

Geomorphological Assessment: Afon Celynog

The Afon Celynog rises on the north-western side of Glasgwm, part of the Arans, at ~650 m OD. It is a relatively short river, and a tributary of the larger Afon Wnion. The Afon Celynog drains westwards over a complex sequence of Ordovician-aged rocks, characterised by the intersequencing of igneous (volcanics), volcanoclastic and meta-sedimentary rocks, with regional (NE/SW trend) faulting. The surficial geology is dominated by glacial sediments (till, diamict, sands and gravels) deposited during the last glacial maximum. The river is a single-thread, meandering system. The river downstream of Pont Rhyd-y-gwair lies within a glacially-deepened (subglacial drainage) valley.

For the purposes of this report, the upper and lower sites on the Afon Celynog will be discussed separately. This also applies to the proposed site on the unnamed tributary (Appendix I).

Planform Geomorphology (form and processes)

Upper Site

The Afon Celynog at Ffridd Celynnog (Fig. 1; Appendix II – photos 1-6 & 15-22) extends to. It is a laterally and vertically stable channel. Between the proposed site of the weir and Pont Rhyd-y-gwair, the reach lies in a very low gradient section of the river, with a slope gradient of 1.8%. The reach planform has a sinuosity index (SI) of 1.9, indicative of a meandering reach, although bends are limited. Where meander bends are present, this reflects the less resistant underlying geology. However, immediately downstream of Pont Rhyd-y-gwair the river enters a bedrock gorge and falls system. Here the gradient becomes very steep, with a slope of 11%, and the channel planform can be described as sinuous with an SI of 1.1.

The reach is typical of an upland stream and drains open moorland and/or improved agricultural land. It can be divided into three zones. In the upper-zone of the reach (Appendix 2: photos 1-6 & 15-18) the channel has a low gradient and gently meandering planform. This upper-zone is entrenched in glacial sediments (drift-bound), which confines the planform, although there is some opportunity for some out of bank flow. The reach starts immediately downstream of a small bedrock step and pool sequence (Appendix II; photo 1). The reach is characterised by a series of low-level step and pool sequences, formed by bedrock and/or in-stream boulders, and a cobble-/boulder-strewn channel bed.

The channel has a wide (9 m) and shallow profile in the upper- and mid- zones. A number of small tributary streams run off the Ffridd Celynnog and drain into the river on its true left bank. There is evidence of sediment deposition (pseudo-alluvial fans), where these small streams enter the upper Afon Celynog (Appendix II; photo 15).

Towards the mid-zone of this upper site (Appendix II; photos 15-18) bedrock is not really present and this is reflected in a more alluvial channel. This contrasts with both the upper-zone and the lower site (discussed below). A small floodplain is present (there is evidence of recent out of channel flow). However, the lower-zone (Appendix II: photos 19-22) is entrenched (few meters) into the valley and demarcates the start of the subglacially-cut channel.



Figure 1: The Afon Celynog (Source: <https://digimap.edina.ac.uk/> © Crown Copyright and Database Rights 2018 Ordnance Survey Digimap Licence).

Lower site

The Afon Celynog at Bryn-coed-lfor (Fig. 1; Appendix I, II: photos 23-28) is a laterally and vertically stable channel. The reach lies in a very steep section of the river, with a slope gradient of 10%. The reach planform has a sinuosity index (SI) of 1.9, indicative of a meandering reach, though bends are limited. The only significant meandering section comprises 6 bends, located at the upper part of the reach. Here the meanders give an SI of 1.7.

This reach is typical of a mountain torrent, despite being located in the lower reaches of the system. It has a confined planform and the reach starts immediately downstream of a natural bedrock gorge. The reach comprises a sequence of steps and pools, permanent features that are either bedrock-derived or boulder-originating. Part of the lower river (in this reach) runs through another natural gorge, where the bedrock forms the bed and bank materials, approximately 1.2 km in length. The lower section of the reach is around 8 m wide, around half the channel width at its widest point (immediately downstream of the existing weir structure).

The upper part of the reach (below the upper gorge) displays the small cascades and plunge pools associated with the bedrock steps. Flow separation is evident at low flow but during high (extreme) flows the channel morphology becomes irrelevant as it cascades over the rock steps. There is some evidence of natural scouring of the bedrock, with incipient pothole features.

Immediately downstream of the upper gorge, the natural step-pool sequence gives way to a prominent meander bend. This has formed a natural embayment and limited erosion has concentrated here during high flow events.

The long profile of the reach has a stepped profile, typical of many west-flowing rivers in North Wales. There is little space for a floodplain given the deeply incised nature of the valley, and the lower reach is heavily wooded throughout. There is no evidence of valley floor geomorphology in the reach, where the Afon Celynog meets the Afon Wnion.

The confined morphology of the Afon Celynog indicates that it will not be subject to alteration.

Sedimentology (bed and bank)

Along the reach the bedrock geology (Fig. 2) changes significantly, and the river flows over Felsic Tuff (igneous), across Siltstones/Tuffaceous Siltstone and volcaniclastic Sandstones, and onto Mudstones and Siltstones (metamorphic). Bedrock exerts significant control on the reach and channel, as mentioned previously.

Upper site

This reach of the Afon Celynog comprises a mixed bedrock-alluvial channel. The channel bed is boulder-strewn, with outcrops of bedrock running across the channel. The channel banks are a mix of bedrock and glacial sediments (inc. boulders). There is some riparian vegetation, as well as woody debris found in the lower sections of this reach (Appendix II: photos 15-22). Many of the channel margin boulders and those in the banks are moss and

grass covered. The presence of vegetation cover suggests there is (currently) a low frequency of high energy events to strip out the vegetation cover. The channel margins suggest a stable system, partially due to their non-erodiability (bedrock and/or boulders/tree roots) but the channel boundary is also erosionally-resistant and hydraulically rough.

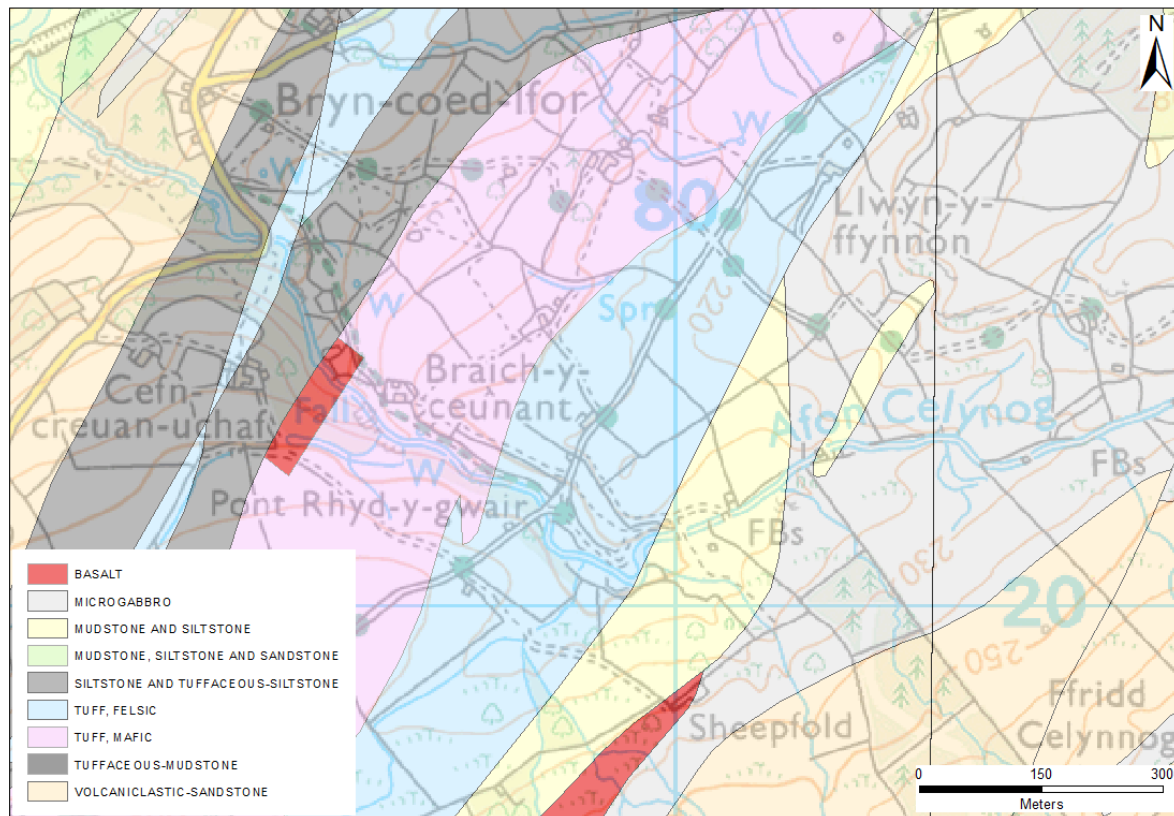


Figure 2: Bedrock geology of the Afon Celynog (Source: <https://digimap.edina.ac.uk/> © Crown Copyright and Database Rights 2018 Ordnance Survey Digimap Licence).

Sediment load can be described as coarse, and transport is bedload dominated. In-channel sediments are not moving under normal flows, but are transported periodically under high flow events. Bedload transport is likely to be highly variable given the nature of the channel sediments, and it is probable that higher thresholds are required to initiate sediment entrainment/motion. In-channel clasts range between sub-angular to sub-rounded in shape, indicative of both geological control and input of sediment from the smaller valley-side streams.

There are gravel lags present in the lee of large boulders and bedrock outcrops. Grain size of the boulders (a-axis 50cm) in the bed and banks is distinctly different from the cobbles and pebbles (a-axis 3-10cm) seen as gravel lags, but there is a limited supply of fine gravel and smaller-sized sediments. Weathering of the bedrock will be required for erosion to take place,

particularly for the more resistant lithologies. This may explain the lack of smaller sediments within the channel.

The British Geologic Survey (BGS) have identified alluvium along part of the upper- and mid-zone (Fig. 3) although these deposits are not very extensive and are not seen at all in the gorge area of the lower-zone of the reach. Given the calibre of the sediments within the present-day channel it is more likely to represent earlier fluvial activity and therefore is not reflective of contemporary processes. There is limited evidence of major valley floor entrenchment in this upper reach, and there is no indication of previous channel activity, i.e. palaeochannels, to suggest lateral mobility. The reach reflects a stable channel, with sediment only moving at threshold, i.e. bankfull or extreme flow events.

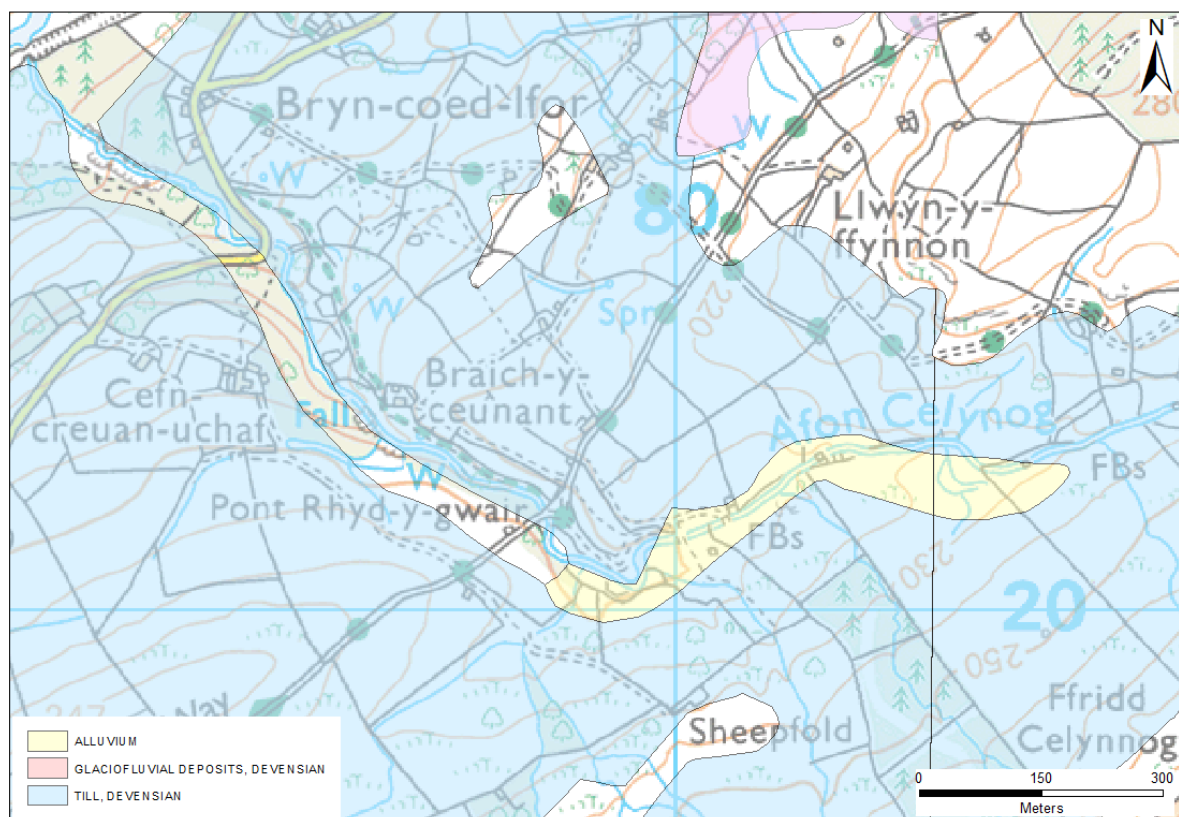


Figure 3: Superficial Geology of the Afon Celynog (Source: <https://digimap.edina.ac.uk/> © Crown Copyright and Database Rights 2018 Ordnance Survey Digimap Licence).

Lower site

The channel is frequently underlain by outcropping bedrock, forming its bed and bank materials. However, it is not exclusively bedrock-lined and the channel bed and banks also comprise large boulders (a-axis 1-2m). The size of these boulders suggest they are not moving under normal flow conditions, and are likely to be relics of glacial transport processes. There is no indication of sediment input from the slopes, and instead sediment enters the reach

from upstream sources. The tree-lined nature of the incised valley means that some tree roots intrude into the banks, but also woody debris is found within the channel.

Where bank material is shown to be sedimentary, it is clear that this is of glacial origin and not alluvial. The BGS superficial geology map for the area indicates that there is no alluvium within the lower reach, and this would fit with the largely rock-lined nature of the system here.

Along the channel bed, aside from the large boulders, there is a mixed sediment profile ranging from fine gravel up to large boulders. The embayment shows temporary storage of fine gravels and cobbles, and on the lee side of large boulders there are also deposits of similar-sized clasts. The channel bed, where gravels are present, is not imbricated nor is it armoured. Gravels can be seen in the pools, with some finer sediments (b-axis 3-5cm) accumulating in the quieter sections (slowing flows). Sediments are well-rounded, indicative of fluvial transport.

The outer bank of the meander bend, where the natural embayment has formed, shows some indication of bank erosion (glacial sediments exposed). This is not unexpected as the channel thalweg meanders out of the upper gorge (bedrock-lined) step-pool feature. These areas are always susceptible to erosion during the extreme events that characterise steep (mountain torrent type) channel reaches.

Afon Celynog

Sediment transport is dominated by bedload processes and sediments are transported through this reach like a jerky conveyor belt, i.e. short-distances, infrequent transfer. Sediments of the mixed-profile type are temporarily stored after each high (extreme) flow event, before being remobilised during the subsequent event. There is no normal flow bedload or suspended sediment transport. The largest boulders are not moving at all in most events, hence the boulder-strewn nature of the reach. A natural bedrock step exists at the confluence with the Afon Wnion. The coarse and large nature of the sediments in this system, combined with the channel planform indicates that sediment transfer takes place only during extreme events. In-channel morphology (or structures) becomes irrelevant and sediment moves unimpeded.

The river comprises bedrock gorges in its lower reaches, as well as both the upper and lower sites comprising a boulder-strewn channel. However, sediment dynamics in this reach are unlikely to be affected by the proposed scheme. Sediment transport takes place during high flows, with sediment is moved between temporary storage areas. The planform is confined, and the bed and bank materials will not be subject to increased erosion or in-channel deposition because these processes are naturally occurring during high flow events only. The

largest boulders within the system are currently not moving during the highest of flows suggesting this reach is, for the most part, fixed in terms of its sediment dynamics.

Channel Flow (Afon Celynog)

Flow percentiles have been estimated for the Afon Celynog as there is no gauging station on this system. The estimated annual flow is 0.388 ms^{-3} . Estimated flow percentiles (Fig. 4) give a Q95 (95% Exceedance) of 0.049 ms^{-3} and a Q10 (10% Exceedance) of 0.889 ms^{-3} . Estimated high flows indicate a high flow of 4.931 ms^{-3} .

Taken together these estimates suggest a 'flashy' flow regime, typical of mountain torrent, and combined with the calibre of the sediment in the reach the data suggests that sediment movement is restricted to these higher (extreme) flow events.

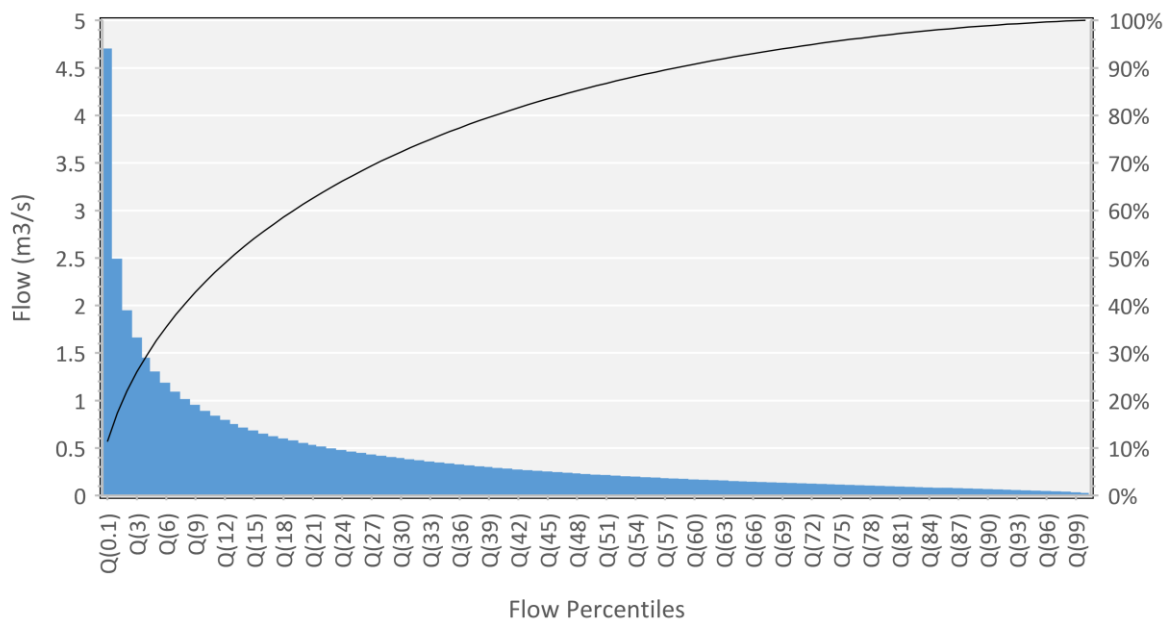


Figure 4: Low Flow Estimates for the Afon Celynog (Source: www.hydrosolutions.co.uk).

High flows within the channel, where the reach is rock-lined, will give rise to extreme bed and channel resistance. Thus, velocity, stream power and boundary shear stress will high. Only the largest flow will be able to overcome inertial resistance and entrain the coarsest sediments. Flow will be effectively routed through this reach. Deposition will occur at the channel boundaries where shear stresses and velocity will be reduced, as evidenced by the embayment in the lower site.

Unnamed Tributary (Planform Geomorphology and Sedimentology)

The unnamed tributary drains the Ffridd Celynnog and flows into the upper-zone of the upper site (Appendix I; Appendix II: photos 7-14). This tributary is a steeply, incised stream typical of a mountain torrent. The tributary has a slope gradient of 13%. Channel planform can be described as sinuous, with an SI of 1.1. The tributary stream flows over a bedrock/boulder-lined and rock-strewn channel. The channel is narrow and confined within an incised valley. The channel margins are tree-lined in the lower-zone, but there is no floodplain. The channel is incised into glacial sediments, and as with the upper site of the Afon Celynnog, it is a drift-confined system.

The channel comprises a series of rock steps and falls, over which the stream cascades. There are large boulders (a-axis 1-2m) present in the channel, which appear out of size with many in the channel bed. This suggests they are probably relicts of the glaciation. This tributary is heavily bedrock-controlled, and in terms of its planform is a stable system. Boulders and exposed bedrock form the channel boundaries. The channel bed comprises a mixed-sediment size, ranging from small pebbles to cobbles. In the lee of the larger boulders and outcropping bedrock, gravel lags can be seen reflecting deposition during the last high flow event. Sediment transport in this tributary is through bedload transport, with sediment only moving during the highest flows. There is no transport under normal flow conditions.

Existing Structures

Upstream micro-hydro scheme:

Located upstream of the proposed schemes on the Afon Celynnog is an existing micro-hydro scheme and associated weir structure. Existing structures can be seen as impediments to sediment transfer along the river. However, the river is typical of upland mountain systems, whereby sediment transfer occurs during high flow events. Furthermore, the calibre of sediment within this river system is not fine grained, and there is no suspended load sediment transfer. Thus, there is no likelihood of fine-grained sediments becoming trapped by in-channel structures. The transfer of the boulders, cobbles and large pebbles typical of this river system, will not be impeded by introducing further small schemes into the system. Sediments will be temporarily stored along the channel (there are numerous natural barriers – rock steps, etc.), but high flow events will flush this large calibre sediment through the system in the ‘jerky’ conveyor belt mechanism mentioned above.

Weir and Fish Ladder (lower site):

At the outlet of the upper gorge (Appendix II; photos 22-23), an existing concrete weir and fish ladder structure have utilised a natural rock step within the reach. Above the weir

structure is a pool, and the weir flows into another pool, which forms part of the embayment identified above. There are loosely accumulated (not imbricated) clasts within the pool, of mixed sediment size. The weir has been in place for almost 100 years, and it is evident that sediment is still passing over and through this part of the reach based on the deposition of gravels seen at the confluence with the Afon Wnion (quasi-fan deposit). As indicated previously, sediment in this system is transported during high flow events, therefore in-channel structures become irrelevant during such events and sediment is transport over such features with ease.

Possible Impacts (upper and lower sites)

Sediment transfer under the proposed scheme:

- Sediment transfer occurs during high flow events. A new hydro-power dam/weir located on an existing weir site (at the lower site) will slightly increase the height of the natural pool but will not affect the sediment transport within this reach. The proposed site utilises an existing rock step-pool feature. It is during high flow events when the sediments are transported through this system. These flows will continue to regularly transporting all grades of sediment through the pool, over the weir and through the reaches' step-pool system.
- The small reduction in flows during abstraction should have no significant effect on sediment transfer, as sediment in these upland systems do not move under normal flow conditions. Natural movement of sediments will continue unimpeded during high flow events.
- Proposed residual flows are relatively high and will maintain natural processes.

Sediment introduction due to temporary works:

- Invariably some sediment will be introduced into the system during the construction phase, however, this will have a short-term residency and be moved through the system during the next high flow event(s). This is true for the decommission phase as well.

Geomorphological adjustment due to the proposed schemes:

- Both the Afon Celynog and the unnamed tributary have confined planforms, thus in geomorphological terms the reach experiences little to no morphological change due to the nature of the bed and banks. As with sediment transfer, any morphological change would occur during extreme high flows that were able to overcome channel and bank resistance, i.e. where boulders are present, and erode the glacialic

sediments that infill the valley. However, this has not been a feature of recent/historic channel behaviour and it is unlikely to be so during the lifetime of the proposed micro-hydro schemes.

- There is unlikely to be any ecological impact as the morphology will not change for the reasons outline above.

Riparian zone adjustment due to the proposed schemes:

- For the most part there is no or very little floodplain along the river or the unnamed tributary, thus there is no riparian zone to be affected. Extreme flows will continue to inundate the limited riparian zone in the mid-zone of the Afon Celynog and maintain the status quo.

Possible Cumulative Impacts

- For the reasons outlined above, there are unlikely to be any cumulative impacts on the hydromorphology of the reach. The nature of the rock-lined/boulder-strewn confined channel planform, combined with the natural propensity for sediment transport to occur only during the highest of flows means it is particularly insensitive to change. Channel width and depth will remain unchanged due to the nature of the channel bed/bank structure, and there is little/no interaction with the riparian zone, thus its structure will also remain unaltered (WFD Article 5; Annex II).

Mitigation

Outflow pipe:

- To minimise any impact from the outflow pipe at the lower site, it is suggested that cobbles/boulders be fixed around the pipe to mimic the channel bedform. This will ensure the dissipation of any excess energy that has the potential to cause localise scouring/disturbance to the channel bed as water re-enters the river.
- There is unlikely to be impact from the outflow pipe at the upper site as the flow is returned into a bedrock section.

Dam/weir:

- To minimise natural erosion in the embayment at the lower site (immediately downstream of the proposed dam/weir site), it is suggested that some large boulders are emplaced on the outer meander bend to dissipate stream energy.

Conclusion

There is unlikely to be any hydromorphological elements impacts on this reach that would result in the deterioration of the rivers' Water Framework Directive (WFD) status. The proposed works and resultant micro-hydro infrastructure will not compromise Article 5 (Annex II, V) of the WFD in terms of the rivers' morphological attributes nor will they add specific pressures (e.g. substrate, impounding, flow manipulation) to put the river and its tributary 'at risk'.

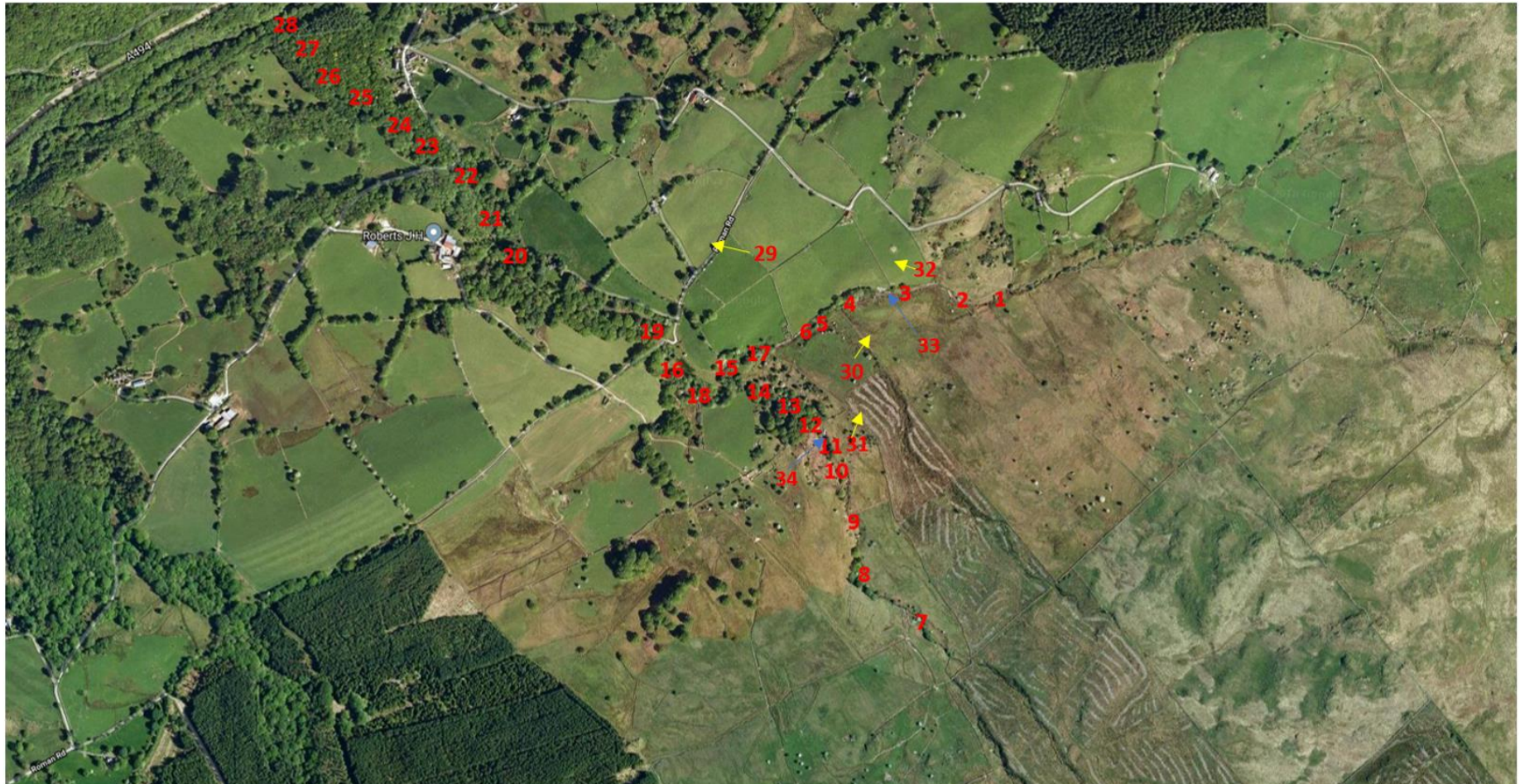
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APPENDIX I

Photo location map: numbers correspond with photos in Appendix II.

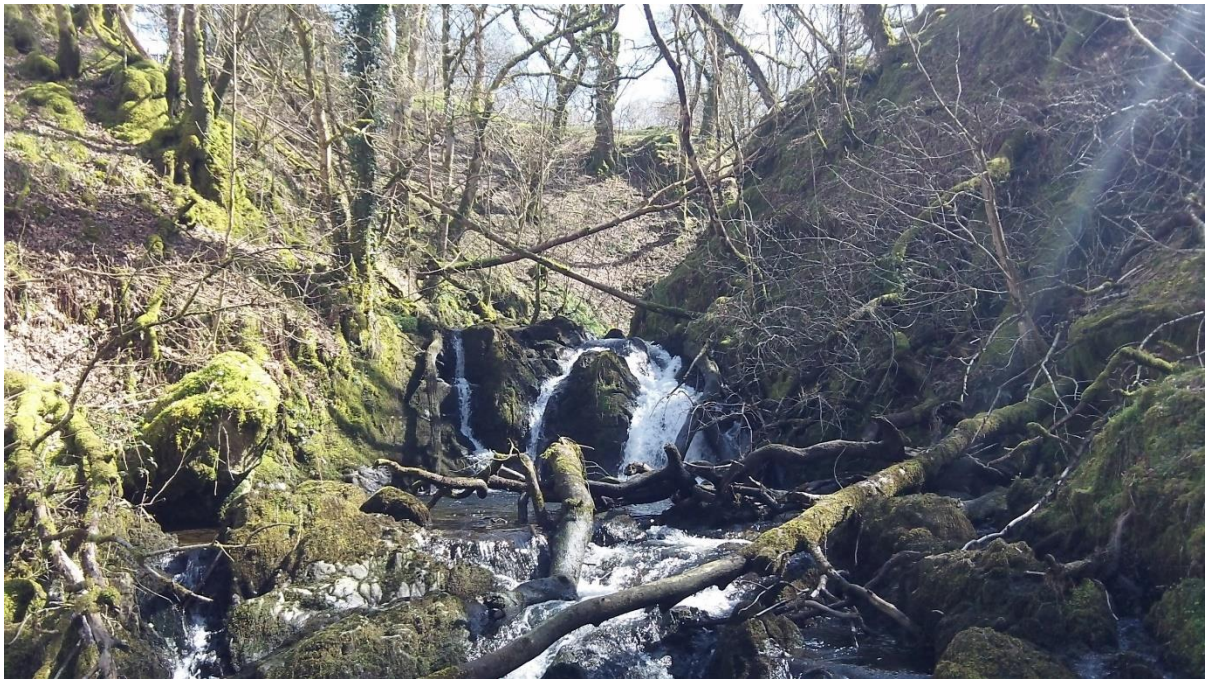


APPENDIX II

Photo Survey of the Afon Celynog (upper and lower sites) and the unnamed tributary site.

1. SH 79593 20266

1 - Edrych i fyny'r afon



1 - Glan yr afon ochr dde



1 – Glan yr afon ochr chwith



1 - Edrych i lawr ar y swbstrad



2. SH 79543 20359

2 – Glan yr afon ochr dde



2 – Edrych i fyny'r afon



2 – Glan yr afon ochr chwith



2 – Edrych i lawr ar y swbstrad



3. SH 79509 20444

3 - Glan yr afon ochr dde



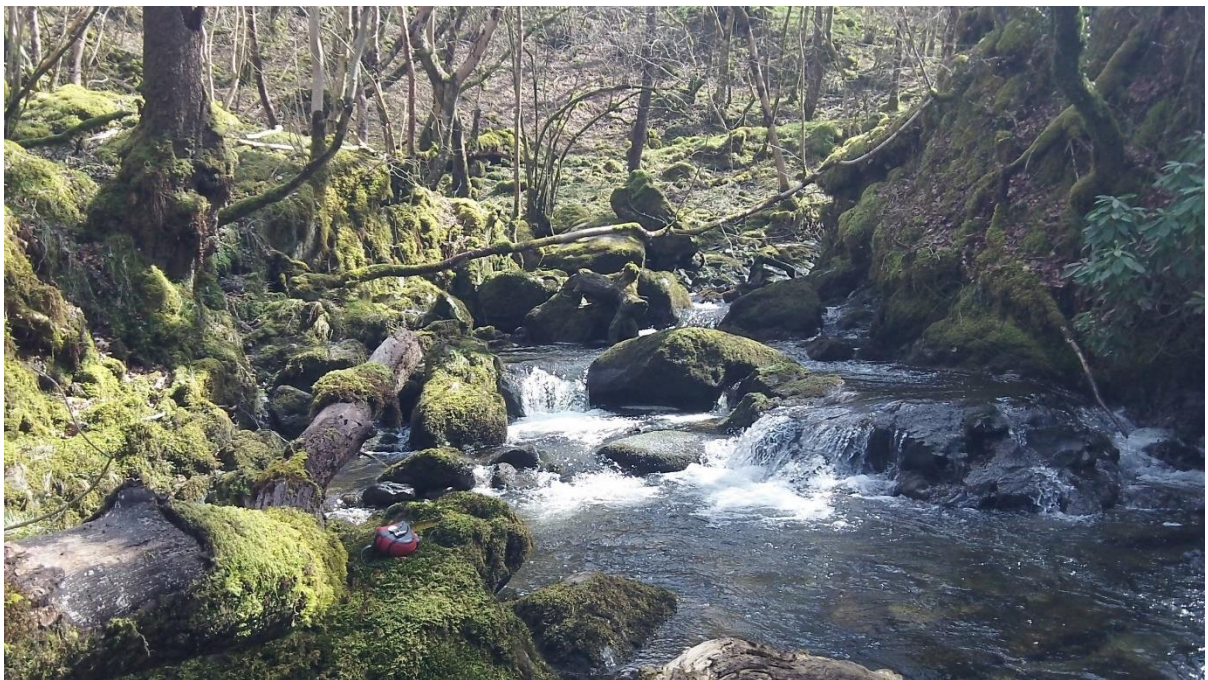
3 – Glan yr afon ochr chwith



3 – Edrych i lawr ar y swbstrad



3 – Edrych i fyny'r afon



4. SH 79467 20450 – Cored hanesyddol

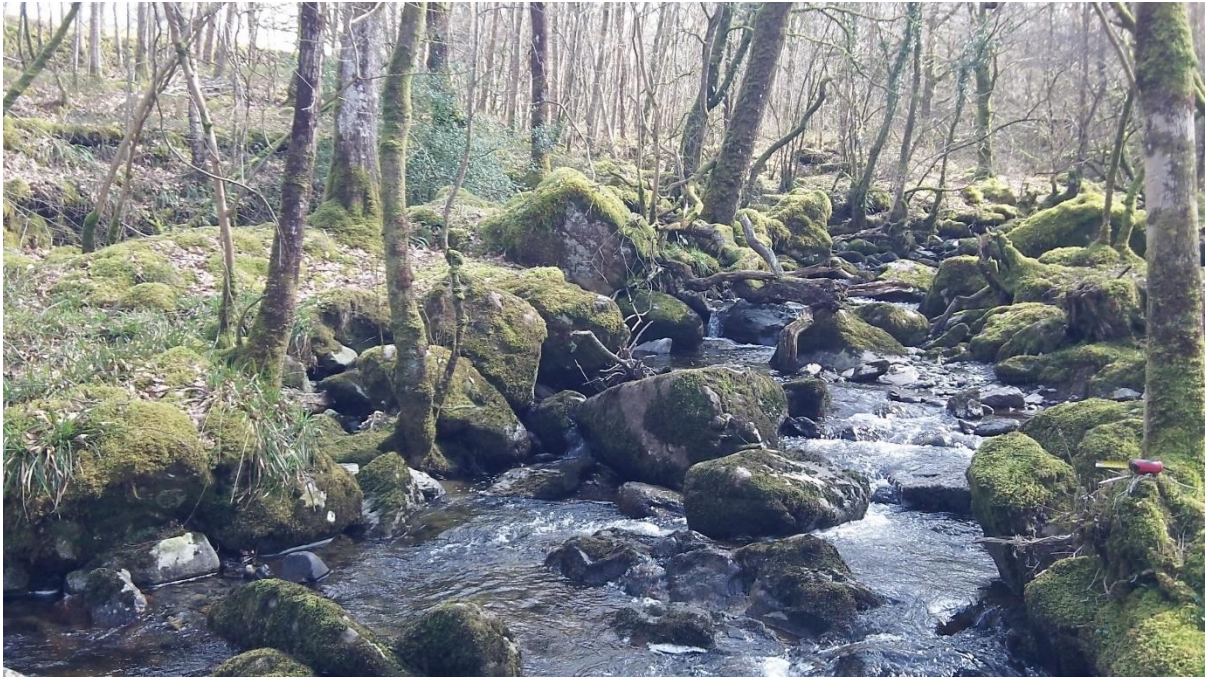


5. SH 79464 20448

5 – Glan yr afon ochr dde



5 – Edrych i fyny'r afon



5 – Glan yr afon ochr chwith



5 – Edrych i lawr ar y swbstrad



6. SH 79351 20536 - Rhaeadr



6 – Edrych i lawr tuag at y ceunant a’r rhaeadr



7. SH 79263 20590

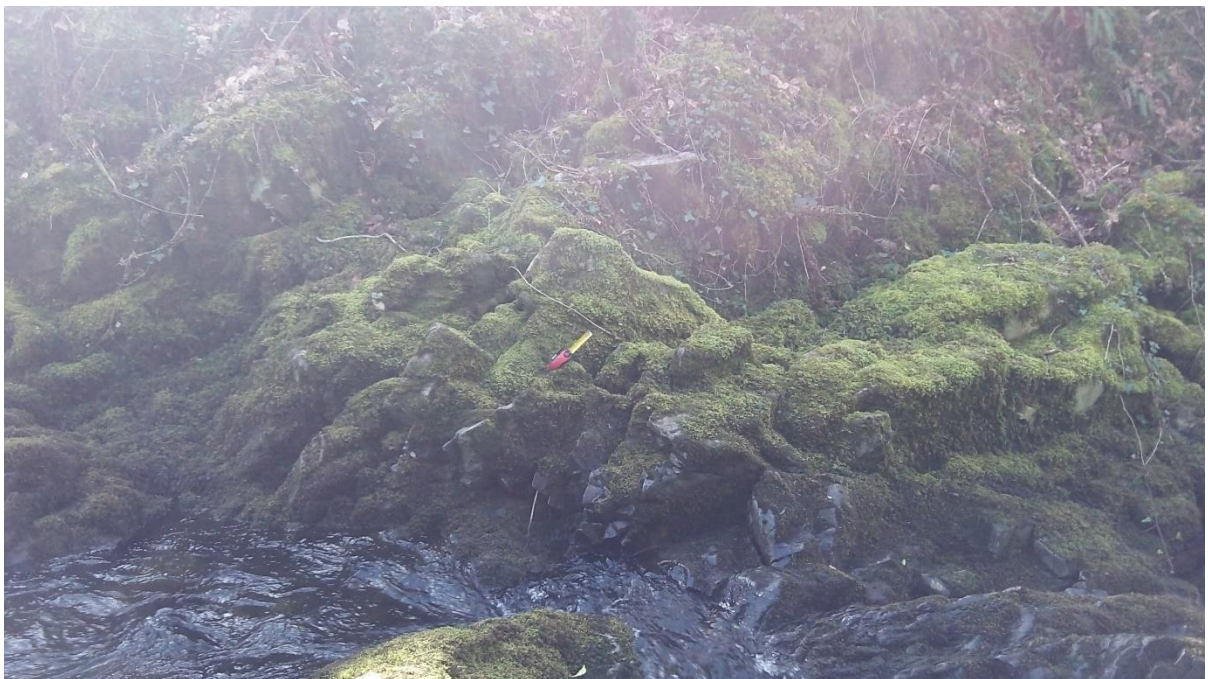
7 – Glan yr afon ochr dde



7 – Edrych i fyny'r afon



7 - Glan yr afon ochr chwith



7 – Edrych i lawr ar y swbstrad



8. SH 79206 20674 – Pwerdy ac Arllwysiad

8 - Edrych i fyny'r afon



8 – Glan yr afon ochr chwith



8 – Glan yr afon ochr dde



8 - Edrych i lawr ar y swbstrad



8 – Glan yr afon ochr chwith



9. SH 79200 20693 Afon Celynog yn ymuno ac Afon Wnion



9 -



10. Llwybr y beipen



11. SH 80130 19940 - Rhaeadr



12. SH 80118 19964

12. Edrych i fyny'r nant



12. Glan yr afon ochr dde



12 - Glan yr afon ochr chwith

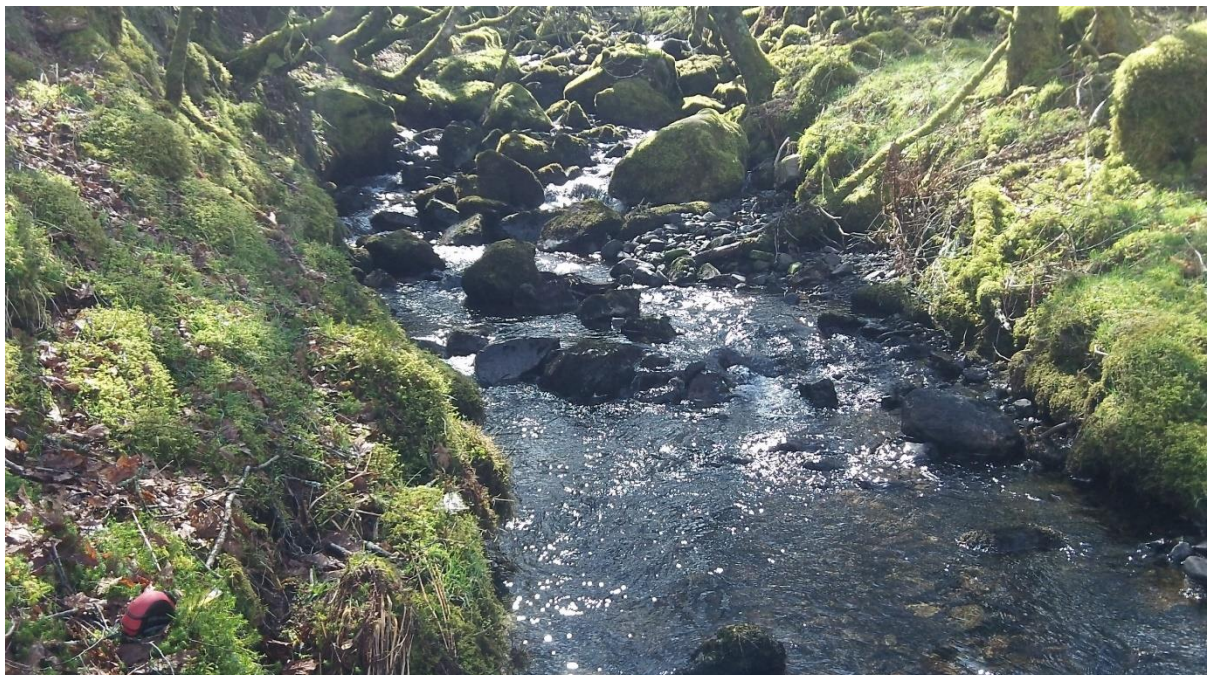


12 – Edrych i lawr ar y swbstrad



13. SH 80081 20007

13 – Edrych i fyny'r afon



13 – Glan yr afon ochr dde



13 – Glan yr afon ochr chwith



13 – Edrych i lawr ar y swbstrad



14. SH 80018 20033

14 – Edrych i fyny’r nant



14. Glan yr afon ochr dde



14 – Glan yr afon ochr chwith



14 – Edrych i lawr ar y swbstrad



15. SH 79962 20072

15 – Edrych i fyny'r afon



15 – Glan yr afon ochr dde



15 – Glan yr afon ochr chwith

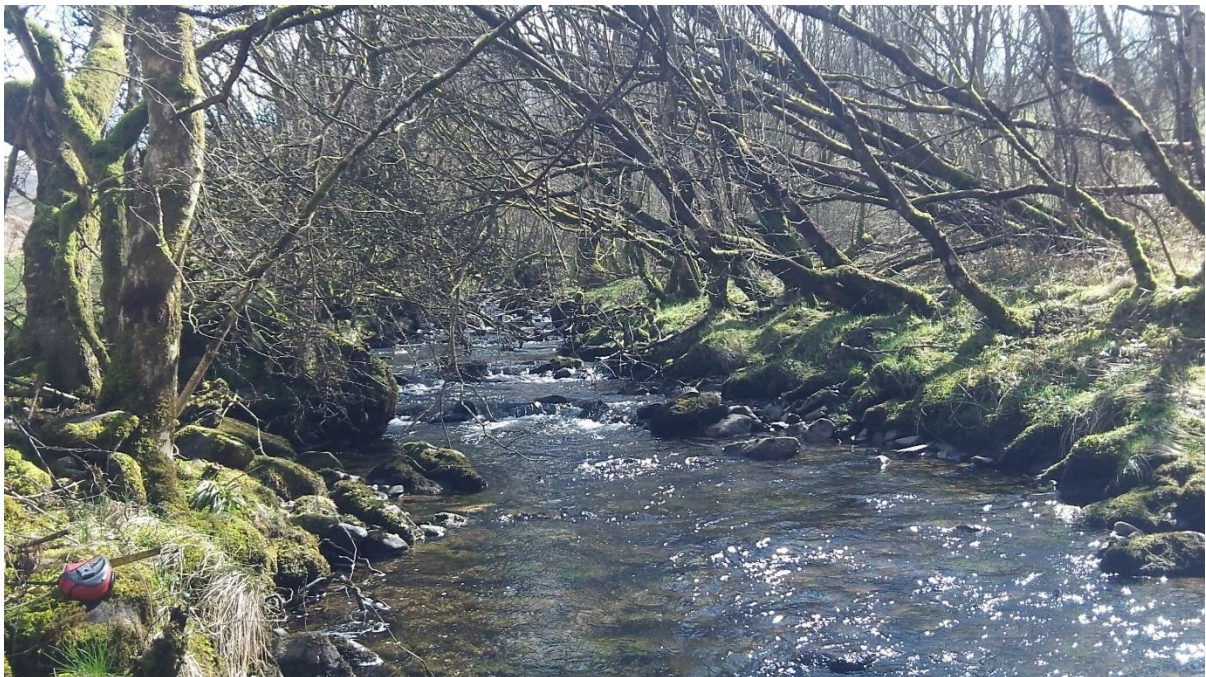


15 – Edrych i lawr ar y swbstrad



16. SH 79862 20061

16 – Edrych i fyny'r afon



16 – Glan yr afon ochr dde



16 – Glan yr afon ochr chwith



16 – Glan yr afon ochr dde



17. SH 79962 20048

17 – Nant yn ymuno



18. SH 79894 200 - Llednant yn ymuno



19. SH 79840 20118

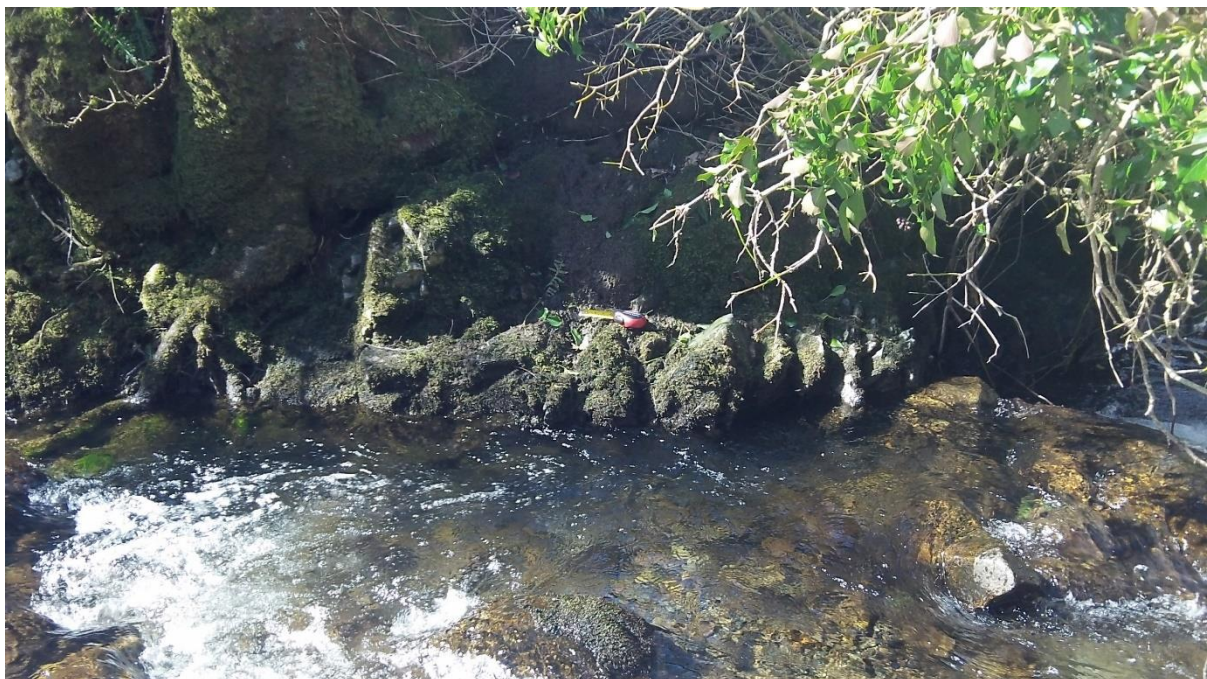
19 – Edrych i fyny'r afon



19 – Glan yr afon ochr dde



19 – Glan yr afon ochr chwith



20. SH 79593 20266

20 – Edrych i fyny'r afon



20 – Glan yr afon ochr dde



20 – Glan yr afon ochr chwith



20 – Edrych i lawr ar y swbstrad



21. SH 79543 20359

21 – Glan yr afon ochr dde



21 – Edrych i fyny'r afon



21 – Glan yr afon ochr chwith



21 – Edrych i lawr ar y swbstrad



22. SH 79509 20444 – Pwerdy ac arllwysiad

22 – Glan yr afon ochr dde – safle'r pwerdy



22 - Glan yr afon ochr dde – safle'r pwerdy ac arllwysiad



22 – Glan yr afon ochr chwith



22 – Edrych i lawr ar y swbstrad



22 – Edrych i fyny'r afon



23. SH 79467 20450 – Cored hanesyddol

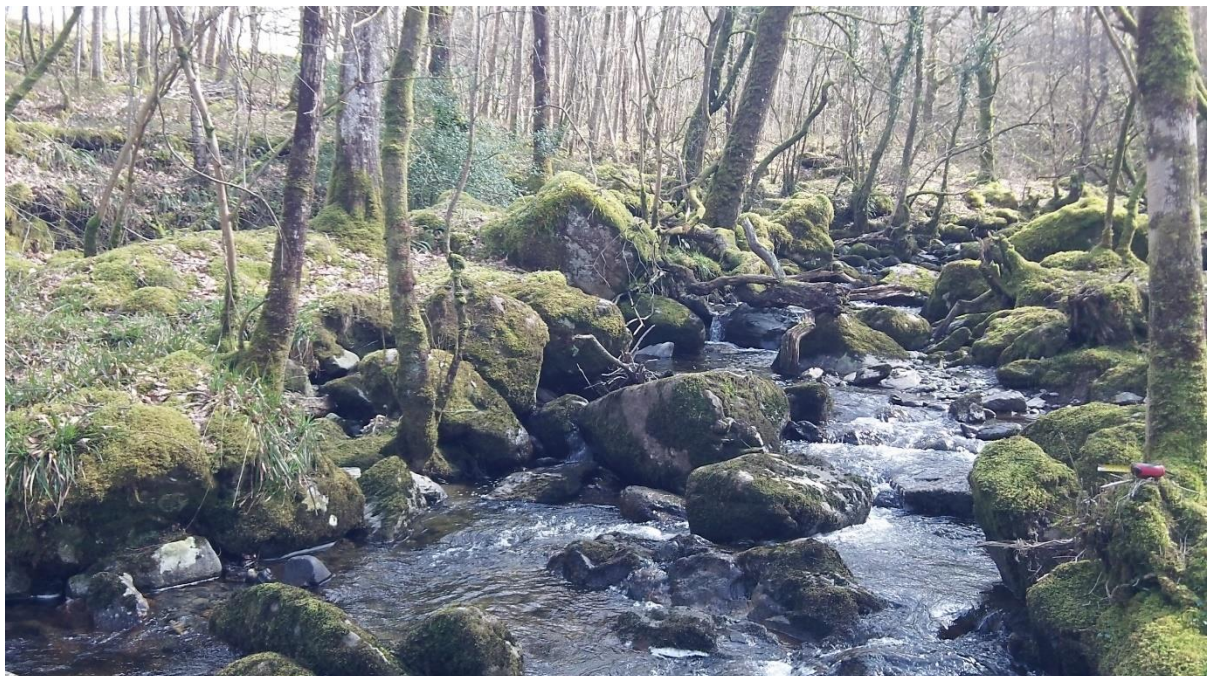


24. SH 79409 20507

24 – Glan yr afon ochr dde



24 – Edrych i fyny'r afon



24 – Glan yr afon ochr chwith



24 – Edrych i lawr ar y swbstrad



25. SH 79351 20536 - Rhaeadr



25 – Edrych i lawr tuag at y ceunant a’r rhaeadr



26. SH 79263 20590

26 – Glan yr afon ochr dde



26 – Edrych i fyny'r afon



26 - Glan yr afon ochr chwith



26 – Edrych i lawr ar y swbstrad



27. SH 79206 20675 – Pwerdy ac Arllwysiad

27 - Edrych i fyny'r afon



27 – Glan yr afon ochr chwith



27 – Glan yr afon ochr dde



27 - Edrych i lawr ar y swbstrad



27 – Glan yr afon ochr chwith



28. SH 79200 20693 Afon Celynog yn ymuno ac Afon Wnion





29 – Llwybr y beipen



30. Llwybr y beipen



31. Llwybr y beipen



32. Llwybr y beipen



33. SH 80253 20192 - Intake

Looking upstream



Intake A - Left bank



Intake A - Looking down at the substrate



Intake A - Right Bank



34. SH 80130 19939 - Intake

Looking Upstream



Intake B – Right Bank



Intake B - Right Bank



Intake B

Looking down at the substrate



22. SH 79509 20444 - Outfall

