) Looking downstream from ~60m downstream of the start of the reach. The large woody debris is controlling flow and causing pooling.
	
c) Looking downstream from ~90m downstream of the start of the reach. Note pooled flow in the reach and the coarse cobble substrate and the flat grassed floodplain on the left bank.	d) Looking upstream from the end of the reach. The flow is essentially lost to the ground at this point.
	

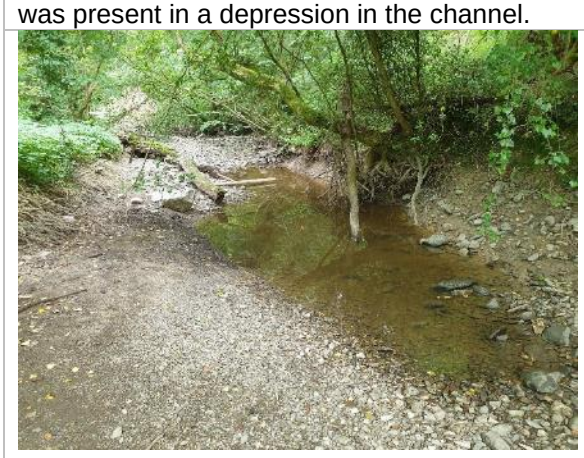
This reach is set in deciduous woodland, however there has been a change in valley form in this reach, with the presence of a grassed and grazed floodplain on the left bank, although the right bank of the channel is high and steep valley side. Throughout this reach there is gradual loss of flow, with the upstream end being dominated by pools and very shallow glides of variable interconnectivity which become shallow and less connected downstream until the flow is lost entirely to the ground at the end of the reach. The flow does not fill the entire width of the channel at any time. Compared to Reach M, the left bank is much less steep, though the right bank remains of a similar steepness. The left bank is extensively reinforced with laid stone for much of the reach. Where there is not bank reinforcement banks are predominantly composed of earth, although bedrock composes a short stretch of the right bank of the channel at the lower end of the reach. There is significantly less bank erosion in this reach, likely due to the reinforced left bank and heavily wooded right bank. There is also much reduced in-channel debris which leads to a reduction in diversity of depositional features seen in the upstream reach. The bed substrate is diverse and is composed of a range of sizes, however pebble and cobble sizes predominate. The reach terminates where the flow was entirely lost on the day of the survey.

2.2.7 Reach O

Reach O consists of a ~1.38km section of the Afon Alun from the point flow was lost on the day of the survey to where a spring reintroduces flow into the river, ~0.1km upstream of the confluence with the Nant Gain. The reach is underlain predominantly by the Carboniferous Leete Limestone Formation with

some sections underlain by the Carboniferous Llanarmon Limestone Formation. The superficial geology is predominantly alluvium, however, there are large sections where there is no superficial geology. Along its course Reach O falls 13.8m with a slope of 0.6º. **Table 2-16** demonstrates eight character photographs for this reach.

Table 2-16 Reach O character photos

a) Looking upstream from ~75m downstream from the start of the reach.	b) Looking downstream from ~0.13km downstream of the start of the reach. Note the steep bedrock right bank.
	
c) Looking downstream from ~0.35km downstream of the start of the reach. Note the fining of bed particle size compared to upstream sections. A discrete disconnected pool of flow was present in a depression in the channel.	d) Looking downstream from ~0.38km downstream of the start of the reach. A wide range of sediment sizes are present in the channel. Note the extensive vertical limestone cliff towards the rear of the image.
	

e) Looking downstream from ~0.52km downstream of the start of the reach. The limestone exposure on the right bank contains multiple caves/sinkholes with an artificially created embankment around them.	f) Looking downstream from ~0.68km downstream of the start of the reach showing large woody debris located within the channel.
	
g) Looking downstream from ~1.23km downstream of the start of the reach. Note the vertical limestone cliff with extensive scour around the base of the cliff.	h) Looking downstream from ~1.34km downstream of the start of the reach showing a disconnected pool of water at the base of a tree. The spring inflow is located ~20m downstream of this location.
	

This reach remains within deciduous woodland, with extensive limestone cliffs located at several locations along the right bank. On the day of the survey the reach was entirely dry, except for a few disconnected stagnant pools (one mid-reach and one towards the end of the reach). Along reach there are numerous sinkholes where it is likely that flow would be lost. These sinkholes were mostly clustered around ~0.5km downstream from the start of the reach. Interestingly, a series of two caves/sinkholes were noted on the right bank and these appeared to have an artificially created bund around them which was located in the channel. Evidence around the caves/sinkholes indicated these were likely caving access points and the bund could be to ameliorate water ingress to the access point during higher flows. There are occasional fallen trees in the channel including a section ~0.15km downstream from the start of the reach where it appears that trees have been felled in to the channel. There is a wide diversity of sediment throughout the reach, although sediment is dominated by pebble and cobble substrates with occasional boulders. There are also sporadic sections of the bed in the reach that are composed of finer sediment which appears to be compacted. There is occasional bank reinforcement which is concentrated mostly around the start of the reach on the left bank. Channel widths are around 6-8m. The reach terminates where a large spring contributes flow to the river, entirely rewetting the channel.

2.2.8 Reach P

Reach P consists of a ~0.1km section of the Afon Alun from a spring reintroduces flow to the Afon Alun to the Nant Gain confluence. The reach is underlain by the Carboniferous Leete Limestone Formation. The superficial geology is predominantly alluvium. Along its course Reach O falls 0.9m with a slope of 0.5°. **Table 2-17** demonstrates two character photographs for this reach.

Table 2-17 Reach P character photos

a) Looking downstream from the start of the reach.	b) Looking towards the spring from at the start of the reach. The outlet of the spring has been artificially modified using laid stone.
	

This reach is set in a deciduous woodland setting with grazed grassland on the right bank. At the start of the reach a large spring was contributing a significant volume of flow to the channel, wetting the entire channel and creating flow. The source of the spring is not known, however the spring has an anthropogenically reinforced outlet using laid stone. The flow in the channel downstream of the spring was characterised by runs and riffles, with glides becoming more common down the reach as flows declined and were lost to the ground again. There is a wide diversity of sediment throughout the reach, dominated by pebble and cobble substrate with several sediment bars. Bank reinforcement is present throughout the reach, especially on the right bank and there are multiple pipelines across the bed which acted like small weir structures. There was also a pipeline on the right bank for ~20m at the start of the reach. Channel width was ~8m and the water width matches the channel width for most the reach. The reach terminates at the Nant Gain confluence.

2.2.9 Reach Q

Reach Q consists of a ~0.14km section of the Afon Alun from the Nant Gain confluence to the Cilcain Road bridge. The reach is underlain by the Carboniferous Leete Limestone Formation. The superficial geology is predominantly alluvium. Along its course Reach Q falls 2.2m with a slope of 0.9°. **Table 2-18** demonstrates four character photographs for this reach.

Table 2-18 Reach Q character photos

a) Looking downstream from the start of the reach. The Nant Gain joins from the left immediately upstream of the gabions on the left bank.	b) Looking upstream into the Nant Gain. Note the channel is dry.
	
c) Looking upstream from ~0.1m downstream of the start of the reach. Flow is being lost to the ground at this point on the right bank. Note the transition from moving to pooled flow.	d) Looking downstream from ~125m downstream of the start of the reach. Note pooled flow beneath Cilcain Road bridge. Most flow has been lost to the ground upstream.
	

This reach is set in deciduous woodland, with some improved grassland adjacent to the right bank and a road running adjacent to part of the left bank. There was no contribution of flow form the Nant Gain, which was dry on the day of the survey. Flow is lost progressively along the reach, most notably at a limestone bedrock exposure on the right bank ~0.13km downstream from the start of the reach. The wetted channel did expand past this point to the bridge, where it became ponded, before being entirely lost downstream of the bridge. The flow through the reach was run and riffle in the upper sections trending to glides and pools around, and downstream of, the point where flow was lost. There are frequent sediment bars within the reach and rare woody debris. There is a wide diversity of sediment throughout the reach, through it is dominated by cobble with occasional gravel and pebble and occasional protruding boulders. There is frequent bank reinforcement on both banks, including gabions on the left bank downstream of the Nant Gain confluence, multiple pipelines, an outfall structure (which was not contributing any flow on the day of the survey) and the stone Cilcain Road bridge. Channel width was around 6-8m. The reach terminates at the Cilcain Road bridge.

2.2.10 Sediment particle size analysis

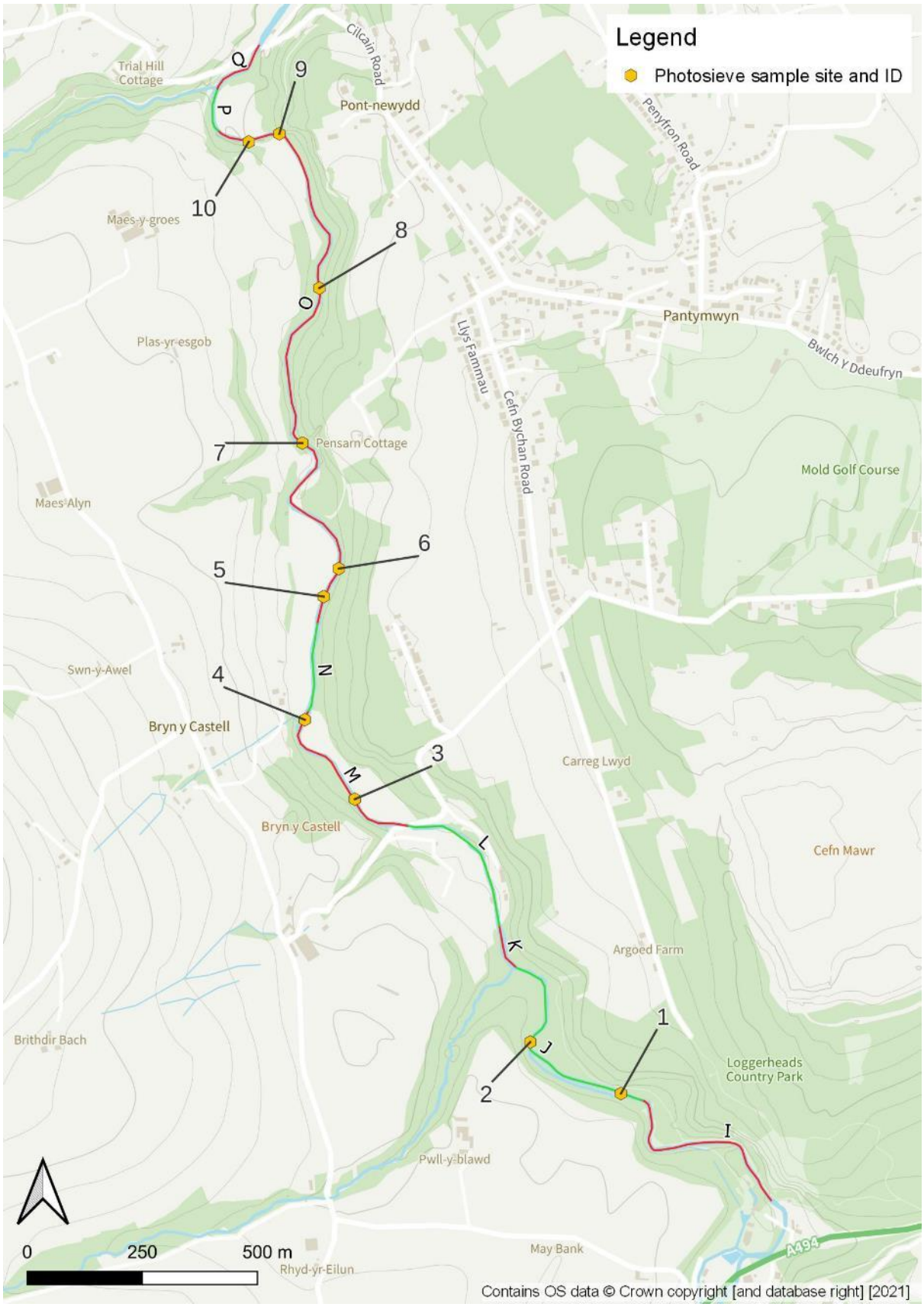
In order to understand changes in sediment size along the reach in the limited time available for the walkover survey, a photosieving technique was adopted. This entailed placing a known scale (in this case a 14.5cm pen) on exposed bed sediments in the dry channel and taking a photograph of the sediments and scale (ensuring the image focal plane was as parallel to the channel bed as possible).

Each photo was then geolocated on return to the office and particle b-axes measured using the image analysis software Fiji[9].

A total of ten images along the study reach (**Figure 2-9**) were analysed to measure sediment particle b-axes in centimetres. The resulting data was statistically analysed and plotted to provide an understanding of particle sizes and changes in particle size along the study reach. The results are discussed below.

[9] Schindelin, J., Arganda-Carreras, I., Frise, E., Kaynig, V., Longair, M., Pietzsch, T., Cardona, A. (2012). Fiji: an open-source platform for biological-image analysis. Nature Methods, 9(7), 676–682. doi:10.1038/nmeth.2019

Figure 2-9 Map of photosieving locations along the Afon Alun study reach



Summary particle size data for the ten photosieve sites is provided in **Table 2-19**.

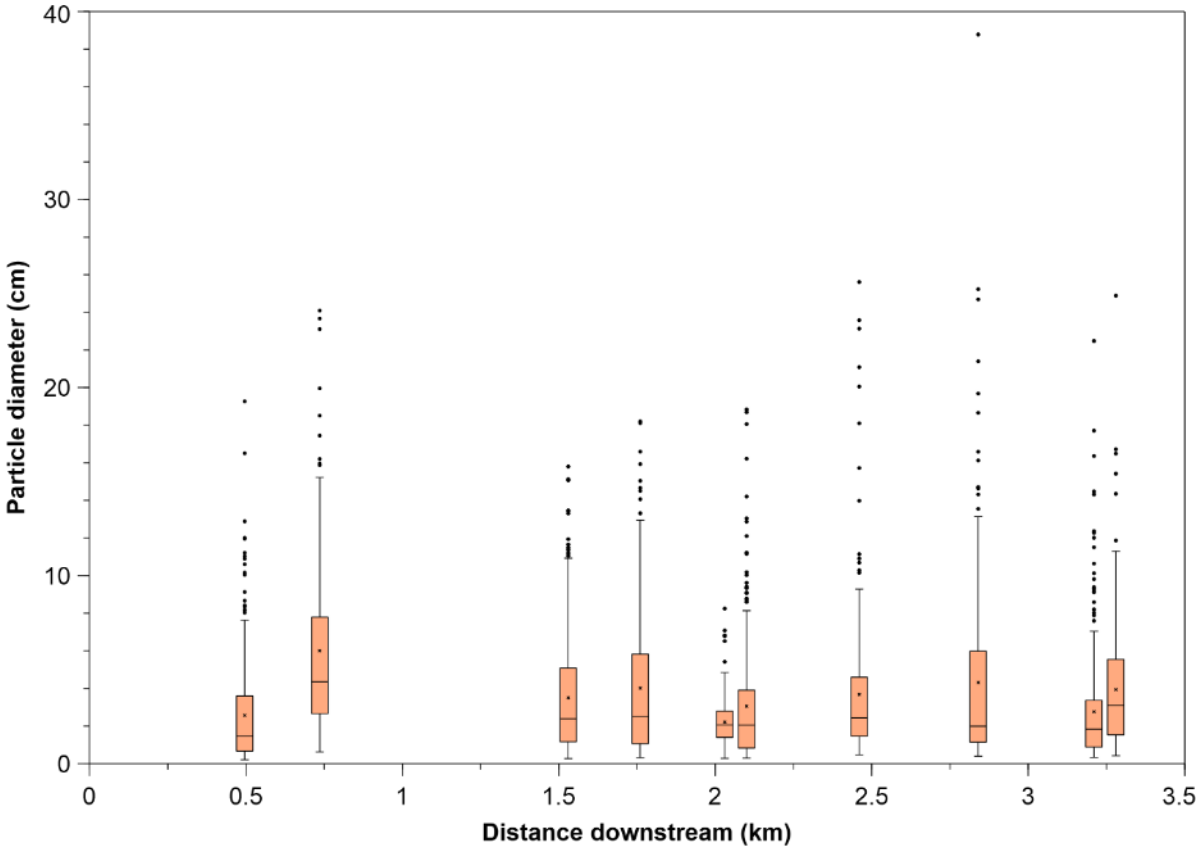
Table 2-19 Summary particle size data for the study reaches

Sample site	Reach ID	Distance downstream (km)	No. of particles measured	Particle b-axis size (cm)		
				Lower quartile (25th)	Median	Upper quartile (75th)
1	J	0.496	397	0.67	1.46	3.60
2		0.736	150	2.66	4.35	7.80
3	M	1.53	339	1.16	2.40	5.09
4		1.76	305	1.07	2.52	5.82
5	O	2.03	334	1.40	2.06	2.79
6		2.1	311	0.83	2.05	3.91
7		2.46	257	1.46	2.43	4.60
8		2.84	218	1.14	2.00	5.98
9		3.21	366	0.89	1.84	3.36
10		3.28	252	1.54	3.11	5.54

All photosieves are taken directly of the river bed as the reach was near completely dry at the time of the survey. The median particle size ranges from between 1.46-4.35cm in Reach J, 2.40-2.52cm in Reach M and 1.84-3.11cm in Reach O. The data show an initial increase towards the end of Reach J, followed by a decline and stabilisation of particle sizes throughout much of Reach O. After an initial increase in interquartile range in Reach J, this declines slightly in Reach M and rapidly at the start of Reach O before gradually increasing towards the end of Reach O. Overall, particle size is on the whole, relatively similar throughout the study reach.

A graphical representation of the particle dimension data as box plots is presented in **Figure 2-10**.

Figure 2-10 Particle size data derived from photosieves of exposed sediment along the Afon Alun in Reaches I to Q



This data supports the conclusions reached above, showing an initial increase in median particle size, followed by a decline and general stabilisation downstream towards the end of the study reach. With the exception of Site 2 in Reach J and possibly Site 10 at the end of Reach O, there are no significant outliers in the data. During the walkover survey there were no observations of processes which could explain the difference in sediment sizes measured at Site 2 and Site 10 (noting the river was dry mostly throughout). Site 1 and Site 2 did occur just downstream of where the river was entirely lost to the aquifer and the section upstream of here was relatively modified, both modern modifications and historical ones from mining and this may have impacted on sediment supply, leading to bed armouring at Site 2. However, this evidence is not clear and therefore, unfortunately, firm reasons for the changes in particle sizes cannot be provided.

2.2.11 Potential impacts on the watercourse from decommissioning

The evidence collected during the walkover survey suggest that the key issues in the Afon Alun study reach are driven by two main issues:

- **Loss of flow through nearly the entire study reach** – this is an ephemeral issue which has been occurring over a long duration due to the geology.
- **Barriers** – these are permanent issues, though are very limited in occurrence.

Specifically, the key barriers are:

1. Temporary weir and concrete step in the channel in Reach I.
2. Unusual armoured bed and step in the channel identified in Reach K.

Both barriers identified are relatively small and are of a magnitude at which they are unlikely to cause any significant barrier to flow, sediment movement and ecology, particularly migration of fish species. Given both are upstream of the confluence with the Aber Eilun these cannot interact with any potential changes associated with the decommissioning of the Brithdir Mawr Reservoir.

The loss of flow in the Afon Alun is predominantly a natural phenomena (although it is exacerbated by human influence). Therefore, the system is ephemerally dry which is a total barrier to sediment movement and species migration and ecology in general. However, it is very likely that the habitats and flora and fauna the watercourse supports, are adapted to this ephemeral loss of water. It should be noted that the flow from the Aber Eilun does enter the Afon Alun, creating localised wetting and flow in the channel, however this is entirely lost to the aquifer within the 0.1km stretch of Reach K.

Based on the proposed decommissioning options for Brithdir Mawr Reservoir and their potential impacts to the Aber Eilun (**Section 2.1.10**), these are concluded to have no impact on the Afon Alun, principally as the benefits of decommissioning will not reach this distance downstream and the decommissioning will have no impact on the loss of flow from the Aber Eilun in the short stretch of the Afon Alun in Reach K.

3 WFD Assessment

This section presents the WFD assessment of the decommissioning of Brithdir Mawr Reservoir on any WFD water bodies that may be impacted. The assessment will be conducted against the WFD assessment objectives outlined in **Section 3.1**.

3.1 WFD assessment objectives

A WFD scoping level assessment will be undertaken for the decommissioning of Brithdir Mawr Reservoir. The 'UKWIR Environmental Assessment Guidance for Water Resources Management Plans and Drought Plans'[10] guidance has been followed. The Guidance sets out the context of a WFD assessment and background to WFD ecological status.

Section 1.2 of the UKWIR guidance sets out three objectives to test for a WFD assessment:

- Objective 1. To prevent deterioration of any WFD element of any water body.
- Objective 2. To prevent the introduction of impediments to the attainment of 'Good' WFD status or potential for any water body. It is accepted that for some water bodies achievement of Good status or potential is currently technically infeasible or disproportionately costly. Where this is the case, the test is applied to the currently agreed objectives for that water body rather than against Good status/potential.
- Objective 3. To ensure that the legally binding planned programme of measures in the [current] cycle of RBMPs to protect and enhance the status of water bodies are not compromised.

The WFD assessment for this scheme has been set out against these three objectives.

Confidence in the assessment has been assigned for impacts on biology. Consistent with other reported WFD approaches, a three-point confidence index has been used: very certain, quite certain and uncertain. Very certain reflects where a confirmed or probable biological change (or no change) would be affected by the scheme, supported by measured evidence or expert judgement of a strong cause-effect relationship. Quite certain reflects where a probable or suspected biological change (or no change) would be affected by the scheme, supported by limited measured evidence or expert judgement of a moderate cause-effect relationship. Uncertain reflects where a suspected biological change (or no change) would be affected by the scheme, supported by expert judgement of a weak or unknown cause-effect relationship.

3.2 WFD waterbodies and RBMP2 status

The area surveyed in the geomorphological walkover surveys (**Section 2**) is entirely covered by a single surface water body, *Alyn - upstream Dolfechlas Brook (GB111067051810).* Brithdir Mawr reservoir itself is not a lake water body. From the geomorphological walkover surveys it is evident that there is a strong interaction between the surface water and groundwater in this water body, specifically in the Afon Alun.

[10] UKWIR (2020) Environmental Assessment Guidance For Water Resources Management Plans and Drought Plans

In order to ensure that no potential impacts on the groundwater are excluded, the *Dee Carboniferous Limestone (GB41101G202200)* groundwater water body has also been considered in this assessment.

Table 3-1 identifies specific details about the waterbodies and lists their current status based on the Natural Resources Wales WFD RBMP2 2015 classification and 2018 interim classification. Criteria are colour coded based on their potential impacts on agreed measures and objectives which is undertaken later in the report. The key for this colour coding is provided below the table.

Table 3-1 WFD RBMP2 waterbodies within the study area

WFD waterbody name		Alyn - upstream Dolfechlas Brook		Dee Carboniferous Limestone	
WFD waterbody type		River		Groundwater	
WFD waterbody ID		GB111067051810		GB41101G202200	
RBMP2 Overall Status		Moderate		Good	
Hydromorphological designation		Not artificial or heavily modified		n/a	
Mitigation Measures Assessment		Not assessed		n/a	
RBMP2 mitigation measures		None		None	
WFD Protected Areas		SAC, NVZ		DrWPA	
		2015	**2018 (interim)**	**2015**	**2018 (interim)**
Biology status elements	Fish	**Good**	**Good**	**n/a**	**n/a**
	Macrophytes & Phytobenthos	**Good**	**Good**	**n/a**	**n/a**
	Invertebrates	**High**	**Good**	**n/a**	**n/a**
	Ammonia (Phys-Chem)	**High**	**High**	**n/a**	**n/a**
	Dissolved oxygen	**High**	**High**	**n/a**	**n/a**
	pH	**High**	**High**	**n/a**	**n/a**
	Phosphate	**High**	**Good**	**n/a**	**n/a**
	Temperature	**High**	**High**	**n/a**	**n/a**
	Acid Neutralising Capacity (ANC)	**Not assessed**	**High**	**n/a**	**n/a**
	Specific pollutants	**Moderate (Good by 2021)**	**High**	**n/a**	**n/a**
Quantitative	Saline Intrusion	**n/a**	**n/a**	**Good**	**n/a**
	Water Balance	**n/a**	**n/a**	**Good**	**n/a**
	GWDTEs test	**n/a**	**n/a**	**Good**	**n/a**
	Dependent Surface Water Body Status	**n/a**	**n/a**	**Good**	**n/a**
Chemical (Overall)		**Fail (Good by 2021)**	**Good**	**Good**	**n/a**
Reasons for not achieving good status (RNAG)		The RNAG indicates that the driver for the overall moderate status in this water body is the **zinc** and **lead** status elements. The RNAG for these elements outlines that the source of the pressure for each of these elements is unknown (pending investigation).		Water body is already at good status, therefore, no RNAG listed.	

Key to Table 3-1:

Review for risk of status deterioration only (Objective 1)
Review for risk of in class deterioration only (Objective 1)
Review for risk of status deterioration (Objective 1) and for risk of impediment to improvement in status to target (Objective 2)
Review for risk of in class deterioration (Objective 1) and for risk of impediment to improvement in status to target (Objective 2)
Review for risk of compromising RBMP2 agreed measures (Objective 3)

3.3 Screening of activities

Table 3-2 presents a Source-Pathway-Receptor approach to screening the potential impacts to each WFD water body with respect to the Brithdir Mawr Reservoir decommissioning. Those receptors screened in will be passed forward onto the scoping level assessment stage.

Table 3-2 Source-Pathway-Receptor approach to screening elements for WFD compliance assessment of the Brithdir Mawr decommissioning on the downstream watercourse

WFD waterbody	Alyn - upstream Dolfechlas Brook (GB111067051810)	Dee Carboniferous Limestone (GB41101G202200)
Source	• Decommissioning of Brithdir Mawr Reservoir leading to a change in outflow regime to the receiving water course.	• Decommissioning of Brithdir Mawr Reservoir leading to a change in outflow regime to the receiving water course.
Pathways	• Change in river flow: the downstream catchment will become more reactive to rainfall events, particularly in periods where the Brithdir Mawr Reservoir would be drawn down under baseline scenarios. This will lead to a more natural flow regime. • Change in sediment supply: The reservoir will no longer act as a sediment trap. This means the downstream catchment will develop a greater sediment diversity. Greater range of lower flows may ameliorate the impacts of poaching downstream.	• Change in surface water contribution to the groundwater water body: There is a high amount of connectivity between the surface and groundwater in the study area. As such, there are potential impacts on the groundwater body associated with the change in river flows.
Receptors screened in	• None	• None
Receptors screened out	• Fish • Macrophytes & Phytobenthos • Invertebrates • Ammonia (Phys-Chem) • Dissolved oxygen • pH • Phosphate • Temperature • Acid Neutralising Capacity (ANC) • Specific pollutants • Chemicals	• Saline intrusion • Water balance • GWDTE Test • Dependent surface water body status test • Chemicals

It is worth noting that any construction activities have been screened out from further assessment. This is because, providing best practice construction techniques are utilised when decommissioning the reservoir, any construction impacts will be short term and will not extend over the 6-year RBMP period. The main concern over the mobilisation of sediment will be mitigated by downstream sediment traps. Any additional sediment that does escape the traps to be transported downstream will be flushed out of the system by high flow events. As such, any receptors screened in for a more detailed assessment have been done so based on operational impacts.

In the *Alyn- upstream Dolfechlas Brook* water body, there are no pathways that would negatively impact any receptors in this water body. There is not expected to be a change in pollutants or buffering capacity to pollutants in this water body as a result of the more variable flow regime, as such, there is no risk of deterioration in any water quality elements. Furthermore, there it is not expected that the zinc or lead elements will be prevented from achieving their target status as a result of the decommissioning of the reservoir.

Any hydrological and geomorphological changes associated with the decommissioning of the reservoir will lead to a greater diversity in habitat for the fish, invertebrate and macrophyte communities. This will improve the ecological resilience in the system, allowing these communities to better withstand any future hydrological/geomorphological pressures. As such, there is no risk of deterioration in WFD status of any of these elements in this water body (in the long term, the status of these elements may improve).

It is worth noting that, due to the presence of barriers in the Aber Eilun and the ephemeral state of the Afon Alun, the realisation of the identified benefits will be limited on the water body scale. The hydrological regime will be unchanged downstream of the point where the flow is lost on the Afon Alyn (the start of Reach L) and the effects of the change in sediment supply will be constrained to upstream of the low-head hydropower scheme (the start of Reach G).

No receptors in the *Dee Carboniferous Limestone* water body have been considered for further assessment. The decommissioning of the reservoir will lead to a change in flow regime, especially under low flow conditions, to mimic that of the natural flow regime prior the construction of the Brithdir Mawr Reservoir. Therefore, there could be a change in the surface water contribution to the

groundwater water body however these changes would be representative of a more natural flow regime in the river. This change is not expected to be sufficient to impact any groundwater status elements sufficiently to cause deterioration in WFD status.

3.4 Scoping level assessment

No receptors in any water body have been screened in for a scoping level assessment.

3.5 WFD Regulations compliance summary

Through the screening of activities (**Section 3.33.3**), the compliance of the discontinuance of Brithdir Mawr Reservoir as a storage reservoir has been assessed against the three WFD objectives set out in Section 3.1. Two WFD waterbodies were screened into the assessment namely the river water body *Alyn - upstream Dolfechlas Brook (GB111067051810)* and the groundwater water body Dee Carboniferous Limestone (GB41101G202200).

The screening of activities has identified that the discontinuance of Brithdir Mawr Reservoir would have a negligible impact on the receptors within either of the identified waterbodies; therefore, it was deemed that there is no risk to any of the WFD objectives as a result of the decommissioning of Brithdir Mawr Reservoir.

However, as noted above, although not the focus of the assessment, the decommissioning of Brithdir Mawr Reservoir will provide a series of benefits with regards to more naturalised habitats, hydrology and geomorphology. As a result, the impacts of the discontinuance of Brithdir Mawr Reservoir are deemed WFD compliant.

4 Conclusions

As part of the decommissioning of Brithdir Mawr Reservoir, a walkover of 1.57km of the Aber Eilun commencing on two tributaries ~75m upstream of the reservoir and ending at the confluence with the Afon Alun, and a walkover of the ~3.4km of the Afon Alun between Loggerheads Country Park and Cilcain Road Bridge were undertaken in April and July 2021 respectively. The rivers were broken up into 17 individual reaches, the Aber Eilun in reaches A to H and the Afon Alun in reaches I to Q, based on changes in geomorphology, hydrology and anthropogenic features. In summary, the key characteristics of these reaches are:

- **Reach A (unnamed tributary)** – A 75m long reach through deciduous woodland forming run-rapid sequence over steps and woody debris trending to a riffle-run sequence towards the lower end of the reach. Bed sediments are diverse and predominantly composed of pebble and cobble sized particles, frequent sediment bars, a berm and predominantly near vertical earth banks. A small weir is located towards the end of the reach before it flows into the reservoir.
- **Reach B (Aber Eilun)** – A 75m long reach through deciduous woodland, largely mirroring Reach A. The channel is predominantly a riffle-run with some rapids and pools around steps and woody debris. Sediment distribution is diverse and predominantly composed of cobble and pebble sized particles and frequent sediment bars. A small laid stone weir is located towards the end of the reach. The reach flows into the reservoir.
- **Reach C (Aber Eilun)** – A 60m long reach comprising the spillway of the reservoir with a mixture of runs, rapids and falls over the stone steps and no sediment features.
- **Reach D (Aber Eilun)** – A 0.25km long reach situated downstream of the reservoir which flows through grazed grassland. It is a riffle-run sequence dominated by coarse cobble sediment with occasional fine sediment due to extensive cattle poaching. Banks are predominantly vertical and eroding.
- **Reach E (Aber Eilun)** – A 85m long reach flowing mostly through improved grassland, with slightly denser deciduous woodland on the right bank. A tributary flows into the reach from the right bank at the start of the reach, while a smaller tributary joins on the left bank at the end of the reach. Flows are run and riffle over a coarse cobble substrate. This reach is much less impacted by cattle poaching than Reach D.

- **Reach F (Aber Eilun)** – A 0.66km long reach which flows entirely through deciduous woodland, with some boggy margins towards the top of the reach. There is extensive control of channel morphology, flow and sediment features by large woody debris. Flows are predominantly run and riffle with occasional pools and falls. Sediment bars are abundant and bed substrate is predominantly cobble, although sizes are diverse with some bedrock substrate towards the end of the reach. Anthropogenic modification is rare, although a pipe is present in the channel. The reach ends at a low head hydropower scheme.
- **Reach G (Aber Eilun)** – A 0.13km long reach flowing through a private garden. A low head hydro power scheme (~2m head) is located at the start of the reach and is a barrier to flow and sediment. A dry bypass channel around the hydropower scheme on the right bank is present. The downstream reach is composed of cobble sediments with no depositional features. The reach terminates at a culvert beneath a local road.
- **Reach H (Aber Eilun)** – A 0.7km long reach flowing mostly through deciduous woodland in a deep and steep sided valley. Flows within the reach are diverse but predominantly a run-riffle sequence with occasional pools, backwaters and rapids around large woody debris. Sediment sizes are diversity but cobble and pebble dominates. Sediment bars are abundant, many of which are controlled by the frequent large woody debris. Lateral input of sediment through bank erosion and mass movement contributes to the sediment in the river and likely ameliorates the impact of the hydropower scheme and culvert on downstream sediment supply. A weir is present at the end of the reach with a head of ~1m, prior the reach joining the Afon Alun.
- **Reach I (Afon Alun)** – A 0.45km long reach which flows entirely through deciduous woodland. Flows within the channel are predominantly run and riffle at the start of the reach changing to glides and pools towards the middle and end of the reach, potentially due to loss of flow to groundwater. Sediment bars are abundant and bed substrate is diverse, though cobble and pebble predominate. Anthropogenic modification is common, with reinforced banks present, particularly at the start and end of the reach and several footbridges cross the reach. A small temporary weir with a spatially discrete concrete bed on the left bank downstream of the feature is located near the top of the reach. The reach ends where all flow is lost to groundwater at a sinkhole on the right bank.
- **Reach J (Afon Alun)** – A 0.5km long reach which flows entirely through deciduous woodland in a deep and steep sided valley. The reach was completely dry on the day of the survey and there was vegetation in the channel which indicated the reach had been dry for an extended duration. There is a range of diverse sediment throughout the reach with cobble and pebble dominating. Sediment bars were visible throughout the reach, though identification was hampered by lack of flow. Two large islands cause channel bifurcation in the middle and end of the reach. Bank reinforcement is common and there is an unusual armoured bed (possibly an old weir) at the end of the reach. The reach ends at the confluence with the Aber Eilun.
- **Reach K (Afon Alun)** – A 0.1km long reach where the input of flow from the Aber Eilun provides sufficient flow to partially wet the channel before being lost to the ground. Where flow is present it is characterised by glides and runs with occasional riffles. This reduces to glides and pools as flow is lost. Bed substrate is predominantly cobble and pebble and sediment bars are present. Bank reinforcement is common.
- **Reach L (Afon Alun) –** A 0.34km long reach. This was mostly inaccessible and was completely dry on the day of survey. Sediment is diverse at the start of the reach, though cobble and pebble were dominant. Bank reinforcement is common and there is a ford with concrete bed and footbridge at the end of the reach. The reach ends at the Meas-Y-Groes STW outfall.
- **Reach M (Afon Alun) –** A 0.39km long reach. Flow was being input via seepage from the STW outfall structure. This flow input appeared to create localised flow in the channel and a gradual gain of flow was noted downstream, creating pools of varying interconnectivity and flow. Most pools were stagnant but some glide flow was noted. Large woody debris was common and modified flow and sediment. Sediment input from bank collapse by mass movement was common at the start of the reach, contributing to the wide diversity of substrates dominated by cobble and pebble sized particles. There was occasional anthropogenic modification.
- **Reach N (Afon Alun) –** A 0.19km long reach. Valley morphology changes here, becoming more open with an extensive floodplain on the left bank. There is a gradual loss of flow in the

reach with pools and shallow glides of varying size and interconnectivity. Sediment substrate is predominantly cobble and pebble size with a reduced diversity of depositional features, likely due to less in channel woody debris. There is significantly less bank erosion in the reach, due to the left bank being extensively reinforced and the right bank being heavily wooded. The reach ends when flow was entirely lost to the ground.

- **Reach O (Afon Alun) –** A 1.38km long reach which was entirely dry, except for a few disconnected stagnant pools. There were several notable sinkholes along the reach and several extensive bedrock exposures forming banks. Sediment diversity is wide, however cobble and pebble dominate, with occasional boulders. Small sporadic sections of the bed appeared to be composed of compacted finer sediment. Bank reinforcement is occasional at the start of the reach though anthropogenic modification is generally rare.
- **Reach P (Afon Alun) –** A 0.1km long reach characterised by complete rewetting of the reach due to a significant inflow from a spring situated on the left bank at the start of the reach. The flow is predominantly run and riffle but glides occur towards the end of the reach as flow begins to be lost. Sediment is diverse though pebble and cobble predominate. Sediment bars are present. Bank reinforcement is common and several small pipes are located on the bed.
- **Reach Q (Afon Alun) –** A 0.14km long reach which begins at the confluence with the Nant Gain (which was dry on the day of the survey). Flow is lost progressively down the reach, starting as run and riffle with some glide, then transitioning to glide and pool as flow declines, ultimately ending in a pool beneath Cilcain Road bridge. Cobble substrate dominates, with occasional gravel, pebble and boulders. Sediment bars are frequent. Bank reinforcement is common and there are multiple pipelines, an outfall structure and bridge on the river. The channel is dry downstream of Cilcain Road bridge.

Particle sediment size through both the Aber Eilun and Afon Alun was measured using the photosieving technique at ten sites. Analysis of the particle size information for the Aber Eilun showed that median particle size ranged from 0.50-1.55cm in Reach A and B upstream of the reservoir to 1.02-1.85cm in Reach C to F and 1.03-3.02cm in Reach H. Median particle sizes were relatively invariant in Reaches A and B and Reaches C to F, followed by a sharp increase (at Site 11) and gradual decline throughout Reach H. This is attributed to reduced sediment supply and armouring of the bed downstream of the hydropower scheme and culvert and subsequent lateral input of sediment downstream in Reach H.

Analysis of the particle size information for the Afon Alun showed that median particle sizes ranged between 1.46-4.35cm in Reach J, 2.40-2.52cm in Reach M and 1.84-3.11cm in Reach O. Although there is some variation in particle sizes on the whole median particle sizes are relatively similar throughout the study reach. Due to the lack of flow in the river firm reasons for downstream changes in particle sizes, such as at Site 2 and Site 10, cannot be provided.

Within the Aber Eilun, the key issue affecting the watercourse is predominantly the presence of barriers, notably in Reach A, Reach B, Reach F, Reach G and Reach H. All of these structures are a barrier to flow, sediment movement and ecology, particularly migration of fish species. Within the Afon Alun the key issues affecting the watercourse are the loss of flow in majority of the study reach (which is an ephemeral issue that is effectively natural) and the presence of two barriers (which are essentially permanent issues). Both barriers are relatively small and unlikely to act as a significant barrier. Importantly they are located upstream of the confluence with the Aber Eilun and cannot interact with any changes due to the decommissioning of Brithdir Mawr Reservoir. The loss of flow in the Afon Alun is essentially a natural, ephemeral phenomena (although in some areas this is exacerbated by human influences) leading to a total barrier to sediment movement and ecology connectivity. However, given this is a natural process it is likely the habitats within the river are adapted to this ephemeral loss of water.

The decommissioning of the reservoir is projected to have a number of positive impacts on the watercourse, predominantly through locally improving connectivity for flow, sediment and ecology, a return to more naturalised flow and sediment regimes in the Aber Eilun immediately downstream of the reservoir, and reconnection of habitats upstream of the reservoir. It is unlikely that any benefits will be transmitted downstream of Reach F in the Aber Eilun due to the low head hydropower scheme and the anticipated more naturalised flow regime is highly unlikely to overcome flow losses in the Afon Alun. Therefore no features of the decommissioning were identified which could lead to negative impacts on

the downstream Aber Eilun or Afon Alun. For maximal benefits from the decommissioning it is recommended that the barriers identified on the Aber Eilun be addressed.

Any short term impacts from decommissioning of the reservoir, such as the release of fine sediments downstream, can be wholly mitigated by good constructions practices and planning.

A WFD assessment of the scheme identified that Brithdir Mawr Reservoir was not classified as a lake waterbody and that the Aber Eilun and Afon Alun study reaches fell into a single waterbody, *Alyn – upstream Dolfechlas Brook*. Due to the influence of losses to groundwater the underlying groundwater water body *Dee Carboniferous Limestone*, was also considered. Currently the overall interim 2018 WFD status for both waterbodies is good.

Using a source-pathway-receptor approach, the key source of potential positive impacts were from changes to the outflow regime towards a more natural flow regime. For the surface water body, the change in river flow and a change in sediment supply (to a significantly more natural regime than they are currently) is identified as the key pathway. For the groundwater water body the change in surface water contribution to the groundwater waterbody is identified as the key pathway. Construction activities were screened out from further assessment due to the implementation of best practice construction techniques. Given that decommissioning and the source and pathways of changes are highly likely to lead to a more naturalised regime all receptors can be screened out. It is concluded that there are no impacts to either WFD waterbody from the decommissioning of Brithdir Mawr Reservoir and the decommissioning is deemed WFD compliant.

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