SETTLE FISH PASS

RIVER RIBBLE

Flow Modelling

Richard McIlwain
Fisheries Team Leader

Tyn-y-Wern
Dolanog, Welshpool
Powys, SY21 0NA

(tel: 01938 810 740)
(fax: 01938 811 115)
(mobile: 07889 900 284)

mike@mbeach.freeserve.co.uk

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1   Introduction

Settle fish pass is located at Bridgend Mill on the River Ribble (SD 81430 63290). The fish pass is of the pool & traverse variety consisting of 4 pools and 5 traverses. It is located below a 36m-long curved weir. About 40% of the weir's crest (15.4m) discharges directly into the top two pools of the fish pass. This results in excessive turbulence at high flows, and renders the fish pass ineffective. A fish pass should function over the Q_{95} to Q_{10} range of river flows; about $0.35\text{m}^3/\text{s}$ to $14.5\text{m}^3/\text{s}$ for the River Ribble at Bridgend. In addition, the turbulence in the fish pass at the Q_{10} flow should enable upstream passage by small sea trout and should not exceed 150W/m^3.

It is proposed to harness the hydro potential at this site to generate electricity using an Archimedean screw turbine with maximum flow capacity of $2.86\text{m}^3/\text{s}$. It is suggested that diverting flow from the fish pass should improve its effectiveness by delaying the onset of high levels of turbulence. A 'hands off' low flow is to be enforced to enable a priority flow to the fish pass and over the main weir, before becoming available to the turbine generator.

Installation of the turbine should take account of its impact on the fish pass, and should attempt to improve the effectiveness of the fish pass without major re-building if possible. A 'hands-off' flow of $0.7\text{m}^3/\text{s}$ has been proposed – $0.6\text{m}^3/\text{s}$ through the fish pass and $0.1\text{m}^3/\text{s}$ over the main weir. Flow modelling is required to determine the turbulence within the fish pass pools over a range of river flows.

The 4 traverses that separate the fish pass pools are of different widths and contain notches of different dimensions. The two weirs supplying the top two pools of the fish pass are at different levels and water entering the top pool can spill over a side wall before discharging to the next fish pass pool. Pools are of different sizes and different volumes. The consequence is that the levels and turbulences in the fish pass pools vary individually as flows increase. Survey data was difficult to obtain; high flows prevented access to the fish pass pools and notches. An excerpt from the latest survey is shown at Figure 1.
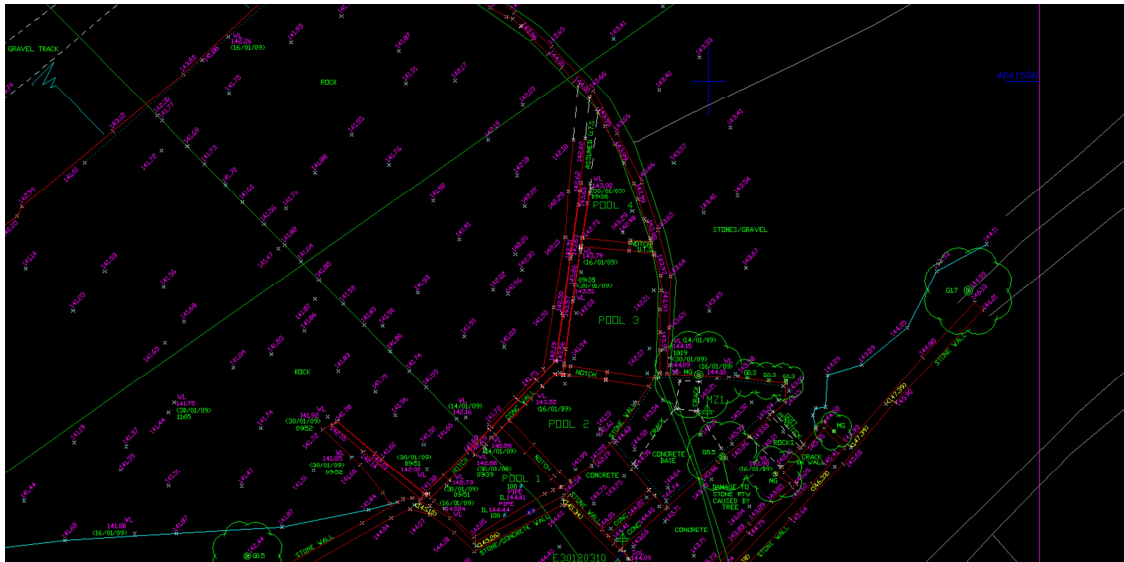
Figure 1. Settle fish pass – survey data (Survey Operations Ltd., January 2009).

Water level data were obtained from Locks Weir (about 1km upstream) but are not referred to the weir level at Settle. Flow data from the Arnford Gauge (about 10 river-kilometres downstream) were used with a 60% reduction factor for Settle.

2   Fish Pass Model – Existing Fish Pass

A model of the flows, levels and turbulences in the fish pass pools was attempted using an Excel spreadsheet (Settle FP Model Original.xls). The approach was based on the flow diagram at Figure 2 below.
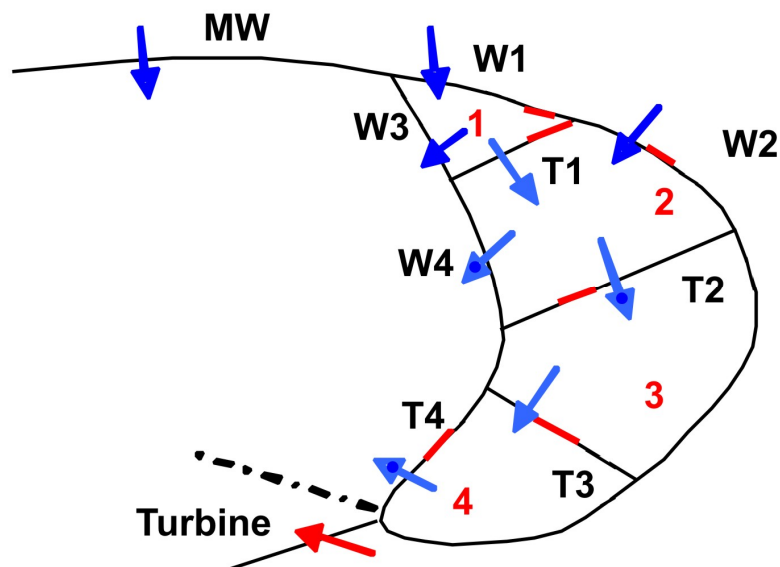

Figure 2. Settle fish pass – flow diagram used for model.

The abbreviations in the diagram refer to the various flows: MW is the flow over the main weir (not into the fish pass); W1 and W2 are flows over the two weirs into pools 1 and 2 of the fish pass (labelled from upstream to downstream); W3 and W4 are the flows over the side-weirs from pools 1 and 2; and T1, T2, T3 and T4 are the flows over each of the four fish pass traverses. Notch dimensions/levels are included in all weirs and traverses to enable the flow dispersion to be modified: if, as in the initial conditions, there is no notch, then zero depth/width is entered. Flows are calculated using approximate broad crest formula:

$$\mathbf{Q = 1.7bh^{1.5}}$$…………….………………………………… (1)

Where, $\mathbf{Q}$ = flow (m^3/s), $\mathbf{b}$ = width of weir/traverse/notch (m), and $\mathbf{h}$ = head over weir/traverse/notch (m).

The equation is approximate, the coefficient of discharge is included in the 1.7 factor, and the levels of weirs/traverses have been approximated since not horizontal and in a poor state of repair (roughness effects).

Water levels for the upper weirs (W1, W2 and W3) are referred to the main weir, MW. Flows MW, W1 and W2 are computed using equation (1). The levels over these weirs for various river exceedence flows are shown in Table 1 below:

Exceedence (%)	River Flow (m^3/s)	Head over MW (m)	Water level (m AOD)
Q_{95}	0.35	-0.0670	143.953
Q_{40}	2.86	0.0854	144.105
Q_{10}	14.50	0.3543	144.374

Table 1   Water head over main weir (MW) for various flow exceedences.

The level over MW is negative at the Q_{95} river flow because of the lower crests of W1 and W2, and the shallow notch in W1. The W1 flow into Pool 1 is divided between W3 and T1. Equation 1 is used again to compute the combined flow of W3 and T1 for a head referred to the T1 traverse. The relation between flow and head is a polynomial equation which is solved using Excel's trend equation facility. The head in Pool 1 for a W1 flow is solved using the polynomial equation. It was necessary to split the flow head relationship into segments and use more than one polynomial equation to get a sufficiently good fit. The head in Pool 1 for a W1 flow is then determined and used to compute the T1 flow into Pool 2. A similar process is used to compute flows W4 and T2 for heads in Pool 2 and the

appropriate polynomial equation solved to give heads in Pool 2 for the combined flow of T1 and W2, and allowing for a flow escapement W4. This head is then used to compute flow T2 which will then equal T3 and T4 since no other flow additions or escapements occur.

The attached spreadsheet shows graphs of the various head/flow relationships used and finally a Q v h graph was generated to include all weirs and traverses so that a head in any pool could be determined from the appropriate flow cascading through the fish pass.

3   Fish Pass Model – New Notches

Visual observation of the fish pass over a range of flows suggests that turbulence in the fish pass will not be excessive if the flow does not exceed 0.6m^3/s. It is proposed that this flow be divided as follows: 0.1m^3/s over the main weir; 0.2m^3/s over W1 into the Pool 1 of the fish pass; and 0.4m^3/s over W2 into Pool 2 of the fish pass. A second model has been generated and is attached (Fish Pass Model New Notches.xls). The aim is to predict the changes in upstream water levels for changes in the crest levels of W1 and W2, and the inclusion of notches in all 3 weir crests. The crest of the main weir (MW) now includes a notch 100mm deep by 5m wide. The crest of W1 is unchanged but includes a notch 250mm deep by 600m wide. The crest of W2 is raised by 100mm and includes a notch 250mm deep by 800mm wide. This results in a flow division at a Q$_{75}$ river flow (about 0.749m^3/s) of 0.179m^3/s into Pool 1 of the fish pass, 0.340m^3/s into Pool 2 of the fish pass, and 0.230m^3/s over the main weir (MW). This division of flows deviates from the original proposal but a significant factor is to not significantly affect upstream water levels.

Changes in upstream water levels for the new proposed configuration are shown at Figure 3 below. Upstream levels have increased by only a few millimetres over the flow range. The relevant spreadsheet is attached: different weir crest heights and notch dimensions can be entered to determine a different apportionment of flows; the effect on upstream levels will be displayed in the attached chart. It is strongly suggested that the calculations are checked for accuracy.
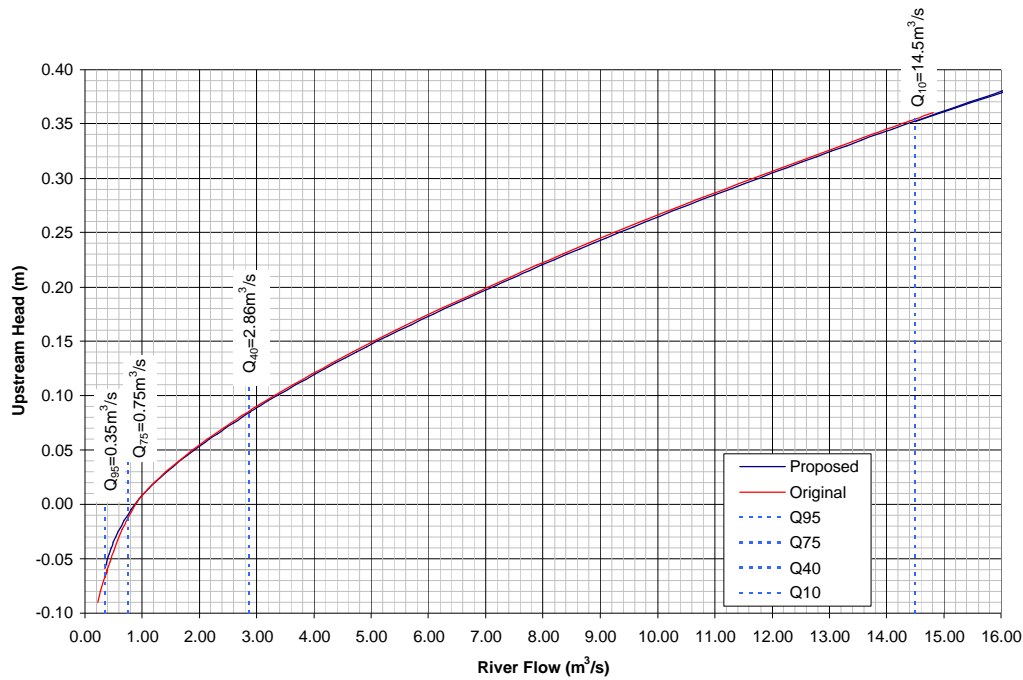
Figure 3. Upstream water level with original crests/notches & with proposed notches.

3   Conclusion and Recomendations

The initial conclusion from using the final Q *v* h graph (original spreadsheet) was that the predicted head over traverse 1 did not accord with the photographed images of the fish pass at specific flows (Fishtek Report, August 2008). The model has become rather complex with many interactions. It is considered that both the overall approach and the various head/flow relations need checking. A calculation error can easily occur and will have a ripple-through effect with so many flow interactions. At present the model is not adequately predicting the current status of the Settle fish pass and therefore cannot be used to estimate the effect of changes to the levels of weirs W1 and W2, or the inclusions of new notches.

Some survey data has now been obtained to estimate the depths of the various fish pass pools, and the levels of traverses, notches and their dimensions – but it is still incomplete (dangerous high flow conditions preventing measurements). The latest survey (5 Feb 2009) gives water levels in the four pools, upstream and downstream water levels, and a little data on the base levels in some of the pools, see Table 2 below:

Pool No (from U/S)	Area (m^2)	Depth (m) very approx.	Head over (m)
W1			0.23
1	16.01	0.94	0.41
2	36.14	1.51	0.19
3	28.20	2.02	0.59
4	23.20	0.8 (from earlier survey)	0.71

Table 2. Depth readings - very approximate.

The estimated river flow on 5 February and attached spreadsheet should enable the flow into the top pool to be estimated, and the turbulence calculated – one point! Additional water levels and flow data (no technical survey skills required), will enable extra turbulence values to be obtained. These data for a range of flows will permit an estimate of the flow at which a turbulence value of 150W/m^3 is exceeded, and hence the range of flows for which the fish pass is effective.

Another approach would be to modify some areas of the fish pass. For example, raise the level of W3 to prevent side spillage, equalise the head differences across the traverses, and make the dimensions of the traverse notches uniform. This would avoid the complicated interaction of flows/heads between the pools and enable pools turbulences to be predicted more easily.

The spreadsheet for predicting upstream heads for changes in weir crest levels and notches (proposed new notches spreadsheet) suggests that a new notch in the main weir, and the proposed changes to the fish pass weirs, will distribute flows in favour of the fish pass at low river flows, as required. Experimentation with different configurations is recommended.