Supporting Information

System Operation

The existing system can be seen in figure 1. It operates via the abstraction of water from an un-named tributary of the River Dulais at Coed Du, Y Creunant at point A. With the turbine jet valves in the turbine house at point D closed, the flow is impeded, and the water is temporarily stored in the penstock and pond until the water level reaches 500mm above the float switch [fig 2].

The maximum abstraction from the stream into the pond (Points A to B to C) would be at a rate of around 29 litres per second and the volume of water in the pond changes by approximately 6%.

When the water level reaches 500mm above the float switch an ON signal is sent to the turbine, the jet valves open and the water flows through the turbine at a maximum rate of 30 litres per second to commence grid synchronisation and subsequent electricity generation.

The turbine generates electricity until the water level reaches 380mm above the float switch, at which point an OFF signal is sent to the turbine and the jet valves close.

The process is then repeated.

The abstracted water is returned to the same un-named tributary of the River Dulais at point E via the tailrace and outfall.

The above system requires the following changes to the abstraction Licences:

- Existing abstraction licence (WA/058/0073/003) needs to be varied to add a purpose of ‘transfer of water’ in addition to ‘power production’.
- A new full abstraction licence will be required at the pond for the purpose of power production.

The supporting calculations are below.

Design Calculations transfer of water into the pond from the abstraction point

The initial 96m of pipe coming from the turbine consist of twenty-five 6m long sections of 150mm PE pipe following a shallow gradient of approximately 0.02 over the length before the pipe is transitioned into a MDPE pipe with a 0.207m bore.

Applying the Hazen Williams equation over this section and ignoring minor losses would give a maximum flow discharge into the pond of approximately 29 litres a second.

Flow calculation:

Applying the Hazen–Williams equation to the above pipe:

$$Q = 1.318C.R^{0.63}.S^{0.54}$$

- S = Head loss (in m of water) per m of pipeline = height drop over pipe/length of pipe = 96/2 = 0.2
- Q = volumetric flow rate [$m^3 s^{-1}$]
- R = Hydraulic radius = inside pipe diameter in m/4
- C = roughness coefficient for PE pipe = 140

For simplicity all abstraction figures requested will be 30 l/s.

Design Calculations for Hydro Scheme

The penstock consists of 493m of 225mm SDR26 PE (internal dia. 207mm) pipe flowing from 218m above sea level at the intake to 125m above sea level at the turbine house. Thus, the static head at the turbine is 93m (218-125).

From continuity the flow is:

$$Q = vA$$

Where Q = Flow $[m^3 s^{-1}]$
v = velocity of flow, $[ms^{-1}]$
A = Area of pipe $[m^2]$
D = Diameter of pipe $[m]$

The Area of the circular pipe is given by:

$$A = \pi \frac{D^2}{4}$$

Therefore, the velocity v =

$$v = \frac{4Q}{\pi D^2}$$

Compute the Reynolds number Re using:

$$Re = \frac{vD}{\gamma}$$

Where γ = Kinematic viscosity of water =2.2 x 10−6$[m^3 s]$

The Colebrook-White-Bar equation to compute the pipe friction factor λ in pipes is given as:

$$\frac{1}{\sqrt{\lambda}} = -2\,log\left[\frac{\varepsilon}{3.7D} + \frac{5.1286}{Re^{0.89}}\right]$$

Where ε = absolute roughness pipe or tubing material = 0.03 mm PE pipe.

And the Frictional head losses h_f are given by the Darcy-Weisbach equation as follows:

$$h_f = \frac{\lambda L v^2}{2gD}$$

Where g =Acceleration due to gravity = 9.81$[ms^{-2}]$.
And L is the pipe length = 493 $[m]$

Therefore, the net head H_{net} $[m]$ is the static head – the head loss (for simplicity these calculations ignore minor losses).

The theoretical power output is given by:

Hydro Power (kW) = $H_{net}.Q.g$

Using an overall system efficiency of 72% (85% water pressure to mechanical energy efficiency and 85% mechanical to electrical efficiency) Table 1 shows the potential electrical output of the system at different rates of flow ranging from 29 litres a second to 31 litres a second.

The changes lower the maximum output of the turbine slightly, to around 20kW, but increase the efficiency and the overall energy output.

Table 1.

Mass flow rate Q [l/s]	Mass flow rate Q [m^3/s]	Flow velocity v [m/s]	Reynolds number Re	Pipe Friction factor	Frictional head losses [m]	Net head [m]	Power [kW]
29.1	0.0291	0.86	81359.84	0.0194	1.76	91.24	18.75
29.3	0.0293	0.87	81919.01	0.0194	1.78	91.22	18.88
29.5	0.0295	0.88	82478.19	0.0194	1.81	91.19	19.00
29.7	0.0297	0.88	83037.36	0.0193	1.83	91.17	19.13
29.9	0.0299	0.89	83596.54	0.0193	1.85	91.15	19.25
30.1	0.0301	0.89	84155.71	0.0193	1.87	91.13	19.37
30.3	0.0303	0.90	84714.88	0.0193	1.90	91.10	19.50
30.5	0.0305	0.91	85274.06	0.0192	1.92	91.08	19.62
30.7	0.0307	0.91	85833.23	0.0192	1.94	91.06	19.75
30.9	0.0309	0.92	86392.41	0.0192	1.97	91.03	19.87
31.1	0.0311	0.92	86951.58	0.0192	1.99	91.01	19.99
31.3	0.0313	0.93	87510.75	0.0192	2.01	90.99	20.12
31.5	0.0315	0.94	88069.93	0.0191	2.04	90.96	20.24

Design Calculations for the outfall.

The outfall consists of 255m of 225mm SDR26 PE (internal dia. 207mm) pipe with a fall of 3m over its length.

Using the same equations and a maximum flow rate of 31 litres a second yields the following:

Gross Head [m]	Pipe bore [m]	Area of pipe [m^2]	Pipe length [m]	Mass flow rate Q [l/s]
3	0.207	0.011	255	31

and

Flow velocity *v* [m/s]	Reynolds number Re	Pipe Friction factor	Frictional head losses [m]	Net head [m]
0.92	86671.99	0.0192	1.02	1.98

Therefore, the velocity of the peak outflow is around 0.9 m/s.

Information regarding natural inflows and outflows from the pond.

Figure 3 shows the Ordnance Survey mapping of water flow in the vicinity of the pond. Sources of water which become streams maintain their original course around the pond and flow onwards in a southerly direction.

There are no inflows which bring additional water into the pond other than minimal local rainfall which could be considered insignificant in the context of the above calculations.