

Lochwinnoch Hydro Feasibility Study





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1. Report summary

1.1. Introduction

Glen Hydro have been commissioned by Lochwinnoch LEAP to conduct a feasibility study into three potential hydro schemes on the Calder, Garple Burn and Millbank Burn. During the initial visit the scope of the study was expanded to include two further potential schemes on the Calder and a desktop review of hydro potential in the wider area.

1.2. Proposed schemes

Historic lade scheme on the Calder

This scheme is not assessed as a viable development. The original arrangement for the intake to the lade is no longer in situ. The costs of creating a new intake plus the difficulties in accessing the site make the estimated capital costs very high at £392,000. Generation potential will be limited to around 10kW as SEPA are only likely to grant an abstraction licence if a limited proportion of the flow is utilised. Overall returns are predicted to be under 2%.

Millbank

The difficult access, topography and ruined nature of the mill make this an awkward and costly site to develop. The presence of the mill pond in relative good repair is a benefit but the output of any scheme would be under 5kW. Estimated capital costs are £316,000 giving a very poor return at just in excess of 1%.

Garple Burn

A high head hydro scheme is possible on the Garple Burn. The scheme would involve an intake high on the right (main) branch of the burn with a turbine near the road bridge. There is potential to generate over 80MWh of electricity annually from a 21kW system. The site topography makes construction of the penstock difficult and costly. Overall capital costs have been estimated at £324,147. Returns are marginal, predicted at 5.26%. The scheme is likely to be acceptable to SEPA but early discussions regarding the assessment of the affected watercourse as a good fish habitat should be commenced.



1.3. Addition potential schemes

Calder upper lade scheme

This scheme lies just upstream of and on the opposite bank to the earlier identified lade. The remains of a lade exist upstream of the ruined mill. Access to the intake site and the lade is difficult and the mill is in a ruined condition. Civil construction costs would be high and the overall capital cost is estimated at £328,000. Allowed abstraction would also be limited giving a potential system sized around 10kW. Returns are poor at just over 2%.

Calder weir scheme

The weir downstream of the originally identified lade represents the best hydro potential so far evaluated. The proposed development would be compact, consisting of an Archimedes screw turbine installed on the east side of the weir. Construction costs are high at £406,547 but power generation and revenues are significant. A 50kW turbine producing circa 190MWh annually is proposed. Overall a return just under 10% is predicted. The scheme should receive SEPA approval and it is possible higher generation levels are achievable if a low or nil compensation flow can be agreed. Grid connection would need to be three phase, probably direct to the grid. A submission has been made to Scottish Power for actual costs to verify the estimate used.

Wider area potential

A number of watercourses in the area warrant further investigation, particularly:

- Maich Water
- River Garnock upstream of Kilbirnie
- Pundeavon Burn
- Carruth Burn
- Gotter Water
- Burnbrae Burn

2. Introduction

Lochwinnoch Local Energy Action Plan (LEAP) has commissioned Glen Hydro to undertake this feasibility study into three identified potential hydro schemes in the Lochwinnoch area. The study has subsequently been expanded to consider two alternative schemes adjacent to one of the original locations and a wider review of potential locations in the area worthy of further investigation.

The Lochwinnoch area has a long tradition of hydro power. In 1795 there were nine working mills in the area. The area contains a number of watercourses, largest of which is the Calder. Generally the watercourses flow in a south easterly direction with the majority feeding into Barr Loch and Castle Semple Loch and thence in to the Clyde catchment area. To the western extremity of the area, the watercourses feed in to the River Garnock which meets the sea at Irvine.

Lochwinnoch Local Energy Action Plan have identified three sites for potential hydro development:

- The Calder on the outskirts of Lochwinnoch
- Millbank Mill, 2km to the south west of the village
- Garple Burn running beside the golf course, 1km to the west of the village



Key potential scheme locations highlighted



General information regarding the source and interpretation of data relating to flow, head, environmental permissions, power generation and revenue are all included in the first section relating to the Calder. For the purposes of brevity these are not repeated in the ensuing sections.

3. Calder at Lochwinnoch

3.1. Site summary

The stretch of the Calder initially identified by LEAP lies on the outskirts of Lochwinnoch where an old lade runs close to the river along the left bank (looking downstream). At the end of the lade are the remains of an old mill site with evidence of a water wheel installation. Both the lade and mill site are in need of significant works to restore them functionally. The intake to the lade is not apparent. The upper end of the remaining lade is significantly above the normal river level and the historic water feed was either from further upstream, by way of a weir across the river creating an impoundment or via a leat above the river carrying water from the upstream mill on the opposite bank. This area is further explored in section 3.5.2 below. This potential scheme is referred to as the middle lade scheme.



*Location of the three potential Calder schemes:
Orange – upper lade scheme
Green – middle lade scheme
Red flag – weir scheme*

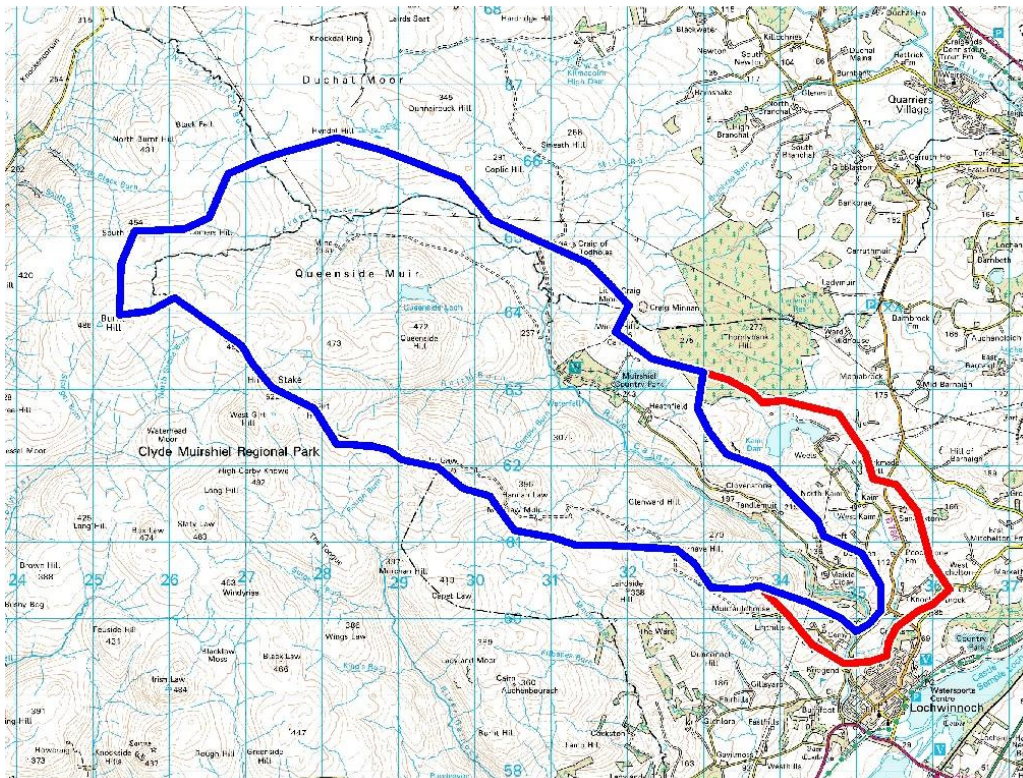
During the initial visit to the site by Glen Hydro, two further potential hydro development sites were identified close to the scheme above. Firstly, upstream is a steeper section of the river consisting of some small falls and natural pools. From the upper reaches of this section a further historic lade runs along the right

bank to the site of another old mill. The lade is broken in parts and the mill in disrepair. This is referred to as the upper lade scheme.

Secondly, the weir downstream of the middle lade and approximately 75 m upstream of the road bridge crossing the Calder also has hydro potential. This is referred to as the weir scheme.

3.2. Catchment area

The catchment area of the two lade schemes is essentially the same and has been calculated via contour mapping at 26.15km². Between the middle lade and the weir the Cloak Burn meets the Calder increasing the catchment area to 30.73km². The two catchment areas are shown on the map below.



Calder catchment area. Lade schemes catchment shown in blue. Extended catchment area of weir scheme shown in red.

Average annual rainfall levels in the catchment area are high, varying between 1600mm and 2800mm. The higher rainfall levels are found in the upland areas in the upper reaches of the catchment. These levels are above both the Scottish average (1436mm) and significantly above the UK average (1079mm).



3.3. Flow analysis

Predictions of the flows in the burn have been made using LowFlows, a software package widely used throughout the industry, including by SEPA. LowFlows calculates predicted flow levels based on historic rainfall levels and data on the local geology/geography which influences the amount of rainfall that runs off into watercourses.

LowFlows analysis gives the following data for the catchment areas detailed above:

| | Lade schemes | Weir scheme |
|--------------------------------------|--------------|-------------|
| Annual average runoff (mm) | 1873 | 1801 |
| Base flow index | 0.27 | 0.30 |
| Mean annual flow (m ³ /s) | 1.553 | 1.755 |

The runoff figure is the annual amount of rainfall flowing out of the catchment as surface water and is a factor of rainfall levels and the effect the local terrain & geology has on water retention/dispersal. It is useful as a relative measure of flow for different sized catchment areas. The predictions are significantly above the Scottish average (1049mm) reflecting the above average rainfall and the nature of the catchment area. They are nearly three times the UK average (645mm).

The base flow index is an indication of how quickly rainfall would result in water flow in the burn and is based on the local geology. Potential values range from 0.1 to 1.0 with lower values representing catchments that are 'flashy', i.e. rainfall will run off very quickly. For a large catchment area, the base flow index is relatively low, indicating that water levels will fluctuate reasonably quickly. A more moderate flow profile (i.e. higher base flow index) is beneficial to a hydro scheme as a steadier flow is available to drive the turbine more efficiently.

There is a Strathclyde Regional Council gauging station on the Calder at Muirshiel Park. The catchment area upstream of this station is 12.4km². Mean annual flow based on a long series of measurement is 0.649m³/s. Extrapolation of that data to the wider catchment areas downstream gives the following comparisons:

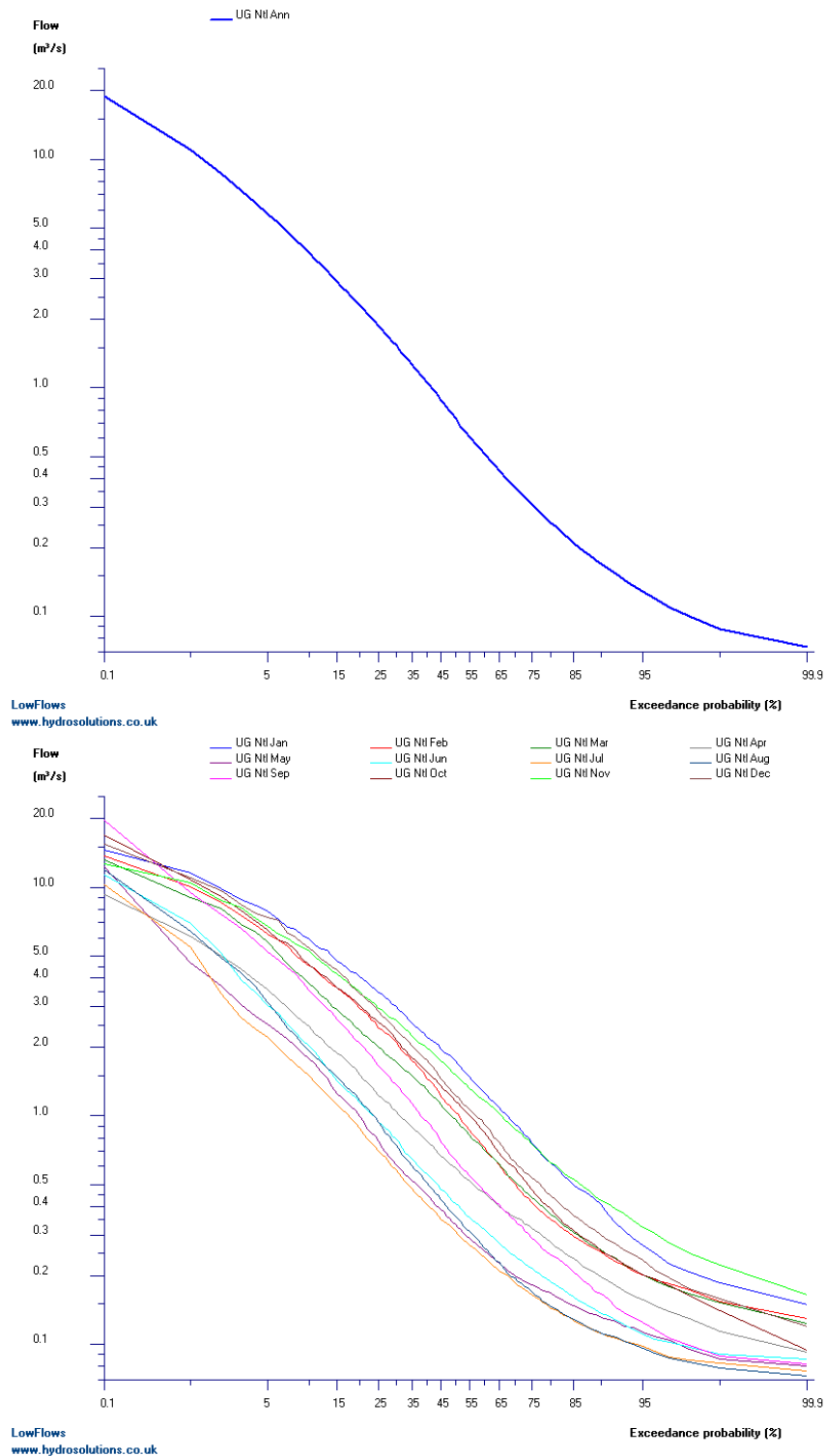


| | Lade schemes | Weir scheme |
|---|--------------|-------------|
| Extrapolated mean annual flow (m ³ /s) | 1.369 | 1.608 |
| Lowflows mean annual flow (m ³ /s) | 1.553 | 1.755 |
| Variance (m ³ /s) | 0.184 | 0.147 |
| Variance % | +13.47% | +9.12% |

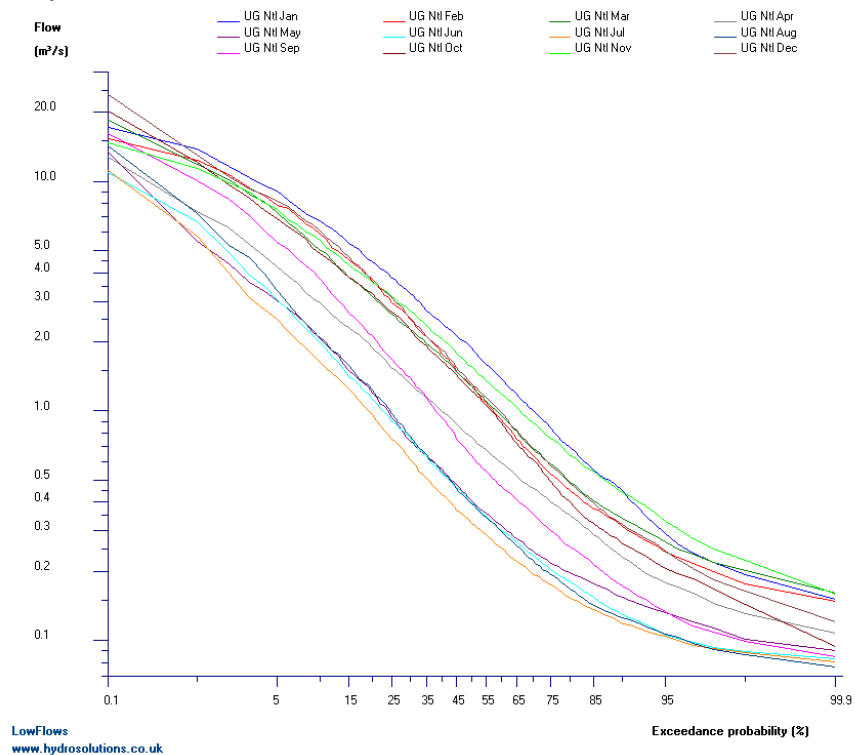
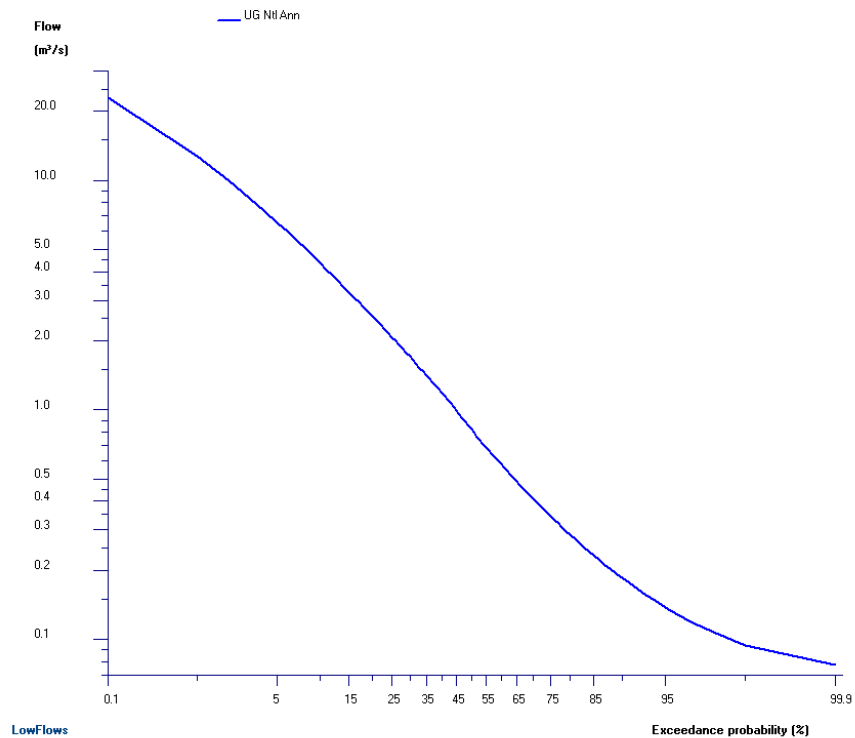
The Kaim Dam to the east of the Calder is the source of an abstraction understood to provide water to 7000 people. It is understood that the dam is fed by a pipe from the upper Calder catchment above Muirshiel Park and above the gauging station. It is expected that the primary source of the variation in flow figures is a result of water abstraction from the Calder to Kaim Dam, possibly with a proportion of that flow returned to the Calder via Cloak Burn. It has not been possible in the timescales of this study to verify the extent of any abstraction with Scottish Water. For the purposes of calculating generation potential and revenues the flow figures derived from LowFlows have been reduced by 185l/s for the lade schemes and 150l/s for the weir scheme, subject to a minimum residual flow of 130l/s. Further investigation of the effect of Scottish Water's systems on the flows of both the upper Calder and Cloak Burn would need to be established before the detailed design phase of any development.

LowFlows reports the flow as exceedence percentiles, commonly referred to as Qn levels. For example Qn30 is the flow level that is exceeded 30% of the time, i.e. 110 days per year. Qn90 is the flow exceeded 90% of the time or 329 days per year. Flow levels within LowFlows are given in m³/second (also known as cumecs). Lower flow levels have been converted to litres per second (l/s). 1 cumec is 1000 l/s.

Flow figures are predicted both annually and by month. The results can be plotted as a flow duration curve showing flow against the exceedence percentile. Both the annual and monthly natural flow plots for each catchment are shown below (i.e. before adjustment for the Scottish Water abstraction). A tabulated format including the Scottish Water abstraction profile above may be found as part of the generation models included in appendices E1, E2 & E3.



Lade schemes catchment area - Annual (upper) and monthly (lower) natural flow duration curves



Weir scheme catchment area - Annual (upper) and monthly (lower) natural flow duration curves



The performance of hydro schemes is impossible to predict with certainty due to variations in rainfall levels and therefore watercourse flows. These figures are based on widely utilised methods of predicting flow levels but are given as guidance only and should not be considered as a guarantee. In river flow monitoring should be undertaken to corroborate these figures and will be required as part of an application for a SEPA abstraction licence.

SEPA will generally require an agreed level of compensation flow. This is the flow which must be left in the river at all times (subject to sufficient natural flow) and cannot be abstracted for generation purposes. Its primary purpose is to maintain the ecology of the watercourse that would be affected by an extended dry regime. Typically SEPA would require the Qn95 flow level as the compensation flow for a catchment area of this size. This is normally the lowest compensation flow level permitted by SEPA (some small schemes require a Qn90 compensation flow). The actual compensation regime may vary from this due to the influence of the Scottish Water abstraction upstream. On the weir scheme it may be possible to agree a lower or nil compensation regime as the length of watercourse affected is minimal and already in an unnatural state. As a cautionary approach a Qn95 compensation has been allowed in the figures detailed in this report.

SEPA also require that the maximum abstraction is 1.3 times the average daily flow and that the compensation flow increase proportionally as abstraction levels increase.



Based on the adjusted LowFlows data and SEPA's abstraction guidelines, the following maximum abstraction regimes are derived:

| Qn % | Lade schemes* | | | Weir scheme | | |
|------|---------------|---------------|---------------------|-------------|---------------|---------------------|
| | Flow | Residual flow | Maximum abstraction | Flow | Residual flow | Maximum abstraction |
| 5 | 5.599 | 3.839 | 1.760 | 6.376 | 4.392 | 1.984 |
| 10 | 3.701 | 1.941 | 1.760 | 4.174 | 2.190 | 1.984 |
| 20 | 2.113 | 0.353 | 1.760 | 2.380 | 0.396 | 1.984 |
| 30 | 1.354 | 0.130 | 1.224 | 1.526 | 0.130 | 1.396 |
| 40 | 0.879 | 0.129 | 0.750 | 1.004 | 0.130 | 0.874 |
| 50 | 0.552 | 0.129 | 0.423 | 0.642 | 0.130 | 0.512 |
| 60 | 0.336 | 0.128 | 0.208 | 0.400 | 0.130 | 0.270 |
| 70 | 0.184 | 0.128 | 0.056 | 0.228 | 0.130 | 0.098 |
| 80 | 0.130 | 0.128 | 0.002 | 0.130 | 0.130 | 0.000 |
| 90 | 0.130 | 0.128 | 0.002 | 0.130 | 0.130 | 0.000 |
| 95 | 0.128 | 0.128 | 0.000 | 0.130 | 0.130 | 0.000 |
| 99 | 0.088 | 0.088 | 0.000 | 0.094 | 0.094 | 0.000 |

All figures m³/s

**see later environmental section for other restrictions on abstraction rates*

Actual maximum abstraction rates are determined by the rated flow of the turbine. On the lade schemes the maximum abstraction would more likely be determined by the lade size.



3.4. Historic (middle) lade scheme

3.4.1. Head

The absolute difference in water levels between the intake of a hydro scheme and the turbine outfall is known as the gross head. It is important that this measurement is established accurately in order to influence the detailed design of the system, in particular selecting the correct turbine, and to predict the power that will be generated.

The actual head available to generate electricity is reduced by two factors:

- a proportion of the potential energy of the gross head is lost in the system due to head loss in the lade or friction losses in the penstock
- the design of the intake structure, turbine and outfall require utilising some of the available head to enable efficient water flow and to site the turbine outfall above any spate river levels.

The resultant head that remains for generation is termed the net head. This is typically around 90% of gross head but varies by scheme type. On the proposed scheme, there is some significant head is lost along the length of the lade. There would also be losses at the outfall of the turbine, which must be sited so as not to become flooded during spate conditions.

The head available at the bottom of the existing lade (i.e. after the head loss along the length of the lade) has been measured by LEAP at 4.2 metres (see survey diagram in appendix A). The design losses in the system at to the outfall structure have been estimated at 0.7 metres. Therefore the resultant net head would be 3.5 metres.

3.4.2. Potential scheme summary, issues and operating principles

This scheme would use the old existing lade to provide a head of water at the foot of the lade. This flow would drive either an Archimedes screw type turbine, or a crossflow type turbine. A screw machine has the advantage that most of the construction work at the turbine site would take place at the top of the river bank where access is relatively easy. The work down at river level would be confined to the construction of a pad for the tail of the screw to sit on. A crossflow machine would involve the construction of a turbine house just above river level, which would be a relatively difficult and expensive process. For this site, we would therefore propose an Archimedes screw machine sited on the location of the old water wheel. This turbine would return water directly to the river Calder below.

LEAP have estimated the design flow of the lade to be circa 500l/s. This is the theoretical flow given by the Manning formula. When we compare this figure with



other similar lades that we have worked on, we believe this estimate is realistic. However, the amount of water that a scheme on this site would be able to abstract is limited by SEPA's guidelines (see environmental section below). When applying these guidelines to the site, the optimal rated flow for the turbine would be no more than 400 l/s, sizing the turbine at 10kW. This would give the scheme a capacity factor of 42.2%. A larger turbine with a higher rated flow would generate more electricity at peak output, but due to the reduced capacity factor and higher capital costs, the total generation and return make this a less attractive option.

The sizing of the turbine for any hydro scheme is a critical part of the design. If the turbine is too small, then some potential energy (and therefore revenue) is wasted. However, as the design size of the turbine is increased, the associated civils work and lade, or penstock, become larger and more expensive. The larger the design flow of the turbine, the lower the total period each year that the turbine will be operating at its rated flow.

Low head hydro schemes such as this are always difficult to construct cost effectively. This is because for any significant power to be generated, a large flow of water must be utilised. To manage and control this quantity of water requires significant amounts of civil engineering and concrete. Any scheme on this site should benefit from the existence of the old lade as the construction of new lades is a costly business. However, the site does have a major problem in that the head of the existing lade is approximately two metres above the current river level. It is thought that this difference in height is too great to have been caused by the erosion of the river bed since the lade was last operable. There is no evidence of the lade continuing further up the left bank of the river. Therefore it is surmised that the lade was fed from either a large impoundment (dam) in the river, or by a leat which could have crossed the river at this point, bringing the outflow water from the old mill situated across the river. An impoundment of the Calder to feed the lade at this point would be a significant structure, of which there is no evidence remaining. This part of the river does not lend itself to the construction of a dam, as the river bed is relatively wide at this point. It is thought that the old lade was therefore fed from the mill outfall on the opposite bank.

We have looked at the possibility of gaining the extra head required to feed the lade by constructing an additional length of lade, or penstock pipe leading from an intake farther upstream. However, the length of river bank along which this structure must be built is very steep and loose. The construction work to build such an extension to the lade would involve heavy machinery and a lot of material and would necessitate the construction of a solid river bank along this stretch of river. Such a scale of construction work in or next to the river would also be highly contentious with SEPA. In order that this work is done without polluting the river with large quantities of silt, a long length of the river would need to be protected by constructing a long, temporary coffer dam. The extended lade would require an intake structure to channel the flow of the river to feed the head



of the lade. This structure would need to span the entire width of the river and would need to be able withstand considerable spate flows. All of these factors make this scheme incredibly expensive to build.

The alternative solution to feed the historic lade would be to construct a large impoundment at the head of the old lade to raise the water level the necessary two metres. This again would be expensive. Access would need to be made along the route of the lade, where a temporary track would be constructed prior to the lade being reinstated. SEPA are not in favour of large impoundments such as this and are unlikely to allow it. In the unlikely event that they did, the conditions they would impose on their close scrutiny of the construction work in the river will only add to the costs.

A scheme on this site would be grid connected at a nearby property (for instance, at the old mill). At 10kW the scheme should be able to be connected via a single phase import/export meter. The grid connection to the property may require upgrading to facilitate this.

3.4.3. Environmental considerations, permissions and planning

The stretch of the Calder under consideration for these three potential schemes does not fall under any statutory environmental designation. Some areas of the upper catchment do fall within the Renfrewshire Heights Specially Protected Area and Area of Special Scientific Interest, but this is not expected to affect the proposed schemes. Within the Scotland River Basin Management Plan the 2008 classification of the Calder is poor. Close to the area there are a number of listed buildings and recorded monuments but none are believed to impact directly on the potential developments.

One of the principle challenges in the development of any hydro scheme is the grant of an abstraction licence from SEPA. In general SEPA are less favourable to schemes with a generating capacity 'under 100 kW' as there is an argument that the environmentally negative effects of a hydro development can outweigh the positive benefits of limited renewable energy production. They have issued comprehensive guidance outlining the factors that are considered in assessing any scheme.

We have assessed the potential middle lade scheme Calder against the checklist criteria set out in the SEPA guidance. These typically favour small, steep streams or those in a degraded part of the water environment. The key points are summarised and explained below. The assessment against the full checklist is shown in appendix B1.



| SEPA checklist assessment area | Affected reach of the Calder |
|--|---|
| Sited in degraded part of the water environment? | No |
| Small, steep rivers & streams | No, catchment area >10km ² |
| Providing benefits from the proposed scheme to the ecological quality of the water environment | No |
| Other proposals | Scheme provisionally acceptable if abstraction limited to levels that would not cause a breach of the river standards for 'good'. |

The scheme fails the majority of the criteria within the SEPA checklists and would only be acceptable if abstraction were limited to a level that is defined as not breaching the standards for a river of good status (as within the River Basin Management Plan). For a river of the category of the Calder this limits abstraction to:

| Maximum volume of water removed per day | | | |
|---|---|---|-----------------------------------|
| At daily flows > Qn ₆₀ | At daily flows < Qn ₆₀ to Qn ₇₀ | At daily flows < Qn ₇₀ to Qn ₉₅ | At daily flows < Qn ₉₅ |
| 25 % of daily Qn | 20 % of daily Qn | 15 % of daily Qn | 10 % of Q n95 |



This would mean that the following maximum abstraction regime is possible:

| Qn % | Middle lade scheme | | |
|------|--------------------|---------------|---------------------|
| | Flow | Residual flow | Maximum abstraction |
| 5 | 5.599 | 4.199 | 1.400 |
| 10 | 3.701 | 2.776 | 0.925 |
| 20 | 2.113 | 1.585 | 0.528 |
| 30 | 1.354 | 1.016 | 0.339 |
| 40 | 0.879 | 0.659 | 0.220 |
| 50 | 0.552 | 0.414 | 0.138 |
| 60 | 0.336 | 0.269 | 0.067 |
| 70 | 0.184 | 0.156 | 0.028 |
| 80 | 0.130 | 0.111 | 0.020 |
| 90 | 0.130 | 0.111 | 0.020 |
| 95 | 0.128 | 0.115 | 0.013 |
| 99 | 0.088 | 0.079 | 0.009 |

This will limit the generating capacity of the scheme from the normal abstraction levels expected.

It is possible that SEPA will require some form of environmental survey(s) once the formal abstraction licence application is submitted, although as the location is not assessed to be particularly environmentally sensitive, these are not expected to be too extensive.

3.4.4. Scheme costs

The construction costs for this scheme would be very high and are not easy to accurately predict. The construction of the turbine site alone, including the cost of a screw turbine would be in the order of £120,000. Unfortunately on top of this price there would be the following costs:

- Building an access track along the route of the old lade
- Repairing and reinstating the lade
- Building the impoundment and intake structure
- Silt contamination measures and river diversion work whilst building the intake structure



We estimate that the above works would involve additional expense of approximately £170,000. With other project costs (grid connection, project management, site preliminaries, etc.) the total cost of this scheme is estimated at £392,000.

On-going costs to cover maintenance and some limited capital replacement are expected to average £1,500 for at least the first 10 years of the project, although expenditure in the early years would be expected to be much lower. These costs allow for 'in house' screen cleaning and routine checks and for third party mechanical and electrical routine maintenance. Additionally LEAP may wish to consider damage and/or loss of income insurance.

3.4.5. System power generation, revenue & return

3.4.5.1 Scheme power generation

The power generation based on the LowFlows predictions has been modelled on a monthly basis using our power generation and revenue model. The key pages of the model are attached in appendix E1. There will be periods of low rainfall and therefore low flow when no generation is possible and other periods when the scheme will generate at partial capacity. The generation models predict the following output:

| | |
|-----------------------------|-------|
| Total annual generation MWh | 37.0 |
| Capacity factor | 42.2% |

The capacity factor is the annual generation expressed as a percentage of the power that would be generated if the scheme were running at full power all the time. Additionally there is some possible power loss in the cable from the generator to the grid connection depending on the length of cable run. An allowance of 1% loss has been made.

3.4.5.2 Feed in tariff (FITs)

The feed in tariffs (FITs) guarantee a revenue for each kWh of electricity generated regardless of whether it is used locally or exported to the grid. The feed in tariff is guaranteed for twenty years from the start date (irrespective of any subsequent changes to the tariff regime – see below). Tariffs increase each April at the rate of inflation (RPI). The tariff rate declines with higher levels of generation as detailed in the table below. This is reflective of the reduced capital costs per kW of larger schemes.



| Generation capacity | Revenue p/kW h |
|---------------------|----------------|
| ≤15 kW | 20.9 |
| >15 - 100kW | 18.7 |
| >100kW - 2MW | 11.5 |
| >2MW - 5MW | 4.7 |

Tariff levels April 2011 – March 2012

This scheme would benefit from the highest band of tariff, currently 20.9p per kWh. This is scheduled to rise to 21.9p in April 2012 (the annual RPI rise) but this has not currently been factored in to the revenue analysis as it is probable that costs will also rise at a similar rate over time.

There has been much recent concern and media comment over the rapid changes made to the feed in tariffs for solar PV by the government. The government have recently issued a consultation document on proposed revisions to all feed in tariffs. In this consultation the only potential short term changes proposed to the hydro tariffs are to cap the lower band at 21p/kWh. This would have a minimal impact on the figures reported here as a rate of 20.9p has been used.

However it is proposed that from April 2014, all tariffs should be subject to a minimum degression rate of 5% per year. The proposed degression for hydro is shown in the table extract below.

Table 5: Baseline tariff profile to 2020/21

| Technology | Tariff band (kW TIC) | Generation tariff for new installations (p/kWh, 2012 prices) | | | | | | | | |
|------------|----------------------|--|--------|--------|--------|--------|-------|-------|-------|-------|
| | | Oct 12 | Apr 13 | Apr 14 | Apr 15 | Apr 16 | 17/18 | 18/19 | 19/20 | 20/21 |
| Hydro | ≤15 | 21.0 | 21.0 | 20.0 | 19.0 | 18.0 | 17.1 | 16.2 | 15.4 | 14.7 |
| | >15-100 | 19.7 | 19.7 | 18.7 | 17.7 | 16.8 | 16.0 | 15.2 | 14.4 | 13.7 |
| | >100-2000 | 12.1 | 12.1 | 11.5 | 10.9 | 10.4 | 9.8 | 9.4 | 8.9 | 8.4 |
| | >2000-5000 | 4.5 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 | 2.3 |

In addition to the annual degression, DECC are proposing that degression of the FiT rate is triggered upon achieving a given level of installed capacity. For example, if 55MW of hydro capacity is installed before 2014 then the 2014 FiT rate will come into force after a 3-month delay.

It should be noted that once a scheme has obtained agreement of its FIT rate, that will not change. The degression in future years refers to a reduction in the FIT offered to a new scheme being developed in the future. The above figures



are at 2012 prices and the index linking should alleviate or potentially cancel the depression in real terms.

The consultation is believed to reflect the worst case scenario for hydro tariffs and the industry are actively lobbying for a less aggressive depression regime, primarily in the form of a later start date. What is certain is that if planning to develop a hydro scheme, a better return will be achieved if developed soon rather than in a few years time.

3.4.5.2 Energy usage & sales

Electricity generated by the system can either be utilised to offset current electricity purchased or exported to the grid and sold. The former has financial benefits in that the cost of the electricity saved is in excess of that paid for exported electricity. As the specific grid connection for this scheme has not been established, no benefit of locally used electricity is included.

Electricity exported to the grid is guaranteed a revenue which is currently 3.1p per kWh and will rise to 3.2p on 1st April 2012 in line with the FITs RPI increase. It is possible to negotiate higher returns with electricity purchasers, up to 6p per kWh for larger schemes at current electricity prices. A conservative estimated sale price of 3.5p per kWh has been used in the financial projections and it is hoped this could be bettered on negotiation of an actual contract and as electricity prices probably increase.

3.4.5.4 Projected income

The breakdown of returns is shown in the generation and return model attached in appendix E1. In summary:

| | |
|---|--------|
| Annual total power generation (MWh)* | 37.0 |
| Annual net power generation, after losses in cable (MWh)* | 36.6 |
| Feed in tariff | £7,726 |
| Exported electricity | £1,281 |
| Gross revenue | £9,007 |

*The feed in tariff is payable on the total power produced, whilst only the net power after losses in the cable is available for export.



3.4.5.5 Return on investment

Allowing for the on-going costs as detailed in section 3.4.4, the following net revenues and returns are delivered by the scheme:

| | |
|------------------------------|----------|
| Net revenue | £7,507 |
| Scheme capital cost | £392,000 |
| Return | 1.92% |
| Undiscounted payback (years) | 52.22 |

Both returns and payback do not utilise discounted cash flows as both the feed in tariff and electricity sale revenues will increase in future years with RPI rises and this approximately negates the discounting of future cash flows. Full discounted cash flow analysis could be undertaken once the source and cost of funding is established.



3.5. Upper lade scheme

3.5.1. Head

The gross head available for this scheme is the difference in water levels between a natural pool formed in the rocks at the intake and the river level next to the old mill building. This has been measured by LEAP at around 4.7 metres. It appears from our observations that around 0.7 metre of this head is lost in the fall required for the lade. In addition a further 0.5 metre is allowed for the outfall from the turbine to ensure clearance from flood river levels. This gives an effective net head of 3.5m.

3.5.2. Potential scheme summary, issues and operating principles

This scheme would be a reinstatement of a historic lade fed scheme which is unusual in that it has an intake structure which is mostly a natural rock formation. This intake is situated in a pool part way down a waterfall. The pool is apparently often used by local children as a swimming venue. Both the lade and the old mill building, at the foot of the lade where the turbine would be sited, are in a ruined state.

The historic construction of the intake is somewhat of a mystery as the river level needs to be quite high in order for water to enter the lade over the natural rock lip at the lade entrance. The lip of the fall was probably artificially raised using some sort of wooden structure when the mill was operated in lower water levels. There is some evidence of old steel or iron fixings in the lip of the waterfall to support this theory.

In order to make a workable hydro scheme the lip of the natural waterfall would, once again need to be raised in order to achieve the desired water supply into the lade at lower water levels. With modern techniques, this would now be most cost effectively done using reinforced concrete. This work may raise environmental concerns that would need to be addressed with SEPA and/or SNH. The intake to the lade would need an automated sluice gate to control flow to the turbine. This could be on the site of the old sluice which is still recognisable. The control gate would be hydraulically operated.

The access route to the intake site is not straightforward. A temporary access track would be required through the private gardens along the river bank, and a ramp to allow access to the site. The construction of this track would need to be done carefully in order to prevent further damage to the lade.

The lade dimensions are similar to those found downstream at approximately 1 metre wide and 0.6 metre deep. The size of a scheme developed on this site would again be restricted by SEPA's limitations with the optimum rated flow of a



scheme also being 400 l/s and generator sized at 10kW. This would give the scheme a capacity factor of around 39%.

The lade is in a reasonable condition for around half of its length. However, there are sections that are in need of some repair and there is a section of around 15 metres which has totally collapsed. All sections would require some refurbishment and the collapsed section would need to be rebuilt. Again access to this work would not be easy; a temporary ramped access track would need to be built to allow civil engineering machinery access.

The turbine for this site could be an Archimedes screw machine or a crossflow machine. The screw machine would cost considerably more than a crossflow turbine. Since a turbine house for a crossflow machine could conceivably be constructed just above spate river level, there is less of a saving available from the reduced civil works necessary for the installation of a screw machine. It is probable, therefore that a crossflow machine would be the best selection for this site.

The planned use of the old lade means that the site of the old water wheel is the obvious selection of a site for a new turbine. The wheel used to run in a wheel well on the back of the old mill building. This building is now not much more than a ruin. It is difficult to see how any of the civil work necessary for the installation of a turbine can be undertaken without either demolishing the old mill, or completely restoring at least part of the old building. Either one of these options is likely to be very expensive and may well require planning permission.

The simplest grid connection would be through the nearby house, which could be done at single phase, but may involve some upgrade of the single phase supply.

3.5.3. Environmental considerations, permissions and planning

The general designation and site comments for the middle lade are also applicable to this scheme.

Similarly, we have assessed the potential upper lade scheme against the checklist criteria set out in the SEPA guidance. The slope of the affected reach is much more significant at 4.7 metres gross over an approximate distance of 60 metres, giving a slope of 7.8%. However, despite this, the catchment area, at over 10km², means the section does not qualify as a small steep stream and the assessment is exactly the same for this section as the middle lade scheme. Therefore the scheme would only be deemed provisionally acceptable if a similar limited abstraction regime were undertaken.



3.5.4. Scheme costs

There are a number of work fronts to this scheme which cumulatively make it a very expensive scheme for its size. These are:

- The work on the modifying the natural fall
- The work to rebuild the parts of the lade which have collapsed
- Access for both the items above
- The necessary civil work for a turbine and turbine house
- The work required to demolish or renovate the old mill building

Without inclusion of any costs for work to the mill building, our estimate for the above work is £328,000. The additional work required at the mill building is very difficult to estimate, but would only add significantly to the costs of this scheme.

On-going costs are expected to average £1,500 for at least the first 10 years of the project, although expenditure in the early years would be expected to be much lower. These costs allow for 'in house' screen cleaning and routine checks and for third party mechanical and electrical routine maintenance. Additionally LEAP may wish to consider damage and/or loss of income insurance.

3.5.5. System power generation, revenue & return

The power generation and return, based on the LowFlows predictions, has been modelled on a monthly basis using our power generation and revenue model. The key pages of the model are attached in appendix E2. In summary:

| | |
|---|--------|
| Annual total power generation (MWh)* | 34.3 |
| Capacity factor | 39.21% |
| Annual net power generation, after losses in cable (MWh)* | 34.0 |
| Feed in tariff | £7,179 |
| Exported electricity | £1,190 |
| Gross revenue | £8,369 |

This scheme would benefit from the highest FIT band of tariff, currently 20.9p per kWh. This is scheduled to rise to 21.9p in April 2012 (the annual RPI rise) but this has not currently been factored in to the revenue analysis as it is probable that costs will also rise at a similar rate over time. As the specific grid connection



for this scheme has not been established, no benefit of locally used electricity is included.

Allowing for the on-going costs, the following net revenues and returns are delivered by the scheme:

| | |
|------------------------------|----------|
| Net revenue | £6,869 |
| Scheme capital cost | £328,000 |
| Return | 2.09% |
| Undiscounted payback (years) | 47.75 |

Both returns and payback do not utilise discounted cash flows as both the feed in tariff and electricity sale revenues will increase in future years with RPI rises and this approximately negates the discounting of future cash flows. Full discounted cash flow analysis could be undertaken once the source and cost of funding is established.

3.6. Lower weir scheme

3.6.1. Head

On the Calder weir scheme the gross head is easily measured using a long measure.



Head measurement on the Calder weir

The gross head currently available at the weir was measured at 4.5 metres. However, we agree with LEAP's view that there are two capping stones missing from the lip of the weir. If the weir was to be reinstated to its original height, then this head would be increased to 5.15 metres.

On the proposed scheme, the short distance between the intake and the top of the turbine means that the losses due to friction are minimal. However, some head is lost at the outfall of the turbine, which must not be permitted to become flooded during spate conditions. These design losses in the system due to the intake and outfall structures have been estimated at 0.75 metres. This estimation is conservative and it is hoped that during the detailed civil engineering design phase it could be improved upon. This would result in a greater generation output and therefore revenue.

The resultant net head that we have used in our calculations is 4.4m.



3.6.2. Potential scheme summary, issues and operating principles

This scheme has the advantage that there is no lade involved. There would be a simple intake structure alongside the existing weir. The abstracted water would then pass through a concrete trough around the side of the weir structure and be fed into the top of an Archimedes screw type turbine. This turbine would have an outfall into the river some metres below the weir.

3.6.2.1 Intake structure

This scheme would have a concrete intake structure constructed in the same position as the former head of the old lade, on the left bank of the river, adjacent to the weir. The relatively large flow of water being used by the turbine means that this structure needs to be substantial. The intake structure would contain a coarse filter to keep out large pieces of debris. Also incorporated in the structure would be a hydraulically operated sluice gate, which would control the flow of water into the turbine. This would enable the turbine to be shut down rapidly if required or for routine maintenance to the turbine. In front of the control gate would be the facility to manually insert wooden shutters to allow work to the control gate.

3.6.2.2 The weir

The existing weir structure makes a hydro scheme viable on this site. It is proposed to restore the weir to its presumed original height by adding 65cm to the lip. It is understood that this height was originally provided by two additional capping stones, which have since been washed away. Rather than replace the stones which could be washed away in spate conditions, this extra height would be best achieved by a reinforced concrete lip. Dowels would be added to the current lip of the weir along its length to tie into the reinforcing bar of the new concrete. This work would require the construction of temporary coffer dams to divert the river away from the section being poured and construction of scaffolding below the weir.

The detailed design of the modifications to the weir would be prepared by experienced civil engineers. We have included costs for this work by a consultancy company with a good pedigree of installed hydro schemes. The weir design could incorporate a v-notch or other means to ensure that any compensation flow required by SEPA is kept flowing over the weir.

In addition to providing additional head for the turbine to use, raising the height of the weir also allows the construction of the intake structure and the removal of the accumulated debris from upstream of the intake side of the weir in relatively dry conditions (i.e. before the lip is raised).



3.6.2.3 Turbine

There are three types of turbines potentially suitable for this site:

- Kaplan
- Crossflow
- Archimedes screw

The Kaplan turbine is essentially a large propeller, usually mounted vertically. The blades of the turbine are variable in pitch to allow efficient operation at partial flows. Kaplan turbines have the disadvantage that they are expensive. They also require significant civil works to duct the water into the top of the turbine and return water to the river from the lower end of the turbine. A Kaplan machine also requires a high degree of filtration of the water. If debris is permitted to pass through the turbine, there would be damage to the runner.

A crossflow turbine ducts the water into the top of a cylindrical runner. The energy from the water is passed to the runner both as it first enters the blades and again as the water exits the bottom of the runner. Compared to a Kaplan and a screw machine, a crossflow machine has a relatively low capital costs. However, the crossflow machine does require a pressurised penstock pipe and a high degree of water filtration. On this site this is a significant disadvantage as a large amount of civil works would be required to construct a filtered intake and penstock. In addition, the turbine house and outfall would need to be constructed down near river level below the weir, which would be very difficult to access.

The Archimedes screw machine works by ducting the water down a large steel screw, inclined at around 25 degrees to the horizontal. This machine has the advantage that the structure is self-supporting. The only civil works required at the bottom of the turbine would be the construction of a concrete pad for the foot of the turbine to rest on. The turbine comes complete with a guarded outfall.

The screw turbine also has the advantage that it is able to allow medium sized pieces of debris (and even fish) to pass through the turbine. Therefore the screen installed as a part of the intake structure can have a wider bar spacing of around 100mm. Both from an overall cost standpoint and for ease of operation, an Archimedes screw turbine is favoured for this site.



A typical Archimedes screw turbine installation, showing two 55kW machines

Based on the abstraction regime detailed in section 3.3, a turbine rated at $1.55\text{m}^3/\text{second}$ is appropriate. Because of the relatively short length of the scheme and therefore lower perceived environmental impact, this site is not subject to the same abstraction limits as the lade schemes. This turbine would generate 50kW at peak operation. The turbine and control system proposed for the Calder site are manufactured in Holland by Spaans Babcock. This company is very experienced in the manufacture of Archimedes screw type turbines and is highly regarded in the industry. If the project proceeds to construction, alternative bids would also be sought from Mannpower, an alternative supplier of these turbines. Spaans Babcock would provide a complete turbine and generator unit, including the control system which is bespoke manufactured in house. This has the advantage that the whole machinery chain is in one single scope of supply, simplifying the resolution of any issues during commissioning. The turbine quotation can be found in appendix D.

3.6.2.4 Generator, control system and method of operation

The generator is mounted on the head of the screw and its control system matches the output to the frequency of the grid. The generator, control panel and switchgear need protection from the weather. The gearbox and generator also emit a level of noise that would require a turbine house to attenuate it. This small turbine house would be built on top of the upper foundations for the screw, once the turbine is installed. The control panel and switchgear for the generator would also be housed in the turbine house. It is important from a safety viewpoint that



the turbine house is secure and cannot allow access to the electrical machinery by unauthorised persons.

The construction of the turbine house walls will be of concrete blocks, which could be faced in order to allow the structure to blend in with the surrounding glen. The exact finish to the turbine house would be decided in conjunction with the client and the Planning Authority. The building is sized to allow work to be undertaken on the machinery and will require a lifting beam for installing and servicing the generator.

The turbine is connected to the screw via a gearbox and a flexible coupling. The proposed generator is a 3-phase induction generator. Turbine operation is controlled by a computerised control system. This system ensures that the turbine optimises the power generation from the available flow. The control system therefore monitors the level of water upstream of the intake screen and controls flow by adjusting the inlet gate, controlling the flow through the turbine. The control system also ensures that the generated electricity is maintained at the correct frequency to match the grid. We would also incorporate a second level sensor behind the intake screen which would enable the control system to highlight when the screen becomes blocked with debris. The control system would be mounted in a lockable panel with the turbine house. The system would include a generation meter to calculate the FITs payment.

In order to be connected to the grid, the control system must comply with Engineering Recommendation G59/2, which specifies the safety and control characteristics of any generating system that is to be connected to a local distribution network. This standard sets out a series of parameters within which the generator must operate and also lists a number of situations in which the generator must be shut down. For example if the voltage or frequency were to rise above acceptable levels, the system would shut down. The unit also must shut down in case of an overall loss of power in the grid. This is very important, as the District Network Operator (DNO) needs to be able to work on repairs to the grid, safe in the knowledge that the turbine will not electrocute their work force.

The supplier of the turbine would have engineers on site during the commissioning of the scheme.

We have included the option of remote monitoring of the generator and control system. This would allow the client, or Glen Hydro, to monitor the unit via a web based portal and highlight any problems in its operation.



3.6.2.5 Grid Connection

As we have so far been unable to locate a nearby property with a 3-phase supply, we have based our grid connection estimate on a connection at the nearest 11kV/400V 3-phase transformer.

There are strict controls enforced by the local District Network Operator (DNO), in this case Scottish Power, regarding the location and method that is used to connect a hydro scheme to the grid. The first stage in the process of obtaining a grid connection is to apply for a grid connection offer. This process and that of evaluating the various options is not made any easier by the slow and laborious channels for communication employed by all DNOs, including Scottish Power.

An embedded generation facility of this size requires a connection at 3-phase. There is no obvious point of connection for a 3-phase supply. We have applied for a budget estimate for a connection for the scheme at the site of the generator. We have also used the experience gained in similar applications to estimate the grid connection costs. It must be stressed that the costs put forward by the DNO's for this work are notoriously difficult to predict. We have based our cost estimate on a grid connection to the 11kV transformer site approximately 400 metres due north-west of the proposed generation site.

3.6.3. Environmental considerations, permissions and planning

This scheme has the distinct environmental benefit that only a short stretch, around 10 metres, of the watercourse is affected. As with the two schemes above, the proposed design has been assessed against SEPA's guidelines for schemes under 100kW. The full analysis is in appendix B2 and is summarised below.

| SEPA checklist assessment area | Affected reach of the Calder |
|--|---|
| Sited in degraded part of the water environment? | No |
| Small, steep rivers & streams | No, catchment area >10km ² |
| Providing benefits from the proposed scheme to the ecological quality of the water environment | No |
| Other proposals | Scheme provisionally acceptable. Water abstracted from immediately above a drop (e.g. a waterfall, cascade or weir) and returned immediately below that drop. |



We assess the proposal as provisionally acceptable as long as the water is returned to the Calder within 10 metres of the foot of the weir.

Given the short distance of watercourse affected it is possible that SEPA would allow a lower or nil compensation flow than that detailed in section 3.3. This would result in a higher overall generation and might mean a slightly larger turbine were appropriate. This would need to be clarified in discussions with SEPA prior to submission of the abstraction licence application. Within this report the lower, cautionary, abstraction levels have been used allowing for a Qn95 compensation flow.

The screw installation and turbine house are likely to require planning permission.

3.6.4. Scheme costs inc. detailed breakdown

A detailed cost breakdown for this scheme is given in appendix C1. The projected total capital costs including project management and contingency are £406,547.

The major elements of cost of this scheme are split between the cost of the turbine generator unit and the civil works. The turbine and generator unit under consideration has been subject to a detailed site specific quote by Spaans Babcock. The turbine generator comes complete with control system, control sluice and an outfall. Installation of the turbine by Spaans Babcock is also included in the price quoted.

The civils work has been estimated following a visit to the site by our civil construction specialist, who has considerable experience at building micro hydro schemes across Scotland. Included in the work are the costs to raise the level of the weir to what we believe to be the original height.

Also a significant expense is the connection of this scheme to the grid. An application has been made to Scottish Power, the DNO, for a budget estimate for this connection. Unfortunately, in common with all DNOs, Scottish Power responds to these requests laboriously and slowly. In the timescale available to compile this report a cost has been estimated using our experience on similar schemes. The actual estimate from Scottish Power will be forwarded when received.

On-going costs are expected to average £4,000 for at least the first 10 years of the project, although expenditure in the early years would be expected to be much lower. These costs allow for 'in house' screen cleaning and routine checks and for third party mechanical and electrical routine maintenance. Additionally LEAP may wish to consider damage and/or loss of income insurance.



3.6.5. System power generation, revenue & return

The power generation and return, based on the LowFlows predictions, has been modelled on a monthly basis using our power generation and revenue model. The key pages of the model are attached in appendix E3. In summary:

| | |
|---|---------|
| Annual total power generation (MWh)* | 190.7 |
| Capacity factor | 43.55% |
| Annual net power generation, after losses in cable (MWh)* | 188.8 |
| Feed in tariff | £35,669 |
| Exported electricity | £6,609 |
| Gross revenue | £42,279 |

This scheme would benefit from the second FIT band of tariff, currently 18.7p per kWh. This is scheduled to rise to 19.6p in April 2012 (the annual RPI rise) but this has not currently been factored in to the revenue analysis as it is probable that costs will also rise at a similar rate over time. As the specific grid connection for this scheme has not been established, no benefit of locally used electricity is included.

Allowing for the on-going costs, the following net revenues and returns are delivered by the scheme:

| | |
|------------------------------|----------|
| Net revenue | £38,279 |
| Scheme capital cost | £406,547 |
| Return | 9.42% |
| Undiscounted payback (years) | 10.62 |

Both returns and payback do not utilise discounted cash flows as both the feed in tariff and electricity sale revenues will increase in future years with RPI rises and this approximately negates the discounting of future cash flows. Full discounted cash flow analysis could be undertaken once the source and cost of funding is established.



3.7. Calder recommendations

Both the originally identified middle lade scheme and the subsequently assessed upper lade scheme are highly unattractive economic developments. Both are likely to be restricted in the available flow for abstraction by SEPA, thus limiting their potential output to around 10kW. This in turn limits the potential revenue. The difficulties in accessing the intake and lade sites plus the significant civil engineering works required make the build costs very high. The resultant return is minimal and we could not recommend the development of either scheme.

The potential scheme identified at the weir will be much less contentious with SEPA and will be able to utilise a significantly higher proportion of the flow. The site has much better access and the overall physical extent of the works is much more compact. The proposed Archimedes screw turbine, associated generator and control system are an expensive item and significant civil works would be required. The only cost still awaiting confirmation is for the three phase grid connection. Subject to the formal estimate from Scottish Power being in line with our estimate we would recommend that this scheme is progressed.

4. Millbank

4.1. Site summary

Milbank lies approximately two kilometres south west of the village, close to the disused railway line. The mill building is now derelict, but the mill pond which fed it seems to be in a reasonable state of repair. There are the remains of an old lade leading from the northern end of the millpond to the back of the mill building. The lade is in the most part in a very poor state of repair; so much so that the top section of the lade is hard to locate. The final part of the lade was a flying leat which took the water into the mill building.

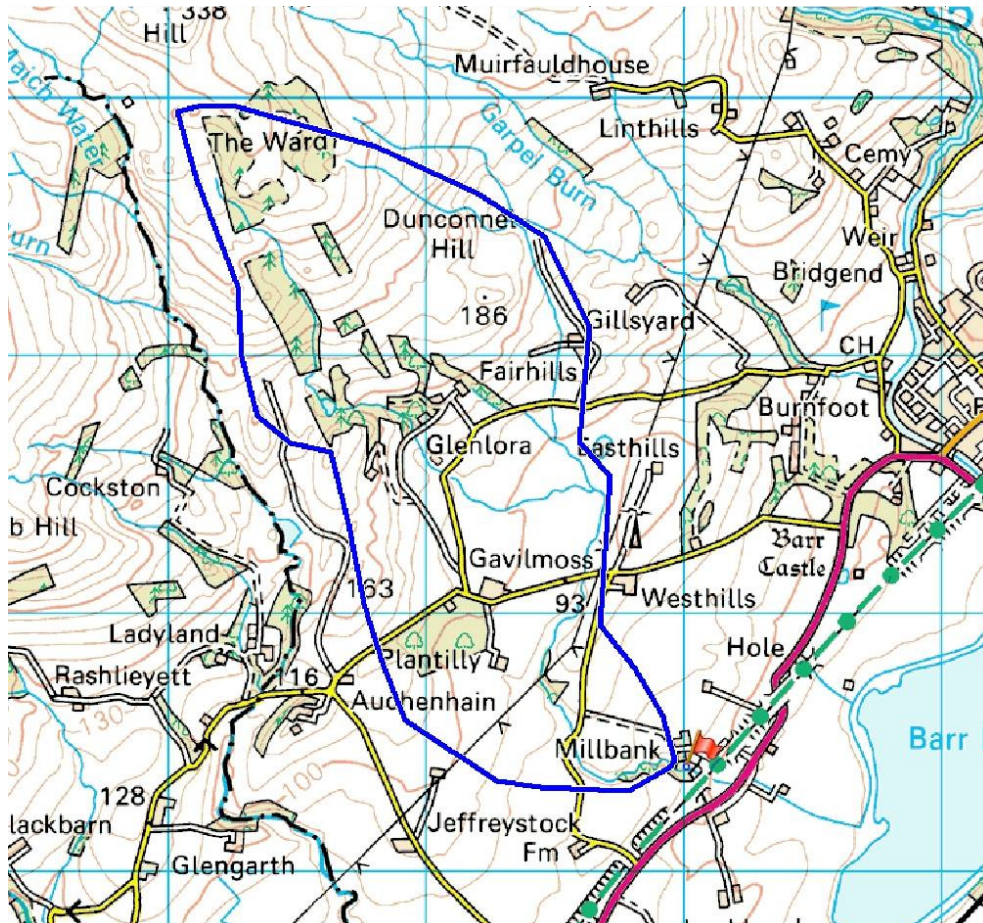
Access to the site is difficult as the primary approach is an old track which is now crossed by the disused railway line. Access to the site would be best made from the buildings to the north. This would require the construction of an access track over the fields and some sort of ramp to allow access to the level of the intake and lade.



Mill building highlighted with red flag

4.2. Catchment area

The catchment area of the potential scheme above the mill pond measures 2.86km² and is shown in the map extract below.



Millbank catchment area

Average annual rainfall levels in the catchment area are reasonably high, between 1600mm and 2000mm. These levels are above both the Scottish average (1436mm) and significantly above the UK average (1079mm).



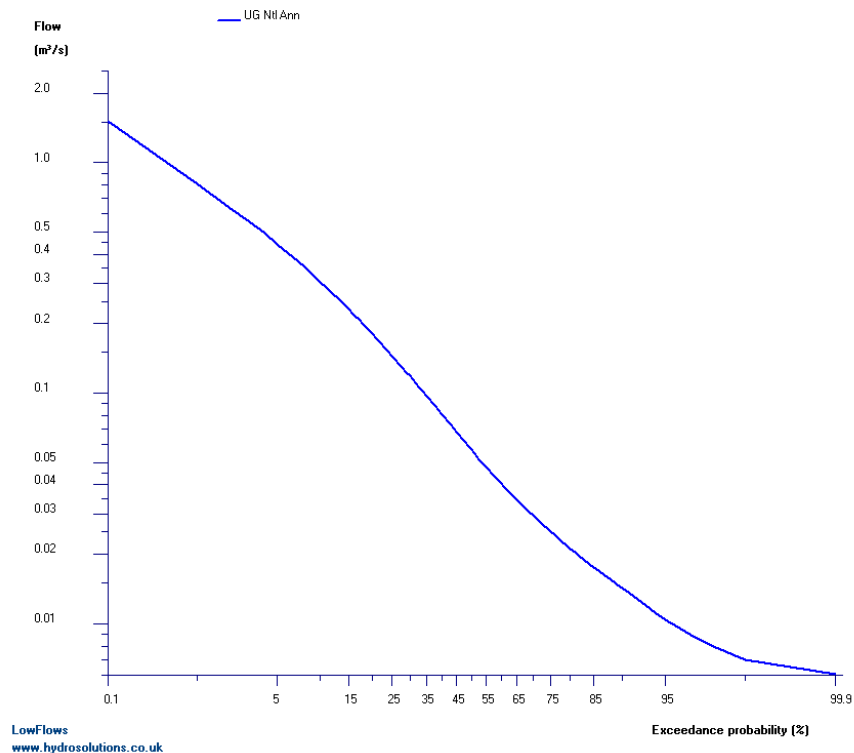
4.3. Flow analysis

LowFlows analysis gives the following data for the catchment area outlined above:

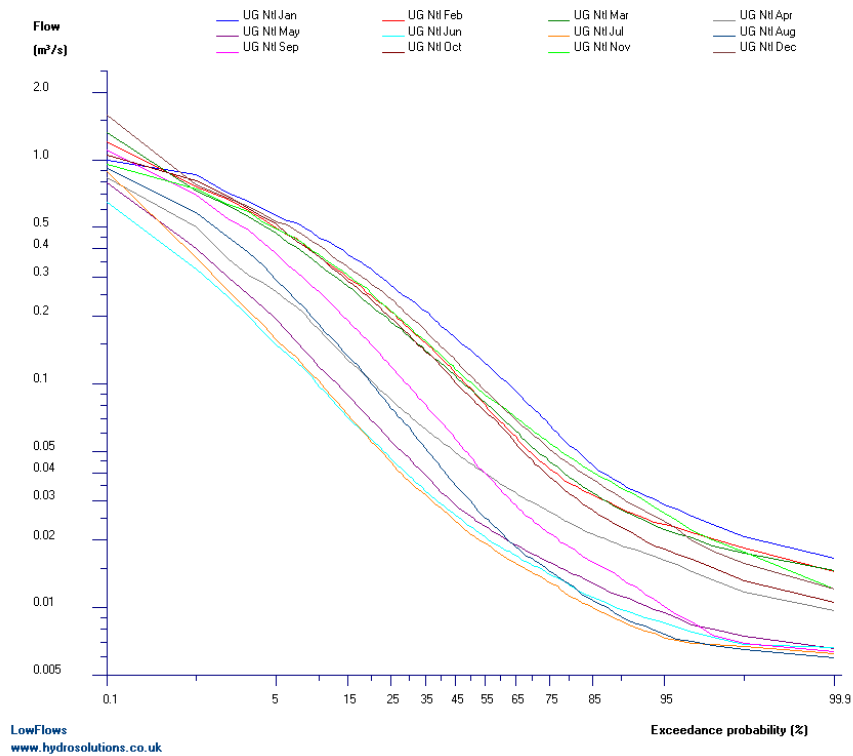
| | |
|----------------------------|------|
| Annual average runoff (mm) | 1328 |
| Base flow index | 0.33 |
| Mean annual flow (l/s) | 120 |

The runoff predictions are significantly above the Scottish average (1049mm) reflecting the above average rainfall. The base flow index is relatively low, indicating that water levels will fluctuate reasonably quickly. This should be moderated to some degree by the millpond, the effect of which is not reflected in the LowFlows predictions.

The flow results plotted as a flow duration curves are shown below. A tabulated format may be found as part of the generation models included in appendix E4.



Annual flow duration curve



Monthly flow duration curve

In river flow monitoring should be undertaken to corroborate these figures and will be required as part of an application for a SEPA abstraction licence.

It is expected that SEPA would require the Qn90 flow level, 14l/s, as the compensation flow as the catchment area is below 10km². Maximum abstraction is 155l/s, 1.3 times the average daily flow (119l/s).



Based on the LowFlows data and SEPA's abstraction guidelines, the following maximum abstraction regime is allowed:

| Qn % | Flow | Residual flow | Abstraction |
|------|------|---------------|-------------|
| 5 | 443 | 288 | 155 |
| 10 | 304 | 149 | 155 |
| 20 | 180 | 25 | 155 |
| 30 | 119 | 21 | 98 |
| 40 | 81 | 18 | 63 |
| 50 | 57 | 17 | 40 |
| 60 | 40 | 16 | 24 |
| 70 | 29 | 15 | 14 |
| 80 | 21 | 14 | 7 |
| 90 | 14 | 14 | 0 |
| 95 | 10 | 10 | 0 |
| 99 | 7 | 7 | 0 |

All figures l/s

4.4. Head, gross, losses, net

A survey was made of the gross head available at the site, which was measured at 9.2 metres. It is estimated that approximately 1 metre of this head would be lost in the inlet structure and over the length of the lade, although the height of the intake aperture in the wall of the mill building seems to indicate that the old lade used more than this. A further 0.8 metres would be required at the outfall to allow for spate river levels at the outfall. This leaves a net head of 7.4 metres.

4.5. Potential scheme summary, issues and operating principles

This is a low head scheme, which could be either lade fed or use a penstock to replace the old lade. It is the good condition of the weir and the short length of the scheme which make this scheme appear attractive.



The weir is in good condition

However, the mill pond that would become the intake structure requires a lot of excavation of debris. The lade is also in need of serious renovation work. The upper section has been filled with debris. This would need digging out and probably re-lining. The lower section has collapsed and requires rebuilding. This work is made difficult by the lack of access. Access to the weir would need to be made from the buildings above, by constructing a temporary access ramp and track. Access to the outfall area would also require a temporary ramp to be constructed.



The upper section of the lade is difficult to locate

The historic waterwheel would have been sited at the old mill building and this would make a natural location for a new turbine. However, this site has a similar issue as the old mill site on the Calder in that this mill building requires either demolishing, or completely renovating. Either option is likely to be expensive.

The alternative and preferable option would be to site the turbine below the ruined mill building which will give the additional head detailed above.

The best selection of turbine for this site is not obvious. A screw turbine has the advantage that it would be able to make use of the old lade. However, the lade requires a lot of work and currently finishes behind the ruined mill building, where it would be difficult to install a screw turbine. A crossflow turbine has the advantage that the lade would not need to be renovated; a penstock pipe could be installed in its place, which would lead from the intake structure to a turbine situated below the old mill building. However, a crossflow turbine would require a high degree for filtration. Some head would also be lost in the intake structure, where the entry to the penstock would need to be kept well below water level, in order to prevent air entering the penstock. The turbine house for a crossflow machine would need to be built down near the level of the burn, which would present problems of access.



We have selected a 4.5kW turbine for Millbank. The size of this turbine is limited by the limited flow available in the burn. At a rated flow of 85 l/s this would run at a capacity factor of 48%. A larger turbine could be used, but the capacity factor would quickly be reduced, while the costs associated with the turbine, penstock and associated civil work would increase.

Unfortunately the lade or penstock route to a new turbine sited below the mill would still need to pass directly behind the ruined building. It is hard to see how any construction work could be carried out so close to the ruin without extensive work to it.

The simplest grid connection for a scheme here would be via the buildings to the north of the site. Such a small scheme could be connected at single phase. It is unlikely that any significant work would be required to upgrade the grid connection to the buildings beyond the installation of an import/export meter.

4.6. Environmental considerations, permissions and planning

This scheme affects a relatively short section of watercourse. The assessment against SEPA's guidelines for schemes under 100kW is summarised below and the full analysis is given appendix B4.

| SEPA checklist assessment area | Affected reach of Millbank Burn |
|--|--|
| Sited in degraded part of the water environment? | No |
| Small, steep rivers & streams | Catchment area 2.86km ² . Slope 0.13 |
| Providing benefits from the proposed scheme to the ecological quality of the water environment | N/A |
| Other proposals | N/A |

Whilst the scheme is not typical of one on a small, steep watercourse (these are normally mountain or hillside burns), we assess the proposal as provisionally acceptable as the catchment area is under 10km² and the slope of the affected reach is over 0.1. The presence of an existing mill pond and the former use of hydro power at the mill will strength the position.

Any works to the mill and to provide better permanent access will probably require planning permission. From our initial research it appears that the mill and possibly the bridge are recorded historic sites.



4.7. Scheme costs

There are a number of aspects of this site which cumulatively make it a very expensive scheme for its size. These are:

- The work to rebuild the parts of the lade which have been buried or collapsed, or work to install a penstock pipe
- Access for this work
- The work to install the necessary civil work for a turbine and turbine house
- Access for this work, particularly given the proximity of the ruined mill
- The work required to demolish or renovate the old mill building

Without any work to the mill building, our estimate for the above work is approximately £316,000. The additional work required at the mill building is very difficult to estimate, but is likely to add significant additional cost.

On-going costs are expected to average £1,000 for at least the first 10 years of the project, although expenditure in the early years would be expected to be much lower. These costs allow for 'in house' screen cleaning and routine checks and for third party mechanical and electrical routine maintenance. Additionally LEAP may wish to consider damage and/or loss of income insurance.

4.8. System power generation, revenue & return

The power generation and return, based on the LowFlows predictions, has been modelled on a monthly basis using our power generation and revenue model. The key pages of the model are attached in appendix E4. In summary:

| | |
|---|--------|
| Annual total power generation (MWh)* | 18.8 |
| Capacity factor | 47.63% |
| Annual net power generation, after losses in cable (MWh)* | 18.6 |
| Feed in tariff | £3,924 |
| Exported electricity | £651 |
| Gross revenue | £4,575 |

This scheme would benefit from the highest FIT band of tariff, currently 20.9p per kWh. This is scheduled to rise to 21.9p in April 2012 (the annual RPI rise) but this has not currently been factored in to the revenue analysis as it is probable



that costs will also rise at a similar rate over time. As the specific grid connection for this scheme has not been established, no benefit of locally used electricity is included.

Allowing for the on-going costs, the following net revenues and returns are delivered by the scheme:

| | |
|------------------------------|----------|
| Net revenue | £3,575 |
| Scheme capital cost | £316,000 |
| Return | 1.13% |
| Undiscounted payback (years) | 88.40 |

Both returns and payback do not utilise discounted cash flows as both the feed in tariff and electricity sale revenues will increase in future years with RPI rises and this approximately negates the discounting of future cash flows. Full discounted cash flow analysis could be undertaken once the source and cost of funding is established.

4.9. Recommendations

Due to the relatively limited flow available and the head, Millbank only has the potential for limited power generation and therefore revenue. The difficulties of the site in terms of access, current state of the buildings and topography make the construction of a hydro scheme very expensive and we would not recommend development. Should the mill be refurbished as part of a heritage development, as part of which the access were improved and the site improved, then a small educational/demonstration scheme could be considered but even this is unlikely to be attractive from a purely financial perspective.

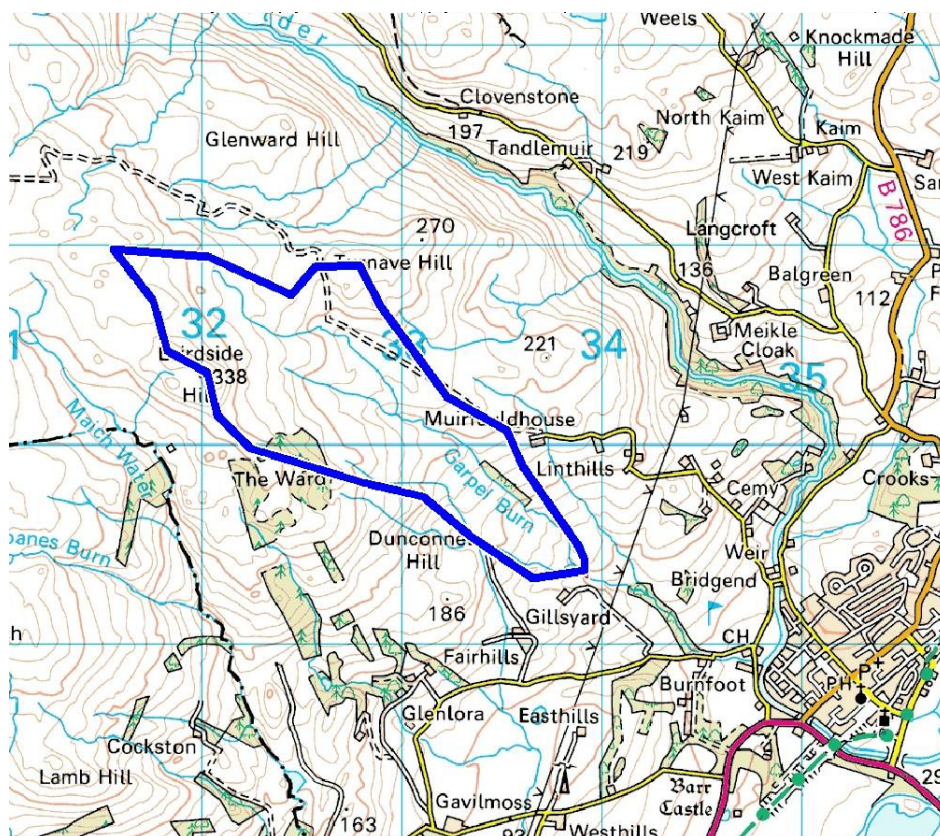
5. Garple Burn

5.1. Site summary

The Garple Burn flows in a general south westerly direction to join the Calder on the outskirts of Lochwinnoch. In the lower reaches under consideration for a potential hydro scheme it flows through enclosed grazing land and a wooded valley next to the golf course. Generally the watercourse lies in a reasonably deep and steep sided valley making construction of the intake and routing of the penstock difficult. The location is shown on the catchment area map below.

5.2. Catchment area

The catchment area of the potential scheme measures 1.52km² and is shown in the map extract below.



Garple Burn catchment area shown in blue

The watercourses above the intake lie on enclosed grazing land and, from studying the maps, would appear to have undergone some manmade channelling. This makes the exact definition of the catchment area tricky and a



detailed walkover of the watercourses would be required at the detailed design stage of any development.

Average annual rainfall levels in the catchment area are reasonable, between 1200mm and 2000mm (the catchment incorporates areas of two catchment bands). These levels are generally above both the Scottish average (1436mm) and significantly above the UK average (1079mm).

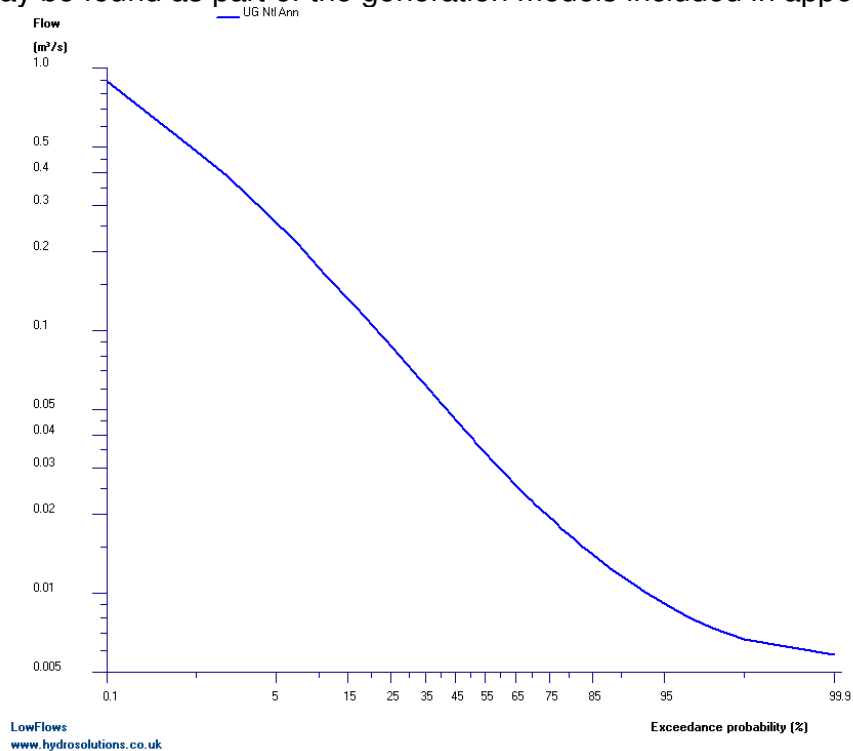
5.3. Flow analysis

LowFlows analysis gives the following data for the catchment area outlined above:

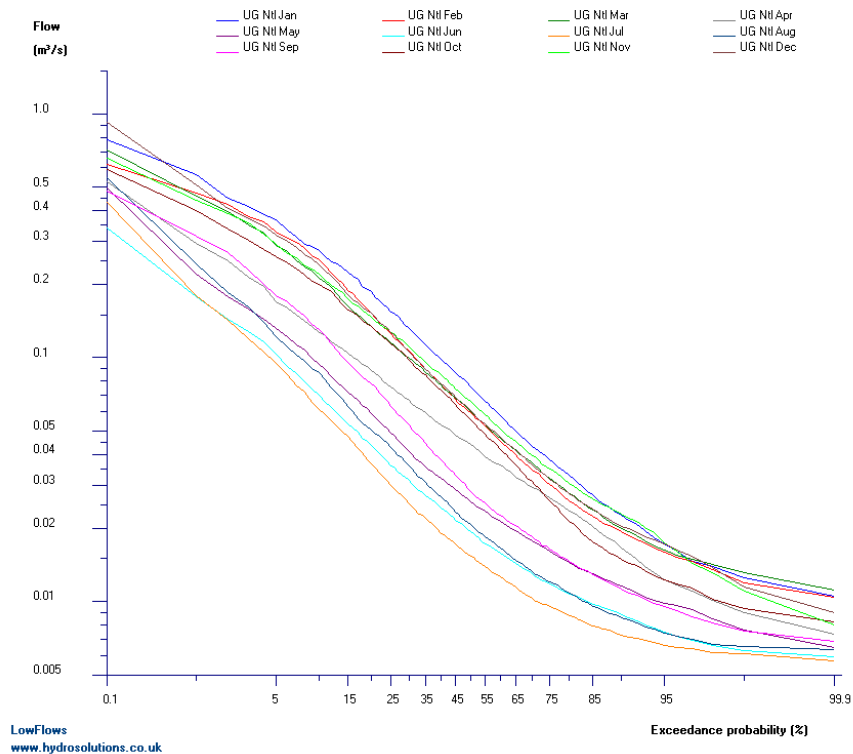
| | |
|----------------------------|------|
| Annual average runoff (mm) | 1512 |
| Base flow index | 0.31 |
| Mean annual flow (l/s) | 73 |

The runoff predictions are significantly above the Scottish average (1049mm) reflecting the above average rainfall. The base flow index is relatively low, indicating that water levels will fluctuate reasonably quickly.

The flow results plotted as a flow duration curves are shown below. A tabulated format may be found as part of the generation models included in appendix E5.



Annual flow duration curve



Monthly flow duration curve

In river flow monitoring should be undertaken to corroborate these figures and will be required as part of an application for a SEPA abstraction licence.

It is expected that SEPA would require the Qn90 flow level, 12l/s, as the compensation flow as the catchment area is below 10km². Maximum abstraction is 94l/s, 1.3 times the average daily flow (72l/s).



Based on the LowFlows data and SEPA's abstraction guidelines, the following maximum abstraction regime is allowed:

| Qn % | Flow | Residual flow | Abstraction |
|------|------|---------------|-------------|
| 5 | 254 | 160 | 94 |
| 10 | 171 | 77 | 94 |
| 20 | 104 | 10 | 94 |
| 30 | 72 | 16 | 56 |
| 40 | 52 | 15 | 37 |
| 50 | 39 | 14 | 25 |
| 60 | 29 | 13 | 16 |
| 70 | 22 | 13 | 9 |
| 80 | 16 | 12 | 4 |
| 90 | 12 | 12 | 0 |
| 95 | 9 | 9 | 0 |
| 99 | 7 | 7 | 0 |

All figures l/s

5.4. Head

On a high head scheme such as this, it is important that this measurement is established accurately in order to influence the detailed design of the system, in particular selecting the correct turbine, and to correctly predict the power that will be generated. The gross (actual) head on the proposed scheme was measured using both an altimeter and mapping software. As part of the detailed design work of any scheme on this site, this would be corroborated via a detailed level survey. The gross head was measured at 54 metres.

The main factor in determining the net head available is the friction loss in the penstock pipe. Using the pipe selected for this scheme (see below) we have calculated the head lost in the penstock to be approximately 3 metres. These losses could be reduced by utilising larger pipe or seam welding the sections, but the gain in head (and therefore power) are limited, whilst the purchase, laying and/or welding costs of the pipe would increase significantly.

Additional design losses in the system have been estimated at 3 metres allowing for appropriate design of the intake structure and for the outfall allowing the



turbine house to be located above any potential flood of the burn. The resultant net head is 48 metres.

5.5. Potential scheme summary, issues and operating principles

The proposed scheme is a high head scheme utilising a pelton type turbine with the intake high on the Garple Burn and the turbine house sited on the bank of the burn, just above the road bridge. Key components of the scheme are:

- Concrete intake structure with screen and large forebay acting as a settling tank
- Buried pressurised penstock pipe, 800m in length
- Turbine house containing the turbine, generator and control systems
- Outfall feeding back into the Garple Burn
- Buried cable carrying the generated power for connection to the grid

The flow of water down the pressurised penstock is controlled via spear valves in the turbine. The flow rate is determined by the bespoke control system which measures the amount of water available to the hydro scheme by monitoring the water level in the forebay. In this way, the control system is able to ensure that the scheme is making optimum use of the available water after the compensation flow set by SEPA is left in the burn. The turbine nozzles produce a very high pressured jet of water which drives the runner (wheel) of the turbine. The shaft of the runner is connected via a flexible coupling to a generator producing single phase electricity at 240V and 50Hz. An underground cable carries this electricity to the nearby house where it is connected via an import/export meter. Electricity not used directly at the house is exported to the grid.

5.5.1 Intake structure

This will be sited high on the Garple Burn at grid reference NS 33941 59367. This is just above a confluence with a small tributary, which is not marked on the maps, below the Gillsyard farmhouse. The exact location of the intake structure and the turbine were chosen taking into account the geography and hydrology of the site. One of the challenges of this scheme is getting the penstock, which must flow downhill at all points, out of the burn. The ground surrounding the burn at this location lends itself to a relatively straightforward route for the penstock pipe away from the burn.



Proposed intake site

Whilst this high location for the intake gives a good head, it does miss out on some catchment due to the tributary entering below.

The intake consists of:

- Concrete weir
- Filtration screen
- Forebay
- Outflow from forebay
- Shut off valve
- Compensation flow pipe

The intake is a concrete structure, erected across the width of the burn and with significant foundations to the side of the burn. The purpose of the structure is not to form a storage dam, but to provide limited impoundment giving an even flow over the level lip of the weir. In times of high rainfall or snow melt the structure is likely to be subject to large forces from the volume of water in the burn. It must be designed in such a way that it is able to withstand these forces without damage or risk of being displaced within the river bed. The intake is usually made from reinforced concrete and would be built at a time of low flow levels with the burn temporarily diverted around the intake site during construction.



Typical Coanda screen intake structure

The intake must contain a method of filtering larger particles from the water before it enters the penstock. Insufficient filtration could result in blockages in the turbine nozzles or damage to the internal parts of the turbine. Pelton turbines require a high degree of filtration and therefore we would recommend a Coanda screen type filter for this scheme. Whilst not the cheapest screens available, Coanda screens have the significant advantage that they are predominantly self-cleaning. In higher river flows the excess water flows over the specially shaped profile to clean the screen of any collected debris. This is particularly important in a remote location where manual regular cleaning would be difficult.

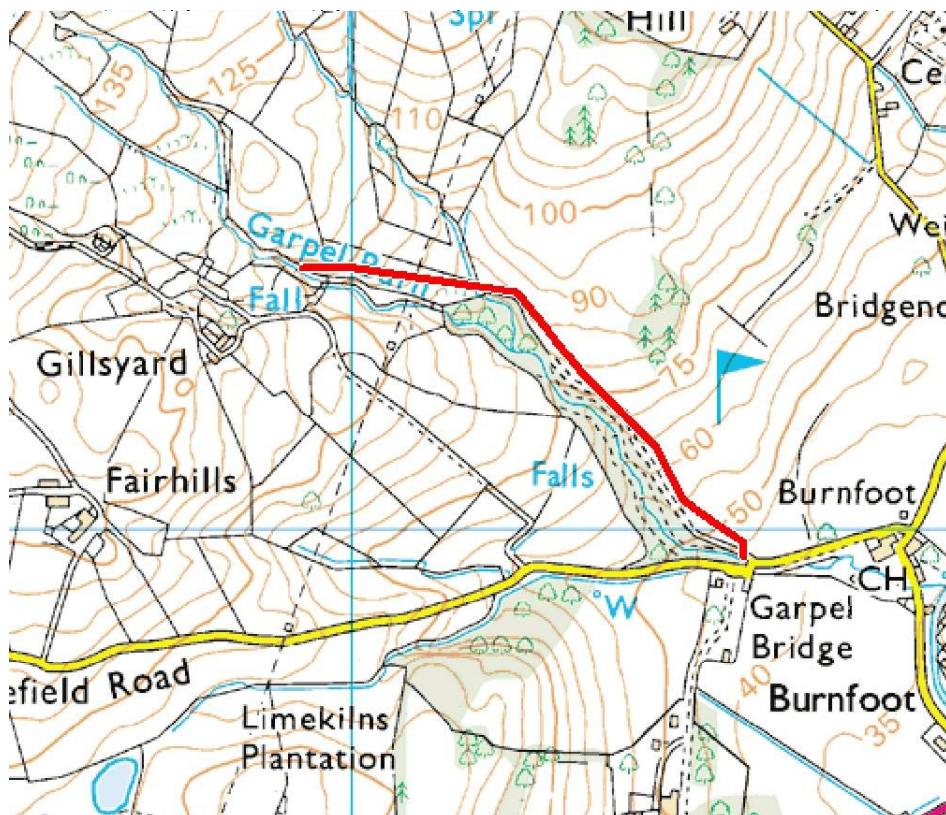
The filtered water is collected below the screen in a tank called the forebay. Once the flow has passed through the screen, it will be aerated. If allowed to pass directly in to the penstock, this aerated water would reduce the efficiency of the turbine and could cause vibration and damage to the fast spinning runner. It is therefore important that this air is removed from the water before it enters the penstock. This sometimes requires the provision of a separate settling chamber. On this scheme, the low flow rates will allow the settling to happen in the large forebay, without the need for a separate settling tank. The forebay therefore provides a direct feed of water into the mouth of the penstock. This must remain significantly submerged at all times to ensure that air is not sucked into the penstock. The pipe entry is made more efficient by using a bell mouth shaped inlet aperture. Just below the outlet from the forebay, there is a valve, which can be used to shut off the supply of water into the penstock for maintenance purposes. The forebay will require cleaning from time to time. This is done using

a sluice gate, which can allow large quantities of water through the forebay in order to flush out any collected sediment.

The intake structure is designed to ensure that there is always a compensation flow maintained in the burn and that in higher flows, the abstraction by the scheme is limited as required by SEPA. The water level in the forebay is monitored using a level transducer and the turbine control system restricts flow down to the turbine such that the residual flow of 12 l/s required by SEPA passes through a pipe in the front of the forebay (when the burn is flowing at 12 l/s or over). Flow for the turbine is abstracted from the forebay into the penstock pipe up to the maximum rated flow for the turbine. Excess flow passes over the Coanda screen.

5.5.2 Penstock

The penstock is a pressurised pipe, which is usually buried. This scheme has a relatively long penstock (800m), for the head of 54m. This makes the engineering, procurement and installation a critical factor in the overall cost of the scheme.



Garple Burn proposed penstock route



The Garple Burn penstock would be buried in a trench for the majority of its length. Whilst this would be required in order to comply with planning regulations, it also has the distinct advantages of protecting and supporting the pipe. This trench is sufficiently deep to avoid any future disturbance from above ground activities. Careful grading of the soil used to back fill the trench is required to ensure no damage to the pipe. The trench would also carry the control/monitoring wire between the level transducer in the forebay of the intake and the turbine control system installed in the turbine house. The trenching, pipe laying and back filling would be done in sections with a minimum section of open trenching at any one time.

The terrain over which the penstock trench must be dug is in places quite steep and could be rocky. The possible presence of rock introduces an unknown factor into the cost of the scheme as the exact quantity of rock requiring removal is unknown until after initial excavation. The civil contractor will normally charge for this after the event, depending on the volume of rock encountered. A conservative estimate for rock has been used in the costings. As the penstock pipe route descends the glen, it must cross a tributary burn. This requires a pipe bridge, which would use a steel beam to support the pipe as it spans the burn.

The penstock will be made from PE100 high density polyethylene (HDPE) pipe. This would be delivered to the site in 12 meter lengths which would be welded together using a diesel powered butt welding machine alongside the pipe trench. The penstock pipe is the most expensive bought out item in the scheme. For this reason both its diameter and wall thickness are carefully calculated in order to ensure that they are adequate for the job, but not over engineered introducing additional cost. As the penstock descends the hillside towards the turbine house the pressure of the water within the pipe increases. At its highest, the pressure of the water close to the turbine house is around 5.5 bar. The wall thickness of the penstock pipe will increase in the lower reaches where the pipe rated to 10bar is used, allowing an appropriate safety factor.

We seek to minimise the penstock pipe diameter in order to keep costs to a minimum. However, as the pipe diameter is decreased, the velocity of the water in the penstock increases, and with it the head lost due to friction increases. The increased cost of a larger pipe can therefore be off-set against the increased revenue that accompanies the resulting increase in net head. In our cost engineering exercise for this scheme, we considered using several different pipes. The most cost effective pipe diameter is 305mm external diameter.

Over time the penstock pipe is prone to collecting growth along its bore. Provision is therefore made to allow the penstock to be cleaned by passing a cleaning "pig" along its length. A special chamber is incorporated at the bottom of the penstock, just before its entry into the turbine house, to allow the pig to exit the penstock after passing down the penstock pipe. This chamber is connected to the outfall pit, beneath the turbine house.



5.5.3 Turbine House

The turbine house serves to protect the turbine, generator and machinery from the elements. It also provides insulation for the noise produced by the machinery. The site of the turbine house is not immediately apparent as there is very little room between the burn and the roads either side of the bridge. To site the turbine on the right (south) bank would necessitate the penstock pipe crossing the burn. The turbine house would be best placed on the left bank of the Garple Burn, just above the road bridge. It may be necessary to modify the position of the track leading up the glen in order to facilitate this. Whilst the visible external dimensions of the turbine house are not great, the foundations need to be significant to anchor the turbine against the considerable forces placed on it by the change of momentum of the water driving the turbine. The foundations also contain the outfall pit, beneath the turbine. It is important from a safety viewpoint that the turbine house is secure and cannot allow access to the electrical machinery by unauthorised persons.

The construction of the walls will be of concrete blocks, which will be faced in order to allow the structure to blend in with the surrounding glen. The exact finish to the turbine house would be decided in conjunction with the client and the Planning Authority. The building is sized to allow work to be undertaken on the machinery.

5.5.4 Turbine, Generator and Control System

The high head and low flow characteristic of the scheme mean that a pelton wheel type turbine is most suitable. These machines have a good efficiency over a wide range of flows.

The larger the capacity of the turbine, the greater the potential maximum generation. However a larger turbine will have a greater initial cost and will run at 100% efficiency for less of the time. We have considered a number of options for this scheme. With the available flows a 21kW turbine generator is recommended. This unit would operate at a capacity factor of approximately 46.7%. The capacity factor is the actual generated power expressed as a percentage of the power that would be generated if the turbine were running at full power throughout the year. Obviously there are times when the water flow levels are not sufficient to run the turbine at full power and indeed some periods when generation will stop completely.

The turbine under consideration is a relatively small unit. There are few models of turbine produced which can operate efficiently at these generation levels and most of these turbines are expensive. The turbine that we recommend is an American built machine from Canyon Hydro. These are very well engineered and reliable machines, considered to be some of the best in the world. An



alternative which would provide a potential saving is a Peruvian made Tepersac unit. Tepersac are represented in the UK by Sustainable Control Systems (SCS). SCS provide a complete turbine and generator unit, including the control system which they bespoke manufacture in house. These machines are also well engineered and there are a number in use in the UK. However, the build quality and reliability cannot be compared with that of the American machine.

The energy of the water from the intake arrives at the turbine in the form of potential energy of the water under pressure. This potential energy is converted to kinetic energy by forcing the water through a specially designed nozzle. The kinetic energy is then imparted to the turbine's runner as it strikes the bucket shaped blades of the runner. The turbine proposed for Garple Burn is a single jet machine (as opposed to the twin jet machine shown below). The flow to the nozzle is controlled by a spear valve which in turn is moved by a hydraulic or electrical actuator controlled by of the control system. The actuators can be seen on the top and bottom left of the machine pictured below.

The turbine housing is made from heavy grade steel, in order to provide the strength and rigidity for the bearings which carry the runner. The amount of force which is exerted onto the turbine housing by the penstock pipe is limited by a thrust block, holding the penstock pipe securely as it enters the turbine house.



A pelton wheel turbine

The turbine is connected to the generator either by direct drive or belt. The direct drive option is only possible with certain combinations of flow rate and head. For this scheme we are able to use a direct drive, which provides a greater degree of



efficiency and some cost savings. The proposed generator is a single phase induction generator, manufactured by ABB of Sweden. In order to use a single phase generator for this duty, it is necessary to use a 10-pole generator, which is slightly unusual and more expensive than the average generator for a site such as this.

The turbine operation is controlled by a computer operated control system. This system ensures that the turbine runs at the correct speed at all times, which in turn ensures that the generated electricity is maintained at the correct frequency. The power generated by the turbine needs to be determined by the flow of water available from the burn. The control system therefore monitors the level of water in the forebay and controls flow by adjusting the spear valve controlling the flow through the turbine to optimise power generation.

The control system proposed for the Garple Burn complies with Engineering Recommendation G59/2 for grid connections. This document specifies a number of circumstances in which the generator must be shut down. For example if the voltage or frequency were to rise above acceptable levels, the system would shut down. The unit also must shut down in case of loss of power to the grid. This is very important, as the DNO needs to be able to work on repairs to the grid, safe in the knowledge that the turbine will not electrocute their work force. The control system would be mounted in a lockable panel with the turbine house. The system would include a generation meter recording the electricity generated and used to calculate the FITs payment. The system would be commissioned by trained personnel from the supplier of the control system, in conjunction with Glen Hydro.

We have included for the possibility of remote monitoring of the generator and control system. This would allow the client, or Glen Hydro to monitor the unit and highlight any problems in its operation.

5.5.6 Outfall

The outfall is the means by which the spent water, falling from beneath the turbine is transferred back to the burn. This consists of a pit, beneath the turbine, which is part of the turbine foundations and an outfall. The pit, or sump, feeds a length of large pipe, carrying the water to the burn. When locating the turbine house and considering the design of the outfall, it is important that there is sufficient height difference between the exit of the turbine and the river level to allow for extreme flood situations (so that the turbine house is not flooded by back flow up the outfall pipe). The outfall into the Garple Burn would be made from twin wall plastic or concrete pipe, at least 0.5 meters in diameter. The outfall pipe would lead to a concrete structure on the burn bank to spread the flow in to the burn. This is done in order to reduce the speed of the water as it enters the burn which helps deter any migrating fish from spending valuable time



and energy trying to enter the outfall. The outfall structure would also be screened to prevent migrating fish trying to enter.

5.5.7 Grid Connection

It is hoped that the Garple Burn scheme could be connected to the grid at a nearby property where the existing meter will be replaced with an import/export meter. This has the advantage that where electricity generated by the scheme is used locally where the saving is significantly greater than the revenue from exporting the same electricity to the grid. The import/export meter measures both the flow of electricity exported from the system to the grid, for which revenue is received, and, at times when the generated electricity is insufficient for local demand, the import of electricity, which is paid for as normal.

It is unfortunate that there appears to be no nearby 3-phase supply to use for the grid connection. The scheme is within Scottish Power's upper limit of 23kW for a single phase connection. However, if a single phase connection is required, it would be more expensive, requiring larger cables and a more complicated generator than a three-phase connection.

We have estimated the cost of grid connection for this scheme at the nearest house, using single phase. We have allowed for a run of 100m of underground cable to achieve this.

A possible alternative to this could be to investigate the grid connection of the scheme at the nearby golf clubhouse, where it is more likely that a 3-phase connection may be available. The costs of the cabling and associated civils work to achieve this would be greater than the nearer connection. However, the electricity usage of the golf club could be significantly more than the house, offering an increased revenue if electricity is sold to the club.



5.6 Environmental considerations, permissions and planning

This scheme is more typical than those on the Calder and therefore the environmental assessment more straightforward. The burn is not classified within the 2008 River Basin Management Plan. The assessment against SEPA's guidelines for schemes under 100kW is summarised below and the full analysis is given appendix B5.

| SEPA checklist assessment area | Affected reach of Garple Burn |
|--|---|
| Sited in degraded part of the water environment? | No |
| Small, steep rivers & streams | Catchment area 1.52km ² . Slope 0.068 Provisionally acceptable if affected reach lacks any ecologically significant area of good habitat for fish. |
| Providing benefits from the proposed scheme to the ecological quality of the water environment | N/A |
| Other proposals | Proposal unacceptable at required abstraction levels. |

The proposed scheme just reaches SEPA lower limit for schemes sited on small steep watercourses. The section under consideration has an overall slope of 0.068 measured over the route of the watercourse. This is above the threshold of 0.06 which means that the section must be deemed to lack any ecologically significant area of good habitat for fish for the scheme to be acceptable. Our initial assessment is that this is likely to be the case but the final decision will rest with SEPA and may well require fish surveys to be undertaken.

The scheme is likely to require planning permission, but subject to lack of any objection from the nearby properties, this is not thought to be a major hurdle.



5.7 Scheme costs

The capital costs of this scheme have been worked up in detail and the breakdown can be found in appendix C2. The projected total capital costs including project management and contingency are £324,147.

Comments on certain specific line items of the scheme which may benefit from clarification are given below. The numbers refer to the comment numbers shown on the cost breakdown.

| Cost item no. | Item | Comment |
|---------------|-----------------|--|
| 1 | Pipe trenching | The ground to be worked is steep in places. The work alongside the burn (near the intake) requires some benching work. The figure of £44.44/m is felt to be realistic given our experience on similar schemes. |
| 2 | Rock removal | The volume of solid rock requiring removal is impossible to accurately estimate without a complete ground survey. The figure of 100m ³ is considered as a conservative estimate to minimise the risk of the project being threatened by a large cost overrun due to this issue. |
| 3 | Pipe bridge | This is required to cross the tributary burn in the wooded area. This will require a considerable span. |
| 4 | Turbine | The cost included is for a high quality machine from Canyon in the USA. There is a potential saving available here of around £35,000 by using a machine of Peruvian origin. |
| 5 | Grid connection | No figures received from Scottish Power for this connection. Our estimate is based on other schemes. |
| 6 | Contingency | A contingency of 15% has been allowed across all costs. This is not excessive and we would forecast that it will be required. |

On-going costs are expected to average £2,000 for at least the first 10 years of the project, although expenditure in the early years would be expected to be much lower. These costs allow for 'in house' screen cleaning and routine checks and for third party mechanical and electrical routine maintenance. Additionally LEAP may wish to consider damage and/or loss of income insurance.



5.8 System power generation, revenue & return

The power generation and return, based on the LowFlows predictions, has been modelled on a monthly basis using our power generation and revenue model. The key pages of the model are attached in appendix E5. In summary:

| | |
|---|---------|
| Annual total power generation (MWh)* | 85.9 |
| Capacity factor | 46.71% |
| Annual net power generation, after losses in cable (MWh)* | 85.1 |
| Feed in tariff | £16,069 |
| Exported electricity | £2,978 |
| Gross revenue | £19,047 |

This scheme would benefit from the second FIT band of tariff, currently 18.7p per kWh. This is scheduled to rise to 19.6p in April 2012 (the annual RPI rise) but this has not currently been factored in to the revenue analysis as it is probable that costs will also rise at a similar rate over time. As the specific grid connection for this scheme has not been established, no benefit of locally used electricity is included. Should connection to the golf club house be possible, the benefit of this could be significant.

Allowing for the on-going costs, the following net revenues and returns are delivered by the scheme:

| | |
|------------------------------|----------|
| Net revenue | £17,047 |
| Scheme capital cost | £324,147 |
| Return | 5.26% |
| Undiscounted payback (years) | 19.02 |

Both returns and payback do not utilise discounted cash flows as both the feed in tariff and electricity sale revenues will increase in future years with RPI rises and this approximately negates the discounting of future cash flows. Full discounted cash flow analysis could be undertaken once the source and cost of funding is established.



5.9 Recommendations

The proposed Garple Burn scheme is viable but the topography means that the construction costs are significant. On purely financial terms we would not recommend its development as the cost of funding is likely to exceed the predicted returns. A connection to the golf club house and subsequent sale of electricity could improve the revenue though would incur some additional capital costs for the connection. Should LEAP wish to progress the scheme we would recommend identification of and discussions with the relevant landowners as the next steps. Initial discussions with SEPA should also be considered to establish the likelihood of success of an abstraction licence application.



6 Wider area hydro potential review

The summary of desktop research into watercourses in the wider area is shown below:

| Watercourse | Hydro potential | Influencing factors |
|--|--|---|
| Calder above Lochwinnoch to Muirshiel Park | Overall gross head 150m over approximately 6km of watercourse. Slope circa 2.5%. Various waterfalls marked on map may have potential of development and would require further detailed local investigation. | Most sections of the upper Calder are likely to be remote from the grid, making connection costly. SEPA's abstraction guidelines are likely to limit the flow available for abstraction. |
| Maich Water | The section upstream of the loch/reservoir north of Ladybank Castle is worthy of investigation. | The terrain looks steep close to the watercourse and construction may be difficult. Grid connection may be lengthy and therefore costly. |
| Lady Burn | Limited catchment area. | |
| River Garnock upstream of Kilbirnie | The section downstream of Glengarnock Castle to the next road bridge is worthy of investigation. Upstream of Glengarnock Castle the steep banks will make any construction difficult. A pipeline is shown on the south bank in the section immediately upstream. This may be worthy of further investigation if still in good repair. | |
| Pundeavon Burn | Possibly worth investigation downstream of Pundeavon Reservoir. | Dependant on current use and abstraction at Pundeavon Reservoir. |



| | | |
|-----------------|---|--|
| St Bride's Burn | Generally insufficient gradient for economic development or regulatory approval. | |
| Locher Water | Generally insufficient gradient for economic development or regulatory approval. | |
| Pow Burn | Generally insufficient gradient for economic development or regulatory approval. | |
| Carruth Burn | Section around Carruth Bridge may be worthy of investigation though catchment is limited. | |
| Gotter Water | Section between reservoir and B786 worthy of investigation. | |
| Burnbrae Burn | Section upstream of South Branchal worthy of investigation. | |



7 Disclaimer

The energy production, revenue generation and capital expenditure estimates within this feasibility study are based on the best available information. However as they are subject to uncertainty arising from a wide range of sources, they are given as guidance only and should not be taken as a guarantee.