Treforest Weir Hydro – New Fish Pass Design Statement (March 25)

<u>Location description</u>

Treforest weir is a historic industrial weir constructed to provide water via a feeder sluice to the tin works approximately 800m to the south. Constructed in 1834-1835, the weir is of stone block construction and is thought to be located on the lip of a natural rock shelf. The horseshoe weir has a continuous curve with a radius of 50m, meeting both bank abutments at an angle of around 27deg upstream from a straight line perpendicular to the river channel. The overall crest length of the weir is approximately 50m. The crest is nominally horizontal across the full width of the river, with an elevation of 46.7mAOD. The riverbed is solid bedrock (type?), with some build-up of gravel deposits immediately behind the weir wall. The differential head across the weir is typically around 3m depending on flow. During very low flow conditions, the maximum head is around 3.2m, and this gradually reduces with increasing river flows.

A topographic survey (the right-hand bank including the feeder sluice structures, and a partial survey of the river above and below the weir) has been undertaken.

The river channel is defined on the right hand (west) bank both upstream and downstream of the weir for some distance by vertical stone block walls. The left-hand bank upstream of the weir is natural bedrock at weir level but is backed by a concrete retaining/flood defence wall which defines the channel during spate flows. The right hand (west) bank immediately below the weir is stone block wall which forms the foundations of former mill buildings. The upper parts of the building overhang the river channel below the weir and are supported on a number of steel columns.

The weir abutment on the right hand (west) bank, where the proposed new hydropower and fish pass structures will be located, is the historic feeder sluice structure. The existing abutment and intake sluice walls are of stone block construction and rise 3.15m above the weir crest to 49.85mAOD. It has not been reported and is not likely that this structure has ever been overtopped during historic flood events. The intake wall, facing directly up the river channel, incorporated historic artefacts from the original iron feeder sluice gates. The weir abutment wall, which extends downstream of the weir for a distance of 10m, includes an aperture and iron artefacts that would have been a used for level control or drain down of the feeder channel.

<u>Existing Fish Pass</u>

A concrete vertical slot fish pass was constructed at the weir in 2003. The fish pass is located behind the feeder sluice head wall, and is fed via the historic sluice aperture, and discharges via the historic drain sluice aperture in the abutment wall immediately below the weir. The fish pass consists of 11 pools and slots. The slots are 350m wide and designed to operate at a depth 500mm at low river flows. The slots have a nominal discharge head of 300m between pools. Velocity head between pools is (2gz)^0.5 = (2x9.81x0.3)^0.5 = 2.42m/s. Estimated slot Cd = 0.6. Estimated fish pass flow at low river levels = Cd.v.area = 0.6x2.42x(0.35*0.5) = 0.254m^3/s or 254lt/s.

The fish pass also incorporates a wicket gate sluice to allow additional flow to be discharged directly into the bottom pool of the pass to create additional attraction flow at the fish pass entrance.

Flow into the fish pass is screened from debris by a vertical bar grille mounted on the upstream face of the feeder sluice head wall. The bars are spaced with 230mm clear opening. Access for manual cleaning (raking) of the grille screen was incorporated during the fish pass construction.

Additional debris screening in the form of a deflector grille was added 1 year after the fish pass was constructed. This consists of a galvanised steel screen structure extending from the upstream end of the abutment wall diagonally at 45deg to the RH riverbank wall. The overall screen structure is approximately 9m. Screening is provided by vertical deflector bars which form a louvre grille screen to deflect large debris downstream and over the weir but allow water to flow through to supply the fish pass. The depth of the screen varies over its length to follow the contours of the river bedrock. The grill bars extend upwards to 48.35mAOD, giving around 2m freeboard over the weir. At the top of the screen is an access gantry walkway and hand railing to allow safe manual cleaning. Overtopping of the deflector screen has occurred during flood events.

<u>Proposed fish pass solution</u>

Construction of the proposed hydropower installation at Treforest Weir will necessitate the removal of the existing fish pass and its replacement with a suitable alternative structure. It is proposed that a new 3 flight Larinier super active baffle fish pass will be installed in the river channel adjacent to the historic feeder sluice structure and embankment wall on the RH (west) riverbank. This design of fish pass has become the gold standard (or preferred options?) for new fish pass installations in the UK in recent years due to it's suitability for the species of migrator coarse fish and salmonids that are prevalent in UK rivers. The fish pass channel will be constructed from cast concrete. Baffles will be installed as bolt-in modular tiles fabricated from either galvanised steel or HDPE (TBC).

The primary design specifications of the Larinier pass are:

- 100mm baffle height
- 15% slope (8.5deg)
- 3m overall width, made from 5 juxtaposed Larinier baffle units of 0.6m width.
- 3 flights of 28 baffles each (7.32m long, 1.038m head change), separated by 2 rest pools, to achieve the nominal 3m elevation change between upstream and downstream levels.
- Design flow and head on top baffle range of 1000-1800l/s and 304-478mm respectively from Q95-Q20.

The upstream intake of the fish pass with be sited on the RH (west) end of the weir, immediately adjacent to the historic feeder sluice wall. A notch will be cut in the weir crest 3.6m wide (fish and eel pass width) and 0.5m deep, to convey sufficient flow depth and velocity of water to the fish pass during the design range of river conditions and hydro operation. The invert of the top baffle tile will be 233mm above the invert of the notch. An approach slope will be formed in concrete between the weir notch and the top tile. Due to the angle of intersection between the fish pass and the end of the horseshoe weir. The approach slope gradient will vary across the width of the fish pass. No debris boom will be installed above the fish pass to allow passage by canoes/kayaks.

Below the first and second fish pass flight there will be a rest pool 4m long, 3.6m wide (fish and eel pass width) and 1.4m deep below the top baffle of the following flight. This gives a working depth of 1.7m+ at river flows of Q95 or greater.

The RH (west) channel wall of the fish pass will be cast against the existing stone wall. A membrane will be placed against the historic wall face to prevent adhesion to and irreversible damage to the stone face. The wall will follow the profile of the fish pass to provide a consistent height of 800mm above fish pass channel invert. This will give minimum 300mm freeboard during functional design flows and, prevent erosion of the stone sluice and embankment walls.

The LH, river facing wall of the fish pass will incorporate a shallow channel 500mm wide, 100mm deep, to be fitted with eel tiles. The channel will run the full length of each of the 3 Larinier fish pass flights but will be terminate at and restart after each rest pool. Eel tiles will be laid continuously from the top to bottom of the entire pass by transitioning to the rest pool walls between the inclined channel sections. The eel pass channel will be horizontal bottomed in transverse section over most of the channel length, but at the channel intake (top) for each flight it will transition to a diagonal section. This will allow some portion of the tile to remain wetted but not submerged during the full range of design flow (Q99-Q20) at the intake end where water level will vary with river flow. Excess flow at the eel channel intake during moderate to higher river flows will quickly drain into the main fish pass channel, allowing the eel pass channel to transition to flat (transversely) to maximise useable wetted area.

The external wall face (river facing) will be stone clad to reflect the construction and look of the historic rough stone black walls of the feeder sluice and embankment walls it will sit next to. The fish pass channel walls may be capped with large smooth faced coping stones similar to the those on top of the downstream embankment wall.

The downstream entrance of the fish pass will be located immediately upstream of the turbine outfall screens as these will be the main attraction flow during applicable river flow conditions. Fish migrating upstream will traverse the outfall screens which are oriented perpendicular to the river channel and be directed to the fish pass entrance.

River flow summary table

Exceedance Probability (%)	Flow Q (m^3/s)	Depth Over Weir (mm)	Fish pass depth Ha (mm)	Fish pass flow (m^3/s)	Abstraction Flow (m^3/s)
Flood	427	2300	n/a	n/a	0.00
1	140		n/a	n/a	15.00
5	75.5	758	n/a	n/a	15.00
10	49.9	537	737	3.30	15.00
20	28.6	278	478	1.80	15.00
Q Mean	21.1	155	355	1.20	15.00
30	19.4	120	320	1.02	15.00
40	14.1	104	304	1.00	10.43
50	10.9	104	304	1.00	7.23
60	8.76	104	304	1.00	5.09
70	7.1	104	304	1.00	3.43
80	5.67	104	304	1.00	2.00
90	4.36	104	304	1.00	0.69
(Startup flow) 90	4.36	119	319	1.05	0.00
HOF 95	3.67	104	304	1.00	0.00
99	2.65				0.00

Hydro Abstraction and Residual Flow Control

Due the low head nature of the site and the 100% abstraction rate above HOF, it is not possible to ensure the abstraction regime is adhered to by means of passive structures, e.g. slots and weirs. Flow control will therefore be controlled actively by the Hydro control system, by means of variable flow turbines and intake sluices.

The minimum viable operating flow for the hydro will be around 5% of rated flow for the installation or 10% of rated flow for a single turbine. This equates approximately to a minimum river flow of Q90, where Q95 is HOF and Q90-Q95=minimum operating flow, ~700-750l/s.

Turbine start-up will be initiated when river level, measured at the weir, is at or above a setpoint that equates to HOF + minimum operating flow. This has been calculated as 119mm above weir crest.

During normal operation, turbine flow will be regulated via guide vanes and/or variable pitch runners, to maintain a minimum water level at the weir that equates to Q95 HOF. This has been calculated as 104mm above weir crest. Gauge boards visible from both banks will be installed for easy visual checks.

System response will be tuned using a PID control loop for optimum sensitivity and response to changes in river flow without introducing control oscillations that would result in cyclic changes in flow over the weir. The short distance between weir and turbines mean that this should be relatively easy to achieve stable operation. As Q95 HOF is relatively high compared to minimum abstraction flow (4-5 times greater), start-up transition should not significantly destabilise residual weir flow.

If river levels are too low to maintain minimum turbine output, or too high allow safe operation, the main intake sluice will be closed until river flow conditions return to within the safe operating window. It is expected that the hydro will operate without issue through the range Q90-Q5.

<u>Abstraction Screening</u>

The hydro installation includes 3 screens, a large debris screen (LDS) at the upstream intake, and automated fish and fine debris screen within the hydro penstock channel, and outfall screens for each turbine.

The large debris screen will be positioned diagonally between the RH bank (west) and the feeder sluice wall, next to the new fish pass intake. This similar to the existing deflector screen but will extend further upstream to provide increased screening area for the higher abstraction flows required by the hydro. It is anticipated that work will be required to lower the river bedrock level at the LDS to achieve sufficient screen depth. The screen will be constructed entirely of galvanised structural steel, with vertical or steeply inclined columns fixed to river bedrock, topped by a gantry structure with handrails to allow access for cleaning and maintenance. Horizontal screen bars will be attached on the channel facing side of the columns, spaced to provide 100mm clear openings. Above weir crest level, the screen will be closed to prevent entrainment of floating debris. Top and bottom guide rails will be included to facilitate manual cleaning. A mechanised but manually operated raking system may be retrofitted to the screen if required. The LDS will provide protective screening up to Q1 flows. During extreme floods the screen may be overtopped, but during these conditions the main intake sluice will be closed so no debris can enter the hydro penstock.

The main fish and fine debris screen will be located within the new hydro penstock channel. This will also be a horizontal bar screen, but of 12mm aperture. The total screen area will be 45m^2 to give a maximum perpendicular impingement velocity of 0.33m/s at rated turbine flow. An automated horizontal raking system running on tracks at the top of the screen will operate periodically to clear debris towards a flush gate at the downstream end of the diagonal screen. This will operate either on a fixed cycle or based on screen condition measured by differential pressure (level) sensing across the screen. The main fish screen is located downstream of the hydro intake sluice gate, so can therefore be isolated and dewatered easily for maintenance and will be protected during flood events.

A continuous by wash flow from the downstream end of the main fish screen will be present whenever the main sluice gate is open. This will discharge via a passive flow slot into the lower rest pool of the fish pass.

Whenever a screen cleaning cycle takes place, raking will be followed by opening of a flush sluice which will discharge via a culvert beneath the fish pass to the main downstream river channel.

Turbine outfall channels will be screened at their termination point at the downstream riverbank wall. Grates of 30mm aperture will be used to prevent entry of upstream migrating fish.

Maintenance of screens and structures

The large debris screen will require occasional manual cleaning, particularly after flood events, to remove accumulated small debris (e.g. plastic sheeting) and larger items such as tree branches. This will normally be achievable from using hand tools from the gantry/walkway on top of the screen. A bank mounted hiab crane arm will be used to extract any large items that cannot be dislodged manually. Most river debris will be deflected by the screen and continue down the river via the fish pass channel, but any manually cleared debris will be removed and disposed of.

The fish pass will require little maintenance in normal operation. Larinier passes are not prone to blockage, and usually any items such as branches that might become temporarily lodged will pass through the next time river levels increase. If the large items do obstruct the fish pass intake and need to be removed, this can be achieved with the bank mounted hiab arm. Routine inspections and any maintenance required to baffles or eel pass tiles can be achieved by dewatering the pass using stop logs at the intake.

Dewatering of the hydro penstock for maintenance of screens, turbine etc will be possible using the main intake sluice gate and stop logs at the outfalls.