Description of the Hafod y Rhedrwydd (Afon y Foel) micro-hydro scheme

(a shortened form of the very detailed weir design document in the Abstraction Licence submission to NRW).

Purpose

- To provide an electricity supply for an off-grid cottage (Hafod y Rhedrwydd, LL24 0RF)
- To improve the domestic water supply to Hafod y Rhedrwydd

Operation

Two Coanda screens will be used to extract water from the stream. These will form part of a weir with a stepped crest: three different crest levels (Figures 10&11) limit the maximum extractable flow at different stream conditions to ensure that there is no significant ecological impact.

- Stream flow < 1 L/s, only 0.05 L/s extractable (domestic water for cottage only)
- Stream flow < 4 L/s (Q95), only 0.6 L/s extractable (provides 300-350 Watts to allow continuous operation of a UV water sterilizer and a few other low-power devices)
- Stream flow > 4L/s, up to 14.8 L/s extractable via a CBS050 screen (in practice the turbine is unlikely to use more than 9 L/s; the over-size screen is however necessary to achieve suitable flow rates once out of the Q95 period).

The turbine hut will contain both the main turbine and a small one for improved efficiency at very low flow rates (Turgo turbines from Hartvigsen Hydro and MOOG GES013 permanent magnet alternators). A fibre-optic link will pass extraction point water levels and house requirements down to the turbine hut (Figure 23). The control software will then adjust the turbine spear valves as required.

The optical fibre and armoured cable will be protected by a 65 mm twin-wall conduit and be buried in the trench alongside the penstock.

The house currently obtains domestic water from a nearby spring. This is prone to drying-out and does not provide enough pressure for any kind of filtration. The new pipe will be much more reliable and provide 3.5 bar water pressure. This is sufficient for the filtering that is necessary before a sterilization system.

Location and pipe route

The stream is the main tributary of Afon y Foel.

The scheme requires 840 m of buried pipe (of which the initial 40 m can only be partially buried but will be hessian-wrapped to encourage the growth of vegetation). The pipe will be butt fusion welded from straight-section 110 mm OD HDPE pipe stock. The head is 150m; a combination of PN10, PN16 and PN20-rated pipe will be used. A pressure relief valve in the turbine hut will ensure that these pressure ratings cannot be exceeded.

Stream works at the extraction point and stream crossings 1 & 2 (SC1, SC2 in Figure 1) will require temporary flow diversion. Other constructions (settling tank ST beside the stream, turbine hut) will not require any diversion. The turbine hut tailrace discharges through the bank above water level.

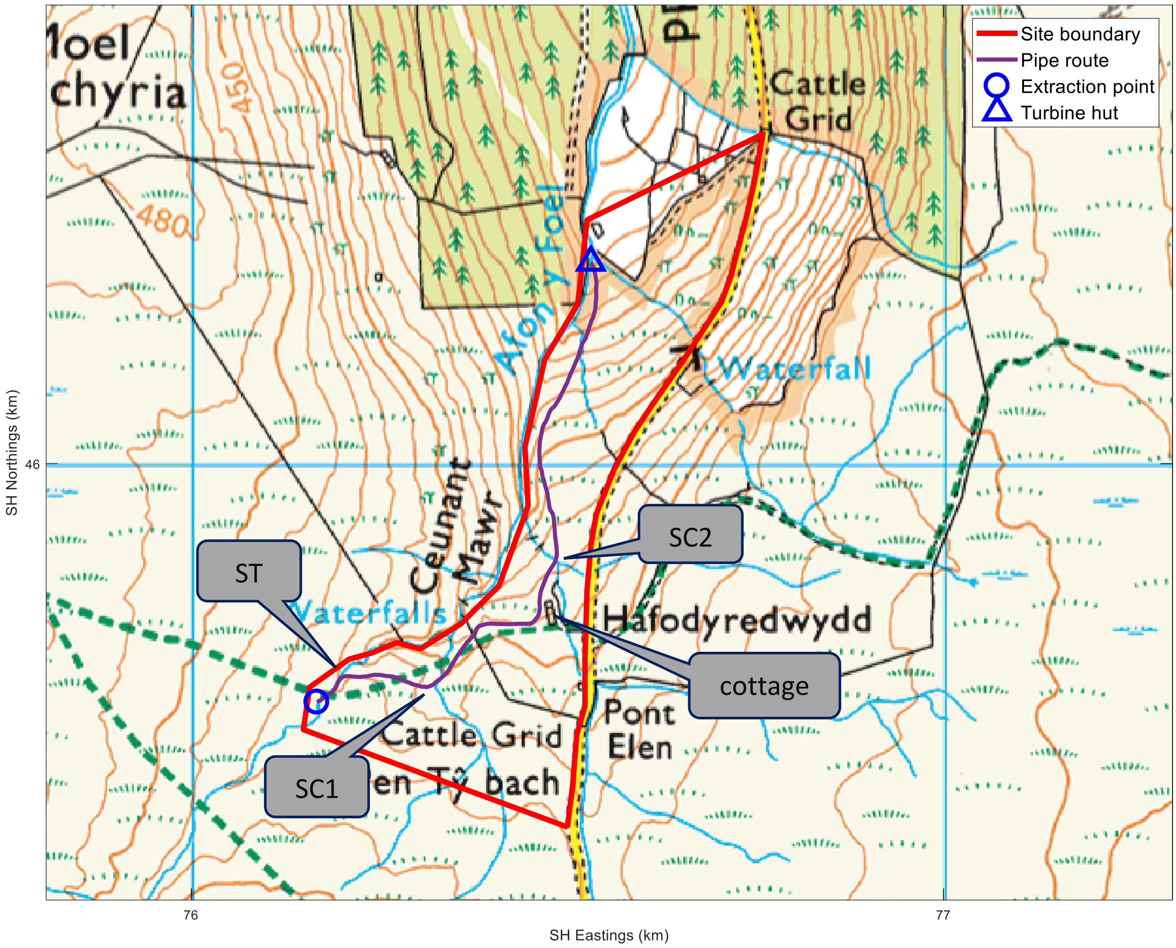

Figure 1. Map showing extraction point, settling tank, pipe route, stream crossings and turbine hut. Map scale 1: 10000 (grid squares are 1 km wide). OS map is © Crown Copyright, reproduced by permission of Ordnance Survey. (Map purchased from Blackwells Mapping Online 5/12/2018, order number BW1-899389-43094-051218).

Figure 2. Pipe route with tee-off to cottage.

Figure 3. Stream crossing 1. This is a very small tributary. The flow falls to 0.8 litre/sec in dry weather; a more typical flow might be 1.5 litres/sec.

Figure 4. Pipe route past cottage.

Figure 5. Stream crossing 2. This is the tributary that flows under Pont Elen; typical flow rate approximately 2 litres/sec in dry weather (i.e. about half the flow of the main Afon y Foel tributary).

Figure 6. Pipe route below house.

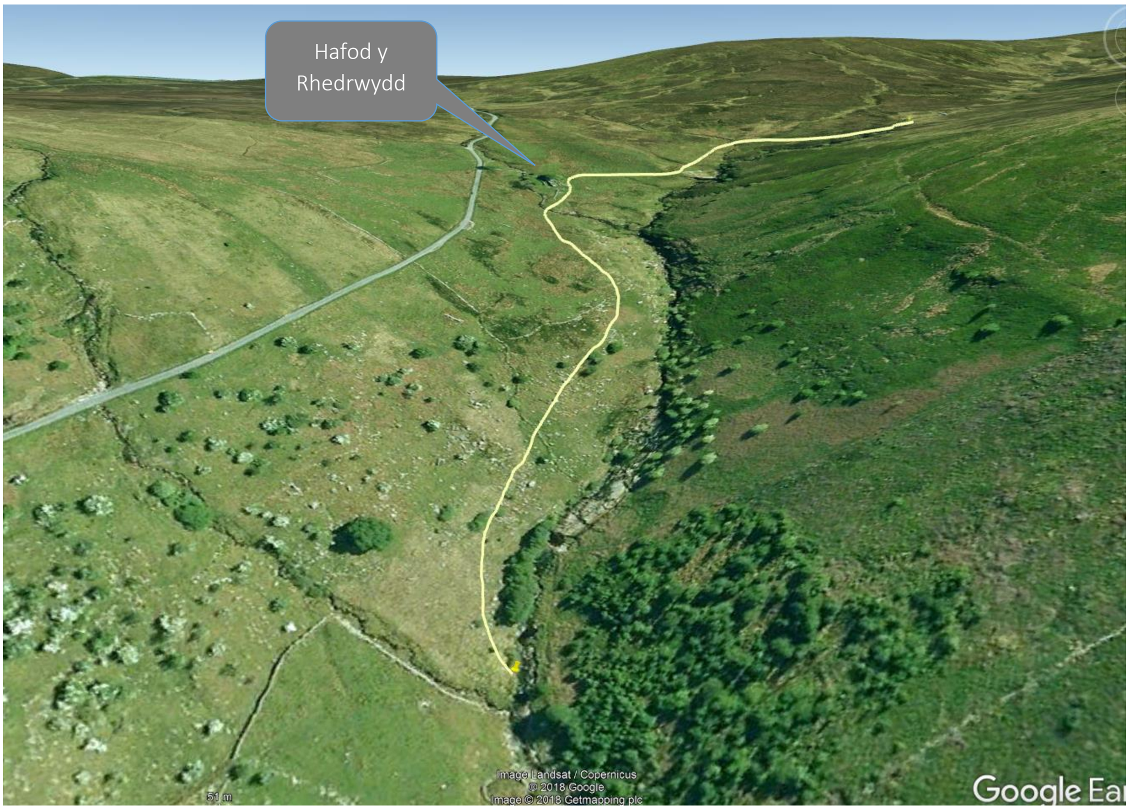

Figure 7. Pipe route in Google Earth.

Components

Extraction system

The extraction system will incorporate a small waterfall, Figure 8. This lies at the start of a steeply sloping section of stream. As the stream falls, the extraction pipe can cross the bank level and pass over the headland behind it without rising above the entry point level.

Figure 8. Small waterfall at the extraction point. Stick with tape at 1 m intervals to show scale.

NRW have requested that the scheme facilitate fish passage, both up and down-stream. To achieve fish jump heights of less than 25 cm there is a plunge pool below the lower weir crest and a barrage or downstream weir to raise the level below the plunge pool, Figure 9.

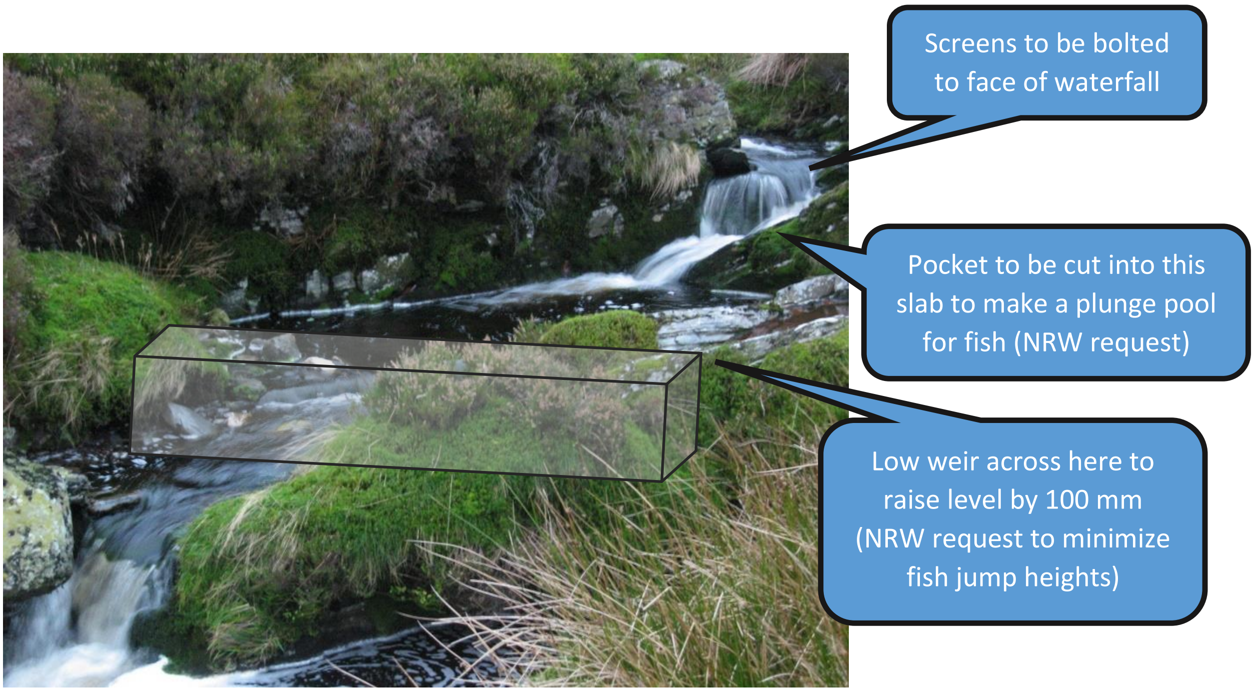

Figure 9. Extraction point, looking upstream.

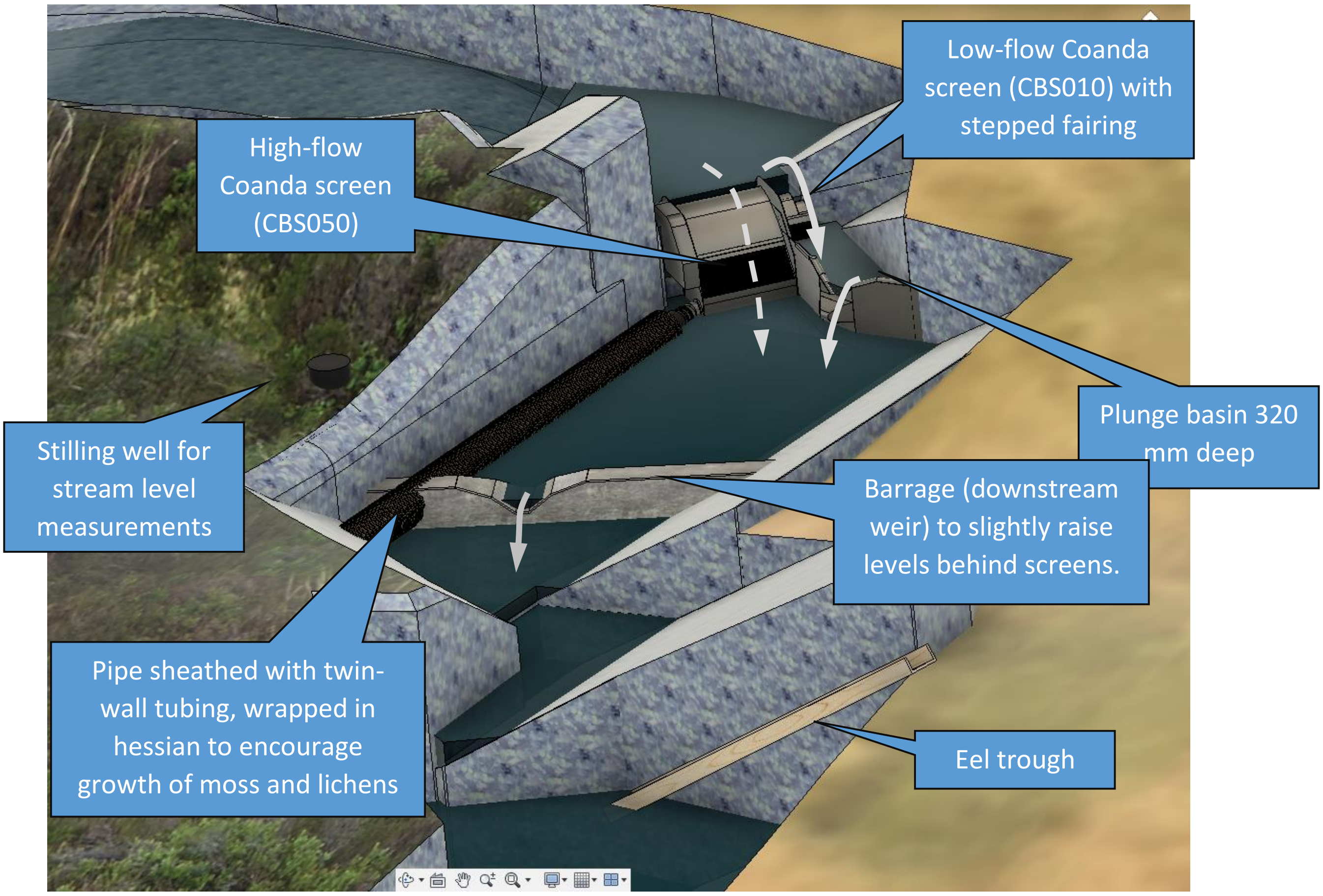

Figure 10. General arrangement of proposed screens and weirs at the extraction point.

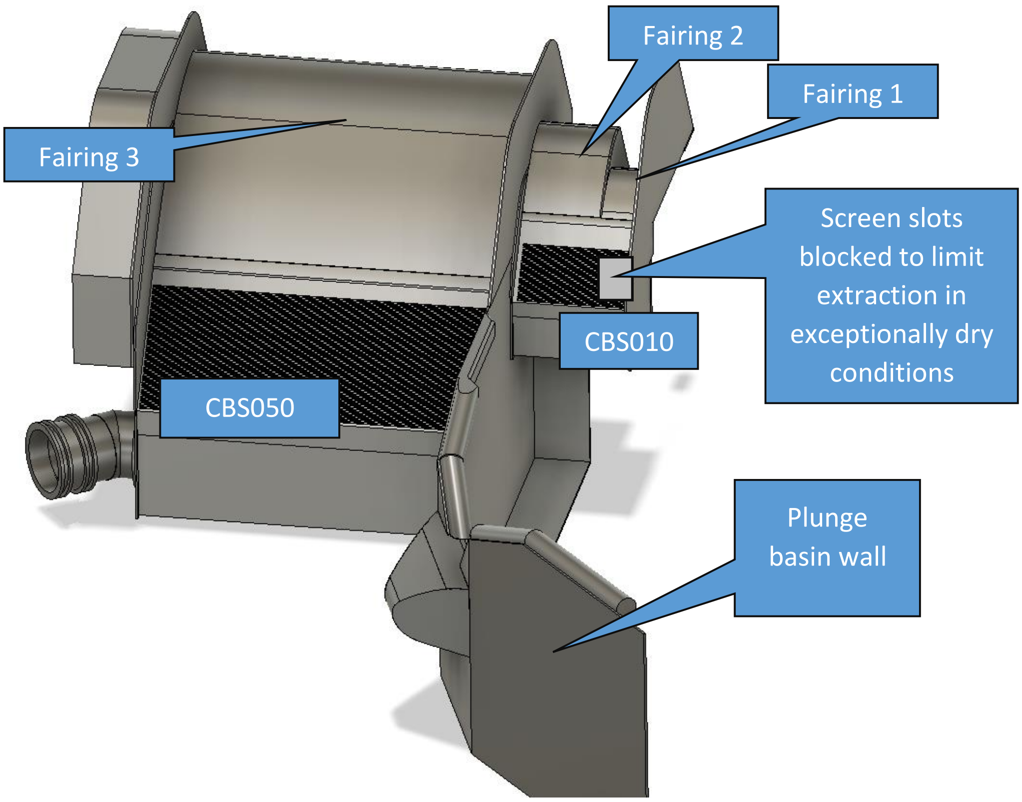

Figure 11. Arrangement of screen boxes and fairings (screen boxes from Elgin Separation).

Figures 10 & 11 show the Coanda screen and plunge pool design. Water can pass from the small (CBS010) screen box into the larger (CBS050) box via an orifice which limits the transfer to 0.6 litres/second. Below Q95 (4 litres/sec) the stream level is not high enough for any water to pass over fairing 3. The orifice then sets the maximum extractable flow.

At higher stream levels some water passes over fairing 3. Some or all of this can be extracted via the CBS050 screen, in addition to the 0.6 L/s from the smaller screen (Figure 12).

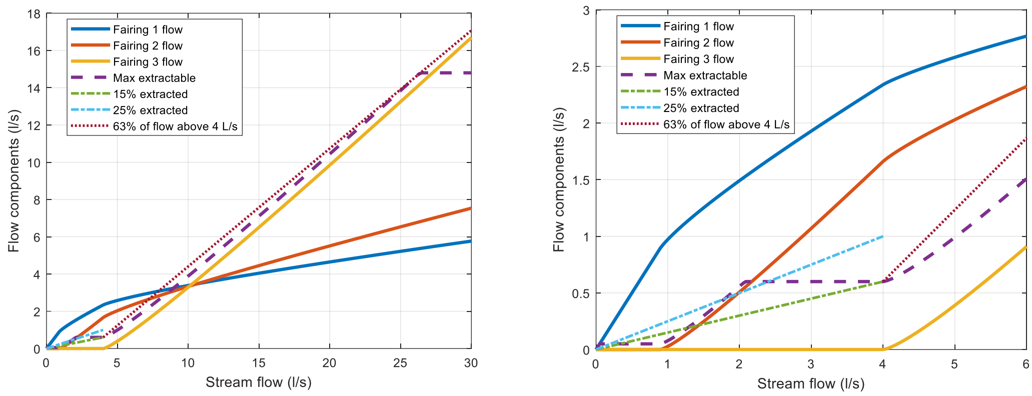

Figure 12. (a) Flow components as a function of stream flow showing split over each fairing and the maximum extractable through the screens. The CBS050 screen (fairing 3) has a maximum capacity of 14.2 litres/sec. (b) Enlarged view showing extraction regulation at low stream flows.

The extraction pipe will be sleeved in 225 mm OD twinwall tubing; the annular gap will be filled with foam to minimize freezing. Assuming the stream itself does not freeze, in a cold winter (an estimated -6°C for 6 weeks was experienced a few years ago) with only 0.6 L/s extraction the foam will help to prevent freezing in the above-ground pipe section leading to the settling tank. The pipe will be bolted to the rock wall (Figure 9) strongly enough to stand both the weight of internal water at low stream levels and the buoyancy of the foam if it should become submerged at high water levels.

Stream and pipe flow rates.

The catchment area above the extraction point is 0.87 km^2. Wallingford Hydro have produced a LowFlows simulation of flow duration curves, Figure 13.

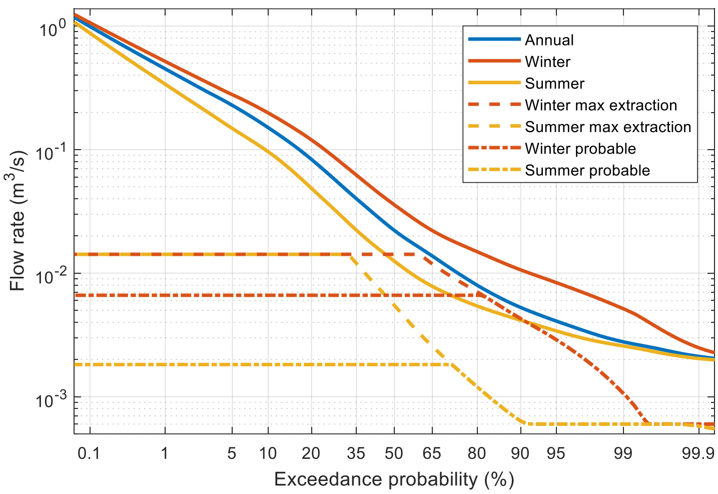

Figure 13. Monthly stream flow rate data from LowFlows grouped into Winter and Summer curves. Dashed lines show typical (6 kW Winter, 1.5 kW Summer) and maximum possible extraction rates.

The wall of the plunge pool is made of stainless steel with a broad tubular rim to avoid any possible injury to fish (Figure 11). The notched crest profile mimics the Coanda screens' flow area versus height relationship so that water levels upstream and in the plunge pool increase similarly as the stream flow increases. This maintains a roughly constant fish jump height regardless of the stream state (Figure 14).

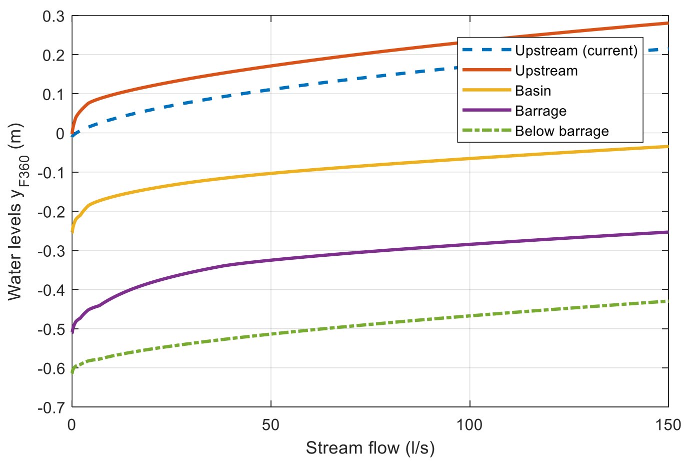

Figure 14. Water levels (based on head *H* in a zero velocity pool) as a function of stream flow, with up to 2 litres/sec extraction. The datum here is the origin in Fusion 360. The barrage raises the level below the waterfall by 10 - 17 cm (dry and wet conditions respectively).

The downstream weir achieves the same effect for the jump up into the plunge pool. The notch here has also been chosen to achieve suitable sensitivity when estimating the stream flow rate based on the water level above this weir (a level sensor will sit in a small stilling well beside the pool). This sensor informs the control system whether more water is available i.e. whether the spear valve should be opened further if there is an increase in electrical demand.

Datum heights

Two bank heights were measured as datum points in the survey. The contour lines in drawing HyR_181006A.pdf suggest that these are at a mean height above sea level of 423.25 m. Heights relative to this datum have been determined from the Fusion 360 model (Table 1).

	yF360	mASL
Bank markers (mean)	1.552	423.25
Top of rock on corner above screens	0.853	422.551
Waterfall lip (lowest corner)	-0.059	421.639
Fairing 1 crest	-0.003	421.695
Fairing 2 crest	0.038	421.736
Fairing 3 crest	0.075	421.773
Plunge basin (bottom of notch)	-0.254	421.444
Barrage (bottom of notch)	-0.510	421.188
Stream bed above screens	-0.314	421.384
Plunge basin bed	-0.568	421.130
Stream bed above barrage/below CBS050	-1.049	420.649

Table 1. Datum heights (metres) for each weir stage.

Settling tank

The settling tank will be 30-40 m downstream from the extraction point and will be built from an off-cut of 500 or 560 mm OD HDPE pipe with welded bottom cap (Figures 15 & 16).

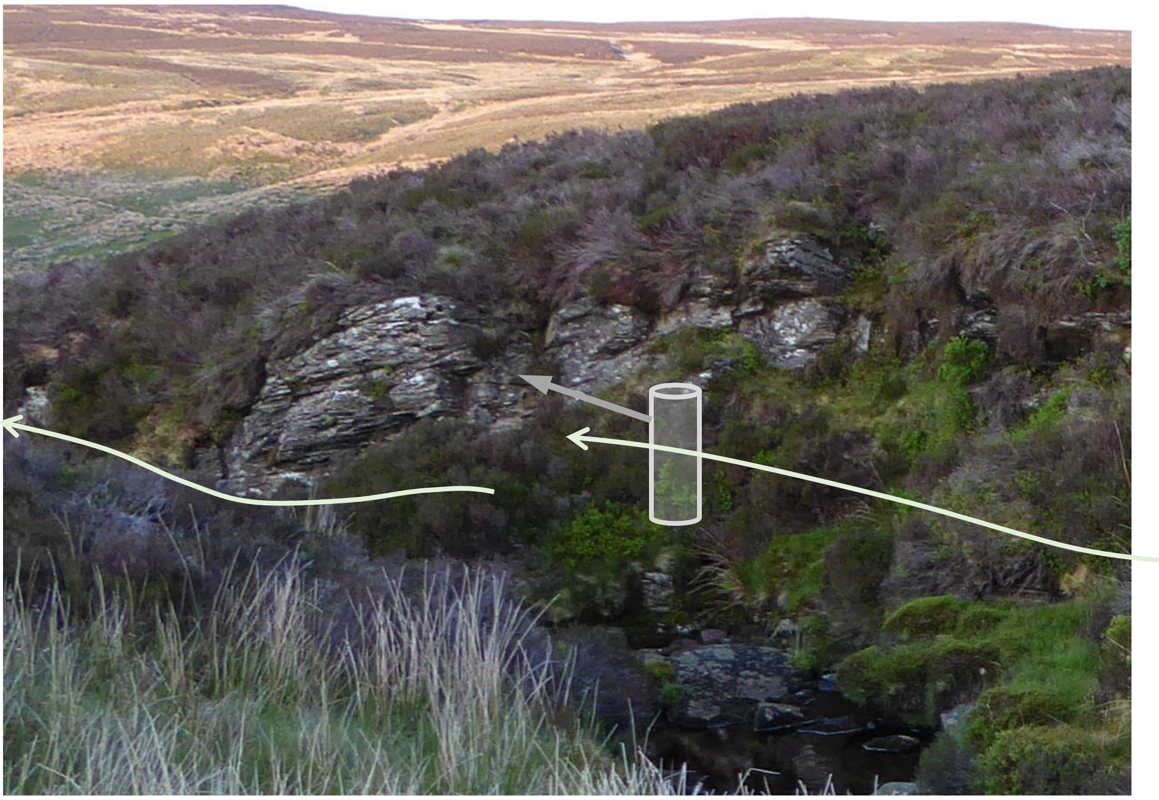

Figure 15. The settling tank will be bolted into a cleft in the rock face; it is approximately 2 m tall so does not protrude above the top of the crag.

Figure 16 (a) Settling tank construction, (b) appearance of wooden fencing cover.

The tank will be insulated with Kingspan foam and hidden behind shiplap fencing. The tank base will sit on bedrock (probably using a paving slab on blockwork to obtain a suitably level foundation).

A level sensor in the tank will indicate whether the screens are providing sufficient water. The water supply flow rate (perhaps 0.3 L/s for brief periods) to the cottage is not measured directly; instead, if the level sensor detects that the tank level is falling (turbine using all the water the screens can provide, no extra available for the domestic use), the spear valves will close enough to prevent the tank emptying and then re-open when the house flow has finished and the tank refilled.

The tank also provides a low velocity location where foam and bubbles can float up and escape rather than being carried down into the main pipe section. The pipeline will have 2-3 small air release valves further downstream (beside stream crossings, with ducting to carry any leakage back to the watercourse) as an added safeguard, since the residence time in the settling tank may not be enough to completely purge bubbles from the flow.

The settling tank has a drainage valve large enough for all the flow to return to the stream rather than passing down the pipe to the turbines. This will allow direct measurement of the flow rates to demonstrate that the extraction system is functioning as intended.

Turbine hut

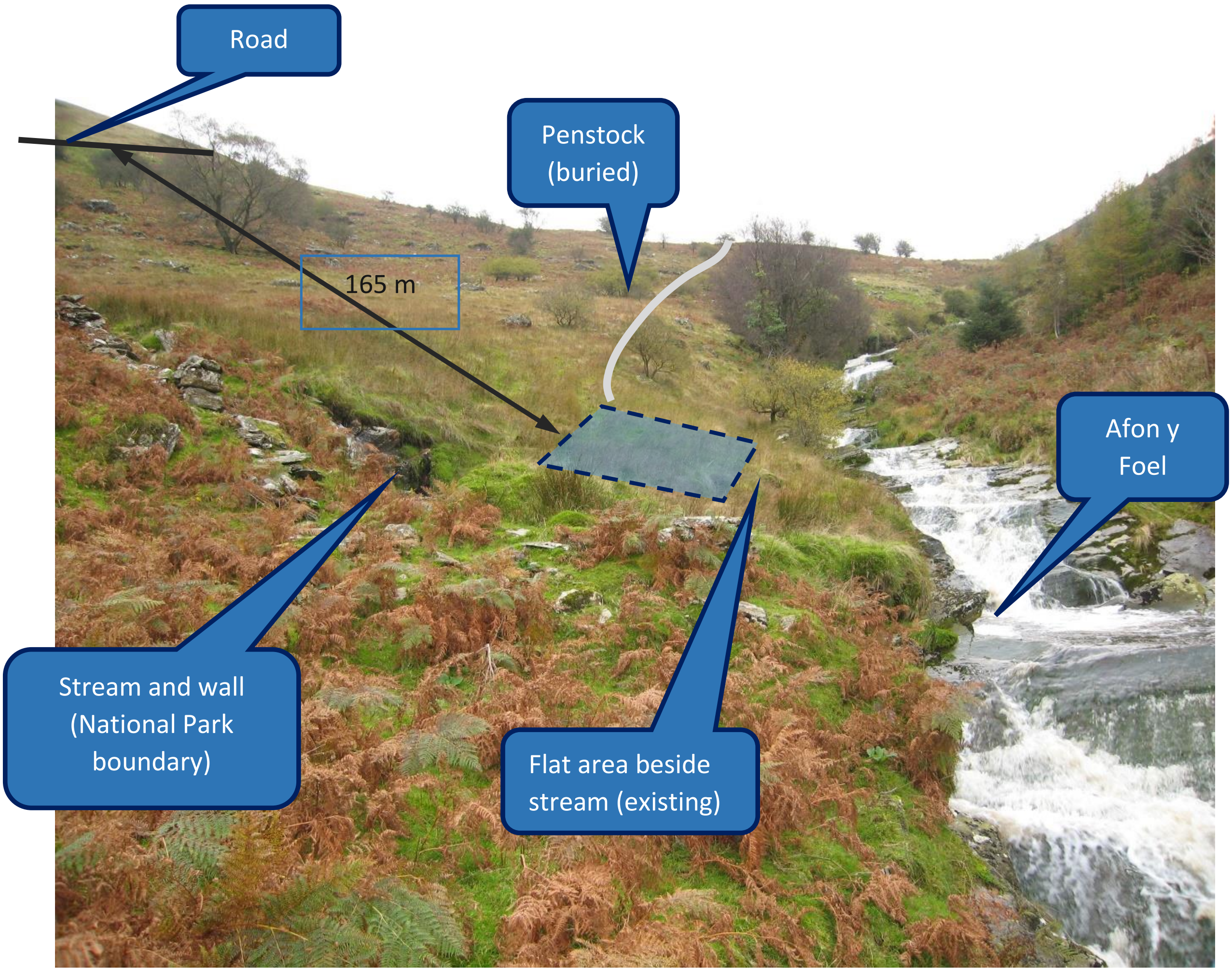

Figure 17. Site for turbine hut.

The turbine hut will be situated at the bottom of the steeply sloping section of hillside, this being the first location where water can conveniently be returned to the stream (Figures 17-21).

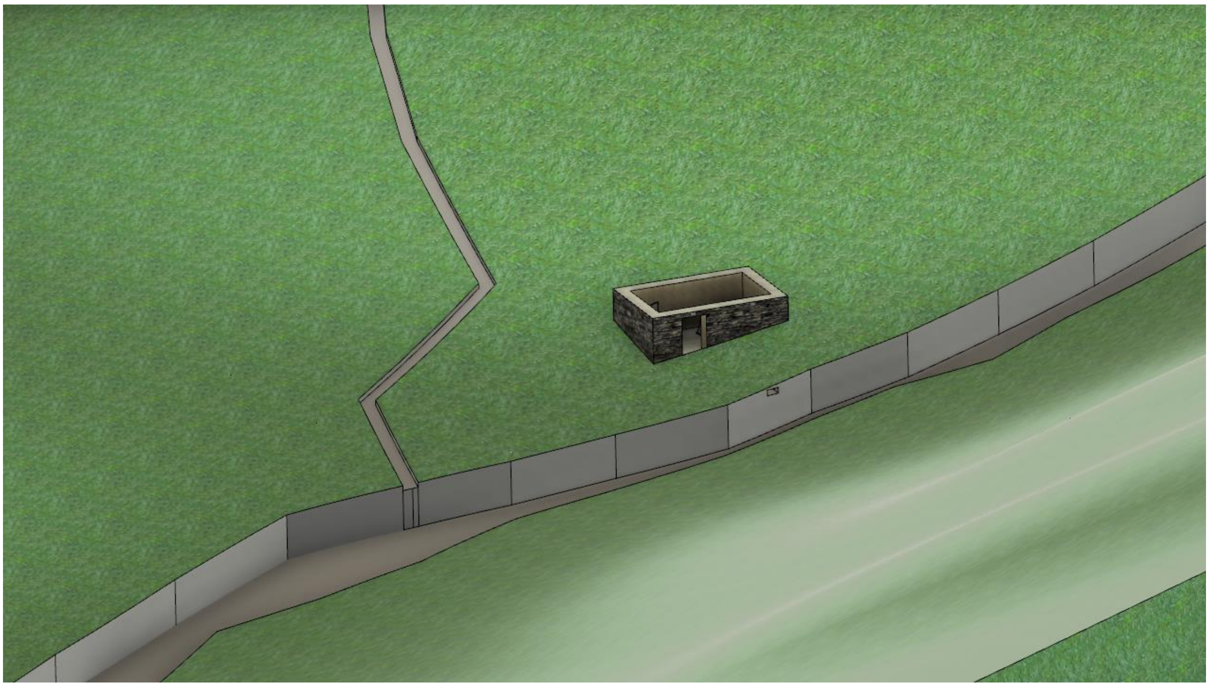

Figure 18. Hut will be partially built into the slope. Tailrace returns water to Afon y Foel.

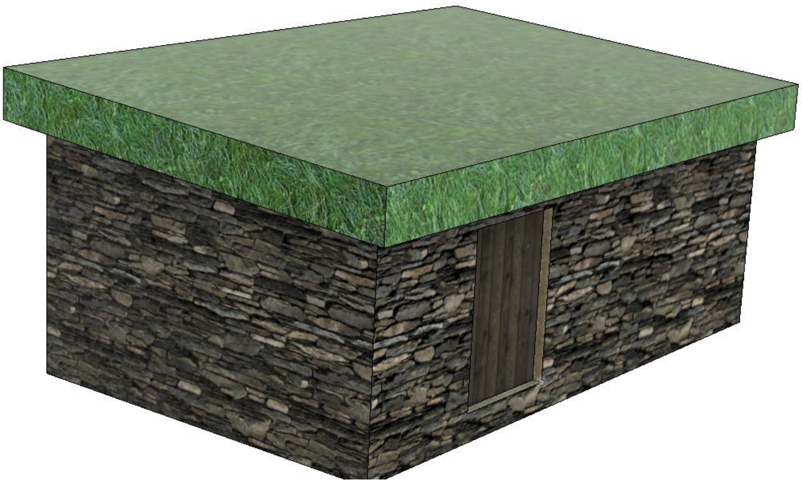

Figure 19. Turbine hut appearance. Wall dimensions (external) 4.6 m long × 2.8 m wide × 1.5 m high (floor to ceiling). Turf roof.

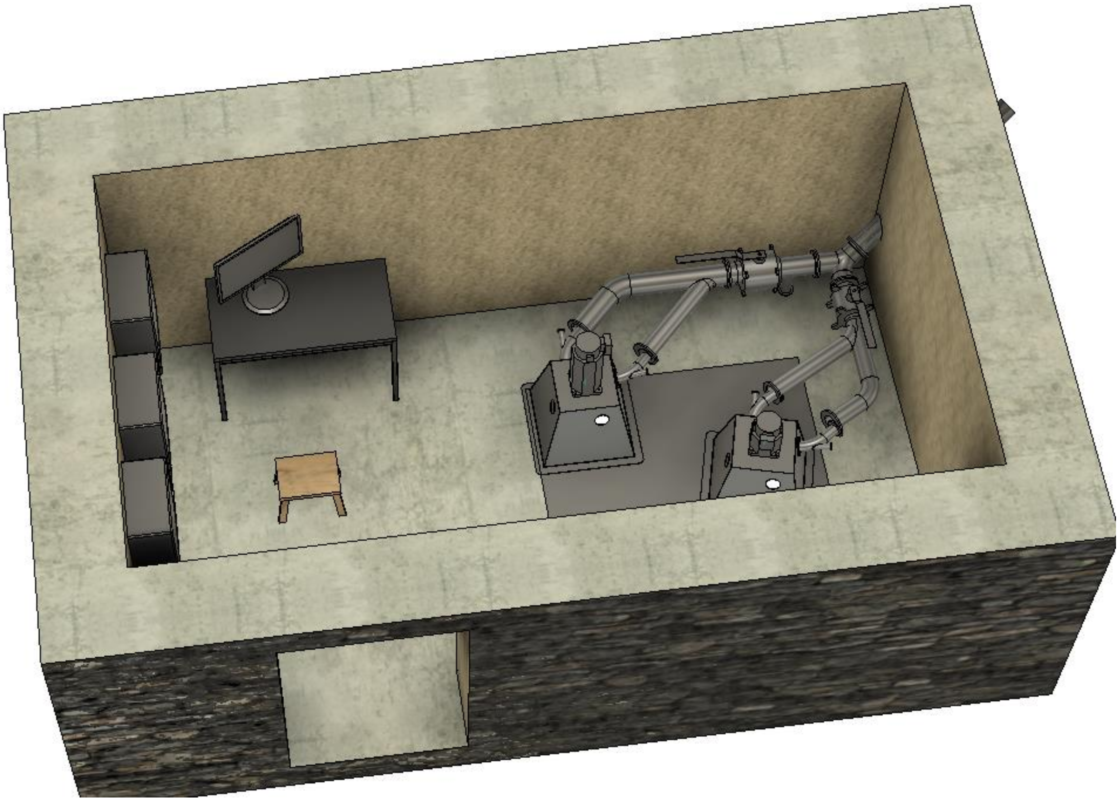

Figure 20. Internal layout showing normal and dry weather turbines, switchgear and screen to access control system software. The tail-race duct runs out to the river bank from the sump below the turbines.

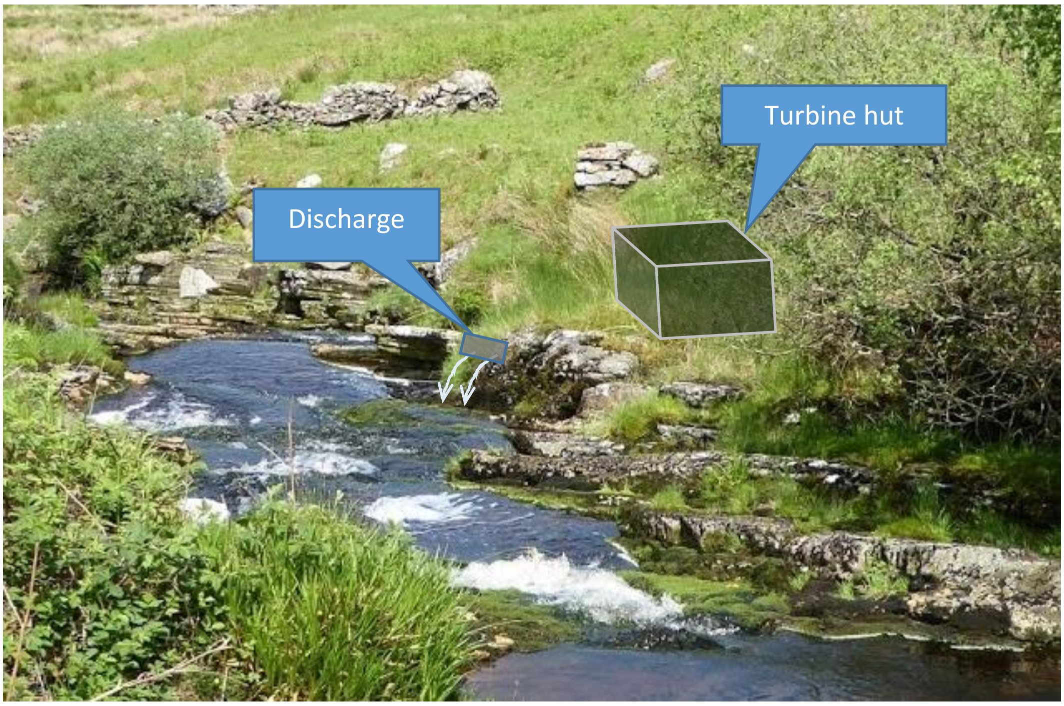

Figure 21. Tail-race duct will discharge into Afon y Foel.

Figure 22. Turbine hut location after very heavy rain (15th September 2017). It does not flood.

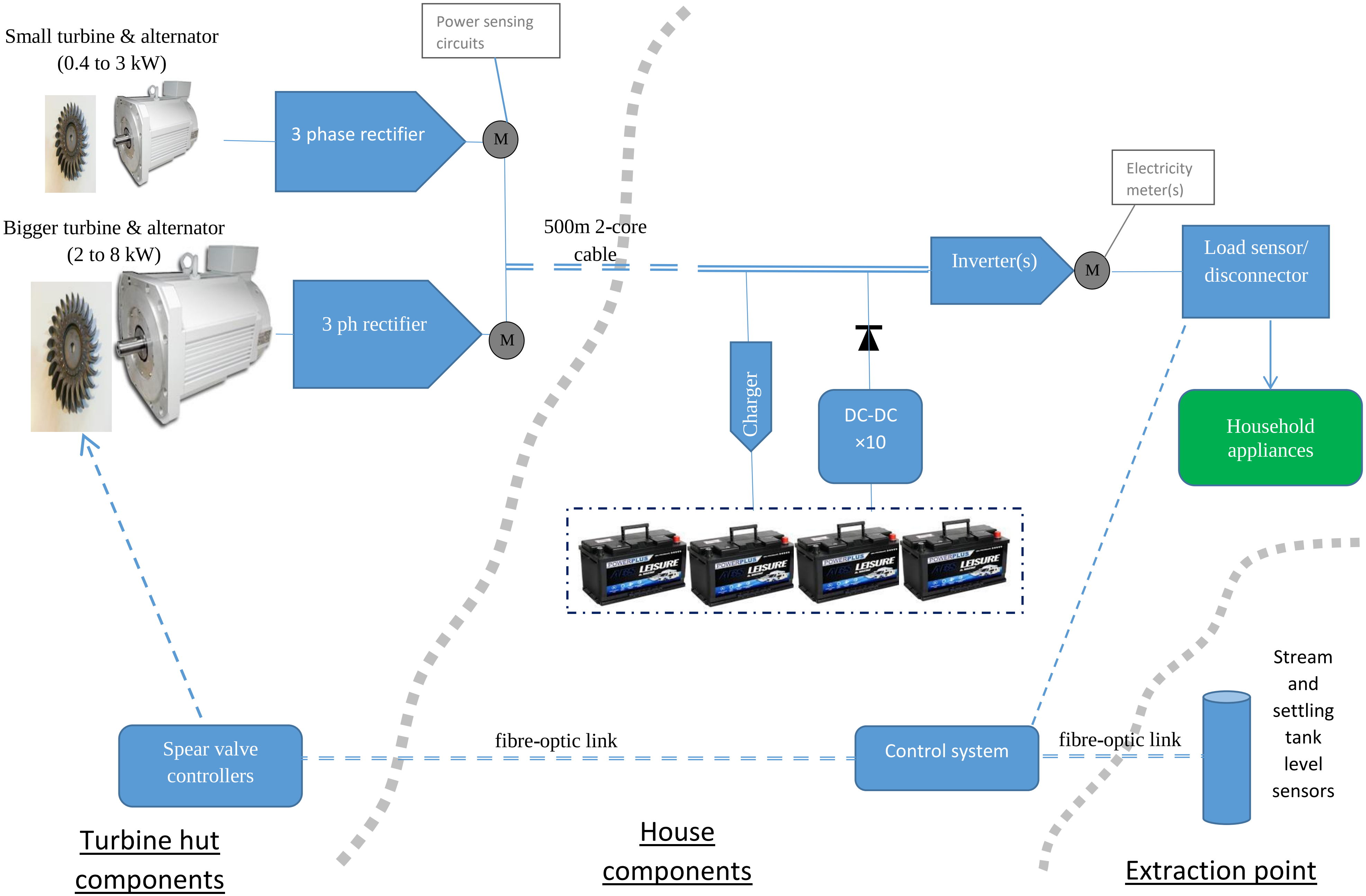

Figure 23. Schematic diagram of the turbine control system.