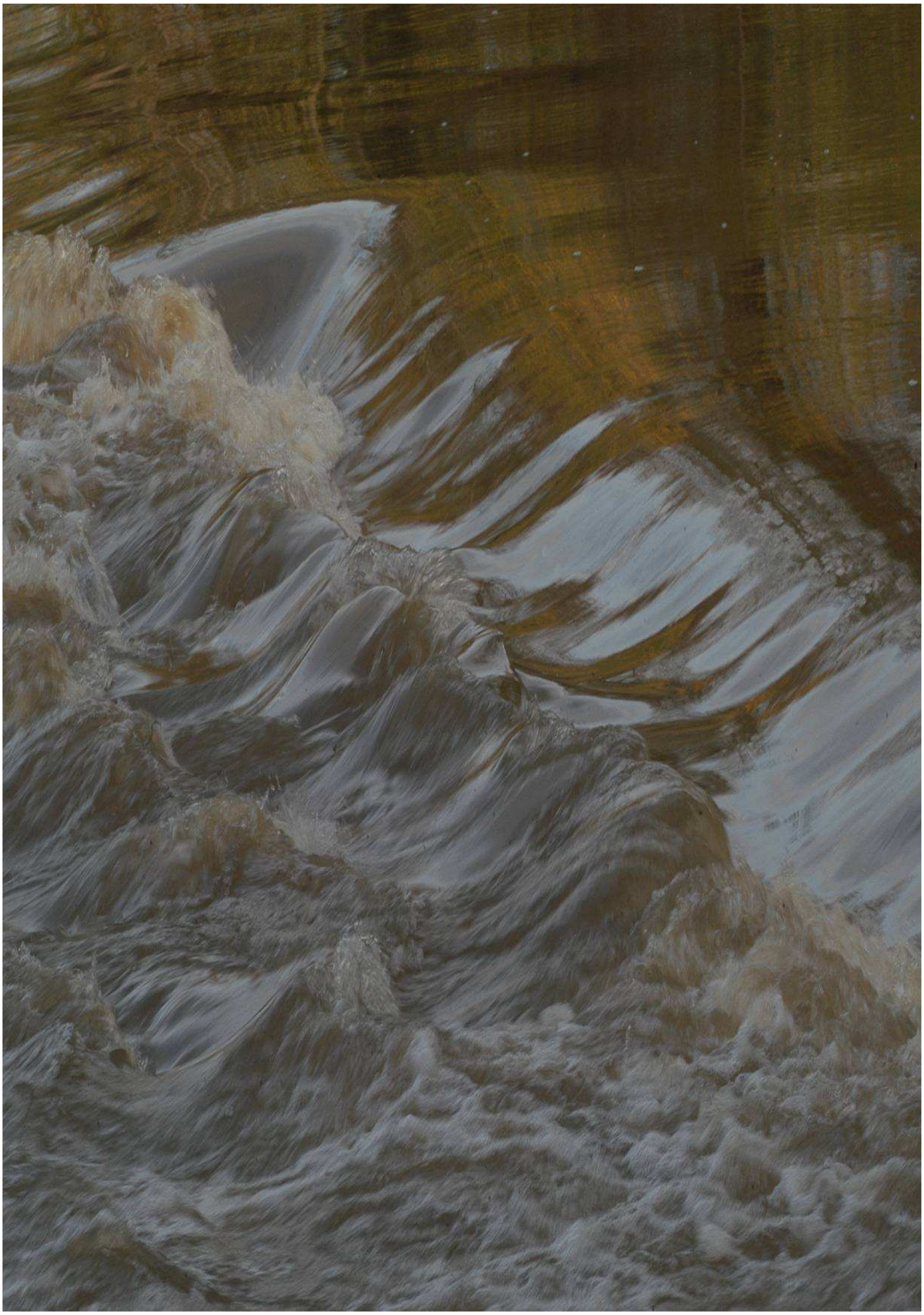
A Feasibility Study for a Hydropower scheme on the River Teifi at Pontwelly, Carmarthenshire

A study commissioned on behalf of the
Zero Carbon Future element of the
Innovative Hubs project

Cronfa Amaethyddol Ewrop ar gyfer Datblygu Gwledig: Ewrop yn Buddsoddi mewn Ardaloedd Gwledig
The European Agricultural Fund for Rural Development: Europe Investing in Rural Areas

Llywodraeth Cymru
Welsh Government

This report has received funding through the Rural Development Plan for Wales 2007-2013 which is funded by the Welsh Government and the European Agricultural Fund for Rural Development



Feasibility Study for a Hydropower scheme on the River Teifi at Pontwelly, Carmarthenshire, making use of an Archimedean Screw Turbine

Author: Adrian Clayton
Issue date: 29th July 2013
Project ref: FS Llandysul 717

Mann Power Consulting Ltd.
Manor Farm
Kirkham Abbey
York
YO60 7JS
01653 619968
info@mannpower-hydro.co.uk
www.mannpower-hydro.co.uk
Registered in England Registration No. 5014120 VAT No. 836353519

Summary

There is potential to install a hydroelectric generating system at Pontwelly near Llandysul. Mann Power Consulting Ltd was commissioned to deliver a hydropower feasibility study, to include recommendations for the potential development of a hydropower scheme at this site. The author met with the Zero Carbon Future officer and Llandysul & Pontwelly Ymlaen group on site on 26th June 2013 to discuss the likely parameters of the scheme. The scheme would use a modern fish friendly Archimedean screw turbine: either by re-establishing a scheme on the former hydropower site, or proposing an alternative location along this section of the river.

Various different types of hydropower system could be used at this site, and a summary of the different alternatives is provided for information (see Appendix). Full independent cost / benefit comparisons have previously been carried out for projects of a similar nature, which have identified the Archimedean screw system as likely to provide the best return on the investment. Screws are particularly suited to sites where the tailwater frequently rises, fine screens are prone to blockage by debris, and the free movement of fish is a priority. As fish can swim through the screw, the water abstracted is still serving a useful purpose to the movement of fish, even at a site where it must pass through a lengthy channel (leat).

This study was therefore commissioned specifically to assess the potential for generation using the Archimedean screw, and looks at a number of different options for scheme size and operating regime in order to provide an indication of an optimum design. This was determined by analysing the results for a range of flows, summarised in Energy Capture and Cost/Benefit Calculations provided with this report.

Options considered

This study considers four different options in detail, investigating the likely costs and the potential return on investment for each.

Option 1a assesses a scheme which uses an Archimedean screw to maximise use of the potential head across the site, including the historic structures and layout of the former hydro scheme where possible. This would install an Archimedean screw close upstream of the Pwerdy, having created head by building a replacement weir on the site of the original hydro weir. This scheme would be capable of accepting a maximum flow of 1.75 m³/s, generating up to 51 kW, and should operate at full power equivalent for 56% of the year. This would cost approximately £2M to install, producing enough electricity to provide a net annual income of approximately £47,300 (at the time of print). This represents a return rate of up to 2.4%, as well as a saving of 108 tonnes of CO_2 emissions per annum.

Option 1b assesses the same scheme enlarged to produce up to 100 kW. This would be capable of accepting a maximum flow of 3.5 m³/s, and should operate at full power for 49% of the year. This would cost approximately £2.29M to install, producing enough electricity to provide a net annual income of approximately £88,000 (at the time of print). This represents a return rate of up to 3.8%, as well as a saving of 184 tonnes of CO_2 emissions per annum.

Option 2 assesses a scheme which surrenders an amount of head in order to avoid the costs and difficulties of using the historic culvert and forebay and crossing property boundaries. This too would involve rebuilding the hydro weir, but would install the Archimedean screw at the riverbank in the paddlers' barbecue area. This would be capable of accepting a maximum flow of 4.5 m³/s, generating up to 100 kW, and should operate at full power for 42% of the year. This would cost approximately £1.95M to install, producing enough electricity to provide a net annual income of approximately £75,000 (at the time of print). This represents a return rate of up to 3.8%, as well as a saving of 157 tonnes of CO_2 emissions per annum.

Option 3 assesses a scheme which avoids rebuilding the former hydro weir. This would install a shorter Archimedean screw in the paddlers' barbecue area, using a much lower head by taking out water only at an existing concrete "weir" crest, situated much closer to the turbine. This would be capable of accepting a maximum flow of 5 m³/s, generating up to 45 kW, and should operate at full power for 43% of the year. This would cost approximately £772K to install, producing enough electricity to provide a net annual income of approximately £29,900 (at the time of print). This represents a return rate of up to 3.9%, as well as a saving of 65 tonnes of CO_2 emissions per annum.

Full figures are presented in tabular form in the appended Analysis Documents.
(All predicted values calculated at date of this document.)

Hydrology Assessment

Energy can be extracted from falling water and harnessed to provide mechanical or electrical power. The theoretical amount of energy available from any given site is directly proportional to two factors: the actual volume of water passing the site (the flow) and the height through which the water falls at the site (the head). In order to fully assess the potential of a site, it is ideally necessary to have measurements of both the changing flow and head over the course of several years. This will determine what might be expected to be the average annual energy capture. The results of a Hydrology Assessment based on available data are presented among the Analysis Documents provided with this study.

Cost/benefit calculation

This study was commissioned to assess the potential for generation using the Archimedean screw. It considers a number of different options for scheme size and operating regime in order to provide an indication of designs suitable for this site. Predicted output from the suggested designs has been determined by analysing performance over the likely range of flows, and the results of these calculations are presented for the client among the Analysis Documents provided with this study.

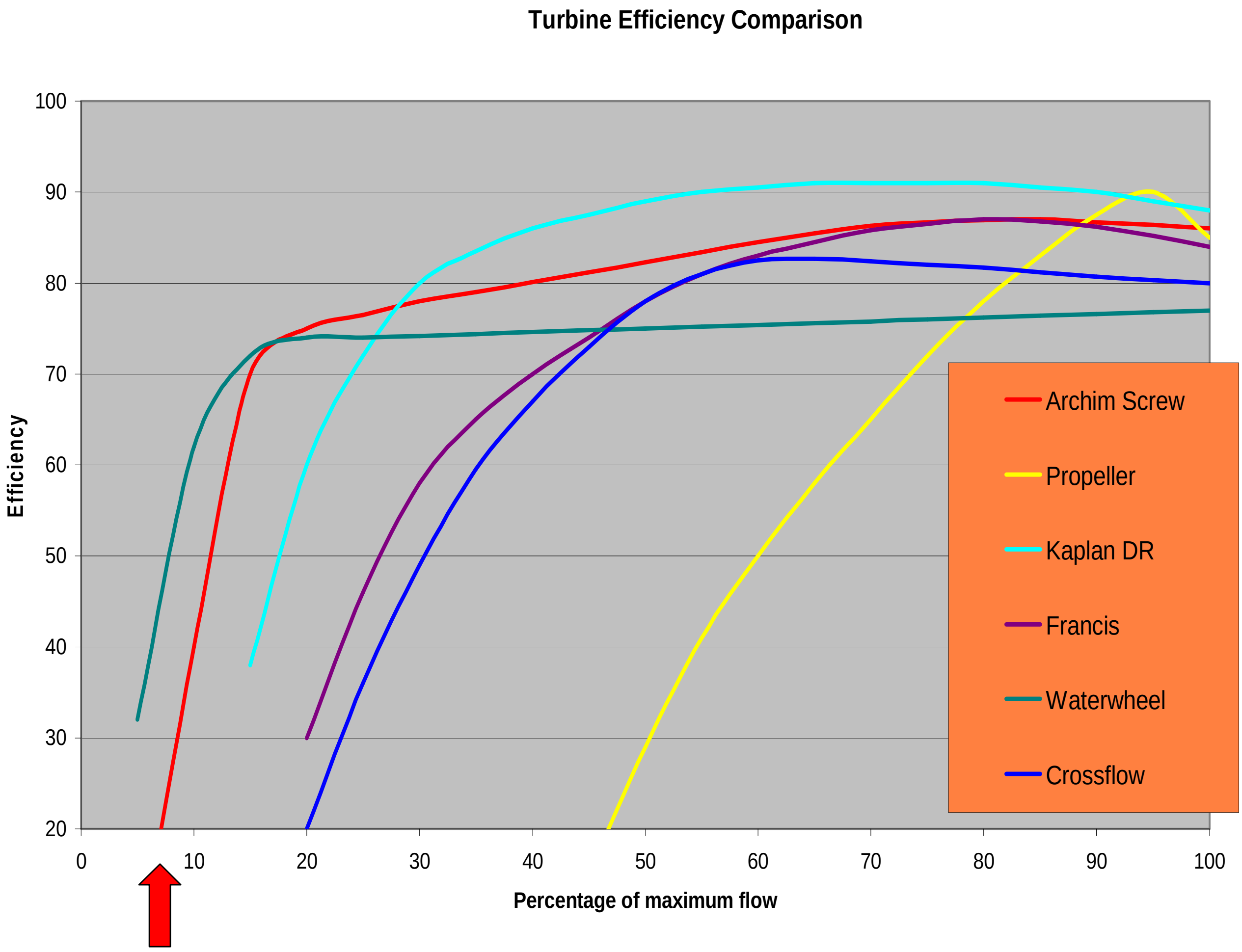
Detailed quotations and additional measurements are required to produce more accurate figures, but the attached estimates are sufficient to form a decision whether to proceed with further design work.

Benefits of the Archimedean screw

There are a number of quite different types of machinery that can be used to generate hydroelectricity at low head. This report was commissioned to consider only an Archimedean screw installation, but a summary of the available hydropower systems is provided in the Appendix to this document to show how the screw compares to other technologies. The Archimedean screw is recognised as one of the most fish-friendly turbines available, as discussed in the Environmental section below. Its competitive technical performance against alternative turbine types is illustrated below.

Efficiency comparison

This chart shows how the efficiency of the different turbine systems changes against an increasing flow.



When estimating the energy delivered over the course of the whole year, it is very important to consider how changing the flow affects the efficiency of the machine. A further benefit of the Archimedean screw is that there is no need for pressure pipes or fine screening, which cause head loss, so it is possible to exploit more of the gross head actually available at the site. The ‘water to wire’ efficiency, which actually determines how much power can be extracted from the water, will therefore remain high. The impact of this is reflected in the calculations for energy capture, detailed in the Analysis Documents.

Economic advantages

Independent studies comparing different technologies have previously been carried out which show that the Archimedean screw turbine usually provides a better return on investment in this type of site than the other most suitable alternative for such sites - the Kaplan solution, which might otherwise appear favourable in terms of technical efficiency.

One such study can be downloaded from CO_2Sense (formerly Future Energy Yorkshire): http://www.co$_2$sense.org.uk/uploads/public/CaseStudy/Archimede's%20Screw.pdf [sic]

The screw enjoys this advantage because the machinery is less expensive to purchase, less excavation is required to install the system, and its comparative fish-friendliness means that there is no need for the maintenance of fine inlet screens. The technology is well proven, with the first system installed 16 years ago, and now with over 120 installations operating in Europe, including 25 supplied by MannPower in the UK.

Figure 1: Close-up of screw profile

Proposed Site

Location description

Pontwelly is situated on the Afon Teifi in Carmarthenshire, which here marks the boundary with Ceredigion. Before the 20th century, the local use of water power for milling was concentrated on the Teifi and on its tributary the Tyweli at Pontwelly, across the river from the larger settlement of Llandysul to the north.

The proposed site lies on the Carmarthenshire side of the Teifi, in the east of Pontwelly close to the road bridge from Llandysul. Here a new water power development was designed and built between 1920 and 1929 under the leadership of a local businessman J Isaac Thomas. This was a hydroelectric scheme, financed by public subscription, intended to power lighting in the town. It took water from the Teifi at a new weir constructed for the purpose, southeast of Llandysul, via an intake and leat leading west towards Pontwelly, passing in a culvert beneath the main road and Lewis Street, emerging on the bank of the Teifi to feed turbines within a powerhouse building or Pwerdy.

In the 1930s the scheme was acquired by the West Cambrian Power Company. The heyday of the hydro scheme was brief: its role in lighting became redundant when GEC brought in the national grid. The scheme continued to operate at least into the late 1940s, but in its declining years was run only as a battery charging service. From the 1980s, the redundant Pwerdy was restored, extended, and converted to community use.

Overall length of the former hydro system is around 550m.
O/S grid reference of the intake (abstraction point) is SN4189540285
O/S grid reference of the powerhouse outfall (discharge point) is SN4135240229

The 1920 hydro scheme required the creation of a weir: apparently on a new site, as no predecessor is seen on the 1914 O/S map. By the 1960s O/S maps, the weir is no longer marked. Site inspection (26/06/13) revealed the remains of concrete footings in the river over a distance of some 20m, apparently laid out in several bands. This could represent concrete baulks between which looser infill was inserted; or perhaps a weir of multiple crests to facilitate fish passage, such as the fishway seen nearby on the Castle Weir at Newcastle Emlyn, which may indeed have been enhanced in this format as part of the hydro scheme there. The remains at Pontwelly suggest that here the weir may have been deliberately and systematically removed, rather than eroded: if this was done during river improvement works, documentary evidence may exist.

Concrete remains in the left bank indicate that the weir crest rose to at least 0.9m above low water level or approximately 1.4m above the bed. A photograph from c.1950 looking downstream over the weir shows an additional structure at the right bank. This appears as a long, light-coloured masonry wall, dividing off the right-hand third of the channel, running from upstream of the weir down to the weir toe, with an additional wing wall protecting the right bank at the downstream end. This channel may have been designed as a fishway or flood overspill channel or both. This feature is no longer evident, unless a large sandstone block on the right bank is a remnant of this.

There is a single break in the south bank walling which most likely marks the position of the former intake. This has been coarsely infilled to bank level to include 2 x 300mm intake pipes to feed an amenity pond. The pond postdates the last OS map; though the intake is likely to have silted up naturally from the 1950s after hydro abstraction ceased. The remains of a debris screen made up of vertical 50mm steel tubes, of an appropriate scale for such an intake, is found displaced and buried in the bank some distance downstream.

The former leat has been obliterated and its course is no longer marked on the ground. The whole area adjacent to the river has been landscaped in recent years, including the creation of the amenity pond, as part of the facilities of Llandysul Paddlers canoe training centre which occupies the site. Surface levels and ground stability may therefore be assumed to have changed since the former scheme.

However, the original leat, once it left the river, did not run through the area which has recently been subject to change: but through the adjacent field to the south. RAF aerial photographs of the area, taken in 1946, were obtained from RCAHMW Aberystwyth (sheet 139, sortie 106G/UK/1471, frames 2243,4021,4022). These confirm the position of the weir, but with insufficient resolution to discern its detailed construction. The aerial photos clearly show the leat as exiting the river some 10m downstream of the existing hedge, departing at a sharp angle for some 10m to cross the field boundary fence, then running along the field south of the fence. The landform here is lower than the riverbank, and it is inferred that this field surrounding the leat may have acted as a flood meadow or washland

- as flood waters would penetrate the raised riverbank via the low spot at the intake. The route of the leat passed through what is now the site of farm buildings, around the south of where the water pumping station now stands, curving northwest back to the paddlers' car park area. Here it again curved southwest to run straight along the north side of the low-lying meadow to the end wall beneath the road, where it entered the culvert entrance. The overall length of the leat to the culvert was around 420m with width apparently 2-3m.

The culvert entrance was inspected. It is set at the foot of a masonry retaining wall at the road: this curves round in two wings to encircle the low-lying meadow, which has the appearance of a flood pond (a small pond is shown here on the 1889 O/S map). What is now visible is an arched opening at the base of the wall, 0.7m wide with its footings buried in silt. Having partly dug this out, the client reports that its total depth is >1m. The first 1m of the culvert has a smooth cement or stone finish; beyond this, the culvert appears to be a vault of rough-laid stones, with no mortar finish evident, protruding into the culvert and possibly unstable. Close to its entrance, the culvert is obstructed with wooden flotsam.

To the north of the culvert entrance is a dense stand of Japanese knotweed, which prevented investigation of the adjacent length of wall: it may be worth confirming that there are no other culverts concealed here. Intriguingly a comparable though slightly larger culvert, cut from the bedrock, emerges at the riverbank at a corresponding level, immediately downstream of the paddlers' bunkhouse building. This cannot have carried flow to the hydro scheme at the Pwerdy, though it may be a safety overspill diverging from within the main culvert. Alternatively it is possible that what remains is simply a drain system, created either before or since the hydro scheme, to allow flood flows to exit from the ponded meadow back to the river. (In the floods of October 1987, for example, the meadow was full to street level.) Both tunnels might usefully be investigated further.

For the hydropower scheme, the culvert crossed the main road and ran diagonally beneath Lewis Street to the former open forebay channel, as may be inferred from maps and photos, giving a length of around 60m. It emerged from beneath the roadside wall immediately downstream of the electricity substation, at a point on the riverbank still marked by a low-lying wall capped with smooth coping, visible from the pavement. From here, the retaining wall of the forebay curved out at a lower level to form a straight edge along the riverbank to the powerhouse. The open forebay appears to have been some 4m wide and 50m long. This broad open channel would act to still the turbulent flow emerging from the culvert. In high flows, and perhaps when the turbines were not operating, excess water spilled over the crest formed by the smooth cement coping along the riverbank wall of the forebay. This wall may also have had a small draindown sluice at some point to allow the forebay to be emptied for maintenance.

The original two turgo turbines were designed to utilise a head of up to 4.27m, and if operated together would have taken a maximum flow of 1.75 m^3/s. To achieve this flow without undue head loss, it is inferred that the culvert must have been around 1.5m deep. This would need to be confirmed by further manual excavation.

Turbines used in the original scheme, 1920-1948:

Gilkes Turgo Turbine # 2824
Year: 1920 (invoiced 1921)
Output: 22.4 Kw
Head: 4.27m
Flow: 0.7 m^3/s

Gilkes Turgo Turbine # 2825
Year: 1920 (invoiced 1921)
Output: 33.6 Kw
Head: 4.27m
Flow: 1.05 m^3/s

Gilkes Francis Turbine # 3111
Year: 1924 (? - or invoiced 1921?)
Output: 51.1 Kw
Head: 2.13m
Flow: 3.17 m^3/s

NB: These specifications provided by the client appear realistic, and are taken to be authoritative. Figures have been cited elsewhere of 34kW + 34kW + 100kW for the three turbines. These over-high figures may derive from a false assumption that both turgos were identical at 34kW, and a misunderstanding that the third turbine was capable of 100kW on its own rather than contributing to a total installed capacity of 100kW. It is highly doubtful that that the culvert would support all three machines running at their maximum capacity.

The right-hand turgo turbine is still in situ, in a very decayed state. It has a diameter of c.650mm, shaft diameter of 75mm, water was injected from the right, and its draft tube (diameter 800mm) exited downwards from the left. Draft tubes to the water below are missing, and the tailrace is silted. The upper side of the turbine slab has been infilled with hardcore and/or concrete, and the building above converted with a solid floor. The tube opening for the other turgo is blocked off, but the turbine appears to have been cut away and removed before infilling took place. Photos of the derelict powerhouse show that the control equipment, generators and belt drives above the turbines had been removed prior to conversion of the building.

The powerhouse, as seen in an early photo, was initially a square single bay housing the two turgos. Within a few years it was extended eastwards with a low building jettied out over the forebay - presumably to accommodate the third turbine which was quickly added as an afterthought to the original layout. This was a Francis type, specified to take a higher flow of 3.17 m^3/s but at a reduced head of 2.13m – i.e. around half of the maximum head. This is said to have been intended to provide an efficient alternative for continued operation in wet conditions when the tailwater rose particularly high. But also, increasing the flow yet further through the narrow culvert would induce even greater head loss and a lower intake level at the turbine. The remains of the extension formerly housing the Francis turbine are not easily accessible and were not inspected during the site visit.

The fall in ground levels between the intake and the Wilkes Head meadow suggests that when the intake was open there would have been a tendency on many occasions for the culvert entrance to become submerged, with the area around it (enclosed by high walls) rising to function as a millpond, storing up a reserve of water. The 1946 aerial photo does not show this at that date - the leat remains narrow. Such ponding could only have been managed if the intake was controlled by a (tall) sluice gate, restricting inflow from the river, and water was allowed to exit freely from the Pwerdy forebay even when not operating.

At the other end of the culvert, the open forebay area could also have served as a storage pond, though its size would not have supported generation (even at minimum power) for more than a couple of hours. It may be speculated that in low flow conditions, the system was run at capacity when there was greatest demand for lighting, allowing the forebay to refill at other times. This may have been the original intention, or an expedient after having undersized the culvert. The fact that a third dissimilar turbine in an irregular extension was added so soon afterwards also suggests a constructive response to underperformance.

Historic photos were provided by the client, including a view of the original weir (below, identified by the copyright holder as dating from c.1950). Here the leat intake is hidden behind the trees to the left. The crest appears to be dry, with all flow passing down a long sloping bypass channel to the right, separated from the crest by a long stone wall. The shape of the shoal downstream of the weir shows how gravel has been deposited at high flows over the weir; then scoured out again by constant flow down the bypass channel, which would have acted in all conditions as a fish pass.

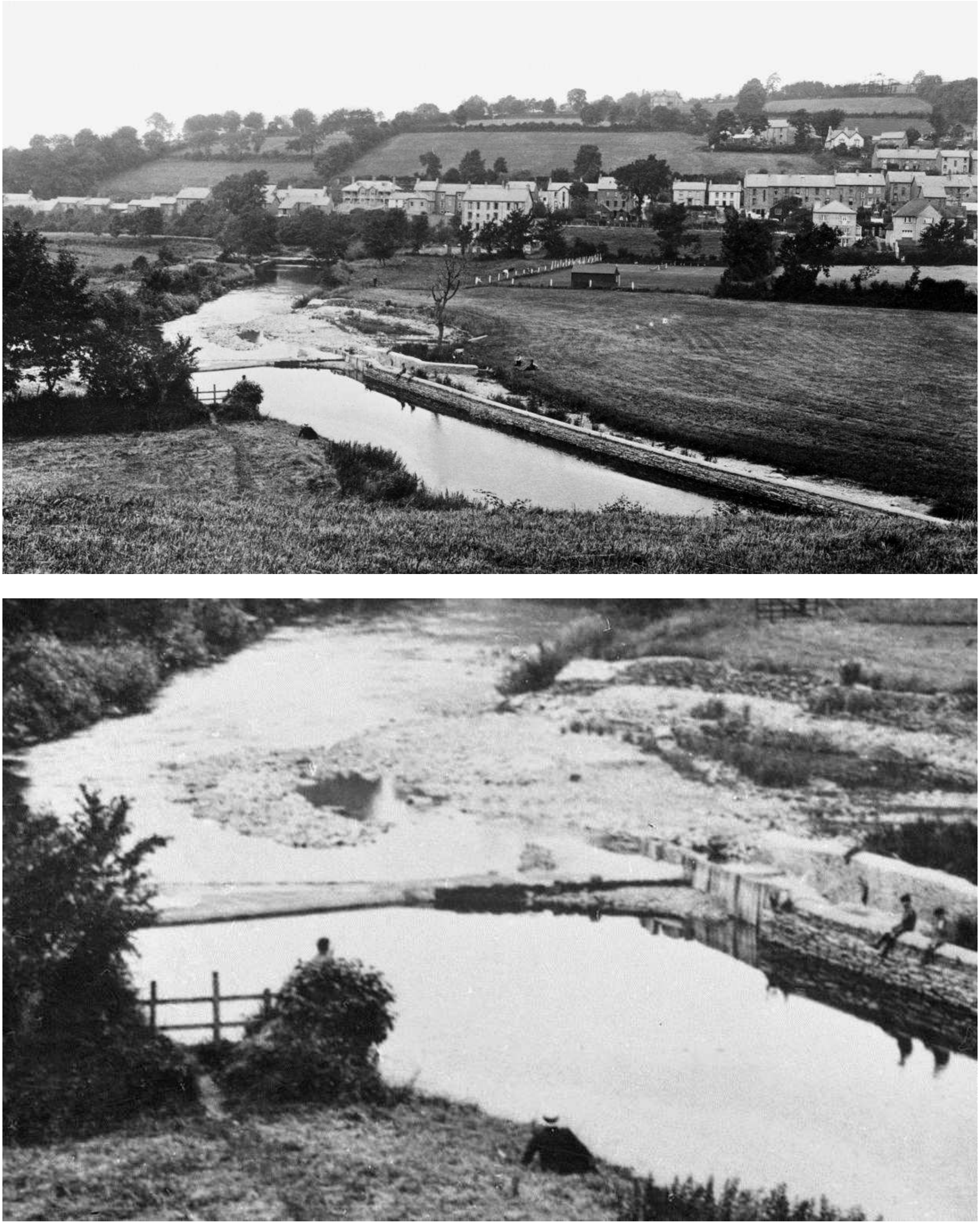


Figure 2: The weir at Llandysul, c.1950-55

Figure 3: Remains of weir foundations (with displaced remains of intake screen?)

Figure 4: Site of missing weir and former leat intake (with pipes to pond)

Figure 5: Recently-created amenity pond (overspill to right) - on potential leat route

Figure 6: Low concrete “weir” crest at river bend (Option 3)

Figure 7: Culvert, in meadow opposite Wilkes Head – before/after hand excavation

Figure 8: Road junction, under which former leat culvert is located

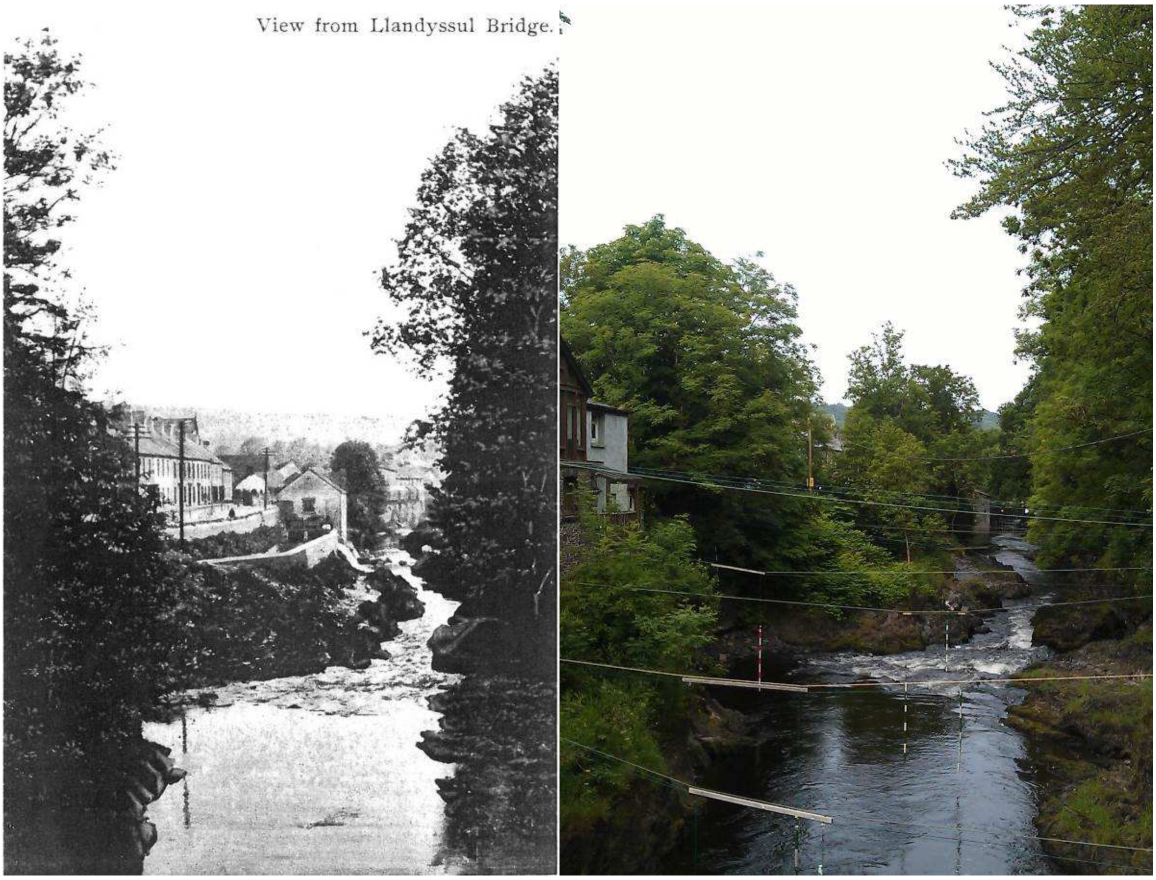


Figure 9: Views downstream from Llandysul Bridge

The historic view from Llandysul Bridge shows the Pwerdy in its earliest form, without the extension “lump” to the north for the third (Francis) turbine. The forebay is empty, or at a very low water level, with a white flash appearing to signify water spilling out of a draindown sluice back to the river, indicating that the scheme is not (yet?) operating. A comparison photo was taken of the same view, now obscured by tree growth. Only the northern extension is visible. Depending on which trees could be retained, a new scheme in this reach might not be visible from this viewpoint.

The historic photo below shows the river in a high flow condition, and overspill from the forebay wall. The comparison photo from the same viewpoint was taken in low flow conditions, hence more rock is exposed. The public toilets (behind trees, centre) now stand on the former forebay channel. To the right, the forebay wall has been rebuilt or renovated along with the Pwerdy. Recent tree growth on both banks obscures views along this reach. To install here (Option 1) would require removal of some trees on the south bank, excavation down through the infilled site of the former forebay, and excavation of the bedrock in the centre of the photo to form a tailrace channel – like the channels cut into the riverbed below the Pwerdy

Figure 10: Views upstream towards the bridge and the former hydro forebay channel

Figure 11: Depleted reach at paddlers' bunkhouse – used as canoe slalom course

Figure 12: View of converted powerhouse, showing outflow arches

Figure 13: Pwerdy tailrace arches, filled with siltation

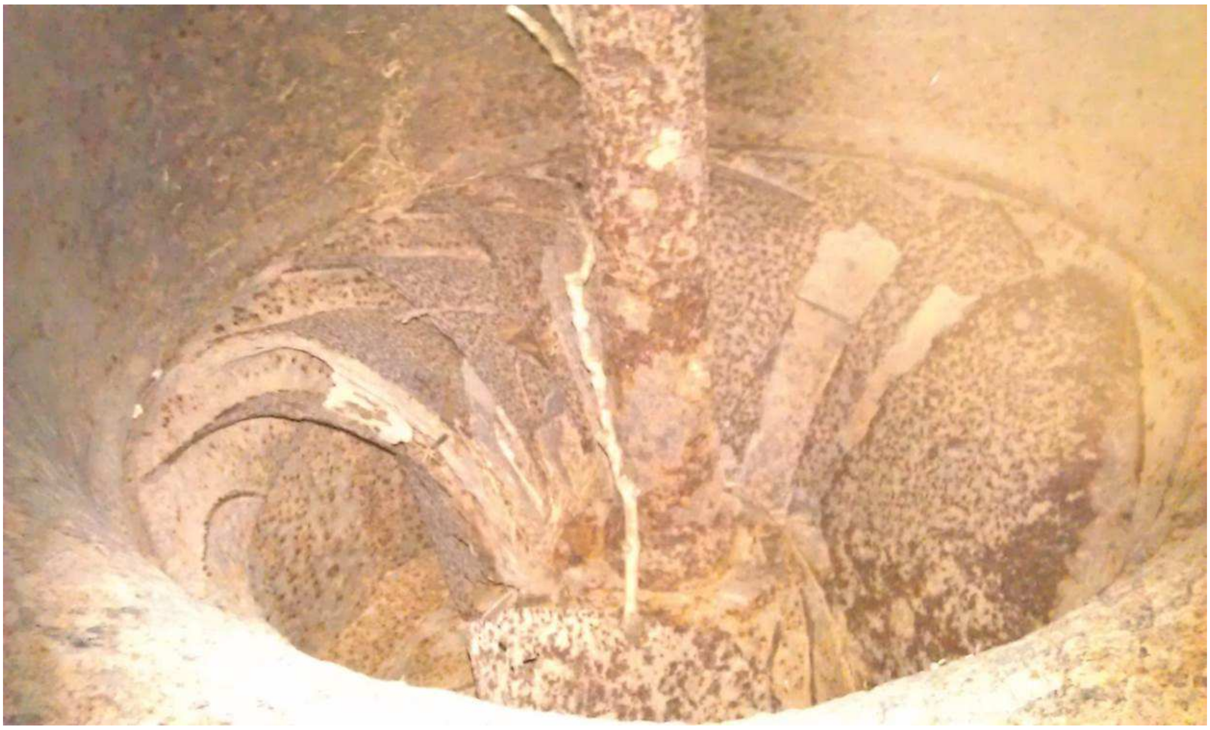


Figure 14: Remains of right-hand turgo turbine, seen from below via discharge tube (shaft is horizontal)

Other features not related to the former hydro scheme

Upstream of the weir site on the right bank is a low concrete platform apparently intended for angling. Reinstating a weir would raise the water level so that the platform was permanently or more frequently inundated. This should be investigated with users of the platform, though its use may have declined since the creation of the adjacent park and footpath has increased footfall in the area.

On the left bank is an open 300mm outfall pipe, believed to be treated water from the sewage works. This empties into ponded water upstream of any weir and abstraction point, therefore it is questionable whether dilution would be materially impacted by the scheme. NRW have however indicated that maintaining suitable dilution would be a concern in any licence application. Therefore it is recommended that the nature and quantity of this discharge is investigated with Dwr Cymru. (Their local trade effluent officer Richard Harman 01792 511813 may be able to assist.)

Llandysul Paddlers' amenity pond is fed by two 300mm pipes from the riverbank at the former intake. At low river flows there is no inflow into the pond and it remains shallow with a dry margin. At increasing river flows it take inflow via first one then the other pipe. Excess flows can exit via an overspill ditch back to the river, which is crossed by a wooden footbridge. Wet ground in a depression at the west end of the pond suggests that a spill also occurs here at least in high flows. A concrete inspection chamber here appears to relate to water services infrastructure (again a question for Dwr Cymru).

If the pond is to be incorporated into a new leat route fed by a weir, this will enter at a higher water level, meaning that the depth and area of the pond would be permanently increased. Modifications to the pond and its overspills could be necessary. Alternatively, if the leat is to bypass the pond, provision would need to be made for moving the pond intake pipes to an appropriate new level (with respect to the river levels maintained by the new weir); and for accommodating the overspills from the pond where these are crossed by the route of the new leat.

A shoal of stone and concrete material, possibly originating partly from the remains of the former weir, is present some metres downstream of the weir site. The presence of this material provides a riffle which is unstable and subject to movement along the river.

At the riverbend, in what was formerly the depleted reach, the river is crossed by a single transverse concrete baulk which forms a low-lying weir crest. The concrete crest is shaped so that the left side allows a smooth flow and the right side creates a turbulent fall. While it acts as a low weir, NRW suggests that this feature may be a sewage pipe. If so, the inspection chamber mentioned above may relate to this. Its status and condition would need to be ascertained if it were form part of any development (see Option 3).

The potential route of a new leat may cross services relating to drainage, water treatment or water supply, and the electricity network. These include the potential sewage pipe and inspection chamber mentioned above, the pumping station and its mains electrical supply, other possible routes from the sewage works, and poles and underground cables near the substation on Lewis Street. Dwr Cymru, the council, and Western Power Distribution should be approached for plans of their infrastructure at this site.

Ground suitability and ground investigation

Much of the area may be assumed to have bedrock close to the surface, and in the river corridor itself the bedrock is clearly exposed. The bedrock of the immediate riverbank at locations where turbines could be sited is quite likely to be suitably stable. Substantial amounts of bedrock would have to be removed to form a wide discharge pool at the turbine tail.

The weir location has borne a substantial concrete weir in the past. It might be informative to confirm whether the weir had remained stable prior to its removal. A new weir would in any case be purpose-designed for the site. It will be important to establish the stability of the adjacent banks.

The old leat route has been built upon, and lies outside the probable site of a new scheme. Therefore it will not be possible to simply re-excavate the former route, taking advantage of any ground suitability or lining material which that channel may have offered. Instead a new route would have to be followed, either through the modern amenity pond, or by digging deeply into the higher ground bordering the river. These areas have recently been extensively landscaped with uncertain material, without an expectation that the ground would bear the weight of structures or conduct moving water. Old maps also show parts of this area within the river bend as having been marshland.

Ground investigation of all areas of the proposed site is therefore highly recommended. If the culvert is to be re-opened, this will require specific structural investigation, and also the adjoining area of the former forebay now occupied by the detached garage. Trial pits could perhaps be dug here and the stability of the outer bank wall assessed.

Land ownership and leases

Much of the proposed site area is owned or occupied by Llandysul Paddlers, who are understood to be favourable to considering the hydro scheme and how it might benefit their activities. A plan should be obtained quantifying the extent of their ownership and identifying which other ownerships are to be taken into account. Not only the use of land, but also the changed flow regime in the river will be of interest, in terms of maintaining amenity for canoeing, or even opportunities to improve conditions for canoeing.

Ownership to mid-river will be sufficient for planning and construction, but for operation it is prudent to identify parties owning the other half of the river and confirm that there will be no grounds for legal challenges to reducing the flow in the depleted reach.

Access routes or permissive paths across the site must be taken into account, and an allowance made for any additional footbridges needed if an open leat channel is recreated. It is understood that there is a proposal to erect a new footbridge across the Teifi from the park upstream of the proposed site, which may influence the layout of a footpath circuit.

For a scheme downstream of the bridge, the ownership, status, and use of the culvert must be confirmed. British Telecom may have some rights on the culvert which is said to contain telephone cables and is presumed to run close to the BT telephone exchange on Lewis Street. In order to accommodate a screw turbine at this location, the grassed plot containing the detached garage, downstream of the electricity sub-station, would have to be bought or leased, including the riverbank and bed to mid-river.

Reinstatement of a weir

For any scheme to perform reliably and effectively, a weir must be recreated to maintain head and inflow in all conditions; and to allow inflow to be quantified and meet operating conditions. Inspection of the features currently in the river concludes that these do not provide a means of guaranteeing head across a system using the former intake location. Without raising the level at the intake, the scheme would operate only intermittently, at higher flows, and would be particularly susceptible to stoppage by the inevitable movement of bedload material in the river. Nor would it be easy to demonstrate an agreed method of measuring and maintaining environmental minimum flows in the river, as would be required to allow operation. A weir of the former dimensions seems suitable - perhaps 1.5m from bed level, rising some 0.9m above current low water level.

Creation of the weir would be the most costly element of the scheme, the aspect likely to require the most environmental assessment and most likely to result in NRW refusing to grant a licence. NRW is opposed in principle to the creation of any new weirs, and has indicated that this one will be regarded as new. The ecological status and designations of the Teifi will exacerbate this opposition. NRW has made clear its stance in its interim advice (see Correspondence, at end):

> “A new impoundment in the river (the proposed re-creation of the weir) would not be acceptable as it would affect the natural functioning and hydromorphology of the river as well as impeding fish migration. This would be contrary to the conservation objectives of the Teifi Special Area of Conservation (SAC).”

The use of a permanent inflatable dam instead of a hard weir could reconcile the need for increased height with the option to lower the weir in very high flows, to reduce flood risk and maintain onward transport of gravels. If a weir is sought, it is therefore recommended that this possibility should be investigated. Any new weir would also require the provision of a fish pass. Interoperation of a collapsible weir with a fixed-height fish pass could be challenging and would require detailed work.

Using the low concrete crest feature as a weir might be a potential alternative way to avoid these fundamental issues, but this raises questions and challenges of its own (as noted in Option 3 below).

Installation: details of options considered

The system location needs to be selected to maximise the output while also minimising the installation cost. The options assessed in this study are described below. Smaller options would also be possible, but the significant overheads of this site would not justify these economically.

Water levels were measured on 26-27th June 2013, when the river (by the Llanfair gauge) was at the "Q83 percentile" of average annual flow. This happens to be representative of conditions in which the system would be just starting to operate. The measurements taken are therefore reasonably indicative of the maximum head likely to be exploited.

<u>Option 1a: Recreate the original scheme at or near the Pwerdy, making use of the former infrastructure as far as is now possible</u>

The Pwerdy once straddled its own intake channel and incorporated its turbines, but now it forms a solid mass presenting an obstacle to flow. An Archimedean screw is a physically much larger machine requiring a sizeable cross-section of intake channel. The presence of the Pwerdy itself therefore practically precludes installing an Archimedean screw here or further downstream. Assuming that the adjacent public toilets would also be retained in their current location, the scheme must then instead terminate on some point at the riverbank upstream of the toilet block. As this is a residential area, a small powerhouse would be built around the top of the screw turbine, to provide soundproofing around the machinery, as well as security: so the chosen location must have space available for this.

An undeveloped site is available immediately adjacent to the paddlers' accommodation, where the overspill tunnel emerges. However this location would give 900mm less head than at the Pwerdy (at Q83 flow), would require ground to be made up for the powerhouse, and also appears more exposed to erosion damage from high flows.

A better site is the grassed area where the detached garage stands. This has the minor disadvantage of losing very little from the head of the original scheme (100mm measured at Q83 flow; which would be offset by lower losses in the improved leat). As flows rise, it is likely that the profile of the bedrock (and indeed the protrusion created further downstream by the Pwerdy itself), would create a bottleneck increasing the tailwater level; this effect should be quantified by taking dated measurements of water level in different conditions.

The garage itself would have to be demolished; but a powerhouse could conceivably be rebuilt nearby with a similar form. Relocating the toilets might also facilitate design and construction, but initially the design could try to avoid this.

Other costs would include obtaining land ownership or leases, works to or under the roads, and preserving stability of the retained riverbank and the roadway of Lewis Street.

This site would have some benefits:

- proximity to the former scheme, for interpretation
- proximity to the adjacent electrical substation
- proximity to the roadside for convenient access by plant and deliveries
- any noise from turbine discharge is directed away from nearest properties, acoustically shielded by steep bank, and masked by water noise from rapids close upstream

Disbenefits would be:

- length and cost of leat route over multiple ownerships and culvert works to cross roads and services
- long depleted reach of river, and culverted leat, least favoured by NRW, with potentially most restrictive conditions on abstraction
- potentially costly and sensitive deep excavations in bedrock landform immediately adjacent to and supporting road and buildings
- services might need to be relocated: overhead electrical poles (and underground cables?) at Lewis Street; underground electrical and water services lying between Llandysul Paddlers and the Dwr Cymru pumping station off Pencader Road
- interruption to traffic during works due to plant movement

<u>Option 1b: As above, but enlarge the culvert to allow more flow</u>

The same infrastructure, but with larger channels sized to allow a scheme of 100kW, to maximise the return from the Feed-in Tariff. Benefits and disbenefits are similar. A horizontal boring company advises that it would not be possible to bore out the culvert, so this would instead be done by traditional shoring (essentially mining, proceeding under overhead protection), which would add significantly to the cost.

Option 2: Install a turbine at a new location upstream of the bridge

Much of the difficulty of restoring the former route would lie in negotiating the road crossing and rebuilt land downstream of Llandysul Bridge. Measurements were therefore taken to consider whether a scheme might instead be installed upstream of the bridge. A lower but still viable head was measured between the restored weir crest elevation and locations between the riverbend and Llandysul Bridge. Given the sequence of bedrock shoals and narrows, the preferable position seems to be at a point marked by two mature ash trees some 75m upstream of the bridge, in which position a turbine would enjoy a net head estimated at 3.4m. Moving any closer to the bridge than this was found to offer negligible additional head (25mm at Q83 flow). One or both trees would be removed.

A site in this area would have some benefits over a scheme nearer the Pwerdy:

- shorter and less expensive leat over level ground
- shorter depleted reach of river, and potentially no culverting - preferable to NRW
- avoidance of culvert works, roads, services
- site within single land ownership
- unobstructed working area with land available for temporary site compound

A scheme 75m upstream of the bridge would have benefits over a scheme immediately upstream of the bridge:

- minimises any risk of potential effect of works on bridge stability
- eliminates any change to flood flows at the bridge itself
- a less quiet site, closer to rapids where there is constant background water noise
- avoids risk that the bridge itself could act as an echo chamber to water noise
- the narrow bed channel upstream would provide a better onward signal to fish migrating upstream past the turbine

Disbenefits include:

- close to Bridge Street properties on the opposite bank: occupants may notice noise from turbine discharge in some conditions

The design flow for this option has been limited to provide a max power of 100kW for optimum economic returns at this FIT subsidy band.

Option 3: At Option 2 location, install a shorter turbine, using only the head from the existing low concrete crest

The low concrete crest at the riverbend provides a ready-made flow control structure which would allow water to be taken off at a new intake just upstream, without introducing a new obstruction in the river. An option, therefore, would be to make use of this much smaller fall in height (~1.6m net), to provide a more modest scheme at the same location as Option 2.

This option has been modelled without raising the crest of the low weir. In practice, the crest is asymmetric and would need to be given an even profile. While NRW advise that this feature is not currently an obstruction to fish, it might become so if flows were diverted, which in turn might prompt calls for a small new fish pass alongside.

This has essentially the same attributes of the location in Option 2, plus other benefits:

- avoids the large cost of a weir rebuild
- shortest possible depleted reach, least unattractive to NRW
- distant from STW outfall, therefore may reduce NRW concern re pollution dilution
- NRW advises that a rare bryophyte (moss) may be present downstream which could be impacted by the other options: this option may avoid the area in question

Disbenefits include:

- greatly reduced output and income
- lower levels needed (in same ground level) makes excavation very deep and costly
- if the crest feature is in fact a sewage pipe, the feasibility of modifying it would have to be established: its protective concrete casing would have to be slightly modified to act as a suitable weir crest; its route within the riverbank might require alteration to allow construction of the intake and leat; the implications of this for sewage transport would have to be acceptable.

The design flow for this option (and hence the max power) has been limited by the largest diameter screw which can perform efficiently with the small head available. To exploit more flow (hence higher max power), this scheme could be doubled (i.e. built with twin screws): but economies of scale in construction would be limited, and the increase in the modelled returns was insufficient to make this attractive. (If a single turbine of a different type could take a larger flow at this limited head, that might be an alternative worth investigating.)

Figure 15: Installation location for Option 1

Existing garage to be replaced with powerhouse, with wall or fence along line of pavement, enclosing a forebay of open water. The powerhouse would be visible here, but need not be obtrusive. The screw turbine would be hidden by the slope of the bank and might be invisible from the street.

Figure 16: Installation location for Option 1

Deep bedrock to be removed down to water level. The turbine would be highly visible from the north bank woodland footpath.

Figure 17: Installation location for Option 1

A simple photomontage sketch to approximate the appearance of a screw turbine installation in this location.

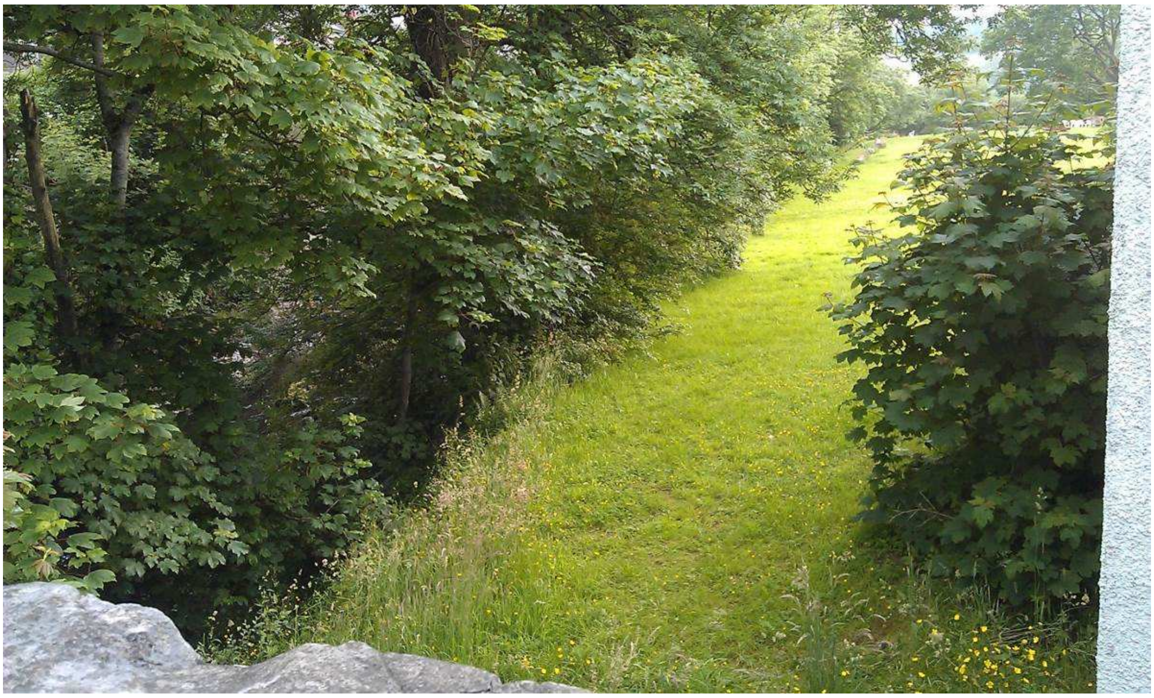


Figure 18: Installation location for Options 2 & 3

Views upstream from Llandysul Bridge. To install here would require removal of 1-2 mature ash trees and excavation of deep bedrock to form a tailrace (centre of upper photo). The lower end of the turbine would be visible from the bridge (to bus passengers - there is no pavement here as the pedestrian route is via the new footbridge to the west). A new powerhouse on the bank would be visible in the distance from here, though partly masked by trees (lower photo).

Figure 19: Installation location for Option 2

A simple photomontage sketch to approximate the appearance of an installation at this location. Option 3 would appear similar, but the water level in the leat would be 2m lower.

Figure 20: Installation location for Option 2

A simple photomontage sketch to approximate the presence of a screw turbine in this landscape. Option 3 would be a shorter screw set lower down, with more concrete at the top end.

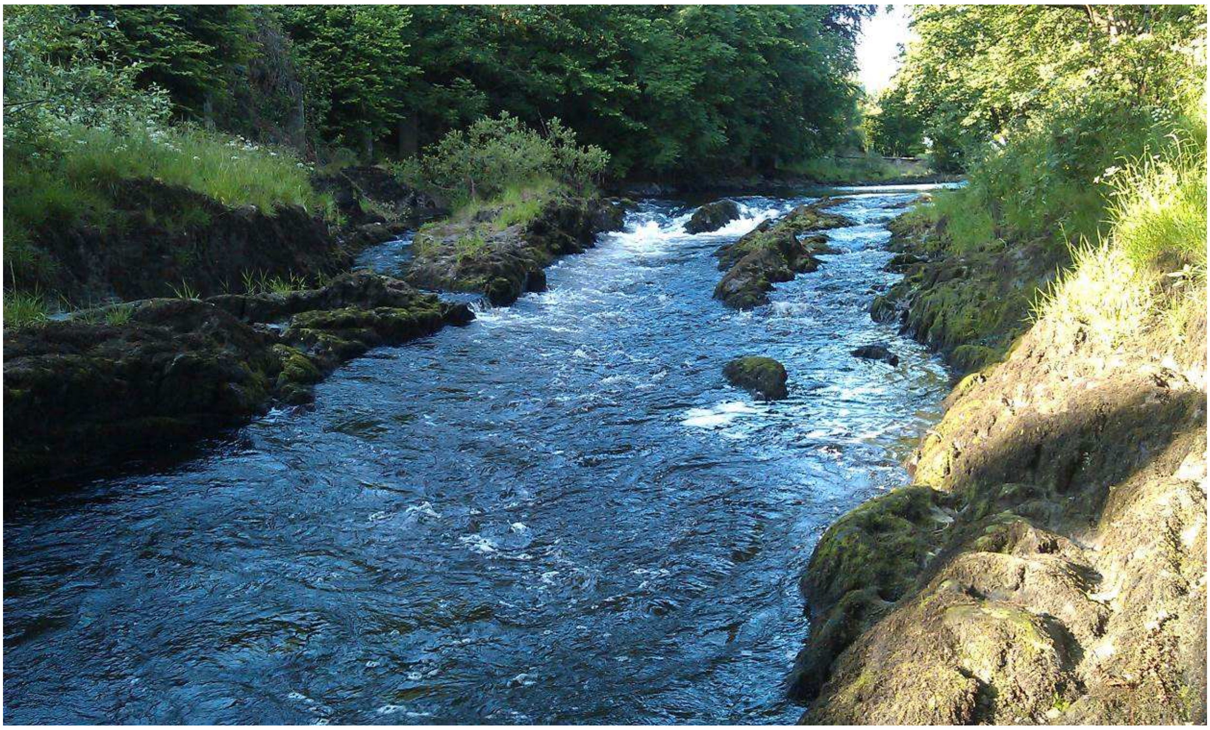


Figure 21: Installation location for Options 2 & 3

A simple photomontage sketch to approximate the presence of a screw turbine in this landscape.

Piped intake in the river channel?

For Option 1, an alternative to using the existing culvert to cross the road might be to convey the water along the river channel in a pipe, either in the riverbed, or suspended along the bank.

Laying such a pipe in the riverbed, which consequently needed to rise up again in order to deliver water at the turbine, would induce head loss and impact performance. It would in any case be challenging and expensive in engineering terms. There are many narrows and rock features, causing bends, so that the pipe could not be laid straight and must instead be assembled from custom-built sections. The form of this reach of the river is a shallow gorge, funnelling high flows and concentrating their force against the rocks further down, so that any pipe in the bed must be engineered to withstand the impact of this water and boulders carried along with it. For these reasons the pipe would be disproportionately expensive. Furthermore the presence of the pipe within the river cross-section would correspondingly reduce the capacity of the channel to hold and disperse flood flows. It would also reduce the amount of deep channel available for fish movement within the river.

If a pipe were instead to be suspended from the riverbank, again this would be a complex undertaking with a bespoke pipe: the rock face of the bank is not straight or consistent, the height above the riverbed is variable, and the pipe would have to be mounted to existing buildings in some places. Such a pipe is also likely to be too large and heavy to mount safely to the bank alone, with the implication of numerous supporting piers to be built up from the riverbed, requiring separate in-river works at all those locations.

Importantly, a pipe mounted along the riverbank would also have to negotiate Llandysul Bridge. While the bridge includes a circular aperture at each bank of a diameter which might seem to lend itself to routing a pipe of that diameter, these apertures are present to protect the bridge by relieving the pressure of flood waters against the abutments of the bridge arch. The bridge is listed Grade II, and there are already evident cracks in the masonry of the south abutment close to the circular aperture. Obstructing the flood relief aperture is therefore undesirable. It has been asked whether the relief function could be maintained by allowing the pipe through the aperture to flow freely under flood conditions. The implications of this expedient would have to be discussed with the bridge owners (council highways?) and Cadw; at the least, there would be a net reduction in the benefit of the aperture, as less water would pass through the aperture due to the wall of the pipe. Also, to have uncontrolled flow in the hydro infrastructure during high flow events is also undesirable, both for longevity and from the perspective of not depleting the river unnecessarily (i.e. when no benefit to electricity production).

In all cases, using a piped intake as a conduit for fish movement is unlikely to be favoured by NRW (see below), particularly for the length and scale proposed at Pontwelly. NRW would be likely to require fish to be kept out of the pipe, requiring screening to achieve this, hence losing a significant benefit of choosing an Archimedean screw over other turbines. For this reason, it has not been proposed that a piped intake should be used e.g. to consider cost reduction for the deep intake in Option 3. This would not exclude proposing a different turbine type; though many of the other obstacles would remain the same.

Multiple turbines to exploit wide variation in head?

The fact that the earlier scheme resorted to a variety of different turbines to make best use of high tailwater conditions raises the question of whether this would not still be an advantageous approach to take in a modern scheme. As regards tailwater rise, none of the locations currently possible at this site are ideal, as all are constricted by a relatively narrow channel downstream, which will act to hold back the tailwater as it exits the turbine, as well as holding back high flows in the river.

Archimedean screws cope relatively well in terms of output reduction due to reduced head. Due to the increased capital and civils costs of multiple screw installations, it has typically been judged more favourable to tolerate the marginal loss due to reduced head rather than increase the number, variety, and cost of screws. Downstream of the bridge, the potential riverbank locations are of limited width to install more than one Archimedean screw, even if these were each of smaller capacity. (Width reduction is not linear with capacity reduction.)

Also the operating regime of a new scheme would differ from the earlier scheme. Firstly, the earlier scheme ran in isolation as the sole means of supply for locally-connected users of electric lighting: it therefore prioritised maintaining a modest base load on all days during the hours of demand. Secondly, compared to screws or other large-flow devices, the turgo turbines could take only a relatively small flow – so the reduction in output at reduced heads was therefore more significant. This is rather different to a contemporary scheme, aiming (within agreed environmental limits) to take a larger flow, to maximise output around the clock and over the whole year, and to attract sale rates and subsidy for reducing national carbon emissions.

General installation considerations for Archimedean screw turbines

The Archimedean screw turbines considered here would be installed at an inclination of 22 to 26 degrees from horizontal.

An automated sluice gate will be required immediately upstream of the turbine, to close it off to flow when necessary, with a debris screen at that sluice to exclude large flotsam and mammals. An automated sluice gate is also recommended at the intake from the river, to enable management of the leat, with a debris screen here too to keep most coarse debris in the main river – ideally, angled to direct debris down the overspill.

Access to the top of the installation locations would be straightforward for all machinery, though introducing plant to excavate bedrock within the river might require temporary shallow sloping access causeways to be created.

Further investigations and consultations with the relevant statutory bodies will need to be made as the scheme design evolves.

In order to protect the equipment, and prevent the ingress of large debris and mammals, a screening system should be used with a wide bar spacing of up to 150mm. It should be positioned across the entrance to the new channel at an oblique angle to the flow of water, which will add an element of self cleaning and prevent the flow being impeded by debris.

Licensing and Planning

NRW licensing and permitting

Natural Resources Wales (NRW) is the successor to the Environment Agency (EA) in Wales, as of April 2013. NRW regulates many aspects of environmental protection and is particularly involved in the protection of inland waters. NRW recognises that hydropower proposals will need to be considered by several of its teams and will require a number of different permits. While there may be statutory periods for determining these permits (see below), in the case of hydropower NRW now expects most of the discussion process to take place within a pre-application period, which is subject to no formal time limit. NRW will then provide a written response of any remaining concerns, giving confidence as to whether a formal application will be approved. When the formal application is submitted, there is a statutory period of 4 (more rarely, 3) months for determining this, though this limit may be extended or exceeded.

Realistically a period of about a year should be allowed for the end-to-end process. It is usually advisable to progress NRW licensing as far as possible to achieve a firm design before applying for planning consent.

NRW levies no charge for its pre-application process, but it does normally require that the applicant has or will have access rights to the abstraction point, and progress may be slow unless a well-developed design is submitted as the starting point for discussion. NRW clearly hopes to dissuade applicants from submitting poorly-conceived schemes (not least to prevent them from gaining over any competing applicants at the same site who have followed due process to create a good design).

In the present instance, in order to prompt early discussion and response within the time frame for this preliminary study, Mann Power submitted a pre-application to NRW at an unusually early stage in the design process (June 2013), making certain reasonable provisional assumptions about the likely scale of the scheme. NRW's account manager for this project is Elizabeth James (Haverfordwest office: 01437 783053; Tuesday-Thursday).

A full response is awaited in mid-August in line with NRW timescales, and will be forwarded to the client. As NRW is expected to raise a number of fundamental concerns about a project at this site, interim advice was also requested (received on 25th July 2013). Correspondence is reproduced below, and reference to this is made in the present text.

During the pre-app process, NRW will decide which of the following are required.

Abstraction licence

An abstraction licence from NRW Water Resources is typically required for removing water from a watercourse. Normally this will be issued to run until the common end date for all licences in the local catchment. While these renewal dates are intended in principle to recur every 12 years, a licence issued now for NRW's Teifi management area will run until the next cycle ends in 2028. Upon review, there is a presumption of renewal if three tests are met: continued need, efficient water use, and environmental sustainability.

Although hypothetically the rules could change at any point, deeming a scheme unsustainable in some new way, most schemes in England and Wales are built upon the regulator's assurances of this presumption of renewal. In theory it is also possible to ask NRW to grant a long-duration licence (for an extra 12 years before renewal) for a scheme which poses no unusual risk; but this is extremely rare - and improbable at Pontwelly.

Impoundment Licence

This is required where changes are to be made to structures which impound water, such as weirs and sluices, or if new structures are to be built. An impoundment licence lasts for the lifetime of the impoundment and is thus not time-limited. (This fact would be of little benefit however, if the scheme also relies upon an abstraction licence to take out water, and if that licence were to be discontinued in future.)

The present scheme would require an impoundment licence to impose conditions on the new works in the watercourse, and also an abstraction licence – either a full abstraction licence (to remove water from an existing "source of supply"), and/or a transfer-type abstraction licence (if creating a new "source of supply", or e.g. directing flow through a fish pass). NRW will determine this based on the relevant legislation and on whether one or other permutation of these licences would add regulatory benefit. Either licence type is likely to attach similar conditions to the development (namely the protection of other water users' rights in the river, as well as issues discussed in the Environmental section).

The application fee payable to NRW is £135 per licence application. A single application fee is charged even if NRW then determines that 2-3 different licences or licence types are required. This excludes any professional fees, and the costs charged by NRW for mandatory advertisement of the applications. The latter may amount to £1000 depending on local newspaper advertising rates, in addition to an NRW administration fee of £100. As noted, NRW is now consulting on introducing charges for pre-app advice also.

However, the main cost of addressing regulatory requirements will be in the commissioning of any specialist reports which are required to satisfy any concerns raised by NRW (and/or by planners in response to statutory objections from NRW).

Fish Pass Approval

If a fish pass is to be installed or changed as part of the scheme, this has to be formally approved by NRW Fisheries before operation. This process is subject to no time limit, and can be protracted over a number of occasional meetings of EA/NRW's National Fish Pass Panel. There is no application fee, but the costs of specialist design and negotiation with NRW should be allowed for. On a salmon river, even a naturalistic channel provided as a new fishway may have to go before the panel for scrutiny, if not full approval.

Works-in-river consent

Consents of this type are required for all works to be carried out in the watercourse or within a certain distance of the riverbank (set in local byelaws). Consents consider the temporary impacts on the river of all construction works to be carried out for the scheme, for example by the release of concrete or oils during construction; and also permanent impacts of the operation of the scheme, to ensure no detriment to third parties.

A watercourse such as the Teifi is classified as "main river", and in this case, the permission is referred to as Flood Defence Consent. This is to be obtained by submitting a form, a cheque, and supporting documentation to NRW's local flood risk team. NRW will decide how many consents must be paid for, depending on the proposed structures and activities. Each individual consent costs £50, and a typical requirement is 1 for each new structure, and 1 for temporary works. There is a 2-month turnaround; but as this application cannot be processed without all supporting materials and plans, it is often sensible not to submit this application until during or after the planning application process.

In Wales, a Flood Consequence Assessment (FCA) is often required to assess the potential impacts of a new in-river development. Such an assessment must be proportionate to the scale and risk: while an informal assessment is often sufficient in smaller micro-hydro projects, in other cases a formal study is required which may entail a considerable cost. It is anticipated that a project reinstating a weir will prompt more detailed study, and NRW confirms that it would expect the FCA for this project to be costly.

Planning permission

Planning regulations were changed in 2010 to allow certain renewable energy projects to be considered within "permitted development", for example at the domestic scale. Hydropower, however, has not been brought under "permitted development", and planning permission will therefore normally be required.

NRW is a statutory consultee to the planning process in addition to its own licensing and consenting roles. NRW typically imposes planning conditions which *inter alia* prevent the operation of the scheme unless it has granted the appropriate abstraction and/or impoundment licence. The usual planning concerns of general design and visual appearance and construction of the new elements may be extended to archaeology of the groundworks and cable route, ecological impacts, safety protection measures and noise assessment. If necessary, the screw can be built so as to buried and hidden from view, though argument has been made that it may form a modern and functional enhancement.

Fees for the planning application depend mainly on the footprint of the proposed works. From Nov 2012, the fee is usually £385 per 0.1ha, plus a smaller supplement for the subsequent discharge of any conditions. Some authorities have held the fee at the old rate of £335. Listed Building Consent, where required, generally attracts no additional fee. Whether LBC is required will depend on the detail of the listing and the specifics of how the proposed works relate to the listed elements. Llandysul Bridge (Grade II) is believed to be the only listed structure in the immediate area.

Statutory EIA (Environmental Impact Assessment)

Hydropower at this scale is exempt from statutory EIA, unless there is a "risk of significant [negative] environmental impact". The relevant environmental concerns can usually be addressed perfectly satisfactorily by assessment and mitigation, without resorting to the additional costs of the specialised formal EIA process. Submitting documents under the title "Environmental Statement" may in itself invoke statutory EIA. Therefore this is inappropriate until and unless planners give a screening opinion that statutory EIA is definitely required. Past experience has indicated that even the presence of a designated area – for example, a SAC/SSSI such as on the Teifi – does not necessarily mean that there is a "risk of significant [negative] environmental impact". Planners will make their own judgement on this risk, informed by the evidence presented. The actual scheme design proposed, and any mitigation incorporated (e.g. fish passage), should be influential in this.

Environmental considerations

There are many potential environmental impacts as a result of installing a hydro scheme, all of which will need to be assessed as not unacceptable before the abstraction licence is granted. Therefore it is very important that the scheme design pays as much attention to these issues as it does to the actual efficiency of extracting the energy from the water.

The present study is written with reference to NRW's best practice recommendations for the design of schemes which are "not expected to pose environmental problems" ('*Good Practice Guidelines Annex to the EA Hydropower Handbook: the Environmental Assessment of Proposed Low Head Hydro Power Developments*': EA August 2009) and subsequent guidance notes published in Dec 2012, to which NRW continues to adhere.

Fish protection

Migratory salmonids (salmon and trout) and eels are at the forefront of NRW conservation efforts, but other species must also be protected. The status of the Teifi as a SAC/SSSI for salmonids will be NRW's prime concern when evaluating a project at Pontwelly.

Current NRW policy requires that the maximum protection must be given to fish, eels and lampreys; this is unlikely to change in the future. Legal protection is also provided through Water Resources Act 1991 (as amended) and compliance is regulated by NRW. To be able to comply with these requirements, there are two solutions:

1. If the machinery installed could potentially injure or kill any aquatic vertebrates, then a screen must be installed to physically keep them out.
2. Select machinery which is designed to permit the safe passage of aquatic vertebrates present in the river. There are currently only two turbine types which allow aquatic vertebrates and debris to pass safely through them: the waterwheel and the Archimedean screw.

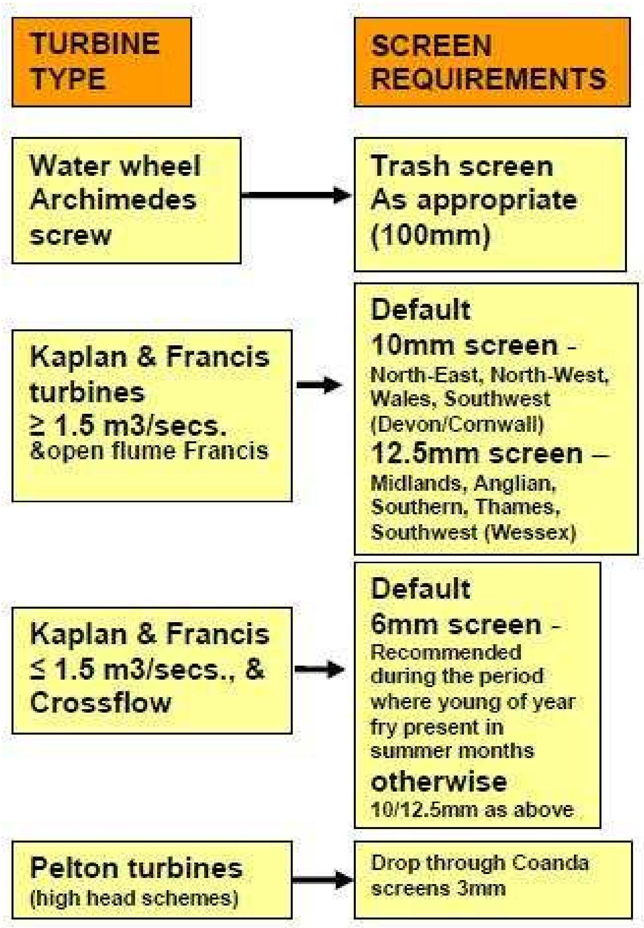
Archimedean screw installations have a proven track record of being fish-friendly and can cope with a range of river debris. NRW's guidance confirms "Archimedean screw turbines have been demonstrated to cause minimal damage to fish" when appropriately installed.

The ability to use more than three blades on a screw can produce improved output for the same amount of water taken. In 2011 the EA requested additional research to demonstrate that screws with 4 or 5 blades pose no additional risk to fish over those with 3 blades. The outcome of this research fed through into EA guidance (Sept 2011) showing that most screw designs (in a matrix of parameters) require no additional mitigation. (The concern in other cases is not that the turbine may cause physical harm - but that making a decision whether or not to enter the screw may cause delay to fish. In these cases it may be deemed necessary to add a downstream bywash so that fish can opt to pass around the screw rather than enter.) In Dec 2012 this guidance was tightened on a precautionary basis, i.e. without any further evidence having been presented. The resulting guidance further restricts the permissible range of turbine rotation speeds before a bywash requirement is applied. Notwithstanding this restriction, typically all but the smallest screw schemes will comply with the limits, and thus do not require a bywash under the guidance.

This acceptance that screws are not harmful to fish is reflected in less demanding recommendations for screening, reproduced below (adapted from EA Good Practice Guidelines 2009): Archimedean screws require only a coarse screen at the intake. The implications of these requirements for other turbine types are considered in the Appendix.

In an Archimedean screw installation, the assumption is that it is not necessary to exclude fish from the intake. Screening requirements are typically limited to providing only a coarse screen which safeguards against larger debris and which excludes mammals. Similarly, some alternative systems also require the outflow to be screened, to prevent fish from swimming into the tailrace. Here, tests on Archimedean screw systems have shown that fish are not harmed by approaching the outflow from the screw. No screening is therefore likely to be required, though there will be concern to ensure that onward upstream passage around the screw is available (see below).

Rubber bumpers are fitted to the edge of the screw blade. NRW has required compressible rubber to be used for screws with a higher rim speed, generally those screws with diameter > 2.5m. Smaller diameters, rotating at slower speeds, have to date been equipped with a standard hard rubber bumper, but this is subject to NRW review.



Effect of change in flow

The installation of a hydro scheme will divert water into the turbine. This creates a length of 'depleted reach' in the river, where there is less water when the scheme is operating. Hypothetically, a scheme could divert all of the water out of a river; but protection of the river environment means that this must not happen. NRW understands that a hydropower scheme may create a depleted reach, but seeks to minimise the length of depleted reach created, and to ensure that this does not have unacceptable impacts. Ensuring that an acceptable amount of water continues to bypass the turbine is usually achieved by NRW via conditions in the abstraction licence, imposing a minimum residual flow in the depleted reach, and a maximum design flow for the turbine.

NRW guidelines indicate that an amount up to the river's mean flow may be taken even if the depleted reach exceeds 200m. However at Pontwelly, the depleted reach at 400m-550m is long: NRW will be looking for mitigation for this, particularly as the river is considered important for salmonids. At this site, the maximum which would be allowed under NRW guidelines – the annual mean flow – is around 16 m^3/s. But the sizing of the new channels which would have to be created would recommend a maximum practical design flow smaller than this. Settling on a maximum flow of 4-5 m^3/s would therefore place a more modest demand on the depleted reach.

However, while NRW will allow an absolute maximum abstraction figure which may be as much as the river's mean flow, NRW also reserves the option – invoked at sensitive sites - to place a further limitation on the amount of flow which may be abstracted at any given time. This is to set a limit of a certain percentage of the flow available above the agreed residual flow. At Pontwelly, NRW has indicated that this limit would be 40%. The maximum abstraction at any time would therefore be only 40% of any water exceeding the agreed residual flow up to a maximum of the mean flow. This requirement proposed by NRW has been included in the present modelling, where it was found to reduce income (from what it might otherwise have been) by between 6% (Option 1b) and 19% (Option 3). Option 3 is particularly hard hit by this, because it relies on flow rather than head. Opposing this requirement would require lengthy and costly argument, which might yet be unsuccessful; but accepting it drives all potential options firmly beyond a 20-year payback period.

As regards NRW's Water Resource function, all options propose to use less than the maximum abstraction normally permissible under NRW's guidelines, so none of them would be held to place excessive demands on water availability for human use.

Derivation of the proposed flows is discussed further in the Hydrology section. Details must be confirmed and agreed with NRW during licensing to inform the design.

Upstream fish passage

Where changes are proposed to obstructions in any river, or flows in the river reduced, such as when diverting flows through a proposed hydropower scheme, NRW guidance has increasingly emphasised that opportunities should be taken to restore or improve fish passage. In all cases, proposed changes should cause no deterioration in fish passage. Where there is an opportunity to improve fish passage, this may favour the development of a hydropower scheme as a commercial means to helping fund such an improvement. However, at Pontwelly, this is not the case, as fish passage is considered optimal already.

Any proposal to replace or construct a new weir is likely to be met with extreme reluctance by NRW, as this runs counter to their programme of removing obstructions to fish passage, under UK compliance with EU Water Framework Directive. Creating a weir where there was no obstruction is very likely to cause deterioration in fish passage. The Teifi is a designated SAC/SSSI for salmon, sewin (sea trout) and other species. Therefore finding a satisfactory proposal for this issue of upstream fish passage is likely to be the largest regulatory challenge for this scheme. A new weir would almost certainly be expected to incorporate a very effective fish pass, as this is the most plausible solution to what would otherwise be a reduction in the ability of fish to pass the site.

Moreover, where the turbine is to be positioned at some distance from a proposed pass, NRW may require a second upstream fish pass to be provided at the turbine also. Any pass sited alongside the turbine will be expected to carry >5%-10% of turbine design flow to ensure that fish can locate the pass beside the outflow from the turbine. Allowance must then be made in flow calculations, and in designing the channel, for conveying this additional flow to the pass. If it was necessary to carry additional flow for a fish pass via a constrained channel such as the existing culvert, this would mean reducing the maximum capacity and output of the hydro scheme accordingly. The pass itself occupies a long space beside the turbine, requiring additional excavation and civils.

All the turbine discharge locations presently proposed would be at (and immediately adjacent to) narrow onward channels supplied with a suitable residual flow - where there is no uncertainty as to the onward route and no scope for fish to delay. For present purposes it is therefore assumed that no upstream fish pass at the turbine itself would be necessary.

Option 3 does not create a new weir, but does propose to modify the crest of the existing low weir, therefore a suitable (here short) fish pass might be called for to mitigate for any loss of passage here. Whether this is feasible depends on adjacent ground & sewage pipe.

At significant sites, the precise conditions and current or prospective fish populations have to be established via a site-specific fisheries study. The specification and feasibility of an appropriate fish pass or passes would then have to be discussed and its cost added into the analysis. As a very first step, therefore, the expectations of NRW Fisheries at this particular site would need to be clarified.

Downstream fish passage

Unlike other turbine types, the screw itself is not screened to exclude fish, and provides a channel through which fish can pass unharmed downstream. It has therefore typically been agreed that there is no benefit in creating an additional bywash to help fish pass downstream around the turbine itself. This avoids having to earmark flow in the leat to feed a dedicated bywash, retaining this flow for generation or to operate an upstream fish pass.

Recent schemes at “sensitive sites” on salmonid rivers have however been subject to a new NRW requirement to make special provision for the downstream migration of smolts. This can influence design of the weir crest and layout.

Transit of fish through new channels

Past EA policy has disfavoured the creation or reinstatement of closed and lightless culverts as transit routes for fish. In screened intakes, this is not a problem, because the fish are kept out. In an Archimedean screw scheme, where fish are allowed into the intake leat system, the new channel constitutes a passage route for fish moving downstream. Concern that fish may hesitate at shaded entrances or refuse to enter closed culverts is likely to mean that NRW will be reluctant to support the use of a piped intake of the length needed at Pontwelly. A scheme which does not make use of a culvert on fish routes will be preferred.

Hydromorphology

The channel at this site is hard bedrock and the scheme should not raise a concern of erosion or mobilisation of sediment within the river. Reducing the frequency of variable water flow in a depleted reach could impact the transport of bedload cobbles along the river; but the impact is unlikely to be unacceptable, as movement generally occurs in the highest flows, which will remain unaffected. A study of this may have to be commissioned.

Other ecology and biodiversity

Investigations should be undertaken at the next stage of the project, but this site is provisionally considered unlikely to raise issues which cannot be satisfactorily addressed by minor detailing.

Flood protection

It is important that, whatever equipment or screens are installed, they do not detrimentally impede the flow of the river while in flood; and this should also be the case even when the system is switched off. This issue is considered when works-in-rivers consents are applied for (above).

It is assumed at this stage that the location of this scheme would not exacerbate flooding. It would have to be demonstrated that the new structures that are introduced in the flood plain do not present an overall reduction in flood storage or flow capacity; that any increase in water levels upstream caused by the new weir will not cause unacceptable detriment to third parties upstream; and that flood levels rising from the leat will not cause unacceptable detriment to third parties. No flood data has been obtained or flood consequence calculations done at this stage. It can however be safely concluded that in terms of flood storage capacity and overland flow, the material excavated in forming the leat would more than compensate for the introduction into the flood plain of the modest structures in question: probably a single powerhouse structure at the top of the screw, at the scale of a large domestic garage.

It is also clearly necessary to ensure that any equipment installed is either waterproof or placed above the highest possible flood level. This is to prevent damage during times of flood. The gearbox and bearings are designed for temporary submersion, but the generator and control equipment are not. Therefore the powerhouse should be built high enough to position the electrical equipment above the worst predicted flood level. The generator can be mounted on the gearbox in the way most appropriate to avoid submersion, or, where this is impracticable, a submersible generator can be specified at a small additional cost; or the generator enclosure can be built as a watertight tank. An assessment would have to be made of what flood level to withstand at this site.

Photos of the floods of October 1987 show the ponded meadow filled to above street level and water flowing along Lewis Street to a depth of perhaps 600mm.
(http://www.ceredigion.gov.uk/utilities/action/act_download.cfm?mediaid=26744&langtoken=eng)
(http://www.ceredigion.gov.uk/utilities/action/act_download.cfm?mediaid=26745&langtoken=eng)
(http://www.ceredigion.gov.uk/utilities/action/act_download.cfm?mediaid=26742&langtoken=eng).

Pollution control

The hydro equipment must be designed and operated so as to prevent any discharge of oils, grease or other pollutants into the water, both when generating and when switched off during times of flooding. As a further precaution, the use of environmentally-friendly industrial products is advised, e.g. biodegradable oil.

Electricity connection

It is assumed at this stage that the electricity generated would be sold into the supply network without feeding a directly-connected local demand. Potential grid connection points exist close by which are likely to be suitable for connection of the proposed options – either at the substation on Lewis Street, or at the pole-mounted transformer for the Dwr Cymru water pumping station. This must be confirmed with the local District Network Operator (DNO), Western Power Distribution, and the cost of such a connection established.

However it is typically more advantageous to identify a local consumer willing to buy some of the output directly at a favourable rate, with benefits to both parties. It is therefore advisable to investigate whether a significant local user of electricity might be interested a direct connection arrangement – for example, the Tregroes plant nearby – before the onward connection to the grid is made.

A three-phase grid connection will be required, complying with the G59/2 standard, which means that stringent parameters must be met to satisfy the DNO. Connection costs consist of fitting a suitable cable between the turbine control system and a three-phase transformer, with possible upgrading of the existing transformer and local power lines. Suitable safety protection equipment, mains interface control unit, total generation meter and export meter will also need to be fitted at the turbine side of the connection.

Operational costs

Ongoing costs which must be taken into account include insurance, rates, meter reading charges, machine overhaul and servicing costs. These appear in the Cost/Benefit Assessment, though the labour component might be absorbed into ongoing site maintenance activities by personnel already present. The Archimedean screw solution dispenses with the need for fine screens, whose cleaning can considerably increase the maintenance. Using a screw not only reduces this operational cost, but minimises the extent to which debris build-up between such cleaning operations reduces the flow and affects the total annual output of electricity.

Income

Since April 2010, income may be calculated on the basis of the Feed-in Tariff (FITs) proposed in the 2009 Renewable Energy Strategy. This is available for the first 20 years of operation of all new small- and micro-hydropower installations built since 15th July 2009, and earlier schemes below 50kW. The previous model of support in the form of Renewable Obligation Certificates (ROCs) is no longer available for schemes below 50kW, and in all cases FITs offer higher returns than ROCs.

For renewables schemes below 50kW (“micro-generation”) to qualify for FITs, it was originally intended in 2010 that both the installer and equipment must be accredited under the Microgeneration Certification Scheme (MCS). DIY schemes are not covered by MCS and so would not attract FITs. For hydropower, however, the MCS process was delayed, then the Government undertook to review whether hydropower would require MCS or not.

Transitional arrangements are in place at present, whereby all hydropower is accredited for FITs in the same way. This requires the operator to register with OFGEM for the ROO-FIT accreditation process, aiming to become accredited at the system commissioning date.

Although indicative of policy at the time of print, the level and availability of FITs is subject to any subsequent change of policy. The Government’s intentions for future years were announced after a consultation in April 2012. The adjusted prices are intended to “rebalance” FITs “in favour of more cost-effective carbon abatement technologies”.

New for 2013 is a provision that even a scheme which has not yet been commissioned can now register in advance with OFGEM to obtain the current FITs rate, provided that it has already obtained the necessary planning and licensing consents. For hydro schemes which are installed and commissioned – or which have registered in advance in this way - by March 2014, FITs will remain at a level similar to the 2011-2012 rate (table below).

For the years from April 2014, degression will begin to be applied. Degression means that new entrants in each successive year will receive a rate which is less than if they had commenced the previous year. The reduction in each new starting year will be around 1p for schemes up to 100kW and 0.5p for larger schemes. In all cases, the policy remains that any scheme which has registered for FITs at a certain rate will continue to receive that rate (modified as index-linked) throughout the 20-year period of its entitlement to receive FITs.

	income (p/kWh output)								
	Feed-In Tariff April-Sept 2012*			**Feed-In Tariff Apr 2013-Mar 2014***			**Renewable Obligation certs (ROCs)****		
rated power	*Generation*	*Export*	*Total*	*Generation*	*Export*	*Total*	*Generation*	*Export*	*Total*
≤ 15kW	21.00	4.50	**25.50**	21.65	4.64	**26.29**	*not available <50kW*		
16 to 100kW	19.60	4.50	**24.10**	20.21	4.64	**24.85**	*>50kW as below*		
101 to 500kW	15.50	4.50	**20.00**	15.98	4.64	**20.62**	4.5	4.5	**9**
501 to 2000kW	12.10	4.50	**16.60**	12.48	4.64	**17.12**	4.5	4.5	**9**

*Index-linked, guaranteed for 20 years, once awarded.
From Apr 2014, annual degression is now proposed for new entrants each year - see text

The price obtained from FITs is made up of a generation element and an export element. Operators may make a one-time choice to forego the export element of the subsidy (at a guaranteed 'floor' of 4.64 p/kWh as proposed above), and instead enter the electricity market to compete for a better sale price. In either case they will still obtain the generation element of the tariff (between 12.48 and 21.65 p/kWh above) in addition to the export element. The nature of entry to this market means that a share of the potential sale price will always go to the wholesale customer and/or to a broker. Although initially (and at present price levels) this may seem more attractive than the fixed rate on offer, the outcome is subject to changing and possibly volatile market conditions. This study therefore applies a nominal export price of 5p/kWh to represent a combination of both.

Any scheme where electricity is consumed on-site ('displaced import') is likely to enjoy benefits in excess of those above, due to the higher retail costs thus avoided. The client advises that the nearby Tregroes bakery currently uses some 60,000kWh per year and might be interested in consuming output from a hydropower scheme. An offset retail rate of 10p/kWh may be used in place of the export element.

However, this more beneficial rate has been applied conservatively to only 40% of scheme output, as there will frequently be occasions when supply exceeds demand (overnight, weekends, cleaning cycles, etc). The resulting net contribution to the scheme income is only some £1200 of the annual total, so the overheads and conditions of such an arrangement would require careful consideration to ensure it was of clear mutual benefit.

There are further rules which modify the above assumptions in certain cases:

FITs have been classified as "state aid".
http://ec.europa.eu/community_law/state_aids/comp-2010/n094-10.pdf (ss59-62)
As of May 2011, applicants are disqualified from receiving FITs if any other grant from public funds has already been received (unless repaid). Recent experience indicates that preliminary costs (e.g. for establishing feasibility) are not subject to this rule. Beyond this, the only exception, i.e. the only cost now allowed to be funded out of public grants without prejudicing FITs entitlement, is that of "justifiable non-standardised expenses". This means grants for expenses which greatly exceed the standardised costs used to derive FITs rates. Exception is made solely for the cost of additional measures to protect the environment. This is subject to Ofgem's interpretation; but can explicitly include costs of providing or improving fish passage. It is reasonable to infer that other such site-specific costs incurred may also fall into this category; but this would have to be tested legally, and OFGEM have in the past declined to provide "comfort" (reassurance) in advance.
http://www.legislation.gov.uk/uksi/2011/1181/pdfs/uksi_20111181_en.pdf (s.8(3,4,6))

While a scheme of below 30kW is unlikely to be economically justifiable at this site, it may be noted in passing that such smaller schemes may benefit from "deeming" of exports. This is an interim arrangement made available under the FITs Order 2010, allowing smaller schemes to avoid installing an export meter until a future date when the rollout of smart metering is more fully clarified. Such schemes need not install an export meter, and instead the export tariff will be paid on a fixed percentage of the electricity recorded on the generation meter.
http://www.legislation.gov.uk/uksi/2010/678/pdfs/uksi_20100678_en.pdf (s14)
This disregards the amount actually exported, which may be as low as nil. While the cost saved by not installing the export meter is negligible, the additional gains may be significant for a scheme where electricity is consumed on site. For 2013-14, the "amount" on which FITs will be paid is confirmed as 75%:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/91914/FITs_QFC_determination_Feb_2013.pdf
In subsequent years the percentage may be changed, or this interim measure may cease.

Recommendations

The choice at Pontwelly would essentially be between:

- taking a modest flow at a high head (as was done in the 1920s) – more favourable to NRW's preferences for the Teifi – but which would now require head to be enhanced with a new weir – antithetical to NRW's guideline policy; or:
- taking a larger flow – less favoured by NRW for the Teifi with or without a new weir.

The Archimedean screw turbine has a proven track record of fish-friendly operation, efficient energy capture over a wide range of flows, and low running costs. It would be technically possible to install an Archimedean screw generating over 120kW at this site, or multiples thereof, if large enough channels were created. But a larger system using much of the available flow will take longer to pay back the investment, as it will operate at full power for a smaller part of the year, and may fall into a Feed-In Tariff band attracting a lower per-kWh return.

The high likelihood of regulatory opposition to a large-flow scheme at Pontwelly (and, on the Lewis Street site, the constraints on physical footprint) set a prudent upper limit of 100 kW. The flow required for this is only a modest proportion of the river, and is so regularly available that any of the options would be productive. Viability, however, is a function of the large civils costs involved - and of whether NRW will licence a scheme at all, for any of the layouts proposed. Where a site requires a weir to be (re)constructed, it is now likely the conclusion will always be "no" unless there are compelling environmental arguments.

Using a Kaplan or crossflow turbine might be an alternative to an Archimedean screw. They could perhaps reduce the footprint of the turbine/powerhouse, which could make choice of a site more flexible which might be an advantage for Option 1 on Lewis Street. Because these types must be screened to exclude fish, they would also not suffer from using a piped intake, which in turn may eliminate some of the cost of deep piled channels. But doing this would require the system (the leat at the intake or turbine, and probably the tailrace also) to be finely screened to exclude fish. This would remove the utility of the abstracted flow as a habitat and as a downstream passage for fish. This may reasonably be expected to be considered by NRW to increase the ecological disbenefit of abstracting from the river, which in turn prompts an even more restrictive flow regime for the scheme.

Further work would be required to confirm the estimates and assumptions made in this study and to start the process of obtaining a licence and procuring the necessary equipment:

- Discuss the various issues considered above with NRW as soon as possible, to identify any concerns, especially those which may be difficult to mitigate
- Obtain budget quotations from suitably experienced contractors for civil works of the scale indicated – the allowances here are estimates which it may be possible to reduce
- Measure the head at a range of different flow conditions, especially when the river is in high flow. Most important is to record the water level at the proposed turbine locations, making a note of date and time.
- Obtain permission and enlist volunteers to further excavate, explore, measure and record the culvert network
- Establish all land ownerships, and investigate willingness and likely costs of any leases or acquisitions needed
- Consult utilities companies to identify all buried and overhead services which may need re-routing or accommodating, and implications for dilution of effluent outfall
- Select the desired system location and sizing
- Draw up more detailed plans for chosen system
- Discuss planning implications with local planning officers, and Cadw if the listed bridge is implicated, and obtain the views of all other statutory consultees
- Consult with local interested parties such as Llandysul Paddlers, fishing organisations (e.g. Llandysul Angling Association and Teifi Trout Association), the Teifi Rivers Trust and other ecological organisations, local and parish councils, local history societies, other water users downstream, and immediate neighbours adjacent to the scheme
- Discuss with other neighbouring electricity users whether any larger demand is present locally, which may further enhance payback
- Obtain a quotation (budget quotation, in the first instance) from the DNO Western Power Distribution for connecting the scheme to the electricity grid
- Allow time for both pre-application and application for NRW licences, and for planning
- Be prepared to fund fisheries and ecological assessments re impacts of the scheme.
- Assess likely cost of local rates and meter reading charges, and electricity sales price

Correspondence with NRW

From: James, Elizabeth [mailto:Elizabeth.James@cyfoethnaturiolcymru.gov.uk]
Sent: 25 July 2013 14:34
To: Adrian Clayton
Subject: RE: HEP pre-application at Llandysul

Dear Mr Clayton,

Further to our phone conversation and your e-mail, I am writing to update you on our consideration of the Llandysul Community HEP pre-application.

We are not yet in a position to give our formal response at this time; we endeavour to respond to HEP pre-applications within 45 working days.

However, I am able to say that the current indications are that we would be unlikely to permit the scheme as proposed. The reasons for this include:

- A new impoundment in the river (the proposed re-creation of the weir) would not be acceptable as it would affect the natural functioning and hydromorphology of the river as well as impeding fish migration. This would be contrary to the conservation objectives of the Teifi Special Area of Conservation (SAC).
- The abstraction is very close to the discharge from the Llandysul Sewage Treatment Works and would reduce the dilution and may therefore impact on the water quality. There is also another permitted discharge location within the depleted reach.
- In addition to the features of the SAC which require protection, the SSSI designation includes a rare bryophyte which would be affected by the depleted reach of the proposal.
- Under the Habitats Directive, an Appropriate Assessment would be needed to look in detail at the impact of the proposal on the Conservation Objectives of the site.
- There are a number of properties at risk of flooding in Llandysul. A Flood Consequence Assessment would need to be carried out to demonstrate that the development has been made safe through design and resilient construction and that it does not increase flood risk elsewhere. The modelling that would be required as part of this assessment would be expensive.

Due to the ecological importance of the Teifi and its European designations, any potential HEP scheme here would score highly under the WALES methodology and the maximum abstraction that would be permitted would be 40% of the flow above the Q95.

During our conversation you asked if an alternative proposal may be more acceptable. We haven't had time to fully consider the alternatives and would need more information about any potential scheme before being able to respond in full, but I would suggest that Option 2 is likely to face all of the issues of Option 1, with the exception of the improved location of the discharge point.

Option 3 is more likely to be the basis of an acceptable scheme if it is able to utilise an existing structure. We are not aware of a weir at this location and believe that the structure which you mentioned is a sewage pipe which crosses the river. This structure could not be altered at all (other than minor agreed modifications); it currently does not cause any issues for fish passage. The abstraction and impoundment points are potentially in better locations. The depleted reach has been greatly reduced. However, at least some, if not all, of the above mentioned assessments and reports would still be required.

I would recommend that following the meeting on Monday 29th July, the community group wait until they have received our formal response and then meet with us to discuss their proposals before proceeding any further. I am happy for them to contact me (or you can send me their contact details) at the earliest opportunity so that we can arrange a meeting.

I hope that this information is useful for your meeting on Monday. If I can be of any further assistance, please do not hesitate to contact me. However, due to training, I am only in the office for the rest of today and then I am next available on Thursday 1st August.

Regards,

Elizabeth.

From: Adrian Clayton <adrian@mannpower-hydro.co.uk>
Sent: 23 July 2013 17:00
To: James, Elizabeth
Subject: RE: HEP pre-application at Llandysul

Hi Elizabeth,
As discussed this morning, please find three sketches of potential leat routes.

Ideally, if this is possible, I would like to receive a list of pointers before the end of the week, so that I can advise the applicant (community group) of main NRW concerns in my summing up (by Mon 29th).

Regards,
Adrian

Adrian Clayton
Hydropower Analyst
Mann Power Consulting Ltd

Archimedean Screw Hydropower Systems
Manor Farm, Kirkham Abbey, York YO60 7JS UK
tel: 01653 619968 / 07764 636270
email: adrian@mannpower-hydro.co.uk
web: www.mannpower-hydro.co.uk

From: James, Elizabeth [mailto:Elizabeth.James@cyfoethnaturiolcymru.gov.uk]
Sent: 27 June 2013 12:28
To: adrian@mannpower-hydro.co.uk
Subject: HEP pre-application at Llandysul

Dear Mr Clayton,

Thank you for your pre-application for a community HEP scheme at Llandysul. I will be your Area Account Manager for this pre-application. I am based in the Haverfordwest office and you can contact me on 01437 783053.

For your information, I am on leave from today until Tuesday 9th July.

I will send your application for internal consultation today so that my colleagues can start their consideration in my absence. I will be in touch with you in due course.

Regards,
Elizabeth.
Elizabeth James

Environmental Planning Officer
Cyfoeth Naturiol Cymru / Natural Resources Wales
Ffôn/Tel: 01437 783053

Please note that my working days are Tuesday, Wednesday & Thursday

www.cyfoethnaturiolcymru.gov.uk / www.naturalresourceswales.gov.uk

Ein diben yw sicrhau bod adnoddau naturiol Cymru yn cael eu cynnal, eu gwella a'u defnyddio yn gynaliadwy, yn awr ac yn y dyfodol.

Our purpose is to ensure that the natural resources of Wales are sustainably maintained, enhanced and used, now and in the future.

Twitter: twitter.com/NatResWales
Facebook: facebook.com/NatResWales
Flickr: Flickr.com/NatResWales
Youtube: youtube.com/NatResWales