Arkwright Society

HYDROPOWER AT CROMFORD MILL

Turbine and Waterwheel

ENVIRONMENTAL REPORT

(Version 2)

Oliver Paish

DerwentHYDRO
40 Holloway Rd
Duffield
Derbyshire DE56 4FE

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HYDROPOWER AT CROMFORD MILL: TURBINE AND WATERWHEEL

ENVIRONMENTAL REPORT

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ENVIRONMENTAL REPORT

SCHEME PARAMETERS

				A	B	
Watercourse	Bonsall Brook		Turbine type	Spiral-Francis	Overshot waterwheel	(ornamental)
Location	Cromford Mill		Gross Head	6.4	6.4	m
Town/Village	Cromford DE4 3QF		Design Head	5.8	4.8	m
Grid Ref. Intake	SK 29840 56970		Design Flow	385	60	litres/sec
Grid Ref. Outfall	SK 29840 56970		Peak output	15	1.5	kW
			Annual Energy	55,000	1500	kWh/year
			Operation	Continuous	Intermittent	

1. INTRODUCTION

This report presents the technical details and environmental appraisal of a proposed, new mini-hydro installation at Cromford Mill near Matlock, in support of the application for an impoundment license for the scheme.

1.1 Background

Cromford Mills is a Grade-I listed industrial mill complex, where waterpower was first used to power a factory system of cotton spinning and weaving at the start of the Industrial Revolution.

The Arkwright Society, who own the Mill, are now seeking to generate hydro-electric power from the wheelpit of the 'Second Mill' at Cromford Mills. This would utilise a modern turbine but would also include the reinstatement of a waterwheel to demonstrate the original technology used at the site.

1.2 Proposal Summary

When Cromford Mill had expanded to its full potential by 1775, the Second Mill contained a substantial 'double' waterwheel (over 3m wide and over 5m in diameter).

This wheelpit (Figure 23) still receives the full flow of Bonsall Brook, cascading 6.4m into the wheelpit below, before discharging back to the River Derwent via a long tunnel.

The head and flow at the wheelpit provide the raw potential for a new micro-hydro scheme to generate renewable energy for consumption within the Mill complex.

As described in this report, the proposal is to install 2 separate hydropower installations on opposite sides of the wheelpit, as follows:

1. a refurbished Francis turbine that would exploit the full potential of the site to generate hydro-electric power to feed into the switchboard of the Mill.

2. a traditional overshot waterwheel, to demonstrate the original technology used on the site, but only generating a nominal output from a small flow.

Part A describes the rationale and detail behind the Francis Turbine proposal. Part B covers the overshot waterwheel.

Site pictures are included in Annex A and design details are provided in the scaled drawings of Annex B.

2. SITE OVERVIEW

The location of the wheelpit is highlighted in Figure 1 and the principal routes for water to flow into and out of the site are summarised in Figure 2.

2.1 Existing Infrastructure

Flow is conducted to the Second Mill (1775) via a stone headrace canal roughly 5m in width and 1m deep (Figure 22). The wheelpit of the Second Mill is 5m wide and 6m long and was sunk over 5m below ground level. This takes it below the level of the adjacent River Derwent so a long tunnel is required to discharge back to the Derwent half a mile downstream.

Flow into the wheelpit initially drops 1.0m onto a stone platform, 3.1m wide, before cascading 5.4m down into the wider wheelpit below (Figure 23). Flow leaves the wheelpit through the archway into the long culvert leading down to the River Derwent (Figure 26).

There are rectangular bearing enclosures on each side of the wheelpit, sunk 1.9m below the side walls (visible in Figure 25).

The existing historic impoundment comprises a set of 6 stop-logs which impound the headrace upstream of the "Second Wheelpit". The top stop-log is adjustable by the rotating of hand-wheels on vertical spindles at each end, allowing the flow into the wheelpit to be regulated (Figure 24).

The lower 5 stop-logs are in a poor state or repair, allowing substantial leakage (Figure 7). As part of the new development, these 5 stop-logs will be replaced with a sold masonry wall, discussed in Section 8.1. The top, adjustable stop-log will be retained.

Figure 1 : Site Location ('Second Mill' of 1775 highlighted)

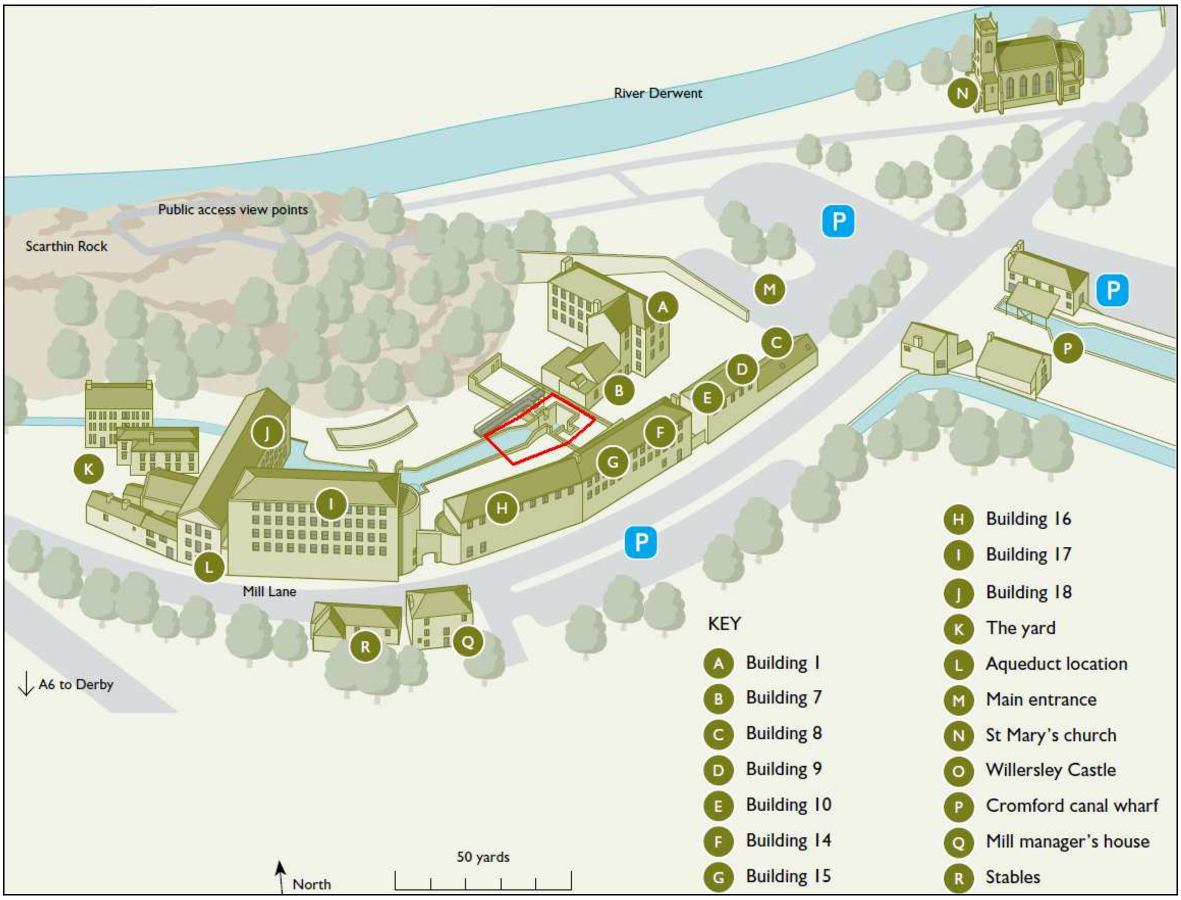
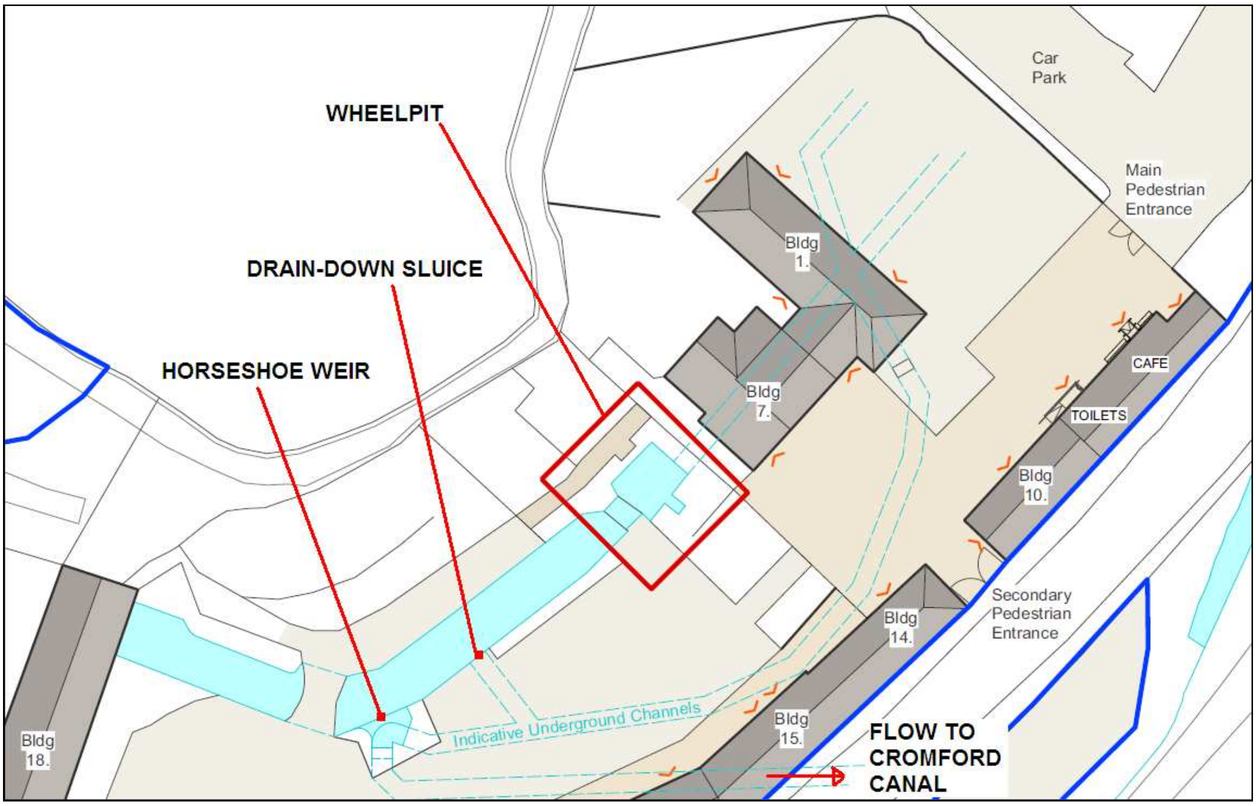


Figure 2 : Watercourses and culverts



Viewing Platform

A raised viewing platform runs along the north side of the millrace and wheelpit (see Figure 25). It is constructed in timber with the support legs set onto concrete foundation blocks located below ground level.

2.2 Land Ownership and Right of Access

The site is in the heart of Cromford Mills, owned by the Arkwright Society.

2.3 Flood Levels

The site does not experience extreme flood levels due to the nature of the flow regime in Bonsall Brook.

There is a crescent-shaped overspill in the headrace upstream of the wheelpit which can divert excess flows back to the river Derwent (also keeping Cromford Canal topped up) – see Figure 27.

Stop-log

Additional flow can be discharged into the wheelpit by raising the stop-log which sits above the overspill and is lifted by a handwheel at each end – see Figure 24. The stop-log is primarily used to control water levels during low flows so as to guarantee a continuous overspill into the Cromford Canal (see Section 3) and during high flows to prevent upstream flooding.

2.4 Environmental Designations

The site itself has no environmental designations, but it lies just upstream of the Cromford Canal, which is both a SSSI and Local Nature Reserve. The canal receives a small, continuous flow from the offtake in the headrace, as discussed in Section 3.

2.5 Planning Designations

The Cromford Mills site is designated as a Grade-I listed building, and the whole area is within the 'Derwent Valley Mills' World Heritage Site.

2.6 Water Framework Directive (WFD)

Bonsall Brook is too small have its own WFD classification and sits within the waterbody "Derwent from Wye to Amber". This is a Heavily Modified waterbody with 'moderate' ecological status.

Cromford Canal is also a defined waterbody within WFD classifications, denoted as an ‘artificial’ waterbody with an ecological status of ‘good’.

3. CROMFORD CANAL

3.1 Horseshoe Weir

The ‘Horseshoe’ side-spill weir 30m upstream of the wheelpit (Figure 27) provides a continuous discharge into a culvert which supplies top-up water into the Cromford Canal, with any excess diverted back to the River Derwent. The crest of the horseshoe weir is at 84.850mAOD and it has an effective length of 5.22m. The flow overspilling this weir can be regulated by the setting of the stop-log above the wheelpit overspill, since this determines the prevailing water level in the mill-race.

The flow over the Horseshoe Weir drops into a well at the base of the weir where it is divided as follows:

- A rectangular orifice plate, 375mm wide x 200mm high, allows flow to enter the feeder channel for the Cromford Canal (Figure 28). The size of the orifice will tend to restrict maximum flows into the canal to less than around 150 litres/sec – in the event that >150 litres/sec is overspilling the Horseshoe Weir.
- Any excess flow will overspill into a diversion culvert which ultimately drains into the River Derwent (Figure 29).

3.2 New Authorisation application

There is currently no licensed abstraction from Bonsall Brook into the Cromford Canal, however an application has been made by Derbyshire County Council under the New Authorisations regulations (ref. NPS/NA/001879).

As part of this application, a flow assessment was undertaken in spring 2020 by Horritt Consulting[1]. This study did not measure any flows, but developed a broadbrush hydraulic model to estimate the flow that would have been taken during different flow conditions in the Brook. <u>The numerical results in this study should be treated with caution, since they rely on a range of assumptions and simplifications, and have not been verified with any actual flow measurements.</u>

As a result, the high flow volumes predicted to have entered the Canal in this report are not credible in practice. The 3 principle reasons being:

1. By extrapolating flow data from the River Lathkill, the model assumes a much higher availability of flow in Bonsall Brook – more than double – than is present in reality (see Section 5).
2. No account is taken of the substantial leakage flow passing through the wheelpit impoundment (Figure 7).
3. No account is taken of the fact that that the top wheelpit stop-log is being continually adjusted to increase flow into the wheelpit during higher flows, so reducing the flow into the Canal.

[1] Cromford Canal Water Resources - Technical Note of July 2020 by Horritt Consulting

3.3 Proposed Regulation of Future Flows into Cromford Canal

Historically, the water levels within the Canal have been regulated by raising or lowering the stop-log across the overspill into the wheelpit. By constricting the flow into the wheelpit, this determines the water level backing up in the mill-race, and hence the quantity of flow overspilling the horseshoe weir 30m upstream.

Adjustment of the wheelpit stop-log has been carried out under an informal agreement with the Arkwright Society, who allow access for Derbyshire County Council (DCC) staff and volunteers to adjust the stop-log as deemed necessary. There is no automated monitoring of water levels or flow rates within the Cromford Canal and any adjustments to water levels are carried out on an ad-hoc basis, guided by the level on a rudimentary staff gauge at the start of the Canal (depicted in Figure 3).

Cromford Canal is a closed system with no locks, so the majority of the water entering the Canal is lost to leakage, estimated at around 50-60 litres/sec (see Case Example below). The operating water level in the Canal was raised in 2014 by 50mm in order to accommodate the newly acquired canal boat, which was otherwise found to ground-out in places. At this time, a 50mm upstand was added to the Leawood overspill, visible in Figure 6. (Note that, in general, higher water levels will tend to increase the water pressure and hence may also increase the rate of leakage; the eastern non-navigable section of the Canal, beyond Leawood Aqueduct, is operated 250mm lower than the navigable section in order to limit leakage flows).

The key parameter for the Canal is the maintenance of the water level, rather than any given flow rate into it. In wetter months, natural run-off into the Canal is high and evaporation is low, so the need for additional flow from Bonsall Brook is reduced or eliminated. During winter, the Canal is operated at a lower water level – typically 25-50mm lower – as an insurance policy against heavy rain over-filling the Canal (spillage out of the Canal would potentially flood the adjacent Derby-Matlock railway track).

The peak requirement for supplementary flow is in dry summer months, but in these months the new turbine is likely to be switched off through lack of flow, so there would be no alternative demand for the water, thus ensuring there would be the maximum flow available for the SSSI.

A recent issue has been the high leakage flow through the impounding stop-logs above the wheelpit (see Figure 7), which deprives the Horseshoe Weir in very low flows (Figure 8). This problem will be resolved when the stop-logs are replaced by a solid wall as part of the hydropower development, hence safeguarding the SSSI during low flows.

Following a meeting with DCC in November 2021, it was agreed that the new hydro scheme will monitor the water level in the Canal (with an electronic sensor). Automated warning signals would then be transmitted if the level drops too low (or rises too high), requiring an adjustment of the wheelpit stop-log and hence the rate of overspill at the Horseshoe Weir.

The ‘control level’ will be seasonal, since a higher level is only required in the months when the ‘Birdswood’ canal boat is operating (April to October). As is already the operational practice of DCC, the Canal level would then be reduced to its historic level (50mm lower) for the rest of the year without impacting the SSSI, whilst reducing the flood risk and also potentially reducing the leakage flow.

To ensure the available water is used efficiently, the maximum flow into the Canal at the Horseshoe weir will be capped at 55 litres/sec – believed to be sufficient to combat the leakage flow at present. However if this leakage flow worsens, it will be the responsibility of DCC (the canal owners) to undertake remedial works to reduce the leakage and maintain water levels, otherwise this would not constitute an efficient use of the water resource. Continuous monitoring of the spill level of the Horseshoe Weir (by the turbine control system) will provide an early warning as to whether leakage flows are worsening.

In practice, this cap means that the overspill at the Horseshoe Weir would not be increased above 35mm if the turbine or waterwheel were able to generate, even if the Canal level was low. This is essentially stating that, in extremis, the water turbine will take priority over the operation of the Canal Boat if the leakage flow out of the Canal is excessive, bearing in mind that the Arkwright Society have no control over DCC's maintenance regime of the Canal.

By preserving the existing water levels of the Cromford Canal (within a 50mm band) any impacts towards the SSSI, through a change in water levels, are not anticipated, as concluded in the Ecological Report (appended in Annex C).

In summary, the provision of flow over the Horseshoe Weir in order to maintain the status quo and health of the Cromford Canal SSSI is proposed as follows:

Target Values for Adjusting the Wheelpit Stop-Log

Boating Season (April-October):			
Either:	**[A].** The water level in the Canal should be at, or above, 2.0 inches on the Canal gauge.	or:	**[B].** The headrace water level should be ≥35mm above the crest of the Horseshoe Weir (spilling ~55 litres/sec).
Off-season (November-March):			
Either:	**[A].** The water level in the Canal should be above Zero on the Canal gauge.	or:	**[B].** The headrace water level should be ≥35mm above the crest of the Horseshoe Weir (so spilling ~55 litres/sec).

Notes:

- The default position (as at present) is to meet Target A.
- Target B is a fall-back to protect the flow to the new turbine/waterwheel in the event that the Canal leakage flow increases significantly.

It should be stressed that, historically, maintaining the Canal level has been an informal, working arrangement. There is no legal requirement for Cromford Mill to provide this flow into the Canal from Bonsall Brook. At present, this flow constitutes an unlicensed abstraction from a source of supply into a man-made navigation. The owners of the Canal currently have neither an abstraction/transfer license for this flow, nor a formal right of access to the point of abstraction (the latter being a minimum requirement for the issue of such a license).

Assessing the Leakage Flow : Case Example

Site observations and measurements were made on 26th Nov 2021, as depicted in Figure 3 to Figure 6.

- The flow entering the Canal at the Horseshoe Weir is depicted in Figure 4. Based on the water depth over the sill, this flow was estimated at 65 - 75 litres/sec.
- The water level in the Canal was 2.25 inches on the gauge (Figure 3); DCC generally try to keep the level above 2 inches when the Canal Boat is operating.
- There had been no recent rainfall events and there was no other visible runoff into the Canal.
- Excess flow can spill out of the upper section of the Canal at only 2 locations:

    1. Over the impoundment after the Leawood Aqueduct (opposite Aqueduct Cottage), depicted in Figure 5, which marks the end of the navigable reach. This flow was estimated at 5 to 7 litres/sec.
    2. The overspill back to the Derwent at Leawood Pumphouse, depicted in Figure 7, estimated at 10 to 15 litres/sec.

It is therefore apparent that the large majority of the incoming flow does not reach these two overspills and must therefore be lost to leakage (there being negligible evaporation in late November).

The above figures give a leakage flow in the region of 50-60 litres/sec.

Figure 3 : Level gauge in the Canal on 26/11/21 (reading 2.25 inches)

Figure 4 : Discharge into the Canal from the Horseshoe Weir on 26/11/21

Figure 5 : Discharge over the Leawood impoundment on 26/11/21

Figure 6 : Discharge over the Leawood spillway into the Derwent on 26/11/21

Figure 7 : Leakage flow through the wheelpit stop-logs (7/9/21)

Figure 8 : Horseshoe Weir – deprived by leakage flow (7/9/21)

4. HEAD & FLOW

4.1 Head

The gross head at the wheelpit (water level in the headrace to tailwater in the wheelpit) was measured at 6.40m. The losses associated with the intake design described in Section 8.1.1 lead to a net head calculation for the Francis turbine of 5.8m.

4.2 Flow modelling

4.2.1 HydrA

Bonsall Brook is not gauged by the Environment Agency. To establish an initial flow estimate, the HydrA hydraulic model from the Institute of Hydrology was run for this catchment with a measured catchment area of approximately 31 km² and average rainfall of 966 mm per year. This leads to an annual mean flow estimate of 460 litres/sec.

4.2.2 Lathkill comparison

The Horritt Consulting report completed a separate flow modelling exercise, using measured flows on the River Lathkill (an adjacent catchment) to predict the flow characteristic on Bonsall Brook by adjusting for catchment area and rainfall data. This predicted a mean flow of 480 litres/sec having calculated a slightly larger catchment area of 34.8km².

4.2.3 Modelled flow characteristics

For both of the above methods, the resulting flow parameters for the Brook are summarised in Table 1. Although the average flows are similar, a key difference is that the Lathkill model predicts significantly drier summer flows, and higher winter flows.

4.2.4 Limestone catchments and sub-surface flows

Whilst rainfall and catchment area methods can be used to estimate the likely flow variation, these methods can be highly unreliable in a limestone catchment where the rainwater 'disappears' underground before emerging at various springs.

In addition, historic mining operations, plus the substantial quarries still active within the catchment, are also likely to disrupt the normal flow paths. Flow may be lost (or gained) between other catchment areas as a result of these sub-surface flows

Therefore a period of flow monitoring was undertaken to measure the flow in Bonsall Brook, as described in Section 5, which has concluded that Bonsall Brook passes substantially less water than indicated in Table 1.

Table 1 : Bonsall Brook - modelled flow characteristics

	HydrA Flow Model	Lathkill Comparison
Exceedance	**Flow (litres/sec)**	**Flow (litres/sec)**
2%	1425	1900
5%	1120	1480
10%	885	1050
20%	645	680
30%	525	530
40%	428	430
50%	363	350
60%	310	290
70%	260	230
80%	218	160
90%	165	110
95%	135	50
97%	115	45
Q-mean	**460**	**480**
Q95:Qmean	***29%***	***10%***

5. FLOW GAUGING

5.1 Gauging Weir at Cromford Cornmill

A system for measuring the flow rate in Bonsall Brook was established upstream at Cromford Cornmill, a short distance upstream of Cromford Mill at Grid Ref. SK 29235 57045.

The flat concrete overspill from the millpond provided a convenient location for setting up a rectangular gauging weir. A sharp-crested weir was created by installing a 2.9m length of angle iron across the end of the overspill – see Figure 9.

In principle, the depth of water passing over the angle iron should correlate directly with the flow being discharged, as estimated by the standard weir equation (see §5.2 below). The water depth over the weir was measured every 10mins by a standard pressure gauge and data-logger.

5.2 Theory of Gauging Weirs

When a flow rate **Q** is passing over a gauging weir of width **L**, the upstream water level **h** is directly related to **Q** by the Weir Equation:

$$Q = \tfrac{2}{3} . C_d . \sqrt{2g} . L . h^{1.5}$$

The coefficient of discharge $\mathbf{C_d}$ for a rectangular weir is taken to be 0.6.

Figure 9 : New upstand with water level gauge

Figure 10 : Flow gauge at low flow

Figure 11 : Flow gauge at medium flow

5.3 Site-Specific Constraints

Ideally, the flow arriving at the gauging weir should be slow-moving and without turbulence, so spread evenly over the crest of the weir. In practice, there were some compromises in the set up at the Cornmill:

- The flow has to pass under a pair of partially-raised sluice gates before reaching the overspill; these do not create an obstruction at lower flows, but at higher flows these restrict the flowpath, forcing the flow to accelerate, so slightly reducing the measured head (h) and leading to artificially low flow calculations at higher flows.
- Even without the above constriction, the depth of water approaching the weir - created by the 150mm upstand - is still relatively shallow for a gauging weir, so at higher flows, the approach velocity is not negligible, as assumed by the weir equation, again leading to an under-estimate of the actual flow. However it is possible to compensate for a high approach velocity (V) using a simple additional calculation[2].

In conclusion, the gauging weir is likely to have been reasonably accurate at lower flows. The accuracy is likely to decrease as the flow rises, generally leading to an under-estimate of the real flow value, although a standard compensatory calculation has been used to minimise this error.

5.4 Results

Hydrograph and Ashford Gauge

A complete 12 months of data has been recorded from 24th March 2021 to 23rd March 2022.

Over the same 12 months, the nearest flow gauge at Ashford on the River Wye recorded a mean flow of 3.77m³/sec, very close to its 10-year mean of 3.76m³/sec. In Figure 12, the 10-year flow duration curve at Ashford is compared with the 1-year curve from 24th March 2021. The close fit confirms that 2021-22 was very close to being an average flow year.

The daily hydrograph of the gauged data for Bonsall Brook is compared with the daily mean flows at Ashford in Figure 13, confirming a reasonably good correlation of peaks and troughs in the overall flow patterns.

Flow Duration Curve

The flow availability for Bonsall Brook is significantly below that predicted by HydrA. The 12-month mean flow of the gauged data is 237 litres/sec (52% of the HydrA prediction), with the main flow parameters listed below.

Exceedance	Flow (m^3/sec)
1%	**0.934**
5%	**0.643**
20%	**0.394**
10%	**0.471**
30%	**0.297**
50%	**0.183**
70%	**0.094**
90%	**0.053**
95%	**0.046**
99%	**0.031**
MEAN	**0.237**

The Flow Duration Curve of the gauged data is plotted in Figure 14. Two curves have been added to this graph, obtained from the HydrA Flow Duration Curve, but scaled by 2 different percentages (39% and 59%) to get the curves to match the gauged curve at both high flows and low flows.

2 The velocity head ($V^2/2g$) of the approach velocity is added to the actual head (h) before making the flow calculation (as described in The Mechanics of Fluids by Duncan, Thom & Young)

Figure 12 : Flow Duration Curves for the EA Gauge at Ashford: 10-year and 1-year

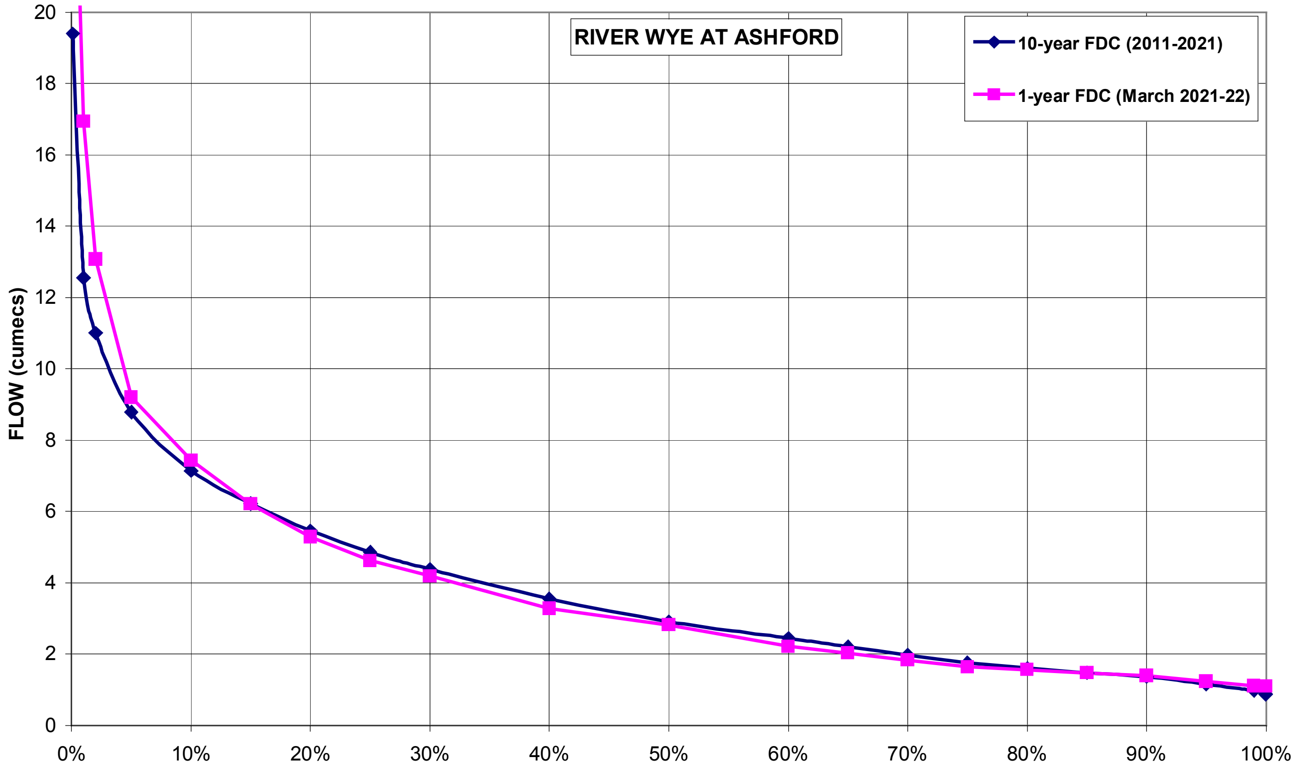


Figure 13 : Hydrographs of River Wye (daily mean flow) vs Bonsall Brook flow gauge

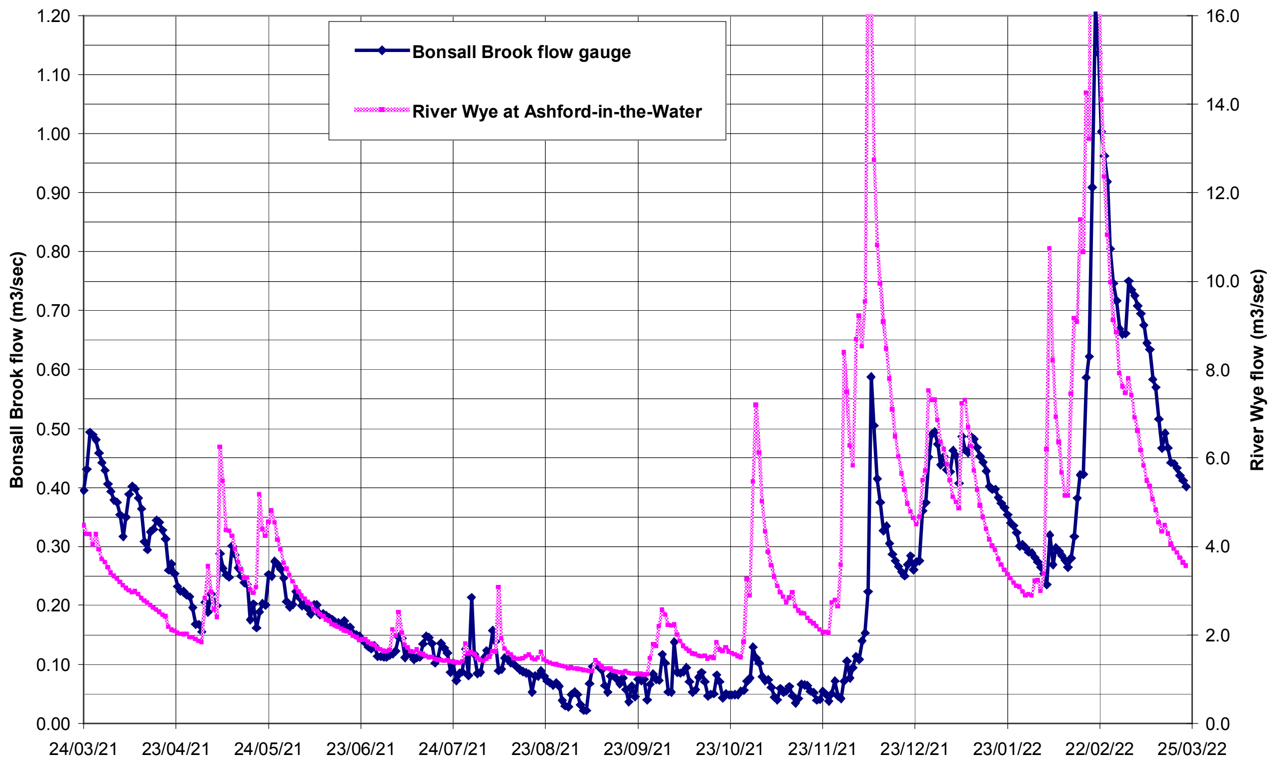
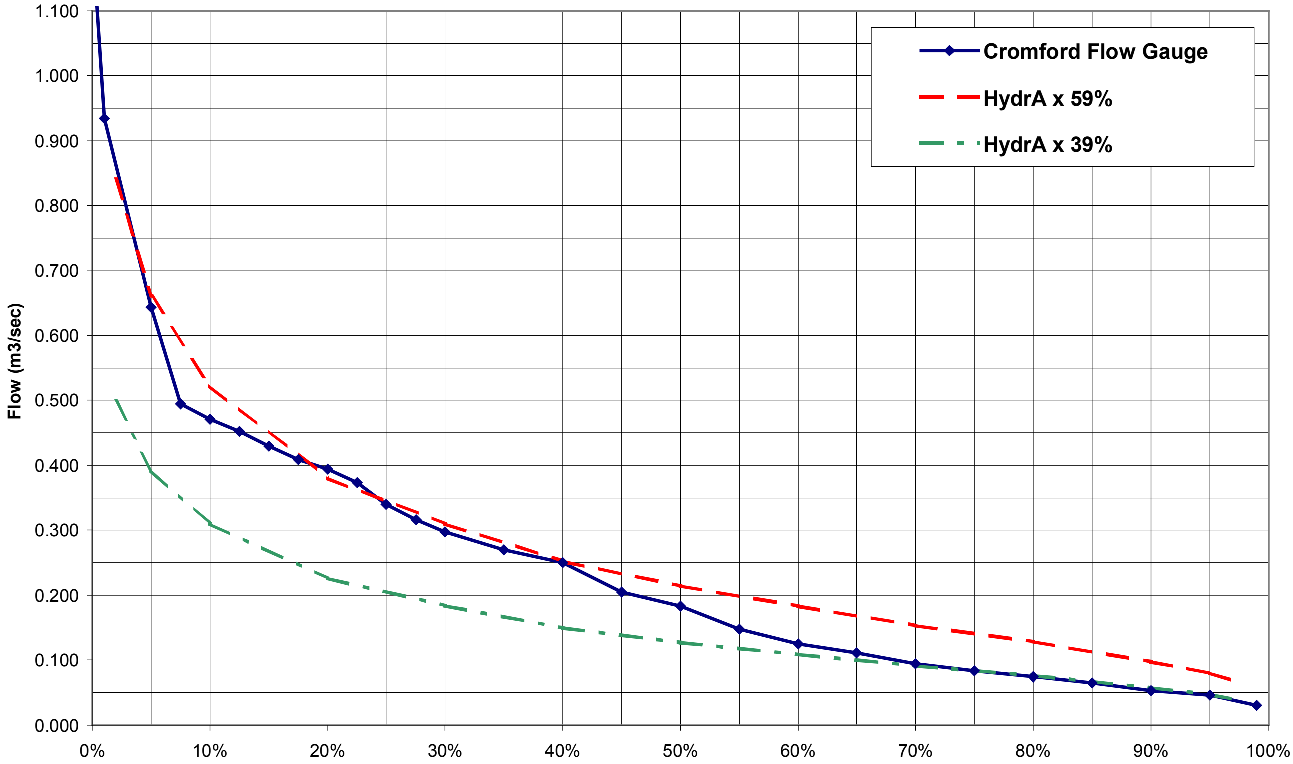


Figure 14 : Flow Duration Curve for Bonsall Brook at Cromford : Gauged flows vs HydrA model



Comment

It appears that Bonsall Brook operates in 2 modes: wet period and dry period.

Below Q70, the 'dry period' flow regime exactly follows the duration curve modelled by HydrA but based on a catchment area reduced to 39% of the measured catchment (i.e. as if only 39% of rainfall is reaching Bonsall Brook).

The 'wet period' regime follows a curve very close to 59% of the HydrA prediction above Q40.

A possible explanation is that substantial runoff is being lost into quarries, old mines and limestone fissures which discharge elsewhere, so this flow never makes it into Bonsall Brook. In wetter periods, some of these features are likely to become saturated, allowing more water to runoff into the Brook.

A. FRANCIS TURBINE INSTALLATION

6. TURBINE DESIGN FLOW

6.1 Base Flow

The ratio of Q95:Qmean is 19%, which indicates a 'medium' baseflow stream.

6.2 Prescribed Flow

The 'prescribed flow' is the flow that would normally be reserved for the deprived reach of the watercourse (for ecological or other reasons).

However in this case there is no deprived reach of watercourse i.e. the flow from the turbine (and waterwheel) will drop directly back into the wheelpit, as at present. Therefore the only flow unavailable for power generation will be the small overspill towards Cromford Canal. This is guaranteed by adjusting the stop-log above the wheelpit overspill.

As already discussed in Section 3, this flow will be adjusted to suit the needs of the Canal by continuously monitoring the water level in the Canal.

6.3 Design Flow

Under Table B of the Environment Agency's Flows Guidance for Hydropower, 'hydropower schemes at an existing weir' can apply for a discharge of 130% of mean flow. Using the data inferred from the Cornmill flow gauge, this would imply a design flow of 308 litres/sec.

However the Table B limits are 'indicative', based on the assumption that there is both a weir and weir pool which require some flow variability – and variability can be preserved by limiting the peak abstraction. There is no such environmental need in this case.

In addition, the mean flow in a lowland watercourse with a medium baseflow would normally be close to Q30. The unusual shape of the flow duration in Figure 14 has led to the mean flow being equal to Q41 – which would normally only occur on a very high base flow river.

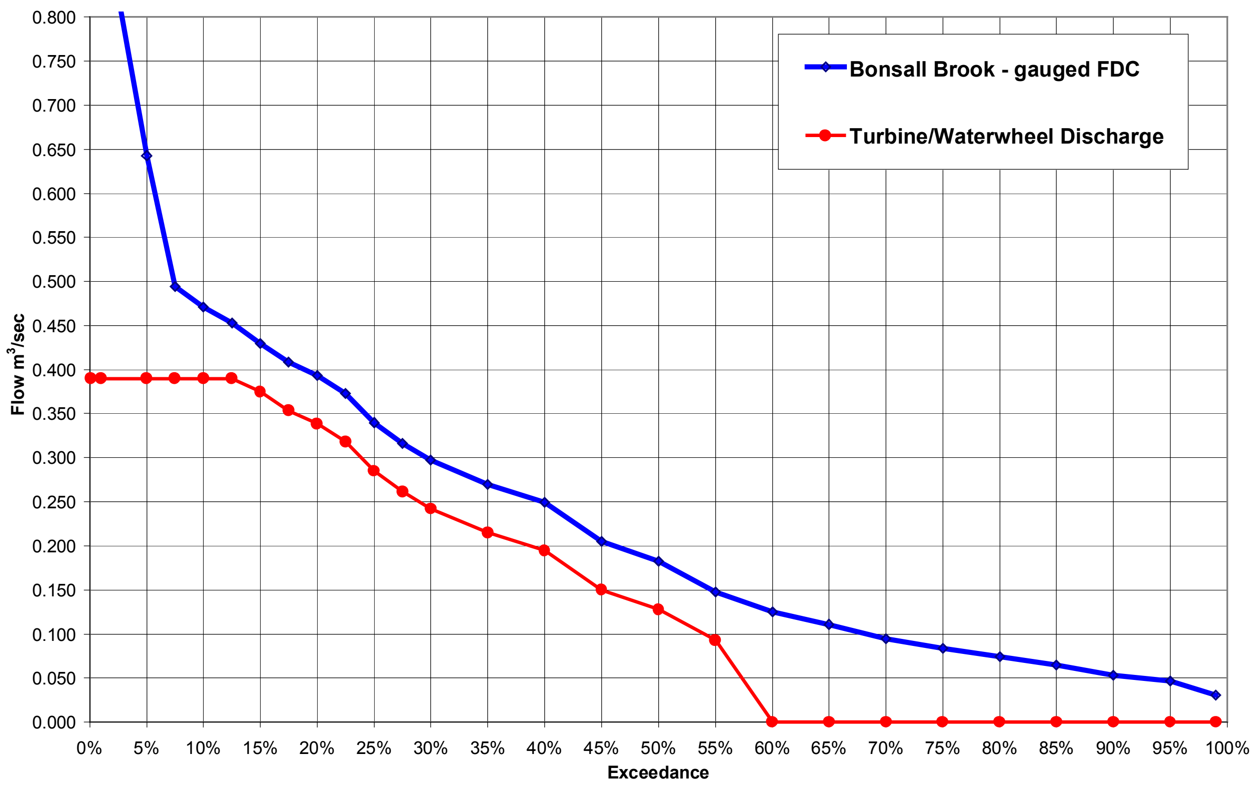
If instead we adopt Q30 as the guiding parameter, then 130% of Q30 would give a design flow of 385 litres/sec.

It is therefore proposed to proceed with a design flow 385 litres/sec in order to maximise the renewable energy potential of the site.

The resulting turbine abstraction, relative to the flow duration curve, is depicted in Figure 15.

Note that the waterwheel proposed for the wheelpit would be limited to a maximum abstraction of 60 litres/sec, but this would only be operated on an intermittent basis (i.e. during visitor opening hours primarily at weekends and holidays). This flow would be deducted from the flow otherwise going to the Francis turbine.

Figure 15 : Flow Duration Curve and proposed turbine discharge



7. TURBINE SELECTION

7.1 Overview

The head and flow available at the site indicate a choice of 3 potential types of turbine:

- A Kaplan (propeller-type) turbine
- A Crossflow turbine
- A low-head Francis turbine

Kaplan Turbine

Quotations confirmed that the Kaplan solution was not going to be economically viable, due to the small size but high complexity of this type of turbine, which is best suited for schemes >100kW.

Crossflow Turbine

With these site parameters, a crossflow turbine would be a relatively large machine and would need to be located within the wheelpit itself, supported 1.7m above tailwater level. This would require steel joists spanning the length of the wheelpit, as well as a permanent access gantry into the wheelpit. The crossflow option was therefore considered unlikely to be realistic in this location, for technical, safety and conservation reasons.

Francis Turbine

A second-hand spiral-case Gilkes Francis turbine is available within the range of machines, with the following original characteristics:

Make:	Gilkes No. 5418	
Type:	Francis turbine 13.5" Series R	
Parameters	Nameplate	Cromford
Rated head:	9.1m	5.8m
Rated flow:	489 litres/sec	385 litres/sec
Rated speed:	560 rpm	450 rpm
Shaft power:	34 kW	17 kW

This machine is a good match for the characteristics at Cromford, and the proposed machinery layout on the north side of the wheelpit is provided in the design drawing in Annex B. Utilising this Francis turbine would have the following advantages:

- the design flow is within the recommended range for optimal exploitation of the available resource.
- the Francis turbine discharges the flow at 90° to the incoming pipework: this suits the layout at the wheelpit, allowing a compact installation with least disturbance to the existing stonework.
- the Francis turbine uses a draft tube which creates suction head below the turbine, so the turbine itself can be elevated up to a level which suits the local infrastructure. In this case, this allows the turbine to be hidden behind the wall of the wheelpit whilst making use of the existing bearing pit to allow the draft tube to pass through the wing wall before bending down into the tailrace.
- the operating speed allows the use of a standard V-belt drive to achieve the design speed of the generator.
- the flow into the turbine would be controlled by a single hydraulic ram which rotates all the inlet guide-vanes in unison; in the event of a power failure - or emergency stop - a weight closes the ram under gravity, so providing a reliable, fail-safe stop mechanism.
- for operation and maintenance, all moving parts can be accessed safely from within the turbine pit, so there will be no need to provide access into the wheelpit.
- the turbine is available at an affordable price.

A second-hand Francis turbine rated at 13kW has been operating nearby at Ladygrove Mill (Darley Dale) since 2014, as depicted in Figure 16. The turbine that is available for Cromford Mill is depicted in Figure 17.

Figure 16 : Francis installation at Ladygrove Mill

Figure 17 : 2nd–hand Francis turbine (Gilkes)

8. LAYOUT DESIGN AND SCREENING

8.1 Intake Works

The intake structure needs to be able to:

- discharge the required flow to the turbine,
- screen out both debris and fish
- keep debris within the watercourse (i.e. avoiding debris collection and disposal).
- allow high flows to continue unimpeded without risk of flooding.
- require minimal maintenance

A number of design options were considered, but the key constraints were:

- the limited space available due to the adjacent overhead walkway
- the 6mm screening aperture requested by the EA
- the cost and upkeep of automated screen-cleaning systems for a project of this size

8.1.1 'Tyrolean' overwash intake

This led to the recommended solution of a 'Tyrolean' overwash intake screen. This is a standard solution on higher head projects, but is rarely used on lower head systems because it involves sacrificing a proportion of the head - in this case around 0.4m, or 6% of the gross head.

In this design, the flow passes over the top of a sloping bar screen which filters out floating debris and allows the water to drop into a sump below (see Figure 18). It is a relatively self-cleaning design and will exclude all wildlife and debris from reaching the turbine.

As depicted on the design drawing, the screen would be located immediately downstream of the existing overspill and stop-log, where the flow currently drops 1m onto a ledge before dropping further into the wheelpit. A new screening tank would be constructed on this ledge, spanning the 3.15m width of the ledge and extending roughly 1.3m beyond the overspill.

The 6mm bar screen would form the roof of the tank, running downhill at 10° to the horizontal. Flow for the turbine would drop through the bars, leaving behind any debris, and collect in the sump below. Any excess flow will fall off the end of the screen and down into the wheelpit, taking any debris with it.

The impoundment currently formed by 5 stop-logs is in a poor state of repair with major leakage problems. Therefore these will be replaced with a sold masonry wall, constructed to exactly the same height as the present overspill level (84.697mAOD). This will form the upstream wall of the new overwash screen.

The top, adjustable stop-log will be reinstated and work in the same way as at present. The stop-log with hand-wheels would remain in situ, and continue to moderate the upstream water level, necessary for providing a continuous overspill into Cromford Canal.

Figure 18 : Overflow bar screen (Tyrolean)

8.2 Forebay Tank

The flow arriving into the sump below the Tyrolean screen will be diverted into a holding tank (or 'forebay' tank) behind the north wing wall before feeding the flow into a short length of 500mm fabricated pipe which supplies the Francis turbine.

A standard wall-mounted sluice gate will be installed across the pipe inlet in the forebay tank for isolating the turbine for maintenance.

8.3 Turbine Enclosure

As indicated on the drawing in Annex B, the Francis turbine will be housed in a sunken 'machinery chamber' extending roughly 2m below existing ground level, with a minimum floor space of 2.1m wide x 2.8m across.

The machinery to be accommodated would consist of:

- Francis turbine, bolted to the floor
- V-belt drive to the secondary pulley on the generator shaft.
- 1000 rpm induction generator mounted on a low concrete plinth
- Weighted lever-arm and hydraulic ram connected to the drive-rod which opens/closes the ring of inlet guide vanes
- Small hydraulic power unit which operates the hydraulic ram, so varying the flow through the turbine.

8.4 Flow Regulation

The Francis turbine would be controlled by a standard control system which would enable fully automatic operation of the system. The control panel continuously monitors the forebay tank level, and opens or closes the turbine guide-vanes in small adjustments, according to whether the water level is rising or falling. If there is insufficient water to generate power, the system would shut down completely, and automatically restart when the Brook is replenished.

In the event of a power failure, or other malfunction, a weight on the lever arm forces the hydraulic ram to close under gravity, bringing the turbine to a stop.

The turbine chamber is not a suitable location for the control panel, so this will be installed within the adjacent mill building to the east.

B. WATERWHEEL INSTALLATION

9. RATIONALE AND DESIGN DETAILS FOR A NEW WATERWHEEL

9.1 Introduction

In addition to the Francis Turbine installation, the Arkwright Society are seeking to install a traditional overshot waterwheel on the south side of the Wheelpit, principally to demonstrate the original technology used on the site for the thousands of visitors that pass through Cromford Mills, and therefore only generating a nominal output from a small flow.

A modern turbine is much better suited (and more efficient) than a waterwheel for capturing the hydropower potential for the purposes of generating renewable electricity. Hence the main proposal for a 15kW Francis turbine located on the north side of the wheelpit.

The principal aims of the waterwheel project are therefore to:

- showcase the original technology used on the site;
- demonstrate the principals of converting waterpower into carbon-free electricity;
- provide an impressive visitor attraction, in keeping with the historic setting.

9.2 Proposal Summary

A relatively compact waterwheel installation is proposed for the south side of the wheelpit, as drawn in Annex B-2 and sketched onto the photographs of Figure 19 and Figure 20.

Flow would be drawn off the headrace channel through a new screened aperture in the south wall to feed a 300dia pipe buried to the south of the channel. This would supply a header tank for delivering the flow to the overshot waterwheel.

The design of waterwheel does not attempt to span across the 5m-width of the wheelpit with a new shaft, but proposes a relatively thin wheel mounted using an overhung bearing arrangement, so allowing the two bearings to be installed within a single bearing enclosure.

9.3 Sizing

The width of the wheel is shown as 600mm, which is a size that would allow the existing overspill into the wheelpit to continue discharging high flows, as at present, without being obstructed by the new waterwheel (as depicted in Figure 20).

With the waterwheel bearings and support plinth located on the base of the existing bearing enclosure, the site dimensions and headrace water level would allow a 16-foot (4.9m) diameter waterwheel. The shaft centre-line would be off-set to the upstream side of the bearing pit to allow space for ladder access into the pit from the downstream side. This results in a gap of over 800mm between the rim of the wheel and the end wall of the wheelpit, plus a clearance of 900mm between the bottom of the wheel and the tailwater below.

A 4.9m dia wheel would rotate at a maximum speed of 7.9rpm. A typical design would allow for 40 buckets holding 12 litres each, with roughly 5 buckets being filled per second, hence a maximum design flow of 60 litres/sec. This would result in a shaft torque of 3000Nm (or 300kg on a lever-arm of 1m). A wheel of roughly this size is shown in Figure 21.

9.4 Flow Regulation

Flow into the top of the wheel will be controlled by an automated undershot sluice gate located at the end of the flume. A second automated gate is included in the system as emergency back-up: shown in the layout drawing as an electric butterfly valve in the supply pipe.

9.5 Transmission

A 2-stage gearbox will be used to receive the high torque from the waterwheel and achieve the majority of speed increase required to match the generator speed. A belt-drive will be used to bring the drive out of the bearing pit and up to ground level where there is more space and better access for the generator.

9.6 Control System

The Waterwheel would be controlled by a standard control system which would enable fully automatic operation of the system.

During start-up, the control system would fully open the butterfly valve in the pipeline so as to fill the header tank and flume, then slowly open the sluice at the end of the flume to commence rotation of the waterwheel. Micro-adjustments of the sluice will eventually discharge exactly the correct flow to fix the waterwheel speed at the target rpm (7.9rpm) allowing the generator to synchronize with the grid at 50Hz. The sluice then opens further to achieve the desired power – up to a maximum of 1.5kW.

The control panel will then continuously monitor the water level in the header tank, and open or close the sluice in small adjustments, according to whether this level is rising or falling. In practice, except in very dry conditions, there should always be sufficient water to run the wheel and little ongoing sluice adjustment will be needed from the control panel.

To stop the wheel, the inlet sluice will be fully closed and the wheel will spin empty until it comes to rest. If there is a problem fully closing the sluice, then the valve in the pipeline will automatically close as well, to ensure the water supply has been stopped. A final back-up option is available at the stop-log slots at the inlet screen, where the pipe entrance can be blocked by manually inserting a solid board.

It would also be possible to consider fitting a disc-brake to the generator shaft, so that the wheel could be stopped from rotating once emptied of water, rather than idling to a stand-still.

9.7 Output

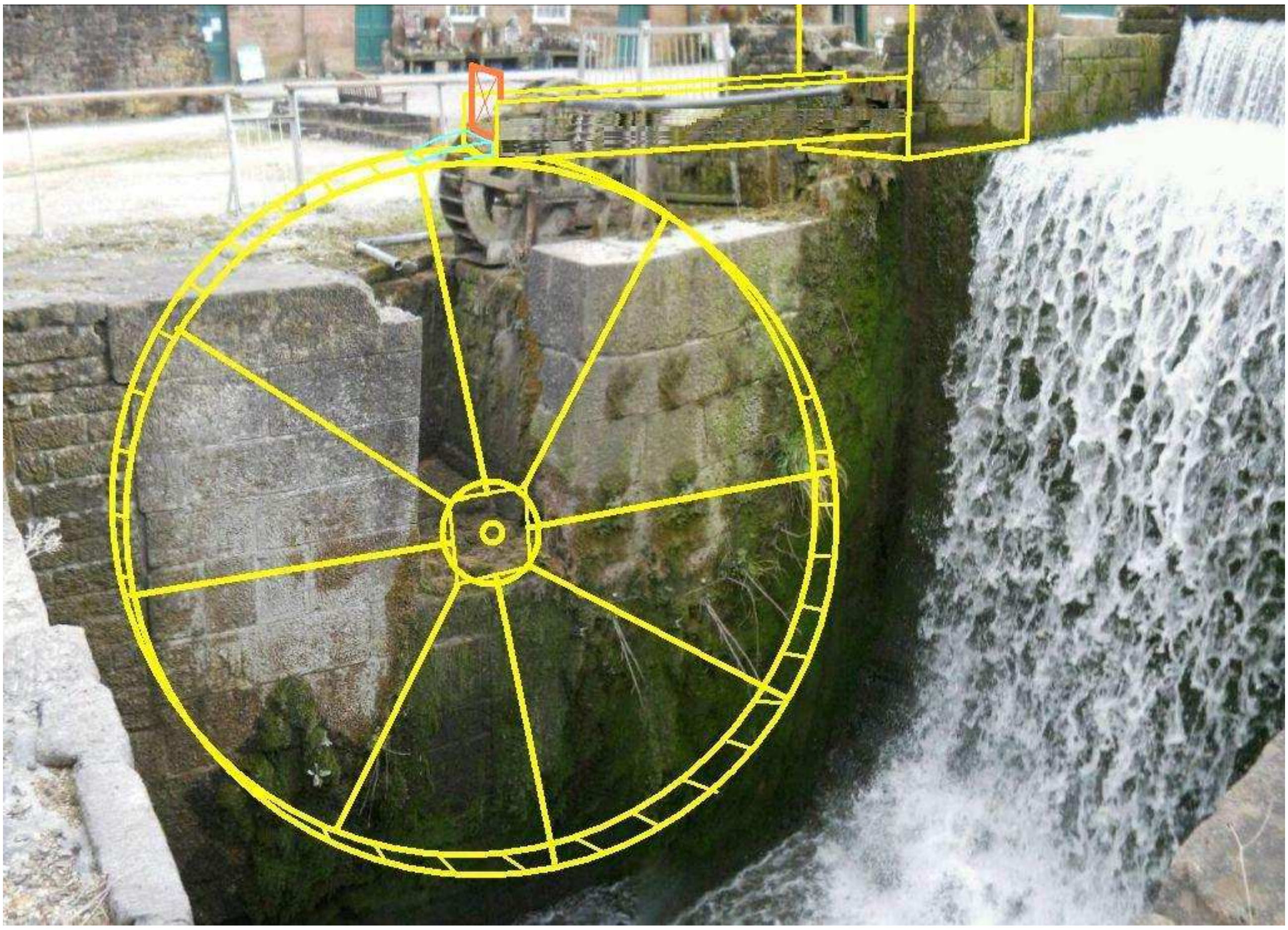
A modern design of overshot waterwheel of 4.9m diameter and width 0.6m could draw a flow of up to 60 litres/sec. An estimated wheel efficiency of 70% combined with a belt-drive/gearbox efficiency of 90% and generator efficiency of 86% would lead to a maximum electrical output of 1.5kW. In practice, since the main aim is the visual aesthetics and educational value of a rotating wheel, the wheel may often be operated more conservatively at perhaps half-power, in order to maximise flow availability for the more efficient Francis turbine.

Assuming that the wheel is only operated when there are significant visitor numbers at the Mill, then it would potentially generate up to 1500 kWh/year.

9.8 Fisheries and Screening

Overshot waterwheels pose little risk to fish, so Environment Agency guidance stipulates only screening for debris e.g. a 100mm-aperture screen. However since the flow in this case will be passing through a 300mm pipeline with butterfly valve, it is proposed to opt for slightly finer screening as a guarantee against pipe-blockage, hence a screen aperture of 60mm.

Figure 19 : Proposed waterwheel location against the south wall



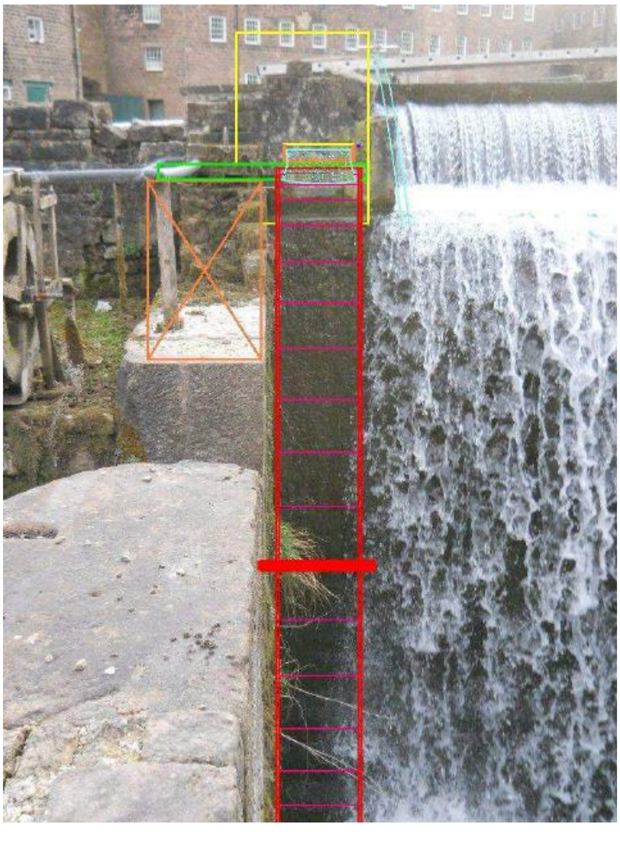


Figure 20 : Proposed waterwheel location

Figure 21 : HydroWatt waterwheel (Germany)

10. ENVIRONMENTAL ISSUES

10.1 EA Consultation

A formal pre-application response was provided by the Environment Agency in October 2020, ref. NPS/WR/034218 which confirmed that the scheme would require an Impoundment License.

10.2 Ecology and Protected Species

A Phase 1 Habitat Survey was undertaken by Baker Consultants to identify if there are any relevant populations of protected species (water voles, white-claw crayfish, otters, bats, etc.) and to examine any potential impacts on either Bonsall Brook or the Cromford Canal SSSI. Their full report is appended in Annex C, but the key conclusions are quoted as follows:

Cromford Mill

- *The headrace canal is heavily silted and supports localised patches of submerged and emergent aquatic vegetation of fairly low extent and limited diversity. The magnitude of the impact of removing silt and aquatic vegetation from the headrace will be insignificant beyond site level.*
- *The adoption of best practice pollution prevention measures during sediment mobilisation will prevent any direct impacts towards other waterbodies, and the species they might support.*
- *There is no suitable habitat onsite capable of supporting water vole or otter. The headrace canal is sub-optimal for white-clawed crayfish, due to it being a sealed stone structure and heavily silted substrate, isolated from suitable connecting habitat: no adverse impacts are anticipated.*
- *Sufficient information has been obtained to fully determine the impacts of the proposed development work and no further surveys are recommended.*

Cromford Canal

- *The Cromford Canal SSSI, owned and managed by Derbyshire County Council (DCC), is designated for its rich submerged and emergent aquatic flora and diverse marsh/wet grassland margin which support a very rich insect fauna.*
- *Natural England last assessed the Cromford Canal in 2010 and found the SSSI to be in unfavourable but recovering condition.*
- *The proposed hydropower works at Cromford Mill are entirely contained within the Mill site and, as such, will not result in a direct impact on the Cromford Canal SSSI, or any other nearby designated sites.*
- *The key parameter for the health of the Cromford Canal is the maintenance of the water level, rather than any given flow rate into it.*
- *By preserving the existing water levels of the Cromford Canal (within a 50mm band) any impacts towards the Cromford Canal SSSI, through a change in water levels, are not anticipated.*

10.3 Fisheries

There are numerous man-made structures making it impossible for fish, eels or lamprey to enter Bonsall Brook from the River Derwent, or to move further upstream to Bonsall.

Communications with the Environment Agency at pre-application confirmed that:

- There are no records of protected or migratory fish species.
- Connectivity between the brook and main River Derwent is effectively impossible for lamprey passage and the species are therefore unlikely to be present.
- No fish, eel or lamprey pass is required.

Any resident fish upstream of the wheelpit (e.g. brown trout, bullhead) will be protected by the 6mm inlet screen.

10.4 WFD Assessment

Bonsall Brook
Key factors for the installation of a new turbine adjacent to the existing wheelpit are as follows:

- This reach of Bonsall Brook (extending back to the village pond) is a man-made watercourse constructed in stone in the late 18th Century. Hence there is no riverine geomorphology to assess.
- The scheme will involve no deprived reach: the same flow will continue to spill over the existing impoundment and end up in the wheelpit below, before continuing to the River Derwent.
- There will be no change to water levels, upstream or downstream.
- There will be no change to fish passage.
- Any resident fish will be fully protected from the Francis turbine by a 6mm screen.
- The intermittent overshot waterwheel poses no danger to fish.

Hence there are no factors which can influence the WFD status of the wider waterbody ("Derwent from Wye to Amber").

Cromford Canal
With respect to the Cromford Canal waterbody and SSSI:

- The Canal is a closed system – essentially a lake – which requires a small flow to compensate for leakage through the ancient infrastructure.
- There has been no recent investment or intervention by DCC to identify and fix the leaks, so relying on a constant spill from Bonsall Brook to maintain the water levels.
- The Ecology Survey has confirmed that it is the water level in the Canal (not any particular flow rate) which sustains the species cited in the SSSI.
- In agreement with DCC, the operation of the hydro-scheme will maintain the status quo by continuously monitoring the water level in the Canal and instructing the operator to raise or lower the wheelpit stop-log accordingly. This automated system will help during both summer low flows and winter high flows (when flooding is a potential issue).
- This will be an improvement on the current ad hoc operation, which requires visual assessment of the water level by DCC staff and volunteers.
- There will be greatly improved flow availability into the Canal at low flows (when the turbine will be switched off) because the major leakage of the existing wheelpit impoundment will be eliminated by construction of a new end-wall as part of the turbine intake.
- As well as monitoring the Canal level, continuous monitoring of the water level in the millrace (and hence the quantity of spill into the Cromford Canal), will highlight whether the leakage out of the Canal is worsening over time and that remedial action is required by DCC.

It is therefore apparent that implementation and operation of the new hydro turbine and control system offers significant advantages to the day-to-day observation and management of the Canal, and therefore that the 'good' ecological status will be protected and enhanced as a result.

11. FLOOD RISK

Bonsall Brook is not classified as 'main river' so the scheme will not require a Flood Risk Permit from the EA. A Flood Risk Assessment would be provided with the 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 project works will not impinge upon the main watercourse or change the level of the wheelpit overspill, so there will be no obstruction to the main channel flow.

- By diverting some of the flow through the new turbine, the overall discharge capacity of the site will be increased.
- The turbine draft tube, to be fixed to the north wall of the wheelpit, will be set back from the line of the overspill so will not impede the flow of water cascading over the overspill and entering the tailrace tunnel.
- Similarly, the new waterwheel is intentionally narrow (600mm) to avoid impeding the existing overspill into the wheelpit.
- Any excavated materials will be removed off site.

12. OUTPUT and NET ZERO

The proposed Francis turbine designed would discharge a maximum of 385litres/sec on a net head of 5.8m and is expected to achieve a peak electrical output of 15kW.

Based on the measured flow data, the electricity generated over one year could be expected to be close to **55,000 kWh per year**, making a major contribution to the net zero ambitions of the Cromford Mills site.

ANNEX A : SITE PICTURES

Figure 22 : Headrace to the 'Second Mill'

Figure 23 : 6.5m fall into the wheelpit

Figure 24 : Overspill with adjustable stop-log

Figure 25 : Wheelpit with symmetrical bearing mounts

Figure 26 : Exit tunnel to the Derwent

Figure 27 : Horseshoe Weir diverting flow towards the Cromford Canal

Figure 28 : Rectangular orifice limiting flow from the Horseshoe Weir into the Canal

Figure 29 : Side culvert & sluices taking excess flow from the Horseshoe Weir back to the Derwent

Figure 30 : Side-sluice allowing the millrace flow to be diverted away from the wheelpit

ANNEX B : LAYOUT DRAWINGS

- Drawing B-0 – Cromford Second Wheelpit at present
- Drawing B-1 – Francis Turbine layout
- Drawing B-2 – Waterwheel layout
- Drawing B-3 – Front Elevation, both units

attached separately

ANNEX C : HABITAT & PROTECTED SPECIES SURVEY

Cromford Mill – Hydro Scheme
Ecological Appraisal

Baker Consultants
December 2021

attached separately

Cromford Mill – Hydro Scheme

Ecological Appraisal

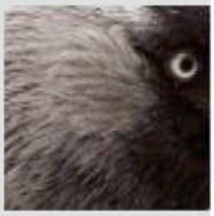
16th December 2021



baker consultants

baker*consultants*





Who we are:
Baker Consultants is an ecology and sustainability consultancy. We work in terrestrial, freshwater and marine environments, providing a range of services to industry, government, developers, public services and utilities.

Baker Consultants comprises a highly experienced team of professional ecologists. We do wildlife surveys - but they are only the first steps in the process for most projects. We are also involved in ecological assessment, environmental law, biodiversity management and design planning.

We don’t just work with wildlife, because we know that communication with clients, design teams and conservation bodies is the key to project success. Explaining the implications of survey data, and interpreting legislation, policy and best practice is one of our strengths. We help decisions to be made and actions taken, allowing constraints to be kept to a minimum and project risks to be managed.

Our approach is scientific, pragmatic and creative. Alongside tried and tested methods, we seek to innovate, introduce clients to new ways of thinking and always deliver sound commercial awareness. You will find us honest and approachable, but we’re not afraid to be robust and challenging - or to ask difficult questions.

We do believe in nature conservation. But we also believe in good development, well delivered. We know that, with our input, projects and plans can provide benefits for both nature and people.

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For more information, look at our web site www.bakerconsultants.co.uk, subscribe to our blog, or call us on 01629 593958.

Client	Arkwright Society
Project	Cromford Mill – Hydro Scheme
Report title	Cromford Mill, Ecological Appraisal
File reference	1560
Team leader	Jim Longley
Contact details	j.longley@bakerconsultants.co.uk

	Name	Position	Date
Author	Jim Longley	Senior Ecologist	3 December 2021
Reviewed	Gavin Ward	Consultancy Director	8 December 2021
Revised	Jim Longley	Senior Ecologist	16 December 2021

Baker Consultants Ltd
Cromford Station
Cromford Bridge
Matlock
Derbyshire DE4 5JJ
info@bakerconsultants.co.uk
www.bakerconsultants.co.uk
01629 593958

Company No. 6702156

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Unless otherwise stated in this document, the assessments made assume that the study site referred to will continue to be used for its current purpose without significant change. The assessment, recommendations and conclusions contained in this document may be based upon information provided by third parties and upon the assumption that the information is relevant, correct and complete. There has been no independent verification of information obtained from third parties, unless otherwise stated in the report.

Where field investigations have been carried out, these have been restricted to the agreed scope of works and carried out to a level of detail required to achieve the stated objectives of the services. Natural habitats and species distributions may change over time and further data should be sought following any significant delay from the publication of this document.

Report Contents

1 Summary

1.1 The Proposed Development

1.1.1 This document provides an ecological appraisal of the site at Cromford Mill, Derbyshire, related to proposals for the installation of a hydro-electric turbine and waterwheel within an existing wheel pit, and a submerged coil for a water sourced heat pump within the adjoining headrace canal.

1.1.2 This report describes and assesses features of ecological value found to be present at the site. It also provides advice to help minimise any adverse ecological impacts, thereby enabling the development to comply with current nature conservation policy and legislation.

1.2 Ecological Receptors

1.2.1 The key ecological receptors are the nearby Cromford Canal Site of Species Scientific Interest (SSSI), aquatic habitats such as submerged and emergent vegetation, and protected/notable species including fish and breeding birds.

1.3 Recommended Actions

1.3.1 The desk-study and field surveys have provided sufficient information to enable the impacts of the proposed works to be fully determined.

1.3.2 There is potential for an adverse impact on low value aquatic habitats and fish (if present), but the magnitude of the impact will depend on timings and the construction methods selected to carry out the works.

1.3.3 Ecological impacts on features of interest will need to be avoided, or appropriate mitigation put in place to reduce the effects of the proposed development and to comply with legislation and planning policy for biodiversity.

1.4 Conclusions

1.4.1 Overall, the conclusion of this report is that there are no significant constraints to development that cannot be addressed through appropriate mitigation measures. There is potential for a net gain in biodiversity resulting from the development.

2 Introduction

2.1 Site Description

2.1.1 The site consists of a large stone-lined wheel pit and 35m section of headrace canal located within Cromford Mill, Cromford, Derbyshire, at Ordnance Survey grid reference SK 29828 56962.

2.1.2 Both the wheel pit and the headrace canal are located within the centre of a complex of historic mill buildings and open space associated with Cromford Mill. The headrace canal is fed by a culverted section of the Bonsall Brook which flows from the north-west through a number of man-made weirs and culverts within the village of Cromford. The water exits the headrace via the wheel pit which is culverted to the nearby River Derwent. A horseshoe weir is also located within the headrace canal that allows overspill into two separate culverts. One culvert feeds into to the River Derwent, whilst the other leads into the Cromford Canal, the start of which is located to the 50m south east of the site. An additional sluice gate and culvert is also located on the south side of the headrace canal.

2.1.3 Figure 1 shows the site location and approximate red line boundary of the site.

Figure 1. Site Location

2.2 Study Scope

2.2.1 Baker Consultants was commissioned by the client to undertake the following works in relation to the Site:

- Desk-based study with local records centres and online databases to identify designated sites of nature conservation importance, areas of priority habitats and records of protected and/or notable species;
- Habitat survey to record the nature and extent of vegetation and habitats within and adjacent to the Site; and
- Appraisals for protected and/or notable flora and fauna.

2.2.2 This report takes into account standard guidance from a variety of sources including the Chartered Institute of Ecology and Environmental Management [1] [2] [3], British Standards Institution [4], and www.gov.uk [5].

2.2.3 The report considers, in particular, potential effects on the following biodiversity features:

- Designated Sites (international, national and local)
- European Protected Species
- National Protected Species
- Habitats and Species of Principal Importance for Conservation
- Habitats and species of local interest

1 CIEEM (2018). Guidelines for Ecological Impact Assessment In The UK And Ireland: Terrestrial, Freshwater, Coastal and Marine. Chartered Institute of Ecology and Environmental Management, Winchester.
2 CIEEM (2015). Guidelines on Ecological Report Writing. Chartered Institute of Ecology and Environmental Management, Winchester.
3 CIEEM (2017). Guidelines for Preliminary Ecological Appraisal. Chartered Institute of Ecology and Environmental Management, Winchester.
4 BSI (2013). BS42020:2013 Biodiversity – Code of Practice for Planning and Development
5 https://www.gov.uk/guidance/protected-species-how-to-review-planning-applications

3 Methods

3.1 Surveyor Qualifications and Experience

3.1.1 The survey was undertaken by Senior Ecologist James Longley BSc (Hons) MCIEEM, who has over 16 years' experience in nature conservation and ecology. He is an experienced habitat surveyor and has undertaken ecological assessments on a wide variety of projects.

3.1.2 Wherever appropriate during surveys, Natural England's Standing Advice on Protected Species [6] was taken into account, along with a wide range of other best practice guidance on survey methods. These are referenced in the text below. However, the professional judgement of the surveyors was also applied in relation to the site conditions and target species/habitats being considered. This may have required changes to the published guidance.

3.2 Desk Study

3.2.1 A data search was undertaken for designated sites of nature conservation interest, priority habitats and records of protected and priority species. Data for these was gained through the sources listed in Table 1 below:

Table 1. Desk-study Data Sources

Organisation/source	Data sought	Search area
Multi-Agency Geographic Information for the Countryside (MAGIC)	Statutory designated sites, Habitats of Principal Importance	1km
Derbyshire Wildlife Trust	Non-statutory designated sites of nature conservation and records of protected/notable species.	1km

3.2.2 Natural England's online Impact Risk Zone tool was utilised [7]. This identifies whether developments are likely to have an impact on SSSIs, based upon their type and location, and whether Natural England should be consulted as part of proposals.

6 https://www.gov.uk/guidance/protected-species-how-to-review-planning-applications
7 Available at: http://www.magic.gov.uk

3.3 Habitat Survey

3.3.1 A habitat survey of the study area was carried out by Jim Longley on the 10 November 2021. The vegetation types and habitats present were described and mapped during a walkover of the site survey area, using the standard published guidelines for UKHAB[8]. Features of particular interest were recorded as Target Notes (TNs).

3.3.2 In addition, the habitats within the site and surrounding land were appraised for their suitability to support protected or notable species, or assemblages that could be sensitive to the development proposals, in accordance with 'Guidelines for Preliminary Ecological Appraisal' [9].

3.3.3 During the survey, consideration was given to features such as potential breeding bird habitat, bat roosting locations, badger sett locations, reptile habitat and the suitability of water features for amphibians and riparian mammals.

3.3.4 Invasive species, such as Japanese knotweed *Fallopia japonica* and giant hogweed *Heracleum mantegazzianum*, were noted by the surveyor if present. These species can have implications for development activity and human health respectively.

3.3.5 Weather conditions during the survey were cool and dry with 100% cloud cover.

3.3.6 The survey approach taken is designed to identify broad habitat types at a site and the potential of these habitats to support notable/protected species, and to assist in providing an overview of the ecological interest at a site. It is the most widely used and professionally recognised method for initial ecological site appraisal.

8 UK Habitat Classification Working Group (2020). UK Habitat Classification – Habitat Definitions V1.1 at https://ukhab.org/.

9 CIEEM (2017). Guidelines for Preliminary Ecological Appraisal. Chartered Institute of Ecology and Environmental Management, Winchester.

4 Results

4.1 Study Limitations

4.1.1 It is important to note that, even where data is returned for a desk study, a lack of records for a defined geographical area does not necessarily mean that there is a lack of ecological interest since the area may simply be under-recorded. Equally, due to the level of recording, some species should be considered more frequent than indicated by the records provided within a desk study.

4.1.2 Whilst every effort was made in the field survey to provide a comprehensive description of the site, no investigation can ensure the complete characterisation and prediction of the natural environment. Also, natural and semi-natural habitats are subject to change, species may colonise the site after surveys have taken place and results included in this report may become less reliable over time.

4.1.3 Survey data is generally only considered valid if it is from the current or previous active season. In some cases, surveys up to 3 years old may be considered acceptable by consultees if the habitats have not significantly changed in the intervening period.

4.1.4 Access was available across the site, and weather conditions were suitable for the scope of the survey.

4.1.5 The habitat survey was carried out at a sub-optimal time of year to detect some plant indicator species and access was limited to the walls of the wheel pit. However, broad habitats were still able to be mapped and assessed for their potential to support protected/notable species.

4.2 Designated Sites

4.2.1 The desk-study provided information on the designated sites listed below in Table 2, with further details provided in Appendix 1 and Appendix 4.

Table 2. Designated Sites

Ref.	Name	Status	Distance	Interest
Statutory				
UK0019859	Peak District Dales	SAC	470m north	Designated for a number of Annex 1 habitats including calamarian grasslands, semi-natural dry grasslands and scrub facies and calcareous rocky slopes. Also, for Annex II species brook lamprey, bullhead and white-clawed crayfish.
1000209	Cromford Canal	SSSI & LNR	50m east	Disused canal. Eutrophic freshwater habitat with a rich submerged and emergent aquatic flora and a diverse marsh-wet grassland margin which supports a very rich insect fauna.
1000510	Matlock Woods	SSSI	460m north	Good example of ash-elm woodland.

Ref.	Name	Status	Distance	Interest
1003309	Mason Hill	SSSI	630m north	Species-rich grassland overlying a complex of mostly impoverished soils which are calcareous, neutral, leached acidic, or contaminated by mineral spoil.
1003009	Via Gellia Woodlands	SSSI	640m west	Ancient woodland site which supports a type of ash-elm-hazel woodland of restricted national distribution.
1002033	Rose End Meadows	SSSI	680m west	Extensive area of unimproved herb-rich grassland.
	Matlock Parks	LNR	900m north	Mixed Ash woodland and 2.3 ha of semi-natural grassland.
Non-Statutory				
DD379	Scarthin Rock, Cromford	LWS & RIGS	Adjacent	Secondary broad-leaved woodland. Also geologically important.
DD460	Scarthin Fen	LWS	100m north	Lowland fen
DD469	Allen's Hill	LWS	120m west	Unimproved calcareous grassland
DD380	Scarthin Nick, Cromford	LWS	150m west	Ancient semi-natural ash woodland
	Wildcat Crags	RIGS	500m north	Geologically important
	Matlock Tufa Deposits	RIGS	550m north	Geologically important
DD324	Cromford Station Pasture	LWS	550m north-east	Unimproved neutral grassland
DD105	Wapping Complex	LWS	550m north west	Ancient semi-natural ash woodland
DD466	Slinter Field	LWS	900m west	Unimproved neutral grassland
	Black Rock Picnic Site	RIGS	950m south	Geologically important
	Sheep Pastures Quarries	RIGS	975m south-east	Geologically important
668	Willersley Castle	pLWS	225m north	Unimproved neutral grassland
597	Cromford Marsh and Stream	pLWS	300m east	Lowland fen
471	Cromford Court Wood	pLWS	500m west	Ancient semi-natural woodland
515	Cromford Meadows	pLWS	600m south	Semi-improved neutral grassland (SNG - 1999)
386	Black Rock and Barreledge Wood	pLWS	800m south	Broad-leaved semi-natural woodland
325	Pina Springs Meadows	pLWS	900m south	Unimproved neutral grassland
470	Woodseats Wood	pLWS	900 north-east	Ancient semi-natural woodland
384	DD CWS	pLWS	950m north-east	Semi-improved neutral pasture

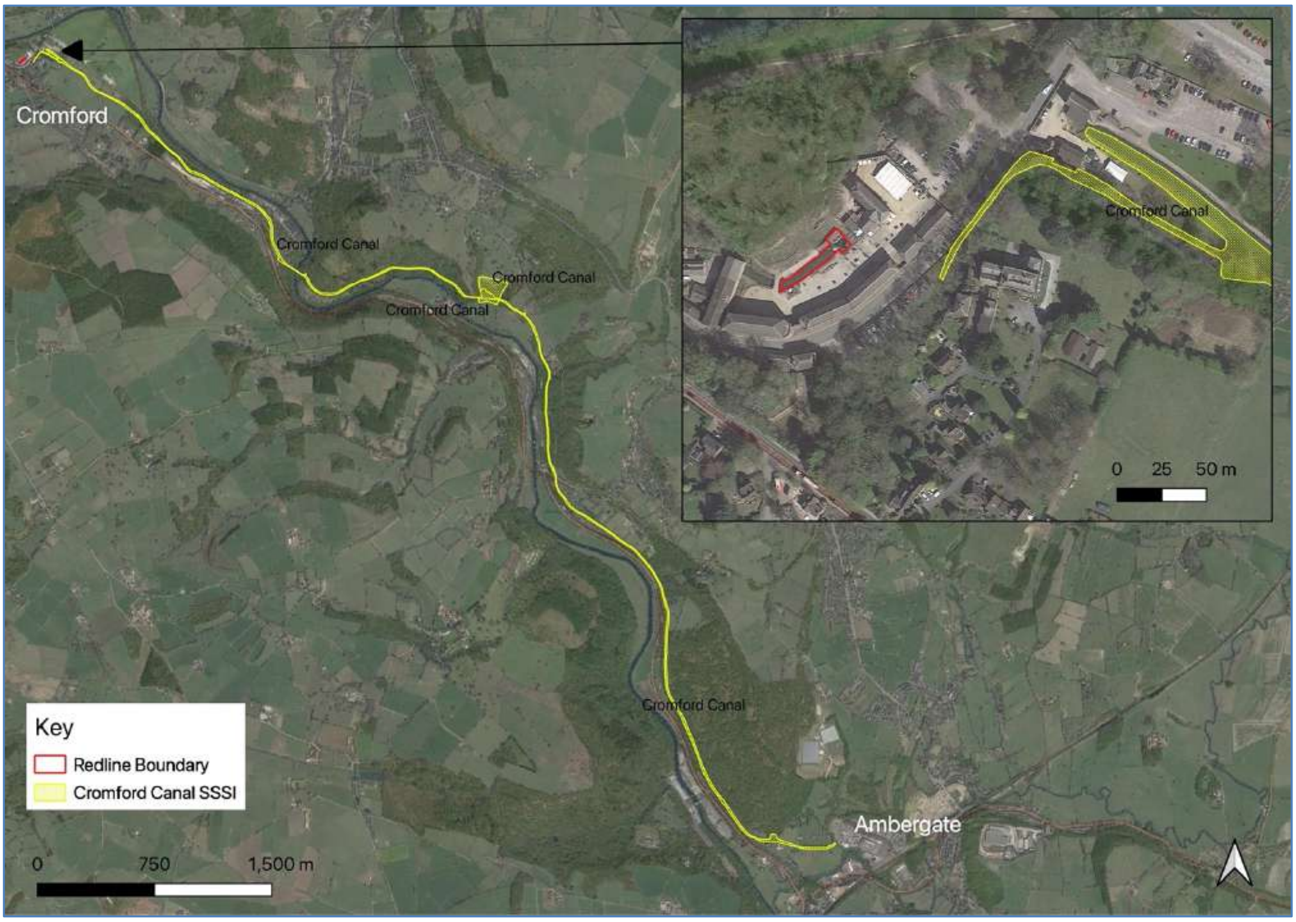
SAC: Special Area of Conservation I SSSI: Site of Special Scientific Interest I LWS: Local Wildlife Site I RIGS: Regionally Important Geological Site I pLWS = Potential Local Wildlife Site

4.2.2 The closest nationally designated site is Cromford Canal SSSI and Local Nature Reserve (LNR), located approximately 50m to the south-east at its nearest point (Figure 2).

4.2.3 Cromford Canal SSSI and LNR consists of approximately six miles of partly disused canal running from Cromford to Ambergate in Derbyshire. It is designated as an important eutrophic water habitat with a rich submerged and emergent aquatic flora and diverse marsh/wet grassland margin which support a very rich insect fauna (Appendix 4). Several rare aquatic plants have previously been recorded within the canal including grass-wrack pondweed *Potamogeton compressus*, small pondweed *Potamogeton berchtodii* and round-leaved crowfoot *Ranunculus omiophyllus*. Where silting has occurred, reedswamp communities dominate with frequent reed sweet-grass *Glyceria maxima* and branched bur-weed *Sparganium erectum*. Occasional rarer plant species, such as water plantain *Alisma lanceolatum*, have been recorded in these silted areas. The canal is fed at Cromford by a culvert originating within the Cromford Mill site, as well as a number of controlled and uncontrolled feeders along its six-mile length.

4.2.4 The site is within the Impact Risk Zone for the Cromford Canal SSSI (MAGIC website accessed 1 December 2021), and is in the zone where '*any development needing its own water supply*' requires consultation with Natural England.

Figure 2. Cromford Canal SSSI Location



4.2.5 There are seven non-statutory designated Local Wildlife Sites (LWS) and five Regionally Important Geological Sites (RIGS) located within the 1km search area. The closest is Scarthin Rock LWS/RIGS which is located immediately north of the site and is designated for its secondary broadleaved woodland and as an important geological feature.

4.3 Habitat Survey

4.3.1 Scientific names are given after the first mention of a species, thereafter, common names only are used. Standard nomenclature [10] is used for vascular plant species.

Habitats Overview

4.3.2 The habitat types recorded on site during the survey are described in turn below (and illustrated in Appendix 2). Particular features of interest, recorded during the survey, are listed as Target Notes in Appendix 3, with their locations shown in the Appendix 2 Habitat plan.

Wheel Pit

4.3.3 The wheel pit is large open rectangular pit that forms part of the historic mill workings (Figure 3). The pit is disused and previously supported a large water wheel. It is constructed entirely from cut stone and directly connects to a headrace canal located to the west, and a culvert which takes water east to the River Derwent. Water enters the top of the pit through a stop-plank system positioned within the headrace canal, it then pools at the base of the pit and exits via an arched culvert (Figure 4). For the most part, the stonework is bare, but in damper sections, particularly near areas of flowing water, support bryophytes, and occasional herb species such as herb-robert *Geranium robertianum*, wall lettuce *Mycelis muralis*, water figwort *Scrophulatie auriculata,* hemp agrimony *Euparorium cannabinum* and common polypody *Polypodium vulgare.* No submerged or emergent vegetation was visible within the base of the pit at the time of survey.

Figure 3. Wheel Pit looking north-west

Figure 4. Wheel pit interior

[10] Stace, C. (2012). New Flora of the British Isles. Third Edition. Cambridge University Press, Cambridge.

4.3.4 There are two recesses positioned opposite each other within the top of the structure, which previously held parts of the main water wheel (Figure 4). The north recess is fairly sheltered and supports herbs such as meadowsweet *Filipendula ulmaria* and perforate St John's wort *Hypericum perforatum*. The southern recess supports a flow of water from a small model water wheel, and in the damper sections, supports bryophytes communities similar to the main walls of the wheel pit.

4.3.5 To the north of the wheel pit, within the application area, there is a level area of gravel and cut foundation stone which supports scattered ephemeral vegetation that includes hemp agrimony, willowherbs *Epilobium* spp. and perforate St John's wort (Figure 5). The whole area is sheltered by a 2m high wooden and steel viewing platform.

Figure 5. Tall herbs and ephemeral vegetation north of wheel pit

Headrace Canal

4.3.6 The headrace canal is a stone lined channel that supplies water to the wheel pit (Figure 6). It starts in the north-west corner of the mill site and turns east under a footbridge, it then extends along a straight section ending at the wheel pit. The area surveyed includes a 35m section between the wheel pit and the footbridge. The headrace canal at this point is approximately 4.5m wide and is constructed entirely from cut stone, forming a 'U' shaped profile. The water exits the headrace via a stop plank system leading directly into the wheel pit, which is culverted to the nearby River Derwent. A horseshoe weir is also located within the headrace canal to the south west, which allows overspill into two separate culverts (Figure 7). One culvert flows to the River Derwent whilst the other feeds into the Cromford Canal, the start of which is located to the 50m south-east of the site. An additional sluice gate is also located on the south side of the headrace canal. It is understood that the water levels within the headrace canal are currently regulated by the use of the stop planks and sluice gate.

4.3.7 The entire channel is heavily silted and the water depth varies from 0.3m to 1m. A large amount of accumulated leaf litter was noted within the water. In the shallower areas where the silt depth is greatest, particularly towards the centre of the channel, localised stands of submerged and emergent vegetation are present and include curled pond weed *Potamogeton crispus* and water speedwell *Veronica anagallis-aquatica*. Towards the western end of the headrace canal, next to the footbridge, there are two small patches of water-cress *Nasturtium officnale* and starwort *Callitriche* spp.. The headrace stone work is mainly bare but does support a number of bryophytes and liverwort species closer to the water. Some joints in the stone wall have been colonised by a range of commonly occurring herbs and grasses such as willowherbs, creeping bent-grass *Agrostis stolonifera*, gypsywort *Lycopus europaeus,* sow-thistles *Sonchus* spp, buddleia *Buddleja davidii,* water figwort and meadowsweet.

Figure 6. Headrace canal - looking west towards footbridge

Figure 7. Headrace canal and horseshoe weir - looking east -

4.4 Species Overview

4.4.1 The relevant notable species recorded on or near the site by desk-study or field survey are summarised in the following sections. Further details of the desk-study results are also provided in Appendix 1.

4.5 Birds

4.5.1 The desk-study returned records for a large number of bird species mainly of garden and woodland passerines such as dunnock *Prunella modularis*, song thrush *Turdus philomelos*, and house sparrow *Passer domesticus*. The only relevant species of waterbird returned was kingfisher *Alcedo atthis*.

4.5.2 During the field survey a single kingfisher was observed landing on the viewing platform above the wheel pit. A small number of mallard *Anus platyrhynchos* were also recorded dabbling within the headrace canal.

4.6 Fish

4.6.1 The desk-study returned 16 records of brown trout *Salmo trutta* within the search area, all of which are located within the River Derwent north of the site.

4.6.2 Consultation between Derwent Hydro and the Environment Agency has identified no records for protected species such as brook lamprey *Lampetra planeri* within the Bonsall Brook catchment area.

4.6.3 During the field survey, no fish were observed within the headrace canal. The running water habitat is isolated from connecting riverine habitats by culverts and significant infrastructure such as roads and buildings and, therefore, is considered sub-optimal to support notable assemblages of fish species.

4.7 Otter

4.7.1 The desk-study returned five records of otter *Lutra lutra* within the search area, all of which are located within the River Derwent north of the site.

4.7.2 No evidence of their presence was found during the field survey and the habitats on site, being isolated from the main river, are considered sub-optimal to support this species.

4.8 Water Voles

4.8.1 The desk-study data lists records of water vole *Arvicola amphibius* within the nearby Cromford Canal and River Derwent.

4.8.2 There is no optimal habitat for water vole within the site. The masonry within the headrace canal is intact and offers no suitable burrowing or nesting habitat that is required to support the species. However, the horseshoe weir supplies water directly to a section of the Cromford Canal offsite, which is known to support water vole.

4.9 White-clawed Crayfish

4.9.1 The desk-study returned 17 records of white-clawed crayfish *Austropotamobius pallipes* within the search area, all of which appear to be from the river Derwent between 1987 and 1992.

4.9.2 No white-clawed crayfish were observed during the survey and the site is considered to be sub-optimal to support this species. As with the comments made in paragraph 4.6.2, the site is isolated from more suitable riverine and brook systems, and the intact stonework and overall lack of refuge habitat is likely to prevent the species being able to occupy the site successfully.

4.10 Invasive Species

4.10.1 The desk-study returned a number of records for nearby invasive species including aquatic plants such as Canadian waterweed *Elodea canadensis*, Nuttall's waterweed *Elodea nuttallii* and curly waterweed *Lagarosiphon major*. Japanesse knotweed *Fallopia japonica* was also noted in the ground of Cromford Mill.

4.10.2 No signs of invasive non-native species were observed on the site. They are not considered further within this report.

5 Assessment

5.1 National Policy

5.1.1 The National Planning Policy Framework (NPPF 2021) sets out the Government's planning policies for England and how these should be applied. It states that the purpose of the planning system is to contribute to the achievement of sustainable development, combining economic, social and environmental objectives, and 'protecting and enhancing our natural --- environment; including ---helping to improve biodiversity'. Within this framework, the requirements in relation to biodiversity are included within several policies. The two most relevant to individual planning decisions are Paragraphs 174 and 180, shown below:

174. Planning policies and decisions should contribute to and enhance the natural and local environment by:

> *a) protecting and enhancing valued landscapes, sites of biodiversity or geological value and soils (in a manner commensurate with their statutory status or identified quality in the development plan);*
>
> *b) recognising the intrinsic character and beauty of the countryside, and the wider benefits from natural capital and ecosystem services – including the economic and other benefits of the best and most versatile agricultural land, and of trees and woodland;*
>
> *c) maintaining the character of the undeveloped coast, while improving public access to it where appropriate;*
>
> *d) minimising impacts on and providing net gains for biodiversity, including by establishing coherent ecological networks that are more resilient to current and future pressures; etc…*

180. When determining planning applications, local planning authorities should apply the following principles:

> *a) if significant harm to biodiversity resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused;*
>
> *b) development on land within or outside a Site of Special Scientific Interest, and which is likely to have an adverse effect on it (either individually or in combination with other developments), should not normally be permitted. The only exception is where the benefits of the development in the location proposed clearly outweigh both its likely impact on the features of the site that make it of special scientific interest, and any broader impacts on the national network of Sites of Special Scientific Interest;*
>
> *c) development resulting in the loss or deterioration of irreplaceable habitats (such as ancient*

woodland and ancient or veteran trees) should be refused, unless there are wholly exceptional reasons and a suitable compensation strategy exists; and

d) development whose primary objective is to conserve or enhance biodiversity should be supported; while opportunities to improve biodiversity in and around developments should be integrated as part of their design, especially where this can secure measurable net gains for biodiversity or enhance public access to nature where this is appropriate

5.1.2 Section 40 of the Natural Environment and Rural Communities (NERC) Act 2006 places a duty on every public authority to have regard to conserving biodiversity. Section 41 of the same Act requires that the Secretary of State must publish a list of the living organisms and types of habitats that are of 'Principal Importance' for the purpose of conserving biodiversity. The Secretary of State must take steps, as appear reasonably practicable, to further the conservation of those living organisms and habitats in any list published under this section. The list of species and habitats of principal importance currently includes 943 species and 56 habitats.

5.2 Legislation

5.2.1 The Wildlife and Countryside Act 1981 (as amended by the CRoW Act 2000) provides for the notification and confirmation of SSSIs. These sites are identified for their flora, fauna, geological or physiographical features by Natural England. The Act also contains measures for the management of SSSIs and protection against damaging operations. Impact Risk Zones (IRZs) define zones around each site which reflect the particular sensitivities of the features for which it is notified and indicate the types of development proposal which could potentially have adverse impacts [11].

5.2.2 The Wildlife and Countryside Act 1981 (as amended by the CRoW Act 2000) is the primary legislation which protects native animals, plants and habitats in the UK. The Act makes it an offence to intentionally kill, injure or take any wild animal listed on Schedule 5, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places. The Act also makes it an offence to intentionally pick, uproot or destroy any wild plant listed in Schedule 8, or any seed or spore attached to any such wild plant.

5.2.3 European Protected Species (EPS), such as bats and great crested newts, are protected under both the Wildlife and Countryside Act 1981 (as amended by the CRoW Act 2000) and under the Conservation of Habitats and Species Regulations 2017. Taken together, these make it an offence to:

a) Deliberately capture, injure or kill an EPS;

b) Deliberately disturb any EPS, in particular any disturbance which is likely to (i) impair their ability to survive, breed, reproduce or to rear or nurture their young; or in the case of hibernating or migratory species, to hibernate or migrate; or (ii) to affect significantly the local distribution or abundance of the species to which they belong.

[11] Available at: http://www.magic.gov.uk

c) To be in possession or control of any live or dead EPS or any part of, or anything derived from an EPS;

d) Damage or destroy a breeding site or resting place of an EPS;

e) Intentionally or recklessly obstruct access to any place that an EPS uses for shelter or protection;

f) Intentionally or recklessly disturb an EPS while it is occupying a structure or place that it uses for shelter or protection.

5.3 Development proposals

5.3.1 The proposed works will involve the installation of a water turbine and waterwheel within the existing wheel pit (Figure 9), and de-silting of the headrace canal to allow the installation of a submerged coil for a water-sourced heat pump.

5.3.2 During the construction phase, temporary works will be required to bund water upstream by use of a cofferdam and divert flow through an existing sluice gate, which delivers flow into the River Derwent. The headrace canal will be de-silted as part of this work to allow the installation of the heat pump coil. Additionally, excavation works will be carried out to the north of the wheel pit to install the water turbine. The existing stone work on the northern elevation of the wheel pit will be retained and a new retaining wall will be constructed behind this to create a sealed void to house the water turbine (Figure 10).

5.3.3 During the operational phase, the upstream water levels will be maintained in the same way as present, by manually adjusting the stop planks above the overspill into the wheel pit. The overspill will be actively managed to maintain a headrace water level within a 10mm band[12]. This level will continue to guarantee a continuous flow over horseshoe weir and into the Cromford Canal.

5.3.4 Flow will be diverted at the top of the wheel pit to both the turbine, and dropped directly back into the base of the wheel pit. A 6mm aperture 'drop through' screen will be used for to protect juvenile fish from entering the turbine. A coarse 60mm aperture will be used on the waterwheel as risk to fish is negligible.

5.3.5 During times of low water flow i.e. during summer, the turbine will be stopped and any available water will be diverted through the horseshoe weir.

[12] Derwent Hydro 2021

Figure 8. View of proposed wheel pit works from above

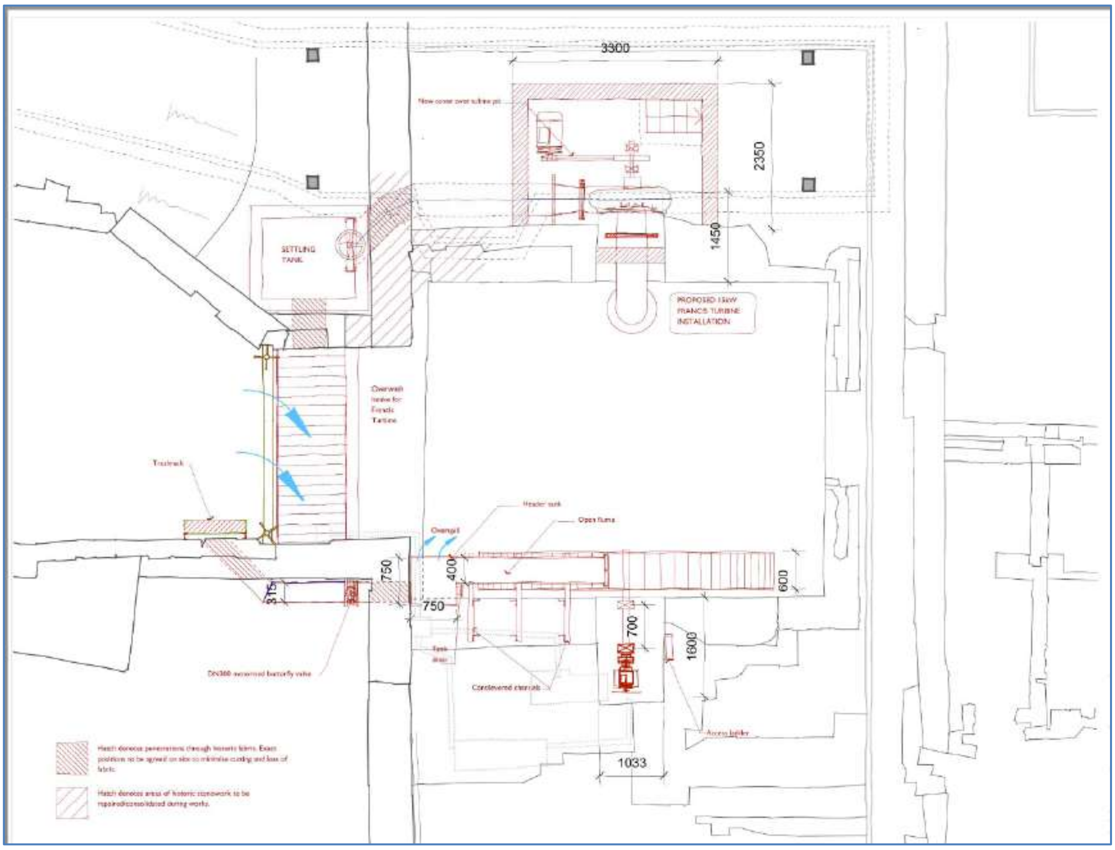
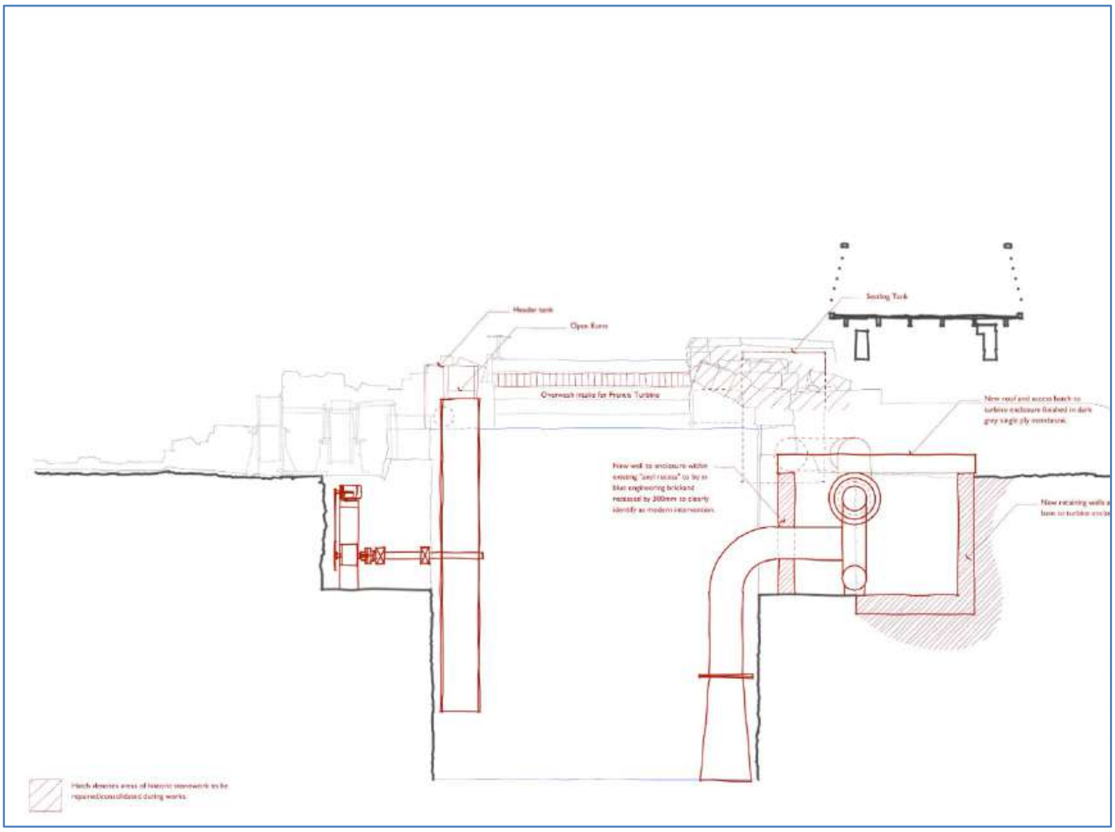


Figure 9. View of proposed wheel pit works looking west



5.4 Impacts on Designated Sites

5.4.1 The section below provides an evaluation, description of potential impacts and assessment of ecological effects for designated sites relevant to the study area.

Cromford Canal SSSI

5.4.2 The Cromford Canal SSSI is designated as an important eutrophic water habitat with a rich submerged and emergent aquatic flora and diverse marsh/wet grassland margin which support a very rich insect fauna. It is currently owned and managed by Derbyshire County Council (DCC). The majority of the canal is disused, however, a navigable section of the waterway exists between Cromford Wharf and High Peak Junction. In agreement with DCC, the Friends of Cromford Canal (FoCC) operate public narrowboat cruises on this section of water at various times throughout the year.

5.4.3 Cromford Canal SSSI is fed at Cromford by a culvert originating within the Cromford Mill site, as well a number of controlled and uncontrolled feeders along its six-mile length. The Mill culvert extends from the horseshoe weir on-site under the mill buildings and Mill Road, until it enters a small channel which feeds the main canal at Cromford Wharf.

5.4.4 Historically, the water levels within the canal have been regulated by raising or lowering a stop-log across the overspill into the wheelpit. By constricting the flow into the wheelpit, this determines the water level backing up in the mill-race, and hence the quantity of flow overspilling the horseshoe weir 30m upstream.

5.4.5 Adjustment of the wheelpit stop-log has been carried out under an informal agreement with the Arkwright Society, whom allow access for DCC staff and FoCC volunteers to adjust the stop-log as deemed necessary. It is understood that there is currently no formal monitoring of water levels or flow rates within the Cromford Canal and any adjustments to water levels are carried out on an ad-hoc basis.

5.4.6 The proposed works will divert water from the headrace canal over the existing stop log overspill into an overwash intake which leads directly into the water turbine. As with the existing overspill, the water will then be returned into the wheel pit and exit through a culvert that leads to the River Derwent. The proposed works are entirely contained within the Mill site and, as such, will not result in a direct impact on the Cromford Canal SSSI, or any other nearby designated sites. However, it needs to considered whether any diversion of water from the headrace canal will reduce flow into the Cromford Canal, and whether this could result in a significant change in water level that might impact features of interest, and the conservation status of the Cromford Canal SSSI.

5.4.7 Natural England last assessed the Cromford Canal in 2010 and found the SSSI to be in unfavourable but recovering condition. An assessment of the current SSSI condition in 2021 has not been carried out, and it has therefore been assumed that the features of interest are present and the SSSI status is extant.

5.4.8 Those features of interest that are likely to be sensitive to any significant long-term changes in water level are the marginal wet/marsh habitats. Some aquatic plant species, such as the rarer potamagetons (*Potamogeton compressus* and *Potamogeton berchtodii),* are likely to be tolerant to some changes in water level, but may be impacted if the water becomes too shallow and the water quality is altered. Although not a feature of interest, water vole, which are known to present in the canal, may also be impacted by significant and sustained changes in water level.

5.4.9 It is understood from anectodical evidence that the existing habitats within the SSSI are already subject to some levels of disturbance from water loss through leakages in the canal structure, and from seasonal fluctuations in levels caused by uncontrolled feeders into the canal. The Canal is a closed system with no locks, so it can be assumed that the majority of the water entering the Canal is likely to be lost to leakages. Derwent Hydro carried out a number of surveys throughout 2021 and estimated this water loss to be up to 50 litres/sec. It is also understood that the operating water level in the Canal was raised in 2014 by approximately 50mm (in order to accommodate the newly acquired canal boat). In general, higher water levels will tend to increase the rate of leakage.

5.4.10 The key parameter for the Canal is the maintenance of the water level, rather than any given flow rate into it. In wetter months, natural run-off into the Canal is high and evaporation is low, so the need for additional flow from Bonsall Brook is reduced or eliminated. The peak requirement for supplementary flow is in dry summer months, but in these months the turbine is likely to be switched off through lack of flow, so there would be no alternative demand for the water, thus ensuring there will be the maximum flow available for the SSSI.

5.4.11 To ensure water is used efficiently, it is proposed that the new hydro scheme will monitor the water level in the Cromford Canal (with an electronic sensor) and then adjust the overspill at the horseshoe weir to maintain the required level. The aim will be to maintain the existing levels where possible, but the exact 'control level' may be seasonal, since a higher level is only required in the months when the canal boat is operating. The level could be slightly reduced to its historic level (approx. 50mm lower) for the rest of the year without negatively impacting the interest features of the SSSI, which can tolerate minor fluctuations in water level. A reduction of water level within a 50mm band also has the potential to reduce the leakage flow, which could help to preserve the structural integrity of the Canal and further protect the SSSI interest features that it supports.

5.4.12 The maximum flow into the Cromford Canal at the Horseshoe weir will be capped at 50 litres/sec – believed to be sufficient to combat the leakage flow at present. However, if this leakage flow worsens, it will be the responsibility of DCC, as the canal owners, to undertake remedial works to reduce the leakage and maintain water levels.

5.4.13 By preserving the existing water levels of the Cromford Canal (within a 50mm band) any impacts towards the Cromford Canal SSSI, through a change in water levels, are therefore not anticipated.

Other Designated Sites

5.4.14 The proposed development is confined to a small area of previously developed land within the Cromford mill site and, therefore, impacts towards any other nearby designated sites are not anticipated.

5.5 Impacts on Habitats

Habitats Overview

5.5.1 The sections below provide an evaluation, description of potential impacts and assessment of ecological effects for each habitat type relevant to the study area.

Wheel pit

5.5.2 The wheel pit is constructed entirely from cut-stone and supports a number of bryophyte and herb communities associated with the damp walls. The installation of a water turbine and water wheel will not require the removal or loss of these habitats because the existing historic stone work will be retained and protected as part of the scheme. During the operational phase, water will continue to enter the wheel pit via the turbine and water wheel, maintaining the damp conditions for the existing plant communities. Therefore, significant impacts towards the habitats present within the wheel pit are not anticipated.

5.5.3 There will be a minor loss of ephemeral and tall herb habitat to create the turbine housing. The plant species likely to be impacted are abundant within the site and local area, and do not make a significant contribution to botanical diversity. Given the relatively small area (2.4 x 3.3m) that will be affected and limited botanical interest it is considered that the impact of the development on the ephemeral and tall herb habitats will be negligible.

Headrace Canal

5.5.4 The headrace canal is heavily silted and supports localised patches of submerged and emergent aquatic vegetation of fairly low extent and limited diversity. The works to de-silt this section of the headrace canal will require the installation of an upstream cofferdam and the removal of silt and aquatic vegetation. Without mitigation, there will be an adverse impact because of the loss of habitat, but the magnitude of the impact will be insignificant beyond site level.

5.5.5 The bryophyte and herb communities associated with the damp walls will be left in situ and de-silting will not impact these habitats, therefore impacts towards this habitat are not anticipated.

5.6 Species Overview

5.6.1 The sections below provide an evaluation, description of potential impacts and assessment of ecological effects for European and nationally protected species/group, or priority species/group, relevant to the study area.

5.7 Birds

5.7.1 All nesting birds are protected under the Wildlife and Countryside Act 1981 (as amended), which makes it an offence to intentionally kill, injure or take any wild bird or take, damage or destroy its nest whilst in use or being built, or take or destroy its eggs. In addition to this, for some rarer species (listed on Schedule 1 of the Act), it is an offence to intentionally or recklessly disturb them while they are nest building or at or near a nest with eggs or young, or to disturb the dependent young of such a bird.

5.7.2 Site clearance or construction works, if undertaken during the bird breeding season, could potentially damage active nests and result in an offence under the legislation. Impacts to consider include damaging or removing breeding sites, disturbing birds and their young, removing vegetation and changing habitats.

5.8 Fish

5.8.1 The installation of a cofferdam and de-silting of the headrace canal is likely to cause displacement and disturbance of fish (if present) during the works, but this will be temporary, and, beyond these, further impacts are not anticipated.

5.8.2 There is a risk of harm to fish during the operation phase if they are swept into the turbine. A 6mm aperture 'drop through' screen will be used to protect juvenile fish from entering the turbine. A coarse 60mm aperture will be used on the waterwheel as risk to fish is negligible.

5.8.3 There is potential for a disturbance to the River Derwent and Cromford Canal and the aquatic species it supports during the construction phase due to sediment mobilisation and accidental pollution incidents. However, the adoption of best practice pollution prevention measures implemented as part of a Construction and Environmental Management Plan (CEMP) will prevent any direct impacts towards the waterbodies, and the species it might support. As such, no significant adverse impacts towards either species is predicted.

5.9 Water Vole and Otter

5.9.1 Water voles and otter are protected under the Wildlife and Countryside Act 1981 (as amended by the CROW Act 2000). In addition, water vole is listed as a Species of Principal Importance under the provisions of the NERC Act 2006.

5.9.2 There is a lack suitable habitat onsite capable of supporting water vole or otter. The connecting River Derwent and Cromford Canal have been known support both species but this habitat is offsite and will not be directly impacted by the proposals.

5.9.3 See paragraph 5.8.3 above for impacts to species that could be present in the River Derwent and Cromford Canal.

5.10 White-clawed Crayfish

5.10.1 White-clawed crayfish is protected under Wildlife and Countryside Act 1981 (as amended by the CRoW Act 2000). This makes it illegal either to take it from the wild or sell it without an appropriate licence from the appropriate nature conservation agency. In addition, white-clawed crayfish is a UK Biodiversity Action Plan species and is listed as a Species of Principal Importance under the provisions of the NERC Act 2006.

5.10.2 The headrace canal is considered to be sub-optimal for white-clawed crayfish, primarily due to it being a sealed stone structure and heavily silted substate that is fairly isolated from suitable connecting habitat. Therefore, no adverse impacts to this species are anticipated as a result of the proposed development. However, given that records do exist for the species within 500m of the site, a precautionary approach should be adopted during the cofferdam installation and de-silting works. Further details on this are provided in Section 6.

5.10.3 See paragraph 5.8.3 above for impacts to species that could be present in the River Derwent and Cromford Canal.

6 Recommendations

6.1 Introduction

6.1.1 The recommendations below for further survey and mitigation are based on the results and assessment set out above, taking into account standard published guidance from a number of sources (as referenced through the report), including the GOV.UK information on Planning and Development [13] [14].

6.1.2 Individual Local Planning Authorities have their own requirements for ecological information to support the validation and assessment of planning applications. These requirements often vary widely between Authorities and sometimes do not accord with national guidance- including that issued by the statutory nature conservation organisations. As a result, we have applied the more consistent national guidance to our survey and mitigation recommendations set out below.

6.2 Further Survey

6.2.1 This ecological appraisal has provided an initial baseline of ecological information to describe the main characteristics of the proposed development site. At this stage it is considered that sufficient information has been obtained to fully determine the impacts of the proposed development work.

6.3 Mitigation Measures

6.3.1 Mitigation measures should be considered through the masterplan design and planning application process, with actions during the construction phases agreed and established in a Construction Environmental Management Plan: Biodiversity (CEMP). This whole process from proposal to implementation should consider the 'mitigation hierarchy' – avoid, reduce, compensate and enhance:

- Aim to avoid negative effects by scheme design;
- If this isn't possible, use mitigation measures to reduce the impacts;
- Use compensation measures if there are still negative impacts, and
- Seek opportunities to make enhancements for biodiversity.

Headrace Canal

6.3.2 In order to minimise impacts towards aquatic habitats and species that could be present in the headrace canal, the installation of the cofferdam and drawdown of the headrace canal will be carried out during the September-February period. If there are unforeseen delays it may also be possible to commence the works during the summer months, when the flow from the Bonsall Brook is at its lowest and water levels in the headrace have naturally reduced.

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13 https://www.gov.uk/topic/planning-development/protected-sites-species
14 https://www.gov.uk/guidance/natural-environment#biodiversity-and-ecosystems

6.3.3 In compliance with the Policy PD3 of the adopted Derbyshire Dales Local Plan (adopted in 2017)[15] and the NPPF (2021) it would be expected that the proposed development demonstrates a net gain for biodiversity. Given the scope of works, small scale of the development, and the likely structural constraints associated with structural heritage, it will be difficult to deliver net gain in terms of habitats. Although, one option could be to install pre-planted floating coir rolls along one side of the headrace canal margin.

6.3.4 The use of a number of small rafts (for example 1-2m long and up to 0.75m wide) on the canal margin, which can be readily attached or detached from neighbouring rafts, would provide flexibility for maintenance of the channel and canal wall, and if die-back occurs in one or more of the rafts, replacement of vegetation. Substrate types and depth can be varied to suit the species appropriate to the setting. Examples of this can be seen in Figure 10 and 11 below. Floating island are available for purchase from a number of suppliers, including SalixRW: https://www.salixrw.com/product/floating-islands/

Figure 10. Example 1 of floating island

Figure 11. Example 2 of floating island

6.3.5 There are numerous options with regards to securing floating rafts to the margin of a canal. It is assumed that the canal bed should not be disturbed due to the presence of heat pump coils and to maintain the integrity of the historic structure. An anchorage system is therefore considered to be inappropriate. The banks of the headrace canal are stone-lined and provide the opportunity to attach the individual rafts by ropes to the masonry. The rafts could then be removed for maintenance or replacement without harming the ecology or the sensitive heritage infrastructure.

6.3.6 An appropriate native plant mix can be developed as part of a detailed method statement that is aesthetically acceptable as well as being of ecological interest and relevant to the

15 Derbyshire Dales District Council (2017). Adopted Local Plan

local area.

Birds

6.3.7 Impacts on nesting birds should be avoided by carrying-out site clearance and similar operations outside of the bird breeding season (April- August). Construction activities that might directly impact upon breeding birds should hence be limited to the September-February period.

6.3.8 If it is necessary to remove vegetation during this period, and in order to identify the presence/absence of nest sites, an experienced ecologist should conduct a survey prior to any vegetation removal. An appropriate buffer zone should be created around any active nests found and works should be delayed until the young have fledged and the nest is no longer in use – such buffers have variable timescales and sizes, depending on the species concerned.

Fish

6.3.9 No specific mitigation is required for fish onsite as the measures highlighted in paragraph 6.3.2 provide sufficient protection for this species group, relevant to the level of impact anticipated.

6.3.10 Pollution prevention measures put in place to protect the River Derwent and Cromford Canal during construction works will prevent potential impacts on fish within these offsite habitats.

Otter and Water vole

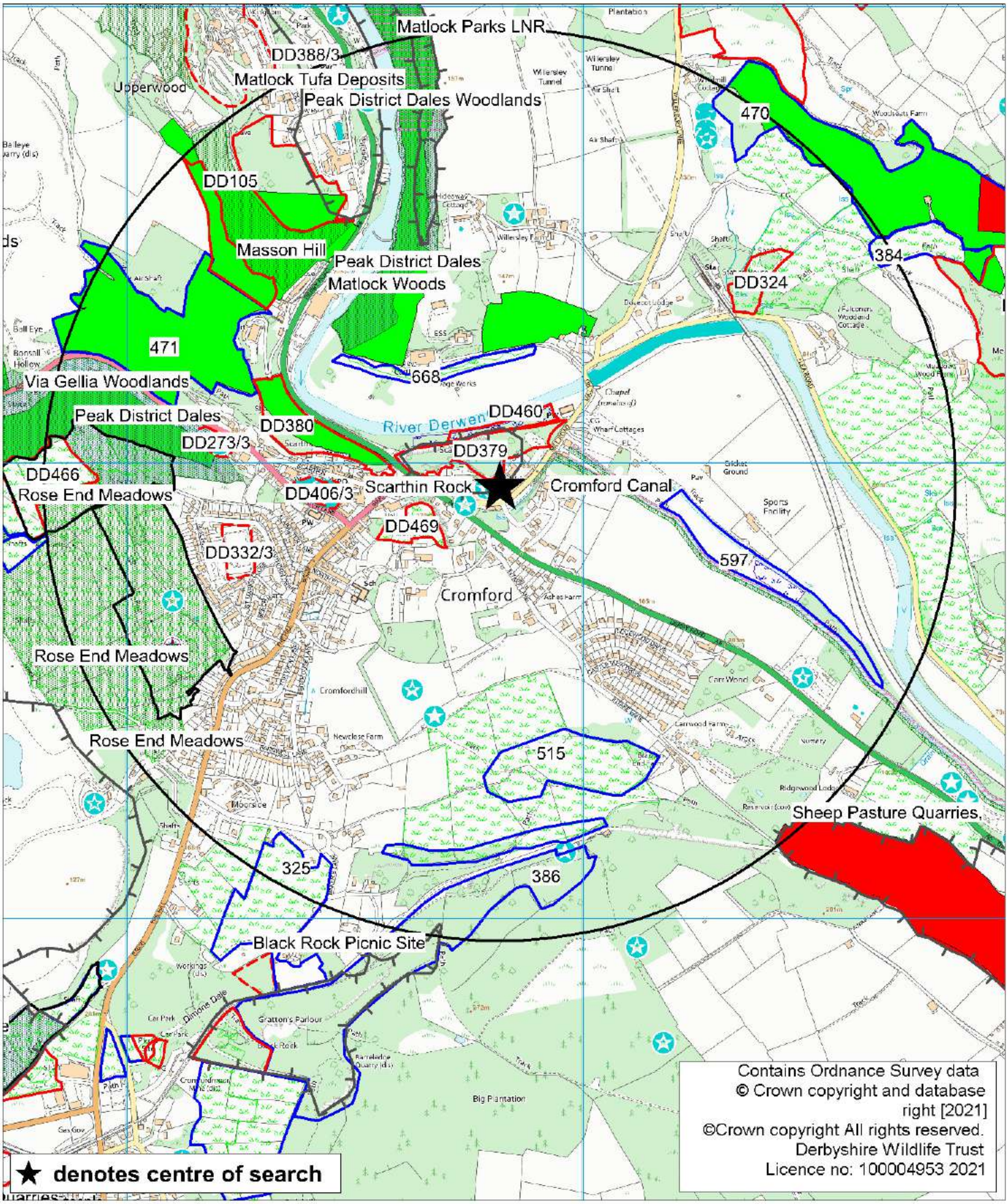
6.3.11 As above, pollution prevention measures will prevent potential impacts on otter and water vole within connecting offsite habitats.

White-clawed Crayfish

6.3.12 The site offers sub-optimal habitat to support white-clawed crayfish and, as such, their presence is not anticipated. However, as a precaution, it is recommended that the cofferdam is installed by hand and drawdown of water is carried out in a controlled and systematically manner. Any de-silting works should commence after drawdown is successfully completed. In the unlikely event that white clawed crayfish is encountered during the proposed development, work should stop immediately and the advice of a suitably qualified ecologist obtained.

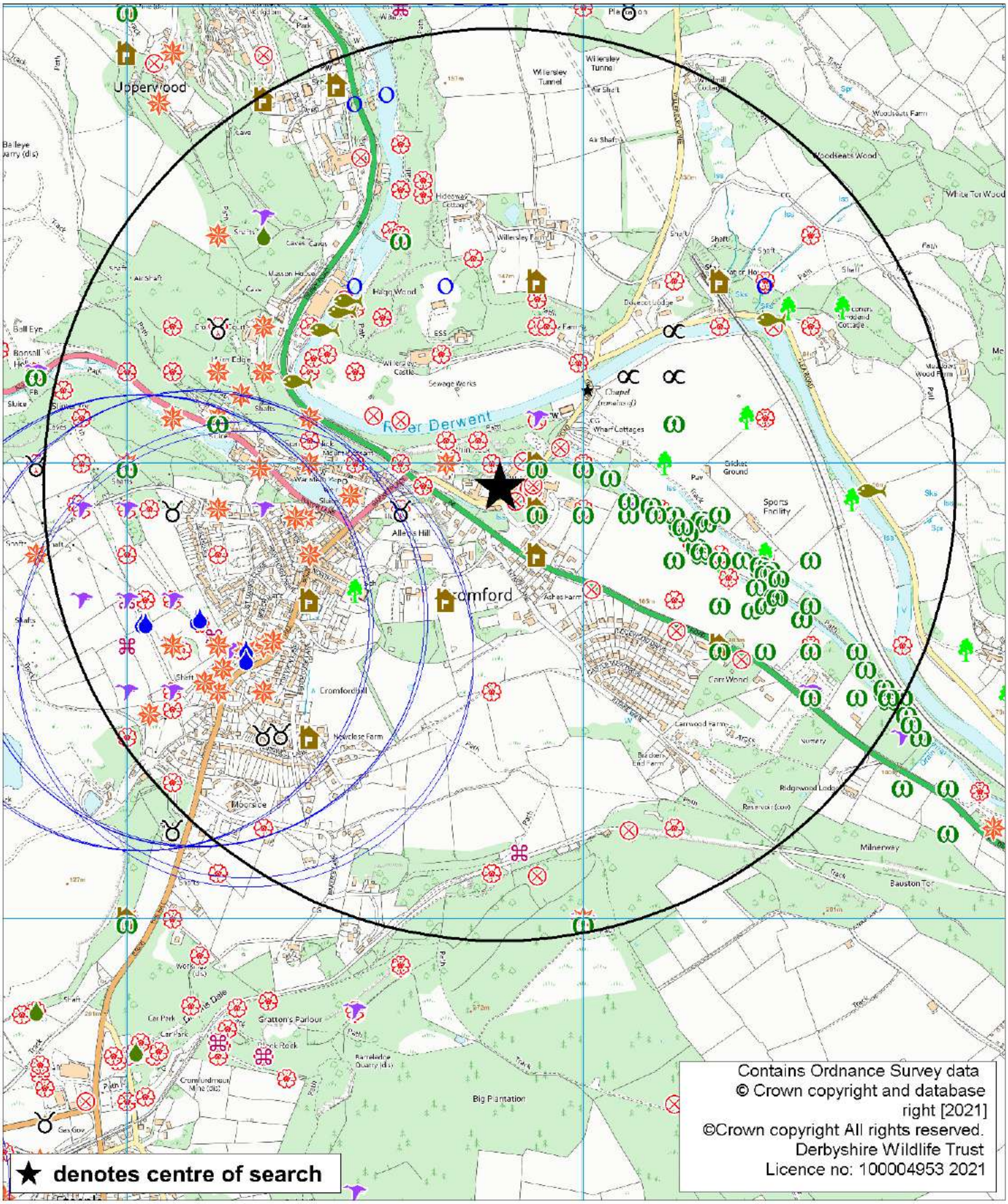
6.3.13 As above, pollution prevention measures will prevent potential impacts on white-clawed crayfish within connecting offsite habitats.

Appendix 1: Desk Study



Produced for Baker Consultants
by Derbyshire Biological Records Centre
November 2021
Cromford Mill (sites)

THE wildlife TRUSTS
Derbyshire Wildlife Trust



Produced for Baker Consultants
by Derbyshire Biological Records Centre
November 2021
Cromford Mill (species)

Derbyshire Wildlife Trust

KEY

Species

- GCN
- GCN 500m buffer
- White-clawed Crayfish
- Otter
- Water Vole
- Reptile
- Bat Roost
- Bat Sighting
- Badger Sett
- Badger Sighting
- BAP Bird
- Schedule 1 Bird
- Swift
- BAP Mammal
- BAP Toad
- Toad Crossing
- BAP Fish
- Black Poplar
- Veteran Tree
- BAP Invertebrate
- Derbyshire Red Data List Plant
- Invasive Species

Habitats

- Traditional Orchard
- Open Mosaic
- Purple Moor Grass and Rush Pasture
- Lowland Heath
- Lowland Fen
- Semi-natural Grassland
- Reedbed
- Lakes
- Historical Wood Pasture and Parkland
- Ponds
- Notable Invertebrate Ponds
- Ancient & Semi-natural Woodland
- Ancient Replanted Woodland

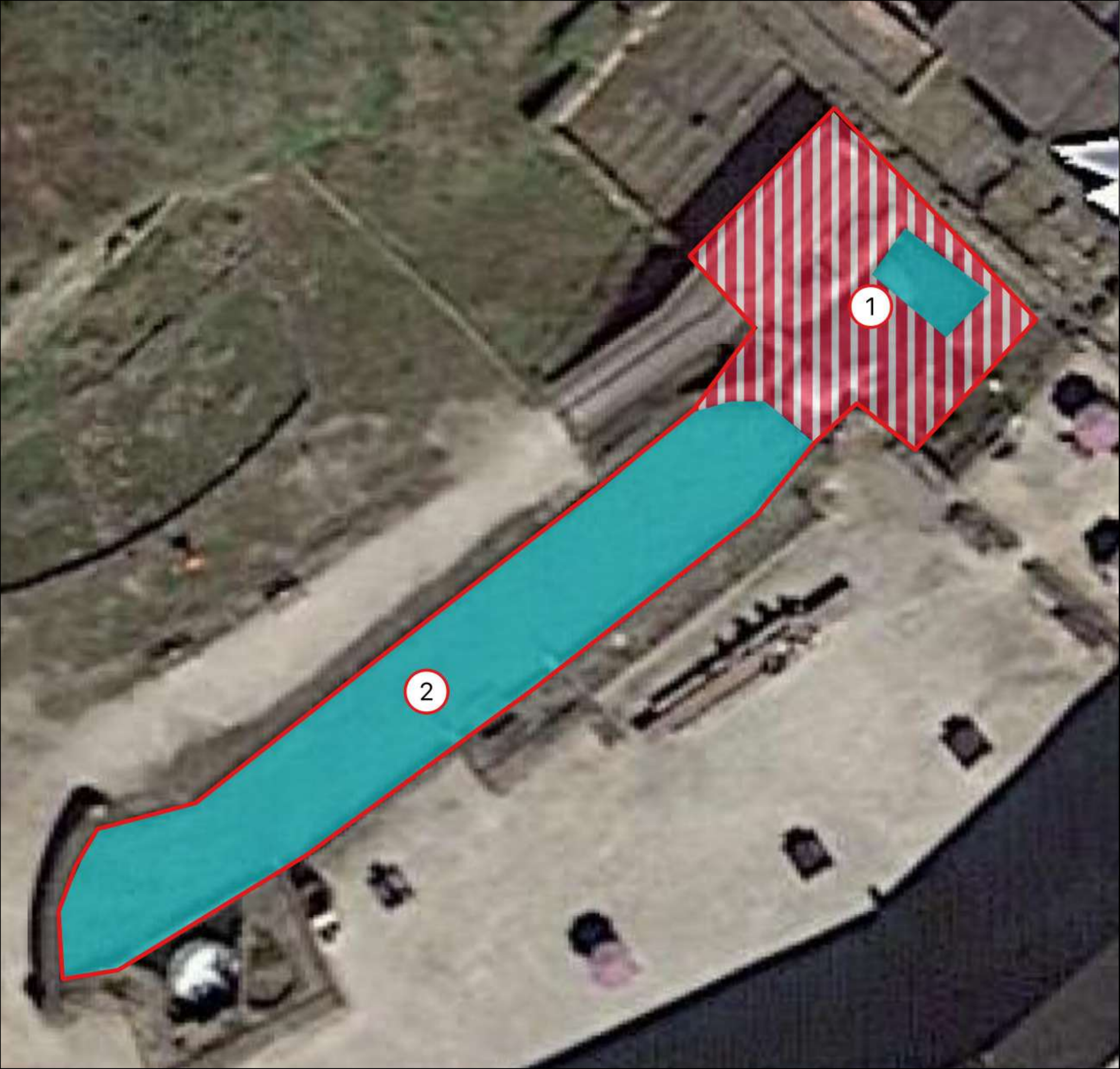
Non-statutory Designations

- Regionally Important and Geological and Geomorphological Sites (RIGS)
- Derbyshire Wildlife Trust Reserves
- Local Wildlife Sites (LWS)
- Potential Local Wildlife Sites (pLWS)
- Grade 3 Sites

Statutory Designations

- Sites of Special Scientific Interest (SSSI)
- Special Protection Area (SPA)
- Special Area of Conservation (SAC)
- National Nature Reserve (NNR)
- Local Nature Reserve (LNR)

Appendix 2: Habitat Plan



Legend

Target Note

Redline Boundary

HABITATS

Developed land; sealed surface

Running Water

Project: Cromford Mill - Hydro Scheme
Drawn by: J Longley
Date: 3 December 2021

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ECOLOGY DESIGN INNOVATION

Appendix 3: Target Notes

No.	Description
1	Wheel Pit - Constructed entirely from cut stone. Water enters the top of the pit through a stop-plank system positioned within the headrace canal and exits via an arched culvert which leads to the River Derwent. Damper sections of stonework near areas of flowing water support bryophytes and occasional herbs including black spleenwort, herb-Robert, wall lettuce, water figwort and hemp agrimony. No submerged or emergent vegetation visible within the base of the pit. Two recesses positioned opposite each other within the top of the structure. North recess is sheltered and supports meadowsweet and perforate St John's wort. The southern recess supports bryophytes communities similar to other part of the structure. North of the wheel pit - Level area of gravel and cut foundation stone. Supports scattered ephemeral vegetation including fairly frequent hemp agrimony, willowherbs. and perforate St John's wort. Sheltered by viewing platform.
2	Headrace Canal - Stone lined channel, 35m long 4.5m wide. Feeds wheel pit and two weirs. Heavily silted with large amount of leaf litter present. Water depth min 30cm max 100cm. Submerged vegetation in deep silt towards centre of channel includes curled pond weed and water speedwell. Stone lined margins consist of bryophytes, liverworts, ruderal and ephemeral vegetation including willowherbs, creeping bent-grass, gypsywort, sow-thistles, buddleia, water figwort and meadowsweet. Towards footbridge there are two small patched of starwort and watercress. Three mallard and one kingfisher present at the start of survey.

Appendix 4: Cromford Canal SSSI Citation

Notification Date: 22 August 1986

COUNTY: DERBYSHIRE SITE NAME: CROMFORD CANAL

DISTRICT: DERBYSHIRE DALES/ AMBER VALLEY SITE REF: 15 WMD

Status: Site of Special Scientific Interest (SSSI) notified under Section 28 of the Wildlife and Countryside Act 1981.

Local Planning Authority: DERBYSHIRE COUNTY COUNCIL, Derbyshire Dales District Council/Amber Valley District Council

National Grid Reference: SK 299569 to SK 351520 Area: 15.2 (ha.) 37.6 (ac.)

Ordnance Survey Sheet 1:50,000: 119 1:10,000: SK 25 NE, SK 35 SW, SE, NW

Date Notified (Under 1949 Act): 1981 Date of Last Revision: 1981

Date Notified (Under 1981 Act): 1986 Date of Last Revision: –

Other Information:
Part of the site is a Local Nature Reserve owned by Derbyshire County Council. Part of the site is managed by the Derbyshire Naturalists Trust as a nature reserve. Site boundary alteration (extension & reduction).

Description at Reasons for Notification:
The site consists of approximately six miles of disused canal running from Cromford to Ambergate. It has been selected as an example of a eutrophic freshwater habitat with a rich submerged and emergent aquatic flora and a diverse marsh-wet grassland margin which supports a very rich insect fauna.

The canal is fed at Cromford by water from the Carboniferous Limestone but for the most of its length there are small feeders of more acidic water from the shales and gritstone. This variation in water chemistry has resulted in a range of plant communities. The canal is sufficiently shallow to be occupied to its full depth by rooted aquatic plants. The most widespread is broad-leaved pondweed *Potamogeton natans*. Where there is sufficient light penetration rigid hornwort *Ceratophyllum demersum* and Canadian pondweed *Elodea canadensis* are locally abundant. Curled pondweed *Potamogeton crispus* is also present and apparently increasing with water starwort *Callitriche* ssp. occupying a more marginal position where the reedswamp communities are suppressed by shade from overhanging trees. Several rarer aquatic plants have been recorded including grass-wrack pondweed *Potamogeton compressus*, small pondweed *Potamogeton berchtoldii*, various-leaved pondweed *Potamogeton gramineus*, the rarer of the two hornworts *Ceratophyllum submersum* and round-leaved crowfoot *Ranunculus omiophyllus*.

Where silting has occurred, reedswamp communities are found right across the width of the canal dominated by reed sweet-grass *Glyceria maxima* or branched bur-reed *Sparganium erectum*. In this zone isolated clumps of water-plantain *Alisma plantago-aquatica* and the rarer *Alisma lanceolatum*, sweet flag *Acorus calamus*, and less frequently flowering rush *Butomus umbellatus* occur. Water forget-me-not *Myosotis scorpioides* and water mint *Mentha aquatica* are characteristic of this zone with water horsetail *Equisetum fluviatile* and the narrow-leaved water-parsnip *Berula erecta* more local. Where the entry of side streams provides more nutrients, species such as unbranched bur-reed *Sparganium emersum*, great yellow-cress *Rorippa amphibia*, water mint and water-cress *Nasturtium officinale* are found.

On the upper banks and towpath margins the marsh grades into grassland. Here 190 herbaceous plant species have been recorded. This diversity is well structured and provides a continuity and variety of food niches for the important insect fauna. Characteristic species are lady’s smock *Cardamine pratensis*, large bitter-cress *Cardamine amara*, meadowsweet *Filipendula ulmaria*, wild angelica *Angelica sylvestris*, hemp agrimony *Eupatorium cannabinum* and gipsywort *Lycopus europaeus*. Skullcap *Scutellaria galericulata* and marsh woundwort *Stachys palustris* are occasional, and the lesser spearwort *Ranunculus flammula* is local. A rare woodland plant found on the canal banks is the small teasel *Dipsacus pilosus*.

Thirty seven tree and shrub species are recorded within the canal boundaries. Alder *Alnus glutinosa* in many stretches forms a continuous fringe on the bank opposite the tow path. The boundary 'hedges' consist mainly of hazel *Corylus avellana* and hawthorn *Crataegus monogyna* with some wych-elm *Ulmus glabra*. Where broad margins exist between the tow path and canal boundary there are scrubby areas with hazel, elder *Sambucus nigra* and goat willow *Salix caprea* and occasionally guelder rose *Viburnum opulus*. For much of its length the canal has the character of a woodland ride, attracting insects from the woodland to feed on the canal flora.

A study of hoverflies *Syrphidae* has recorded nearly 80 species including a number of uncommon ones. Many are species whose larvae live in the reed swamp. Other groups of invertebrates have also been studied and confirm the value of this site.

The site is of local importance for grass snakes *Natrix natrix* and water shrews *Neomys foetidens*.

  

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