Arkwright Society

HYDROPOWER AT CROMFORD POND

PRE-FEASIBILITY STUDY

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1. SCHEME SUMMARY

Watercourse	Bonsall Brook		Turbine type	Crossflow	
Location	Cromford Pond		Gross Head	2.75	m
Town/Village	Cromford DE4 3QF		Design Head	2.3	m
Grid Ref. Intake	SK 29475 56930		Design Flow	400	litres/sec
Grid Ref. Turbine	SK 29485 56935		Peak output	6.0	kW
Grid Ref. Outfall	SK 29485 56935		Annual Energy	30,000	kWh/year

2. INTRODUCTION

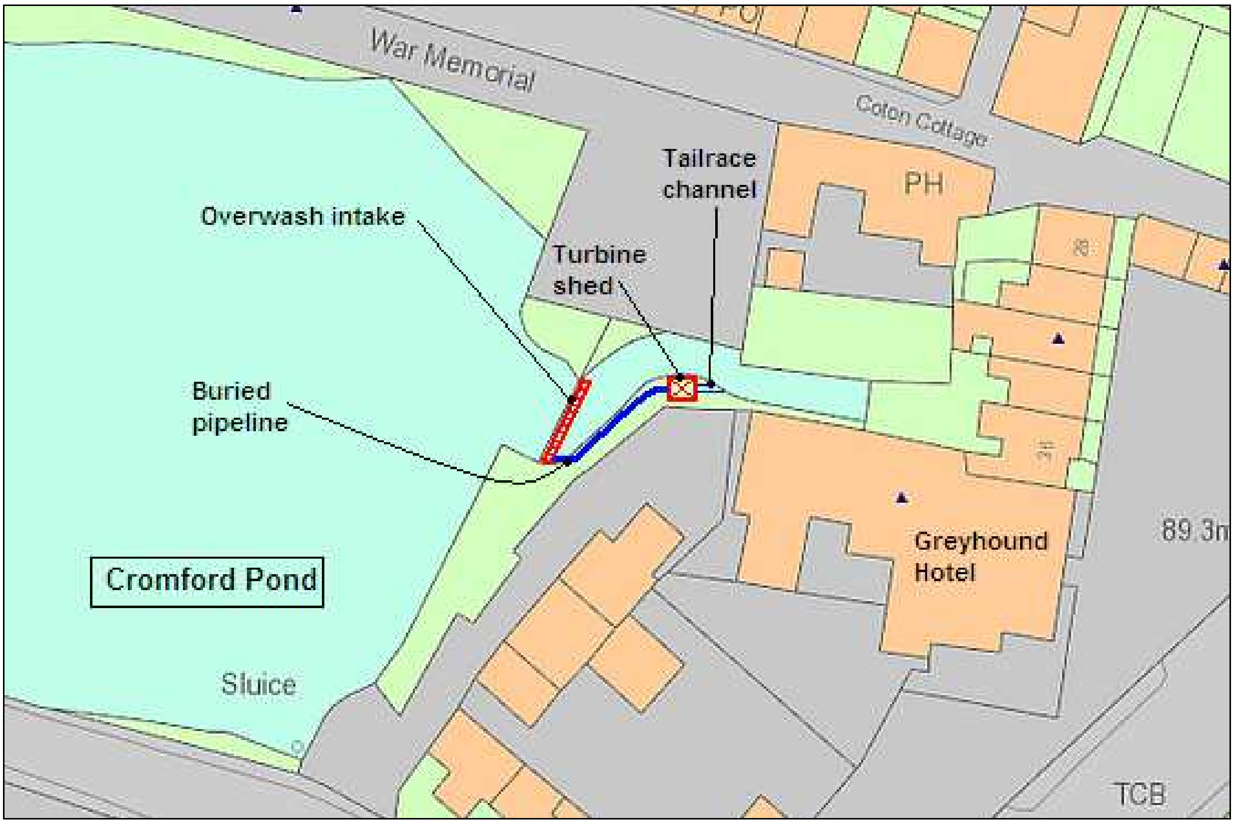
Derwent Hydro were asked to assess the hydropower potential available at the outfall of Cromford Millpond.

The pond in the centre of Cromford village is created by a man-made impoundment of the Bonsall Brook. The outfall weir provides an opportunity for a modern micro-hydro scheme to utilise the head and flow available at this point to create zero-carbon electricity, for example to supply the nearby Greyhound Hotel.

A site survey was completed by Oliver Paish of Derwent Hydro Developments on April 28th 2020. The key observations and conclusions are summarised below, with pictures at the end of the document.

As described below, the potential scheme would involve installing a new screened intake, a short length of buried pipeline, and a small crossflow turbine within a riverbank enclosure, discharging back into the brook a few metres downstream of the weir.

Figure 1 : Site Layout



3. SITE OVERVIEW

The site location and proposed scheme layout are illustrated in Figure 1.

3.1 Existing Impoundment

Cromford Millpond (Figure 5) is marked on maps dating from the establishment of Cromford Mill in the 1760s and, with a surface area in excess of 5000m², will have been used as storage to provide extra water for one or more of the waterwheels at the Mill.

A stone/concrete weir, founded on bedrock at the eastern extent of the pond, allows the flow in the pond to drop into the downstream reach of the Bonsall Brook, as depicted in Figure 6.

The overspill is roughly 7m across. The southern end of the crest is formed by an upturned C-channel bolted to the top of the stonework (Figure 7). This channel is not present at the northern end, so the majority of the flow is drawn to this end of the overspill.

3.2 Land Ownership and Right of Access

The ownership of the pond, the overspill weir and the relevant riverbanks of Bonsall Brook are unknown, but presumed to lie with the parish council.

3.3 Flood Levels

There is a relatively small amount of freeboard on the adjacent bank of the millpond (approx. 0.5m), implying that the millpond does not experience excessive water level rises during flood conditions.

The limestone catchment of Bonsall Brook tends to absorb high rainfall events and distribute the flow into the streams over an extended time period, so avoiding major short-term peaks.

3.4 Grid connection

The location is in the heart of Cromford village, with several properties nearby. The most cost-effective use of the power would be to supply the fuseboard of a nearby commercial property consuming a consistent electrical load (and preferably with a 3-phase connection): the obvious candidate would be the Greyhound Hotel, but there may be other options.

3.5 Access

There is good access to the site from Water Lane, via the shared driveway which serves the properties fronting the eastern edge of the Millpond. Permission would be required to traverse across the forecourt of the final property (see Figure 10).

3.6 Environmental Designations

The site itself has no environmental designations, but it lies upstream of the Cromford Canal, which is both a SSSI and Local Nature Reserve; the canal receives a small flow from Bonsall Brook via an offtake downstream at Cromford Mills.

3.7 Planning Designations

The whole area is within the 'Derwent Valley Mills' World Heritage Site.

There are also Grade-II listed buildings nearby, including the Greyhound Hotel, so this site may be considered 'within their curtilage'.

3.8 Water Framework Directive (WFD)

- *All significant UK watercourses have been classified in terms of their ecological status. The EU Water Framework Directive (WFD) requires improvements to be made to ensure that minimum standards are achieved on all watercourses.*
- Bonsall Brook is too small have its own classification and sits within the waterbody "Derwent from Wye to Amber". This is a Heavily Modified waterbody with 'moderate' ecological status.

4. HEAD & FLOW

Two quantities make up the available power potential at a hydropower site: a Volume Flow Rate of water ***Q***, and a Pressure Head ***H*** (Head is the available vertical fall in the water, from the upstream level to the downstream level).

4.1 Head

The overspill weir drops over 2m onto a bedrock platform. There is then the a further drop of around 0.5m from the bedrock into the departing watercourse, before it takes a right-hand bend towards the culvert under the Greyhound Hotel (Figure 9). The gross head was measured during the survey from the pond level down to the Brook after it has passed around the bend (which is where a turbine would discharge). This yielded a figure of 2.75m. There will inevitably be some losses through the intake and pipeline, so for the purposes of this report, a turbine design head of 2.3m will be assumed.

4.2 Flow

Bonsall Brook is not gauged by the Environment Agency.
The flow on the day of the survey was estimated to be in the region of 300 litres/sec (after a long period of dry weather).

Rainfall and catchment area methods can be used to estimate the likely flow variation, but these can be less reliable in a limestone catchment where the rainwater 'disappears' underground before emerging at various springs. Flow may be lost or gained between other catchment areas as a result of these sub-surface flows.

It is therefore advisable to undertake a period of flow monitoring, and this forms a separate element of this project.

In the meantime, to establish an initial flow estimate, the HydrA hydraulic model from the Institute of Hydrology was run for this catchment with an estimated catchment area of 28 km² and average rainfall of 980 mm per year.

The resulting flow parameters for the Brook can be summarised as follows:

Q95	Flow exceeded 95% of the time	130	litres/sec
Q80	Flow exceeded 80% of the time	205	litres/sec
Q50	Median Flow – flow exceeded 50% of the time	341	litres/sec
Q30	Flow exceeded 30% of the time	494	litres/sec
Q10	Flow exceeded 10% of the time	832	litres/sec
Qmean	**Average Flow**	470	**litres/sec**
Q95:Qmean	*Ratio of dry flow to average flow*	*27%*	

4.3 Base Flow

The ratio of Q95:Qmean indicates a relatively high baseflow stream.

4.4 Design Flow and Prescribed Flow

4.4.1 Prescribed Flow

Some flow (the 'prescribed flow') would need to be left over the weir to maintain its visual appearance. Depending on negotiations with the EA, the flow available for hydropower is likely to be reduced by around 100 litres/sec.

4.4.2 Design Flow

On this basis we would recommend a turbine design flow in the range 400 to 500 litres/sec.

5. TURBINE OPTIONS

5.1 Archimedes Screw

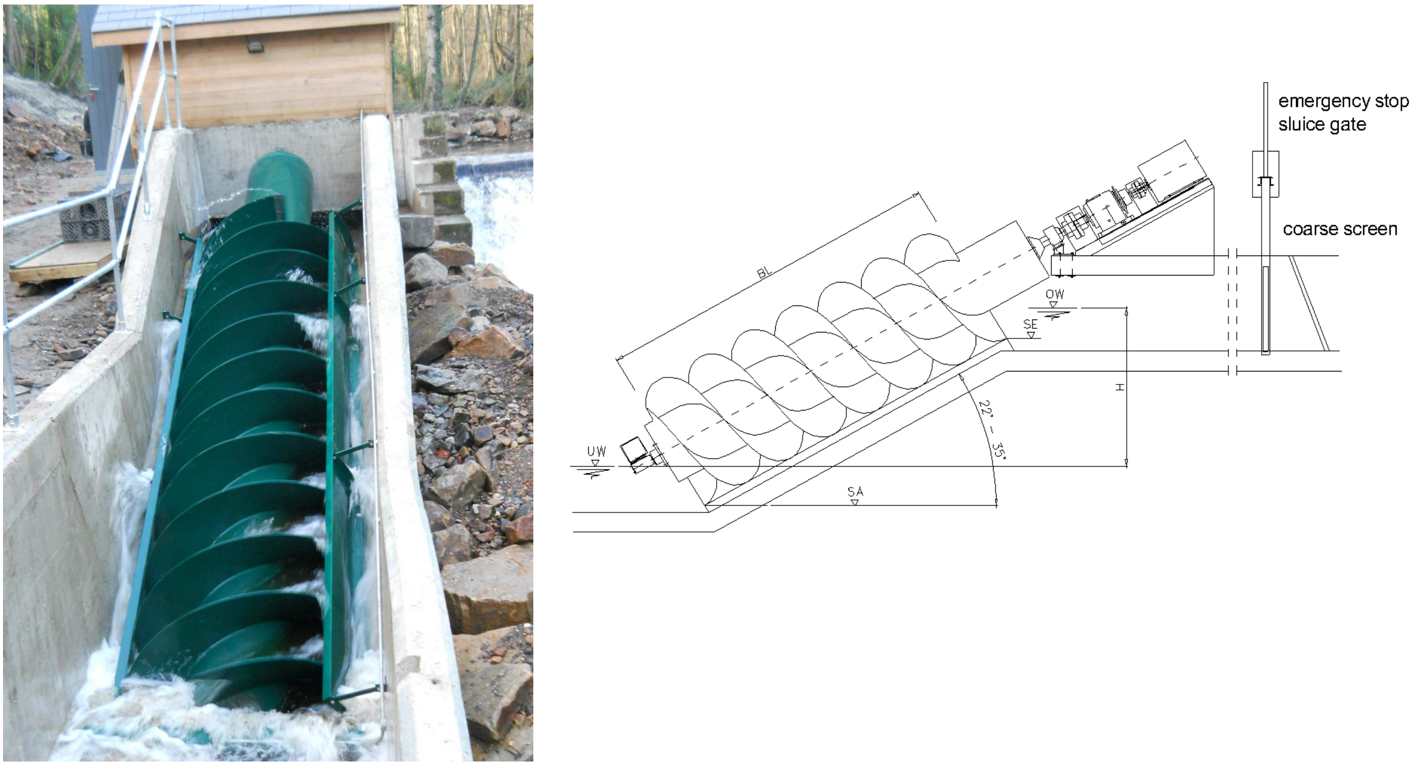
The standard turbine solution for a site with this head and flow would be an Archimedes Screw turbine (Figure 2).

The Screw is a fish-friendly turbine, requiring only a relatively coarse screen which can be cleaned manually, so avoiding the need for a fine inlet screen and resulting maintenance.

This flow rate would require a Screw of 1.2m diameter. The Screw needs to be aligned at between 22 to 26° to the horizontal, so at this location the helix would be roughly 6m long. An inlet sluice gate is used to vary the flow reaching the turbine, and to shut it down.

However, the Archimedes Screw has an inherent noise impact due to the splashing of the blades at both the inlet and outlet of the Screw. Although measures can be taken to reduce this impact, it is considered to be a risky choice at this location due to the close proximity of properties adjacent to and downstream of the turbine location, including the Greyhound Hotel.

Figure 2 Archimedes Screw turbine



5.2 Crossflow turbine

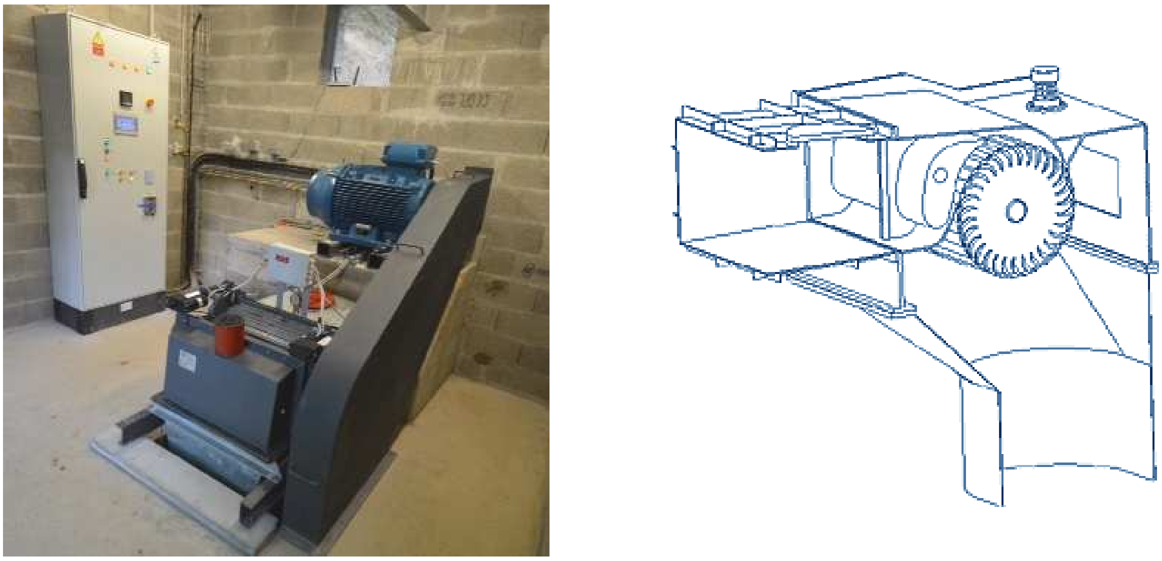
The only other type of turbine likely to be efficient and cost-effective for this head and flow is a crossflow turbine.

A crossflow turbine can be fully-enclosed in a sound-proof powerhouse, so minimising any potential for noise disturbance.

The crossflow is a variable-flow machine which, in its twin-cell version, can still operate at 10% of design flow. It will run sufficiently fast to allow a low-cost belt-drive to connect to the generator.

A crossflow turbine is self-cleaning with regard to ‘soft’ debris such as leaves, but requires a reasonably fine screen to keep out twigs and stones of a size which might jam between the runner blades, as well as protecting fish.

Figure 3 Small crossflow turbine unit, plus schematic illustration



5.3 Intake

To reduce the maintenance burden of having to clean a fine-aperture inlet screen, we recommend using an overwash or 'Tyrolean' screen installed immediately downstream of the existing overspill.

In this design, the flow passes over a sloping screen which filters the abstracted flow and allows the water to drop into a sump below (see Figure 4). The screen would use thin steel bars separated by a 6mm aperture. It is a relatively self-cleaning design and will exclude all wildlife and debris from reaching the turbine.

The intake works would be constructed as an extension to the existing overspill i.e. the pond will spill directly onto the sloping Tyrolean screen.

The intake structure would therefore be 7m across and would have bars 400mm long in order to abstract 400 litres/sec.

Below the screen would be a concrete sump (7m across x 0.4m breadth x 1.75m deep) to collect the flow and feed it into a short section of pipeline located at the southern end of the weir.

Figure 4 : Tyrolean overwash intake

5.4 Pipeline

Roughly 15m of low-pressure pipe would need to run along the south bank of the brook to reach the turbine location – there is a 2m width of riverbank to bury the pipeline under (see Figure 8). The required flow could be delivered with standard twin-wall socketed drainage pipe of diameter 0.5m.

5.5 Control System

The control system will enable fully automatic operation of the turbine. It will continuously monitor the pond level, and will open or close the turbine valve in small adjustments, according to whether the upstream level is rising or falling. If there is insufficient water to generate power, the turbine will shut down completely, and will automatically restart when the pond is replenished.

The control system also provides the necessary grid-connection switchgear to meet the G99 standard for embedded generators.

5.6 Fisheries & Ecology

5.6.1 Overview

A Phase 1 Habitat Survey would need to be undertaken as part of the planning permission to identify if there are any relevant populations of protected species (water voles, white-claw crayfish, otters, bats, etc.) and to recommend any mitigation measures.

There are not believed to be any significant fish populations in Bonsall Brook itself, due to its small size and heavily modified nature as it passes through Cromford via numerous man-made structures. However there are likely to be fish in Cromford Pond, but these will be protected by the inlet screen.

5.6.2 Fish Passage

Bonsall Brook is not populated by migratory salmon or eels and is completely impassable due to the underground tunnels, Cromford Wheelpit, etc. which have totally altered the natural watercourse.

6. FLOOD RISK

A Flood Risk Assessment would be provided with any Planning Application, but in summary, neither the completed hydro-scheme, nor the construction works, will present any risk to flood defence for the following reasons:

- The overspill weir will remain as 7m across, as at present.

- The project works will not impinge upon the main river channel, and there will be no obstruction to the main channel flow.
- By drawing up to 0.4m^3/sec into the new pipeline, the overall discharge capacity of the site will be increased.
- Although a small turbine shed will need to be installed on the riverbank, the building will be limited to 3m x 3m in plan and located above the normal flood level.
- The design will be flood resilient, with all electrical equipment located well above peak flood level.
- All excavated materials will be removed outside the Floodplain.

7. OUTPUT

A crossflow turbine designed for 2.3m net head and 400litres/sec design flow would generate a peak electrical output of 6.0 kW.

Based on the modelled flow characteristic, the electricity generated over one year could be expected to be close to 30,000 kWh/year. This estimate would be refined once more accurate flow data becomes available.
[Note: a typical UK home consumes around 4000 kWh/year].

8. REVENUE

The system would run 'in parallel' with the local network, i.e. any power generated by the turbine would first be consumed in a local property (reducing the electricity that would otherwise be bought in) and any excess power would pass back into the grid through a meter, and could be sold to an electricity company.

The overall value from the scheme will therefore depend on what proportion of the power would be consumed on site vs. sold into the grid. One way to guarantee that all the power is used on site would be to install a battery bank of sufficient size to absorb the power at times of low usage. The main alternative would be to identify a 'dump' load - usually water heating or space heating - which could usefully absorb excess electrical power, displacing the heating fuel that would otherwise be used.

If we assume that 100% of the hydro output will be consumed on site (0% export), displacing electricity otherwise bought in at 16p/kWh, then the maximum 'annual value' of the scheme would be:

£0.16 x 30,000 kWh = £4800 per year.

If only 50% is consumed on site, and the rest is exported at 5.5p/kWh, then the annual value would fall to £3225 per year.

9. COSTS

9.1 Electro-Mechanical Equipment

The initial broad-brush estimates for the electro-mechanical equipment and installation costs are estimated as follows:

Item	£
Crossflow Turbine, belt-drive and Generator	30000
Control panel and cabling	8000
6mm Intake screen	2000
Inlet valve	3000
Workshop assembly, installation and commissioning	12000
Detailed design & project management	8000
Sundry fixtures, transport, inflation	3000
TOTAL (ex VAT)	**66000**

9.2 Additional Works

Additional works will be required to cover:

All civil construction works, including:

- structural design
- temporary works and site clearance,
- intake works
- procuring and installing the pipeline
- building the turbine shed, with sump below the turbine location.
- running the power cable to the network connection.

Depending on final designs, the civil construction costs are estimated to fall in the range £40k-£60k

2. Gaining planning and licensing permissions, as appropriate with possible additional specialist surveys (river ecology, protected species, archaeology, etc.).

3. Securing a grid connection agreement (expected to be a formality in this case).

10. NEXT STEPS

A formal license from the Environment Agency will be required, as well as planning permission. The main environmental criteria to be satisfied would involve fish-protection, flood defence and the amount of water to be preserved for the watercourse.

The logical next steps to develop the scheme would be:

- Submit a pre-application enquiry to the Environment Agency and local Planning department, followed by a site meeting to discuss their comments.
- Submit an Application for Embedded Generation to the local electricity company (Western Power) to confirm the ability of the network to accept a generator of this size.
- Commission the scheme design to support the full license and planning applications, and in order to define the civil works requirements.
- Obtain firm quotes for the cost of the electro-mechanical equipment and civil construction works.

11. FURTHER INFORMATION

Further background information on developing a mini-hydro site can be found at:

www.british-hydro.org/wp-content/uploads/2018/03/A-Guide-to-UK-mini-hydro-development-v3.pdf

SITE PICTURES

Figure 5 : Cromford Pond

Figure 6 : Pond overspill

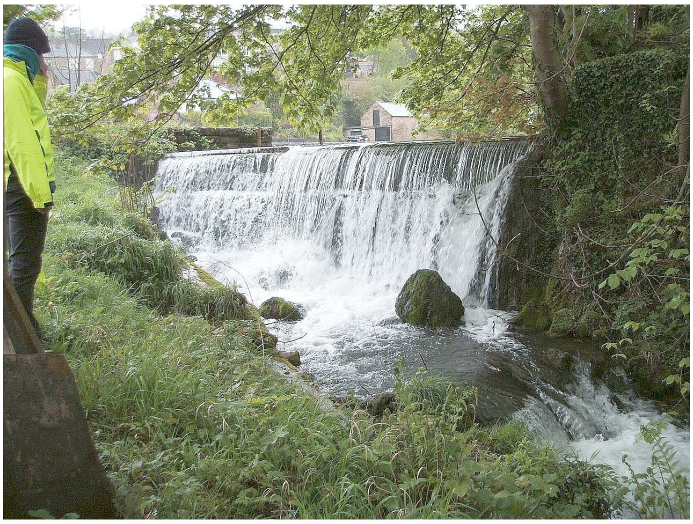


Figure 7 : Upturned channel on part of the weir crest

Figure 8 : 2m width of riverbank for pipeline

Figure 9 : Downstream reach towards the Greyhound

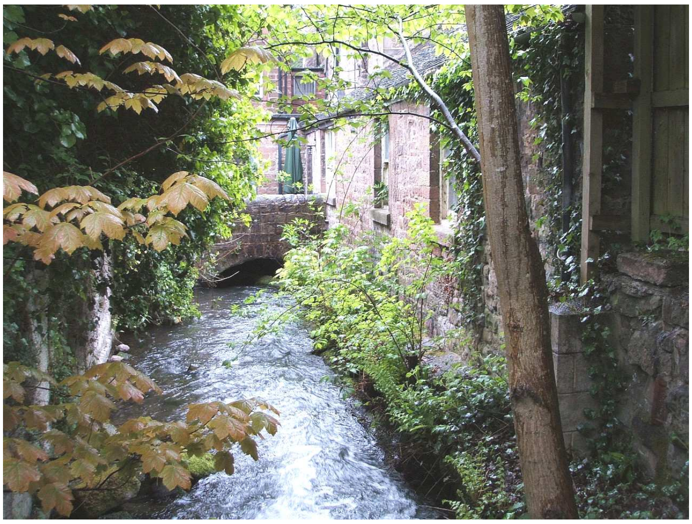


Figure 10 : Site access via the neighbouring forecourt

Figure 11 : Montage of proposed scheme